PROLINE-CE
WORKPACKAGE T2, ACTIVITY T2.2

IMPLEMENTATION OF BEST PRACTICES FOR WATER PROTECTION IN PILOT ACTIONS

D.T2.2.2 PARTNER-SPECIFIC PILOT ACTION DOCUMENTATIONS

PILOT ACTION: PA2.2 Kozłowa Góra

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1. Introduction

Best management practices (hereinafter BMPs) for drinking water protection and management derived from T1 were reviewed and relevant BMPs were selected for particular pilot action. Implementation status of BMPs was verified in Pilot Actions (T2); in case of lacks identified, possibilities of improvement and implementation were also assessed. Drinking water protection and management and best practices are strategically implemented in the pilot actions, in order to achieve a function-oriented land-use based spatial management for water protection at the operational level. Measures and actions were analysed and proposed concerning mitigation of extremes and achieving a sustainable drinking water level. PROLINE-CE pilot actions reflect the broad range of possible conflicts regarding drinking water protection, such as: forest ecosystem service function; land-use planning conflicts; flooding issues; impact of climate change and land-use changes; demonstration of effectiveness of measures including ecosystem services and economic efficiency.

Review of main land use conflicts and BMPs on Pilot Action level has already been done in Pilot Action BMPs reports, which were a basis for *D.T2.1.2 Transnational case review of best management practices in pilot actions*. Description of natural characteristics of Pilot Site is presented in *D.T.1.4 Descriptive documentation of pilot actions and related issues*.

Activities within Pilot Action were done according to set-up which was described in *D.T2.1.5 Set-up report about adaptation of the transnational concept to pilot action level*.

The Deliverable *D.T2.2.2 Partner-specific pilot action documentations* presents final Pilot Action report regarding the management actions examined in the Pilot Action, description of conducted activities and identified solutions for case-specific adaptations of management concepts. This report presents final work report regarding the implementation of best management practices for drinking water protection in pilot action PA2.2 Kozłowa Góra.

2. Testing of BMPs in Pilot Action

2.1. Objective(s) of Pilot Action

Within a year in Kozłowa Góra reservoir water quality parameters changing is observed. Preliminary results of field and laboratory investigations indicate that pollution loads, supplied mainly through inlets, cause yearly phytoplankton bloom.

In summer season, especially in June, sometimes July, algal bloom, causing decrease in quality parameters, is reported. This condition entails difficulties in water treatment and clogging of filters by diatoms and radiators, and, consequently, significant increase in treatment costs. For years the result has been closing the Water Treatment Plant until stabilization of parameters and algal bloom disappearance. The closure of water treatment technological line is associated with additional expenditure spends on f.e. filters perfusion to keep their cleansing capacity.

The motivation to select Kozłowa Góra reservoir as a Pilot Action area was to identify possible sources of pollution and prepare plan of preventive measures and practises implementation.

Main objectives of pilot action are:

1. Establishing multi-aspect water monitoring network
2. Setting up coupled models to predict water quality and provide flexible fitting of water treatment technology due to current raw water quality
3. Community meeting and workshop organization to raise awareness and increase their knowledge
4. Preparation of proposal of DWPZ on the Kozłowa Góra reservoir

2.2. BMPs of Pilot Action

▪ Identified GAP provoking action		
GAP short name	**Small scope of water monitoring**	
GAP short description	In the catchment area there is only one water gauge, on the Brynica River, where the measurements are carried on. There is lack of additional measurements spots, located on inlet streams what cause gap in information about discharge water amount or loads of pollution.	
▪ Best management Practice / Management Action		
Name of BMP	**Establishment of constant, multi-aspects water monitoring in the catchment scale**	
Type of land use regarded	Agriculture / partly forestry /	
Location	plain land (Brynica River sub-basin)	
BMP description	In the PA 2.2 Kozłowa Góra area there is a lack in surface water monitoring (only one water gauge is located) there is a need to extend the surface water monitoring network for wider information about water quality and water discharge value concerns all tributaries to Brynica River.	
Advantages of this BMP in PA	• Complex information of surface water discharge and water quality • Data can be used as base for estimation of pollution loads to the drinking water reservoir. • Information will be used as model input and model calibration data.	
Challenges of this BMP in PA	Make the BMPs obligatory to implement and conducting in the future.	
Relevance	Water protection functionality	high
	Cost of the measure	Medium / high
	Duration of implementation	long
	Time interval of sustainability	long
Limitations		
Implementation of the BMP in PA		
Comments		
References / sources		

▪ Identified GAP provoking action		
GAP short name	**No DWPZ established**	
GAP short description	Kozłowa Góra reservoir is a drinking water source for the Upper Silesia region which has no Drinking Water Protection Zone established.	
▪ Best management Practice / Management Action		
Name of BMP	**Proposal of DPWPZ establishment**	
Type of land use regarded	Agriculture / partly forestry /	
Location	Area of Kozłowa Góra reservoir	
BMP description	Proposal of establishment of DWPZ in the area of Kozłowa Góra reservoir. The proposal assumed the limitation in land use and land management in the area of established zone.	
Advantages of this BMP in PA	Establishing limitation in land use will lead to decrease in pollution loads to water environment and, thus, improve reservoir water quality.	
Challenges of this BMP in PA	Main challenge will be raising awareness of the society since human activities is a main factor for water contamination.	
Relevance	Water protection functionality	High
	Cost of the measure	Medium
	Duration of implementation	Long
	Time interval of sustainability	Long
Limitations	Possible long-lasting administration procedure after application.	
Implementation of the BMP in PA	Implementation in the project lifetime based on raising awareness by discussion panels with residents, educational campaign. In near future the document will be applied for implementation at water management authority level.	
Comments		
References / sources		

▪ **Identified GAP provoking action**		
GAP short name	**No complex evaluation of water hazards**	
GAP short description	There are no methods for complex water hazard evaluation in the area of Kozłowa Góra reservoir catchment.	
▪ **Best management Practice / Management Action**		
Name of BMP	**Complex catchment modelling**	
Type of land use regarded	Agriculture / forestry / urban	
Location	Brynica River sub-basin	
BMP description	Catchment modelling, using Soil Water Assessment Tool, will provide complex information about possible water quality and quantity threats and make prediction of water quality through scenario's simulations included i.e. CC, waste water discharges, using more fertilizers and so on.	
Advantages of this BMP in PA	Complex information about water resources, quick reaction on possible impact.	
Challenges of this BMP in PA	Good quality input data	
Relevance	Water protection functionality	High
	Cost of the measure	Medium (depending on input data)
	Duration of implementation	Medium
	Time interval of sustainability	
Limitations	Low quality of input data – little possibility to calibrate model results	
Implementation of the BMP in PA	SWAT model of Brynica catchment is prepared to simulate possible scenarios and quality water prediction.	
Comments		
References / sources		

▪ Identified GAP provoking action		
GAP short name	**No information about ecology of water reservoir**	
GAP short description	There is a lack in information about ecology of water reservoir Kozłowa Góra concerning whole ecosystem and possibility of the reservoir to i.e. self-cleaning.	
▪ Best management Practice / Management Action		
Name of BMP	**Establishment of an ecology model of water reservoir**	
Type of land use regarded	Agriculture / forestry / urban	
Location	Kozłowa Góra reservoir	
BMP description	Establishment of ecology model of water reservoir gives a complex information on reservoir's ecosystem (including flora and fauna) and factors possibly have an influence on water quality and water quantity.	
Advantages of this BMP in PA	Complex information on water ecosystem.	
Challenges of this BMP in PA	Collecting good quality data.	
Relevance	Water protection functionality	High
	Cost of the measure	Medium (depending on input data)
	Duration of implementation	Medium
	Time interval of sustainability	
Limitations	Low quality data use to set up the model and to calibrate it	
Implementation of the BMP in PA	Building ecological model of Kozłowa Góra reservoir for better understanding processes in the reservoir's water.	
Comments		
References / sources		

▪ Identified GAP provoking action		
GAP short name	**Low level of ecological awareness of society**	
GAP short description	Actions, undertaken by the society, such as inappropriate water, wastewater and waste management, indicate a low level of ecological awareness within society.	
▪ Best management Practice / Management Action		
Name of BMP	**Raising awareness and increasing knowledge**	
Type of land use regarded	Agriculture / forestry / urban	
Location	Brynica River sub-basin	
BMP description	Set of society and stakeholders' meetings to raise awareness and increase their knowledge.	
Advantages of this BMP in PA	Direct contact with society to raise awareness and increase their knowledge.	
Challenges of this BMP in PA	Gathering and motivating the community for discussion and future actions.	
Relevance	Water protection functionality	High
	Cost of the measure	Low - medium
	Duration of implementation	Long term
	Time interval of sustainability	Long term
Limitations	Little public interest in the subject	
Implementation of the BMP in PA	Organisation of society discussion panels and stakeholders' workshop.	
Comments	Biggest challenge is to reach small, closed communities.	
References / sources		

3. Activities in the Pilot Action

Within Kozłowa Góra reservoir's catchment several activities were carried out. Most of them were conducted for testing BMPs.

3.1. Multi-scale water monitoring

Within PROLINE-CE lifetime multiscale water monitoring studies were conducted, which include surface water monitoring and groundwater monitoring concerns both qualitative and quantitative aspects. The monitoring results will be used as a validation data to coupled modelling.

3.1.1. Surface water monitoring

Two series of hydrometric measurements, in wet and dry season, were carried out at main tributaries and Brynica River in 10 measuring locations (Figure 1). The results show discharges of water flow at selected cross-section (Table 1).

Table 1. Measurement main results.

Station no.	Gauging station name	Q [$m^3 s^{-1}$]	
		15.11.2017	10.03.2018
1	Trzonia – Zendek	0.081	0.035
2	Czeczówka – mouth	0.182	0.054
3	Dopływ spod Żyglinka - mouth	0.031	0.009
4	Brynica – gauging station	1.09	0.310
5	Brynica – downstream from the water treatment plant discharge	1.11	0.316
6	Potok Ożarowicki – mouth	0.189	0.103
7	Brynica – Niezdara, upstream from the mouth to Kozłowa Góra reservoir	1.47	0.519
8	Dopływ spod Nakła – mouth to Kozłowa Góra reservoir	0.165	0.066
9	Dopływ spod Siemoni – mouth to Kozłowa Góra reservoir	0.084	0.064
10	Wymysłów tributary (no name) – mouth to Kozłowa Góra reservoir	0.004	0.001

Two series of physicochemical and biological sampling of surface water, 6 located on main tributaries of Brynica and Brynica itself (**Error! Reference source not found.**) and 6 sampling site within reservoir, were conducted (

Figure 3). Wide range of tested parameters allows to execute an ecological and chemical status classification.

According to assessment of ecological status and chemical status, based on two monitoring series, the status of tributaries should be described as weak.

The chemical state of the JCWP of the Kozłowa Góra Reservoir should be described as good, taking into account the fact that it is a strongly changed type of water (abiotic type "0"). Nevertheless, concentrations of nitrogen and phosphorus compounds indicate a high potential of the reservoir for phytoplanktonic blooms.

The significant tributaries’ impact on the Kozłowa Góra reservoir’s quality, which are characterized by different (often worse) water parameters in relation to the reservoir waters. In this context, particular attention should be paid to water quality parameters in the Brynica River (eg point 6, the Potok Ożarowicki). Buffer capacity of the reservoir and the use of nutrients by phytoplankton affect a significant reduction in concentrations of all forms of nitrogen in relation to the water from the Brynica River.

Also, complex investigation of physicochemical status of reservoir water were carried out. In 300 points, located in a grid 250 m x 250 m within reservoir, using multiparametric combined probe Hydrolab MS 5, physicochemical data were collected (Figure 4). The data were an input to Kriging model which shows spatial variation of particular parameters in reservoir water. Measurements shows that f.e. nitrate pollution plum is loaded to Kozłowa Góra reservoir through main tributary – Brynica river (Figure 5).

