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The Vistula Canal, the state after 120 years of activity

Przekop Wisły, stan po 120 latach funkcjonowania

Authors' Contribution:
A – Study Design
B – Data Collection
C – Statistical Analysis
D – Data Interpretation
E – Manuscript Preparation
F – Literature Search
G – Funds Collection

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Abstract: During the catastrophic flood caused by the ice dam in 1840, a new river mouth was created. Nevertheless some series of floods were observed in the next years. In order to facilitate of river waters run-off, the artificial crosscut was performed in 1891-1895 years. The artificial channel was opened in 31st of March 1895. Since, at the time of continuous exploitation of the channel, high effectiveness of the engineering project which is unique in the world scale has been confirmed. A permanent flood hazard for Gdansk city and adjacent lowland areas has been receded. Since this time, the external delta is being formed by acumulation of bed-loaded sediment that is transporting by the river. Consequently free run-off of the river water is reducing due to the external delta growing.

During the years 2009-2014, detailed monitoring researches of the Vistula Canal as well as the Vistula River External Delta have been performed. The obtained results constitute a basis for the evaluation of flood risk in the area, as well as for prognosis of morphological changes of the Vistula River External Delta and sand supply to the Gulf of Gdansk. The state of the Vistula River mouth canal is briefly presented after 120 years of its history.

Keywords: artificial river channel, external delta, flood hazard, the Vistula River mouth

Streszczenie: Podczas katastrofalnej powodzi w 1840 roku doszło do utworzenia nowego ujścia, tak zwanej Wisły Śmiałej. W ciągu kolejnych lat nadal jednak wystepowały sytuacje powodzie. Podjeto wiec decyzję o wykonaniu odpowiedniego przekopu dla zapewnienia skutecznej ochrony przeciwpowodziowej. Przekop został otwarty 31 marca 1895 roku. Podczas kolejnych lat użytkowania Przekopu Wisły jego skuteczność została potwierdzona. Rumowisko piaszczyste wynoszone przez rzekę, składane przy jej ujsciu, zaczeło formowac stożek ujściowy – tak zwana zewnetrzną deltę.W miarę jej wzrostu następuje jednak zmiejszanie możliwości swobodnego spływu wód.

W latach 2009-2014 przeprowadzono szczegółowe badania monitoringowe Przekopu Wisły i delty zewnętrznej. Uzyskane wyniki stanowią podstawę do oceny stanu przekopu i jego mozliwosci zapewnienia swobodnego spływu, wraz z prognozą zmian delty zewnetrznej i szacowniem ilosci dostarczanego materiału piaszczystego do Zatoki Gdańskiej.

Słowa kluczowe: kanał ujściowy, delta zewnętrzna, zagrożenie powodziowe, ujście Wisły

INTRODUCTION

Poland's primary river, the Vistula, is the largest river of the southern Baltic Sea and is one of the least regulated amongst large rivers in Europe. With the 1047 [km] of total length, the Vistula plays a dominant role as regards both the catchment area 194424 [km^2] and the quantity of discharged fresh water flowing into the Gulf of Gdansk. The average yearly river runoff amounts to 34 [km^3] as given by Majewski (2013). The Vistula has a vast delta with many river branches of different size and the External Delta is the mouth fan (cone) which is the contemporary form of its main estuary in the form of an artificial cross-cut channel made in 1895. Since its opening, the channel was frequently expanded and currently has a form of the channel with a strengthening banks of about 7000 [m] length, 400 [m] width and up to 10 [m] depth. At the present time, it plays a role of the main Vistula River mouth

Fig. 1. MLocation of the study area (on the left). Historical photo of the Vistula River artificial channel opening ceremony in 31 of March 1895 (in the middle; source of the photo: www.zulawy.info). Present-day photo of the Vistula River mouth channel (on the right; source of the photo: www.visitzulawy.pl).

and due to existing hydro-technical systems situated at the lower reach of the river, about 95% of total Vistula water outflows into the Baltic Sea through this channel (the long-term average annual water discharge reaches 1081 [m³/s]). The instability of the channel riverbed within the outlet cone, due to floods and sea storm surges, makes proper management of the river mouth area very problematic and requiring hydrographic monitoring.

METHOD

In a period of time between August 2009 and October 2014, series of bathymetric measurement campaigns were carried out in the main Vistula River mouth area located in Polish coastal waters (Fig. 1). An area of the interest was mapped using boat-mounted high-resolution Reson SeaBat 7101 multi-beam echosounder (MBES) operating at 240 kHz and additionally—with using of Deso 15 single-beam echosounder (SBES) operating at 200 kHz in areas shallower than 4 [m]. The sound velocity probe Reson SVP-70 was fixed to the MBES head, and the portable sound velocity profiler Reson SVP-15 were used to obtain the sound speed on the depth of the MBES draft and in the whole water column, respectively. The positioning system DGPS RTK Trimble SPS 851 together with Ixsea Hydrins inertial navigational system were integrated with MBES (or SBES) using the QINSy data acquisition software package. Based on operational data acquired in the internet information service of the Polish Institute of Meteorology and Management (www.pogodynka.pl), the hydrological regime at the lower reach of the river and sea level height were observed regularly.

