# MULTIVARIATE INTERPRETATION GEOPHYSICAL DATA FOR EVALUATION OF GEOTECHNIC CONDITION OF PART EMEBANKMENT VISTULA RIVER

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## Introduction

This article presents the results of research using a selection of geophysical methods for the recognition of geophysical parameters of the flood embankment body. Three independent geophysical methods were used for this study, along a 500-meter long test section. Geophysical measurements were made along 5 profiles parallel to the embankment and 32 perpendicular to it. Archive data was made available for the geotechnical analyses carried out during the implementation of this project. The applied methods allowed to determine such physical parameters as: resistivity, apparent conductivity and magnetic susceptibility. A comprehensive approach to this solution allows for the recognition of the impact of geological and hydrotechnical changes on the value of the obtained result.

Performed measurements using Electric Resistivity Tomography method (ERT), Electromagnetic Conductivity Method (ECM) and Ground Penetrating Radar (GPR) allowed to delineate in detail the geological structure between geotechnical boreholes. Geotechnical data were used for verification of interpretation of the geophysical results. The comprehensive application of geophysical methods has enabled delineation of zones with anomalous values of individual physical parameters identified mainly with zones of soil relaxation and zones of increased filtration. Such zones located within the body of the embankment as well as at its base pose a direct threat to its stability.

## Methods

Computational and interpretation works included field data processing and then calculation of the apparent resistivity values for the geological subsurface. During the interpretation for the electro-resistivity imaging, it was possible to apply the method of modelling the 2D resistivity distribution using the so-called reverse modeling, commonly referred to as inversion. The assumed geoelectric model of the subsurface accounted for the variability of electrical resistivity in both vertical and horizontal directions. Subsequently, the resistivity values were calculated from the conductivities obtained from the ECM measurements. The results are presented in the form of resistivity distribution maps at a given depth as well as graphs of the apparent conductivity distribution along the profiles. The obtained results were then compared with depth sections resulting from the geo-radar survey. The developed models were further confronted with geotechnical drilling results, which allowed for the correlation of drilling results with geophysical anomalies.

## Results

It was observed that the body of the flood embankment consists mainly of low-resistivity deposits. Therefore, all zones with increased resistivities may indicate zones of soil relaxation. A similar situation was observed in the front of embankment. At the surface there are layers of low resistivity, which are typical for impermeable deposits, clays and loam. Another situation is found in inter-embankment zone. A significant increase in resistivity and thus a decrease in conductivity was registered there. This situation is identical to the described geological situation, which addresses a very large lithological variability between the studied zones (Walczowski A., 1968]. Observed differences are the result of intensive transport of mineral material, mainly sand deposited in the form of sandbanks or beaches, visible at the river bed. The summary results allowed to indicate changes in geotechnical parameters in regions not yet explored by drilling. Thanks to this methodology, it was possible to determine the condition of the embankment thus limiting the need to increase the number of drilled boreholes. Thanks to the processing of data from the profiles located in the body and at the base of the embankment it was possible to assess the condition of the ground below the embankment, thus indicating the zone of potential occurrence of hydraulic breaks. Some of them correlated with the zones marked as places of permeation during high water levels in the Vistula River.

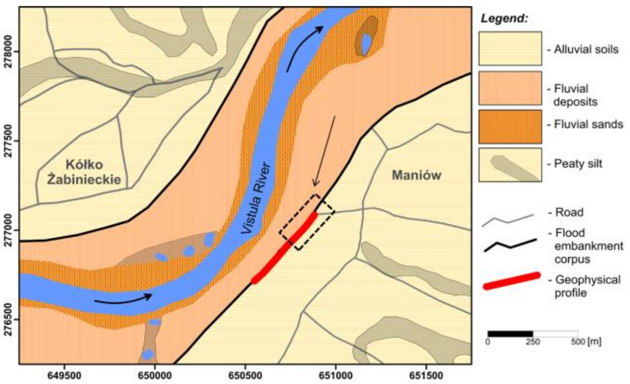


***Figure 1.*** *Location of the study area and geophysical profile on a geological map background; sheet M34-67A Szczucin, 1:50 000 (edited by Rostowska 1967, changed; Cygal et al., 2016).*

## Conclusions

Flood embankments belong to hydrotechnical constructions performing functions of water damming during river flooding periods. The dynamics of the phenomena occurring during floods is especially dangerous, because the water during rising is normally in motion and the embankment is under the pressure of a huge mass of water. It is important then to preserve the structure of flood embankments and the structure of the foundation of these embankments, where the main building blocks should be impermeable layers (such as clays and loam). Particularly dangerous are permeability (hydraulic) breaks both in the body and the foundation of the embankments, inadequate compaction of soils, especially sands that are highly permeable to water (causing water to seep through during river floods) or poor condition of protections, such as erosion shields (Cygal et. al., 2015). Geophysical methods such as ERT or GPR allow to receive high-resolution results, unfortunately in sudden and crisis situations there may be no possibility nor time for such work to be carried out. The conductometric method is a very good one and at the same time a quick one to carry out. The results of these profilings correlated well with archive geological surveys, which suggests that they can certainly be used in researching and monitoring the condition of flood embankments and other linear terrestrial infrastructure facilities. Nevertheless, the research methodology should be adapted to the geological conditions in the surroundings and the foundation of the embankments as well as to the used materials and geometry of flood embankments. It should also include carrying out complete geophysical surveys during low water levels for preventive action aimed at detecting potential changes in the body of the flood embankment.

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