FINAL REPORT:

RECAPITULATION

OF ACTIONS TAKEN FOR MODELLING AND NATURE INVENTORY TAKING FOR THE AREA COVERED BY MEASURE 1A.3

"RESTORING NATURAL VALUES OF LOWER ODRA VALLEY BY IMPROVING THE RETENTION AND FLOOD PROTECTION CAPACITIES OF MIĘDZYODRZE"

CONTRACT 5.3/ZZMiUW

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Contents

1. Grounds for the report and its purpose

The recapitulation has been prepared to present the manner and results of the hydraulic modelling of Międzyodrze as well as the results of the taken nature inventory. The activities have been undertaken under Odra-Vistula Flood Management Project, Contract 5.3/ZZMiUW *Design and construction supervision. Project management, technical support and support for project implementation units in execution of Odra-Vistula Flood Management Project, Contract 1A.3: "Restoring natural value of Lower Odra Valley by improving water retention and flood protection capability of Międzyodrze area"* and the legislation requiring flood protection.

The purpose of the performed analysis titled *"Mathematic / hydraulic 1D and 2D modelling of Międzyodrze"* is to, among others, identify the solutions that would improve flood protection in the area.

It should be pointed out that the recapitulation is an abstract and generalized presentation of the activities undertaken. The details, including explanations, can be found in the full version of the Report.

2. Scope of the report

The report covers Międzyodrze area (see the map), highlighting its hydrological and natural considerations in historical and current state and presents expected results of potential future activities.
The hydrological and natural modelling results have been supplemented with the results of analyzing the physical and chemical properties of water and bottom sediments.

3. Historical background

Full characteristics of Międzyodrze area in the model required taking into consideration its origin and functioning. It provided the input from the processes that take place there and their direction and intensity.

The current status of lower Odra area results from the works that were performed there between 1906 and 1939. Key of those included shaping the river bed, i.e. making the eastern branch the main bed called Odra. It was decided that it was the shortest route for the river's water and load to Dąbie lake. That required making a cutting from Odra to Regalica branch below Widuchowa near Gryfino (as presented on the figure below) and filling and closing many side branches along the river that merged the bed. The western branch of Odra was converted into a navigation canal. Additionally, to support navigation, a water passage from Szczecin to Eastern Odra was built.

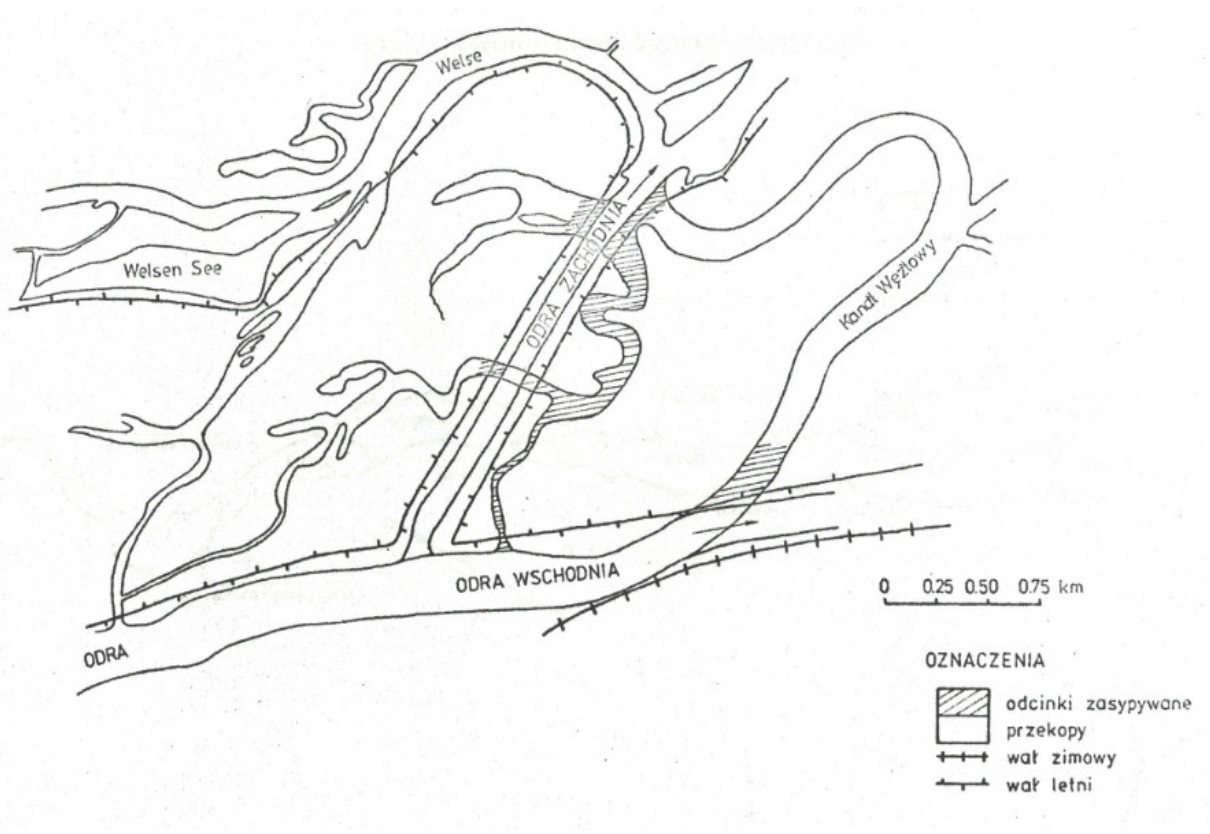

Figure 1 Regulation of Odra in Widuchowa vicinity

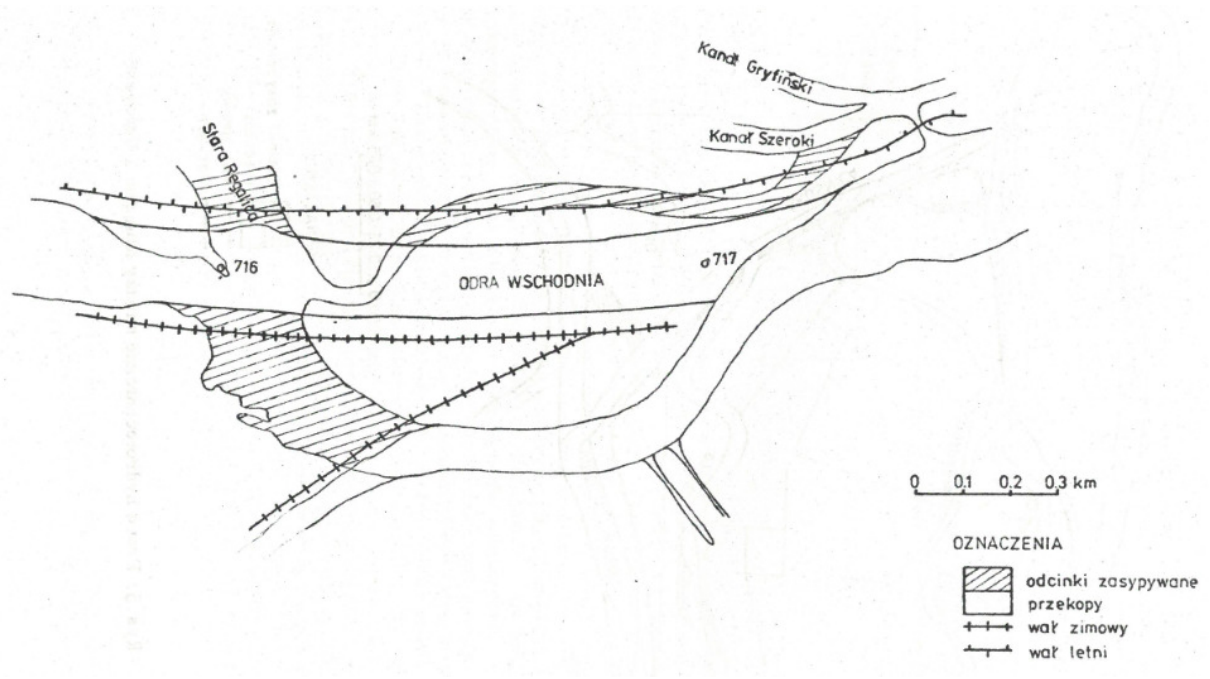

Figure 2 Regulation of Odra in Gryfino vicinity

It should be pointed out that all the regulation activities, such as

- building the flood protection embankments (that created Międzyodrze polders),
- reducing the load on the right river branch by making the cutting below Widuchowa (toward Western Odra),
- making embankments on both sides of the cutting,
- building a gate weir for controlling the water distribution for the river's branches.
- building about 30 facilities (navigation and farming chamber locks, embankment culverts, and draining pump stations),

were to support the farming activities in the area, and, indirectly, improve the navigation conditions. Until the end of the 60's of the 20th century Międzyodrze was used for agricultural purposes. The growing degradation of the hydrotechnical structures and increasing cost of operation lead to leaving the area unattended. The resultant land turning into marshes and secondary natural succession provided a base for creating Lower Odra Valley Landscape Park in 1993.

4. Hydrological modelling

As part of the modelling, it was decided to create a hydraulic model of Międzyodrze that would simulate flood water passage and predict its potential results, revealing the area's critical points and determining the necessary and feasible scope of works that would improve safety and flood protection. The modelling covered the area between Widuchowa water gauge to Szczecin Most Długi (Western Odra) and Most Cłowy (Odra) water gauges. 35.8 km of Odra (from km 701+800 to km 737+600) and 36 km of Odra Zachodnia (from km 0+000 to km 36+000) were modelled. Canals within Międzyodrze were included. The total area covered by the modelling was 128.28 km^2. It was decided that the model would image Międzyodrze during an areal/run-off flood from the south. Although the area is within backwater range, due to the nature of the flood, its rapid course, short duration, lower peak water (compared to areal floods) and its dependence on the water level and not on the flow as well as no possibility of controlling the structures in such a short period, including backwaters in the model was considered unjustified.

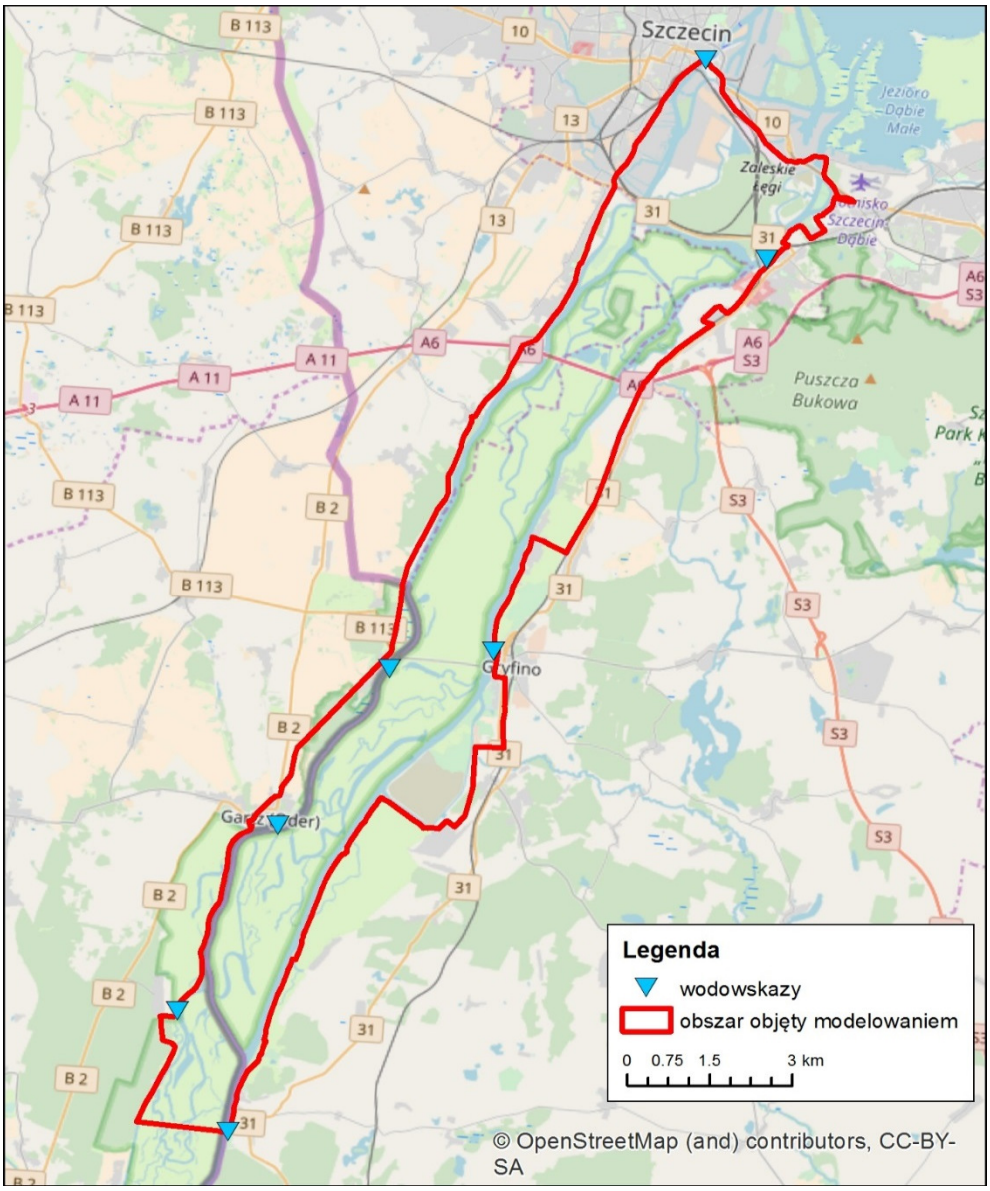

Figure 3 Area covered by the model

Because of the area's specific character, i.e. little elevation difference and surface sloping, the hydraulic calculations were done using a 2D model: MIKE 21 FM (flexible mesh) that consisted of an irregular network of elements (triangles and tetragons). The calculations were based on a numerical solution of a two-dimensional shallow water equation.

