Environment AECOM

Offshore Energy Research Association of Nova Scotia (OERA)

Marine Renewable Energy: Background Report To Support a Strategic Environmental Assessment (SEA) for the Cape Breton Coastal Region, inclusive of the Bras D'Or Lakes

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Executive Summary

In order to lessen Nova Scotia's dependency on imported fossil fuels and reduce greenhouse gas and air pollutant emissions, the Government of Nova Scotia tabled the 2010 *Renewable Electricity Plan,* which requires 25% of the electricity consumed in Nova Scotia to be generated from renewable sources by 2015. This was followed in 2012 by the *Marine Renewable Energy Strategy,* which describes the steps being taken to support and expand the marine renewable energy industry in Nova Scotia. In Cape Breton, a Strategic Environmental Assessment (SEA) is proposed to guide the incremental development of marine renewable energy in that region. Results from the Cape Breton SEA will be used to plan, implement and regulate and marine renewable energy projects in the region.

The SEA is consultative process aimed at exploring the social, economic and environmental features and effects associated with marine renewable energy projects. This Background Report, commissioned by the Nova Scotia Depart of Energy through the Offshore Energy Research Association (OERA), is the first step in the SEA process. It provides a comprehensive reference tool for residents, project developers, regulators and First Nations people interested in this industry. The Background Report describes the current state of marine renewable energy (MRE) technologies in the world. It also describes Cape Breton's existing biophysical environment and the socio-economic resources available to support this industry. The Report describes environment-project interactions, identifies information gaps and reviews the recommendations made following the 2008 SEA for the Bay of Fundy.

Nova Scotians are among the highest per capita consumers of electricity in the world. Almost 80% of Nova Scotia's electricity supply is generated from imported coal, petroleum coke and fuel oil while the remainder comes from natural gas and renewable sources. An estimated 1,700 GWh of new renewable electricity will be needed to meet the 2015 targets and an additional 1800 GWh to achieve the 2020 goals. Among the five programs begun under the *Renewable Electricity Plan* to help the province reach these targets, the COMFIT program provides fixed rates for community-based renewable energy projects (including tidal projects), while the FIT program provides tariffs for early stage tidal array projects.

In keeping with the study approach adopted for the Phase I Background Report for the Fundy SEA, this report identifies Key Environmental Issues (KEIs) that describe the environmental and socioeconomic issues of interest around MRE projects. The KEIs are: Critical Physical Processes; Fisheries and Aquaculture; Fish and Fish Habitat; Marine Benthic Habitat and Communities; Pelagic Communities; Marine Mammals; Marine Birds; Species at Risk; Marine Transportation; Tourism and Recreation; Marine and Coastal Resources; and Economic Development.

Given the varied coastal and inland environments available in Cape Breton, several different emerging marine renewable energy technologies may be applicable in this region including:

1. Offshore wind energy conversion through the use of wind turbines.
2. Wave energy Conversion (WEC).
3. Tidal lagoons.
4. Tidal in-stream energy conversion (TISEC).

As requested by OERA, TISEC technologies are addressed in greater detail than other MRE project types.

To a certain degree, Marine Renewable Energy (MRE) projects are similar to other major projects in the marine environment such as bridges or offshore oil drilling platforms. In all cases, project activities associated with construction, operation and removal have the potential to impact marine ecosystems and organisms, both at local (near-field) and regional (far-field) scales. With respect to MRE projects, typical issues of concern include changes in physical processes (wave, current and sediment transport regimes), alteration and loss of habitat, contaminants, electromagnetic fields, noise and vibrations and the physical interaction between MRE devices and fish, birds, marine mammals and other organisms

To the degree that offshore wind, wave and tidal projects have similar components common to all three technologies (foundations, mooring lines, subsea cables, etc.) they will tend to interact with marine ecosystems and organisms in similar ways, although actual interactions will vary depending on the type of energy conversion technology, the ultimate design deployed and the characteristics of marine environment hosting the deployment. The following table summarizes the typical interactions between MRE projects and the different environmental components of the marine environment.

Project Phase	Physical Process Interaction	Biological Component Interaction
Seabed Preparation	• Sediment transport during preparation • Waves/currents through obstruction and changes to the seabed shape • Introduction of additional hard substrate • Spills from vessels	• Benthic and infauna communities • Benthic and infauna habitat • Fish habitat • Marine mammals
Pile / Mooring Installation	• Sediment transport (suspension and scour) • Introduction of additional hard substrate • Noise and vibration • Spills from vessels	• Benthic and infauna communities • Benthic and infauna habitat • Fish habitat • Marine mammals
Gravity Foundation Installation	• Sediment transport & deposition (suspension and scour) • Introduction of additional hard substrate • Spills from vessels	• Benthic and infauna communities • Benthic and infauna habitat • Fish habitat • Marine mammals
Scour Protection Installation	• Sediment suspension, transport & deposition • Introduction of additional hard substrate	• Benthic and infauna communities • Benthic and infauna habitat • Fish habitat
TISEC/WEC/Wind Turbine Installation	• Waves/currents through obstruction • Spills from vessels	• Benthic and infauna communities • Benthic and infauna habitat • Fish & Fish habitat • Marine mammals • Birds
Cable Installation	• Sediment suspension, transport, scour & deposition	• Benthic and infauna communities • Benthic and infauna habitat • Fish • Fish habitat • Marine mammal (displacement
Project Operation	• Waves/currents through obstruction and energy extraction • Water quality through degradation of antifouling coatings and sacrificial anodes; release of lubricants • Electromagnetic fields • Noise and Vibration • Sediment transport & deposition	• Benthic and infauna communities • Benthic and infauna habitat • Fish • Fish habitat • Marine mammals • Reduction of downstream nutrients and food supply for benthic filter feeders

Project Phase	Physical Process Interaction	Biological Component Interaction
		• Changes to prey types and availability
Maintenance	• Water quality through degradation of antifouling coatings • Waves/currents through obstruction and changes to the seabed shape • Spills from vessels and • release of lubricants	• Disruption of marine communities attached to devices • Spill impacts to marine biota including birds
De-Commissioning	• Sediment transport (suspension and scour) • Spills from vessels	• Benthic and infauna communities • Benthic and infauna habitat • Fish • Fish habitat • Marine mammal displacement

With respect to coastal Cape Breton, little detailed research has been done to quantify the tidal resource for the specific purposes of tidal energy development. More tidal flow information is available in Bras d'Or Lakes, including data recently collected at Barra Strait and within the Great Bras d'Or Channel on behalf of OERA (McMillan *et al.* 2012). There is also more information available on the biophysical attributes of the Bras d'Or Lakes compared to coastal Cape Breton.

This report also describes the data and information gaps that will need to be addressed if MRE projects are to receive regulatory approval in the future. There are two categories of information gaps. First, outstanding questions remain regarding the nature and extent of certain interactions between MRE technologies and marine biota. Second, there is a general lack of detailed information describing baseline conditions such as the distribution and habitat use of many marine species, especially in coastal areas. These information gaps will make it difficult to compare pre- and post-project conditions and verify the predictions of project-environment interactions made in Environmental Impact Assessments.

The following table provides a summary of the data gaps and associated recommendations by KEI. Table entries in bold text indicate priority data gaps while underlined table entries indicate data gaps that have partially addressed since the 2008 Phase I SEA.

Key Environmental Issue	Data Gap	Recommendation
Critical Physical Processes	• **Limited information on the actual energy resource potential in coastal Cape Breton.** • Lack of detailed, site-specific current and substrate information for validation of models. • <u>Inadequate fine-scale hydrodynamic and sediment models relevant to selected MRE sites.</u> • Limited knowledge of the overall distribution and dynamics of sediments in Bras d'Or Lakes and coastal Cape Breton.	• Gather site-specific substrate, sediment movement and current information for MRE sites using in situ current measurements and sediment sensors. • Complete high density multibeam bathymetric studies, especially in shallow waters that have not yet been surveyed. • Adapt or refine hydrodynamic models to provide adequate small-scale analyses of the potential for, and the effects of, energy extraction developments. • Use hydrodynamic modeling to assist in site selection,

Key Environmental Issue	Data Gap	Recommendation
	• Inadequate application of hydrodynamic models to assess the impacts of TISEC developments. • Insufficient information regarding the cumulative effect of many devices on scour, sediment distribution and effects of ecological linkages.	optimizing the extractable energy potential and minimizing cumulative effects on physical or biological processes. • Validate monitoring methods / protocols to be used by developers. • Use modeling to link small projects to commercial scale arrays.
Fisheries	• Insufficient information on fish interactions with TISEC devices. Monitoring results are limited, inconclusive and lessons learned not necessarily transferable to commercial developments. • Inadequate knowledge on effects of remobilized sediments on commercially important species. • Questions about EMF from sub-sea cables and the effects on demersal fish and shellfish. • **More specific information required regarding the number of fishing operations, vessels, products and locations of fixed gear fisheries.** • Lack of clarity on access restrictions for MRE projects.	• Conduct additional experimental and in-water monitoring of fish behavior and mortality in the vicinity of TISEC devices. • Conduct experimental studies of fish responses to noise and EMF generated by TISEC devices and cables. • Develop information about likely electrical and magnetic field strengths associated with generating units, offshore substations, transformers and submarine cables. • Conduct experimental studies of effects of high suspended sediment concentrations on migratory and commercial fish species. • Work with fishing groups to obtain better fisheries data, particularly with respect to activities near proposed development sites. • Gather detailed information on potential adverse effects on local fisheries, and necessary mitigative measures (including project site selection). • Establish a consultative group, including fishers and developers to manage site use / access conflicts.
Fish and Fish Habitat	• Data on distribution, seasonality and trophic relationships of many non-commercial species are not available. • **Insufficient information on fish behaviour and / or mortality with respect to TISEC technologies, particularly for noise and vibration.** • Questions about EMF from sub-sea cables and the effects on demersal fish.	• Conduct experimental and in-water monitoring of fish behavior and mortality in the vicinity of TISEC devices. • Conduct experimental studies of fish responses to noise and EMF generated by TISEC devices and subsea cables. • Establish an ongoing and updatable database of knowledge about local and migratory fish stocks. • Identify potential mitigative measures for effects on fish populations.
Marine Habitat and Benthic Communities	• Limited data available on existing benthic communities in coastal Cape Breton. • Limited data available on existing benthic communities of the Bras d'Or Lakes, which is expected to be especially sensitive to changes that may result from energy extraction. • Little existing data for many areas of coastal Cape Breton.	• Initiate benthic surveys in proposed project sites, in areas that may be expected to be affected by project-related disturbances, and in non-affected control sites. • Create a coordinating agency to ensure consistency and quality of monitoring activities.
Pelagic Communities	• Similar to Fisheries and Fish and Fish Habitat issues noted above with respect to pelagic species.	• Similar to Fisheries and Fish and Fish Habitat issues noted above with respect to pelagic species.

Key Environmental Issue	Data Gap	Recommendation
Marine Mammals	• Limited data on behavioural responses of marine mammal to TISEC devices. • Limited data available on the occurrence of marine mammals in coastal Cape Breton.	• Compile information on long-term effects on mortality, migration, avoidance and attraction with respect to marine mammals. • Establish long-term monitoring programmes for marine mammals in coastal Cape Breton.
Marine Birds	• Lack of data on marine seabird and shorebird activity in the area of priority sites. • Lack of information on the trophic relationships of many marine birds, and their ability to adjust feeding preferences.	• Establish long-term monitoring programmes for marine birds near potential project sites. • Conduct background surveys to support project-specific environmental assessment process prior to deployment. • Identify and assess possible mitigation measures for effects of TISEC development on birds, including secondary effects associated with changes in prey availability.
Species at Risk	• Requirement for better site–specific information on species presence (depending on species and location).	• Establish an ongoing and updatable database of knowledge about local and migratory species at risk. • Identify and assess potential mitigation measures for different species at risk. • Work with Species Recovery Teams to develop comprehensive strategies for species at risk that use areas of high priority for energy extraction. • Where necessary, conduct species-specific surveys in high priority areas.
Marine Transportation	• Uncertainty regarding level of interaction with other marine transportation users in the study area.	• Stakeholder consultation with other marine users
Tourism and Recreation	• Lack of information on informal and unregulated recreational activities.	• Project-specific data gathering as part of site-specific EA process (including shore based facilities).
Marine and Coastal Archaeological and Heritage Resources	• Uncertainty regarding the location and condition of many potential archeological and heritage resources (marine and shore-based).	• Undertake a Traditional Ecological Knowledge Study for coastal Cape Breton and the Bras d'Or Lakes. • Detailed site-specific bathymetric survey using side-scan sonar as part of project specific EA process. Follow up with ROV survey if sonar shows potential resources. • Detailed archeological survey may be necessary as part of shore-based facility site selection and EA process.
Economic Development	• Uncertainty in identification of specific business opportunities for local business. • Local capacity not clear.	• Initiate supplier information sessions. • Establish networking organisations • Undertake local capacity/benefits study • Collaborate with development agencies and nearby jurisdictions • Host project-specific job fairs.

The MRE industry has continued to evolve since the Phase I SEA was completed for the Bay of Fundy in 2008. Many tidal power technologies have moved out of the prototype phase and into or past the demonstration phase. The leaders in this industry are currently seeking sites and financing to develop grid connected pre-commercial and commercial arrays. In Bras d'Or Lakes, near-term opportunities exist for community-based small scale commercial tidal energy projects. If successful, knowledge gained from these projects may be exported to support other

Canadian or international projects. In addition, there appears to be potential for larger scale commercial tidal, offshore wind and wave energy projects off coastal Cape Breton over the longer term. The nature and extent of these resources have not been studied in detail. Nevertheless, wave and tidal energy is not yet competitive with onshore renewable wind energy and considerable capital investment would be required to implement these longer term projects. Continued support is needed to move MRE technologies from single demonstration deployments into the first commercially viable grid connected arrays (5 MW range).

With respect to array deployments, the primary concerns relate to the effects of large-scale energy extraction and the consequent changes to water movement, sediment dynamics, and effects on aquatic species. At the same time, research is needed to understand how the outstanding questions for single device deployments scale up when multiple devices arranged in arrays.

MRE projects share the seabed and water column with other marine users. To the extent that these uses overlap in space or time, a strategic and consultative process is required to resolve conflicts that may develop. The upcoming Phase II SEA will also provide a forum for information exchange, solicitation of questions and concerns, and identification of additional area-use conflicts that may exist.

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- may be based on information provided to Consultant which has not been independently verified;
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- must be read as a whole and sections thereof should not be read out of such context; and
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List of Acronyms

ABSN – Aboriginal Business Service Network
AC - Alternating Current
ACOA – Atlantic Canada Opportunities Agency
AOI – Area of Interest
CB – Cape Breton Island
CBRM – Cape Breton Regional Municipality
CEDIF – Community Economic Development Investment Fund
CHS – Canadian Hydrographic Service
CLC – Community Liaison Committee
CMER – Canadian-Marine Energy Research
COMFIT – Community Feed-in Tariff
CORE – Cornwall Ontario River Project
COSEWIC – Committee on the Status of Endangered Wildlife in Canada
CSSP – Canada's Shellfish Sanitation Program
DC – Direct Current
DEVCO – Cape Breton Development Corporation
DFO – Department of Fisheries and Oceans Canada
DOMCO – Dominion Coal Company
EBSA – Ecologically and Biologically Significant Area
EEDC – Economic Development Officer
EESIM – Eastern Scotian Shelf Integrated Management
EIA – Environmental Impact Assessment
EMAC – Environmental Monitoring Advisory Committee
EMEC – European Marine Energy Centre
EMF – Electromagnetic fields
EPRI – Electric Power Research Institute
FERN – Fundy Energy Research Network
FIT – Feed-in Tariff
FORCE – Fundy Ocean Research Centre for Energy
GDP – gross domestic product
GHG – greenhouse gas
GIS – graphic information systems
GSC – Geological Survey of Canada
GWh – Gigawatt hour
HADD – Harmful Alteration Damage or Destruction
IBA – Important Bird Area
ICZM – Integrated Coastal Zone Management
ICM – Integrated Coastal Management
IEA-OES – International Energy Agency – Ocean Energy Systems
KEI – Key Environmental Issues
KMKNO – Kwilmu'kw Maw-klusuagn Negotiation Office
Kts – knots
kWh – kilowatt hour
LFAs – Lobster Fishing Areas
M - metre
MEKS – Mi'kmaq Ecological Knowledge Study
MRC – Marine Renewables Canada

MRE – Marine Renewable Energy
MSX – Haplosporidian parasite
MW – Megawatt
NAFO – North Atlantic Fisheries Organisation
NAREC – National Renewable Energy Centre/New and Renewable Energy Centre
NB – New Brunswick
NL – Newfoundland
NOTMAR – Coast Guard Notices to Mariners
NS – Nova Scotia
NSCC – Nova Scotia Community College
NSDOE – Nova Scotia Department of Energy
NSPI – Nova Scotia Power Inc.
OEER – Offshore Energy Environmental Research Association
OERA – Offshore Energy Research Association of Nova Scotia
OREG – Ocean Renewable Energy Corporation
ORPC – Ocean Renewable Power Company
PAHs – Polycyclic aromatic hydrocarbon
PCBs – Polychlorinated biphenyl
PEI – Prince Edward Island
R&D – Research and Development
RAMSAR – Term used for an internationally designated wetland of significance (named after the town in Iran where the Convention on Wetlands was signed in 1971)
ROV – Remotely Operated Vehicle
SARA – Species at Risk Act
SCOTIA – Nova Scotia Steel and Coal Company
SEA – Strategic Environmental Assessment
TAC – Total allowable catch
TISEC – Tidal In-Stream Energy Conversion
UEBO – Unama’ki Economics Benefits Office
UNESCO – United Nations Educational, Scientific and Cultural Organization
UNIR – Unama’ki Institute of Natural Resources
WaveEc – Wave Energy Centre
WEC – Wave Energy Conversion

1. Introduction

1.1 Study Objectives

The Offshore Energy Research Association of Nova Scotia (OERA, formerly the Offshore Energy Environmental Research Association – OEER) has been retained by the Nova Scotia Depart of Energy (NSDOE) to manage the Strategic Environmental Assessment (SEA) for marine renewable energy in coastal Cape Breton and the Bras d'Or Lakes. Similar to the work completed for the Bay of Fundy in 2008 - the Phase I SEA - the Cape Breton Phase II SEA is a consultative process aimed at exploring the social, economic and environmental features and effects associated with marine renewable energy (MRE) projects. The SEA is an early step in the province's incremental approach to developing Nova Scotia's marine renewable energy resources.

The objective of the Background Report is to provide a reference tool for use in the Phase II SEA for the deployment of MRE projects in coastal Cape Breton and the Bras d'Or Lakes. The report complements and expands on background information collected during the Phase I SEA undertaken for the Bay of Fundy, evaluates the progress of the marine renewable industry relative to 2008 when the Phase I SEA was completed, and describes various project scenarios that will be used during the Phase II SEA to help decision-makers determine when and under what conditions commercial MRE projects will be allowed in Cape Breton.

The Background Report describes the biophysical, socio-cultural and economic features of the region, outlines Nova Scotia's existing energy landscape and infrastructure, describes the government's energy policies and renewable energy goals, and shows how a mix of renewable energy projects can be integrated into that landscape.

Within this broad overview of the province's current energy situation and Nova Scotia's future energy needs, the Background Report:

- Describes the wave, wind and tidal regimes in coastal Cape Breton and the Bras d'Or Lakes;
- Identifies the geographic areas potentially favourable for different types of offshore MRE projects; and,
- Describes how different scale projects using differing technologies may be developed.

To be useful to residents who may be affected by these projects, and to community, municipal, provincial and federal decision-makers who will be called upon to support or facilitate these projects in the future, the Background Report adopts a cautionary approach to marine renewable development. The Report broadly assesses the potential interactions between the energy conversion devices and the marine and social ecology of Cape Breton. While MRE projects are not common, several existing international projects are examined for lessons learned on marine ecosystem interactions, likelihood and significance of impacts, mitigation measures, monitoring and conflict resolution with fishers, tourist operators, recreational fishermen and other resource users.

Finally, since MRE projects may have environmental and social effects on the region, stakeholders such as residents and business owners, local government and First Nation communities; need to know what potential economic benefits may be realized under differing development scenarios. The Background Report presents both potential positive and negative economic outcomes associated with these projects.

The project area is shown on Figure 1, which includes many of the place names used in this report.

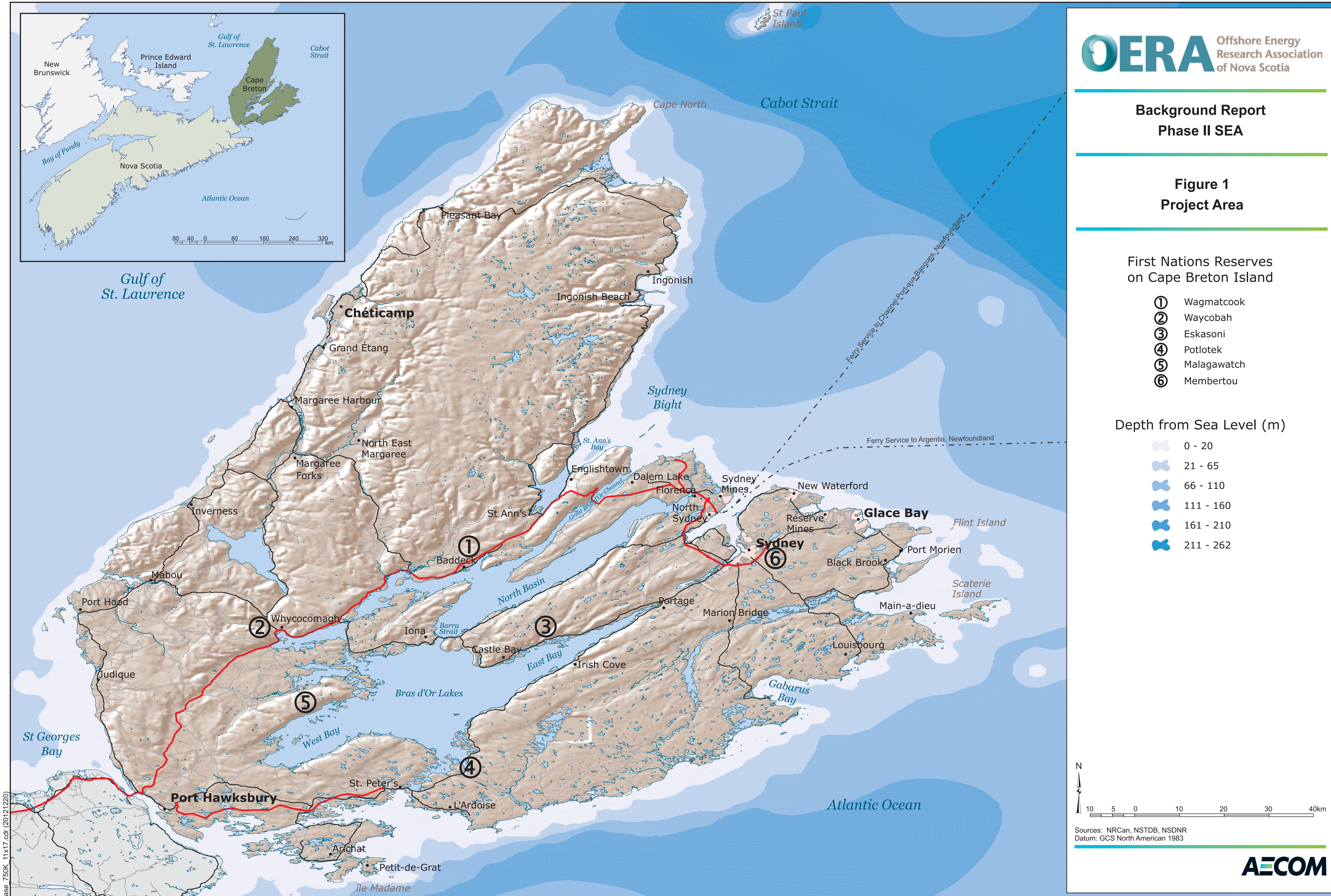


Figure 1
Project Area

1.2 Background

Efforts to exploit tidal energy in Nova Scotia date to 1607 when a grist mill partially dependant on tidal energy was constructed by early French colonists in Port Royal, NS. The potential to generate electricity from tidal power in Nova Scotia was later explored by entrepreneurs and provincial governments, mainly within the Bay of Fundy, during the 1960s and 1970s. In 1984 the Annapolis Royal Generating Station was completed and this 20 MW turbine-based power plant has been functioning without significant interruption since its installation.

In recent years, work undertaken by the Electric Power Research Institute (EPRI) on behalf of the NSDOE and Nova Scotia Power Inc. (NSPI) identified Nova Scotia as one of the most promising locations for tidal power generation in North America. Among other sites, EPRI identified Great Bras d'Or Channel as one of eight project sites in Nova Scotia with tidal energy potential (EPRI 2006).

In 2007 NSDOE commissioned the Offshore Energy Environmental Research Association (OEER, now OERA) to complete a Phase I SEA to guide the development of marine renewable energy in the Bay of Fundy. The SEA was completed in 2008 and the Environmental Assessment for the Fundy Tidal Energy Demonstration Project began shortly after.

In 2010, the province released the Renewable Electricity Plan and Renewable Electricity Regulations, and introduced the Community Feed-in Tariff (COMFIT) program to help reduce greenhouse gas emissions, provide a local supply of clean energy and create employment in Nova Scotia. The program began accepting applications in September 2011. Almost 100 community-based COMFIT proposals have been received from more than 20 community groups. The COMFIT program allows eligible groups to receive a fixed price per kilowatt hour (kWh) for projects producing electricity from wind, biomass, in-stream tidal and run-of-the river hydroelectric developments. Rates were established for small scale tidal energy by the Utility and Review Board at $ 0.652 per kWh, including two project initiated by Fundy Tidal Inc. in Cape Breton. The COMFIT program will help the province reach its renewable electricity targets of 25% renewable electricity by 2015 and 40% by 2020.

In mid-2011, the Fournier Report on Marine Renewable Energy Legislation was tabled, followed by the Marine Renewable Energy Technology Roadmap in late 2011. Finally, Nova Scotia's Marine Renewable Energy Strategy was released in May, 2012. The current Background Report, funded by the Nova Scotia Department of Energy through OERA, builds on this long history of government and public support for the renewable energy industry in Nova Scotia.

Given that Nova Scotia's government, industry and private citizens wish to consider MRE projects in Cape Breton, the Government of Nova Scotia will complete the SEA process before evaluating the merits of any specific project. The SEA assesses the environmental and social impacts of potential MRE projects in general and provides stakeholders with an early opportunity to influence decisions related to planning, policies, regulation, and management before specific projects are allowed to proceed. As noted, the Phase II SEA for Cape Breton will build on the lessons learned from the successfully received Phase I SEA undertaken for tidal energy development in the Bay of Fundy.

1.3 Renewable Energy in Nova Scotia

Nova Scotians are among the highest per capita consumers of electricity in the world (NSDOE 2009). The 450,000 business and residential users currently consume approximately 12,000 gigawatt hour (GWh) of electricity annually, of which about 11% came from renewable sources in 2010 and 17% from these sources in 2012 (NSDOE 2010; NSPI 2012). The province uses a peak load of about 2200 megawatt (MW) of electricity during cold winter periods and approximately 700 MW on warm summer evenings. Moreover, electricity consumption is increasing at an approximate rate of 1% per year (NSDOE 2009). Given that the province has only limited links to additional power sources in the rest of Canada (see below), Nova Scotia is essentially isolated from these sources and must produce nearly all the electricity it consumes.

Currently, almost 80% of Nova Scotia's electricity supply is generated from imported coal, petroleum coke and fuel oil while the remainder comes from natural gas and renewable sources such as hydro, wind and tidal power (NSDOE 2010). The government of Nova Scotia has long realized that the over-reliance on imported coal and oil exposes the province to extreme international price fluctuations, potential disruption in supply and excessive greenhouse gas and air pollutant emissions (NSDOE 2009).

Nova Scotia has four coal and petroleum coke-fired generating stations with a combined installed capacity of 1,252 MW (Nova Scotia Power in SLR 2010). To supplement the power generated at these stations Nova Scotia has 33 hydro generating stations with a combined installed capacity of 360 MW. The Annapolis Tidal Power Plant, one of only three such stations in world, adds an additional 20 MW to the grid. Approximately 35 wind farms or wind turbine projects provide an additional estimated 290 MW of power (SLR 2010). Together, these sources provide an estimated 2,340 MW of electricity.

In order to lessen the province's dependency on imported fossil fuels and reduce greenhouse gas and air pollutant emissions, the Government of Nova Scotia tabled the 2009 *Renewable Electricity Strategy* followed by the 2010 *Renewable Electricity Plan*. These reports describe an approach to integrate progressively larger amounts of low-emission renewable energy into the provincial electrical grid. At the same time, development of the renewable energy industry is expected to promote employment opportunities and other economic benefits in rural Nova Scotia. To achieve these objectives, the *Renewable Electricity Plan* requires fully 25% of the electricity consumed in Nova Scotia to be generated from renewable sources by 2015. By 2020, this target rises to 40%. Also by 2020 the province intends to achieve a 20% increase in energy efficiency and will reduce greenhouse gas emissions by 10% below 1990 levels. Following consultation in 2010, renewable electricity targets for 2011, 2013 and 2015 were enacted into law in the *Renewable Electricity Regulations* (2010) made under section 5 of the provincial *Electricity Act.*

An estimated 1,700 GWh of new renewable electricity will be needed to meet the legislated 2015 targets. To achieve the 2020 targets (which are not yet regulated into law), an additional 1800 GWh of renewable electricity will be required on an annual basis (NSDOE 2010).

The *Renewable Electricity Plan* describes three initiatives that will be implemented to meet the renewable energy targets:

1. An Enhanced Net Metering program, which provides individuals the opportunity to receive payment for the extra renewable electricity they produce while powering their home or business. Qualifying projects may be up to 1 MW in size;

2. A series of feed-in tariffs, one for community-based entities and one for developmental tidal projects;

    - The COMFIT program that pays fixed rates (65.2 cents per kWh) for electricity generated from small-scale, in-stream tidal energy projects owned by community-based entities such as First Nations, municipalities, co-operatives, universities, community economic development investment funds (CEDIFs) and non-profit groups. Launched in September 2011, approximately 100 MW is expected to be connected to Nova Scotia's distribution grid through the COMFIT program. These projects are small in size as they are connected to the distribution grid, ensuring the power they produce stays within the local community. As of July 2012, more than 25 community groups have submitted COMFIT applications for over 100 renewable energy development projects; and,

- A feed-in tariff (FIT) rate for developmental tidal projects to encourage research and development in Nova Scotia's tidal energy industry. The Nova Scotia Utility and Review Board is expected to set the rate for these projects in spring 2013. Developmental tidal projects are defined as those projects that are greater than 500 kilowatts in capacity and are connected to Nova Scotia's transmission grid.

3. A Renewable Energy Administrator to supervise independent power producer competitions for medium and large scale renewable electricity projects. A total of 600 GWh has been allocated to these larger projects, to be equally split between independent power producers and NSPI.

While it appears that the 2013 renewable electricity targets can be met with modest investments in transmission infrastructure and careful management of electrical loads on the existing grid, meeting future targets will require new lines to serve remote project locations, increased line capacity to deliver newly-produced renewable electricity, and modifications to infrastructure that will allow accommodation of intermittent wind and tidal power (NSDOE 2010). This topic is expanded in section 5.11.6.

1.4 Role of Tidal Energy

Within the 2010 *Renewable Electricity Plan*, the Government of Nova Scotia expressed its commitment to promote the development of tidal energy through its continuing support of the Fundy Ocean Research Centre for Energy (FORCE), and announced additional plans and programs intended to build on the momentum generated by the FORCE Project (NSDOE 2010). These programs include:

- Establishment of a government-led interdepartmental Marine Renewable Energy Task Force with input from the private sector to develop strategies for commercializing marine renewable energy;

- Establishment of a FIT program to help offset the costs of designing, building and deploying grid-connected arrays of tidal turbines; and,

- Identification and assessment of additional tidal sites for their potential to generate electricity.

The Background Study to support the Phase II SEA for coastal Cape Breton and the Bras d'Or Lakes originates from the third of these programs.

In May 2012, the Government of Nova Scotia released the *Marine Renewable Energy Strategy* to guide and support the development of tidal, offshore wind and wave power projects in Nova Scotia (NSDOE 2012). The *Strategy* outlines the economic, legal and policy conditions needed to advance the renewable energy industry in Nova Scotia and capitalize on opportunities for investment and economic growth. It describes the technologies and services that will promote commercial energy projects and help establish a world-class MRE industry in Nova Scotia that can in turn be exported around the world. The *Strategy* has three main components:

1. A Research Plan – the province will "foster partnerships and multi-disciplinary research projects that address knowledge gaps and develop an integrated long-term research plan that brings key players together." This includes the formation of a research group called the Tidal Energy Research Forum and the upcoming Phase II SEA for marine renewable energy in Cape Breton;

2. A Development Plan – the province will encourage MRE projects by assisting technology development for both large and small-scale tidal projects, opening markets to electricity and helping to build a Nova Scotia-based supply chain for tidal power; and,

3. A Regulatory Plan – the province will develop a legislative framework and regulatory system to help licensing, environmental assessment and protection, community benefits and provincial tax revenue. This will entail new regulations and a comprehensive stakeholder engagement plan.

1.5 First Nation Participation

In 2011, the Government of Nova Scotia funded the development of a Mi'kmaq-specific Renewable Energy Strategy. The Mi'kmaq Renewable Energy Strategy supports the Assembly of Nova Scotia Mi'kmaq Chiefs in successfully pursuing direct and indirect renewable energy opportunities in Nova Scotia, ensuring the participation of the Mi'kmaq of Nova Scotia in the growing renewable energy sector

The Nova Scotia Department of Energy has also funded the hire of an Energy Advisor to work at the Kwilmu'kw Maw-klusuaqn Negotiation Office (KMKNO) to provide energy sector technical and policy support capacity to the Assembly. Additionally, the Department has hired an Aboriginal Business Development Officer to work with the KMKNO and Nova Scotia's Mi'kmaq communities to assist in exploring potential energy sector prospects. These initiatives build Mi'kmaq capacity on energy issues and will help the Assembly identify energy sector business opportunities and implement the Mi'kmaq Renewable Energy Strategy (NSDOE 2012).

1.6 Study Limitations

The scope of this study is outlined in the Request for Proposal issued by OERA (at the time, OEER), and certain limitations are expressed within that document. The scope of work is broad and inclusive of many coastal and community features but is not intended to address each issue in detail.

General corporate limitations that apply to this study are given at the beginning of the report. Specific limitations to the work in this report are similar to those expressed in the Phase I Background Study (Jacques Whitford 2008) and include:

- This report does not to assess the commercial viability of any particular ocean energy technology, development scenario or project location;

- The marine renewable energy development scenarios presented as examples are based on a general overview of site characteristics favorable to tidal energy development. This study does not identify "preferred" scenarios or conclude that other locations would not be viable;

- As was the case in 2008, there is limited information on the cumulative interactions of more than one ocean renewable energy project in an area, or the effects of large scale energy extraction from a particular location. Although work is being conducted to address these knowledge gaps, the lack of data is due to the lack of grid-connected commercial scale device arrays at this time; and,

- This report focuses primarily on potential environmental and socio-economic interactions within the *marine* environment. Potential impact of the *land-based* components on nearby residents and the environment would be more appropriately evaluated during project specific assessments, and are not the focus of this Background Study.

1.7 Study Team

The study team assembled to complete this work consisted of:

Cape Breton University
- Dr. Bruce Hatcher
- David Alderson
- Qi Xu
- With contributions from Amanda Tarr

Unima'ki Economic Benefits Office
- Alex Paul
- Janice Basque

Atlantic Marine Geological Consulting
- Gordon Fader

Oceans Ltd.
- Simon Melrose
- Adam Wadsworth
- Judith Bobbitt

AECOM Canada Ltd.
- Russell Dmytriw
- Candace Harding
- Stephen Pinto
- Krista Phillips
- Iain Bell
- Blair Shoniker

AECOM wishes to express our gratitude for the input, professionalism and guidance provided by members of the project team during the course of this work.

2. Study Methods and Issues Scoping

2.1 Approach

This report differs from the 2008 Phase I Background Report for the Fundy SEA in two respects:

1. The study area consists of two distinct biophysical environments: offshore of coastal Cape Breton, and the Bras d'Or Lakes. These two areas are described separately so that the potential environmental effects of MRE projects within each area can be more clearly understood. Distinctions between the offshore environments of the Scotian Shelf and the Gulf of Saint Lawrence are also made; and,

2. The terms of reference require an evaluation of three different types of MRE project: offshore wind, wave energy conversion and tidal energy conversion. While all three are addressed in this report, the terms of reference specifically requests that more emphasis is placed on tidal energy projects, which are thought to be more suitable than wind and wave projects in these areas.

With respect to the existing biophysical and socioeconomic environments that have potential for energy harvesting, this report attempts to provide the same level of detail as the Phase 1 Background Report for the Bay of Fundy. But where available, it makes reference to current summary descriptions so as to avoid needless repetition. Similarly, high level descriptions of the different tidal technologies and their environmental interactions are provided in order to remain consistent with the format of the Phase I report.

In keeping with the study approach adopted for the Phase I Background Report for the Fundy SEA, this report identifies **Key Environmental Issues (KEIs)** that describe the environmental and socioeconomic issues of interest around MRE projects in coastal and offshore Cape Breton and the Bras d'Or Lakes. In addition to describing potential environmental and socioeconomic interactions, this report presents an overview of project planning and management considerations that may be used to avoid or reduce potential environmental interactions.

The report describes typical "large scale" and "small scale" tidal power projects and their potential interactions with the region's environment. Large scale refers to tidal energy conversion devices that are typically 1MW or larger, while small scale devices are typically less than 1 MW.

This report focuses on several broad areas of interest for tidal energy development:

1. The Bras d'Or Lakes (specifically, Barra Strait and the Great Bras d'Or Channel);
2. Mid-way up the western coast of Cape Breton Island off Cheticamp;
3. Off Cape North and around St. Paul Island;
4. Around Scatarie Island/Flint Island; and,
5. Along the south east coast of Cape Breton to Forchu.

These areas were selected based on earlier current measurements and limited recent studies that appear to indicate adequate velocities, sea bottom characteristics, and these sites' location relative to shoreline transmission infrastructure.

2.2 Issues Scoping and Key Environmental Issue Selection

In keeping with standard environmental assessment methodology, the KEIs (the factors or issues selected for assessment) are

- Those aspects of the biophysical and socioeconomic environment that may be affected by the implementation of MRE projects; and/or,

- Those aspects that are valued by local residents, businesses and government regulators.

A list of these KEIs was presented in the Phase I Background Study to the Bay of Fundy SEA, which in turn was based upon typical environment-project interactions established at MRE project sites in other jurisdictions. These KEIs, along with other topics specific to Cape Breton, were included in the terms of reference issued by OERA for this report. In order to update this list for the current report, both sources (the Phase I SEA and the Phase II Request for Proposal) were used.

Table 1 compiles the KEIs from the Phase 1 Background Report and RFP, describes why these issues are important and directs the reader to the report section that describes or evaluates each specific issue.

Table 1. Scoping of Key Environmental Issues

Environmental Component [1]	Scoping Considerations	Selected Key Environmental Issue
Currents, Tides Waves and Wind	These factors are critical to the siting and economic success of MRE* projects. Energy extraction may cause negative biophysical effects	• Critical Physical Processes (Section 6.1)
Seabed Type, Topography and Sediment Transport	Seabed characteristics are an important consideration in project location and mooring design. They may provide critical habitat for species affected by MRE installations.	• Critical Physical Processes (Section 6.1)
Noise and Vibration	Natural background noise levels vary considerably by location and over time. Increases in background noise at specific sites may have negative effects on marine life.	• Fisheries (Section 6.2) • Fish and Fish Habitat (Section 6.3) • Marine Mammals (Section 6.6) • Marine Birds (Sections 6.7) • Aquaculture (Section 6.9)
Benthic Ecology	As above, aspects of MRE projects may negatively affect marine species, both directly and indirectly. Also MRE projects occupy marine habitat space. Projects may affect protected or vulnerable species listed under the *Species at Risk Act.* Fish and fish habitat are protected under the Canadian *Fisheries Act.*	• Marine Benthic Habitat and Communities (Section 6.5)
Sediment and Water Quality	Marine sediment and water are pathways for potential ecosystem effects on benthic communities and fish. Fish habitat is protected under the *Fisheries Act.* Both sediment and marine water quality are inherently linked to habitat quality for aquatic species.	• Pelagic Communities (Section 6.5) • Marine Benthic Habitat and Communities (Section 6.5) • Fish and Fish Habitat (Section 6.3)
Protected Sites and Species	Biodiversity protection is legislated under the *Species at Risk Act, Nova Scotia Endangered Species Act, Nova Scotia Wildlife Act,* and the federal *Migratory Birds Convention Act.* Protected Sites such as listed RAMSAR sites, marine protected areas, biosphere reserves and wildlife protection areas can be affected by MRE projects.	• Species at Risk (Section 6.8) • Marine Birds (Sections 6.7) • Marine Mammals (Section 6.6) • • Fish and Fish Habitat (Section 6.3)
Ice	Ice cover can interfere with surface piercing components of MRE projects and some wave energy converters. Ice also	• Critical Physical Processes (Section 6.1)

Environmental Component [1]	Scoping Considerations	Selected Key Environmental Issue
	interferes with maintenance and monitoring activities. Ice serves an essential role in the life cycles of many cold water life forms (e.g. seals).	
Shipping and Navigation	Shipping concerns (excluding fisheries listed below) are linked to potential impediments to navigation, safety issues, and exclusion from MRE project areas. These factors are regulated under the *Navigable Waters Protection Act.*	• Marine Transportation (Section 6.10)
Recreation and Tourism	Recreation and tourism are highly prized attributes of the Bras d'Or Lakes and coastal Cape Breton. In addition, permanent and seasonal residents value the existing aesthetic appeal of these areas. MRE projects have the potential to both facilitate and interfere with tourism and the enjoyment of aesthetic values.	• Tourism and Recreation (Section 6.11)
Historic Resources	Both marine and coastal historical resources may be affected by the installation of MRE projects. Protection of these resources is legislated under the Nova Scotia *Special Places Protection Act.*	• Archeology and Heritage Resources (Section 6.12)
Community Economic Development	MRE projects have the potential to promote economic activity on many levels: education and training, manufacturing, assembly, sales & payroll tax, direct labour and a multitude of support services.	• Economic Development (Section 6.13)
Marine Birds and Marine Mammals	These species have high cultural, economic and aesthetic values. Regulatory protection under the *Species at Risk Act, Nova Scotia Endangered Species Act,* and *Nova Scotia Wildlife Act.*	• Marine Birds (Section 6.7) • Marine Mammals (Section 6.6
Pelagic and Benthic Marine Communities	Certain species are critical to the economic and cultural well-being of the region. Such organisms are always supported by communities and habitats, the integrity and resilience of which are ultimately required to sustain benefits to humans. Concerns have been expressed over the potential negative effects of MRE projects on species abundance, biodiversity and accessibility to harvested resources (commercial, recreational and Aboriginal fisheries). Fish and fish habitat is protected under the *Fisheries Act.* Species of special concern are protected under the *Species at Risk Act.*	• Fish and Fish Habitat (Section 6.3) • Pelagic Communities (Section 6.5)
Commercial Fisheries and Aquaculture	An important (and in the case of aquaculture), growing facet of the regional economy; fundamental socio-cultural and economic activity. Includes recreational fishing.	• Fisheries (Section 6.2)

(1) Other topics listed in the Request for Proposal (OEER Feb. 16th, 2012) are described elsewhere in the report
*MRE = Marine Renewable Energy

2.3 Issues Addressed in this Report

This section briefly outlines the major issues with respect to MRE projects that are of interest to potential project developers, regulators, and community residents. These issues were identified in the scope of work issued by OERA for this project and reflect concerns raised during the Phase I Background Report, as well as subjects thought to be helpful for a general understanding of MRE projects in Cape Breton. Each of these issues is presented in more detail in subsequent sections of the report.

2.3.1 Potential Biophysical and Socio-Economic Interactions

Projects may have both positive and negative impacts to the biophysical environment and nearby economy. When debating the various attributes of MRE projects, these impacts often form the core of most discussions. Given the importance of potential project impacts to stakeholders and decision-makers, section 6.13 of this report describes these positive and negative interactions in as much detail as possible, given the existing state of knowledge of local ecosystems and the fact that that no specific project has yet been designed. To the extent possible, the nature, likelihood and significance of these interactions are described. Information regarding potential project impacts is taken from research and reports from wave, offshore wind and tidal energy projects in various jurisdictions around the world.

With respect to the biophysical environment, MRE projects may affect a specific biological component (for example a fish's habitat or a particular seabird's offspring), or a general physical process that in turn affects a specific biological component (such as changes to currents or sedimentation patterns that in turn affect the settlement of lobster larvae). Table 2 summarizes the potential MRE project impacts on both biological components and the physical process that affect these components.

Table 2. Potential MRE Project Interactions

Project/Construction Phase	Physical Process Interaction	Biological Component Interaction	Socioeconomic Component Interaction
Project/Cable Installation	• Sediment transport (suspension, scour)	• Marine Benthic Habitat and Communities • Marine Mammals (temporary displacement) • Fish and Fish Habitat	• Marine Transportation • Economic Development • Fisheries • Aquaculture • Tourism and Recreation
Project Operation	• Reduced or altered current velocities • Reduced tidal amplitude • Modified wave height, period or direction • Degradation of anti-fouling coatings into the marine ecosystem • Electro-Magnetic Fields (EMF) and noise	• Marine Pelagic and Benthic Habitats and Biological Communities • Marine Mammals • Fish and Fish Habitat • Sea birds	• Marine Transportation • Economic Development • Fisheries • Aquaculture • Tourism and Recreation
Maintenance	• New anti-fouling agents • Removal of marine life affixed to the MRE unit • Spills from maintenance vessels • Re-introduction of lubricating oils	• Marine Benthic Habitat and Communities.	• Marine Transportation • Economic Development • Fisheries • Aquaculture • Tourism and Recreation
De-commissioning	• Similar to installation	• Similar to installation	• Similar to installation

(Source: Michel *et al.* 2007 in Jacques Whitford 2008)

2.3.2 Identification of Data Gaps

Each of the contributors to this report was asked to identify information or data gaps that were encountered during the data collection phase of the project. In addition, each researcher was asked to describe the significance of the data gap in preventing a full assessment of the component or process in question. Finally, each was asked for recommend methods or steps that can be taken to fill these information gaps, either through future research or during the course of a project-specific environmental impact assessment. The data gaps are summarized in section 9.

2.3.3 Cumulative and Residual Environmental Interactions

The interactions between individual MRE projects and the environment (both biophysical and socioeconomic) can overlap in space and time to create cumulative interactions. Should such a cumulative interaction occur, its positive or negative impact on a biological component, a physical process or a local economy may be larger than the sum of individual impacts from each separate project element. It is also possible for a MRE project to interact cumulatively with other, non-MRE projects in the area. For these reasons cumulative impacts are described separately in section 7.

To certain degree, this description is necessarily general since there are no actual commercial MRE projects in place that we can use for examples. Nevertheless, cumulative interactions for each key environmental issue are described at a conceptual level so that readers will have a broad sense of how these projects may interact with the environment. Residual impacts (those that remain after a project proponent has done his best to reduce or eliminate project impacts) are also described in general terms. Again, since it is not possible to predict the type or success of mitigation measures a project proponent might use, the description of residual effects relies on experiences from other jurisdictions.

2.3.4 Conflict Mitigation

In contrast to the Minas Passage where commercial traffic is minimal and the extreme tidal currents restrict the fishing community to a few specialized operators, coastal Cape Breton and the Bras d'Or Lakes are frequently traversed by a wide variety of commercial and recreational vessels. The potential for conflict between MRE project developers and other more traditional users of these waterways is a key issue expressed by all people interested in MRE projects. Section 7.3 describes how possible conflicts may develop in the context of an MRE project, and outlines some methods that may be used to resolve or minimize these conflicts.

2.3.5 Contributions to Community Economic Development

As was clearly demonstrated during the Phase I SEA undertaken for the Bay of Fundy, MRE project development must be accompanied and underpinned by local economic development throughout the project lifecycle. While it is not possible at this early stage to calculate economic benefits to local communities, section 5.12 outlines the nature of the benefits that may be realized, while at the same time describing how such benefits can be maximized and retained within Cape Breton for the benefit of local aboriginal and non-aboriginal communities.

3. Ocean Renewable Energy

3.1 State of the Marine Renewable Energy Industry

The marine renewable energy industry has continued to evolve and expand since the Phase I SEA for the Bay of Fundy was completed in 2008. There are more technically viable prototypes and demonstration-phase tidal and wave converters than in 2008, while certain leading technologies have advanced through additional testing and grid connection. Although offshore wind turbines have been deployed in commercial array configurations, to date no wave or tidal converter arrays have yet been installed.

The most advanced technology, offshore wind power, has undergone 30 years of development in northern Europe. Land-constrained northern European countries such as the UK, Denmark and the Netherlands have installed most of the world's existing off-shore wind capacity, although China has at least one offshore wind project and others in the planning stage. As of June 2011, there was over 3,200 MW of grid connected offshore wind capacity in Europe (Sun *et al.* 2012), an amount exceeding Nova Scotia's electricity requirements.

The UK continues to lead the world in deployment and testing of both wave and tidal energy converters. The European Marine Energy Centre (EMEC) was established in 2003 to test both wave and tidal energy technology and quickly became the centre of a vibrant technological research and development industry in the UK. As of early 2011, EMEC wave energy projects include Voith Hydro Wavegen's LIMPET device, Aquamarine Powers' Oyster 1 unit and EON's Pelamis P2 wave energy converter. With respect to tidal power, EMEC has hosted Open Hydro's early demonstration device, Marine Current Turbine's SeaGen unit, Atlantis Resources' AK1000 device and Tidal Generation Limited's DeepGen converter. In addition to EMEC, Pulse Tidal deployed its Pulse Stream 100 generator in the Humber River Estuary in 2009 while Marine Current Turbines deployed a SeaFlow unit off the coast of Devon.

As of March 2011, the UK had an installed grid-connected capacity of 1.31 MW of wave energy capacity and 2.05 MW of tidal capacity (Renewable UK 2011).

Another indication of the growth and momentum of the MRE industry is the number of government-supported test or demonstration facilities around the world. These include (Mueller *et al.* 2010):

- The European Marine Energy Centre in Orkney, northern Scotland;
- The National Renewable Energy Centre/New and Renewable Energy Centre (NAREC) in northeast England;
- Wave Hub (a grid-connected wave device testing facility) in southwest England;
- The Southwest Marine Energy Park in Bristol, Cornwall and Plymouth, UK;
- The Marine Institute in Galway, Ireland;
- The Wave Energy Centre (WaveEc) in Portugal;
- Nissum Bredning wave plant test site in western Limfjord, Denmark;
- The Northwest National Marine Renewable Energy Centre at the University of Oregon in Portland, USA;
- The Hawai'i National Marine Renewable Energy Centre;
- The Florida Atlantic University Centre for Ocean Technology in Dania Beach, Florida;
- The New England Marine Renewable Energy Center based in Massachusetts, USA; and,
- The Fundy Ocean Research Centre for Energy FORCE, near Parrsboro, Nova Scotia.

Over the past number of years as governments and project developers have invested more and more resources and funding in the MRE industry, it has become apparent that a series of internationally recognized standards for a variety of project components would be needed to attract the capital investment required for commercialization.

Through the International Energy Agency – Ocean Energy Systems (IEA-OES) group, an agreement has been reached by which guidelines for the testing of ocean energy systems will be introduced. EMEC in 2009 produced 13 Draft Standards for the Marine Renewable Energy Industry, including device performance standards, wave and tidal resource assessment standards, and guidelines for project development. The goal of this independent, co-operative work is to issue through the International Electrotechnical Commission (who established the Technical Committee 114, Marine Energy – Wave and Tidal Energy Converters) a collection of international best practice guidelines and recommended procedures that will become standards for the industry.

3.2 Greenhouse Gas Abatement

Tidal power has the potential to become a significant source of carbon-free, renewable, and predictable electrical energy located close to coastal load centers with high electricity demands (Polagye *et al.* 2010). However, the commercial tidal power industry is still relatively undeveloped and there are a number of technical and non-technical challenges to installing and operating commercial-scale arrays. These challenges include, for example, managing deployment and maintenance in high energy tidal environments, deploying and connecting subsea cables in these environments, and assessing cumulative environmental effects of multiple devices. Once these challenges are overcome, tidal energy may begin to replace coal and fuel powered generating plants and offset their greenhouse gas (GHG) emissions.

In Nova Scotia, approximately 46% of our GHGs come from electricity generation (NSDOE 2008). Research completed by Carbon Trust, a United Kingdom-based carbon reduction organization, suggests that the volume of carbon that could be avoided through the implementation of tidal energy could be tens of millions of tonnes of carbon dioxide per year in the UK, and hundreds of millions of tonnes of carbon dioxide worldwide (Carbon Trust 2006). The embedded emissions from construction are counter-balanced by many years of zero emissions electricity generation once the devices are operational. For example, the Severn Cardiff-Weston tidal barrage is estimated to emit 2.42 gC02 per kWh of electricity produced. This places tidal power in the very lowest category for power generation and compares well against other low carbon technologies such as nuclear power at 16 gC02 per kWh (Hammons 2011).

Carbon Trust (2006) suggests that up to several gigawatts capacity of each of wave and tidal stream energy could be installed in Europe by 2020 and notes this is comparable to the worldwide growth of wind energy during the 1980s. They estimate that this level of investment in marine renewable energy will lead to annual carbon dioxide abatements of 2.0 to 7.0 million tonnes of CO_2 per annum.

3.3 Principal Technology Types

Given the varied coastal and inland environments available in Cape Breton, several different emerging MRE technologies may be applicable in this region. This section describes the main characteristics of the most advanced technologies in four categories:

1. Offshore wind energy conversion through the use of wind turbines;
2. Wave energy conversion (WEC);
3. Tidal lagoons; and,
4. Tidal in-stream energy conversion (TISEC).

3.3.1 Offshore Wind Energy Conversion

Technology Description

In the past, offshore wind turbines were adaptations of devices designed for onshore use. In contrast, modern fabricators are developing turbines which have been specifically designed for offshore environments (AWS Truewind 2009). Modifications include corrosion protection adapted to the salt water environment, internal climate control to regulate the heat generated by the turbines, high-grade exterior paint, and built-in cranes for maintenance (Sun *et al.* 2012). Commercial turbines can be clustered to create wind farms where infrastructure can be shared and efficiencies created.

Large capacity horizontal axis wind turbines are the most common type deployed in commercial scale offshore wind arrays. Each turbine generates approximately 3MW of electricity, although turbines of up to 5 MW have been deployed. A vertical axis turbine generating a rated power of 10MW has also been prototyped by VertAx Wind Ltd. (AECOM 2011).

The main components of offshore wind energy conversion systems are the turbines, towers, foundations, and electrical collection / transmission systems. The electricity-generating turbine is set on top of a support structure consisting of a tower and foundation. Electrical equipment collects the generated electricity and transmits it to shore. Offshore electrical substations may also be installed to convert the wind energy prior to transmitting it onshore.

Today, the standard turbine design consists of a nacelle (gearbox, generator, and drive shaft), three blade-rotor assembly, the hub, and pitch systems (Figure 2). To maximize the efficiency, modern turbines have pitched blades and turbines are designed to pivot around the top of the towers to catch winds from all directions.

Towers typically range from 60 to 80 m above the surface of the water while the height to the tip of blade may reach 80-120 m. Towers are usually tubular shaped, although lattice-type towers are also used, and are fixed to the foundation on the sea floor. Monopiles (drilled into the seafloor) and gravity-based foundations (resting on the sea bottom) are the most commonly used bases; however, with the increasing number of projects planned in water depths exceeding 20-30 m, research and pilot installations have been undertaken for designs with broader bases such as jackets, tripods, and tripiles (AWS Truewind 2009).

The depth requirement depends on the foundation technique. Proven monopile technologies allow deployment in waters depths of up to about 40m. Floating structures could potentially be deployed in much deeper areas (>100m).

Over the long term, average wind speeds can be predicted and wind maps developed to provide reasonable estimates of available wind resources and the amount of electricity that can be generated. However, one of the shortcomings of both onshore and offshore wind energy is the technical problem of integrating intermittent wind-generated electricity with the power grid, which must provide a reliable load of power to its users on a continuous basis. If the wind is not blowing, the electricity shortfall must be made up with power from other sources. If these sources are coal and petroleum fired generating stations, then additional costs are created if a station must be kept on standby for extended periods of time or “fired up” on short notice.

Figure 2. Example of an Offshore Horizontal Axis Wind Turbine Array

Source: Ocean Power Magazine.net

State of the Technology

Offshore wind energy technology is essentially the same as that used onshore, making offshore wind energy conversion the most developed of the marine-based renewable energy technologies. Since the first offshore turbine was installed in Sweden in 1990, Europe has been the front-runner in the commercialization of offshore wind. As of June 2011, 49 offshore wind farms (a total of 1,247 turbines producing 3,294 MW) have been connected to the grid in nine European countries (Sun *et al.* 2012). In contrast, there are no offshore wind turbines installed in America[1]. This is be due to the fact that many of the potential sites are located in deeper waters, the relatively high cost of offshore wind energy compared to onshore wind (where many sites are still available), the lack of experience with offshore devices, proprietary technology, and the complexity and resulting length and expense of the US permitting process (Sun *et al.* 2012). Despite these difficulties, the Bureau of Ocean Energy Management created a Wind Energy Lease Area in early 2012 for future projects. The Area measures 743,000 acres and is located on the outer continental shelf off the coast of Massachusetts.

In Canada, three projects are proceeding through the regulatory process for installation in the Great Lakes of Ontario[2], while a fourth project has been proposed (to much opposition) for the Pacific Coast of Haida Gwaii, formerly called the Queen Charlotte Islands. In Asia, China is leading other countries with the 102 MW Donghai Bridge Wind Farm project near Shanghai, which has been contributing electricity to the grid since 2010. China has at least 10 additional offshore wind farms in the planning stage and intends to expand its offshore wind capacity to 5 GW by 2015 and 30 GW by 2020 (Sun *et al.* 2012).

Offshore wind energy is more expensive than onshore wind energy and larger investments are required to install offshore turbines. Current costs to deliver offshore wind energy to the grid range from $0.17 to $0.35 per kWh (International Energy Agency 2011, in NSDOE 2012), and this cost increases with water depth. For comparison, Nova Scotia's onshore wind is currently priced at $0.20-$0.75 per kWh, while coal and oil based generators sell power to residential consumers at $0.126 per kWh before taxes (NEB 2012, for June 2012).

The design of turbines and foundations has generally been optimized and numerous marine contractors exist with the competencies and experience necessary to install these devices. Most commercially installed offshore turbines have a rated output between 2 MW and 3 MW. Larger turbines with a rated output of 5 MW have been developed, and giant 10 MW and 15 MW turbines are currently being designed, although these turbines have not been tested commercially (Figures 3 & 4).

[1] the 130-turbine Cape Wind Offshore Wind Farm situated off Cape Cod anticipated for 2015 is expected to be one of the world's largest offshore wind projects.

[2] In February 2011 the Ontario government imposed a moratorium on all offshore wind farms in order to conduct more research on the impacts on human health and environment.

Figure 3. Conceptual 10 MW Vertical Axis Wind Turbine

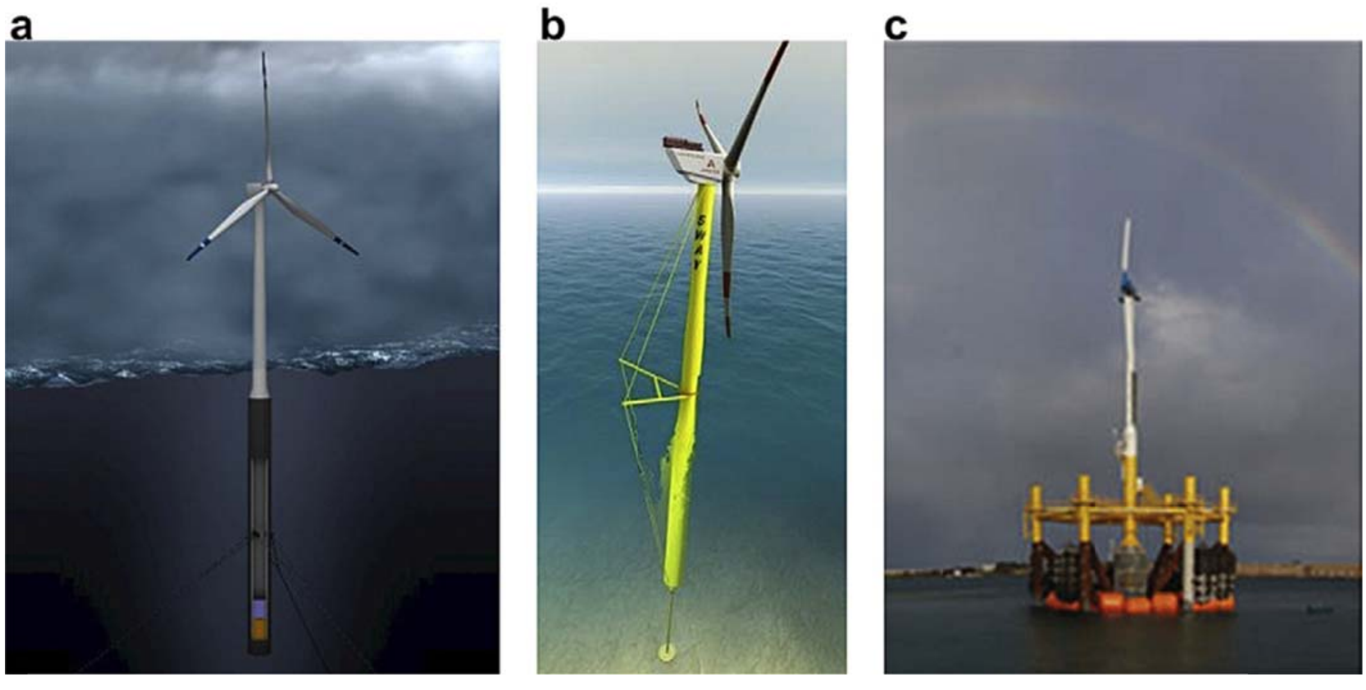
Source: vertxwind.com

Figure 4. Arup Engineering's Conceptual 10 MW Aerogenerator X

Source: Arup 2010

The horizontal axis "windmill" design is the most common turbine type although researchers have found that vertical axis turbines may perform better and be more cost effective in deep water. In addition, floating foundation technology is currently being developed, and some of these foundation designs have moved from the concept stage to the development of prototypes (Sun *et al.* 2012). Statoil's Hywind project is currently testing a full scale floating wind platform located 10 km off the coast of Norway. These new foundations include spars, tension leg platforms, and semi-submersible/hybrid systems (Figure 5).

Figure 5. Floating Wind Turbine Prototypes



(a): HyWind (spar); (b) Sway (tension leg/spar); (c) Blue H (tension let platforms) (source Roddier *et al.* 2010).

The first offshore wind turbine to be assembled on land, towed in place and installed without any heavy lift vessels or piles at sea was inaugurated in Portugal in June 2012 (Figure 6).

Figure 6. Windfloat 2 MW Turbine Installed in 2012, Portugal

Source: oceanpowermagazine.net

3.3.2 Wave Energy Conversion

Technology Description

There are a great number of designs for the conversion of wave energy to electricity, and more than 1,000 patents for this technology have been granted in North America, Europe, and Japan (Waveplam 2009). These designs are generally categorized depending on their installation location and design type. In terms of location, devices may be situated at the shoreline or nearshore, where they are close to transmission lines and other infrastructure, less expensive and easier to access for maintenance, and exposed to less extreme weather conditions. These smaller nearshore devices tend to have lower power ratings compared to more robust and expensive offshore designs. In both cases, WECs must be tethered or anchored to the bottom using anchoring or mooring systems.

Despite the large variation in design, the most advanced WEC technologies can be grouped into three types: attenuators, point absorbers, and terminators. Attenuators lie on top of the water and are installed perpendicular to the predominant wave direction. These devices "ride the wave" and movements along its length can be harnessed to produce energy (Figure 7). Point absorbers are smaller in size and may be floating or submerged. They absorb energy in all directions through bobbing movements at or near the water surface (Figure 8). Oscillating wave surge converters and oscillating water column converters are variations of point absorbers. Terminators (also called overtopping devices) physically intercept waves, and lie perpendicular to the predominant wave direction (Figure 9). Water is physically captured from the waves and held in a reservoir above sea level before being returned to the sea through a conventional turbine.

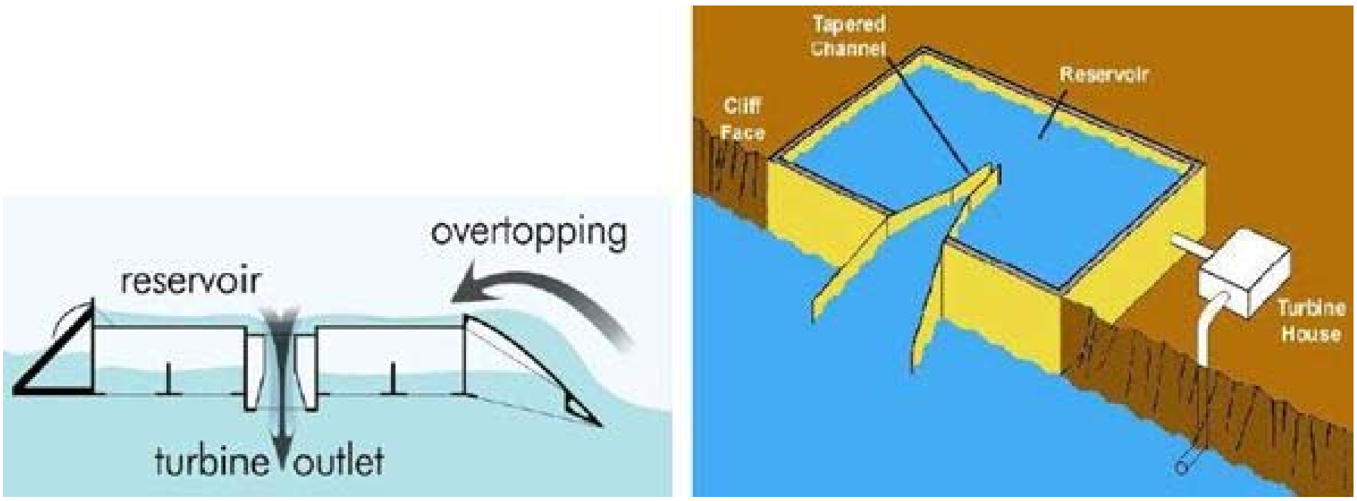
Figure 7. Attenuator WEC: Pelamis Wave Farm Concept

Source: Drew *et al.* 2009

Figure 8. Point Absorber WEC: OPT Powerbuoy Devices

Source: Drew *et al.* 2009

Figure 9. Terminator Type WEC



Source: www.coastalenergyandenvironment.web.unc.edu/

Within the three groups described, most devices can be further categorized by their mode of operation. Submerged pressure differential devices are point absorbers; as the crest of a wave passes over the device, the water pressure compresses the air in a cylinder moving the upper cylinder down. Then, as a trough passes over the device, the reduction in pressure causes the upper cylinder to rise back up. The device converts the vertical motion into electricity. Oscillating wave surge convertors are terminators; as a wave passes by a hinged deflector positioned perpendicular to the waves. The deflector moves back and forth, exploiting the horizontal particle velocity of the wave. Oscillating water column devices can be point absorbers or terminators; as waves approach the device, water is forced into a chamber with an opening below the waterline which applies pressure on the air within the chamber. This air escapes the chamber through a turbine used to generate electricity (Drew *et al.* 2009). Finally, floating articulating devices are terminators; a series of floating cylinders linked together are positioned perpendicular to incoming waves. As waves pass over the device, the wave bends each cylinder differently and the joints (containing pistons) compress gas or fluid used to spin a turbine.

Depending on design, WECs operate in depths ranging from 4 to 200m. Shoreline oscillating water column WECs operate in depths greater than 4m but require an abrupt slope at the shore. Wave rotor devices operate in shallow waters of 10-15m depth. Point absorbers can be used for a wide range of water depths, between 5m and 200m depending on the design. Attenuators and overtopping devices generally require waters deeper than 50m to operate (AECOM 2010). High energy waves are associated with deeper waters (more than 50m). As water becomes shallower, the wave energy is attenuated by interaction with the seabed. Given this, most wave devices are designed for deeper waters where it is possible to extract higher levels of energy.

State of Technology

WEC technology is relatively immature when compared to other renewable energy technologies. In the 1980s it was expected that WECs would reach commercialization within seven years; this sentiment was again expressed in 2000 when a new generation of WECs was under development. These ambitious schedules have led to contradictory perceptions: either the industry is further advanced than it actually is, or that the industry is not progressing at all (Waveplam 2009).

A number of technical challenges must still be overcome to achieve commercial competitiveness. As of 2009, "conversion efficiency" has been verified in these devices, but both "operational longevity" and "array economics" have yet to be confirmed. "Solo economics" have been partially verified (Waveplam 2009). The design of these devices has not been optimized and only a small number of devices have been tested at the large scale and deployed in the ocean (Drew *et al.* 2009). No single technology has demonstrated a significant advantage over the others but this is mainly due to the limited number of WECs deployed at the prototype scale (Waveplam 2009).

For wave projects the swell frequency and type, seasonal variations and extreme conditions will have an influence in the power output, marine energy converter survivability and weather windows for maintenance operations (EMEC 2009). Early estimates indicate that wave energy can be generated for a cost of $0.61 – $0.77 per kWh, which is expected to decrease as regulations are streamlined and technologies improve (to $0.51 per kWh by 2020).

A number of active research projects, both large and small scale, are currently underway in Europe including Waveplam in Spain (addressing non-technical barriers that may influence the growth of the industry), CORES in Ireland (addressing issues and knowledge gaps in specific critical components required for successful deployment), EquiMar in Scotland (proposing guidelines and procedures for ocean energy development and best practices to mitigate technical and financial risks) and Supergen Marine in the UK (research including Doctorates and training courses). One of the most promising WECs, the second generation Oyster 800 unit developed by Aquamarine Power, is currently being tested at EMEC in Orkney, as is Wello's 0.5 MW Penguin device. Additional WEC sites are planned for the coast of Ecuador (S.D.E. Ltd.). Alstom and the leading Scottish marine developer, SSE Renewables, have signed a joint venture agreement to develop the Costa Head Wave Project, an up to 200 MW wave energy site located north of mainland Orkney, in The Crown Estate's Pentland Firth and Orkney Waters Strategic Area.

The Aguçadora Wave Farm located approximately 5 km off the northern coast of Portugal is the world's first multi-unit wave farm and commercial wave energy project. Established in 2002, the Aguçadora Wave Farm has three Pelamis 750 kW WEC devices with a total installed capacity of 2.25 MW (Cornett 2006). Ireland has inaugurated a 1:4 scale WEC test centre in Galway Bay and is currently developing a full scale grid connected test centre at Belmullet (AECOM 2010). The Belmullet test site will operate for up to 20 years and will provide three separate test locations at various depths of water depending on the specific devices being tested:

1. Near-shore 10m to 25m water depth
2. Mid-water 50m water depth
3. Deep-water 100m water depth

Currently the most advanced WEC devices include:

Oyster 1 and Oyster 2 (Aquamarine Power of Edinburgh, Scotland). The company tested a 315 kW unit at EMEC in 2009 and will connect three Oyster 2 units to the grid at EMEC in 2012, producing 2.4 MW of electricity. In 2010 Aquamarine and their partner SSE Renewables were awarded the right to develop a 200 MW project in Scotland's Crown Estate marine lease area. This project is financially supported by the international power company ABB.

BOLT (Fred Olsen, Norway). This point absorber unit was originally tested off coastal Norway. A second generation 100 kW unit is scheduled for testing at WaveHub in the UK in the coming years.

PowerBouy (Ocean Power Technologies, US). The PowerBouy point absorber has been under development since 1994. The first grid connected unit was deployed off coastal Hawai'i in 2009 while a 150 kW demonstration model was installed at EMEC in 2011. OPT is currently designing an upgraded model, the PB500. In July 2012, OPT and Lockheed Martin announced an agreement to develop a 19 MW wave energy project off the coast of the state of

Victoria, Australia. OPT's Reedsport Wave Park power station, approved by federal regulators in August, 2012 will consist of ten large buoys that will collectively generate 1.5 MW of electricity. The power wave station will be located 2.5 miles off the Oregon coast and will be connected to the electric grid by an underwater cable.

Pelamis (Pelamis Wave Power and EON, Edinburgh, Scotland). The Pelamis P2 wave attenuator is being tested at EMEC, where the 0.75 MW device is grid connected. Pelamis Wave Power is developing the Farr Point Wave Farm in the Pentland Firth, Scotland at an initial capacity of less than 10 MW but the project is allocated up to 50 MW of capacity.

