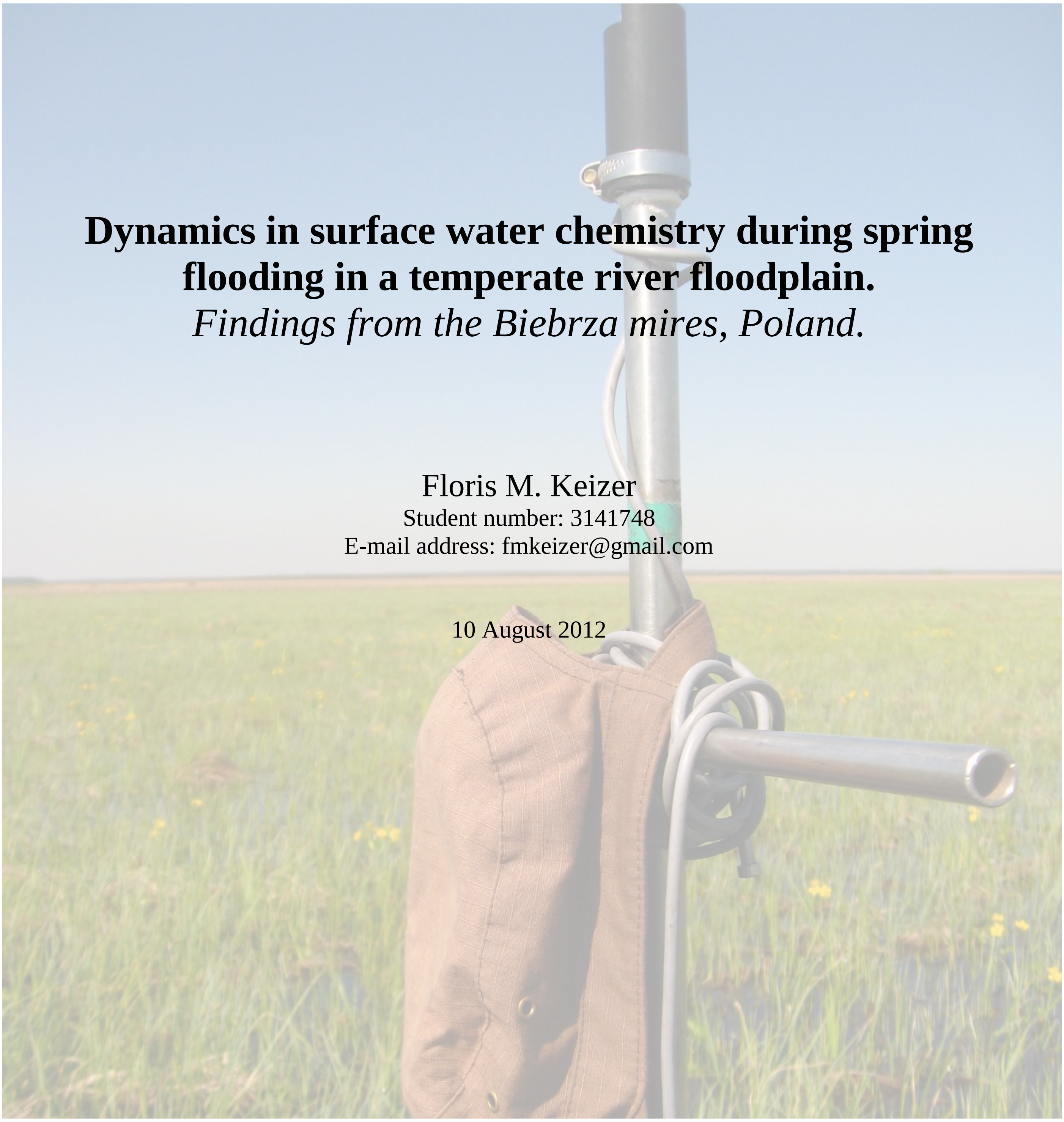

Dynamics in surface water chemistry during spring flooding in a temperate river floodplain.

Findings from the Biebrza mires, Poland.

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10 August 2012

Master thesis: final version

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Dynamics in surface water chemistry during spring flooding in a temperate river floodplain. *Findings from the Biebrza mires, Poland*

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Abstract. Dynamics in surface water chemistry during spring flooding in a temperate river floodplain were studied in the Biebrza fens (Poland). Variation in hydrochemistry between years and variation during yearly occurring spring flooding were analyzed using surface water sampling. Meteorological data were used to relate observed dynamics to weather conditions before and during flooding. For analysis of dynamics between years, data was used of 2001-2010. For determination of small-scale variation, a weekly sampling campaign was set up in transects with a high sampling density, during the spring 2012 flooding. The objective was to determine zones with different water types: river water, rain- or snowmelt water and groundwater, and dynamics therein. Additional evidence was gathered with groundwater samples and Electro Conductivity and temperature profiles of the peat soil up to a depth of 1.60 m below the water surface. Results showed that dynamics between years were highest where river water flooded the floodplain and where groundwater discharge occurred. The location of the border between river water and rainwater varied spatially over 250 m and depended on flood magnitude and amount of snow present before flooding. A zone could be identified which was flooded with river water each year independent of flood magnitude. Zones with groundwater discharge showed high variation because of mixing with rainwater at the discharge location. Zones were horizontally stable over the course of four weeks during the flood peak and subsequent drawdown. Only the border between river water and rainwater moved riverwards over 50 m during a rain period. Identification of groundwater discharge zones using surface water sampling is problematic in some cases because of high similarity of local groundwater and rainwater. For these cases, EC and temperature profiles of the peat soil provide enough evidence to determine groundwater discharge zones. Groundwater discharge zones are narrow (< 100 m) and flow of groundwater from these zones on the surface and in the shallow soil enables to characterize significant parts of the Biebrza Lower Basin as throughflow mire with stable water quality instead of inundation mire. The current results show that dynamics in water quality between years are substantial and that variation during flooding can be as large as between-year variation. This should be taken into account when characterizing the system and drawing relations between vegetation and hydrology. Use of small scale sampling and EC and temperature profiles makes identification of groundwater discharge zones possible and proves a useful technique.

Keywords: Biebrza; Flooding; Water chemistry; Dynamics; Groundwater; Inundation mire; Through-flow mire.

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1. Introduction

Riparian wetlands have become subject to interference by human activities at increasing levels over the past 60 years (Van Den Brink et al. 1996). Floodplains, fens and marshes were cultivated and natural flooding reduced. Restoration of the remaining wetlands is of large importance because they house rare flora and fauna species that require environmental conditions that are found only in these wetlands (Pfadenhauer, Grootjans 1999). For restoration to be successful, knowledge of variation in hydrology and water quality variables in both space and time is essential (Wassen, Peeters & Olde Venterink 2003).

The water quality of fen systems has been researched extensively, but spatial and temporal *dynamics* in water quality have only rarely been paid attention to (De Mars, Wassen & Olde Venterink 1997); probably because repeated sampling over time or on smaller scales is expected to yield similar results and not add significantly to system understanding. However, research on dynamics in the Biebrza fens and marshes (De Mars, Wassen & Olde Venterink 1997) found that dynamics determine the vegetation distribution across the floodplain. In addition, research found that water quality differs between years and seasons. Different spatial water quality distributions occur over time. This is reflected in the vegetation distribution through presence or absence of species that tolerate dynamics (De Mars, Wassen & Olde Venterink 1997).

So far, it is still not known how and how fast water quality changes between states of different water quality found throughout a year. Intra-seasonal short-term fluctuations at small scales and short periods of extreme conditions are therefore of interest for more research. One of these periods of extreme conditions is the flood period after spring thawing, during which small scale variability in water quality was observed (Chormański et al. 2011). Periods of high flow contain a large part of the annual variation and have conditions which are most adverse for river ecology. These include amongst others submergence of vegetation and input of substances through runoff which negatively affect plant growth. Therefore they require more attention in water sampling surveys (Jarvie et al. 2001)

In wetland science, flooding is considered important for the ecological functioning of river floodplains (Mitsch, Gosselink 1993). The flood pulse concept (Hudson, Heitmuller & Leitch 2012) notes the importance of dynamics that occur perpendicular to the river for nutrient input and linkage of floodplain compartments so exchange of energy, biota and matter takes place during floods (Poole 2002). In wetland science, this theory is widely established and used in wetland research (Poole 2002, Benke et al. 2000, Cabezas et al. 2011, Tockner, Malard & Ward 2000). Wetland restoration and creation uses this concept of flood pulse, where the river is the source and driver for flooding of the floodplain, as a fundament (Mitsch et al. 2005, Huang, Mitsch & Zhang 2009).

However, Chormański et al. (2011) showed that this theory is too simplified for the Biebrza River. River flood water does not cover the entire floodplain during flooding, but only a (small) part adjacent to the river. Other parts are covered with snowmelt-/rainwater and groundwater. All three water types appear at the same time in a spatial pattern with sharp boundaries, gradual transitions and mixing zones all present in the floodplain. This new insight is expected to change thinking on wetland restoration and creation.

The distribution of water types depends on groundwater fluxes and precipitation patterns before and during flooding (Beumer et al. 2007, 2008). During wet periods the surface water is diluted while during dry periods it is concentrated (De Mars, Wassen & Olde Venterink 1997, Robson et al. 1993). Precipitation not only dilutes the surface water during periods of extreme precipitation, but also expand local groundwater systems at the cost of regional systems (Wassen et al. 1988, 1990b). On the other hand, dry periods with high evapotranspiration concentrate the surface water (Appelo, Postma 1993). During flooding, a stratigraphy is observed within the root zone of the vegetation. The deeper root zone correlates strongly with calcium-rich groundwater, whereas the upper root zone is subject to much stronger fluctuations that result from interaction between groundwater, river water and rainwater (De Mars, Wassen & Olde Venterink, 1997).

Processes in ecosystems operate at scales that range from molecule to catchment, regional and even global scale and in time from second, hour to daily and even century scales. When variation in a certain process is of interest for research, the spatial and temporal resolution at which this process is mapped needs to be small enough to capture this variation. Mostly, in water quality sampling only one sampling moment is taken for one or a few locations, which limits the larger-scale applicability of the conclusions. For the present research into dynamics of surface water chemistry during spring flooding, the sampling scale in both space and time is essential to capture dynamics. Because earlier research of water quality during spring flooding found water quality to vary between years (Jarek Chormański, personal communication, February 1, 2012; this report), but determination of the exact border between different water quality types was problematic due to the coarse sampling scale, small scale sampling was expected to give more clear indication for sharp borders, gradients or mixing zones in space between different water quality types.

It is clear now that conclusions drawn from water quality research come with limited general applicability when the system is not understood or sampling scale is too coarse. If relations between vegetation and environmental variables are to be characterized, then much more attention should be paid to dynamics in environmental variables. De Mars et al. (1997) suggested that presence or absence of plant species is strongly related to the amplitude of environmental conditions – the extremes – at the plant site rather than average site conditions. This hypothesis deserved further research. Two of the most important detrimental factors for vegetation growth, in which extremes are observed, are water quality and flooding (De Mars, Wassen & Olde Venterink 1997) and dynamics therein. Sampling surveys in the Biebrza valley already showed significant differences between spring and summer (De Mars, Wassen & Olde Venterink 1997), but dynamics during extreme conditions of spring flooding were not investigated yet. Therefore, this study focuses on dynamics during spring flooding.

Because Chormański et al. (2011) indicated that the sampling scale used in the Biebrza Lower Basin was too coarse, a smaller sampling scale was used in this research. The locations of the sampling points were determined through an orienting sampling campaign where only EC was measured at very fine scale (50-100 m). In this way, optimal placement, capturing the highest amount of variation, of the sampling points was guaranteed.

Water sampling is useful to characterize water types when typical water types (river water, rain- and snowmelt water, groundwater) are substantially different in water quality. When rainwater has a high resemblance to groundwater identification is difficult. This is the case when rainwater discharges relatively short after infiltration or when the medium through which rainwater flows after infiltration does not exert an observable change in water quality. Groundwater similar to rainwater is found in the research area. Unsure identification of this water is noted as one of the deficiencies of the hydrochemistry method of Chormański et al. (2011). In this situation, recordings of peat temperature up to 1.5 m below the peat surface can give insight in groundwater discharge locations (Van Wirdum 1990). In addition, a relatively accurate quantitative estimation of vertical water flow can be made using a heat transport model that identifies if and to what extent upward or downward flow of water contributes to the observed temperature profile (Van Wirdum 1990). More recently, the temperature of bed sediment and water column of rivers was used to distinguish groundwater-surface water exchange (Kalbus, Reinstorf & Schirmer 2006, Conant Jr. 2004, Silliman, Booth 1993).

So far, the temperature method has not been applied in floodplains where flow velocities are much lower and standing water occurs. This research hopes to indicate the applicability and accuracy of temperature measurements for determination of groundwater-surface water exchange in flooded floodplains. The method is accurate and reliable because of simple gathering of thermal data (Anibas et al. 2009, 2011). Spatial and temporal temperature measurements were also used as a tool to assess groundwater-surface water interaction in the river bed of the Biebrza Upper Basin (Anibas et al. 2011).

The present study is carried out in a temperate floodplain where dominant hydrological processes determining vegetation distribution are flooding with river water (Überflutungs-Moore, De Mars, Wassen & Olde Venterink 1997), discharging groundwater that also flows through the upper peat layer (Durchströmungs-Moore, van Loon et al. 2009) and infiltrating rainwater (Wassen et al. 1990b, 1992).

The current research tried to answer two questions. The first question was:

- *To what extent does water quality fluctuate between years during spring flooding and how does this relate to flood characteristics and meteorological conditions before and during water quality sampling?*

This question was dealt with using data of 2001-2012. The second and third questions were:

- *Does spatial and temporal sampling of a selection of chemicals allow to distinguish zones flooded with groundwater from zones with rainwater/snowmelt water?*

- *Does addition of sampling of water temperature and soil temperature profiles reduces uncertainty therein?*

These questions were answered using measurements carried out during the spring 2012 flood.

The first hypothesis was that the water quality in a temperate floodplain is subject to strong variation during flooding, which can only be captured by small scale sampling of water quality spatially and temporally. The strong variation is expected to result from atmospheric conditions before and during the sampling campaign. The second hypothesis was that the uncertainty in determination, which results from the similarity of rainwater and groundwater, can be eliminated by including temperature and EC profile measurements of the soil and surface water.

The data analysis of 2001-2012 answered the question how meteorological conditions and flood characteristics relate to water type distribution in the Biebrza Lower Basin floodplain. Processed data retrieved with fieldwork for 2012 shed light on small scale variability over a short period during spring flooding and answered the question whether temperature sampled at small scale is a good predictor of water type distribution and adds considerably to reducing uncertainty in water type classification.

2. Research area and transects

2.1 Research area

The Biebrza valley is located in northeastern Poland, Podlaskie Voivodeship (23°30' to 23°60' E and 53°30' to 53°57' N (Fig. 1). The Biebrza River floodplains contain fairly undrained and undisturbed peatland (Okruszko 1990) with pristine marshes, fens and grasslands where large scale human interference in hydrology is absent. Therefore, the Biebrza Wetlands are important as a reference area for fen ecosystems and hydrologic research will show processes and patterns as they occur in a natural situation. This can give insights into ways to restore human-affected wetlands along similar lowland rivers (Wassen 1995).

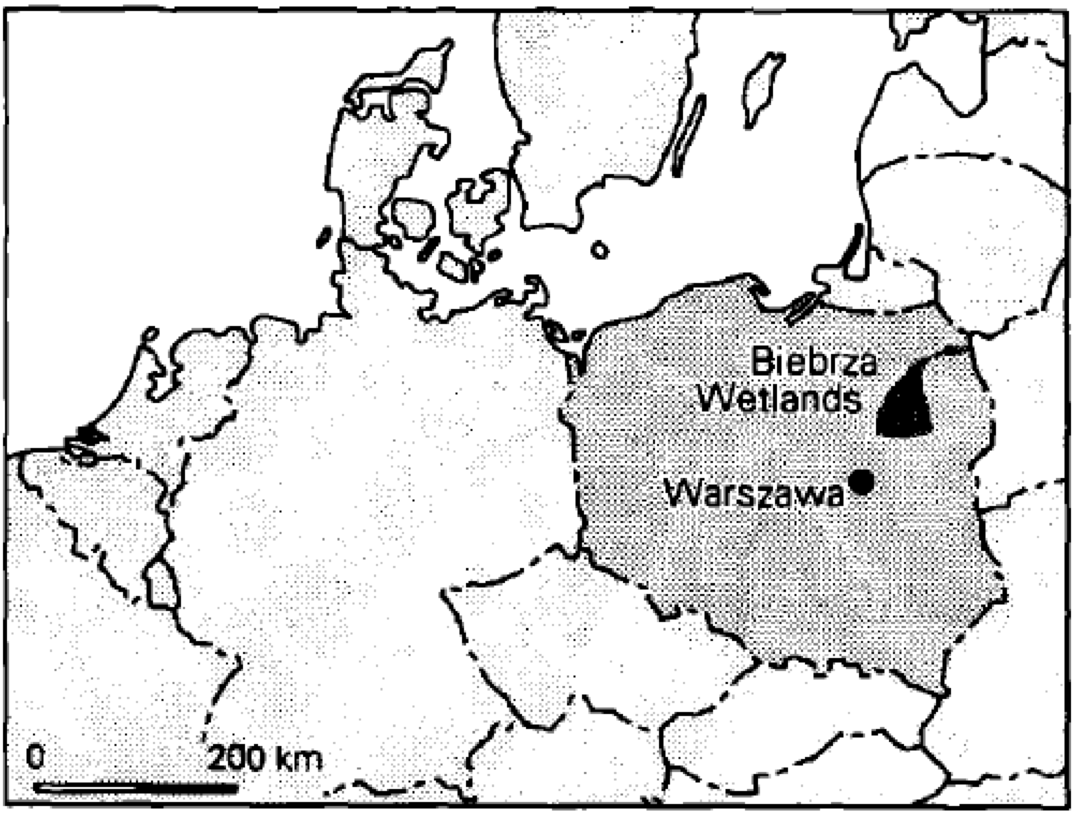

Fig. 1. The location of the Biebrza watershed in Central Europe. Taken from Wassen (1995).