The following existing data were used in the model:

- Numerical Terrain Model (NMT) for Polish and German site,
- Orthophotomaps,
- Database of Existing Topographic Objects (BDOT),
- Parameters of the existing and planned hydrotechnical structures (based on the geodetic inventory of hydrotechnical structures, point 4.1),
- Hydrological data (for calibration and scenario calculations),

- Hydraulic models created under ISOK and PZRP projects.

The hypothetical high water situations were determined using Warsaw University of Technology method. The reason was using the data from the Institute of Meteorology and Water management that applies the same calculative approach. Therefore, it was justified to use the same method.

Preparations to the modelling included geodetic inventory of hydrotechnical structures in Międzyodrze. 35 structures were identified. The geodetic inventory of hydrotechnical structures along Wester Odra banks from km 0.00 to km 29.50 and Eastern Odra from km 704.00 to km 730.00 included the following:

a) altimetric measurement of water level, depth in the canal axis, width between bank lines directly before the structure, in the middle of the structure, and directly behind the structure toward Międzyodrze 50 m, 100 m, and 150 from the structure for every available canal going out from the structure,
b) schematic determination of the structure's length, width, and height,
c) brief description of the structure (drive, baffle, obstacle) and its technical condition (operational, damaged, scope of damage),
d) photo documentation.

The inventory showed that all the hydrotechnical structures in Międzyodrze area, due to their technical condition, could not be used as designed. They are corroded, often damaged. Many of them lack key elements (baffles, bridges) that make them inoperative. Most of the locks are silted. In many cases at the locks' entries and exits disconcerning overdeepenings were reported; they might mean significant bottom erosion near the structures. Additionally, the canals' depth was often smaller than the locks'. It could stem from a lack of proper water flow through the canals that leads to settling of the material carried by water. The hydrotechnical structures' vicinity is overgrown with vegetation (most often reeds) that obstructs water movement, reducing the speed of water flow in the canals.

4.1 Scenarios and calculation variants

The hydrodynamic calculations were prepared for 3 scenarios:

- Q0.2% - low flood probability (every 500 years),
- Q1% - medium flood probability (every 100 years),
- Q10% - high flood probability (every 10 years).

Calculations of the input flow hydrogram (upper boundary condition) for Międzyodrze hydraulic model located at Widuchowa water gauge were based on the 1D hydraulic model from ISOK model. The model covered the section stretching to Gryfino. After an analysis of the shape of Odra flood valley at the section from Bielinek to Widuchowa it was decided to modify the ISOK model. The modification included determining the alluvial terraces necessary for correct directing of flow waters and proper modelling of the flow between Odra embankments and the Lower Odra Valley National Park and Hohensaaten-Friedrichshtal canal. The alluvial terraces were connected to the main watercourse using link channels, modelling the geometry of the flood protection embankments or a high bank. The models that have link channels are often called quasi-2D models

because they model flow also perpendicularly to the main flow direction. Parameters of the link channels are selected in a manner that would properly model water flow from the river to the floodplains and the other way around.

The calibration and verification of the model consisted in comparing the recorded hydrogram (historic high water) with the hydrogram obtained in result of the hydraulic model simulation. The verification was performed using historical high water data other than the ones the calibration was performed for. The calibration and verification assessment was based on a graphic and statistical analysis.

The model was parametrized by adjusting the Manning-Stickler coefficients M to the highest possible match between the calculation (simulation) values with the recorded (historical) values.

The calibration and verification was based on the data recorded at the water gauges in Widuchowa, Gryfino, Szczecin Most Długi, Szczecin Podjuchy, Gartz, and Mescherin for the following periods:

- October 2009,
- October 2016,
- January 2017,
- July and August 1997,
- May and June 2010.

The above data includes water level only. Therefore, the statistical model assessment was not done for flows because the data is not recorded at the water gauges. The characteristics of the data obtained for calibration and verification is presented in the following table. Szczecin Podjuchy water gauge was installed in 2004, so no data is available for 1997 from the location.

The following chart presents comparison of one selected historical and calculated hydrogram for Gryfino water gauge.

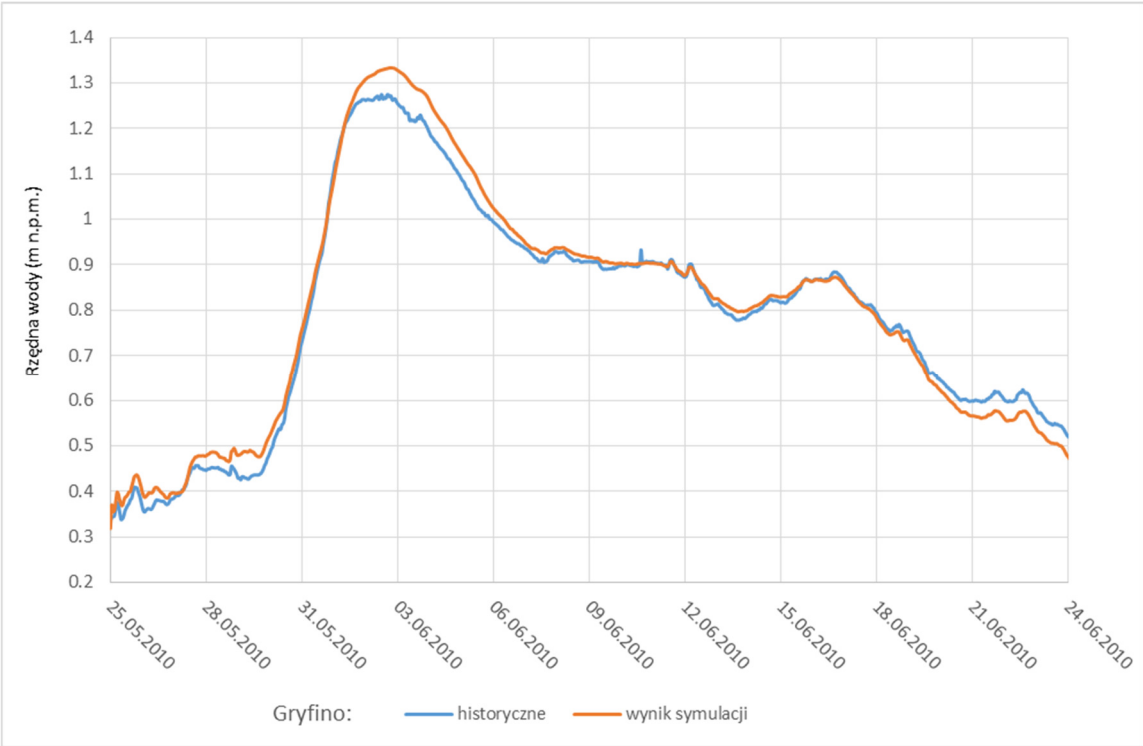

Figure 4 Comparison of the historical and calculated hydrograms for 2010 high water at Gryfino.

Comparison of historical hydrograms for all the analyzed high water cases with the results of the calculations shows that the model very accurately represents the shape of the high water wave: the correlation coefficient is very high. The peak error for Gryfino was from 1 to 7 cm, depending on the high water.

Additionally, water flow directions were verified for comparison of the simulation to the actual, recorded directions. A lot of water flows to Międzyodrze area through the navigation lock at km 710+600 of Easter Odra: the maximum flow reaches 32 m^3/s. The following map shows also directions of water flow.

Figure 5 Navigation locks at km 008+500 of Western Odra and at km 710+600 of Eastern Odra

*wartości dodatnie – kierunek przepływu od Odry do Międzyodrza
*wartości ujemne – kierunek przepływu od Międzyodrza do Odry

Figure 6 Flows through the navigation lock at km 008+500 of Western Odra

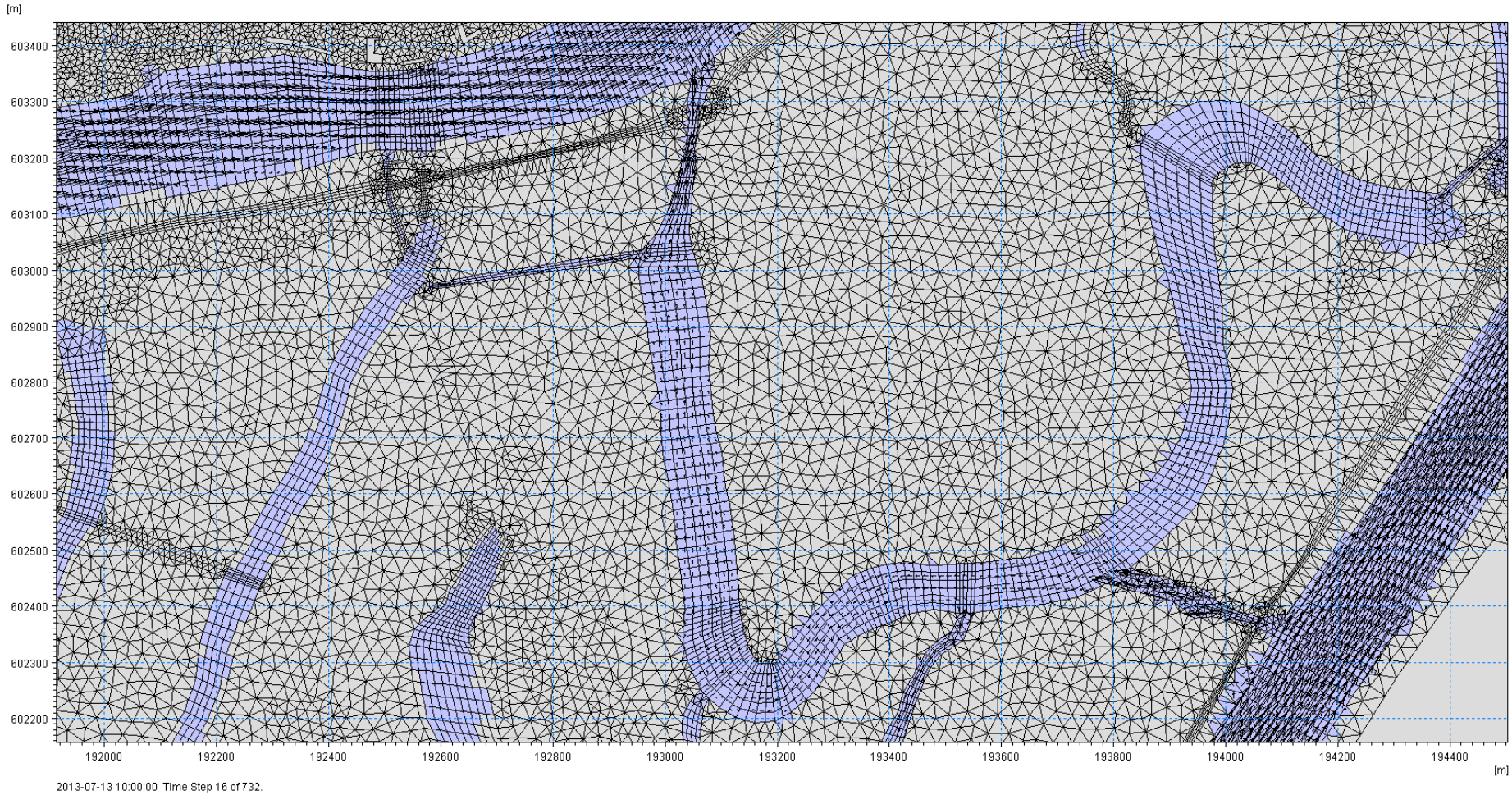

Figure 7 Flow directions for the following flows: 622 m³/s at Eastern Odra and 300 m3/s at Western Odra

The calibration, verification and analysis of flow directions showed that the model very accurately represented the course of historical high water cases in terms of the shape and low, high, and peak water levels. The hydraulic model results were also very good for determining the peak time. Therefore, it was decided that the model could be used for running the simulation planned under this project.

