Physics-informed AI model for River Velocity Estimation and Regional Hydrokinetic Potential Assessment

Authors:
Haniyeh Taghipour Yousefdeh, Carleton University
Kristen R. Schell, Carleton University
Jinxing Huang, NRCan (Natural Resources Canada)
Saber Ansari, NRC (National Research Council Canada)

Abstract ID: 118
Submitted: May 12, 2026
Call:: MRC 2026 Research & Technical Track – Call for Abstracts
What Theme Are You Submitting for?: Energy Production, Storage, and Grid Integration
Presenter Name: Haniyeh Taghipour Yousefdeh
Focus Area: River Current
Keywords: Environmental Proxies (Env-Proxy), Hydrokinetic Power Assessment, Manning's Equation, Physics-Informed Neural Networks (PINNs), River Velocity Estimation

Accurate river velocity estimates are key to advancing sustainable hydrokinetic energy. Traditional hydraulic models and conventional machine learning methods often depend on geographical coordinates, but this causes feature dependencies that limit model transferability. This research develops the Env-Proxy PINN, a physics-informed neural network (PINN) deep learning model designed to overcome dependencies on geographic coordinates by utilizing environmental proxies. By integrating high-resolution data from the ERA5 reanalysis, specifically aerodynamic surface roughness (Z0) and Leaf Area Index (LAI), the model replaces static coordinates with dynamic physical predictors. These proxies serve as indicators of the hydraulic resistance, land-cover characteristics, and temporal and seasonal changes of the location that dictate flow behavior. In this model, Manning's equation is embedded directly into the neural network's loss function. This integration enforces physical consistency, penalizing predictions that deviate from this hydraulic law. The Env-Proxy PINN was utilized to assess hydrokinetic potential across major river systems in Western and Northern Canada, covering Alberta, British Columbia, Saskatchewan, the Northwest Territories, and Yukon. Through statistical analysis and specific selection criteria, the study characterizes seasonal and regional variations in stream power density, identifying high-potential hotspots for hydrokinetic development. The results demonstrate that the Env-Proxy framework significantly improves model generalizability, outperforming coordinate-based models. Ultimately, this research provides a scalable, physics-based model for renewable energy mapping.