The Biebrza valley can be subdivided in three basins: the Upper, Middle and Lower Basin. This research was carried out in the Lower Basin (453 km^2) where extensive flooding occurs every spring after snow- and icemelt. The Lower Basin floodplain is situated 100-106 m above sea level between Osowiec and about 30 km downstream, the confluence with the Narew river. It consists for large parts of inundation mires along the Biebrza river that spread about 3 km wide at Osowiec and gradually widen up to 15 km at Bagno Ławki. Within the floodplain, remains of the ice-marginal valley terrace covered with river dunes are present on the east bank from Osowiec to Nowa Wies. Locally, river dunes occur as islands within the floodplain, most pronounced in the northern part of the basin. A moraine plateau borders the valley in the east and west. This moraine plateau rises to 135-160 m further away from the basin (Zurek 1984). Peat thickness in the basin is usually not more than 2.5 m. The peat is more silty closer to the river (De Mars, Wassen & Olde Venterink 1997).

2.2 Hydrology

Bankfull discharge at Osowiec equals about 25 m^3/s (Grygoruk et al. 2011). In this respect, even lowest spring peak discharges of the last 30 years can be seen as floods exceeding bankfull discharge. Peak discharge exceeded 100 m^3/s only 7 times from 1951-2009 and 50% highest peak discharges, as determined by a Pearson III distribution fit on peak discharges of 1951-2009, are higher than 70.0 m^3/s. The highest 10% peak floods exceed 125 m^3/s.

Bankfull and peak discharge at Burzyn – the downstream end of the Lower Basin – are considerably higher than at Osowiec. Inflow of water from several other channels into the Biebrza causes higher discharges at Burzyn (Byczkowski, Kicinski 1986), of which the Rudzki canal just downstream of Osowiec and the Kosódka canal between Gugny and Barwik should be mentioned. The Biebrza river also drains the extensive fens which in their turn drain the river dunes and morainic uplands. The fact that a large amount of water is stored in the Lower Basin during and for a long period after flooding can be contributed to the geomorphological setting with a narrow outflow width of the valley (Zurek 1984), which inhibits fast transport of water out of the Lower Basin.

2.3 Climate

Mean annual precipitation sum (1979-2008) is 585 mm, of which 39% falls in November-April (hydrological winter half-year) and 261 mm falls in the relatively wet summer. February is generally the driest month with 31.5 mm on average, followed by January, April and March (36.8, 36.9 and 37.9 mm respectively) (Institute of Meteorology and Water Management – National Research Institute (Poland), 2012).

Average annual maximum temperature (1979-2008) is 11.4°C and average annual minimum temperature is 2.5°C (Institute of Meteorology and Water Management – National Research Institute (Poland), 2012). The mean temperature during the growing season is 12.3°C (Kossowska-Cezak 1986).

2.4 Transect locations

Four transects with sampling points (n = 41) were set up in the Biebrza Lower Basin (Fig. 2). Because temporal dynamics in hydrochemistry were also of interest in this research, all four transects were sampled four times with an interval of one week (n_{tot} = 265). The transects were placed perpendicular to the river, to most clearly capture the direction of spatial variability, on the eastside of the Lower Basin in areas known to have either ombrotrophic or calcareous fen vegetation (Palczynski 1986, Martin Wassen, personal communication, November 2011) and where gradients were observed in EC and Chormański et al. (Chormański et al. 2011, Jarek Chormański, personal communication, February 1, 2012) indicated transitions between water types to be present. Three transects start at the dune covered remains of the ice-marginal valley terrace; one starts at the moraine plateau. Only one transect reached the zone with river water influence.

Transect 'O' – near the village of Olszowa Droga – has a length of 500 m and contains 10 sampling points, of which 5 with a piezometer. It starts at the ice-marginal valley terrace covered with dunes and ends in the river water zone. In general the river floods most of the transect in spring; in summer water levels drop due to drainage by the river. Only at the dune edge, water levels remain close to the surface due to groundwater exfiltration from the dunes (De Mars, Wassen & Olde Venterink 1997).

Transect 'B' – near the hamlet of Barwik – has a length of 1400 m and contains 9 sampling points, of which 5 with a piezometer. It starts at the same geomorphologic feature as transect O, however does not end in the river water zone but before a large river dune island. Sampling points are located close to a path that is supplemented with sand and used in summer to drive into the floodplain. This disturbance is expected to change water chemistry (Martin Wassen, personal communication, April 19, 2012).

Transect ‘G’ – near the village of Gugny – has a length of 1400 m and contains 11 sampling points, of which 5 with a piezometer. It starts at the southern part of the ice-marginal valley terrace covered with dunes and ends before a hard to penetrate birch-alder forest.

Transect ‘S’ – near the village of Szorce – has a length of 3200 m and contains 11 sampling points, of which 6 with a piezometer. It starts at the moraine ridge that borders the river valley and ends far out of reach of the river across the dike that underlies the Tsar’s Road. This transect has one reach where the distances between point are large (> 500 m). Research indicated little variation between sampling points here (Chormański et al. 2011, this report: Fig. 7, Appendix A: Table A.)), justifying the choice for low sampling density here. Groundwater discharges in the zone bordering the moraine; further away it recharges into the peat and flows laterally in the direction of the river (De Mars, Wassen & Olde Venterink 1997).

More information on the already extensively researched transects ‘O’ and ‘S’ can be found in Wassen et al. (Wassen, Peeters & Olde Venterink 2003, Wassen 1995, Wassen et al. 1990a, 1996), where they are named ‘B’ and ‘C’ respectively.

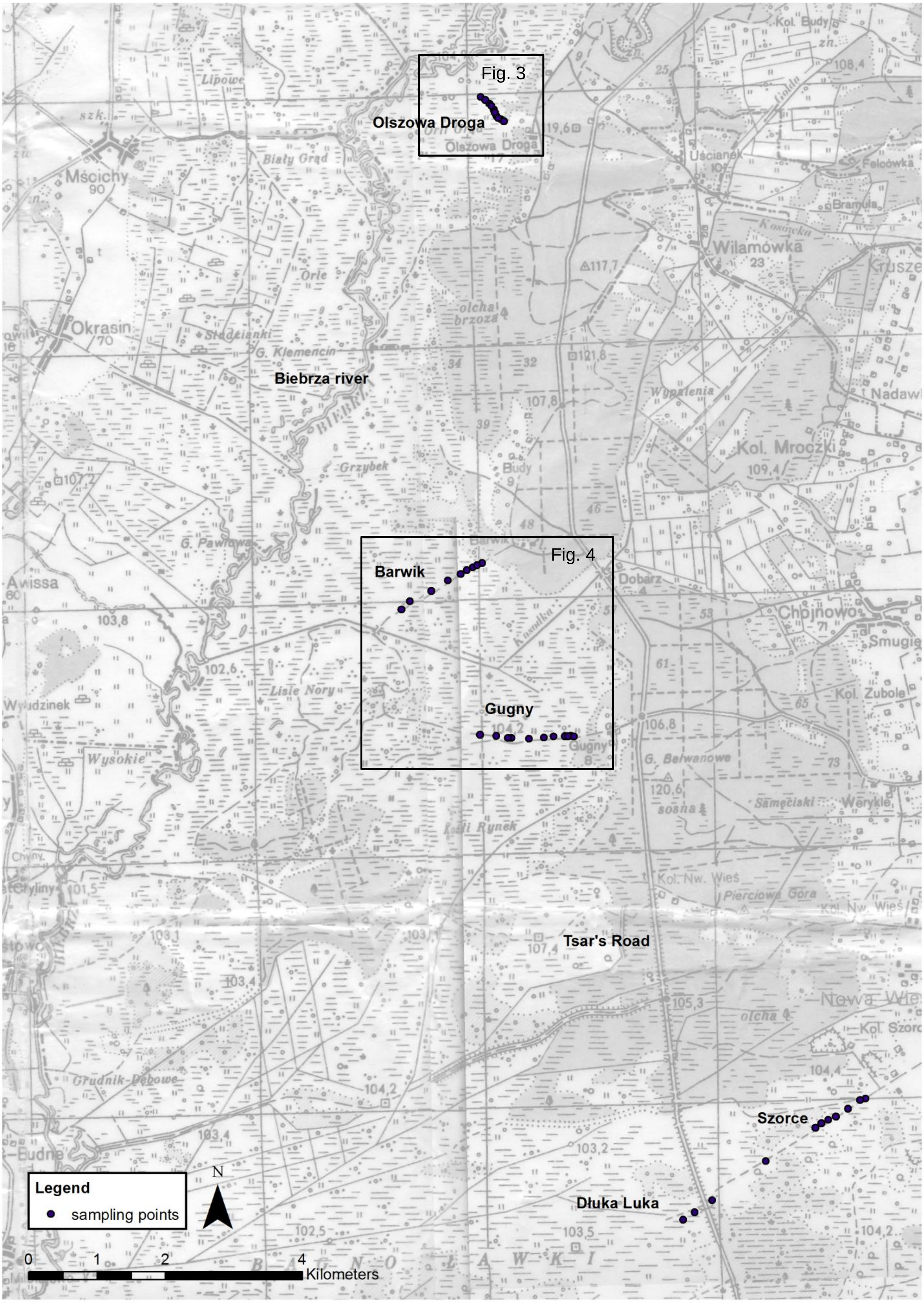

Fig. 2. Sampling point locations of the repeated sampling campaign in the Biebrza Lower Basin. Enlargements are shown in Figure 3 and 4.

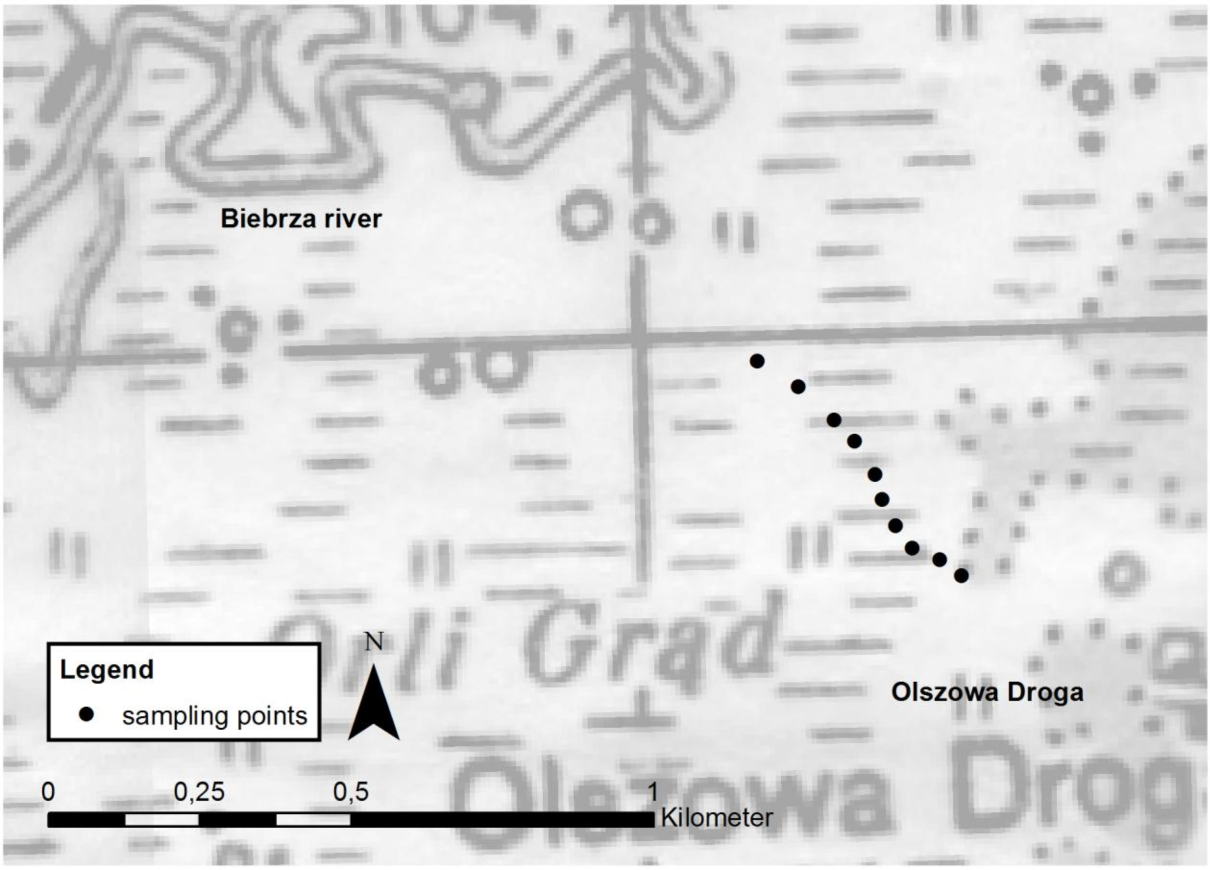

Fig. 3. Sample locations of the repeated sampling campaign at the Olszowa Droga transect.

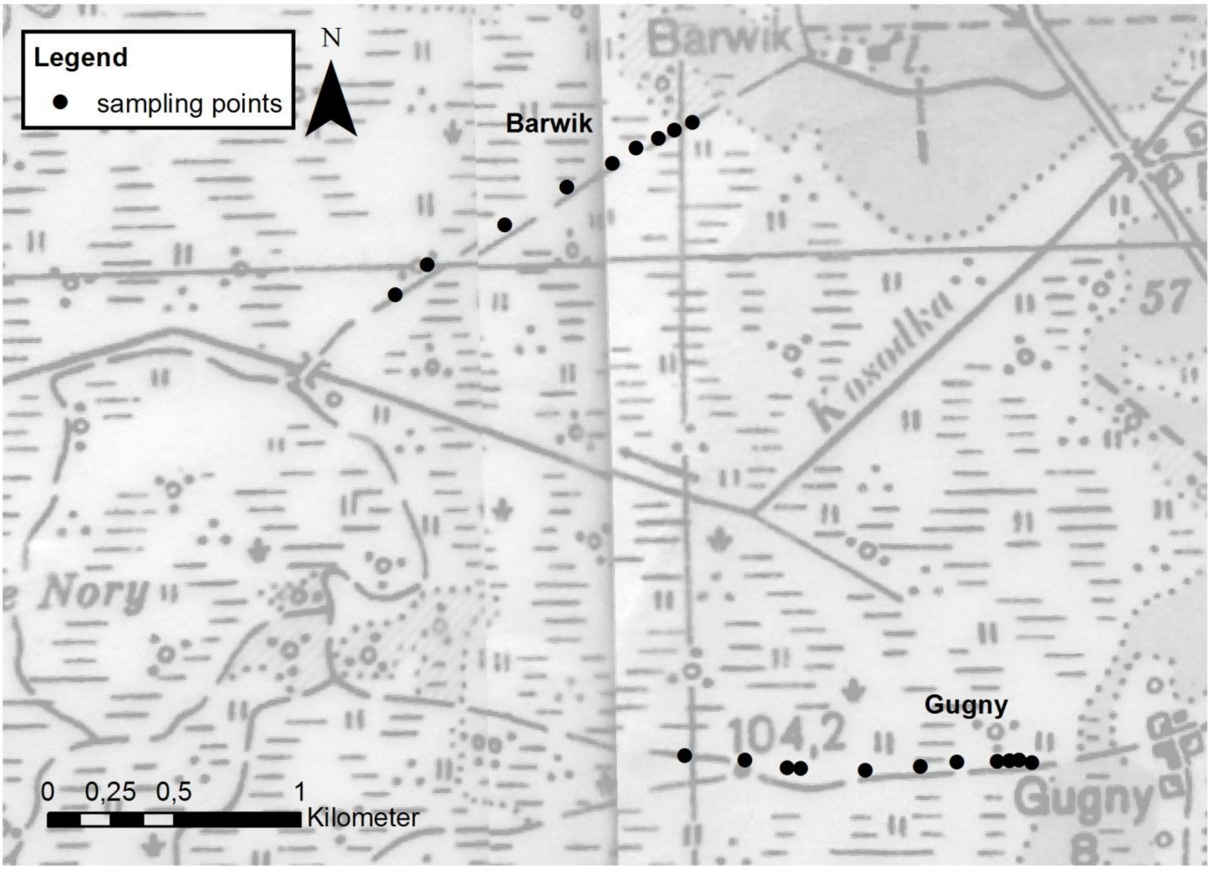

Fig. 4. Sample locations of the repeated sampling campaign at the Barwik and Gugny transects.

3. Material and Methods

3.1 Meteorological conditions 2001-2012

Discharge data for Osowiec and Burzyn was retrieved for 1979-2009, and discharge and water level for the study period from 11.02-03.05.2012 (Institute of Meteorology and Water Management – National Research Institute (Poland), 2012). Daily weather data (minimum and maximum temperature at Biebrza village, and precipitation measured at Burzyn) of 1979-2009 were retrieved from (Institute of Meteorology and Water Management – National Research Institute (Poland), 2012). The 2010 temperature and precipitation were measured in the Middle Basin. Data for snow cover and November and December 2011 and January and February 2012 precipitation were recorded at Laskowiec.

3.2 Part one: analysis of meteorological, hydrological and hydrochemistry data of 2001-2012

Meteorological data were used to calculate monthly average minimum and maximum temperature and monthly precipitation sum for 2001-2012. Furthermore, duration and snow cover thickness indicated how much snowmelt-/rainwater was present in the basin after snowmelt and if there was a relation between the amount of snowmelt and flood discharge. Overall, detailed analysis of meteorological data enabled to see to what extent analyzed years deviated from average climate conditions and could show possible causes for differences in hydrochemistry.

Years with high or low peak discharge were determined on the basis of discharge hydrographs and calculated peak discharges for 1979-2009. Furthermore, hydrographs were analyzed for flood magnitude (difference between discharge before and at peak discharge), peak timing and flood duration.