The model calculations were prepared in three variants:

- V0: current status variant,
- V1: variant assuming closing all the hydrotechnical structures that feed water to Międzyodrze,
- V2: variant assuming optimized control of the hydrotechnical structures aimed at reducing the flood risk in Gryfino, restoring the hydrotechnical structures, modernizing the embankments around Międzyodrze, and lowering bottoms of selected Międzyodrze canals.

4.1.1 Variant V0

To be able to properly compare the results, Variant V0 was prepared for the current status. Variant V0 is the base for comparing the effectiveness of the activities proposed in V1 and V2 variants.

Variant V0 is based on the previously described elements of the hydrotechnical structures inventory and the current status of Międzyodrze embankments. The figure below shows a cross-section example of one of the embankments from the inventory.

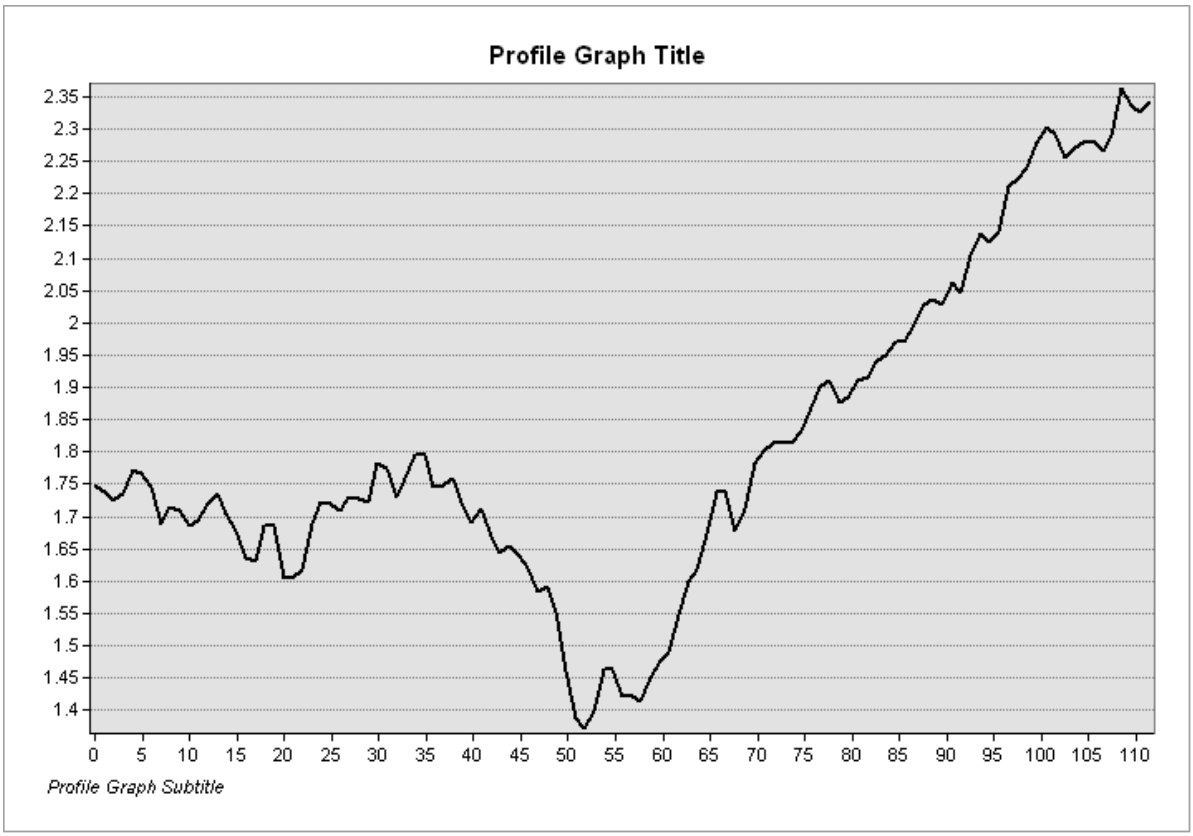

Figure 8 Embankment cross-section. Eastern Odra at km 706+200

4.1.2 Variant V1 and Variant V2

Variant V1 represents a purely hypothetical situation of closing all the hydrotechnical structures. It refers to the results of the natural inventory taking that clearly indicates the on-going succession and overgrowing of Międzyodrze canals. The assumed hypothetical "closing" would actually mean complete overgrowing of the canals and no flow there. In this variant water could flow to and from Międzyodrze only over embankment crowns.

Variant V2, however, assumed also control of the hydrotechnical structures. In the model, the structures at Western Odra were closed during water rising and peak water. They were opened during water lowering to allow for water outflow from Międzyodrze. The structures at Eastern Odra were controlled on the basis of water levels at selected Odra cross-sections. At the beginning of the water rising, the structures were closed. Then they were opened gradually to delay and reduce the flood risk in Gryfino. The opening time was also adjusted for the height of embankments near the structures, so as to prevent water flowing over the top. The variant also assumed restoring the hydrotechnical structures operability and desilting the canals in direct vicinity of the structures. The model also included lowering inlets and outlets of specific structures by 0.5 m combined with reducing by the same amount the directly adjacent canals in the calculation grid.

The next measure proposed in Variant V2 was reducing by 0.5 m the bottom ordinate of about 50% of Międzyodrze canals (by length). The operation did not apply to those canals that were excluded from any technical measures after the inventory and natural analyses. The last activity

assumed restoring the embankments around Międzyodrze. It consisted mainly in leveling the embankment top for the areas where lower crown was identified. In all the locations with missing embankment parts new structures (with the ordinate matching the existing embankment) were inserted. Locations of the measures are presented at the following map.

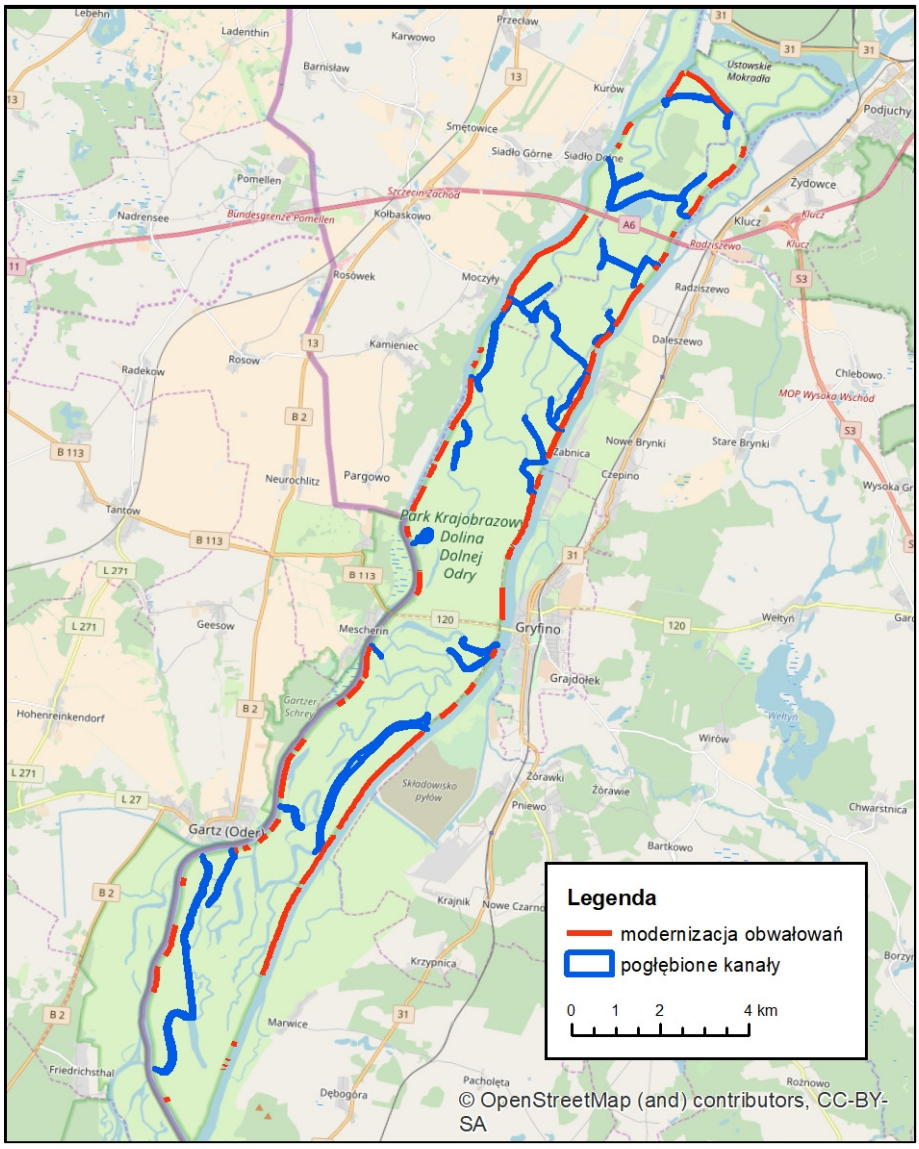

Figure 9 Location of measures planned in variant V2 (canal dredging and embankment improvements)

4.2 Calculation results

For the purpose of analyzing the volume of water flowing through Międzyodrze, the area was divided into four parts:

- south: from Widuchowa to Gryfino-Mescherin road,
- north I: from Gryfino-Mescherin road to A6 highway,
- north II: from A6 highway to Skośnica,
- north III: from Skośnica to Kanał Leśny.