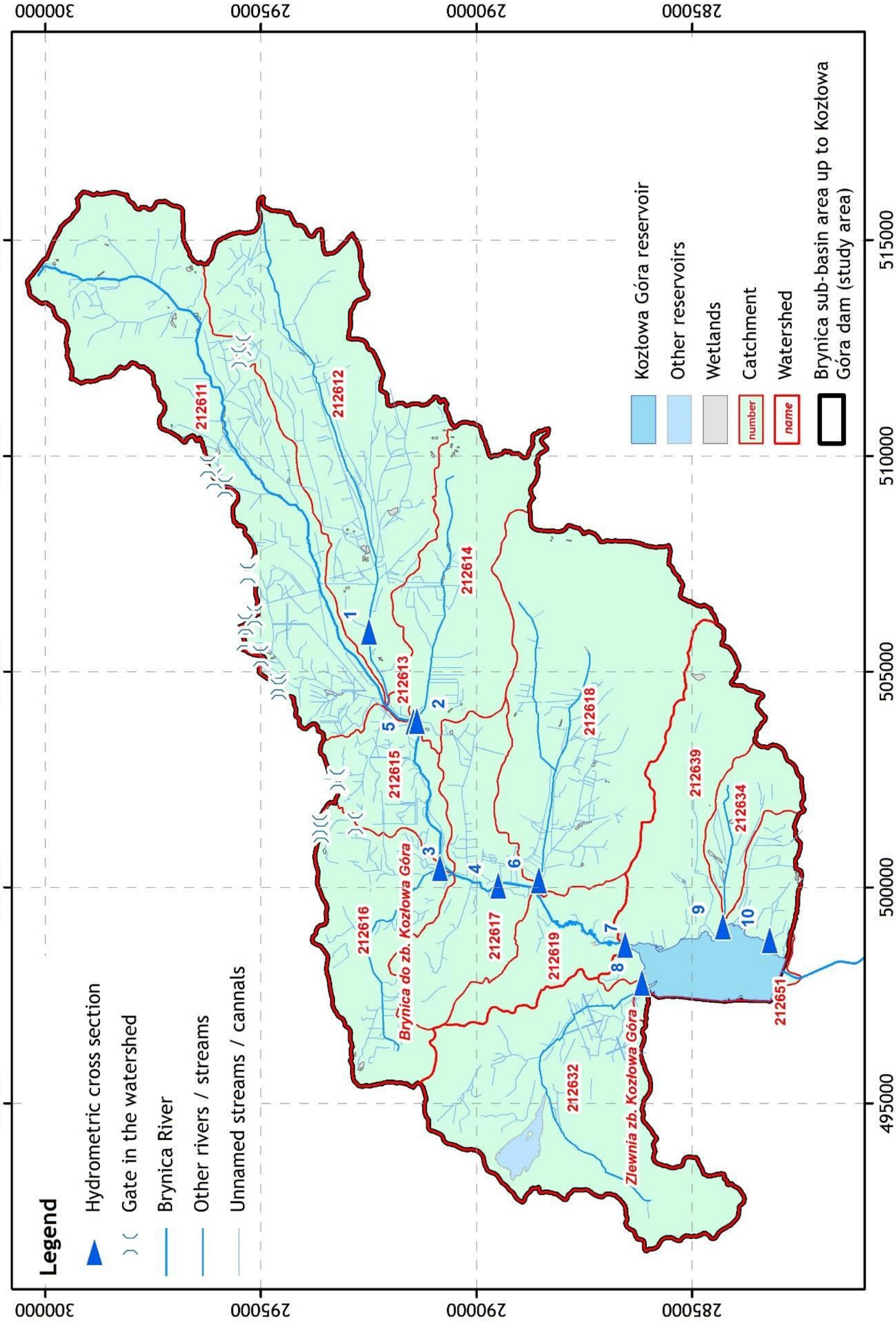

Figure 1: Location of hydrometric cross section.

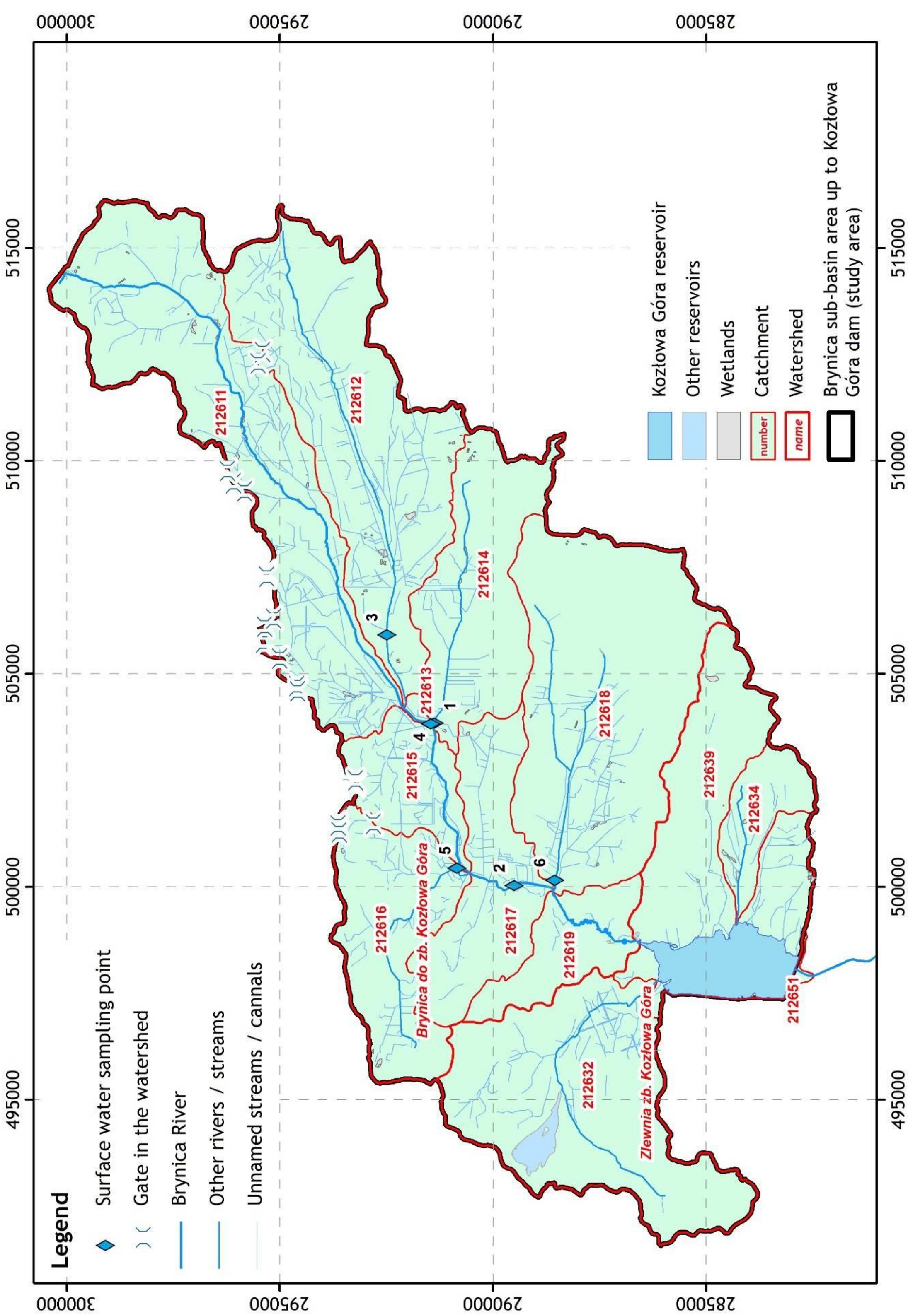

Figure 2: Location of measuring and control points.

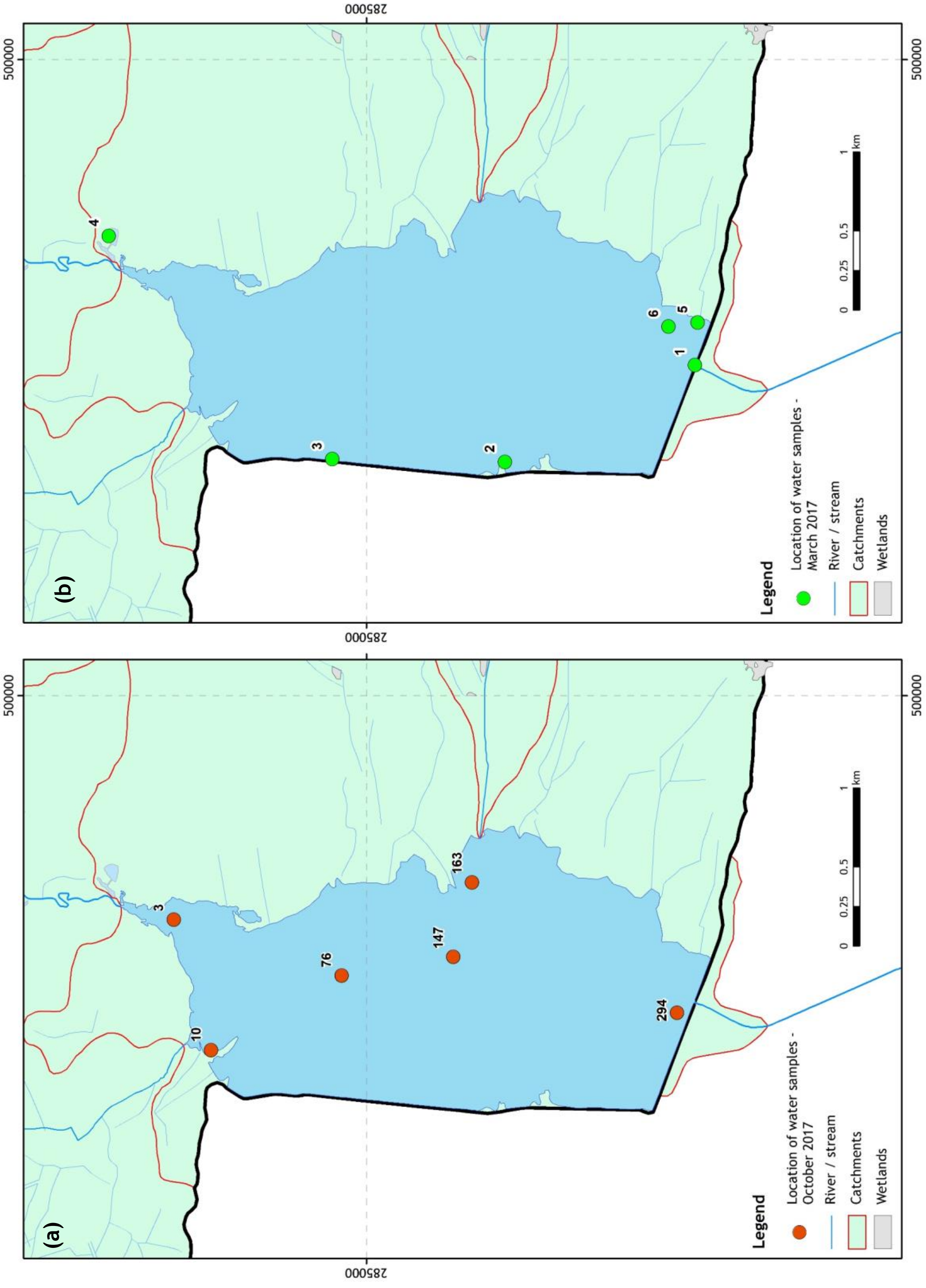

Figure 3: Location of sampling points in the Kozłowa Góra reservoir: fall serie (a), spring serie (b).

