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NATURAL AND ANTHROPOGENIC CHANGES OF THE VISTULA OUTLET TO THE SEA

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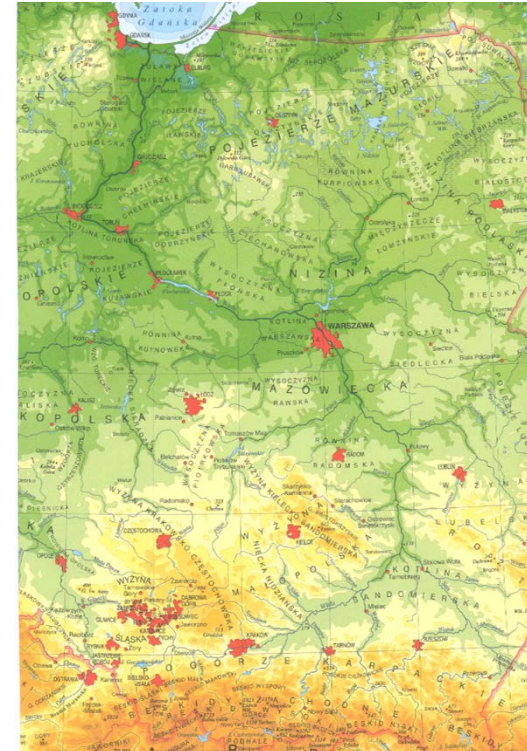


OUTLINE OF THE PRESENTATION

- Polish Parliament instituted 2017 „THE YEAR OF THE VISTULA RIVER”
- General characteristics of the Vistula
- The Lower Vistula
- Żuławy – the delta of the Vistula
- Present outlet of the Vistula
- Situation in the XIX century
- Floods 1829, 1840, 1855, 1888
- Design of the Direct Channel (DCh) Przekop Wisły
- Implementation of DCh
- Opening of the DCh and first discharge
- Follow-up actions
- Conclusions

GENERAL CHARACTERISTICS OF THE VISTULA

- River length - 1047 km, flow direction,
- River basin – $194 \cdot 10^3 \text{ km}^2$, in Poland $169 \cdot 10^3 \text{ km}^2$ (87%)
- Hydrographic division: Upper Vistula, Middle, Lower
- Second largest river of Baltic Sea basin
- Recorded discharges after Second World War:
max. 7840; av. 1080; min. 253 m^3/s P1%; 9190 m^3/s
Present observations: decrease of discharge at the mouth
- Outflow to the sea: max. 50.8, min. 20.5, av. 34 km^3
- Climate: mild, with variation along Vistula course
- Precipitation: average – 620 mm, (1100 – 550)
- Ice conditions: severe along LV, various break-up time
- Land cover: forests 29%, arable land 49%
- Hydraulic structures: on the main course and tributaries
- Total retention volume: approx. 10% of the av. Outflow
- The whole course – ecologically protected areas
- Important economic, social cultural and ecological axis



