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Characterizing Tidal Stream Energy Resource in the Salish Sea

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Introduction

Harvesting tidal stream energy has been gaining strong global interest as an energy resource alternative to fossil fuels for mitigating the impact of climate change and providing energy security. The Salish Sea is one of the top sites for tidal stream energy development in the USA because of its strong tidal currents in many tidal channels. This paper presents a modeling study conducted to characterize the tidal energy resource in the Salish Sea, a critical step towards deployment of tidal turbine farms.

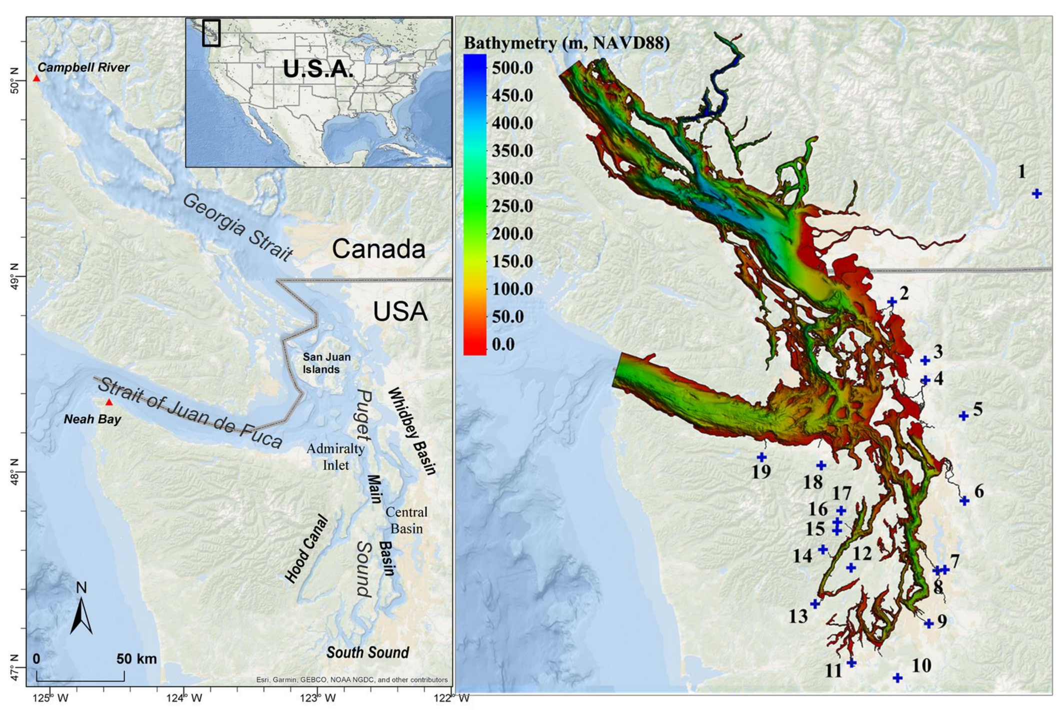

Fig.1. (a) The Salish Sea and its sub-basins with the tide gauge stations used for the open boundary condition setup shown as red triangles; (b) tidal hydrodynamic model bathymetry in NAVD88 and locations of the 19 river gauges where river discharge is added to the model. The numbers denote the river identification numbers that are considered in the model

Methods

The Salish Sea tidal hydrodynamic model is based on the Finite Volume Community Ocean Model (FVCOM, Chen et al., 2003). Model resolution varies from 50 m in tidal channels to about 500 m at open boundary (Fig. 2). The model grid consists of 843,000 nodes, 1,632,000 elements and 20 vertical layers. The model is driven by water levels at the open boundaries and stream flows. Model validation was conducted using 10 real-time tide gauges and 132 ADCP stations. Resource assessment was carried out following the International Electrotechnical Commission Technical Specification.

