MINING SURVEYING WORKSHOP
10 SEPTEMBER 2022
Warsaw, Poland

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Comprehensive method of assessing the flood threat of artificially-drained mine subsidence areas for identification and sustainable repair of mining damage to the aquatic environment

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THE MAIN GEODETIC GOAL OF THE METHOD

SPECIAL PROJECTION OF THE ARTIFICIALLY-DRAINED SURFACES OF A MINE SUBSIDENCE AREA (MSA) FOR DIFFERENT STAGES OF TRANSFORMED RELIEF

(THE SPATIAL HYDROMORPHOLOGICAL MAP OF THE MSA)

FOR:
- **IDENTIFICATION AND MONITORING THE THREAT OF FLOODING,**
- **SUITABILITY OF LAND USE,**
- **SPATIAL DEVELOPMENT AND ZONING.**

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THE AUTHOR BIOGRAPHY

- 1984 -1988 AGH University of Science and Technology, Cracow, Poland
  Master of Science (MS) in Geodesy
  Bachelor of Science (BS) & Mining Geodesist Engineer

- 1988 – 2015 „Knurow-Szczyglowice" Undeground Hard Coal Mine
  Head of Department of Geology, Mine Surveying
  Environmental Protection and Repair of Mining Damage

- 2010-2015 Central Mining Institute
  (GIG Research Institute), Katowice, Poland
  Ph. D. in Mining and Geological Engineering

- 2016-2021 GIG Research Institute
  Head of Department of Surface and Infrastructure Protection

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METHOD OF ASSESSING THE FLOOD THREAT OF ARTIFICIALLY DRAINED MINE SUBSIDENCE AREAS - PUBLICATIONS

1) Ignacy D.: *Metoda oceny zagrożenia zawodnieniem terenów górniczych=Method of assessing the threat of flooding in mining areas*, Ph.D. Disertation, **Central Mining Institute**, Katowice, **2015**, 1-183.

2) Ignacy D.: *Metoda oceny zagrożenia zawodnieniem terenów górniczych i pogórniczych=Method of assessing the threat of flooding in mining and post-mining areas*, **Przegląd Górniczy (Mining Revue)**, Nr 1, Katowice **2017**, 26-38.

3) Ignacy D.: *Relative elevations of the surface of artificially drained mine subsidence areas as significant aspects in formulating environmental policy*, **Journal of Hydrology**, Vol. 575 (**2019**): 1087-1098, doi.org/10.1016/j.jhydrol.2019.05.091.

4) Ignacy D.: *Comprehensive method of assessing the flood threat of artificially drained mine subsidence areas for identification and sustainable repair of mining damage to the aquatic environment*, **Water Resources and Industry**, Vol. 26 (**2021**): 1-19, doi.org/10.1016/j.wri.2021.100153.

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SCIENTIFIC FIELDS RELEVANT TO THIS MULTI-DISCIPLINARY METHOD

1) HYDROLOGY,
2) HYDROGEOLOGY,
3) ENVIRONMENTAL PROTECTION,
4) MINING,
5) GEOLOGY,
6) MINING LAW,
7) SPATIAL PLANNING,
8) GEODESY.

THE SUBJECT OF THE PRESENTATION

1. The environmental aspect of **forced drainage and flood threat** (surface and groundwater inundation) **of mining and post-mining areas**.

2. **Algorithm of the method of assessing the flood threat of artificially drained mine subsidence areas**.

   a) Identification of ***the main watercourse(s) draining the mine subsidence area*** and the range of their catchment areas,

   b) Hydrometric measurements of *the main watercourse(s) draining the mine subsidence area(s)* and identification of historic extreme flood water levels at the point of outflow of waters from the mine subsidence area,

   c) Identification of ***the hydrometric reference point*** (*normal* and *conditional*),

   d) Mapping the surface of the mine subsidence area using *relative elevations* of its surface,

THE SUBJECT OF THE PRESENTATION

e) Identification of the ranges of artificially drained morphological basins and their classification into two types: ***the boundary of artificially-drained area*** or ***a closed basin lake***,

f) Identification of the next three types (ranges) of potential reservoirs: ***the inundated area***, ***the boundary of potential backwater*** and ***the boundary of extreme flood water level*** in each identified morphological basin,

g) **Hydrological modeling of** strips of land threatened by **100-year flood** in the valleys of the main watercourses draining the mine subsidence area and their tributaries,

h) **Zoning of the mine subsidence area surface** with taking into account the threat of flooding.

3. Summary.

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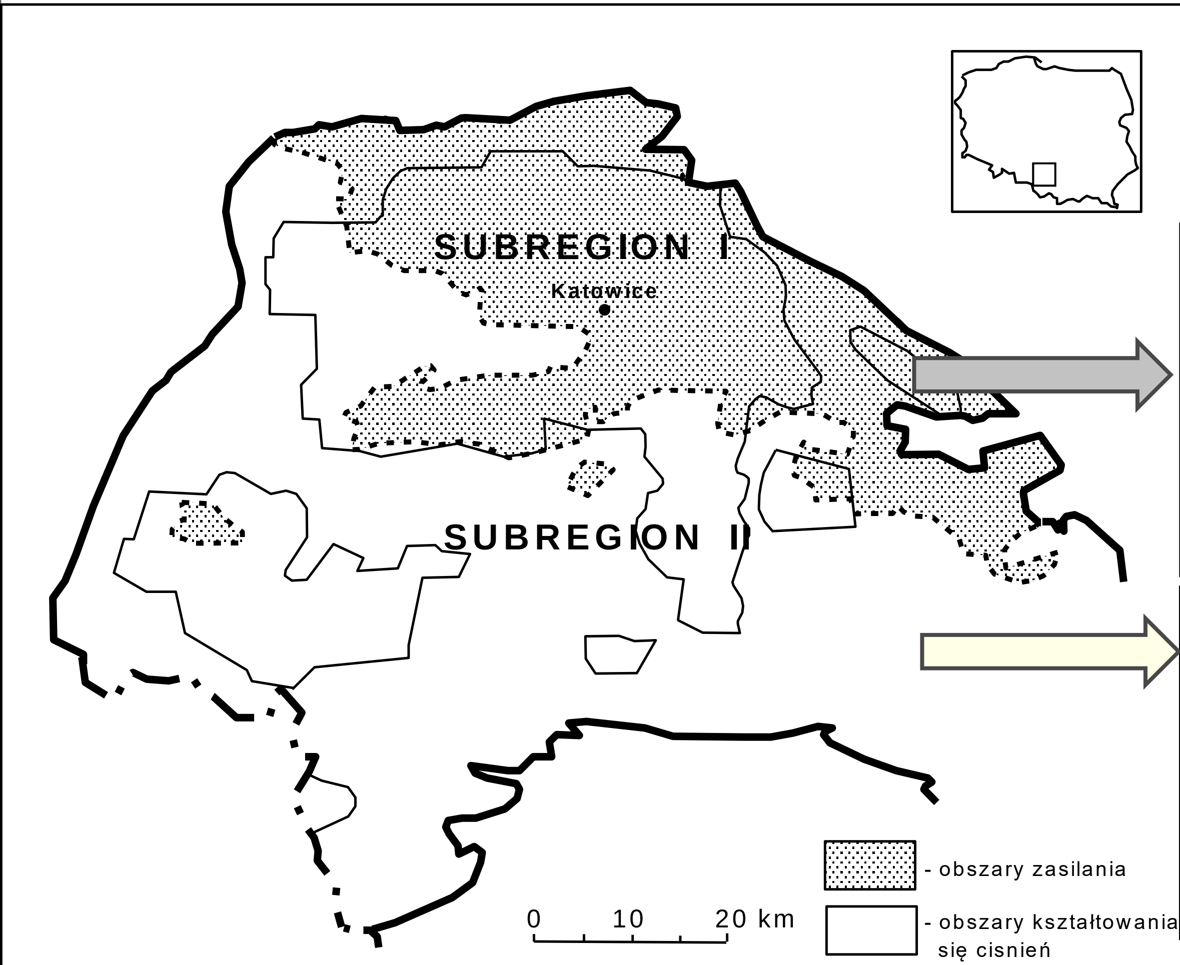
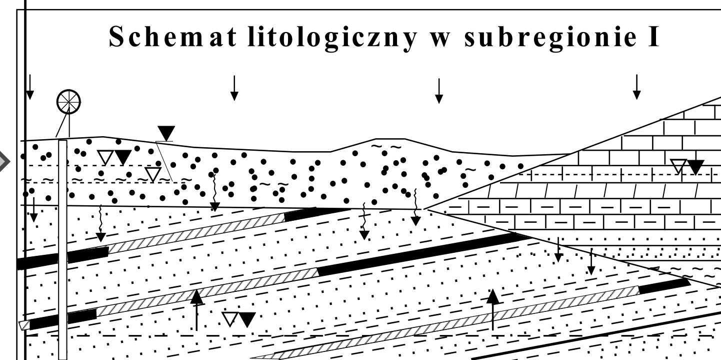
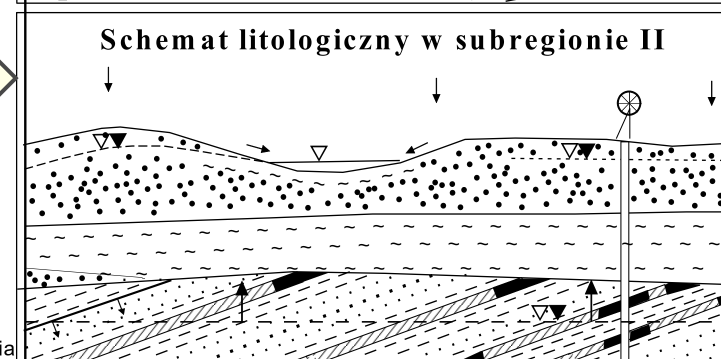
ENVIRONMENTAL ASPECT OF FORCED DRAINAGE AND THE THREAT OF FLOODING IN MINING AND POST-MINING AREAS

CASE STUDY OF THE UPPER SILESIAN COAL BASIN (based on P. Bukowski)



Lithological diagram of Subregion I





Lithological diagram of Subregion II

Subregion I – hydrogeologically non-isolated,

Subregion II – hydrogeologically isolated

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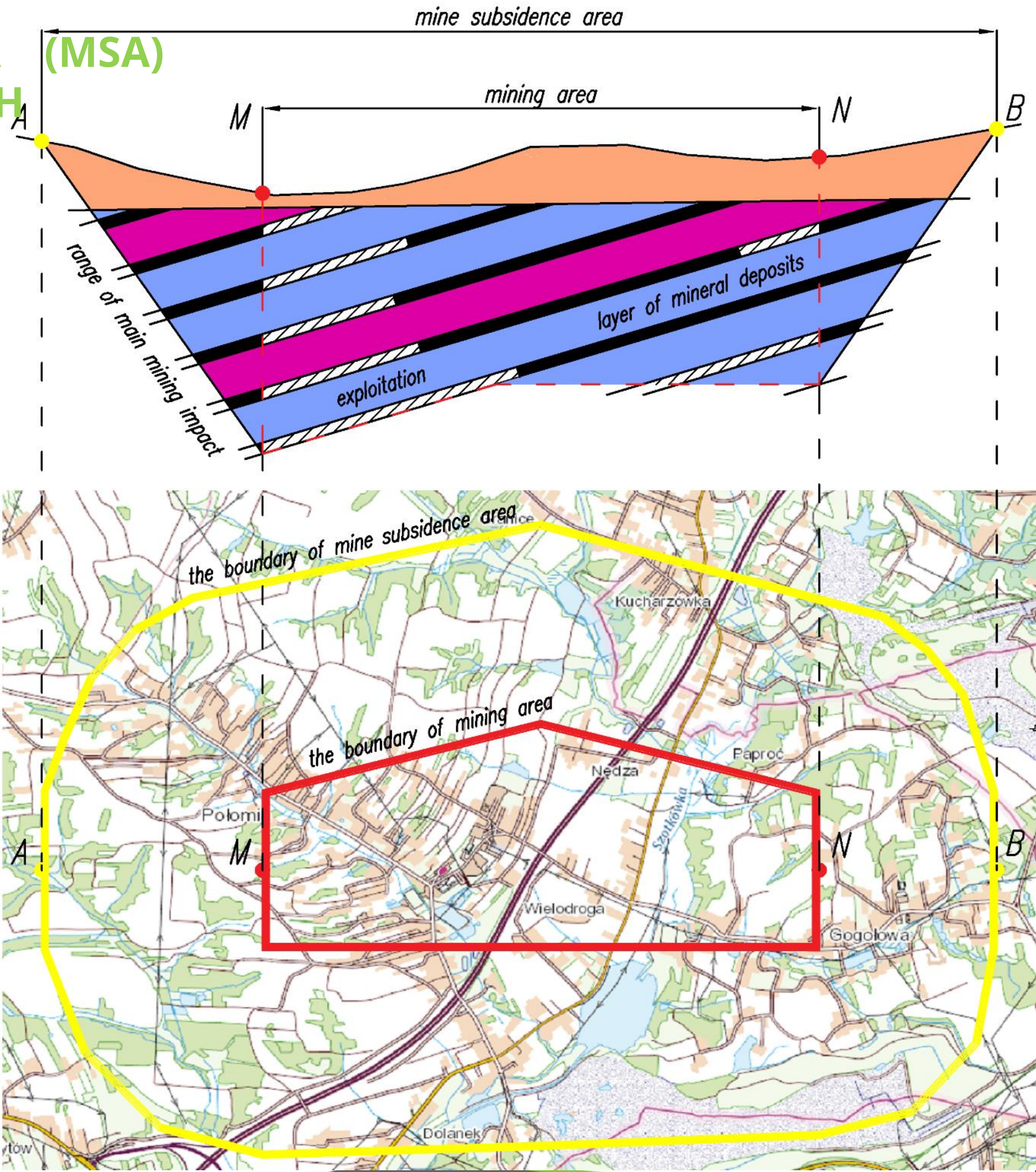
THE MINE SUBSIDENCE AREA (MSA) AS THE SUBJECT OF RESEARCH



Cross-section diagram and the topografic map of the MSA

RESEARCH MATERIALS REQUIRED FOR THE METHOD

1) Numerical model of terrain (covering the MSA surface for current, projected and archival states of surface relief),
2) A topographic map (mostly for assessing the archival state of the MSA surface),
3) Mining and geological data and analysis (about mining of minerals and impact of mining),
4) Hydrological data and analysis (hydrometric measurements of the main watercourses draining the MSA).