THE LOWER VISTULA

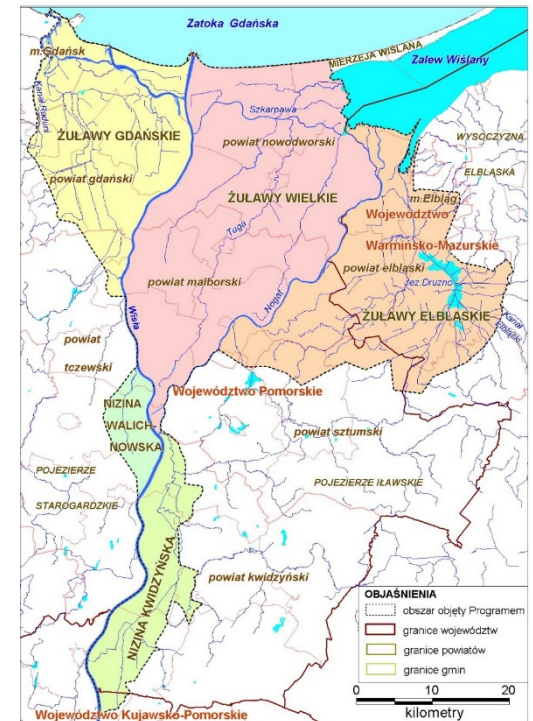


- Section 391 km long, river basin $41 \cdot 10^3 \text{ km}^2$
- Very important for energy and navigation
- Part of this section was trained for navigation, the Pomorska Vistula
- Bydgoszcz Channel and Bydgoszcz Water Node
- Important cities and industrial centers
- Hydraulic Project Wloclawek with run-of-river reservoir (1970), whole section under Natura 2000
- Section ice jam prone, numerous floods caused by ice jams
- At the mouth very important area Żuławy,

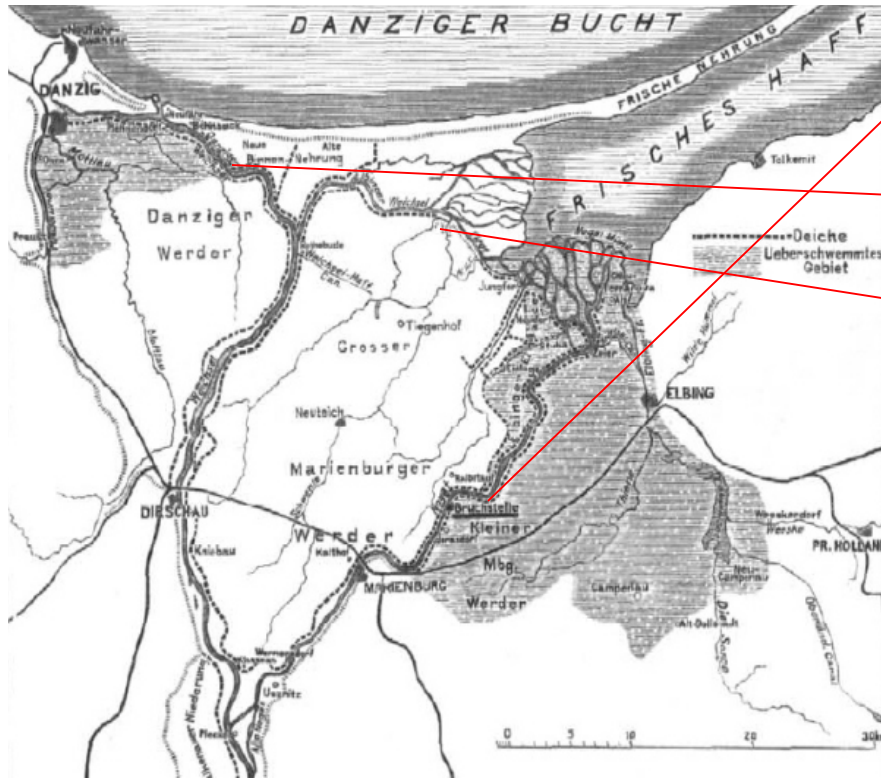


ŻUŁAWY THE DELTA OF VISTULA

- Żuławki Wiślane have the area 1700 km²
- Żuławki have 3 distinct parts: Żuławki Gdańskie, Malborskie, Elbląskie
- The main hazards: from the main Vistula channel, from wind upwellings in the Bay of Gdańsk and in Wiślany Gulf, and local floods
- Żuławki create a very important area from economic, social and ecological point of view
- Present safe operation of Żuławki is due to implementation of Direct Channel (Przekop) in 1895.



