PHYSICAL MODELLING STUDIES FOR THE SCARBOROUGH WATERFRONT PROJECT

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PROJECT BACKGROUND

The Scarborough Bluffs are an iconic feature of the Lake Ontario shoreline; however, due to limited access and existing public safety hazards, the water's edge along this section of Toronto's waterfront is not formally accessible to the public. The Scarborough Waterfront Project aims to create a system of naturalized spaces along Lake Ontario, and will balance waterfront revitalization and public access with natural heritage and natural hazard protection and management.

DESIGN CONSIDERATIONS

(1) The existing Bluffer's Park sand beach is currently at capacity for sand retention. Sand moving alongshore accumulates in the harbour entrance, creating unsafe boating conditions. Dredging has been undertaken by the City of Toronto every 1-2 years to manage the risk in the interim. (2) Under high water level conditions the beach is subject to flooding, with large areas becoming saturated with water, thus creating an undesirable user experience. (3) The existing aquatic habitat along this stretch of shoreline lacks substrate and profile diversity, and currently supports only a small number of open coast fish species. (4) The existing beach and backshore vegetation are frequently trampled and severely fragmented by a large number of informal trails due to unmanaged public usage. (5) There is no shoreline protection in place, resulting in continuing bluff toe erosion, slope failure, and landward crest migration. Users of the shoreline east of the beach are at risk due to the resulting landslide activity. (6) There is limited public access along the shoreline, resulting in challenging and unsafe conditions to reach Meadowcliffe from Bluffer's Park Beach.

PROPOSED SHORELINE DEVELOPMENTS

Firstly, a significant expansion of the Bluffer's Park Headland was proposed: to promote sand retention at the beach, reducing the need for dredging of the harbour entrance and thus creating safer boating conditions; to provide significantly larger recreational space along the waterfront, featuring seating areas with views of both the iconic Scarborough Bluffs and Lake Ontario; and to provide habitat expansion (see Figure 1).

Secondly, an expansion of the Meadowcliffe Headland and Eastern Beach was proposed to promote sand retention at the beach over the long-term, with more recreational space to accommodate thousands of annual visitors. An interim groyne will be constructed towards the east end of the beach, with cobble and gravel fill on the east side that will eventually be covered with sand through natural processes. In addition, improved shoreline accessibility will be provided with a paved separated multi-use recreational trail to accommodate both pedestrian and cyclist usage along the beach.

Terrestrial and aquatic habitat enhancement will: provide greater movement and improved access to water for terrestrial animals; provide increased opportunities for expansion of sensitive beach habitats; provide stop-over habitat for migratory bird and butterfly species; and provide improved underwater habitat for a wider range of fish species.

Figure 1 - Proposed shoreline developments

STUDY OBJECTIVES AND GENERAL APPROACH

A series of 3D physical modelling studies was required to verify the stability and response of the proposed shoreline developments for the Scarborough Waterfront Project under a range of design conditions, including storms approaching from southerly and easterly directions, at low and high lake levels. Where possible, the physical model studies would also help to optimize various design elements to improve their performance and/or lower overall costs.

A two-pronged approach involving the design, construction, and operation of two separate but closely related physical models was undertaken by the National Research Council Canada (NRC), in collaboration with Shoreplan Engineering Ltd., the Toronto and Region Conservation Authority, and the City of Toronto. Both models were carried out in NRC's 30m long x 36m wide Multidirectional Wave Basin which was outfitted with a segmented wave machine to generate a wide range of realistic sea states and equipped with instrumentation to measure wave and current conditions (including wave overtopping), to monitor damage to coastal structures, and to monitor sediment transport.

BLUFFER'S PARK HEADLAND EXPANSION

The first study focused on the Bluffer's Park Headland expansion. Model construction involved the faithful recreation of the proposed headland expansion and surrounding lakebed bathymetry at 1:30 scale (see Figure 2). The various cross-sections of the proposed headland, which included a central cobble beach, were constructed to a high degree of accuracy using seven classes of rock materials placed with construction techniques to accurately mimic the real-world.

Fifteen wave probes were deployed to measure wave conditions at various locations within the wave basin. Two overtopping collection systems were deployed to measure the amount of wave overtopping at each roundhead. A photographic damage analysis system comprising eight

remotely-operated digital cameras mounted on tripods was used to monitor the movement of armour stones after each test segment. A FARO® 3D laser scanner was used to measure the shape of the headland revetment (and in particular the central cobble beach) at key points during the testing program. Scans from different time intervals were compared using NRC's BlueKenue™ software to identify areas of damage or zones of erosion and accretion.

Conducted over three phases (with over 115 individual test segments), the headland design elements (including varying crest elevations and varying armour stone sizes) were optimized and verified to ensure they were well adapted to typical and extreme conditions.

Figure 2 - Testing for the Bluffer's Park Headland Expansion

BLUFFER'S PARK BEACH AND MEADOWCLIFFE HEADLAND EXPANSION

The second study focused on the Meadowcliffe Drive Headland expansion and monitoring of beach fill material to be used in the west segment. Model construction involved a similar faithful recreation of the proposed headland expansion, beach, and surrounding lakebed bathymetry at 1:25 scale (see Figure 3). Two gradations of sediment were placed as a mobile-bed: fine sand (D_{50} ~0.17mm) to represent the native beach material and coarse sand (D_{50} ~0.58mm) to represent the proposed beach fill material.

Thirteen wave probes were deployed to measure wave conditions at various locations within the wave basin. Two 2-axis electromagnetic current meters were deployed to measure orbital velocities and wave-induced currents at key locations. A photographic damage analysis system comprising four remotely-operated digital cameras mounted on tripods was used to monitor the movement of armour stones after each test segment.

Various techniques were used to monitor and document the dynamic response of the model beach, primarily involving the precise surveying of the horizontal position of the still waterline and beach crest at the beginning and end of selected tests using a robotic total station. Numerous survey points were recorded to capture the overall shape of the beach, particularly at points of inflection in the curvature of the beach and on either side of the groyne (where the waterline position could vary significantly). This data was subsequently used to illustrate the changes in waterline and crest location over time. Coloured marker flags were also placed at regular intervals along the beach to visually track the changing position of the waterline. The same 3D laser scanner was also used to measure the overall shape of the beach at key points during the testing program and identify areas of erosion and deposition.

Conducted over three phases (with over 105 individual test segments), the crescent-shaped beach and other design elements were optimized and verified to ensure they were well adapted to typical and extreme conditions.

Figure 3 - Testing for the Bluffer's Park Beach and Meadowcliffe Headland Expansion

PHYSICAL MODELLING BENEFITS

Both models provided significant benefits to the design of the Scarborough Waterfront Project. The Bluffer's Park Headland Expansion model identified two vulnerable locations where the revetment armour was more susceptible to damage than the adjacent sections. Both stone size and layer thickness were increased in those locations. The model also identified locations of heavier overtopping than had been predicted using numerical methods. A portion of the crest was raised in the final design to reduce the risk of backshore damage during design conditions.

The Bluffer's Park Beach and Meadowcliffe Headland Expansion model showed higher than anticipated overtopping along a portion of the headland above the gravel beach. As a result, the splash pad width and stone size were increased in the final design. The model also showed the potential for excessive beach scour near the west end of the gravel beach should there be sustained severe wave conditions. The final design was modified to include additional armouring on the containment berm along the back of the beach in that area. This will prevent damage to the waterfront trail (located on the crest of the berm) should excessive beach movement occur.