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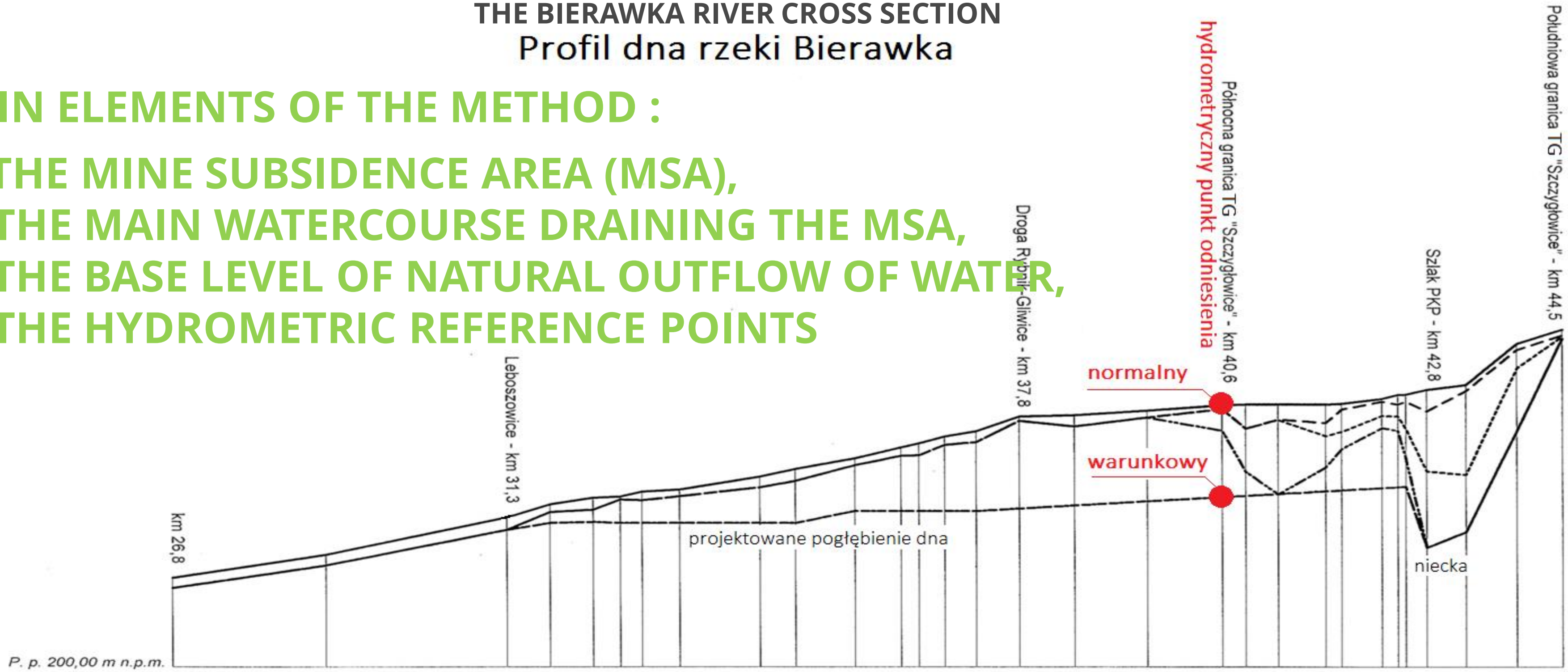
THE BIERAWKA RIVER CROSS SECTION

Profil dna rzeki Bierawka

MAIN ELEMENTS OF THE METHOD :

1) THE MINE SUBSIDENCE AREA (MSA),
2) THE MAIN WATERCOURSE DRAINING THE MSA,
3) THE BASE LEVEL OF NATURAL OUTFLOW OF WATER,
4) THE HYDROMETRIC REFERENCE POINTS



Stan na kwiecień 2006r. (lustro wody)	207,43	209,36	212,46	213,56	214,10	214,21	214,61	214,77	215,86	216,50	217,38	218,29	218,64	219,20	219,64
Stan na kwiecień 2006r. (dno)	206,58	208,46	211,43	212,91	213,10	213,96	213,89	214,22	214,96	215,50	216,81	217,59	217,64	218,50	218,74
Prognoza na rok 2020 (dno)	206,58	208,46	211,43	212,91	213,10	213,96	213,89	214,22	214,96	215,50	216,81	217,59	217,64	218,50	218,74
Prognoza docelowa (dno)	206,58	208,46	211,43	212,91	213,10	213,96	213,89	214,22	214,96	215,50	216,81	217,59	217,64	218,50	218,74
Dno projektowane	206,58	208,46	211,43	212,00	212,10	212,00	212,00	212,00	212,00	212,00	213,00	213,00	213,00	213,00	213,00

Stan na kwiecień 2006r. (lustro wody)	220,88	220,98	221,37	221,81	221,87	221,87	221,87	221,94	222,33	222,68	222,69	223,10	223,50	226,90	228,10
Stan na kwiecień 2006r. (dno)	220,51	220,05	220,79	221,49	219,86	220,62	220,32	221,44	222,10	221,86	222,10	221,30	223,00	226,40	227,60
Prognoza na rok 2020 (dno)	220,51	220,05	220,79	221,49	219,86	220,58	219,22	219,58	220,91	220,88	219,85	216,31	216,00	224,88	227,50
Prognoza docelowa (dno)	220,51	220,05	220,79	219,69	216,26	214,37	216,61	218,14	219,89	219,67	217,36	209,94	211,23	219,64	227,35
Dno projektowane											215,00	209,94	211,23	219,64	227,35

CONSTANCY OF NORMAL WATER STATES IN LOWER SECTIONS OF WATERCOURSE BEDS IN MSAs

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DETERMINATION OF THE ELEVATION OF THE BASE LEVEL OF NATURAL OUTFLOW OF WATER ON THE MSA BOUNDARY

The median value of the Bierawka River water stages in the place of the outflow of water from the „Szczyglowice” MSA

No.	Date	Set of observations	Notes
1	2001.10.24.	222,10	
2	2002.05.22.	221,83	
3	2002.11.19.	221,90	
4	2003.05.	221,85	
5	2003.05.13.	221,91	
6	2003.11.18.	221,89	
7	2004.11.05.	221,90	
8	2005.11.10.	222,00	
9	2006.05.	221,86	
10	2006.05.19.	222,10	
11	2006.11.24.	221,95	
12	2007.06.13.	221,91	
13	2007.11.26.	221,90	
14	2008.11.17.	222,00	
15	2009.06.13.	221,98	
16	2009.06.	221,74	
17	2009.11.07.	221,92	
18	2010.06.16.	222,27	Flood
19	2011.07.12.	221,90	
20	2012.07.13.	221,71	
21	2013.07.11.	222,20	
22	2014.07.16.	221,72	
23	2015.07.13	221,62	
24	2016.07.14	221,63	
25	2017.11.27.	221,91	

No.	Ordered set of observations
1	221,62
2	221,63
3	221,71
4	221,72
5	221,74
6	221,83
7	221,85
8	221,86
9	221,89
10	221,90
11	221,90
12	221,90
13	221,90
14	221,91
15	221,91
16	221,91
17	221,92
18	221,95
19	221,98
20	222,00
21	222,00
22	222,10
23	222,10
24	222,20
Median	**221,90**

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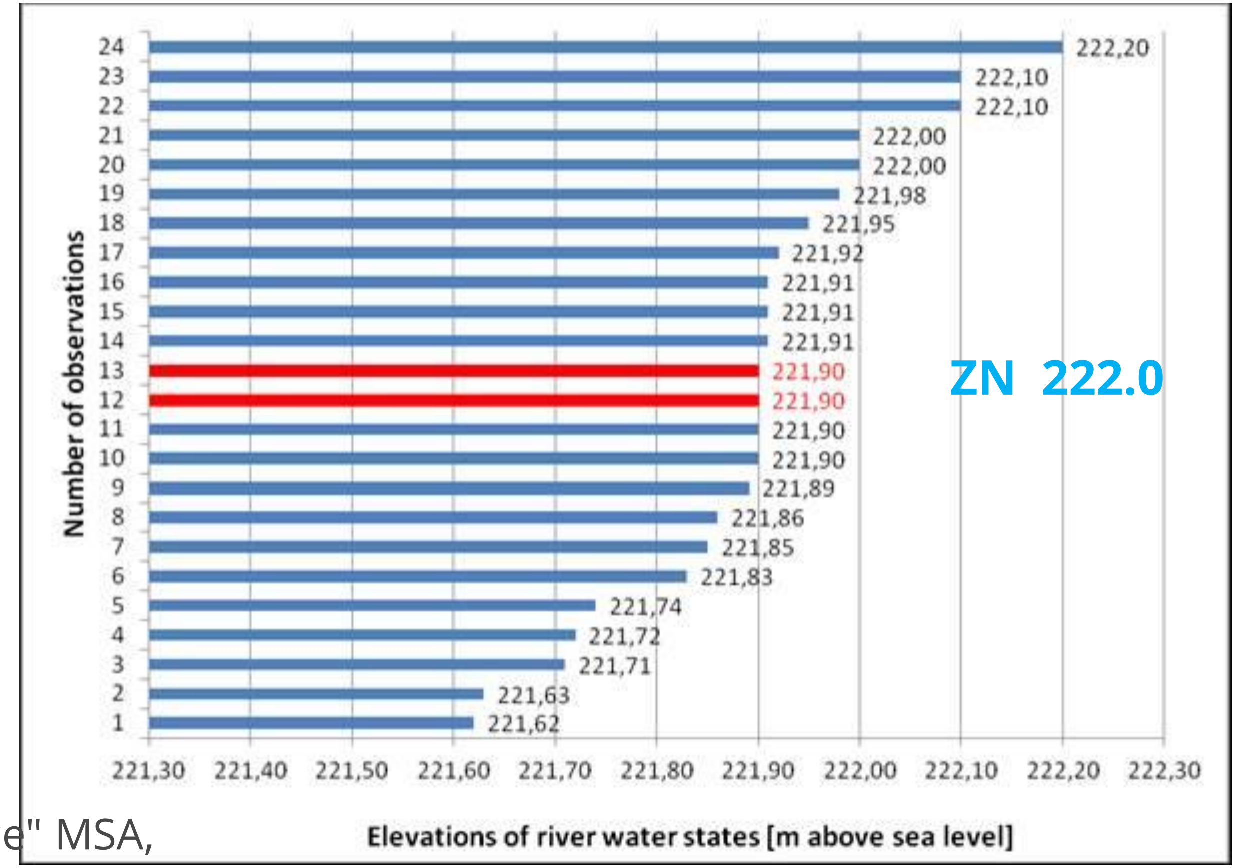
DETERMINIG THE ELEVATION OF THE NORMAL HYDROMETRIC REFERENCE POINT USING THE BASE LEVEL OF NATURAL OUTFLOW OF WATER AT THE PLACE OF IT'S OUTFLOW FROM THE MSA



Graphical interpretation
of the ordered set
for the measurements
of the Bierawka water table
in the place of the outflow
of water from the "Szczyglowice" MSA,
the designated **median**
and establishing the elevation of
the ***normal hydrometric reference point***.

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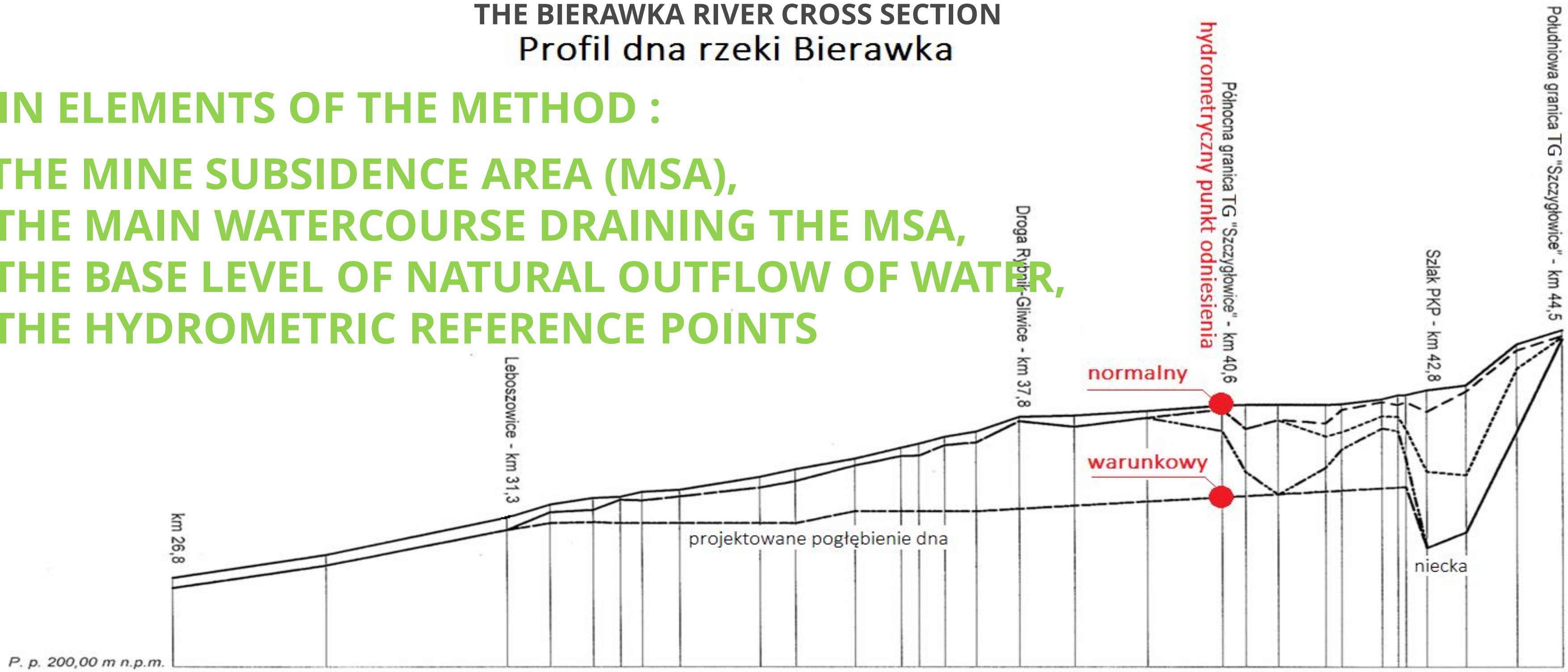
THE BIERAWKA RIVER CROSS SECTION

Profil dna rzeki Bierawka

MAIN ELEMENTS OF THE METHOD :

1) THE MINE SUBSIDENCE AREA (MSA),
2) THE MAIN WATERCOURSE DRAINING THE MSA,
3) THE BASE LEVEL OF NATURAL OUTFLOW OF WATER,
4) THE HYDROMETRIC REFERENCE POINTS



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Dno projektowane	206,58	208,46	211,43	212,00	212,10	212,00	212,00	212,00	212,00	212,00	213,00	213,00	213,00	213,00	213,00

Stan na kwiecień 2006r. (lustro wody)	220,88	220,98	221,37	221,81	221,87	221,87	221,87	221,94	222,33	222,68	222,69	223,10	223,50	226,90	228,10
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Prognoza docelowa (dno)	220,51	220,05	220,79	219,69	216,26	214,37	216,61	218,14	219,89	219,67	217,36	209,94	211,23	219,64	227,35
Dno projektowane											215,00	209,94	211,23	219,64	227,35