Hydrochemistry for 2001-2010 was obtained from Warsaw University of Life Sciences (Ignacy Kardel, personal communication, January 14, 2012). For 2001-2006, a description and analysis of the data can be found in Karalewich (2007). Information on data processing can be found in the data analysis section (p. 16).

3.3 Part two: water sampling and temperature and EC profiles

During an orienting campaign, six locations were studied intensively for EC (Fig. 13) and pH of the surface water (5-10 cm below the water surface) to verify assumptions about presence or absence of a groundwater or rainwater zone and its extent and to determine optimal placement of piezometers and locations of repetitive water quality and temperature profile sampling.

After determination of sampling sites, they were sampled four times over the course of four weeks, from March 31 onwards. After the fieldwork, the transects of Barwik and Szorce were sampled again on a small scale for EC to see if there was variation between sampling points that was not taken into account.

3.3.1 Water sampling

Water samples were collected in the field by wading through the area (cf. Chormański et al. 2011). Sampling point GPS coordinates were registered in ArcPAD (ESRI 2011) using a Trimble JUNO SD portable device.

Water samples were collected at three depths for each location where the water was deeper than 25 cm: 5 cm below the water surface, 5 cm above the soil and with the use of piezometers with a filter (length 10 cm) at a depth of 25 cm below the peat surface. Where water depth was less than 25 cm, only one surface water sample was taken, at a depth of 5 cm below the water surface. Piezometers were pushed into the peat. In locations where the soil was still frozen, a hole was drilled through the frozen top layer using a metal pipe with sharp 'teeth' at the end. Piezometers were equipped with a 30 x 30 cm square flexible rubber sheet around the tube, which after installation was covered with some peat and plant material at the surface to prevent downward inflow of surface water along the piezometer and into the filter. Piezometers were emptied and because of slow refill speeds, water samples collected one or two days after they were emptied.

Electro Conductivity (converted to 25°C; EC_{25}, EC Tester 10 low+, EUTECH) and pH (Waterproof pH Tester 30 EUTECH) was measured in the field, alkalinity (at present pH levels only HCO_3^-, Merck; Aquamerk 11109 alkalinity test) was determined the day the sample was taken. Water samples (70 ml) were stored for maximum one week at 5 °C before analysis. Water samples were analyzed using ion chromatography (Ca^{2+}, Mg^{2+}, K^+, Na^+, Li^+, $NH4^+$, SO_4^{2-}, Cl^-, Fl^-, Br^-, NO_2^-, NO_3^-) and colorimetric for Fe^{2+} and PO_4^{3-}. Because of nitrification during transport and storage and because sampling round 2 showed abnormally low nitrite concentrations, NO_3^-, NO_2^- and NH_4^+ were recalculated to inorganic-N. One missing sample was interpolated on the basis of the two nearest known samples.

3.3.2 Temperature and EC profiling

Rainwater and surface water with different water quality and solute concentrations have different electrical conductivities and may be distinguished on the basis of their electrical conductivities (Van Wirdum 1990). Samples with similar EC can still have different solute compositions. So, chemical analysis of water samples is still needed to accurately confirm the hypothesized water type.

Temperature and EC profiles of the water and soil column were measured with the use of a temperature and EC sensor on a long, metal stick, connected to an EC and temperature device (WTW LF92). Profiles were measured of the surface water and soil up to a depth of 160 cm below the water level at intermediate depths of 10, 20, 30, 40, 50, 75, 100, 125 and 150 cm for EC and 10 cm deeper for temperature since the temperature sensor was located 10 cm lower on the stick. The stick and the WTW LF92 EC and temperature sensors were calibrated using solutions of KCl with known molarity 0.01, 0.0025 and 0.00167 mol/L in the Physical Geography lab (Utrecht University) for the range of EC_{25} 200-1400 µS/cm found in the Biebrza Lower Basin in previous fieldwork campaigns (Wassen, Peeters & Olde Venterink 2003, Chormański et al. 2011). Stick values were found to be related to the WTW LF92 sensor linearly (R^2 0.99) as:

(1) $WTW\ LF92 = stick * 0.30 + 2.02$

for the range 246-824 µS/cm, where *stick* is the EC value measured by the stick. The WTW LF92 sensor was verified with a calibrated EC-meter in the Physical Geography lab (Utrecht University) and showed values that were 2.6% too low over the range 200-1412 µS/cm (R^2 0.99).

The EC and pH meters used to sample the surface water were calibrated in the hydrochemistry lab of Warsaw University of Life Sciences against stable EC and pH meters. Before analysis, all WTW LF92 EC values were converted using equation (1) and increased by 2.6% to match the calibrated EC meter.

There were, however, some confounding factors related to the accuracy of temperature profile interpretation. Water depth influenced the speed at which the water column warmed up due to solar radiation (source) and had to be measured. Shallower water will warm up faster than deeper water. This will be visible in the temperature of the underlying peat soil. Furthermore, during fieldwork atmosphere temperatures increase, so they should be registered to be able to correctly see if warming of the soil profile is the result of atmospheric temperature increasing or warmer surface water covering the surface. However, unfortunately it was not possible to retrieve daily temperature measurements for the research period. Instead, it was assumed that temperatures increased during the field research.

4. Data analysis

4.1 Part one: analysis of hydrochemistry data of 2001-2012

Point data of water quality was retrieved for the Biebrza Lower Basin. Of the measured variables, the following variables were used for this research.

- 2001: EC, pH, Ca^{2+}, Mg^{2+}, K^+, Cl^-, Na^+, SO_4^{3-}, PO_4^{3-}, NO_3^-, NH_4^+
- 2002: EC, pH, Ca^{2+}, Mg^{2+}, K^+, Cl^-, Na^+, SO_4^{3-}, PO_4^{3-}, NO_3^-, NH_4^+
- 2004: EC, pH, alkalinity, Cl^-, PO_4^{3-}, NO_3^-, NH_4^+
- 2005: EC, pH, alkalinity, Ca^{2+}, Mg^{2+}, K^+, Cl^-, F^-, Na^+, SO_4^{3-}, PO_4^{3-}, NO_3^-, NH_4^+
- 2006: EC, pH, Ca^{2+}, Mg^{2+}, K^+, Cl^-, Na^+, SO_4^{3-}, PO_4^{3-}, NO_3^-, NO_2^-, NH_4^+
- 2010: EC, pH, Ca^{2+}, Mg^{2+}, K^+, Cl^-, F^-, Na^+, SO_4^{3-}, PO_4^{3-}, NO_3^-, NO_2^-, NH_4^+, Li^+
- 2012: EC, pH, Ca^{2+}, Mg^{2+}, K^+, Cl^-, F^-, Na^+, SO_4^{3-}, PO_4^{3-}, Fe^{2+}, NO_3^-, NO_2^-, NH_4^+, Li^+, Br^-

Because only for the area of Olszowa Droga and Szorce (for location, see Fig. 2), transect data was available that covered more than two years, two subsets (Olszowa Droga: n_{tot} = 46; Szorce: n_{tot} = 66) were made (see also Fig. 6 and 7).

First, hydrochemistry was used to distinguish water sources for sampling locations of 2001-2012. Samples were analyzed one by one for signs of river water, groundwater, rainwater and pollution. Past research (Wassen, Peeters & Olde Venterink 2003, De Mars, Wassen & Olde Venterink 1997, Chormański et al. 2011, Wassen et al. 1990b, 1996) showed typical values of solutes for the different water types. River water was characterized with high values of EC, pH, alkalinity, Ca^{2+}, Mg^{2+} and a pollution signal. Groundwater was characterized with high values in EC, pH, alkalinity, Ca, Mg and Fe. Its water quality is very similar to river water, although often much higher concentrations occur and the pollution signal is smaller than in river water. Rainwater was characterized with low concentrations of all variables, especially EC, pH, alkalinity, Ca^{2+} and Mg^{2+}. It should be noted that what is called 'rainwater' also includes possible snowmelt water. For convenience, only the term 'rainwater' is used here. A pollution signal was characterized as having high values for Cl^-, Na^+, K^+, SO_4^{2-} and nutrients. But because Na^+, K^+, SO_4^{2-} and nutrients are biochemically reactive, chloride was used as the main indicator of pollution. The other solutes were used as additional evidence for pollution.

EC is known to be a good predictor of water quality and water source (Van Wirdum 1990, Chormański et al. 2011). Therefore, trends in water quality were analyzed on the basis of EC first. When EC did not provide enough evidence for water source, more variables were added. Years were compared on the basis of EC by drawing cross-sections of EC of the sampled points (2001, 2002, 2004, 2006, 2010 and 2012 for Olszowa Droga; 2001, 2002, 2004, 2005 and 2012 for Szorce). This indicated reaches in the transects which were stable in EC over the plotted years and reaches that had more variation in EC. For Szorce, in reaches where variation in EC was seen, Ca^{2+}, Mg^{2+}, pH and Fe^{2+} were included in the analysis to identify for example if the variation in EC resulted from variation in these solutes. High concentrations of these solutes indicate groundwater discharge. Furthermore, for Olszowa Droga, the gradient and location of the border between river water with a higher EC and rainwater or groundwater with a lower EC was of interest. For Szorce, the variation in gradient and location of the border between groundwater with a higher EC and rainwater with a lower EC was of interest.

4.2 Part two: water sampling and temperature and EC profiles of spring 2012

4.2.1 Water sample analysis

The hydrology found in previous research (Wassen, Peeters & Olde Venterink 2003, De Mars, Wassen & Olde Venterink 1997, Chormański et al. 2011, Wassen et al. 1990b, 1996) indicated which water types with their specific water quality to expect in the transects. This led to identification of zones with river water, rainwater, groundwater and pollution according to the following theoretical cross-section (Fig. 5).

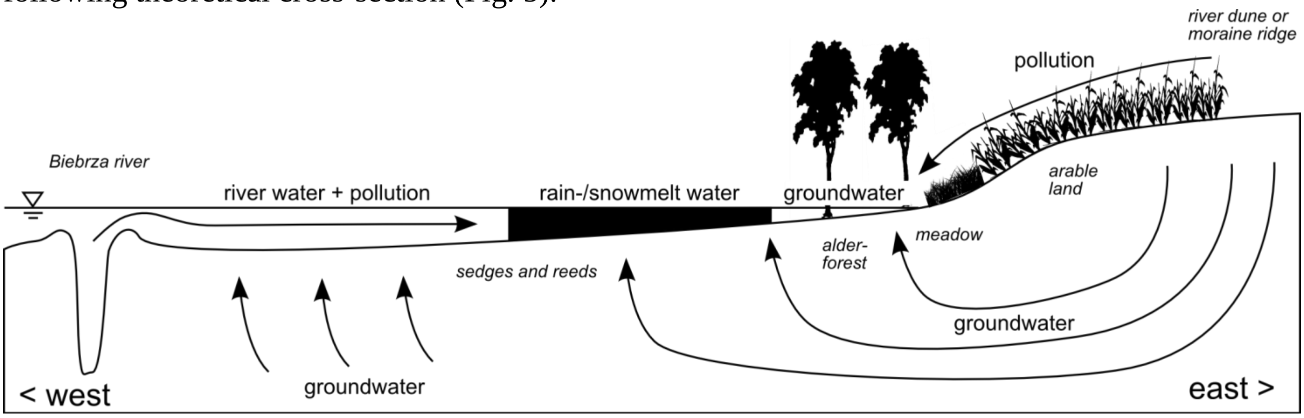

Fig. 5. Schematic cross-section of the eastern side of the Biebrza Lower Basin. Hydrology is shown with arrows; theoretical water type distribution during flooding is indicated above the water surface. In italic, land cover and simplified geomorphology is given. Figure based on findings presented in De Mars, Wassen & Olde Venterink (1997) en Chormański et al. (2011).

In previous research, a clearly visible drop in concentrations was seen from one zone into the adjacent zone. Therefore, borders between zones were identified on the basis of (significant) differences in mean values of measured variables grouped according to the different water type zones. Significant differences between zones in a transect were determined using a Mann-Whitney U test on each variable.

To determine if there was exchange between the surface water and the groundwater or if the surface water was a separate hydrologic system, surface water samples and groundwater samples were compared in pairs. This was done using a Paired Samples T-test on each variable that showed where surface water was significantly different from groundwater.

To determine variation in water quality over time, a Paired Samples T-test was performed for each variable on pairs of samples (round 1 – round 2; round 2 – round 3; round 3 – round 4) taken at the same location. This showed whether consecutive sampling rounds were significantly different for each variable.

4.2.2 EC and temperature profile analysis

For each transect and sampling round, EC and temperature measurements of the profiles were plotted as x-y data with horizontal distance on the x-axis and depth on the y-axis. Then, isolines were drawn by hand with an interval of 100 μS/cm for EC profiles and an interval of 1.0 or 1.5°C for temperature profiles, depending on the range in the cross-section. The isolines resulted in an interpolated cross-section of EC or temperature. This enabled to analyze large scale variability and groundwater recharge-discharge locations, relate surface water to groundwater and detect changes in water type, vertical stratification and horizontal distribution.

Expected trends in the EC and temperature profiles were as follows:

- River water, where higher temperatures in the shallow soil water were observed, caused by warmer river water flowing on the surface.
- Groundwater discharge, where higher temperatures in the deeper soil water were observed, caused by upwelling of relatively warmer groundwater.
- Groundwater discharge, where EC profiles showed higher or lower EC in an 'upwelling' pattern starting in the deeper soil.
- Rain water, where temperatures are significantly lower in the upper 50 cm below the water surface.

To see if temperature measurements relate to identified zones, the average temperature and standard deviation of the upper 50 cm below the water surface was calculated for each zone. A Mann-Whitney U-test was performed on the averages of adjacent zones to see if the average temperature was significantly different between adjacent zones.

Raw data can be found in Appendix B. It contains the following data:

- Table A: EC (and pH) of the orienting profiles (14.03.2012 – 24.03.2012)
- Table B: Water level of the Biebrza river at Osowiec (B.1) and Burzyn (B.2).
- Table C: Water level of the sampling points where piezometers were installed. Readings are for the sampling campaign from 31.03.2012 to 28.04.2012 with weekly intervals approximately.
- Table D: Temperature and EC profiles of the sampling campaign from 31.03.2012 to 28.04.2012 for all sampling points (Olszowa Droga: D.1-D.4, Barwik: D.5-D.8, Gugny: D.9-D.12, Szorce: D.13-D.16) with weekly intervals approximately.
- Table E: Hydrochemsitry of the sampling campaign from 31.03.2012 to 28.04.2012 for all sampling locations.
- Table F: Hydrochemsitry of the historical years 2001, 2002, 2004, 2005, 2006 and 2010 for Olszowa Droga and Szorce as used in the analysis of dynamics between years.

5. Results

5.1 Meteorological, hydrological and hydrochemical 2001-2012 data

5.1.1 Weather conditions 2001-2012

Mean annual precipitation is 585 mm, of which 227 mm falls in spring and winter (November up to and including April). January and February are the driest months, when rainfall hardly exceeded 20 mm/month over the past 30 years (Grygoruk et al. 2011). Temperatures frequently drop below zero in winter and a large proportion of the precipitation falls as snow. Because only winter and spring meteorological conditions are of interest for spring flooding, summer and autumn data are neglected. Average and flood year monthly precipitation sums are shown in Table 1.

Table 1. Monthly precipitation sums in the Biebrza river valley in mm (average precipitation and 2001-2006 precipitation measured in Burzyn, 2010 precipitation measured in the Middle Basin, 2012 precipitation measured in Laskowiec in the Lower Basin).

	Month					
Flood year	November	December	January	February	March	April
Average	43	42	37	32	38	37
2001	71	42	21	23	29	83
2002	33	20	45	54	47	10
2004	45	55	35	45	28	48
2005	56	37	30	33	41	10
2006	30	52	11	39	9	29
2010	61	51	20	25	26	34
2012	11	26	38	unknown	unknown	unknown

Average winter temperatures drop below zero, with January and February as coldest months (Table 2). An increase in temperature and associated melting of snow and frozen peat soil occurs generally in March or April, when average temperatures rise above zero.

Table 2. Daily minimum and maximum temperatures (°C) in the Biebrza valley averaged per month. From January 2010 onwards, values show mean daily values recorded in the Middle Basin. 2012 data were not available quantitatively, only a qualitative estimation is given.

	Month					
Flood year	November	December	January	February	March	April
Average	-0.8/4.5	-4.2/0.8	-5.8/-0.4	-5.9/0.4	-3.2/5.0	1.4/12.6
2001	2.6/8.1	-1.2/2.9	-3.2/0.5	-6.0/1.2	-4.0/5.2	2.8/12.7
2002	-0.9/4.6	-9.8/-2.3	-4.0/1.3	-0.9/6.0	-1.0/8.6	1.8/13.6
2004	1.4/5.8	-2.2/2.4	-10.4/-4.4	-4.7/0.9	-1.7/5.2	0.5/12.3
2005	-0.6/4.9	-1.2/2.7	-2.2/2.1	-9.4/-1.4	-6.8/1.3	1.6/14.0
2006	0.3/5.1	-3.8/0.4	-10.8/-5.2	-9.6/-2.1	-8.6/1.5	0.8/12.8
2010	1.9/6.4	-5.6/-0.3	-10.2	-3.3	2.3	8.9
2012	unknown	warm	warm	cold	warm	warm

The 2001 flood occurred after a wet November (71 mm; average 43 mm), average December but dry first three months of 2001 (sum 72; average sum 107 mm). Temperatures were above average, except for February and March being slightly colder. Snow cover was absent before flooding.

The 2002 flood occurred after a dry November and December (20 mm; average 42 mm), but wet January (45 mm; average 37 mm) and February (54 mm; average 32 mm). Temperatures were above average, with only December below average. Snow cover started at the end of November and lasted until the end of January when rapid melting occurred. A rain period followed until the sampling moment.