Oscillating Water Column (Wavegen, Scotland). This 20-250 KW scale project in Islay, Scotland is a shore-based installation to demonstrate technology that will ultimately be installed in a 4 MW project located in the Western Isles of Scotland.

Penguin (Wello Oy, Finland). The Penguin WEC has a power capacity of 0.6 MW and is currently being tested in Orkney, Scotland. The unit was installed in July 2012.

Wave Dragon (Wave Dragon Ltd., Denmark). The grid-connected Wave Dragon prototype was deployed in Nissum Bredning, Denmark in 2003. The company is currently developing a 1.5 MW model that can be scaled to 4 MW and 7 MW capacity. Using the 4 MW units, the company plans to build a 50 MW wave farm off the coast of Portugal.

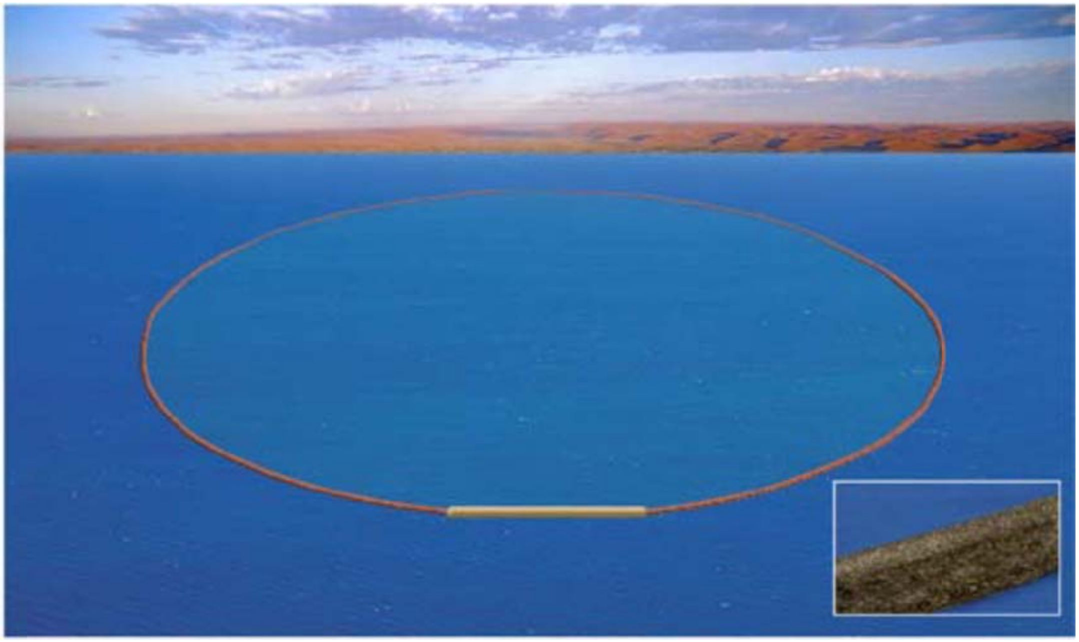
3.3.3 Tidal Lagoons

Technology Description

Tidal lagoons adapt the technology used for barrages or dams to the tidal environment. Situated in shallow water, tidal lagoons are typically self-contained circular impoundments, unlike a barrage that spans a natural gap in a bay (Figure 10). It is similar to certain WEC overtopping devices, except that tides rather than waves provide the energy. As the tide rises the lagoon fills creating a head pond. When the tide recedes there is a difference in the water level on either side of the lagoon wall. The water is released back to the ocean through turbines converting potential energy into electric energy. Turbines are bi-directional, such that lagoons can generate electricity four times a day, on each flood and ebb tide (INAZIN 2012, EAC 2009).

As a concept, tidal lagoons are considered to be technically and economically feasible (Friends of the Earth Cymru 2004) and may be less damaging to the environment than tidal barrages; however their effects on the environment are largely unknown. Tidal lagoons would likely occupy a large area, potentially smothering bottom habitats and affecting currents and water circulation (EAC 2009).

Figure 10. Tidal Lagoon Impoundment



Source: Tidal Electric Ltd.

State of Technology

Tidal Electric Limited has patented a tidal lagoon concept but at present there are no commercial scale tidal lagoons. The technology is reportedly well known since it is commonly applied in hydroelectric applications, tidal barrages (such as at Annapolis Royal and La Rance in France) and other power projects (Jacques Whitford 2008). As of 2009, a 60 MW project was proposed for Swansea Bay in the United Kingdom and a 300 MW project was proceeding to the installment phase in a lagoon off the coast of China (USDOE 2009a).

3.3.4 Tidal In-Stream Energy Conversion

Technology Description

TISEC requires flowing currents to turn a rotating element, converting mechanical rotational movement into electrical energy. This is similar to the technology used in wind energy conversion but since water is much denser than air the energy potential of tidal currents is significantly higher than that of winds (E3 Inc. 2007). As a result, TISEC turbines can be built considerably smaller than those used for the conversion of wind energy.

TISEC devices are generally categorized by the orientation of the axis from which the turbine is suspended. Horizontal axis TISECS are the most common: the axis is parallel to the sea surface. TISEC devices with horizontal axis most closely resemble the design of modern wind turbines and extract energy from moving water in much the same way as wind turbines extract energy from air currents. These devices are oriented into the direction of the current and blades rotate perpendicular to the axis (Figures 11-14).

TISEC devices with vertical axis have blades oriented parallel to the axis of rotation, rather than perpendicular to it, but energy is extracted in the same manner (Figure 15).

Figure 11. Marine Current Turbines SeaGen Technology (Horizontal Axis)

Source: www.marineturbines.com

Figure 12. Open Hydro Technology (Horizontal Axis)

Source: this study

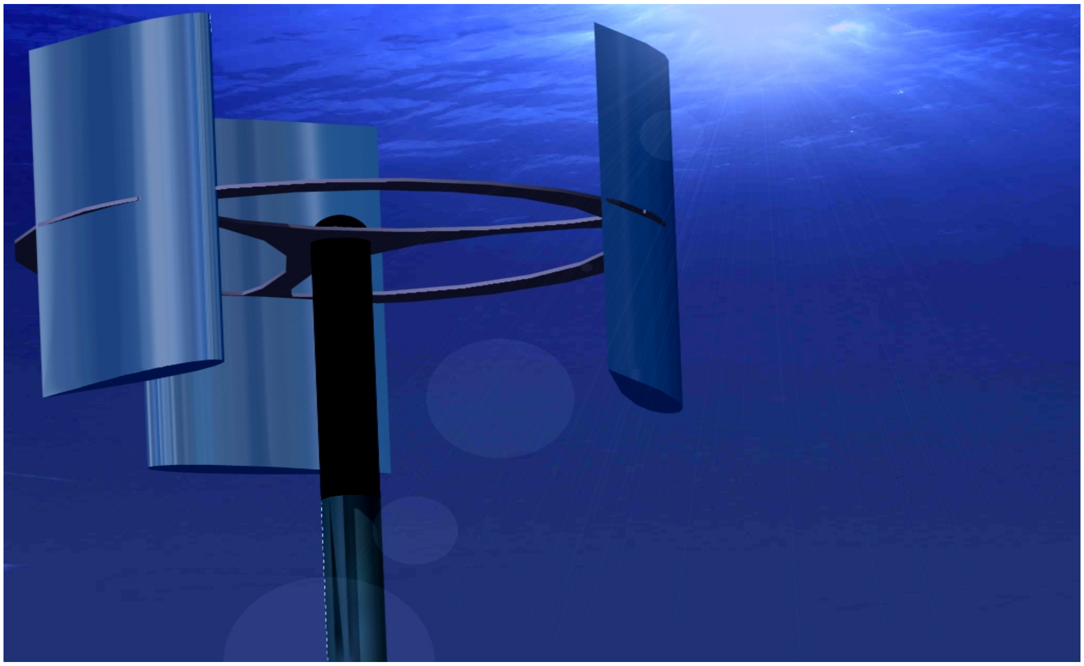
Figure 13. Open Hydro Technology (Horizontal Axis)

Source: this study

Figure 14. Ocean Renewable Power Company Technology (Horizontal Axis)

Source: used by permission of ORPC

Figure 15. Conceptual Vertical Axis Tidal Turbine



Source: University of Strathclyde

Less common designs include the oscillating hydrofoil and a duct-protected turbine that exploits the venturi effect to increase the efficiency of tidal energy extraction.

TISEC devices are typically composed of rotor blades (converting kinetic energy from currents into rotational movement), the drive train (consisting of a gear box and generator to convert the rotational movement into electricity) and a base structure (supporting the rotor blades and drive train). Each of these components can be further categorized by specific characteristics. Rotors can be either open to the flow of water or can be shrouded or ducted, blades can be either fixed or have a variable pitch, and the base structure can be mounted to the bottom, supported by pylons or towers, or can be tethered to a barge or dock (E3 Inc. 2007).

Large scale TISECs are typically deployed in 30-50 m of water while smaller devices are suitable for shallower locations closer to shore. TISECs rest on the seafloor fixed in place by a weighted gravity base or mounted on piles in a similar way to offshore wind turbines. Floating units may use a flexible tether to attach to the seabed, a rigid mooring or a floating platform that rises and falls with the tide (Renewable UK 2011).

State of Technology

The TISEC industry is undergoing a phase of rapid technology development but overall this sector is not as advanced as the offshore wind industry. The tidal industry has not yet converged on a single general design which has prevailed over the others (Statens vegvesen 2012). Presently there are at least 20 different types of TISEC devises on the market at various stages of development (OEER Association 2008). Many have gone through the testing and demonstration phases but currently there are no commercial TISEC arrays currently in place (Drake 2012).

Most TISEC devices are still in the conceptual stages or have been tested in short-term trials. Several technologies (described below) have been demonstrated for extended periods and are approaching the final pre-commercialization or commercialization stage of development.

Open Hydro (Open Hydro-DCNS, Ireland) The Open Hydro turbine was deployed at EMEC in 2007 and became the first tidal energy company to deliver electricity to the UK grid in 2008. A larger Open Hydro turbine was installed in the Bay of Fundy in 2010, but this unit was not connected by cable. The company is currently pursuing projects in France, the US, Scotland and Ireland. In France, the company in partnership with the French utility EDF intends to install four 16 m diameter turbines off the coast of Brittany. Each turbine is expected to produce 2 MW of electricity.

TidGen (Ocean Renewable Power Corporation, US). The ORPC unit was deployed in Cobscook Bay near the border between Maine and New Brunswick in July 2012. This small scale unit is the first grid connected tidal project in the US and will generate up to 180 kW of electricity. The ORPC unit is modular and scaleable and company also has designs for run-of-river and deep ocean installations. Established in 2004, ORPC is advancing projects in Alaska, Florida and in the Digby area of Nova Scotia.

Beluga 9 (Clean Current, Canada / Alstom Hydro, France). Originally developed in Canada and tested since 2008 at Race Rocks Ecological Reserve in BC, this unit has been redesigned for commercialization. This 1.0 MW unit is slated for deployment at the FORCE test site in Minas Passage and is expected to be grid connected in 2013. The company is also planning to install their Orca 7 unit in Paimpol, France in 2013. In September 2012, Alstom announced it had signed an agreement with Rolls-Royce to acquire Tidal Generation Limited, the manufacturer of a 500 kW unit successfully tested at EMEC.

AK-1000 (Atlantis Resources Corp, Australia). Atlantis installed a grid connected 100 kW prototype in San Remo, Victoria, Australia, in 2006. This unit was replaced with the 150 kW Nereus I unit in 2008. In 2010, an Atlantis-led consortium received authorization to install 400 MW in Pentland Firth, Scotland which it plans to complete by 2020. This project will rely on the AK-1000 series of turbines. The AK-1000 turbine will also be tested at EMEC in Orkney and, in partnership with Lockheed Martin and Irving Shipbuilding, at the FORCE site in Nova Scotia.

HS1000 (Andritz Hydro Hammerfest, Norway). Established in 1997, this company develops and supplies turn-key tidal power arrays for international power companies. A 300 kW prototype was installed in Finnmark, northern Norway in 2003 and was grid connected in 2004. The company is currently proceeding through the Environmental Impact Assessment process for their 10 MW pre-commercial array project in the Sound of Islay (Scotland), which was approved by the Scottish Government in March 2011. This project will employ ten 1 MW capacity HS1000 mark turbines.

SeaFlow and SeaGen (Marine Current Turbines-Siemens, UK). The 300 kW experimental single rotor SeaFlow turbine was installed in Lymounth, North Devon in 2003 and was decommissioned in 2009. In 2008, MCT installed the 1.2 MW SeaGen device in Strangford Lough, Scotland, which supplied in excess of 2.5 GWh of electricity to the national grid. MCT is currently developing a 5 MW array in Kyle Rhea, Skye and a 10 MW array near Skerries, Anglesey. Both projects are expected to be under construction by 2015. The company has also received approval for a 100 MW project in the Pentland Firth. Marine Current Turbines is currently partnered with Minas Basin Pulp and Power to deploy the latest generation SeaGen device at the FORCE site in Minas Passage.

Pulse Stream (Pulse Tidal, UK). In 2009 Pulse installed a 100 kW grid connected oscillating hydrofoil unit in the Humber River estuary. Building on this prototype, the company is designing a 1.2 MW commercial scale device for deployment in 2014 in the South West Marine Energy Park off Lynmouth, UK.

Delta Stream (Tidal Energy Ltd, South Wales). TEL has been testing various horizontal axis turbine components in tidal environments since the early 2000s. The first full-scale 1.2 MW Delta Stream unit is currently being deployed in Ramsey Sound, Pembrokeshire for a 12 month test period.

TGL (Tidal Generation Ltd, UK). Tidal Generation assembled a 500 kW device in 2005 that was installed and grid connected at EMEC in 2010. The unit continues to produce electricity as of late 2012. Purchased by Rolls-Royce in 2009, the company was then acquired by Alstom Hydro in 2012. The company is currently designing a 1 MW pre-commercial unit that will be deployed in a 10 MW demonstration array in 2013.

Triton (TidalStream, UK). Built by a company started in 2005, the Triton device has passed through tank testing, modeling and testing in the Thames River. There are two versions: one that can mount three turbines and one that can mount six turbines on two cross arms. The turbines are 20 m in diameter. The Triton system relies on a mounting frame to host multiple turbines (up to 10 MW on a single frame), which in turn reduces overall project costs. TidalStream is currently focused on designing a 3MW installation.

Voith HyTide 1000-16 (Voith Hydro Ocean Current Technologies). Voith has operated a 110 kW test turbine near the South Korean island of Jindo since 2011. A 1 MW grid connected device was deployed at EMEC in 2011 and is currently undergoing additional testing.

Free Flow (Verdant Power, US). In early 2012 the Federal Energy Regulatory Commission issued the first commercial license for tidal power in the US to Verdant Power. Building on the 2006-2008 testing of its technology in the East River (New York), Verdant is approved to install up to 30 turbines in the East River, making up a 1 MW pilot tidal energy project. Verdant is also exploring project opportunities in Canada at their early stage Cornwall Ontario River (CORE) Project, where it plans to install two 60-80 kW turbines in a run-of-river environment.

3.4 Summary of Commercial MRE Project Operating Requirements

Commercial offshore wind turbine output is in the 2 - 3 MW range although 5 MW turbines are common. Turbines are generally installed in water depths of up to 40 m but floating structures could be deployed water depths exceeding 100m. In Europe, wind farms are located 20-30 km from shore and may consist of 30-50 turbines. Minimum wind speeds of 7.0 m/s are required.

Wave devices operate in a variety of water depths. Shoreline oscillating water column WECs require a minimum of 4m while wave rotor devices operate in 10-15m water depth. Point absorbers can operate between 5m and 200m depending on the design. Attenuators and overtopping devices generally require waters deeper than 50m to operate. To avoid interfering with other uses of coastal waters, WEC farms are proposed for areas 100 km or more offshore although none has been installed to date. The current offshore wave farm model assumes that devices are laid out in wide farms that are only a few rows of devices deep. A 50 MW farm, for example, might be 5-10 km long but only 1-2 km deep.

Large scale TISECs are 1-2 MW in output and are typically deployed in 30-50 m of water. Large scale arrays are expected to remain within 100 km of shore, and probably will be installed considerably closer (within 10 km to shore). Small scale TISECs of 500 kW output or less are suitable for shallower locations and will be deployed much closer to shore, typically within two kilometers. Large scale arrays may occupy from 0.5 km^2 of seafloor (20 units) to 2.2 km^2 (100 units). Minimum current speeds of 1.0 – 1.2 m/s are required for small scale developments while larger units generally require speeds of at least 1.5 m/s.

Table 3 summarizes the general operating parameters of these technologies, with the exception of tidal lagoons for which this information is not available.

Table 3. Technology Operating Parameters

Operating Parameter	Offshore Wind (Fixed)	Small Scale Tidal*	Large Scale Tidal	Wave
Average Water Depth	10m to 60m	10m to 30m	20m to 80m	10m to 100m
Maximum distance from shoreline – based on maximum distance for AC export cables	100km	5km	100km	100km
Constraining Threshold	> 7.0 m/s mean annual wind speed at 100 m height	Peak Spring Current Flow >1.0 m/s	Peak Spring Current Flow >1.2 m/s	Mean annual wave power (kilowatts) per metre of wave crest (WC) >20 kW/mWC
Approximate MW/km^2	10	Not available	50	10
Average Turbine/Device Generating Capacity	2-3 MW	100-500 kW	1MW	0.5MW to 5MW
Cost to Generate Power	$0.17 to $0.35 per kWh	Not available	$0.44 to 0.51 per kWh	$0.61 – $0.77 per kWh
Average Scale of Commercial Development / Array Size	300MW	1-3MW	50MW	30MW
	30km^2	500m^2	1km^2	3km^2

(source: modified from AECOM 2010); *estimated values – this study

3.5 Generalized and Typical Biophysical Impacts of MRE Projects

To a certain degree, MRE projects are similar to other major projects in the marine environment such as bridges or offshore oil drilling platforms. In all cases, project activities associated with construction, operation and removal have the potential to impact marine ecosystems and organisms, both at local (near-field) and regional (far-field) scales. With respect to MRE projects, typical issues of concern include changes in physical processes (wave, current and sediment transport regimes), alteration and loss of habitat, contaminants, electromagnetic fields, noise and vibrations and the physical interaction between energy conversion devices and fish, birds, marine mammals and other organisms (Issacman and Lee 2010). The sections below describe the biophysical effects of all MRE projects, with a focus on TISCEC technologies.

As noted above, MRE projects may affect biological components directly, or may modify certain physical processes that in turn affect biological components. To the degree that offshore wind, wave and tidal projects have similar components common to all three technologies (foundations, mooring lines, subsea cables, etc.) they will tend to interact with marine ecosystems and organisms in similar ways, although actual interactions will vary depending on the type of energy conversion technology, the ultimate design deployed and the characteristics of marine environment hosting the deployment. On the other hand, large differences in environment-project interactions between technologies are typically related to the differing ways in which the technologies extract energy from the system. For example, both wind and tidal turbines may negatively impact diving seabirds but wind turbines are expected to have a significantly more negative effect on seabirds in general since the birds are exposed to the turbine blades above the sea surface. Similarly, foundations used to anchor wind turbines and TISECS may displace benthic habitat and cause scour and local sediment redistribution in similar ways but TISECS also extract energy from the water column, and this can lead to changes in current velocity over greater distances affecting biophysical components far removed from the immediate area of the turbine.

Table 4 summarizes the typical interactions between MRE projects and the different environmental components of the marine environment. The sections that follow provide more detail on each project component and their typical interactions.

Table 4. Project Phase and Typical Interactions

Project Phase	Physical Process Interaction	Biological Interaction
Seabed Preparation	• Sediment transport during preparation • Waves, currents, mixing & turbulence through obstruction and changes to the seabed shape • Introduction of additional hard substrata • Spills from vessels	• Benthic communities & habitat (organisms that live on the seafloor) • Infauna (organisms that live in sediments) • Fish habitat • Marine mammals
Pile Installation	• Sediment transport (suspension, deposition & scour) • Introduction of additional hard substrata • Noise & vibration • Spills from vessels	• Benthic communities & habitat • Infauna • Fish habitat & behaviour • Marine mammals
Gravity Foundation Installation	• Sediment transport & deposition (suspension and scour) • Introduction of additional hard substrate • Spills from vessels	• Benthic communities & habitat • Fish habitat • Marine mammals
Scour Protection Installation	• Sediment suspension, transport & deposition • Introduction of additional hard substrate	• Benthic communities & habitat • Epifauna • Fish habitat
TISEC/WEC/Wind	• Waves/currents through obstruction, redirection and	• Benthic communities & habitat

Project Phase	Physical Process Interaction	Biological Interaction
Turbine Installation	induction of mixing & turbulence • Spills from vessels	• Fish habitat & behaviour • Marine mammals • Birds
Cable Installation	• Sediment suspension, transport, scour & deposition • Introduction of additional hard substrata	• Benthic communities & habitat • Epifauna • Fish habitat & behaviour • Marine mammal (displacement)
Project Operation	• Waves, currents, mixing & turbulence through obstruction and energy extraction • Alteration of tidal amplitude and lag • Water quality through degradation of antifouling coatings and sacrificial anodes; release of lubricants • Electromagnetic fields • Noise and Vibration • Sediment transport & deposition	• Benthic communities & habitat • Fish habitat & behaviour • Marine mammals • Reduction of downstream nutrients and food supply for benthic filter feeders • Changes to prey types and availability
Maintenance	• Water quality through degradation of antifouling coatings • Waves, currents, mixing & turbulence through obstruction and changes to the seabed shape • Spills from vessels and release of lubricants	• Disruption of marine communities attached to devices • Spill impacts to marine biota, including birds
De-Commissioning	• Sediment transport (suspension, deposition & scour) • Loss oif hard surfaces & associated fouling communities • Introductions of discarded materials on seabed • Spills from vessels	• Benthic communities & habitat • Epifauna & infauna • Fish habitat & behaviour • Marine mammals (displacement)

Foundations and Mooring Structures

All existing MRE devices are anchored or moored to the seafloor. Although some offshore wind manufacturers are experimenting with floating platforms, none have yet been deployed and all are moored via cables to the seafloor.

The type of foundation used is mainly dependent on the device design, although seabed composition can also influence the foundation type. The Open Hydro TISEC was originally deployed at EMEC on pile foundations and was later redesigned to accommodate a gravity base for deployment in the Bay of Fundy. These two foundation types, the pile foundation and the gravity foundation, are the most common for TISECS. Offshore wind turbines typically use pile foundations while WEC devices are most often cable-moored to the seafloor.

Piles may be driven into the seafloor if the rocks are soft enough or (at much increased cost) drilled if the bedrock is resistant. The installation of piles in deep water is fairly common, and piles have been used for many years to stabilize offshore drill rigs, bridges and jetties.

A gravity foundation relies on the weight of the foundation itself to keep the MRE device in place on the seafloor. These hollow tubular steel structures are filled with rock or concrete and placed on a level spot on the seafloor. The energy conversion device mounted on top of the gravity base and is deployed with or following gravity base deployment.

Floating or suspended devices such as WECs and floating offshore wind platforms are attached to the seafloor with heavy, corrosion-resistant cables. These cables are typically bolted to the seafloor (a form of pile driving) although a gravity-based anchoring system can also be used.

These physical structures alter the flow of water and can cause scouring of the sea bottom, sediment re-suspension and changes to the depositional environment. This in turn may cover and suffocate benthic organisms and fish habitat and disturb or disrupt organisms in the water column such as fish, amphibians and marine mammals. With respect to the noise generated during pile installation, drilling and pile driving, along with the associated vessel traffic, may cause short-term behavioral responses (avoidance), and temporary or permanent hearing damage and fatality to certain fish and marine mammals (Issacman and Lee 2010). The general and specific effects are presented in more detail in section 6.

Seabed Preparation

Seabed preparation refers to dredging or infilling that may be required to create a level surface for the placement of a gravity based foundation. In some cases, a flat but erodeable surface may be dredged to bedrock (or at least a more erosion-resistant layer) to provide a stable installation surface.

Both dredging and infilling have similar ecological impacts. Benthic habitat is removed, added or altered, and sediments are re-suspended in the water column where they are washed downstream to be eventually re-deposited, which can potentially alter, damage or destroy existing benthic habitat. The dredging or infilling may result in changes to current and wave patterns, with consequent changes to mixing, turbulence, sediment movement, water column and benthic habitat quality, and coastal erosion. Finally, subsea disposal of dredged material may have further negative consequences on benthic habitat.

Seafloor Scour

Scour is the term used to describe the erosion of the seabed resulting from the installation of a new structure. In the case of an offshore wind turbine monopole or a TISEC gravity base, scour occurs as water flows past the foundation and the currents are accelerated in certain locations, causing turbulence and erosion of the sea bed (Jacques Whitford 2008). This sediment erosion tends to undermine the structure and may cause tipping and device destabilization. The eroded sediment may disturb or disrupt species in the water column downstream from the eroding area, while the deposited sediment may destroy or damage marine habitat considerable downstream from the project area.

While scour is not typically a problem when MRE devices are installed on durable bedrock, scour must be taken into account when planning device deploy in areas of unconsolidated sediments or soft bedrock. Moreover, where scour occurs around the base of a single device, it is likely to be more severe and potentially more problematic when an array of such devices is deployed. The cumulative effect of turbulence from many devices and the resulting severity of scour are difficult to predict and remain recommended research areas (Issacman and Lee 2010).

Scour effects can be reduced or prevented by a variety of methods, most commonly by the use of protective stone placed around the device foundation. This increases the “footprint” of the project on the seafloor, with consequent effects on more benthic communities and their habitat in the immediate area. Additional impacts include the introduction of new substrate and the additional noise impacts resulting from vessel traffic and protective rock installation.

Cabling

The installation of electrical cabling in marine environments to transmit the electricity generated at MRE projects is an established technology. While many of the activities undertaken during cable installation are well known (such as excavation, cable deployment and cable anchoring) and the associated impacts such as scouring have been studied in other industry applications, the impacts of MRE cabling are somewhat unique.

The electrical cable represents a significant part of the project's capital cost, both in terms of its manufacture and its cost of installation. The cable delivers electricity from the marine facility to shore and may also be used to send and receive operational and monitoring data from the MRE device and nearby monitoring equipment. In addition, cables placed in high current environments may move in response to tidal cycles, abrading the protective covering and allowing seawater into the wiring. Seafloor cables are also exposed to vessel anchors and entanglement with fishing gear. Given its cost, vulnerability to damage and vital importance to the project, cables are typically buried in shallow trenches or laid along rock crevices (if possible) in shallow areas where the cable is particularly susceptible to damage.

It is this trenching and burying process that causes most of the environmental interactions. As may be expected, trenching disrupts benthic habitat and releases suspended sediment to drift with the current, potentially smothering nearby habitats. The clouds of suspended sediment may temporarily disturb fish, shellfish and marine mammals in the vicinity. The cable itself, if installed in a high current environment, may increase local scour, destabilize bottom sediments and cause erosion over a considerable period of time. If laid on the surface of unconsolidated sediments, the cable provides a substratum for the attachment and protection marine organisms that would not otherwise be found in this habitat.

Both alternating current (AC) and direct current (DC) cables create electromagnetic fields (EMF) when electricity flows through them. The electric current induces a magnetic field in the immediate vicinity that is proportional in extent and strength to the magnitude of the current. These magnetic fields, in turn, can result in secondary electrical fields when organisms move through the magnetic field (USDOE 2009b). Gill *et al.* (2005) in their review of the technical literature regarding the effects of EMF on marine organisms concluded that significant knowledge gaps remain on this subject. They noted that cable networks, such as those that would be installed at tidal arrays, would likely have overlapping and potential cumulative effects. Cable burial is proposed as the most effective way to shield marine organisms from EMF effects (CMACS 2003).

Maintenance

Tidal turbine maintenance consists of performing a variety of periodic repairs to above water or submerged structures. Other MRE types will also require routine maintenance. These activities include removing attached organisms, lubricating moving parts, repainting structures, and carrying out needed repairs. Maintenance activities will result in temporary impacts similar to those that occur when the units are installed, such as increased vessel traffic, increased noise, increased risk of hydrocarbon spills and disturbance to marine life (Polagye *et al.* 2010). Maintenance activities may affect marine habitats and organisms periodically, but the effects are likely to be short lived.

For TISECs, more significant repairs, such as the replacements of gear boxes or blades may require returning the component or the entire device back to shore. It is not clear how often this type of maintenance would be required, however device design life is on the order of 20-25 years (Li and Florig 2005). Given that TISEC technology remains at a relatively early stage in its development, it is likely that initial deployments of TISEC devices in Cape Breton (as in the Bay of Fundy) would require more frequent inspections and maintenance than the final large-scale commercial installations (Jacques Whitford 2008). To the extent that wind turbines and WECs are accessible at the sea surface, repairs may be less expensive and less intrusive to the marine environment compared to repairing TISECs.

Exclusion and Safety Zones

As submerged, moored or floating infrastructure, MRE technologies represent a potential risk to other vessels and water born organisms during their construction, operation, maintenance and decommissioning. This risk may take the form of collisions or navigational hazards with installation/maintenance vessels, the device or its mooring cables, or entanglement of fishing lines, nets, traps, anchors or grappling hooks with the device, its mooring lines or subsea cables. The risks to operators of water craft, as well as to water skiers, swimmers and divers are obvious, and may have fatal consequences.

To reduce this temporary risk during construction and maintenance project operators in collaboration with Transport Canada establish a safety zone around the work area for the duration of the work. The size of the safety zone will vary depending on the work to be undertaken, current and tide conditions and other factors, but 300 m was used at the FORCE site during installation of the Open Hydro TISEC.

In Canadian offshore waters, Transport Canada is responsible for regulating navigational hazards through the *Navigable Water Protection Act*. Transport Canada issues permits for installations in all navigable waters, both fresh and marine. In contrast, Transport Canada does not establish or impose safety zones or marine exclusion areas. The Department of Fisheries and Oceans Canada (DFO) through the Canadian Coast Guard is responsible for ensuring mariners are aware of submerged or moored infrastructure such as MRE devices. Immediately prior to deployment the project proponent is required to post “no anchorage” signs and issue, through the Coast Guard, a notice to mariners indicating the location and nature of the hazard. The notice to mariners is posted on the Coast Guard Notices to Mariners (NOTMAR) website. The website allows interested parties to update their navigational charts and publications with the latest information regarding navigational hazards.

DFO may establish a marine exclusion area, but only for specific and limited purposes. A marine exclusion area may be established to keep mariners (including fishers) away from a contaminated site (for example, an exclusion zone was established around the Irving Whale shipwreck area) or for wildlife protection purposes (for example to protect spawning grounds of a rare species). All other safety or exclusion zones, including those that may be suggested around operational marine renewable energy projects, are established jointly by the project proponent and local users of the area.

4. Tidal Energy Development Scenarios

The introduction of any new industry to a region is a complex process dependent on a host of variables. In the case of the tidal energy industry, which has not yet reached an economically viable stage of development and for which no truly commercial projects exist, it is much more difficult to predict and describe the course that may be taken in Cape Breton.

As MRE projects have evolved from the laboratory to test tanks to ocean deployment, a series of development steps has been defined that chart how these technologies mature over time. These steps are: *pilot phase, demonstration phase (non-grid connected* and *grid connected),* and *commercial phase*. The tidal industry is now sufficiently developed that TISEC developers are testing grid-connected pre-commercial single units and will deploy in the near future pre-commercial and commercial arrays in different areas around the world. Given this state of development, it is unlikely that pilot stage deployments will be made in Cape Breton. Instead, project developers will prefer to test grid connected units or small arrays to assess their commercial viability and attract investment capital.

Various jurisdictions within the UK have undertaken SEAs and marine spatial planning exercises in order to make lease space available for marine renewable energy projects. By streamlining the permitting requirements and establishing baseline environmental conditions in different offshore areas, many more MRE projects (compared to Canada) are moving into the pre-commercial and commercial stages. Given the longer history of offshore wind, tidal and wave power project development in the UK, a large amount of information has been generated that can be used by project proponents, residents and regulators to evaluate the positive and negative aspects of a project. EMEC has issued a draft guideline for MRE project development (EMEC 2009). An outline of the information typically required for these projects is given below.

This first step in developing a MRE project is to identify one or more potential locations for the proposed project. A suitable project site depends on a number of legislative, technical, physical, environmental and economic factors. More detailed information and in-depth site assessments will be required at later stages in the project development. With respect to legislative requirements, all projects require a clear understanding of the authority and duties of the provincial and federal levels of government, the First Nations perspective, and an appreciation of the permitting and seabed leasing process. The “permitting roadmap’ is established at the earliest possible stage so that all participants understand the expectations and timelines of the permitting agencies and the stakeholder consultation process.

4.1 Siting and Oceanographic Considerations

The list below outlines the technical and environmental information that must be obtained and assessed for a tidal energy project to proceed (EMEC 2009).

<u>Technical and Physical Considerations</u>

Tidal Resource Availability: this will vary from site to site and between technology types. The site must maximize the opportunity for energy extraction for pilot, demonstration and commercial-phase projects. The tidal range and tidal current velocities should be well characterised in three dimensions throughout the water column where generators are to be placed. Ideally this is done by the deployment of Acoustic Doppler Current Profilers in upward or down-looking modes, programmed with enough resolution to resolve the vertical shear forces at the scale of the forced dimension of the generator (e.g. blade diameter). The temporal dimensions of the data set should span at least one full lunar tidal cycle, and the time step should be less than 5 seconds. Knowledge requirements derived from measured tidal currents include the depth averaged, in-stream power density at ebb and flood peak flows (kW/m^2), as well as the mean energy flux per tidal cycle, and the annual average energy flux per unit aperture area of TISEC device (EPRI 2006). As it is best that the tidal currents be linear (non-turbulent), estimates of channel bottom and side friction coefficients and vertical velocities should be determined as well. Using these metrics, the predicted power output of various TISEC devices may be predicted for any given installation (MacMillan *et al.* 2012).

Bathymetry: The selected site must have appropriate water depths to prevent navigational hazards and operate efficiently. Large scale turbines with 20-25 m diameter rotors and 1 MW or more capacity typically require deeper water than smaller capacity units designed for community energy projects. The larger turbines are installed in 30-70 m water depth while smaller versions may occupy depths of 10-30 m.

Seabed Morphology: the shape and composition of the seabed must be appropriate for the installation of the TISECs, their mooring lines and subsea electrical cables. A hard, flat bottom substrate of exposed bedrock is preferable to erodible unconsolidated sediments and the deployment area should be free of changing "bedforms" – deposits of sediments that move with the currents. Similarly, as TISECS may be installed on existing infrastructure (e.g. bridge pylons), it is essential to determine their shape and potential to generate turbulence that may influence the performance of the TISEC.

Logistics: Installation, operations and maintenance of TISECs require suitable harbour facilities nearby, and specialist services such as work boats, divers, and instrumentation experts.

Grid Connection: The project should be located in close proximity to a transmission grid having sufficient capacity to accept the electrical load. In addition, a suitable landfall location must be available to allow connection to the electrical grid. To the extent possible the landfall must free of technical, environmental and economic constraints that will negatively affect the project.

Environmental and Social Considerations

Designated/Protected Areas: International, national, provincial, and regional protected areas are generally not suitable for MRE projects. An exception to this generalization would be multiple use protected areas that include sustainable human development as a management goal. As a UNESCO Man and the Biosphere Reserve, the Bras d'Or Lake and watershed ecosystem is an example of such a multiple use site (BLBRA 2011). Military test sites and former ordinance disposal sites must also be identified and avoided.

Ecology: The site selection process must evaluate the ecological sensitivity of potential sites and avoid those that have essential habitat for, or critical concentrations of protected species (e.g. species at risk). Typical organisms of this category include certain populations of some species of birds, cetaceans, fish, and shellfish. Habitat includes not only environments and locales where organisms shelter, feed and breed, but also transit corridors that allow essential connection between such habitats (e.g. the sole channel connecting the North and South basins of the Bras d'Or Lakes). Some marine and coastal environments include communities of high biodiversity, or support harvested productivity that is of significant commercial or societal value (e.g. seagrass meadows and oyster fisheries, kelp beds and sea urchins fisheries). Both pelagic and benthic organisms, communities and their habitat must be evaluated in the context of marine and coastal ecosystem goods and services that might be affected by the installation and operation of MRE at a particular location.

Archeology and Historical Heritage: Shipwrecks and flooded archeological sites must be identified and, to the extent possible or required by regulators, avoided.

Traditional Use of Resources by Aboriginal Peoples: Aboriginal people often enjoy a special relationship to the natural world. There is a legal duty to consult First Nations' peoples during the planning and evaluation of any of development that may have an effect upon their traditional access to natural resources. A Traditional Ecological

Knowledge Study is required to identify and evaluate areas of historical significance and on-going use of marine and coastal resources that might be affected by marine energy extraction in the Cape Breton region.

Other Sea Users and Infrastructure: Since MRE projects share the ocean with various other user groups and may impinge on existing infrastructure, logistics and resources, these factors must be understood in detail. Examples of other uses include recreational and commercial fishing, recreational and commercial navigation, water sports (skiing, diving, surfing) and military activities. Existing infrastructure may include cables, pipelines, and aggregate mining.

Consultation: In addition to the legal (regulatory) requirements to consult or engage local aboriginal and non-aboriginal populations, the site selection process will benefit from local knowledge and expertise to identify constraints to development and propose mitigation measures to lessen impacts. This potential benefit encompasses the social-cultural spectrum from local communities of residence to specialized institutions (e.g. universities).

Other advantages that may encourage project developers include existing utility easements for new transmission lines, high local demand combined with an expected increase in demand over time, plans for a roadway or railway bridge to cross a tidal channel, thereby allowing the TISEC project to attach to the structure and offset the costs of the civil works, and local public advocacy for the project (EPRI 2006). Government subsidies in the form of loans, grants, funding for research and feed-in tariffs also factor into a project proponent's decision to deploy within a particular jurisdiction.

4.2 Wind and Wave Resources in Cape Breton and the Bras d'Or Lakes

This section describes the offshore wind and wave resources of Cape Breton. Tidal resources in Bras d'Or Lakes and off coastal Cape Breton are described in more detail in subsequent sections.

In earlier work undertaken for the Bay of Fundy, it was apparent that the physical conditions of that area were not appropriate for the installation of wave and offshore wind projects (Cornett 2006). The Bay of Fundy is not well positioned to generate significant and reliable sources of wave energy, while the extreme tides and ice conditions make offshore wind projects less economically attractive compared to tidal energy (Jacques Whitford 2008). Tidal energy exploits the dominant physical characteristic of the Bay, its extreme tidal displacement.

In contrast, coastal Cape Breton does not appear to exhibit the same limitations to wave and offshore wind power projects as found in the Bay of Fundy. There are significant wind and wave energies available off coastal Cape Breton, even if these energies may not be as promising as elsewhere in the world. However, it must be underlined that the success of MRE projects depends on a variety of factors, of which resource availability is only one. Offshore wind projects do not become economically viable until onshore sites are no longer available (Sun *et al.* 2012). Similarly, wave energy is not cost competitive with other forms of power generation in its current state of development. Given these factors, Cape Breton at this time appears less attractive for offshore wind or wave energy projects compared to tidal energy.

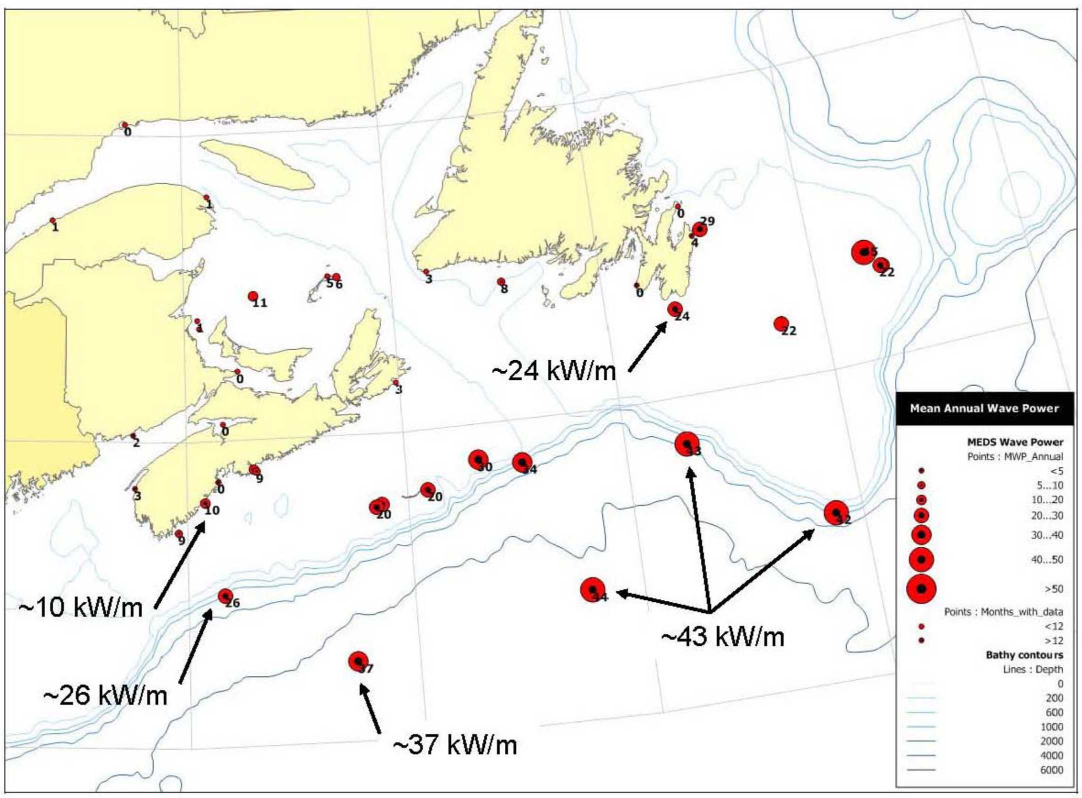
The Bras d'Or Lakes do not have significant wind and wave resources, due largely to the same factors that limit the availability of these resources in the Bay of Fundy. Fundamentally, the base wind and wave energy needed to support a commercially viable offshore wind farm or wave array does not appear to be available within the Bras D'Or Lakes. In contrast, at least two areas have been identified as having tidal resources that suggest a commercial TISEC deployment may be feasible (EPRI 2006, McMillan *et al.* 2012). In addition, the tidal characteristics in certain areas around coastal Cape Breton appear to be appropriate for the installation of small and large-scale commercial TISEC devices. These areas are described in more detail in sections 5.6 and 5.9.

Wave Power Resource

During 1991-1993, Transport Canada funded and published a Wind and Wave Climate Atlas of Canada focused on four different geographic regions, including Atlantic Canada. The Atlas presents detailed information on wind speeds, wave heights and wave periods, but do not give data on wave energy flux or power (Cornett 2006).

Wave power along a coast can vary considerably due to sheltering and bathymetric effects such as shoaling, wave diffraction and refraction. Annual mean wave power values of 20 to 25 kW/m seem representative for the waters near Sable Island, while values near 10 kW/m are representative of conditions along the southern shore of Nova Scotia (Cornett 2006 – Figure 16). This varies considerably by season, with the highest wave energy available in the winter months and the least in June, July and August. As Cornett notes, the wide continental shelf of the northwest Atlantic tends to reduce the energy of the waves washing across it so that wave energy resource nearer to shore is considerably less than that at edge of the continental shelf. Compared to wave resources off Ireland and Scotland (75 kW/m), the 5-10 kW/m available off near shore Cape Breton is considerably less.

Figure 16. Northwest Atlantic Wave Energy Power Potential

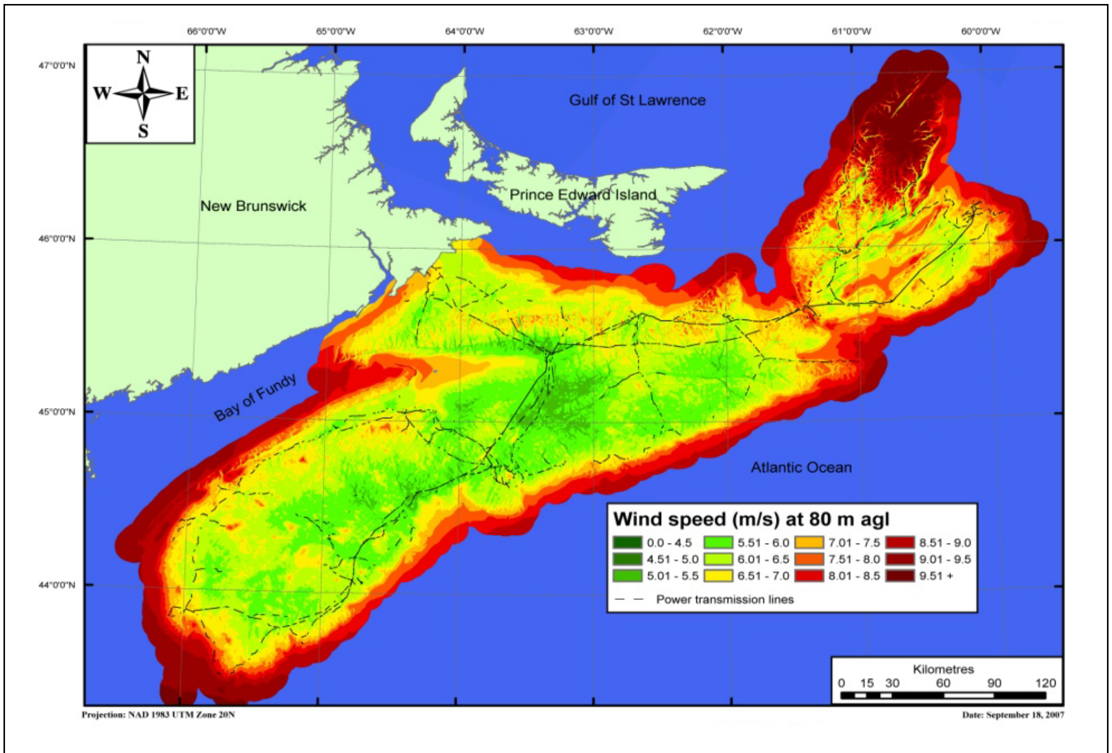


Source: Cornett 2006

Wind Power Resource

The Nova Scotia Department of Energy recently released the Nova Scotia Wind Atlas to help wind project developers, residents and regulators understand the wind energy resource within the province. The Atlas includes representations of wind speed at different elevations above ground level and extends these representations up to 10 km offshore. The highest wind speeds occur at the highest elevation, 80 m above ground level. On Figure 17 some of the highest wind speeds in Nova Scotia (greater than 9.51 m/s – dark red) occur off the northwestern tip of the Cape Breton Highlands, while similar speeds occur east of Scatarie Island.

Figure 17. Wind Resource Map of Nova Scotia + 10 km Offshore (80 m Above Ground)



Source: NSDOE and others; http://www.gov.ns.ca/energy/renewables/explore-invest/maps.asp

4.3 Tidal Resources in Cape Breton and Bras d'Or Lakes

There is an upper limit to the power that can be extracted by turbines in tidal channels because too many turbines simply block the flow. Similarly, there is a maximum amount of energy that can be taken from the tidal current by a single turbine – after the maximum is reached the water will go around the device rather than through it. Various researchers have attempted to quantify the amount of power that can be extracted from a tidal system in order to describe the amount of energy available at different locations around the world (Cornett 2006; EPRI 2006; Karsten *et al.* 2008; Garret and Cummins 2005; Garret and Cummins 2007; McMillan *et al.* 2012). Extractable energy depends on a variety of factors such as the width and depth of the channel and tidal flow characteristics.

Extractable or available energy is a primary concern to project developers since it strongly influences both TISEC design and the commercial potential of the deployment site. At the same time, there is considerable debate (but only limited research) regarding the amount of energy that can be safely extracted from tidal systems without causing harm to the ecological functions of the system. Removing energy from tidal currents reduces water velocities (Bryden *et al.* 2004). This will reduce currents, tidal amplitude and water exchange, which may change water temperature, sedimentation and nutrient distribution patterns, behaviour of aquatic organisms, animal population dynamics, and the movement of suspended organisms such as plankton and larvae (Ahmadian *et al.* 2011; Neill *et al.* 2011). Modeling results in the Minas Basin suggest that extracting 4 GW of power would reduce the tidal amplitude by less than 10% while extracting 2.5 GW would reduce the amplitude by less than 5% (Karsten 2008). No similar assessments have yet been done for coastal Cape Breton or the Bras d'Or Lakes.

The environmental and ecological effects of extracting tidal energy on entire ecosystems, their structures and functions, are even less well known than those on individual species populations, which have received the majority of attention (e.g. Risk *et al.* 1978). Older research has suggested 15% as the maximum amount of energy that can be safely extracted from a tidal system (EPRI 2006) although a degree of uncertainty has been expressed in this report (Jacques Whitford 2008). A dated but comprehensive assessment was undertaken by Black and Veatch on behalf of the UK's Carbon Trust in 2005. Those authors suggested a range of energies that could be extracted from different types of tidal streams without causing "significant impact", defined as negative economic or environmental effects. According to this study, the degree to which energy can be extracted without impact depends on the physical characteristics of the tidal stream where the project is installed: "resonant estuaries" are very sensitive to energy extraction while "sea lochs", which are confined systems similar to hydroelectric reservoirs are much less likely to experience negative effects as energy is extracted. Tidal flow in confined channels, around headlands and in the open sea was reported to fall between these two extremes (Black and Veatch 2005). OERA is funding additional research on this subject from researchers at Dalhousie and Acadia Universities and well as DFO; these studies are expected to be completed in 2013.

Tidal Power Resource Assessment

A full understanding of the available tidal resource is a critical factor in attracting project developers to a region. This is primarily because each TISEC technology operates most efficiently within a defined range of tidal currents and because the resource must be sufficiently robust to support a community or commercial scale development. Unfortunately, few areas in Cape Breton have been systematically assessed for their tidal potential. The exceptions are Barra Strait and Great Bras d'Or Channel (McMillan *et al.* 2012; Cornett 2006; EPRI 2006).

Cornett (2006) identified three potential tidal energy sites in Cape Breton: Barra Strait, Great Bras d'Or Channel and Flint Island north of Scatarie Island. Table 5 summarizes their characteristics.

Table 5. Characteristics of Potential Tidal Sites in Cape Breton

	Max Current Speed Flood (kn)	Max Current Speed Ebb (m/s)	Mean Max Depth Ave Current Speed (m/s)	Mean Power Density (kW/m^2)	Width of Passage (m)	Average Depth of Passage (m)	Flow Cross Sectional Area (m^2)	Mean Power Potential (MW)
Great Bras d'Or Channel (Entrance)[1]	5 (2.6)	5 (2.8)	2.19	1.22 (1.21)	320	8	2,832	3
Barra Strait	3 (1.1)	3 (1.1)	1.31 (0.7)	0.26 (0.08)	455	20	9,487	3 (0.759)
Flint Island	2.5	3	1.20	0.20	500	20	10,425	2

Note 1: although not specified in Cornett (2006), this is assumed to be at Carey Point.

Data summarized from Cornett 2006, Table 18. **New data in parentheses presented in McMillan *et al.* 2012**.

Using depth averaged tidal in-stream mean power densities, EPRI (2006) calculated the Great Bras d'Or Channel held a total of 2.8 MW of energy. These data are consistent with recent measurements in McMillan *et al.* (2012) undertaken on behalf of OERA for NSDOE. A total of 2.8 MW does not appear sufficient to host a large scale project aimed at generating power to the provincial transmission grid. In contrast, this potential may be adequate for commercial distribution to local consumers. EPRI (2006) note a 500 kW project could connect to a 25 kV distribution line within approximately 1 km distance but a larger project would be located greater than 10 km from the nearest 138 kV transmission line at Point Aconi. In 2012, Fundy Tidal Inc. received approval for a small, commercial 500 kW COMFIT project proposed for the Channel (Figure 49).

Similar "available energy" calculations were completed for the Barra Strait and Flint Island (Table 5), which according to Cornett (2006) contain 3 MW and 2 MW of energy, respectively. Recent current velocity data collected by McMillan *et al.* (2012) suggest that flows are much lower than those estimated in 2006, indicating the available energy is correspondingly lower as shown in Table 5. Recently, a 100 kW COMFIT project application, again by Fundy Tidal Inc. was approved for the Barra Strait (Figure 49). The Barra Strait is approximately 15 km from the 138 kV transmission line that connects Wreck Cove generating station to Port Hastings. Flint Island is at least 25 km from the Lingan Generating Station and the major power lines linking it to the Halifax area.

With respect to coastal Cape Breton, no detailed research has been done to quantify the tidal resource for the specific purposes of the tidal energy. The northwestern and northeastern coasts of Cape Breton Island, in particular the Cheticamp, Flint Island and Scatarie Island areas, may include sites of interest for tidal energy development projects. Depth and current ranges appear to be suitable for certain project types. Geographical, hydrological and oceanographic (including tidal depth and current ranges) data for a number of embayment sites along the western, northern, and northeastern coasts representative of the Cheticamp, Flint Island and Scatarie Island areas are excerpted from Gregory *et al.* (1993) and presented in Appendix A.

Appendix A presents site area at high water, perimeter, low water volume, width and area at inlet mouth, as well as axis length and maximum depth, and watershed area. The oceanographic parameters include mean and large tidal range, mean tidal range, mean tidal volume, tidal current inlet mouth, and estimated flushing time. The hydrological parameters are the monthly mean and standard deviation of the discharge of freshwater into the inlet. Accompanying each set of parameters is a map of the embayment site. The sites are presented in their geographically clockwise order around Cape Breton Island from George Bay (St. Georges Bay) in the southwest around to Gabarus Bay in the northeast. Regions with the maximum of the average kinetic power density larger than 500 W/m^2 (corresponding to a current speed of ~1 m/s), surface area larger than 0.5 km^2 and depth greater than 5 m are defined as hotspots (GTRC 2011). Many areas have sufficient depths and surface areas, but adequate current speeds are typically found only around headlands and between islands where water flow is constricted.

4.4 Tidal Development Project Types

4.4.1 Commercial Models

The tidal energy industry has evolved considerably since 2008 when the Bay of Fundy SEA was completed. Two fundamental changes have occurred that will influence how tidal energy projects are developed in Cape Breton. First, as more and more TISECs reach the commercialisation stage, the industry is seeking sites less often to test prototypes or demonstrate their technology. Generally speaking, the tidal energy industry is now seeking sites that can host arrays of TISECs for commercial purposes. Given this, the tidal resource must not only meet the minimum requirements to spin the turbine but also must meet the broader requirements of a commercial project.

A second contrast to the situation in 2008 is that the industry has developed to service two distinct end-users or markets. On the one hand, large utility scale projects designed to transmit electricity for sale consist of large diameter turbine arrays deployed in high current, deep water environments, typically 1-10 km offshore. These projects are generally >10 MW in total and follow the offshore wind energy model. On the other hand, smaller scale, lighter units suited to lower current speeds can be deployed in shallow water nearer to shore with the ultimate objective of distributing electricity to local consumers where power costs are high. Projects that serve this community model, which may be applied to isolated communities, mining projects, and forestry camps, are typically less than

5MW and may be less than 1 MW. This model also applies to highly urbanized areas when power demand is high. In these cases, no new infrastructure needs to be built and the power can be readily integrated into the electrical system. The small scale model is also being developed for run-of-river applications and installation in hydroelectric dam tail races, canals and power plant water discharges.

In Nova Scotia, the differences between these two models are represented by the large scale FORCE site in Minas Passage which ultimately aims to *transmit* power, compared to the small scale projects proposed for locations in Bras d'Or Lakes and near Digby which aim to *distribute* power to the local communities. Over the long term, both models are commercially-oriented although both must proceed through demonstration phases to achieve commercialization.

The technological differences between large and small scale projects are likely to increase rather than decrease in the future. Large project developers are scaling up their plans to take advantage of efficiencies gained by mass production of turbines and other project components while smaller developers are looking to lighten their units and custom design them to fit into the remaining unconstrained near shore areas open to their projects.

The current state of development requires installation of multiple arrays in different tidal environments. This will allow manufacturers to design, produce and sell turbines and other components, which in turn reduces their costs and stimulates the industry to advance. Turbine technology itself is proven (or nearly so) and the most advanced units have been shown to generate reliable power. Remaining critical challenges to this industry is the development of electrical connectors and techniques for use in subsea high current environments (unlike the offshore wind where cables run up the shaft and can be connected in the dry), optimization of foundation designs, and an understanding of “wake effects” where multiple turbines interfere with each other by causing turbulence in the tidal stream reducing energy extraction efficiency. Further work is also required to reduce deployment costs for both the turbines and subsea cables.

In addition to the physical site characteristics required for project developers (peak flow, power density, appropriate water depths and channel widths, proximity to transmission assets), a FIT is also a critical driver of this industry. A FIT gives the project developer an end market and fixed price for the electricity generated and provides financial return to offset project costs. This allows investors to understand how a project can be financed and how their capital will be recovered over the lifetime of the project. Since the early stages of any industry are the most expensive, this allows developers to move quickly into the market, develop a client base for a particular technology type and demonstrate return on investment to new clients.

Experience with international off-shore wind projects suggests that base structures must be assembled (and often manufactured) near the deployment site. Cost considerations suggest that this will also apply to large scale tidal projects although wave energy converters tend to be smaller and so can be transported at less cost. CWS *et al.* (2011) predicts that exports of offshore wind turbines or base components manufactured in Nova Scotia would be transported by road or rail to a major port with break bulk cargo/ container terminal facilities for shipping to the project site. These ports become the main operations and maintenance base for the MRE project. Large scale tidal and offshore wind energy projects require a “wet port” (where water depth is adequate [8 m] at low tide), a mature marine service supply chain capable of providing fabrication, assembly, erection, loadout and berthing for support vessels and barges. Small scale tidal projects such as those proposed for the Digby area can be supported from any number of smaller ports that do not have the heavy lifting capacity, robust wharf structures, and space available to support larger projects (CWS *et al.* 2011).

As noted by CWS *et al.* (2011), the large size of offshore wind and tidal devices necessitates transport by water to and from the deployment site. High transportation costs require the assembly, deployment, and maintenance to be conducted at ports located as close as possible (ideally within 50 km) to the deployment site. The Port of Sydney and the Canso Superport appear to meet these requirements and would likely be able to support tidal, offshore wind and wave projects without significant marine structure upgrades or expansion.

The sections below describe and provide examples of several different project types that have been developed elsewhere in the world.

4.4.2 Pilot & Non-Grid Connected Projects

A pilot project scenario is a short term TISEC deployment focused on testing the technical feasibility of the design. Pilot projects may deploy reduced-scale prototypes or partial TISECs intended to test specific design features.

A small scale pilot project is a critical early step toward evaluating the potential of a specific device for commercial application. A pilot scale device can be deployed within a tidal zone, either moored suspended from a bridge, or the device can be pulled behind a barge. These deployments or mobilizations are short term, near shore and are typically not connected to an electrical grid, thereby minimizing costs. With no electrical grid connection and therefore no revenue generated, the pilot projects are not economically viable for long term testing.

The intention of the pilot project is to evaluate the device's performance, to confirm theoretical power generation calculations, and to determine on a preliminary basis the feasibility of a demonstration project or commercial application. Of the many different designs that undergo pilot testing, some are found to be technically or economically unfeasible and do not make it to the demonstration stage.

Site selection for pilot projects must consider ease of site access, the nature and adequacy of tidal resource or simulated of a tidal resource (in the case of a barge tow), and the specific objectives of the testing routine. To keep costs as low as possible pilot projects are typically small (less than 1 MW), single device deployments.

Permitting requirements vary depending on the scale of the project and the nature of the deployment. While environmental assessments are not typically required for testing small scale units in the marine environment, both federal and provincial permits may be required.

Clean Current and Verdant tested TISEC prototypes at Race Rocks, BC and in the East River, NY, respectively.

4.4.3 Demonstration Projects

A demonstration project deploys the full scale or near full scale device under natural tidal conditions in order to "demonstrate" commercial viability. Installation at a demonstration facility allows the developer to test deployment and retrieval technology and cost, energy conversion and electrical performance, and understand impacts to and from the tidal environment.

Compared to pilot deployments, demonstration projects are larger and more expensive undertakings and are completed to evaluate a particular TISEC in a long-term operating scenario. Demonstration TISECs are full scale grid connected units, almost but not quite commercial ready. Areas of interest evaluated during the demonstration phase include the device's energy-generating potential and efficiency, device component durability and maintenance requirements, deployment and retrieval costs, and the potential effects of the unit on the surrounding marine environment. These projects are in large part aimed at proving the commercial viability of the device in order to attract the considerable investment capital required for commercialization but they also provide regulators and the general public with the opportunity to learn about the technology and express concerns regarding its potential impact.

The demonstration device is deployed directly within the tidal resource of interest and is typically connected to an electrical grid so that the energy generated can be measured and performance evaluated. A demonstration project, while not a commercial development, may be used as the first phase of a future commercial array. Deployment sites are selected that imitate the conditions of future commercial sites so the device can be tested in real world conditions. Site selection criteria include a suitable current regime, appropriate bottom substrates, paucity of environmental and cultural sensitivities, proximity to the transmission grid, etc. EPRI (2006) indicates that tidal velocities (both ebb and flood) must attain at least 1.5 m/s (3 knots) to support a commercial installation, and by extension, a demonstration project that seeks to demonstrate commercial viability.

The size of the demonstration scenario varies by project, but individual full scale TISECs typically generate 1.0 to 2.0 MW of electricity. Although grid-connected, projects at the demonstration stage do not rely on the electricity generated to provide a return on investment, but payment for electricity does help to financially support the project. Several demonstration facilities have been constructed around the world to host wave and tidal power devices that have reached the demonstration phase. These facilities offer dedicated “berths” and certain infrastructure components such as subsea cables, electrical substations and monitoring equipment. Other facilities may already have completed partial permitting thus reducing costs and time delays for the device owner, while others offer financial incentives, grants or rebates to offset the cost of deployment or operation.

The growth and occupation of these facilities represent significant progress in the MRE industry since the Phase I SEA was completed in 2008. A considerable body of information relating to device performance, technical innovation, and the effects on the environment is now available to guide future project development. Appendix B describes several demonstration facilities currently operating around the world. Each facility website provides reports and other documentation that can be downloaded by the interested reader.

4.4.4 Commercial Sites

Commercial development is the final stage where grid-connected devices or device arrays are deployed for commercial power generation. Pre-commercial arrays of five to six TISECs are in the planning stages in the UK. For larger tidal arrays, the spacing between TISECs is about 10 times larger in the direction of the flow than perpendicular to it. Currently, it is expected that early large scale arrays will be formed of 1 or 2 rows of about 10 devices each. Such arrays would cover an area of less than 0.5 km^2, depending on the type of device, and generate an estimated 50-60 MW/km^2 (AECOM 2010).

A commercial power generation array may consist of an array of 30 to 100 TISECs capable of generating 30 to 50 MW of electricity. The seabed area occupied by a commercial tidal array is relative to the type of device and configuration of the array used. It has been estimated that a 30 unit array would occupy approximately 0.5 $km^{2.}$ or greater (Faber Maunsell and Metoc PLC 2007). An array of 50 to 100 devices, of dimensions 20m by 50m, such as MCT’s SeaGen, and requiring 50m spacing perpendicular to the flow and 200m along the flow, would cover an area of 1.1 to 2.2km^2. The power density of this example array, if formed of devices generating each 1.5MW, would be 70MW/km^2 (AECOM 2010).

At this time, there are no fully commercial TISEC arrays in operation, although several grid connected units are providing power in the UK, the US and elsewhere. There are considerable technical challenges to successful commercialization of this technology. These challenges include:

Marine Environment	The harsh conditions require experience and expertise;
Inappropriate Technology	Some TISECs will not perform efficiently and/or dependably and will not meet performance targets;
Installation Techniques	Complex, expensive and requires scarce equipment;

Maintenance Requirements	Significant source of safety, cost and performance risk;
Funding Availability	High cost, high risk, new technology = funding challenges;
Pricing	Governments and utilities not setting reasonable price targets for first developments;
Environmental Unknowns	Key issues are impacts to fish and mammals; occupation of area by other users;
Regulatory Hurdles	Overly cumbersome process results in major delays and costs;
Tidal Array Power Extraction	Unit spacing and maximum extraction levels;
Resource Identification	Paucity of relevant tidal information for energy uses;
Resource Allocation	Control by government or open for development; and,
Development Risks	New technology + Marine environment = Risk exposure.

4.5 Summary of Cape Breton Opportunities and Constraints

This section summarizes the characteristics of MRE development potential in Cape Breton. Although many factors leading to the successful commercialization of MRE projects have naturally not been studied for specific projects, the summary below presents the general opportunities and constraints of the two major project scales that may be anticipated. The existing biophysical environment of specific areas of interest for TISEC projects is described in the next section. The summary below emphasizes the technical opportunities and challenges rather than the potential social and community concerns, which are described sections 6.3, 6.10 and 6.11.

Small Scale, Near Shore Community Tidal Power (Bras d'Or Lakes)

Opportunities

- Locally available energy resource
- Community interest and COMFIT program support project opportunities
- Distribution capacity is available nearby
- Potential for export of technology and know how
- Project opportunities are small scale and relatively non complex
- Relatively small capital investment required for project initiation
- Projects may be expected to proceed in the near future

Constraints

- Energy resource is limited to a few specific, spatially confined areas
- Total extractable energy resource is limited (array potential is limited)
- Significant commercial and recreational traffic may be impeded by TISEC installation
- Constricted channels are critical for transit of marine organisms
- Bras d'Or Lakes may be more sensitive to ecological effects of energy extraction

Open Ocean, Large Scale Commercial Tidal Arrays

Opportunities

- Several, possibly numerous areas with sufficient energy
- Technology is now at the commercial array stage
- Can build upon expertise generated at the FORCE site
- Potential for export of technology and know how
- FIT for commercial tidal projects will be available in the near future
- Potential to contribute to the economic future of coastal Cape Breton

Constraints

- Energy resource and biophysical environments are not known
- Currents are not especially elevated relative to other areas around the world

- Total amount of nearby or easily extractable energy is low compared to the Bay of Fundy
- Greater distance to electrical grid increases overall project costs
- Upgrades to the transmission grid will likely be required
- Project opportunities are large scale and complex
- Large capital investment required for project initiation
- Projects are not expected to proceed in the near future

Large Scale Commercial Offshore Wind Arrays

Opportunities

- Significant offshore wind energy potential

Constraints

- Not cost competitive with onshore wind projects
- Greater distance to electrical grid increases overall project costs
- Upgrades to the transmission grid will likely be required
- Project opportunities are large scale and complex
- Large capital investment required for project initiation
- Limited local project and technological experience
- Projects are not expected to proceed in the near future

Large Scale Commercial Offshore Wave Arrays

Opportunities

- Significant offshore wave energy potential

Constraints

- Technology not significantly advanced for full scale commercial arrays
- Greater distance to electrical grid increases overall project costs
- Upgrades to the transmission grid will likely be required
- Limited local project and technological experience
- Project opportunities are large scale and complex
- Large capital investment required for project initiation
- Projects are not expected to proceed in the near future

5. Existing Environment

5.1 Physical Components

The offshore region surrounding the island of Cape Breton has been studied for over 50 years to assess the bedrock and sediment geology and to understand the area's geological history. As a result of this research, coastal Cape Breton has generally been divided into two offshore regions plus the Bras d'Or lakes. This division is largely the result of the geological and geographic setting of the region as well as the oceanographic characteristics of these areas. The offshore regions are the Gulf of St. Lawrence area from Cape North to the western entrance to the Strait of Canso and the eastern offshore area from Cape North to Ile Madame/Chedabucto Bay, commonly referred to as the eastern Scotian Shelf (Figure 18).

An assessment of general oceanographic characteristics will identify areas of promise for in-stream tidal power development and eliminate certain areas from further consideration. From a marine geological and oceanographic perspective, the critical factors affecting the viability of a site for the deployment of marine renewable energy devices are:

1. Currents (tidal converters);
2. Wind regime (offshore wind converters);
3. Wave regime (wave converters);
4. Bottom type – sediments and bedrock (all devices; mooring and anchoring); and,
5. Existing seabed bedforms (all devices; mooring and anchoring).

These critical factors are described in more detail in the sections that follow.

5.2 Coastal Cape Breton - Regional Physiography and Morphology

Cape Breton Island lies to the northeast of mainland Nova Scotia and is connected to the mainland by the Canso Causeway constructed in 1955. The southeastern side abuts the submerged Scotian Shelf, which extends from Canso Strait, through Chedabucto Bay, to Sydney Bight and ends in the Cape North region. In this northern area the wide, deep Laurentian Channel lies close to the land (Figure 21). The Channel is a major conduit extending from the Gulf of St Lawrence through the eastern Scotian Shelf, dividing the Shelf from the western Grand Banks of Newfoundland. On the western side of Cape Breton Island lies the Gulf of St. Lawrence. The southeastern part of the Gulf is known as St. Georges Bay and it joins the western end of the Canso Strait.

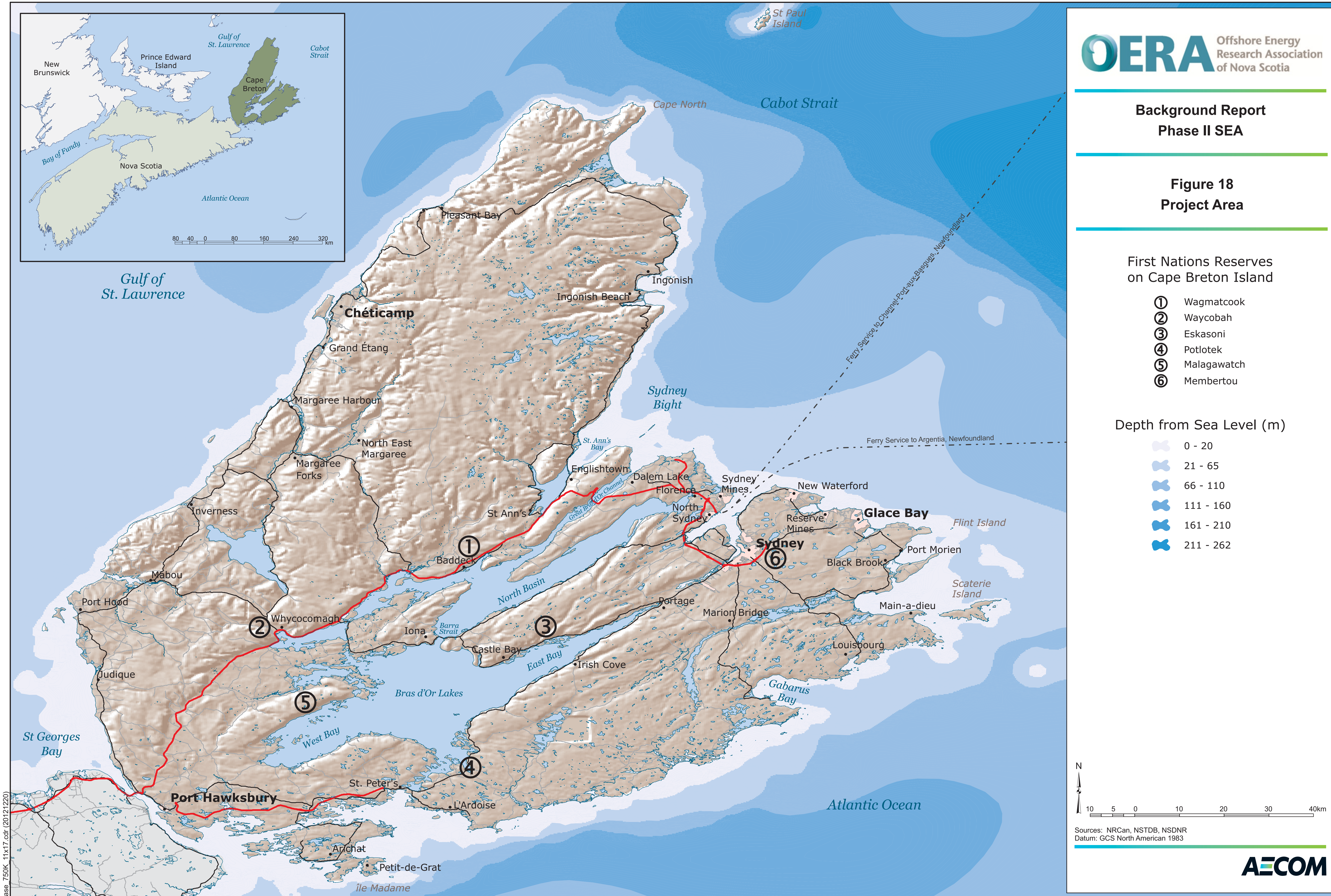
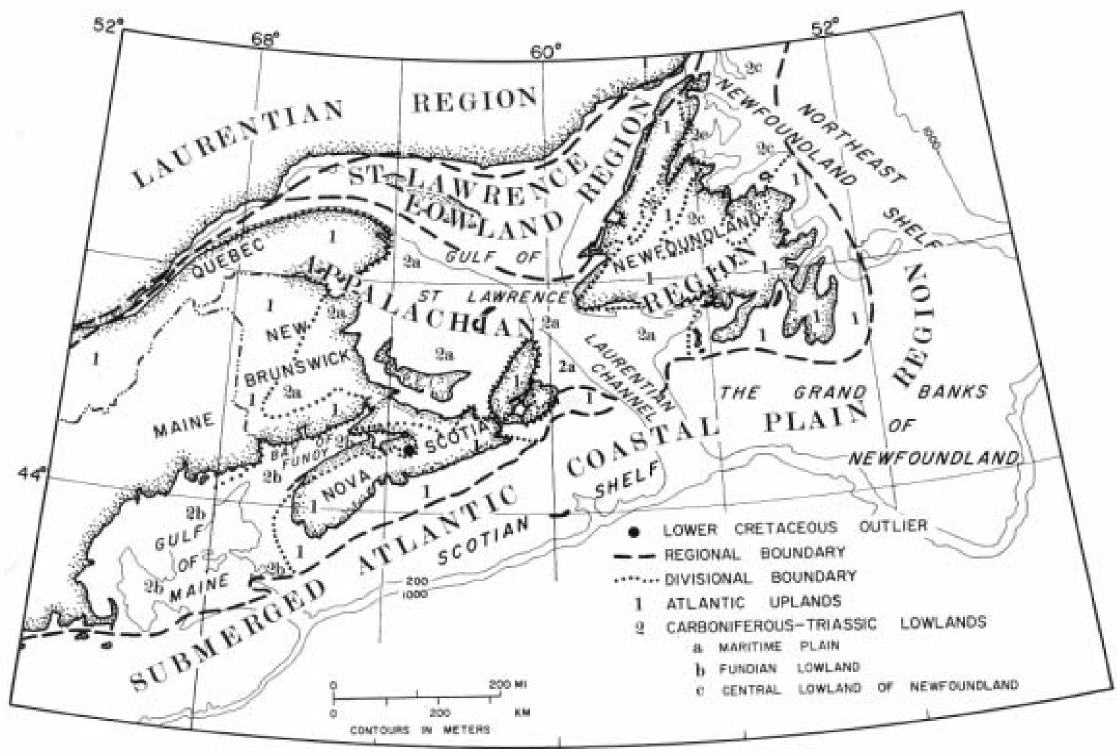


Figure 18
Project Area

Cape Breton Island and much of the Scotian Shelf fall within the Appalachian Region geomorphic province (Williams *et al*. 1972) (Figure 19). The Appalachian Region is composed largely of hard metamorphic and crystalline rocks, which form the Atlantic Uplands (mainland Nova Scotia and Cape Breton as well as the inner, rugged part of the Scotian Shelf near land) and the Carboniferous Triassic age Lowlands physiographic province (offshore areas including the Laurentian Channel, Gulf of St. Lawrence and the Gulf of Maine).