CONSTANCY OF NORMAL WATER STATES IN LOWER SECTIONS OF WATERCOURSE BEDS IN MSAs

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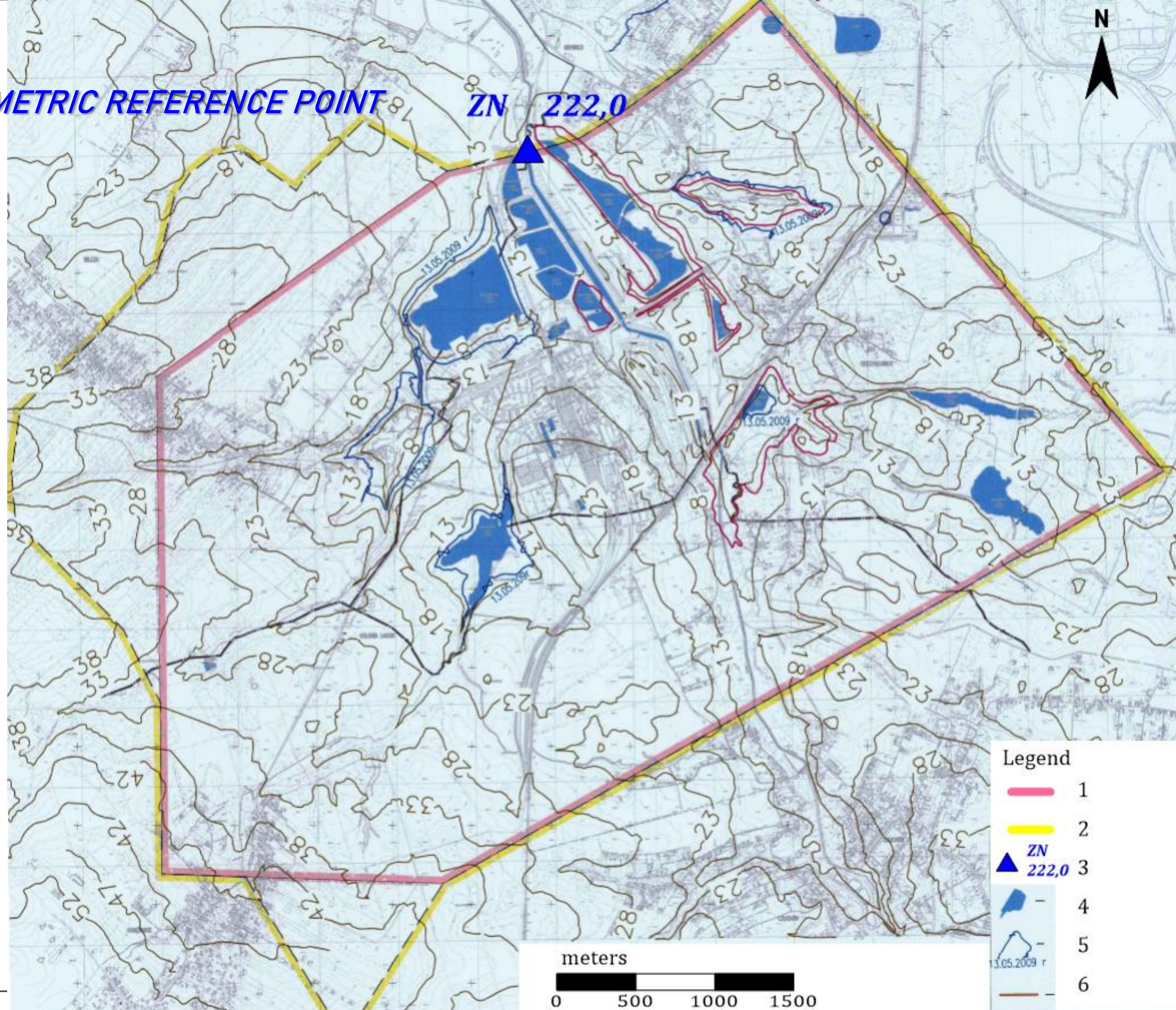
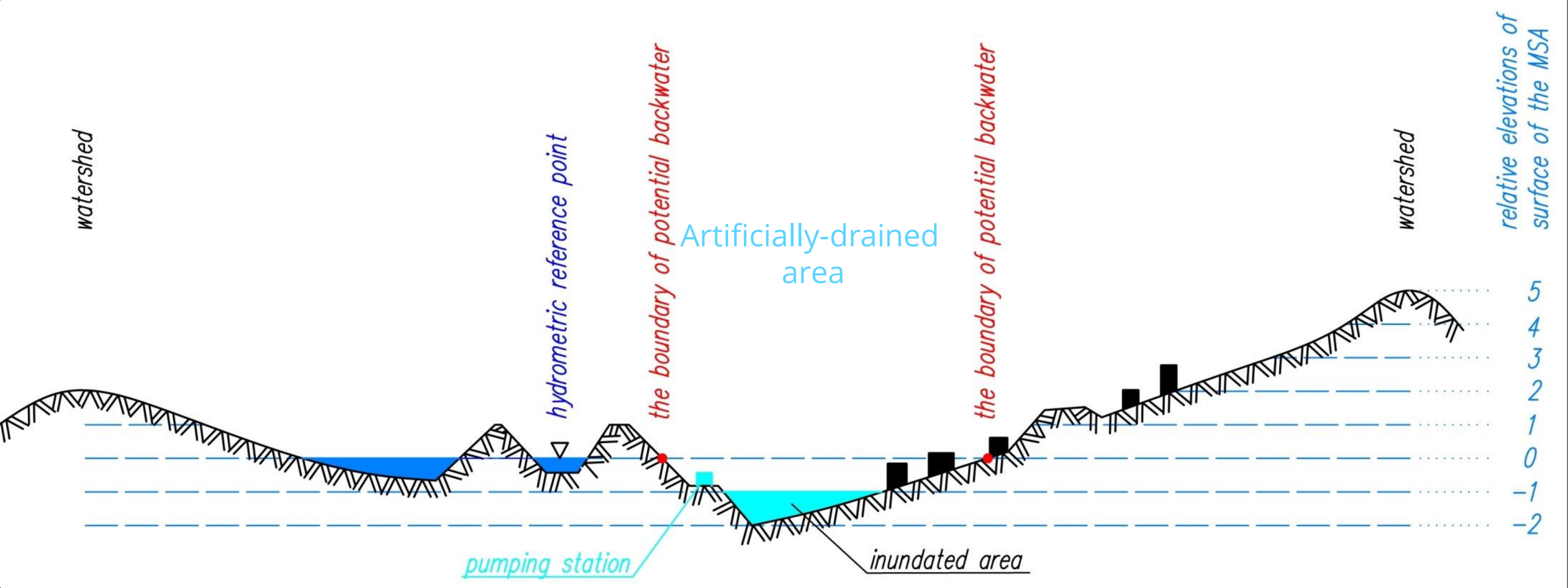


RELATIVE ELEVATIONS OF THE MSA IN THE BIERAWKA RIVER CATCHMENT AREA

SAMPLE DIAGRAM OF THE RELATIVE ELEVATIONS OF A SINGLE CATCHMENT AREA IN AN ARTIFICIALLY-DRAINED MSA



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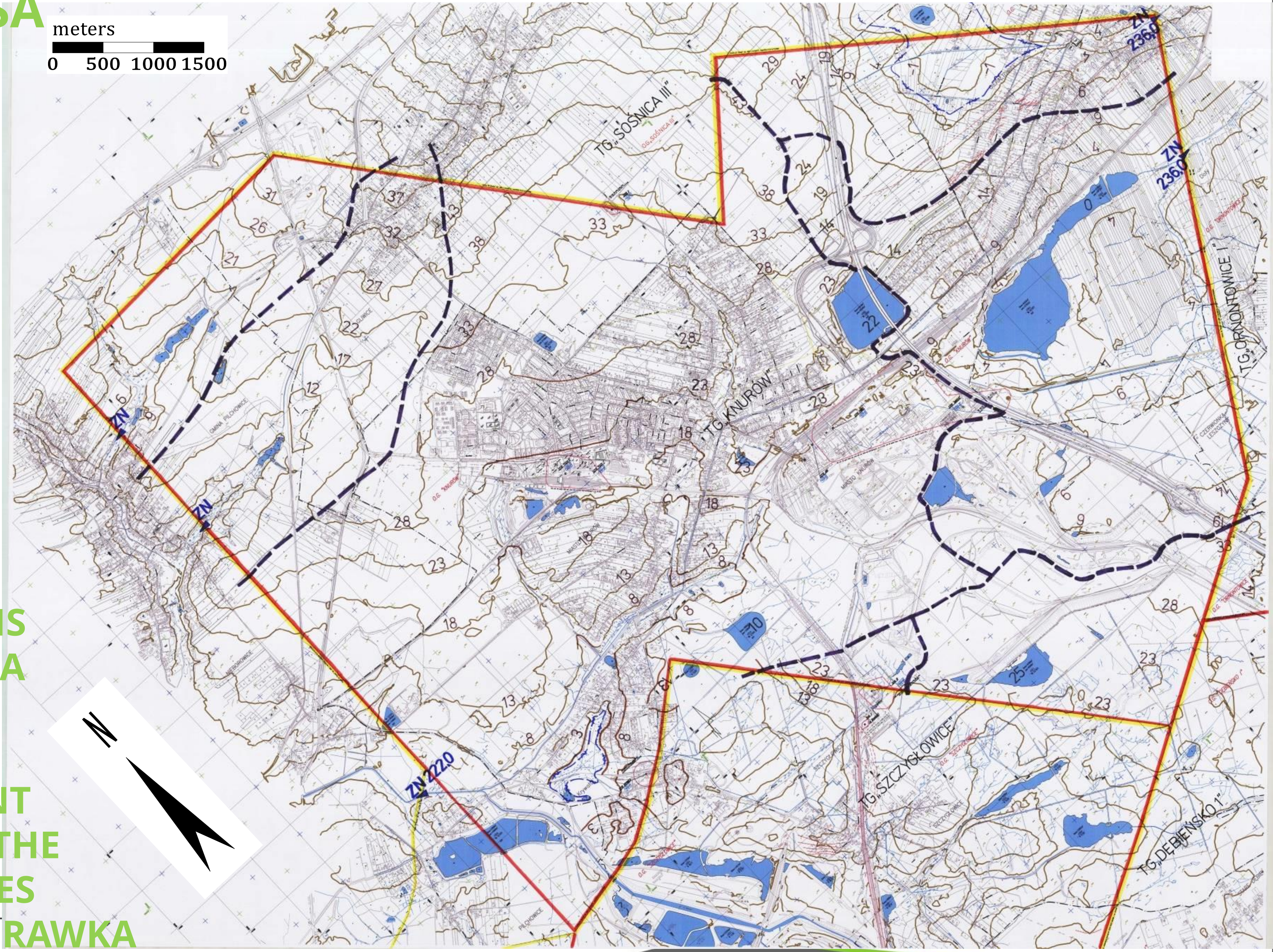
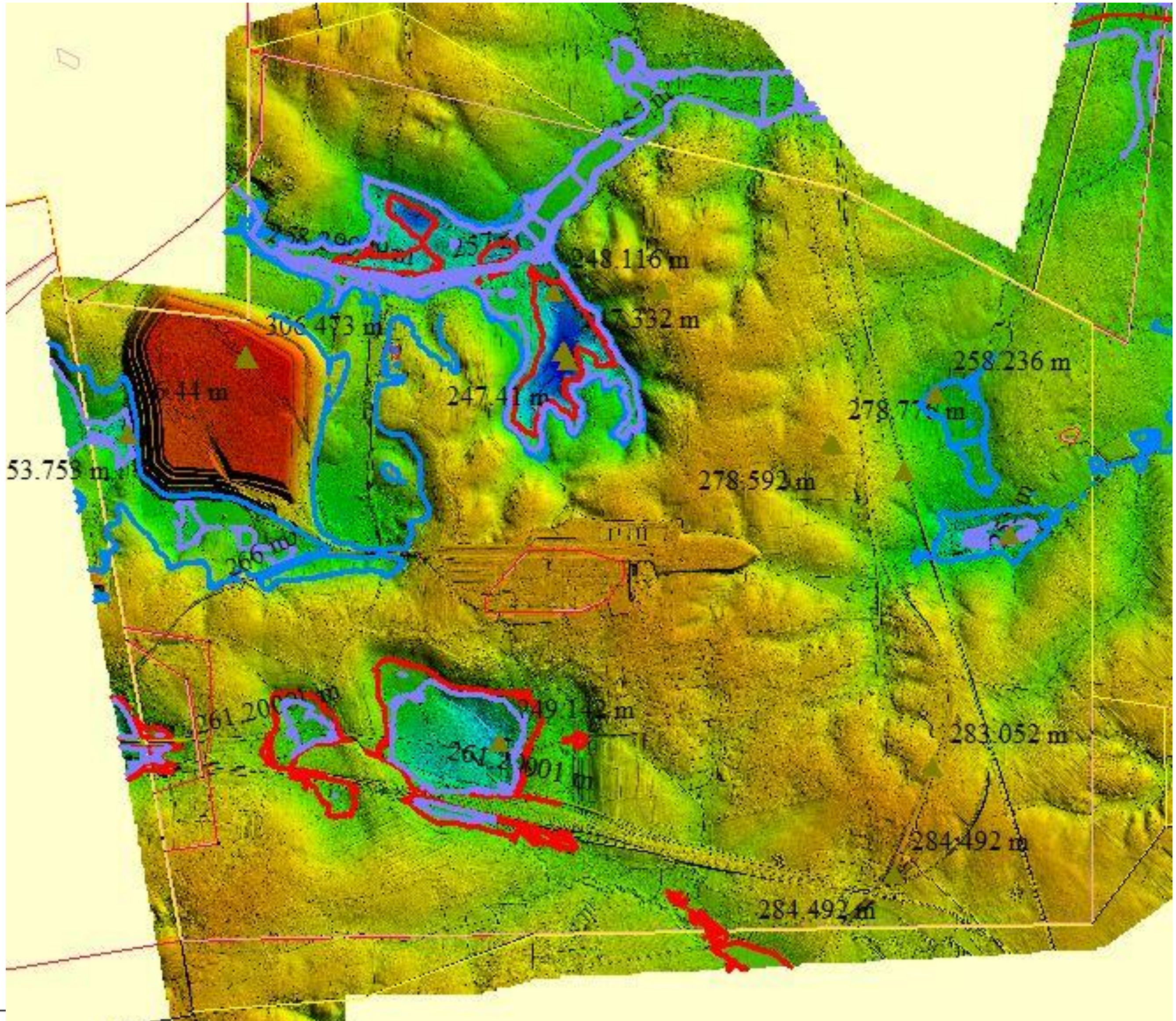
PROJECTION OF SEPARATE CATCHMENT AREAS IN A MSA



RELATIVE ELEVATIONS OF THE MSA SURFACE IN THE CATCHMENT AREAS OF THE TRIBUTERIES OF THE BIERAWKA AND KLODNICA RIVERS

IDENTIFYING ALL SEPERATE ARTIFICIALLY-DRAINED MORPHOLIGICAL BASINS AND THE FIVE (5) TYPES OF POTENTIAL RESERVOIRS INSIDE THEM