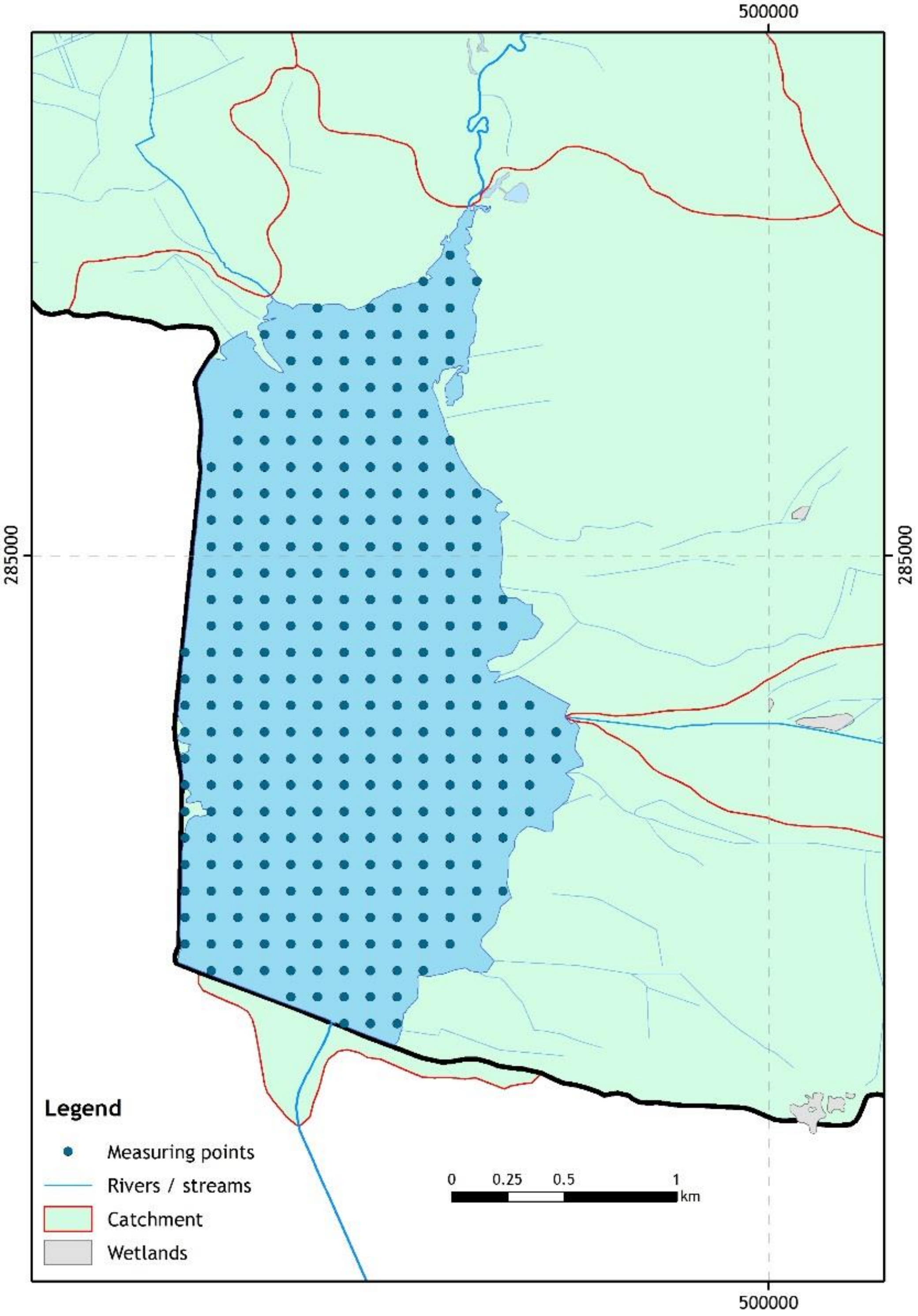

Figure 4: Location of measuring points in a grid 250 m x 250 m, of the Kozłowa Góra reservoir waters.

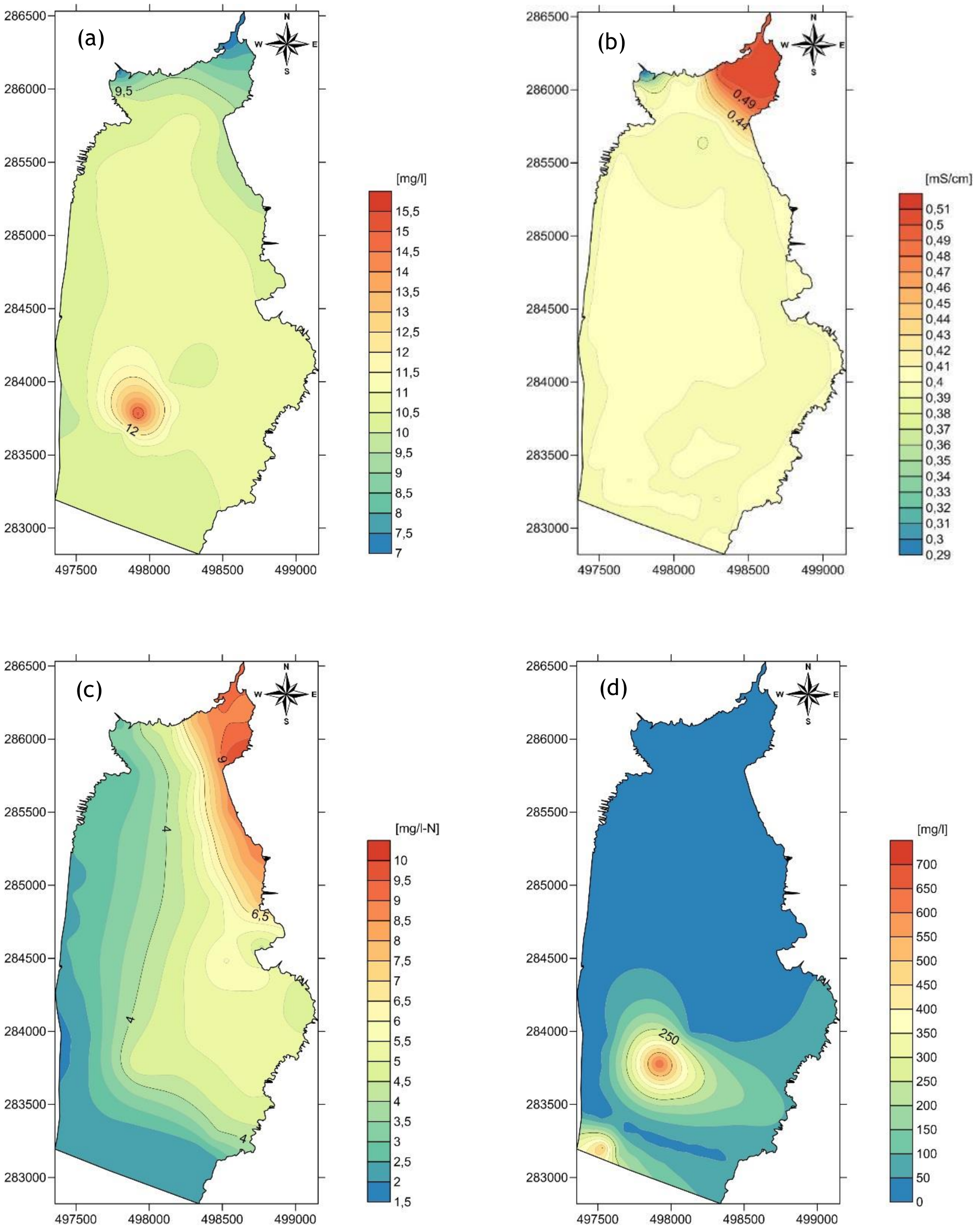

Figure 5: Physicochemical properties of water in the Kozłowa Góra reservoir based on Hydrolab MS 5 probe measurements – 13 October 2017 (a) DO, (b) EC, (c) nitrates, (d) chlorides.

3.1.2. Groundwater monitoring

Four series of groundwater level measurements were conducted in 227 household wells. Based on the results groundwater table contour map was developed (

Figure 6). The results indicate Brynica river as a groundwater drainage base.

In selected 24 also qualitative monitoring was carried out in wide range of parameters included Temperature, EC, pH and 35 chemical parameters, such as organic and mineral nitrogen compounds, main ions, heavy metals and TOC. Assessment of the chemical status of groundwater was conducted. The analysis shows that in 14 out of 24 wells groundwater is poor chemical status (

Figure 7). Main cause for poor chemical status of groundwater are increased concentration of nitrogen compounds, phosphates, potassium and sulphates – main indicators for agricultural source of pollution.

According to Szczukariew – Prikłoński classification examined groundwaters belong to very diverse chemical types, from two-ionic (HCO_3-Ca) to six-ionic (eg. HCO_3-SO_4-NO_3-Cl-Ca-K and HCO_3-SO_4-NO_3-Ca-Mg-Na). Almost all testes wells are characterized by dominant concentration of hydrocarbons ion but one, where sulphate ion dominates (Figure 8).

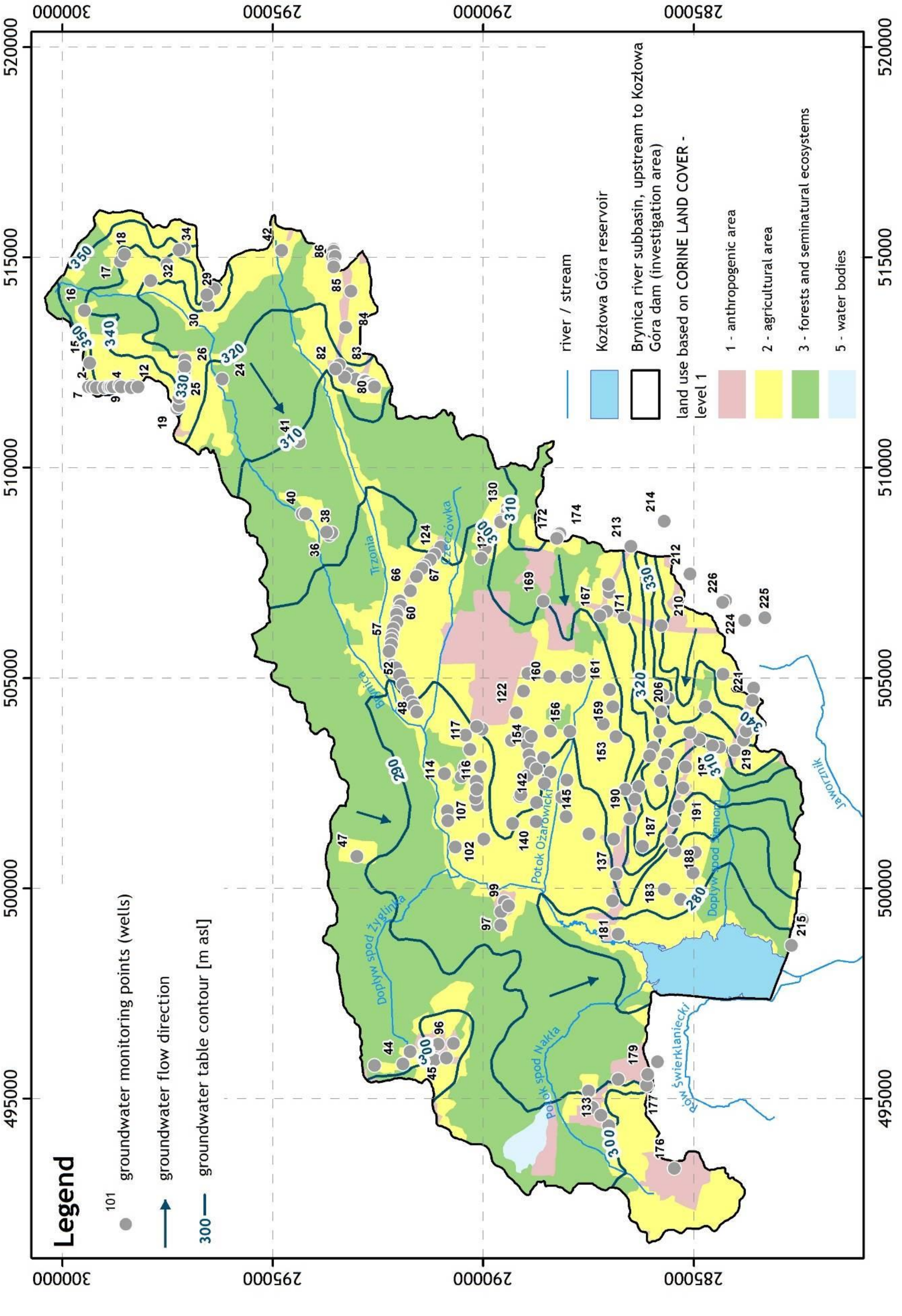

Figure 6: Groundwater contour map.

