New Request for Proposals and Hydrodynamic Modelling Project Updates

In this issue of ‘Currents’ OEER Association (OEER) introduces its new Request for Proposals (RFP) for tidal marine energy research, as well as shares outcomes from its Tidal Energy Research Program’s first completed project. In January 2011, Martec Limited presented its final report with interesting insights into the near-field effects of tidal power extraction in the Bay of Fundy. We also provide an update on another tidal energy project led by researchers at Dalhousie University and the Department of Fisheries and Oceans Canada.

Future issues of ‘Currents’ will continue to highlight OEER-funded researchers and their projects. Other research in progress, not mentioned in this issue, includes projects led by Dr. Anna Redden and Dr. Michael Stokesbury, Acadia University; Dr. Peter Smith, Department of Fisheries and Oceans Canada; Dr. Richard Karsten, Acadia University; Dr. Norman Cochrane and Dr. Gary Melvin, Department of Fisheries and Oceans Canada; Dr. Danika van Proosdij, Saint Mary’s University; and Dr. Andrew Cornett, National Research Council - Canadian Hydraulics Centre.

Request for Proposals: Research on Tidal Marine Energy

OEER is pleased to announce a new Request for Proposals (RFP) to fund new projects in several priority research areas. In October 2010, OEER and Fundy Ocean Research Center for Energy (FORCE) held a Tidal Energy Workshop in Wolfville, Nova Scotia. The objective of the workshop was to provide an opportunity for researchers to present and discuss the status of research currently being undertaken in relation to tidal energy in Nova Scotia, and related findings to-date. The meetings provided guidance in determining important remaining questions concerning the environmental impacts of tidal energy. As a result of this workshop, priority areas of research have been identified and OEER has released a new RFP that addresses topic areas in relation to Tidal In-Stream Energy Conversion (TISEC) devices. All details including specific topic areas, submission deadlines, and other requirements can be found in the full RFP on the OEER website: http://www.offshoreenergyresearch.ca
Near Field Effects of Tidal Power Extraction on Extreme Events and Coastline Integrity in the Bay of Fundy

Dr. James Warner, Dr. John Warner, Dr. Ron Watanabe, Dr. Frank Lin and Mr. Jim Covill, Martec Limited

Large scale tidal power extraction from the Bay of Fundy has the potential to directly influence the near-field and cause variations of wave energy levels that can alter the physical and ecological environment. Extreme storm events passing through the Bay of Fundy can cause coastal flooding, shoreline erosion and sediment re-distribution from the combined influence of storm waves and currents. Relatively small changes in tidal flows due to power extraction will influence the wave refraction and shoaling patterns in the near-field and cause variations of wave energy levels. Focusing of wave rays causes changes in wave direction, increases in wave energy and decreases in directional wave spreading. This effect has implications not only for the design of the power extracting units, but also the potential for significant changes in shoreline wave energy and the development of sections of increased erosion or accretion.

Objectives

Martec Limited is a leading Canadian engineering firm specializing in advanced engineering simulation technology for the design and analysis of complex structures and systems - such as ships, offshore structures, armoured vehicles, ports and harbours. Martec is known for providing smart, practical solutions to difficult engineering and technical challenges. Martec is a member of the Lloyd's Register Group of Companies and received funding from OEER in 2010 to undertake a project that would quantify the near-field effects of large scale tidal power extraction from the Minas Passage in the Bay of Fundy (see Figure 1). The researchers’ objective was aimed at establishing any resulting changes in wave conditions caused from the use of tidal energy extraction devices, which would indicate the effect of the turbines on shoreline erosion and coastline integrity.

Process & Results

The researchers implemented a spectral wave model to numerically simulate wave transformation for tidal conditions with turbines (operational), and for tidal conditions without turbines (non-operational). The predicted current fields for the operational and non-operational conditions were obtained with the use of the hydrodynamic modeling of the Bay of Fundy developed by Dr. David Greenberg of Fisheries and Oceans Canada. Time-dependent current predictions for the near-field models were input directly into the wave spectral model to assess the effects of power extraction on wave transformation. The wave-current modeling analysis was organized into three phases:

- **Phase I**: Seasonal (Non-Storm) Wave Conditions
- **Phase II**: Storm Wave Conditions
- **Phase III**: Extreme Wave Conditions

![Figure 1: Canadian Hydrographic Chart for Minas Passage, NS (Chart #4010)](chart.png)
The researchers evaluated the changes in wave conditions caused by the removal of energy from the tidal currents, which indicate the effect of tidal energy turbines on shoreline erosion and coastline integrity. To replicate the effects of tidal currents on the wave conditions in the Bay of Fundy, it was essential to combine the models for tidal currents and ocean waves, which may use different grid types, geographical coordinate systems, domains and grid resolutions. Spectral wave models called SwanOne (one-dimensional) and STWAVE (two-dimensional) were integrated with the existing circulation models for tidal currents in the Bay of Fundy to reproduce the wave-current interaction. The STWAVE wave-current model was refined to help define areas of interest in the near-field in regard to the shoreline response to changing conditions.