Figure 19. Physiographic Divisions of Atlantic Canada



Source: modified after Williams *et al.* 1972

The final rise in sea level after about 10,000 years ago gradually smoothed and redistributed previously deposited glacial sediments in water depths generally less than 60 to 110 m, producing a series of drowned beaches across the banks and inner shelf areas. This complex geological and depositional history is reflected in the sediments and subsequent bedforms that developed on the ocean floor of coastal Cape Breton.

5.3 Bras d’Or Lakes - Regional Physiography and Morphology

A major source of information regarding the Bras D’Or Lakes is contained in Nova Scotia Institute of Science, Volume 42, 2002, a series of papers that describes the oceanography, ecology, geology and coastal processes. The Geological Survey of Canada (GSC) in cooperation with the Canadian Hydrographic Service (CHS) has also published a comprehensive suite of multibeam bathymetric maps on the lake bottom (Shaw *et al.* 2002a; Shaw and Potter 2007) and interpreted the surficial geology of the lakebed. Much of what is contained in the following sections is summarized from these publications.

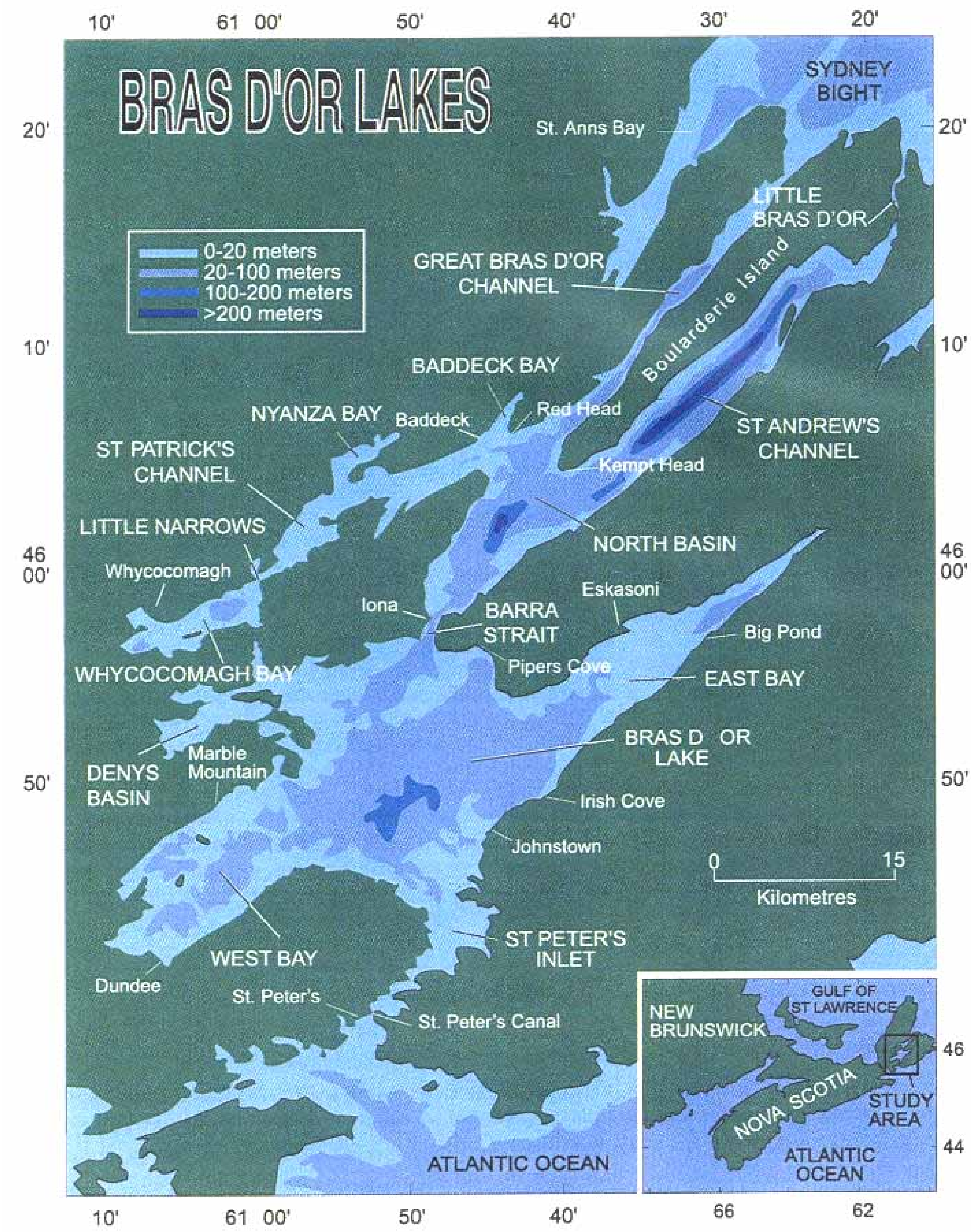
The Bras d'Or Lakes are a series of deep (max 280 m), estuarine water bodies surrounded by land (Figure 20). Oriented in a northeast-southwest direction, the irregularly shaped lakes are approximately 90 km long by 43 km wide. Containing an estimated volume of 32,000 m^3 of water, the lakes cover a surface area of almost 1,200 km^2, into which drains a watershed exceeding 2,400 km^2. The Lakes are semi-enclosed with limited connection to the adjacent ocean, receive considerable freshwater input from the large watershed, and therefore exhibit a wide range of water temperature and salinity (Petrie and Bugden 2002).

The Bras d'Or Lakes are situated over poorly-resistant bedrock lowlands formed by rifting and tectonic plate movements over 360 million years ago (Shaw *et al.* 2002b). Following this period, low-lying areas were flooded by sea water, which deposited mud and evaporites such as gypsum, anhydrite and salt. Evaporite rocks are formed by the evaporation of mineral-rich seawater in basins with limited access to the open ocean. These deposits were overlain by coal-bearing Carboniferous-age sandstones which host the coal seams found in the Sydney and Donkin areas. Since this time (about 300 million years ago) Cape Breton Island has been uplifted and eroded particularly in the Great Bras d'Or region where rocks are much softer than in the nearby uplands. Thus the lake basins have existed for a very long time and preserve a complex sequence of sedimentary rocks.

The lakes are connected to the Atlantic through three narrow passages. Great Bras d'Or Channel is by far the largest entrance to the Bras D'Or Lakes, and has been identified as a potential site of tidal energy development (EPRI 2006; Cornett 2006). The Channel is located on the west side of Boularderie Island and is oriented northeast-southwest. At approximately 17 nautical miles long (30 km) and averaging 0.75 nautical miles wide (1.3 km), it is the longest of the three entrances. The channel is narrow (320 m) and only 16 m deep near its northern end at Carey Point/Noir Point, effectively restricting tidal flow through this passage. Further north, the channel opens up and enters Sydney Bight and the Gulf of St Lawrence. Currents are strong throughout the Channel, ranging up to 3 m/s in the narrowest section (Petrie and Bugden 2002). Water depths range from 20 m in the northern part of the channel and down to 95 m in the deeper southern area. The minimum depth in the channel is 8 m while the average depth is 19.5 m.

The Little Bras d'Or Channel located 10 km east has a much more restricted circulation than the Great Bras d'Or Channel (Yang et al 2007). It is only 8 km long, less than 100 m wide and averages 5 m deep (Petrie and Bugden 2002). The third and southern-most exit of the lakes is St. Peters Canal connecting St Peters Inlet to St Peters Bay. The Canal is 800 m long by 30 m wide and is designed to regulate water levels between the Bras d'Or Lakes and the Atlantic Ocean. St. Peters Canal is opened from time to time to allow vessel traffic to pass, but does not contribute significantly to water exchange with the Atlantic Ocean (Petrie and Bugden 2002).

Figure 20. Map of Bras d'Or Lakes Showing Simplified Bathymetry



Source: Lambert 2002

5.4 Glacial History of Cape Breton Island

5.4.1 Glacial Deposits

Till deposits (heterogeneous mixtures of clay, sand, cobbles and boulders) left by melting glaciers have been identified throughout the Gulf of St. Lawrence and on the Scotian Shelf (Josenhans and Lehman 1998). The presence of a widespread glacial till indicates that approximately 20,000 years before present, glaciers covered the entire region and also extended down the Laurentian Channel as ice streams to the shelf edge south of Newfoundland. Over time, the ice rapidly retreated through the formation of icebergs at the ice front (calving) as it became detached from the seabed. By 13,200 years ago the ice was confined to the near shore regions of the Gulf of St Lawrence with a few isolated ice tongues in the deeper channels.

In late glacial and post-glacial times sea levels have been both higher and lower than they are today, with the result that most of the Scotian Shelf has experienced several erosional and depositional episodes.

5.4.2 Relative Sea Level History

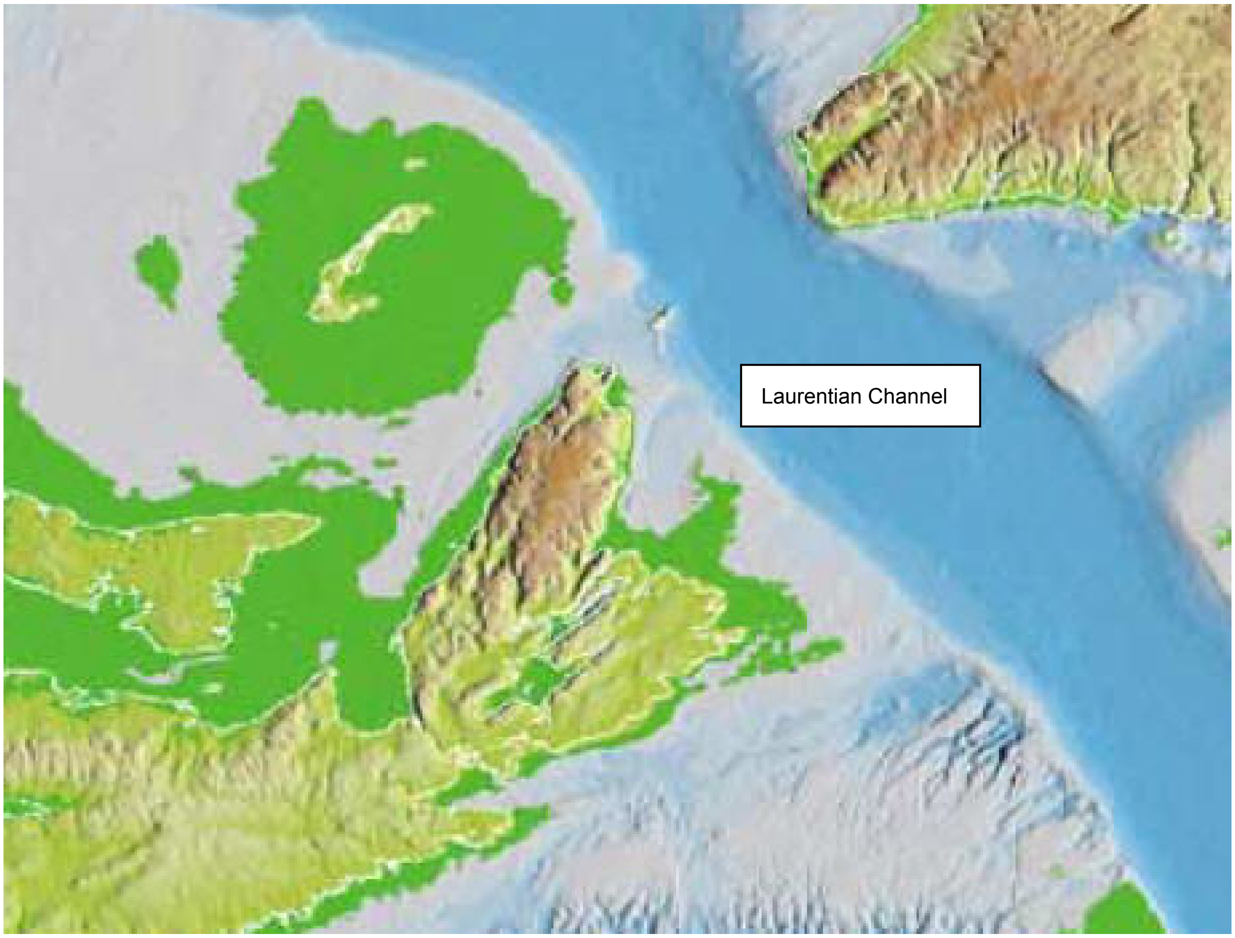
Sea level is of critical importance to the harvest of marine energy because the energy in waves and currents is modified greatly by the depth of water and the topography of the seabed and shoreline.

The relative sea level history of the continental shelf also plays a major role in the development and occurrence of sediments, which are in turn reworked by currents to sculpt the bedforms visible on the sea floor today. The presence and type of sediments will influence the type and scale of marine renewable technology that may be deployed, as well as the design of systems to attach these structures to the seabed.

Post-glacial low sea levels separate sediments that were “transgressed” during sea level rise from those sediments that have always been below water (not transgressed). As sea levels slowly rise the water transgresses across previously deposited glacial sediments and bedrock. This results in winnowing, sorting and erosion of previously deposited materials. Fine grained silts and clays are removed and transported to deeper water while gravels and sands remain. Since bedrock surfaces are stripped of sediment, transgressed regions are often represented by large areas of bedrock exposed at the seabed. This is common across the inner Scotian Shelf; these exposed bedrock areas can provide stable platforms on which to deploy marine renewable energy converters.

Given that exposed bedrock is typically found above (shallower than) the lowest glacial sea level, these stable bedrock platforms will be found above the lowest sea levels reached during glacial times. In the Gulf of St. Lawrence, sea level may have fallen to approximately 120 m (Josenhans and Lehman 1998) while levels in the St. Anns Bank region may have reached 50-70 m King (2012) or even110 m (Fader *et al.*1982). Shaw *et al.* (2002b) reported the lowest level for the region off Cape Breton occurred 9,000 years ago as and reached 80 m water depth (Figure 21). From this information it appears that stable exposed bedrock is most likely found in water less than 100 m deep. The 100 m depth contour line is generally at or within 10 km from shore.

Figure 21. Interpreted Low Sea Level at 9000 Years Ago



Source: Shaw *et al.* 2002b. Note : Exposed land is shown in dark green

5.5 Geological Setting

5.5.1 Coastal Cape Breton - Bedrock Geology

The oldest rocks in Cape Breton are referred to as “basement rocks” and consist of metamorphic and igneous crystalline sequences that underlie most of terrestrial and offshore Cape Breton (Figure 22). These rocks collectively are known as the Avalon Terrane and contain rocks dating from the Precambrian to Devonian periods (600 to 360 million years ago) (Lackey *et al.* 2007).

Terrestrial geology continues seaward to the offshore. The inner Scotian Shelf is an extension of coastal bedrock, which reaches seaward approximately 25 km to a depth of 100 to 120 metres (NSMNS 1996). Overlying these ancient basement rocks, the Gulf of St. Lawrence and Laurentian Channel host Carboniferous-age sedimentary rocks extending further offshore into the Magdalen and Sydney basins. These rocks also extend outward from shore beneath the Scotian Shelf but here, at about 25 km offshore, are overlain by younger Jurassic, Cretaceous and Tertiary-age sedimentary beds, which are not found on shore. The younger rocks form the broad platforms, which are the bases for the large offshore banks (NSMNH 1996).

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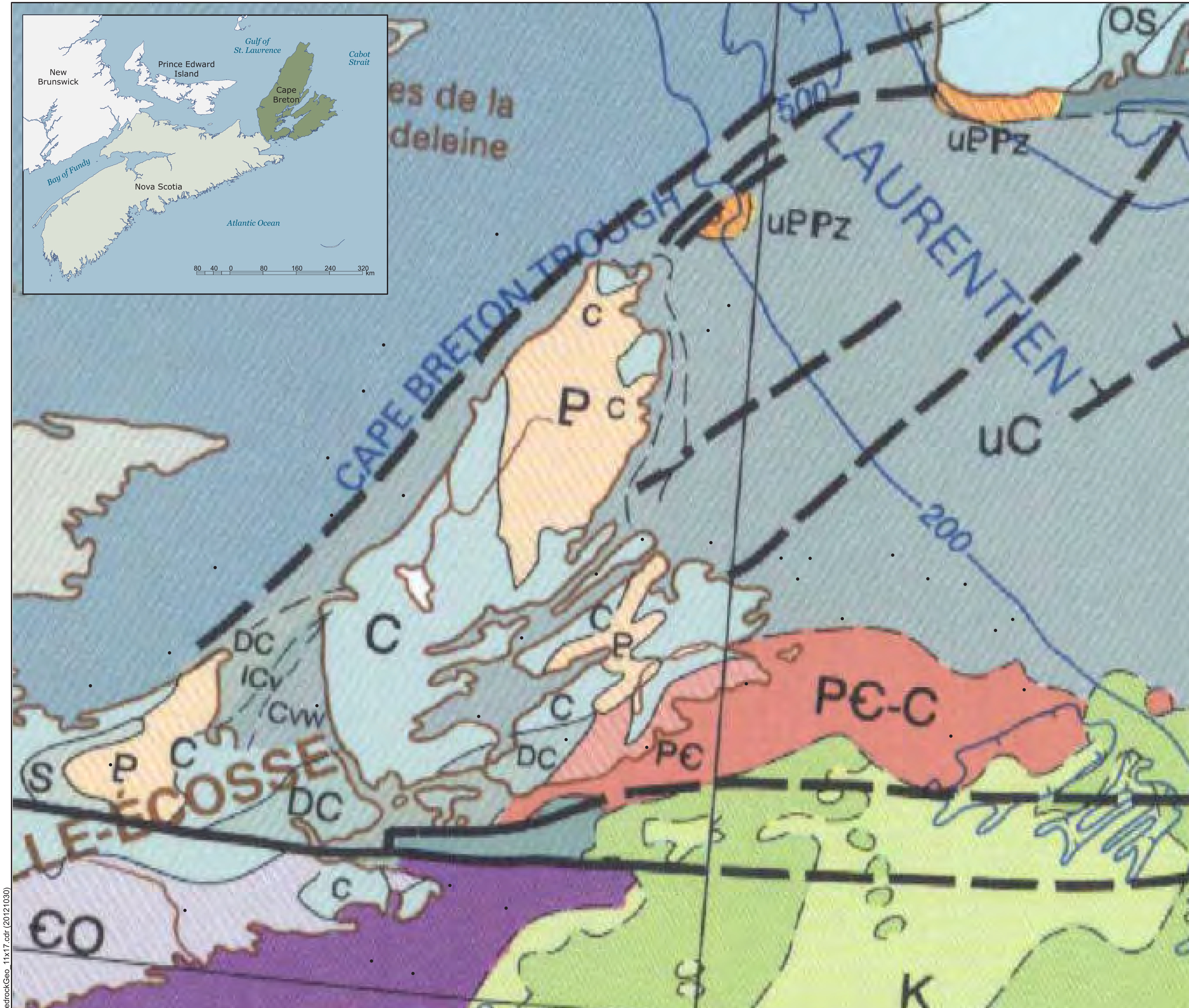
Figure 22
Bedrock Geology of the Gulf of St Lawrence and Sydney Bight



BEDROCK GEOLOGY

- KT, *Cretaceous-Tertiary;*
  uKT, *upper Cretaceous-Tertiary*
- K, *Cretaceous (undivided)*
- Pz, *Paleozoic*
- C, *Carboniferous;*
  uCP, *upper Carboniferous-Permian*
- uC, *upper Carboniferous,*
  Cvw, *Carboniferous (Visean to Westphalian)*
- lcv, *lower Carboniferous (Visean); l*
  CT, *lower Carboniferous (Tournaisian)*
- DC, *Devonian-Carboniferous*
- OS, *Ordovician-Silurian*
- ЄO, *Cambrian-Ordovician*
- PЄ, *Precambrian;*
  PЄ-C, *Percambrian-Carboniferous*

N

20 10 0 20 40 60km

AECOM

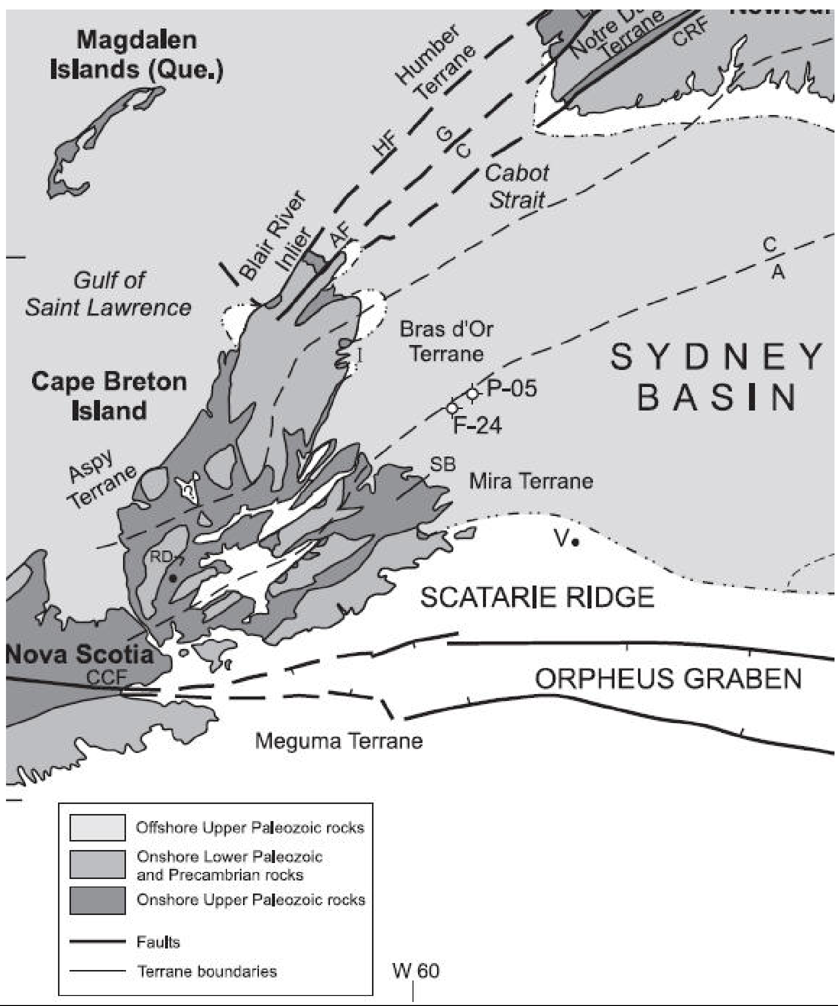
BedrockGeo_11x17.cdr (20121030)

Sydney Basin

The Sydney Basin comprises a large part of the offshore of Cape Breton (Figure 23). Deepest in the basin are found mid Devonian to Permian-age rocks on the order of six to seven kilometers thick (Pascucci *et al.* 2000). Younger Carboniferous-age rocks, some of which contain coal, occur over much of the northern region. The rocks continue to the north and west and cover a large region between Cape Breton Island and the south coast of Newfoundland.

In the Gulf of St. Lawrence, Upper Carboniferous to Permian-age sedimentary rocks cover the remaining areas of the Gulf in the south including the southeastern part of the Laurentian Channel, the Cabot Strait and most of the Magdalen Shelf (Figures 22 and 23).

Figure 23. Bedrock Geology Map of Offshore Cape Breton



Source: Pascucci et al. 2000

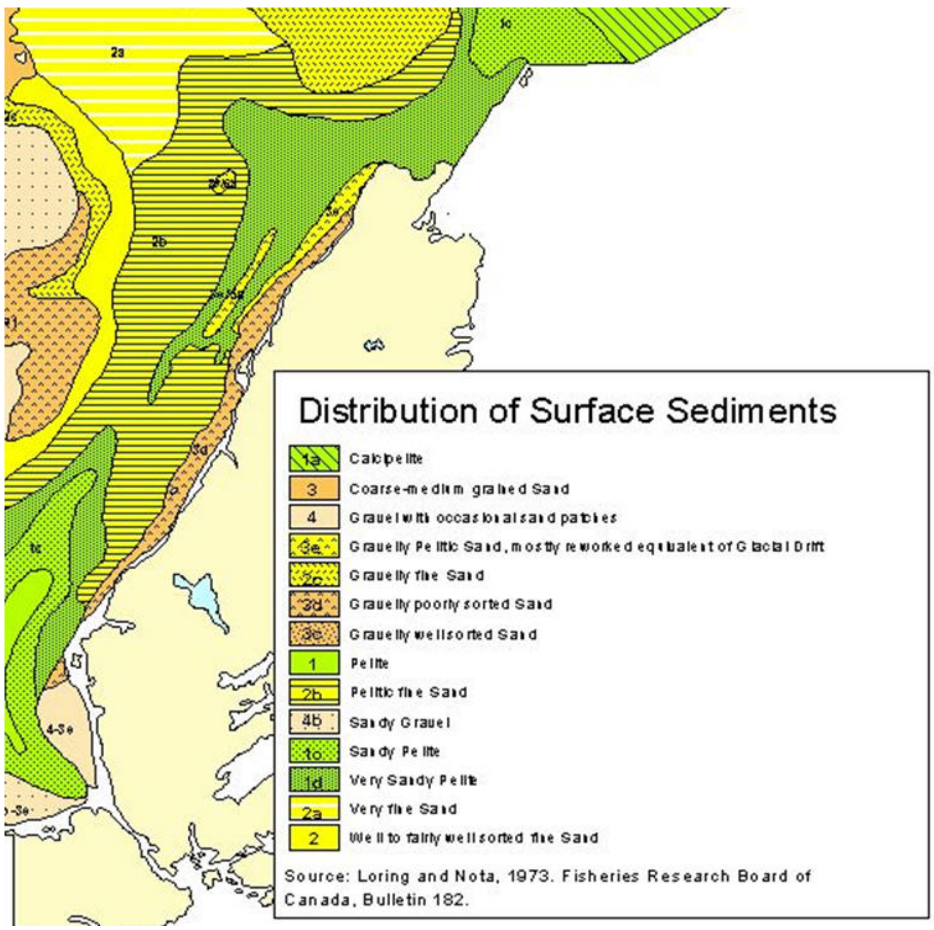
Note: This figure shows the major structural features in dashed Lines, terranes, offshore well sites and the location (V) of a bedrock drill core sample from Scatarie Ridge.

5.5.2 Coastal Cape Breton - Surficial Sediments

Western Cape Breton

A comprehensive assessment of the physiography, sedimentology and geological history of the Gulf of St. Lawrence was undertaken by Loring and Nota (1973). The nearshore zone (within 10 km) is dominated by “gravelly, poorly sorted sand” closest to shore where wave energy is the highest (orange on Figure 24), “very fine sand” (striped yellow and black) and “very sandy pellite” (dark green) further offshore in low energy environments.

Figure 24. Surficial Geology Map Showing the Sediments of Northwestern Coastal Cape Breton



Source: Josenhans 2007, interpreted by Loring and Nota 1973

Eastern Cape Breton

The surficial geology of the St. Anns Bank region was originally mapped by Fader *et al.* (1982) and was more recently remapped using multibeam bathymetry (Figure 25). This figure also portrays, in symbolized form, survey tracks showing such features as exposed bedrock, sand bedforms, iceberg furrows, sediment grain size, and shallow gas-charged sediments. On Figure 25 the red box is DFO’s Proposed Area of Interest and the brown box is the region of multibeam bathymetry shown in Figure 30. Sidescan interpretations of seabed features and sediments are shown on this map as track line interpretations (source: Fader *et al.* 1982 Map 4015G).

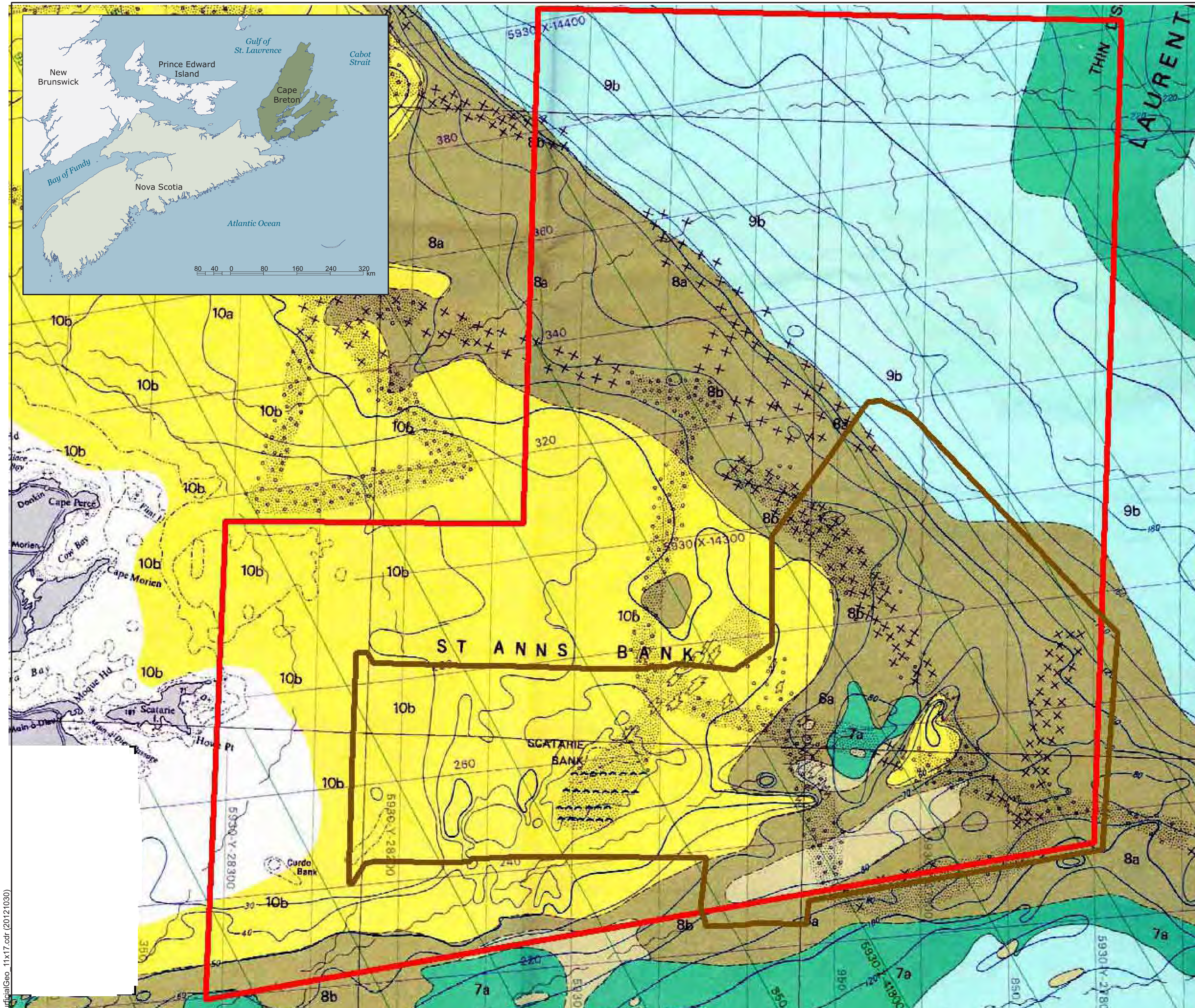


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Figure 25
Surficial Geology of st Anns Bank and Smokey Bank

Quaternary Cenozoic

10	Sable Island Sand and Gravel: 10a, sand with less than 50% gravel; 10b, gravel with less than 50% sand
9	La Have Clay: 9a, silty clay; 9b, clayey silt; 9c, silty sandy clay and clayey sandy silt grading locally to silty clayey sand (more than 20% sand)
8	Sambro Sand: 8a, mainly silty and clayey sand with less than 10% gravel; 8b, sand silt and clayof 8a, with more than 10% gravel
7	Emerald Silt: 7a, poorly sorted, claey and sandy silt; 7b, silt of 7a, with gravel
6	Scotian Shelf Drift, Newfoundland Shelf Drift; 6, glacial till, may include some stratified drift.

St Anns Bank Area of Interest

DFO Multibeam

N

7.5 3.75 0 7.5 15 22.5 30km

AECOM

SurficialGeo_11x17.cdr (20121030)

The following is a description of the surficial sediments of the St. Anns Bank region from Fader *et al.* (1982), King (2012), and Fader (2012). In water depths shallower than 110 m, most areas are covered by the Sable Island Sand and Gravel formation. This deposit formed as a result of a post glacial low sea level stand at or below this depth, and a subsequent sea level rise across shallower depths. Numerous large boulders were interpreted from sidescan sonograms near Scatarie Bank. Bedrock was exposed mainly on Scatarie Bank and the southern portion of St. Anns Bank. A small outlier of Sable Island Sand and Gravel occurs on East Scatarie Bank, the shallowest part of the Scatarie Ridge to the east of Scatarie Bank. Samples collected in water depths of less than 95 m mostly consist of various mixtures of sand and gravel. At some sites no samples could be collected, suggesting that the seabed is very hard possibly composed of bedrock or a dense gravel lag.

Seaward of St. Anns Bank toward the Laurentian Channel, the bank is surrounded by a deposit of muddy sandy gravel. This deposit extends to water depths of 220 m, reaching 293 m in places. The seabed in this region is covered by generations of criss-crossing iceberg furrows giving the seabed a distinctive random linear berm and trough topography.

5.5.3 Coastal Cape Breton - Bathymetry

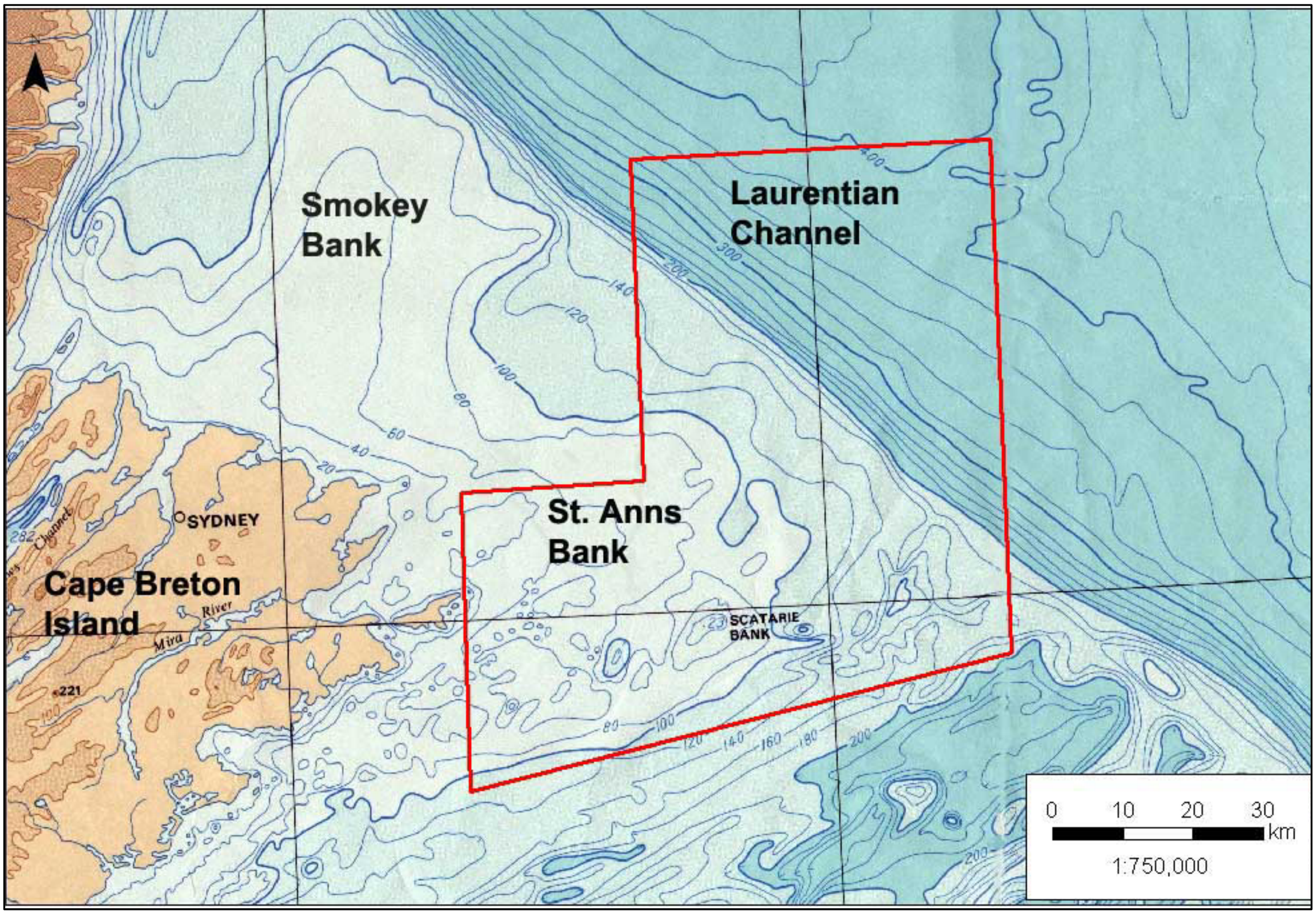
The nearshore bathymetry off the east coast of CBI deepens rapidly with a uniform slope to the 100 m contour, which is located on average approximately 10 km offshore (Figure 26). South of Scatarie Island and extending eastward toward Scatarie Bank, the Scotian Shelf shallows and flattens, becoming a wide shallow shelf of broad banks extending to 80 km offshore. In Sydney Bight lies a large re-entrant (an indentation of the shelf) that extends southwestward from the Laurentian Channel toward Sydney Bight. A second re-entrant is found in the Gulf of St. Lawrence where a large channel called the Cape Breton Trough parallels the northwest coast of Cape Breton approximately 20 km offshore. The edge of the Trough is defined by the 100 m contour while the deepest depths plunge to over 170 m. Along the southwest coast of Cape Breton and extending into St. Georges Bay, the seabed is regionally flat and featureless with depths rarely exceeding 60 m.

Figure 26. Generalized Physiography, Topography and Bathymetry of Terrestrial and Coastal Cape Breton Contour interval = 100m

Source: Sandford and Grant, GSC Map 1399A, 1976

Off eastern Cape Breton two large banks are located in water depths less than 100 m (Figure 27). The northwestern bank is unofficially called Smokey Bank and lies to the northwest of St. Anns Bank. A prominent east-west trending ridge south of St. Anns Bank is called Scatarie Bank. Water depths as shallow as 23 m occur on Scatarie Bank. The seafloor gently dips to the east from the 100 m contour of St. Anns Bank to the edge of the Laurentian Channel where the slope steepens down the flank.

Figure 27. Bathymetric Map of Smokey Bank, St. Anns Bank and the Laurentian Channel



Source: Fader 2012 (Canadian Hydrographic Chart 801). Note: The red boundary marks the limited of DFO Area of Interest for the potential future establishment of a Marine Protected Area.

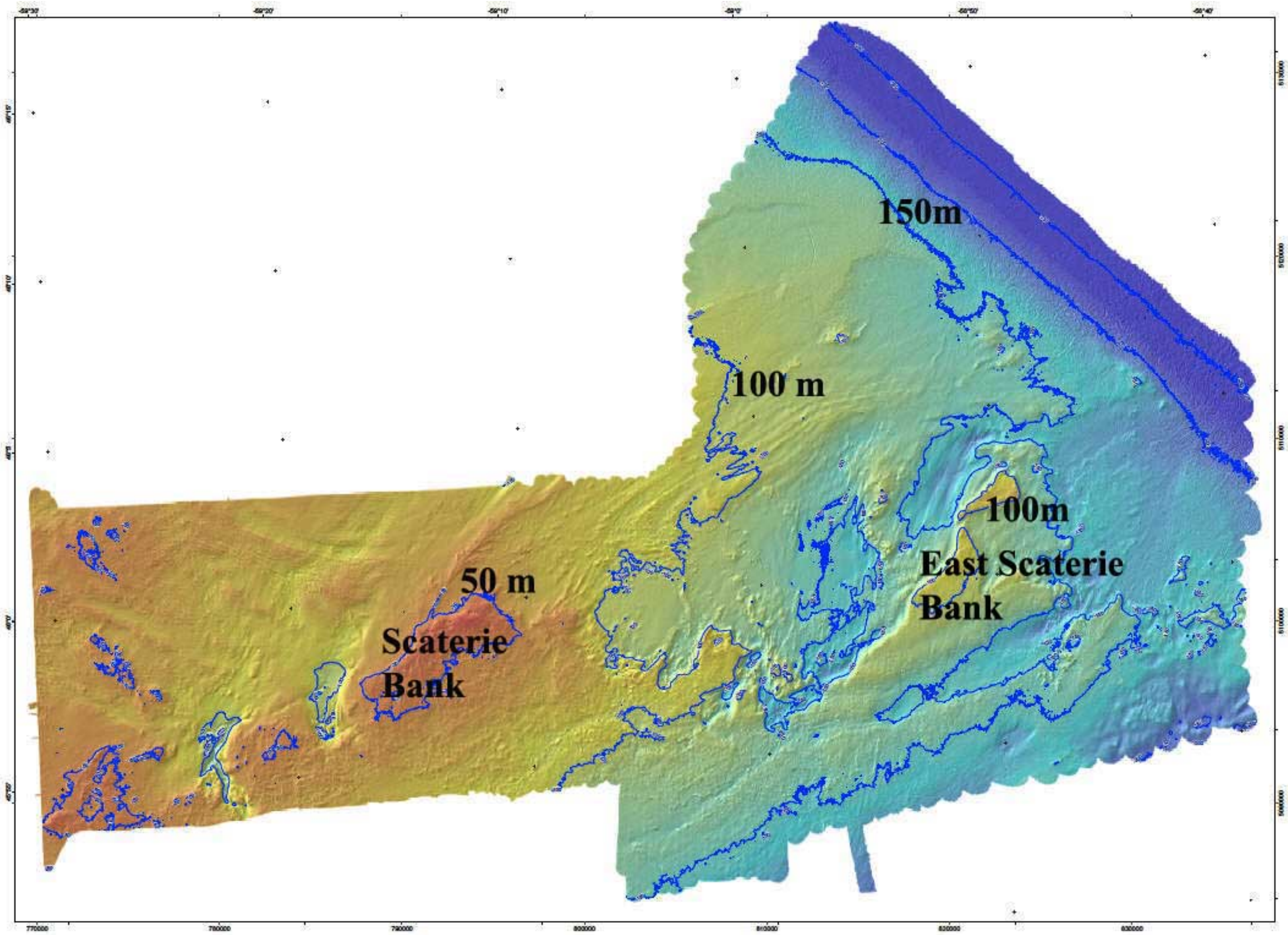
Multibeam Bathymetry

The modern standard in understanding morphology of the seabed is the application of multibeam bathymetry. This system provides high resolution imagery of seabed relief and can be processed for “backscatter” from which sediment type can be determined. Multibeam bathymetry has been collected for most areas of the Bras d’Or Lakes and certain offshore regions including the Strait of Canso, parts of Chedabucto Bay, southeast of Ile Madame, Louisburg Harbour, south of Gabarus, off Sydney Mines and Point Aconi and a large region off the central west coast of Cape Breton (Figure 28). Additional regions not shown on Figure 28 include an area to the east of Scatarie Island and along the APOCS telecommunications route from North Cape around St. Paul Island to the Newfoundland Coast. An extensive multibeam bathymetric survey has been conducted across St. Anns Bank (Figures 26 and 30), and interpretation of the imagery is presented in King 2012 and Fader 2012. Recent multibeam bathymetry data has also been collected near Point Aconi extending across the shelf to Newfoundland as part of a study of the Maritime Link, a proposed electrical transmission project. This multibeam bathymetry may become available through environmental assessments associated with project approval.

Figure 28. Cape Breton Offshore Region Multibeam Bathymetric Datasets

Source: Fader 2012; Note: Multibeam bathymetric datasets from the NRCan and GSC multibeam bathymetric web sites. Additional multibeam has been collected in a few areas in the Sydney Bight and St Anns Bank region – not shown. Deeper water is represented by darker colors.

Figure 29. Multibeam Bathymetric Map of the St. Anns Bank Region, East of Scatarie Island



Source: Fader 2012

Most of the offshore studies around coastal Cape Breton have been conducted using large research vessels. These vessels cannot operate in shallow nearshore coastal waters so many of the resulting maps have not covered this critical region: adjacent to the coast in less than 20 m water depth where in-stream tidal power potential may occur. Notable recent multibeam and benthic habitat surveys focused on relatively small areas in the region include the Sydney Harbour Dredging and Habitat Compensation surveys (McGregor GeoScience 2011; 2012), the Cabot Strait Power Cable Crossing survey (Stantec Ltd. 2012), and the St. Anns Bank Area of Interest survey (King 2012).

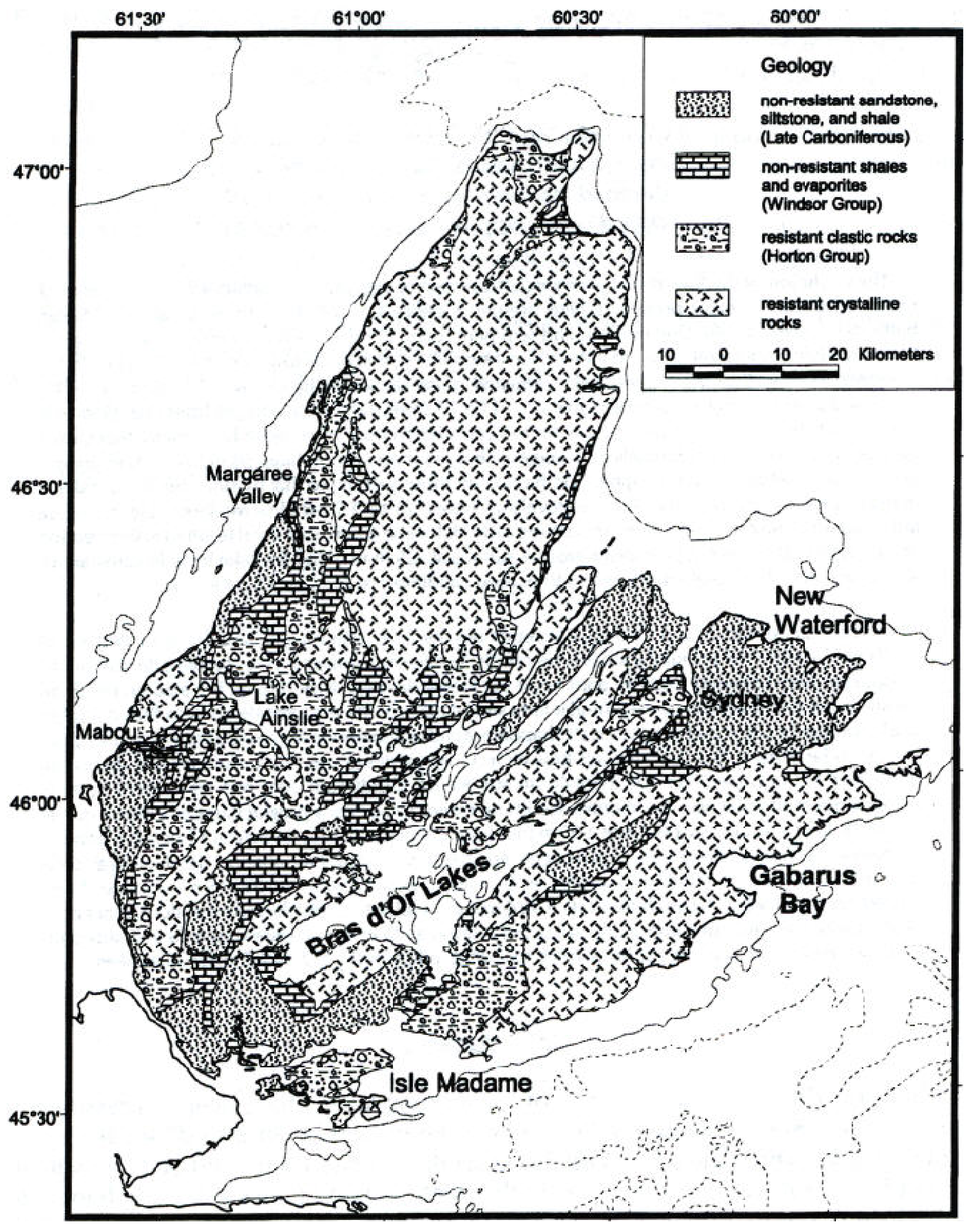
The multibeam bathymetry can be used to identify bedforms indicative of strong currents and moving sediments. However, not all areas of strong currents have these bedforms, as seabed scouring can totally remove sediments to expose the bedrock beneath. The presence of bedforms of varying shape, composition and origin can be used as a first approximation of where strong currents exist in a region in the absence of ocean current velocity data. Assessment of the multibeam bathymetry for the nearshore regions of Cape Breton are consistent with the oceanographic measurements and modelling that show the location of strong currents.

5.5.4 Bras d’Or Lakes – Bedrock Geology

As noted, the lake basins occur over deeply eroded softer rock lowlands (Grant 1994). Rifting at the end of the Devonian period over 360 million years ago formed a series of fault-bounded basins between adjacent highlands made of resistant crystalline rocks. Flooding of these basins 20 million years later deposited a thick sequence of mud and evaporite rocks including gypsum, anhydrite and salt, which underlie most of the Bras d’Or Lakes. Younger Carboniferous-age coal bearing sandstones were later deposited over these rocks. Subsequent regional uplift and river erosion removed much of the sandstone and developed the lowlands of the region. The deep water depressions of the Bras d’Or Lakes, including Great Bras d’Or Channel, owe part of their origin to dissolution of the evaporites through contact with freshwater, resulting in sinkholes and karst (cave-like) topography on the lake bottom (Shaw et al. 2002a).

The regional bedrock geology of Great Bras d’Or Channel can be assessed by mapping the rocks on both sides of the narrow channel (Keppie 2000) (Figure 30). In the east (inclusive Boularderie Island) the bedrock is Carboniferous-age sandstone, siltstone and shale. To the west the bedrock on the mainland across the Channel is largely resistant crystalline rocks although softer shale and evaporite rocks occur on the southwestern side of the Channel. The contact between the Carboniferous-age sediments and the older crystalline rocks lies largely beneath the Channel and is likely fault controlled in places.

Figure 30. Simplified Bedrock Geology Map of Cape Breton



Source: Keppie 2000

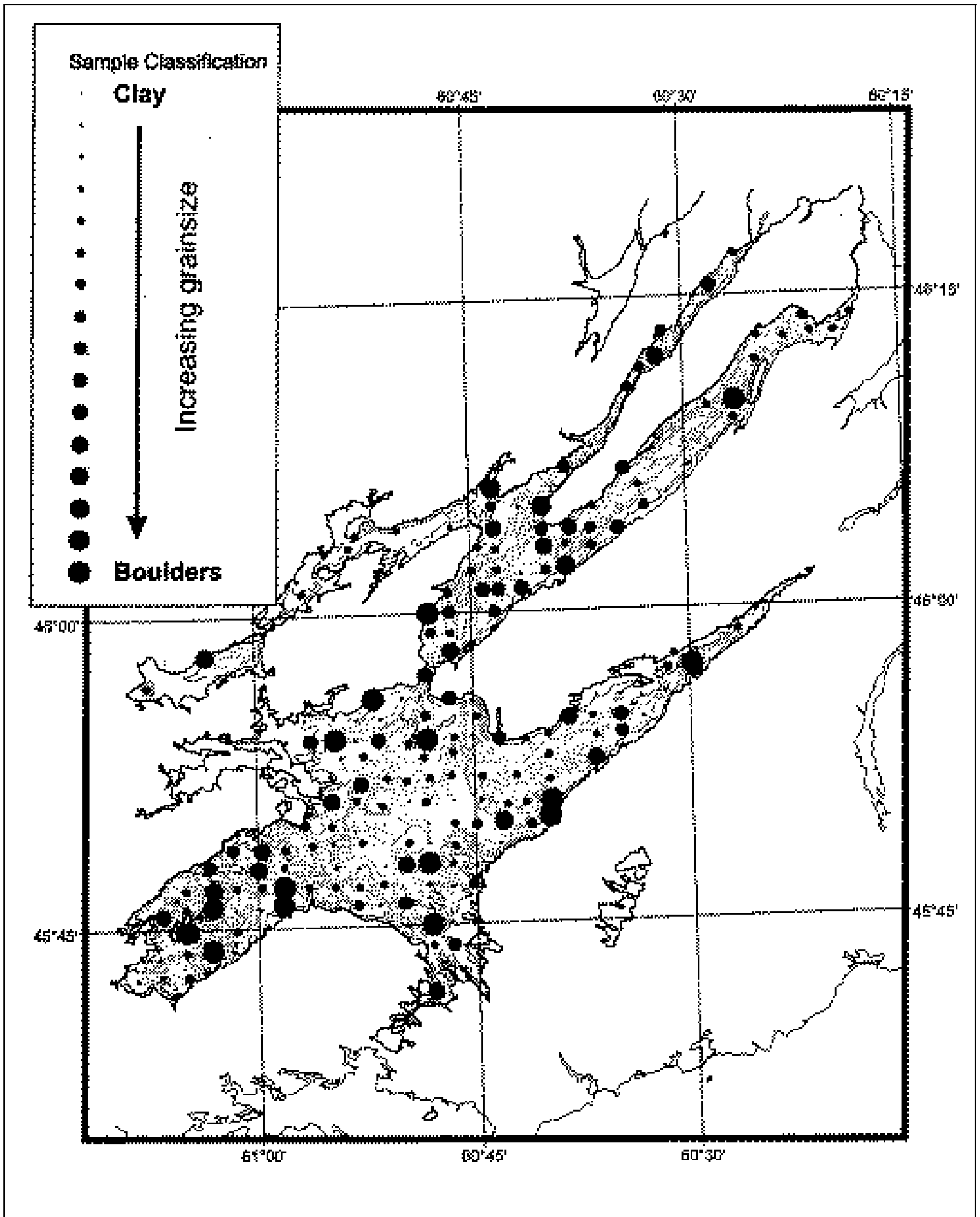
5.5.5 Bras d'Or Lakes – Surficial Sediments

Information on the surficial geology comes from seismic reflection surveys and sediment cores collected in 1985 and 1996 (Shaw *et al.* 2002a). During the last interglacial period approximately 125,000 years ago, sea level was 2-7 m higher in the region. The last major glaciation took place from 75,000 to 10,000 years ago and occurred over eight phases of advance and retreat with consequent lowering and rising of sea levels (Grant 1994). From 15,000 to13,000 years ago, an ice cap developed on Cape Breton Island and produced many of the glacial deposits now found on land and in the Bras d'Or Lakes.

Seismic reflection data and drill cores provide information on the sediments on the lake bottom. Sitting on the bedrock is a widespread glacial till layer up to 40 m thick, although this till is absent from the northern Great Bras d'Or Channel (Shaw *et al.* 2002a). Overlying the till is a silty, muddy glacial lake or marine unit up to 20 m in thickness that was deposited at the front of the glacier. This unit is tens of meters thick in certain lake basins including the Great Bras d'Or Channel. The uppermost unit is a mud whose deposition is controlled by the shape of the channels and their strong currents. This unit is generally confined to deeper and less energy intense areas.

Vilks (1967) collected a suite of samples in the lakes and Figure 31 represents the generalized grain size pattern. In general, the surface sediment in low energy deep basins is mud, while in areas of high energy and strong currents (such as Barra Strait and Great Bras d'Or Channel) the sediments are quite coarse and are classified in the gravel range. The shoreline of the Great Bras d'Or Channel is rocky along most of its length rather than unconsolidated sediments (Taylor and Shaw 2002).

Figure 31. Map of Typical Sediment Grain Sizes in the Bras d'Or Lakes



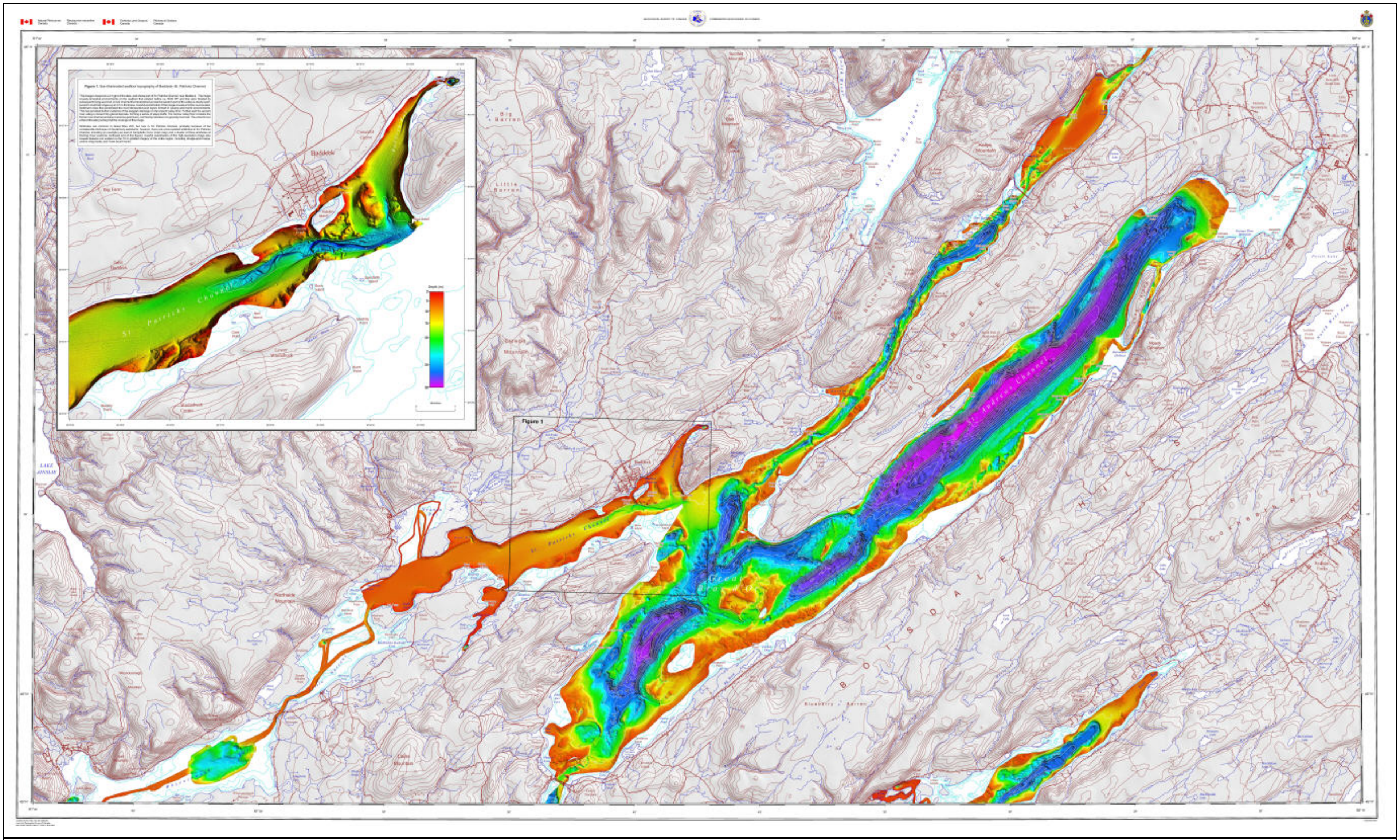
Source: Vilks 1967

5.5.6 Bras d'Or Lakes – Bathymetry

The Bras d'Or Lakes consist of several major interconnected basins and channels. St Andrews Channel is the deepest, attaining depths of 280 m, while North Basin exceeds 200 m depth, and the larger, South Basin reaches 157m depth. Great Bras d'Or Channel has an average depth of 19.5 m and a maximum depth of 95 m. At Carey Point/Noir Point where the Channel outlets to Sydney Bight and the Atlantic Ocean, water depth is only 16.2 m and the narrow channel is 320 m wide (Petrie and Bugden 2002). On average, the lakes are 30 m deep while many of the small bays and coves are 10 m or less in average depth (UINR 2007).

Figure 32 is a multibeam bathymetric, colour depth-coded, shaded-relief map of both Great Bras d'Or Channel and St. Andrews Channel to the southeast. The northern part of the Great Bras d'Or Channel is very shallow (<20 m) and a field of large bedforms, possibly gravel waves formed by strong currents, occurs just inside Carey Point where the Channel exits to the Atlantic.

Figure 32. Multibeam Bathymetric Map of the Great Bras d'Or Channel and St. Andrews Channel



Source: Shaw and Potter, 2007

Note: Red tones indicate shallower water, blue and purple tones indicate deeper water .

The seabed becomes rougher with a variety of ridges and a central deeper channel near the Seal Island Bridge crossing. South of the bridge the channel is much deeper and a series of ridges perpendicular to the channel are present. These may represent either bedforms or bedrock ridges. John Shaw suggests that bedrock is not exposed at the seabed throughout most of Great Bras d'Or Channel. Rather, the seafloor is covered by sediments of varying thickness with gravel at the surface of the lake bed (J. Shaw, pers. comm. 2005).

5.6 Physical Oceanography

5.6.1 Weather

The Atlantic Provinces experience a maritime climate characterised by the ocean's moderating effect on temperature. In general, maritime climates exhibit cooler summers and milder winters than continental climates and have a much smaller annual temperature range. Maritime climate tends to be fairly humid resulting in reduced visibilities, low cloud heights, and significant amounts of precipitation.

The climate of the region is governed by the passage of high and low pressure circulation systems. These systems are embedded in, and steered by, the prevailing westerly flow that occurs in the upper atmosphere in the mid-latitude regions. This westerly flow is the consequence of the normal tropical-to-polar temperature gradient, the intensity of which determines the mean strength of the flow and the amount of energy available to the low pressure systems. Therefore, during the winter[3] months when this temperature gradient is strongest, low pressure systems are generally more intense and tend to move faster than in the summer months.

Two main winter storm tracks, one from the Great Lakes Basin and the other from the Cape Hatteras/Cape Cod coastal area, direct low pressure systems toward the region (Bursey *et al.* 1977). The principal area where the low pressure systems develop extends from Cape Hatteras to the waters around Newfoundland. The intensity of these systems ranges from relatively weak events to major winter storm systems, many developing gale to storm force winds during their passage up the eastern seaboard.

During the winter months, Cabot Strait is subject to cold arctic air flowing south from northern Quebec. As arctic air moves across the warm waters of the Gulf of St. Lawrence the cold air acquires heat and moisture from the ocean forming streamers of snow showers which, during periods of prolonged northwesterly winds, may reach Cabot Strait. Frequently, intense low pressure systems become 'captured' and slow down or stall as they move through the Atlantic Provinces. This may result in an extended period of little change in conditions over Cabot Strait. When this happens, weather conditions may range, depending on the position and overall intensity and size of the system, from relatively benign to extremely unsettled.

Recent studies have shown that there exists a poleward shift of the jet stream, and consequently storm tracks, at a rate of 0.17 to 0.19 degrees/decade in the northern hemisphere (Archer and Caldeira 2008). This shift has been related to an increase in the equator-to-pole temperature gradient. McCabe *et al.* (2001) obtained similar results, finding that there has been a decrease in mid-latitude cyclone frequency and an increase in high-latitude cyclone frequency. In addition, McCabe (2001) found that storm intensity has increased in both the high and mid-latitudes.

There is a general warming of the atmosphere during spring due to increasing heat from the sun. This spring warming is greater in north latitudes than at the equator, resulting in a decrease in the north-south temperature gradient. Due to this weaker temperature gradient during the summer, storms tend to be weaker and not as frequent. The weaker summer tropical-to-polar temperature gradient also results in the storm tracks moving further north. With the low pressure systems passing to the north of the region, the prevailing wind direction during the

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[3] In meteorological science, the calendar year is divided into four quarters of three months each (e.g., winter is December, January, February; spring is March, April, May and so on).

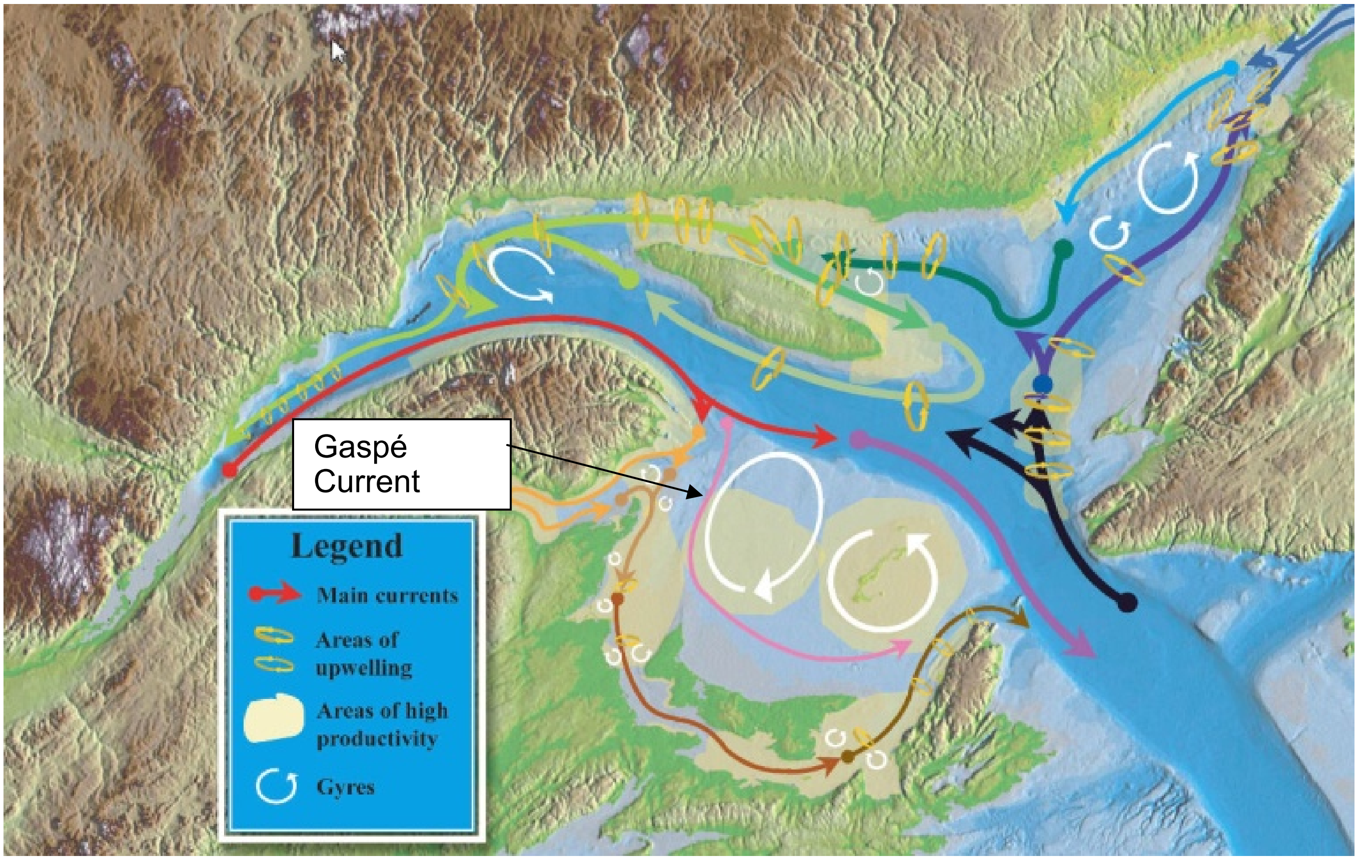
summer months is from the southwest to south. As a result, the incidences of gale or storm force winds are relatively infrequent in Cabot Strait during the summer.

5.6.2 Tides and Currents

Coastal Cape Breton

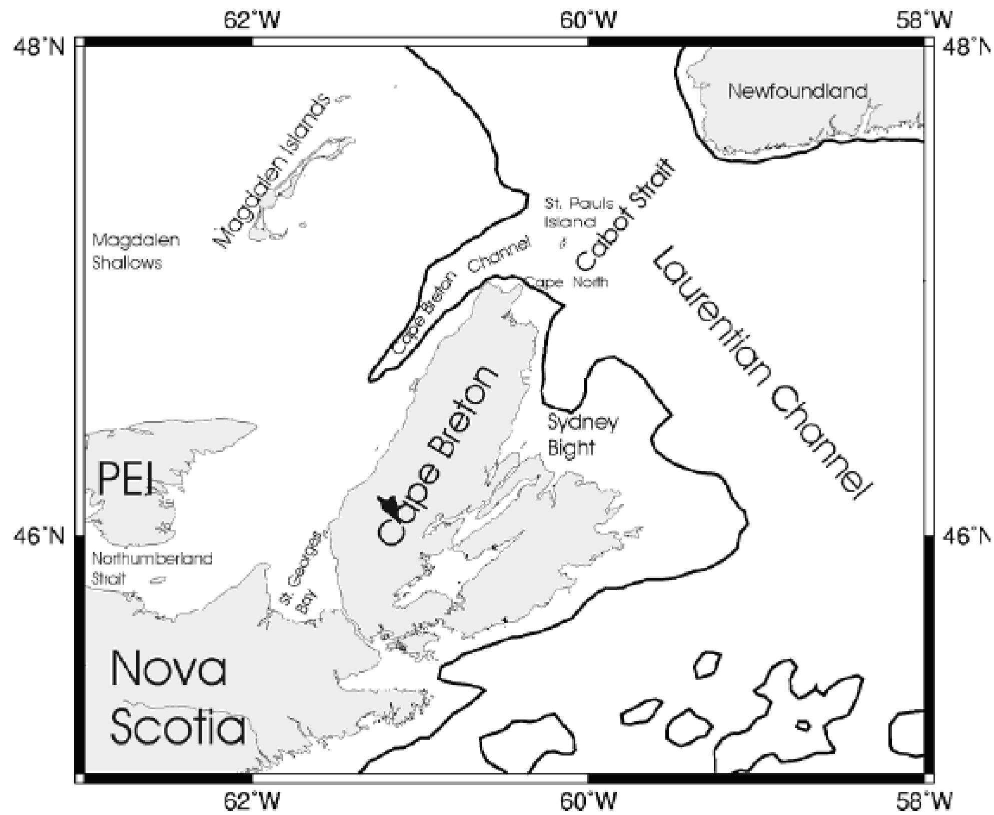
The Gaspé Current runs southeastward over the Magdalen Shallows and drives a coastal current along the north shore of Prince Edward Island (PEI). The coastal current then veers southwestward toward the eastern end of PEI until it reaches the western coast of Cape Breton Island, where it merges with the current flowing out of the Northumberland Strait (Figure 33). The semi-circular shape of the Gulf of St. Lawrence Basin and freshwater input causes a general estuarine-type cyclonic circulation in the southern Gulf and favors a predominantly northwestward coastal current along the west coast of Cape Breton Island. This coastal current is modulated and can be reversed by tide and wind action. Northerly winds exert a greater influence than southwesterly winds on the coastal current along the western shore of Cape Breton (Chassé 2001). The marine geography of this area in shown in Figure 34.