The 2004 flood occurred after a wet February (45 mm) and a dry March (28 mm; normally 38 mm). Temperatures were around average except for a cold January (T_{max}/T_{min} 4.0/4.5°C below average). Snow cover started at the beginning of January and lasted until March 10 with a short period of no snow cover at the beginning of February. After snowmelt temperatures increased and rain followed.

The 2005 flood occurred after an average winter in terms of precipitation. Only January was drier than average (30 mm). Temperatures were above average until January. February and March were colder than average. Snow cover started at January 20 and lasted until March 23, when within a few days 25 cm of snow melted when temperatures increased quickly. Substantial rain did not fall before or during the flood.

The 2006 flood occurred after a very dry winter (November to April 168 mm; normally 227 mm). Only December and February had precipitation sums above average, whereas January, March and April were extremely dry. Temperatures were below average for all months, minimum temperatures reached -26.3°C and -15.4°C on some days at the end of March. Snow covered the area from the end of December until the end of March and snow thickness remained above 10 cm until the start of thawing. After snow melt, temperatures remained low and precipitation little.

The 2010 flood occurred after precipitation conditions similar to 2001 (dry first three months of the year), although November and December were wet. Temperatures were low in December and January, average in February and March. Snow cover started at the end of December and lasted until March 19, thickness reached 49 cm in February. After snowmelt, temperatures increased to average daily values above 10°C. Rain occurred some days before and during sampling, but was not substantial.

The 2012 flood occurred after a relatively warm winter. November and December had less precipitation than average. January had an average precipitation sum. Snow cover started in January and lasted until half of March. Snow cover thickness was low. During the first two sampling round temperatures remained low and precipitation little. Between sampling round 2 and 3, it rained for some days.

5.1.2 Discharge of the Biebrza river

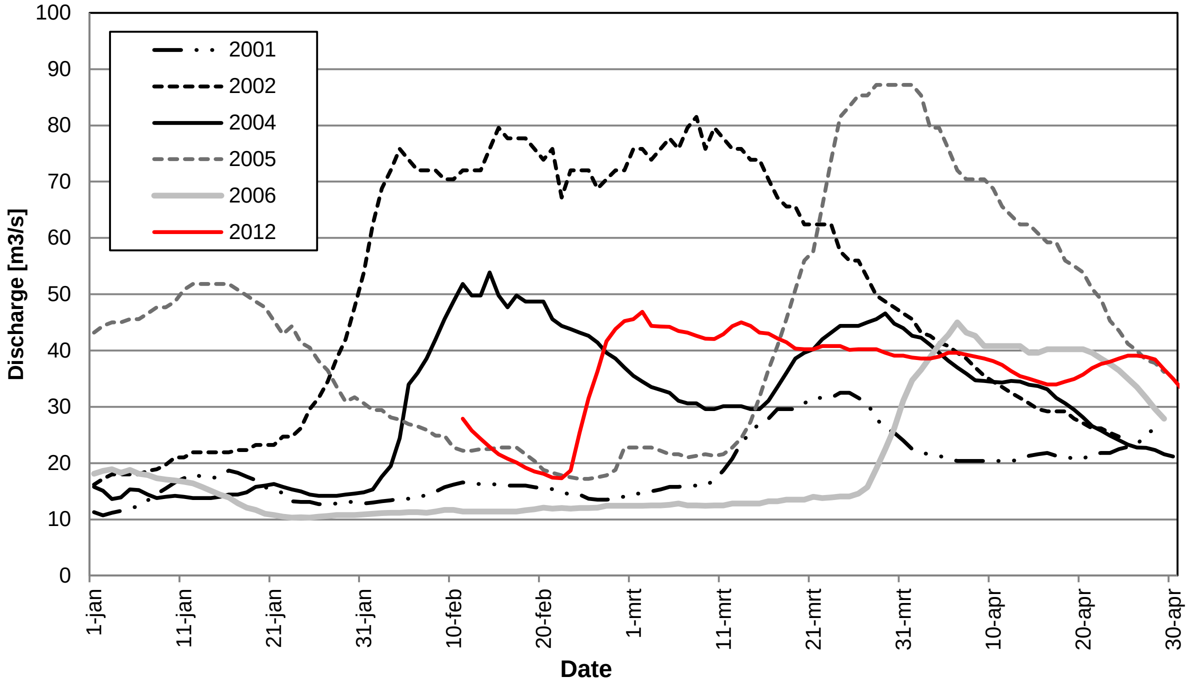

Fig. 6. Discharge of the Biebrza river at Osowiec (measured at the railway bridge upstream of Rudzki Canal) for selected years of the period 2001-2012.

Discharge for 2001-2012 is shown in Figure 6 and can be described as follows:

- *2001* – discharge remained very low until the beginning of March, when a small high flood stage occurred that lasted only for about 20 days.
- *2002* – discharge increased after snow melt and increased even more after days of rain before flood sampling.
- *2004* – discharge increased in February during a period of rain, but decreased until the moment of snowmelt mid-March, when discharge increased again to reach the 30-year average flood discharge at the moment of water sampling.
- *2005* – discharge showed the most dramatic increase of the analyzed years. A first flood peak occurred around mid-January, coinciding with an increase in temperature (no snow cover present before this peak). Discharge then dropped gradually and a second flood peak occurred in March. After this peak, discharge decreased quickly.
- *2006* – discharge remained extremely low until the end of March, to increase to slightly below average flood level at the beginning of April.
- *2010* – no discharge data could be obtained, but the flood was large and above average and flooding lasted until June (Dorota Swiatek & Ignacy Kardel, personal communication, March 14, 2012).
- *2012* – discharge increased after snowmelt and diminishes slowly, to increase again slightly the second half of April.

5.1.3 Hydrochemistry

River water – rainwater dynamics near Olszowa Droga

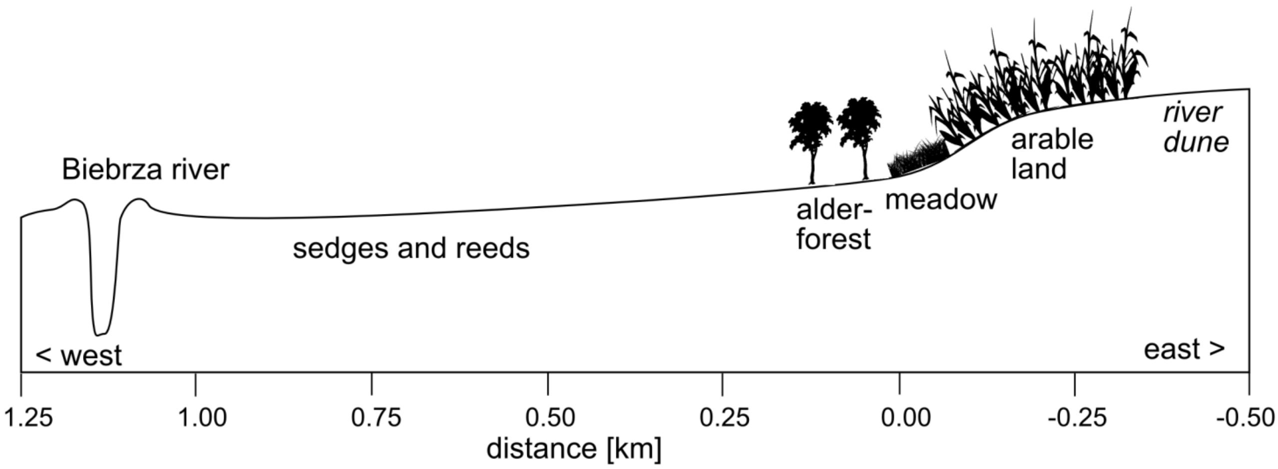

Fig. 7. Schematic cross-section of the Olszowa Droga transect in the Biebrza Lower Basin with land cover indicated. Distance is taken from the eastern alder forest boundary (see also Fig. 8).

A schematic cross-section of the Olszowa Droga transect is given in Figure 7. Sampling locations for 2001-2012 were spread out over a larger area, but all transects were perpendicular to the river (Fig. 8). River water covered the floodplain near Olszowa Droga entirely (EC 435-463 μS/cm) in 2001, with some dilution with rainwater or local groundwater at the edge of the floodplain (EC 386 μS/cm) (Fig. 9). In 2002, the same situation was present, although river water EC was much lower and showed less variation (EC 397-409 μS/cm). At the flood margin, within the alder forest, rainwater or local groundwater (EC 264-349 μS/cm) mixed with river water was present in a band of about 100 m width. In 2004, the river water zone extended less far into the floodplain, and had a more gradual border with the rainwater or local groundwater zone. The year 2006 had only one sampling point at the floodplain border near Olszowa Droga and three points in the floodplain, located far apart (Fig. 8). For 2006, the point near the border had rainwater (EC 306 μS/cm), at all other points within the floodplain, river water was sampled. 2010 had only one point, at the same location as the 2006 floodplain border point. It had river water (EC 394 μS/cm). 2012 resembles 2004, although a more pronounced border between the two water types was present. River water (EC 392-471 μS/cm) was significantly different from rainwater or local groundwater (EC 229-304 μS/cm). Within the rainwater zone, locations with higher EC corresponded to locations with a very minor river water influence.

Summarizing:

- 2001 – The entire transect was covered with river water. Near the floodplain border, within the alder forest, it was slightly diluted with rainwater.
- 2002 – The entire transect was covered with river water with a very homogeneous water quality. Rainwater or local groundwater was only present at the floodplain border, within the alder forest. There was a sharp border between the rainwater and river water zone.
- 2004 – Part of the transect was covered with river water, only a zone of 150 meter close to the dune was with another water type. There was no sharp border between water types.
- 2006 – Rainwater was found at the edge of the floodplain. The border with river water could not be observed due to low sampling density.
- 2010 – River water was found at the edge of the floodplain, which indicates that the entire transect was flooded with river water.
- 2012 – River water covered a part of the transect. A large zone (250 m) of rainwater or local groundwater covered the valley border. There was a sharp border between water types.

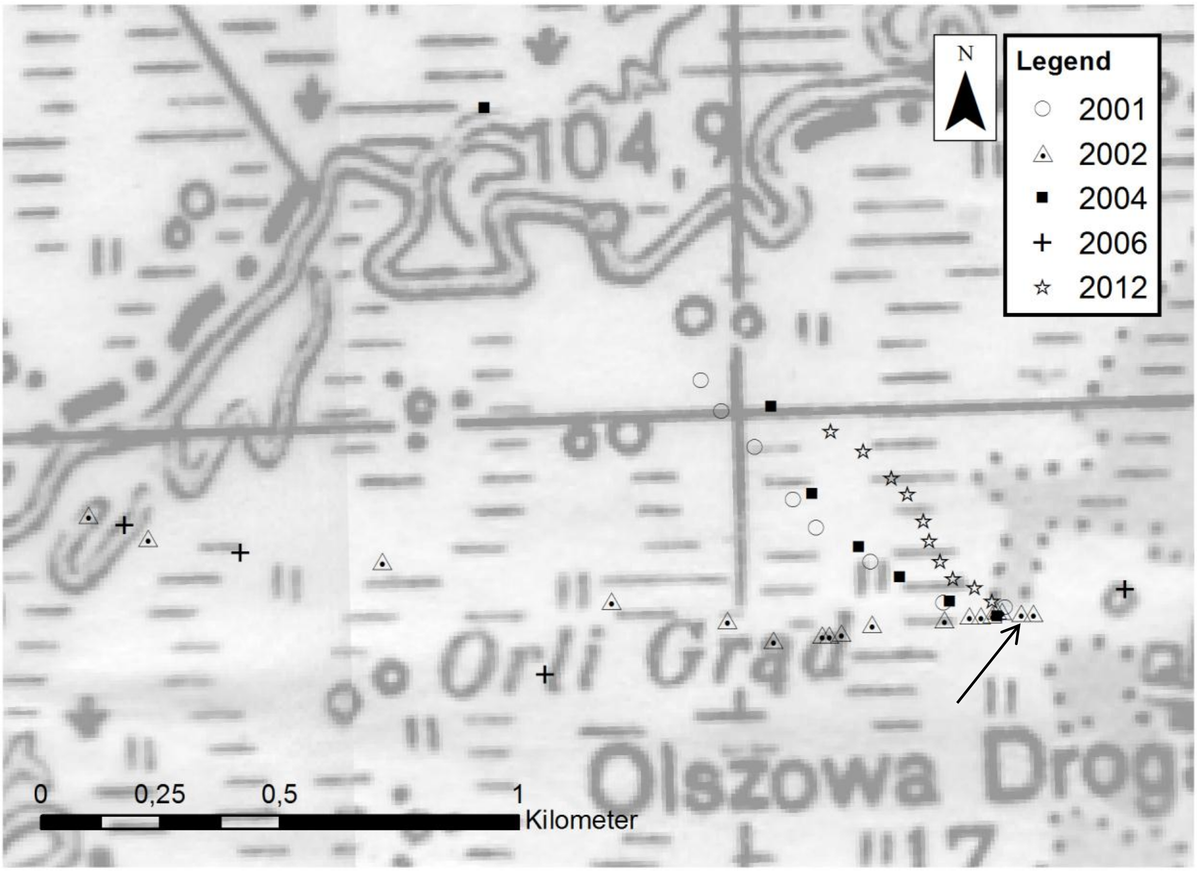

Fig. 8. Sampling points of the river water dynamics zone for 2001-2012 near Olszowa Droga in the Biebrza Lower Basin. The 2010 sampling point is located at the right side of the map, above the village and is the same as one of the sampling points of 2006. The eastern boundary of the alder forest where distance = 0 in Fig. 9 is indicated with an arrow.

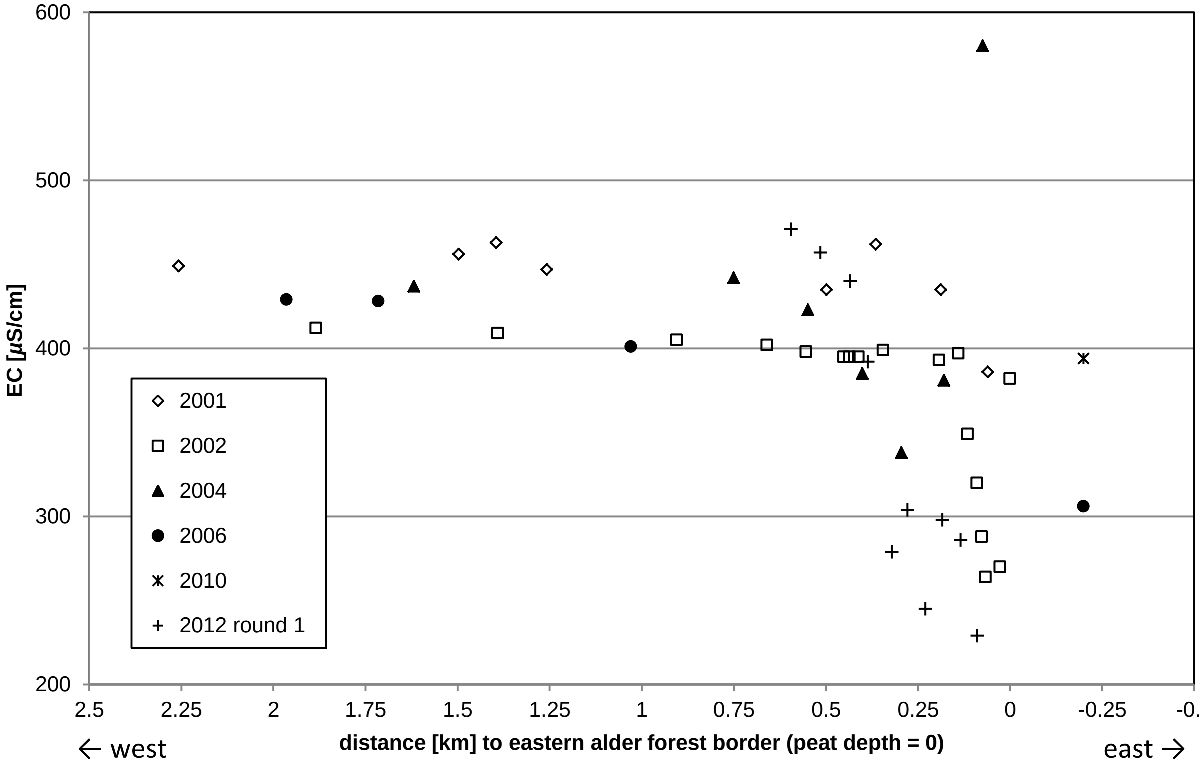

Fig. 9. EC values of the Olszowa Droga transect for the years 2001, 2002, 2004, 2006, 2010 and first round of 2012. Distance is taken from the start of the transect at the eastern alder forest boundary where peat depth is 0 (see also Fig. 4). For sample locations, see Fig. 8.

Rainwater – groundwater dynamics near Szorce

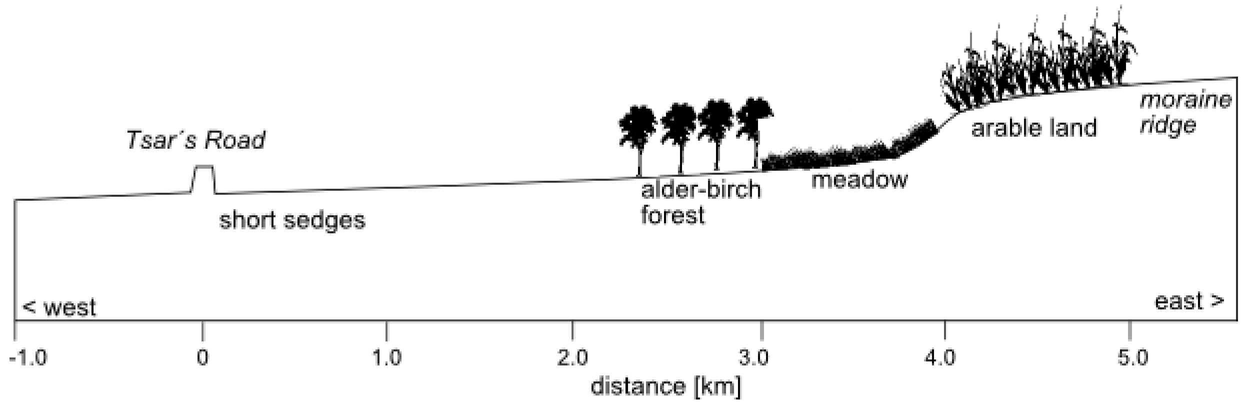

Fig. 10. Schematic cross-section of the Szorce transect in the Biebrza Lower Basin with land cover indicated. Distance is taken from the Tsar's Road (see also Fig. 11).

