Assessment of Vistula delta cone development under sediment deficit condition (Poland)

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Introduction: The construction of large reservoirs on plain large river affects the functioning of river system. Changes have been noted, such as: hydrological (incl. changes in flood frequency and their magnitude, changes hydrodynamics within estuaries), morphological (changes in the continuity of sediment transport) and ecological (the impact on the ecological and hydromorphologicial state - consistent with Water Framework Directive). In the case of large, single dam, the impact of its functioning can reach up to the estuary. The catchment area of the Vistula River is 194 424 km^2, of which about 75% is a lowland part. Total length of the Vistula River is 1092 km. It flows into the Gdansk Bay (Baltic Sea) in the northern part of the Poland. The background of the research represents Wloclawek Reservoir, located at 674.85 km of the river, ie. 260 km from the estuary. Commissioned in 1970, it is the largest artificial reservoir in Poland (area of 70 km^2, length of 55 km, capacity – approx. 270 million m^3). As the only one was executed in the plan of cascade of the lower part of the Vistula River. It had an impact on the sediment yield on the lower section of the Vistula River (to the estuary). High-energy Gilbert type delta with a well-shaped topset beds and advanced foreset beds zone. Is located at the end of an artificial dig channel, which was created in the years 1981-1895. Delta cone is built by the bedload material supplied by the Vistula River and is dilapidated as a result of waves activities of the Gdansk Bay.

Methods: The research included: (i) morphological analysis of bed load transport on the basis of archival and own bathymetric maps of the Vistula and the observation of the dynamics of sandbars. The size of bedload movement was determined based on the dynamics of bars, their movement rate and the layer thickness of these forms. (ii) Suspended sediment particle-size and concentration of suspended material including real-time assessment in cross-sections was demonstrated by field measurements in longitudinal profile of the Vistula river. Investigation were based on the use of a LISST-25X optical sensor developed by Sequoia Scientific, Inc. (turbidity in Nephelometric Turbidity Unit – NTU) and sampling of suspended load material (in mg_*l^{-1}). Morphological data was collected using single-beam echo sounder (SBES). Bathymetric analysis were supplemented with archival bathymetric soundings from the 20's of the XX century. It helps to determine the reference conditions of bedload transport. Modelling was carried out using the GIS tools - ArcGIS v.10.0.

Results: The conducted research shows that a mean annual bedload supply to Wloclawek Reservoir amounted to 2.2 mln tons. The study below single dam show reduction of bedload transport to the approximated level of 1.0 mln tons per year (Torun, km 731) and up to 1.2 mln tons at the estuary to the sea. While suspended sediments in 42% is stopped in Wloclawek Reservoir. Below the dam there is quantitative and qualitative renewal of suspended sediment transport. However, it is not the same level of concentration as above the dam.

Discussion: Before carrying out the regulation procedures on the Vistula River at the beginning of the 20th century and Wloclawek Dam commissioned, almost 100% of the sediments were supplied into the delta of the Vistula. Currently, the bedload sediments are whole accumulated in the reservoir. The observed growth of dynamics of the bedload transport below the single dam is determined by the supply of sediment from tributaries, supply of material from the erosion of banks and the zones in between groynes. Below the reservoir there is erosion zone, where a strong degradation of the river is observed. It moves approx. 2.2 km per year in the direction of the mouth, displacing the newly created sediment accumulation zone. The concentration of suspended sediment is growing in an accumulation zone. It is forecasted that in about 100 years erosion zone will reach the delta of the river. It will lead to the lack of sediment supply and degradation of topset beds and foreset beds of the delta cone. It will definitely change the type of the delta and environmental conditions. This will be the beginning of final degradation of Vistula river delta cone.

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