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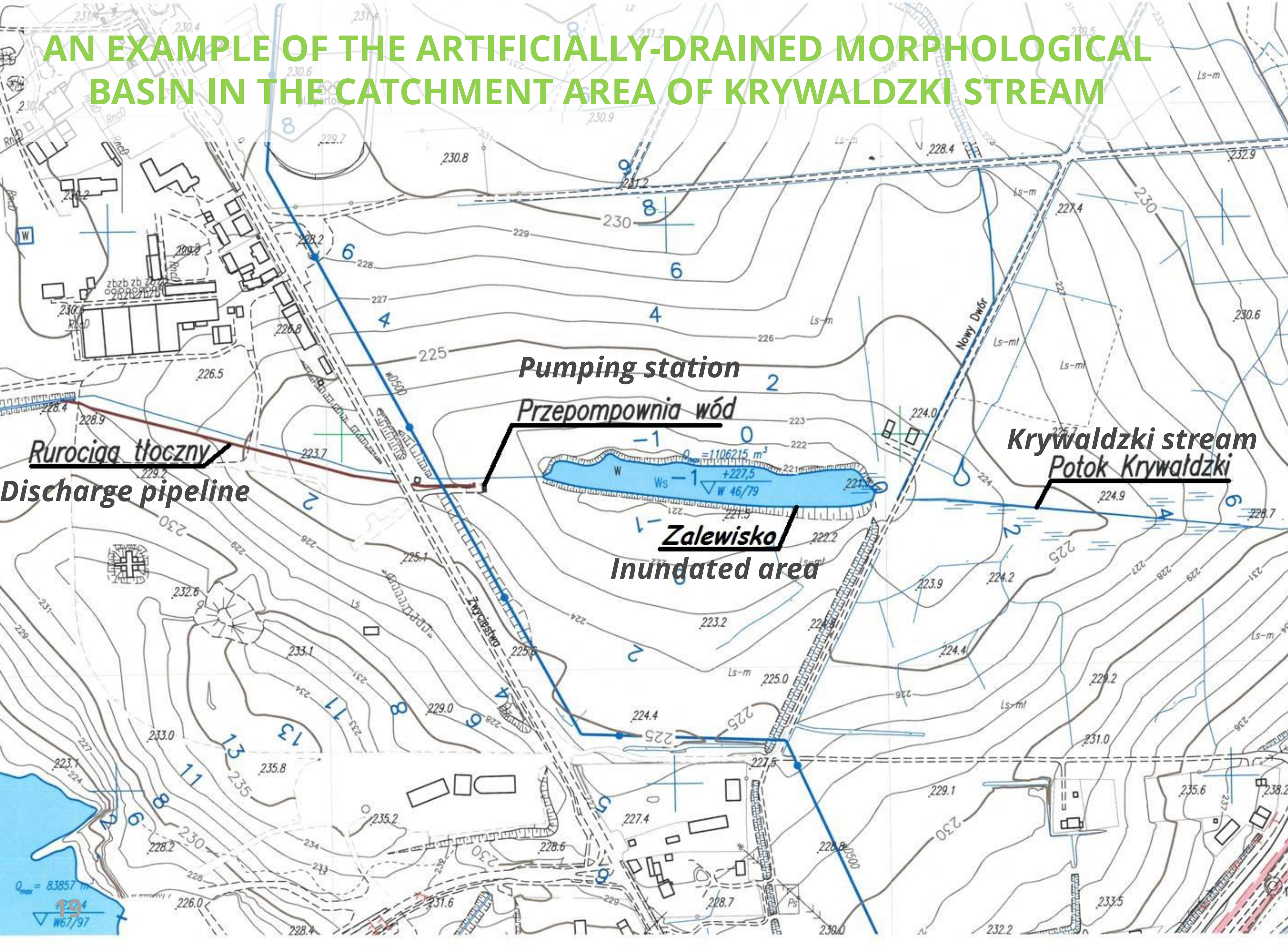
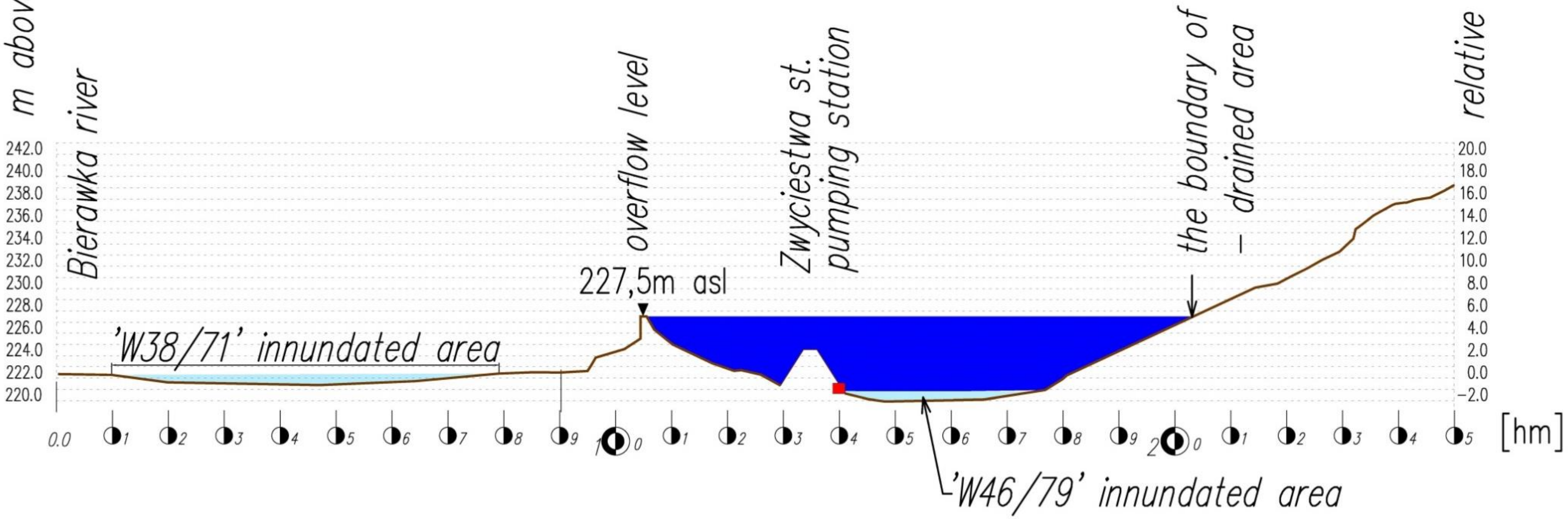
AN EXAMPLE OF THE ARTIFICIALLY-DRAINED MORPHOLOGICAL BASIN IN THE CATCHMENT AREA OF KRYWALDZKI STREAM



THE DEFINITION OF FIVE (5) TYPES OF POTENTIAL RESERVOIRS – CROSS SECTION THROUGH THE ARTIFICIALLY-DRAINED MORPHOLOGICAL BASIN OF KRYWALDZKI STREAM

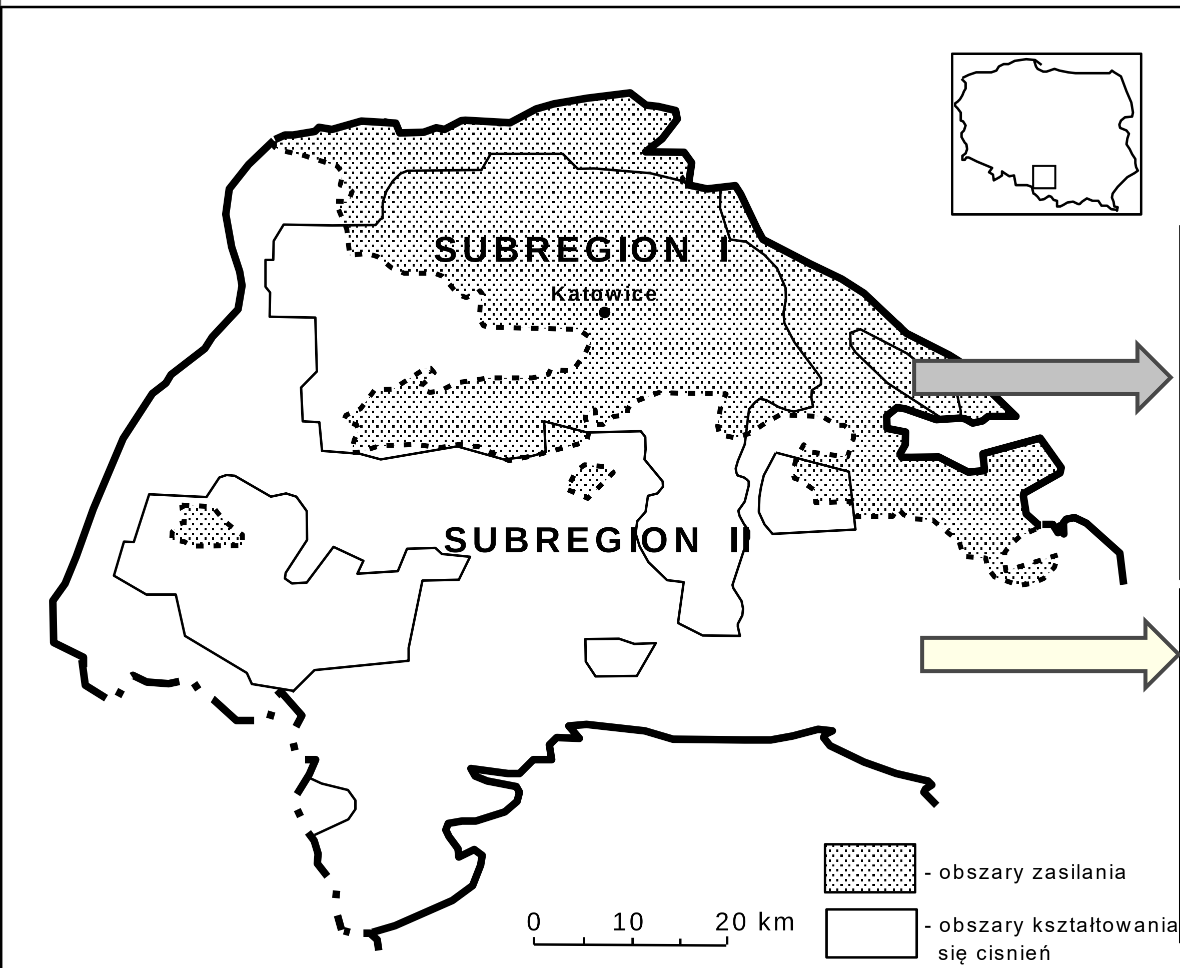
1) ***The inundated area*** – 1st extent and level of inundation

2) ***The boundary of artificially-drained area*** and
3) ***The closed basin lake***
   – 2nd and 3rd potential reservoirs are characterized by the same extent and level of inundation

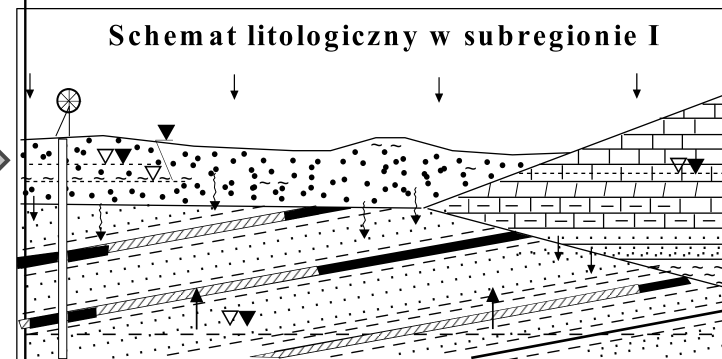


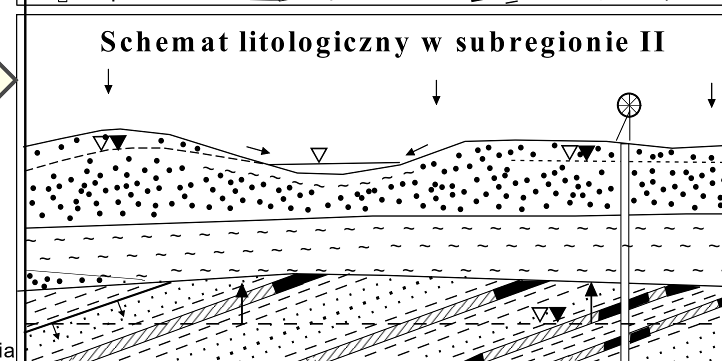
THE HYDRO-ISOLATING PROPERTIES OF THE CARBONIFEROUS OVERBURDEN IN SUBREGIONS OF THE UPPER SILESIAN COAL BASIN

(based on P. Bukowski)