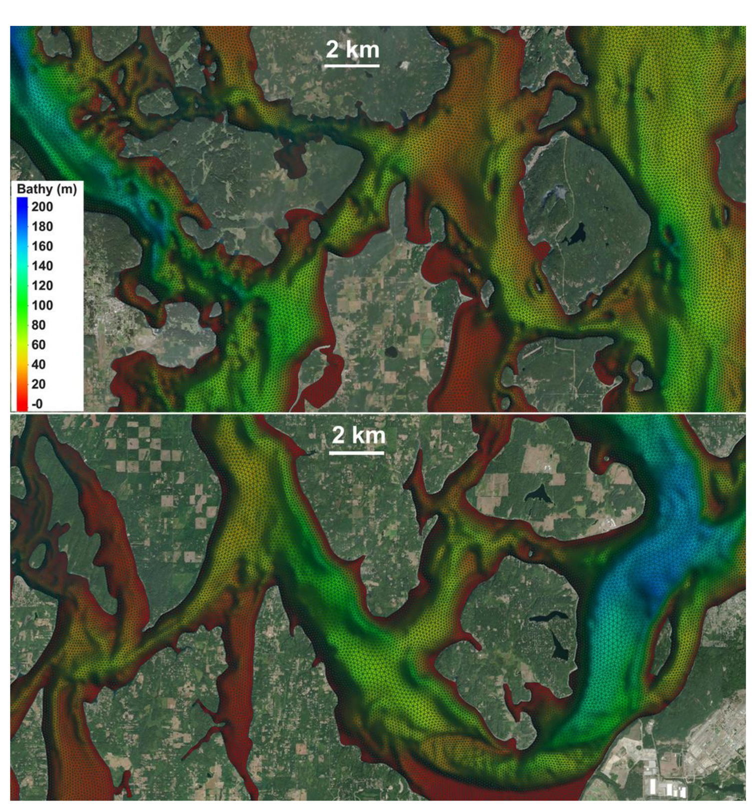

Fig.2. Model grid in the San Juan Islands (upper panel) and in South Puget Sound (lower panel).

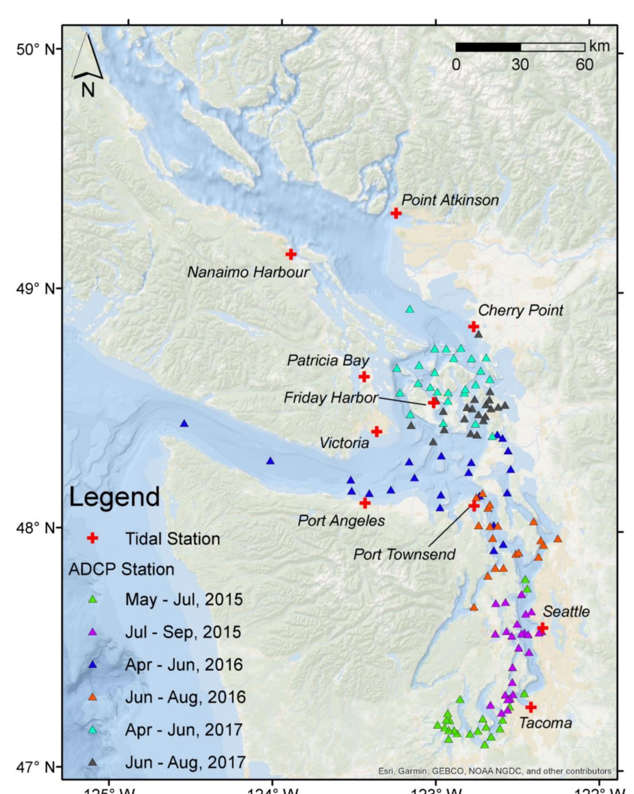

Fig.3. Distribution of tide gauges and ADCP stations in the Salish Sea.

Results

Model performance was evaluated with a set of error metrics and tidal resource parameters. *Overall, model results matched the observed data well, which demonstrates that the model is able to simulate the tidal hydrodynamics accurately in the Salish Sea (Fig. 4 and 5)* (Yang et al., 2021).

