

# XBEACH MODELLING OF A MIXED SAND AND GRAVEL SHORELINE: EAST VANCOUVER ISLAND

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## INTRODUCTION

The study site is a coastal spit located in the Englishman River estuary, located at Parksville, British Columbia approximately 80 km west of Vancouver as shown in Figure 1. In this paper, we present a holistic approach to evaluating nature-based solutions and assessing coastal processes of a mixed sediment shoreline by integrating coastal process modelling using XBeach (Deltares, 2018) with geomorphic assessment.



Figure 1 - Site location (highlighted by red circle) in the Englishman River estuary

Mixed sand and gravel beaches are prevalent globally, but aspects of their morphodynamics are poorly understood (Mason, Coates, 2001) due to the mixture of sediment and the complex hydrodynamic response to storm events. However, understanding these beaches is important because they are commonly natural analogs for nature-based designs and beach restoration projects in British Columbia and elsewhere.

This study applied a hybrid approach using both XBeach 2D which has been shown to have good quantitative skill in predicting storm response of sandy beaches and a modified 1D version, XBeach-G, which has been applied with some success to modelling uniform gravel beaches (McCall et al, 2014). The 2D (sand) and 1D (gravel) versions were applied in the surf beat mode and non-hydrostatic mode, respectively.

## SITE DESCRIPTION

The spit is primarily composed of alluvium and anthropogenic fill material that was placed by previous owners to raise the elevation of the site. A seawall

previously installed to retain the site fill was removed in 2023 with the goal of re-establishing the natural processes within the estuary and restoring the beach. The results of the study were used to inform the engineering design of the seawall removal and subsequent beach nourishment. The lessons learned in this study have informed our subsequent use of XBeach along the eastern shoreline of Vancouver Island for the design of nature-based solutions.

## METHODS

Field work completed for this study includes geomorphic mapping and repeat photogrammetric drone surveys. Publicly available data used in the study includes historical aerial photography dating back to 1932, surficial geology maps, and LiDAR collected by the provincial government in 2019. Recent changes to the shoreline are assessed by comparing the drone surveys (Figure 2) and the LiDAR. Numerical modelling includes a SWAN wave model of the Strait of Georgia to estimate wave conditions offshore of the estuary, a TELEMAC model of tidal currents in the Strait of Georgia, and XBeach to model sediment transport. The results from the TELEMAC model show tidal currents are relatively weak in this part of the estuary and were therefore not used in the XBeach model.

The site presents several challenges when applying the XBeach model including the relatively large model domain and long simulation durations - especially when applying spatially varying sediment types; sediment characteristics range from sand on the tidal flats to cobble on the upper beach; and longshore sediment transport is a significant driver of coastal processes due to the orientation of the coastline and the prevalent storm directions oriented in the northwesterly and southeasterly directions. Due to these factors, this study uses a hybrid approach for modelling mixed sand and gravel beaches including an XBeach 2D surf beat model for the sand flats and lower intertidal, and an XBeach-G 1D model for the upper beach composed of sand, gravel, and cobble. The XBeach 2D model is qualitatively calibrated by comparing the observed cumulative bed level changes between October 2022 and January 2023 (Figure 2) to the results of the model at the site (Figure 3). The model is run for the top fourteen coastal storm events occurring during this period. The model was first run without river discharge, and it was found that the processes at the western point of the spit and in the estuary were not accurately reproduced. Therefore, river discharge was included in the subsequent model. The three largest riverine discharges for the calibration period were also included in the XBeach 2D simulation.

## RESULTS

The XBeach 2D model successfully reproduces the overall changes to the shoreline of a coastal spit over a winter storm season. The cumulative sedimentation and erosion at the end of the simulation are shown in Figure 3. The model correctly predicts the net sediment transport patterns, especially around point A and at the apex of the spit at point B, caused by river scour. However, the model overpredicts changes to the channels and sand flats in the estuary at point C which could be attributed to sediment deposited in the estuary by the Englishman River which is not included in the model. The latter is estimated to range between 5,000 and 26,000 m<sup>3</sup>/year (Northwest Hydraulic Consultants, 2023) based on the relationship between specific sediment yield and drainage area (Church, Slaymaker, 1989). The model also overpredicts erosion of the upper beach, as demonstrated by comparing the results to the field data between points D and E where the shoreline is composed mainly of gravel and cobble. The XBeach-G model was used to provide more accurate simulation of the erosion of the upper beach along the northwest shoreline of the spit and to assess the stability of the restored beach profile to storm events (Figure 4).