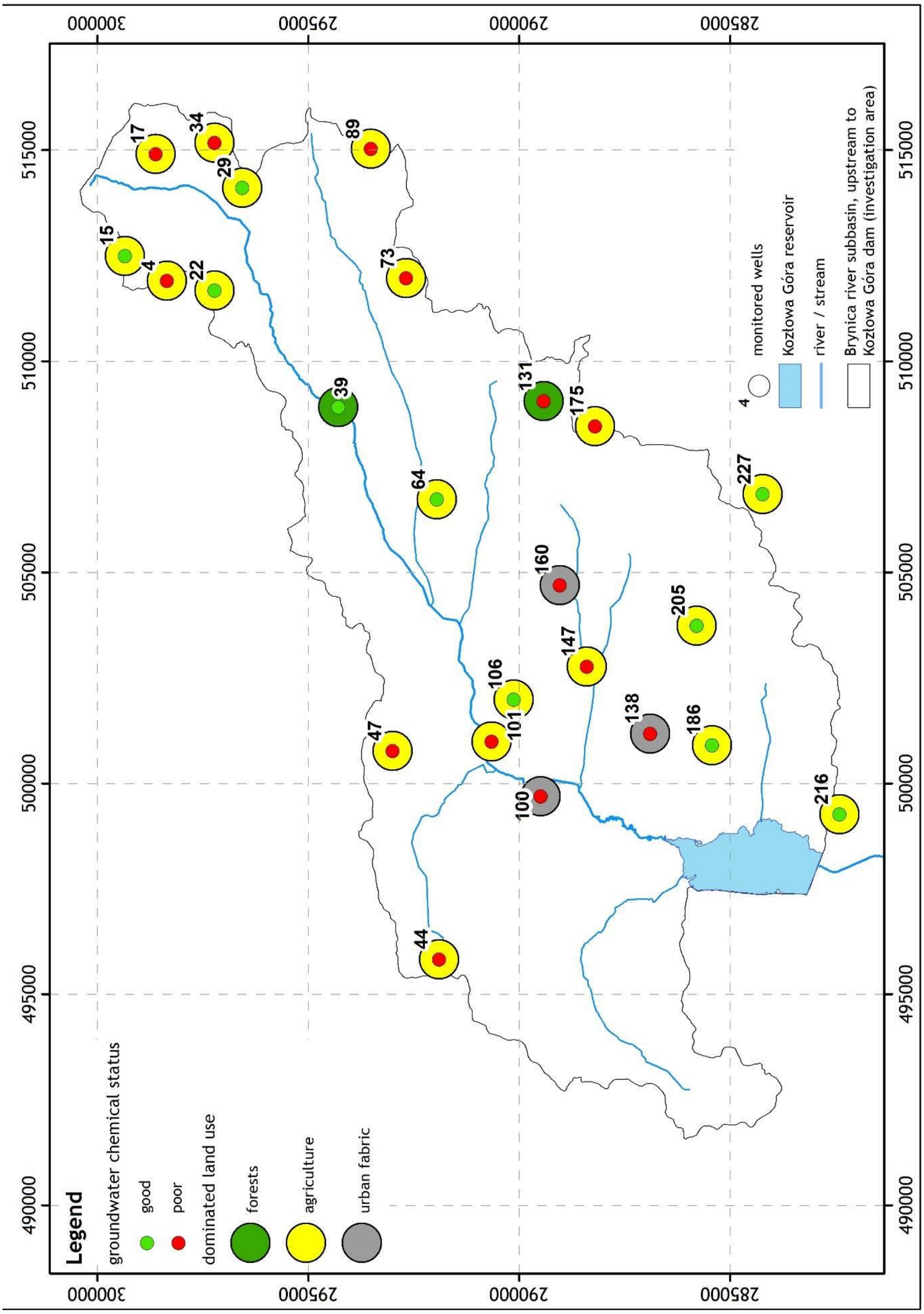

Figure 7: Groundwater chemical status.

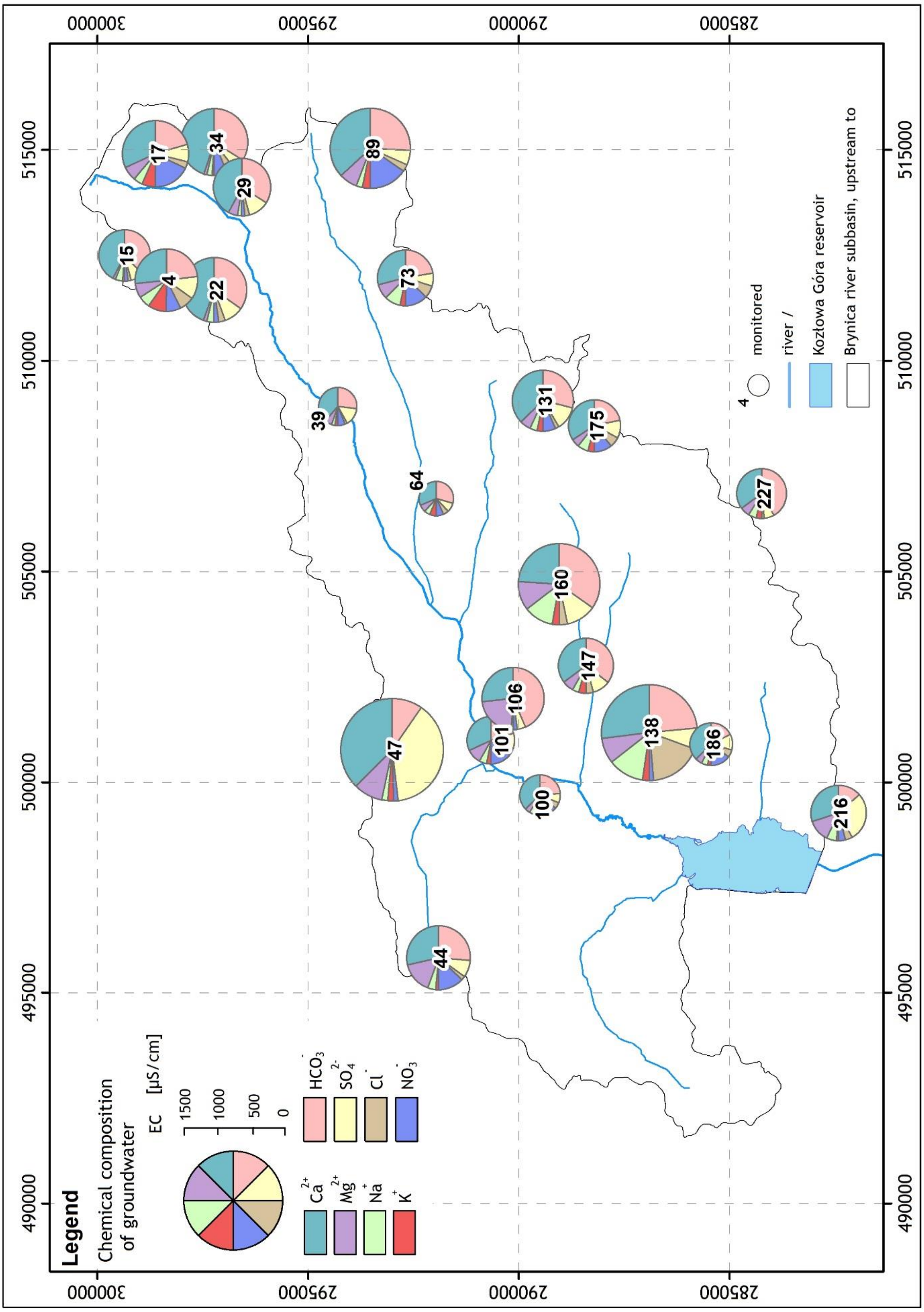

Figure 8: Groundwater chemical composition of sampled wells – Udluft pie chart, November 2017.

3.2. Identification of potential sources of pollution

Within activities conducted on Kozłowa Góra PA verification of potential sources of water pollution based on data in selected wells and in surface water sampling points was done. Also, identification of pollution origin, using sulphur and oxygen isotopes in sulphates, was performed in several sampling points (Figure 10). The study shows that main sulphates source of pollution for water environment is sewage (manure commonly use as natural fertilizer), mixed origin (various sources i.e. agricultural fertilizers, municipal sewage, atmospheric precipitation or soil sulphur) and natural origin of sulphates in water (most likely from atmospheric precipitation or dry deposition)

Figure 9, Figure 10).

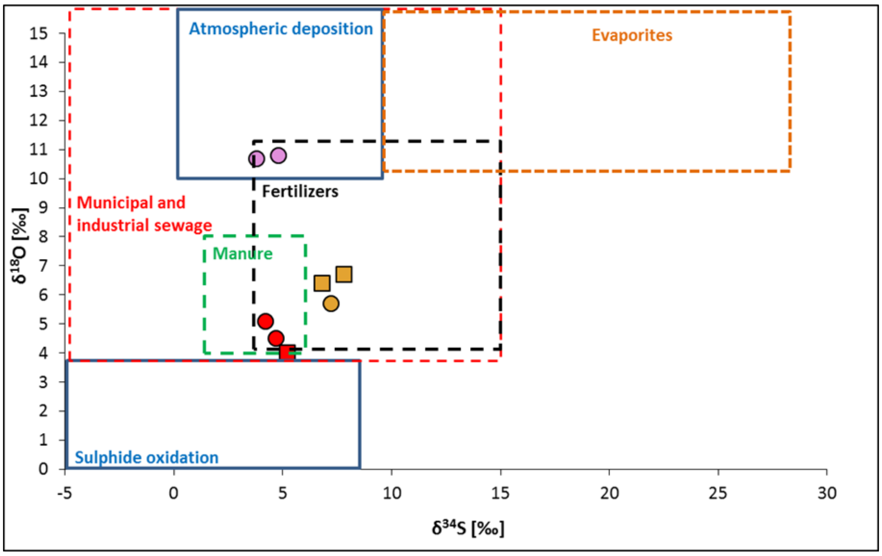

Figure 9: The isotopic composition of sulphates in groundwater and surface water and ranges characteristic for typical sulphate sources. The shape and colour of points refer to the symbols used on the map with the location of sampling points (Figure 10).