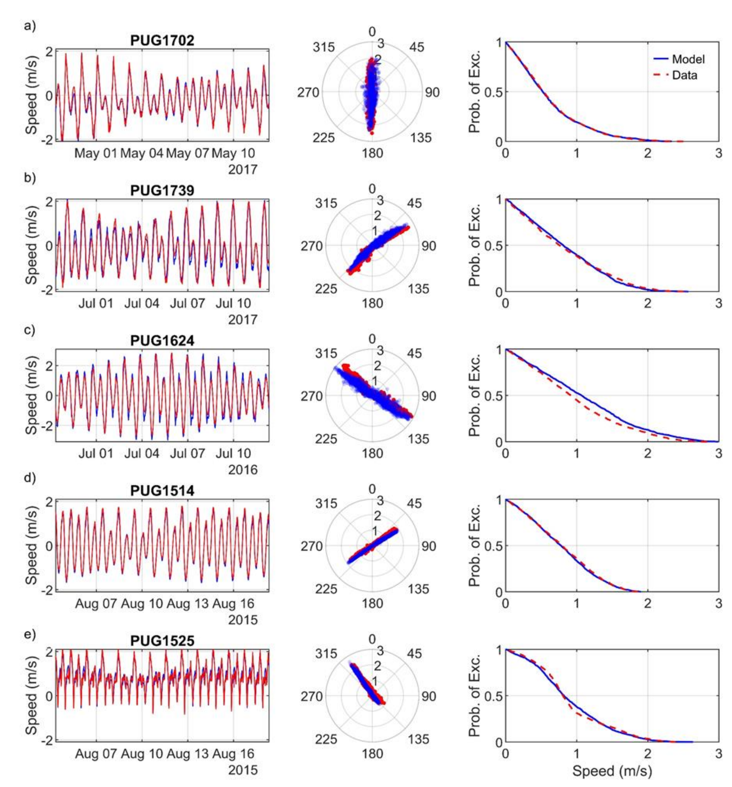

Fig. 4. Comparisons of modeled and observed depth-averaged principal velocity time series, scatter point, and velocity exceedance plots at (a) Rosario Strait (PUG1702), (b) Bellingham Channel (PUG1739), (c) Admiralty Inlet (PUG1624), (d) Rich Passage (PUG1514), and (e) Tacoma Narrows (PUG1525).

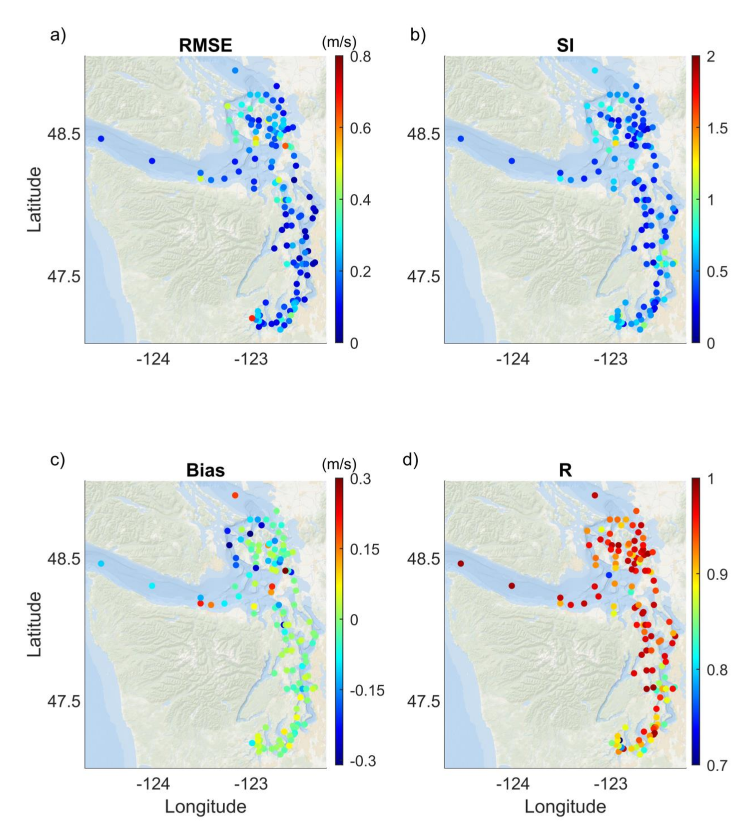

Fig. 5. Spatial distributions of the error statistics of the simulated depth-averaged velocities in the Salish Sea, including a) Root-Mean-Square-Error (RMSE), b) Scatter Index (SI), c) Bias and d) linear correlation coefficient R.

Model outputs were used to identify energy hotspots in the Salish Sea, 16 tidal channels with high current speeds (Fig. 6) and kinetic energy fluxes were identified (Fig. 7) (Yang et al., 2021).