For individual states, digital terrain model (DTM) of the bed surface was obtained from echosounder's data. The bathymetric data were gridded with a cell size of 2.5 [m]. The relief image and bathymetric map (isobaths interval of 0.25 [m]) were elaborat-

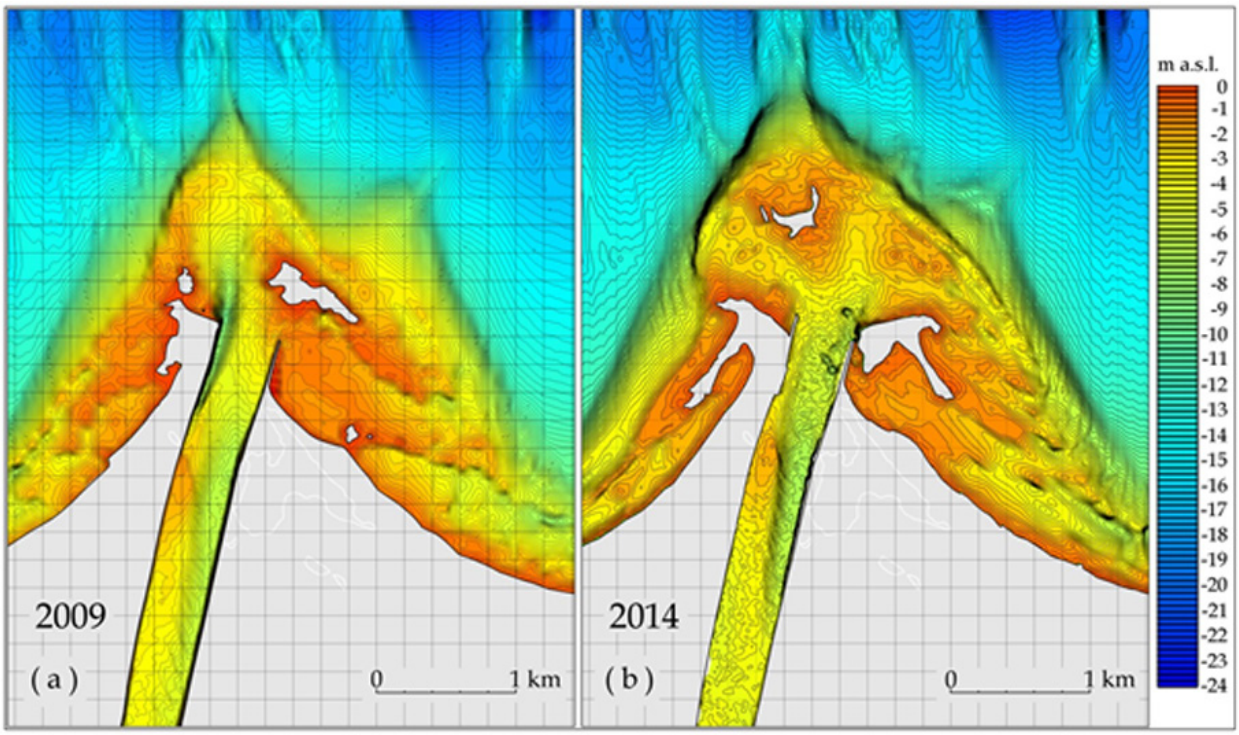

Fig. 2. Bathymetric maps of the Vistula River mouth area based on data obtained in measurement campaigns performed in August 2009 (a) and October 2014 (b). Colorbar scale in meters.

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ed. These formed a basis for a compilation of geomorphological and differential maps (Wróblewski *et al*. 2015).

RESULTS AND CONCLUSIONS

The detailed bathymetrical maps (Fig. 2) were executed within the Vistula River Mouth area, where main geomorphological units as supply and distributary channels, delta plain, delta front and prodelta were highlighted. The bottom relief of the supply channel consists of two biggest forms – sand bar and trough, located along the border of the channel. As in the previous study (Lisimenka *et al.*, 2013), the occurrence of multiple generations of small to large subaqueous dunes, both two- and three-dimensional of various orientations, whose asymmetries indicate a general seaward migration, was observed. There are a couple generations of bars, shoals and efemeric islands on the area of the delta plain with a depth up to about 5 [m]. The front of the delta descends with a steep slope to the depths of about 12-13 [m]. The prodelta with depth up to about 17 [m] is characterized by a mild seaward inclination and contains elongated, ovoid, fingerlike formed tongues of a faraway deposited bedload.

During the years 2009-2014, the most significant changes were observed in the frontal section of the delta plain with shifting of its edge up to 200 [m] in a seaward direction. Formation of the frontal bar with a shoal transformed into an island became a cause of separation of the distributary channel into two side branches. Moreover, due to mainly of May 2010 flood, complete disappearing of an erosional deepening observed at the west side of the river mouth was verified. In turn, the most significant erosional processes were identified at the east side of the river mouth where the river mainstream is observed. Development and morphological changes of the Vistula River External Delta are prepared based on the differential maps. The obtained results are the next basis of evaluation of the current state and prognosis of the delta and neighbouring marine waters changes. The Vistula River mouth area monitoring in the context of the sediment transport is particularly important and may give a potential opportunity to prepare an emergency warning against extreme hydrological conditions in the area.

However, it should be admitted that the state of the Vistula River Mouth artificial Channel is not sufficient at present for fully protected against flood because shallow delta plain make difficult to free water flow, especially in drift ice parade condition.

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