Figure 33. Major Currents, Upwelling, Gyres, and Areas of High Productivity in the Gulf of St. Lawrence Region



Source: Josenhans 2007

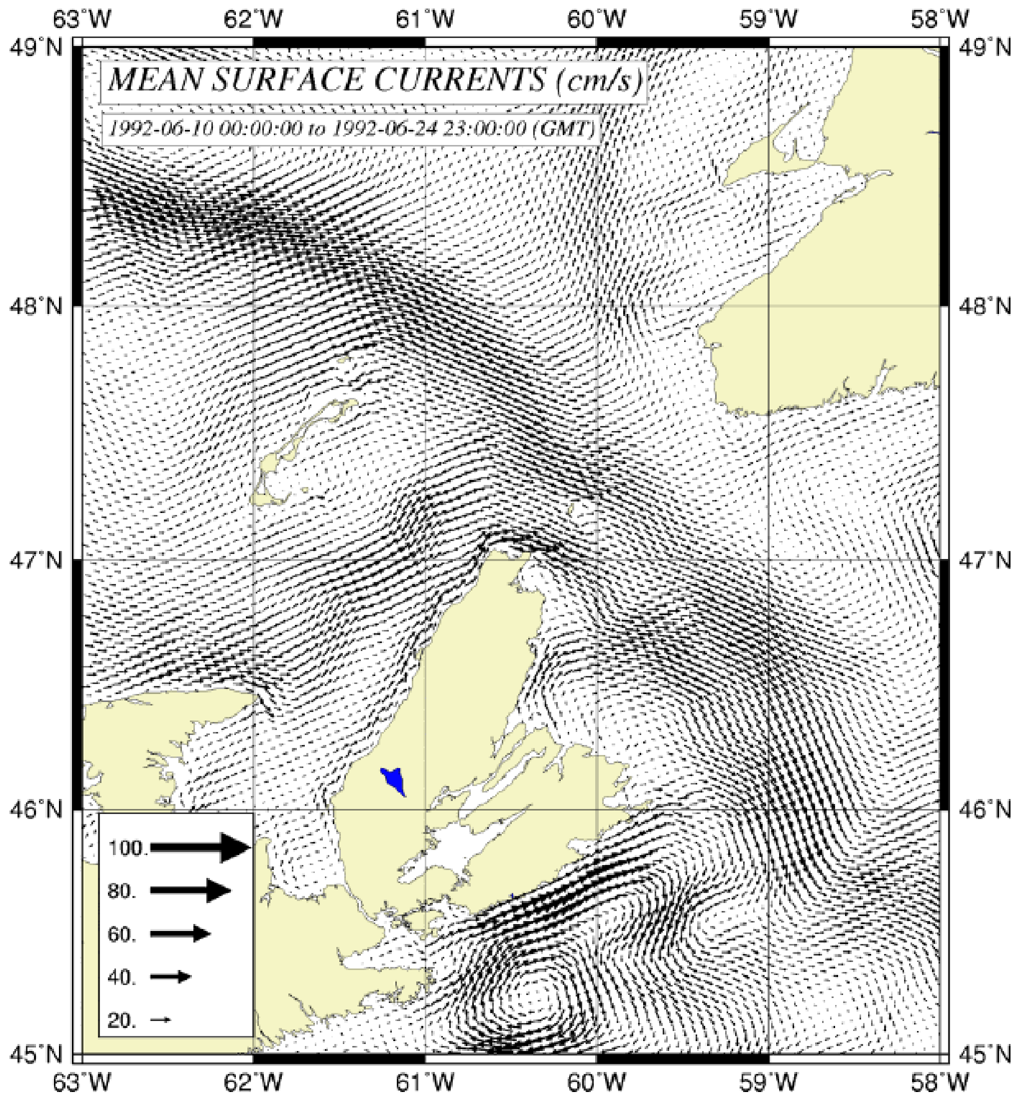
Figure 34. Marine Geography in the Vicinity of Cape Breton Island



Source: Chassé 2001 Note: The 100 m depth contour is shown in black.

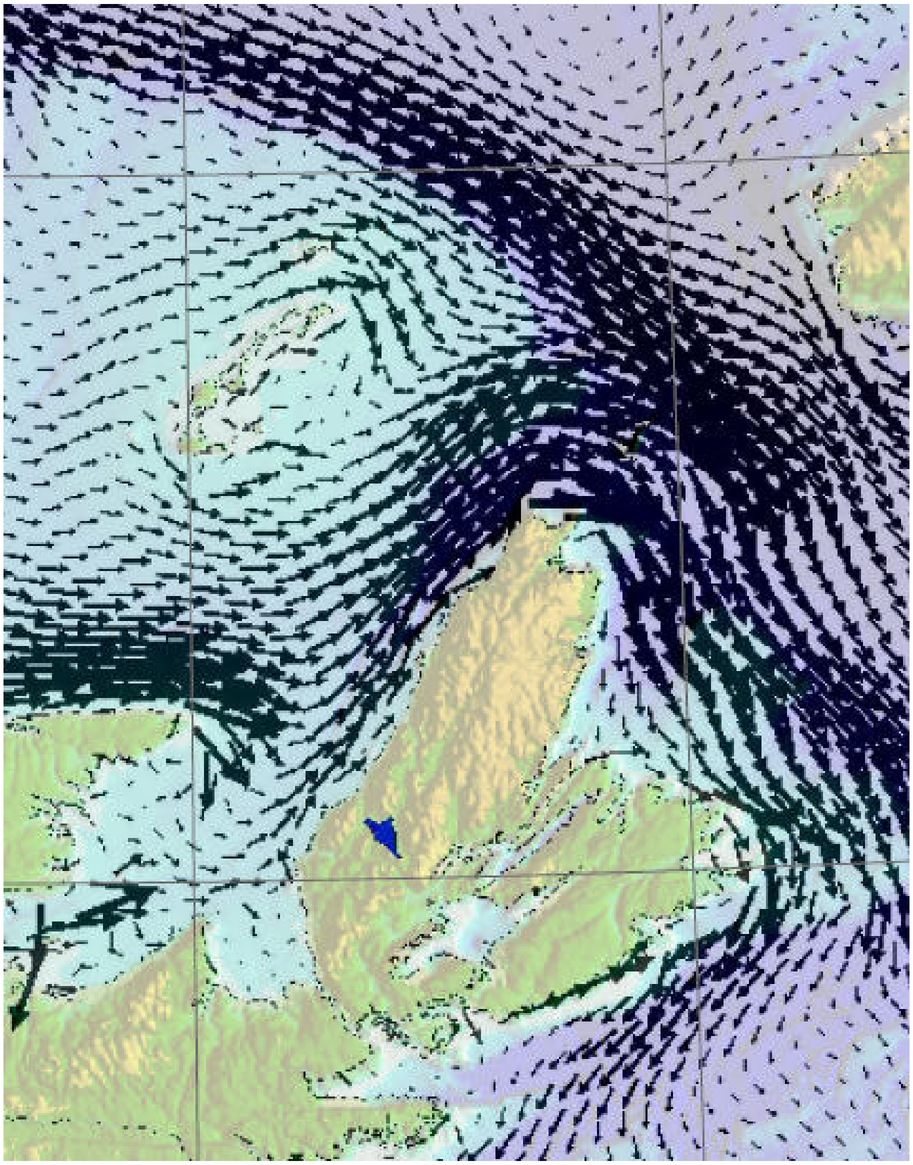
Part of the Gaspé current flushes the Magdalen Shallows before exiting on the southern side of the Cabot Strait where it merges with the main course of the Gaspé current following the slope of the Laurentian Channel. The Magdalen Shallows are deep enough to allow for wind-driven circulation. These wind-driven currents here show strong oscillations, which contribute up to 20% of the current energy. Mean surface currents are stronger in summer than in winter along the western coast of Cape Breton and in the Sydney Bight area. At the Cabot Strait, the surface water flows mainly between Cape North and St. Paul Island. Gyres are generated west of Cape Breton and at depth in the Sydney Bight area, where the flow moves either southwestward to follow the coast of Nova Scotia or moves offshore following the Laurentian Channel. Modeled residual mean surface currents (including wind forcing) in the vicinity of Cape Breton Island (for two weeks in 1992) are shown in Figure 35 (Chassé 2001). Figure 38 is a map showing the relative magnitudes and directions of depth averaged currents (0-20 m) for the month of August shows the areas where strong currents occur (Josenhans 2007). The strongest currents on the Gulf of St Lawrence side occur mid-way up the western coast of Cape Breton off Cheticamp, increase in velocity in the Cape North and St. Paul Island region and remain high offshore in a southeasterly direction to the region east of Scatarie Island, then swing around to the south west off southern Cape Breton. Regions of low velocity currents occur in St. Georges Bay, the southwestern part of Cape Breton, nearshore in the Sydney Bight and in most of Chedabucto Bay. These areas of high current would be of most interest to offshore tidal energy project developers. Figure 37 shows the seasonal relative depth averaged currents between 0 and 20 m for 2010 (Galbraith *et al.* 2011).

Figure 35. Modeled Residual Near Surface Currents with Wind Forcing



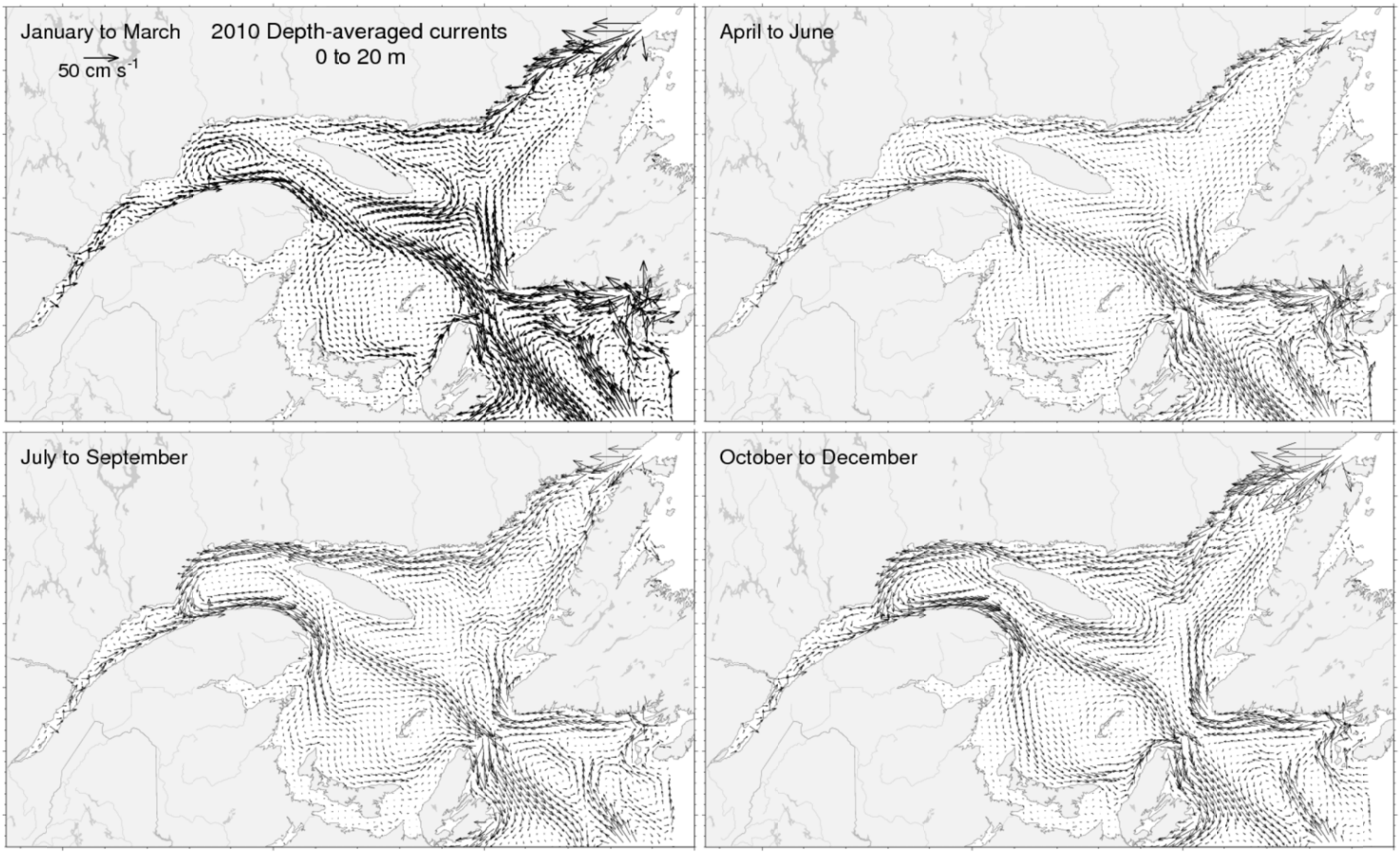
Source: Chassé 2001 Note: Averaged over two weeks in June 1992

Figure 36. Relative Magnitude and Directions of Depth Averaged Currents (0-20 m) in cm/s.



Source: Josenhans 2007

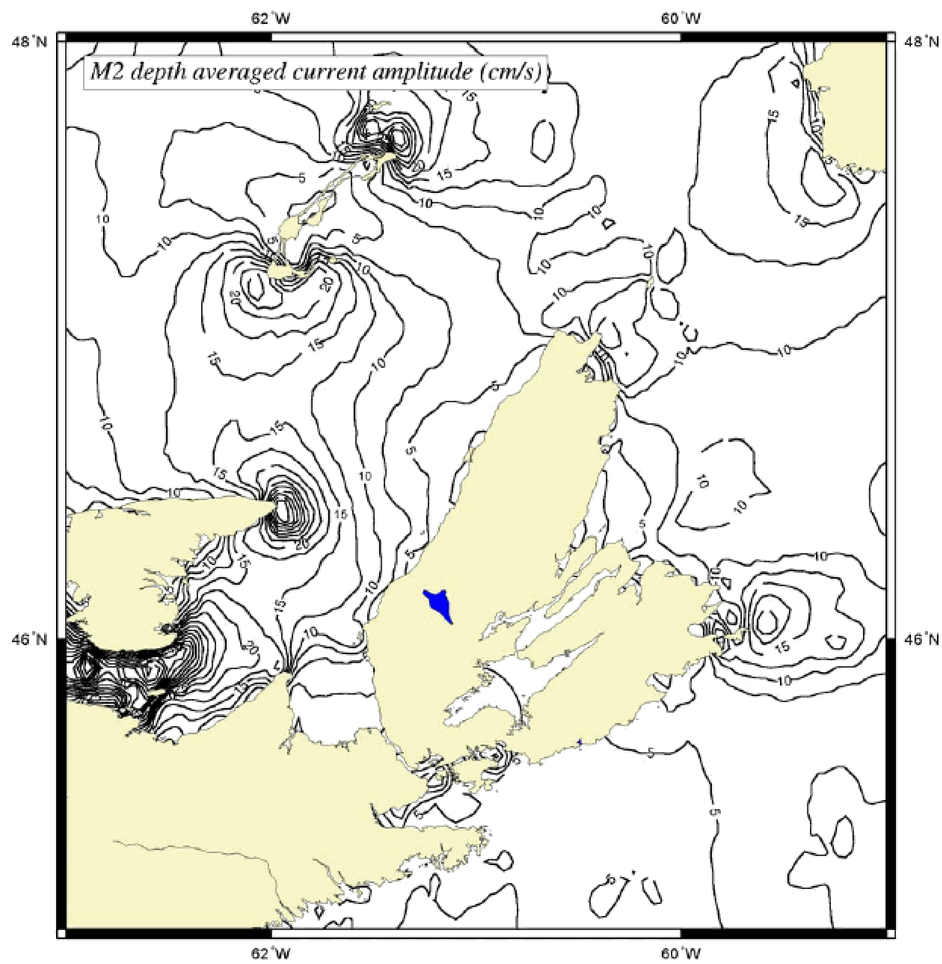
Figure 37. Relative Magnitudes and Directions of Depth Averaged Currents (0-20 m) for Each Season, 2010



Source: Galbraith *et al.* 2011

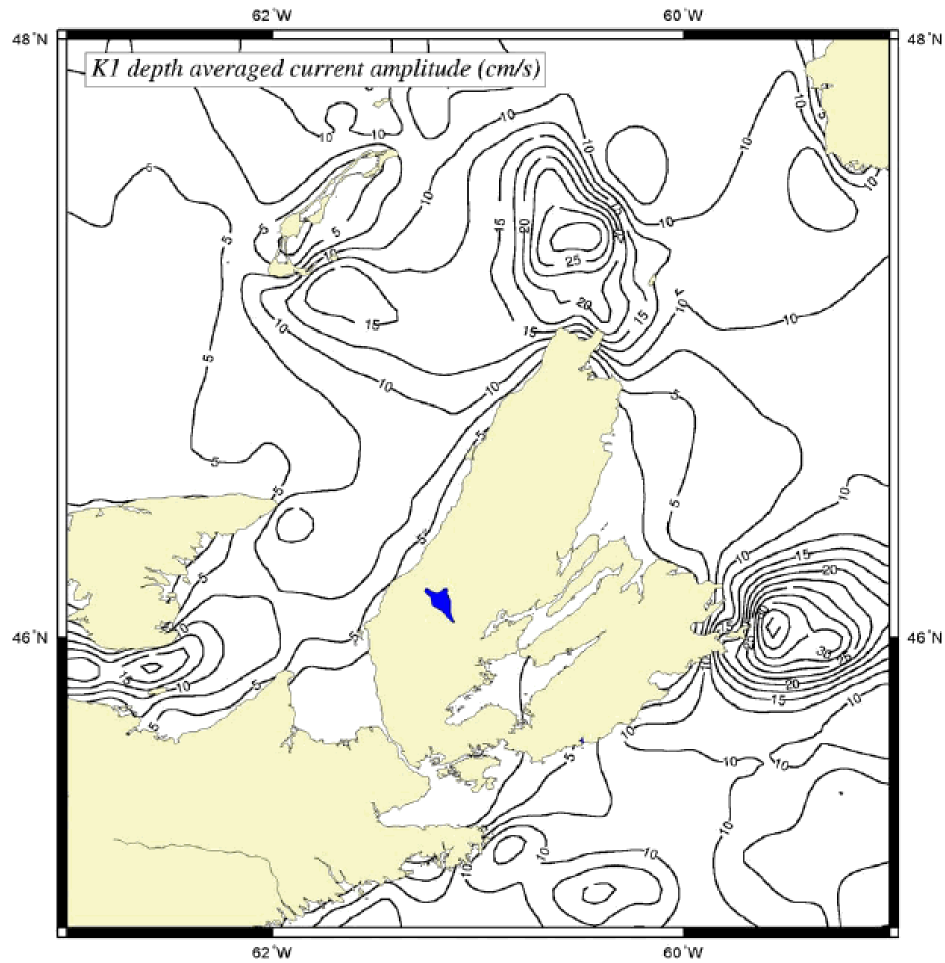
The tides that affect the Gulf of St. Lawrence are mainly due to the influence from the Atlantic Ocean to the west through the Cabot Strait. The amplitude of tidally induced semi-diurnal oscillations increases with distance away from the Magdalen Islands and the western part of the Northumberland Strait. Diurnal currents are the same order of magnitude as the semi-diurnal ones along the western side of Cape Breton Island. Figure 38 shows the depth-averaged current amplitudes of the M2 (principal semidiurnal) tidal constituent, and Figure 39 shows the current amplitudes of the K1 (principal diurnal) tides. Tidal current amplitudes range from about 5 to 10 cm/s for M2 and 5 to 15 cm/s for K2. Strong amplification of the K1 signal can be seen around St. Paul Island and east of Louisbourg near Scatarie Island. Tidally generated residual currents exist at Cape Breton's capes and at the tips of Magdalen Island and the western tip of PEI (Chassé 2001).

Figure 38. Depth-averaged Current Amplitude for Principal Semidiurnal Tidal Component M1



Source: Chassé 2001

Figure 39. Depth-averaged Current Amplitude for Principal Diurnal Tidal Component K1



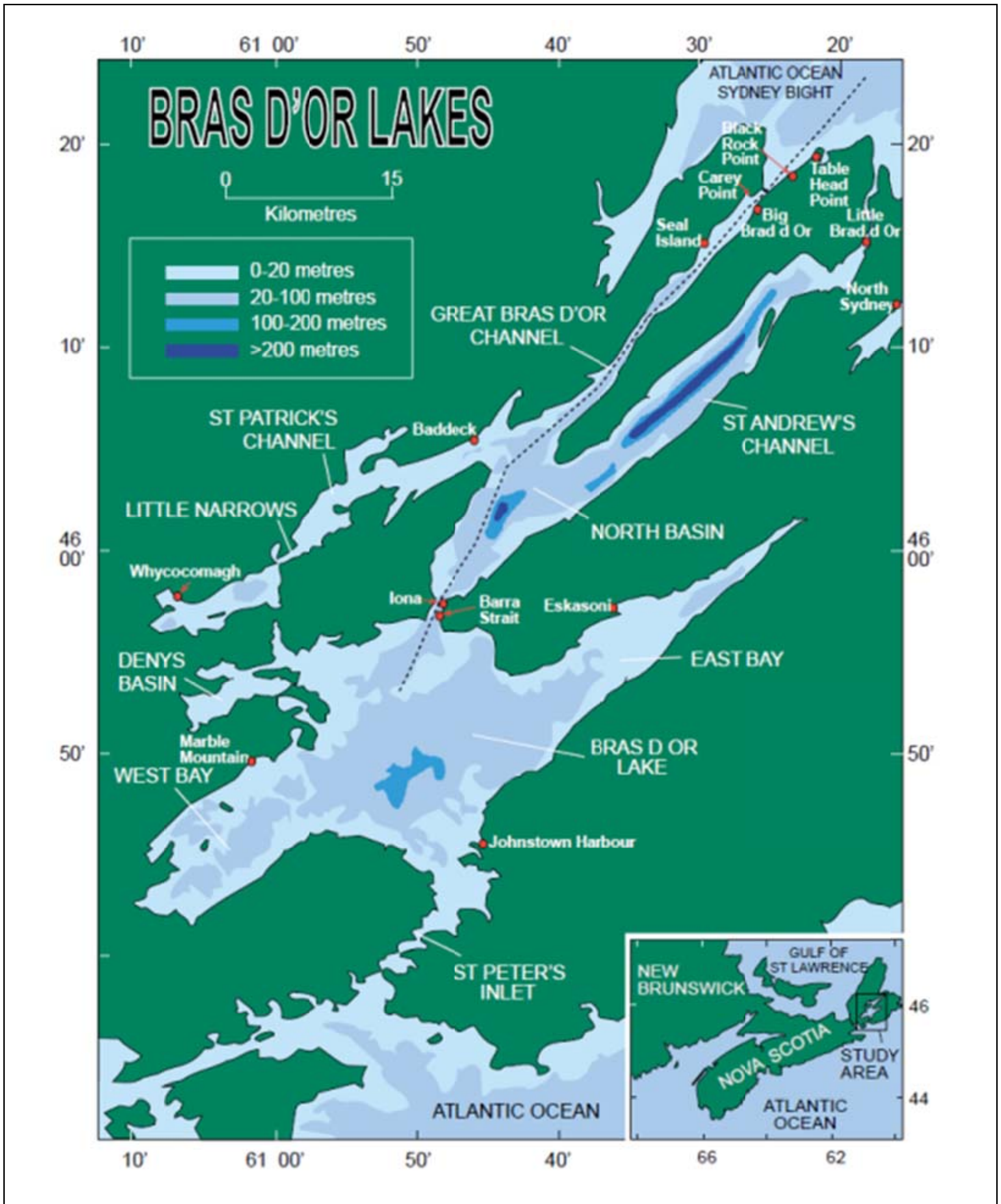
Source: Chassé 2001

Bras d'Or Lakes

Water circulation in Great Bras d'Or Channel consists of surface flow toward the ocean and subsurface flow from the ocean toward the lakes. Surface flow moves warm freshwater runoff from the upland watersheds out into the ocean while denser, more saline water flows into the lakes from the ocean (Petrie and Bugden 2002). In some places currents are minimal while in others they rival those of the Bay of Fundy with flows up to 3 m/s. Tidal range moderates rapidly from the Great Bras d'Or channel inward, with tidal ranges of 35 cm at Table Head near the entrance to 7 cm at Seal Island to 4 cm at Iona (Yang *et al.* 2007; Gurbutt et al. 1993; Petrie and Bugden 2002).

The Bras d'Or Lakes have been identified as a potential site for tidal energy development projects in Cape Breton (EPRI 2006). Observational Bras d'Or Lakes sea level and current data (Gurbutt *et al.* 1993), backed in part by results of tidal models designed by DFO (Dupont *et al.* 2003), reveal the strong tidal flows at the mouth of the Great Bras d'Or Channel and in the Barra Strait. These areas are shown on Figure 40.

Figure 40. Detail of Bras d'Or Lakes within Cape Breton Island



Note: Dotted line shows where comparisons between modeled and observed tidal elevations have been made (source: Dupont et al. 2003)

F. Dupont and colleagues at the Ocean Sciences Division of DFO constructed a two-dimensional, depth-averaged, finite element tidal model of the tidal circulation of the Bras d'Or Lakes taking into consideration the five principal tidal constituents (M2, S2 and N2 semidiurnal, and K1 and O1 diurnal). The sites of interest in the model (where major dissipation and strong tidal current occur) are at the mouth of the Great Bras D'Or Channel at Carey Point, along the Channel at sites such as Seal Island (about one third of the way along the Channel from the mouth), and at the northeastern side of the Barra Strait. Other sites, including Little Bras D'Or Channel and St. Peters Inlet, the only other connections to the ocean, and Deny's Basin have comparatively weaker tidal flows (Dupont *et al.* 2003).

Modeled and measured tidal currents (speeds) at Carey Point in the Great Bras d'Or Channel range from 1.14 m/s (4.5 m depth and in the local model) to 1.24 m/s (9.5 m depth) for the M2 constituent, and from 0.17 m/ s to 0.41 m/s for the other four major constituents. Modeled and measured tidal currents off Seal Island are lower than those at Carey Point, and are larger than those at Barra Strait, but are too uncertain to give useful results. Tidal currents in the Barra Strait range from 0.31 m/s (22 m depth) to 0.79 m/s (5 m depth). Table 6 gives tidal current values for Carey Point and the Barra Strait. Tidal currents in the rest of the Bras D'Or Lakes as a whole are generally less than 0.1 m/s. The M2 amplitude decreases from about 0.37 m outside the mouth of the Great Bras D'Or Channel to about 0.05 m at Seal Island and to about 0.04 m in the North Basin. The amplitudes of the four other major tidal constituents are about an order of magnitude smaller. Table 7 gives amplitude data at various locations shown on the map in Figure 40. Figure 41 gives a graphical interpretation of both tidal currents and amplitude information in the entire Bras D'Or Lakes area over the six stages of the M2 tide cycle. Agreement between modeled and observed elevation harmonics was within a few centimeters of amplitude and twenty degrees of phase. Agreement between modeled and observed tidal currents was between 5% for M2 and 39% for K1 (Dupont *et al.* 2003).

The circulation of the Bras d'Or estuary has subsequently been modeled with tidal, wind and buoyancy forcing using a high resolution numerical model (Yang et al 2007). The results capture the attenuation of tidal flows into the estuary, the significance of wind and buoyancy driven flows to complex surface circulations, and identify the potential importance of a low frequency atmospheric pressure induced water movement in the major basins that may drive vertical mixing and obscure or even reverse tidal flows in some channels.

Table 6. Tidal Currents in m/s for the Five Provincial Tidal Constituents

Phases Relative to Greenwich, and Orientation at Carey Point (Part A), and Barra Strait (Part B)

Depth (m)		M2	S2	N2	K1	O1
4.5	Amplitude	1.14	0.33		0.28	0.23
	Phase	192.5	222.2		123.3	67.3
	Orientation	45.6	48.7		40.4	41
9.5	Amplitude	1.24	0.38		0.30	0.25
	Phase	191.8	220.0		128.4	71.2
	Orientation	45.8	45.1		37.1	35.9
18.5	Amplitude	1.21	0.38		0.30	0.28
	Phase	190.4	218.6		124.5	68.1
	Orientation	42.7	43.5		42.0	39.5
Model	Amplitude	1.15	0.25	0.17	0.18	0.23
	Phase	193	231	162	145	112
	Orientation	52.5	50.8	50.9	48.7	50.1
Local Model	Amplitude	1.14	0.41	0.22	0.22	0.28
	Phase	202	237	169	159	119
Acceleration	Amplitude	3.7	1.28	0.73	1.23	1.82
Friction	Amplitude	1.2	0.43	0.23	0.22	0.28

Part A: Carey Point

Depth (m)		M2	S2	N2	K1	O1
1973, 5m	Amplitude	0.55	0.15	0.11	0.10	0.09
	Phase	217	278	186	121	167
	Orientation	20	22	20	19	19
1973, 22m	Amplitude	0.31	0.06		0.06	0.06
	Phase	199	302		94	131
	Orientation	28	30		33	25
1974, 5m	Amplitude	0.79	0.11	0.10	0.13	0.14
	Phase	223	273	207	126	167
	Orientation	26	21	28	24	24
1974, 10m	Amplitude	0.58	0.11	0.13	0.15	0.13
	Phase	188	255	163	97	136
	Orientation	27	23	22	26	23
1974, 20m	Amplitude	0.45	0.08	0.04	0.10	0.10
	Phase	201	264	92	86	141
	Orientation	30	31	33	28	29
Model	Amplitude	0.32	0.07	0.05	0.05	0.04
	Phase	213	256	193	131	172
	Orientation	28	29	28	29	29

Part B: Barra Strait

(source: Dupont *et al.* 2003).

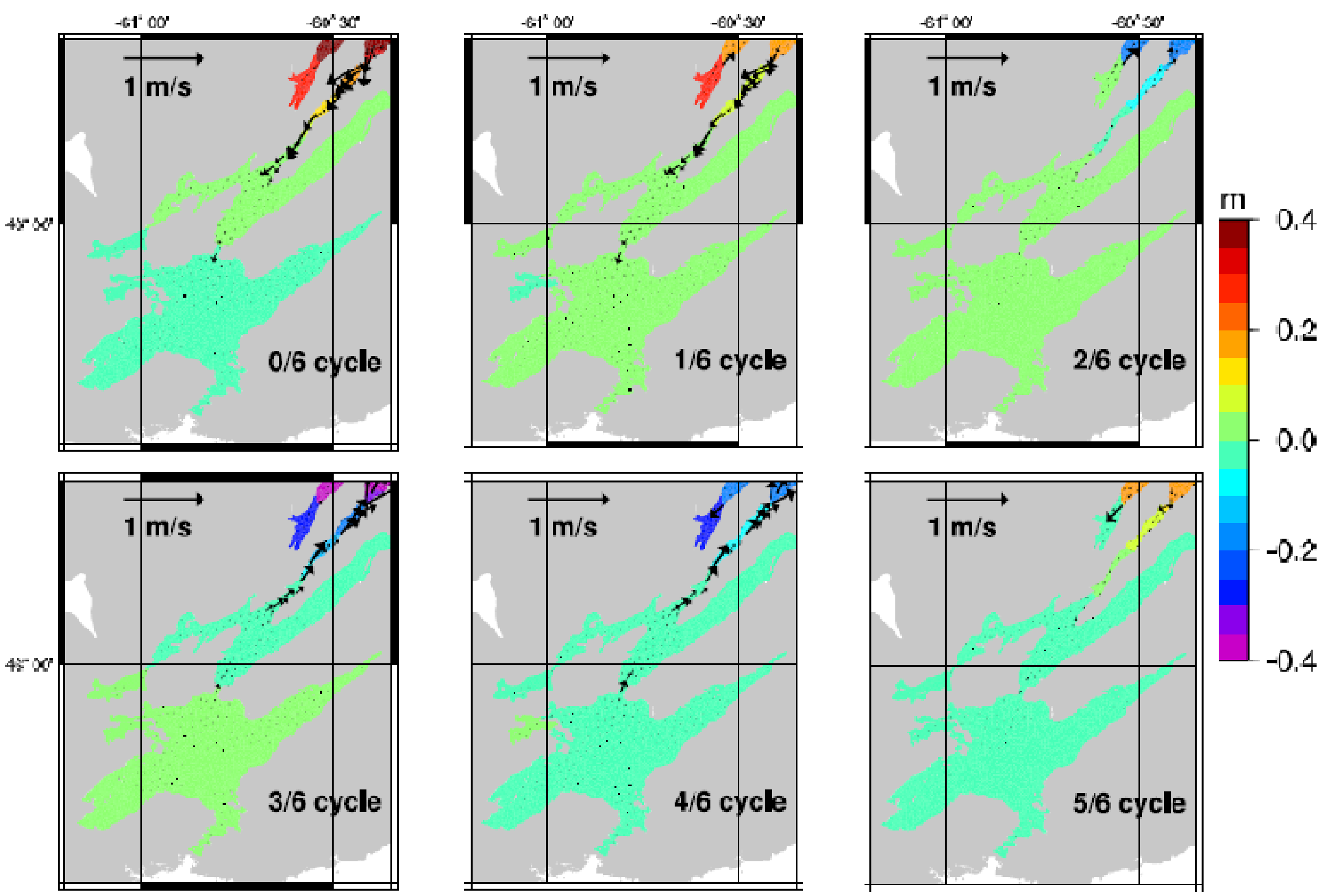
Table 7. Harmonic Constants for the Principal Tidal Constituents within Bras d'Or Lakes

Amplitude (m) (Ratio)	Tidal Constituent (period, h)					Record Length (d)
Phase (Phase Lag)	M2 (12.42)	S2 (12.00)	N2 (12.63)	K1 (23.93)	O1 (25.82)	
Table Head	0.342 (0.93)	0.081 (0.74)	0.067 (0.88)	0.064 (0.83)	0.082 (1.05)	37
	353 (0)	41 (-4)	322 (8)	320 (5)	283 (4)	
Big Bras d'Or	0.165 (0.45)	0.033 (0.3)	0.035 (0.46)	0.038 (0.49)	0.032 (0.39)	47
	339 (14)	33 (4)	328 (2)	320 (5)	282 (5)	
Seal Island	0.073 (0.20)	0.011 (0.13)	0.016 (0.21)	0.012 (0.16)	0.014 (0.17)	42
	343 (10)	30 (7)	320 (10)	360 (-35)	305 (-18)	
Baddeck	0.037 (0.10)	0.010 (0.09)	0.009 (0.12)	0.015 (0.19)	0.015 (0.18)	34
	68 (-75)	121 (-84)	40 (-70)	68 (-103)	9 (-82)	
Iona	0.038 (0.103)	0.008 (0.07)	0.006 (0.08)	0.014 (0.18)	0.012 (0.15)	31
	77 (-84)	155 (-118)	58 (-88)	81 (-116)	354 (-67)	
Marble Mountain	0.046 (0.125)	0.006 (0.06)	0.007 (0.09)	0.018 (0.23)	0.017 (0.23)	35
	124 (-131)	183 (-146)	121 (-151)	58 (-93)	28 (-101)	
Johnstown Hbr.	0.045 (0.12)	0.007 (0.06)		0.016 (0.21)	0.017 (0.21)	22
	127 (-134)	205 (-168)		84 (-119)	31 (-104)	
Eskasoni	0.041 (0.12)	0.008 (0.07)	0.009 (0.12)	0.017 (0.22)	0.018 (0.22)	45
	121 (-128)	185 (-148)	91 (-121)	73 (-113)	25 (-98)	

(Source: Dupont *et al.* 2003)

Note: Amplitude ratios and phase lags (in brackets) are relative to North Sydney (record length 362d), whose amplitude values are 0.368, 0.109, 0.076, 0.077, and 0.082m, and whose phase values (relative to Greenwich) are 353, 37, 330, 325, and 287, for M2, S2, N2, K1, and O1, respectively.

Figure 41. Tidal Currents (black vector arrows) and Elevation (colour) at Various Stages of the M2 Tide Cycle (relative to North Sydney high tide)



Source: Dupont *et al.* 2003

Within the Bras d'Or Lakes, sea level rise is approximately 36.7 cm/century (Shaw *et al.* 2006), a combination of the effects of global warming combined with regional subsidence. Sea level rise may be amplified in the Bras d'Or Lakes compared to the outer coast (UINR 2007). More than 75% of the coast of Bras d'Or Lakes consists of unconsolidated sediments at elevations below 15 m above sea level. These coasts are vulnerable to erosion and flooding as sea levels rise (Taylor and Shaw 2002). Total sea level rise from 1990 to 2100 is expected to be on the order of 75 cm (Shaw *et al.* 2006).

5.6.3 Wind and Waves

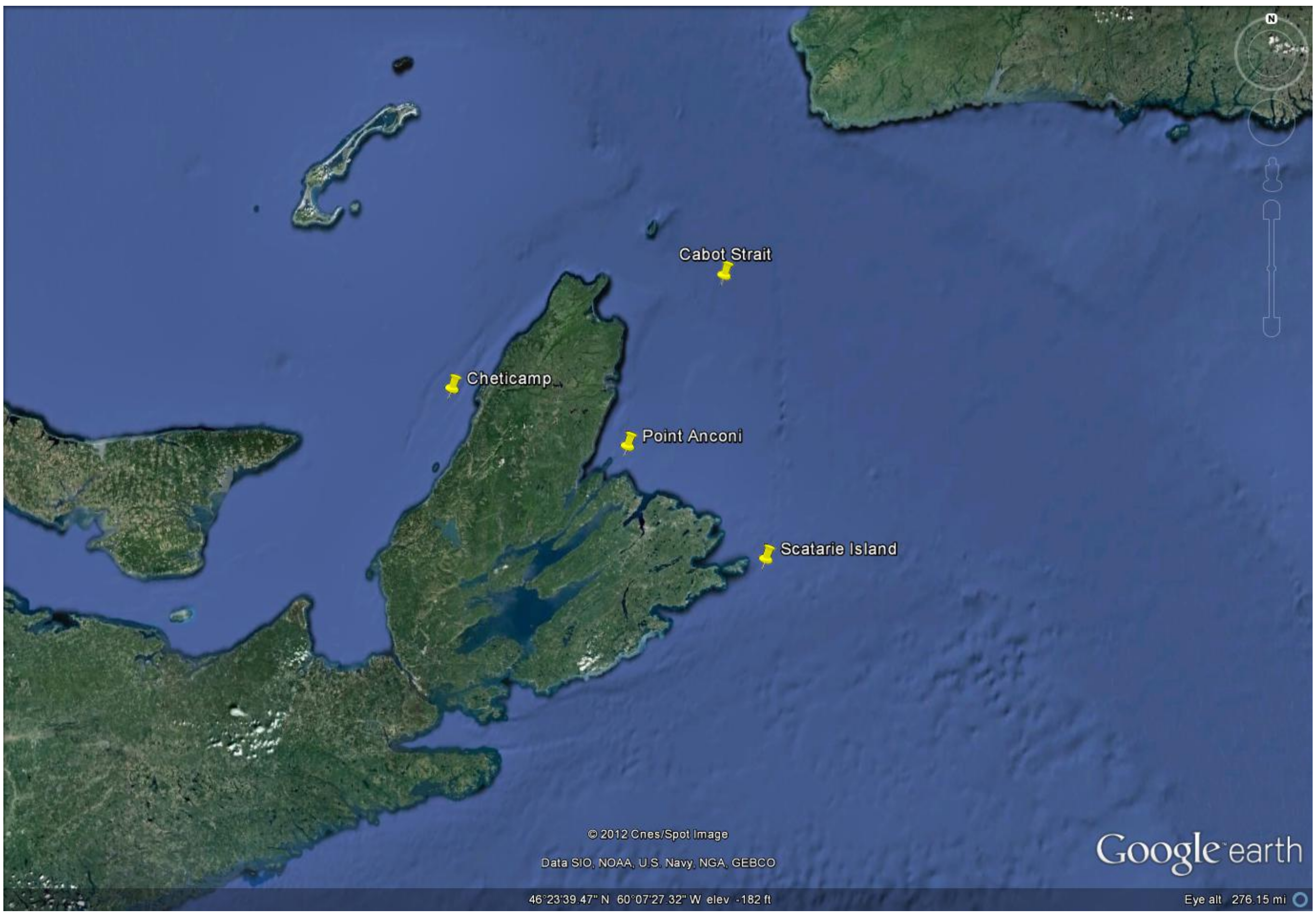
Wind

Wind and wave climate statistics presented in this section were prepared by Oceans Ltd. and were extracted from the MSC50 North Atlantic wind and wave climatology data base compiled by Oceanweather Inc. under contract to Environment Canada. The MSC50 database consists of continuous wind and wave hindcast data in 1-hour time steps from January 1954 to December 2010, on a 0.1 degree latitude by 0.1 degree longitude grid. Winds from the

MSC50 data set are 1-hour averages of the effective neutral wind at a height of 10 m. Wave heights and periods in the MSC50 database are computed using a Pierson Moskowitz spectrum.

Four grid points were chosen to represent conditions within the area under consideration: grid point 10714 located at 46.4ºN; 60.3ºW near Cheticamp; grid point 11519 at 47.0ºN: 59.8ºW in Cabot Strait; grid point 10714 located at 46.6ºN; 61.2ºW near the eastern tip of Scatarie Island; and grid point 09608 located at 46.0ºN; 59.6ºW near Point Aconi. These four points are illustrated on the map in Figure 42.

Figure 42. Map Showing the Locations of Four Representative Points for Which Wind and Wave Data are Presented



Source: Google Earth

The wind and wave statistics are presented in the form of rose plots and percentage occurrence graphs. Each wind rose is a circular magnitude and direction histogram plot containing information about wind direction and speed in knots. The wind speed percentage occurrence graphs are in the form of bar graphs which present percentage occurrence of wind speeds using groupings from the Beaufort Scale (calm, light, moderate, strong, gale, storm, hurricane). Similarly, there are wave roses and percentage occurrence graphs, where each wave rose is a histogram with information about wave height (in metres) and wave direction. The wave height percentage occurrence graphs are bar graphs analogous to those in the wind section.

Cabot Strait experiences predominantly southwest to west wind flow throughout the year. There is a strong annual cycle in the wind direction. West to northwest winds, which are prevalent during the winter months begin to shift counter-clockwise during March and April resulting in a predominant southwest wind by the summer months. As autumn approaches, the tropical-to-polar temperature gradient strengthens and the winds shift slightly, becoming predominantly westerly again by late fall and into winter. As noted, low pressure systems crossing the area are more intense during the winter months. As a result mean wind speeds tend to peak during this season.

In addition to mid-latitude low pressure systems crossing the region, tropical cyclones often move northward out of the warm waters south of the Gulf Stream. Once the cyclones move over the colder waters north of the Gulf Stream they lose their source of latent heat energy and often transition into fast-moving and rapidly developing mid-latitude or “extratropical” cyclones producing large waves and sometimes hurricane force winds.

Wind roses in Figure 43 for the four locations of Figure 44 show that the winds have similar characteristics in all four areas. The frequency of occurrences of wind with speeds between 9.8 and 17.0 m/s are slightly lower near Cheticamp and subsequently a slightly higher frequency of light winds (Figure 45). Gale force winds at all four locations occur approximately 2.5 % of the time. The wind roses show that the winds are predominately from the southwest to west northwest in the waters around Cape Breton. There are seasonal changes in the distribution of winds. The winds are predominately from the west northwest in winter, more distributed over all direction in spring, from the southwest in summer, and from the west in fall. This wind pattern is shown in Figure 46 produced from the wind data offshore the eastern tip of Scatarie Island. The data from the other three locations show the same pattern.

Figure 43. Annual Wind Roses around Cape Breton

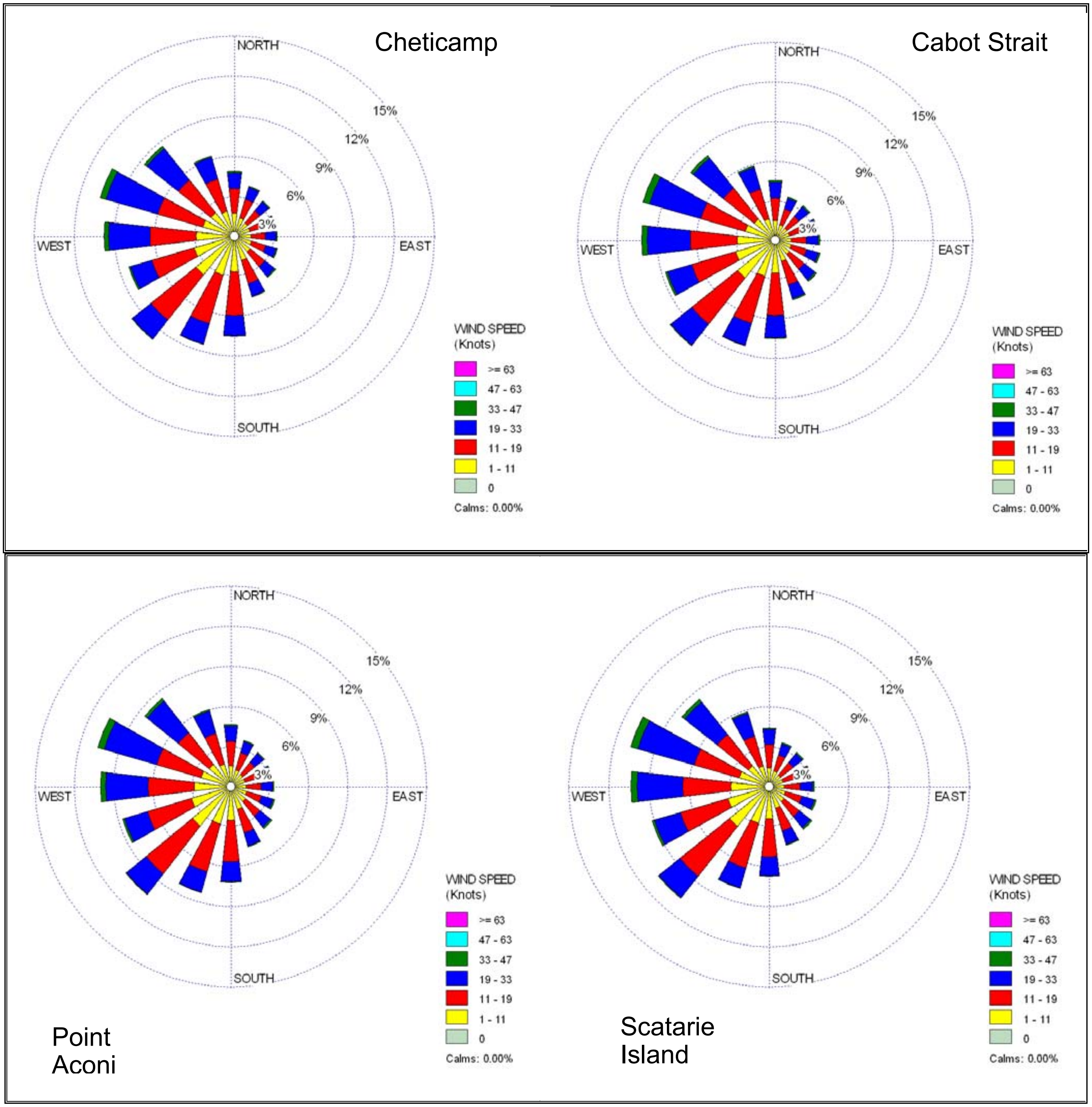


Figure 44. Annual % Frequency of Wind Speed around Cape Breton

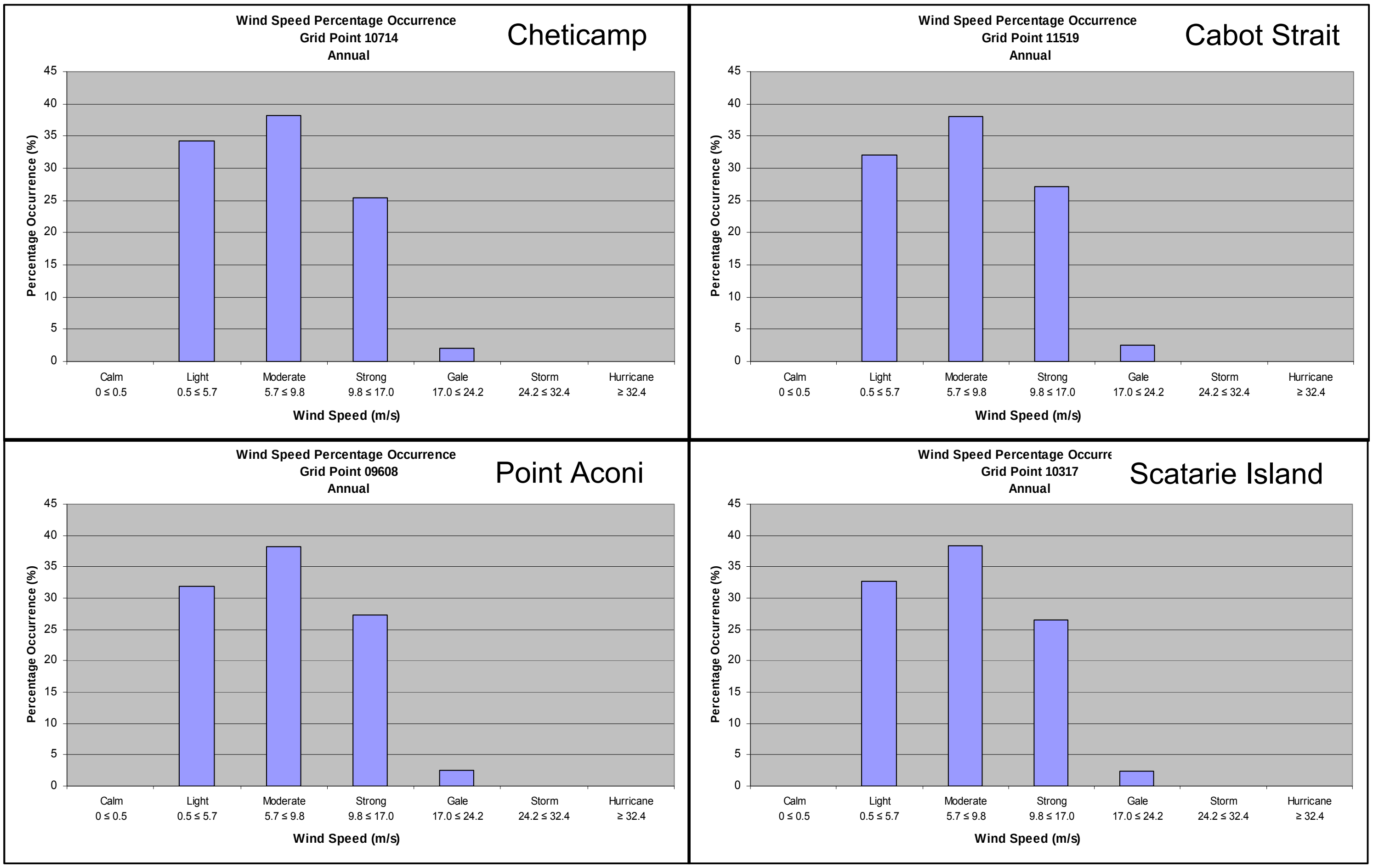
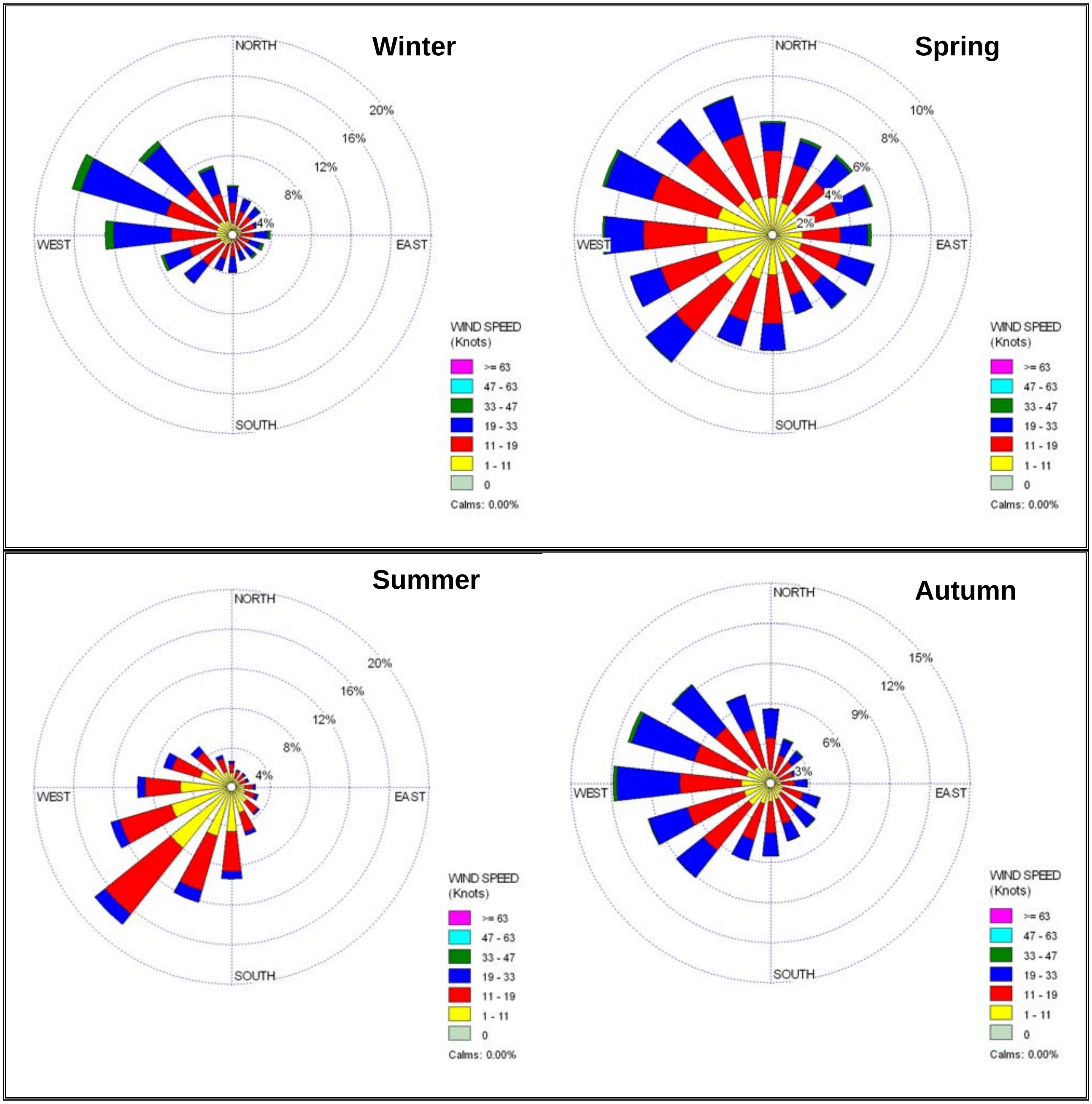


Figure 45. Seasonal Wind Roses near Scatarie Island



Waves

The wave climate of Cabot Strait is dominated by extratropical storms, primarily during October through March, although severe storms may occur outside these months. Storms of tropical origin may occur during the early summer and early winter, but occur most often from late August through October. Hurricanes are usually reduced to tropical storm strength or evolve into extratropical storms by the time they reach the area. However, they are still capable of producing storm force winds and high waves.

Annual wave roses, which show the significant wave heights and their frequency of occurrence were produced for the same four points as the wind roses. The significant wave height is defined as the average height of the 1/3 highest waves, and its value roughly approximates the characteristic height observed visually.

The annual wave roses are presented in Figure 46 and the frequency of occurrence in Figure 47. The significant wave heights are higher in Cabot Strait and off the eastern tip of Scatarie Island than at the other two locations. The waves were lowest near Point Anconi because the location is slightly more sheltered from swell propagation. At Cheticamp the waves are propagating from the Gulf of St. Lawrence and are highest during the months of November, December and January. At the other three locations the waves are highest in the period of November to March.

Due to the presence of Newfoundland to the northeast and the Maritime provinces to the southwest, there are only two main directions from which significant wave heights propagate into Cabot Strait. During the winter months, the dominant direction of wave propagation is from the northwest. This direction shifts to the southeast during spring and remains predominantly south-easterly into late fall.

In the Point Anconi region, the majority of waves propagate from the north-northeast to east-southeast, whereas near Scatarie Island the wave energy is mainly from the south. However, near Scatarie Island there is also a significant amount of wave energy form the north during the period of October to February.

Figure 46. Annual Wave Roses for the Water around Cape Breton

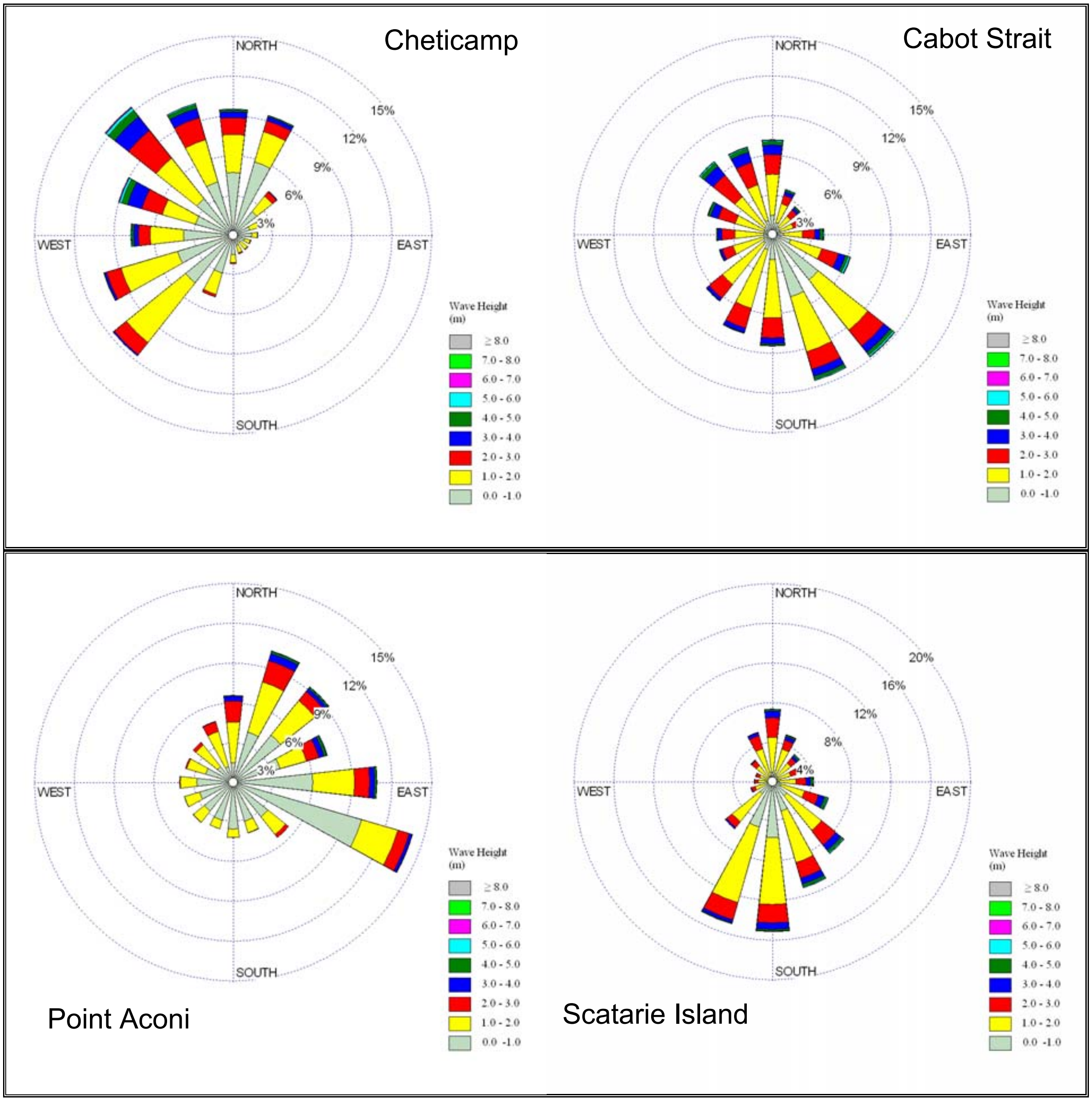
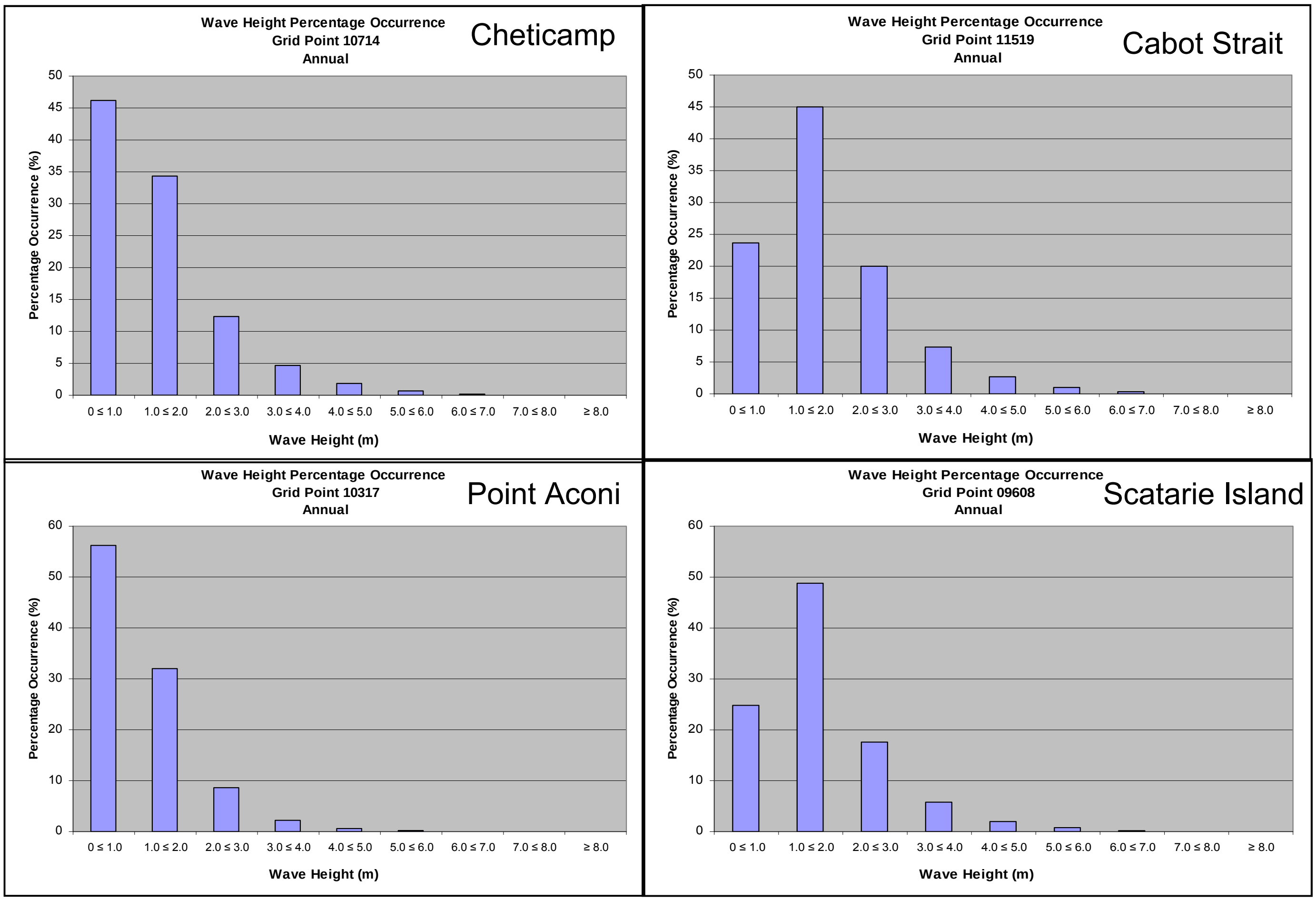


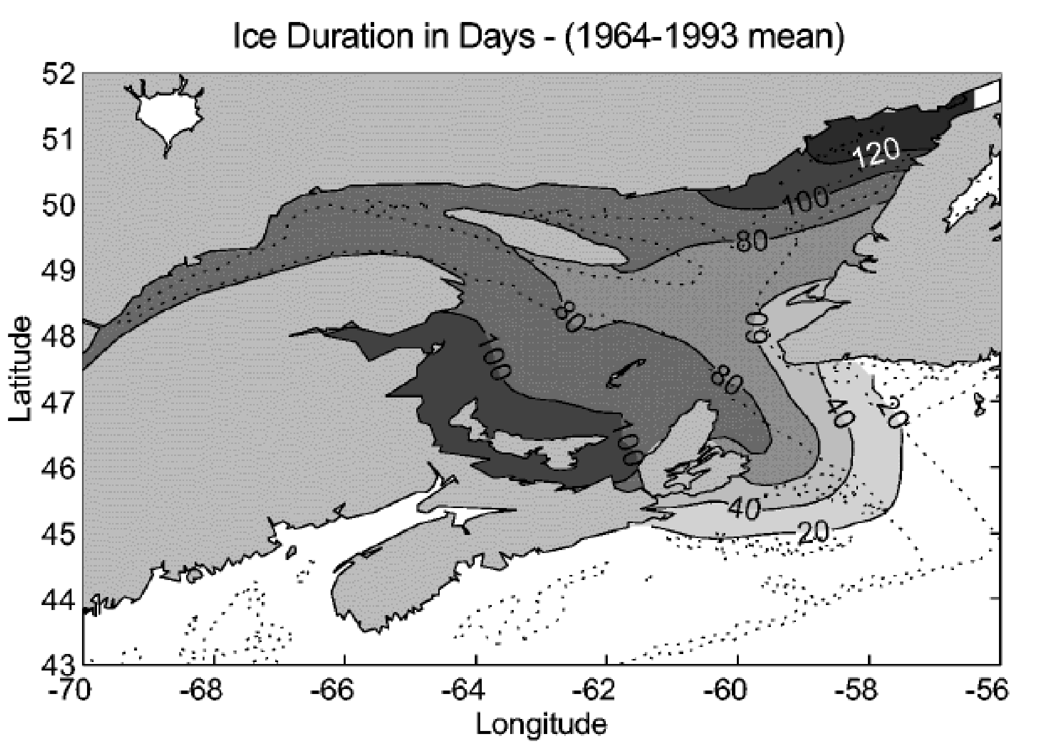
Figure 47. Annual % Frequency of Significant Wave Heights around Cape Breton



5.7 Ice

Ice occurs around Cape Breton Island with a mean duration of 80 to 100 days on the west coast, and with a mean duration of 40 to 60 days on the east coast (Figure 48). Ice first appears on St. Georges Bay around January 15 on average, and most of the water around Cape Breton is icebound by the beginning of February. Ice is usually present until the second week of April, and until the end of April up to 33% of the time (Chassé 2001).

Figure 48. 30-Year Average for Number of Days of Sea-Ice Presence Annually



Source: Chassé 2001

Ice cover in the Bras d'Or Lakes varies considerably from year to year and does not cover the entire surface in any year. Based on data collected by Environment Canada since the 1960s, approximately 70% of the lake surface will be covered by ice during an average winter. Ice typically begins to develop in January in the sheltered bays to the north and south of Barra Strait, peaking in March, decreasing rapidly in April and melting completely by the first week in May (Petrie and Bugden 2002). There has been a notable decline in the extent and thickness of ice cover since 2002, with no ice cover in either of the large basins during the 2010 and 2011 seasons.

Ice can interfere with routine maintenance and may damage surface piecing or floating structures. On the positive side, areas of consistent winter ice cover are typically not used for regular shipping.

5.8 Summary of the Areas of Interest for MRE Development

Existing current flow models suggest that the strongest currents occur in the nearshore of the western Cape Breton Island extending from the Margaree Harbour northward to the Cape North region; in the area around Cape North and St. Paul Island swinging to the southeast; and in the region off eastern Cape Breton Island in the Scatarie Island

and Scatarie Bank area. An area of slightly lower current velocity occurs from Scatarie Island to Forchu. These current velocity model results are broadly consistent with bedforms observed during sea floor mapping programs.

Based on the seabed conditions and the oceanographic information, four coastal sites are tentatively identified as having the greatest potential for tidal power development and are candidates for a more detailed assessment (Figure 49). Information is also provided below on the wind and wave climate, to the extent this information is available. The Bras d'Or Lakes comprise a fifth area of interest, but the resource is limited to tidal energy alone.

1) Mid-way up the western coast of Cape Breton Island off Cheticamp

A region of complex sand bedforms that include sand waves, mega-ripples and three-dimensional crescent-shaped "barchan" dunes is located off the western coast of Cape Breton centered off Cheticamp and Polletts Cove. These bedforms suggest dominant and active sediment transport to the northeast, parallel to the shoreline. The nearshore region also shows features that likely represent exposed bedrock at the seabed. These active bedforms have the potential to complicate the development of foundations for moored and bottom mounted tidal energy devices.

Water depth is under 60 m in the south ranging to 100 m water depth on the eastern flank of the Cape Breton Trough. In this area, Mabou Harbour is the only coastal embayment where reported tidal currents exceed 2 m/s.

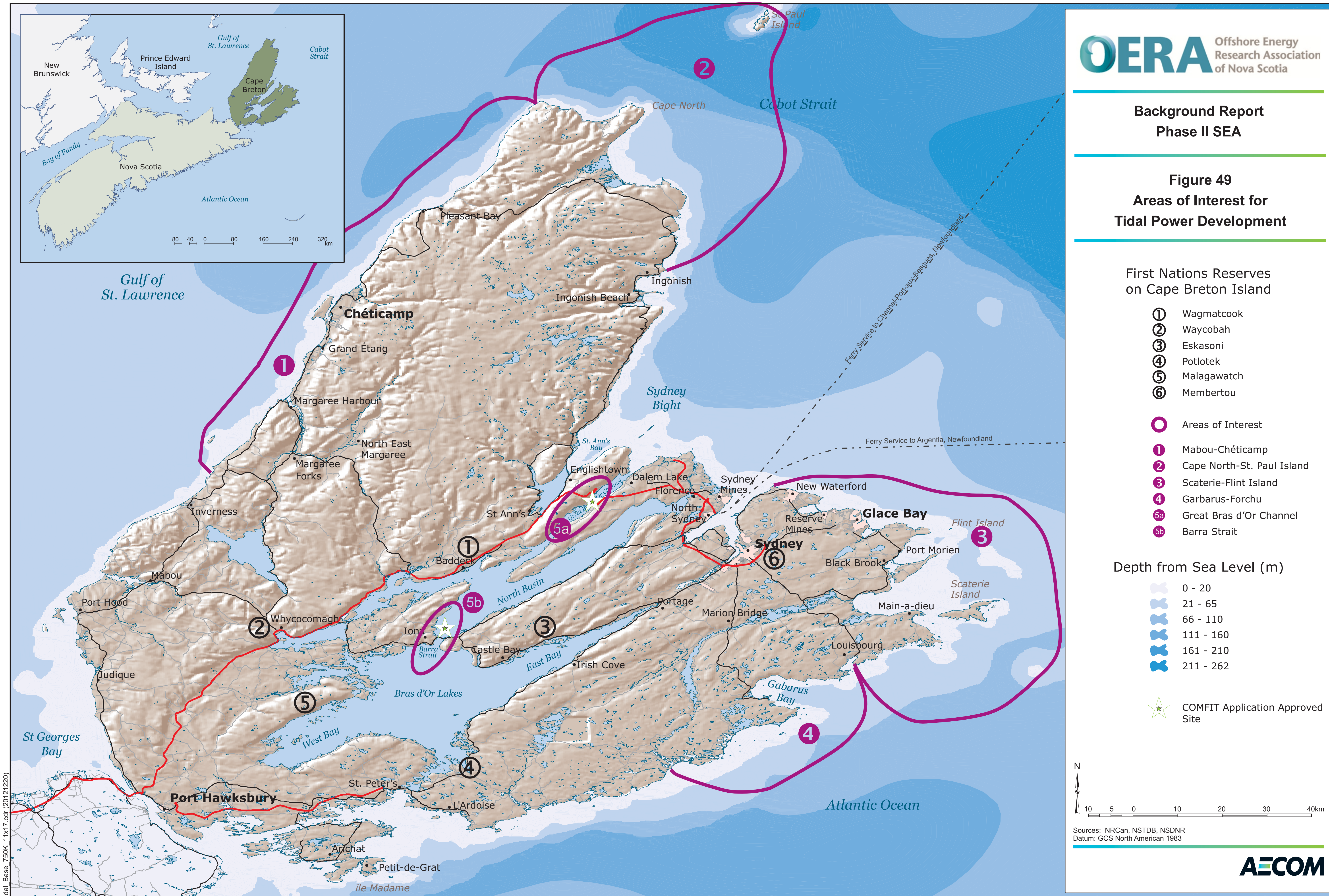
The currents along this section of the coast are controlled by the circulation in the Gulf of St. Lawrence. Chassé (2001) reports that the Gaspé current running south-eastward over the Magdalen Shallows, drives a coastal jet along the north shore of Prince Edward Island. This coastal jet merges with the current flowing through the Northumberland Strait to flow along the western coast of Cape Breton. Additionally, a component of the flow out of the Gulf of St. Lawrence which flows along the southern side of the Laurentian Channel gets diverted along the western side of Cape Breton Trough to meet up with the eastward flow across the Magdalen Shallows (bathymetry between 50 – 100 m). This combined current would then flow northeast along the eastern side of the Cape Breton Trough in coastal waters between Chéticamp and Cape St. Lawrence. This description of the flow in the Cape Breton Trough is supported by Lauzier (1967) who found a north-eastward current flow close to the shore of Cape Breton and south-westward currents on the north-western side of the Cape Breton Trough. The highest currents are most likely to occur between Pleasant Bay and Cape St. Lawrence. The magnitudes of the current velocities are unknown because there are no current measurements for this region.