Lithological diagram of Subregion I





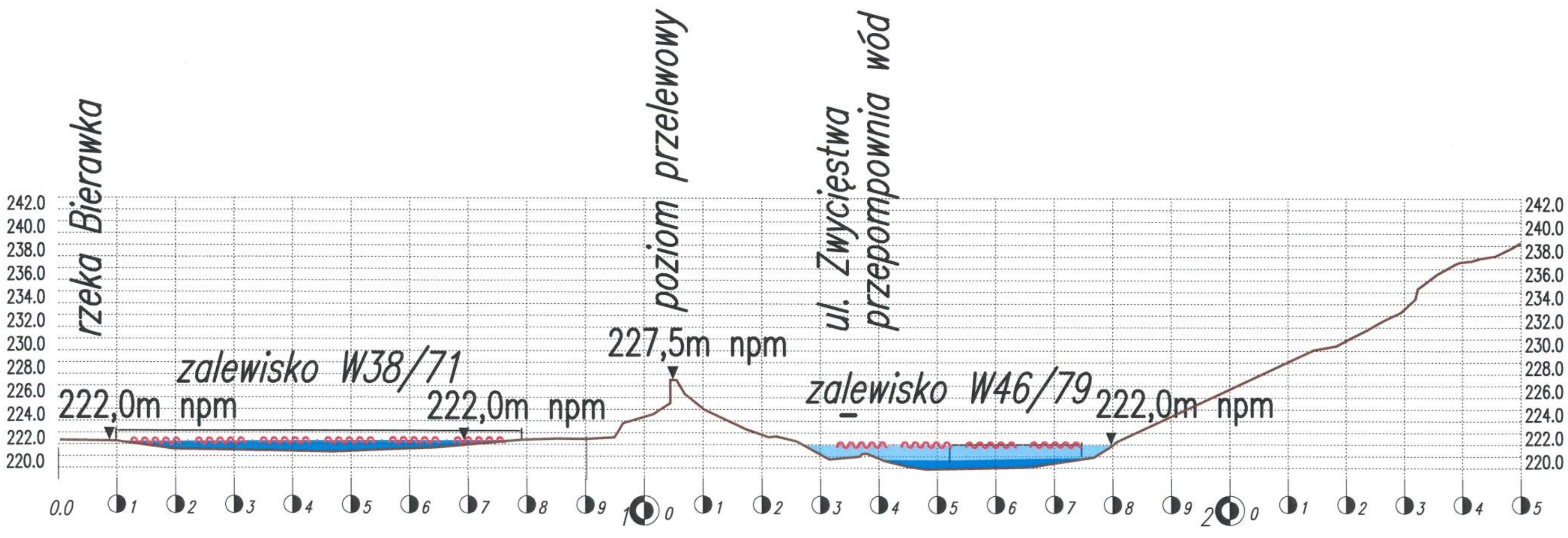
Lithological diagram of Subregion II

Subregion I – hydrogeologically non-isolated,

Subregion II – hydrogeologically isolated

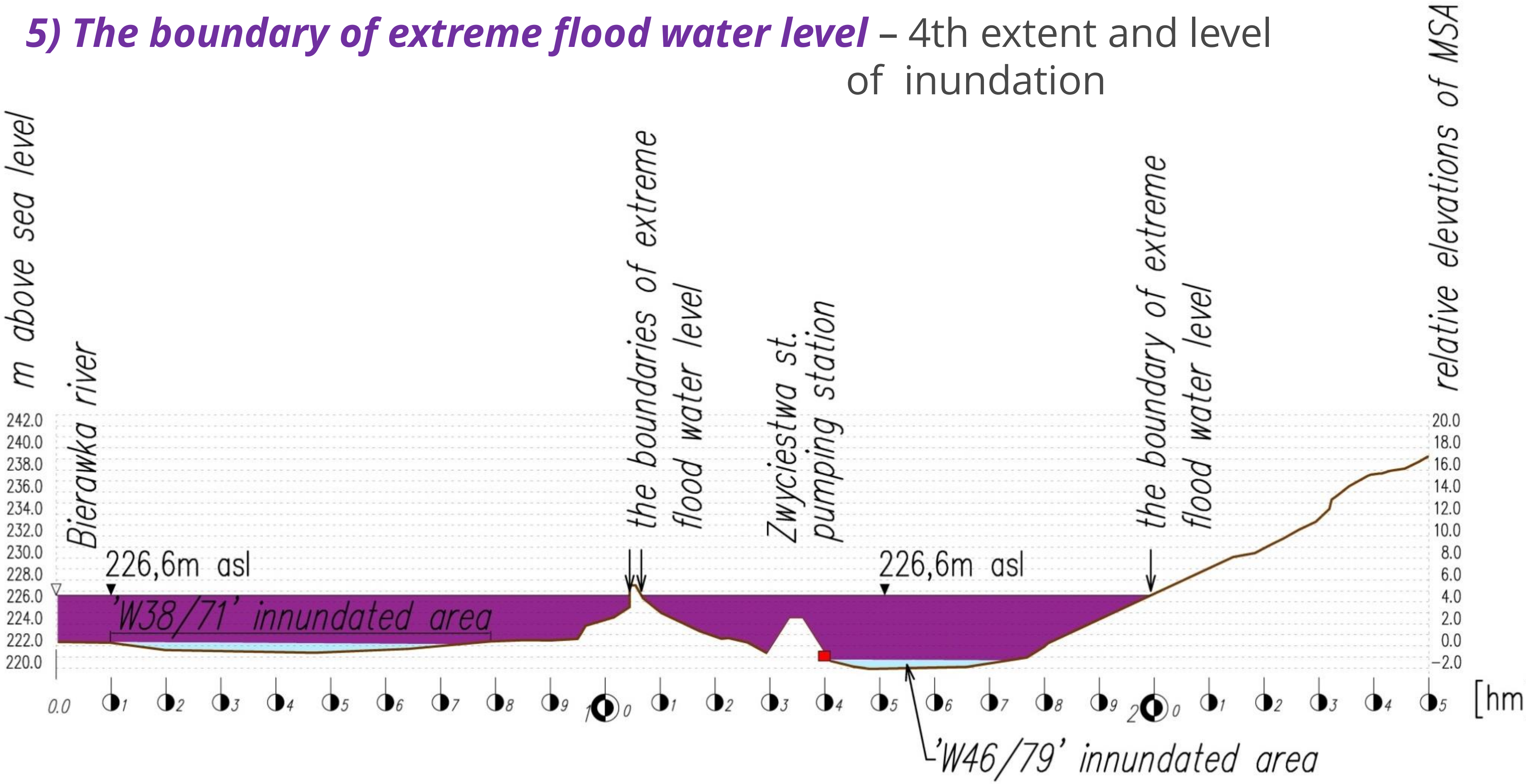
THE DEFINITION OF FIVE (5) TYPES OF POTENTIAL RESERVOIRS – CROSS SECTION THROUGH THE ARTIFICIALLY-DRAINED MORPHOLOGICAL BASIN OF KRYWALDZKI STREAM

4) The boundary of potential backwater – 3th extent and level of inundation

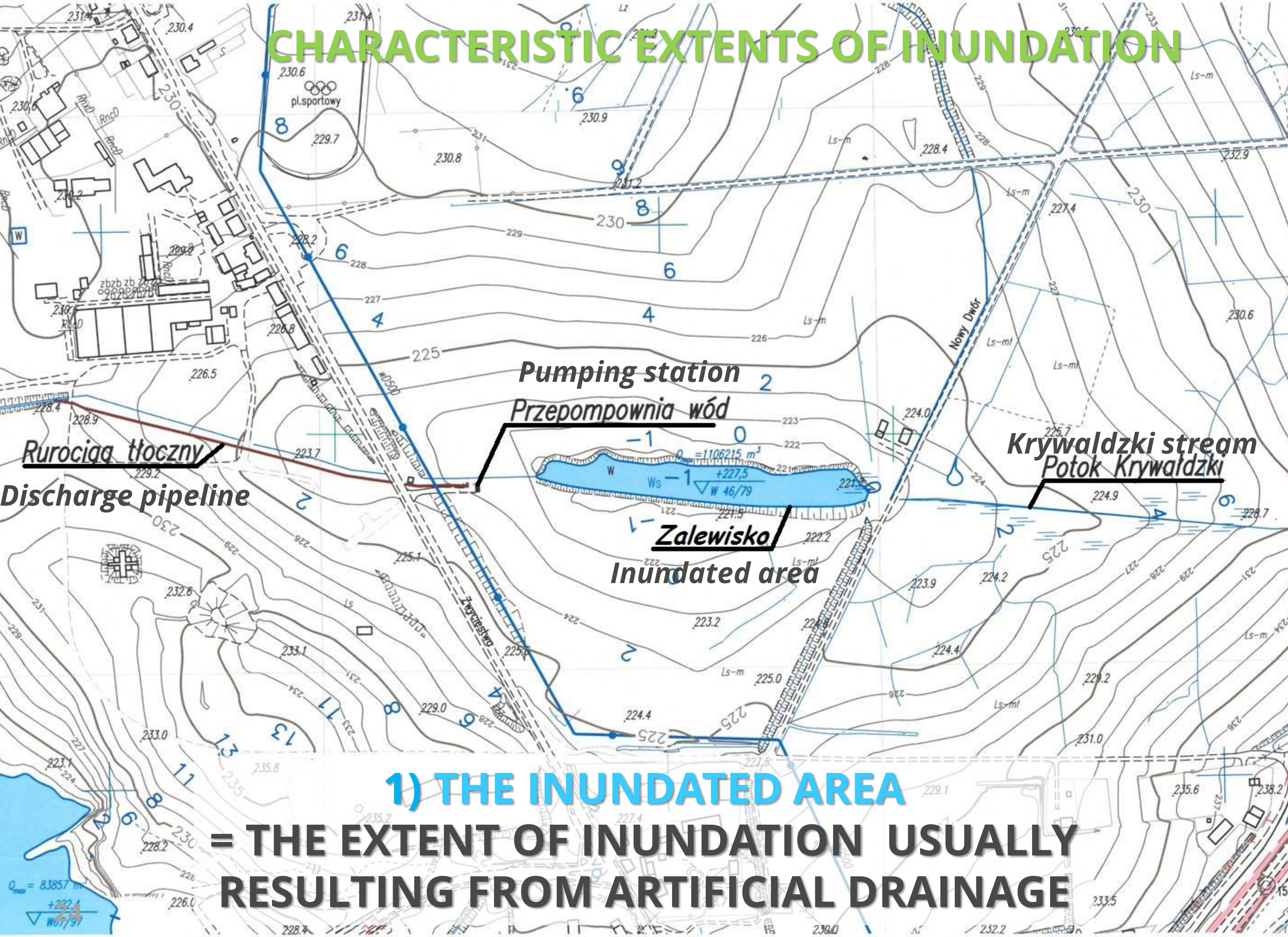


THE DEFINITION OF FIVE (5) TYPES OF POTENTIAL RESERVOIRS – CROSS SECTION THROUGH THE ARTIFICIALLY-DRAINED MORPHOLOGICAL BASIN OF KRYWALDZKI STREAM

5) The boundary of extreme flood water level – 4th extent and level of inundation