Results of the analysis, using the SwanOne wave model, show that changes in the current affect the spectral shape of the waves and redistribute wave energy to different frequency bands. As predicted, changes in the current produce a net change in the characteristics of energy propagating through the model. A more detailed analysis of the transformations taking place, particularly the redistribution of energy to the various frequency bands, was performed using the two-dimensional models.

The modelling of the wave-current interaction using the two-dimensional STWAVE model with the BIO tidal current model has been shown to be a powerful tool in quantifying expected changes in wave energy throughout the model domain.

Modelling results from on-going research at the Bedford Institute of Oceanography and Acadia University were integrated into the analysis to incorporate any expected changes in the flow field with the introduction of tidal energy extraction devices. In particular, Acadia University researchers simulated an extreme case of an intense concentration of 225 tidal turbines (20m diameter) that would generate an average extracted power of 600 MW. In the simulation the turbines were positioned across a portion of the Minas Passage and produced a decrease of up to 20% in current magnitude in close proximity to the turbines. Using this value of change in the current field in a portion of Minas Passage, and combining with a series of wave conditions, nearshore effects produced only small localized changes in wave energy levels at the adjacent shoreline. Therefore, it can be expected that under the conditions analyzed, the energy extraction could cause increased deposition of suspended sediment in some near-field regions of the Minas Channel, Minas Passage and the entrance to Minas Basin.

Assessing the Far Field Effects of Tidal Power Extraction on the Bay of Fundy, Gulf of Maine and Scotian Shelf

Dr. Jinyu Sheng, Dr. Daisuke Hasegawa, Dr. Keith Thompson, Dr. Paul Hill, Dalhousie University; and Dr. David Greenberg, Fisheries and Oceans Canada

Significant tidal energy extraction in the Minas Passage could affect environmental conditions in the upper and lower parts of the Bay of Fundy, the Gulf of Maine and the Scotian Shelf.

Objectives

This project's purpose is to quantify the far-field effects of tidal energy extraction in the Minas Passage on the physical environment in the Bay of Fundy, the Gulf of Maine and the western Scotian Shelf by using an ocean circulation model.

Process

As a first step, a four-level nested-grid ocean circulation modeling system was developed
using the Princeton Ocean Model. The nested-grid modeling system has a storm surge model for the eastern Canadian seaboard from the Labrador Sea to the Gulf of Maine. There are also three sub-level ocean circulation models nested inside the storm surge model.

The modeling system has been used to examine the far-field effects of tidal energy extraction in the Minas Passage on tides and tidal currents in the Bay of Fundy and Gulf of Maine system in two cases of harnessing tidal energy. The two cases examine energy extraction from (a) the entire water column and (b) the lower water column (within 20 m above the ocean-bottom) in the Minas Passage. Tidal energy extraction in the model is parameterized in terms of turbine drag (a non-linear Rayleigh friction).

**Preliminary Results**

The model results demonstrate that far-field effects in the two cases are characterized by an increase in tidal elevations and tidal currents in the Gulf of Maine and a decrease in tidal elevations and circulation in the upper part of the Bay of Fundy. The lower water column energy extraction case can only extract up to 26% of the maximum extractable tidal energy in the entire water column case, but has less impact on the tidal elevations and circulation in the Bay of Fundy and the Gulf of Maine system. The tides in the Gulf of Maine have an amplitude increase of less than 5 cm in the case of maximum energy extraction from the lower water column in the Minas Passage. This is about 25% of the expected increase by extracting the maximum energy from the whole water column (see Figure 1).

Figure 1: Normalized tidal power extraction rate ($P_{avg}/P_{max}$) in the Minas Passage (upper panel). Relative change in amplitude (color in m) of modeled $M_2$ surface elevation at the peak power extraction for the lower water column energy extraction case (lower panel).

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