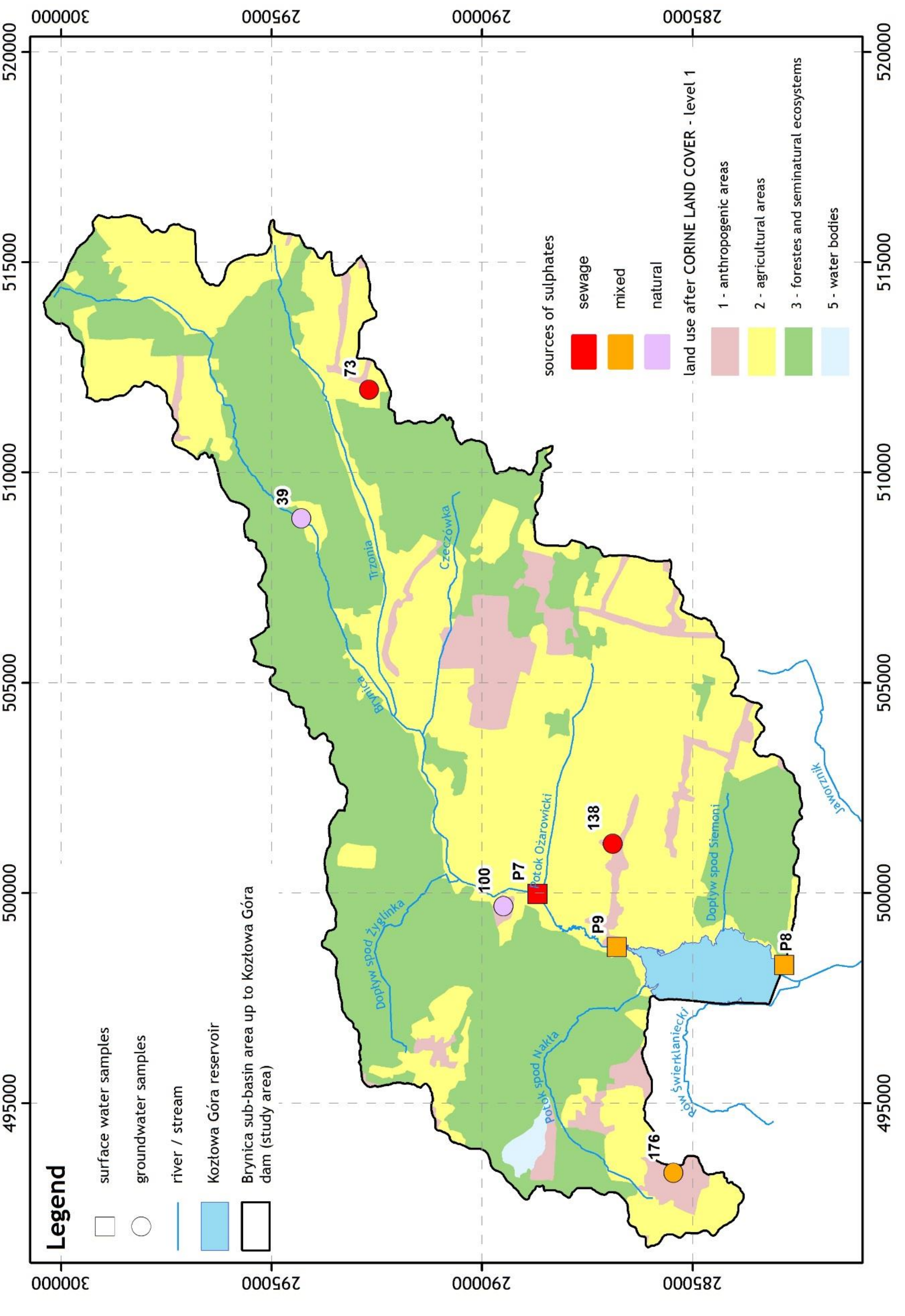

Figure 10: Location of water samples taken for isotopic analysis.

3.3. Proposal of DWPZ

Since there was no DWPZ established in the area of Kozłowa Góra reservoir within the project a proposal for DWPZ (direct and indirect) borders and limitation in the possible area of Drinking Water Protection Zone was performed. The proposal contains analysis of currently conducting fishery management with cause and effect assessment of an impact of the fish species and its catches on reservoir status.

In order to maximize protection of the drinking water resources and ensure the appropriate quality of source water from the Kozłowa Góra intake in Wymysłów, prohibitions and restrictions on the use of water and the area within planed primary and secondary protection zone were included in the proposal.

3.4. Analysis of water treatment plan efficiency

Based on water treatment plan (herein after WTP) water quality data, efficiency analysis of the treatment process was done. Results of laboratory testing in treated water samples, after each state of water treatment process were taking into account. Water treatment process includes seven stages as follows (in parenthesis colour of points on water quality graph (Figures 11-15) are quoted):

1. Water intake – raw water (green color)
2. WTP Kozłowa Góra - raw water, pomped to preozonation chambers (dark green color)
3. WTP Kozłowa Góra – water, after preozonation (light purple color)
4. WTP Kozłowa Góra – filtrated water, after rapid filtration process (brown color)
5. WTP Kozłowa Góra –water, after intermediate ozonation (dark Purple color)
6. WTP Kozłowa Góra – filtrated water, after GAC filtration (black color)
7. WTP Kozłowa Góra – treated water, injected to water supplying system (blue color)

After each stage of the process measurements/analyses of following selected parameters were performed: color (Figure 11), TOC (Figure 12), NH4 (Figure 13), total number of microorganisms (Figure 14) and total number of microorganisms (Figure 15).

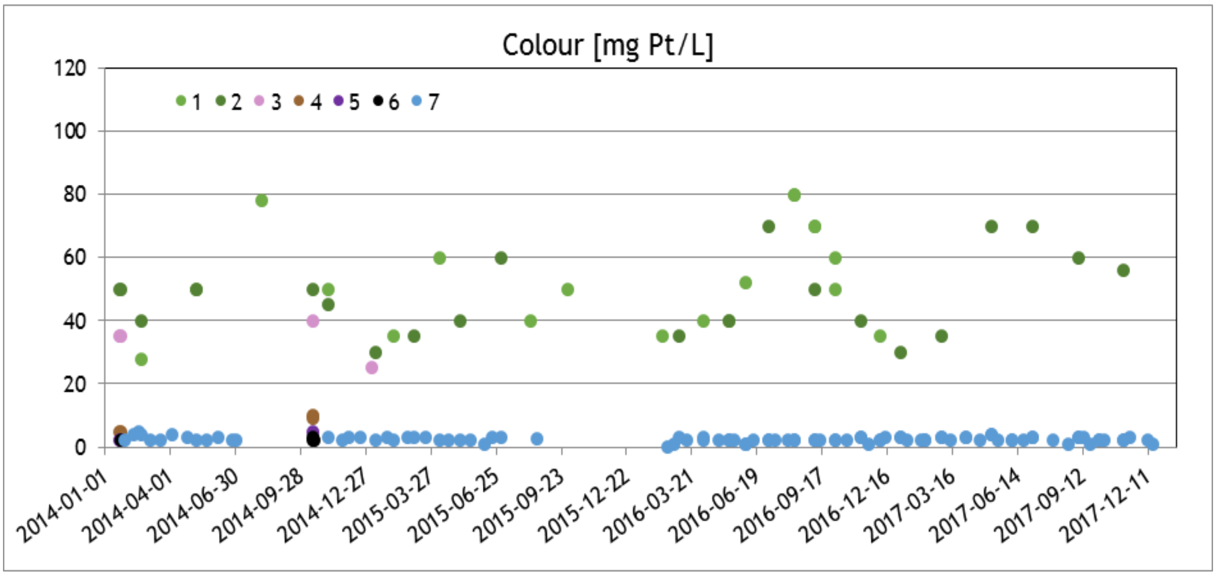

Figure 11: Variability of the water colour value at particular stages of treatment process.

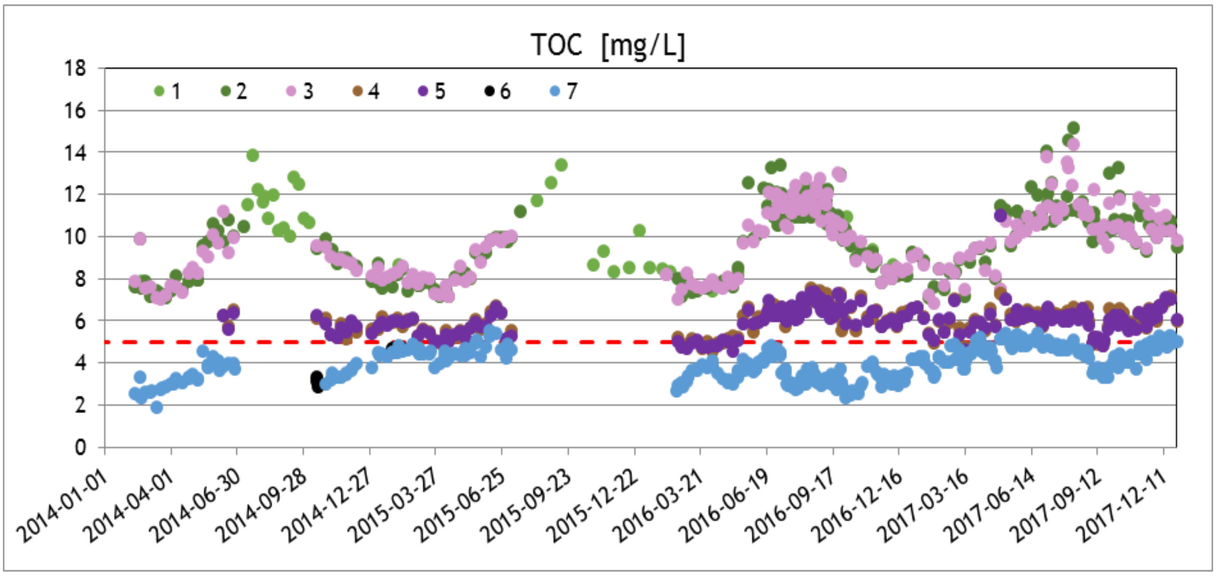

Figure 12: Variability of the TOC value at particular stages of treatment process.

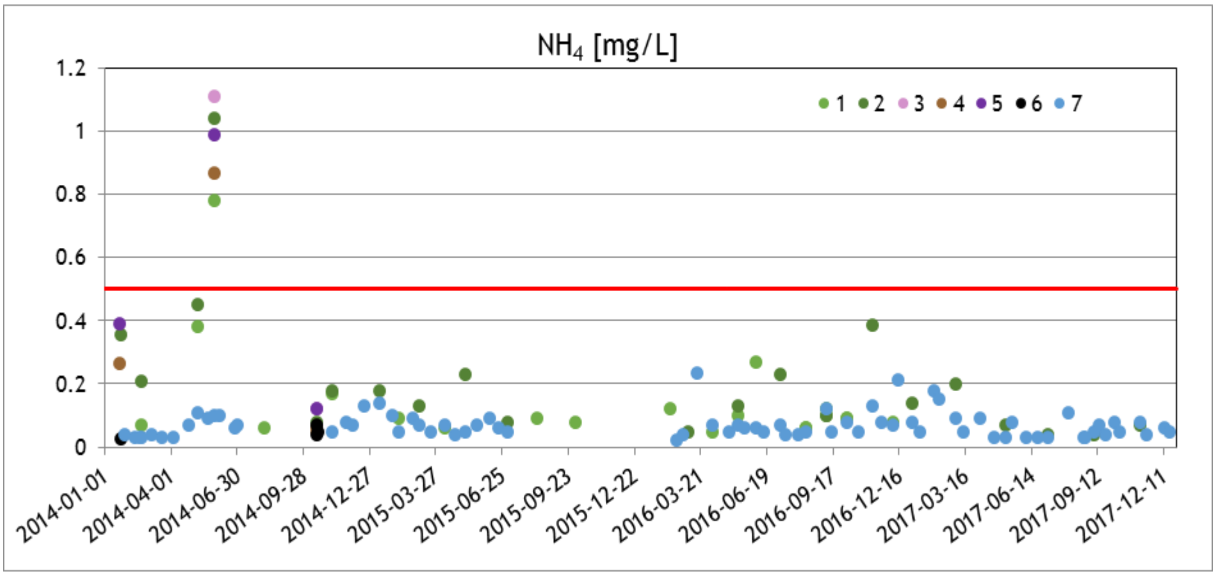

Figure 13: Variability of the ammonia concentration at particular stages of treatment process.

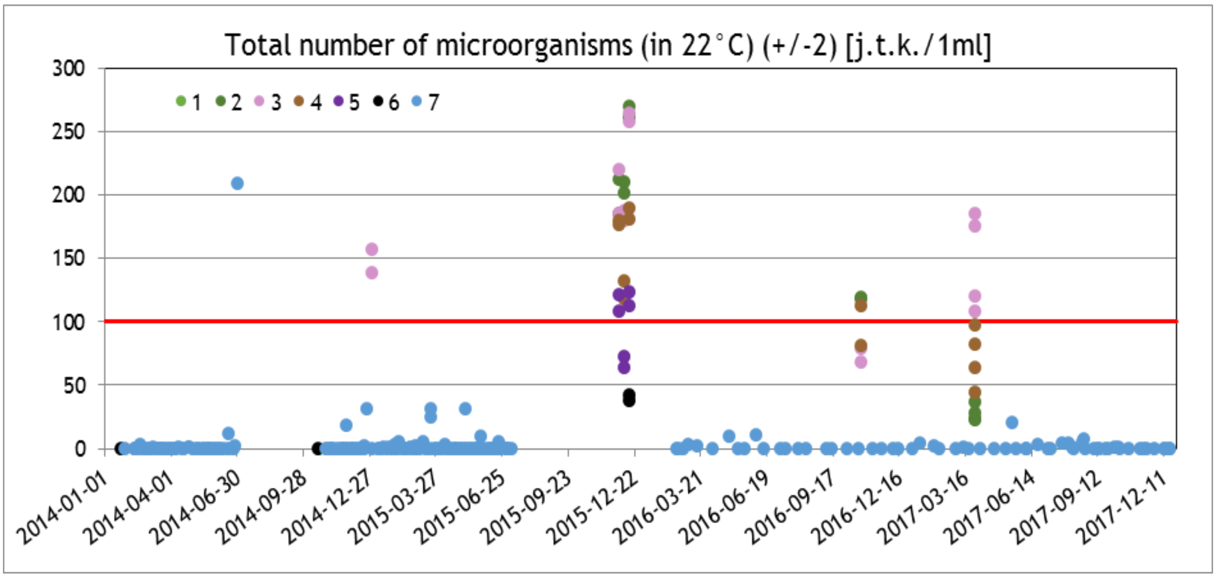

Figure 14: Variability of the total number of microorganisms (in 36°C) at particular stages of treatment process.