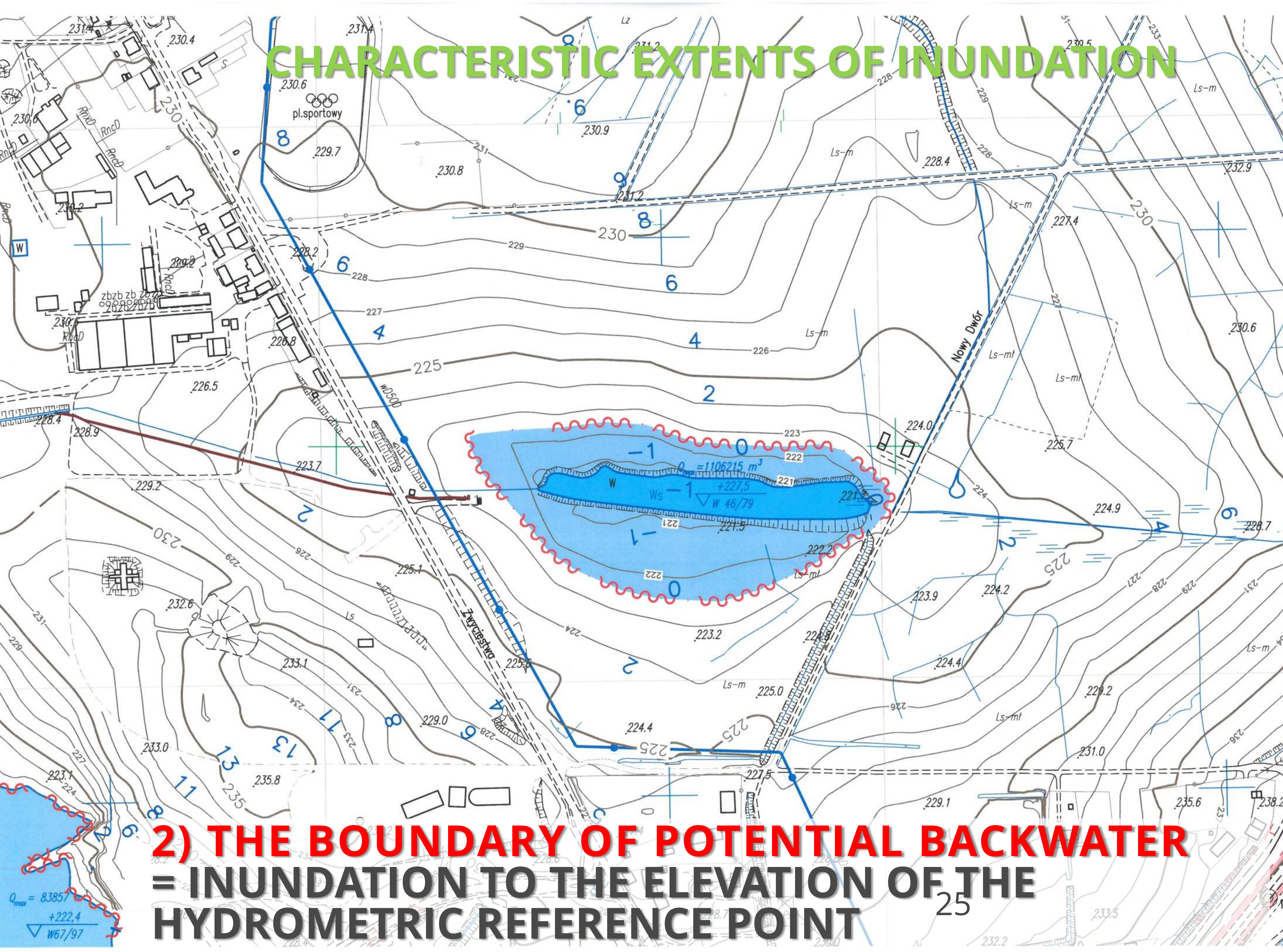
CHARACTERISTIC EXTENTS OF INUNDATION



1) THE INUNDATED AREA

= THE EXTENT OF INUNDATION USUALLY RESULTING FROM ARTIFICIAL DRAINAGE

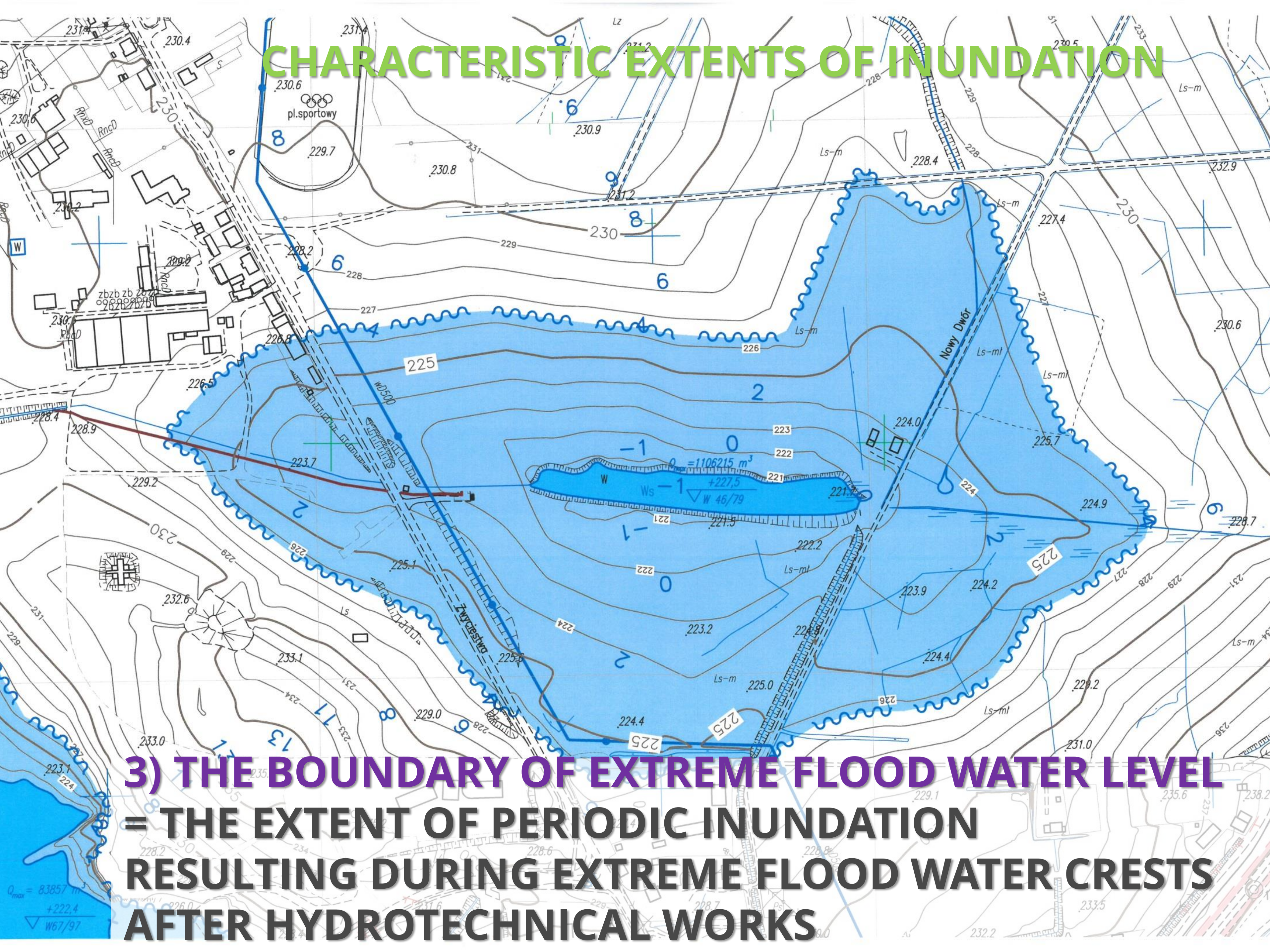
CHARACTERISTIC EXTENTS OF INUNDATION



2) THE BOUNDARY OF POTENTIAL BACKWATER

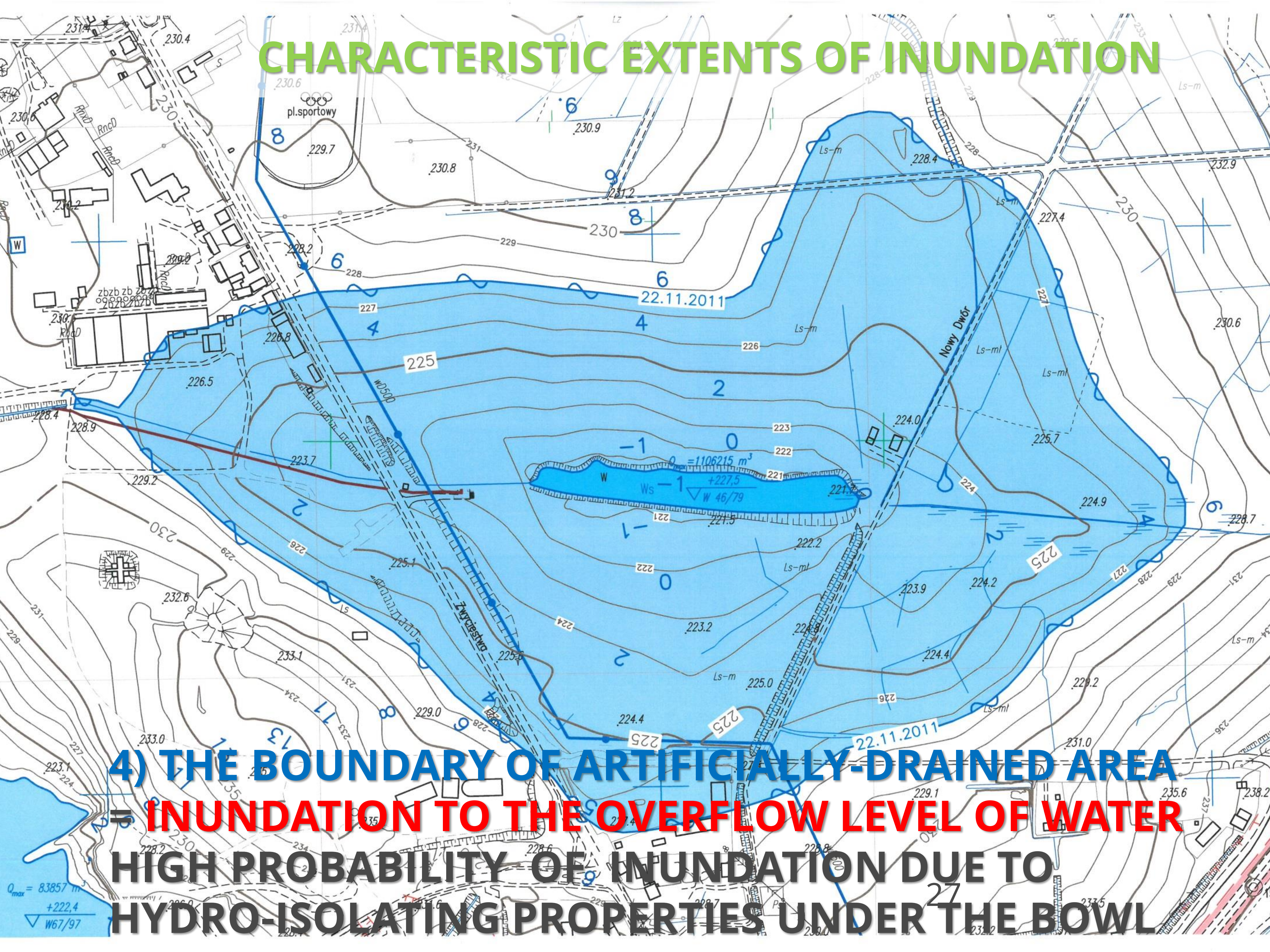
= INUNDATION TO THE ELEVATION OF THE HYDROMETRIC REFERENCE POINT

CHARACTERISTIC EXTENTS OF INUNDATION



3) THE BOUNDARY OF EXTREME FLOOD WATER LEVEL = THE EXTENT OF PERIODIC INUNDATION RESULTING DURING EXTREME FLOOD WATER CRESTS AFTER HYDROTECHNICAL WORKS

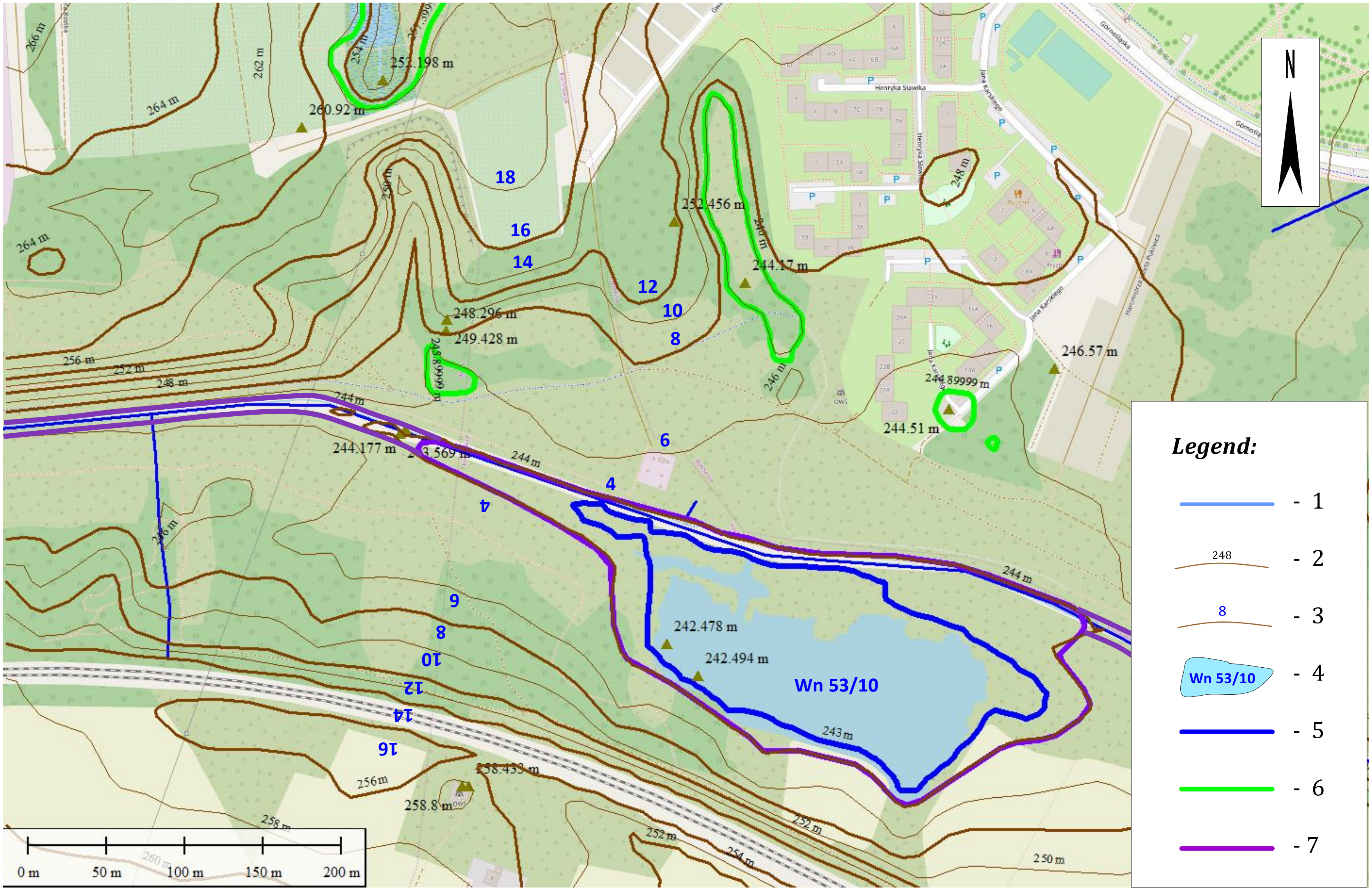
CHARACTERISTIC EXTENTS OF INUNDATION



4) THE BOUNDARY OF ARTIFICIALLY-DRAINED AREA = INUNDATION TO THE OVERFLOW LEVEL OF WATER

HIGH PROBABILITY OF INUNDATION DUE TO HYDRO-ISOLATING PROPERTIES UNDER THE BOWL

CHARACTERISTIC EXTENTS OF INUNDATION



5) THE CLOSED BASIN LAKE

= INUNDATION TO THE OVERFLOW LEVEL OF WATER

LOW PROBABILITY OF INUNDATION DUE TO NON-HYDROISOLATING PROPERTIES UNDER THE BOWL

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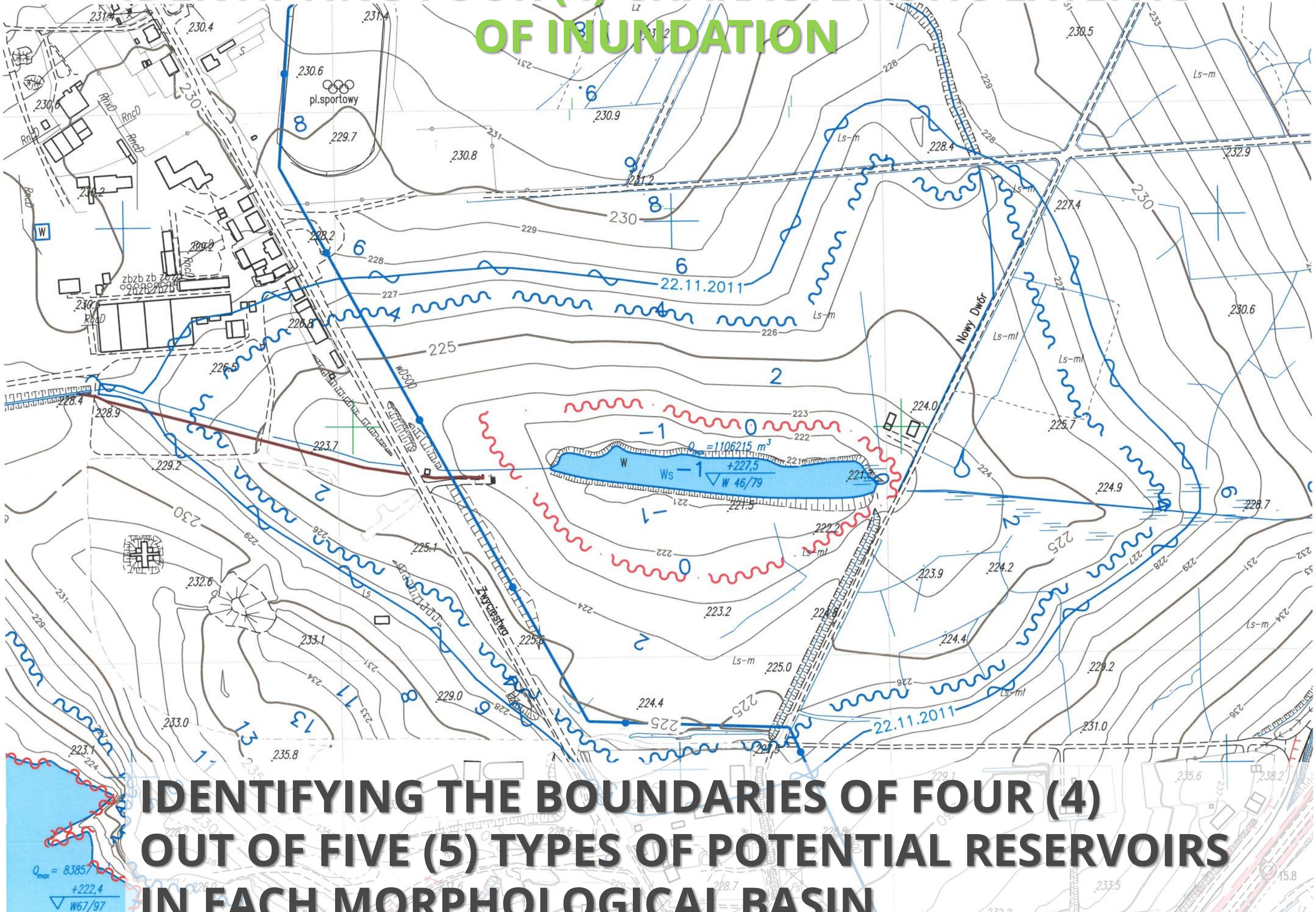
IDENTIFYING FOUR (4) CHARACTERISTIC EXTENTS OF INUNDATION



IDENTIFYING THE BOUNDARIES OF FOUR (4) OUT OF FIVE (5) TYPES OF POTENTIAL RESERVOIRS IN EACH MORPHOLOGICAL BASIN

ZONING THE SURFACE OF MINE SUBSIDENCE AREA TAKING INTO ACCOUNT THE THREAT OF FLOODING

A four-level scale is proposed for zoning MSAs:

Category I flood hazard is proposed for those parts of MSAs, which were subject to mining transformations and in which the restoration of natural water flows will cause insignificant changes in the hydrogeological conditions of the subsurface layer of the rock mass, and for which there is no basis for classification higher than Category I flood hazard. These areas are characterized by changes to the waterlogging of the bedrock below. Such waterlogging is insignificant for spatial development purposes.

Category II flood hazard is proposed for those parts of MSAs which include mining areas that are or will be covered by *the boundaries of the extreme flood water level* and/or the *closed basin lakes* and/or strips of land along the main watercourses and their tributaries in valleys threatened by flooding, excluding from them areas classified higher than Category II of flood hazard. These areas are characterized by a low probability of the occurrence of flooding (occasional inundation).

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ZONING THE SURFACE OF MINE SUBSIDENCE AREA TAKING INTO ACCOUNT THE THREAT OF FLOODING

Category III flood hazard is proposed for mining areas that are or will be covered by *the boundaries of the artificially-drained area*, with the exception of areas included in Category IV flood hazard, as well as additionally parts of *inundated areas*, characterized by inventoried, positive *relative elevations* of their bottom. These areas are characterized by a high probability of occurrence of flooding (permanent inundation).

Category IV flood hazard are those (areas) that are or will be covered (after the restoration of natural water flows) by *the boundaries of potential backwater* and/or waterlogging and/or *inundated areas*, with the exception of those parts of *inundated areas* classified in the Category III flood hazard, The mining areas under Category IV flood hazard should additionally include land strips necessary for conducting hydrotechnical gravitational drainage works. These areas are and/or will be flooded and/or waterlogged in the future once natural (free) water flows have been restored and necessary hydrotechnical gravitational drainage works have been carried out.