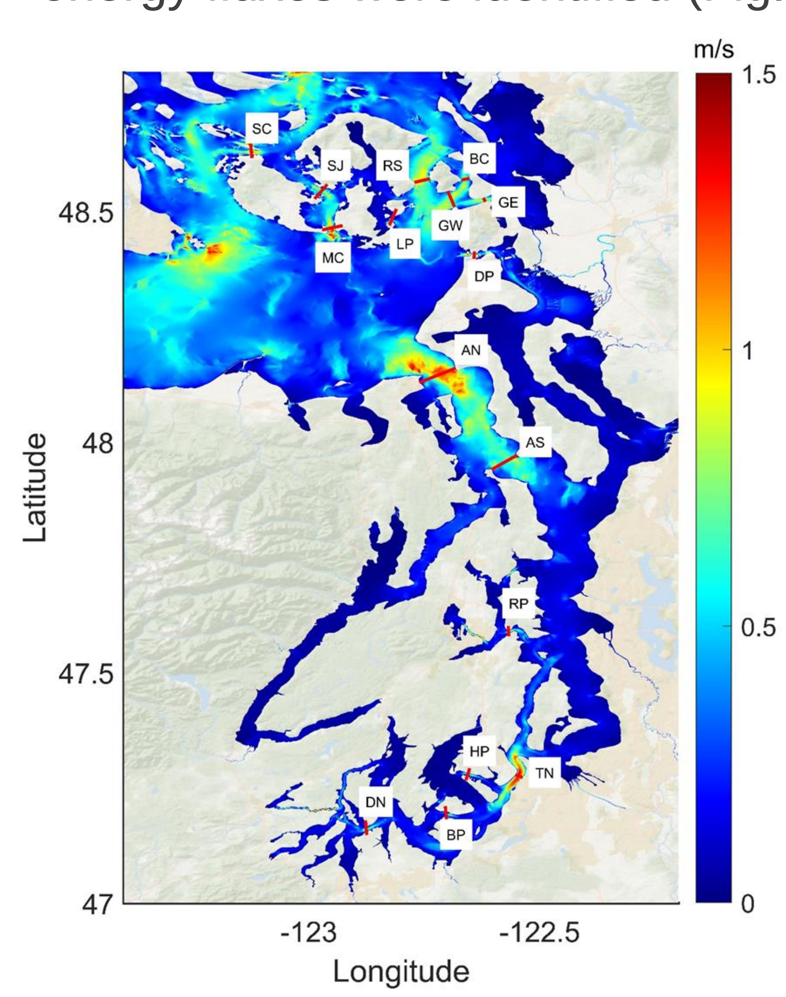

Fig. 6. Simulated depth-averaged current speed in the Salish Sea. Red lines across the channel denote the hotspot identified in the channel.

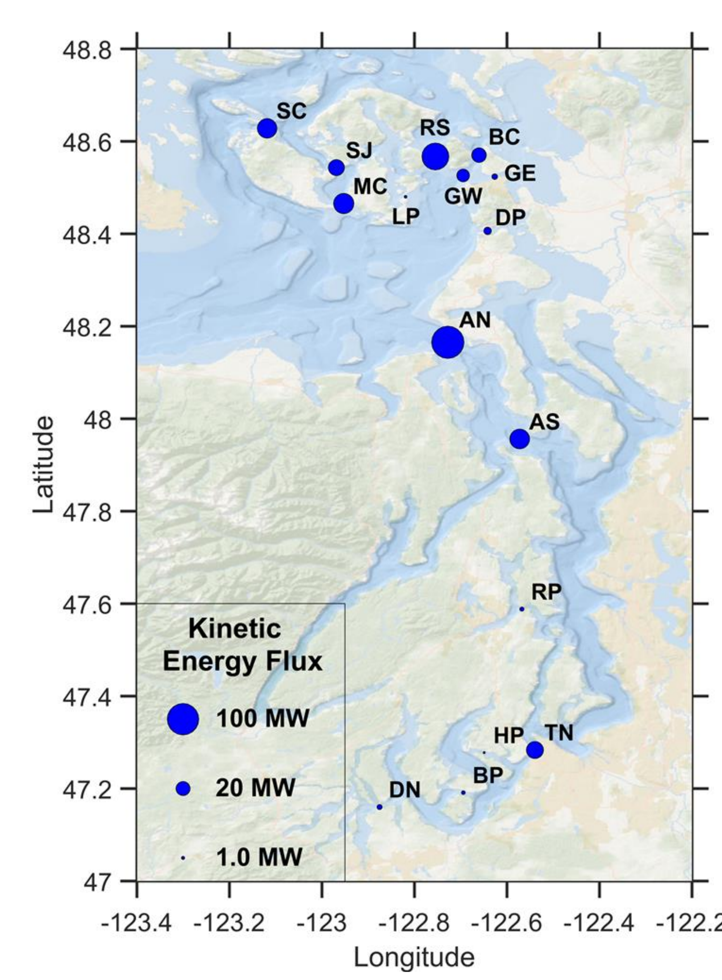

Fig. 7. Ranking of tidal energy hotspots by mean kinetic energy flux. The labels are abbreviations of the channel names .

