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Seabed characterization for the development of marine renewable energy on the Pacific margin of Canada

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ABSTRACT

An inventory of Canada's marine renewable energy resources based on numerical modeling of the potential tidal, wave and wind energy has been published that identifies areas with maximum resource potential. However, the inventory does not consider the seabed geological conditions that will control the safe development of seabed installations and cable corridors. The Geological Survey of Canada (Natural Resources Canada) has therefore undertaken an assessment of seafloor geological characteristics and physical environmental parameters that will be encountered during any extensive deployment of marine renewable energy systems for the Pacific offshore of Canada. Here we present an overview of seabed characterization for key sites for each of the three energy types.

Narrow passages exiting the Salish Sea near the Canadian boundary with the United States and northwards out of the Strait of Georgia provide very promising sites for tidal generation. Here, elliptical fields of very large subaqueous dunes, from 12 to 28 m in height, present a significant challenge to site development. Along the exposed continental shelf of Vancouver Island focused wave-energy close to shore (40–60 m water depth) offers significant energy potential, but any engineering systems would have to be founded on a seafloor made up of a mobile gravel lag and an extensive boulder pavement. A large wind farm proposed for the Pacific North Coast would be built on an extensive shallow bank that has active sediment transport and a large field of sand ridges that have developed within a macrotidal environment. A significant challenge is providing for a safe seafloor cable corridor of over 100 km that crosses a large subaqueous dune field to connect to the electrical grid on the mainland. These examples show how geoscience has and will provide critical information to project proponents and regulators for the safe development of marine renewable energy.

1. Introduction

Marine renewable energy (tidal, wave and offshore wind) is a significant new resource that will be integrated into the Canadian energy supply. More than 2 gigawatts of wind power capacity has been installed offshore Europe in the past 20 years and the application of that experience is rapidly spreading to other parts of the globe, including Canada. Differing environmental and geological conditions require that experience related to foundation design and construction be extrapolated within a rational framework (Schneider et al., 2010). Knowledge of the geological and geophysical characteristics of the seabed is critical to understanding the geotechnical conditions on which marine renewable conversion systems are founded or anchored. For example, tidal and many wave systems, whether flexible or rigid, require moorings that must be anchored to the seabed so that both the turbine and mooring are secured against movement. This can be done by a penetrating anchor or by using a gravity foundation. For an equivalent resistive load, the footprint of a gravity foundation, such as a wind turbine monopole on the seabed, is greater than a penetrating foundation (IEA-RETD, 2012). Both systems are susceptible to scour. In addition, electrical transmission to shore is an integral aspect of any renewable energy project and knowledge of the seabed characteristics for cable routing is critical.

The Pacific margin of Canada has many advantages for renewable energy generation such as a meso- to macrotidal environment, the entire north Pacific for wave fetch, and some of the strongest and most consistent winds anywhere in North America. Consequently, proposals for the development of all three types of power are presently under review. Our objective here is to interpret the seabed characteristics and sedimentary processes active at the key sites where renewable energy systems will eventually be installed. The site with the highest potential for each type of energy source was selected for more detailed site analyses. Definition of areas suitable for potential marine renewable resource development for the Pacific offshore of Canada is derived from Cornett (2006) for tide, Cornett (2006) and Cornett and Zhang (2008) for wave and from the

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Canadian Wind Energy Atlas developed by Environment Canada (2011) for wind.

2. British Columbia offshore setting

The western Canadian continental margin comprises the convergent boundary between the Juan de Fuca Plate and the North America Plate along western Vancouver Island, and the transform fault boundary between the Pacific and North America Plates along the west coast of the Haida Gwaii (Fig. 1). The western Canadian continental shelf can be broadly divided into three geographic regions, Salish Sea, Vancouver Island Shelf and the Pacific North Coast. Each region's physiography has been uniquely impacted by a history of glaciation, tectonism, oceanography and sea level change.

2.1. Salish Sea

The Salish Sea consists of three inland straits surrounded by the British Columbia (BC) mainland, Washington State and Vancouver Island, making it one of the world's largest inland seas encompassing 400 islands and 7500 km of coastline (Fig. 1). The inland sea connects with the open sea in the south, first through two channels and then through Juan de Fuca Strait and in the north the Strait of Georgia connects to the Pacific first through four narrow channels then Johnstone Strait (Fig. 1).