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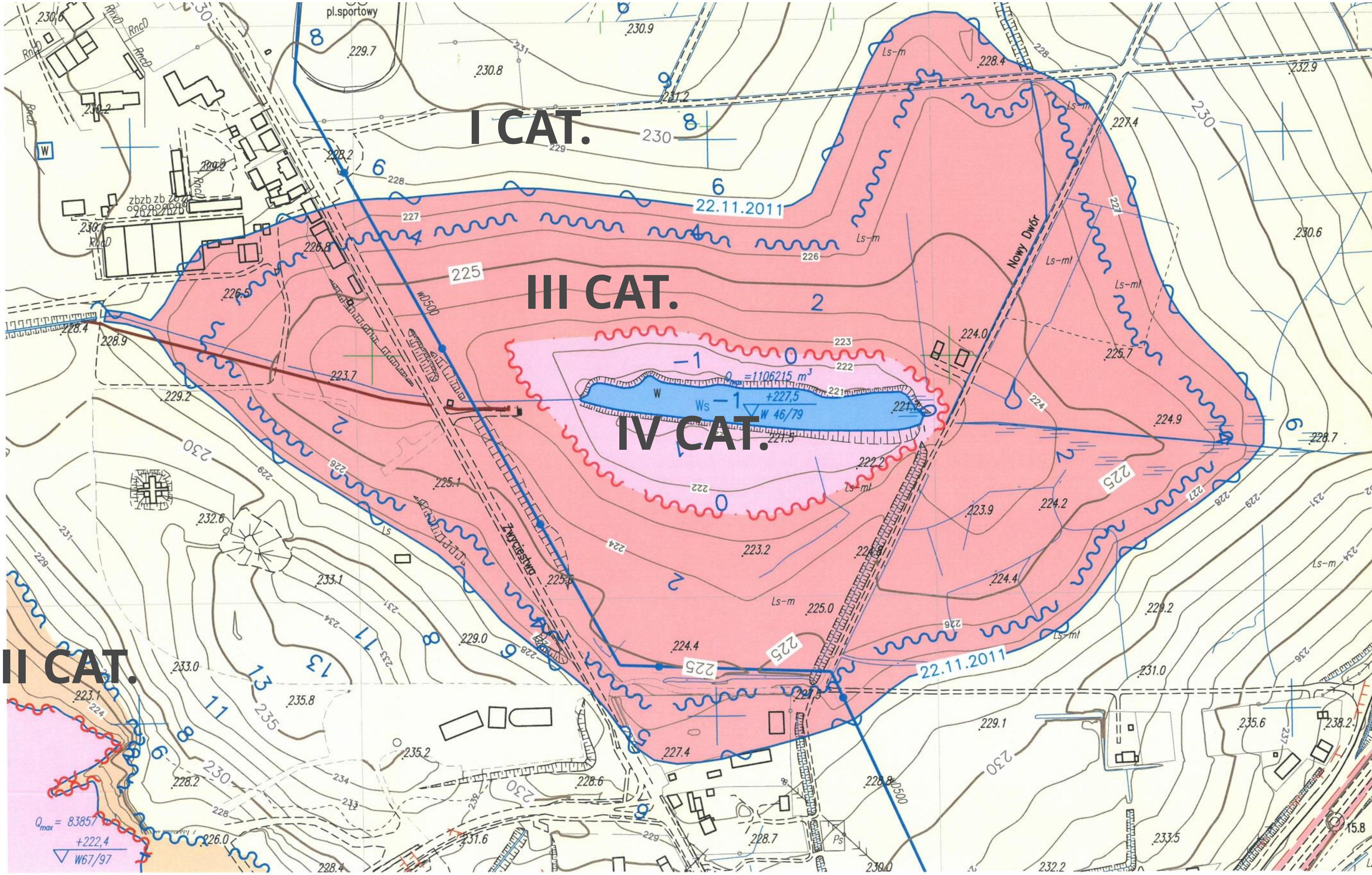
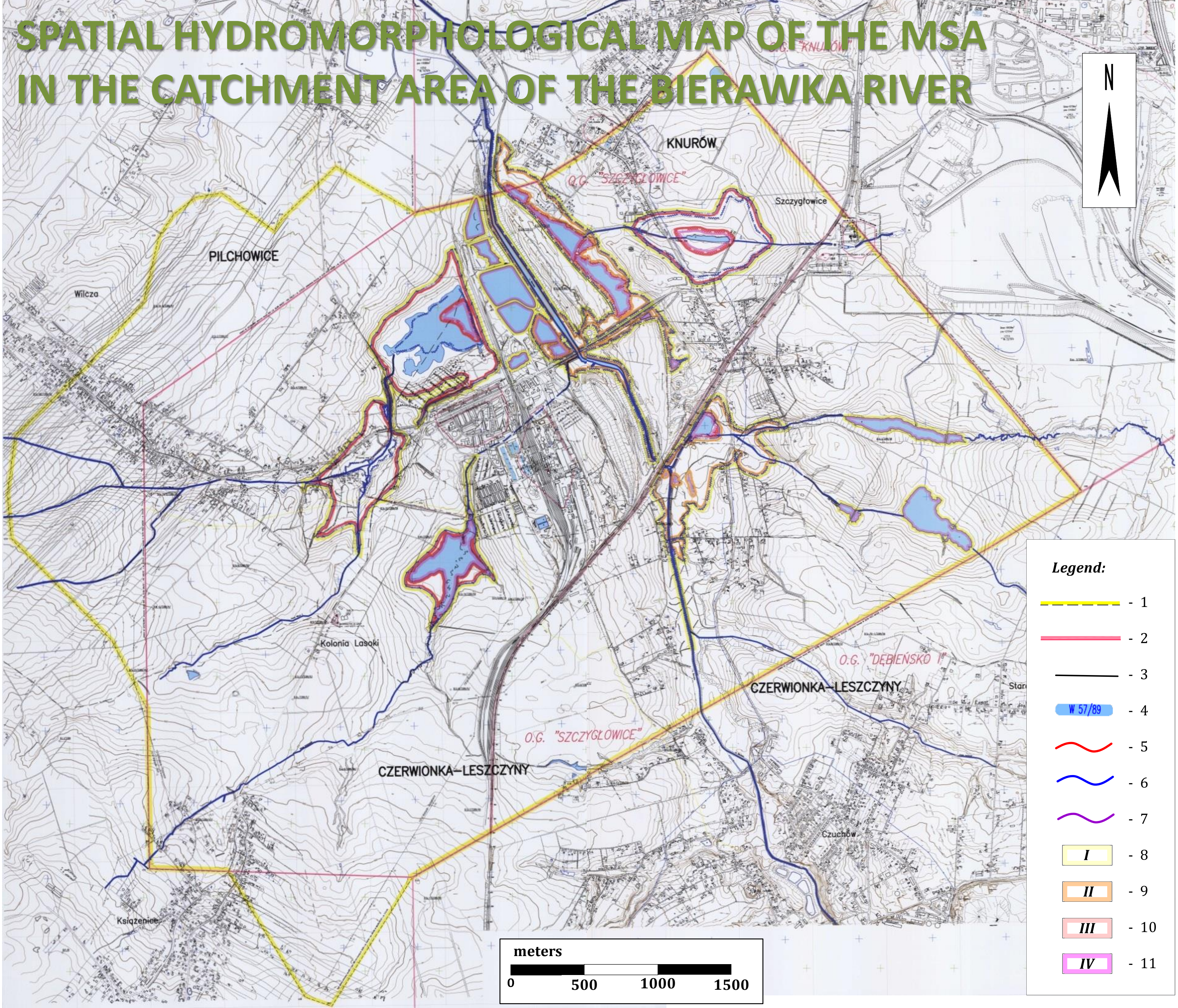
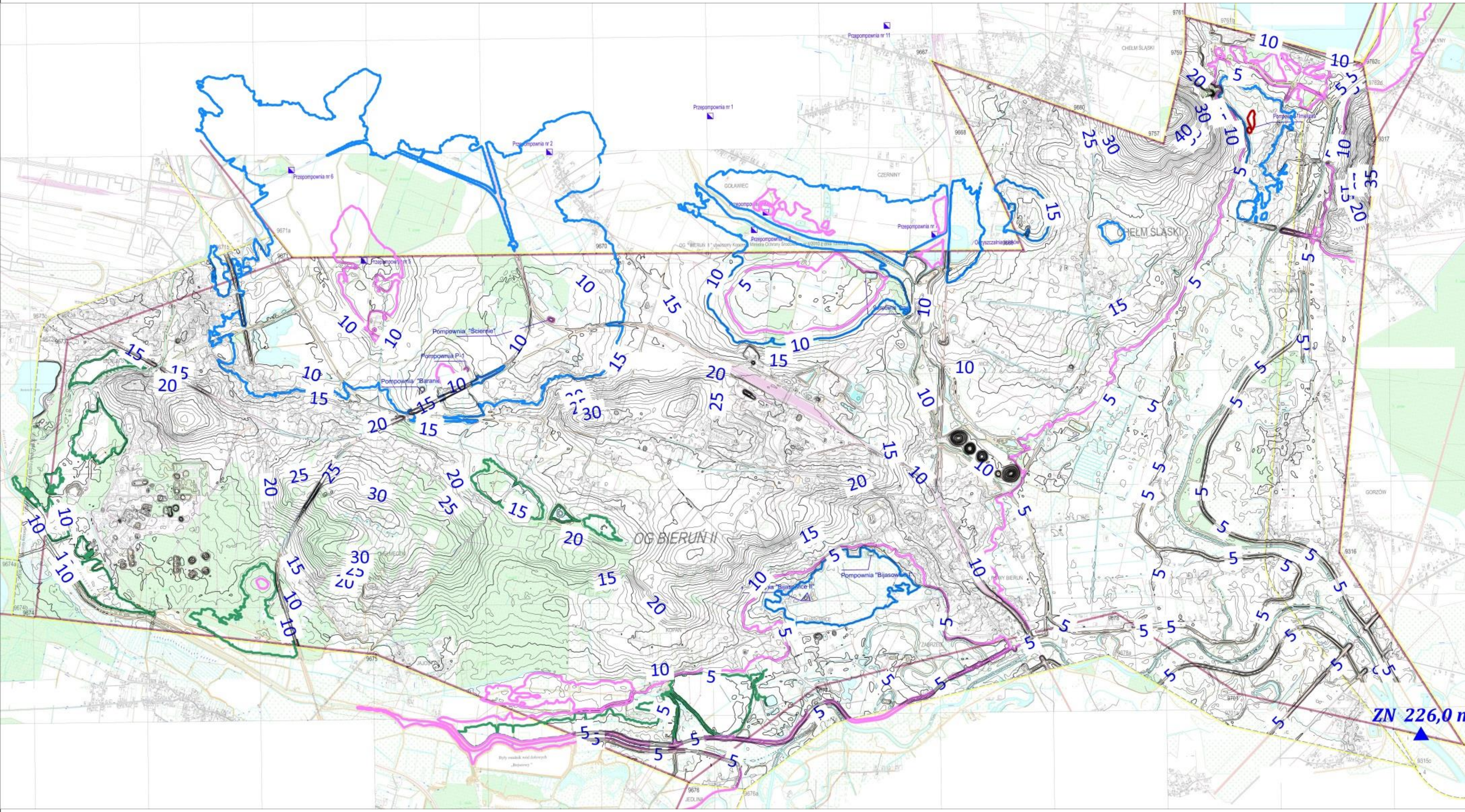
ZONING THE SURFACE OF MINE SUBSIDENCE AREA TAKING INTO ACCOUNT THE THREAT OF FLOODING



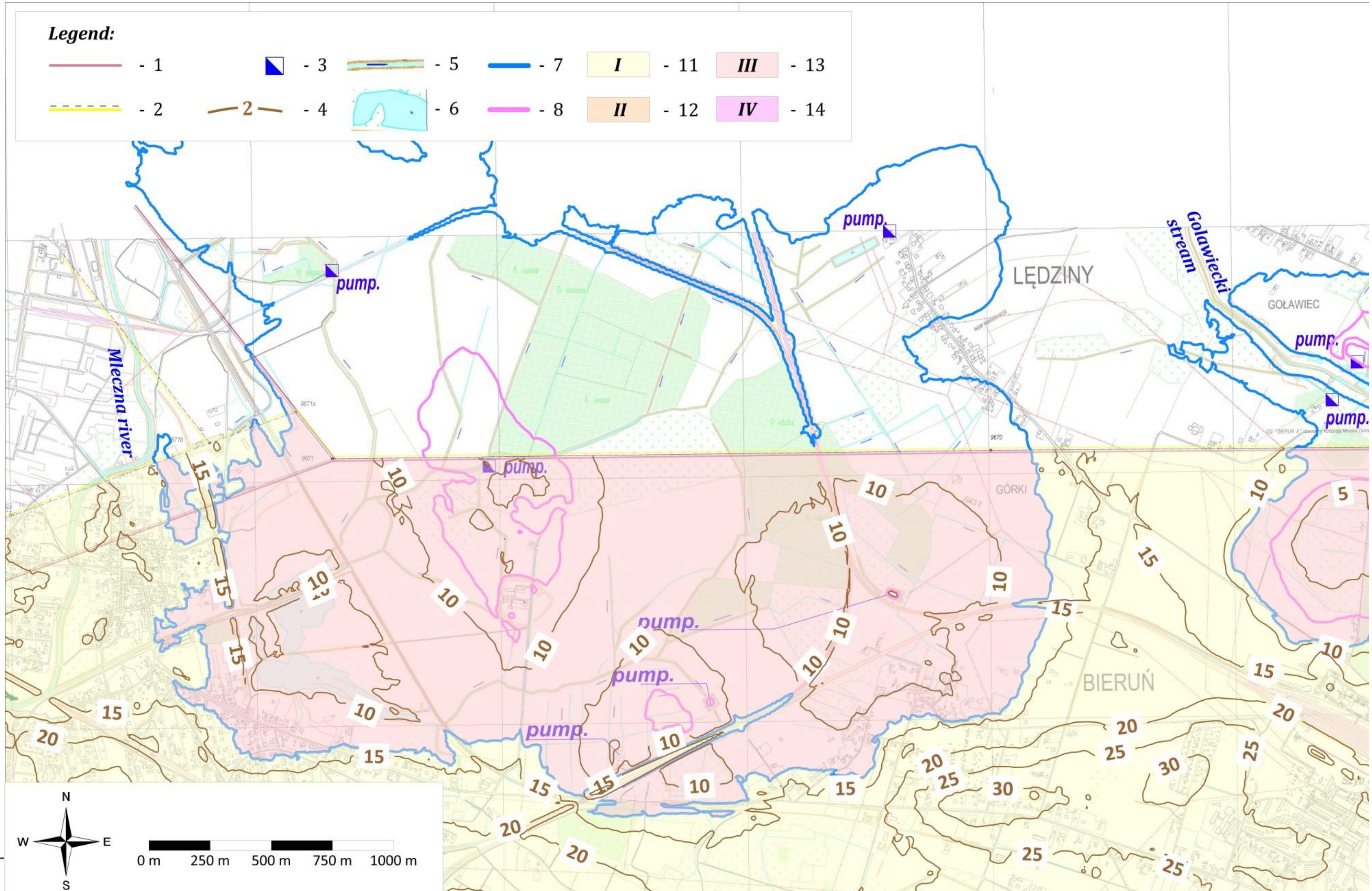
SPATIAL HYDROMORPHOLOGICAL MAP OF THE MSA IN THE CATCHMENT AREA OF THE BIERAWKA RIVER