A schematic cross-section of the Szorce transect is given in Figure 10. Higher values for EC are found close to the moraine ridge (Fig. 12). Here, variation within and between years is also higher than closer to the Tsar's Road. Higher EC values at 2.2 km (> 500 μS/cm) that were observed in 2012 are not that pronounced in other years. Although for 2005 the highest value in the transect is measured at the same location. The year 2002 shows very little variation over the transect and overall the lowest values (mean 285 μS/cm, σ 65 μS/cm), other years have higher EC values (2001: 305 +/-

79 μS/cm; 2004: 308 +/- 45 μS/cm; 2005: 302 +/- 49 μS/cm; 2012: 402 +/- 65 μS/cm). 2001 has the highest within-year variation.

Groundwater influence in the surface water can be observed in high calcium concentrations in the surface water. Calcium decreases from 85 mg/L at the moraine ridge to 34 mg/L near the Tsar's Road in 2001. In 2002, calcium decreases from 75 mg/L at the moraine ridge to 30 mg/L near the Tsar's Road. For 2012, highest calcium values do not occur at the moraine ridge, but at 2.2 km, after which concentrations decrease from 66 mg/L to 34 mg/L near the Tsar's Road.

Close to the road on the western downstream side, concentrations of groundwater influenced EC, calcium and magnesium show more variability than on the eastern upstream side. For all analyzed years combined, EC values on the western side of the Tsar's Road ranged from 197 to 608 μS/cm with also large differences within years between sampling points over a distance of 600 m. Close to the road, all years (except 2012 for which no sample was taken close to the road) show values that deviate (EC > 300 μS/cm) from the decreasing trend riverwards (Fig. 12). For 2002, increased EC is the result of extremely high concentrations of potassium (27 mg/L) and chloride (33 mg/L). Calcium and magnesium followed the decreasing trend riverwards for this year.

Summarizing, for large parts of the Szorce transect variation in EC over the analyzed years is less than 50 μS/cm. Only between 0.00 and -0.25 km, close to the Tsar's Road on the western side and between 2.00 and 2.80 km, close to the moraine variation in EC is higher than 50 μS/cm. High values at 2.00-2.80 km are the result of high values measured in 2012. Higher EC, pH, alkalinity, calcium, magnesium and iron values of the shallow groundwater and surface water compared to other reaches of the transect proved that these two zones correspond to locations with a groundwater influence in the surface water.

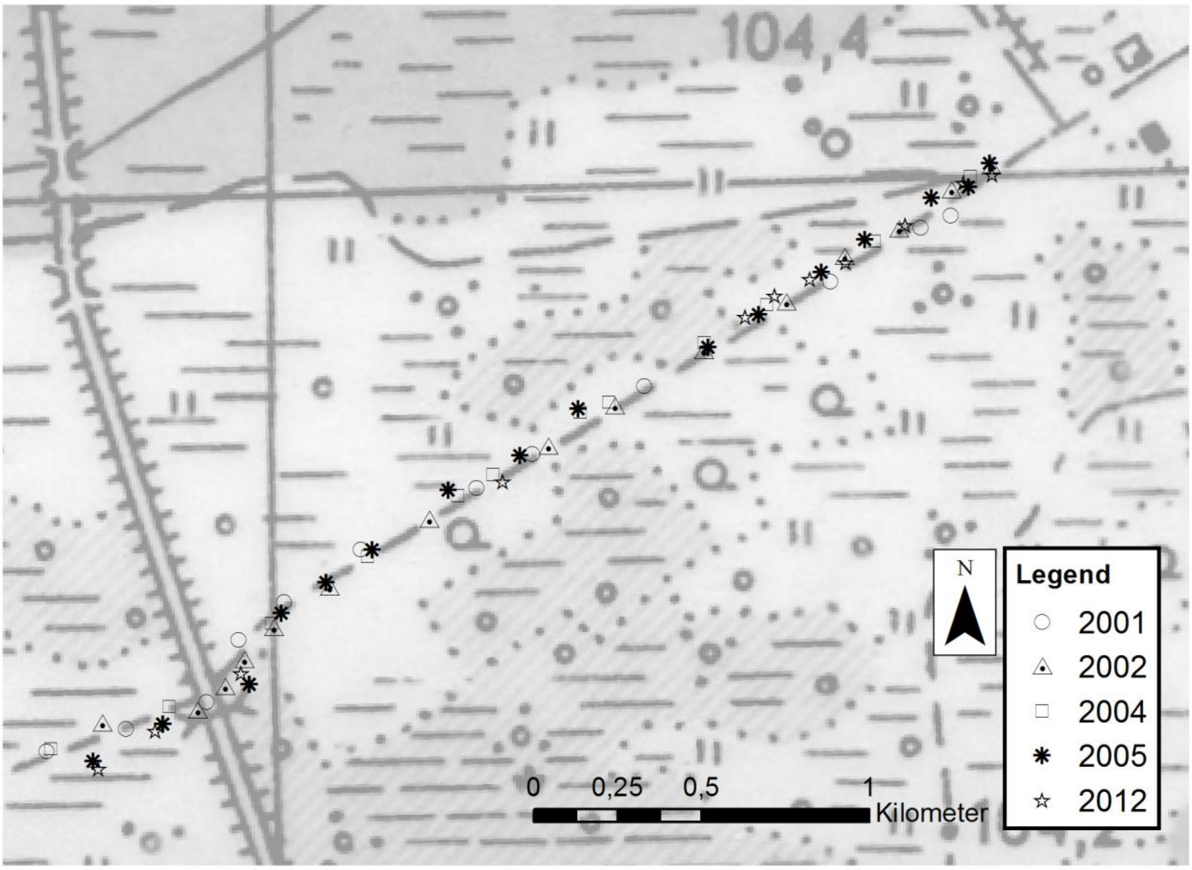

Fig. 11. Sampling points of the rainwater – groundwater dynamics zone for 2001-2012 near Szorce. The road on the western side of the map is taken as distance = 0.

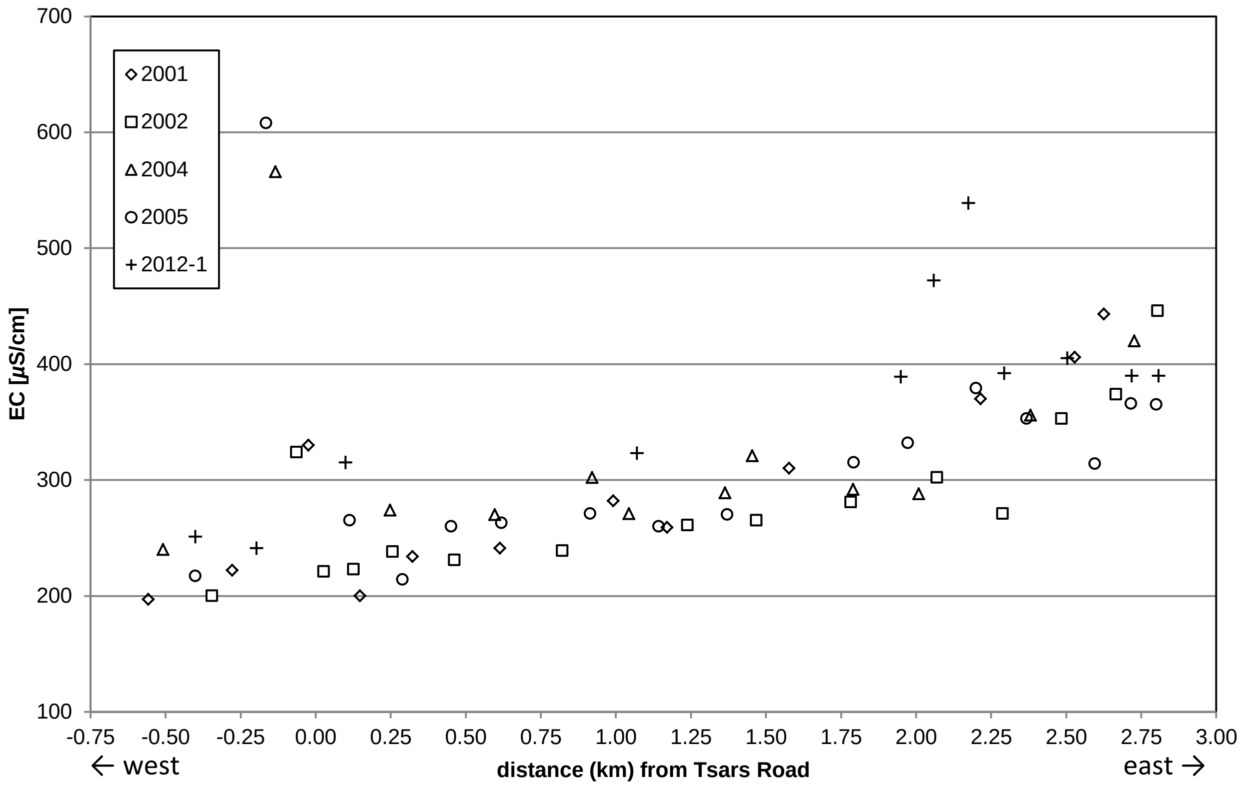

Fig. 12. EC values of the Szorce transect for the years 2001, 2002, 2004, 2005 and first round of 2012. Distance is taken from the start of the transect at the Tsar's Road. At 2.8 km, the valley border with a moraine ridge is located. For sampling locations, see Fig. 11.

5.2 Spring 2012 small scale sampling

5.2.1 Weather conditions for 2012

The spring of 2012 and preceding winter did not have average meteorological conditions. Snow cover was very thin (maximum 5 cm, Mateusz Grygoruk, personal communication) but occurred during an extremely cold period at the end of February. During the sampling campaign, temperatures remained low and night temperatures dropped below zero. Precipitation was little during the first two sampling rounds. During sampling round 2, temperatures were below zero also during the day and combined with precipitation, resulted in some snow to fall. Only between sampling round 2 and 3 did substantial precipitation occur. During the last sampling round, temperatures increased to values around and above 20°C and even 30°C was reached, which was abnormally hot for the time of the year.

5.2.2 Orienting sampling campaign and verification after data collection

The orienting EC sampling campaign showed gradients in EC (Fig. 13). The Grobla Honczarowska transect showed too much unexpected variation and was excluded from further investigation. In Olszowa Droga, two transects were researched and the transect where river water was observed was taken for further analysis. The Barwik and Gugny transects showed high variation closer to the river, where even a rainwater zone was observed.

Much variation was observed close to the river dunes and the moraine ridge. Therefore, in these locations, sampling points intended for repeated sampling were placed closer together than in other reaches of the transects.

Verification of small scale variation in between sampling points for Barwik and Szorce after the fieldwork period showed no extreme variation that was missed because of coarse sampling scale (Fig. 18 and 19). Olszowa Droga and Gugny had sampling scales that were small enough to capture small scale variation, so no check was performed there.

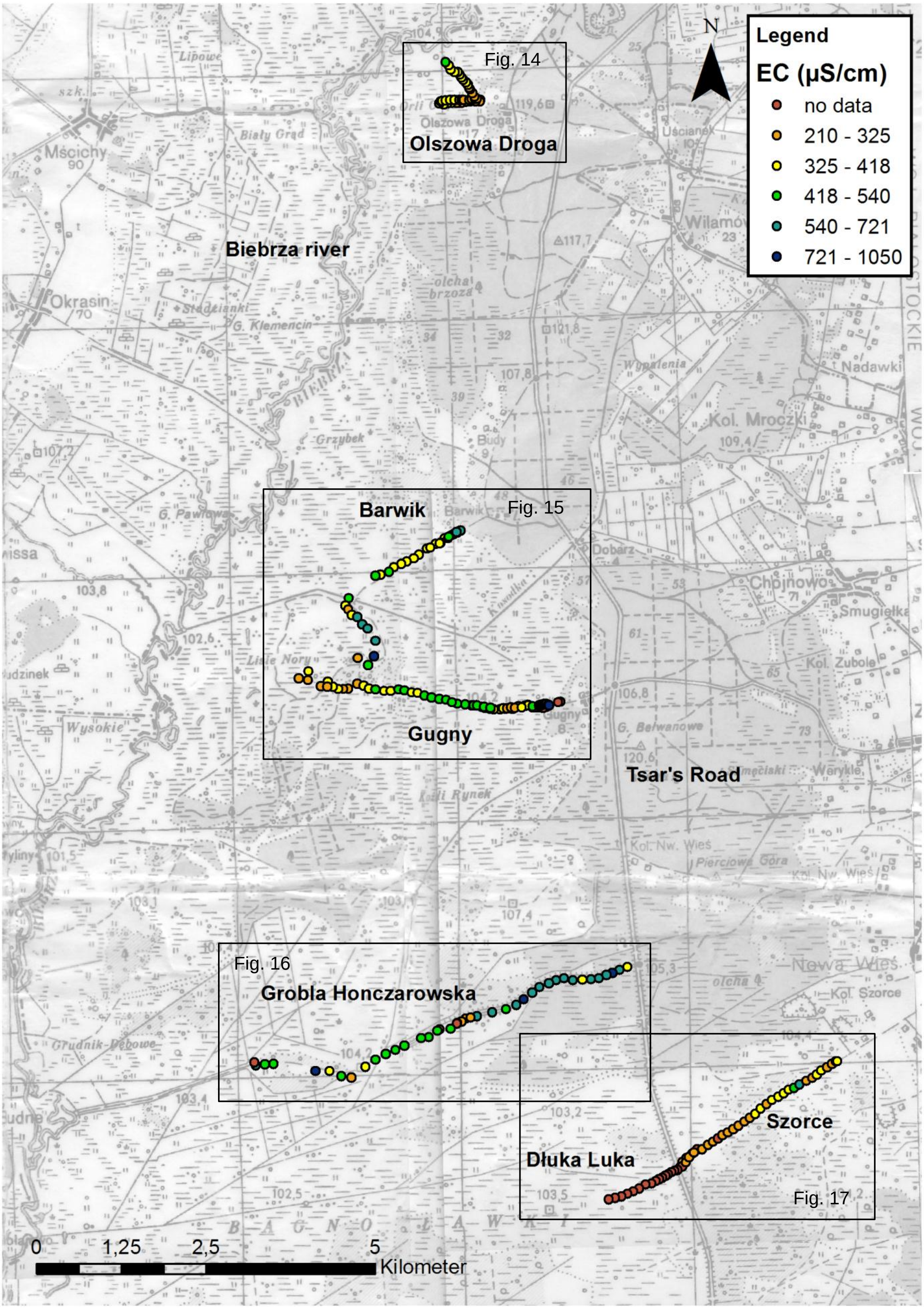

Fig. 13. Electro Conductivity for the points that were sampled during the orienting campaign from 14.03.2012 to 24.03.2012 in the Biebrza Lower Basin. Enlargements of the transects are shown in Fig. 14, 15, 16 and 17.

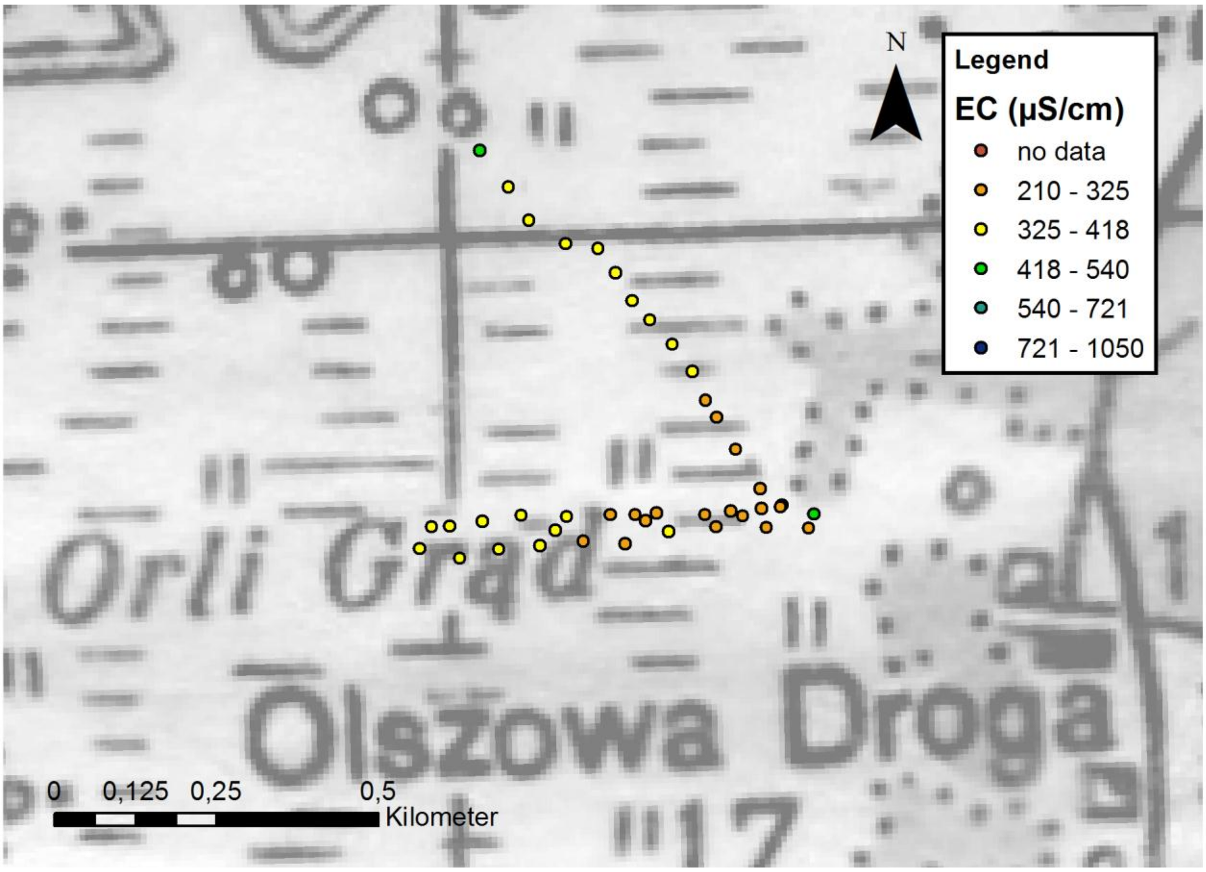

Fig. 14. EC of the sampling points of the orienting sampling campaign near Olszowa Droga. For overview map, see Fig. 13.