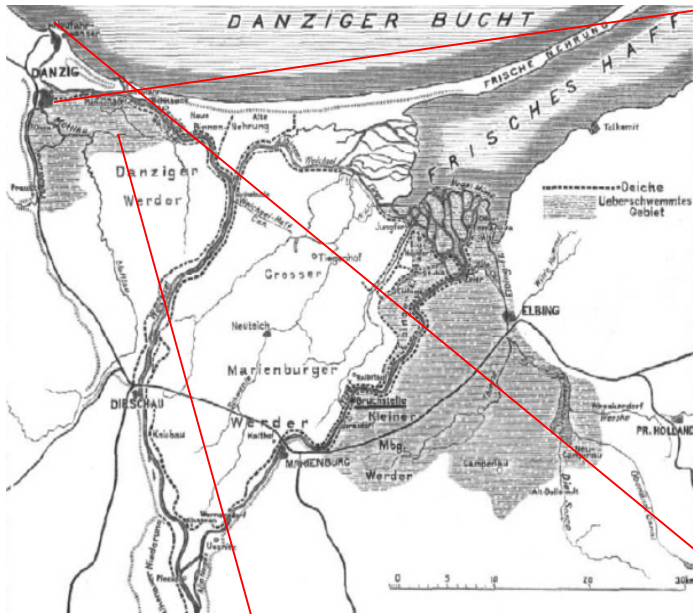
SITUATION IN THE XIX CENTURY



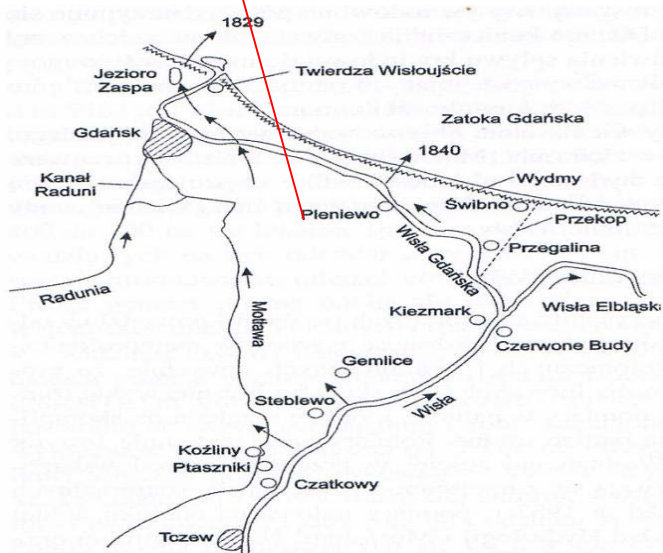
- The first branch of Vistula is the Nogat leading to the Vistula Gulf
- Next branch of Vistula turns to the west forming the Gdańsk Vistula
- There is also branch to the east forming the Elbląg Vistula leading to the Gulf of Vistula
- None of these branches had flow control structure - consequences
- Main hazards were from the Vistula in case of ice jams and from the storms on the Bay of Gdańsk and on the Vistula Gulf.

The map of Żuławy area from XIX century

FLOOD 1829

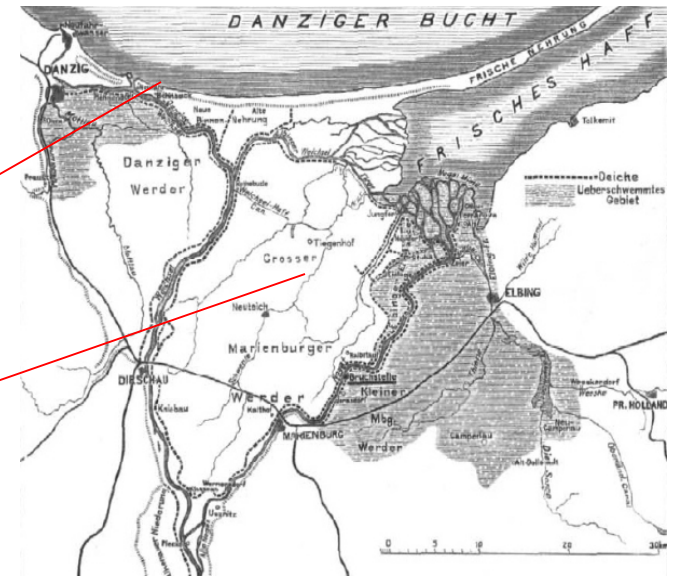


- Flood 1829 was very severe caused by an ice jam, which formed at the mouth of Vistula and the breach of left flood dyke of the Vistula. Flood appeared in March after a very severe winter with large amounts of snow. Discharge was estimated as 10 thousand m^3/s . Ice thickness reached 1m. Area flooded was 340 km^2 , 10 thousand people were homeless.
- Result – the Vistula turned to the west forming new outlet to the Bay of Gdansk. The city of Gdansk was flooded up to the first floor. There were important social and economic losses over the whole area of Żuławy Gdańskie