The Salish Sea is comprised of a series of structural depressions, over-deepened by Tertiary fluvial erosion and Quaternary glaciation and partially infilled by glacial and post-glacial sediments (Barrie et al., 2005). Most of the Salish Sea is presently sediment starved with sediment capture within the coastal fjords and inlets, except in the southern Strait of Georgia where sedimentation from the Fraser River dominates the surficial geology with Holocene sediment thicknesses varying from zero on Pleistocene ridges to greater than 300 m within the basin (Mosher and Hamilton, 1998).

2.2. Vancouver Island shelf

The continental shelf west of Vancouver Island ranges from 5 to 75 km wide and is characterized by an inshore region of complex

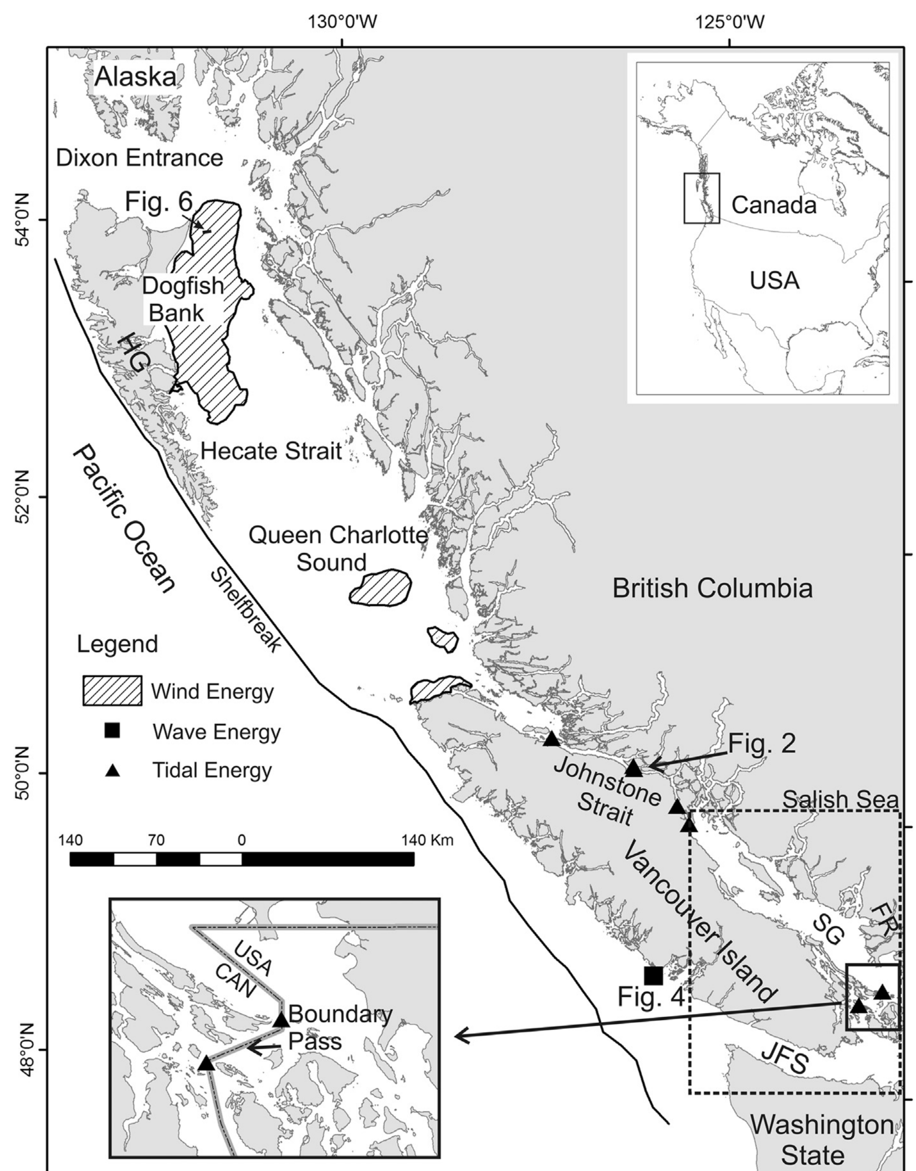

Fig. 1. The Pacific margin of Canada, highlighting the locations of potential tidal, wave and wind energy sites (HG is Haida Gwaii, SG is Strait of Georgia, FR is Fraser River, JFS is Juan de Fuca Strait). The locations of Figs. 2, 4, and 6 are shown.