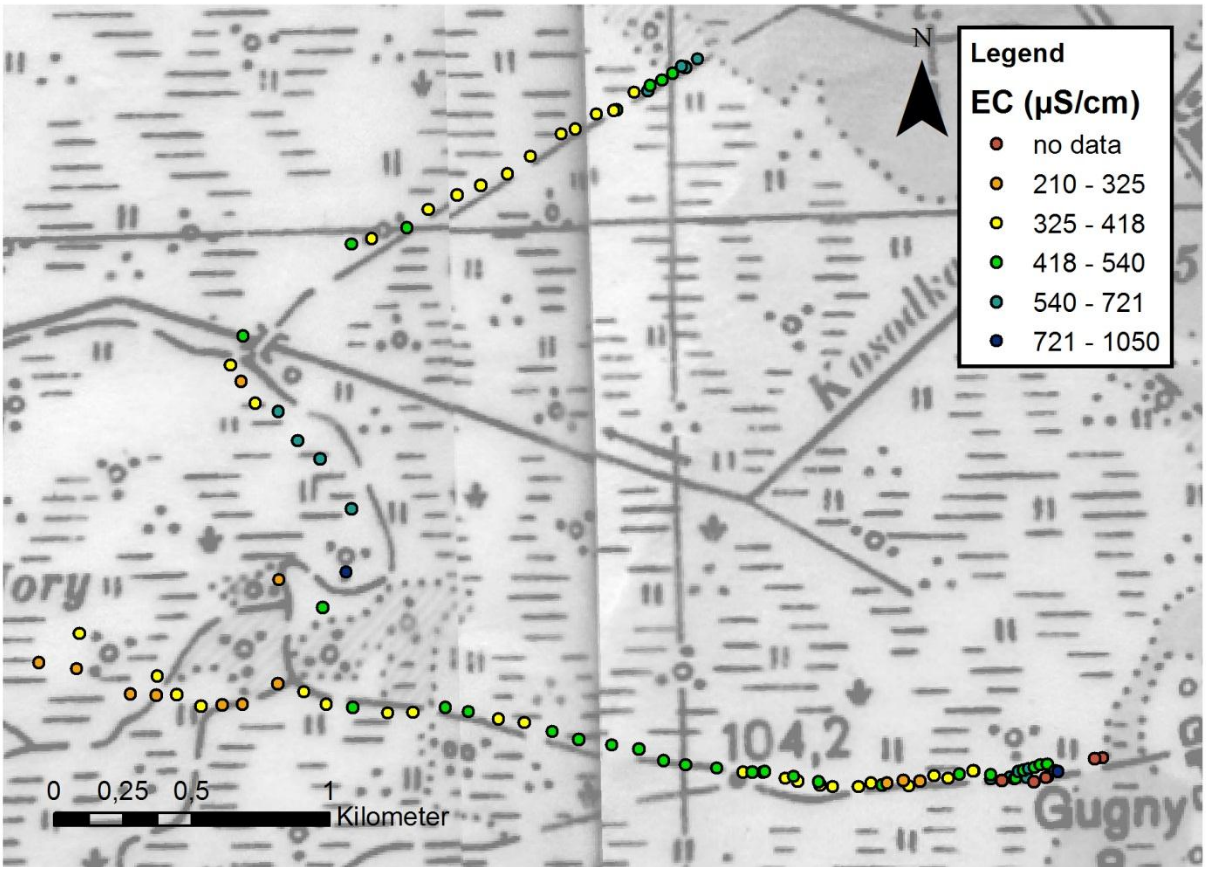

Fig. 15. EC of the sampling points of the orienting sampling campaign near Barwik and Gugny. For overview map, see Fig. 13.

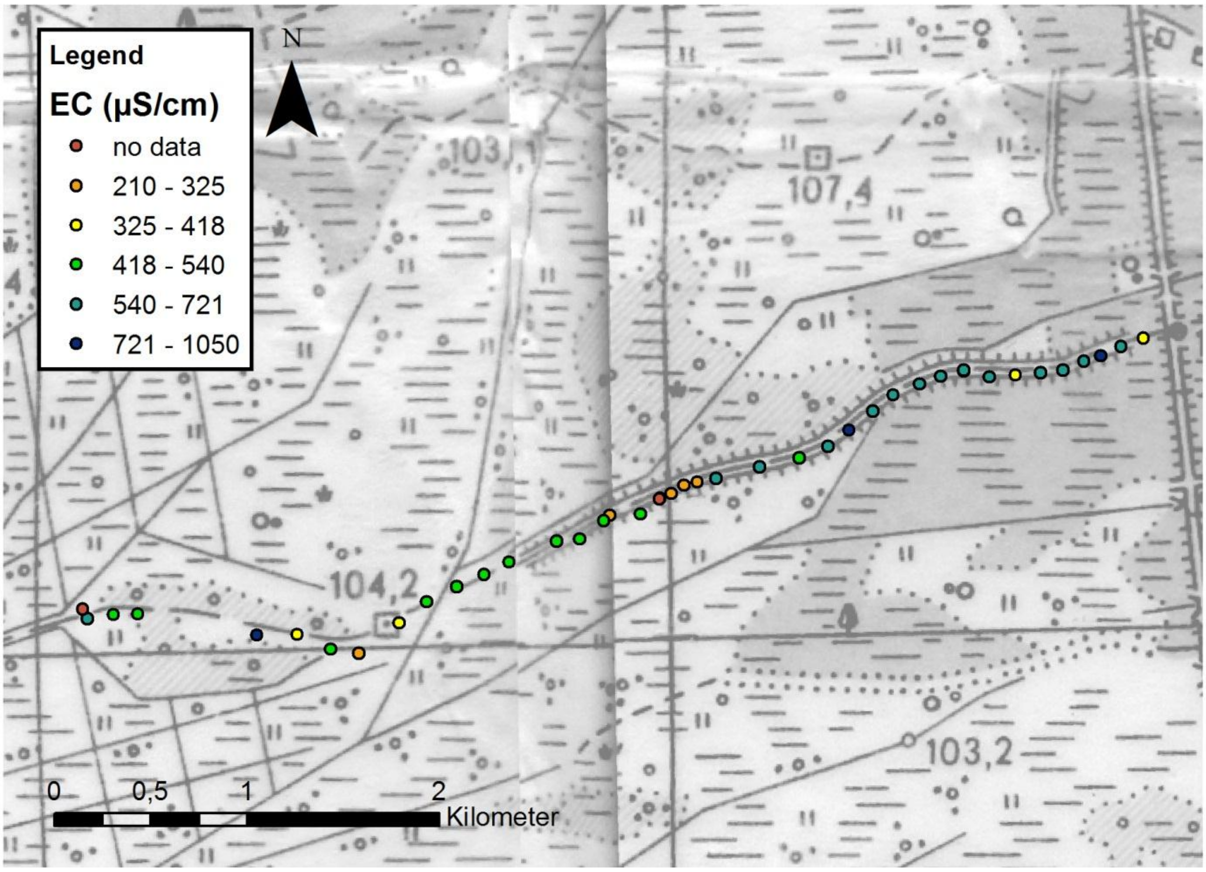

Fig. 16. EC of the sampling points of the orienting sampling campaign at Grobla Honczarowska. For overview map, see Fig. 13.

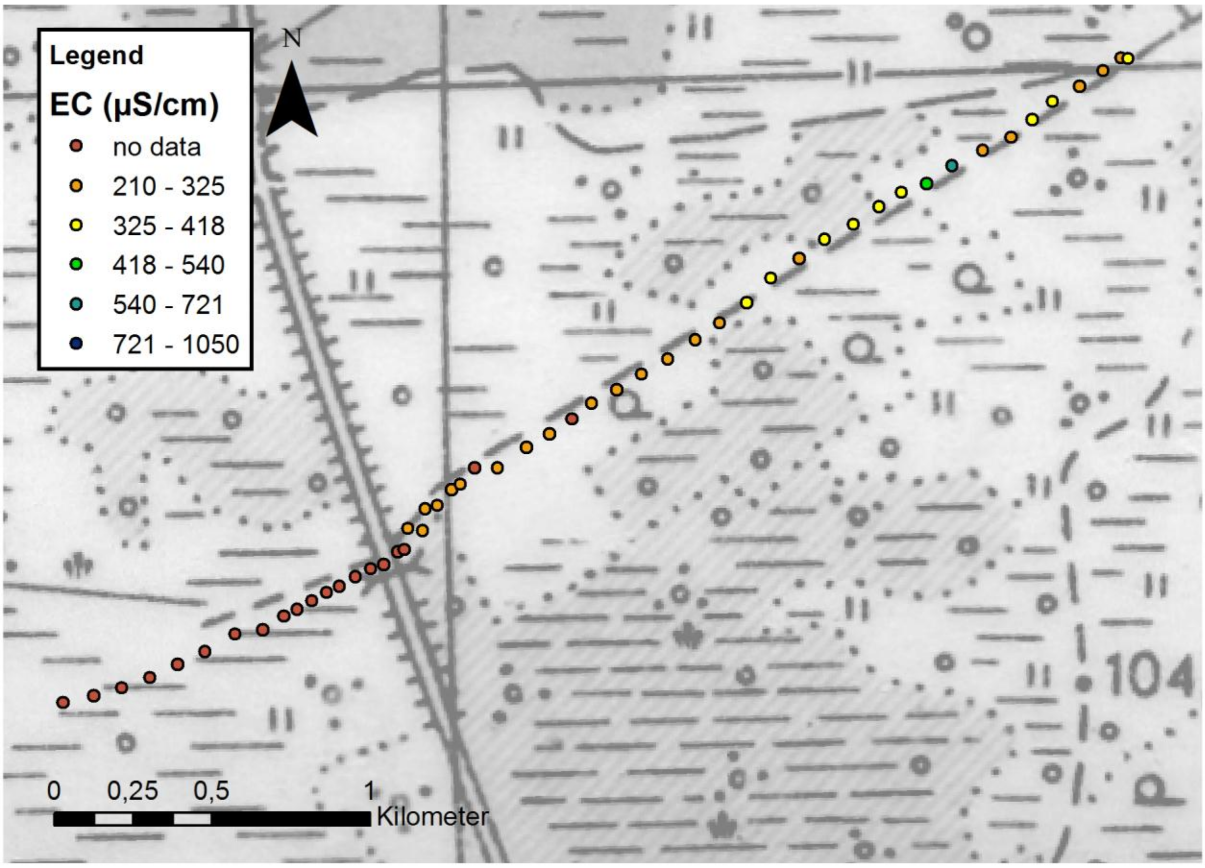

Fig. 17. EC of the sampling points of the orienting sampling campaign near Szorce. For overview map, see Fig. 13.

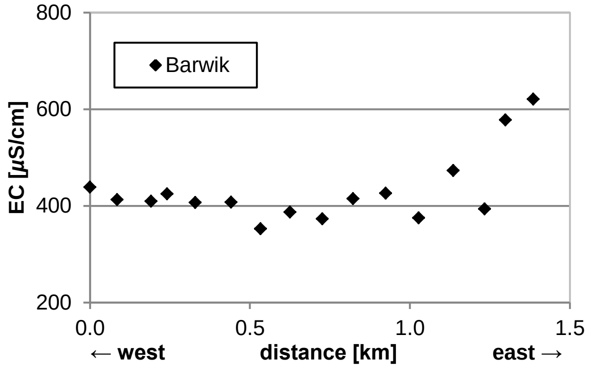

Fig. 18. EC of Barwik transect after the fieldwork period (03.05.2012) to verify variation in EC in between sampling points. Distance is taken eastwards from the western end of the transect. For transect location, see Fig. 2.

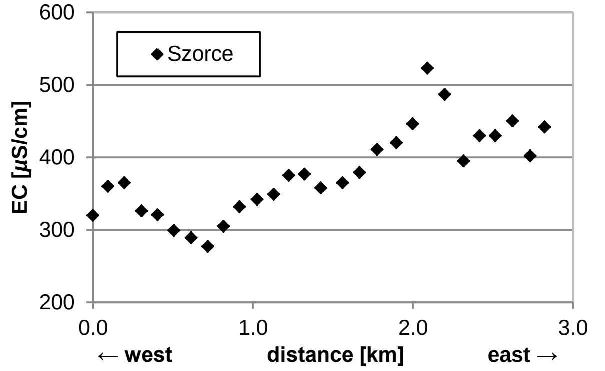

Fig. 19. EC of Szorce transect after the fieldwork period (04.05.2012) to verify variation in EC in between sampling points. Distance is taken eastwards from the Tsar's Road. For transect location, see Fig. 2.

5.2.3 Water depth

Change in water depth between the four sampling rounds is shown in Figure 20. For reference, initial water depth (round 1) is shown in Table 3.

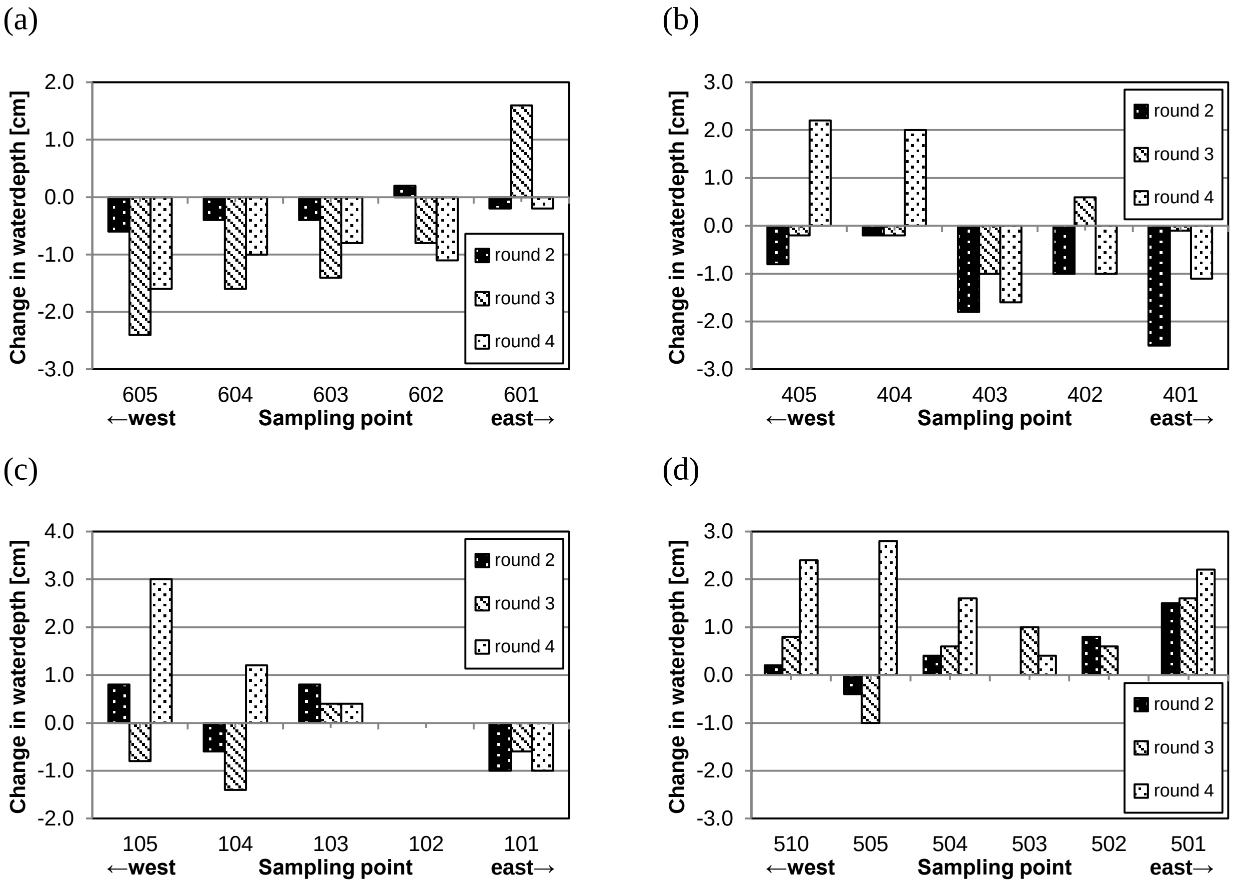

Fig. 20. Change in water depth for the transects Olszowa Droga (a), Barwik (b), Gugny (c) and Szorce (d). The difference in water depth is given for each sampling round compared to the water depth for the previous round. Sample locations are shown in Figure 2. Initial water depths shown in Table 3. Approximate directions of the transects are indicated with W and E.

Table 3. Initial water depth in sampling round 1. All values are positive, indicating that in all cases there was standing surface water. Sampling dates are 03.04.2012 (Gugny and Szorce), 05.04.2012 (Barwik), and 31.03.2012 (Olszowa Droga).