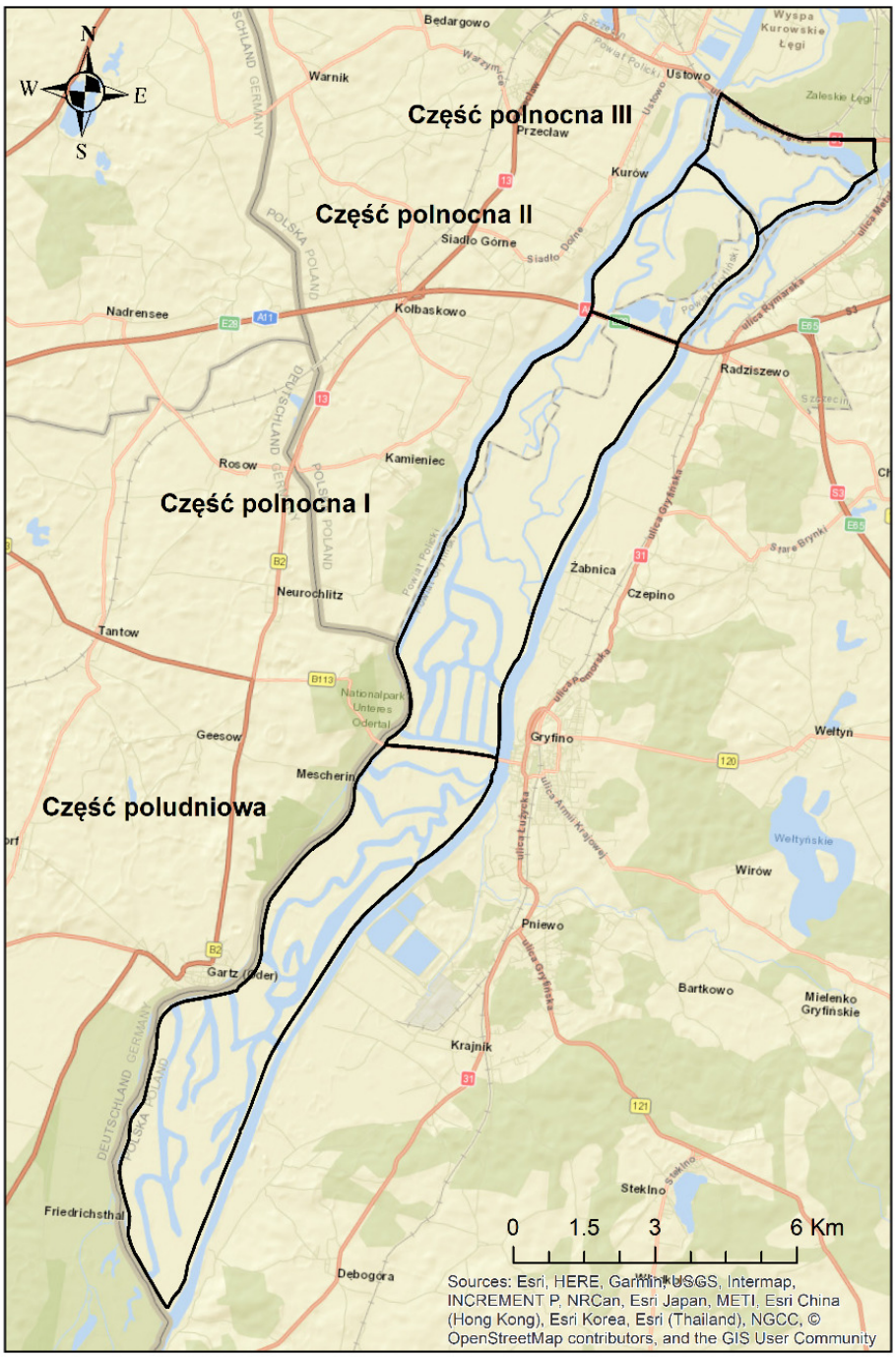

Figure 10 Division of Międzyodrze into four parts for the purpose of water flow analysis

Table 1 Maximum water volumes calculated for individual parts of Międzyodrze in Variant VO

Part	Scenario – volume [m³]		
	Q10%	Q1%	Q0.2%
South	37 280 160	56 155 231	66 640 960
North I	19 162 112	35 440 077	44 583 127
North II	5 112 030	10 178 983	13 174 110
North III	8 374 635	11 824 896	13 849 383

Part	Scenario – volume [m³]		
	Q10%	Q1%	Q0.2%
Total	69 928 937	113 599 187	138 247 580

For Q10% scenario southern part of Międzyodrze fills with water from Odra in Variant V2 later and more rapidly than in Variant V1. Under Variant V1 water flows to Międzyodrze through lower and missing parts of the embankments in poor technical condition. Under Variant V2 the embankments were modernized and, additionally, the structures at Western Odra were closed. Quick water volume increase in Międzyodrze starts upon opening hydrotechnical structures at Eastern Odra. The introduced control of the structures delays the moment of maximum filling of the area. Water run-off after the peak wave also more slowly. The first part to fill is the south, then, after a dozen or few dozen hours, the north.

For Q1% and Q0.2% scenarios the impact of the proposed measures was smaller than in the Q10% scenario because of the greater volume of flood waves.

The following table shows the trend of the decreasing impact of the proposed measures following increasing volume of water. The activities only slightly increased the maximum retention capacity.

Table 2 Comparison of maximum water volumes in individual parts of Międzyodrze in variants V0, V1 and V2 for the Q1% scenario

Part	V0 and V1		V0 and V2		V1 and V2	
	Difference [m³] V0-V1	Ratio (V0-V1)/V0	Difference [m³] V0 – V2	Ratio (V0-V2)/V0	Difference [m³] V1 – V2	(V1-V2)/V2 ratio
South	3 896	0.00007	-609 650	-0.01000	-613 547	-0.01000
North I	-10 345	-0.00030	-449 639	-0.01000	-439 293	-0.01000
North II	-13 068	-0.00100	-183 574	-0.02000	-196 643	-0.02000
North III	5 701	0.00050	11 236	0.00090	5 535	0.00050

Table 3 Comparison of maximum water volumes in individual parts of Międzyodrze in variants V0, V1 and V2 for the Q0.2% scenario

Part	V0 and V1		V0 and V2		V1 and V2	
	Difference [m³] V0-V1	Ratio (V0-V1)/V0	Difference [m³] V0 – V2	Ratio (V0-V2)/V0	Difference [m³] V1 – V2	(V1-V2)/V2 ratio
South	-10 378	-0.00020	-646 839	-0.01000	-636 461	-0.00900
North I	-10 073	-0.00020	-391 288	-0.00900	-381 215	-0.00800
North II	- 1 112	-0.00008	-127 661	-0.01000	-126 549	-0.01000
North III	1 142	-0.00008	553	0.00004	-588	0.00004

Results of modelling the current status (Variant V0) helped identify the areas with the highest flood risk. For each of the areas flood course characteristics were prepared and the risk factors were described.

There are two towns on the left bank of Western Odra: Gartz and Mescherin. In Gartz a few buildings are threatened with flooding, they are located near Salveybach tributary. Rising Odra waters gradually flood the least elevated areas. The range of the flood gradually grows from Q10% scenario to Q0.2% scenario. Depth of water reaches, 0.5 m, from 1.0 m to 1.5 m, and from 1.5 m to 2.0 m in Q10%, Q1%, and Q0.2% scenarios, respectively. Most of Gartz remains safe due to its location on a higher ground. In Mescherin a few buildings are threatened with shallow (11-19 cm) flooding but the risk is present only in 0.2% scenario; the buildings are located next to Western Odra river bed. In the remaining two scenarios water poses no threat to buildings in the town.

In the case of Gryfino, on the right bank of Eastern Odra, the existing embankments ensure protection of buildings during high and medium probability floods. The part of the town (between ul. Sportowa and ul. Targowa) that is in direct vicinity of Odra is not protected by the embankments, so over a dozen buildings, mostly not residential, is threatened to flooding with 10-50 cm of water by Q1% floods. For low probability floods (0.2%), water in the area would be up to 1.0 m deep, still threatening mostly non-residential buildings. The spot marked on the map as the end of the embankment near ul. Sportowa is the place where water (Q0.2%) would flow over and flood the area behind the embankment. Additionally, water from Odra would flood Kanał Ciepły and Tywa and at its peak level would flow over the embankment flooding a large portion of the town, posing threat to a few dozen buildings (depth up to 1.5 m).

There are two villages directly in Gryfino vicinity: Żabnica and Dębce. Between the two, there is a 850 m long embankment along Odra. The villages are not embanked because they are located on elevated terrain. In Q10% scenario buildings in both villages are not threatened, the only part that is flooded are low-elevation areas along Odra banks. For low and medium probability floods, there is high risk of water flowing over the lowest parts of Żabnica and flooding vast stretches of land behind the flood embankment. Other flooded places in scenarios Q1% and Q0.2% would be, respectively, a dozen or so buildings (0.5 m of water), and nearly 30 buildings (water depth from 0.5 m to 1.5 m).

On the left bank of Western Odra the following villages are located: Moczyły, Siadło Górne, and Kurów, where buildings are flooded. In Moczyły the flood risk is present in all the modelled scenarios in the parts of the village along Odra banks. For Q10% scenario some buildings are not flooded, while other are flooded with water up to 0.5 m deep. For Q1% and Q0.2% scenarios, all the buildings are flooded, including 25 residential and summer houses, with water from 0.5 m to 1.5 m deep. In Siadło Górne only low probability flood causes shallow flooding (few inches) of a few buildings located closest to Odra banks. In Kurów a few buildings are flooded a few inches in the Q10% scenario. For other probabilities the flooded area and water depth are increasing. For Q1% and Q0.2% scenarios over a dozen buildings is flooded with 1.0 m and 1.5 m of water, respectively.

In the part of Szczecin covered by the model the highest risk characterizes Wyspa Pucka area. For high probability flood, the area remains unflooded but water from Odra enters Kanał Rybny and floods low-elevated areas on the right bank of the canal. Although Wyspa Pucka is protected by an embankment (water does not flow over the top), buildings on the island are flooded with up to 2.0 m and 2.5 m of water in, respectively, Q1% and Q0.2% scenarios, by water from Odra entering the area through Kanał Rybny. On the opposite bank of Odra, in Pomorzany district, the lowest

elevation areas and non-residential buildings are flooded in Q1% and Q0.2% scenarios. For low probability flood, there is also risk of flooding about 150 m of Tama Pomorzańska street.

High probability of flooding characterizes "Nad Regalicą" fishing harbor. It is an area located on the left bank of Eastern Odra, near Pionierów Miasta Szczecina bridge. Due to its location in a low-lying area, in Q1% and Q0.2% scenarios the buildings are exposed to 1.0 m flooding.

Different variants of modelling results are shown on the maps presenting maximum water differences between specific scenarios.

In the case of medium probability floods the difference in the maximum water depth results between V1 and V2 scenarios for the whole area was very low. In all the threatened towns and villages the changes varied from -1 cm to + 1 cm. Very similar result was achieved for low probability floods.

The measures proposed under Variant V2 increase the maximum water depth for Q1% and Q0.2% scenarios in northern Międzyodrze in Variant V0 by a few centimeters. In Gryfino the range of medium probability flood slightly increased. However, in the case of Q0.2% scenario the maximum water depth results differ very little for Variant V2 and Variant V0. Similar result characterizes the area behind the embankment between Żabnica and Dębce villages. For Q1% scenario, the depth of flood water increased by 8 cm in Variant V2. For Q0.2% scenario, however, the differences were negligent. In other towns and villages threatened by flooding the changes specified in Variant V2 neither decreased nor increased the medium or low probability flood risk.

5. Nature inventory

Flora and natural habitats

The study is based on data collected during field work carried out in the growing season of 2017 in the months from June to October 2017.

In the area covered by the study, the occurrence of 8 protected species has been documented, including three strictly protected. None of these species is protected by Natura 2000 area, although these species are typical for protected natural habitats. Due to the high threat category on the national scale and the exceptionally rare presence in the northern part of the country - the populations of fringed water lily and water caltrop are a very significant value of the area. Both species were discovered in the Lower Odra Valley after decades of absence. Another species under strict protection - the floating fern is locally very widespread and occurs en masse (not only in Międzyodrze for that matter but also in the area of the Lower Odra Valley to its estuary in the Szczecin Lagoon). The remaining species belong to the widespread species and having large resources on a regional scale, with the exception of medium numerous watercress and the marsh pea. The dwarf everlast, recorded only once in the Międzyodrze (locally rare due to unfavorable habitat conditions) is a very common species in the surrounding areas and on a regional scale.

In the Międzyodrze area, the presence of three natural habitats has been documented:

1. Oxbow lakes and natural eutrophic water reservoirs with with *Nympheion* and *Potamion* communities [3150] – at least 22 patches occupying 40.97 ha,

2. Mountain herbs (Adenostylion alliariae) and riparian tall herbs (Convolvuletalia sepium) [6430] - 28 patches occupying 3.27 ha,
3. Riparian willow, poplar, alder and ash forests (Salicetum albo-fragilis, Populetum albae, Alnenion glutinoso-incanae, black alder forests)* [91E0] - 60 patches occupying 165.05 ha.

Hydrotechnical works may have a significant impact on habitats of protected and endangered species and natural habitats at Międzyodrze.

Any intervention that could worsen the habitat conditions of two priority species in the context of legal protection, threat status and rarity should be considered significant impact with regard to biodiversity. Any hydrotechnical work carried out in the Marwicki Canal (the fringed water lily habitat) as well as the Obnica Polnocna (habitat of the source population of the water caltrop) involve a very high risk of destruction of these populations. Furthermore, work carried out in the vicinity of the upper part of these canals (in Regalica at the mouth of the Marwicki Canal and Skosnica at the mouth of Obnica) may involve a significant impact on the habitat of the species (change of physico-chemical conditions of the water, influx of bottom sediments).

With regard to other protected and endangered species as well as species diversity of flora in general, any hydrotechnical project implemented on a large scale over a large area of Międzyodrze or in the area with presence of a significant part of resources of a specific species or a group of species may have a significant impact. The impact associated with a large scale of hydrotechnical work involves difficulty in maintaining species diversity (maintaining the necessary resources of species that enable the reconstruction of their population). Due to the specificity of the distribution of habitats of many species a significant threat would be posed by, in particular, works carried out simultaneously or in a short time over the entire inter-embankment area of the Western Odra and Eastern Odra (on the external side of the embankments that surround Międzyodrze).