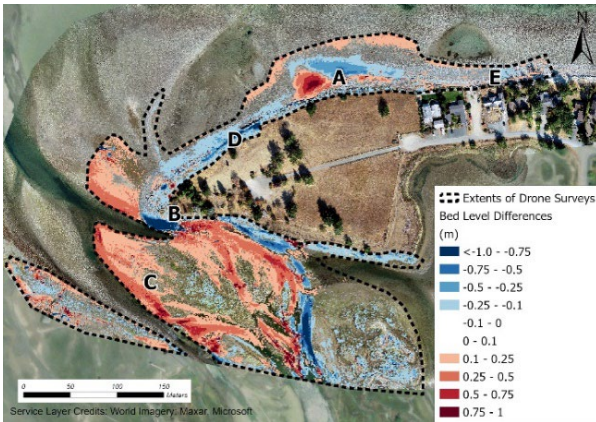


Figure 2 - Observed bed level changes between October 2022 and January 2023

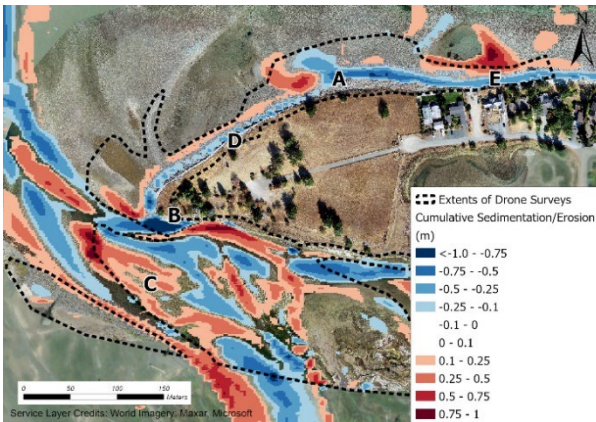


Figure 3 - Cumulative sedimentation (red) and erosion (blue) at the end of the XBeach-2D simulation

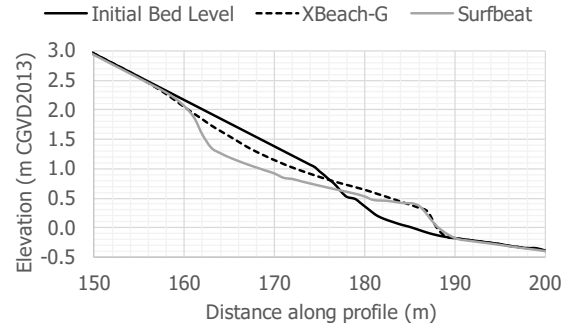


Figure 4 - Results of XBeach-G 1D model versus XBeach 1D surfbeat model

The geomorphic assessment informs the development of the model through mapping sediment characteristics, understanding historical changes to the shoreline, and providing context for interpreting the results of the model. By understanding historical and current sources of sediment and classification, we can more accurately model mixed sand and gravel beaches. The combination of observed bed level changes and site observations on coastal processes and sediments provide a way to verify and improve model results in complex mixed sand and gravel beach environments.

This study shows XBeach can be effectively used in conjunction with a geomorphic assessment and drone survey to understand coastal processes and inform the design of nature-based solutions. We achieved the best results using both XBeach 2D to model the lower intertidal and estuary and XBeach-G 1D to model the upper gravel beach. This hybrid approach can be used to understand the risk of erosion to the shoreline and predict the performance of nature-based sediment solutions in similar environments. However, extending the capabilities of the XBeach-G model to include mixed sand and gravel beaches in 2D would be especially useful for evaluating nature-based solutions on complex gravel shorelines - which are prevalent throughout the Pacific Northwest and many other regions globally.

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