To assess the cross-sectional variability of energy resource, mean power densities at selected tidal channels were calculated (Fig. 8-11).

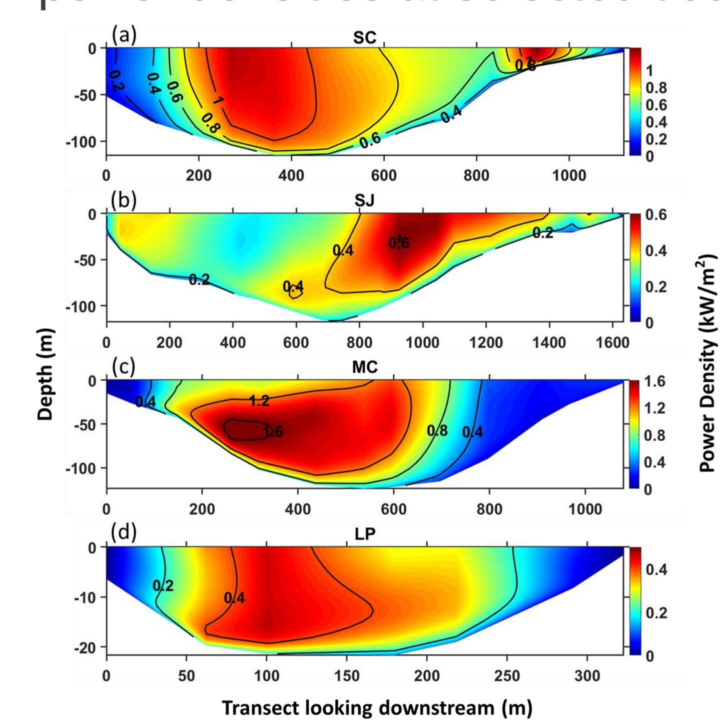

Fig. 8. Mean power density distribution in selected tidal channels in the San Juan Islands region: (a) SC; (b) SJ; (c) MC; (d) LP..

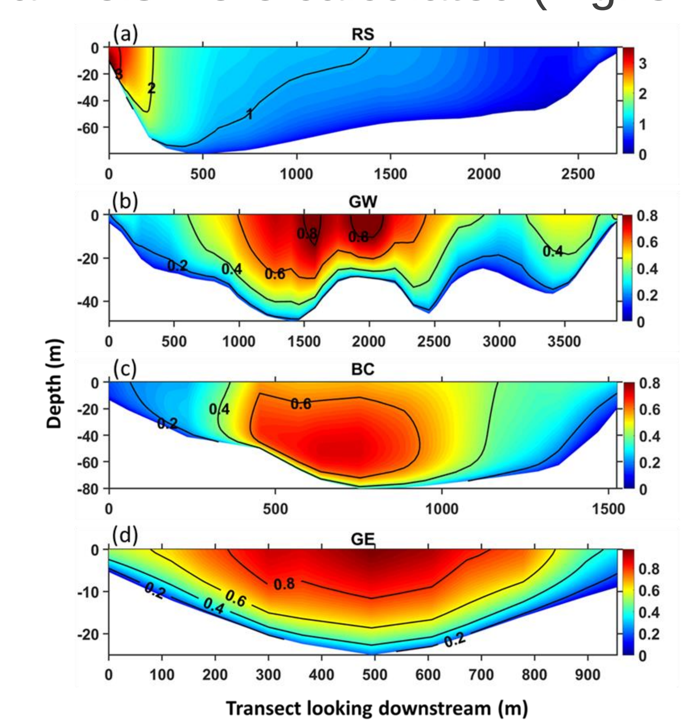

Fig. 9. Mean power density distribution at selected tidal channels in the Rosario Strait and Bellingham Bay regions: (a) RS; (b) GW; (c) BC; (d) GE.