Such action, i.e. interference into the inter-embankment, in particular, involving the removal of the vegetation cover and changes in habitat conditions (replacement or fertilization of land, hydrotechnical fixing of the bank or the foot of embankment, etc.) would also have a significant impact on natural habitats - alluvial forests (91E0) and riparian herbs (6430). These habitats develop almost exclusively on the inter-embankment within Międzyodrze. Consideration of local conditions of habitat formation would require undertakings related to the reconstruction or renovation of the embankments. Thus, in many places their slopes and foot is a habitat for herbaceous plants and riparian forests.

All earthworks involving movement of local soil and bringing soil from other places involve a high risk of spreading and carrying invasive species. In particular, in this way invasive knotweed is spread along the rivers.

With regard to oxbows (3150), a significant impact would be made by interference causing deterioration of living conditions of species and communities typical for the habitat, resulting in a degradation of its natural values – thus, in particular, when implemented in places where well-developed habitats have been preserved. Significant interference in the bottom or embankments of the basin (dredging, reinforcement of banks, etc.) would have serious impact in such cases.

In order to preserve the diversity of species of flora it is essential to keep the habitats in the inter-embankment (located between the Eastern Odra and the Western Odra currents and the embankments surrounding Międzyodrze) and a dense network of river tributaries and canals with various habitat conditions (land creation stage and water flow velocity) in a state close to natural.

To protect the values of the embankment and minimize negative impacts, the distribution of natural habitat patches - riparian forests (91E0) and herbaceous plants (6430) should be considered when planning possible interference in this area. If the embankment is occupied by well-developed riparian and herbaceous habitats its possible reconstruction should be considered on a parallel course on the inner side of Międzyodrze, while preserving the existing site as a place of protected habitats. In the case of the development of natural habitats on the foot of the embankment - the restoration should be limited to the crown if this allows to restore the functional values of the building.

To maintain the dynamics of water habitats and habitats dependent on water typical for the valley of a large lowland river it is essential to increase the flow of water through the Międzyodrze river network. It is recommended to improve the conditions of water flow through sluices and gates in the embankment (desludging, removal of obstacles), proceed to remove rush vegetation that overgrows canals, eventually also allow water flow under the road embankment of the A6 motorway. Depending on the needs, possibly also desludging selected sections of canals or fragments of the former river network.

Infusorial phytobenthos

The sampling of infusorial phytobenthos in Miedzyodrze was carried out from 26 to 29 September 2017. During the sampling, basic physical and chemical parameters of water were measured directly in the field: proper electrical conductivity, pH, water temperature and oxygen content.

During the research work the basic physical and chemical parameters of water were measured: electrical conductivity, pH, water temperature and oxygen content.

During an infusorial analysis to determine the ecological status of particular research sections using the diatomic index, a total of 120 diatom species belonging to 32 genera were identified.

In the presented results of the infusorial phytobenthos natural inventory there is an assessment of the ecological condition of the river on particular canals of the Międzyodrze area. The assessment of ecological condition by means of the multiparametric diatomic index is based on three indicators: the TI trophic index, the SI saprobic index and the GR reference species abundance index and expressed in 5 classes. The analyses carried out made it possible to conduct an objective and standardized assessment of the ecological status of the river during the sampling campaign, thus prior to the commencement of investment works. This will allow an objective assessment of changes in the river's ecosystem as a result of the works and after their completion and it will be a specific reference point, necessary for proper assessment of the investment's impact on the environment. At the same time, the analyses carried out allowed an inventory (review) of diatom taxa on the studied section of the river, which will allow assessment of changes in this ecosystem component as a result of ongoing works during and after their completion. In

the case of infusorial flora present in this type of habitat, compensatory measures are not expected.

After conducting the analysis it is concluded that the diatomaceous flora growing in the area under study does not differ from the previously recorded teams in this type of habitats - a large lowland river. Sparse presence of rare species has been reported.

Macrobenthos and malacofauna

The methodology provides for two dates of monitoring work in May-June and September-October, that is, in the period of the largest taxonomic macrobenthos differentiation. The samples were finally collected in two dates: June and September 2017.

The area currently occupied by Międzyodrze in Poland is the effect of transformations made by man in the Odra River estuary. However, thanks to this, a particularly precious natural area was created. In the past, the Odra River was a multi-channel river with several beds and numerous oxbow lakes. The current area of Międzyodrze has been embanked, cut off from the main stream, the only connections with the current are the channels leading through sluices (currently not functioning, mostly open). The main stream of the river was brought to the Eastern Odra which is mainly a man-made ditch and the Western Odra which largely reproduces the natural course of the river. Miedzyodrze's channels are very diverse. Large flow channels are quite deep, the bottom is hard in places, peaty with an admixture of sand or it is covered with soft deoxygenated saproplla sediments. The banks are steep with a very narrow fitolittoral, consisting mainly of common reeds and small assemblages of elodeids, with a domination of the soft hornwort. Large non-flow canals are similar to flow canals with the difference being an increased amount of sapropel and submerged vegetation-elodeids, nimfeids may be found. Narrow channels are, in turn, very rich in various plant habitats. Underwater meadows created by elodeids or underwater leaves of the yellow water-lily can be found here. In more secluded places one can spot pleuston, represented by duckweed family, floating ferns (Salvina natans and Azolla sp.). In narrow non-flow canals there is often a very thick layer of bottom sediments, in some places almost reaching the water surface. Narrow flow channels often tend to undergo land creation. When an obstacle disturbs the flow of water in such a channel, for example, an overturned tree, there is a rapid development of vegetation in the obstacle, the reed canary grass can often come from the mainland, which causes the formation of floating mat. The floating mat quickly grows from the end side of the canal, covering the water surface; the canal is filled with sediments and turns into land in the final phase. Narrow flow canals in comparison with non-flow ones have less soft organic sediments and fewer plant habitats, however, compared to the habitats of wide canals, the habitats are much richer. Lake-like canals are a completely different habitat of Międzyodrze. An extreme example of such a reservoir is Lake Samotne (lake canal located in the northern part of the area under study). It is an artificial lake with a depth of around a dozen meters. It was created in the 1930s as a result of sand mining for the construction of the nearby A6 motorway. Unlike natural lakes it has very sloping edges, with a poor fitolittoral. The elodeids and a narrow strip of reed bed can be found here, with the dominance of reed beds and occasionally *Typhetum latifoliae* or *Typhetum angustifoliae*. Beyond the narrow littoral the depth increases considerably. There is a lot of shellfish debris and detritus in the sublittoral. The profundal zone of this lake is dominated by deoxidized organic, particulate sapropel-like sediments. The lake-like canal located in the

southern part of the studied area is not so deep. It is a fragment of a natural canal, probably dredged and widened in order to obtain sand for the construction of the nearby Gryfino-Mascherin road. Its depth is comparable to the depths of nearby flow canals. A somewhat broader strip of elodeids than in the Lake Samotny can be found here as well as nimfeids with a dominance of the yellow water-lily and narrow strip of reed beds.

The main problem of Międzyodrze is the disappearance of smaller canals and thus the decline of biodiversity.

The area of Międzyodrze is located within the Natura 2000 area. In PLH320037 the lesser ramshorn snail *Anisus vorticulus* (according to SDF from 2008) is the object of protection. This species can be found mainly in small reservoirs of stagnant water with clear water and dense vegetation - shallow ponds, oxbow lakes, flooded areas, marshlands, drainage ditches and peat bogs as well as other water reservoirs on peat bogs. These habitats are typical of its occurrence. According to the Conservation Measures Plan for PLH320037 Dolna Odra, part 3. protection status for items covered by the Plan in Table 3, with regard to the lesser ramshorn snail it was noted that the current state of knowledge makes it impossible to assess the conservation status of the species being the subject of protection. The population parameters are not known, nor are there any complete data regarding the habitat. According to the map in the Conservation Measures Plan, the nearest habitat of this species is located outside the Lower Odra River.

As a result of the monitoring carried out in June and September 2017 at the examined monitoring stations no presence of the lesser ramshorn snail *Anisus vorticulus* (Planorbidae family) was detected. **The reason for the regression of this species from the area of Międzyodrze is probably the impairment of water circulation in the canals, especially those with underwater vegetation – which is in places of potential existance of this species**. With stagnant waters and a large amount of organic matter in bottom sediments, oxygen deficits occur. The lesser ramshorn snail is an organism with high oxygen requirements and in the above-mentioned canals the oxygen conditions have not been satisfactory, especially in bottom sediments in which this species overwinters. Noteworthy is the extremely low numbers of other species of the Planorbidae family that have been found as a result of monitoring in 2017 which do not have such high oxygen requirements. Only single individuals were found.

During monitoring of Międzyodrze in 2017 no bivalves from the Unionidae family were found. They are especially important in the river ecosystem due to the fact that they are filterers and in case of their mass occurrence contribute significantly to the self-purification process of the river.

In addition, they are necessary for the reproduction of protected amur bitterling fish, which spawns in them. Probably these bivalves are in Międzyodrze only in very low densities, much lower than in the bordering Odra River. Catching with a dragnet or a bottom sampler does not ensure exploration of bottom areas large enough to find living individuals. The presence of a small population of bivalves from the Unionidae family in Międzyodrze is confirmed by the presence of a small number of amur bitterling in this area and the presence of shells of these bivalves in the feeding areas of lutra. The reason for such low density of bivalves from the Unionidae family is probably the impairment of water circulation in the canals, causing stagnation of water, deposition of a large amount of organic matter in bottom sediments, which leads to oxygen

deficits. The Unionidae that live in bottom sediments do not have good habitat conditions, as was the case with their presence in inter-groyne areas on the bordering Odra River, where the circulation of water was intense.

Miedzyodrze waters are very natural, there are no signs of direct human activity, no visible signs of water pollution. In spite of visually good habitat conditions, the assessment of water quality using the Ecological Condition Assessment Method based on macrozoobenthos MMI PL has qualified the Międzyodrze waters to the 3rd and 4th class. Such a low rating results from the progressing degradation of Międzyodrze, which is caused by the impairment of water circulation in this region. Reducing the flow of water causes the canals to fill up with sediments, low oxygen content in water, overgrowing with swamp vegetation, which in the extreme stage leads to land creation. The process of overgrowing and land creation concerns mainly small (narrow) canals, thus diminishing the diversity of the habitats of the entire area. Small canals rich in submerged vegetation (elodeids) are the potential most valuable habitat of the protected lesser ramshorn snail species, protected in PLH320037 Lower Odra. Larger canals are less subject to degradation but even in large flow canals the degradation process progresses, although the symptoms are not visible for the time being. Major part of the bottom of these canals are covered with deoxidized organic sapropel-like sediments. Only invertebrates resistant to oxygen deficits, such as Chironomidae or Oligochaeta larvae can live in such a sediment. The bivalves of the Unionidae family, important for the protection of the amur bitterling and the process of self-purification of water, cannot live in such conditions, and there are no rare and protected species.

Useful measures that can be carried out in Międzyodrze as part of investment works for flood protection along with activities to minimize the impact of this investment.
All measures that trigger the flow of water through Międzyodrze are the useful measures that can stop or even to some extent reverse the degradation process and these are:
- unblocking and reconstruction of sluices and keeping sluices open beyond the period of flood water collection
- construction of culverts under the roads that would restore circulation in canals buried during the construction of these roads
- removing congestion and overhanging vegetation, combined with dredging so as to restore patency of the cut-off canals
- induction of more intense water flow through Międzyodrze by adjusting the amount of water on the sluice gate in Widuchowa
- perhaps reconstruction of the pumping stations - provided that they ensure the flow of water through the Międzyodrze area or discharge excess water accumulated during the flood

Disadvantageous measures that can be taken in Międzyodrze as part of investment works for flood protection.
All measures that reduce the flow of water through Międzyodrze are unfavorable measures that may accelerate the degradation process and these are:
- reconstruction and sealing the embankment separating Międzyodrze from the West Odra River and the East Odra River
- keeping the sluices closed, causing the flow of water through Międzyodrze to stop
No measures taken

- canals will continue to be filled with organic sludge
- smaller canals cut off and overgrown by vegetation, land creation
- reducing the diversity of habitats.

Entomofauna and land malacofauna

The study of terrain, the composition of species and the quantity of animals began in July and ended in October 2017.