FLOOD 1840 and 1855

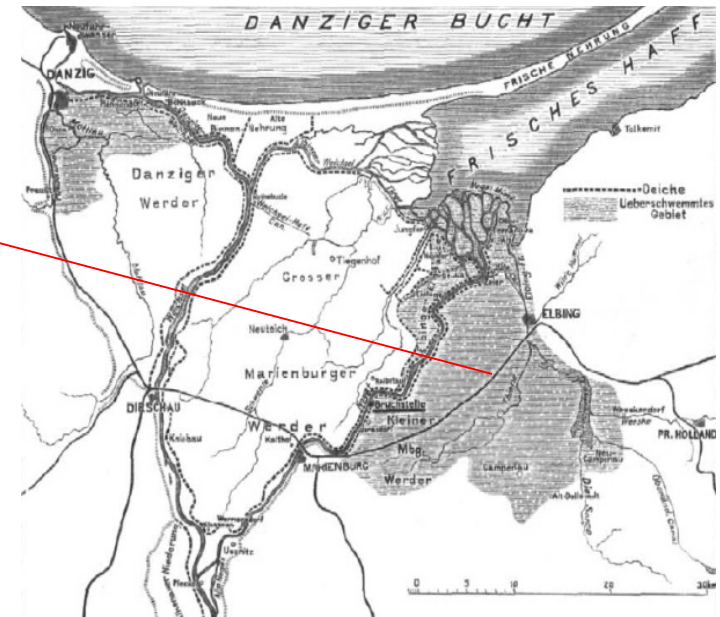
- In January 1840 large ice jam formed on the Gdańsk Vistula. Increase in water level caused the breach of shore dunes and made a new river outlet to the sea. This new channel is about 2.5 km long and creates new Vistula connection with the Bay of Gdańsk. Estimated discharge of Vistula was about $10 \cdot 10^3 \text{ m}^3/\text{s}$. This outlet is now called Śmiała Wisła and is used for various purposes.



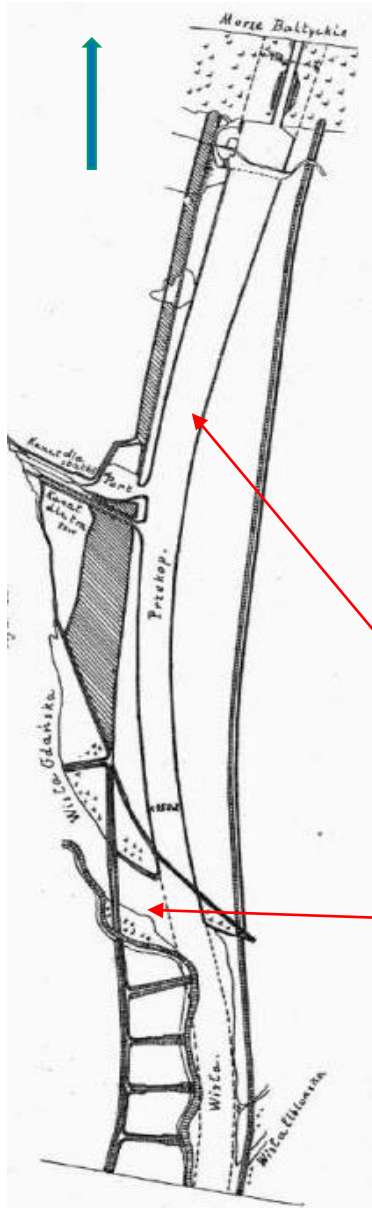
- Flood 1855 appeared in spring after a very cold winter with a lot of snow. Ice cover reached 0.9 m. Discharge was estimated at $9900 \text{ m}^3/\text{s}$. Right hand flood dykes of Vistula were breached and 600 km^2 was flooded. 100 persons lost life. Economic and social losses were very high.
- After flood there were alarming voices that something must be done to avoid such high social and economic losses. First projects appeared. They were very interesting but also very expensive.