The winds of western offshore Cape Breton are predominately from the northwest between November and March, and from the southwest between May and September. April and October are transitional months when the wind directions are more variable. Winds higher than 5.6 m/s occur 66% of the time and strong winds higher than 9.7 m/s occur 28% of the time.

The highest waves are generated by winds from the northwest which occur during late fall and winter. On an annual basis, significant wave heights greater than 2 m and 3 m occur 20% and 7% of the time, respectively.

2) Off Cape North and around St. Paul Island

Multibeam bathymetry from the region around St Paul Island and to the north of Cape North shows bedforms in sand and other linear features indicative of strong currents impacting the seabed (Josenhans 2007). In this region these patterns are interpreted to result from the narrowing of the Cabot Strait and the proximity of St Paul Island close to the mainland, which restricts the current flow and increases its velocity. In this area, water depths deepen rapidly from the shoreline to 200 m water depth surrounding St. Paul Island.



OERA Offshore Energy Research Association of Nova Scotia
Background Report
Phase II SEA
Figure 49
Areas of Interest for Tidal Power Development
First Nations Reserves on Cape Breton Island
1 Wagmatcook
2 Waycobah
3 Eskasoni
4 Potlotek
5 Malagawatch
6 Membertou
Areas of Interest
1 Mabou-Chéticamp
2 Cape North-St. Paul Island
3 Scaterie-Flint Island
4 Garbarus-Forchu
5a Great Bras d'Or Channel
5b Barra Strait
Depth from Sea Level (m)
0 - 20
21 - 65
66 - 110
111 - 160
161 - 210
211 - 262
COMFIT Application Approved Site
N
10 5 0 10 20 30 40km
Sources: NRCan, NSTDB, NSDNR
Datum: GCS North American 1983
AECOM
New Brunswick
Prince Edward Island
Gulf of St. Lawrence
Cabot Strait
Cape Breton
Bay of Fundy
Nova Scotia
Atlantic Ocean
80 40 0 80 160 240 320 km
Gulf of St. Lawrence
St Paul Island
Cape North
Cabot Strait
Pleasant Bay
Ingonish
Ingonish Beach
Chéticamp
Grand Étang
Margaree Harbour
North East Margaree
Margaree Forks
Sydney Bight
St. Ann's Bay
Englishtown
Dalem Lake
Florence
Sydney Mines
North Sydney
New Waterford
Glace Bay
Reserve Mines
Flint Island
Sydney
Port Morien
Black Brook
Inverness
St Ann's
Baddeck
Great Bras d'Or Channel
Mabou
Port Hood
Whycocomagh
North Basin
Iona
Barra Strait
Castle Bay
East Bay
Irish Cove
Portage
Marion Bridge
Scaterie Island
Main-a-dieu
Louisbourg
Gabarus Bay
Judique
Bras d'Or Lakes
West Bay
St Georges Bay
St. Peter's
Port Hawksbury
L'Ardoise
Arichat
Petit-de-Grat
île Madame
Atlantic Ocean
Ferry Service to Channel-Port-aux-Basques, Newfoundland
Ferry Service to Argentia, Newfoundland
Tidal_Base_750K_11x17.cdr (20121220)

Based on the general current circulation flow out of the Gulf of St. Lawrence and the bathymetry of the Cape Breton Trough and Laurentian Channel, there is a potential for high current speeds east of Cape North. Between Cape North and St. Paul Island, the current that flows along the western side of Cape Breton merges with the main outflow from the Gulf that follows the bathymetric contours of the Laurentian Channel. Moored instruments measured some currents in this area for the periods of June to October 1993, and June 1996 to May 1997. The currents were very strong between Cape North and St. Paul Island, and in the region east of Cape North where the water depth is greater than 100 m. Near surface currents were found to have speeds reaching 0.15m/s between Cape North and St. Paul Island, and speeds reaching 0.21m/s east of Cape North. At depth of 75 m and 140 m, the current speeds reached values of 0.16m/s and 0.12m/s, respectively.

In the Cape North area, the winds are predominantly from the west-northwest between November and March, and from the southwest between May and September. April and October are transitional months when the wind directions are more variable. Winds higher than 5.6 m/s occur 68% of the time and strong winds higher than 9.7 m/s occur 30% of the time.

The highest waves are generated during the fall when the winds are predominately from the west northwest. Overall, the predominant wave direction and higher waves are from the southeast due to swells propagating into the area during all seasons. On an annual basis, significant wave heights greater than 2 m and 3 m occur 31% and 11% of the time, respectively.

3) Around Scatarie Island/Flint Island

Scatarie Ridge is an east trending ridge extending from Cape Breton Island across Scatarie Bank and the Laurentian Channel to St. Pierre Bank. Water depths slowly deepen from the shoreline to the east ranging to between 60 and 80 m with a shallow depth of 40 m on Scatarie Bank.

The surface of many areas of Scatarie Bank and Ridge displays varying and unique patterns of bedrock outcrop. Some areas are smooth while others exhibit a series of small linear ridges. North of Scatarie Ridge is a series of large, linear, equally spaced, broad ridges on the seabed. Also present north of Scatarie Ridge are linear features that occur both on bedrock and sediments; these features appear as large, parallel flutes or gouges. They may result from present-day strong current modification of sediments or may be relict glacial gouging of till and bedrock. Much of the seabed in the eastern and north eastern part of the image is criss-crossed with linear features interpreted as iceberg furrows caused when grounded icebergs scraped over the seafloor. There is no multibeam imagery from the region between Scatarie Island and the mainland where currents would be expected to be strong in the narrow strait.

The offshore multibeam bathymetry shows a number of glacial features in the St. Anns Bank region (King 2012). These include various glacial till deposits (moraines and drumlins) while regions of the seabed in depths greater than 120 m are covered with iceberg furrows. Samples from across this seabed reveal mixtures of gravel, sand and mud.

Modelling studies suggest high currents offshore Scatarie Island. However, no data have been collected in these areas to measure the strength of the current flow. The currents in this region will originate from the surface flow out of the Gulf of St. Lawrence, and a continuation of the flow that occurs between Cape North and St. Paul Island. There are many places along the coast where local fishermen's observations indicate the presence of tidal currents exceeding 2 kts (approx. 1m/s). An example that has recently attracted some modelling and measurement is the channel between Cape Percy and Flint Island at the mouth of Morien Bay. It would be useful (and cost effective) to survey fishermen's knowledge of coastal sites experiencing strong current flows as a focusing mechanism for future expensive measurements and models.

In the Scaterie - Flint Island region, the winds are predominantly from the west-northwest between November and March, and from the southwest between May and September. April and October are transitional months when the wind directions are more variable. Winds higher than 5.6 m/s occur 68% if the time and strong winds higher than 9.7 m/s occur 30% of the time. The higher waves are from two directions; the northwest and southeast. On an annual basis, significant wave heights greater than 2 m and 3m occur 26% and 9% of the time, respectively.

4) Along the southeast coast of Cape Breton to Forchu

Along the southeast coast of Cape Breton to the south of Scatarie Island, depths increase uniformly seaward to 100 m depth approximately 10 km offshore. In these coastal nearshore regions bedrock usually occurs at the seabed in a zone extending several kilometers offshore. Further offshore, thicker deposits of sand and gravel overlie both bedrock and subsurface tills. Where the currents are strong, sand and gravel bedforms are common and these features can occur down to approximately 100 m water depth. The southward current flow in this area is a continuation of the surface flow out of the Gulf of St. Lawrence. There are no current measurements in this area to assess the strength of the currents.

On the eastern side of Cape Breton, the winds are predominately from the west-northwest between November and March, and from the southwest between May and September. April and October are transitional months when the wind direction is more variable. Winds higher 5.6 m/s occur 68% of the time and strong winds higher than 9.7 m/s occurs 30% of the time. The predominant wave direction is from the south. Significant wave heights greater than 2 m and 3 m occur 18% and 7% of the time, respectively.

5) Bras d’Or Lakes

A fifth area of interest has been identified through previous and recent work in the Bras D’Or Lakes. Two potential project sites have the potential to host tidal projects: the Great Bras d’Or Channel and Barra Strait. The most obvious source of potential tidal power is Great Bras d’Or Channel, which was assessed by EPRI (2006) and by McMillan *et al.* (2012). The highest reported currents are at Carey Point (2.19 m/s) and in Barra Strait (0.07-0.26 m/s). The low volume of water flowing through the channels may not be sufficient for large generator arrays due to the limited total available power. There may be points along the Great Bras d’Or Channel (e.g. near the Seal Island Bridge) that have current speeds high enough to be of further consideration. There is effectively no wave or offshore wind potential within the Lakes.

5.9 Water Quality

5.9.1 Contaminants

There are several point and non-point or diffuse sources of pollutants that may affect water quality around coastal Cape Breton and in the Bras d’Or Lakes. Potential sources of contaminants/pollutants are presented in Table 8.

Table 8. Potential Point and Non-Point Sources of Contamination

Point Sources	Non-Point Sources
Municipal effluents: bacteria, metal, organic and chemical contaminants emanating from municipal infrastructure (sewage treatment plants, storm sewers outlets)	Dredging and ocean dumping of contaminants: sediments, PAHs, polychlorinated biphenyls (PCBs), trace elements, oil and organic matter, e.g., fish offal
Pulp and paper effluents: wood fibre, other suspended solids, metals and other contaminants. These effluents have a high	Wharves and coastal structures and the activities that use this infrastructure: metals and organic compounds in paints,

Point Sources	Non-Point Sources
biochemical oxygen demand (BOD). There are currently four pulp and paper mills in Nova Scotia	creosote and preservatives, e.g., from wolmanized lumber, to be released into coastal waters
Petroleum refining: oil and grease, sulphide, ammonia, phenol, suspended solids and polycyclic aromatic hydrocarbons (PAHs)	Aquaculture activities: organic matter and trace metals into the water column and associated sediments, causing nutrient enrichment and eutrophication
Food processing: effluents having a high BOD, suspended solids, oil and grease, bacteria and organic and inorganic contaminants	Shipyards and their activities: organic metals and antifouling chemicals, e.g., tributylin, lead, etc.
Thermal generating plants: thermal pollution from cooling operations, PAHs from coal ash and leachates, and PAHs and metals from atmospheric deposition	Offshore oil and gas production: hydrocarbon and heavy metal contamination in inshore waters
Mining and associated industries: acid mine drainage, and metals, organics and arsenic from sources such as gold tailings	

(Source: CBCL 2009)

The most significant sources of bacteriological contaminants include untreated sewage, inputs from malfunctioning septic systems, industrial discharges, agricultural and urban runoff and boat discharges. Chemical pollutant sources include agricultural runoff, urban storm sewers, mine wastes, landfills, golf courses, unauthorized dumpsites, aquaculture operations and industrial cooling water (UINR 2007).

Coastal Cape Breton

Most of the smaller communities in Cape Breton are without sewage treatment facilities, although the Cape Breton Regional Municipality, which includes Sydney, has a number of treatment plants as do the larger towns on the island. Of people living on the shores of Bras d'Or Lakes and along coastal Cape Breton west of Sydney (including all the communities along the western shore), over 75% have no access to municipal wastewater treatment and rely on private septic systems (NRCan 2004a). The eastern shore is better serviced although 50-75% of the population remains without municipal sewage treatment. Untreated sewage outfalls and malfunctioning septic systems may negatively impact water quality and the marine environment, and represent a threat to water quality in the Bras d'Or Lakes (UINR 2007). Human and animal fecal matter can disrupt natural lake process causing excessive plant growth and oxygen depletion, while the pathogens in fecal matter can cause serious illness and death if ingested. This type of contamination has rarely resulted in the closure of public beaches but does represent a concern to the aquaculture industry, in particular shellfish producers (CBCL 2009).

There are approximately 30 point and non-point industrial pollutant discharges along coastal Cape Breton (NRC 2004b). Nova Scotia Power Inc. has two coal-fired thermal generating plants in the area, one at Lingan and one in Point Aconi. Cooling water for the Lingan plant is drawn in from and discharged into Indian Bay; at Point Aconi water is taken from and released into the Sydney Bight in the area bordering the north side of Point Aconi.

In addition to current discharges, contamination has been created by past industrial activity at the Sydney Steel Corporation's (SYSCO) steel mill and related coking facilities in Sydney, as well as past coal and other mining activities. Before they closed, steel smelters and coke ovens on the shores of Sydney Harbour were responsible for the release of pollutants including PAHs, other organic contaminants and metals into the shallow estuarine system.

Bras d'Or Lakes

There are no industry-related pollution discharges to the Bras d'Or Lakes. Both First Nation and non-aboriginal populations continue to increase, leading to declines in water quality that can be traced to over-capacity wastewater treatment facilities, increased number and age of septic systems, expanding campgrounds and RV parks, and increased recreational boating activity. Farming and livestock also contribute pollutants to the Bras d'Or Lakes (UINR 2007).

Only six communities on Bras d'Or Lakes have municipal or local waste water treatment facilities:

1. Eskasoni First Nation;
2. Chapel Island First Nation;
3. Wagmatcook First Nation;
4. Whycocomagh / We'koqma'q First Nation;
5. St. Peters; and,
6. Baddeck.

Eskasoni and Baddeck employ sequential batch reactors with ultraviolet disinfection and were functioning under capacity as of 2007 (UINR 2007). We'koqma'q is connected to the town of Whycocomagh but its five lift stations report problems with overflow. Although the treatment plant in Whycocomagh is generally under capacity, there are times when its maximum capacity is exceeded and overflows occur. Both Wagmatcook and Chapel Island use older, lagoon-based systems with chlorination and are at or exceeding capacity. The Chapel Island sewage treatment lagoon discharges into a low-flowing brook rather than directly into the Bras d'Or Lakes. The town of St. Peters discharges its treated wastewater into the Atlantic (UINR 2007).

Water quality (based on bacterial parameters) within the Bras d'Or Lakes in 2005, as measured for the purposes of shellfish harvesting, is very good. Approximately 50% of the surface area of the lakes is included in the shellfish water sampling program. Of this surface area less than 3% was closed due to water quality problems in 2005. Bacterial water quality parameters remained largely unchanged from 1997 to 2007 (UINR 2007).

In 2003-2004, the Bedford Institute of Oceanography and the Eskasoni Fish and Wildlife Commission Inc. collected a number of sediment, water and biota samples in Bras d'Or Lakes, St. Anns Bay and Sydney Harbour as part of a marine environmental quality survey. In general, contaminants such as PCBs, PAHs and metals were below federal sediment and water quality guidelines for the protection of aquatic life (UINR 2007). Elevated zinc, arsenic cadmium copper and lead concentrations were reported in the water south of River Denys Basin, while lead, copper and zinc were noted in sediments off the village of Eskasoni while other metals were found at background levels or slightly higher. Sydney Harbour exhibited higher concentrations of lead and zinc in a larger range of samples (UINR 2007).

Coastal Cape Breton and the Bras d'Or Lakes are subject to a number of water and sediment sampling programs, summarized in Table 9.

Table 9. Currently Active Water Quality Monitoring Programs Coastal Cape Breton and Bras d'Or Lakes

Program	Sponsor & Implementer	Objective	Additional Information
Environmental Monitoring Program (1)	Nova Scotia Fisheries and Aquaculture	Monitors effects of aquaculture on coastal waters	www.gov.ns.ca/fish/aquaculture
National Agri-	Agriculture and Agri-food	Monitors effects of agriculture	www.agr.gc.ca

Program	Sponsor & Implementer	Objective	Additional Information
Environmental Health Analysis and Reporting Program (2)	Canada	on the environment	
Atlantic Zone Monitoring Program	Fisheries and Oceans Canada / Cape Breton University	Provides information on the status of coastal & offshore ecosystems in Atlantic Canada	http://www.meds-sdmm.dfo-mpo.gc.ca/zmp
Atlantic Coastal Action Program – Cape Breton (3)	Environment Canada & CBRM / ACAP-CB	Helps restore and sustain watersheds & coastal areas	http://www.acapcb.ns.ca
Community Aquatic Monitoring Program	Fisheries and Oceans Canada / UINR, NSCC, MHCMPC, SGRC	Offers guidance and protocols to community-based groups to enable them to monitor watersheds and estuaries in southern Gulf of St. Lawrence	http://www.glf.dfo-mpo.gc.ca/e0006182
Canadian Shellfish Sanitation Programme	Environment Canada / CBCL Ltd. & Cape Breton University	Protect the health of consumers of shellfish by measuring Coliform bacteria in water samples. CBU also analyses 6 other water quality metrics at selected sites	www.cssp.ec.gc.ca

(updated from: CBCL 2009)

Notes: 1. There are currently only two sites being regularly monitored under this programme in Cape Breton (none in the Bras d'Or Lakes).

2. This programme has not been operational for at least the past 7 years.

3. Not currently making any measurements of water quality.

5.9.2 Biophysical Processes

Coastal Cape Breton

Cape Breton Island is exposed to three distinctive but interconnected marine provinces: The Gulf of Saint Lawrence to the northwest, the Eastern Scotian Shelf to the southeast, and the Bras d'Or Lakes estuary occupying the centre of the island. The first two are connected by the Laurentian Channel (Cabot Strait) on the northeast of the island, and the main linkage of the Bras d'Or estuary to the ocean is also into the Cabot Strait via the Sydney Bight. These three marine provinces experience a range of increasing water salinity, with the Bras d'Or estuary having the lowest values (approx. 18psu on average), the Gulf of St. Lawrence being slightly lower than NW Atlantic surface water (approx. 29 psu on average) because it receives the outflow of the second largest river system on the North American continent, and the Eastern Scotian Shelf being the highest because of its greater exchange mixing with the Atlantic Ocean.

The proportionally greater ratio of coastline to water volume through this sequence (greatest in the Bras d'Or, lowest on the Eastern Scotian Shelf) means that terrestrial influences on marine communities broadly decrease through this sequence. The generalized pattern of flow among these marine provinces (Figure 33) is clockwise around the Island, from west east in the Gulf, around St. Paul's Island into the Cabot Strait and Sydney Bight, where the waters of the Bras d'Or estuary join the flow to round Scatarie Island and head southwest in the Nova Scotia Current. Thus, the marine ecosystems of Cape Breton are connected by the advection and mixing of water masses with different chemical, nutrient and biotic compositions. The apparent ecological connectivity is complimented by the migrations of mobile marine fauna which need not follow the current flows (e.g. herring, cod, and seals), as well as by sporadic intrusions of water masses from the Greenland Current, Gulf Stream and Newfoundland. Despite their ecological connections, the broad biophysical differences among the three marine provinces of Cape Breton mean that the types and magnitudes of MRE effects on the biodiversity and productivity of marine and coastal communities may differ.

The biophysical environment of the Eastern Scotian Shelf, including coastal Cape Breton, is dominated by the presence and mixing of three major currents, as well as the varied topography of the seabed. The seabed consists of a series of submarine banks and channels that guide water flow along the bottom. Cool fresh water pours into the eastern end of the Scotian Shelf from the Gulf of St. Lawrence and the Newfoundland Shelf, while warm salty water moves up from the south and west in the Gulf Stream. This movement results in increasing temperature and salinity from near shore coastal waters to offshore deeper areas over the Scotia Shelf. Overall there is a net transport of water and organisms from the northeast towards the southwest (Zwanenburg *et al.* 2006).

On the western side of Cape Breton, the enclosed Gulf of St. Lawrence promotes a coastal current, flowing northeast along Cape Breton's west coast. The current combined with tidal flow generates a pumping mechanism creating gyres and upwellings that bring deep nutrient-rich water to the surface (DFO 2001). In places where currents are obstructed, such as around St Paul Island, erosion and further upwelling occurs; the nutrient rich water promotes high biological productivity and species diversity in these areas. Within the Cape Breton trough, the water column is stratified in the summer at 20-40 m depth; in contrast, stratification is generally deeper in Sydney Bight, at 30-50 m depth (DFO 2001).

Marine organisms have evolved to thrive within a limited range of environmental conditions, such that temperature, salinity and ocean currents in turn affect the distribution, growth and health of organisms (DFO 2003). Water currents transport nutrients and oxygen, and disperse the eggs, larvae and adults of certain species that would otherwise remain stationary.

The interaction of currents with the seabed creates a variety of habitats along coastal Cape Breton (Zwanenburg *et al.* 2006). As noted, some habitats are regularly scoured by tidal currents, creating environments that tend to be rich in nutrients. Other habitats experience much less mixing and nutrients are limited. Each of these habitat types is home to a diverse assemblage of marine organisms that continually interact among themselves and with neighboring species in other habitats. Disturbing the seabed in an area that is regularly disturbed, mixed, and renewed by tidal currents is expected to have less of a long-term impact than disturbing a stable deep-water coral reef that is adapted to a low energy environment (Zwanenburg *et al.* 2006).

During the past 20 years, the temperature of cold subsurface waters (below 50 m depth) has declined on the northeastern Scotia Shelf, dropping significantly below normal (DFO 2003). The cause of the temperature drop appears to be related to flow from both the Gulf of St. Lawrence and off southern Newfoundland. This change has been accompanied by an increase in density stratification, possibly related to a decrease in storminess since the early 1990s.

<u>Bras d'Or Lakes</u>

The Bras d'Or Lakes is a low salinity estuarine system, in which water within the Lakes is exchanged via restricted tidal flow with the Atlantic Ocean. Freshwater originating in upland watersheds discharges into the Lakes, diluting the salt water. The Bras d'Or Lakes is a two layer system where warmer, less saline water flowing toward the ocean sits atop a cooler, more saline layer that brings marine water into the Lakes. Given the restricted width and depth of channels that allow water exchange with the open ocean, the Bras d'Or Lakes experience very low tidal amplitudes compared to most of the Atlantic coast. As a result, the dominant physical oceanographic character of the Lakes is slow mixing, water movement and tidal exchange. Although tidal currents allow complete water column mixing in a few areas (namely the Barra Strait and Great Bras d'Or Channel), a well established thermocline separating warmer surface waters from cold bottom waters exists across most areas of the Lakes (Parker *et al.* 2007).

Shallow sills (cross channel obstructions) divide the Lakes in various areas and appear to affect both water chemistry and species movement within the Lakes. These sills limit water exchange, creating a slow flushing rate which causes measurable differences in temperature, nutrient availability, biological productivity and species distribution (Parker *et al.* 2007).

Salinity and temperature stratification are the fundamental components of the Bras d'Or Lakes ecosystem. Within the Lakes, there are three layers with distinct temperature and salinity characteristics: a relatively fresh surface layer and a more saline middle layer that can mix vertically with each other; and a third deep layer found in Whycocomagh Bay, St. Andrews Channel and the North Basin, where only vertical mixing with the middle layer can occur (Parker *et al.* 2007). Despite this stratification, vertical mixing due to wind-driven circulation, topographic upwelling and internal barometric tides is sufficient to ensure that anoxia rarely occurs in bottom waters even in the deepest areas of the estuary (e.g. St. Andrews Channel at 280 m). Only in the highly isolated waters of the upper Whycogomagh basin (where mean water residence time approaches two years) is there a permanent anoxic bottom layer.

Upwelling, which mixes salinity, dissolved oxygen, nutrients, and temperature from the deep bottom layer to the surface, is also limited. The strongest upwelling areas are found in the North Basin and Bras d'Or Lake, separated by the Barra Strait. The presence of deep basins on each side of the Strait further contributes to the temperature profile and marine nutrient stores that are key components of upwelling. In contrast, Whycocomagh Bay has no upwelling, despite the two deep basins in the Bay (Petrie and Bugden 2002).

The accelerated tidal currents within the Barra Strait are thought to be essential to the ecology of the Lakes. The turbulence mixes surface and deeper waters, bringing up nutrients needed to promote summer plant production. This vertical mixing at the Barra Strait has been proposed as the primary engine driving biological productivity within the Bras d'Or Lakes (Kenchington and Carruthers 2001).

5.10 Biological Components

5.10.1 Primary Production

5.10.1.1 Phytoplankton

Coastal Cape Breton

Phytoplankton are microscopic plants that drift in the sunlit surface layer of the oceans, estuaries and lakes. While their biomass is very small, their very rapid reproduction supplies the base of food web in deep marine and fresh water ecosystems. Since other organisms depend on phytoplankton for food, the abundance or biological productivity of these plants establishes an upper limit on the biological productivity of species higher in the food web, such as shellfish, finfish, marine mammals and certain bird species. Any condition that limits the growth of phytoplankton ultimately limits the aggregate abundance of these higher species. Light, which is used to generate energy through photosynthesis, and nutrients used to build the phytoplankters' structure are the limiting factors to phytoplankton growth rates (Zwanenburg *et al.* 2006).

Phytoplankton rapidly increase in population ("bloom") when both light and nutrients are available. Past studies have shown that both the time and location of these blooms varies seasonally, as well as over cycles of many years. The most commonly observed variation is a wide-spread spring bloom followed by a less pronounced fall bloom.

These blooms are thought to be directly linked to strong year classes of certain fish species, such as haddock (Zwanenburg *et al.* 2006).

Mixing of the ocean surface determines where phytoplankton are situated within the water-column and thus their access to light. Less mixing and increased stratification promotes a more favourable light environment; however, these conditions also limit upwelling, thereby reducing the supply of deep-water nutrients required by phytoplankton at the surface. Studies that have tracked spring blooms on the Scotian Shelf indicate that blooms begin earlier now than they did in the 1960s and 1970s, are now more intense and last longer (DFO 2003). Regular monitoring and reporting of phytoplankton community composition, chlorophyll biomass and associated primary productivity is undertaken in all of Cape Breton's three marine provinces as part of the Atlantic Zonal Monitoring Programme (AZMP, 2012).

Within the Bras d'Or Lakes, phytoplankton productivity is relatively low which is attributed to low nutrient inputs (Strain and Yeats 2002). Localized areas of high nutrient concentrations are associated with sewage inflows and sheltered areas having water bodies of long residence time. The western end of Whycocomagh Bay sporadically experiences eutrophication, a nutrient enrichment process that leads to excessive plant growth resulting in oxygen depletion and harmful effects to marine life (Lambert 2002).

The large majority of species, such as fish, clams, oysters, scallops, starfish, sea urchins sea worms, barnacles, crabs and lobsters have a planktonic stage (either eggs or larvae) during their life cycle. These plankton drift with the currents or swim weakly within them, and so can be affected by disruption to natural water movements, including those that may be caused by the extraction of energy by MRE projects. Many areas of the Lakes also have a low water exchange rate due to the restricted passages connecting them to the Atlantic Ocean, making the Lakes vulnerable to the effects of accidental spills and other pollutants (Lambert 2002).

5.10.1.2 Macrophytes

In shallow waters near the coast and island shores around Cape Breton, light penetrates to the seabed, supporting the growth of large (macro) algae, as well as small (micro) algae that usually live on grains of sediment or within the pore water between them. The depth of light penetration is generally higher on the Atlantic than on the Gulf coasts because of differences in the amount of suspended particulate material in the water column. The macroalgae must be attached to bedrock or boulders or cobbles unless the near-bed currents are extremely slow (which itself is an inhibitor of algal growth). These include the brown kelps and red algae. In high light, well-mixed rocky environments (i.e. the intertidal and shallow subtidal zone down to about 10 – 20m depth), mixed stands of these algae form dense forests of high biomass and productivity that is disproportionately high relative to the small portion of the total ocean area they occupy. Similarly, in protected, shallow sedimentary environments (e.g. estuaries), marine grasses form meadows of spectacularly high aerial productivity. These macrophyte beds provide not only an immense amount of organic material to support microbial and macrofaunal production in situ, but they export large streams of detritus that feeds consumer communities in deeper water down-slope or downstream below the photic layer. In addition, the juveniles of many species take shelter from predators amongst the fronds of these large, strong plants, and benefit nutritionally from consuming the detritus they generate as a by-product of growth. Kelps and seagrasses are foundation species that create habitat and sustain benthic communities (and human communities) of Cape Breton's marine ecosystems. Anything that compromises the delivery of light and nutrients to them, or the export of detritus from them, compromises the ecology of the marine ecosystem, and thereby the economic resilience of the human society that depends on their structure and function.

Coastal Cape Breton – West Coast and Sydney Bight

Shallow subtidal areas of western coastal Cape Breton and Sydney Bight are home to significant concentrations of benthic algae, dominated by twelve species including rockweed, knotweed, kelp, Irish moss and sea lettuce (DFO 2001). Plant communities inhabiting waters less than 8 m deep are stable over a surveyed 20 year period, but those found in deeper waters are reported to be "unstable" in Sydney Bight (DFO 2001). No information is available on the distribution of eelgrass in the Sydney Bight/western Cape Breton area.

Bras d'Or Lakes

Because of the low tidal range within the Lakes, the surface area of the intertidal zone, a highly productive ecosystem hosting a diverse variety of marine species, is reduced relative to marine environments experiencing the full tidal range. This, combined with the relative scarcity of silt-free, nearshore, bottom substrates and the unusual salinity characteristics, restricts the distribution of benthic macroalgal communities within Bras d'Or Lakes (although their distribution and abundance has not been mapped). Nevertheless, a total of 92 seaweed species have been documented within the Lakes. The dominant species include rockweed, knotweed, kelp, Irish moss, sea lettuce, twig weed, chenille weed and banded weed (McLachlan and Edelstein 1971 cited in Parker *et al.* 2007).

In contrast, eelgrass can colonize muddy substrates and is widely distributed within the shallow photic zone of the Lakes. Eelgrass is closely linked to the productivity and species diversity of the Lakes, providing spawning grounds for herring and settlement substrata for oyster (Lambert 2002). The abundance and distribution of eelgrass within the Lakes is not well known (Parker *et al.* 2007), although detailed mapping of eelgrass meadows has been undertaken recently in some areas of the Bras d'Or estuary using remotely sensed survey methods (Hatcher, Vandermeullin, unpublished data).

5.10.2 Secondary Production

5.10.2.1 Benthos

Coastal Cape Breton

Bottom-dwelling or benthic organisms are key components of the marine food web. The larger of these species include lobster, crabs, whelks, periwinkles, mussels, scallops, oysters, starfish, sea urchins, sea cucumbers, sea anemones and corals, which live on the surface of rocky or sedimentary seabed substrata. Other species live within the sediments, including clams, sea pens and anemones, as well as smaller organisms, such as worms, nematodes and amphipods, which live within or just above the surface of the sediment. Mysid shrimp, an important food source for bottom-dwelling fish, also live near the seabed.

Substrate type, texture and topography are basic components of benthic habitat which, along with water temperature and ventilation (related to near-bed current velocity), and the frequency and intensity of disturbance, are key factors that influence the distribution of benthic organisms (DFO 2003). The substratum can provide shelter from currents and predators, as well as feeding, breeding and nesting opportunities. At the same time, boulders and outcrops influence current patterns and affect water mixing, which in turn influences nutrient and sediment distribution.

Sand dollars prefer fine sandy sediments, while ocean quahaugs and Arctic surf clams are found on coarser grained substrates, along with northern propeller clams and sea cucumbers. Sea scallops are typically found on sandy-gravel bottoms at the base of banks (DFO 2003) and in relatively shallow waters near shore. The west coast of Cape Breton and Sydney Bight host several commercial invertebrate fisheries, including lobster and snow crab, and to a lesser extent, rock crab, scallops and sea urchins (DFO 2001).

It has been proposed that the characteristics that shape benthic communities are determined by the frequency and intensity of habitat disturbance (Southwood 1988 in Zwanenburg *et al.* 2006). Long-lived, slow growing and slowly reproducing species are more likely to occur in habitats that are stable and where food availability is low. Fast-growing, productive species are more likely to occur in areas that experience more frequent natural disturbance and where food availability is relatively high. Areas of low disturbance with slow-reproducing species would be more sensitive to human disturbance than areas that experience regular disturbance and contain fast-growing, fast-reproducing species.

A classification system has been developed for benthic habitats on the Scotian Shelf. This work maps habitat features (e.g. sediment grain size, bottom temperature, dissolved oxygen, food supply, etc.) and benthic communities to develop guidelines for human activities and ensure the long-term conservation of these habitats (Zwanenburg *et al.* 2006).

Bras d'Or Lakes

Low salinity within the Lakes limits the distribution of sea urchins, scallops, rock crab and possibly lobster. Lobsters are observed to be less common within the Lakes than in similar habitats in coastal Cape Breton. This is possibly due to the reduced salinity and limited areas of preferred cobble habitat, combined with low food availability and, as a result of past overfishing, low egg production (Tremblay 2002). Sea urchins and starfish are abundant in areas that receive little input of fresh water.

Although habitat and water temperature conditions appear to be ideal for oysters, they are not nearly as common as they once were. Oysters have been overfished in the past and suffer natural predation by starfish and crab, competition from mussels, and continued fishing pressures (Tremblay 2002). The arrival of the Haplosporidian parasite (MSX) to the Bras d'Or Lakes in 2002 essentially shut down the oyster industry that once landed more than 1M lbs per annum.

In summary, the productivity and distribution of the larger benthic species of the Bras d'Or is limited by low salinity, variable temperatures with season and depth, low tidal amplitudes and restricted inputs of larvae and food from the open Atlantic.

5.10.2.2 Fish and Shellfish

Coastal Cape Breton

A variety of fisheries operate on the Scotian Shelf, harvesting groundfish (cod, haddock, pollock, etc), small pelagic species (mackerel, herring and capelin), a wide range of invertebrates (lobsters, crab, clams, scallops), and large pelagic species (sharks and tunas). An array of fishing techniques are used including bottom and mid-water trawls, bottom longlines, gillnets, traps, dredges (both hydraulic and traditional), and pelagic long-lines (Zwanenburg *et al.* 2006).

Fisheries of the Eastern Scotian Shelf collapsed and were closed in the early 1990s. For groundfish, only the halibut longline fishery and some flatfish fisheries are currently operating on the Eastern Scotian Shelf. In addition to the overall reduction of biomass of commercially exploited fishes, the overall size structure, weight and condition of the groundfish communities has declined (DFO 2003). Reduced numbers of larger fish also impact fish populations over the long term, since smaller fish produce fewer eggs that are less likely to survive to adulthood. This combination of effects may impair the populations' ability to sustain itself (Zwanenburg *et al.* 2006).

Since the collapse of the groundfish fishery, the eastern Scotian Shelf has switched to harvesting lower trophic level invertebrates such as lobster, sea scallop, snow crab and shrimp, which are now of greater economic importance than groundfish (Coffen-Smout *et al.* 2001). These species have increased in abundance since the collapse of the groundfishery, likely due to a combination of predator decease and cooler water temperatures. Fisheries for small pelagic species (herring and mackerel) are mainly located in coastal waters, but an apparent resurgence of herring stocks has supported a relatively robust fishery since 1996 (Coffen-Smout *et al.* 2001).

In summary, the Eastern Scotian Shelf ecosystem has been deeply altered by commercial fishing; there has been a significant decrease in the biomass of groundfish species (80% since the early 1980s) and a significant increase in the biomass of grey seals, small pelagic species, commercial crustaceans, and phytoplankton (Zwanenburg *et al.* 2006).

The most important diadromous fisheries (salmon, gaspereau, striped bass, eel and smelt) occur in coastal and estuarine areas of the region. Many of these species pass through the Cabot Strait during their annual migration (DFO 2001). The southern Gulf of St. Lawrence is a critical spawning, rearing and feeding area for many marine fish species, and is the main spawning ground for mackerel in Canadian waters (DFO 2001). Trawl surveys indicate that the southern Gulf of St. Lawrence hosts the highest groundfish densities in Atlantic Canada, although many of these stocks are at record low levels FRCC, 2011). Inshore spawning grounds of white hake in the region are restricted to St. Georges Bay and the Eastern Northumberland Strait, while these areas also see spring and fall herring spawning. Herring also spawn in more limited numbers along most of the coast of Cape Breton. Researchers have observed an eastward shift in the summer distribution of groundfish, making the eastern side of the southern Gulf of St. Lawrence (i.e. the west coast of Cape Breton) an increasingly important feeding area for these species (DFO 2001). The west coast of Cape Breton is also the main migration route for marine fish (mackerel, herring, tuna, cod, plaice, white hake and witch flounder) between spawning and feeding areas within the Southern Gulf of St. Lawrence and over-wintering areas outside the Gulf. Sydney Bight itself is home to a diverse commercial fishery and is a nursery for cod and other species.

<u>Bras d’Or Lakes</u>

There is an unusually large range of habitats within the Bras d’Or estuary. Benthic substrata include karst limestone bedrock, boulders, cobble, gravel, sand and mud. The latter dominates in surface area because the great depth of the Lakes serves as a trap for sediment from the 2,400 km^2 watershed. Salt marsh flats, hundreds of pond-like embayments (“Barrachois” ponds), bays and inlets of all sizes, narrow, fast channels, deep basins and a 280 m deep trench all combine to provide a diverse assortment of habitats for sub-tropical to boreal species of marine plants, invertebrates, fish, mammals and birds. The result of this habitat diversity is a high diversity of marine species – (e.g. a total of 46 fish species have been recorded in the Bras d’Or Lakes - Lambert 2002). The greatest species diversity is found in St. Andrews Channel, the North Basin, the Great Bras d’Or Channel and the Barra Strait. These areas have the greatest range of depth, temperature, salinity and currents. In the case of the channels, they are transitional between the influence of the Sydney Bight (NW Atlantic) and the more restricted areas of the Lakes.

The Lakes are home to both resident species, typically bottom-dwelling (demersal), and non-resident or migratory species, which occupy the Lakes on a seasonal basis. Resident species include herring, cod, winter flounder, windowpane flounder, plaice, yellowtail flounder and possibly witch flounder. White hake, winter skate, haddock and pollock are part of larger populations distributed around coastal Cape Breton, while mackerel, herring and salmon are migratory (Lambert 2002).

One, possibly two resident populations of cod are present within the Lakes, and at least one population of resident spring-spawning herring are also found here. Other migratory species, such as salmon, spawn in the Lakes as part of larger populations that extend into and past Sydney Bight. Other species, such as cod and striped bass, likely spawn in the Lakes as strays (Parker *et al.* 2007).

Most cod within the Bras d'Or Lakes spawn in St. Andrews Channel and East Bay (Lambert 2002). In the past the main herring spawning areas were along the western shore of West Bay, in Denys Basin, St. Peters Inlet, and East Bay. Eggs are deposited on eelgrass and green algae. Eelgrass-dominated areas include St. Patricks Channel, Denys Basin, North Basin, and the upper reaches of East Bay and St. Peters Inlet, all of which correspond strongly with historic herring spawning areas. However, an increased demand for herring as lobster bait resulted in the closure of the commercial fishery in 1999 (Lambert 2002). Spawning at the time of closure was nearly non-existent south of the Barra Strait, while Baddeck Bay was one of the more significant spawning sites in the Lakes; a reversal of the traditional spawning site distribution. During trawl surveys in 1997, no spawning was observed in West Bay, East Bay, and St. Peters Inlet. During 2002 spawning surveys, it was noted that spawning was still absent in some traditional areas, and the observed biomass of spring spawners was very low (Parker *et al.* 2007).

American plaice, once widespread in the Lakes, is now confined to deep water of St. Andrews Channel and Great Bras d'Or Lake (Lambert 2002). It is possible that these areas are also the main spawning locations for this species. Atlantic salmon migrate into the Lakes to spawn in the larger rivers, including the Baddeck, Middle, Skye and Denys Rivers (Parker *et al.* 2007).

When fish stocks within the Bras d'Or Lakes are compared over the roughly 40 year period between 1952 and 2000, significant differences in abundance are distribution are observed (Lambert 2002). In 1952, 7,000 kg of winter flounder and 4,600 kg of cod (the two most abundant fish species in the Lakes) were netted in trawl surveys. In the 2000 surveys, these numbers were reduced to 1500 kg and 1300 kg of winter flounder and cod, respectively. American plaice, once abundant (2,250 kg netted in the 1952 surveys) are now rare (50 kg netted in the 2000 survey). Eel, pollock, haddock, dogfish and pout were present in 1952 but were not observed in the 2000 trawl surveys.

5.10.2.3 Sea Birds and Gulls

Coastal Cape Breton

The productive coastal ecosystems of Cape Breton include species of fish such as herring and capelin that are preferred food of many sea birds. The Eastern Scotian Shelf supports large numbers of wintering dovekies, sooty and greater shearwaters. For other species such as thick-billed and common murres, Atlantic puffins, northern fulmars, glaucous and Iceland gulls the area constitutes their southern wintering range (Zwanenburg *et al.* 2006). The Shelf also lies on the flyway for Canadian herring gulls, great black-backed gulls, and northern gannets during spring and fall, and is an important feeding area for Leach's and Wilson's storm petrels.

The waters surrounding the Sea Wolf Island National Wildlife Area support over forty species of birds (Environment Canada 2012). Colonial birds breeding here include the great cormorant, great blue heron, great black-backed gull, herring gull and black guillemot. The great cormorant colony, consisting of upwards of 100 pairs, is significant, as there are few colonies of these species known to occur in the region. Northern gannet and common loon are regularly observed around the island.

Bras d'Or Lakes

Six species of sea birds and gulls have been documented in the Bras d'Or Lakes watershed: great cormorant, herring gull, Arctic tern, double-crested cormorant, great black-backed gull and common tern. Of these species, the great cormorant and Arctic tern are possible breeders, while the other four species are confirmed breeders in the area (Erskine 1992). The common tern nests on several islands in the West Bay and Malagawarch areas, while Spectacle Islands host a double-crested cormorant colony (Parker *et al.* 2007). Piping Plovers are known to nest on certain secluded, low energy beaches in the Bras d'Or estuary. Bald eagles are perhaps the most charismatic of the Bras d'Or's birds. They maintain multi-year nests in large, white pine trees near the shore line and are major predators in the ecosystem.

5.10.2.4 Marine Mammals

<u>Coastal Cape Breton</u>

Two groups of marine mammals, cetaceans (whales and dolphins), and pinnipeds (seals) are found seasonally or throughout the year in coastal Cape Breton. These groups include 23 species of cetaceans and 4 species of seals (grey, harbour, harp, hooded). Only the grey and harbour seals are common to abundant (DFO 2003).

With respect to whales and dolphins, there are few species for which either population size or trends in abundance are available on the Scotian Shelf (Zwanenburg *et al.* 2006). Fin whale, minke whale, humpback whale, sperm whale, pilot whale, common dolphins and Atlantic white-sided dolphins have been observed in the Eastern Scotian Shelf area. While sighting rates vary from year to year, there is no evidence of any trend (DFO 2003). Biomass estimates suggest that white-sided dolphins are most common, followed by pilot whales, fin whales, common dolphins and humpback whales (Bundy 2004).

A non-migratory species, grey seals are found along most of Nova Scotia's coastlines. Seasonal changes to their distribution are thought to be related to changes in the distribution of prey (Bowen *et al.* 2005), but also reflect the aggregation of adults at a handful of land/ice breeding colonies, such as Hay Island off the northeast coast of Cape Breton. Tracking studies indicate that grey seals are mostly confined to the continental shelves off eastern Canada and the US (Bowen *et al.* 2005).

Over the past 50 years, the number of grey seals on the Scotian Shelf and Southern Gulf of St. Lawrence has increased significantly; the Sable Island colony is the largest in the world, increasing exponentially at an annual rate of 13% per year for the past four decades (DFO 2003; Bowen *et al*. 2003).

Harbour seals are widely distributed at both coastal sites and on Sable Island, but less is known about their abundance. Like grey seals, the species is non-migratory, but their seasonal movements are not well documented. During the 1990s, pup production fell significantly, probably as a result of increased shark predation and competition for food from grey seals (Bowen *et al.* 2003).

Harp and hooded seals are seasonal residents of the southern Gulf of St. Lawrence and Sydney Bight, while grey and harbour seals are permanent residents. Although 15 species of whales are known to inhabit the Cabot Strait, the six most common marine mammals are fin, minke, humpback and pilot whales, white-sided dolphins and harbour porpoise (DFO 2001). The Cape Breton Trough is a key feeding location for whales and the area is particularly important to pilot whales.

<u>Bras d'Or Lakes</u>

Of the 32 species of marine mammals found off the coast of Nova Scotia, only two are commonly found within Bras d'Or Lakes (Parker *et al.* 2007). Harbour seals and grey seals are often sighted during the winter months, but are rarely reported in the summer. Seals are most often observed in the North Basin between Baddeck Bay and Grand Narrows, and in the St. Patrick's Channel between Baddeck Bay and Little Narrows. They appear to enter the Lakes for feeding and leave to raise their young on coastal beaches.

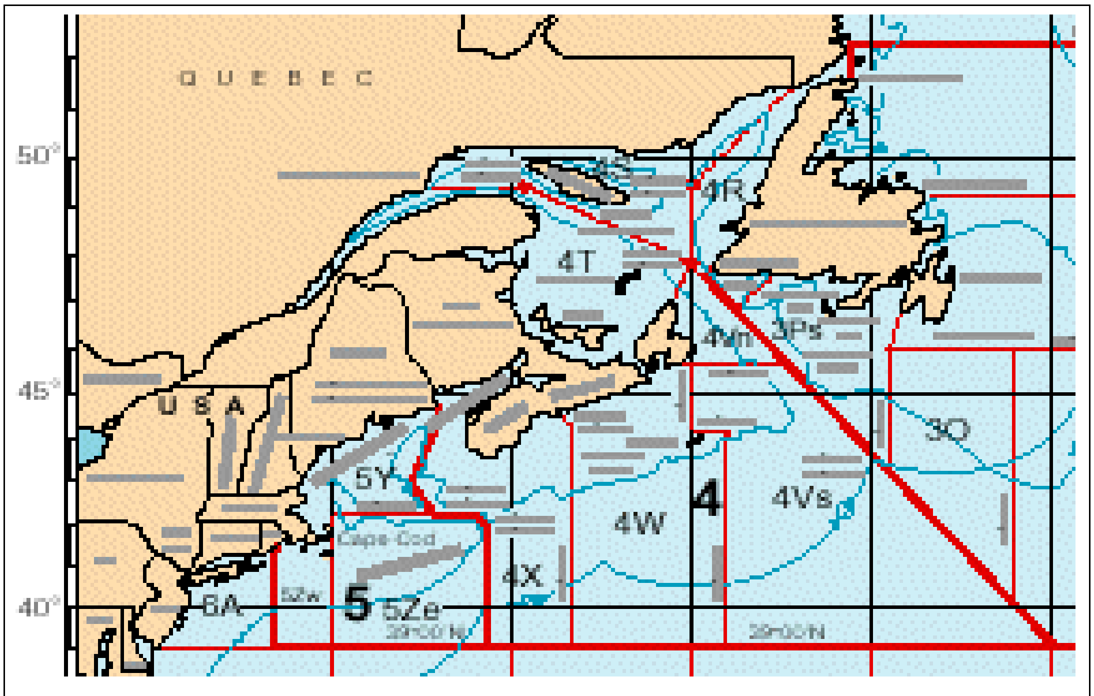
5.10.3 Fisheries and Aquaculture - Overview

General Fisheries

The Northwest Atlantic ocean is highly productive, and the extensive areas of shallow water and long coastlines in Atlantic Canada provide “hot spots” of secondary productivity. Humans (and other large predators) have exploited these yields for centuries, such that fisheries and, more recently, aquaculture often constitute the dominant primary industry. Indeed, fishing and aquaculture, and the coastal communities that they sustain constitute the dominant human use of coastal and ocean spaces and resources outside of the relatively few urban centres. When new development takes place in the coastal zone, it is these marine capture and culture industries that must adapt to accommodate them (CBCL 2009). It follows that MRE initiatives must pay particular attention to fishing and aquaculture interests.

The North Atlantic Fisheries Organisation (NAFO) has divided the fishing grounds between Greenland and Canada into a series of Fisheries Management Areas to manage and conserve fisheries resources in the region. NAFO, with Canada as member, administers fishing for most species except whales, tuna/marlin, salmon and shellfish. In Canada, the Scotia-Fundy fisheries management region includes the Scotian Shelf, Bay of Fundy and Gulf of Maine, while Fisheries Management Area 4Vn includes most of coastal Cape Breton from Cape North in the west to Forchu in the east. The coastal area southwest of Forchu falls within Fisheries Management Area 4Wd, while waters west of Cape North are within Area 4T (Figure 50). NAFO Fisheries Management Areas are also described in the Canadian Atlantic Fisheries Regulations made under the federal Fisheries Act. These Regulations delineate management areas for other species such as herring, crab, lobster, mackerel and shrimp.

Figure 50. NAFO Fisheries Management Areas



Source: DFO 2005

Boats from Cape Breton and other areas of Nova Scotia fish along the coasts and offshore of the Island and, to a much lesser extent in the Bras d'Or Lakes. Landings from the various fisheries are recorded by Statistical District; Districts 1-9 cover coastal Cape Breton (Figure 51). Lobster landings are also recorded by Atlantic Canada District, of which Districts 26b and 27 cover the nearshore coastal zones of Cape Breton with tidal potential (Figure 52). There is only limited commercial fishing for a few species within Bras d'Or Lakes, and the recreational fisheries are not large either but are important to the permanent residents and temporary visitors who exploit them. In addition to lobster fishing by aboriginal and non-aboriginal license holders, a small First Nations food fishery exists for eel, mackerel, oyster, and lobster in the Bras d'Or Lakes (UINR 2007). Until recently, there was a substantial commercial capture fishery for oyster in the Bras d'Or as well, but that fishery is currently closed because of very low stock levels.

Figure 51. Fisheries Statistical District Boundaries

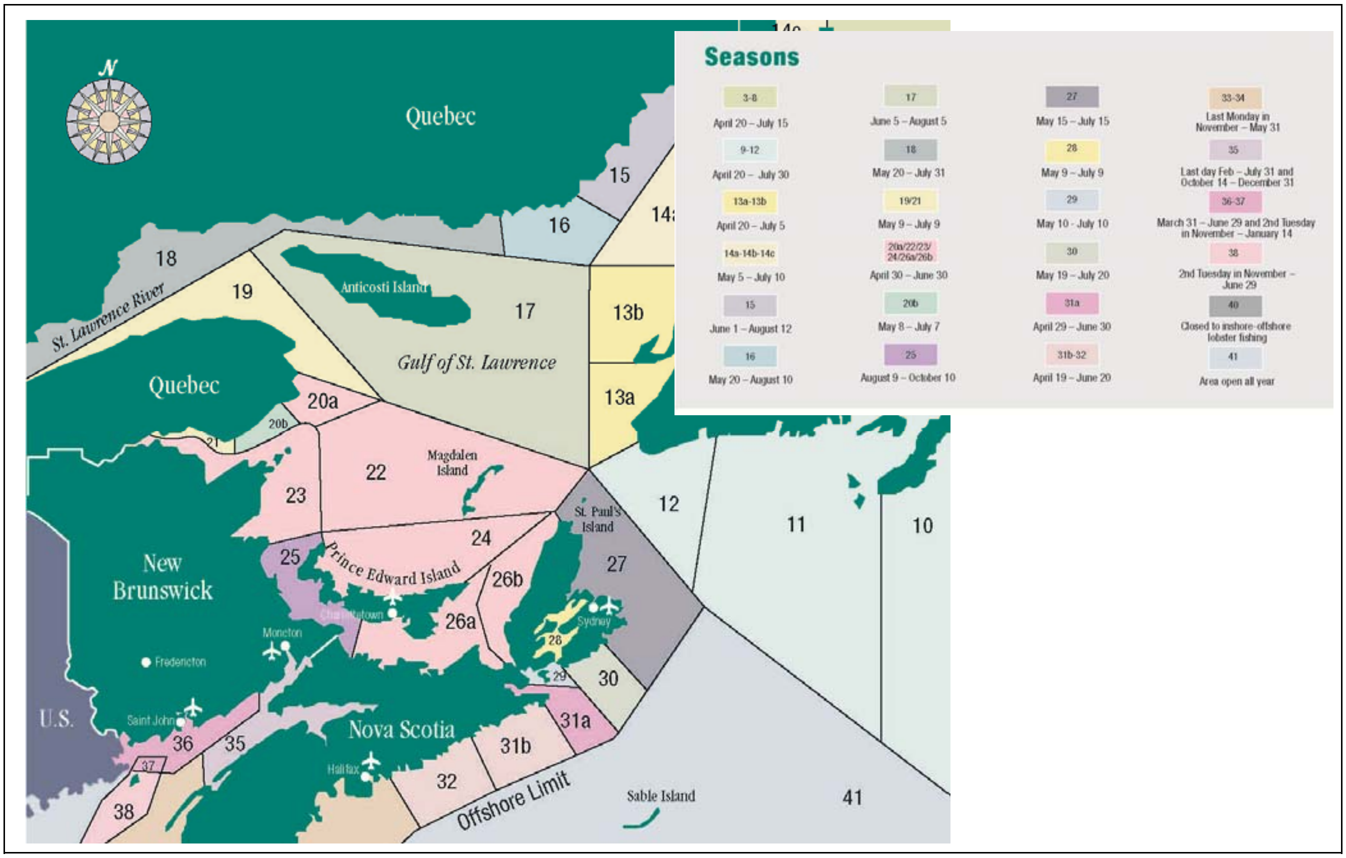
Shellfish

Lobster

The fishery for Atlantic lobster is the most valuable single-species fishery in Canada. Most of the lobster fishing in Cape Breton occurs in Lobster Fishing Area 27 (LFA), which employs almost 1400 fishermen and extends along the entire north coast of the island (Figure 52). There are two commercial lobster fishing areas in the Bras d'Or Lakes. The larger southern portion is LFA 28, while the northern portion–the North Basin, Great Bras d'Or and St. Andrew's Channels are part of LFA 27, which extends well beyond the Bras d'Or Lakes to the adjacent Sydney Bight in the Atlantic Ocean (UINR 2007).

The preferred habitat of lobster consists of rocky and muddy bottom, with the majority of the catch coming from shallow water usually within 9 miles (15 km) of shore. Most fishing effort in LFA 27 has been at depths less than 32 m, and the port of landing is typically within 10 km of where lobsters are caught. With the exception of soft-bottom areas, the entire coastline of Cape Breton is considered to be lobster habitat (Tremblay *et al.* 2001). In LFA 27 the fishing season for lobster extends from May 15 through July 15 with the majority of landings occurring in the central portion of Sydney Bight, although lobster fishing is generally widespread along the coast (Schaefer *et al.* 2004). Within the lakes (in LFA 28), lobster landings are extremely low compared to coastal Cape Breton. West Bay has higher concentrations of lobsters and crabs than East Bay, likely resulting from generally low availability of good lobster habitat (Tremblay *et al.* 2005). The fishing season in LFA 28 is May 9 to July 9.

Figure 52. Atlantic Canada Lobster Fishing Districts



Note: also called Lobster Fishing Areas – LFAs

Approximately 524 lobster licenses are currently fished in LFA 27, with each license holder permitted to fish 275 traps. The 2010 landings were 2,568 tonnes, and in 2011 lobster stock health indicators in LFA 27 were positive (DFO 2011a). It is thought that less than ten fishers exploit the portion of LFA 27 that falls within the northern portion of Bras d'Or Lakes, and even then only a portion of their gear is set within the estuary (Parker *et al.* 2007).

In 1997 there were 18 lobster licences in LFA28 (south of Barra Strait). In 2010 there were 16 licenses in LFA 28 and the trap limit was reduced from 275 traps in 1997 to 250 traps in 2003 (Parker *et al.* 2007; DFO 2011a). Catches within Bras d'Or Lakes are reported as 5-20 t/year over the past 20 years, with 11 t harvested in 2011 (DFO 2011a). Lobsters are taken from many of the rocky areas of the Lakes but harvest are reportedly poor (Lambert 2002).

Crab

Sydney Bight is located within Snow Crab Fishing Area N-ENS (formerly Crab Fishing Areas 20-22). Snow crabs were first harvested commercially in the late 1970s, peaking in 1973 with 1,634 tonnes captured. Following the near extinction of the commercial stock in 1985 landings have gradually increased with the exception of a 23% decline in landings in 1994.

Snow crab is generally fished following the closure of the lobster season, between July 22 and September 15. The crabs are typically found in deeper waters (between 140-250 m) at this time of the year and they are fished using baited, fixed crab traps/pots (Schaefer *et al.* 2004). The size of the vessels in the snow crab fishery varies depending on whether the fishery is inshore, mid-shore or offshore. In 2010, CFA 20-22 had 78 license holders (House of Commons Canada 2011). Currently, the total allowable catch for snow crab is 603 tonnes per license, with each license initially limited to 30 traps (DFO 2012). In 2010 the landings were 576 tonnes (DFO 2011b).

A directed fishery for rock crab began in eastern Cape Breton in 1993 and is considered to be an emerging fishery in the Sydney Bight area. The fishing season for this species extends from late July through the wall and winter until May, with the majority of fishing occurring between August and October (Tremblay *et al.* 2001). A directed experimental fishery for the waved whelk within 40 nautical miles of the Atlantic coast began in 2006, and transitioned to an exploratory fishery under the New Emerging Fisheries Policy in 2011. Exploratory offshore licenses in NAFO zones 4Vs and 4W were also granted in 2011 (Rawlings *et al.* 2011).

Other Shellfish Species

The Bras d'Or Lakes have been a popular oyster capture and culture location for many years. Although most American oysters take between four and seven years to reach market size, and there are records of 100 year old oysters found in Bras d'Or Lakes (NSFA 2007c). It has been estimated that only 5% of the total area of the Bras d’Or Lakes is suitable for bottom cultivation of oysters. Significant wild oyster production within the Bras d’Or is limited to Denys Basin, St. Patricks Channel, Whycocomagh Basin, West Bay, East Bay and St. Peters Inlet (Parker *et al.* 2007).

Currently, oysters are harvested from both public grounds and private leases. There are three types of oyster harvest that occur in the Lakes:

1. The aquaculture fishery: Harvesting occurs only on leased grounds or beds by means of tongs, or by hand-picking using SCUBA, or snorkel diving, or wading. This fishery is administered by the Nova Scotia Department of Fisheries and Agriculture. In 2004 there were a total of 18 active leases encompassing a total area of 76.6 ha of Bras d’Or Lakes seabed. The number of active lease sites has declined markedly since the advent of the MSX parasite in 2002.

2. The relay fishery: oysters are harvested from public beds that have been closed by Environment Canada’s Shellfish Sanitation Program (CSSP). The oysters are transferred into areas approved for the growing of shellfish. This fishery is administered by DFO. There were 14 relay license holders in 2001. The fishery is currently closed.

3. The commercial and recreational fishery on public beds: oyster fisheries occur in areas deemed open by Environment Canada. This fishery is administered by DFO. Approximately 170 commercial licenses and less than 50 recreation licenses were granted since 1993 (Parker *et al.* 2007). Since the advent of the MSX parasite in 2002, the fishery has been sporadically limited or closed, as it currently is.

Oysters have been over fished in their native habitats within the Lakes (Lambert 2002). Although small pockets of wild oysters still exist, oysters today are only found in large numbers at aquaculture sites, and even there mortality associated with MSX has greatly reduced population densities. Denys Basin is of particular interest for both wild oysters historically and currently for farmed oysters. The Basin is the most extensive area providing water within the species' tolerance limits for both temperature and salinity. It has also been suggested that the warmer waters of Denys Basin reduce the competition from blue mussels that compete with oysters for the limited habitat available (Parker *et al.* 2007).

Similar to lobster, scallops inhabit near shore areas of gravel and silt substratum. Most landings come from localized areas in the southern portions of the Sydney Bight and in Morien and Mira Bays. Landings for any given port are usually not more than 10 metric tonnes (DFO 2001). Scallops are relatively intolerant of low salinities and so are not found in most areas of Bras d'Or Lakes. A small commercial fishery occurs on the outer part of the Great Bras d'Or Channel where the salinity requirements for this species are met (Lambert 2002). Species distribution is not well documented, but they have been found incidentally in fish surveys, trawling in Great Bras d'Or Channel, St. Andrews Channel, and in the North Basin (Parker *et al.* 2007).

Pelagic Fisheries

A number of herring stocks use the Sydney Bight during some portion of the year and several fisheries exploit these populations (Schaefer *et al.* 2004). Herring used to be harvested by local bait fisheries using gillnets and trapnets in the Bras d'Or Lakes and along the coast during the spring, as well as by local trapnets and small seiners during the fall. North of Cape Smokey a Gulf of St. Lawrence-based seining fleet operates a commercial fishery for overwintering herring in depths greater than 65 feet.

The southern Gulf of St. Lawrence herring fishery is limited to the area above the Cape Dauphin Line (north of Cape Smokey) within division 4Vn. To the southeast, the Scatarie Line marks the boundary of division 4WX, and fishing by large seiners is prohibited between these lines. Harvesting of herring is managed through the imposition of size limits, closed areas, and by setting the opening date for the fishery (typically November 1) well into the migration of this stock out of the area. The intent of the management plan is to restrict large seiners from fishing near the only entrance/exit for Bras d'Or Lakes herring (Claytor 1997).

Herring were once the primary commercial fisheries in the Lakes. Historically, the Bras d'Or Lakes herring fishery occurred in the spring following ice off and lasted about 30 days from early April until the first or second week of May. From 1978 to 1997 herring landings in the Bras d'Or Lakes averaged 181 tonnes, an increase from the 86 tonnes harvested in the early 1970s (Denny *et al.* 1998). Herring appear to return to the same spawning grounds year after year, making these populations particularly vulnerable to over-fishing (Parker *et al.* 2007). Of the stocks that use the Sydney Bight area, the Bras d'Or Lakes herring are a concern for management, as they have been absent from traditional spawning areas and because the fishing effort for this species has intensified (Power *et al.* 2002). The Bras d'Or Lakes have been closed to commercial herring fishing since 1999 (FRCC 2009).

Annual mackerel landings from the eastern coast of Cape Breton (statistical District 1) are the third highest in the province, averaging approximately 1,135 tonnes. The majority of landings in District 1 occur in June, September and October using traps but mackerel is commercially fished between May and November in the Maritimes and Quebec. Districts 6 and 7 are also important coastal fishing areas, with the majority of landings occurring in September and October using jiggers, handlines, and purse seines (Schaefer *et al.* 2004). There has been a marked decline in landings within division 4Vn, with only 125 tonnes in 2001, 308 tonnes in 2002, and 59 tonnes in 2003 (Gregoire *et al.* 2004).

Ground Fisheries

Historically the haddock fishery in division 4VN yielded some of the highest landings in offshore eastern Canada (Gromack *et al.* 2012). Haddock were traditionally fished using shore traps and both large and small vessels. Within Bras d'Or Lakes, haddock were found in trawl surveys undertaken in the 1950s and 1960s but were not found in surveys completed in1999-2000 (Parker *et al.* 2007).

Atlantic cod was heavily exploited by the fishing industry in the past, severely reducing stocks particularly during the late 1980s and early 1990s. The division 4Vn stock has been described as the most depleted of any of Canada's cod populations (Schaefer *et al.* 2004). Atlantic cod is presently listed as an endangered species by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC 2012).

Traditionally, cod was a summer inshore longline fishery concentrated on the banks south of the Laurentian Channel (DFO 2002). There is currently no winter cod fishery in division 4Vn and a groundfish moratorium has been in place since 1993 (Schaefer *et al.* 2004). The summer cod fishery re-opened in 1999 with annual catches in the range of 6,000 tonnes, a fraction of historic levels (Archambault *et al.* 20011). The failure of the stock to recover is reported to be the result of the absence of any strong year-classes entering the fishery and a high rate of natural mortality (DFO 2002, FRCC 2012). Within the Bras d'Or Lakes, cod were reported to be numerous during the trawl surveys conducted from 1952-2000, however a steep decline in the population was observed once a long line fishery was allowed in the 1980s. The Bras d'Or Lakes cod population is afflicted with the seal worm, which severely limits in market value (Parker *et al.* 2007).

In the summer months redfish are found in large concentrations both in Sydney Bight and in the southern Gulf of St. Lawrence. Most of these fish move into the Laurentian Channel to overwinter. Given this, the fishery is considered a part of the Gulf of St. Lawrence management unit (Unit 1) from January to May, and a part of the Laurentian Channel management unit (Unit 2) from June to December (Schaefer *et al.* 2004). The Gulf of St. Lawrence Unit (Unit 1) has been under a moratorium due to low stock abundance since the early 1980s (Archambault *et al.* 2001). The Unit 2 fishery occurs only from July to September in the Laurentian Channel and redfish is the most important species harvested in division 4Vn. This species is fished using bottom otter trawls, Danish seines, and longlines (Schaefer *et al.* 2004). In 2010, the total allowable catch (TAC) for redfish in Unit 2 was limited to 8,500 tonnes (NLFA 2011). The Unit 2 stock is considered to be "poor" and it is not expected to improve in the near future (DFO 2000).

The American plaice fishery has historically accounted for approximately 15% of total groundfish landings in division 4Vn. The fishery in division 4Vn typically uses Danish seines and otter trawls, although handlines and longlines have also been used. The majority of landings for this species are from the area known as the "Glace Bay Hole" during the spring and fall months of the year (Schaefer *et al.* 2004).

The fisheries for American Plaice on the Scotian Shelf (including division 4V) are managed under multispecies flatfish TACs, where the component species are not required to be identified in the commercial landings data. Landings have dropped over the last 20 years to below 5,000 tonnes, and to only a small percent of the TAC between 2005 and 2010 (approximately 4,000 tonnes) due to significant declines in stock abundance. In 2009, the Maritime stock was designated as Threatened by COSEWIC (DFO 2011c). Within the Bras d'Or Lakes, American plaice fish stocks have gone from abundant to scarce and are now confined to the deeper areas of the lake and St. Andrews Channel. There is no commercial fishery for American plaice in the Bras d'Or Lakes (Parker *et al.* 2007).

Diadromous Fisheries

In the Sydney Bight area gaspereau are harvested in the spring and early summer (April until July) using trap nets, set gillnets, and dip nets. Landings are largely used for bait in the lobster fishery and consumed by fishermen. There are a number of important coastal areas for gaspereau fishing including Main-a-Dieu, North Sydney and Sydney, Ingonish, Sydney River, and Mira River.

American Eels are fished in many of the rivers and estuaries in the Sydney Bight area. Landings from eel pots or traps have historically been sold by local fishermen out of Sydney and Glace Bay, or consumed personally by fishermen. In recent years, the largest eel landings have come from the North Aspy and Mira Rivers.

Rainbow smelt and shad represent only small components of the commercial fisheries in the Sydney Bight area. Gillnets are used to harvest both smelt and shad. The fishery for rainbow smelt generally takes place through the winter (early October through February). Of late, the fishery for rainbow smelt has been concentrated in Lingan Bay, North River and Sydney (Schaefer *et al.* 2004).

Within the Bras d'Or Lakes watershed there are five rivers with historically reported Atlantic salmon caught by angling: Baddeck River, Middle River, Indian Brook, River Denys and Skye River. In Eastern Cape Breton (Salmon Fishing Area 19 which encompasses the majority of the Bras d'Or watershed), the commercial salmon fishery was shortened in 1984 and has remained closed since 1985 (Parker *et al.* 2007). No commercial salmon fishing licenses remain in SFA 19.

Aboriginal Fisheries and Harvest

The Supreme Court's Marshall Decision in 1999 recognized Mi'kmaq and Maliseet First Nations commercial fishing rights in Atlantic Canada for what was defined as "a moderate living". As of 2011, 27 of the 34 Marshall Decision-affected First Nations have established Contribution Agreements with the Department of Fisheries and Oceans and are currently engaged in commercial fishing. It is reported that Atlantic First Nation fishing returns increased from $4.4 million in 1999 to $35 million in 2009 (Scott 2012). Following the 1999 Marshall Decision, government public policy and programs have been created to help First Nation communities obtain fishing licences and equipment, establish business plans and support the communities to fulfill those plans (Scott 2012).

While there is relatively little commercial fishing activity in general within the Bras d'Or Lakes, the majority of it occurs in the North Basin, St. Andrew's and the Great Bras d'Or Channels (UINR 2007). The three main fish species harvested within the Bras d'Or Lakes, oysters, herring, and lobster, have experienced population declines over several decades. Populations of lobster within the Bras d'Or also appear to have declined based on catch per unit effort data. Lobster declines have been attributed to habitat impacts from land use, industrial impacts, ecological influences from marine invasive species, and poaching (Naug 2007).

Within the Bras d'Or watershed, a total of 220 salmon per year are alloted to a maximum of 22 harvesters of the Native Council of Nova Scotia. The fishing of salmon by angling, snaring, spearing and dip netting were permitted methods of achieving quotas (Parker *et al.* 2007).

In 2006, Crane Cove Seafoods was established in Eskasoni (located on the shores of the Bras d'Or lakes) as the primary division of their commercial fishery operations. As of 2011, Crane Cove is a fully functional fishery actively harvesting wild-caught snow crab, shrimp, lobster, groundfish, scallop, and tuna. Crane Cove reportedly employs up to 140 members of the Eskasoni community as fishers or processing plant workers. Crane Cove operates 13 vessels holding 36-38 licences that extend from Ingonish to Yarmouth, NS. Crane Cove annual revenues have reportedly exceeded $10 million (Scott 2012). This subject is further described in section 5.11.8 First Nations Perspective.

Aquaculture

There is little aquaculture taking place in Cape Breton's coastal zone at present relative to levels occurring in other Atlantic Provinces. Oyster culture of various kinds (discussed above) was until recently an ecologically and economically significant activity in partially enclosed estuarine waters of the Bras d'Or Lakes, Atlantic and Gulf coasts, such as Mabou Harbour, the Mira River, St. Ann's Bay, and the North and South Harbours of Aspey Bay. Now, oyster aquaculture barely hangs on in a few, small areas spared the worst of the impacts of over-fishing and the MSX pathogen. In contrast, the largest blue mussel farm in Atlantic Canada is located in St. Ann's Bay, occupying some 43% of the total surface area of that large embayment. Finfish (open pen) culture of salmonids has also waxed and waned over the years from Arichat to St. Ann's Bay, but currently there is but a single enterprise of 12 pens operating in the Whycogomagh Basin. In general, it is fair to say that Aquaculture faces significant environmental challenges to development within the domain of Cape Breton marine waters

5.10.4 Species at Risk

Table 10 lists the species inhabiting Coastal Cape Breton and the Bras d'Or Lakes that are considered to be at risk by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). This table includes only those species likely to be encountered in nearshore and offshore waters in depths less than 100 m.

Four *Species at Risk Act* Schedule 1 (endangered, threatened, and special concern risk categories) marine species are present within the Bras d'Or watershed: Barrows Goldeneye, Harlequin Duck, Piping Plover, and Atlantic Wolffish (BLBRA, 2010).

One additional SARA Schedule 1 species occurs on Cape Breton Island, but is not recorded within the Bras d'Or Lakes watershed. The yellow lampmussel (*Lampsilis cariosa*) is listed as special concern and is reported in Sydney River by Environment Canada.

During winter while extensive areas of the Bras d'Or Lakes are frozen, Barrows Goldeneye (a small diving duck) feeds on mollusks and crustaceans in Atlantic coastal waters. Once the Lakes are ice free, Barrows Goldeneye nests in inland wooded areas. Harlequin Duck has been documented near St. Peters Inlet and along the eastern shoreline of Cape Breton Island (Parker *et al.* 2007). The Piping Plover (*Charadrius melodus melodus*) is endangered. It is recorded on sand beaches and dunes in the northwestern and southwestern extents of the Island, as well as on two sand bars in the Bras d'Or Lakes.

The Atlantic wolffish is also listed by the COSEWIC and the SARA as a species of special concern although its preference for cold, deep water rocky bottom habitat makes it a rare resident in Bras d'Or Lakes (Parker *et al.* 2007). Atlantic cod are distributed throughout the Bras d'Or Lakes; the Maritimes population was designated special concern by COSEWIC in 2003. The Eastern Scotian Shelf population of winter skate was designated threatened by the COSEWIC in 2005. Although winter skate was widespread in the Bras d'Or Lakes (Lambert 2002), it is less plentiful now than in past.