The study of the surveyed section of the Odra River in places of planned works along with the buffer revealed the presence of:

- **7 species of insects**:
  bumblebees: the buff-tailed bumblebee, the red-tailed bumblebee, the common carder bee, the garden bumblebee, the new garden bumblebee, the shrill carder bee and dragonflies: the green snaketail**;**
- **0 species of the moss chrysalis snail:** 19 material samples were collected, no bivalves were found

Documents indicate the presence of several rare and protected insect species in the Odra River valley. These include the great capricorn beetle *Cerambyx cerdo*, stag beetle *Lucanus cervus*, the hermit beetle *Osmoderma spp*., the large copper *Lycaena dispar*, the large white-faced darter *Leycorrhinia pectoralis* and the green snaketail *Ophiogomphus cecilia*. The first three species are representatives of the beetle's order with specific habitat requirements. They require for their development hollow trees in which eggs are laid and larvae develop. Unfortunately, such trees were not found in the area under study. The next species is a butterfly of the Lycaenidae family. It is also a species that requires suitable habitats. Most often it can be found in wet meadows where the plant feeding its larvae - the great water dock *Rumex hydrolapathum* grows (the development of larvae on other species of this genus has recently been spotted). There are no suitable habitats at Miedzyodrze, i.e. meadows with sorrel, for this species. Another species is the large white-faced darter. Tyrphophiles species which is associated with peat bog habitats. It can also found in other types of habitats. Some canals, especially non-flow canals, could be habitats for this species. However, the species is early, appears in early May and disappears in mid-June. July inspections are too late to find a large white-faced darter. One species from Annex II of the Habitats Directive - the green snaketail *Ophiogomphus cecilia* – has been found in Międzyodrze. The dragonfly was found regularly, along the entire length of the outer bank of Międzyodrze - on the banks of the Odra River. Unfortunately, the late period of inspection caused that it was impossible to find exuvia that would confirm the reproduction of the species on the examined sections of the river. However, the findings of exuvia at sites located upstream on the Odra River and the presence of habitats suitable for the species on the shores of the Odra flowing through Międzyodrze indicate the development of this species here.

Another 6 identified species belong to the Hymenoptera order. There are bumblebees from the Bombus genus: the buff-tailed bumblebee, the red-tailed bumblebee, the common carder bee, the garden bumblebee, the new garden bumblebee and the shrill carder bee. All are subject to partial protection. A small number of observations made and a small number of observed individuals clearly indicate suboptimal habitat conditions for these insects. They require flowery meadows

where they can find food for larvae. It would be best if these were "wild" meadows, rarely mowed, preferably without the participation of the common dandelion Taraxacum sp., whose presence indicates the impoverishment of species of flora.

The mentioned species are not rare, in some places even numerous, common ones. They are not threatened with extinction.

The area under inventory did not prove to be rich in "natural" species. We managed to confirm the existence of one such species. This is due to the lack of appropriate habitats for other species. The green snaketail is a river species and in this case the habitats suitable for the species are not lacking. However, the identified bumblebees have not found an optimum here for their living. They are insects under partial protection, very important from the point of view of the human economy - pollinators of useful plants.

All proposed measures consisting in starting the water flow through Międzyodrze (construction of the embankment or reconstruction of the sluice system) are beneficial for the nature of this area. From the list of identified species only the green snaketail is directly and inseparably connected with water (undergoes development in it). The existence of species is limited to the environments with flowing water. Such conditions are ensured by the banks of the Odra River. The Miedzyodrze area is characterized by rather stagnant water which directly translates into the lack of species within this area. The other species found are typical terrestrial animals. Bumblebees belong to insects associated with blooming plants. The best conditions are found on the edges of the embankments and on adjacent meadows. The Miedzyodrze area, as it was previously, is not an optimal habitat for them. *Carabus coriaceus* is a forest species. Suitable habitats are found on the few fragments of the Odra River bank, those covered with smaller or larger trees. It is not found in Międzyodrze.

Carrying out the investment from water will have a limited and scarce effect on the population of the green snaketail. If the species develops in this area during the investment "deliberate killing of the protected species" may occur as the dragonfly larvae develop in the water, at the bottom of the river. Considering its even distribution along the banks of the Odra River, the population will be rebuilt very quickly.

Ichthyofauna

In August 2017, inventory work was carried out in Międzyodrze regarding Ichthyofauna. Due to the specificity of the research area the results obtained were compiled for several types of contractual habitats. These were small canals, absolutely dominated by roach and perch, individuals of various sizes, sometimes numbering several hundred. In addition, single pike, tench and rudd spawners were fished as well as single spined loaches and amur bitterlings of the protected species. Medium-sized canals with the prevalence of fry of bleak, at least a few dozen individuals per site. There are also young perch and roach and single rudd, asp and ide, and at places of hard, sandy bottom - the pumpkinseed. Only small roers were found on large canals. The last type of habitats were proglacial lakes of various size, where mainly fry of roach, numerous young perches and bleak were observed as well as individual ides, tenches, rudds, zopes, white breams, sunbleaks, common breams and pikes - usually small in size. The spined loach was very

rare and in one case the pumpkinseed was also caught. Unfortunately, the obtained results, both quantitative and qualitative, are very bad.

Among the species found there were those covered by the Habitats Directive - Annex II. Animal species of Community interest whose protection requires the designation of Special Areas of Conservation (without birds). Annex II is a continuation of Annex I concerning the establishment of a coherent network of special areas of conservation. At the test sites, the asp, spined loach and amur bitterling listed in Annex II were found.

In total, 20 fish taxa were found during the nature inventory. Considering the use of only one method of electrofishing in such a large area, it was possible to capture a significant part of the ichthyofauna existing here in a relatively short time, revealing not only species that are frequently found but also those very rare. The number of species found in the Międzyodrze waters provided on the basis of various authors is quite diverse and depends on the type of sources and the time frame in which the data was collected. For example, in his study on the ichthyofauna of Międzyodrze Neja states that most of the 46 fish species recorded here from various sources are native species, characteristic of the bream region and the transitional region of the smelt. Among them, as many as 11 species, are alien species. According to the economic records of the fishermen here the number of species caught in fishing nets in the districts of Międzyodrze varies between 27 and 31, which was also influenced by the identified accessory species and alien species.

According to Neja (2011), the group of species in the Międzyodrza ichthyofauna considered as existing en masse include the European eel (*Anguilla anguilla)*, the bream (*Abramis brama)*, the white bream (*Blicca bjoerkna*), the zope (*Ballerus ballerus*), the roach (*Rutilus rutilus*), the rudd (*Scardinius erythrophthalmus*), the bleed (*Alburnus alburnus*), the perch (*Perca fluviatilis*) and the zander (*Sander lucioperca*).

Among the species often found carp he mentioned the carp *Cyprinus carpio*, the tench *Tinca tinca*, silver carp Hypophthalmichthys molitrix, the silver carp *Hypophthalmichthys nobilis*, the asp *Aspius aspius*, the ide *Leuciscus idus*, the wels catfish *Silurus glanis*, the smelt *Osmerus eperlanus* and the pike *Esox lucius*.

Referring to the rare species in the Międzyodrze waters he mentioned the crucian carp *Carassius carassius*, the Prussian carp *Carassius gibellio*, the grass carp *Ctenopharyngodon idella*, the sunbleak *Leucaspius delineatus*, theide *Leuciscus leuciscus*, the common chub *Squalius cephalus*, the burbot *Lota lota,* three-spined stickleback *Gasterosteus aculeatus*, the pumpkinseed *Lepomis gibbosus and* the ruffe *Gymnocephalus cernua*.

Among the very rare species, the author lists the lamprey *Lampetra fluviatilis,* alien sturgeon species: the Siberian sturgeon *Acipenser baerii*, bastard sturgeon *Acipenser nudiventris*, the twait shad *Alos fallax*, the common barbel *Barbus barbus,* the Romanian barbel *barbus petenyi*, the gudgeon *Gobio gobio*, the European bitterling *Rhodeus amarus*, the vimba bream *Vimba vimba*, the sichel *Pelecus cultratus*, the schneider *Alburnoides bipunctatus*, the spined loach *Cobitis taenia*, the European weatherfish *Misgurnus fossilis*, the stone loach *Barbatula barbatula*, the alien species brown bullhead *Ictalurus nebulosus*, the lavaret *Coregonus lavaretus*, the Salmonidae family – the Atlantic salmon *Salmo salar*, the brown trout *Salmo trutta m. trutta* and the rainbow trout *Oncorhynchus mykiss*.

With regard to some species, the existence in particular groups with varied frequency of presence seems to be underestimated. This is due to the differences in methodologies and the use of the results of commercial fishing, where in the catch statistics they do not appear as separate species of small body size often treated as "non-commodity fare." This is the case with the spined loach or the ruffe. Some parts of species could not be identified during the works, however, based on other data, including the data quoted above, one should assume that the number of taxons permanently existing here is actually higher by at least several.

Habitat diversity of the analyzed waters of Międzyodrze covering both large canals and smaller branches but also lake-like sections or even lakes offers diverse habitats for a variety of ichthyofauna. However, one should not forget about the negative factors affecting the species living here but also their diverse vulnerability. Witkowski et al., comparing information on the state of threat to 37 taxa of river lamprey and fish in Poland, found that only 19 species (29.7%) on the national scale can be characterized as non-threatened species (LC - low- concern species). The species for which the NT category was established in 2009 - near threat include, after ten years from the first assessment, among other species the common dace *Leuciscus leuciscus*, the crucian carp *Carassius carassius* or even the zope *Ballerus ballerus*. Below is a selection of more important information on the species of fish that exist in a larger number and were found during research as well as rare species.

Weatherfish *Misgurnus fossilis*

Despite the fact that no weatherfish was found directly in the inventory catches most authors dealing with Międzyodorem show this species in their lists as very rare (Neja 2011).

Weatherfish is a difficult species in monitoring catches, it lives in specific inhabits hardly available for other fish, being relatively resistant to unfavorable environmental conditions.

As the authors of monitoring textbooks for this species emphasize, population indices may be subject to significant fluctuations, which is why the decreases in the number between two successive surveys assessed as bad or very bad cannot determine the assessment of the species' preservation prospects. This species was not confirmed in the inventory research conducted with the use of electrofishing, although it is possible that in the habitats of standing canals particular populations may have significant numbers. The low depth of these canals and their becoming grown over make it impossible to conduct research using the nets, while the high electrolytic conductivity of water practically excludes the use of electrofishing as a research method. As the research in the German part of Międzyodrze in the German Lower Odra Valley National Park has shown, locally the populations of the weatherfish may be extremely numerous (Raczyński et al., 2013). It concerns canals that were under the influence of extensive polders and it is the construction of polders near the habitats for this species that is included in the proposals mentioned in the literature for active conservation measures regarding the habitat of this species. In addition to maintaining the relative stability of flowing water systems, aquifers and stagnant water, an active form of habitat protection is the restoration of connections between small reservoirs and the river, which as a result of shallowing and overgrowing have ceased to be a specific water environment. At the same time, natural, disappearing reservoirs should be protected against melioration and backfilling, which is indirectly supported by the natural

connection of oxbow lakes with the main canal. Maintaining the state of destruction of the natural environment of the weatherfish, additionally preserved by tight embankments and canal drainage may create isolated species populations with increased susceptibility to extinction. An example that illustrates the resistance of this species to the activities of water engineering is the situation of the weatherfish in the northern part of the Odra estuary, where Dąbie Lake and the Szczecin Lagoon are surrounded by an extensive network of drainage canals designed to dry the adjacent areas. These canals (Opaska Canal, Łąka Canal, Lubczyński Canal, Komorowski Canal, Święta Canal, Jedliny Canal, Czarnociński Canal, Śmieć Canal, Ognica Canal, Międzyzdroje Canal) which used to be directly connected with the waters of the lake and the lagoon were natural spawning grounds for fish species living in these waters. . Currently, due to the existence of pump stations at the mouths of the canals they constitute separate, heavily eutrophicated reservoirs. In 8 out of 9 analyzed canals there were numerous, partially isolated populations of the weatherfish (Biernaczyk et al., 2013).

For most species forming the river ichthyofauna complex of particular importance are the floodplains and heavily covered with aquatic vegetation of shallow zones of river ecosystems. The richest in feeding fauna are open proglacial lakes and those closed ones that have a permanent connection with the river. They are rich feeding grounds, spawning grounds and often in deeper oxbow lakes – wintering grounds for a number of species of ichthyofauna. The preservation of these environments, and therefore the wealth of ichthyofauna, depends on the preservation of the natural hydrological cycle of the river which is characterized by periodic floods of waters outside its bed (Backiel et al. 1978, Wiśniewolski 2002).