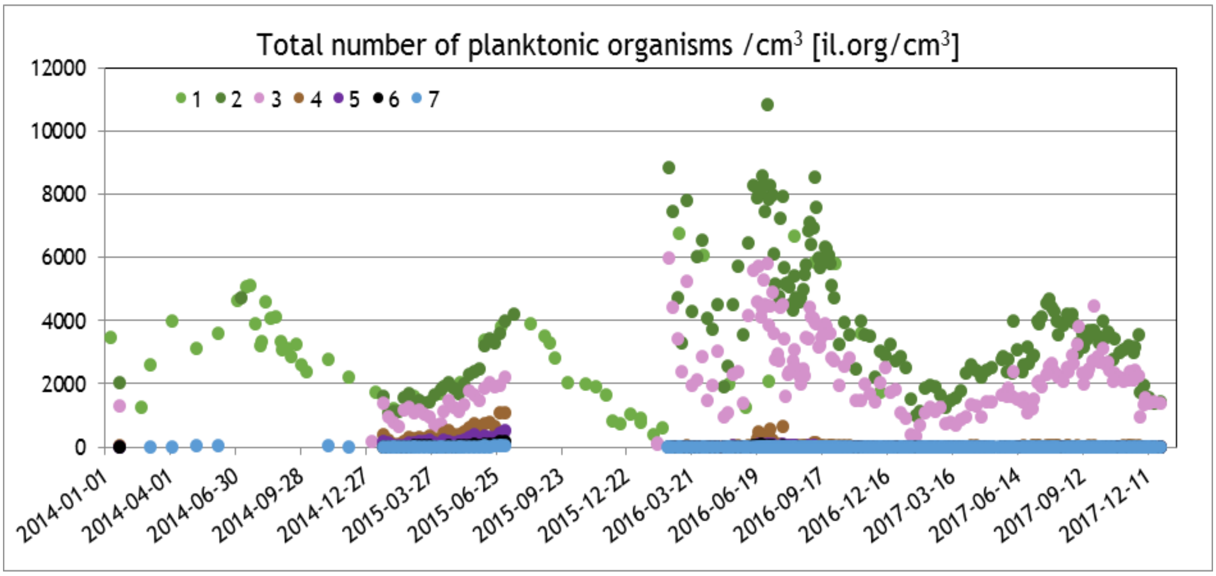

Figure 15: Variability of the total number of planktonic organisms at particular stages of treatment process.

3.5. Catchment modelling

Based on available data and data collected during field investigations campaigns watershed model were set up. Model were build using ArcSWAT application with time interval up to 1 month. Model allows for simulations of surface water discharge to reservoir, including estimation of nutrients loads, and take into account an impact of, both, natural (such as precipitation, slope and land surface roughness) and human (waste water discharges, fertilizers) on water quality. Also, total water budget, including atmospheric, surface and groundwater (percolation) was estimated. Model is calibrated using field data, collected during monitoring campaign. Model description and results are presented in Chapter 4.1.

3.6. Ecology modelling

3D ecological model of water reservoir was established to simulate water discharge, nitrogen compounds concentration, both mineral and organic, phosphorous compounds (mineral and organic), biomass of phyto- and zooplankton and biomass of fish population. The used time interval did not exceed 1 day.

Ecological model is integrated with watershed model, what means that it takes results of the watershed model and use it as an input to ecological simulations. Model is also calibrated using field data, collected during monitoring campaign.

Model description and results are presented in Chapter 4.2.

3.7. Stakeholders and society involvement

Within PA were several actions were undertaken such as discussion panel for society or conference communication which contained main assumption for PROLINE-CE project and presentation of BMPs, identified within preliminary stage of PA action, to raise awareness.

In early November 2017, in Wojanów, Poland, during Polish Symposium on Contemporary Problems of Hydrogeology (WPH), PROLINE-CE overview, PA Kozłowa Góra characterization and activities conducted were presented to stakeholders (Figure 16).

Figure 16: Ms. Joanna Czekaj (GPW) presents assumption of PROLINE-CE project on WPH Wojanów.

In December 2017 GPW invited residents of the Kozłowa Góra pilot action which is the Brynica river sub basin area, upstream Kozłowa Góra dam to discussion. Residents got familiar with PROLINE-CE project, its realization phase, activities conducted within Kozłowa Góra PA and BMP. There was also an opportunity for discussion and raising awareness of the society concerning human activities impact on water, especially drinking water, resources.

Figure 17: Ms. Joanna Czekaj (GPW) during her presentation concerning PROLINE-CE project and activities conducted within Kozłowa Góra PA.

Figure 18: Mr. Andrzej Siudy (GPW) during discussion.

During International Conference on Groundwater Vulnerability, held in Ustron, Poland, on 4-8 June 2018, representatives of GPW gave a speech *The Kozłowa Góra drinking water reservoir's catchment as a pilot area in a multi aspect survey in order to assess the impact of land use management and climate change on groundwater resources* presenting a.o. results of activities carried out within PA Kozłowa Góra (Figure 19).

Figure 19: Ms. Joanna Czekaj (GPW) during speech given on Groundwater Vulnerability Conference in Ustroń.

4. Modelling

4.1. Watershed modelling

Watershed modelling, using SWAT application, allows to perform simulation of

- surface water inflow to the reservoir,
- load of following substances /compounds:
  - organic nitrogen,
  - mineral nitrogen (including nitrates and ammonia)
  - organic phosphorus,
  - mineral phosphorus,
  - sediments (clay, silt and sand),
  - chlorophyll a,
- concentration of dissolved oxygen,
- water temperature,
- evapotranspiration,
- percolation,
- load of nitrates nitrogen to the shallow aquifer.

The model's time step is one day, however, part of outputs is presented in an aggregated form for months and years in order to ensure the clarity of presented data. A simulation period includes 11 years (2007-2017), however, data for 2012-2017 are generated by the model and presented in the report because first 6 years of simulation are used as a “warmup period”.

The model takes into account following factors:

- atmospheric conditions, i.e. precipitation, temperature, humidity, wind speed and solar radiation;
- impact of roughness and land slope on the surface runoff and consequently inflows to the reservoir;
- impact of fertilization, harvesting, point discharges of pollution, atmospheric deposition on surface water quality.

Part of the work was aimed at the sensitivity analyses of the model. The analyses provided an information about input variables which are most important for the simulation of:

- rate of inflows to the reservoir;
- concentration of following parameters at inflows to the reservoir:
  - nitrogen (nitrate, ammonia, organic),
  - mineral and organic phosphorus,
  - chlorophyll a,
  - dissolved oxygen,
  - sediments (clay, silt, sand).
- nitrate nitrogen in the recharge to the shallow aquifer;
- evapotranspiration;
- percolation;
- surface runoff.

Calibration and validation of the model were based on observations regarding:

- flow rate,
- concentrations of ammonia, nitrate and organic nitrogen,
- concentrations of organic and mineral phosphorus,
- concentration of chlorophyll a,
- concentration of suspended solids.

In addition to above-mentioned, the validation included also:

- concentration of dissolved oxygen,
- water temperature.

Output variables in the SWAT model are calculated for all time steps and for all subbasins (or subareas called HRU). The reservoir’s catchment area has been divided into 17 subbasins in the model. Subbasins are the main spatial units in the SWAT model. However, these subbasins include various types of land use, land morphology and soils. Therefore, in the model, each subbasin consists of areas called Hydrological Response Units (HRUs). HRUs are not interrelated spatially but related to the subbasin only. In the model of the reservoir’s catchment area there are 965 HRUs, which represent unique combination of following data in each subbasin (1) land use / land cover, (2) soil parameters and (3) land slope.

The model of catchment area simulates (after the calibration) suspended sediments’ concentrations close to the observed ones. The average 20 observed concentration is 11,43 mg/l and the simulated average of concentrations in respective locations and dates is 7,28 mg/l. Taking into account that calculated concentrations may be affected by error resulting from the simulation of flow rate, the observed concentrations were also compared to concentrations calculated for appropriate locations months instead of exact dates. In such case the simulated average concentration of suspended solids in 10,05 mg/l.

Simulated concentrations of nitrogen are not as accurate as in the case of suspended solids. Mode, despite the calibration, overestimates the concentration and load of nitrogen – especially the nitrate nitrogen. The average observed concentration of organic nitrogen is 0,80 mg/l, whereas, the calculated concentration is 0,90 mg/l. Calculated concentration of mineral nitrogen is however twice the observed value.

In case of phosphorus the model also overestimates the concentration, and similarly, the overestimation is related to the mineral form mainly. Calculated average monthly concentrations of organic P are half the observed ones, however, at the same time the load is 15% greater than observed. It means, that the error results from the calculated flowrate. The average calculated concentration of organic P in the entire simulation period is exactly the same as observed (0,37 mg/l).

Validation of the simulated concentration of chlorophyll a was based on 4 observations. The observed values were compared to the average simulated for the entire catchment only. The average load calculated basing on four observations is 0,2 kg/d whereas the simulated load for the entire catchment is 0,53.

Simulation of concentrations of dissolved oxygen resulted in outputs very close to observed values. The average of 20 measurements is 9,78 mg/l, and the simulated concentration for the same locations and dates is 10,28. Loads of oxygen are also close and are 204,8 and 231,6 kg/d for observations and the simulation respectively.

The more advanced validation was possible for the water temperature only. The validation was based on nearly 2 thousand observations and resulted in NSE coefficient equal to 0,33 and R2 = 0,90 even without calibration of model basing on the observed temperature. A simple statistical correction of outputs (out of the SWAT model) resulted in the same R2 and much greater NSE equal to 0,81.

Main outputs of the SWAT model are related to the water balance in a river basin. Average water, sediments and nutrients balance for the 2012-2017 period is presented in the table below.

Model enabled calculation of monthly water inflow to the reservoir as well as loads inflow.

Table 2: Average water, sediments and nutrients balance for the 2012-2017 period.

