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Sand island reshaping in response to selected discharges,Vistula River returning to nature

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ABSTRACT

The reason why the authors undertook this subject are the morphodynamic processes, unfavourable from the point of view of bird fauna, which resulted in the island connecting to the right bank of the Vistula in 2017. The purpose of this paper is to identify the conditions for the formation and disappearance of sand islands within the limited discharge (well below bankfull). There are studies which suggest that rivers with these discharge magnitudes can self-naturalize. The changes to the shape of the sandy island caused by the passage of two waves of various characteristics of the discharge intensity and period, during which processes of bottom material erosion or accumulation start. The analyses were based on the parameters of water flow velocity, shear stresses, and changes to the island's shape.

The studied sector including the island is located in the Upper Vistula, km 281+500 – 282+500, approx. 2 km downstream from the mouth of the San River. The catchment area at the Zawichost water gauging station is 50,655 km2. The width of the channel is approximately 400 m, and the distance between embankments is 1 km. The measured slope of the water surface ranges from 0.00025 to 0.00329. In some cases, the San causes the discharge to increase by over 40%. Below the mouth of the San, the Vistula channel slope decreases, which coincides with the bed material accumulating in the channel. After the completion of river training works, the regulated Vistula channel is reverting to its natural state and recovering habitats of valuable water and land species. A protected species is the little tern (Sternula albifrons), included in Annex 1 of the Bird Directive. For this species, sandbanks not connected to the bank (mid-channel bars) are a key habitat element in the nesting season. The island under research has formed on the convex bank. Its length is approx. 700 m, and its maximum width is 136 m for the discharge 300 m^3s^{-1}. In 2016, it was only locally overgrown with grass, while in 2018 it was seen to connect to the bank and the first shrubs appeared.

Field measurements and numerical modelling of the Vistula river have been performed along a 1900 m section in which a sandy island with a nesting area for two species of tern exists. The following data were analysed: i) survey measurements, discharge, and the flow velocity using an Acoustic Doppler Current Profiler; ii) bars, islands, and water surface; iii) the granulometric composition of bed material; and iv) resources of the Head Office of Geodesy and Cartography in Poland (GUGiK). The main simulations were performed for unsteady flow conditions. The waves were selected after analysing the changes in the discharge at the Zawichost gauging station in 2015-2017. This data allowed us to select two waves differing in duration and culmination. To simplify the fluvial processes interpretation, the unimodal course was used. The discharge of 498 m3s-1 is slightly above the annual average (2015; Wave_1, total time 10.75 days), while 1106 m3s-1 is well beneath the bankfull discharge (2016; Wave_2, total 58.17 days). Wave_1 covered a part of the island; Wave_2 covered it completely for 17 days.

Fluvial processes in distinguished wave stages were analysed along a horizontal plane (map of changes of hydraulic and morphological parameter), a vertical plane (longitudinal profile), and at selected characteristic points lying on the profiles or in their vicinity. Island bathymetry changes were analysed

along 798 m of a longitudinal profile drawn across the island's top (Fig. 1). Modelling results as a time series were analysed at six points: MW-02, MW-05, F, J, O, and MW-14 (Fig. 2).

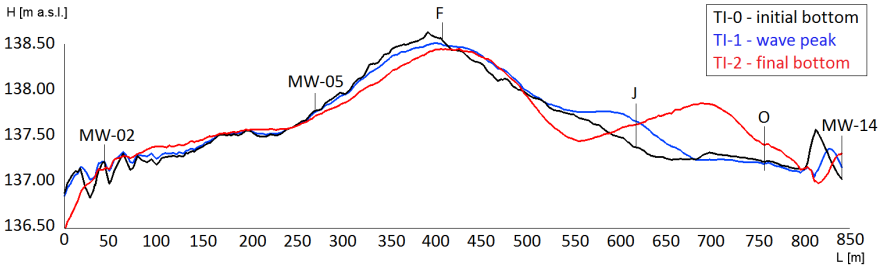

Fig. 1 Longitudinal profiles PR-T along the Kępa Chwałowska Island, Vistula; initial bottom - measured (black), blue and red - calculated bed elevation during and after passage of Wave_2, respectively.

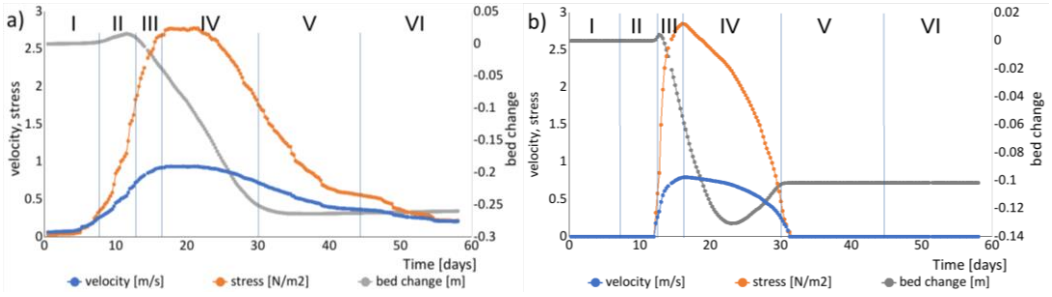

Fig. 2 Time variation of parameters for Wave_2 at monitor points: a) MW-02- upstream part of the island, b) F - the top of the island.

The analysed island is not uniform in shape. On its ridge there are shallow or cross-wise rapids which become active at various water levels. The intensity of fluvial processes during the peak of the Wave_2 contributed to insignificant erosion of the island head, while the areas downstream of its top can experience both erosion and material accumulation, but accumulation processes become stronger. Even though they were very intensive during the passage of the wave, at the last phase, the moving water may, once again, have carried a part of the accumulated material from this area.

Wave_1 caused only processes which smoothed the lower parts of the island and did not break the nesting. When flows similar to Wave_1 pass and do not cover the top of the island (point F), this may lead to gradual expansion on areas downstream of its top. Wave_2 produced a strong effect of depositing and shifting the island, although it seems that a wave that fits in the channel may cause its shape to change to more elongated and narrow (fusiform), and to relocate the island downstream. Additionally, this wave turned the breeding unsuccessful in the nesting colony.

An analysis of processes causing the formation or erosion of islands cannot be made locally. Neither does the analysis of isolated parameters lead to correct conclusions. Islands are irregular in shape, which reflects the local hydraulic conditions of the river section. The 2D modelling carried out provided data supporting the thesis that exceeding the conditions of bed material movement does not always lead to activation of the erosion processes. With the right load of material transported in the river bed, the transport capacity of the stream may be exhausted and, as a result, the bottom will not be eroded. For this reason, the next step in the analyses will be to establish the transport balance along different cross-sections of this island.