Miedzyodrze played this role for the Lower Odra River for many years. Unfortunately, at the moment many canals became very grown over, shallow with the bottom covered with a thick layer of silt, where oxygen is lacking in the water in the summer due to decaying organic matter. This process increases due to the lack of permanent flow of water in most of the canals and the rapidly progressing eutrophication of the Międzyodrze waters.

In this context, some activities related to the flood protection project could at the same time improve the living conditions of ichthyofauna. First of all, regardless of the adopted option of the action the remnants of structures or other elements blocking the flow of water should be removed from the water near the weirs. Secondly, those canals that are completely overgrown and silted and have no habitat importance for other animals or there is lack of valuable phytocenoses there, should be cleared. In the case of the decision to renovate the weirs, except for the period of flood protection, the weirs should always be open. These two elements, i.e. the renovation of weirs and the unblocking of certain canals could be used to create a permanent flow within the area of Miedzyodrze, an additional river where the water movement will reduce the sedimentation processes of organic matter while reducing the negative effects of eutrophication. However, if during flood protection measures controlled flooding of the Międzyodrze area takes place the release of the collected water must take place under such a time regime that the fish which in the meantime get there will not be cut off from the main river bed. In addition, in the spring season, when most of the fish in the Odra River spawn, the flow of water could be intentionally held, thus creating additional spawning grounds for fish.

Herpetofauna

The inventory was carried out on 14 June 2017, 19 June 2017, 14 July 2017, 17 July 2017, 18 July 2017 and 19 July 2017. Due to the vastness of the terrain and homogeneity in terms of the usefulness as a herpetofauna habitat and breeding site as well as the lack of migration barriers, not the idea to penetrate the whole area was given up and an inventory was carried out along pre-selected transects representative of the entire area.

It is extremely important to look at the results of the inventory through the prism of the specificity of the area. Międzyodrze is a relatively homogeneous area; there are no migration barriers for herpetofauna and animals can be transferred passively through water, abounding in convenient habitats. Therefore, this spot on the map in which the specimens of a given species were found cannot be regarded as the only habitat - the whole of Międzyodrze remains the habitat. In addition, due to the conditions prevailing here the detectability of some amphibian species (newts that do not produce mating voices) and all reptiles is significantly lower than the actual state of the population.

The most precious species found in Międzyodrze is the great crested newt for which smaller canals, partly overgrown with vegetation with limited penetration by fish, is the valuable habitat. It should be remembered that the total loss of these habitats as a result of the removal of underwater and coastal vegetation will lead to the decline or disappearance of the population, but yet in the present situation uncleaned canals will become more and more overgrown, which in the long term will also lead to the disappearance of habitats.

The investment may involve the following threats for herpetofauna:

- for amphibians with the exclusion of the great crested newt - partial loss and degradation of habitats during dredging of the canals with a high risk of scaring and incidental killing of individuals during dredging and repair of embankments which may lead to a temporary decrease in the population size.
- for the great crested newt - the loss of the most valuable habitats (smaller, partially overgrown canals) during their dredging with a high risk of killing, disturbing during dredging and repairing the embankments, which may lead to a significant decrease in the population size and significant or complete reduction of available habitats
- for reptiles - the risk of disturbing, incidental killing during dredging of canals and repair of embankments, for the grass snake it may additionally be a temporary limitation of accessibility of the food base, which probably will not have a significant impact on the condition of the population.

The renovation of the existing hydrotechnical equipment is not a significant threat to herpetofauna.

It should be noted that the investment, although initially harmful, will lead to the recovery of habitats of deteriorating quality (too much overgrown canals and filled with rotting organic matter). Therefore, it is possible to implement the investment, subject to the following modifications:

- limiting the time-frame for the works to the period beyond the date of amphibian activity, in particular the period of the great crested newt remaining in the water - the period from March 1

to August 31 should be a protective period during which work should not be carried out. This period can only be cut short if the herpetological supervision has verified that the breeding sites have been vacated, though this is not particularly sensible - the great crested newt is a secretive species that is difficult to find and the lack of observed individuals is not equal to their actual absence.

Conducting work beyond the wintering period – approximately in the period between November 30 and March 15, this period should be verified annually by the herpetological supervision.

Dividing of the process of canal clearing into parts - it would be optimal to clear e.g. 10-20% of the canals to be cleaned annually. At this point, it would lead to spontaneous restoration of habitats and animal movement, in particular, great crested newt, from the damaged to the good sites, which would limit the losses caused by insufficient availability of places suitable for reproduction and living.

Avifauna

In the period from April 2017 to February 2018 47 ornithological inspections were carried out, on average 8 hours each.

In 2017, 100 breeding species or probably breeding birds were found in Międzyodrze, 14 of them are listed in Annex I of the Birds Directive.

On the national scale, noteworthy is the high number of the gadwall (2.1-3.0% of the population nesting in Poland), the black tern (3-5% of the national population), the bluethroat (3.5% of the national population) and the Savi's warbler (1, 1-1.5% of the national population).

In recent years, declines in the numbers of many bird species associated with wetland habitats have been observed throughout Poland. One of the most endangered groups are the Charadriiformes nesting on the meadows. In the area in question they are represented by the northern lapwing, the common redshank and the common snipe. In 2017 the most attractive habitat for these birds were flooded meadows in the southern part of Międzyodrze (around Widuchowa). All breeding common redshanks (2 pairs) and most of the northern lapwings (about 30-35 pairs) were identified there. Unfortunately, in June the water from these meadows went down, for which reason probably most of the birds lost their broods.

In previous years in Międzyodrze numerous ducks nesting in meadows were spotted: the northern shoveler and the garganey. In the 90s and at the beginning of the 21st century, 30-35 pairs of the northern shoveler were identified, in 2013 there still were 8 pairs of this duck but in 2017 no nesting of this species was found. Also, the number of the garganey has decreased significantly - by 2013 there were around 40-50 pairs, while in 2017 only about 10 pairs were found. The decline of these species can be explained by the predation of the American mink and the disappearance of meadow habitats in Międzyodrze (with these areas being overgrown with reed and withes). As the number of another duck species – the gadwall - shows an upward trend (this year about 80-100 pairs, while in 2006 and 2013 about 70-80 pairs) it can be assumed that habitat changes are a more important factor causing the decline in the number of ducks mentioned above.

In 2017 the highest number of black terns (about 100 pairs) was recorded in the Międzyodrze area which were nested mainly in two large colonies in the southern part of the area (on the Leniwy Lake and on the Old Regalica River near the Lower Odra River). The number of this tern may be related to the project of protection of this species commenced this year by building special breeding platforms which the American mink cannot access.

In the "Kurowskie Błota" nature reserve there is a colony of the gray heron in which almost 1000 pairs of this species nested in 1990s. In 2006 only 400 nests were found so far, while later this colony was not controlled. During the work only 40 gray heron nests on trees were found only on the northern edge of the reserve. They were not detected in other places despite the inspection of the reserve on foot. However, it cannot be ruled out that the late start of work (the first inspection was conducted at the end of April, when the first leaves were in the trees) could result in failure to find all the nests. It is planned to inspect this area again in the winter months after the leaves have fallen from the trees.

For most valuable breeding birds in Międzyodrze the biggest threats are: ecological succession (overgrowing of optimal habitats by reeds and shrubs), changes in the water level in the breeding season (mainly drop in water level during the breeding season, which facilitates access for predators to nests built on flooded territories) and the predation of the American mink. Obviously, for some birds slow succession creates better conditions for nesting (bluethroat, Savi's warbler).

Międzyodrze is a very important place for migrating and wintering birds. It is a place of rest, a roosting site and a feeding ground. Concentrations of roosting cranes reach the number of over 17 thousand here in autumn, thousands of geese in flocks also roost here.

A large number of canals in Międzyodrze is strongly overgrown, some of them host black tern colonies. Natural valuable canals should be left without interference. Some of them could be made available for canoeing and designated as tourist routes. The largest canals (between the sluices) could be used to adjust the water flow.

Controlled flooding of the Międzyodrze area in the early spring period would be very advantageous for the birds, therefore the restoration of the functionality of the sluices and pumping stations would be desirable.

Repair or reconstruction of the embankments should take place in the non-breeding period, i.e. from September to the end of February.

Teriofauna, including chiropterofauna

List of protected species of mammals.

Order	**Family**	**Genus**	Species
shrew-form SORICOMORPHA	shrews Sorcidae	*Sorex*	the common shrew (*Sorex araneus* Linneaus 1758)
			the pygmy shrew (*Sorex minutus* Linneaus 1766)
		Neomys	the water shrew (*Neomys fodiens* Pennant, 1771)

Order	Family	Genus	Species
	Talipadae	mole *Talpa*	the European mole (*Talpa europaea* Linneaus, 1758)
Rodents RODENTIA	*The* Arvicolidae	the water rat *Arvicola*	the European water vole *(Arvicola amphibius*, Linneaus 1758)
	murids Muridae	*Micromys*	the harvest mouse (*Micromys minutus*, Pallas 1771)
	Castoridae	beaver Castor	the European beaver (*Castor fiber,* Linnaeus, 1758)
carnivorans CARNIVORA	Mustelids Mustelidae	weasel *Mustela*	the stoat (*Mustela erminea* Linnaeus, 1758)
			the weasel (*Mustela nivalis,* Linnaeus, 1758)
		Lutra	the European otter (*Lutra lutra* Linnaeus, 1758)
	Canids Canidae	Canis	Gray wolf (*Canis lupus*, Linnaeus, 1758)

List of protected species found in the pellets from barn owls.

Protected species	Location of the pellet group			total
	Kurowo	Garzt_1	Garzt_2	
S. araneus	34	0	5	39
S. minutus	15	4	2	21
N. fodiens	7	1	1	9
M. minutus	15	5	2	22
A. amphibius	0	3	1	4

When planning a change in the flow of water (through the repair of hydrotechnical equipment), biology and habitat requirements of individual species should be taken into account. All repairs of hydrotechnical equipment should be carried out with the least possible interference in the area of embankments, canals and grass vegetation of Międzyodrze.

Access to hydrotechnical equipment should be carried out only by water.

Possible service/access routes to hydrotechnical equipment and pumps at the external embankments of Międzyodrze will cause a destruction of valuable habitats of the species. As a consequence, this will contribute to the deterioration of the population status of the species.

The study of the area for the presence of bats began in April 2017. The area of the investment was surveyed for the significance for individual species of bats. Transect recordings were made cyclically from May to September.

Chiropterological survey of the section of the Odra River under inventory in sites of planned works revealed the presence of 6 species/groups of bats:

- The nathusius' pipistrelle (*Pipistrellus nathusii)*
- The common pipistrell (*Pipistrellus pipistrellus s.s.*)
- The soprano pipistrelle (*Pipistrellus pygmaeus)*
- The common noctule (*Nyctalus noctula)*
- The lesser noctule (*Nyctalus leisleri*)
- The serotine bat (*Eptesicus serotinus)*
- The pond bat (*Myotis dasycneme*)
- The mouse-eared bat (*Myotis sp.)*

Międzyodrze functions for bats as a feeding ground and reservoir of shelters in hollow trees. The basic feeding place for bats are the canals above which insects gather. Mature hollow trees in turn, are a reservoir of shelters. They concentrate mainly in the area of the Kurowskie Błota nature reserve (approximately 190 ha) and embankments on the western boundary of Międzyodrze (a 26 km-long strip and 40 m wide on the average, approximately 104 ha). In the central part of the area there are mainly low bushy vegetation and single mature hollow trees suitable for settlement by bats. On the embankments there are also old hydrotechnical structures and construction facilities that can provide shelter for bats during winter or summer.

Based on the obtained data it can be concluded that Międzyodrze is an important area for bats, which is consistent with the knowledge that water-related biotopes are characterized by the highest activity of bats.

Possible use of night lights for vehicles taking part in works and for construction sites will disturb the bats and exclude those areas from feeding. Dredging the existing canals alone should not result in deterioration of the quality of feeding grounds. The biggest threat for bats in the Międzyodrze area will be the loss of old hollow trees. Tree felling should be limited to the minimum.

Examination of bottom sediments

The works of modeling Międzyodrze included taking samples of and examining bottom sediments, which aimed at determining the content of substances that contaminate spoil. The samples were taken from 10 places [April 2018]. The location selection was determined by the vision of obtaining the full spectrum of the substances' content in Międzyodrze and possibility of determining the dependence of their amount on location.