Table 10. COSEWIC Species at Risk in Coastal Cape Breton and the Bras d'Or Lakes

Status	Common Name	Scientific Name	Area
Endangered	Piping Plover	*Charadrius melodus melodus*	Coastal Cape Breton/Bras d'Or Lakes
	Leatherback Sea Turtle – Atlantic population	*Dermochelys coriacea*	Coastal Cape Breton
	Atlantic Cod – Maritimes population	*Gadus morhua*	Coastal Cape Breton
	Atlantic Salmon – Eastern Cape Breton – Nova Scotia Southern Upland population	*Salmo salar*	Coastal Cape Breton/Bras d'Or Lakes
	White Shark – Atlantic population	*Carcharodon carcharias*	Coastal Cape Breton
	Winter Skate – Southern Gulf of St. Lawrence population	*Leucoraja ocellata*	Coastal Cape Breton
Threatened	American Eel	*Anguilla rostrata*	Coastal Cape Breton/Bras d'Or Lakes
	Atlantic Sturgeon – Maritimes population	*Acipenser oxyrinchus*	Coastal Cape Breton
	Shortfin Mako – Atlantic population	*Isurus oxyrinchus*	Coastal Cape Breton
	American Plaice – Maritime population	*Hippoglossoides platessoides*	Coastal Cape Breton/Bras d'Or Lakes
	Northern Wolffish	*Anarhichas denticulatus*	Coastal Cape Breton
	Spotted Wolffish	*Anarhichas minor*	Coastal Cape Breton
Special Concern	Harbour Porpoise	*Phocoena phocoena*	Coastal Cape Breton
	Fin Whale – Atlantic Population	*Balaenoptera physalus*	Coastal Cape Breton
	Killer Whale – Northwest Atlantic/Eastern Arctic Population	*Orcinus orca*	Coastal Cape Breton
	Spiny Dogfish – Atlantic population	*Squalus acanthias*	Coastal Cape Breton
	Atlantic Salmon – Gaspe-Southern Gulf of St. Lawrence population	*Salmo salar*	Coastal Cape Breton
	Basking Shark – Atlantic population	*Cetorhinus maximus*	Coastal Cape Breton
	Blue Shark – Atlantic population	*Prionace glauca*	Coastal Cape Breton
	Smooth Skate – Laurentian-Scotian population	*Malacoraja senta*	Coastal Cape Breton
	Winter Skate – Georges Bank-Western Scotian Shelf-Bay of Fundy population	*Leucoraja ocellata*	Coastal Cape Breton
	Atlantic Wolffish	*Anarhichas lupus*	Coastal Cape Breton/Bras d'Or Lakes

While not at risk, harbour seals and grey seals are frequently sighted in Bras d'Or Lakes during the winter months (Parker *et al.* 2007).

5.10.5 Ecological Reserves and Protected Areas

Certain areas of coastal Cape Breton and the Bras d'Or Lakes have been designated for conservation/preservation or special management under international, national, provincial, and non-governmental programs, as listed in table 11. Most notably, the entire Bras d'Or Lakes and its watershed is designated as the world's newest Biosphere Reserve under UNESCO's Man and the Biosphere Program. In general, most protected and designated areas are not suitable for marine renewable energy development, although this stricture does not apply to the Biosphere Reserve (which has sustainable economic development as a primary goal), and exceptions have been noted elsewhere (e.g., testing of the Clean Current TISCEC at the Race Rocks Ecological Reserve in coastal British Columbia). Terrestrial protected area, including protected beaches (not listed below) may limit the availability of suitable landfall locations for cable landings, substations and transmission lines. The locations of these protected sites are shown on Figure 53.

Table 11. Ecological Reserves and Protected Areas

UNESCO Biosphere Reserves	1	Bras d'Or Lake Biosphere Reserve, NS
National Wildlife Areas	2	Sea Wolf Island, NS
Migratory Bird Sanctuaries	3	Big Glace Bay Lake, NS
Important Bird Areas	4	Margaree Island – Dunvegan, NS
	5	Big Glace Bay Lake, NS
Canadian National Historic Sites	6	Alexander Graham Bell National Historic Site – Baddeck, NS
	7	Fortress of Louisbourg National Historic Site– Louisbourg, NS
	8	Marconi National Historic Site – Table Head, NS
	9	Royal Battery National Historic Site – Louisbourg, NS
	10	St. Peters Canal National Historic Site – St. Peter's, NS
Canadian National Parks	11	Cape Breton Highlands National Park
Canadian Heritage Rivers	12	Magaree-Lake Ainslie River System
Nova Scotia Provincial Parks	13	Cabot's Landing
	14	MacIntosh Brook
	15	Big Intervale
	16	Corney Brook
	17	Broad Cove
	18	Cheticamp
	19	Ingonish
	20	Cape Smokey
	21	Plaster
	22	North River
	23	Southwest Margaree
	24	Lake O'Law
	25	Uisge Bahn Falls
	26	St. Anns
	27	Dalem Lake
	28	Bras d'Or
	29	Groves Point
	30	Barrachois
	31	Peters Field
	32	Ross Ferry
	33	Dominion Beach
	34	Port Hood Station
	35	Mabou
	36	Trout Brook
	37	Whycogomah
	38	MacCormack
	39	Ben Eoin
	40	Mira
	41	Irish Cove

	42	Point Michaud
	43	Battery
	44	Pondville Beach
	45	Lennox Passage
	46	Dundee
	47	Long Point
Nova Scotia Wildlife Management Areas	48	Spectacle Island Game Sanctuary – Spectacle Island, NS
	49	Bird Islands Wildlife Management Area – Cape Dauphin, NS
	50	Scatarie Island
Non-Government Protected Reserves	51	Maskell Harbour Bras d'Or Preservation Nature Trust – Pony's Point, NS
	52	Boulacette Farm Bras d'Or Preservation Nature Trust – Maskell Harbour, NS
	53	Beinn Bhreagh Bras d'Or Preservation Nature Trust – Baddeck, NS
	54	Hertford Island Nova Scotia Bird Society Sanctuary - Cape Breton, NS
	55	French River Nova Scotia Wilderness Area
	56	North River Nova Scotia Wilderness Area
	57	Pollets Cove – Aspy Fault Nova Scotia Wilderness Area
	58	Port Morien Old French Mine
	59	MacFarlane Woods Nature Preserve
	60	Bornish Hill Nature Preserve
	61	River Inhabitants Nature Reserve
	62	Washabuck River Nature Reserve

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OERA Offshore Energy Research Association of Nova Scotia

Background Report
Phase II SEA

Figure 53
Ecological Reserves and Protected Areas

- Canadian National Historic Sites, Parks, and Heritage Rivers
- National Wildlife Areas, Migratory Bird Sanctuaries, and Important Bird Areas
- UNESCO Biosphere Reserves
- Nova Scotia Provincial Parks
- Non-Government Protected Reserves
- Nova Scotia Wildlife Management Areas

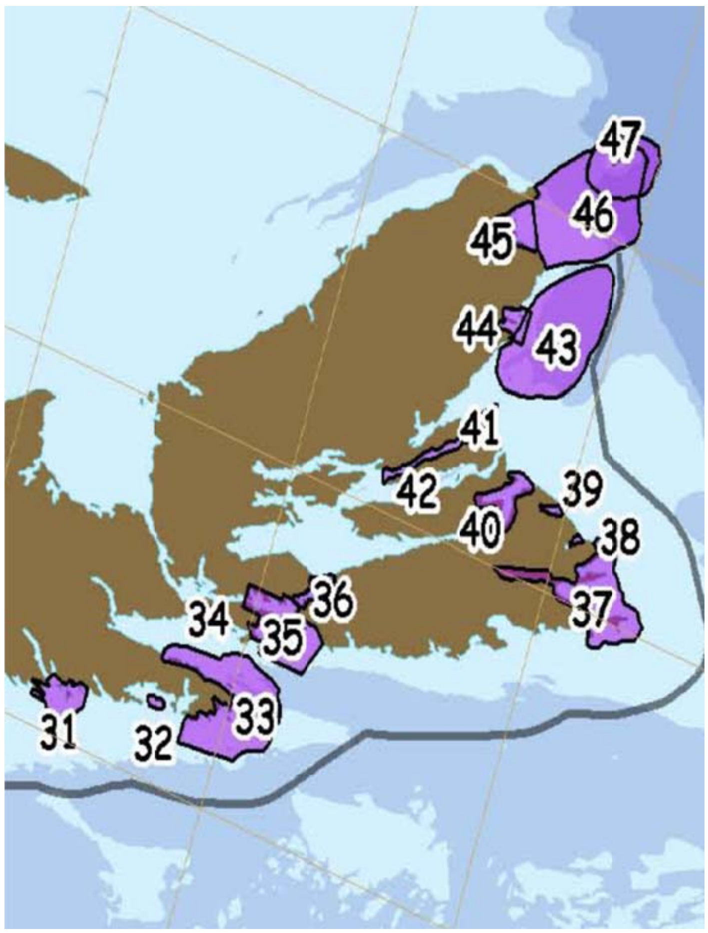
The names of these sites are given in the table preceding this figure.

Sources: NRCan, NSTDB, NSDNR
Datum: GCS North American 1983

AECOM

In a 2007 study of ecologically and biologically significant areas (EBSA) on the Scotian Shelf, Doherty and Horsman 2007 identified 47 areas of high significance in the inshore Scotian Shelf. Some of these areas include designated bird sanctuaries or other significant habitats. Of these 47 proposed EBSAs, four areas were identified by a minimum of five experts. Two of these are found in the Cape Breton Region: Bird Islands area and St. Paul's Island area, largely due to their bird and cetacean populations. These and the other areas identified in the region are shown on Figure 54 and described below. No EBSAs were identified off the west coast of Cape Breton Island, between Cape North and St. Georges Bay.

Figure 54. Inshore Ecologically and Biologically Significant Areas



source: Doherty and Horsman 2007

Most of the inshore EBSAs do not extend past the 12 nautical mile limit and so share the zone that may be of commercial interest to tidal project developers. Only three areas off eastern Cape Breton extend past the 12 nautical mile limit: Western Sydney Bight, Cabot Strait-Asby Bay to St. Paul's Island, and St. Paul's Island Area. The authors note that that the relative lack of EBSAs farther offshore may reflect the overall lack of lack of information regarding the use of the inshore ecosystem by fish, marine mammals, invertebrates, and marine plants.

Location 37: Mira Bay Area Scatarie Island.

Scatarie Island, located off the eastern coast of Cape Breton approximately 25 km from Sydney, is provincially designated as the Scatarie Island Wildlife Management Area and the Scatarie Island Wilderness Area. The island and surrounding waters is an area of high biological productivity, upwelling/mixing and species aggregation, supporting Leach's storm-petrel, Black Guillemot, Common Tern and Great Cormorants. The waters are known herring spawning grounds, areas of refuge for juvenile fish and significant habitats for marine algae and eelgrass (Gromack *et al.* 2010).

The Northern Head/South Head is an Important Bird Area and is a breeding ground for cliff-nesting seabirds including Black-legged Kittiwakes and Great Cormorants. Approximately 7% of the North American population of Great Cormorants nest in this area. The endangered Harlequin Duck is found in the winter off the heads. Scatarie Island is an Important Bird Area and a grey seal pupping area. It is a wilderness area with breeding colonies of Double-crested and Great Cormorants. South Head and Wreck Point are principle breeding areas for the Great Cormorant. Myra Gut has an interesting salinity regime, eelgrass and oysters. Port Morien has a bay behind a barrier beach that is highly productive with large eelgrass beds and migratory birds (Doherty and Horsman 2007).

Areas of interest for marine life include herring spawning grounds in False Bay and extensive areas of preferred lobster, rock crab, oyster and scallop substrates. Nearby Hay Island has the largest seal breeding colony in Nova Scotia (Gromack *et al.* 2010). Two COSWIC-listed species, Atlantic cod (endangered) and Red Knot (endangered) are also present.

Location 38: Big Glace Bay

Eelgrass behind a barrier island.

Location 39: Indian Bay and Lingan Bay

Principle breeding area for Great Cormorants. Includes three cliff faces and eelgrass behind a barrier island.

Location 40: Sydney River-Sydney Harbour Area

A spawning/breeding/feeding area for multiple species exhibiting a high diversity of fish species. Very big freshwater streams entering the area (smelt runs, gaspereau runs). This area is unique in Nova Scotia for yellow lampmussels, a freshwater species of special concern (Doherty and Horsman 2007).

Location 41: Bird Islands

The Bird Islands are located in the shallow waters (20-25 m average depth) of western Sydney Bight, approximately 4 km off Cape Dauphin in St. Anns Bay. The near shore areas have extensive kelp beds and elevated concentrations of invertebrates and fish.

The area is considered unique for birds and marine mammals and was recently designated a Wildlife Management Area and Important Bird Area (Gromack *et al.* 2010). The Islands are an important breeding area for colonial seabirds and host significant colonies of Great and Double-crested Cormorants, Puffins, Razorbill Auks and Kittiwakes from April to end of August/beginning September. The islands host the largest colony of Great Cormorants in North America, supporting 10% of the continental population (Doherty and Horsman 2007).

The area is also important for juvenile fish which likely provide a ready food source for resident seabirds. There is a good, consistent and stable lobster fishery around the area and fishermen fish throughout the season. This area is the only shelf area in the whole of Sydney Bight that is shallow and yet quite a large area (Doherty and Horsman 2007).

The Islands are on an important migration route for fish and marine mammals and are at the end of one of the main migration routes and water flow in and out of the Bras d'Or Lakes (Gromack *et al.* 2010). Spawning grounds for cod, herring and caplelin are located nearby and the area is a nursery for cod, plaice, yellowtail flounder and winter flounder. The waters around the Bird Islands are used by overwintering herring from Bras d'Or Lakes and the islands are also a seal haul out area. A healthy population of mainland salmon use the area, which also contains scallop beds, lobster bottom and a thriving commercial lobster fishery.

The site is important for whale and seal species and is a lobster overwintering area (Doherty and Horsman 2007). Two COSWIC-listed species, Atlantic cod (endangered) and winter skate (endangered) are also present. The fin whale (a SARA "special concern" species) frequents the waters around the island, as do other whales that move through the area (Gromack *et al.* 2010).

Location 42: Great Bras d'Or Channel

Inflow of salt water for the Bras d'Or system; gradient of salinity along its length. The Channel is a transportation corridor for species and international shipping moving in and out of the Bras d'Or Lakes. The Bras d'Or Lakes are a UNESCO Biosphere Reserve.

Location 43: Western Sydney Bight

The area is considered unique because 4Vn cod spawn here (late April - end of May). Nursery area for cod and probably other species. Newly settling cod (young-of-the-year) each September (Doherty and Horsman 2007).

Location 44: Ingonish Bay

Whales breeding and feeding in the area.

Location 45: Asby Bay

Marine mammals feeding in the area.

Location 46: Cabot Strait-Asby Bay to St. Paul's Island

This channel between Cape North and St. Paul Island is a migration route used by cod, herring, mackerel, marine mammals and possibly white hake.

Location 47: St. Paul Island Area

St. Paul Island (an Important Bird Area) is located approximately 34 km north of Cape North, the northern tip of Cape Breton. Numerous ships have been wrecked on the rocky reefs surrounding the island, which is referred to as "the Graveyard of the Gulf" (Gromack *et al.* 2010).

The area is dominated by strong currents and large waves, making fishing difficult. Ice, which affects navigation in the area, is carried by currents to St. Paul Island.

The area is considered unique for birds and marine mammals; a Leach's storm petrel colony is likely present on the Island. The Island is also home to 1% of the Canadian population of Bicknell's thrush (SARA-listed as being of special concern), a land bird which nests here (Doherty and Horsman 2007). The island hosts a number of breeding great black-backed gulls as well as a number of waterfowl (goose, bay duck, sea duck, dabbling duck) (Gromack *et al.* 2010).

The area is an important herring spawning ground and may be important for certain species such as mackeral during their migration between the Gulf of St. Lawrence and the Atlantic Ocean. It is an overwintering and spawning area for cod and also supports the SARA-listed Atlantic wolffish (special concern) and leatherback turtle (endangered) (Gromack *et al.* 2010).

There are general reports of concentrations of cetaceans in this area. It may be important habitat for other marine species although there is limited information on the marine environment surrounding the island (Gromack *et al.* 2010). There are a variety of species including sperm whales, baleen whales, pilot whales and dolphins. It is probably a feeding area for cetaceans. Sperm whales may be there year-round but other species are probably not (Doherty and Horsman 2007).

There is a good, consistent and stable lobster fishery around the Island. The area may be unique for lobster which aggregate around the island, along with snow crab, toad crab, scallops and redfish (Gromack *et al.* 2010; Doherty and Horsman 2007).

St Anns Bank Area of Interest

St Anns Bank has been selected as an Area of Interest (AOI) for further evaluation that may lead to the designation of a Marine Protected Area under the federal Oceans Act (DFO 2009).

The St Anns Bank AOI includes St Anns Bank, Scatarie Bank, and a portion of the Laurentian Channel. These areas provide a variety of habitats for commercial species (e.g., redfish, cod, white hake, witch flounder and halibut), non-commercial species (e.g., sponges, corals, anemones) and several at-risk species. The Bank is also a migration route for many marine mammal and fish species. Fish that use this route include herring and mackerel, Atlantic cod and other groundfish as well as large, migratory species like bluefin tuna. The endangered blue whale is known to migrate through this area, as are fin, humpback, minke and pilot whales, harbour porpoises and white-sided and white-beaked dolphins The St Anns Bank AOI serves as important habitat for several at-risk species, including Atlantic wolfish (listed as “special concern” under the *SARA*) and Atlantic cod (considered “special concern” by COSEWIC). This site is also a key foraging area for the endangered leatherback turtle (listed under the *SARA*).

Like the Sydney Bight, the oceanographic conditions around St. Anns Bank are largely dictated by the outflow waters from Gulf of St. Lawrence, which turn the corner and give rise to the Nova Scotia current in this area. As a result, the area displays a large annual sea surface temperature range, which may account for the variety of species found here. St Anns Bank also contains areas that are thought to be rarely disturbed by natural processes such as underwater currents and storms. As such, they are more vulnerable to human disturbance and the habitat and species that occur there may take a long time to recover.

5.11 Socio-Economic Components

5.11.1 Introduction

Cape Breton Island consists of four counties: Cape Breton County (which includes Cape Breton Regional Municipality), Inverness County, Richmond County, and Victoria County. Together, these counties are home to almost 140,000 people (Figure 55). Historically, the primary industries of the island have been commodity-dependant, exploiting coal, forest products and fisheries. Over the last century many of these resource-dependent industries have become uneconomical or the resources themselves have become depleted. With the lack of significant secondary industries, out-migration of working-age men and women to other industrial centers in Canada and the US has been occurring for decades. The economy is now transitioning toward a post-industrial, service-based economy (Gruters 2008).

Approximately 70% of the island's population lives in the Cape Breton Regional Municipality (CBRM). In contrast, Inverness County is home to the majority of Cape Breton's rural population. Since the mid-1800s, CBRM has been the industrial core of Cape Breton beginning with the emergence of a coal mining industry, which continued until 2001 when mining ceased in Cape Breton. In Inverness County coal mining begin in the late 1800s but following an early industrial growth period neither the coal industry nor the forestry industry gained enough momentum to displace other subsistence occupations such as agriculture and fishing (Gruter 2008). Over the last number of years the proportion of service sector jobs has increased while the numbers of jobs based on natural resource exploitation has declined in CBRM and Inverness County (Statistics Canada 2001 in Gruter 2008).

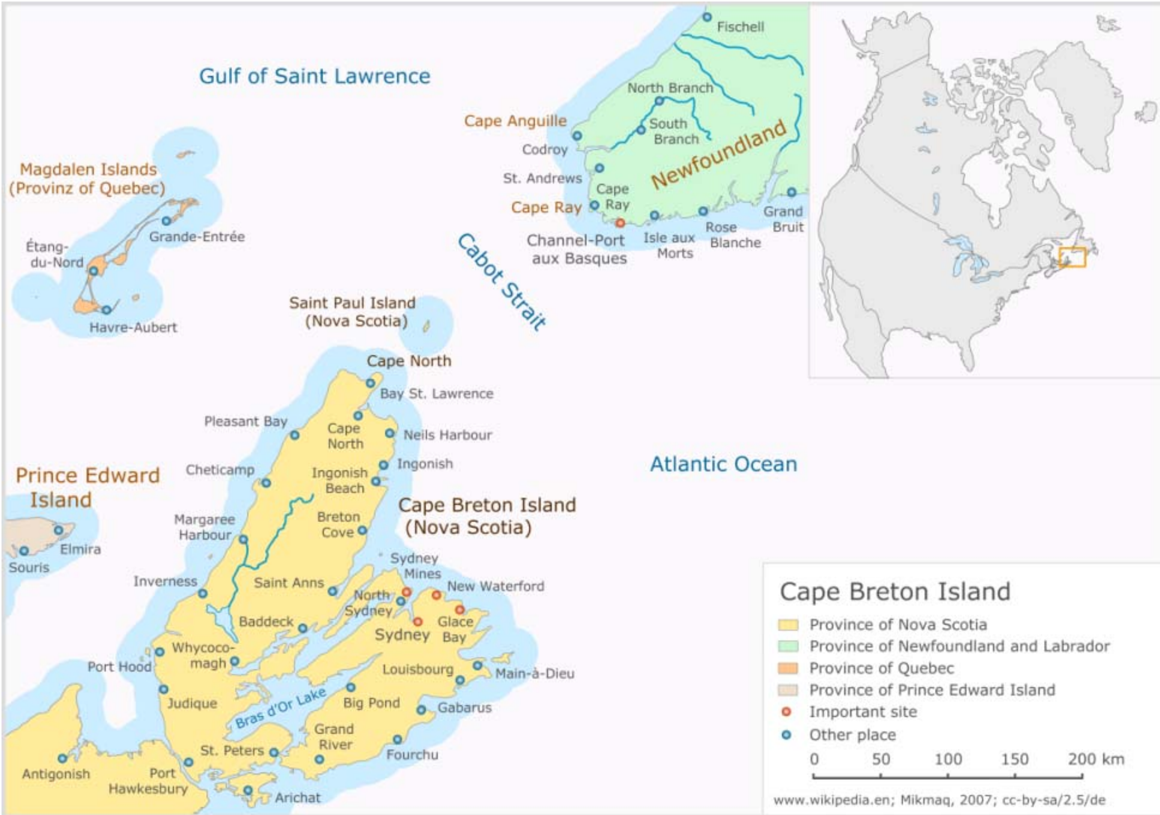
As noted in the *Cape Breton – Mulgrave Integrated Strategic Framework:*

> "There is no one single Cape Breton Island and Mulgrave economy – rather, there are a series of sub-regional economies, each led by the sectors with the greatest strength in each of the sub-regions" (Economic Growth Solutions Inc. 2011).

These sub-regional economies include the Sydney area dominated by past coal mining and steel making activities, the Bras d'Or Lakes region with its local resident-driven economy, and the Cape Breton Highlands where the seasonal economy is largely based on tourism and natural resource exploitation such as forestry and fisheries.

The closure of the steel plant and cessation of coal mining activities removed more than $100 million in wages, directly affecting 10% of the Cape Breton labour force. Today, 5.2% of Cape Breton's population is employed in agriculture, forestry, fishing and hunting, compared to 4.6% of Nova Scotia's total population (Economic Growth Solutions Inc. 2011). This industrial transition has been accompanied by population shifts: a 10.1% decline in Cape Breton's population from 1996 to 2006, with a disproportionate number of people in the 20-34 age group leaving the Island (30.5% decline in the population of this age group).

Figure 55. Main Population Centres of Cape Breton Island



source: Wikipedia "Cape Breton Island", 2012

5.11.2 First Nations Perspective - Introduction

There are five First Nation Communities in Cape Breton, called Unama'ki in the Mi'kmaq language, whose land holdings total a surface area of over 5,426 ha (54.26 km^2). Each community occupies one or more reserves and all five have partial ownership of the Malagawatch reserve. Many of the Cape Breton First Nation communities are located on the shores of Bras d'Or Lakes, although the Membertou Band is located in and around the town of Sydney.

Today, the Mi'kmaq people have the fastest growing and youngest population in all of Nova Scotia. There is a significant age difference in Cape Breton when comparing Mi'kmaq and the Island's non-first nation population. The median age of the Mi'kmaq people is 22, while for the rest of Cape Breton the median age is 44. In 2010, the total First Nation population in Cape Breton was 4,322 people, living both on and off reserve (AANDC 2010).

Education is a critical cultural issue in Mi'kmaq communities. In an effort to meet the educational needs of their children three First Nation communities in Unama'ki have opened their own high schools since the late 1990's, and all five have elementary schools. The opening of these schools presented job opportunities for the Mi'kmaq people of their communities and education remains a significant employer in most communities.

The major fields of study are geared towards social sciences and education with less interest in fields of science, technology and businesses. Despite this, Cape Breton University established the Purdy Crawford Chair in Aboriginal

Business Studies to promote interest in the study of business and develop a business network for aboriginal youth. This mentoring program has generated great interest and involvement by the Aboriginal youth and their mentors.

In 1998, the Mi'kmaq College Institute was established at Cape Breton University to provide Aboriginal students with educational material specific to their academic and cultural interests. In 2006 the Mi'kmaq College Institute was transformed into Unama'ki College of Cape Breton University. The mission of the College is to promote excellence in Aboriginal education, research and scholarship for Aboriginal people locally, regionally, nationally and internationally, in collaboration between Unama'ki College and Aboriginal people.

5.11.3 First Nations History

Mi'kmaq people of Unama'ki were part of a larger group of pre-contact First Nations people who inhabited Mi'kma'ki, an area of seven geographical districts consisting of mainland Nova Scotia, Cape Breton, Prince Edward Island and parts of New Brunswick and northern Maine (CMM *et al.* 2007). Archaeological evidence indicates that Mi'kma'ki has been occupied by First Nations peoples since prior to 10,500 years ago, immediately following the last glaciation.

The early Mi'kmaq people of Unama'ki were communal and used the land as traditional hunting and gathering grounds; land was held in common and the concept of land ownership was unknown. The Mi'kmaq always considered hunting, fishing, gathering, and trading as important parts of their livelihood. The Mi'kmaq were a nomadic people, moving their communities throughout Mi'kma'ki in response to the seasonal changes and consequent availability of plants, fish and game. Small communities would typically settle in areas with access to water where the use of canoes made travelling long distances achievable in shorter periods of time, compared to overland travel through dense forests. The waterways have always been an important part of the Mi'kmaq culture and continue in this role today.

The date of first contact with Europeans is difficult to determine with certainty. Basque fishermen were reportedly harvesting cod and other species off Nova Scotia in the 1370s, while fishermen from Bristol, England reached the Maritimes in 1490 (Mi'kmaq Spirit 2012). There is no documented evidence of encounters with First Nations peoples, although it is not difficult to imagine such encounters during shore stops for food and fresh water. In 1497, John Cabot (Gionvanni Caboto) brought evidence of First Nation inhabitants of "Cape Breton" to his sponsors in England, but stated he did not meet any native inhabitants in the lands he visited. Between the beginning of the 1500s and Jacques Cartier's voyages to the Maritimes in 1534, several European explorers reached the Atlantic Provinces and likely made contact with First Nations people. Organized fur trade began by the French in the 1580s and was fully established by 1600. In 1605, the first permanent French settlement was established in the heart of Mi'kma'ki, at Port Royal in the Annapolis Valley of mainland Nova Scotia.

In 1610, Grand Chief Membertou was baptized in the Catholic religion and a Concordant was signed with the Vatican affirming the right of the Mi'kmaq to choose Catholicism, the Mi'kmaq tradition, or both. Between 1600 and the fall of the French fort at Louisboug to the English in 1759, the First Nations people of Unama'ki taught and traded with the French fur traders and colonists. The English and the Mi'kmaq signed a number of treaties in subsequent years, and the non-native population of Cape Breton Island increased significantly. The first reservations inhabited by the Mi'kmaw were established at the end of the eighteenth and early nineteenth centuries; Potlotek was designated in 1792, Eskasoni #3 in 1832, Waycocomagh # 2, Wagmatcook #1 and Malagawatch in 1833 and Margaree #25 in 1834. The Membertou reservation of Caribou Marsh #29 was established 1882, while Membertou #28a and #28b were not established until 1921 and 1925, respectively. The second Eskasoni band reserve (Eskasoni #3a) was designated in 1948.

In 1942 the Mi'kmaq people of Nova Scotia underwent a centralization process; the government's intention was to reduce administrative costs by moving the people into two central communities, Shubanicadie on mainland Nova Scotia and Eskasoni on Cape Breton (CMM *et al.* 2007). The people were promised homes and employment. The families who refused to leave their homes managed to retain in trust the land and homes of those who moved away during the centralization process. When those who relocated eventually realized the Federal government would not make good on their promises, they moved back to their home communities.

5.11.4 Post Contact Economic History of Cape Breton Island

In 1504, almost 100 years before a successful attempt was made to develop a colony, Breton-speaking fishermen from Brittany arrived on Cape Breton and became the first Europeans to interact and trade with the Mi'kmaq peoples of the island. Early European settlers came to the shores of Cape Breton, with the English clustered around English Harbour, today's Louisbourg. The French were based at St. Ann's Bay, the Portuguese at Ingonish, and the Spanish and Basque in Spanish Bay, today's Sydney Harbour.

At the close of the battle of succession to the Spanish Throne between England and France in the early 1700s, Cape Breton Island became a prominent bargaining chip in the peace negotiations of 1713. To the French, Cape Breton was valued for its access to the fishing resources upon which thousands of families in Western France depended for their livelihood, its strategic location at the entrance to the Gulf of the St. Lawrence River, and the lucrative triangular trade route between North America, the West Indies and France. By 1745-1755, the British controlled mainland Nova Scotia and fought the French for control of Cape Breton Island. In 1750, French settlers at Louisbourg were forced to diversity their economy as the French and English colonies competed over food supplies from New England. Louisbourg settlers established agriculture in the Mira River area and began to exploit nearby coal resources to trade along with fish.

The French fortress of Louisbourg was eventually lost to the English in 1758 and Cape Breton Island was ceded to Britain in the Treaty of Paris of 1763. In 1784, Cape Breton became a colony separate from Nova Scotia, with the loyalists making Sydney the capital. Sydney was soon overwhelmed by successive waves of Scottish immigrants, such that most of the available arable land along the seacoasts and the Bras d'Or Lake come to be occupied. These Scottish immigrants, along with a few hundred of returning Acadians, essentially made up the largely rural population of Cape Breton, who then subsisted mostly on farming and the inshore fishery (Canadian Encyclopedia 2012). By the 1790s, an age of large scale ship building (schooners, brigs and brigantines) had begun in coastal communities, peaking in the 1850s. Initially, settlers who came to Cape Breton hugged to coastline due to the difficult terrain, however as land was cleared, Cape Breton began to develop an agricultural and forestry base, with farms being not only able to support themselves, but to trade their products by sea.

The development of the Sydney Coalfield in the 1830s coincided with another large influx of highland Scots numbering about 50,000 people. This transformed the island's economy and attracted rural migrants to the Sydney area for work in the mining industry. By the 1890s, the Dominion Coal Company (DOMCO) had merged all of the mines south of Sydney Harbour and built the Sydney and Louisburg Railway to assist in transportation. This railroad further helped to settle of the island. In 1899, DOMCO built the Dominion Iron and Steel Mill in Sydney. The Nova Scotia Steel and Coal Company (SCOTIA), formerly GMA, was simultaneously developing mines on the north side of the harbour and building their own steel mill in nearby Sydney Mines. However, the coal and steel economic boom only lasted up to the Second World War (Canadian Encyclopedia 2012).

The early twentieth century was a prosperous time in Cape Breton with the expansion of resource extraction (fish, timber, coal, etc.) and the increase in agricultural acreage under cultivation. Technological and scientific advances were made by Alexander Graham Bell working in Baddeck and Guglielmo Marconi near Glace Bay. These historic sites are now tourist attractions, along with the cultural attractions of the Gaelic College of Celtic Arts and Crafts and

Gaelic Language School near Saint Ann's Bay, national parks in the Highlands of Cape Breton and at the Fortress of Louisbourg, and the fishing communities of Ile Madame and Chéticamp.

The recent economic history of Cape Breton Island is strongly linked to the rise and decline of coal mining in the Sydney and Inverness coalfields, the pulp and paper industry, steel making and fishing. The industrial heartland of Cape Breton, concentrated in the Sydney area, has experienced structural economic decline with the closure of Cape Breton Development Corporation's (DEVCO) coalmines and SYSCO's steel mill. Following a more than a century of coal mining and steel production, in 1967 the Cape Breton Development Corporation was established to phase out the coal mines and steel making finally ceased in 2000. Work is on-going to remediate contaminated industrial sites and close mine workings in the Sydney area, but this work is expected to end by 2014.

5.11.5 Tourism and Recreation

Hosting 2.1 million visitors annually, Nova Scotia's tourism industry currently employs over 35,000 people and generates over $225 million in annual tax revenues (TIANS 2012). From 1995-2007, the tourism industry on Cape Breton Island generated an estimated 6,500 jobs and over $200 million in annual revenue (Destination Cape Breton Association 2011), representing approximately 11% of the total Nova Scotia tourism revenues of $1.8 billion (TIANS 2012). Tourism is a primary economic focus in much of rural Cape Breton Island (Economic Growth Solutions Inc. 2011).

The tourism industry in Cape Breton is built on sightseeing and touring, cultural events, entertainment and heritage, outdoor activities, and experiential accommodations (Destination Cape Breton 2011). Cape Breton Island has several internationally significant attractions, including the Cabot Trail, Cape Breton Highlands National Park, Fortress Louisburg, the Alexander Graham Bell Museum, the Bras d'Or Lakes UNESCO World Biosphere Reserve and the many communities along the coastlines and the Bras d'Or Lakes. The ocean coastline and Bras d'Or Lakes play an invaluable role in attracting tourist and recreational users to the island through the provision of beautiful scenery, habitat for plants and wildlife, and venues for cultural and recreational activities, including golf, bird watching, fishing, boating, sailing, hiking, kayaking, marine wildlife viewing, sightseeing, bicycling, motorized touring, scuba diving and swimming.

5.11.5.1 First Nation Perspective

First Nation-related tourism in recent years has received increasing support from the federal department of Northern and Indian Affairs, which has provided financial and administrative support to develop tourism-related industries in partnership with aboriginal community leaders (Aboriginal Cultural Tourism 2011). To date, Wagmatcook, Waycobah, and Membertou First Nations have supported the construction of community centres, museums, art galleries, arts and crafts production rooms, gift shops and restaurants that would facilitate tourism services. The Mi'kmaq Unamak'i communities have acquired growing socio-economic benefits from these developments, described in more detail below.

Tourism is a growing trend among the Mi'kmaq communities of Unama'ki. Within the past few years Wagmatocook has taken the leading role through the opening of the Wagmatocook Cultural and Heritage Centre. The Centre is used to highlight the Aboriginal and non-Aboriginal cultures of Cape Breton. For example, the Celtic Colours music festival has used this facility annually since 2001.

In an effort to share the First Nation cultural experience with Aboriginal and non-Aboriginal visitors, the elders of Membertou conceived the idea of a heritage park that would attract people to their community. In 2012, after eight years of planning and construction, the Membertou Heritage Park was opened on land donated by a local resident. The Park highlights the living experience, culture and heritage of the people of Membertou.

In the summer of 2012 the community of Eskasoni opened up its community to tourism for the first time. As part of an effort to showcase their community and its heritage, Eskasoni has been working to share their new community vision “OUR Eskasoni” with neighbouring communities and tourists who visit Cape Breton. To help attract visitors, the community constructed a walking trail that connects Eskasoni to Goat Island. Eskasoni has developed a unique cultural experience that includes traditional fishing practices and gives a sense of how the Mi’kmaq people lived in past times. In addition, the community collaborated with Nova Scotia Highland Village to offer multi-cultural package tours to interested visitors (ECJ 2012).

5.11.6 Fisheries and Aquaculture – Economic Value

In terms of landed value, the southern portion of the Gulf of St. Lawrence (NAFO Divisions 4T and 4Vn) was the most valuable NAFO fishing area in Canada between 2006 and 2008, averaging 436 million dollars per year (DFO, 2008). The fisheries of Sydney Bight and the Bras d’Or Lake fall within NAFO Division 4Vn, the majority of which is fished commercially (Schaefer *et al.* 2004). Based on landings, the top five commercial species fished in Sydney Bight between 1993 and 2000 were cod, redfish, American plaice, white hake and herring; however, the majority of the fisheries in this division were either closed or severely limited during this period as a result of low abundance and productivity (Zwanenburg *et al.* 2002). In the period between 1996 and 2001, the principal species caught in division 4Vn were lobster, herring, snow crab, and groundfish (Schaefer *et al,* 2004).

The stock of lobster in Sydney Bight has historically been one of the most productive in coastal Nova Scotia. Sydney Bight is located within LFA 27. In the late 1960s and 1970s landings along much of the coast line dropped to near record lows, but then increased to levels not experienced since 1900. In the southern Gulf of St. Lawrence (LFA 27), this increase began in the mid-1970s, earlier than the cooler areas of the Scotian Shelf and Gulf of Maine (Pezzack 1992). Throughout the 1990s total lobster landings in LFA 27 dropped from the record high of 3,790 tonnes to 1,265 tonnes. This drop was more significant in southern portions of the fishing area than in northern portions (Tremblay *et al.* 2001).

Recreational fishing is also important to some areas of coastal Cape Breton and, to a lesser extent, in the Bras d’Or Lakes. There, cod, mackerel, rainbow smelt, and American eel support limited recreational fisheries. Salmon fishing is strictly recreational in division 4Vn. In 2003, the recreational salmon angling season for rivers was open for catch-and-release fly fishing from June 1 to July 15, and again from September 1 to October 31, with a limit of 2 fish per angler (Parker *et al.* 2007).

Aquaculture in Nova Scotia employs up to 750 people in 21 active seafood processing plants and over 1,000 people in fish harvesting and aquaculture (Economic Growth Solutions Inc. 2011). Following the decline of the traditional groundfish fisheries leading to the major closures of 1992-1994, the aquaculture sector started slowly in the early 1980s, with moderate growth into the early 1990s. It expanded rapidly after 1995, achieving a five-fold increase in the value of production (NSFA 2007b). The government of Nova Scotia is committed to future growth and supports the aquaculture industry based on its merits as a sustainable rural economic activity (NSFA 2005a). Between 2009 and 2010 Nova Scotia Fisheries and Aquaculture invested $2.5 million in aquaculture (NSFA 2007b) and in May 2012 the Government of Nova Scotia tabled its Aquaculture Strategy intended to guide the growth of the industry in a long term, sustainable manner. Table 12 summarizes the portion of the aquaculture industry in Cape Breton.

Table 12. Cape Breton Aquaculture Activity

County	Body of Water	No. of Licenses	Species Produced
Cape Breton	East Bay (Bras d' Or Lakes)	8	American Oyster
	Great Bras d'Or	1	American Oyster
	Mira River	5	American Oyster
Inverness	Denas Pond	3	American Oyster
	Mabou Harbour	6	American Oyster
	Malagawatch Harbour	3	American Oyster
	Margaree – Old Miller Trout Farm (U-Fish)	1	Brook Trout, Rainbow Trout
	North Denys Basin	10	American Oyster
	Portage Inlet	3	American Oyster
	South Denys Basin	6	American Oyster
	Strait of Canso North	1	American Oyster, Blue Mussel
	Whycocomagh Bay	10	American Oyster, Steelehead
Richmond	Bras d'Or Lake	4	American Oyster
	Cape Auget Bay	1	Blue Mussel, Sea Scallop
	Hatchery near L'Ardoise	1	Rainbow Trout, Brook Trout, Atlantic Salmon
	Lennox Passage	11	Blue Mussel
	St. Peter's Fish Hatchery	1	Arctic Char, Brook & Rainbow Trout, Atlantic Salmon
	St. Peter's Inlet	25	American Oyster
Victoria	Aspey Bay	10	American Oyster, Blue Mussel
	Cape North Area (land-based)	1	Brook Trout, Rainbow Trout
	Mackinnons Harbour	2	American Oyster
	Portage Inlet	3	American Oyster
	St. Ann's Bay	6	Blue Mussel
	St. Patrick's Channel	1	American Oyster
	Total No. of Licenses	**125**	

Note: This inventory is based on publically available information compiled by consultants from numerous maps.
Source: Nova Scotia Department of Fisheries & Aquaculture in Economic Growth Solutions Inc. 2011, pg. B-24.
-it is difficult to obtain an accurate and up-to-date list of aquaculture activities. This list is outdated and likely overestimates the aquaculture activity currently taking place.

There are several areas in Sydney Bight (SHACI Unit 11) where there are bays and estuaries with naturally high productivity, protection from heavy seas, and good tidal flushing. These areas are reportedly ideal locations for aquaculture (Davis and Browne 1996).

The principal areas in Sydney Bight used for aquaculture are Aspy Bay and St. Anns Harbour, where there are many leases for American oyster and blue mussel (Schaefer *et al.* 2004). There are also leases for American oyster aquaculture in Mira River and Mira Bay (NSFA 2007c). Within these four areas there are 18 leases for American oyster and 10 leases for blue mussel (NSFA 2007c; NSFA 2007d; NSFA 2010). Surface areas for cultivated species in these areas are presented in Table 13.

Table 13. Surface Areas of Cultivated Species in SHACI Unit 11

Location	Species	Surface Area	Percent of Total Aquaculture Area
Aspy Bay	American oyster	143 ha	57%
Aspy Bay	Blue mussel	110 ha	43%
St. Anns Harbour	American mussel	24 ha	4%
St. Anns Harbour	Blue mussel	561 ha	96%
Mira River	American oyster	9 ha	100%
Mira Bay	American oyster	1 ha	100%

Finfish have been reared in the past within the Bras d'Or Lakes, however almost all of these aquaculture leases are no longer active (Parker *et al.* 2007). The Whaycobah First Nation is currently operating twelve steelhead pens in the Whycogomagh Basin.

Off-bottom culture for oysters is commonly used in the aquaculture fishery in the Maritimes. This technique uses rafts, floating longlines and fences. Cultch (a substance used to attach spat) is strung like beads on wire or nylon rope, which is suspended above the bottom to collect the setting larvae. The collected spat are grown in suspension until they reach the desired length when they are separated from the cultch and either planted on the bottom or placed on trays that are suspended in the water. Held in suspension, the oysters grow quickly and develop plumper meats than those grown on the bottom (NSFA 2007).

5.11.7 First Nation Communities in Cape Breton

There are five First Nation communities on Unama'ki. A sixth reserve, Malagawatch, is equally owned by the other five First Nations.

Wagmatcook

The Wagmatcook Mi'kmaq community covers approximately 320 ha (3.2 km^2) and is located on the Bras d'Or Lakes (Pitu'paq in Mi'kmaw) and Highway 105 near the town of Baddeck. In 2010, it was home to 665 people, a population that has increased by 27% in the past five years. The community of Wagmatcook built the Wagmatcook Culture and Heritage Centre, a multi-use complex for meetings, conventions, events and dining. The Centre displays Mi'kmaq culture in the form of arts and crafts and visitors can also tour the Interpretive Centre's multimedia presentation on Mi'kmaq storytelling, song and imagery. The Culture and Heritage Centre is the home of the Clean Wave restaurant, a community hall, and has fully equipped meeting rooms that can be used for various events and conferences.

This community shares some economic similarities with other First Nation communities, such as education–related jobs and employment in the health, housing, fisheries and gaming sectors. Employment is also found in the community-owned gas station. Although there are few privately-owned business in Wagmatcook, there are two small stores that mainly sell tobacco. In 2006 Wagmatcook had an employment rate of 42.6% and an unemployment rate of 17.9%.

Nova Scotia Community College (NSCC) Strait Area Campus offers college courses at the Culture and Heritage Centre. The courses offer indirect economic benefits to the community and also encourages community members to learn valuable trade skills in various disciplines.

Waycobah

The community of Waycobah is 7.36 square kilometers and is located between the Sky Mountain and the Bras d'Or Lakes, on the north shore of Whycocomagh Bay.

Waycobah has a 2010 population of 943 people and the average age in the community is 22 years. The population has increased by 28.4% within the past five years (Statistics Canada 2012). Waycobah opened its new school in 2007, which accommodates students from kindergarten to grade 12. High school graduates have been increasing over the years; in the 2006 census, Waycobah had a total of 130 high school graduates and there were 16 graduates in 2012 to add to the growing list.

In 2006, the employment rate was 39.2% and the unemployment rate was 27.3%, which represents a significant improvement since 2001. In the mid 1900's, men from Waycobah used to harvest oysters in the Bras d'Or Lakes around a small island off Waycobah and parts of Malagawatch. At that time, as a community member recalls, the oysters were twice the size of their present size. Their business employed a few men throughout the season, and the harvested shellfish were sold to passing tourists. Today the main sources of employment in Waycobah are through the community schools and education department, band operational jobs, construction, daycare, heath care, fishers, fitness Centre, gaming, construction, the local gas bar, and security, all of which are operated by the community. In addition, Waycobah has been providing adult education training for the past few years.

The community's fishery operation involves both commercial and ceremonial harvesting. As part of their commitment to maintain high water quality and a healthy marine ecosystem they have partnered with the Nova Scotia Youth Conservation Corps. The partnership's goals include on-going communication between the youth and elders, environmental education and career skill development for the youth in the fields of marine ecology and wildlife (Clean Nova Scotia 2012).

There is a trout farm operation that on average maintains approximately 360,000 fish. Once mature, the fish are sold to market. There are very few private businesses currently operating in this community; some of the more successful businesses are typically related to crafting. Other Important sources of revenue for this community are the fishing industry, gaming, and tobacco sales.

Community members have shown interest in reducing energy consumption, and some have undertaken energy audits at their residences while others have purchased of renewable energy technology. Mi'kmaq Alternative Energy is a privately owned business that sells and installs a variety of solar panels.

Waycobah with its ideal location on Whycocomagh Bay has the potential to expand its economy by accessing the Cape Breton tourism industry as has been done by other First Nation communities in Unama'ki.

Eskasoni

At 36.13 km^2, Eskasoni is the largest Mi'kmaq community in Cape Breton and has a population of 4060 people (AANDC 2010). Eskasoni is located on the Bras d'Or lakes, on the northern shore of East Bay.

Economic development has been expanding in this community over the past several years. Eskasoni has several community-operated businesses such as the Eskasoni Supermarket, Crane Cove Seafoods, Dan. K Stevens Memorial Arena, the Fitness Centre and Daycare, Eskasoni Gaming Centre, the Sarah Denny Cultural Centre, and Eskasoni Television. In addition, the community has numerous privately owned businesses: construction services, a building supply outlet, trucking company, gift shop, pool & billiards hall, hair and day spa, catering company, pizza shops, bakeries, gas stations, tobacco shops, convenience stores, auto shops, and electrician services.

The Eskasoni Fish & Wildlife Commission and Crane Cove Seafoods are located on the shores of the Bras d'Or Lakes, which allows them direct access to the waterways. The Eskasoni Fish & Wildlife Commission helps to implement the Aboriginal Fisheries Strategy signed in 1991 and collaborates with scientists at Fisheries and Oceans Canada, Environment Canada and the Department of Natural Resources to research marine ecology and help manage the fisheries in a sustainable fashion. Crane Cove harvests snow crab, shrimp and groundfish and operates a full science lab, with biologists, lab technicians and researchers. The company employs between 160 and 200 full and part-time workers. Related to the fishery, the Unama'ki Processing Plant is a seasonal crab packing operation which employs 22-26 people from 12-16 weeks per year.

The Eskasoni band operates several departments and is a large employer for the people in the community. The Public Works department is responsible for the fire department, sewage treatment plant and water utility. Public works is also responsible for snow removal and the management of solid waste. The Housing Department has a carpenter training program offered through Nova Scotia Community College (NSCC) and graduates are in turn hired on with the Housing Department. The community also benefits from employment and training provided by the Mi'kmaq Employment and Training Secretariat (METS), which coordinates and administers services to community members through training, skill development, work experience, job creation programs, and self-employment programs.

The **Eskasoni Corporate Division** was recently established to identify employment and training opportunities for band members, as well as investment opportunities for the band, so that revenue generated through economic activity can be invested back into the community. In June 2012, Eskasoni partnered with Juwi Wind Canada and Community Wind Farms Inc. to develop a 4.4-megawatt community feed-in tariff project. The partnership will build, own and operate the Harmony Community Wind Project to be built near Truro, NS.

The **Eskasoni Economic Development Corporation** (EEDC) assists the economic development within the community by promoting business development, resource management and other activities that generate employment and a capital base with the ultimate goal of community economic self-reliance. The EEDC participates in:

- Eskasoni Supermarket;
- Eskasoni Commercial Mall Development;
- Eskasoni Comprehensive Community Plan;
- Eskasoni Wind Energy;
- Open for Business;
- Junior Achievement;
- Entrepreneurship Summer Camps;
- Youth Summit;
- Individual Clients; and,
- Unama'ki Economic Benefits Office.

The **Unama'ki Institute of Natural Resources** (UINR) represents the five First Nation communities of Cape Breton. The UINR is located Eskasoni and is focused on the protection of the marine system and watersheds of Bras d'Or Lakes and the traditional lands of the Unama'ki. UINR mandate includes monitoring programs, data collection, analysis and reporting of natural resource-related information. In recent years UINR has been working to protect eel and salmon habitat. In April 2012 they placed a smolt wheel in Middle River to research the salmon population during migration and to collect related biological and ecological information. When the Port Hawkesbury pulp mill was operational, the mill owners and UINR worked in partnership to conserve rare and valuable plants that were culturally significant to the Mi'kmaq (UINR 2012). UINR developed a moose management plan in partnership with Nova Scotia Department of Natural Resources and Parks Canada in order to help implement the wildlife management responsibilities that originate in the treaty rights of the Mi’kmaq. The implementation of this plan requires the support of the Grand Council and Unama’ki Elders (UINR 2009).

UINR is expressly engaged in Unama’ki First Nation children and youth. Through the establishment of partnerships and programs, UINR is creating community interest in employment careers connected with natural resource management. A partnership with Georgia Pacific and NewPage was established to provide scholarships to students interested in science, technology, and forestry. More recently, a team at UINR has been working to establish the Mi’kmaq Environmental Learning Centre, to “to collect and preserve traditional Mi’kmaq knowledge on environmental sustainability, create and deliver educational programs to promote and share Mi’kmaq traditional knowledge, and partner with other groups sharing the desire to promote environmental sustainability for the benefit of future generations” In of 2012 the first summer camp was offered to First Nation youth. Their ultimate goal is to create continuing interest in the First Nation youth towards natural resource management using the traditional Mi’kmaq knowledge on environmental sustainability (UINR 2012).

Potlotek

Situated in St Peters Inlet, Richmond County in southern Bras d’Or lakes, the Potlotek First Nation occupies 5.93 km^2 and has a total population of 665 people, including those at Malagawatch. Potlotek owns Chapel Island, a designated National Historic Site used for traditional and religious purposes. Chapel Island is the spiritual capital of the Míkmaq Nation and the annual summer gathering place of the Míkmaq Grand Council, Mniku.

One of the main economic drivers at Potlotek First Nation is the Apaqtukewaq Fisheries Co-op, established in 1995, which employs four to seven people depending on the season. The Co-op cultivates oysters but also manages lobster, snow crab and tuna fishing activities.

Potlotek First Nation has an Economic Development Officer (EDO) who is responsible for negotiating with government agencies to secure funding for different projects of interest to the community. Business plans are presented to the Council and, once approved, the EDO locates partners to contribute funding and other expertise to the project. The EDO also advises community members on establishing their own business within the community.

Current economic development projects include increasing tourist access to Chapel Island and the construction of a gasbar/coffee shop and general store near the Band Office. The Band is also exploring funding sources for the construction of an oyster packing plant. Future projects may include a gaming facility, a golf driving range, walking trails and a boat tour business.

With respect to economic development within the community, Potlotek First Nation, in collaboration with the Atlantic Canada Opportunities Agency (ACOA) and the Aboriginal Business Service Network (ABSN), is working to improve access to information, services and training to meet the needs of the community.

Malagawatch

Established in 1833, Malagawatch is 661.3 hectares in size and is equally owned by the five First Nation communities of Unama’ki. This community is located on the western shore of the Bras d’Or Lakes in the vicinity of Marble Mountain. The closest convenience store and gas station is located in Orangedale, approximately 20 km from Malagawatch. There is little economic development in this area and only a few of the community’s residents live at Malagowatch on a permanent basis.

Membertou

The Membertou Band has a total 2010 population of 1,288 people (AANDC 2010) and occupies three reserves in the Sydney area. Due to the forced relocation in 1916 from Sydney Harbour to its current location, Membertou is one of the only Mi'kmaq communities in Unama'ki that is not directly located on the Bras d'Dor Lakes. This community has seen great economic development success over the past number of years. In 2002, Membertou became the first Aboriginal government to hold ISO 9001 certification.

There are several community-owned businesses, partnerships, and investments that have contributed to this community's economic success. The Membertou corporate division includes the Membertou Entertainment Centre (MEC) which holds nightly bingos, the Membertou Trade and Convention Centre, which attracts over 600 people daily for dining, conferences and special events (and which is now connected to the Hilton Hotel via pedway), the Membertou Data Centre, Membertou Geomatics Solutions, First Fishermen Seafoods, Membertou Insurance Brokers, A.P Reid Insurance-Membertou Office, Membertou Gaming Commission, Membertou Market, Petroglyphs Gift Shop, and Kiju's Restaurant. The community also has investments in the Laurentian Energy Cooperation.

In the late 1990s, the **Membertou Corporate Office** was established in Halifax. The Office has contributed to the formation of private sector partnerships in a number of industries, including oil and gas, engineering, mining, geographic information systems (GIS), information technology, aerospace, business managmenet and consulting services. Combined with these partnerships, the community leadership began education and career training programs for Membertou residents to take advantage of the new business partnerships and initiatives.

Since 1995, Membertou's budget has grown from 4 million dollars, to a current 65 million dollar operating budget. The number of employees has increased from 37 to 531 people. This expansion has resulted in the formation of new internal departments and businesses such as the Membertou Market, Membertou Advanced Solutions, Membertou Mapping Service, Membertou Quality Management Services, and most recently the Membertou Trade and Convention Centre. Additional economic activity is generated through the Membertou Community Access Program site, Membertou Entrepreneur Centre, Membertou Radio C99FM, Membertou Research, and Environmental Services. The successful Membertou business model is being used to teach business and administrative skills in the Purdy Crawford Chair in Aboriginal Business Studies at Cape Breton University.

The **Unama'ki Economic Benefits Office** (UEBO) was formed through a partnership of the five Cape Breton First Nations to capitalize on economic development opportunities and partnerships with business and government. The main office is located in Membertou with satellite offices in Eskasoni and Wagmatcook. The UEBO targets energy and environmental sustainability as future areas of opportunity. The Office has formed partnerships with industry, government and Cape Breton University to advance economic development, research and training.

5.11.8 MRE Opportunities for First Nations

The Atlantic Aboriginal Economic Development Integrated Research Program recently commissioned a study to gather and disseminate information regarding renewable energy and the First Nations Communities in Nova Scotia and New Brunswick (Campbell 2011). Among the eight broad topics addressed by the study the following questions are applicable to this Report. These topics are addressed in more detail in Campbell (2011); excerpted recommendations from that report are summarized below.

1. How can First Nations participate in the economic benefits from investment in renewable energy? Where does the capital to participate in opportunities come from?

2. What is the capacity of First Nations to participate in new development opportunities?

3. What are the opportunities/challenges for First Nations to participate in economic development ventures related to renewable energy?

4. What more can be done to facilitate greater participation?

During the course of the research, a survey was used to determine how familiar Native Employment Officers (NEOs) were with the technology or job opportunities in the field of renewable energy. Only 20% of the NEO's surveyed were somewhat familiar with job or training opportunities in this field. The NEOs identified training in renewable energy technologies as important to their community needs in the future. None of the respondents to the survey were aware of any community members currently employed in the renewable energy field.

Abridged Recommendations (Campbell 2011)

- **Aboriginal Renewable Energy Business Development Forums:** It is recommended that Atlantic Policy Congress advocate for support to host a local renewable energy forum targeted to First Nations.
- **Funding:** Atlantic Policy Congress should advocate for the continued funding of programs that assist First Nations in developing renewable energy opportunities since many of the provincial and federal funding programs are ending or are no longer available.
- **Partnerships and Community Models:** Fabrication, installation, and service and maintenance expertise that will be required for these emerging technologies provide an opportunity for First Nations to develop this expertise. Community, or cooperative, ownership models have proven very successful in Europe and community-based wind projects provide economic development and keep jobs in the community. First Nations must promote training and community ownership models to raise the investment capital for renewable energy projects and to retain the economic development benefits.
- **Develop a Renewable Energy Toolkit for First Nations:** revise technical information and distribute this information non-technical modular toolkits that can be accessed by First Nations communities.
- **Energy Efficiency and Conservation Education:** develop community educational programming, informational packages and toolkits, to build community awareness of the benefits of energy efficiency and conservation.
- **Make linkages between education, training, and employment regarding renewable energy opportunities:** Linkages must be made between those staff responsible for assisting First Nations in the development of renewable energy opportunities. Conferences and workshops must be targeted to these individuals, as well as the leadership, to ensure information is disseminated. Tools must be developed which link the information systems used and maintained by these individuals, so they know what their capacity is to participate in renewable energy now, and into the future.

5.11.9 Marine Resources, Shipping and Recreational Boating

In Nova Scotia there are more than 200 companies working in the oceans technology sector, either in the research and development of technology, products and services, or as manufacturers or suppliers of products and/or services related to the oceans sector. The ocean has defined both the physical and economic landscape of the province for centuries, such that Nova Scotia has thousands of independent fishing vessels, dozens of boat builders, offshore energy projects, ports, shipyards, and other ocean-related assets (Government of Nova Scotia undated). In addition, the province has strong knowledge capabilities, with ocean-related centers of excellence at Cape Breton University, Dalhousie University and Acadia University.

The Cabot Strait is the primary shipping lane for vessel traffic moving into and out of the Gulf of St. Lawrence. Major shipping routes providing access to the ports of Sydney and North Sydney Along are located along the coast of

Sydney Bight (Parker *et al.* 2007). Sydney is an active port while North Sydney hosts the Marine Atlantic Ferry Terminal connecting Cape Breton to Newfoundland. The Marine Atlantic Ferry and the Sydney Marine Terminal's cruise passenger facility accommodate tens of thousands of passengers annually. In 2006, 36 cruise vessel calls were recorded in Sydney Harbour, carrying about 46,600 passengers and 21,700 crew members. In North Sydney at the MV Osprey Ltd. Terminal (15 calls per year), various government vessels utilize a range of berths depending on availability and the Canadian Coast Guard College operating out of Westmount, immediately adjacent to Sydport (Parker *et al.* 2007).

Port Edward on the west side of the Sydney Harbour hosts Sydport, a former navy base now operated as a container facility. Other facilities in Sydney Harbour handle coal, petroleum, breakbulk and project cargoes in well sheltered marine facilities with ample deep water, wharf length, storage areas and rail and road connections. Logistec operates the International Coal Terminal on behalf of NSPI and receives approximately 2 million tons of coal annually via 50 transports. The former SYSCO dock owned by the Crown corporation Nova Scotia Lands Inc. receives a small number of general cargo vessels each year (Parker et al. 2007). It is estimated that 2,125 jobs are generated by maritime activities at the marine terminals within Sydney Harbour. In 2006, marine cargo activity at the terminals generated a total of $132 million of total economic activity in Nova Scotia (TEC Inc. 2007).

Glace Bay, a former coal mining centre and today a major fishing port is the second largest population centre in Cape Breton. Port Hawkesbury, with the Canso Causeway and Canso Canal, has created a deep water port which in turn promoted the development of petrochemical, pulp and paper and gypsum handling facilities. The remainder of Cape Breton outside of the Sydney-Glace Bay industrial area has a relatively stable economy based on fishing, forestry, small-scale agriculture and tourism.

The Bras d'Or Lakes can be accessed through three channels. The majority of marine traffic travels through the Big Bras d'Or Channel and the St. Peters Canal. Traffic through the Little Bras d'Or Channel is limited to local boats familiar with the narrow passage. Commercial vessel traffic in the Lakes occurs from May to December while the majority of recreational boating takes place from May to October (Parker *et al.* 2007). Boat traffic is recorded at the southern entrance of St. Peters Canal and at Barra Strait Bridge connecting Grand Narrows and Iona. Parks Canada at the St. Peter's Canal estimates 625 boats annually, a slow increase from 250 in the early 1980s. Approximately 80% of vessels entering are pleasure crafts and about 12% are commercial vessels such as fishing boats, tugs and barges (UINR 2007).

The bulk of industrial shipping in the Lakes (average of 45 industrial/commercial vessels per year) is the transport of gypsum from Little Narrows Gypsum Company, in Little Narrows, which is typically closed from the beginning of January to the end of April (weather dependent). During peak times (May to December), about two ships per week enter and leave the facility. Smaller cruise ships occasionally cruise into the Lakes and dock overnight at Baddeck, however this is not a common occurrence. A small, year round, vehicle and passenger cable ferry crosses the small channel of Little Narrows (less than 0.5 km) and is operated by the Department of Transportation and Public Works.

There are a number of public boat ramps in the Bras d'Or Lakes available for recreational boating use, some of which are maintained by provincial departments, campgrounds/trailer parks and community groups. In addition to the public ramps, there are many private ramps administered by the group operating them and may offer restricted use by the public for a fee or under certain rules (Parker et al. 2007).

5.11.10 Onshore Grid Connections and Transmission Capacity

In 2006, approximately 85% of Nova Scotia's electricity came from five thermal generating plants: Lingan and Point Aconi and Point Tupper in Cape Breton and Trenton and Tufts Cove on the mainland. The remaining 12% of electricity was obtained from 33 hydroelectric plants, the Annapolis Royal tidal generating plant, four combustion turbine plants, and a variety of renewable energy projects (Hatch 2008). In 2012, approximately 17% of electricity in Nova Scotia is generated from renewable sources, including 20 windfarms (NSPI 2012). These largest of these are Glen Dhu Windfarm (27 turbines generating up to 62.5 MW) and the Nuttby Mountain Windfarm (22 turbines generating up to 50.6 MW).

The transmission network within Nova Scotia consists of 69 kV, 138 kV, 230 kV and 345 kV transmissions lines (Figure 56). A single 345 kV transmission line runs from Woodbine near Sydney to Onslow, near Truro. From Onslow, a single 106 km long 345 kV line connects to Lakeside in the Halifax area. In parallel with the 345 kV line, two 230 kV transmission lines run from Lingan near Sydney to Port Hastings. From Port Hastings, three 230 kV circuits are connected to Brushy Hill in the Halifax area via Onslow (Hatch 2008). In addition, two 230 kV circuits connect Brushy Hill to Bridgewater and a 10 km 69 kV line connects the Fundy Tidal Energy Demonstration Project to Parrsboro.

Nova Scotia is interconnected with New Brunswick through one 345 kV line from Onslow, NS to Salisbury, NB and two 138 kV transmission lines.

Hatch (2008) was requested by the Nova Scotia Department of Energy to assess the impacts of adding large amounts of land-based wind-generated electricity to the electrical grid. To a certain extent, their findings apply to other renewable energy sources, such as tidal, wave and offshore wind, at least with respect to limitations of the existing grid system. Among many other conclusions, the analysis indicated that transmission corridors between the Sydney and Truro would operate at their maximum limits more often than other transmission corridors, should these renewable energy projects be situated on Cape Breton.

Hatch (2008) concluded that the current transmission system can transmit no more than about 130 MW of additional power from wind projects from the Canso Strait and Sydney zones. If more power capacity is required, a new transmission line (they suggest a new 345 kV transmission line from Canso to Halifax) would be needed. The cost of this line and its associated substations was estimated at approximately $262 million. This explanation somewhat simplifies a complex problem since renewable energy such as wind and tidal are intermittent power sources. Integrating marine renewable electricity into the grid requires balancing a number of priorities and costs related to other system components. These projects should be developed in locations that do not increase current system stresses, or trigger uneconomic transmission needs (SNC Lavalin 2009).

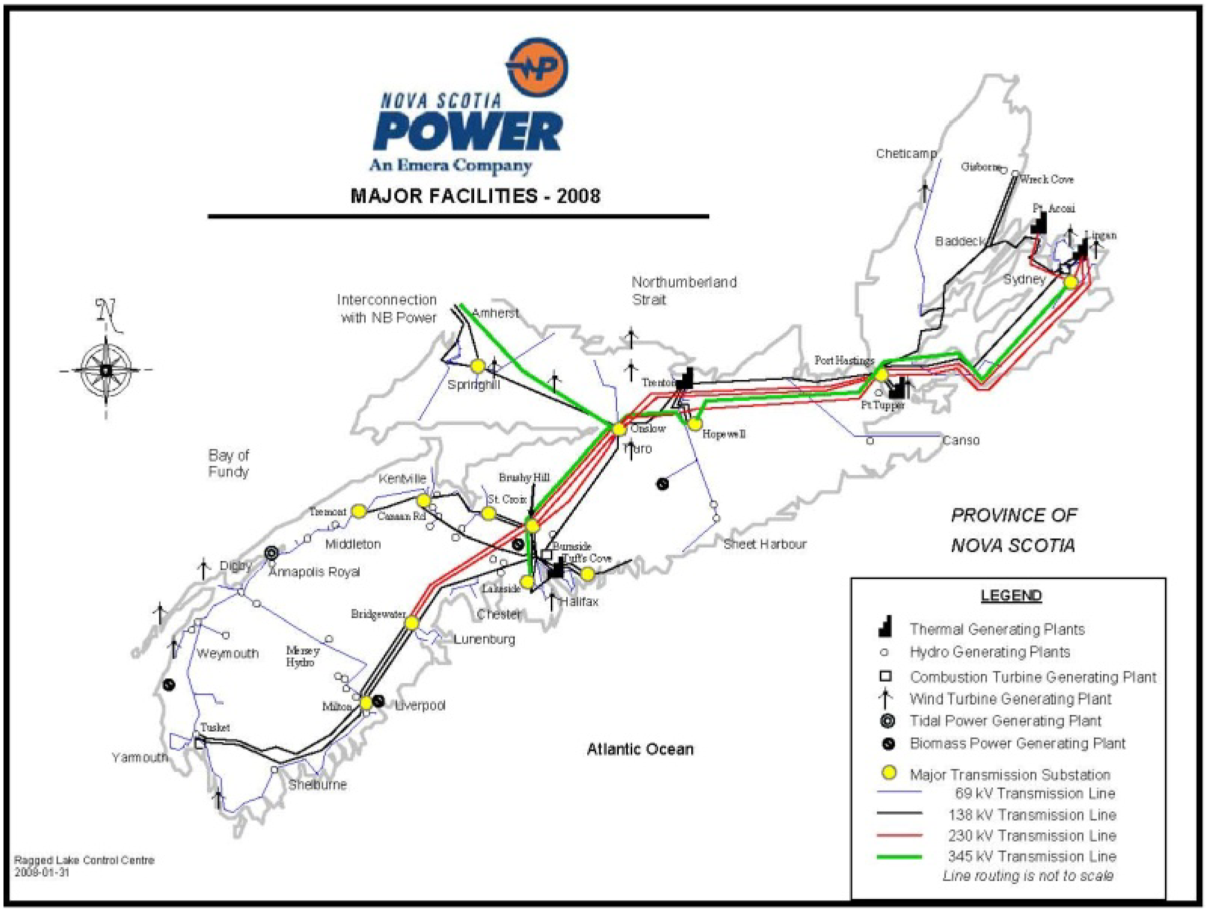
As noted by Hatch (2008):

> “All components of the delivery system will experience greater load variations. The system may be called on to operate in ways it was not designed for and the total cost impacts are not well understood at this time. There could be significant infrastructure costs involved ($100s of millions) to upgrade Nova Scotia’s transmission system to integrate these levels of wind. Costs will also depend greatly on how the system evolves in the next several years, particularly Nova Scotia’s interconnections to neighbouring regions.”

Hatch 2008 went on to conclude that more detailed system impact studies are required to assess the different variables that affect transmission system operation and cost. They identified the follow factors as key influencers of cost and grid stability:

- location of new projects;
- system upgrades;
- regional interconnections (including NB, NL, and USA);
- back-up supply issues; and,
- technological innovation.

Figure 56. 2008 Nova Scotia Electricity Transmission Grid



source: Hatch 2008

As noted, cost effective connection not only depends on the distance to the distribution grid but also on the available capacity of the grid. For small scale community projects, the cost to connect to the grid may consume a significant portion of the revenue from electricity sales. As part of the COMFIT application, a grid connection/capacity assessment is conducted by NSPI for each application. Projects over 100kW must submit a Distribution Generator Interconnection Request. The NSPI connection/capacity assessment provides the magnitude of costs associated with any necessary upgrades to the grid.

At this time, grid connections have not been mapped and overlaid with tidal resources and tidal access points. In addition, concern has been expressed regarding how MRE projects will be affected by NSPI's control of interconnections (Howell and Drake 2012). To address these uncertainties, Howell and Drake (2012) recommend that future strategic investments in grid connection infrastructure can be determined by assessing the location of current interconnection capacity and access points relative to tidal resources.

In summary, the transmission system will experience greater demands with the integration of MRE projects and may require transmission upgrades. The limitations identified for wind integration can be expected to apply to MRE projects. There are likely to be cost implications to the actions taken to integrate this power into the grid. These actions may include importing additional electricity (when renewable are off-line), starting and stopping thermal generation units, managing interruptible load and limiting wind and MRE generation at certain times (NSDOE 2008). Moving forward past 2013, additional analysis is required to understand infrastructure costs (which may be significant), system stability and interconnection options to neighboring regions.

5.12 Economic Development Opportunities

In 2009, the Cape Breton Prosperity Study identified a significant economic prosperity gap between Cape Breton Island and its comparators, the Province of Nova Scotia and Canada as a whole (Lionais 2009). The report findings indicate that Cape Breton is significantly underdeveloped relative to these entities. In 2008, Cape Breton's Gross Domestic Product (GDP) per capita was $25,909 while its comparison peer group and Canada had a GDP per capita of $33,964 and $39,648, respectively. According to the study, bridging the prosperity gap in Cape Breton entails developing higher value-added activities that will employ the population in better paying jobs. The main economic challenges for Cape Breton, as indicated in the study, include:

- Demographic pressures from a declining and aging population;
- Relatively low participation rate, indicating a lack of perceived employment opportunities ;
- Relatively low productivity rate, indicating work undertaken in Cape Breton is of lower economic value and pays lower wages; and,
- Relatively low employment rate, indicating a lack of employment opportunities.

The marine renewable energy industry has the potential to contribute to the economic prosperity in Cape Breton by employing local services to produce marine energy devices for domestic and export markets, while gaining from associated 'green-collar' jobs in research and development, engineering and design, manufacturing, construction and maintenance. At the same time, the MRE industry would benefit from the highly skilled workforce and world-class shipping and marine infrastructure resources to support the manufacturing, installation and maintenance of MRE projects. The MRE value chain is illustrated in Figure 57. From an economic development perspective, government agencies such as Nova Scotia Business Inc., Atlantic Canada Opportunities Agency, In*Nova*corp and Enterprise Cape Breton Corporation have shown interest in tidal and wave energy development in Cape Breton.

The Nova Scotia Department of Energy estimates that there will be over 4,000 person-years of employment created by the wind projects installed by 2020 over the estimated life span of those turbines. The deployment of 55 two-megawatt tidal turbines by 2020 would create 340 person-years, while the service and maintenance over the life-span of the tidal turbines would add another 550 person-years (SLR 2010).

At the same time it is important to underline the fact that to date, only limited tidal energy resources have been identified in coastal Cape Breton and the Bras d'Or Lakes. With respect to offshore wind and wave energy development, no systematic regional scale exploration of these resources has been undertaken so far and little interest has been expressed by offshore wind and wave energy project developers in this region. Within Bras d'Or lakes, a total energy potential of only 1.5 MW has been identified. Compared to the 40 MW potential of Digby Gut and the much larger potential of the Bay of Fundy, this resource may be insufficient to attract commercial array projects. This means that the economic potential associated with the smaller projects that could be developed here, while positive, will not be excessive. A proposed marine research and education centre proposed for Iona may bring additional funding, training and tourism opportunities to the region.

Figure 57. Value Chain for Marine Renewable Energy

source: NSDOE 2012

As part of the value chain for marine renewable energy, the starting point for the cycle lies between Research and Development (R&D), including the training of highly qualified professionals, and the engineering and design of technologies, projects, and institutions to support commercialization. Various recent studies suggest that technology development is a fundamental issue that should be addressed to more rapidly reach commercialization of TISEC and other marine renewable technologies (Drake 2012). In the early days of a emerging industry, it is important to foster strong relationships between the R&D community and industry, as synergistic collaboration between these groups has the greatest chance of establishing a firm industrial base. There are many foci for early stage R&D (Table 14) and many of these subject areas support commercialization and post-commercial environmental effects monitory.

Table 14. Potential R&D Focus for Marine Renewable Energy

R&D Focus	Description
Device Development	Developing new technological concepts for wave and tidal devices and improving the efficiency and economics of existing wave and tidal devices.
Environmental Impact	Investigating the impact that wave and tidal devices have on the surrounding environment.
Resource Assessment	Improving the accuracy and consistency of resource assessments and identifying the best locations for sites.
Flow Modeling	Improving the modeling of fluid flow, to aid with the research and development of devices. This takes the form of both computational fluid dynamics and accurately simulating flow in a test tank.
Power supply variability and grid connection	Investigating methods of producing a steady power supply, for input into electricity networks, from the variable energy flows resulting from marine energy converters.
Materials	Producing low cost materials that are able to survive both the corrosive surroundings and the complex loads.

Cape Breton's post-secondary academic institutions – Cape Breton University and Nova Scotia Community College – provide world-class researchers who can facilitate technology development and conduct research required by industry developers and government regulators, as well as provide custom education and training services specific to industry needs.