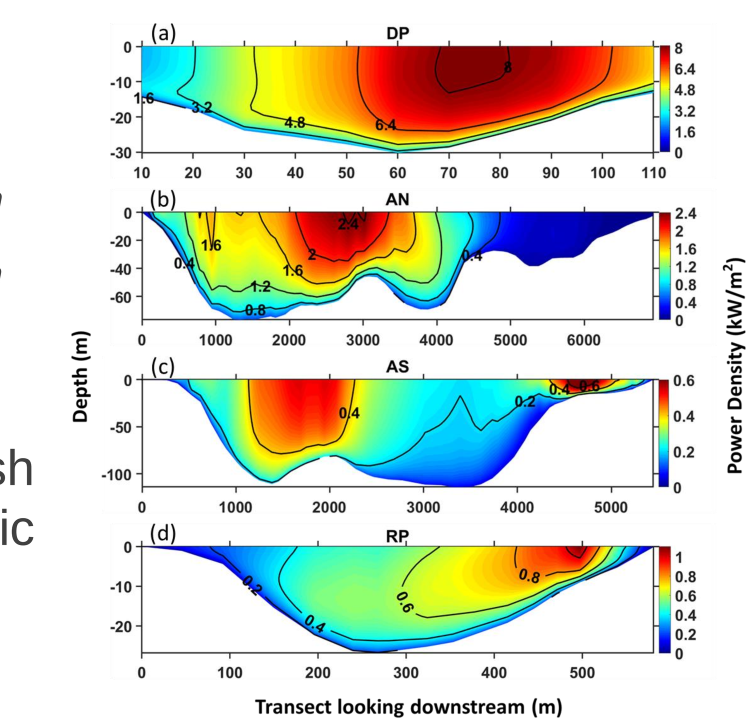

Fig. 10. Mean power density distribution at selected tidal channels: (a) DP; (b) AN; (c) AS; (d) RP.

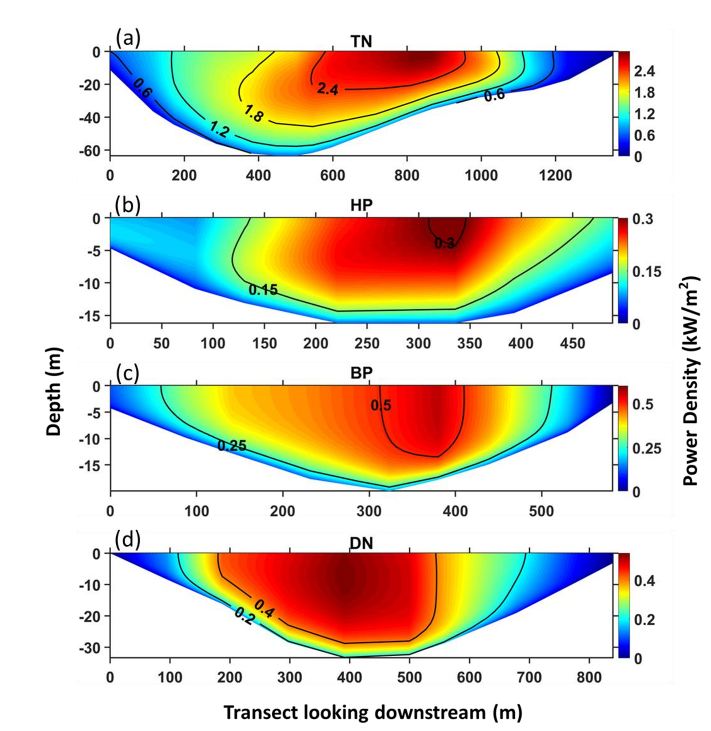

Fig. 11. Mean power density distribution in selected tidal channels: (a) TN; (b) HP; (c) BP; (d) DNP.

Conclusions

- A high-resolution tidal hydrodynamic model for the Salish Sea was extensively validated for water levels and tidal currents.
- A total of 16 channels were identified for potential tidal energy development based on the of criteria velocity magnitude, kinetic energy flux, and channel depth.

Literature cited

1. Chen, C. H. Liu, R. C. Beardsley. 2003. An unstructured, finite-volume, three-dimensional, primitive equation ocean model: application to coastal ocean and estuaries. *Journal of Atmospheric and Oceanic Technology*, 20: 159-186.
2. Yang, Z., T. Wang, R. Branch, Z. Xiao, and Deb, M. 2021. Tidal stream energy resource characterization in the Salish Sea, *Renewable Energy*, 172, 188-208.

Acknowledgment

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