Gugny		Barwik		Szorce		Olszowa Droga	
Sample point	Water depth (cm)	Sample point	Water depth (cm)	Sample point	Water depth (cm)	Sample point	Water depth (cm)
101	6.0	401	21.7	501	11.4	601	6.4
102	6.4	402	11.4	502	11.2	602	13.4
103	7.0	403	17.2	503	10.0	603	19.6
104	8.8	404	22.2	504	7.4	604	32.4
105	25.4	405	26.4	505	24.0	605	42.8
				510	14.6		

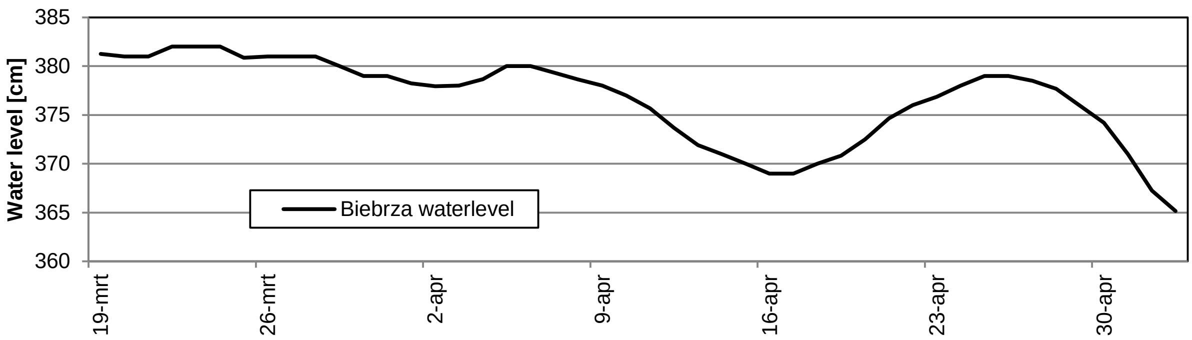

Fig. 21. Water level of the Biebrza river for the period before and during the spring 2012 fieldwork. Water levels are measured at the railway bridge near Osowiec, upstream of Rudzki canal.

The Olszowa Droga, Barwik and Gugny transects all end in the zone which can be covered with river water in spring. In these transects, sampling points located more close to the river show higher fluctuation in water level, most clear in sampling round 4 (Fig. 20). In round 3, water level at sampling points closer to the dune increases while at points closer to the river it decreases, remains stable or gets only slightly higher. Round 2 shows no clear pattern, although water levels decrease in general for Olszowa Droga and Barwik. The Szorce transect ends in the zone which is never covered with river water and is not under influence of fluctuations in river water. Water levels here show no clear pattern, but in the middle of the transect, water levels are most stable of all sampling points.

In Olszowa Droga, the three points closest to the river show similar trends over time, with increasing amplitude closer to the river. Close to the dune, water level is stable, except for a sharp peak in round 3. In Barwik, the two points closest to the river show similar trends: relatively stable with a sharp increase in round 4. The other points show more stable water levels, water level close to the dune fluctuated most. In Gugny, water levels close to the dune are more stable, at the other end of the transect they fluctuate with a sharp increase in round 4, similar to Barwik. In Szorce, water levels increase close to the moraine ridge, on the west side (downstream) of the Tsar's Road and in the middle of the transect. Water levels decrease at the eastside of the transect, but peak sharply in round 4 here. Between the moraine ridge and the middle of the transect, water levels follow similar trends; highest in round 2 or 3 and lower in round 4.

Comparing the transect water depths to water level of the Biebrza river at Osowiec (Fig. 21), there is only a relation between the water level at Osowiec and the water depth at Olszowa Droga for the first three rounds. Water depth closer to the river decreases, which is in accordance with lower water levels at Osowiec.

5.2.4 Water types in the transects

The transects were divided in sections (influence of river water, rainwater, groundwater, pollution or mixing, Fig. 22, 23, 24 and 25). They showed different trends in surface water chemistry. Mean values and standard deviations of measured variables are shown in Table 4, 5, 6 and 7. River water was only observed in one section (Olszowa Droga: section O-1). Rainwater was observed in all transects: O-2/O-3, B-2, G-2 and S-1/S-2. Groundwater was observed in Barwik (B-3), Gugny (G-1, G-3) and Szorce (S-3/S-4). Pollution was observed in all transects: O-3, B-3, G-1/G-3 and S-4. Mixing zones were observed in Barwik (B-2), Gugny (G-2) and Szorce (S-2).

Fig. 22. Transect Olszowa Droga sampling points and sections. Mean and standard deviations of sections O-1, O-2 and O-3 are given in Table 4.

Table 4. Mean and standard deviation of measured variables for Olszowa Droga, grouped according to the sections. High values are given in bold; low values in italic. EC values in μS/cm, pH (-), alkalinity in mg HCO_3/l, temperature of the upper 50 cm below the water surface in °C, all other values in mg/l. Significant difference between groups given: *** $p \leq 0.01$, ** $p \leq 0.05$, * $p \leq 0.10$.

	Mean					Standard deviation		
Variable	O-1 (n=15)	sig.	O-2 (n=13)	sig.	O-3 (n=11)	O-1	O-2	O-3
EC	**430**	***	258		*241*	32.2	32.6	31.9
pH	**7.30**	***	7.05	***	*6.68*	0.07	0.14	0.26
Alkalinity	**231.86**	***	140.95	**	*122.64*	23.19	15.86	21.36
Ca^{2+}	**51.79**	***	34.03		*30.59*	8.51	6.36	6.12
Mg^{2+}	**18.06**	***	9.40	***	*7.16*	3.23	2.06	1.57
K^{+}	**1.85**	***	*0.57*		0.85	0.93	0.42	0.65
Fe^{2+}	*0.17*		0.22		**0.42**	0.12	0.10	0.50
PO_4^{3-}	0.02		*0.00*	***	0.01	0.03	0.00	0.02
SO_4^{2-}	**11.35**	***	2.15		*1.81*	4.66	1.67	1.05
Cl^{-}	8.51	***	*4.20*	***	8.48	1.56	2.30	2.50
Fl^{-}	**0.20**	**	0.16		0.16	0.07	0.05	0.06
Na^{+}	**6.42**	***	*3.40*	***	4.39	1.49	1.00	0.88
Li^{+}	0.00	***	0.00		0.00	0.00	0.00	0.00
Br^{-}	0.00		0.00		0.00	0.00	0.00	0.00
Inorganic-N	**0.21**	**	*0.15*	**	0.18	0.09	0.06	0.08
T(50cm) 1	**1.81**	***	*0.66*		1.16	1.04	0.93	1.21
T(50cm) 2	**9.54**	***	7.02	***	*4.74*	1.31	1.54	1.60

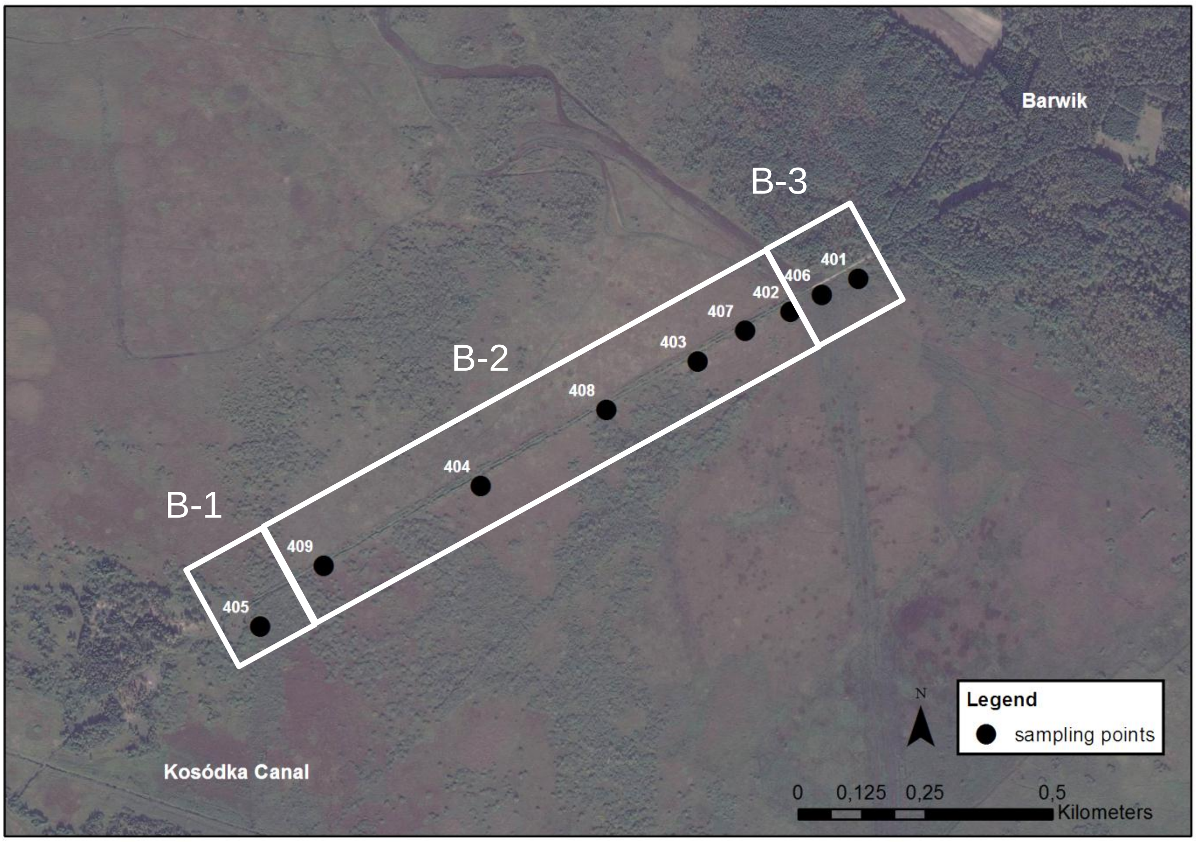

Fig. 23. Transect Barwik sampling points and sections. Mean and standard deviations of sections B-1, B-2 and B-3 are given in Table 5.

Table 5. Mean and standard deviation of measured variables for Barwik, grouped according to the sections. High values are given in bold; low values in italic. EC values in μS/cm, pH (-), alkalinity in mg HCO_3/l, temperature of the upper 50 cm below the water surface in °C, all other values in mg/l. Significant difference between groups given: *** $p \leq 0.01$, ** $p \leq 0.05$, * $p \leq 0.10$.

	Mean					Standard deviation		
Variable	B-1 (n=4)	sig.	B-2 (n=24)	sig.	B-3 (n=8)	B-1	B-2	B-3
EC	429	***	*369*	***	**619**	26.4	55.5	177.3
pH	**7.27**	**	*7.11*		7.20	0.08	0.15	0.17
Alkalinity	259.32	***	*200.14*	***	**343.15**	31.73	36.00	68.95
Ca^{2+}	58.75	***	*48.92*	***	**87.65**	7.70	5.30	13.63
Mg^{2+}	18.05	***	*10.77*	***	**20.75**	3.04	1.72	2.96
K^+	0.73		*0.70*	***	**3.12**	0.24	0.74	1.33
Fe^{2+}	*0.18*	**	1.40	*	**1.59**	0.10	2.35	1.07
PO_4^{3-}	*0.01*	***	0.19		**0.27**	0.00	0.43	0.39
SO_4^{2-}	**1.67**		1.24		*0.82*	1.04	1.02	0.76
Cl^-	*4.89*		5.29	*	**5.95**	0.68	0.95	1.09
Fl^-	0.23		*0.22*	*	**0.27**	0.04	0.07	0.08
Na^+	*5.23*	*	6.37	**	**7.41**	1.15	1.06	1.21
Li^+	0.00		0.00		0.00	0.00	0.00	0.00
Br^-	0.02		*0.01*	**	0.02	0.02	0.03	0.02
Inorganic-N	*0.18*		0.20	***	**0.54**	0.10	0.11	0.39
T(50cm) 1	**3.05**	***	*1.69*	***	2.85	0.17	0.53	0.68
T(50cm) 2	**6.25**	***	*2.64*	**	4.15	1.13	1.23	1.92

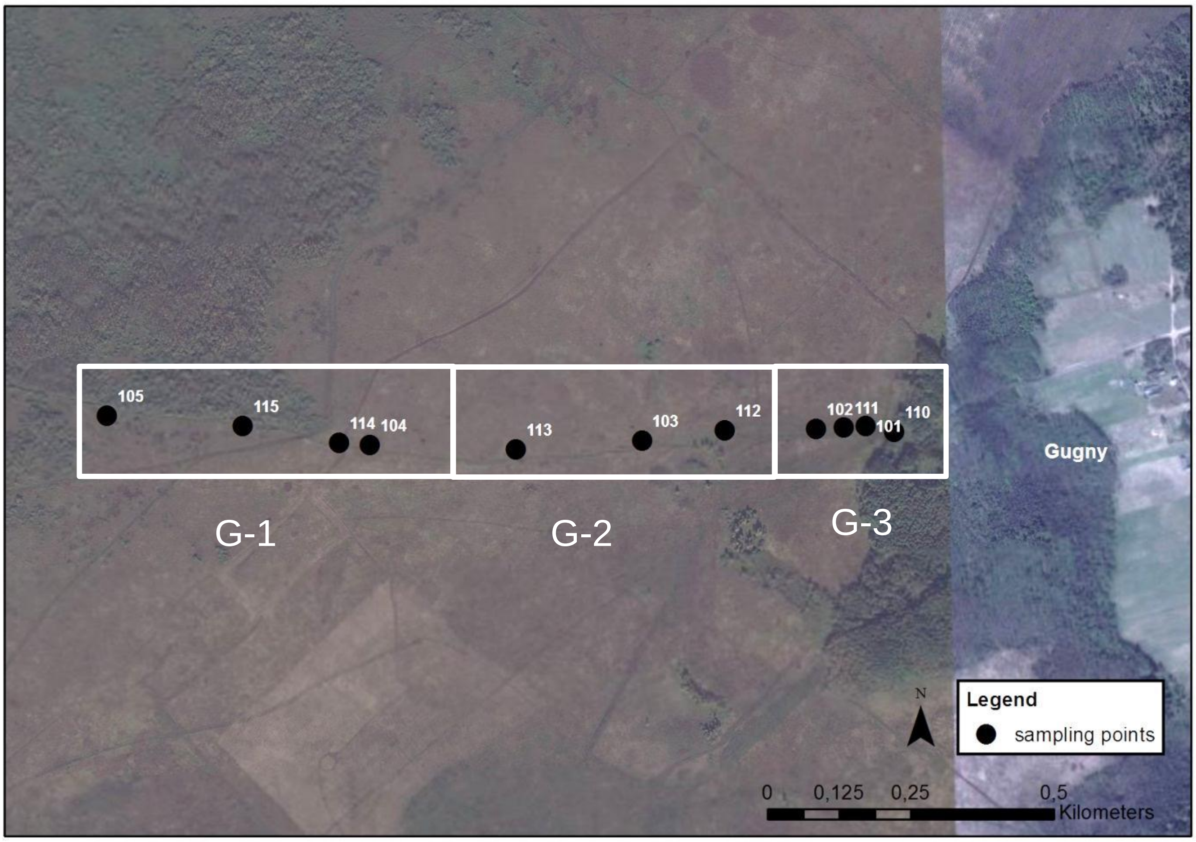

Fig. 24. Transect Gugny sampling points and sections. Mean and standard deviations of sections G-1, G-2 and G-3 are given in Table 6.

Table 6. Mean and standard deviation of measured variables for Gugny, grouped according to the sections. High values are given in bold; low values in italic. EC values in μS/cm, pH (-), alkalinity in mg HCO_3/l, temperature of the upper 50 cm below the water surface in °C, all other values in mg/l. Significant difference between groups given: *** $p \leq 0.01$, ** $p \leq 0.05$, * $p \leq 0.10$.