An overview of Canada's early stage MRE supply chain opportunities identified both weakness and strengths (NRCan CanmetENERGY 2011). The country's strengths include: deep sea ports, marine construction expertise, resource monitoring and analysis, environmental assessment, marine supplies, commercial diving and transport. Areas of weakness include: device manufacturing, engineering construction and foundations/anchoring experience. These subject areas are described in more detail in Stantec 2011, NSDOE 2011, and Gereffi *et al.* 2012.

Marine infrastructure and established support services are present in Sydney and Port Hawkesbury, as well as in certain smaller communities with historic ties to the fishing industry. Cape Breton harbours and associated services are available to provide industrial marine services, fabrication, assembly, docking, shipping facilities for marine renewable energy devices, in addition to supporting and maintaining an industrial workforce.

Precision metal-works and other fabrication services are available in the Sydney and Strait-Highlands regions, and engineering services are available in Sydney and Port Hawkesbury, as well as associated offices elsewhere in Nova Scotia. Shipbuilding and fabrication continues to be a major industry in Nova Scotia. In October 2011, Irving Shipbuilding-owned Halifax Shipyard was awarded a $25-billion shipbuilding contract to build 21 ships over the next 25 years. This contract will increase Nova Scotia's capacity not only to build ships but also to undertake other marine services in Atlantic Canada, including support to MRE projects.

There are similarities between MRE systems and other offshore infrastructure in terms of materials, offshore operations, and electrical collector systems. These similarities allow marine support services that are accustomed to serving the offshore energy and offshore construction industries to provide certain common services to the MRE industry (NSDOE 2011). However, a challenge to the manufacturing of MRE devices is that they vary widely in design, such that component parts are particular to a single design, reducing economy of scale benefits at the early stages of the industry. In addition, companies that invest heavily in R&D may be reluctant or unable to have parts manufactured elsewhere, consequently lowering the potential for manufacturing jobs where the devices are eventually deployed. In some cases, the design and economic considerations may necessitate the manufacture or assembly of components near deployment sites. Given these considerations, any MRE development strategy should fully consider what can be produced locally and what will need to be imported (NRCan Canmet 2011).

In general, easy access to service ports and the availability of skilled service personnel with appropriate equipment are essential for the effective development of the marine energy industry (Carbon Trust 2011; Drake 2012). The suitability and access to ports is central to establishing reliable and cost-effective construction and maintenance infrastructure for MRE projects. The development of appropriate support locations is essential to ensuring that the benefits of operations and maintenance hubs for offshore projects are captured in the local economy (SEAI & IMDO 2011). While port access is a necessary feature so is the availability of vessels with the capacity to carry the equipment and loads required to install and service MRE devices. The availability of these specialist vessels is limited and they can be costly; however, the long range benefits to a region from construction is dependent on the consistency of contracts, the availability of skills and experience, and the ability to develop skills and experience that can be exported (Drake 2012).

A variety of vessels are required for the MRE industry including dynamic positioning vessels, remotely operated vehicles, barges with large cranes capable of lifting up to 400 tonnes, catamaran barges, tugs, and smaller vessels. Larger vessels may also be needed, such as jack-up barges and purpose-built offshore installation vessels. Many of these vessels also serve the offshore oil and gas industry.

Transportation to deployment sites may be a limiting factor, due to the very large size of wind and tidal turbines and bases. The transportation challenges also create business opportunities for those with specialist expertise such as logistics providers, truck trailer and rail car manufacturers, railroads and train crews, trucking companies and drivers, port operators, and barge and ocean vessel owners and crews (NSDOE 2011).

Valuable lessons can be learned from commercial scale projects located elsewhere. In Orkney (Scotland), a plan to install 1 GW of marine renewable energy by 2020 is currently underway. The plan includes 3-4 new or ports, 2-3 assembly and maintenance yards, 20-30 maintenance boats, several large purpose–built vessels, a major electricity grid upgrade and a local workforce of 500-1000 people. In Maine, Ocean Renewable Power Company (ORPC) states that 100 jobs have been created or retaining to date and estimates the tidal energy industry will attract 1 billion dollars in investment and create another 400 to 500 jobs over the next 7-10 years (Stantec 2011).

5.13 Socio Economic Impacts of Marine Renewable Energy

As pointed out by Howell and Drake (2012), tidal energy projects are typically and necessarily located near small, rural coastal communities. While the potential for rural regeneration, infrastructure investment and improved quality of life for nearby residents is real, the nature and effect of these benefits is difficult to assess in this emerging and largely untested industry.

A recent overview of stakeholder interest in offshore wind projects identified the following general arguments typically expressed for and against these developments (EquiMar 2011):

<u>Arguments in Support</u>

1. Energy independence / promotion of renewable energy;
2. Positive effects to the local economy, taxation benefits and job creation;
3. Helps to reduce the effects of climate change; and,
4. Increased port and harbour development.

Arguments in Opposition

1. Damaging to the aesthetic qualities of the landscape;
2. Interferes with nature conservation and natural ecosystem functions;
3. Negative effects on tourism;
4. Negative effects on fisheries; and,
5. Negative effects on shipping safety.

The Victoria County Alternative Energy Strategy Study outlined the results of community discussions concerning energy development and its relationship with the County's tourism industry (Genivar 2012). The report takes a positive view on marine renewable energy development and recommends early involvement by the Municipality, as a significant local stakeholder, in the SEA process. The report correctly identifies factors that could encourage or discourage alternative energy projects in the Municipality, including policy development and the Municipality's expanding role in advocating for the County's alternative energy interests.

The report calls for early partnership with municipalities in the process of marine energy policy and industry development. Early municipal involvement may facilitate MRE development, will address community concerns in due course, and will help shape the future of their region and that of the interdependent stakeholders.

The development of MRE projects within Cape Breton would have both direct and indirect economic impacts on local and regional communities and businesses. Certain Nova Scotia ports, including Sydney/North Sydney, could either individually or collaboratively support the industry in the short term without the need for major marine structure upgrades or expansion (NSDOE 2011). However, specific industry requirements and physical asset availability must be reassessed as the MRE moves towards commercial scale projects (NSDOE 2011). In the short term, existing port communities such as Sydney/North Sydney may benefit through local economic development and experience increased employment, taxation and tourism. Negative effects may also result, including conflict between uses, access restrictions, spoiled seascape or landscape, and/or decreases in tourism (Drake 2012).

Over the longer term, existing marine and supporting infrastructure may not be sufficient to support industry needs and certain upgrades may be required. Due to the large size of offshore wind and tidal devices, fully assembled units are typically moved to deployment site by water. High transportation costs will drive the requirement for production, assembly, deployment, operation and maintenance facilities at suitable ports located as close as possible to the deployment site (NSDOE 2011). The long term development of the industry may have additional direct and indirect economic impacts, including the addition of new regional infrastructure such as transmission lines, electrical substation and roads, increased engineering and construction activity, and expanded capacity of local and regional industries.

Successful licensing, planning, deployment and operation of a marine renewable energy technology depend largely on a comprehensive stakeholder consultation program (EquiMar 2011). Experience shows that participatory processes facilitates consensus and conflict management, creates confidence, and promoted greater cooperation among participants. The consultation process also helps to build a sense of property and local pride in the ultimate project.

Public opinion is generally shaped by awareness of environmental and socio-economic impacts. Onshore ocean energy devices may create a "Not in my backyard" effect, meaning that although people accept the concept of ocean energy, they do not want developments in their neighbourhood (EquiMar, 2009b in Howell and Drake 2012). Other negative attitudes may arise due to conflicts with activities such as fishing (commercial, recreational and subsistence), navigation, oil and gas infrastructure, aquaculture, proximity to designated conservation areas, and recreation such as boating, sightseeing and diving. More research needs to be conducted on space-use conflicts of tidal energy in Cape Breton.

Space-use conflict may be addressed through Integrated Coastal Zone Management (ICZM) or Integrated Coastal Management (ICM), or other stakeholder consultation programs. ICZM and ICM high-level, comprehensive planning tools that identify conflicting uses and establish governance processes to ensure that any development plans for contested areas are integrated with existing environmental and social goals and are made with the informed input of those people affected by the development. The ongoing Eastern Scotian Shelf Integrated Management (ESSIM) Initiative is reportedly approximate to an ICZM (Howell and Drake 2011), and could be used as a model for development planning that incorporates future MRE projects in coastal Cape Breton.

5.14 Promotion/Retention of Socio Economic Effects in Cape Breton

As noted, Nova Scotia has a well-developed ocean industry sector with considerable experience and expertise in the provision of marine services. If commercial scale MRE projects are expected in Cape Breton, supply chain industries can be fostered through:

- Supplier information sessions/networking events to inform suppliers of potential opportunities, educate them on the goods and services required by the MRE industry and enable them to showcase their expertise and capabilities;

- Building on previous events and established networks to further inform suppliers and discuss how best to address identified gaps. These events and networks include Fundy Energy Research Network (FERN), Ocean Renewable Energy Group (OREG – now Marine Renewables Canada - MRC) conferences, Commercialization Workshop, NS Tidal Energy Symposiums, OERA/FORCE Research and Development Workshop and university events such as Dalhousie's Oceans Week;

- Aligning infrastructure and supply chain requirements to develop the marine renewable energy sector with economic development and sector development agencies and initiatives; and,

- Collaboration with adjacent jurisdictions to identify shared interests and opportunities (Drake 2012).

5.15 Socio-Economic Data Gaps

Four workforce development issues have been identified for the MRE industry, summarized in Drake (2012):

1. Availability of professional skills, in particular for engineering and project management professionals,
2. Availability of general labor in communities where devices are deployed (quantity and skills mix),
3. Inter-industry interactions and movement of workers between industries, and
4. Quality and duration of jobs and how they address income distribution within the community.

In order to address skills shortages in the marine renewable energy industry, a comprehensive review of the current skills base is required. To determine future requirements at national or regional levels consultation with industry is needed, as well as realistic growth targets for the offshore renewable energy sector (Mott MacDonald 2011). A strategy should be developed to address skills shortages, and it should be supported by industry, public and private education providers and other stakeholders (Mott MacDonald 2011; NRCan 2011).

Additional socio-economic data gaps were highlighted in Howell and Drake (2012). These included the need for:

- A strategic plan to guide the development and deployment of TISEC devices that is consistent with the Marine Renewable Energy Technology Roadmap (Stantec 2011);
- Jurisdictional and regulatory clarity;
- Streamlining of the evaluation, permitting and decommissioning process;
- Community buy-in to projects and protecting lower income Nova Scotians from severe energy rate increases; and,
- Clarity on how benefits to the community will be incorporated into development agreements.

At a 2011 workshop to identify challenges and data gaps to the development of small scale tidal energy projects in Nova Scotia, the following socio-economic data gaps and recommendations were compiled (Stantec 2011). Although some of these data gaps are currently being addressed through the Marine Renewable Energy Strategy and changes to legislation, others remain.

Gaps / Barriers

1. The socio-economic effects of tidal power on local communities are not well understood;
2. Regulatory requirements for small tidal power projects are not well established and understood;
3. There is a shortage of funding for projects, technology development, and research facilities;
4. Young human resources are needed to support the vision of small tidal power development in communities;
5. There is a need for more collaboration with other jurisdictions (e.g., Maine, New Brunswick, etc); and,
6. Devices are not yet cost-effective and insurance costs are very high.

Short Term Recommendations (<18 months)

1. Conduct a socio-economic impact analysis of tidal power which considers, among other things, competing resource users and economic effects on local communities;
2. Conduct stakeholder consultation to improve awareness of tidal power opportunities for community participation as well as to improve appreciation of competing resources for the tidal/ocean resource (shipping lanes, whale watching, fishers, recreational groups);
3. Encourage community participation in COMFIT program through awareness/education programs;
4. Invest in resources to support municipalities including technical training sessions, economic development resources (e.g., economic development officers), and communication capabilities (e.g., high speed internet);
5. Encourage business/economic researchers to work together and coordinate research similarly to what has been done by scientists studying biophysical issues of tidal power;
6. Invest in the promotion and marketing of Nova Scotia tidal resources internationally to improve awareness, attract investment, and improve opportunities to export technology;
7. Engage regulatory authorities to identify opportunities to improve regulatory framework and awareness of regulatory requirements; and,
8. Develop a creative business model with economic incentives (e.g., feed in tariffs) and suggested compensation models to encourage community participation and acceptance.

Long term Recommendations (>18 months)

1. Improve access to financing opportunities for small/medium businesses. This is in part accomplished by proving tidal technologies and minimizing risk for investors;
2. Export technology internationally;
3. Invest in local infrastructure improvements (e.g., wharfs, boats, cranes) to support tidal development.
4. Develop markets for energy during off peak hours;

5. Job creation needs to be a priority to minimize “brain drain” from rural communities and maximize opportunities for skill-set utilization; and,
6. Encourage collaborate with other jurisdictions, including international (e.g., Maine) to advance technology and awareness and lower costs.

6. Environmental Issues

Since MRE is essentially an exploitation of marine environmental attributes (wind, wave, tide), the "environment" should not be viewed as an external impediment that must be overcome to market electricity, but rather as the actual source of the marketable product. Hence, "environmental issues" are not separable from commercial product issues. Every joule of energy taken from the marine ecosystem is a joule that does not drive marine ecological processes such as fisheries production. Perhaps the most profound element of a MRE environmental assessment is the recognition that energy yield is directly related to environmental impact.

Each type of MRE technology differs in terms of the environmental issues that would be addressed during a project-specific Environmental Impact Assessment (EIA). The selection of issues or factors described below is intended to touch upon the majority of interactions that the three main MRE technologies (wave and offshore wind) have in common. The discussion is presented at a general level due to the lack of local, project-specific information. At the request of OERA, this Report focuses on the potential impact of tidal energy devices; to a certain degree similar environmental interactions may be expected with the other technology types. But we recognize that this is a significant simplification: there are fundamental differences among the MRE technologies. For example, tidal flows deliver nutrients to marine communities, waves do not. Changes to the magnitude and frequency of tidal fluxes may impact the fundamental process of marine ecological connectivity. In contrast, energy extraction using wave trains in deep water exerts no significant influence on horizontal connectivity or benthic-pelagic coupling.

In evaluating both the environmental and socio-economic effects of TISEC devices in coastal Cape Breton and the Bras d'Or Lakes, there are numerous ways that the construction and operation of these devices will interact with physical processes, ecological systems and existing or future infrastructure and activities. The following sections provide an overview of these interactions for each of the KEIs identified in Table 1.

As described in more detail in section 5.8, five areas with the potential to host tidal power projects (possibly offshore wind and wave arrays) were identified on a preliminary basis in this study:

1. Mid-way up the western coast of CBI off Cheticamp;
2. Off Cape North and around St. Paul Island;
3. Around Scatarie Island/Flint Island;
4. Along the south east coast of Cape Breton to Forchu; and,
5. Great Bras d'Or Channel / Barra Strait in the Bras d'Or Lakes.

These are not presented as a definitive or exclusive list of opportunities because the essential assessment work has yet to be done. They are proposed as examples of the range of opportunities for MRE extraction in the Cape Breton marine ecosystem.

6.1 Critical Physical Processes

6.1.1 Definition and Rationale for Physical Process Selection

There are a number of critical physical processes that define a geographic area and its ecological characteristics (i.e. a marine ecosystem). For the purposes of this report, these processes include **wind energy vectors, water circulation** (tides, currents), **sediment dynamics** and **ice formation**. Any significant change to these processes will have an effect on the regional ecology and may impact economic activities. Predicting these impacts depends on a systemic understanding of local ecosystem processes that influence fluxes of ecologically significant materials (e.g. nutrients, reproductive propagules[4], migrating organisms, etc.). Our current state of knowledge of these processes is poor and so our ability to predict outcomes is seriously limited. In such circumstances precautionary approaches are prudent. From a management perspective, it is sensible to assume substantive negative impacts until observations prove otherwise.

Water movements caused by wind, waves or tidal currents affect the exchange transfer of nutrients, contaminants, oxygen, and biological materials; determine erosion rates and the associated re-suspension and transport of sediments. Energy extraction, especially from tidal and wind-driven marine ecosystems systems, will affect water movement and sediment dynamics, which in turn will affect local and regional ecological process of connectivity, benthic-pelagic coupling, and productivity. The questions of the magnitudes of these effects frame the scientific challenge of predicting the ecological effects of MRE.

Bottom sediments are a critical component in determining the biological communities that inhabit a particular area. Sediment transport may carry contaminants into new areas of disposition, making them available for uptake by benthic and epi-pelagic species (e.g. invertebrate suspension feeders). In addition, suspended sediments have the potential to compromise the health of the benthos by interfering with oxygen uptake, food intake, and light penetration.

In general, the presence and quantity of ice in a particular marine area is determined by internal factors such as salinity and temperature, and external factors related to upstream delivery processes. These factors are unlikely to be affected by a TISEC project. There is potential for enhanced ice formation within tidal lagoon enclosures during winter months. Ice buildup within a lagoon may have negative impacts on the efficiency of such a project.

6.1.2 Potential Environmental Interactions

The installation and decommissioning of TISEC devices and their electrical cables in the marine environment may cause temporary degradation of habitat and water quality through an increase in turbidity in the water column resulting from disturbance to the seabed. While suspended sediments characterize and play important roles in the marine environment, particularly for benthic organisms; sustained, high levels in the water column can decrease habitat quality for pelagic organisms by reducing light intensity and dissolved oxygen content (Park 2007; Ntengwe 2006).

TISEC devices extract energy from the marine environment, reducing the overall energy density of the system and affecting all of the physical and ecological processes that respond to water circulation. The energy density of flowing water is a cubic function of current velocity: lower velocities result in lower kinetic energy potential, while higher velocities contain exponentially more energy. If a significant fraction of the available kinetic energy is removed from a tidal stream, the overall effect may reduce turbulent mixing and change current patterns. This in turn may affect sediment distribution, larvae dispersion and nutrient availability. In this regard, arrays of TISEC devices are expected to have more pronounced effects than single device deployments.

Changes in the distribution of sediments and nutrients, which are food sources for benthic organisms, may affect the distribution and mortality of these species, and consequently the fish and other species that feed upon them. Many organisms are adapted to, and critically depend upon particular bottom substratrata. Changes to these substrata resulting from the installation of MRE devices, and subsequent sediment redistribution, are likely to have negative impacts on immobile organisms. Finally, these changes are particularly acute in relatively low energy and sensitive environments, such as the Bras d'Or Lakes. While considerable kinetic energy can be extracted with little measureable effect from the high energy Minas Passage and open ocean coastal regions, the "maximum safe

[4] *propagule is any material that is used for the purpose of propagating an organism to the next stage in their life cycle via dispersion.*

extractable energy threshold" will be significantly lower for the Bras d'Or Lakes, where attenuation of tidal energy into the system is extreme (Garbut, 1974). Additionally, the presence of any structure in the marine environment will affect current velocities in the immediate area of the structure. When a structure is placed on the seabed, the flow is disturbed locally around the structure. In areas where the seabed is composed of loose surface deposits (silt, mud, sand, gravel), the accelerated flow around the structure may scour away the seabed around the base of the structure and redeposit it further downstream (CREST Energy Limited 2006). These changes may impact the local biota and undermine the structure. Erosional effects may be magnified when arrays of MRE devices are installed.

The presence of ice can interfere with routine maintenance activities and may damage surface piecing or floating structures. In general, ice-free areas are preferred in order to avoid the inconvenience and additional costs associated with ice cover. On the positive side, areas of consistent winter ice cover will not be places where MRE installations compromise shipping. Sub-ice tidal generators are thus relatively free of interference from surface waves or maritime traffic. Countering this potential benefit is the current trend of reduced ice cover in our inland and coastal seas.

6.1.3 Environmental Planning and Management Considerations

Studies suggest that removing energy from confined tidal streams, especially those in relatively low energy channels, may cause more profound hydrodynamic and ecological effects than extracting energy from high energy, open ocean systems (Black and Veatch 2005; Neill *et al.* 2009; Neill *et al.* 2011). The potential development sites in the Bras d'Or Lakes are relatively low energy environments compared to the exposed coastal sites offshore of western and eastern Cape Breton. The Bras d'Or Lakes would likely not experience significant impacts from individual TSICEC devices of less than 1 MW, but multiple devices deployed in arrays may have effects that are far-reaching and difficult to predict. In both cases, the effects of energy extraction require additional modeling verified through field measurements to determine the amount of energy than can be extracted without causing unacceptable, second order effects such as reduced productivity and ecological connectivity.

Localized scour and downstream redistribution of sediments may be expected on all types of bottom substrata except exposed bedrock. These effects will occur during project installation and possibly during TISEC operation. Sediment may accumulate in the shelter of operational TISEC devices at all locations. None of the potential development sites appear to experience high turbidity (elevated suspended sediment concentrations) on a regular basis; so any localized sediment re-suspension would likely have observable, but temporary effects on marine organisms in the immediate area.

6.1.4 Data Gaps and Follow-up

The placement or installation of MRE projects on the seabed is similar to construction occurring on other marine projects in terms of direct, local impacts on benthos, but differs in the significance of second-order effects on exchange processes and downsteam connectivity. The immediate effects of these construction activities have been studied around bridge piers, wharfs and offshore oil and gas installations. In addition, MRE projects in other jurisdictions, including in the Bay of Fundy, are being monitored to understand the effects of localized sediment redistribution around turbines. Results from these studies can be used to predict effects at project sites in Cape Breton. The effects are expected to be different at each location, and will vary with the type of TISEC device and the specific environmental conditions. In this sense, data gaps will exist at all potential project sites until the site-specific current, substratum and connectivity conditions have been explored.

Refinement of existing hydrodynamic models is required to better predict the effects of energy extraction at different sites identified as having high potential. In particular, the 3-D, semi-prognostic models developed by Sheng *et al*. (2002) for the Scotian Shelf and by Yang *et al*. (2006) for the Bras d'Or estuary are amenable to adaptation for predicting both hydrodynamic fluxes and bedload transport. Modeling can also be used to estimate sustainable energy extraction levels that mitigate potential negative effects. Water circulation and sediment dynamics are extremely complex processes that are difficult to predict using models alone. These models must be calibrated to account for local channel and seabed conditions, as well as currents, tides and ecological sensitivities. Finally, the model predictions should be verified using field measurements and observations.

6.2 Fisheries and Aquaculture

6.2.1 Definition and Rationale for Selection

Commercial and recreational fisheries, as well as aquaculture, are considered a KEI due to their importance for the local communities and regional economies, and their cultural and economic importance to individual fishermen. Several fisheries operate along and off the coasts of Cape Breton and are fished by boats from Cape Breton and other areas of Nova Scotia. The installation of MRE devices in coastal areas would likely interfere with the operation, and possibly the resource supply of these fisheries. Effects on fisheries may be both direct and indirect, but due to the variety of fishing gears and methods from region to region, the exact nature of interactions will differ.

The fisheries of Sydney Bight and the Bras d'Or Lakes fall within NAFO Division 4Vn, the majority of which is fished commercially (Schaefer *et al.* 2004). Based on landings, the top five commercial species fished in Sydney Bight between 1993 and 2000 were cod, redfish, American plaice, white hake and herring; however, the majority of the fisheries in this division were either closed or severely limited during this period as a result of low abundance and productivity (Zwanenburg *et al.* 2002). Currently, the lobster fishery is by far the most significant fishery in the region, followed by snow crab, which is fished much further offshore, scallop and rock crab fisheries. Recent experiences with proposed alterations and installations in nearshore habitats, such as the Sydney Harbour and Morien-Mira Bays, have demonstrated the capacity of the local fishing industry to mount substantive opposition, or provide substantive assistance to planned developments within fishing areas (Hatcher *et al*. 2010).

Recreational fishing is also important in coastal Cape Breton and the Bras d'Or Lakes, where, cod, mackerel, smelt, and American eel support limited recreational fisheries. Salmon fishing is strictly recreational in Division 4Vn, and is rarely undertaken beyond river mouths.

Aquaculture is not currently practiced to the same extent in coastal Cape Breton and the Bras d'Or Lakes as it is in other areas of coastal Nova Scotia where TISEC projects are more advanced (i.e., the Bay of Fundy and southwest Nova Scotia). Nevertheless, MRE projects have the potential to occupy sites that are favourable to aquaculture, such that site use conflicts may arise if MRE projects are proposed in Cape Breton. The principal areas in Sydney Bight used for aquaculture are Aspey Bay and St. Anns Harbour, where there are many leases for American oyster and blue mussel (Schaefer *et al.* 2004). There are also aquaculture leases for American oyster in the Mira River and Mira Bay (NSFA 2007c). Within these four areas, there are 18 leases for American oyster and 10 leases for blue mussel (NSFA 2007c; NSFA 2007d; NSFA 2010).

The Government of Nova Scotia is actively encouraging the development of aquaculture as a means to increase economic activity in rural areas. This suggests that over time, additional aquaculture sites may be developed near sites that are proposed to host MRE projects. Wind and wave energy projects will likely occupy sites too far offshore to be of commercial interest for aquaculture developers, while TISEC devices typically require current speeds in excess of those favoured by fish farmers. Should TISEC devices begin to occupy lower energy sites, or should aquaculture come to develop in areas of higher current speeds, then conflicts may develop over the right to use certain sites between these industries. More significantly, TISEC installations, especially tidal barrier types, have the potential to interfere with the flux of nutrients and reproductive propagules to aquaculture sites, or the flux of wastes away from such sites.

There are close linkages between the assessment of potential effects on fisheries and the environmental effects on fish and fish habitat, marine benthic habitat and communities described below.

6.2.2 Potential Environmental Interactions

The installation of MRE devices may affect the livelihood of finfish and shellfish harvesters by:

- Temporarily restricting access to traditional fishing areas during installation, maintenance, and decommissioning; or permanently restricting access due to the implementation of fisheries exclusion zones;
- Displacing fishers from the MRE project site onto nearby fishing grounds, increasing fishing pressure on available species and reducing catches of other fishers;
- Loss or damage to fishing gear due to snagging on MRE structures and cables as well as when fishers on displaced into areas already fished by others;
- Increasing navigational and anchorage risks due to increased MRE-related vessel traffic and the presence of MRE infrastructure and cables; and,
- Loss of or damage to fishing stocks resulting from changes to species movements and behaviour due to project effects such as noise, collisions, vessel traffic, changes to water circulation, changes to sediment patterns and the presence of electromagnetic fields. Indirect effects are more diverse and difficult to predict. They include mortalities or other changes in local abundances of foundation and forage species that support the production of commercially exploited fish; the alteration, damage or destruction of fish habitat as a result of mooring construction; and possible alterations in the fluxes of nutrients and reproductive proagules that sustain harvestable secondary production.

There is potential for interference with the movement of fishing vessels during the installation and removal phases of the project, because the device deployment will require large barges, tugs and support vessels for pile drilling and cable laying. Additional vessel traffic will result from project monitoring and maintenance activities. All additional vessel traffic increases the risk of collision and accidental fuel spills.

Site preparation and MRE installation, with the associated suspended sediment and potential changes to current regimes and sediment dynamics, may negatively affect fishing stocks and aquaculture sites by releasing suspended sediments or disrupting currents required to flush fresh water through the fish cages.

It must also be acknowledged that some of the direct and indirect effects of MRE installations and operations may serve to enhance fishery production (e.g. by creating new, complex habitat structure in otherwise featureless domains, providing “no go” areas where fish are sheltered from fishing pressure, or by enhancing the vertical mixing of nutrients in stratified water columns.

6.2.3 Environmental Planning and Management Considerations

The effects of future MRE projects on existing fisheries and aquaculture occupations will depend on the exact location and extent of the projects. At the same time, the level of impact will vary depending on the type of fishery affected and the nature or extent of any access restrictions required at the project site.

Fisheries are a critical economic and of social value in coastal Cape Breton. The Bras d’Or Lakes play an important role in the health and persistence of certain fish stocks of commercial, recreational, food and ceremonial value (e.g. Atlantic Salmon). In contrast to the FORCE site where extreme tidal conditions limit the number of fishers in the immediate area, the lower energy environments of coastal Cape Breton support a variety of fisheries and harvesting techniques. Given the diversity of fishing that occurs and the greater number of fishers involved in the industry, the potential for area-use conflicts is much higher is this region compared to the Minas Passage. It follows that the potential for negative economic and social impacts is correspondingly higher in coastal Cape Breton. Under these circumstances, project developers and government regulators should anticipate that considerable effort will be required to identify, discuss and resolve area-use conflicts such as exclusion, access limitations, fisher displacement onto other fishing grounds, and navigational and safety issues.

6.2.4 Data Gaps and Follow-up

Efforts to measure the effects of TISEC devices on fish behaviour and mortality continue, but no conclusive results have been reached. This work is especially difficult since different effects may be experienced by groundfish versus pelagic species versus shellfish. Different species may feel impacts for different reasons (i.e., EMF or collisions) and/or at different times during their life cycles (i.e., during larval dispersion or adult migration). Finally, species may be affected by sudden, near field changes to their environment or longer term, far field changes that are even more difficult to quantify. The effects of TISEC technologies on fish behavior and mortality remain one of the most important data gaps in this industry. The recent installation of an array of acoustic receivers throughout the Bras d'Or estuary (Hatcher 2012) allows the tracking of digitally tagged fish before, during and after the installation of TISEC devices. These data, combined with the fine resolution ecological connectivity model of the Bras d'Or estuary (Yang *et al.* 2008) afford the prospect of coupled bio-physical modelling of the response of fish populations to MRE installations within the Bras d'Or ecosystem.

It is also important to underline the difficulty in establishing the economic value of the fishing industry to individual fishers. This information would be useful to help determine the magnitude of impacts from displacement and exclusion so these impacts can be mitigated and potentially compensated. Currently, landings are often aggregated from catches taken in different areas. This makes it almost impossible to determine the fisheries value of a single area, such as a MRE project site, to a community or its fishers. Research and record keeping would be helpful to document the number of boats, locations and harvest statistics at future MRE project sites. Recent initiatives in Sydney Harbour (Hatcher *et al.* 2010) demonstrate robust techniques for quantifying the value of marine ecosystem goods and services provided to fishing communities at scales relevant to those of MRE operations.

6.3 Fish and Fish Habitat

6.3.1 Definition and Rationale for Selection

This element describes those aspects of marine biodiversity and productivity not directly related to commercial fisheries. Fish and Fish Habitat is selected as a KEI in consideration of the importance of healthy fish habitat and fish populations to the people of Cape Breton. Impacts on fish may also indirectly affect other ecosystem components that rely on fish as a food source, while impacts to this KEI may negatively affect commercial and non-commercial fisheries. This KEI was also selected to meet the specific regulatory requirements under the *Fisheries Act*. The *Fisheries Act* defines "fish" to mean all fish, shellfish, crustaceans, marine animals and any parts of shellfish, crustaceans or marine animals, and the eggs, sperm, spawn, larvae, spat and juvenile stages of fish, shellfish, crustaceans and marine animals. Surprisingly, the definition also includes aquatic plants. Therefore, all aquatic organisms in habitats defined as fish habitat are considered fish under the *Fisheries Act*.

The federal *Fisheries Act* defines "fish habitat" as spawning grounds, nursery, rearing, food supply and migration areas on which fish depend directly or indirectly. Suitability of fish habitat is determined by a number of chemical (salinity, dissolved oxygen, pH, and nutrients), physical (structure and composition of the benthic substratum, water depth, temperature, flow velocity and volumes) and biological factors (fish, plankton, invertebrates, aquatic plants, microbes, etc.) that are required by fish to carry out spawning, rearing, maturation, overwintering, feeding and migration. Water quality (i.e. degree of pollution and contamination) is also considered in the context of Fish and Fish Habitat, as the quality of water directly affects the quality of the aquatic habitat for fish.

Species at risk in Canada and Nova Scotia are also considered within the Fish and Fish Habitat KEI, as they are important indicators of ecosystem health and regional biodiversity, and their preservation often ensures the preservation of rare or representative habitats. In the context of this report, species at risk include those identified by federal or provincial agencies as being endangered, threatened, rare, special concern, or otherwise of conservation concern; and which have the potential to interact with MRE technologies. Species at risk require special attention since their populations and habitats are sensitive to man-made stressors. This KEI also includes fish species not considered to be rare, but which may be particularly sensitive to MRE projects because they are easily disturbed by human activity, or tend to occur in localized concentrations such that a substantial proportion of the population could be adversely affected by a particular development.

6.3.2 Potential Environmental Interactions

The installation and decommissioning of TISEC devices and associated infrastructure may result in harmful alteration, damage or destruction (HADD) to fish habitat. Some components of a single unit or array, such as the gravity base and subsea cable, will cover existing habitat, producing a potential for direct mortality or injury to fish. Installation may also result in temporary degradation of water quality through an increase in turbidity associated with seabed disturbance. Most adult pelagic and demersal fish will likely avoid construction and decommissioning areas because of the noise and vibration, which will limit direct mortality and injury. Some species tend to hide rather than flee from threats, and others (e.g. infauna) are unable to move quickly out of harm's way, and so will be more likely to suffer injury or mortality.

Elevated concentrations of suspended sediment may damage gills, decrease feeding efficiency, reduce rates of embryo development and somatic growth, decrease resistance to disease, and reduce the ability of fish to avoid predators. They also reduce the amount of light reaching submerged vegetation, thereby decreasing photosynthesis and oxygen production (Park 2007). High levels of suspended sediment also pose a problem for filter-feeding species. Effects will vary depending on the susceptibility of the species and the nature of the substratum. Sub-lethal effects on a variety of fish species have been reported when species were continually exposed for a period of several days in waters with suspended sediment concentrations of approximately 650 mg/L or greater (Appleby and Scarratt 1989).

Noise and vibration associated with construction and decommissioning of MRE projects may also negatively affect fish. Most species of fish have the ability to detect low frequency sounds over great distances (Chapman 1973). Physiological effects of sound on fish have been summarized in Turnpenny and Nedwell (1994). The importance of such effects, particularly on migratory species, is poorly understood. Increased noise (magnitude, frequency, duration and character) above background levels may result in short and long-term changes to behaviour and habitat use, injury or mortality of fish. Few studies have been conducted on the effects of ambient sound on fish, but behavioural responses may include avoidance of primary feeding or spawning areas for the duration of the disturbance (Smith et al. 2004; Popper 2003). Such behavioural responses could in turn affect migratory patterns, reproductive success and survival rates. Other potential effects of high levels of ambient sound include hearing damage, which may increase predation, alter reproductive, feeding, or flight behaviours, which may further increase the risk of hearing damage (Popper 2003).

While TISEC devices are in the operational phase, there is potential for fish mortality caused by collisions with the turbines themselves. Fish mortality may occur if fish strike rotating blades, housings, or fixed parts of the device, or if there is a sudden pressure drop as the fish proceeds through or around the device. If fish are not able to avoid the devices, their vulnerability to damage on passage through the turbine will vary according to the design characteristics, the location of the device, and the specific characteristics of the species. While there is a general expectation that fish will avoid TISEC devices in the same way they avoid other subsea obstacles, TISEC noise and vibration may affect avoidance, while predation and migration may increase collision risks.

When operational, subsea cables produce EMFs. EMFs are generated during the transmission of electricity through the cables. These fields may interact with fish that are sensitive to such fields. Many fish, particularly elasmobranches (skates and rays), are sensitive to EMF because of their dependence on the geomagnetic fields for navigation and prey detection. The nature and scale of EMF impacts on marine organisms is not known. The concern for EMFs extends beyond the creation of the fields themselves: it also considers the colonization of species on artificial substrata, and the impact that may have on electro sensitive predator species. There is little information about the effects of EMF on the behaviour of marine organisms associated with particular substrata, such as dermesal fish and mobile invertebrates.

6.3.3 Environmental Planning and Management Considerations

The potential environmental effects outlined above will be better informed by on-going research. In order to reach valid conclusions regarding the species and habitat types in coastal Cape Breton, additional research, focused on those aspects of fish and fish habitat most likely to be disrupted by MRE projects is required. This work should be tailored to the environments and species of this region, including species at risk. Ecosystem research of this type provides an opportunity for locally based researchers and students to liaise with their colleagues at other Nova Scotia institutions to create collaborative projects that build on work undertaken elsewhere.

6.3.4 Data Gaps and Follow-up

While the general distribution of fish species is fairly well known in the region, there are significant data gaps for practically every fish species in the region. Certain areas have been more closely evaluated (St Paul Island, Scatarie Island, etc.) and more is known about certain species than others, but fish populations have changed drastically in recent years. This may reflect both local anthropogenic impacts and climate change, and suggests that further change can be expected. Stock abundance, spawning and rearing areas, migration routes, predator-prey relationships, and many other factors continue to evolve on local, regional and coastal scales. In anticipation of future MRE projects, additional research will be required to more clearly understand fish and fish habitat dynamics, sensitivities and the potential effects of MRE projects.

Additional research related to effects of MRE projects on fish behaviour and mortality, as described in the section on Fisheries and Aquaculture, also applies to fish and fish habitat.

6.4 Marine Benthic Habitat and Communities

6.4.1 Definition and Rationale for Selection

Marine Benthic Habitat, and its associated biological communities, is identified as a KEI in consideration of the evident project-related impacts on the seabed and existing benthic communities. Marine benthic habitat and communities includes all of those organisms that are associated with seabed or solid structures located on or in the seabed (e.g., TISEC devices). Plants in benthic communities provide habitat and food for organisms in the marine ecosystem, and stabilize marine sediments. Benthic communities include several species of herbivores, and make up a significant portion of the marine food web. In turn they serve as prey for carnivorous pelagic and demersal fish, and contribute to marine nutrient cycling and benthic-pelagic coupling. Benthic fauna includes species that are stationary (i.e. sessile), as well as numerous species that are mobile, but stay close to the bottom rather than moving in the water column. This group of animals includes a number of invertebrates, such as scallops, lobster, crab and a variety of shrimp-like crustaceans, as well as demersal fish.

Benthic communities are the most diverse and productive elements of shallow coastal seas. They include a band of plants in shallow water that include kelp beds and sea grass meadows, which provide essential habitat and primary production that support biodiversity and fishery yields *in situ* and downstream in benthic communities deeper than the photic depth. Hard substrata (rock) provide habitat for assemblages of sessile (attached) organisms, and soft substrata (sediment) provide habitat for infaunal organisms. In both community types, the water above the sea floor is a critical component of the habitat. It determines the physical-chemical properties of the water just above the seabed environment, in which many demersal species that feed on the benthos live. It connects benthic communities to each other by transporting nutrients, organic material and larvae amongst them, and it links the benthos to the pelagic communities of the water column above through upwelling and vertical migration. Maintenance of the diversity of benthic ecosystem types, and of the resiliency of benthic communities is a key goal of Canada’s Oceans Act. Strategic assessments of the potential of marine energy resources must consider not just the direct impacts on marine organisms, but also the possible effects on marine ecosystem integrity.

Since marine benthos are associated with the substrata, and many benthic organisms live and interact directly in or on sediments, changes to the quality and distribution of marine sediments can have a direct impact on the health of benthic communities, either through physical interactions (behavioral effects, habitat loss, changes in prey abundance or distribution) or chemical interactions (uptake of nutrients and toxins). Any MRE project that results in changes to sediment quality can therefore result in changes to benthic communities, their productivity and diversity, which in turn can affect other trophic levels in the marine food web (e.g., marine fish, mammals, birds).

6.4.2 Potential Environmental Interactions

Apart from the inevitable alteration of benthic habitat that occurs when MRE devices are installed on the seabed, benthic communities may be directly affected by changes to sediment distribution (removal of unconsolidated sediment through scouring, sediment redistribution through energy extraction) including direct burial of substrata due to localized changes in current patterns. At the same time, the MRE device may serve as a colonisable substratum, providing additional suitable habitat in addition to what was covered over during device installation.

Re-suspension of unconsolidated sediment may also interfere with, or limit the ability of filter feeders to feed successfully, and may affect the distribution and reproductive success of various species. Finally, colonization of the MRE device (biofouling) may further change current patterns in the local area, and these new colonies will likely suffer during maintenance activities and again when the device is decommissioned.

6.4.3 Environmental Planning and Management Considerations

The enormous extent and diversity of benthic communities and their habitats in coastal Cape Breton and the Bras d’Or Lakes means that assessment and mitigation strategies that apply in one area may not be appropriate in other areas. As with impacts to other constituents of the biological community, impacts to benthic organisms will depend largely on the location, nature and extent of MRE projects. Certain substrata and benthic communities, such as those that live in rarely disturbed low energy environments, will be more sensitive to disturbance by MRE projects than communities adapted to rapidly changing, high energy environments. Project planners and regulators must anticipate the differing sensitivities to impacts across the region.

6.4.4 Data Gaps and Follow-up

Very little long term, systematic research has been conducted on benthic communities in this region. Although generalities can be drawn from past studies in the areas of interest, or from nearby areas of similar habitat, comprehensive assessments of benthic community structure and composition will be needed prior to MRE project development. These studies should establish the existing habitat characteristics before deployment, and then return to surveyed areas for long-term follow-up monitoring. A number of standard methodologies can be followed, including the use of bottom transects through the proposed project area in combination with reference transects through areas that will not be affected by the proposed project. The goal of this work is to document natural changes to benthic communities over time, so that the prediction of potential affects from MRE projects can be verified.

6.5 Pelagic Communities

6.5.1 Definition and Rationale for Selection

Pelagic fish species are described in general terms in Fisheries and Aquaculture and Fish and Fish Habitat above.

The water column is the habitat of the major biomass of fish and mammals in the marine ecosystems of Cape Breton, and also supports high abundances of phytoplankton and zooplankton which drive marine food webs in all the shallow zones where benthic production dominates. Tidal and wave energy harvesting operates on the water column, and so it is the pelagic community that is of first consideration when examining potential MRE impacts on marine ecosystem structure and function. There are several passive planktonic and mobile nektonic species present within the water column. Most are very small in size and unlikely to be affected by MRE devices; however, the larger nektonic species play significant roles in the food web and may be affected as they move through turbines (i.e., jellyfish, squid). These species consume plankton or juvenile fish, and are food for many larger species such as whales and turtles. Larval forms of fish and lobster may also be affected by passage through a turbine. Pelagic communities are retained as a KEI due to their importance as the main element of ocean food web, and the mode of linkage to benthic communities.

6.5.2 Potential Environmental Interactions

The majority of pelagic species are relatively small in size and unlikely to be affected by pressure changes during movement through MRE devices. However, there are larger species that also exhibit limited mobility and are therefore unable to avoid TISEC devices. These species are susceptible to changes in pressure and to shear force that occur when they are carried through a turbine. They may also be affected by increased noise and vibrations associated with the installation, operation and decommissioning of turbines and wave generators. The effects may not be limited to macrofauna. Of particular concern are the eggs and larvae of species that play key roles in the ecosystems of Cape Breton (e.g. lobster), or which are at risk (e.g. cod).

6.5.3 Environmental Planning and Management Considerations

Single turbine and small array deployments are unlikely to damage pelagic communities, but preparation for larger installations must include consideration of the critical ecological role played by these organisms. Changes to water circulation resulting from energy extraction may have important effects on the dispersion and survival of some planktonic and nektonic species, as well as the dispersive phases of benthic species.

6.5.4 Data Gaps and Follow-up

Pre-project (background) surveys and studies aimed at fish distribution and benthic communities should also include study components targeting passive and mobile pelagic species. While these studies may not be critical in open ocean environments, they should be used if projects are proposed in confined passages, areas of upwelling and mixing, and known fish and mammal feeding areas. Laboratory studies of the effects of continuous noise, turbulence and vibration on sensitive species and life history stages should be used to assess the possible significance of putative negative impacts.

6.6 Marine Mammals

6.6.1 Definition and Rationale for Selection

Marine mammals refer to seals, dolphins, whales and porpoises that may be present at least part of their life cycle (e.g., breeding, feeding and migration) off coastal Cape Breton. The subject of marine mammals is a KEI in consideration of the potential environmental effects of MRE developments on existing populations of these species in coastal Cape Breton and to a lesser extent in the Bras d'Or Lakes where they are less common. This KEI was selected to meet regulatory requirements that protect certain mammals and due to the important role that marine mammals play in the ecosystem. These species are also of public concern and of socio-economic importance for the tourism industry.

6.6.2 Potential Environmental Interactions

Potential interactions between TISEC devices and marine mammals relate primarily to:

- Mortality due to vessel strikes during installation, maintenance and decommissioning;
- Disturbance and area avoidance caused by the installation and presence of turbines and installation of monitoring equipment and vessels, particularly with regards to collisions;
- Noise and vibration generated by the turbines during operation leading to masking of cetacean vocalization; temporary threshold shift or hearing impairment; behavioural effects (e.g., avoidance, changes in migration, or reproductive and feeding behaviours); or physical injury;
- Mortality due to turbine strikes;
- Indirect effects through changes in prey distribution and abundance; and,
- Accidental spills leading to potential contamination of marine mammals and species at risk.

Cetaceans (i.e., whales, dolphins and porpoises) have low reproductive rates, rendering them particularly vulnerable to man-made impacts. Marine mammals are sensitive to noise, some species more than others, so it is not possible to generalize when describing noise impacts to marine mammals. There is limited information related to the behavioural responses of marine mammals to TISEC devices although studies at MCT's SeaGen installation in Strangford Lough, indicate marine mammals tend to avoid turbines. Studies at offshore wind farms suggest that porpoises initially avoid newly constructed wind farms, but return to the area in the following years (Jacques Whitford 2008).

6.6.3 Environmental Planning and Management Considerations

Project planning to mitigate effects to marine mammals must anticipate the areas of critical use to these species. This includes migration routes, feeding areas and key breeding grounds. Many marine mammals remain far enough offshore during most of their life cycles to avoid contact with coastal MRE projects; however project-specific interactions will depend on the ultimate location of these projects, their layout and use of proposed project areas by various marine mammals.

6.6.4 Data Gaps and Follow-up

Research to date suggests that marine mammals will avoid MRE installations, but little is known about secondary effects such as noise, EMF and project effects on marine mammal food sources. Proposed project areas must be carefully surveyed for marine mammal species prior to project deployment and follow up studies should continue after the project is operational. Certain marine mammals such as seals can be fitted with electronic trackers to help understand their use of, and movement through, proposed project areas. Other species, such as whales will require comprehensive observer-based monitoring programs to develop a long term understanding of their behavior patterns before and after project deployment.

6.7 Marine Birds

6.7.1 Definition and Rationale for Selection

Marine birds are retained as a KEI in consideration of various regulatory requirements and due to the important role that marine birds play in the marine ecosystem. Marine birds are valued by coastal residents and play an economic role as one subject of the eco-tourism industry.

Marine birds include all species which are present for at least part of their life cycle (e.g., breeding, feeding, and migration) in coastal Cape Breton and the Bras d'Or Lakes. Birds that are considered at risk of interacting with MRE projects are those species that spend large parts of their life cycle in suitable MRE project areas and that have been identified by federal or provincial agencies as being endangered, threatened, rare, special concern or otherwise of conservation concern. Species of risk are important indicators of ecosystem heath and regional biodiversity.

6.7.2 Potential Environmental Interactions

There are a number of activities associated with construction, operation and decommissioning of TISEC devices that could interact with marine birds. Potential effects on marine birds may be direct or indirect, and may include direct mortality, alteration, disruption, or destruction of key habitats and food sources. There is limited information related to the behavioural responses of marine birds to TISEC devices.

If there are surface piercing structures associated with MRE technologies, bird strikes may occur at any time during the life of the MRE project. In addition, bird strikes with marine vessels can lead to the direct mortality or injury of marine birds. Increased vessel traffic associated with MRE projects can lead to increased noise levels causing some marine birds to exhibit localized temporary avoidance behaviour in the area of vessels. Finally, diving birds are at risk of collision with submerged structures and mooring cables.

An increase in vessel traffic also increases the risk of accidental spills in the marine environment, which in turn may have environmental effects on marine bird populations and their habitats. Some species of marine birds are attracted to or are particularly sensitive to the bright lights of marine vessels. Certain marine birds may be attracted to such lighting on vessels operating at night, which would further increase the risk of collisions.

Increases in noise (magnitude, frequency, duration and character) above background levels from construction or decommissioning or increased vessel traffic, may result in changes to behaviour and habitat use by marine birds. Noise associated with installation activities may cause some marine birds to temporarily avoid the particular area of the device(s). Once these activities are complete, the disruption to marine birds is expected to subside. In addition to potential interactions associated with vessel traffic, the presence of turbines themselves and the noise emissions for their operation has the potential to interact with marine birds that may be present or migrate through the area, causing direct or indirect effects.

6.7.3 Environmental Planning and Management Considerations

As with marine mammals, project planners must anticipate interactions with marine birds and avoid coastal areas that are heavily used by these species. While all nearby marine birds are expected to be disturbed by increased vessel traffic during TISEC installation and maintenance (and some may be attracted by these vessels), this disturbance will likely be of the same type and duration these species experience from on-going marine traffic. Diving birds may be more at risk in coming into contact with submerged TISEC devices.

6.7.4 Data Gaps and Follow-up

Marine bird surveys will be required in advance of an Environmental Impact Assessment for any proposed MRE project. These surveys should focus on establishing existing species types and habitat uses in the area so that post-project comparisons to bird distribution can be made. Local eco-tourism operators and shore observers can be enlisted to contribute to these surveys so that long terms records are maintained.

6.8 Species at Risk

6.8.1 Definition and Rationale for Selection

Species at risk are a KEI due to their rarity and because they have been designated by regulation for conservation purposes. In addition, great value is generally placed upon these species by aboriginal and non-aboriginal residents. This study has identified at least 20 COSEWIC listed species inhabiting the Bras d'Or Lakes and nearshore areas (within about 10 km) of coastal Cape Breton.

6.8.2 Potential Environmental Interactions

The potential interactions of these species with MRE projects are the same as the interactions described in other sections for the same types of species that are not currently designated at risk. Please see sections on Fish and Fish Habitat and Marine Mammals.

6.8.3 Environmental Planning and Management Considerations

Potential project effects to federally-listed species at risk are a critical factor to the regulatory approval, commercial viability and social acceptability of MRE projects. Should species at risk be identified within an area proposed for MRE project development, federal and provincial regulators must be consulted to establish pre- and post-project monitoring programs. Mitigation measures designed to protect species at risk may increase project costs and make regulatory approvals more difficult to obtain.

6.8.4 Data Gaps and Follow-up

The distribution and habitat types used by many species at risk are not tracked in a detailed and comprehensive manner, although much general information is available regarding species ranges and habitat preferences. Once specific project sites are identified, existing monitoring programs can be extended, or new programs developed to cover these sites. Monitoring programs must be designed to obtain information on existing distributions and must continue through project operation so that any changes to species behaviour or distribution will be documented. Federal and provincial regulators should be engaged to review and comment on species at risk monitoring plans and mitigation measures, and follow up discussions with regulators will help identify modifications to existing programs to increase their usefulness.

6.9 Marine Transportation

6.9.1 Definition and Rationale for Selection

Marine transportation, including commercial fishing and recreational vessel traffic, is considered a KEI due to the potential area conflict between small and large MRE projects and the day-to-day requirements of the marine transportation industry. Commercial marine transportation requires unimpeded access to and from port facilities, regular and emergency anchorages, and adequate passage through confined channels. Navigational rights and conflicts are regulated under the federal *Navigable Waters Protection Act*.

6.9.2 Potential Environmental Interactions

The *NWPA* assessment required for any MRE project would include construction, operation and decommissioning phases. An approved site would be required to be marked as directed by Transport Canada to create no entry zones and would require the issuance of Notices to Mariners and Notices to Shipping.

There are essentially two types of generalized interactions between existing marine traffic and MRE projects. The first type consists of temporary access limitations (including exclusion) during installation / maintenance / decommissioning. During these project phases large, slow moving barges, tugs, drill rigs and other support vessels will transit to and remain on station during the work. Access limitations would be similar to those during other marine construction projects and would require prior approval by Transport Canada. The duration of these restrictions will vary depending on the nature and phase of the project. Single TISEC deployments can be completed in a day or two, while larger arrays may take several weeks. Subsea cables are typically laid over a period of several days, depending on the cable length and complexity of seabed and tidal environments.

The second type consists of permanent barriers to access or area-use limitations that will endure while the project is operational. These restrictions are intended to:

1. Prevent snagging of underwater infrastructure by fishing gear and anchors thereby preventing damage to surface vessels and MRE project infrastructure;
2. Formalize any changes to standard navigation routes resulting from the new project; and,
3. Maintain safety at sea by restricting vessels from areas of unsafe anchorages.

Transport Canada may require an MRE project site to be marked with buoys and is responsible for posting Notices to Mariners, but exclusion areas, including any compensation that may be appropriate, are typically negotiated between project proponents and local resource users affected by the project.

6.9.3 Environmental Planning and Management Considerations

Project boundary markings and navigational alerts will be established through discussions and submissions by the project proponent to Transport Canada. Neither Transport Canada nor Fisheries and Oceans Canada can establish exclusion zones for MRE projects. Negotiations regarding temporary and permanent access limitations are held between project proponents and other area users with interests in the project site. These people may include finfish and shellfish harvesters, marine transporters, First Nations peoples, tourism operators, recreational boaters and in some cases, coastal residents. The Great Bras d'Or Channel and Barra Strait are relatively narrow passages which are highly used by recreational boaters, fishers and certain types of marine transport. Areas along coastal Cape Breton have competing fishing interests, in addition to other forms of vessel traffic, aquaculture sites and other uses. Given the number of users and interests in the region, project proponents should anticipate early and on-going consultation throughout the project preparation phase so that conflicting interests can be identified and competing claims resolved prior to deployment.

6.9.4 Data Gaps and Follow-up

Specific data gaps regarding the use of potential project sites by other users would be identified when MRE projects sites are announced. Stakeholder consultation is required at various stages during the project development process.

6.10 Tourism and Recreation

6.10.1 Definition and Rationale for Selection

Tourism and recreation is retained as a KEI since these activities are of value to the communities of coastal Cape Breton. Tourism and recreational activities may be water based or land based. There is potential for the development of MRE technology to interact with tourism and recreation, and these projects also present some potential to increase in tourism in the project area.

6.10.2 Potential Environmental Interactions

Any temporary or permanent access limitations or exclusion zones instituted for marine transportation and safety will naturally apply to recreational boating and sightseeing excursions. Similarly, access limitations during construction / maintenance / decommissioning will also apply to tourism and recreational vessels. As noted above, some restrictions would be temporary and similar to those that occur during other marine construction projects, while any permanent restrictions would be negotiated between the project proponent and the affected parties.

Land-based facilities may also directly affect recreational and tourism-based uses, since historically public spaces may no longer be available to casual visitors once substations and transmission lines are built.

MRE projects may also negatively affect the visual appeal of a coastal landscape or seascape. While most TISEC devices are entirely submerged, certain types along with wave energy converters and offshore wind turbines are visible at and above the sea surface and so will alter the existing view. The significance of these changes will depend on the nature, size and location of the project, as well as the aesthetic and economic value that residents place on exiting views.

6.10.3 Environmental Planning and Management Considerations

Environmental planning and management considerations would be similar to those described above for Marine Transportation. Tourism and recreational uses include boating, fishing, kayaking, whale and seabird observation and coastal uses such as hiking, sight-seeing and bird / whale watching.

6.10.4 Data Gaps and Follow-up

Specific data gaps regarding the use of potential project sites for tourism and recreational purposes would be identified when MRE projects sites are announced.

6.11 Archaeological and Heritage Resources

6.11.1 Definition and Rationale for Selection

Archaeological and Heritage Resources were selected as a KEI since the general area is known for First Nation, French and British Empire settlements. These resources include terrestrial and now underwater settlements or other remains, as well as shipwrecks. Both regulatory agencies and the public have on-going interests in the effective management of archaeological and heritage resources.

6.11.2 Potential Environmental Interactions

As with any construction project, there is potential for damage to archaeological sites, including First Nations / Aboriginal Sites, when these projects are undertaken. The installation of terrestrial electrical facilities such as substations and transmission lines may disturb historic resources. By the same token, installation of individual or arrays of MRE devices may destroy or obscure historical sites on the seabed.

Should energy extraction affect the currents, tidal or wave regime, then alterations of shoreline erosion may result. This may uncover and destroy archaeological remains or may bury remains in newly eroded sediment. Similarly, changes to sedimentation patterns in offshore areas may uncover or further obscure historic resources.

6.11.3 Environmental Planning and Management Considerations

Detailed bathymetric studies (multibeam and side scan sonar) will help to identify submerged archeological resources prior to project installation. Once identified, remotely operated vehicle surveys can be used to examine and evaluated historic sites. Mitigation plans can be developed to limit or prevent any damage to these sites or excavation and removal of the resources may be required. Depending on the nature of the historic site, the presence of such resources may prohibit deployment at or near the historic site and so may critically affect the project's ultimate viability.

6.11.4 Data Gaps and Follow-up

No Mi'kmaq Ecological Knowledge Study (MEKS) has been conducted for areas of MRE project interest and there is uncertainty regarding the location and condition of heritage resources at potential project sites. A MEKS is recommended for the region. Site-specific bathymetric surveys will be required during the site characterization stage.

6.12 Economic Development

6.12.1 Definition and Rationale for Selection

Economic development is often raised as an item of critical interest to nearby communities and municipal leaders. To certain degree, many communities may be willing to accept some level of environmental impact, provided the economic returns justify these effects. At the same time, MRE projects are generally perceived as a potential source of economic renewal for disaffected rural communities, provided that support services for installation, maintenance and monitoring are locally sourced. There is also the potential to use infrastructure created or upgraded for the MRE industry for other uses, providing additional economic and social benefits to local communities. Finally, MRE projects are perceived as helping to meet provincial renewable electricity goals and reduce greenhouse gas emissions, leading to future energy price stability and moderated climate changes effects.

6.12.2 Potential Environmental Interactions

The list below is reproduced from Jacques Whitford (2008) and was modified slightly to remain applicable to coastal Cape Breton and the Bras d'Or Lakes. These interactions described in more detail in CWS 2001; SLR 2010; and CanmetENERGY 2011.

Pre-Deployment Considerations

Community, provincial and national pre-deployment economic interactions and effects may include:

- Technology design and innovation;
- Materials research and testing including antifouling materials and coatings;
- Vessel deployment logistics;
- Device manufacturing and fabrication;
- Device transportation and assembly;
- Services related to baseline data collection and analysis;
- Environmental assessments; and,
- Project planning and permitting.

Trained personnel will be required to operate specialized equipment and provide various pre-deployment services. Potential support services may include:

- Provision of diving and remotely operated vehicle (ROV) equipment and services;
- Land and marine-based geotechnical surveys and mapping;
- Environmental assessments and environmental effects monitoring;
- Bathymetric and terrestrial surveys and mapping;
- Resource mapping and modelling;
- Project management, planning and permitting;
- Sub-sea and land-based cable laying;
- Substation construction, operation and management;
- Utility upgrades and integration with existing infrastructure;
- Transportation upgrades to existing roads including planning and construction;
- Planning and construction for upgrades to existing docking facilities; and,
- Supply, operation, and maintenance of heavy-left, survey, and maintenance vessels.

Deployment and Maintenance Considerations

The deployment of TISEC technologies will require the use of some local infrastructure, equipment, and personnel. Potential equipment may include:

- Deployment and survey vessels;
- Diving equipment;
- Technical instrumentation;
- Conveyors;
- Cranes; and,
- Other loading equipment.

Additional operational services may require environmental and marine life monitoring, as well as TISEC device operation, monitoring, and maintenance. Required infrastructure may include:

- New and existing roads;
- Commercial and industrial space;
- Land-based maintenance facilities;
- Accommodations;
- Use of wharfs; and,
- Docking facilities.

6.12.3 Environmental Planning and Management Considerations

Local capacity to support MRE projects is one of the key factors in reducing the costs of MRE projects. To a certain extent, the availability of general labor and professional skills will not be known until the need for these specific skills is requested by project developers. Once interest in moving forward with an MRE project has been expressed for a particular area, proponents should seek out community and business leaders to assess resources and skills, and consider programs to access the required skills and products.

As more and more interest is shown in developing MRE projects in Cape Breton, communities will become increasingly interested in understanding how economic benefits will be incorporated into development agreements. Project proponents and local governments would benefit from understanding how economic benefits have been distributed and retained within local communities in other jurisdictions.

6.12.4 Data Gaps and Follow-up

In order to address any skills shortages that may develop as a result of TISEC development, a review of the current skills base is required. A strategy should be developed to address skills shortages, and it should be supported by industry, public and private education providers and other stakeholders.

The community would also benefit if proponents and provincial regulators could provide clarity on how benefits to the community will be incorporated into project development agreements.

Local benefits can be maximized through several different strategies. These include:

- The use of supplier information sessions and industry-specific job fairs,
- Networking organizations that connect workers, suppliers, manufacturers and project developers;
- Coordination with existing development agencies and initiatives; and,
- Collaboration with other jurisdictions to identify and develop shared interests and benefits.

7. Cumulative Interactions

Environmental and socio-economic interactions of individual projects have the potential to overlap, both in space and in time, to create cumulative interactions. In some cases cumulative effects may interact in an additive fashion, creating an effect equal to the sum of the individual project effects. In other cases cumulative effects may reinforce and magnify each other, creating cumulative effects greater than the sum of each individual effect. As noted in the Background Report to the Phase I SEA, cumulative effects are especially difficult in aquatic environments where projects may create off-site impacts that can be felt over long distances (Jacques Whitford 2008).

The cumulative effects assessment attempts to consider the effects of other past, present and likely future projects and activities in combination with the potential impacts from the specific project being evaluated. Guidance provided under the *Canadian Environmental Assessment Act* indicates that “future projects and activities” must have a reasonable likelihood of occurring. For this Report, no specific project is being proposed and so the following sections can only outline the general types of cumulative interactions that may be expected in future MRE project scenarios.

It is important to underline that MRE research has so far been limited to the short-term impacts of individual prototype or demonstration-scale devices. As pointed out by Issacman and Lee (2010).

> “There has yet to be any published models or practical research on the cumulative and synergistic impacts of large-scale TISEC or WEC arrays or arrays in conjunction with other nearby offshore industries…To date, there have been no published studies or models investigating the actual or potential long-term and regional impacts on marine and coastal biodiversity or ecosystem processes due to existing or proposed WEC and TISEC installations.”

7.1 Effects of Energy Extraction

At the most basic level, removing kinetic energy from the tidal stream will reduce the speed of the tidal currents. Although the amount of energy removed by TISECS and the ultimate effects of energy removal are not yet fully understood (and will naturally depend on TISEC type and project configuration), it is expected that changes to current patterns and sediment dynamics, with attendant effects on biological communities, may result.. It is also to be expected that any hydrodynamic and ecological effects resulting from a single turbine would be magnified by multiple turbines installed in arrays.

Reducing current velocity will affect the transport and deposition of sediments and alter their properties. The magnitude of these changes, especially in shallow low energy areas (which are of high importance for primary productivity) is not currently known (Van Proosdij 2012).

Using a one-dimensional model to examine changes to flow in tidal channels and estuaries, Neill *et al.* (2009) showed that small changes to the current flow caused by energy extraction could affect the transport of sediments up to 50 km from the site of energy extraction. Around coastal islands and headlands, where flows are more complex but which are also attractive areas for tidal resource extraction, three-dimensional models demonstrate little change to sedimentation patterns, despite extracting a relatively large amount of energy from the tidal streams (a rated 300 MW TISEC array) (Neill *et al.* 2011). These results suggest that open ocean coastal areas may be less vulnerable to large amounts of energy extraction than confined channels and estuaries, such as Bras d’Or Lakes.

In Nova Scotia, three-dimensional modeling results suggest that “maximum” energy extraction in the Minas Passage increases tidal elevations and tidal currents throughout the Gulf of Maine and reduces tidal elevations and circulation in the upper Bay of Fundy. Maximum tidal energy extraction in the Minas Passage also has perceptible effects in the density-driven currents and temperature/salinity distributions over the central Gulf of Maine and western Scotian Shelf. With respect to sediment distribution, when tidal energy is extracted from the lower water column (within 20 m from the bottom) far-field changes to bottom sediment properties are noted within the Bay of Fundy (Sheng *et al.* 2012).

The ultimate effects of large energy extraction can be predicted through hydrodynamic modeling, which is becoming more refined as researchers examine the effects of TISECs in tidal streams. To improve the accuracy of these models, additional and detailed current flow measurements are required over the entire water column. These data are usually not gathered until specific sites are chosen for an MRE project. The predictive ability and accuracy of the computer models will then be verified by observations and measurements made once a project is operational.

7.2 Effects of MRE Device Installation

Each site selected for MRE project development will have unique seabed and current characteristics. Much of the seabed beneath Bras d'Or Lakes is covered by unconsolidated fine-grained glacial deposits. In contrast, many areas of offshore coastal Cape Breton exhibit scoured, exposed bedrock or large dynamic bedforms resembling sand dunes and broad sand ripples. The cumulative effects of multiple TISEC devices in these areas, with or without other nearby projects, will be different in each case.

TISEC installation can disturb fine grained sediments and scour coarser grained materials from the seabed. While this effect may be temporary and limited to the area immediately around a single device, it may also be possible to change the current patterns sufficiently to cause more widespread erosion. This is particularly a risk where underlying fine grained material is protected by coarser sediments at the surface. Once this protective cover is broken by a TISEC device, more extensive sediment transport may result. The presence of multiple devices may worsen this problem resulting in relatively large areas of unstable sediments. Sediment transport itself may have subsequent effects on the biota.

In the situation where an MRE project is installed in an area of moving bedforms, energy extraction has the potential to reduce current velocities immediately downstream from the installation. The cumulative effect of many TISECs in a localized area may affect the formation and movement of seafloor bedforms, affecting benthic habitat and causing other changes to the downstream ecosystem. Current hydrodynamic models do not provide a definite understanding of the amount of energy that can be extracted before significant changes to sediment pattern occur. At the same time, the effects will be very site specific, related to current and substrate conditions as wells as the number, layout and different design characteristics of the TISEC arrays.

7.3 Effects of Exclusion Zones

Potential space-use conflicts are common to all types of MRE projects since these projects occupy portions of the seabed, employ vessels during installation, maintenance & decommissioning, and may represent impediments to navigation and safe anchorage. Other users may include commercial fisheries, subsistence fishing, marine recreational activities such as boating, fishing, and sightseeing, commercial navigation, aquaculture, proximity of designated conservation areas and other alternative energy projects (Equimar 2009).

Although some potential conflicts can be avoided during site selection, other conflicts with commercial and recreational users cannot always be avoided since these activities occur in most marine coastal areas. Some restrictions may be imposed to limit public access and ensure safety and it is reasonable to assume that larger projects will require larger restricted areas.

Exclusion zones and access restrictions are regulated by Transport Canada and DFO but conflict with other resource users can also be addressed through clear coastal management policies developed in collaboration with local and regional resource users. These policies are typically developed in advance of MRE projects, allowing time to identify potential conflicts and establish consultation mechanisms to document coastal uses, sensitive areas and stakeholder interests. The Strategic Environmental Assessment is one type of policy tool used for this purpose. Integrated Coastal Zone Management planning has also been used to prioritize coastal uses and identify areas that are not suitable for certain types of uses, including MRE projects.

As in most other large projects touching multiple stakeholders, early and ongoing communication and consultation, combined with project-specific environmental impact assessments, are fundamental methods used to identify potential conflicts. The ultimate mitigation measures aimed at resolving user space conflicts and reducing impingements on other activities are best arrived at through a collaborative, multi-stakeholder process.

7.4 Effects of Other Developments

As noted, the *Canadian Environmental Assessment Act* requires a cumulative effects assessment of future projects and activities that have reasonable likelihood of occurring and provincial level environmental assessments also require cumulative effects assessment. This detailed evaluation is initiate by the project proponent occurs once the details of the project (design, location and layout) are sufficiently well known to begin the environmental assessment process.

The assessment process identifies past, present and likely future projects and activities with potentially overlapping, measurable environmental and socioeconomic effects. The environmental assessment process also describes measures designed to reduce or mitigate these effects, as well as a monitoring program to verify the assertions and predictions of the impact assessment.

Although it is not possible to describe the likely future projects at this time, coastal Cape Breton and Bras d'Or Lakes have experienced development in the past and will continue to develop into the future. Many of these activities have the potential to interact cumulatively with MRE projects. Examples of coastal development in the region include:

- Marble and gypsum mining in Bras d'Or Lakes; coal mining in coastal Cape Breton;
- Coastal residential and agricultural development;
- Harbour expansion, harbour dredging, shipbuilding and related activities;
- Bridge and causeway construction;
- Marine resource exploitation;
- Aquaculture operations; and,
- Commercial shipping. fishing and other boating activities.

Additional marine infrastructure, such as the Maritime Link, future telecommunication cables, pipelines and other projects will need to be considered if MRE projects are proposed.

8. Status of the Phase I SEA Recommendations

The 2008 Phase I SEA of the Bay of Fundy concluded with a series of recommendations to help guide the development tidal energy in Nova Scotia, with a specific focus on the Bay of Fundy. This section of the Background Report reviews those recommendations and comments on their status, validity and applicability to coastal Cape Breton and the Bras d'Or Lakes.