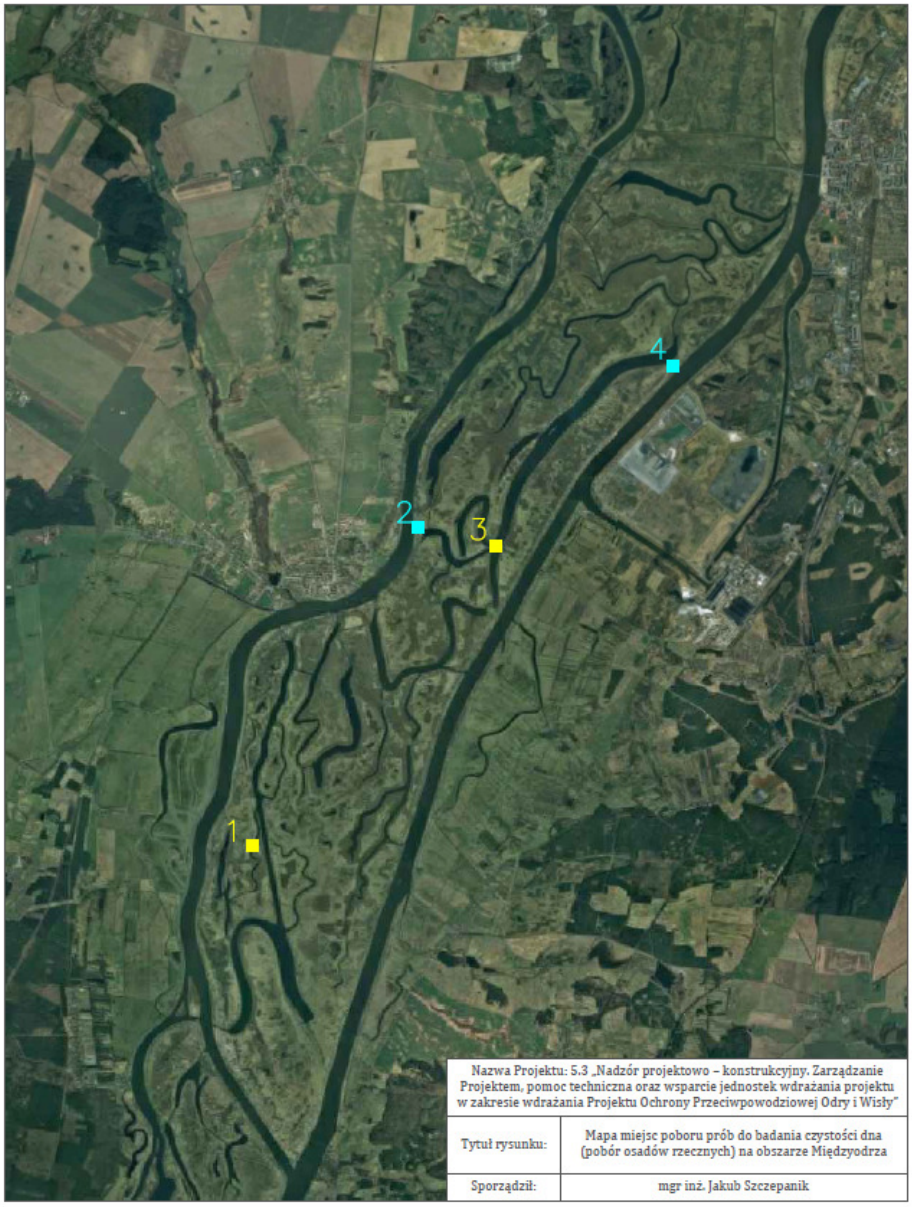

Figure 11 Map of bottom sediments sampling points from 1 to 4 [south]

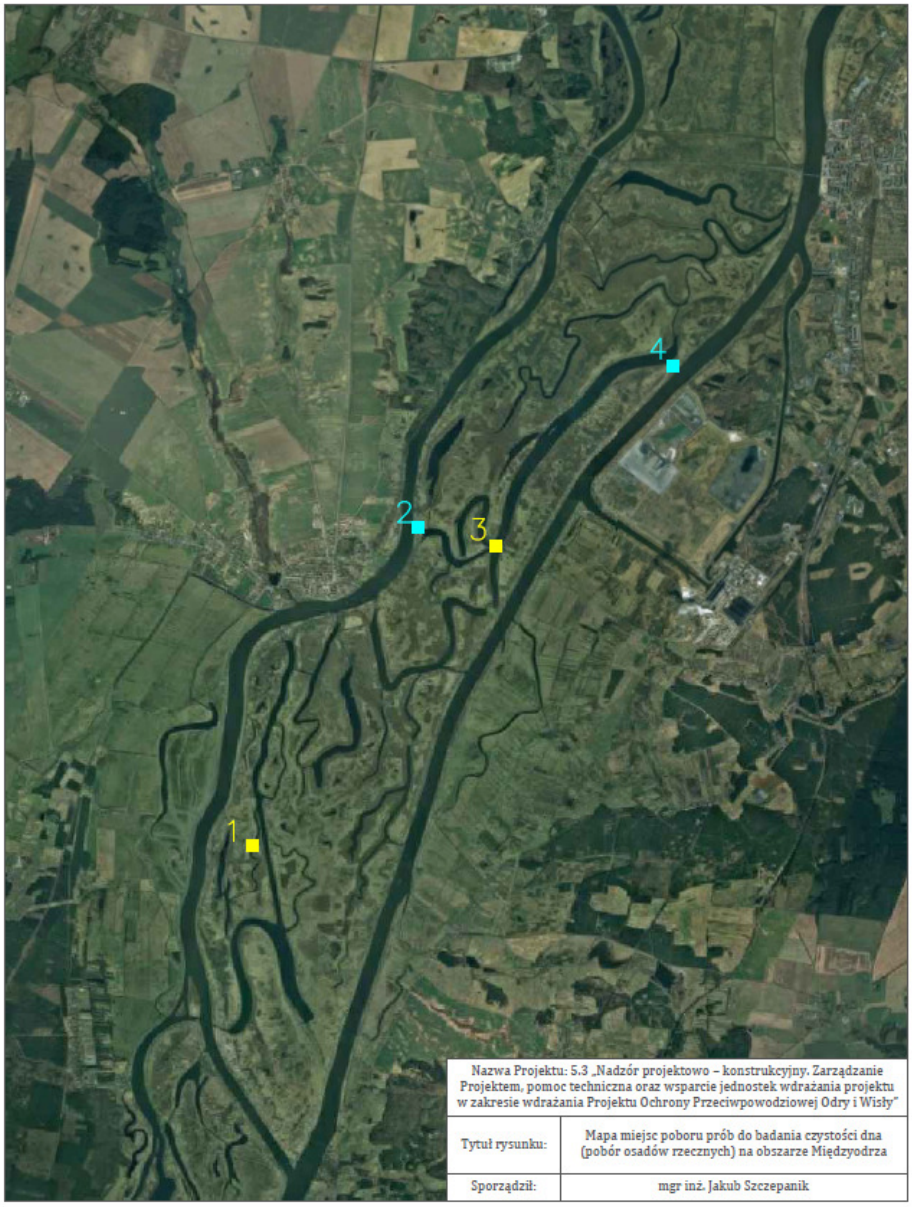

Figure 12 Map of bottom sediments sampling points from 5 to 10 [north]

The samples were examined for content of heavy metals and such organic compounds as aromatic hydrocarbons and polychlorinated biphenyls. The Regulation of the Minister of Environment dated 16 April 2002 on the types and concentrations of substances contaminating spoil specified the types and concentrations of the substances that contaminate spoil from dredging water reservoirs, ponds, natural watercourses, canals and diches related to maintenance and regulation of waters. It should be pointed out, though, that the Regulation dated 16 April 2002 on the types and concentrations of substances contaminating spoil was waived on 1 January 2018 without any succeeding regulation. Therefore, when assessing the spoil, one should refer to the Act on Waste and Catalog of Waste supplemented with a list of hazardous waste. According to the provisions of Art. 4, Section 2, the substances that can lead to classification as hazardous waste are specified in Appendix 4 to the Act. According to the Catalog, codes 17 05 05 and 17 05 06, spoil from dredging

containing or contaminated with hazardous substances is hazardous waste. Based on that, any spoil containing any substance specified in the Act should be classified as hazardous waste. Therefore, all of the spoil from Międzyodrze (based on the 10 samples examined), subject to the regulations in force (including the lacking Regulation of the Minister, as specified under Art. 4, Section 3 of the Act) should be classified as hazardous waste.

Natural conditions in Międzyodrze in the context of organic soil protection and reduction of greenhouse gas emissions

Międzyodrze is a peat area structure containing considerable organic carbon resources that is not currently in the atmospheric circulation. The potential restoration of the agricultural use of dehydrated peat soils involves the risk of highest greenhouse gas (GHG) emissions to atmosphere.

Międzyodrze is diversified into polders of various hydrological, soil, and biocenotic conditions.

The lowest exposure to anthropogenic pressure characterizes the southern polder (soils), followed by the central, and northern one. In terms of natural vegetation and its biodiversity, the order of the areas is reversed.

For a few decades Międzyodrze ecosystem has been subject to dynamic changes. In the period covered by this report, the vegetation succession and peat deposits decomposition and mineralization processes can have the following positive and negative impact:

vegetation succession: limiting GHG emissions, development of natural processes (peat forming and alluvial process), biodiversity decrease, change in natural habitat structures, limiting economic use options, reducing retention capacity (by growing overground biomass: trees and shrubs);

decomposition and mineralization: loss of C, growing GHG emissions (mostly CO2, when overdry peat deposits are flooded, the share of methane is higher), lowering the terrain ordinate (greater land turning into marshes, more difficult regulation of water balance), growing eutrophication of waters.

Detailed analysis of soil and water conditions and their transformation requires further analysis of the collected material and possible additional field works that are not covered by this hydrological and natural modelling. They indicate a need of potential further research works.

Updating the data on vegetation dynamics requires an analysis and update based on the current cartographic materials (orthophotomap, aerial imagery). Similarly to point 5, they indicate a need of potential further research works.

6. Conclusions

Analysis of the model lead to the following conclusions:

- The calculations performed showed that the following towns and villages are most exposed to flood risk: Gryfino, Żabnica, Dębce, Moczyły, Kurów, and Wyspa Pucka in Szczecin.
- The maximum retention capacity of Międzyodrze is less than 140 million m^3.
- The measures proposed under Variant V2 consisting in lowering the bottom of selected canals increase Międzyodrze retention capacity by 0.7 million m^3.
- They lead to increasing Międzyodrze retention capacity but in the extent that is lower compared to the original retention potential and to the volume of the flood wave with medium (1%) and low (0.2%) probability of occurrence.
- The measures proposed under Variant V1 and Variant V2 have little impact on the flood risk for Q1% and Q0.2% scenarios in all the threatened areas.
- Controlling the flow at Międzyodrze hydrotechnical structures impacts only the course of high probability (10%) flood. Impact on medium and low probability floods is low and limited to their initial stages. When water starts to flow over Międzyodrze embankment tops, the flood gets beyond the control.
- The greater the volume of the flood wave, the smaller the impact of the proposed measures.
- Finding optimal principles for controlling such a complex system as Międzyodrze with its few dozens of structures controlling the water flow is a very complex task that requires many iterations of the calculations and analyses of the results.
- The results of the performed comprehensive nature inventory and hydrological analysis show that there are no reasonable grounds for undertaking technical measures to increase the water retention capacity of the area. The possible effects would be insignificant in relation to the potential needs and possible (and hardly predictable) environmental effects.
- At the same time, the studies and analyses carried out as part of the Project made it possible to diagnose the condition of the natural and aquatic environment, as well as the directions and intensity of the processes taking place in the area.
- There is a high risk that, unless specific measures are taken to restore the flow of water in Międzyodrze area, the current flood potential of the area may be lost and the process of silting the area may continue.
- The experience gained from the comprehensive information and consultation campaign accompanying the project shows that the area of Międzyodrze attracts the attention of many different stakeholders, who often present different opinions on the effects of the diagnosed condition and the processes taking place in this area.

  In view of the above, it was decided to organize a comprehensive consultation campaign, using the collected information, aimed at developing a joint "pro-environmental action plan" for the area of Międzyodrze.