	Component	Value	Unit
Water balance in basin	Precipitation	845.8	mm
	Snowfall	103.89	mm
	Snowmelt	101.82	mm
	Sublimation	0.62	mm
	Shallow aquifer contribution to soil (evaporation)	141.88	mm
	Deep aquifer recharge	4.17	mm
	Total aquifer recharge	188.81	mm
	Percolation out of soil	140.36	mm
	Evapotranspiration	529.8	mm
Water balance in streams	Surface runoff to streams	164.87	mm
	Lateral flow from soil to streams	6.32	mm
	Shallow aquifer contribution to streams	4.14	mm
	Deep aquifer contribution to streams	3.77	mm
	Transmission losses	57.77	mm
	Total water yield to streams	120.53	mm
Sediment balance	Total sediment loading	0.53	t/ha
Nutrients balance	Organic N loading to stream	0.605	kg/ha
	Organic P loading to stream	0.119	kg/ha
	N-NO3 loading to stream in surface runoff	1.547	kg/ha
	N-NO3 loading to stream in lateral flow	0.078	kg/ha
	Soluble P loading to stream	0.217	kg/ha
	N-NO3 percolation past bottom of soil profile	5.303	kg/ha
	amount of P leached into second soil layer	0.055	kg/ha
	Plant uptake of N	57.264	kg/ha
	Plant uptake of P	12.035	kg/ha
	N fertilizer applied	19.757	kg/ha
	P fertilizer applied	1.083	kg/ha
	amount of N moving from active organic to nitrate pool	3.089	kg/ha
	amount of P moving from active organic to mineral pool	0.773	kg/ha
	amount of N moving from fresh organic (residue) to nitrate and active organic pools	43.196	kg/ha
	amount of P moving from fresh organic (residue) to labile and organic pools	9.544	kg/ha
	amount of NO3 added to soil by rainfall	2.867	kg/ha

	Component	Value	Unit
	N removed in yield	11.141	kg/ha
	P removed in yield	1.882	kg/ha
	Ammonia volatilization	1.644	kg/ha
	amount of N moving from the NH3 to the NO3 pool by nitrification	3.698	kg/ha

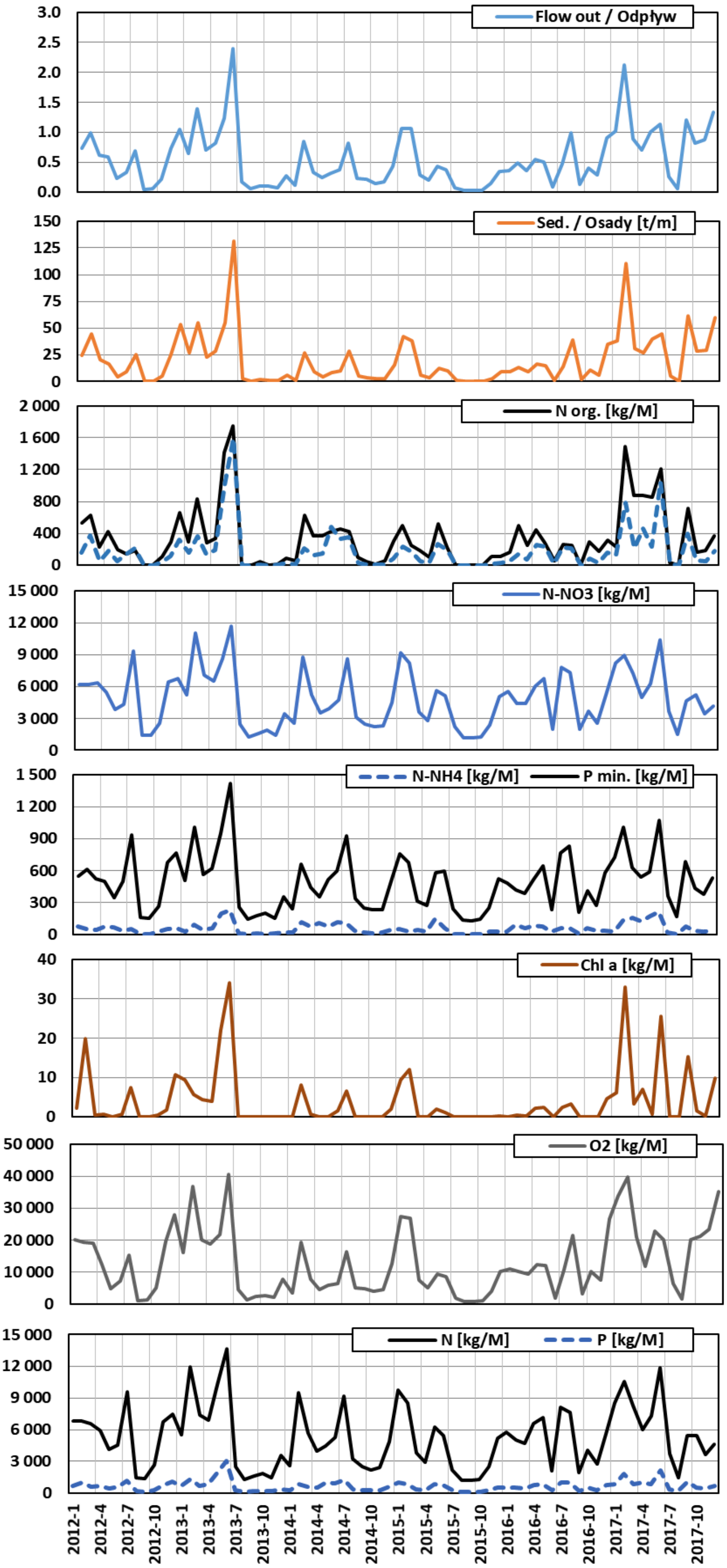

Figure 20: Monthly inflow to the reservoir and loads in the inflow (Brynica river) in years 2012-2017.

The spatial variations of output parameters are presented below with flowrate, evapotranspiration, percolation, surface runoff and load of organic nitrogen as examples (Figure 21 - Figure 25).

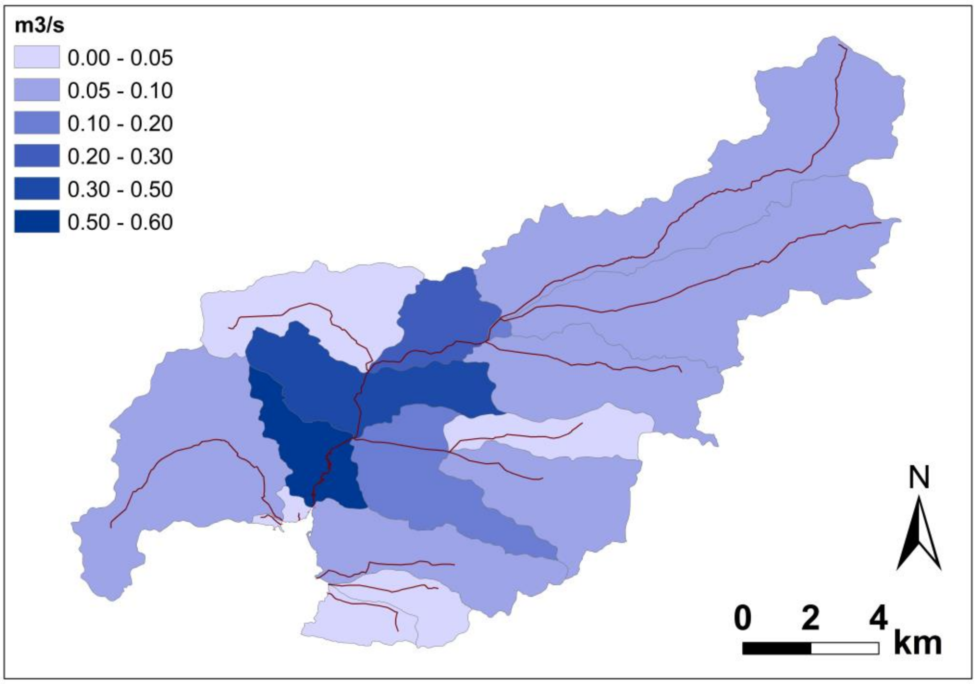

Figure 21: Spatial distribution of the average outflow from subbasins in the 2012-2017 period.

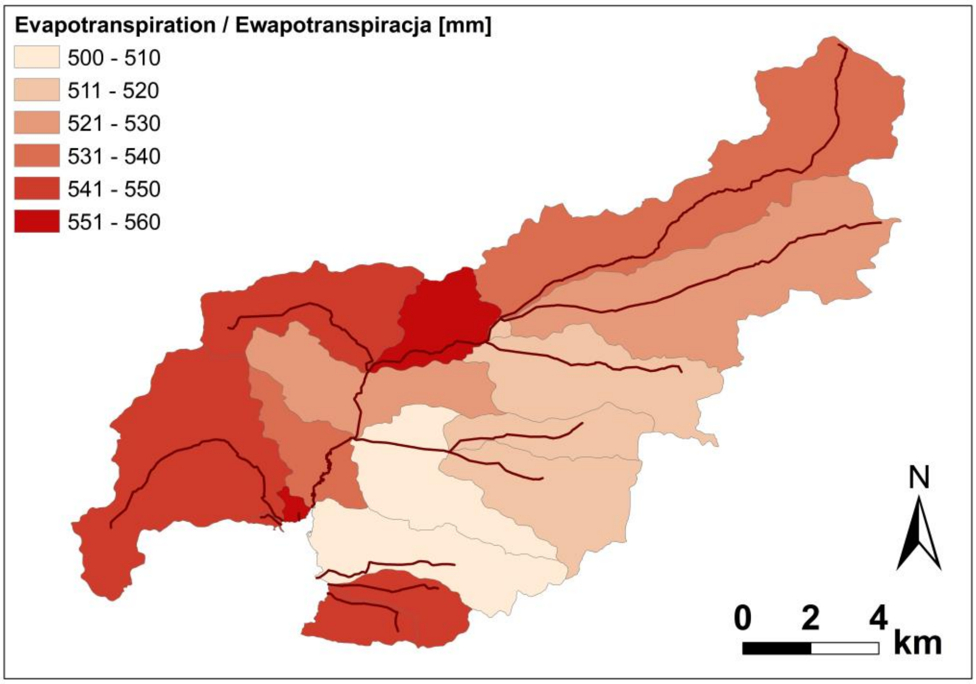

Figure 22: Spatial distribution of the average evapotranspiration in the 2012-2017 period.

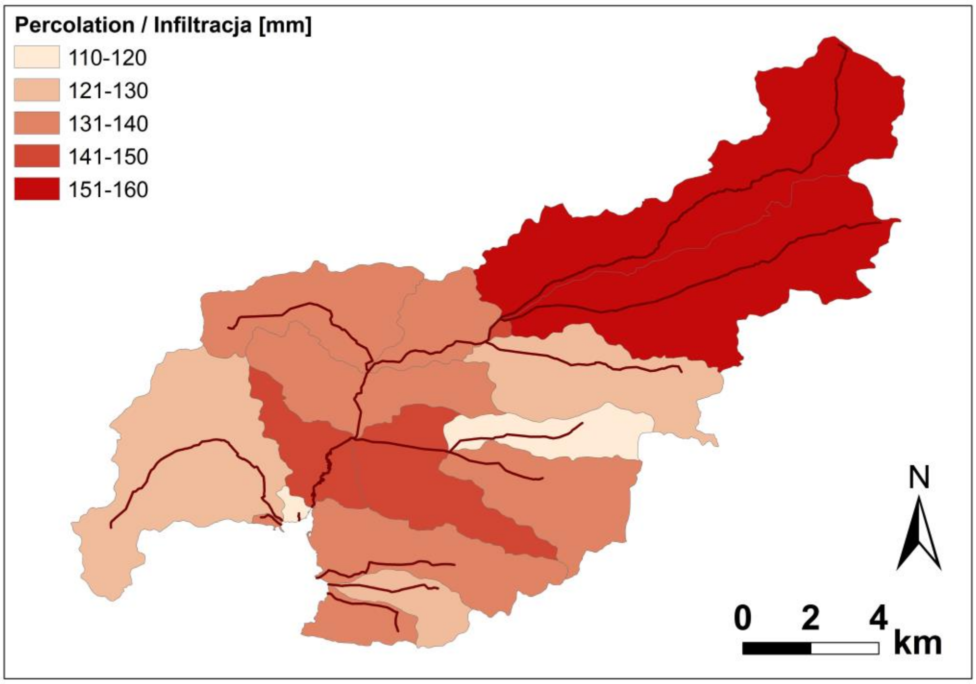

Figure 23: Spatial distribution of the average percolation in the 2012-2017 period.