FLOOD 1888 AND ITS CONSEQUENCES

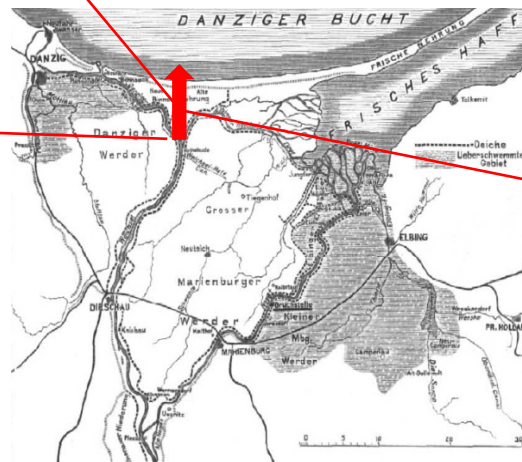
- 1888 was a severe winter with large amounts of snow
- Ice thickness on the Vistula was 0.4 m and on Nogat 0.8 m
- Main flow was directed to Nogat because of ice jams on the Vistula
- Right hand flood dykes of Nogat were breached and the area of 400 km² was flooded
- Very high social and economic losses. The whole drainage system on this area was destroyed
- Losses were compared to the cost of the proposed project of direct channel to the sea
- Final decision to implement direct channel was accepted



DESIGN OF THE DIRECT CHANNEL



- In XIX century several proposals to solve this problem were prepared
- In 1877 the design of Arsen and Fahl seemed to be very good as it solved many hydraulic problems of this area in a comprehensive way
- This project proposed Direct Channel from Przegalina to the Bay of Gdańsk
- Direct Channel was 7.1 km long, widths 250 – 400 m with flood dykes on both sides and fascine lining. The crest of flood dykes was 7.5 to 8.5 m above average sea level
- Bottom of the channel was 1.3 – 1.8 m below average sea level
- Project included also river training of Pomorska Vistula and construction of new hydraulic structures
- Final section of the channel 1.4 km long, going through the dunes was only 50 m wide
- Company, which just completed Kiel Channel was commissioned for this project



