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Modelling of wave climate and sediment transport patterns at a tideless embayed beach, Pirita Beach, Estonia

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ABSTRACT

Nearshore sand transport patterns along the tideless, embayed Pirita beach, Tallinn, Estonia, have been investigated utilizing high-resolution modelling of wave processes combined with bathymetric surveys and sediment textural analyses of the nearshore sea floor. Textural analysis showed the mean grain size is about 0.12 mm. Fine sand (0.063–0.125 mm) accounts for about 77% of the sediments. Coarser-grained sand (0.28 mm) dominates along the waterline. Based upon the spatial distribution of the mean grain size and basic features of the local wave activity, properties of the Dean Equilibrium Beach Profile were determined.

Alongshore sediment transport was calculated based upon a long-term time series of wave properties along the beach, and the CERC formula applied to about 500 m long beach sectors. The time series of wave fields and the properties of the local wave climate were modelled using a triple nested WAM wave model with an extended spectral range for short waves. The model is forced by open sea wind data from Kalbådagrund for the years 1981–2002. Results indicate that typical closure depth at Pirita is 2.5 m. The width and mean slope of the equilibrium profile are 250 m and 1:100, respectively. Southward transport dominates in the northern sections of the beach whereas no prevailing transport direction exists in the southern sections. This pattern has several nontrivial implications for the planning of beach protection activities.

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1. Introduction

Pirita Beach, a typical small, embayed beach of the southern coast of the Gulf of Finland, is located at the south-eastern bayhead of Tallinn Bay, Estonia (Fig. 1). This young coast obtained its contemporary shape only a few millennia ago and is in active development. The area experiences relatively rapid postglacial uplift, about 1.8–2.5 mm/year according to estimates of Zhelnin (1966), Miidel and Jantunen (1992), and Vallner et al. (1988).

The sandy area of Pirita Beach is limited to a ~2 km long section extending from the northern mole of the Pirita River mouth to a till cliff located about 400 m southwards from Merivälja Jetty (Fig. 2). The width of the dry beach is a few tens of meters, extending to tens of meters where trapped by the mole at the southern end of the beach. The dunes are relatively low with a maximum height of the cut dune scarp of ~1.5 m.

As the entire northern coast of Estonia generally suffers from sediment deficit (Orviku, 1974; Orviku and Granö, 1992), it is not surprising that a certain net loss of sand at times occurs in the Pirita area. Prior to the mid 20th century the beach was apparently stabilized by the postglacial uplift and natural sediment supplies. During recent decades, however, a gradual decrease of the dry beach width, rapid recession of the till cliff at the northern end of the beach, and extensive storm damage to the dunes, have occurred despite the postglacial uplift and attempts to renourish the beach with material dredged from Pirita Harbour or transported from mainland quarries (Soomere et al., 2007).