Sustainability Principles and Overall Recommendations		
Recommendation 1	Sustainability Principles	The Province of Nova Scotia adopt ten specific sustainability principles to guide marine renewable energy development in the Bay of Fundy. **Comment: with minor changes to wording these ten sustainability principles remain valid and are applicable to MRE projects in Cape Breton/Bras d'Or Lakes. For reference, they are reproduced in Appendix B.**
Recommendation 2	Allowing the Demonstration of TISEC Technologies	The Province of Nova Scotia give the necessary approvals, contingent on satisfactory completion of a project-specific environmental assessment, to allow demonstration of a range of TISEC technologies in the Bay of Fundy. **Comment: this recommendation remains valid and is applicable to MRE projects in Cape Breton/Bras d'Or Lakes. As this Background Report suggests, pre-commercial or commercial array projects may be preferred to demonstration-phase projects**
Recommendation 3	Marine Renewable Energy Legislation	Before large-scale commercial development proceeds, the Province of Nova Scotia enact legislation respecting the renewable energy resources in the Bay of Fundy. **Comment: this recommendation remains valid and is applicable to MRE projects in Cape Breton/Bras d'Or Lakes. The applicable legislation has been modified since 2008 following a consultation process; additional changes to regulation are expected.**
Information Gaps and Research Requirements		
Recommendation 4	Research Program	The Province of Nova Scotia facilitate the development of a collaborative research program for marine renewable energy development in the Bay of Fundy. The design of the research program should include all levels of government, Aboriginal peoples, research institutions, and stakeholders. **Comment: this recommendation remains valid and is applicable to MRE projects in Cape Breton/Bras d'Or Lakes. OERA is mandated and funded by the provincial government to coordinate research respecting offshore energy including the subject of MRE.**
Recommendation 5	Mi'kaq Ecological Knowledge Study	The Province of Nova Scotia ensure that a MEKS is carried out before marine renewable energy projects proceed in the Bay of Fundy, either as part of the research program identified in Recommendation 4 or as a requirement for project-specific environmental assessment. **Comment: this recommendation remains valid and is applicable to MRE projects in Cape Breton/Bras d'Or Lakes. As complementary work to the MEKS completed for the Phase I SEA, a second MEKS is suggested for portions of coastal Cape Breton and Bras d'Or Lakes.**
Recommendation 6	Provincial Standard for Ecological Data	The Province of Nova Scotia require all marine renewable energy proponents and their consultants to ensure that ecological data is geo-referenced and metadata compiled in accordance with the relevant

		provincial standard. **Comment: this recommendation remains valid and is applicable to MRE projects in Cape Breton/Bras d'Or Lakes.**
Recommendation 7	Bay of Fundy Socioeconomic Background Study	The Province of Nova Scotia undertake a socioeconomic background study, as soon as possible to describe fully the communities, economies and cultures of the Bay of Fundy region and Mi'kmaq communities with fishing interests in the Bay. **Comment: this recommendation remains valid and is applicable to MRE projects in Cape Breton/Bras d'Or Lakes. For this region, OERA commissioned the current Background Report, which builds on a recent OERA funded study entitled: Scoping Study on Socio-Economic Impacts of Tidal Energy Development in Nova Scotia: A Research Synthesis & Priorities for Future Action (Howell and Drake 2012).**
Implementing an Incremental Approach		
Recommendation 8	Marine Renewable Energy Demonstration Program	The Province of Nova Scotia establish a Marine Renewable Energy Demonstration Program (with a Stakeholder Advisory Board) to (a) encourage the development of a range of tidal energy and other marine renewable technologies (b) gather knowledge about environmental and socioeconomic impacts and benefits, and (c) initiate longer term research needed to predict cumulative and far-field effects in the commercial phase. **Comment: It is not clear whether this recommendation remains valid and is applicable MRE projects in Cape Breton/Bras d'Or Lakes. OERA, in collaboration with the Ocean Renewable Energy Group (OREG), appears to be meeting the requirements enumerated above. No Stakeholder Advisory Board has been established although FORCE has an active Community Liaison Committee (CLC) and Environmental Monitoring Advisory Committee (EMAC). A Tidal Energy Stakeholder Forum is proposed in the Marine Renewable Energy Strategy (2012)**
Recommendation 9	Siting Demonstration Projects	The Province require proponents to consult with local fishers, other marine resource users including marine transportation stakeholders, and adjacent communities in the selection of sites for demonstration projects and to avoid or compensate the displacement of productive fishing activity. **Comment: this recommendation remains valid and is applicable to MRE projects in Cape Breton/Bras d'Or Lakes. Proponents are legally required to consult with the stakeholders described above during the Environmental Assessment process.**
Recommendation 10	Environmental Assessment of the Demonstration Facility	The Province of Nova Scotia amend the provincial Environmental Assessment Regulations to designate tidal energy projects that produce 2 MW or more of energy as Class I undertakings. **Comment: The Environmental Assessment Regulations currently designate as Class I any project with a production rating of at least 2 MW derived from wind, tides or waves.**
Recommendation 11	Fundy Tidal Energy Research Committee	The Province of Nova Scotia initiate the formation of a federal-provincial Fundy Tidal Energy Research Committee, also involving the Province of New Brunswick, to determine baseline research requirements and to develop research and monitoring requirements for demonstration and future commercial projects. **Comment: with minor changes in wording, this recommendation remains valid and is applicable to MRE projects in Cape Breton/Bras d'Or Lakes. The Province, through OERA, is represented on OERA's Research Advisory Committee. OERA continues to identify research needs and provide research funding to address issues related to MRE**

		projects. Other research networks include FERN and the Canadian-Marine Energy Research Network (CMER).
Recommendation 12	Commercial Development Framework	The Province of Nova Scotia work with New Brunswick and the Government of Canada to develop a commercial development framework (guided by sustainability principles) for marine renewable energy, either through an expansion of the existing SEA process, or through a new process that includes stakeholder involvement. **Comment: this recommendation remains valid and is applicable to MRE projects in Cape Breton/Bras d'Or Lakes. To date, no commercial development framework has been established – such a framework might benefit project developers in Cape Breton as well as in southwest Nova Scotia and the Bay of Fundy.**
Recommendation 13	Incremental Development and Removability	Larger commercial developments be required to develop incrementally in stages with an appropriate effects monitoring program; that all installations be designed in such a way that the machines, their footings and all cables can be completely removed if necessary and the site remediated to close to its former condition. **Comment: this recommendation remains valid and is applicable to MRE projects in Cape Breton/Bras d'Or Lakes.**
Integration of Marine Renewables and End Uses		
Recommendation 14	Nova Scotia Energy Priorities	The Province of Nova Scotia takes steps to maximize the benefits of commercial marine renewable energy projects to Nova Scotia. The Province's first priorities should be to (a) satisfy provincial, national and international greenhouse gas reduction commitments and (b) improve provincial energy security. **Comment: this recommendation remains valid and is applicable to MRE projects in Cape Breton/Bras d'Or Lakes. The province has taken several steps to reduce GHGs and improve energy security. These steps include tabling the Renewable Electricity Regulations, introducing the COMFIT program and issuing the Marine Renewable Energy Strategy.**
Recommendation 15	Conservation, Efficiency and Carbon Credits	Nova Scotia Renewed Energy Strategy and Climate Change Action Plan (a) place high priority on conservation and efficiency measures, and (b) implement a carbon credit trading scheme, or comparable measures, to strengthen the economic viability of the tidal energy industry. **Comment: this recommendation is not specifically applicable to MRE projects in Cape Breton.**
Recommendation 16	Grid Capacity	The Province of Nova Scotia study (a) the advantages and disadvantages of developing more decentralized generation, (b) the current capacity of the grid to support additional renewable energy developments, and (c) required upgrades and how these should be financed. **Comment: this recommendation remains valid and is applicable to MRE projects in Cape Breton/Bras d'Or Lakes. To meet this recommendation, the province has commissioned the Wind Integration Study to understand how to integrate intermittent renewable energy projects into the existing grid. It appears the currently legislated renewable energy targets can be met but transmission upgrades and operational demands may increases costs.**
Recommendation 17	End Uses	The Province of Nova Scotia study alternate uses of marine renewable power generation to maximize benefits. **Comment: this recommendation remains valid and is applicable to MRE projects in Cape Breton/Bras d'Or Lakes. As noted in the Phase I SEA, such alternate uses may include small-scale application, on and off-grid, hydrogen storage methods, and how electricity**

		regulation contributes to opportunities and constraints.
Interactions with the Fisheries and other Marine Resource Uses		
Recommendation 18	Fisheries Database	The Province of Nova Scotia (a) assist DFO to develop and maintain a geo-referenced database of fisheries resources and activities to be used to determine where tidal energy development would have least impact on the fishery and other marine resource uses, and (b) develop a detailed study of potential tidal energy exclusion zone requirements by type of activity (including different types of gear use), potential impacts and possible mitigative strategies. **Comment: this recommendation remains valid and is applicable to MRE projects in Cape Breton/Bras d'Or Lakes.**
Recommendation 19	Compensation and Liability	The Province of Nova Scotia facilitate the development of a preliminary mitigation process to address compensation for fisheries displacement, damage to gear, and other environmental impacts, and limits to liability before any demonstration project proceeds. **Comment: this recommendation remains valid and is applicable to MRE projects in Cape Breton/Bras d'Or Lakes.**
Recommendation 20	Aboriginal Fisheries	The Province of Nova Scotia require marine renewable energy proponents to engage with aboriginal communities at an early stage of project development to address issues and concerns, and facilitate discussion and information sharing. This engagement would be in addition to, and would not replace, the Province's duty to consult with First Nations. **Comment: this recommendation remains valid and is applicable to MRE projects in Cape Breton/Bras d'Or Lakes. Early engagement is expected to occur during the Phase II SEA process, anticipated for early 2013. Additional consultation is legally required once a proponent intends to move forward with a project (during the Environmental Assessment process).**
Recommendation 21	Fisheries Consultation and Involvement Protocol	The Province of Nova Scotia work with marine renewable energy proponents, local fishers and other fisheries interests to develop procedures and protocols to ensure that fishers and fisheries stakeholders are informed and consulted at every stage of tidal development, both by the Province and by proponents. **Comment: this recommendation remains valid and is applicable to MRE projects in Cape Breton/Bras d'Or Lakes. The province, through OERA will participate in the engagement component of Phase II SEA process, anticipated for early 2013. Additional consultation is legally required once a proponent intends to move forward with a project (during the Environmental Assessment process).**
Maximizing Regional and Community Benefits		
Recommendation 22	Marine Renewable Energy Benefits Strategy	Nova Scotia develop a Nova Scotia Marine Renewable Energy Benefits Strategy to ensure that the people of Nova Scotia benefit substantively from the development of these technologies. **Comment: this recommendation remains valid and is applicable to MRE projects in Cape Breton/Bras d'Or Lakes. To date, a Marine Renewable Energy Benefits Strategy has not been developed.**
Recommendation 23	Community Participation and Benefits	The Province of Nova Scotia, in consultation with municipalities, community development organizations, and other stakeholders, develop a Marine Renewable Energy Community Participation and Benefits Strategy to ensure the delivery of lasting socioeconomic benefits in the Fundy Region. **Comment: with minor changes to wording, this recommendation remains valid and is applicable to MRE projects in Cape Breton/Bras d'Or Lakes. The province has initiated this**

		activity through the COMFIT program; other initiatives as suggested in the Phase I SEA may also benefit the Cape Breton region.
Other Marine Renewables		
Recommendation 24	Offshore Wind, Wave, and Tidal Lagoon Technology	The Province of Nova Scotia should apply the Sustainability Principles in Recommendation 1 to consideration of all types of marine renewable energy technology. The Province of Nova Scotia should support a full Federal-Provincial panel review for any proposed tidal lagoon project. **Comment: This recommendation is not applicable to Cape Breton; there does not appear to be interest or opportunities for tidal lagoon development in Cape Breton**.
Integrated Management for the Bay of Fundy and Stakeholder Involvement		
Recommendation 25	Integrated Coastal Zone Management	The Province of Nova Scotia develop an Integrated Coastal Zone Management (ICZM) Policy for the Bay of Fundy before large scale commercial marine renewable energy developments are allowed to proceed. **Comment: with minor changes to wording, this recommendation remains valid and is applicable to MRE projects in Cape Breton/Bras d'Or Lakes. The province current uses the Coastal Management Framework to manage coastal areas. Should commercial arrays be proposed, more focused ICZM planning may help to minimize overlapping claims and mitigate conflict.**
Recommendation 26	Geo-Referenced Tools to Indicate Opportunities and Constraints	Nova Scotia, New Brunswick and Canada collaborate to prepare and maintain geo-referenced tools to indicate opportunities and constraints for the full range of marine renewable energy technologies, to support the allocation of marine renewable resources within the context of an Integrated Coastal Zone Management Policy. **Comment: this recommendation remains valid and is applicable to MRE projects in Cape Breton/Bras d'Or Lakes.**
Recommendation 27	Municipal Involvement	The Province of Nova Scotia consult with the Union of Nova Scotia Municipalities to develop procedures and protocols to ensure that municipalities are informed and consulted at every stage of tidal development, both by the Province and by proponents. **Comment: this recommendation remains valid and is applicable to MRE projects in Cape Breton/Bras d'Or Lakes.**
Recommendation 28	Public Education and Awareness	The Province of Nova Scotia work with marine renewable energy proponents, research institutions and environmental and community organizations involved in sustainability education, to develop a strategy for public education and awareness about marine renewable energy technologies. **Comment: this recommendation remains valid and is applicable to MRE projects in Cape Breton/Bras d'Or Lakes. Since 2008 the province has collaborated with research groups and industry to promote tidal energy development and will laiise (through OERA) with communities during the upcoming Phase II SEA for Cape Breton.**
Recommendation 29	Long-term Integrated Management in the Bay of Fundy	The Province of Nova Scotia, partnering with New Brunswick, Canada, and the Gulf of Maine Council, study ICZM requirements, approaches and experiences, to provide the background for a major workshop to be held in 2009 to examine integrated management issues and organizational options for the Bay of Fundy. **Comment: this recommendation is now outdated and does not apply Cape Breton/Bras d'Or Lakes.**

9. Summary and Conclusions

In support of the Phase II SEA for coastal Cape Breton and the Bras d'Or Lakes, this Background Report describes MRE technology and presents information on the biophysical and socio-economic characteristics of the region.

In keeping with the Phase I SEA conducted for the Bay of Fundy, as well as the list of critical subjects requested by OERA, a selection of KEIs was presented at the beginning of the Report. The KEIs represent topics of particular interest and importance to the development and implementation of MRE projects, particularly tidal energy, in Cape Breton. A discussion of the study findings is also presented in this section, following Table 15 below.

Coastal Cape Breton has not been studied in great detail for their capacity to host MRE projects in a cost-effective and sustainable manner, although more information is available for Bras d'Or Lakes. These detailed studies will be required in support of an Environmental Assessment or Environmental Impact Assessment once regulatory approval is sought for a defined project. In addition to the lack of detailed information regarding potential project sites and their associated energy resources, there are certain data gaps regarding the effects of MRE projects on the existing environment. While some of these data gaps have been addressed in part since the 2008 Phase I SEA, information gaps still remain. Table 15, reproduced and updated from the Phase I SEA, summarises the KEIs and the data gaps associated with each issue. Priority data gaps are shown in bold text, while data gaps that have been partially addressed since 2008 are underlined. Additional information gaps not directly related to the KEIs are listed after Table 15.

Table 15. Summary of KEIs and Associated Data Gaps

Key Environmental Issue	Data Gap	Recommendation
Critical Physical Processes	• **Lack of data to identify areas with adequate energy resource in coastal Cape Breton.** • Lack of detailed, site-specific current and substrate information for validation of models. • Inadequate fine-scale hydrodynamic and sediment models relevant to selected MRE sites. • Limited knowledge of the overall distribution and dynamics of sediments in Bras d'Or Lakes and coastal Cape Breton. • Inadequate application of hydrodynamic models to assess the impacts of TISEC developments. • Insufficient information regarding the cumulative effect of many devices on scour, sediment distribution and effects of ecological linkages.	• **Gather site-specific substrate, sediment movement and current information for MRE potential sites using in situ current measurements and sediment sensors.** • Complete high density multibeam bathymetric studies, especially in shallow waters that have not yet been surveyed. • Adapt or refine hydrodynamic models to provide adequate small-scale analyses of the potential for, and the effects of, energy extraction developments. • Use hydrodynamic modeling to assist in site selection, optimizing the extractable energy potential and minimizing cumulative effects on physical or biological processes. • Validate monitoring methods / protocols to be used by developers. • Use modeling to link small projects to commercial scale arrays.
Fisheries	• Insufficient information on fish interactions with TISEC devices. Monitoring results are limited, inconclusive and lessons learned not necessarily transferable to commercial developments. • Inadequate knowledge on effects of remobilized	• Conduct additional experimental and in-water monitoring of fish behavior and mortality in the vicinity of TISEC devices. • Conduct experimental studies of fish responses to noise and EMF generated by TISEC devices and cables. • Develop information about likely electrical and magnetic

Key Environmental Issue	Data Gap	Recommendation
	sediments on commercially important species. • Questions about EMF from sub-sea cables and the effects on demersal fish and shellfish. • **More specific information required regarding the number of fishing operations, vessels, products and locations of fixed gear fisheries.** • Lack of clarity on access restrictions for MRE projects.	field strengths associated with generating units, offshore substations, transformers and submarine cables. • Conduct experimental studies of effects of high suspended sediment concentrations on migratory and commercial fish species. • Work with fishing groups to obtain better fisheries data, particularly with respect to activities near proposed development sites. • Gather detailed information on potential adverse effects on local fisheries, and necessary mitigative measures (including project site selection). • Establish a consultative group, including fishers and developers to manage site use / access conflicts.
Fish and Fish Habitat	• Data on distribution, seasonality and trophic relationships of many non-commercial species are not available. • **Insufficient information on fish behaviour and / or mortality with respect to TISEC technologies, particularly for noise and vibration.** • Questions about EMF from sub-sea cables and the effects on demersal fish.	• Conduct experimental and in-water monitoring of fish behavior and mortality in the vicinity of TISEC devices. • Conduct experimental studies of fish responses to noise and EMF generated by TISEC devices and subsea cables. • Establish an ongoing and updatable database of knowledge about local and migratory fish stocks. • Identify potential mitigative measures for effects on fish populations.
Marine Habitat and Benthic Communities	• Limited data available on existing benthic communities in coastal Cape Breton. • Limited data available on existing benthic communities of the Bras d'Or Lakes, which is expected to be especially sensitive to changes that may result from energy extraction. • Little existing data for many areas of coastal Cape Breton.	• Initiate benthic surveys in proposed project sites, in areas that may be expected to be affected by project-related disturbances, and in non-affected control sites. • Create a coordinating agency to ensure consistency and quality of monitoring activities.
Pelagic Communities	• Similar to Fisheries and Fish and Fish Habitat issues noted above with respect to pelagic species.	• Similar to Fisheries and Fish and Fish Habitat issues noted above with respect to pelagic species.
Marine Mammals	• Limited data on behavioural responses of marine mammals to TISEC devices. • Limited data available on the occurrence of marine mammals in coastal Cape Breton.	• Compile information on long-term effects on mortality, migration, avoidance and attraction with respect to marine mammals. • Establish long-term monitoring programmes for marine mammals in coastal Cape Breton.
Marine Birds	• Lack of data on marine seabird and shorebird activity in the area of priority sites. • Lack of information on the trophic relationships of many marine birds, and their ability to adjust feeding preferences.	• Establish long-term monitoring programmes for marine birds near potential project sites. • Conduct background surveys to support project-specific environmental assessment process prior to deployment. • Identify and assess possible mitigation measures for effects of TISEC development on birds, including secondary effects associated with changes in prey availability.

Key Environmental Issue	Data Gap	Recommendation
Species at Risk	• Requirement for better site–specific information on species presence (depending on species and location).	• Establish an ongoing and updatable database of knowledge about local and migratory species at risk. • Identify and assess potential mitigation measures for different species at risk. • Work with Species Recovery Teams to develop comprehensive strategies for species at risk that use areas of high priority for energy extraction. • Where necessary, conduct species-specific surveys in high priority areas.
Marine Transportation	• Uncertainty regarding level of interaction with other marine transportation users in the study area.	• Stakeholder consultation with other marine users
Tourism and Recreation	• Lack of information on informal and unregulated recreational activities.	• Project-specific data gathering as part of site-specific EA process (including shore based facilities).
Marine and Coastal Archaeological and Heritage Resources	• Uncertainty regarding the location and condition of many potential archeological and heritage resources (marine and shore-based).	• Undertake a Traditional Ecological Knowledge Study for coastal Cape Breton and the Bras d'Or Lakes. • Detailed site-specific bathymetric survey using side-scan sonar as part of project specific EA process. Follow up with ROV survey if sonar shows potential resources. • Detailed archeological survey may be necessary as part of shore-based facility site selection and EA process.
Economic Development	• Uncertainty in identification of specific business opportunities for local business. • Local capacity not clear.	• Initiate supplier information sessions. • Establish networking organisations • Undertake local capacity/benefits study • Collaborate with development agencies and nearby jurisdictions • Host project-specific job fairs.

<u>Additional Data Gaps Identified During Background Report</u>

- The ability to accurately predict wind speed and direction would help remove barriers to the development of offshore wind energy by allowing utilities to commit to power purchases in advance (NREL 2012).

- Key areas where research is urgently needed include innovative and efficient wind turbine design, offshore electricity transmission, innovative offshore foundation concepts and installation techniques, and new operations and maintenance strategies. In addition, policy support is important for offshore wind cost reduction, as these policies will help achieve economies of scale and promote R&D development (Sun *et al.* 2010).

- Additional study is required to better understand the wave potential of the southeastern shore of Cape Breton (Cornett 2006).

- Develop a risk management framework that integrates environmental and socio-economic factors to evaluate cost / benefit of tidal development (Stantec 2011).

- A risk assessment should be undertaken to quantify risks of tidal energy development, placing these risks in the context of other energy sectors (Stantec 2011).

- Encourage business / economic researchers to work together and coordinate research, similar to what has been done by scientists studying biophysical issues of tidal power (Stantec 2011).

- Research and development should focus on cable technology that is suitable for specific tidal environments in Nova Scotia (Stantec 2011).

- Additional research should be undertaken to focus on grid connection / energy storage and usage (Stantec 2011).

- Beyond design, construction and commissioning risks, there are risks associated with supply chain and completion, commodity price volatility, weather, health and safety, energy yield, loss of equipment, plus a plethora of other risks. Mitigation of such risks is important for developers and for obtaining financing. Risk mitigation must be more closely explored (MacDougal 2011).

- Finding capital at the various project stages (design, testing, implementation, commercialization, etc.) is a barrier at the present time. Government grants and incentives provide help at some stages, and venture capital will participate later in the process. Banks are reluctant to participate until the technology is relatively mature. Throughout the process, there are funding gaps. What methods of financing are most appropriate? (MacDougal 2011).

- The DFO Research Vessel Trawl Survey has an inshore limit of 50 fathoms or 12 nautical miles. Thus there are no trawl survey data for the inshore area (Doherty and Horsman 2007).

Summary of Findings

The MRE industry has continued to evolve since the Phase I SEA was completed for the Bay of Fundy in 2008. Offshore wind energy generation in Northern Europe is cost-competitive with other forms of electrical generation and the technology is moving towards larger turbines supported by floating platforms in deeper water environments. A new generation of wave power devices has been developed and is currently being tested at coastal sites in the UK and the US. Many tidal power technologies have moved out of the prototype phase and into or past the demonstration phase. The leaders in this industry are currently seeking sites and financial investment to develop grid connected pre-commercial and commercial arrays. Nevertheless, wave and tidal energy is not yet competitive with offshore wind energy; in Canada offshore wind is unlikely to compete with onshore wind energy until the remaining onshore sites are occupied and the transmission grid capacity is increased.

In the UK, the cost of wave and tidal energy must be reduced by 50-75% by 2025 in order to compete with offshore wind energy (LCIGC 2012). Continued innovation and significant economies of scale in manufacturing, combined with supply chain optimization and new forms of financing and risk management must be realized to achieve these cost reductions.

Continued support is needed to move MRE technologies from single demonstration deployments into the first commercially viable grid connected arrays (5 MW range). The primary objectives of initial arrays are to prove that multiple devices can work in one location with minimal disruption to the natural environment, to optimize energy yield, and to prove the ability to achieve commercial-scale cost efficiencies. Moving to arrays also supports and promotes the formation of MRE supply chains to an extent that single prototype projects do not. Once the technical expertise to deliver these projects has been developed in Nova Scotia, these skills can be exported to international markets in support of other MRE projects. Additional research and development is required to address technical questions regarding subsea cabling, multi-unit and multi-array deployments, device interactions and ways to reduce the installed cost and risks to investors.

As the MRE industry, especially the tidal energy component of the industry, moves to deploy device arrays, a number of environmental concerns require additional attention. Single device project-environment interactions are not fully understood, especially the effects of tidal energy devices on fish and marine mammal behaviour and survival. Work is on-going at the FORCE site in the Bay of Fundy on these, and other engineering and biophysical data gaps. With respect to array deployments, the primary concerns relate to the effects of large-scale energy extraction and the consequent changes to water movement, sediment dynamics, and effects on aquatic species. At the same time, research is needed to understand how the outstanding questions for single device deployments play out when multiple devices arranged in arrays.

Five areas with the potential to host tidal power projects were identified on a preliminary basis in this study. To various degrees, these areas appear have wave and offshore wind energy potential although only limited data are available regarding the tidal, wave and wind energy resources. The five areas are:

1. Great Bras d'Or Channel / Barra Strait in Bras d'Or Lakes;
2. Mid-way up the western coast of CBI off Cheticamp;
3. Off Cape North and around St. Paul Island;
4. Around Scatarie Island/Flint Island; and,
5. Along the south east coast of Cape Breton to Forchu.

With the exception of the two sites in Bras d'Or Lakes which were the subject of more detailed current flow measurements in 2012, none of these areas has been studied to the extent required to identify appropriate sites for tidal energy projects. Significant data gaps remain with respect to seabed type, sediment movement, current patterns, tidal resource availability and biological diversity. Other considerations, such as the distance to the nearest grid connection and the availability of a suitable landfall may limit the potential of these areas. Finally, each of these areas hosts a unique assemblage of marine organisms that will be exposed to the potential effects of MRE projects. Studies conducted to date indicate that the effects on marine biota are limited, but these studies, often conducted in difficult, high energy tidal environments, are not yet conclusive. In addition, they have not evaluated the cumulative effects of many devices operating in array formations. Of the data gaps listed above, priority must be given to identifying and assessing the tidal resources in coastal Cape Breton, since an available energy resource is the necessary prerequisite to all other work.

The table below summarizes the MRE device operating parameters, constraints and opportunities presented in this report.

Table 16. Summary of Operating Parameters, Opportunities and Constraints

Operating Parameter	Offshore Wind (Fixed)	Small Scale Tidal*	Large Scale Tidal	Wave
Average Water Depth	10m to 60m	10m to 30m	20m to 80m	10m to 100m
Maximum distance from shoreline	100km	5km	100km	100km
Constraining Threshold	> 7.0 m/s mean annual wind speed at 100 m height	Peak Spring Current Flow >1.0 m/s	Peak Spring Current Flow >1.2 m/s	Mean annual wave power (kilowatts) per metre of wave crest (WC) >20 kW/mWC
Approximate MW/km^2	10	Not available	50	10
Average Turbine/Device Generating Capacity	2-3 MW	100-500 kW	1MW	0.5MW to 5MW
Cost to Generate Power	\$0.17 to \$0.35 per kWh	Not available	\$0.44 to 0.51 per kWh	\$0.61 – \$0.77 per kWh
Average Scale of Commercial Development / Array Size	300MW	1-3MW	50MW	30MW
	30km^2	500m^2	1km^2	3km^2
Opportunities for Development	• Significant offshore wind energy potential	• Locally available energy resource • Community interest and COMFIT program support project opportunities • Distribution capacity is available nearby • Potential for export of technology and expertise • Project opportunities are small scale and relatively non complex • Relatively small capital investment required for project initiation • Projects may be expected to proceed in the near future	• Several, possibly numerous areas with sufficient energy • Technology is now at the commercial array stage • Can build upon expertise generated at the FORCE site • Potential for export of technology and expertise • FIT for commercial tidal projects will be available in the near future • Potential to contribute to the economic future of coastal Cape Breton	• Significant offshore wave energy potential
Constraints to Development	• Wind resource is not fully quantified • Not cost competitive with onshore wind projects • Greater distance to electrical grid increases overall project costs • Upgrades to the transmission grid will	• Energy resource is limited to a few specific, spatially confined areas • Total extractable energy resource is limited (array potential is limited) • Significant commercial and recreational traffic	• Energy resource and biophysical environments are not known • Currents are not especially elevated relative to other areas around the world • Total amount of nearby or easily extractable energy is	• Energy resource is not fully quantified • Technology is not adequately advanced for full scale commercial arrays • Greater distance to electrical grid increases overall project costs • Upgrades to the

Operating Parameter	Offshore Wind (Fixed)	Small Scale Tidal*	Large Scale Tidal	Wave
	likely be required • Project opportunities are large scale and complex • Large capital investment required for project initiation • Limited local project and technological experience • Projects are not expected to proceed in the near future	may be impeded by TISEC installation • Constricted channels are critical for transit of marine organisms • Bras d'Or Lakes may be more sensitive to ecological effects of energy extraction	low compared to the Bay of Fundy • Greater distance to electrical grid increases overall project costs • Upgrades to the transmission grid will likely be required • Project opportunities are large scale and complex • Large capital investment required for project initiation • Projects are not expected to proceed in the near future	transmission grid will likely be required • Limited local project and technological experience • Project opportunities are large scale and complex • Large capital investment required for project initiation • Projects are not expected to proceed in the near future

*Operating parameter data for small scale tidal arrays are estimated for this study

Modeling studies regarding the effects of energy extraction are being employed, tested through field validation and refined in different parts of world. At this time, the results appear to indicate that commercial-scale energy extraction from open ocean, high energy environments has little effect on the overall energy budget of a region. In contrast, extracting energy from confined tidal streams, especially where the overall system has limited total energy, may result in downstream or "far field" effects on system hydrodynamics and by extension, the ecological processes that depend on water movement. The models are not yet sophisticated enough to identify the maximum safe extractable energy from a given area, although work is continuing on this subject.

Each potential project area has a number of unique and even rare characteristics that must be taken into account in future studies to characterise these areas prior to MRE project development. Scatarie Island is a Wildlife Management Area and a Wilderness Area known for its high biological productivity, colonial seabirds and species diversity. The Great Bras d'Or Channel is a key fish migration route and part of a UNESCO Biosphere Reserve. Moreover, the Lakes are an example of a relatively low energy, biologically diverse environment that may be sensitive to commercial-scale energy extraction (although less so for community-scale COMFIT projects). Western coastal Cape Breton hosts migratory fish, seabirds and marine mammals whose use of the area has not been fully documented. Each of these areas would naturally require further study on a number of fronts to support any future project-specific Environmental Impact Assessment.

Existing transmission capacity appears to be sufficient to meet the province's renewable electricity goals to 2013. Moving forward from 2013, transmission corridors between Sydney and Truro would soon reach their capacity should significant MRE projects be located in Cape Breton. In addition, there are likely to be cost implications to integrate large amounts of MRE into the existing grid. These costs may be related to importing additional electricity when MRE systems are off-line, starting and stopping thermal generation units, managing interruptible load and limiting wind and MRE generation at certain times. Studies are currently underway to address transmission capacity limitations and integration problems.

MRE projects share the seabed and water column with other marine users. To the extent that these uses overlap in space or time, a strategic and consultative process is required to resolve conflicts that may develop. The Eastern Scotian Shelf Integrated Management Initiative is in the process of developing a collaborative Integrated Ocean Management Plan for this region; this represents an opportunity to incorporate planning for future MRE projects within an overall regional planning strategy. The upcoming Phase II SEA will also provide a forum for information exchange, solicitation of questions and concerns, and identification of additional area-use conflicts that may exist. Finally, any future MRE project will be subject to a site-specific Environmental Impact Assessment process. Area-use conflicts and potential access limitation to MRE project sites will again be identified and addressed during and after the assessment process.

The Phase I SEA for the Bay of Fundy recommended a cautionary, staged approach to the implementation of MRE projects in Nova Scotia. This approach seeks to address the unknown factors associated with these projects in an open, proactive and consultative manner. Work undertaken at individual device deployment sites elsewhere in the world, as well at the FORCE site in the Bay of Fundy, will provide valuable lessons for future projects in Cape Breton.

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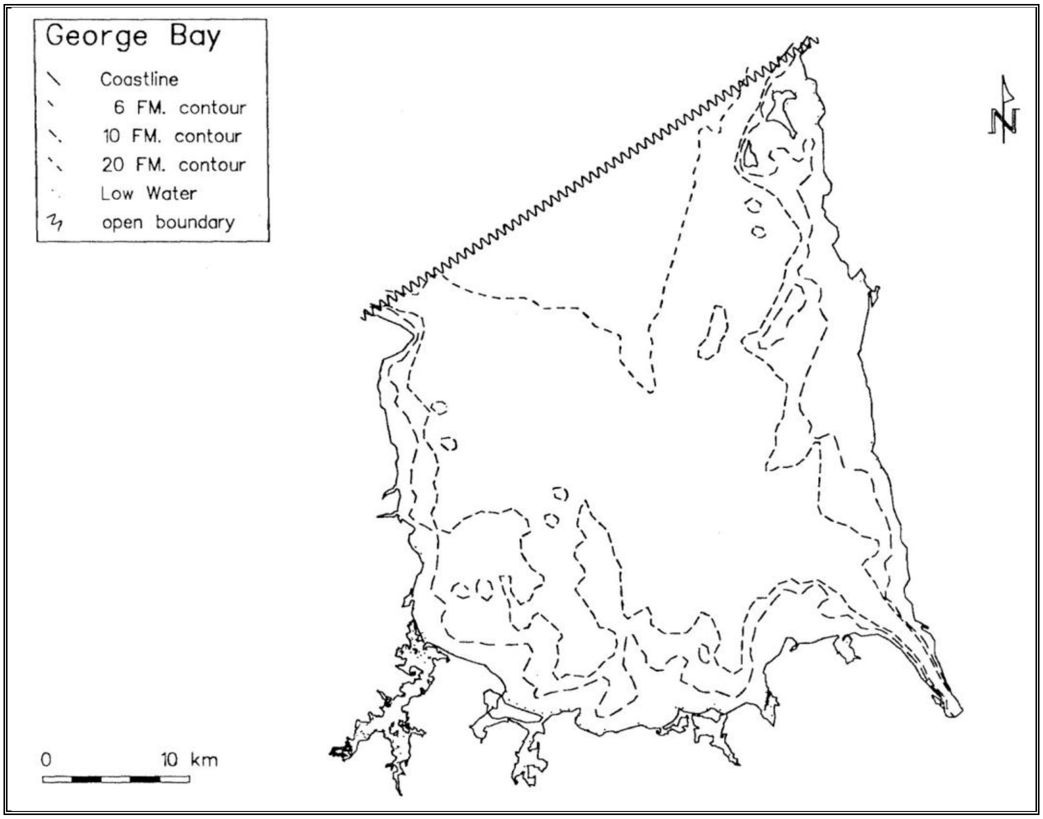
AECOM

Appendix A

Tidal Characteristics of Coastal Embayments

List of Figures



GEORGE BAY Zone 4Tg Chart 4023
Bay ID..CT

Area (CD)	1137.9 km^2	Area (HW)	1164.6 km^2
Perimeter	221.1 km	Volume (CD)	24120.0 10^6m^3
Axis Length	41.5 km	Maximum Depth	41.1 m
Section Width	35.1 km	Section Area	1121011.5 m^2

Tidal Range		Tidal Volume	Tidal Current	
Mean	Large	Mean tide	Mean	Peak
0.90 m	1.50 m	1036.1 10^6m^3	0.04 m/s	0.06 m/s

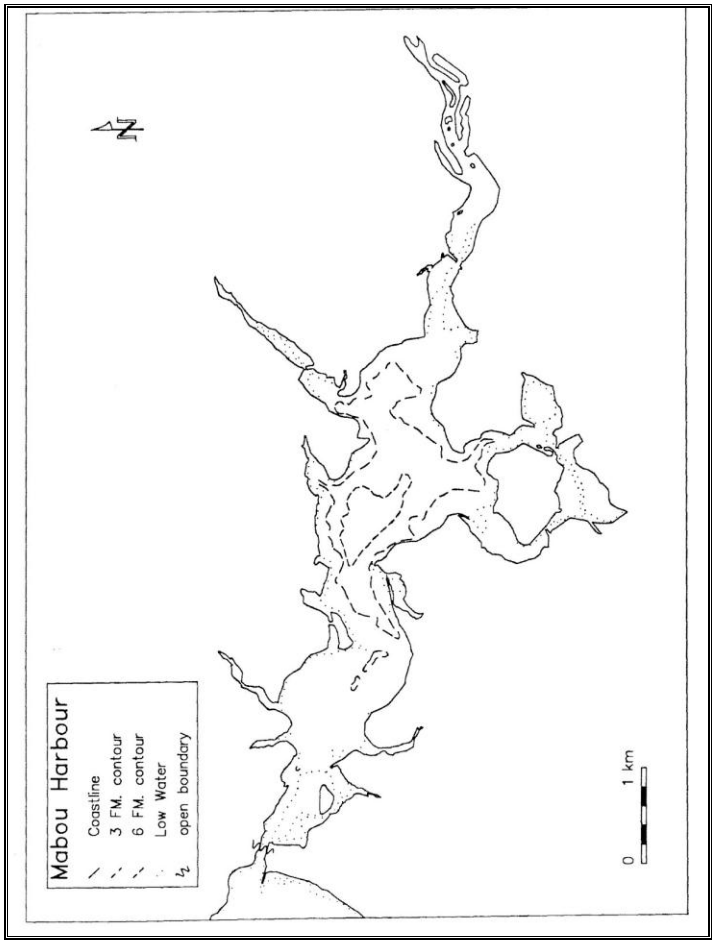
Flushing time 295.2 hr
Tidal/Freshwater volume ratio 543.80

Watershed Area 2747.5 km^2

Freshwater Discharge m^3/s (Standard Deviation)

Jan	108.0 (51%)	May	106.0 (65%)	Sept	40.2 (78%)
Feb	82.9 (72%)	June	38.4 (73%)	Oct	68.0 (63%)
Mar	121.6 (44%)	July	26.7 (100%)	Nov	108.0 (52%)
Apr	167.7 (40%)	Aug	32.9 (118%)	Dec	122.4 (39%)

Figure 1. George Bay (also known as St. Georges Bay), extreme southwest of Cape Breton Island (Gregory et al., 1993)



MABOU HARBOUR Zone 4Tg Chart 4448 Bay ID..CM

Area (CD)	5.0 km^2	Area (HW)	7.1 km^2
Perimeter	32.7 km	Volume (CD)	23.0 $10^6 m^3$
Axis Length	8.3 km	Maximum Depth	14.6 m
Section Width	1.7 km	Section Area	169.2 m^2

Tidal Range		Tidal Volume	Tidal Current	
Mean	Large	Mean tide	Mean	Peak
0.80 m	1.30 m	4.8 $10^6 m^3$	1.28 m/s	2.02 m/s

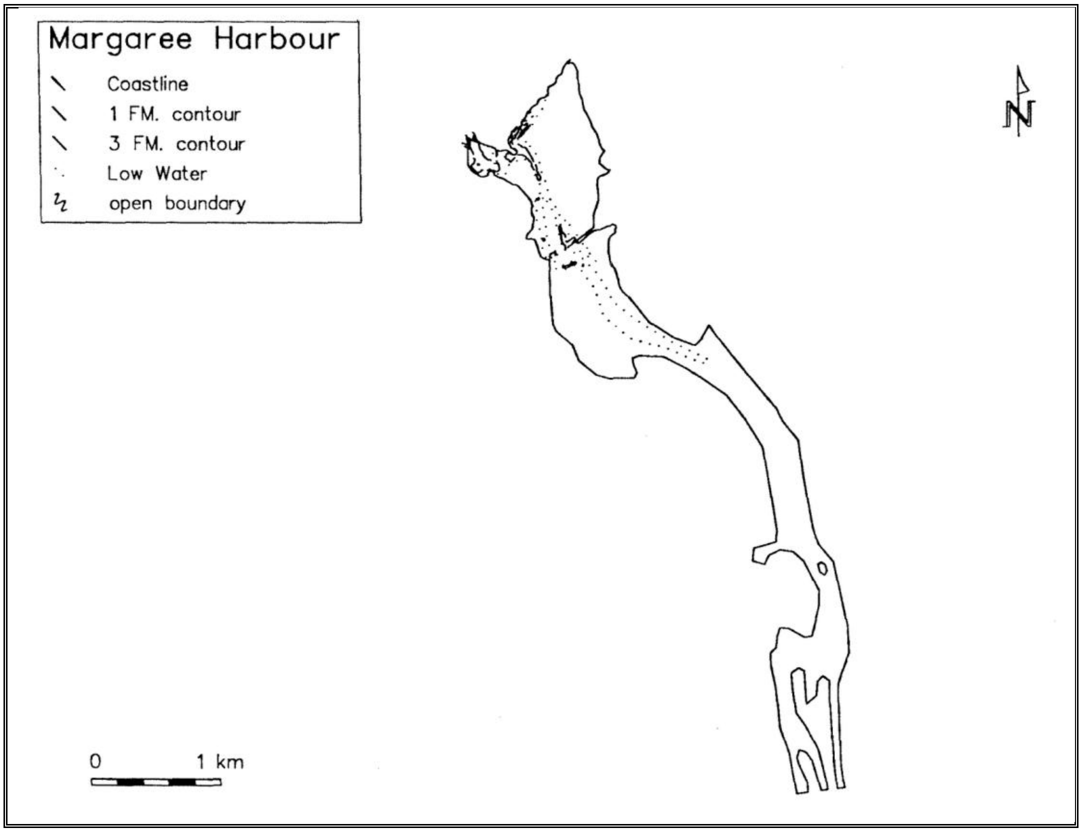
Flushing time 64.8 hr
Tidal/Freshwater volume ratio 13.27

Watershed Area 360.7 km^2

Freshwater Discharge m^3/s (Standard Deviation)

Jan	15.2 (61%)	May	44.2 (37%)	Sept	9.3 (51%)
Feb	11.2 (59%)	June	15.9 (54%)	Oct	9.3 (42%)
Mar	12.0 (70%)	July	6.7 (39%)	Nov	22.0 (35%)
Apr	24.7 (47%)	Aug	7.3 (72%)	Dec	18.8 (42%)

Figure 2. Mabou Harbour, about 60 km south of Cheticamp (Gregory et al., 1993



MARGAREE HARBOUR Zone 4Tg Chart 4449
Bay ID..CW

Area (CD)	0.3 km^2	Area (HW)	2.4 km^2
Perimeter	7.4 km	Volume (CD)	0.0 $10^6 m^3$
Axis Length	6.1 km	Maximum Depth	6.6 m
Section Width	0.1 km	Section Area	169.3 m^2

Tidal Range		Tidal Volume	Tidal Current	
Mean	Large	Mean tide	Mean	Peak
0.70 m	1.10 m	0.9 $10^6 m^3$	0.25 m/s	0.39 m/s

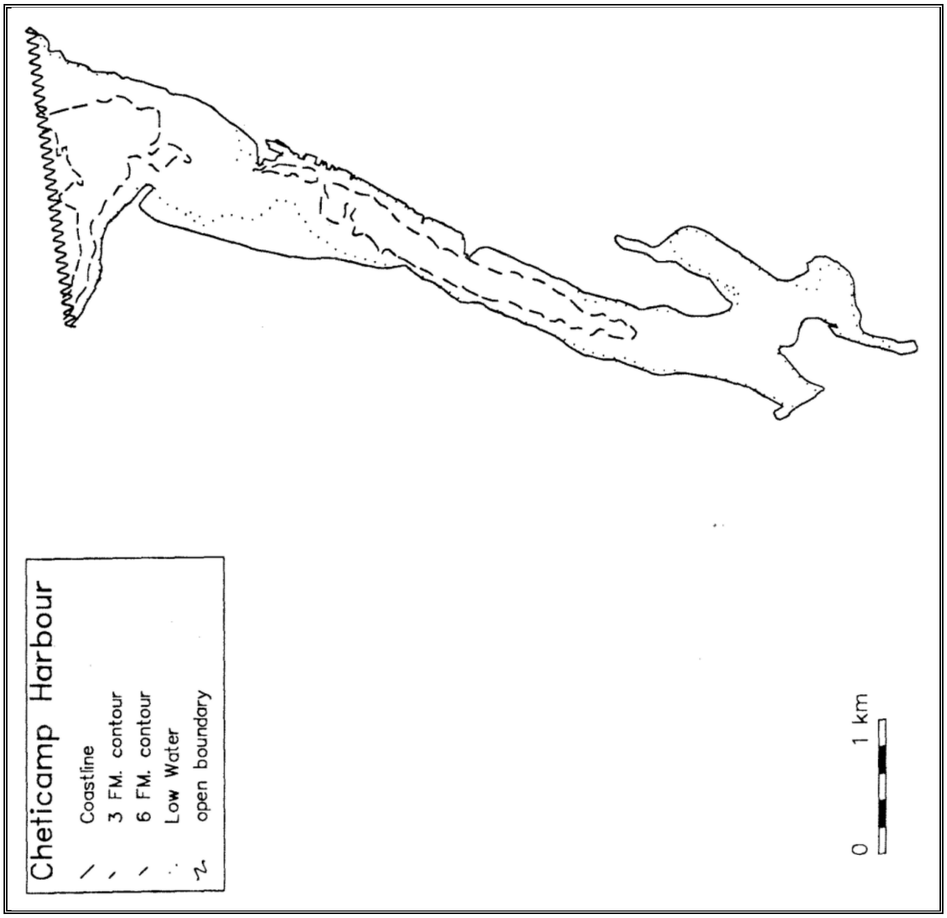
Flushing time 2.7 hr
Tidal/Freshwater volume ratio 0.79

Watershed Area 1151.7 km^2

Freshwater Discharge m^3/s (Standard Deviation)

Jan	48.5 (61%)	May	141.1 (37%)	Sept	29.6 (51%)
Feb	35.7 (59%)	June	50.7 (54%)	Oct	49.4 (42%)
Mar	38.2 (70%)	July	21.4 (39%)	Nov	70.1 (35%)
Apr	78.9 (47%)	Aug	23.3 (72%)	Dec	60.1 (42%)

Figure 3. Margaree Harbour, about 60 km south of Cheticamp (Gregory et al., 1993)



CHETICAMP HARBOUR Zone 4Tg Chart 4449
Bay ID..CV

Area (CD)	3.9 km^2	Area (HW)	4.5 km^2
Perimeter	19.2 km	Volume (CD)	16.0 10^6m^3
Axis Length	6.8 km	Maximum Depth	14.6 m
Section Width	2.1 km	Section Area	17907.3 m^2

Tidal Range		Tidal Volume	Tidal Current	
Mean	Large	Mean tide	Mean	Peak
0.70 m	1.10 m	2.9 10^6m^3	0.01 m/s	0.01 m/s

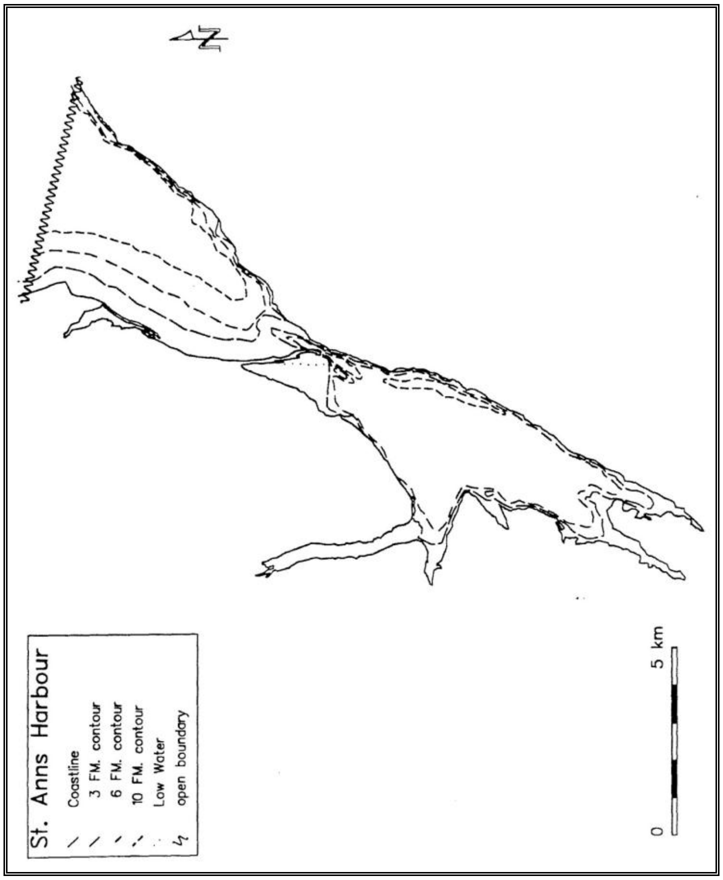
Flushing time 73.0 hr
Tidal/Freshwater volume ratio 41.55

Watershed Area 51.3 km^2

Freshwater Discharge m^3/s (Standard Deviation)

Jan	1.7 (50%)	May	9.7 (30%)	Sept	1.7 (56%)
Feb	1.9 (56%)	June	3.9 (62%)	Oct	3.1 (37%)
Mar	1.9 (68%)	July	1.0 (50%)	Nov	4.4 (27%)
Apr	4.1 (65%)	Aug	1.5 (58%)	Dec	3.4 (38%)

Figure 4. Cheticamp Harbour (Gregory et al., 1993)



ST. ANNS HARBOUR Zone 4Vn Chart 4367
Bay ID..BJ

Area (CD)	49.9 km^2	Area (HW)	50.2 km^2
Perimeter	77.2 km	Volume (CD)	590.3 $10^6 m^3$
Axis Length	19.1 km	Maximum Depth	27.4 m
Section Width	10.5 km	Section Area	86292.8 m^2

Tidal Range		Tidal Volume	Tidal Current	
Mean	Large	Mean tide	Mean	Peak
0.90 m	1.30 m	45.0 $10^6 m^3$	0.02 m/s	0.04 m/s

Flushing time 168.8 hr
Tidal/Freshwater volume ratio 49.77

Watershed Area 364.8 km^2

Freshwater Discharge m^3/s (Standard Deviation)

Jan	23.2 (45%)	May	109.1 (32%)	Sept	16.3 (76%)
Feb	23.4 (60%)	June	47.5 (62%)	Oct	35.7 (45%)
Mar	30.6 (71%)	July	15.1 (136%)	Nov	64.0 (45%)
Apr	53.4 (65%)	Aug	15.7 (76%)	Dec	52.0 (42%)

Figure 5. St. Ann's Harbour, about 20 km west of Sydney, west of and parallel to but independent of the Great Bras d'Or Channel (Gregory et al., 1993)

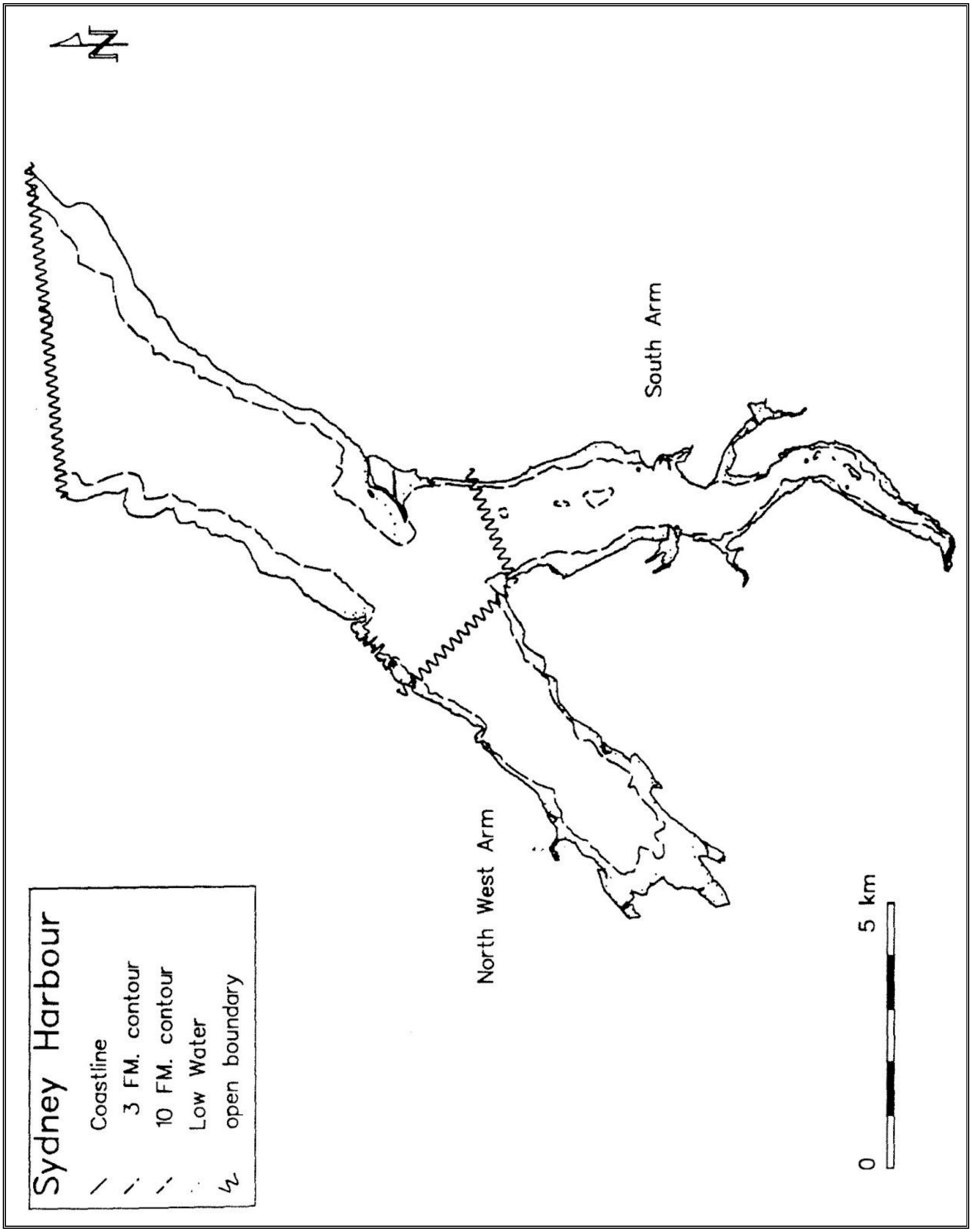


Figure 6. Sydney Harbour, including the south and north west arms, east of the Great Bras d'Or Channel and St. Andrew's Channel (Gregory et al., 1993)

SYDNEY HARBOUR Zone 4Vn Chart 4315 Bay ID..CB

Area (CD)	52.0 km^2	Area (HW)	54.4 km^2
Perimeter	78.2 km	Volume (CD)	517.0 $10^6 m^3$
Axis Length	21.3 km	Maximum Depth	19.0 m
Section Width	6.2 km	Section Area	73021.8 m^2

Tidal Range Mean	Tidal Range Large	Tidal Volume Mean tide	Tidal Current Mean	Tidal Current Peak
0.90 m	1.40 m	47.9 $10^6 m^3$	0.03 m/s	0.05 m/s

Flushing time 140.1 hr
Tidal/Freshwater volume ratio 104.01

Watershed Area 490.6 km^2

Freshwater Discharge m^3/s (Standard Deviation)

Jan	22.1 (54%)	May	23.5 (68%)	Sept	10.8 (57%)
Feb	17.3 (66%)	June	12.8 (67%)	Oct	19.4 (50%)
Mar	24.4 (44%)	July	8.5 (62%)	Nov	30.8 (44%)
Apr	38.0 (45%)	Aug	8.9 (85%)	Dec	30.8 (37%)

SYDNEY HARBOUR SOUTH ARM Zone 4Vn Chart 4315 Bay ID..CBa

Area (CD)	11.1 km^2	Area (HW)	11.9 km^2
Perimeter	32.4 km	Volume (CD)	114.0 $10^6 m^3$
Axis Length	10.7 km	Maximum Depth	19.0 m
Section Width	2.2 km	Section Area	27264.6 m^2

Tidal Range Mean	Tidal Range Large	Tidal Volume Mean tide	Tidal Current Mean	Tidal Current Peak
0.90 m	1.40 m	10.3 $10^6 m^3$	0.02 m/s	0.03 m/s

Flushing time 142.4 hr
Tidal/Freshwater volume ratio 41.04

Watershed Area 269.4 km^2

Freshwater Discharge m^3/s (Standard Deviation)

Jan	12.1 (54%)	May	12.9 (68%)	Sept	5.9 (57%)
Feb	9.5 (66%)	June	7.0 (67%)	Oct	10.7 (50%)
Mar	13.4 (44%)	July	4.7 (62%)	Nov	16.9 (44%)
Apr	20.9 (45%)	Aug	4.9 (85%)	Dec	16.9 (37%)

SYDNEY HARBOUR NORTH WEST ARM Zone 4Vn Chart 4315 Bay ID..CBb

Area (CD)	12.8 km^2	Area (HW)	13.5 km^2
Perimeter	23.9 km	Volume (CD)	93.0 $10^6 m^3$
Axis Length	8.1 km	Maximum Depth	17.0 m
Section Width	2.6 km	Section Area	21767.4 m^2

Tidal Range Mean	Tidal Range Large	Tidal Volume Mean tide	Tidal Current Mean	Tidal Current Peak
0.90 m	1.40 m	11.8 $10^6 m^3$	0.02 m/s	0.04 m/s

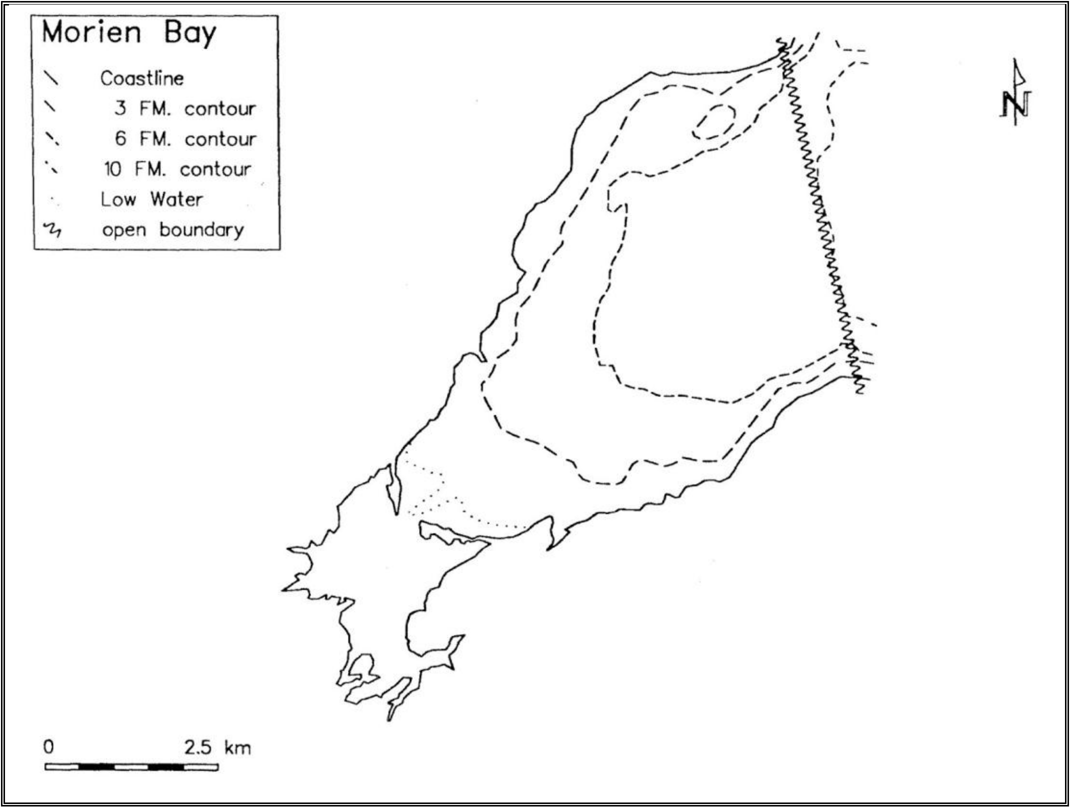
Flushing time 103.4 hr
Tidal/Freshwater volume ratio 83.80

Watershed Area 151.4 km^2

Freshwater Discharge m^3/s (Standard Deviation)

Jan	6.8 (54%)	May	7.2 (68%)	Sept	3.3 (57%)
Feb	5.3 (66%)	June	3.9 (67%)	Oct	6.0 (50%)
Mar	7.5 (44%)	July	2.6 (62%)	Nov	9.5 (44%)
Apr	11.7 (45%)	Aug	2.7 (85%)	Dec	9.5 (37%)

Figure 6. (cont) Sydney Harbour, including the south and north west arms, east of the Great Bras d'Or Channel and St. Andrew's Channel (Gregory et al., 1993)



MORIEN BAY Zone 4Vn Chart 4375
Bay ID..BO

Area (CD)	26.7 km^2	Area (HW)	31.4 km^2
Perimeter	19.5 km	Volume (CD)	210.0 10^6m^3
Axis Length	9.3 km	Maximum Depth	18.2 m
Section Width	4.7 km	Section Area	47205.3 m^2

Tidal Range		Tidal Volume	Tidal Current	
Mean	Large	Mean tide	Mean	Peak
1.00 m	1.50 m	29.0 10^6m^3	0.03 m/s	0.04 m/s

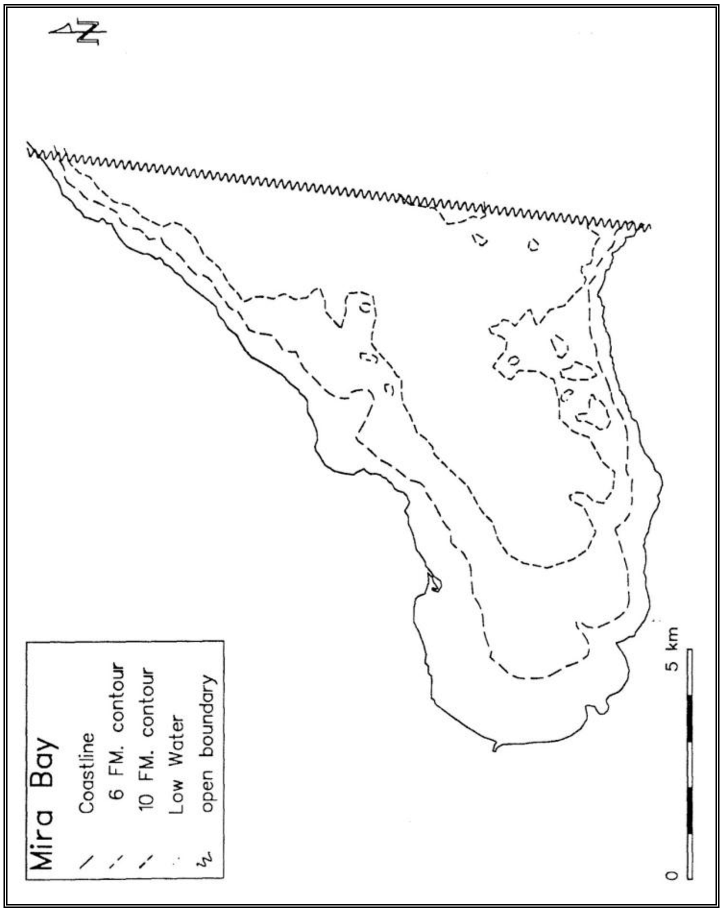
Flushing time 95.7 hr
Tidal/Freshwater volume ratio 360.49

Watershed Area 92.4 km^2

Freshwater Discharge m^3/s (Standard Deviation)

Jan	4.8 (45%)	May	3.9 (50%)	Sept	1.8 (93%)
Feb	2.7 (73%)	June	1.8 (63%)	Oct	2.7 (57%)
Mar	4.6 (53%)	July	1.3 (87%)	Nov	4.0 (45%)
Apr	9.6 (53%)	Aug	1.3 (87%)	Dec	4.8 (32%)

Figure 7. Morien Bay, near Glace Bay and Flint Island, west of Scatarie Island (Gregory et al., 1993)



MIRA BAY

Zone 4Vn · Chart 4375
Bay ID..BI

Area (CD)	78.6 km^2	Area (HW)	78.7 km^2
Perimeter	34.7 km	Volume (CD)	1115.0 10^6m^3
Axis Length	12.8 km	Maximum Depth	27.4 m
Section Width	13.1 km	Section Area	225139.0 m^2

Tidal Range		Tidal Volume	Tidal Current	
Mean	Large	Mean tide	Mean	Peak
1.00 m	1.50 m	78.6 10^6m^3	0.02 m/s	0.02 m/s

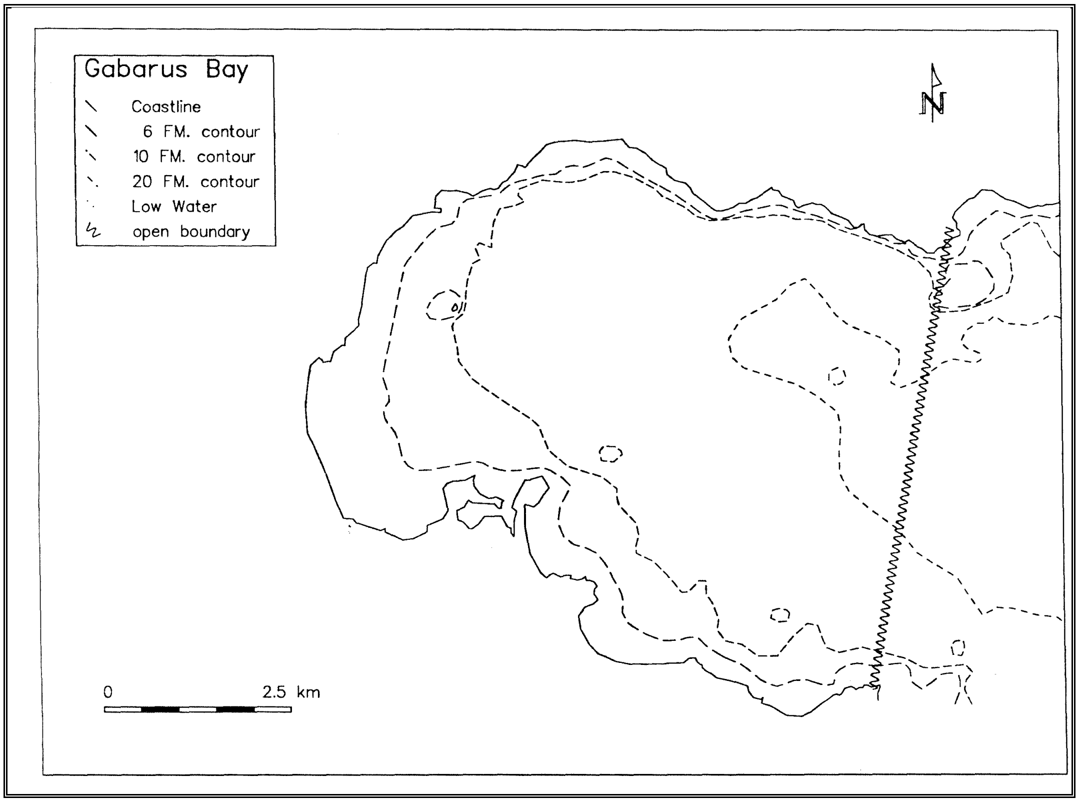
Flushing time 182.1 hr
Tidal/Freshwater volume ratio 59.18

Watershed Area 1415.8 km^2

Freshwater Discharge m^3/s (Standard Deviation)

Jan	63.7 (54%)	May	67.8 (68%)	Sept	31.1 (57%)
Feb	50.0 (66%)	June	36.9 (67%)	Oct	56.3 (50%)
Mar	70.4 (44%)	July	24.7 (62%)	Nov	88.9 (44%)
Apr	109.4 (45%)	Aug	25.5 (85%)	Dec	88.9 (37%)

Figure 8. Mira Bay, east of Glace Bay, near Scatarie Island (Gregory et al., 1993)



GABARUS BAY Zone 4Vn Chart 4375
Bay ID..BH

Area (CD)	38.8 km²	Area (HW)	42.6 km²
Perimeter	28.1 km	Volume (CD)	922.0 $10^6 m^3$
Axis Length	8.3 km	Maximum Depth	36.6 m
Section Width	5.6 km	Section Area	157696.2 m²

Tidal Range		Tidal Volume	Tidal Current	
Mean	Large	Mean tide	Mean	Peak
1.10 m	1.70 m	44.8 $10^6 m^3$	0.01 m/s	0.02 m/s

Flushing time 261.6 hr
Tidal/Freshwater volume ratio 564.76

Watershed Area 84.1 km²

Freshwater Discharge m^3/s (Standard Deviation)

Jan	3.8 (54%)	May	4.1 (68%)	Sept	1.9 (57%)
Feb	3.0 (66%)	June	2.2 (67%)	Oct	3.4 (50%)
Mar	4.2 (44%)	July	1.4 (62%)	Nov	5.3 (44%)
Apr	6.5 (45%)	Aug	1.5 (85%)	Dec	5.3 (37%)

Figure 9. Gabarus Bay, between Louisbourg and Gabarus, south of Scatarie Island (Gregory et al., 1993)

Appendix B

Sustainability Principles

OEER recommends that the Province of Nova Scotia adopt the following ten sustainability principles to guide marine renewable energy development in the Bay of Fundy. These principles should be incorporated as appropriate into:

- Provincial policy on marine renewable energy development or coastal zone management;
- Any new legislation regarding marine renewable energy development;
- Guideline for all environmental assessments of marine renewable energy proposals;
- Terms of reference for future phases of the SEA; and
- Terms of reference for any ongoing research, integrated management, or stakeholder involvement body or process.

1.1 The marine renewable energy resource in the Bay of Fundy should remain under public control and management.

1.2 Marine renewable energy developments should be planned, approved and managed within a strategic context that will ensure net reductions of Nova Scotia's greenhouse gas emissions.

1.3 Nova Scotia, New Brunswick and the Government of Canada should collaborate in the management of the marine renewable energy resource to ensure protection of the entire Bay of Fundy ecosystem.

1.4 Commercial application of marine renewable energy developments should go ahead only when a proponent can demonstrate that there will be no significant adverse effects on the fundamental hydrodynamic processes of the Bay of Fundy tidal regime (energy flow, erosion, sediment transportation and deposition) or on biological processes and resources.

1.5 Until near and far-field effects of marine renewable energy are well understood and deemed to be acceptable, development should take place incrementally, supported by an effective and transparent research and monitoring program, installations should be removable, and clear thresholds should be established to indicate when removal would be required.

1.6 Adverse effects on the fishery or on aquaculture by energy developments should be avoided, or should be minimized. If displacement takes place, or if adverse environmental effects occur, compensation must be addressed.

1.7 Development of marine renewable energy should be planned and managed to ensure lasting stewardship of the resource in order to deliver durable socioeconomic benefits to present and future generations in Nova Scotia

1.8 Nova Scotia's marine renewable energy development strategy should strengthen local community development capacity, through measures such as access to the resource, encouragement of community-scale technology developments and uses, or revenue sharing.

1.9 Marine renewable energy development should be part of an Integrated Coastal Zone Management approach for the Bay of Fundy, including the informed participation and cooperation of all stakeholders in order to balance environmental, economic, social, cultural, and recreational objectives, within the limits set by ecosystem dynamics.

1.10 Research, monitoring and decision making related to marine renewable energy should be carried out in an open and transparent manner. The public should have access to all environmental information. The public should have access to resource assessments information, respecting the need to keep certain commercial information confidential. Requests by proponents to keep information confidential should undergo stringent review.

AECOM

Appendix C

Tidal and Wave Energy Demonstration Facilities

1. EMEC - Orkney, Scotland

The European Marine Energy Centre (EMEC), located in Orkney, Scotland, was opened in August 2004 to provide a site for wave and tidal energy converter research. The centre's goal is to facilitate the advancement of tidal and wave devices from prototype to commercial development. EMEC has 14 full scale berths and two smaller scale test sites.

EMEC hosts a wave test site (Billia Croo) a tidal test site (Fall of Warness) a nursery wave test site (Scapa Flow) and a nursery tidal test site (Shapinsay Sound) For tidal, EMEC's infrastructure consists of 5 subsea cables, transmission lines, substation, and connection to the Scotland national power grid. Each subsea cable is capable of conducting 5 MW of electricity (Faber Maunsell and Metoc PLC 2007). EMEC provides the following services: power performance verification and certification, reliability verification, electrical system testing, safety system testing, noise measurements, structural load measurements and verification, and subsystem testing. Their tidal clients include:

- Andritz Hydro Hammerfest;
- Atlantis Resources Corporation;
- Bluewater Energy Services;
- Kawasaki Heavy Industries;
- Open Hydro;
- Scotrenewables;
- Tidal Generation Ltd; and,
- Voith Hydro.

Their current and past wave energy clients include:

- Aquamarine Power;
- E-On;
- ScottishPower Renewables;
- Seatricity;
- Vattenfall;
- Wello Oy;
- Pelamis Wave Power; and,
- Aw Energy.

EMEC currently hosts eleven utility scale wave and tidal technologies undergoing deployment and testing, with three more currently under construction (www.emec.org.uk).

2. FORCE – Minas Passage, Nova Scotia

Located in Nova Scotia's Bay of Fundy, the Fundy Ocean Research Centre for Energy (FORCE) is a not-for-profit corporation that provides environmental monitoring and common infrastructure to test in-stream tidal energy technology. The infrastructure provided consists of four subsea cables (to be installed in 2012-14), a substation and 69 kVa transmission line to the main grid at Parrsboro, NS. FORCE receives funding from the federal and provincial governments, Encana Corporation and the participating developers who wish to test their TISEC technologies. FORCE administers the facility, which has four berths and is permitted to host TISECs producing a combined output of 5 MW of electricity. The FORCE site has an approved environmental assessment from both provincial and federal regulators. Berth holders are required to obtain specific federal and provincial operating permits, including clearance from DFO and Transport Canada.

Four technologies/designs are slated for testing: Open Hydro/Nova Scotia Power Inc., Marine Current Turbines/ Minas Basin Pulp and Power, Alstom Hydro/Clean Current, and Irving Shipbuilding/Lockheed Martin/Atlantic Resources Corporation (Government of Nova Scotia 2011a).

3. Open Hydro/Nova Scotia Power Inc.

Open Hydro's 1MW TISEC is a 6.0 m diameter open-centred rotor encased in a shroud to accelerate the water flow over the blades. It was deployed at the FORCE site using a custom designed heavy lift barge in November, 2009 and retrieved a year later. A 400-tonne gravity base, built by Cherubini Metal Works in Dartmouth, NS held the unit in place. The TISEC was not grid connected. Unfortunately, the rotor blades failed shortly after deployment although the shroud and gravity base remained undamaged through the 1-year deployment.

4. Marine Current Turbines/Minas Basin Pulp and Power

Marine Current Turbines (MCT) proposes to install one or more 3 MW units, each with two open propellers similar to an onshore wind turbine before 2016. MCT uses reversing pitch propellers to maximize efficiency of energy extraction from the tidal stream (FORCE 2012). The unit will be constructed in Hantsport, NS on the Minas Basin Pulp and Power Company property.

Marine Current Turbines (MCT) began operating a demonstration tidal turbine in 2003 at Lynmouth, Devon. The SeaFlow unit consisted of a single 300 kW tidal turbine prototype with an 11 m diameter rotor. The turbine is designed for deployment in water depths of 20 to 30 meters with a resource of 2.3 - 2.6 m/s (4.5 to 5 knots) during peak spring tides (Jacques Whitford 2008). MCT has also installed their 1.2 MW SeaGen device in Strangford Lough, Ireland. The SeaGen turbine has twin 16 m diameter bi-directional rotors. The system is connected to the local electrical grid adjacent to a substation south of Strangford.

5. Clean Current / Alstom Hydro

Clean Current's TISEC was developed in Canada and the 3.5 m diameter, 65 kW prototype tested at Race Rocks, offshore from Vancouver Island in BC. Clean Current's 1 MW, open-centred rotor is designed to operate at depths of 30 metres or greater (FORCE 2012) and is expected to be deployed in 2013. The prototype successfully generated electricity in currents up to 3.4 m/s (6.6 knots) and remained operational for 6 months.

6. Irving Shipbuilding / Lockheed Martin and Atlantis Resources Corporation

Atlantis Resources Corporation will deploy their 1 MW AR1000 Mark II turbine, one of the largest in the world in FORCE's fourth berth. Lockheed Martin will complete the engineering design elements, production drawings and procurement of major turbine components as well as systems testing while

Irving Shipbuilding will supervise construction of the turbine base and device assembly. Atlantis has been developing in-stream turbine technology since 2002 and has tested numerous designs in Australia and at EMEC.

7. Wave Hub - Cornwall, Southwest England

Wave Hub is an eight square kilometer grid connected wave technology test facility located 16 km offshore of southwest England. Similar to FORCE and EMEC, it provides share infrastructure for single units and arrays. The heart of the facility is the subsea electrical hub to which the wave energy devices are connected. The hub is connected to the mainland via a 15 km subsea cable. The facility has four berths, each with a capacity of 4-5 MW and the entire site is permitted for a maximum output of 20 MW.