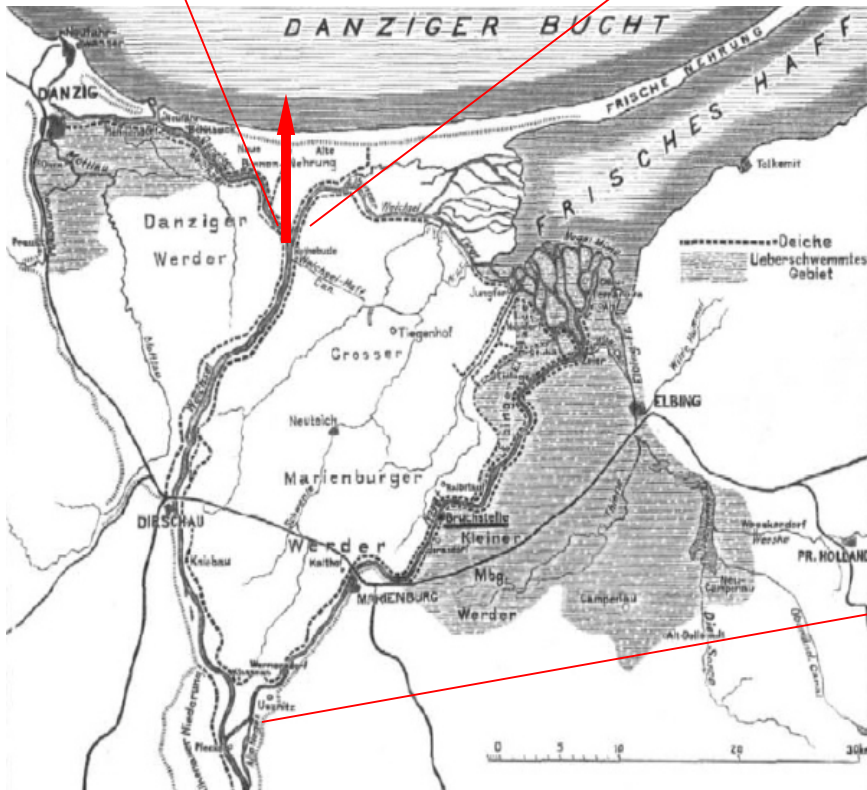
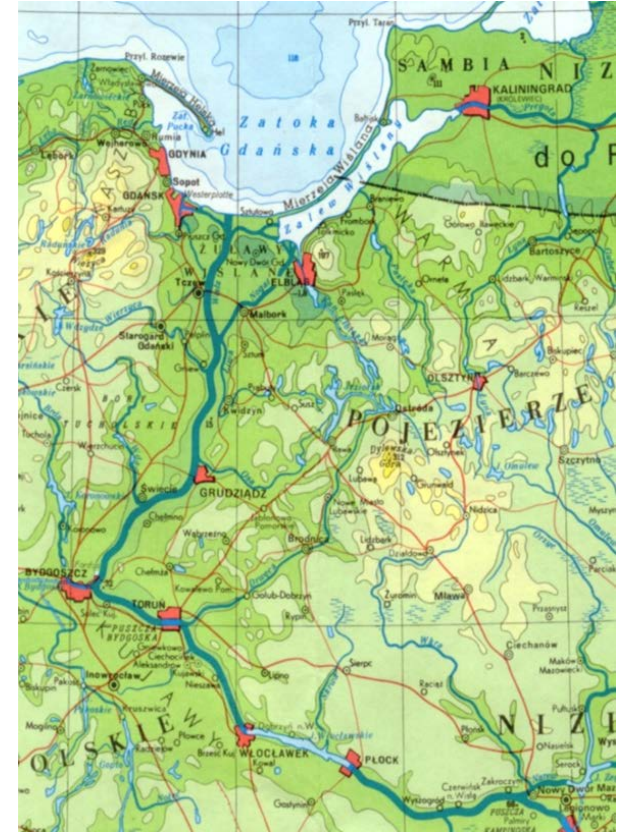
OPENING OF THE DIRECT CHANNEL

- In 1894 all earth works were completed. Total earth volume was 7 mil. m³
- The main part of the channel was filled with water and the channel was ready for opening.
- Opening was realized on the 31 March 1895 by the President of East Prusia on behalf of Ceaser Wihelm II.

- After 45 min. the channel width increased to 100 m, after 3h 200 m and after 16 h to 300 m.
- During 16 h. 2 mil. m³ of soil were transported to the sea.
- After spring season the proper dimensions of the channel were achieved with the consequence of transporting 9 mil. m³ of sediments



FOLLOW-UP ACTIONS



CONCLUSIONS

- Winters in the XIX century were very severe with large amounts of snow, low air temperatures and high discharge in spring
- The layout of the outlet of the Vistula was very complicated thus causing numerous ice jams, which resulted in devastating floods in various parts of Żuławy
- Two natural changes in the Vistula outlet layout appeared after floods 1829 and 1840
- There were several proposals to solve this problem, however, very expensive
- Finally the direct channel to the sea was chosen according to the proposal of Alsen and Fahl
- Design and execution of the channel were perfectly done and the opening of the channel was on the 31 March 1895.
- During one day water completed the final shape of the channel
- Subsequently three old branches were cut out by means of hydraulic structures
- Training of the whole section of Pomeranian Vistula for navigation was carried out
- The new outlet initiated new sedimentation cone but solved flood problems in this area.
- Maintenance of the channel is constantly necessary as well as the assistance of icebreakers.

Aerial View of the present Vistula Direct Channel

View of recently reconstructed outlet of Vistula Direct Channel



THANK YOU FOR YOUR
ATTENTION