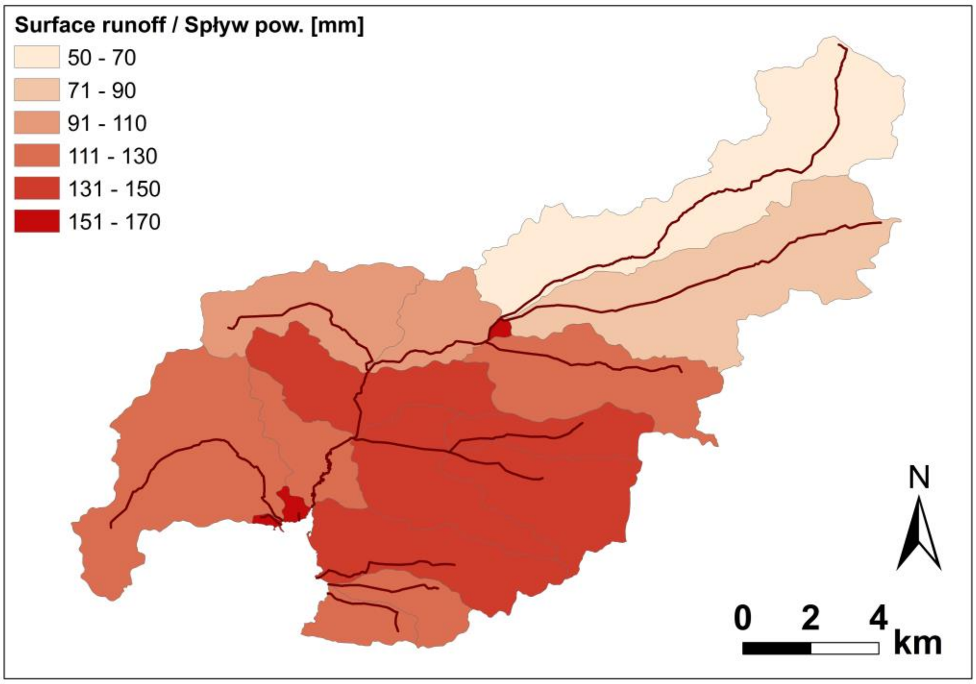

Figure 24: Spatial distribution of the average surface runoff in the 2012-2017 period.

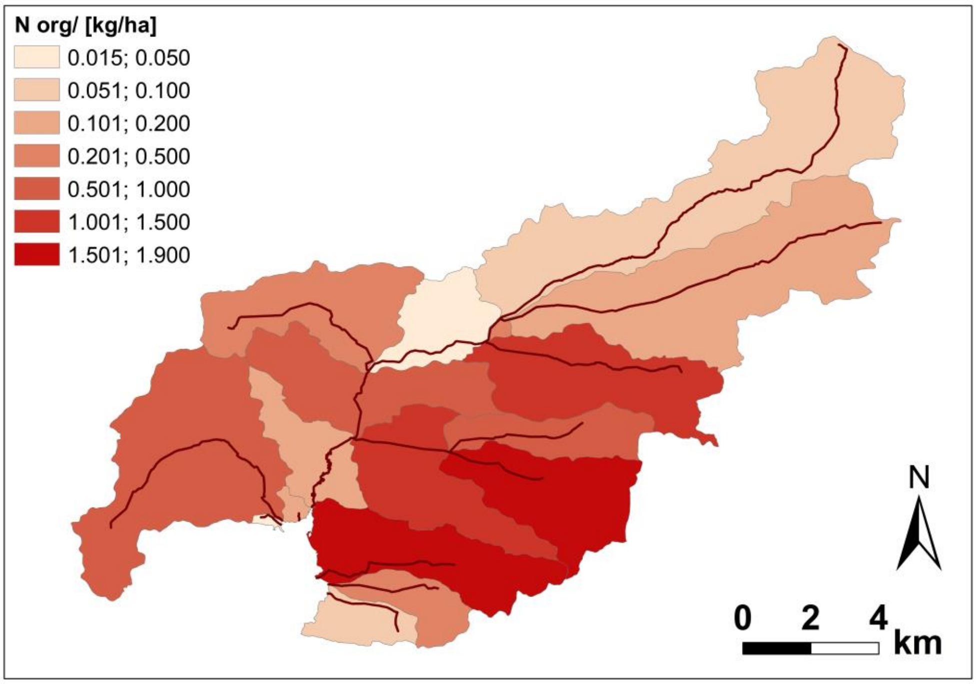

Figure 25: Spatial distribution of the average load of organic nitrogen in the 2012-2017 period.

4.2. Ecological model of the reservoir ecosystem

Within PA activities ecological model of the reservoir ecosystem, using AEM3D, was also performed. The AEM3D model allows for the simulation of:

- flow velocity,
- water temperature,
- concentration of:
  - dissolved oxygen,
  - sediments,
  - organic and mineral nitrogen and phosphorus,
  - phytoplankton (4 groups),
  - zooplankton,
  - fish,
  - virtual tracer,
- retention time.

Time step of calculation in the model of the Kozłowa Góra reservoir is 180 seconds. Period covered by simulations include over five years, i.e. January 2012 – March 2017. It is the most recent 5-year period with all input data available.

The AEM3D model uses SWAT's outputs as a part of input data. These SWAT outputs include daily flow rate and water temperature in 7 streams flowing into the reservoir. Remaining inputs are based on observed data.

Horizontal resolution of model is 50 metres.

Calibration was on observed:

- water level,
- water temperature,
- concentration of nitrogen and phosphorus.

Validation was based on data regarding:

- water temperature,
- concentration of:
    - nitrate, ammonia and organic nitrogen,
    - mineral and organic phosphorus,
    - dissolved oxygen,
    - chlorophyll a,
    - suspended solids.

The model includes following boundary conditions:

- Bottom outflow,
- 7 surface water inflows,
- Inflow or outflow of groundwater at depths up to 277 m a.s.l. (piezometers around the reservoir suggest the elevation of 276 m but it is assumed that there is also a reservoir-groundwater interaction above).

Preliminary results show that minimal, maximal and average temperature simulated for the location near the outflow from the reservoir are 0, 25.9 and 9.0 °C respectively. Observed values in the same location are 4, 24.7 and 13.6 °C. Average and minimal simulated temperature is lower than observed, however, it is justified because sampling does not cover all depths and is not frequent in winters.

Simulated water level and temperature near the outflow from the reservoir are presented below (Figure 26).

Figure also shows the water retention time, which is closely related to the water level and rate of inflows. The retention time in the Kozłowa Góra reservoir varies from 100 to 270 days for periods of the largest and smallest inflows respectively. The average retention time is almost uniform in the reservoir except areas close to main inflows. The average retention time is approximately 160-170 days in individual years of the analysis.

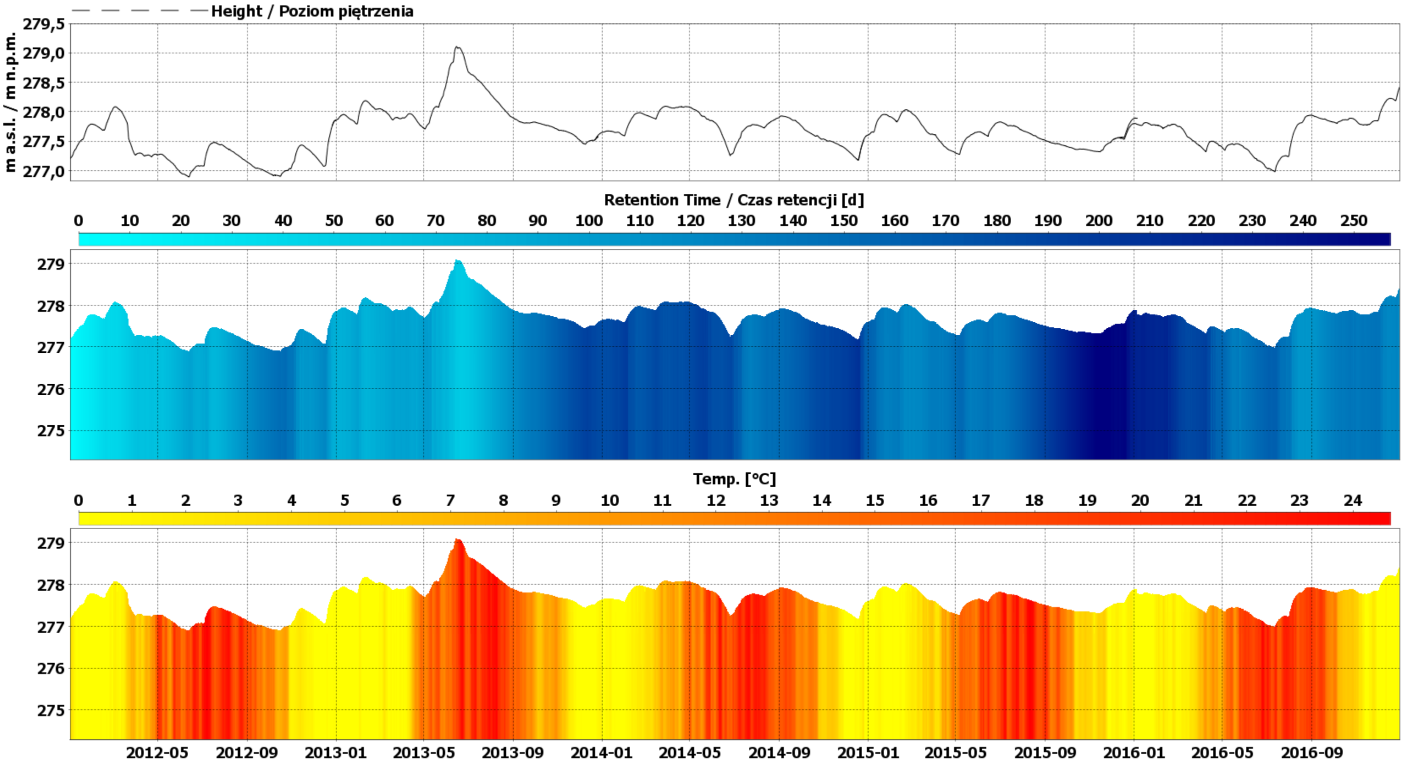

Figure 26: Simulated water level, water temperature and retention time in the water column near the outflow.

5. Solutions for case specific adaptation of best management practices

Table 3: GAPs and proposed BMPs with recommendations for implementation in Pilot Action.

Actual management practice (GAP)		GAP1: Little range of water monitoring	GAP2: No complex evaluation of water hazards	GAP2: No information about ecology of water reservoir	GAP4: No DWPZ established	GAP5: Low level of society awareness
Proposed BMP		Establishment of constant, multi-aspects water monitoring in the catchment scale	Complex catchment modelling	Establishment of an ecology model of water reservoir	DWPZ establishment proposal	Raising awareness and increasing knowledge
Proposed solutions and recommendations	adaptation of existing land use management practices	No adaptation required	It is highly recommended that within preparation of local land use management plan procedure results of the catchment modelling should be taken into account	It is highly recommended that within preparation of local land use management plan procedure results of the ecological modelling, integrated with catchment models, should be taken into account	Limitations and prohibitions are included within the proposal	Participants are getting familiar with current land use management practises and proposal for BMP
	Adaptation of existing flood/drought management practices	Investment in monitoring system contains constant monitoring system	It is highly recommended to use results of the catchment modelling simulation in flood/drought management	It is highly recommended to use results of the ecological modelling simulation in flood/drought management	Limitations and prohibitions are included within the proposal	Participants are getting familiar with current management practises and proposal for BMP
	Adaptation of policy guidelines	Need of conducting proper, multi-aspect monitoring of water system should be emphasized in guidelines at local, regional and also national level	Recommendation to include catchment modelling as a one of the tool using to improve water management	Recommendation to include the ecological modelling, integrated with catchment models, as a one of the tool using to improve water management	Proposal considers current Water Law and policy guidelines;	Participants are getting familiar with current policy
Remaining issues to be solved				Good quality input and calibration data	Good quality input and calibration data	Limited channels of information flow in small communities

6. Conclusions

Within Kozłowa Góra PA several GAPs were identify included Little range of water monitoring, No DWPZ established, No complex evaluation of water hazards, No information about ecology of water reservoir and Low level of ecological awareness of society. During PA activities GPW actions responded the identified GAPs.

In June 2017 multiscale monitoring of the water resources was set up to investigate and assess water resources, sources of pollution and possible hazards. Based on the results mathematical models of hydrology and ecology of the Kozłowa Góra reservoir was established. Simulations run allowed to assess a.o. an impact of land use and water management to water quality and quantity and its ecology. A proposal for DWPZ was prepared and is being implemented. The proposal includes a.o. limitation in land use, waste water management, fishery.

The most important BMP is reaching the society and raise the awareness. In a situation where the guidelines, policies exist and are not enforced raising awareness among society, especially small, local ones is crucial to implement.

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- Analysis of raw water quality influence on effectiveness of water treatment process on WTP Kozłowa Góra
- Proposal of location of the water intake’s protection zones
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