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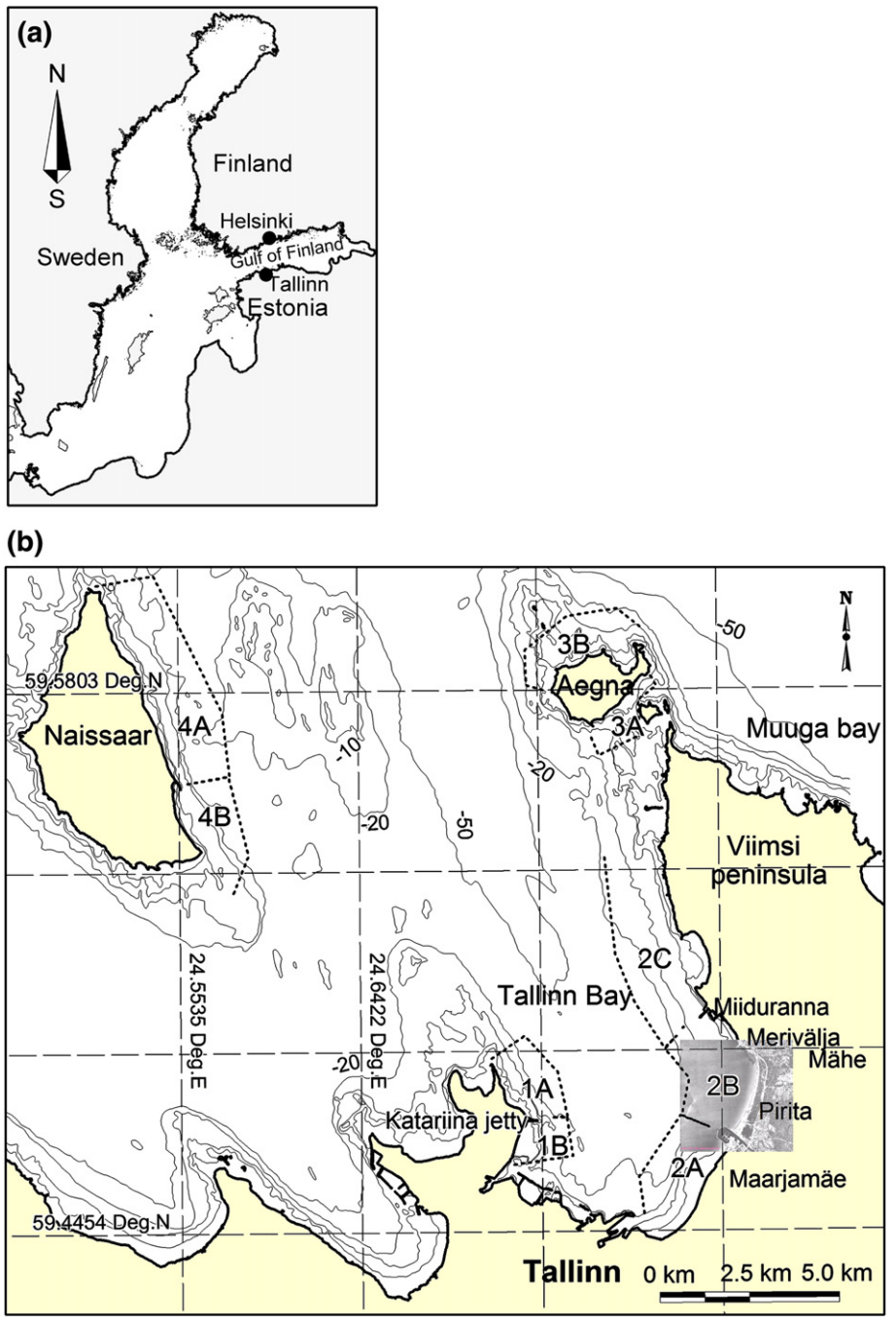

Fig. 1. (a) Location scheme of the Baltic Sea and the Gulf of Finland and (b) location of Pirita Beach in Tallinn Bay, showing identified cells of sediment transport after Soomere et al. (2007) and isobaths of −2, −5, −10, −20, and −50 m. Courtesy of Estonian Journal of Earth Sciences.

Alterations of natural conditions such as large-scale changes in storminess in the 1960s (Alexandersson et al., 1998), may have caused increasing loads on Baltic beaches (Orviku et al., 2003). Yet a more probable reason for large scale recent changes at Pirita Beach relates directly or indirectly to a number of major coastal engineering structures (Soomere et al., 2007). For example, construction of Miiduranna Port has essentially blocked all littoral transport from the North since the 1970s, while construction of Pirita Harbour substantially decreased the river supply of sand.

Pirita, therefore, is a typical example of a beach whose evolution has been largely controlled by development works. An important issue for its sustainable management is establishing the parameters of its equilibrium regime, the magnitude of the sediment supplies, and the basic mechanism of the natural sediment transport processes. Based on this information, well-

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