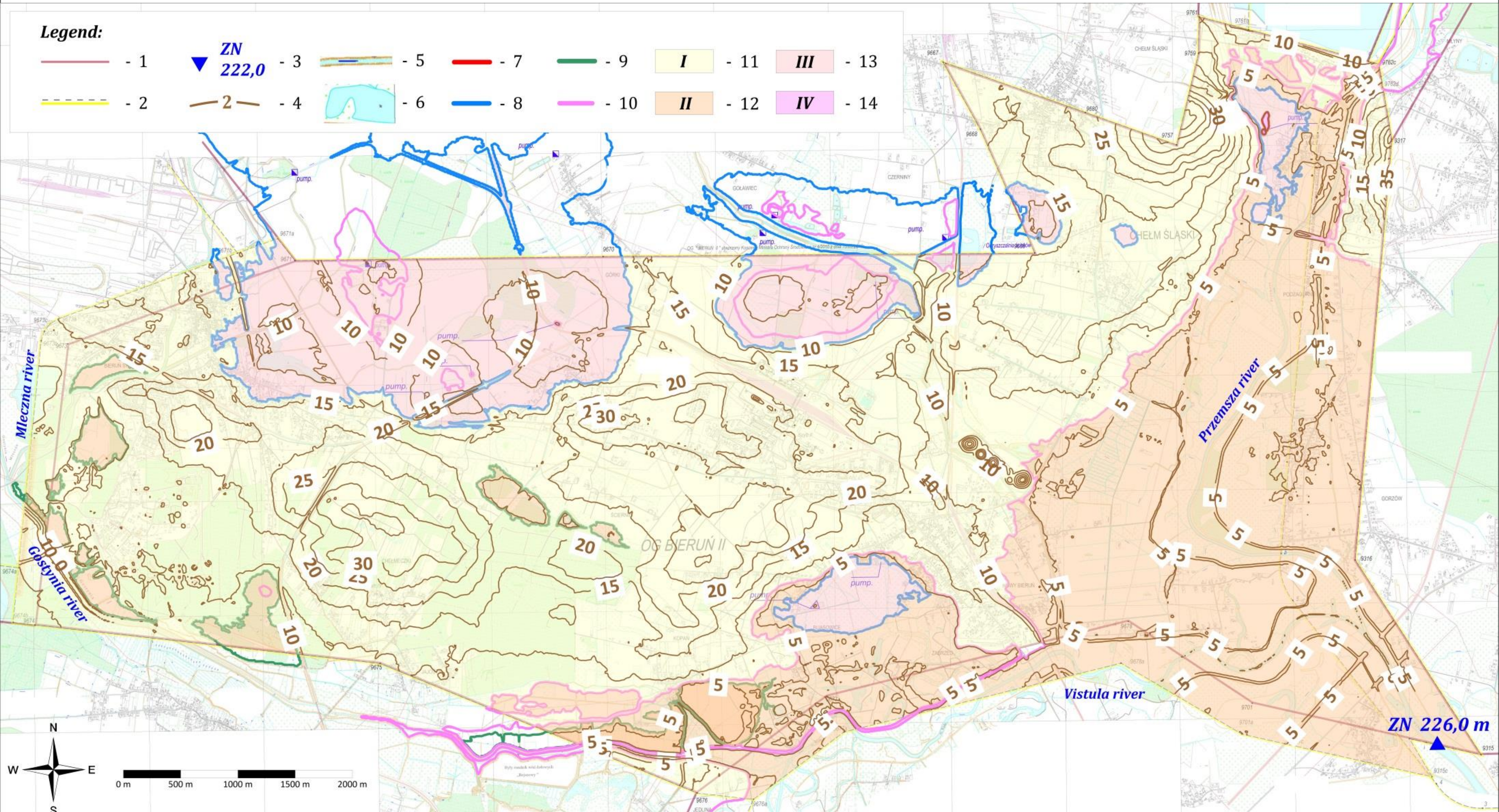




RELATIVE ELEVATIONS OF THE MSA SURFACE IN THE CATCHMENT AREA OF THE VISTULA RIVER AND NEARBY TRIBUTARIES

THE SIZE OF THE BIGGEST POTENTIAL RESERVOIRS AND TYPES OF STRUCTURES THREATENED BY FLOODING





SPATIAL HYDROMORPHOLOGICAL MAP OF THE MSA SURFACE IN THE CATCHMENT AREA OF THE VISTULA RIVER AND NEARBY TRIBUTARIES

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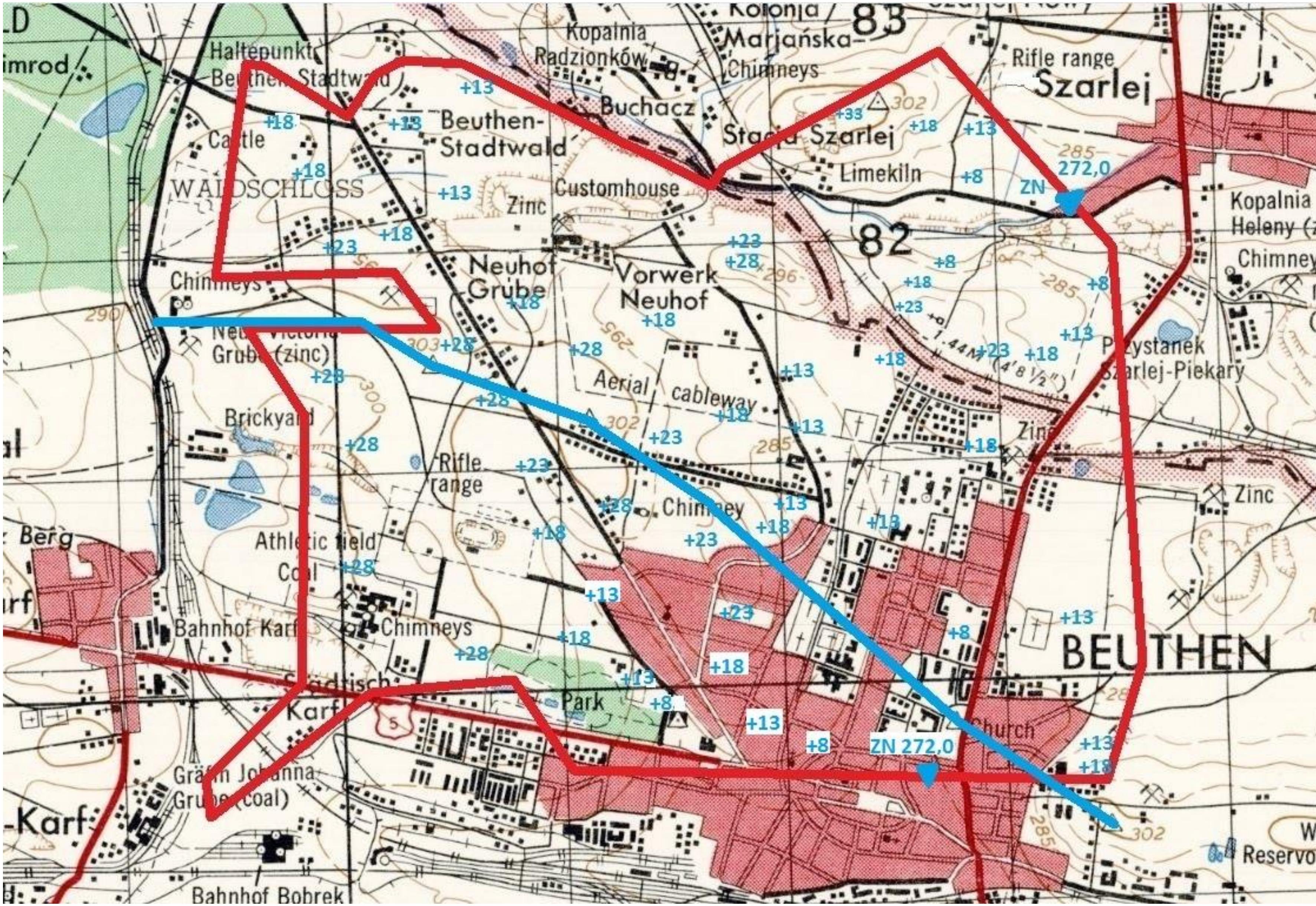
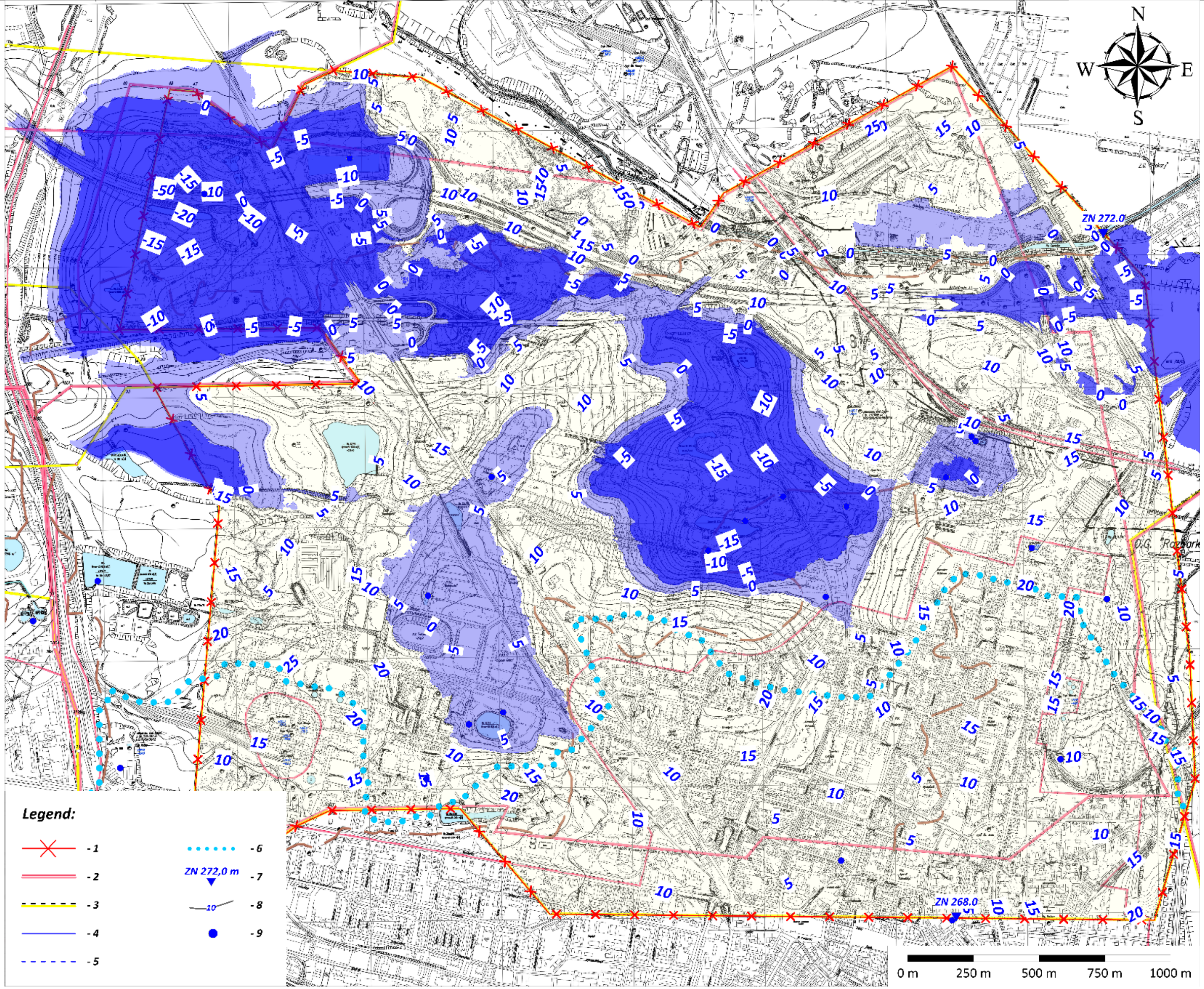


RELATIVE ELEVATIONS OF THE MINE SUBSIDENCE AREA WITHIN THE BYTOM (BEUTHEN) URBAN CONURBATION - STATE IN 1939.



RELATIVE ELEVATIONS OF THE MSA AND THE BOUNDARIES OF CLOSED BASIN LAKES AND POTENTIAL BACKWATER WITHIN THE BYTOM (BEUTHEN) URBAN CONURBATION STATE IN 2020.

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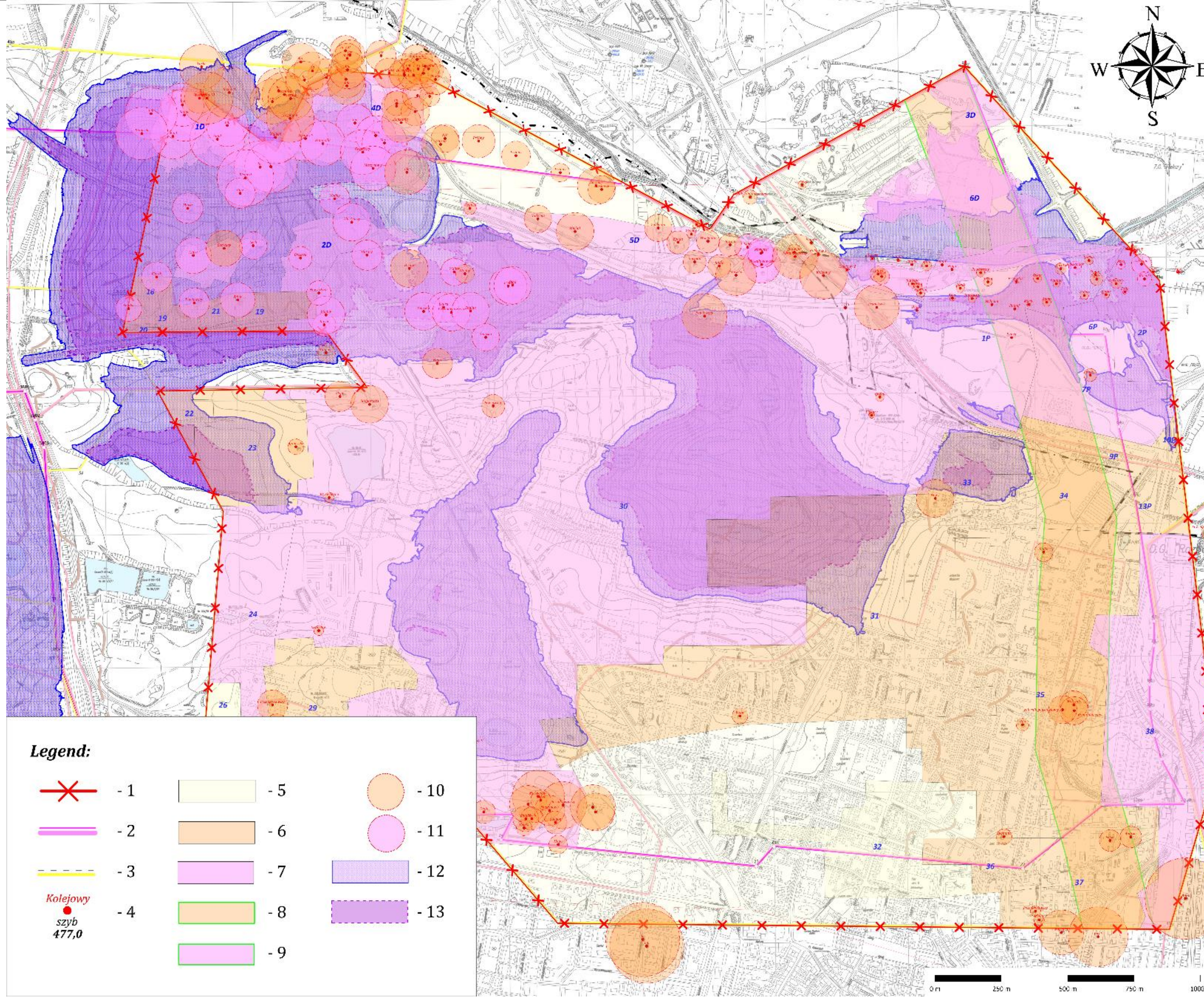

MAP OF THE DEVELOPMENT SUITABIILITY OF LAND WITHIN THE BYTOM (BEUTHEN) URBAN CONURBATION STATE OF 2020.

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SUMMARY

1) The introduction of *hydrometric reference points* allows for special mapping of the mine subsidence area by describing its surface with *relative elevations* above the *hydrometric reference point*. This method is fundamental for assessing the threat of flooding in artificially-drained mining and post-mining areas.

2) The *relative elevation* of the mine subsidence area surface better describes the possibility of natural drainage of its surface than the absolute elevation above the sea level method used until now.

3) Elements of this method can and should be a significant aspects of environmental policy and water management as well as spatial development for water management governing bodies, environmental managers, local government and state authorities responsible for issuing mining concessions, as well as for mining supervisory authorities and commercial mining entities.

THANK YOU FOR YOUR ATTENTION.

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