	Mean					Standard deviation		
Variable	G-1 (n=16)	sig.	G-2 (n=12)	sig.	G-3 (n=16)	G-1	G-2	G-3
EC	504	***	*427*	***	**654**	40.1	30.1	121.0
pH	**7.47**	*	7.43		*7.31*	0.10	0.11	0.23
Alkalinity	297.76	***	*245.90*	***	**355.73**	33.56	17.08	53.69
Ca^{2+}	67.30	***	*62.68*	*	**93.02**	8.96	9.11	13.87
Mg^{2+}	**23.16**		15.10	***	*14.78*	3.27	2.33	2.71
K^{+}	**1.23**	**	*0.19*	***	0.69	0.34	0.13	0.68
Fe^{2+}	0.41	***	0.41		**6.50**	0.54	0.37	9.66
PO_4^{3-}	0.02	**	0.02		**0.08**	0.02	0.03	0.15
SO_4^{2-}	*4.62*		5.10		**7.78**	6.05	10.36	19.43
Cl^{-}	5.66	***	*3.64*	***	**7.29**	1.70	0.95	2.61
Fl^{-}	0.30	***	*0.22*	***	0.29	0.07	0.06	0.06
Na^{+}	**7.61**	*	*5.98*	***	6.26	1.41	1.17	0.66
Li^{+}	0.01	**	0.01	**	0.01	0.00	0.01	0.02
Br^{-}	0.02	*	*0.01*		**0.03**	0.03	0.01	0.04
Inorganic-N	**0.18**		0.22		0.35	0.10	0.13	0.29
T(50cm) 1	2.84	***	1.68	***	4.20	0.66	0.36	0.36
T(50cm) 2	3.32	**	2.07	***	4.70	1.50	1.26	0.56

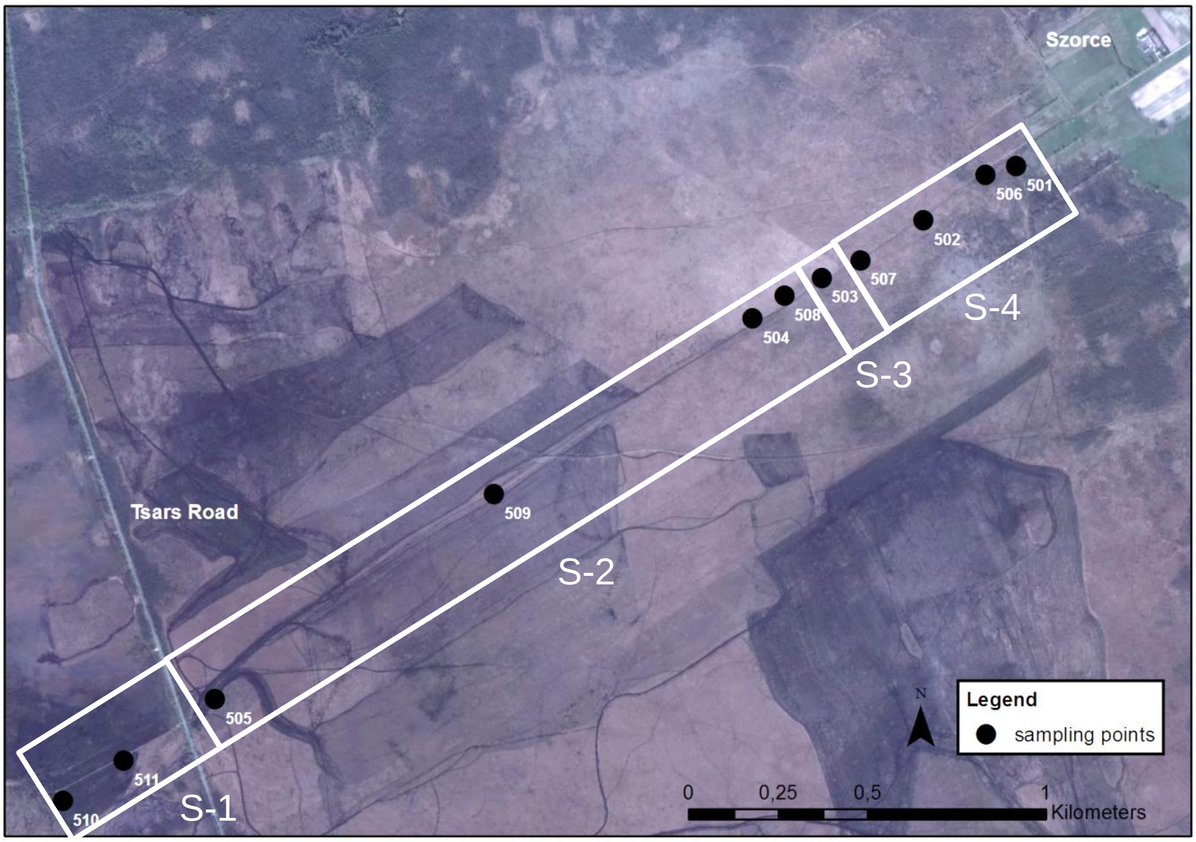

Fig. 25. Transect Szorce sampling points and sections. Mean and standard deviations of sections S-1, S-2, S-4 and S-4 are given in Table 7.

Table 7. Mean and standard deviation of measured variables for Szorce, grouped according to the sections. High values are given in bold; low values in italic. EC values in μS/cm, pH (-), alkalinity in mg HCO_3/l, temperature of the upper 50 cm below the water surface in °C, all other values in mg/l. Significant difference between groups given: *** $p \leq 0.01$, ** $p \leq 0.05$, * $p \leq 0.10$.

	Mean							Standard deviation			
Variables	S-1 (n=8)	sig.	S-2 (n=16)	sig.	S-3 (n=4)	sig.	S-4 (n=16)	S-1	S-2	S-3	S-4
EC	*268*	***	354	***	**496**	**	389	30.3	52.3	74.6	38.1
pH	7.21		7.18		*7.11*	*	**7.23**	0.08	0.08	0.15	0.13
Alkalinity	*137.90*	***	201.97	***	**303.86**	***	208.68	7.93	34.17	15.86	21.97
Ca^{2+}	*29.11*	***	43.42	***	**59.69**	**	47.92	5.07	10.36	10.13	6.89
Mg^{2+}	*15.58*	***	18.76	***	**26.97**	**	19.78	2.19	3.58	5.65	2.81
K^{+}	*1.34*		1.54		**1.94**		1.53	0.35	0.72	0.66	0.60
Fe^{2+}	0.13		0.44	***	**5.36**	***	0.13	0.17	0.86	4.70	0.11
PO_4^{3-}	0.01		**0.11**	***	0.02	***	0.01	0.00	0.42	0.01	0.01
SO_4^{2-}	2.41		2.75	***	*0.29*	***	**9.60**	1.09	2.25	0.13	3.70
Cl^{-}	4.80	***	**6.43**	***	*3.37*	***	6.31	0.24	0.96	0.29	0.93
Fl^{-}	*0.18*		0.20		0.20		0.20	0.05	0.07	0.05	0.06
Na^{+}	*2.93*	**	3.50		2.97	**	**3.80**	0.48	0.75	0.80	0.67
Li^{+}	0.00		0.00	***	0.00		0.00	0.00	0.00	0.00	0.00
Br^{-}	0.00		0.00		0.02	*	0.00	0.01	0.01	0.02	0.00
Inorganic-N	*0.12*	**	0.19		0.22		0.22	0.06	0.11	0.11	0.10
T(50cm) 1	2.96	*	3.41		**3.35**	***	*1.66*	0.34	0.74	1.00	0.53
T(50cm) 2	**5.20**		4.93		4.65	**	*3.08*	1.48	1.40	0.72	1.05

River water dynamics
Only in one transect river water was found (O). Therefore, the presented results only apply to the O transect. A sudden decrease in EC, alkalinity, calcium and magnesium (more than a factor two) from the river zone (O-1) into the rainwater zone (O-2) (Fig. 22, Table 4) can be observed between sampling point 609 and 603. The identified river water and rainwater zone are distinguishable in terms of higher values of EC, alkalinity, calcium, magnesium, potassium, chloride, sodium, fluoride and sulphate ($p \leq 0.05$). The distance between sampling points in the reach of the sudden decrease is 50 m, indicating a gradient of maximum length 50 m.

The boundary between river water and rainwater is not stationary, in sampling round 3 the rainwater zone has moved towards the river one sampling point, while in sampling round 4 it receded again one point. Over time, the difference in alkalinity, calcium, magnesium, sulphate, sodium and potassium between the river zone and the rainwater zone reduced; water types were more similar in round 4 than in round 1.

The EC cross-section of Olszowa Droga showed very high values of EC below the peat surface in the river water zone (Fig. 26). This is also reflected in samples below the peat surface here, they belong to groundwater with higher values for EC, pH, alkalinity, calcium, magnesium, potassium, sodium, sulphate and phosphate ($p \leq 0.01$).

The temperature cross-section of Olszowa Droga (Fig. 26) shows remarkable warming of the shallow soil to increasing depths in direction of the river and at one point close to the dune. In round 1 and 2, the upper 50 cm below the water surface of river water zone (O-1) is significantly warmer than the middle reach (O-2) ($p \leq 0.01$). Over time, the soil is heated up to greater depth in section O-2, but most pronounced closer to the river.

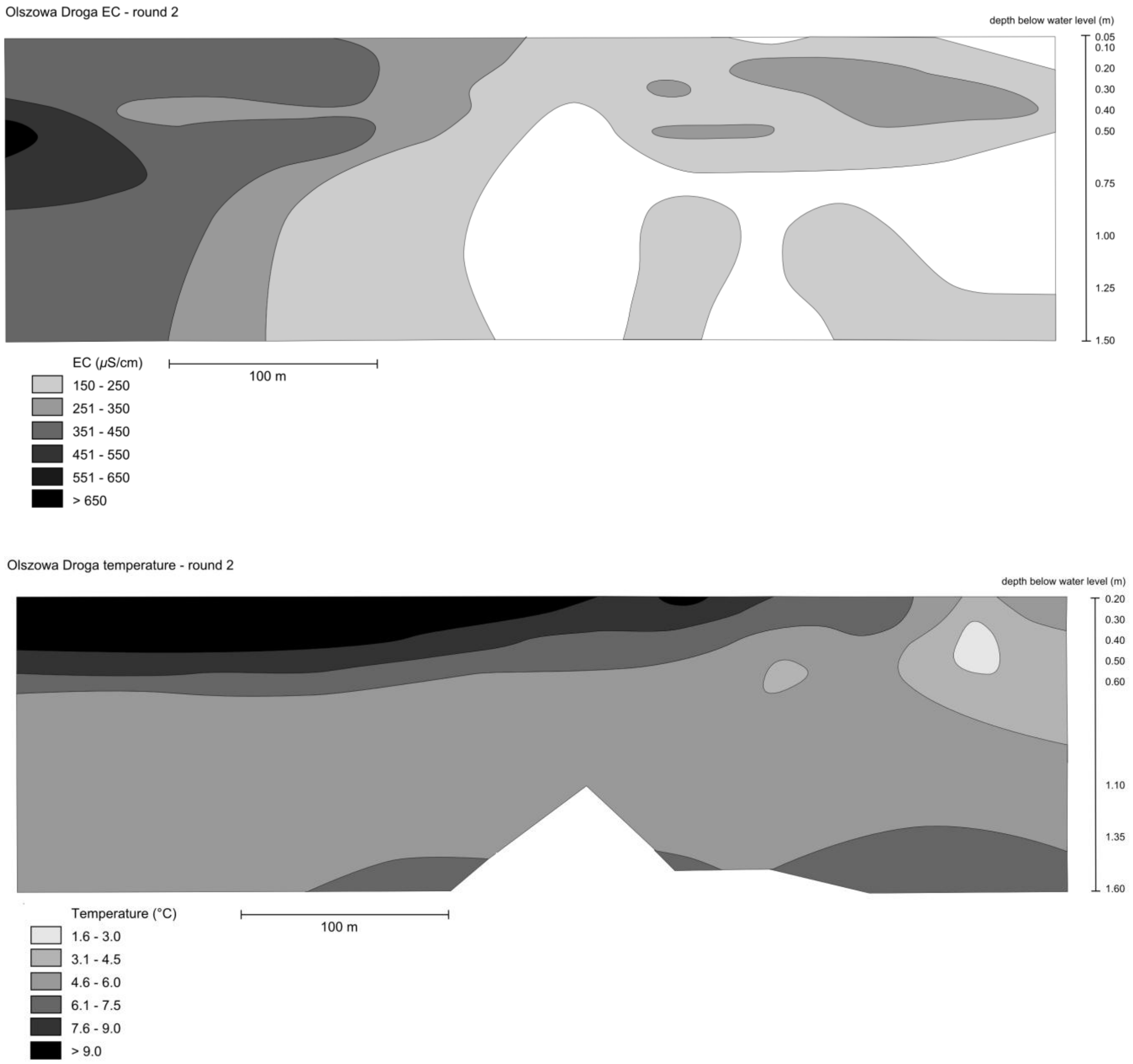

Fig. 26. Cross-section of transect Olszowa Droga (round 2) with interpolated EC (µS/cm) and temperature (°C).

Rainwater dynamics

Clean rainwater was observed at O-2 (Fig. 22), B-1 (Fig. 23), B-2, G-2 (Fig. 24), S-1 (Fig. 25) and S-3. This water is not or only slightly influenced by river water or groundwater. The rain water zone O-2 showed lower values for chloride, sodium, potassium, fluoride and sulphate than the river water zone (O-1) ($p \leq 0.05$). Another zone where clean water was observed, was in the middle of the transects, adjacent to the zones close to the river dunes (O-3, B-3, G-3) or moraine ridge (S-4). Lower values of chloride (transect O-2/G-2/S-1), sodium (O-2/B-2/G-2/S-1), potassium (B-2/G-2), fluoride (G-2), inorganic nitrogen (B-2/S-1) and sulphate (S-1) (all $p \leq 0.05$) were found in the middle zones, next to the zones close to the dunes (O-2/B-2/G-2 compared to O-3/B-3/G-3) or moraine ridge (S-1 compared to S-4).

In round 3, after a period of rain, surface water samples showed lower values for all variables ($p \leq 0.01$) except sodium, lithium and inorganic nitrogen compared to round 2. Round 2 showed lower values for calcium, magnesium, potassium, sodium, chloride, inorganic nitrogen and lithium ($p \leq 0.05$) compared to the round 1.

During the same third sampling moment, EC profiles showed lower values in the upper layer below the surface. Samples taken below the peat surface did not indicate sampling round 3 to be significantly lower because for most variables sampling round 4 was even lower than round 3.

Analogously, during sampling round 3 the rainwater zone (O-2) increased in extent at the cost of the river water zone (O-1), this was visible in water quality because of decreasing values.

Temperature profiles showed colder zones in the middle of the transect in Gugny (G-2; Fig. 28) and Barwik (B-2; Fig. 27) and at Olszowa Droga (Fig. 26) and Szorce (Fig. 29) also closer to the dune and moraine ridge respectively. In zones identified as rainwater zones, temperatures in the upper 50 cm below the water surface are much lower than in other zones. Significant colder zones are present in Olszowa Droga (round 1 and 2: $p \leq 0.01$), Barwik (round 1: $p \leq 0.01$; round 2: $p \leq 0.05$), Gugny (round 1: $p \leq 0.01$; round 2: $p \leq 0.05$), Szorce (round 1: $p \leq 0.01$; round 2: $p \leq 0.05$). These zones also remain colder during the sampling campaign. However, in sampling round 4 in all transects the difference between these zones and other zones in temperature has been reduced.

Groundwater dynamics

In EC cross-sections, a very clear distinction can be made between reaches with groundwater from local origin having a relatively low EC and reaches with groundwater from regional origin having a much higher EC. Reaches with groundwater from local origin are found close to the river dunes at Olszowa Droga (O-3; Fig. 26), Barwik (B-3; Fig. 27) and Gugny (G-3; Fig. 28), whereas regional groundwater with high EC is found further away from the dunes below the ground surface (Fig. 26, 27 and 28) and at Szorce closer to the dunes and at one particular point (S-3; see Fig. 29).

Fig. 27. Cross-section of transect Barwik (round 2) with interpolated EC (μS/cm) and temperature (°C).

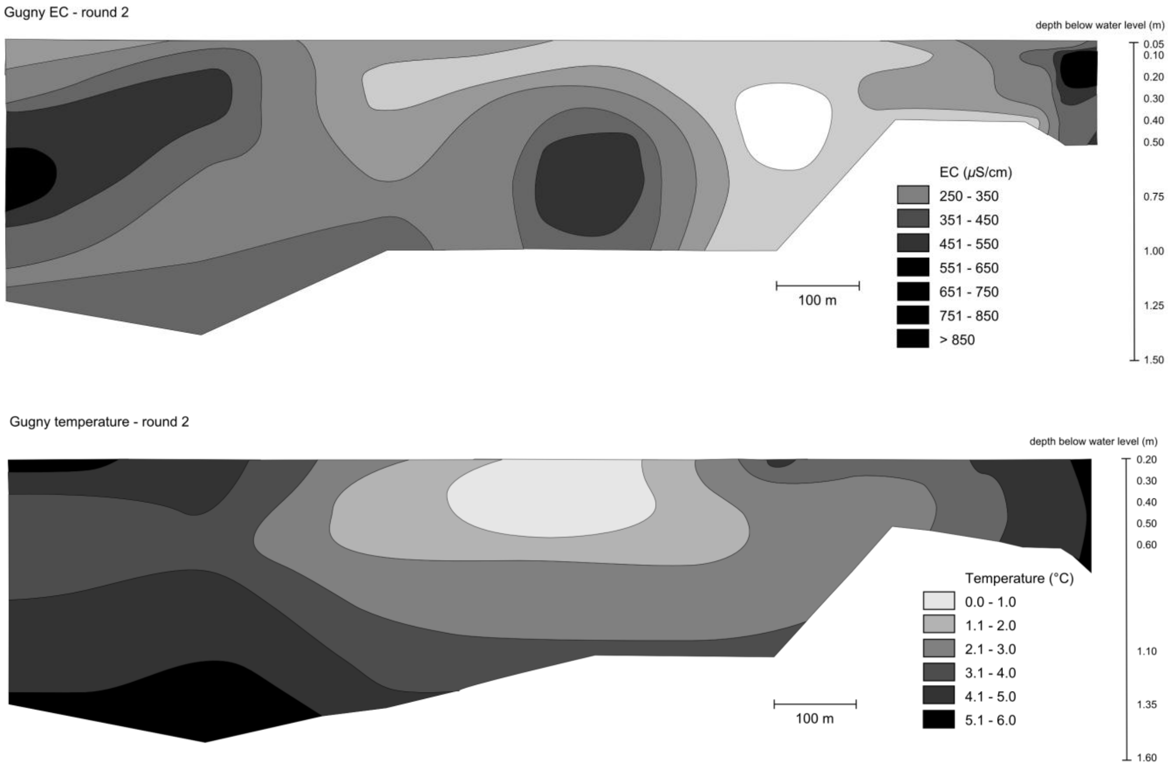

Fig. 28. Cross-section of transect Gugny (round 2) with interpolated EC (µS/cm) and temperature (°C).

Groundwater from local origin reaches the surface in all transects (O-3, B-3, G-3, S-3/S-4) as confirmed by EC profiles (Fig. 26, 27, 28 and 29), increased soil temperature at locations of discharge (Fig. 26, 27, 28 and 29) and more alike groundwater and surface water quality. Regional groundwater on the other hand does not reach the surface and is covered with a different surface water type.

After having reached the surface, local groundwater flows in direction of the river over the surface and in the shallow root zone as confirmed by similarity of groundwater and surface water in these reaches (Barwik: B-2, Szorce: S-2) which have an increase in EC, alkalinity and calcium and are similar in magnesium from sampling round 2 onwards when groundwater starts discharging. In Szorce, on the upstream side of the Tsar's Road, much lower EC in the surface water but also in deeper groundwater is observed. On the other side of the road (S-1), EC in deeper groundwater is much higher and temperatures indicate surface water infiltration in the soil on the upstream side of the Tsar's Road and groundwater upwelling on the downstream side of the Tsar's Road (Fig. 29).

Zones identified as having groundwater discharge or groundwater flow on the surface or in the shallow soil are more stable over time in chemistry than other zones.

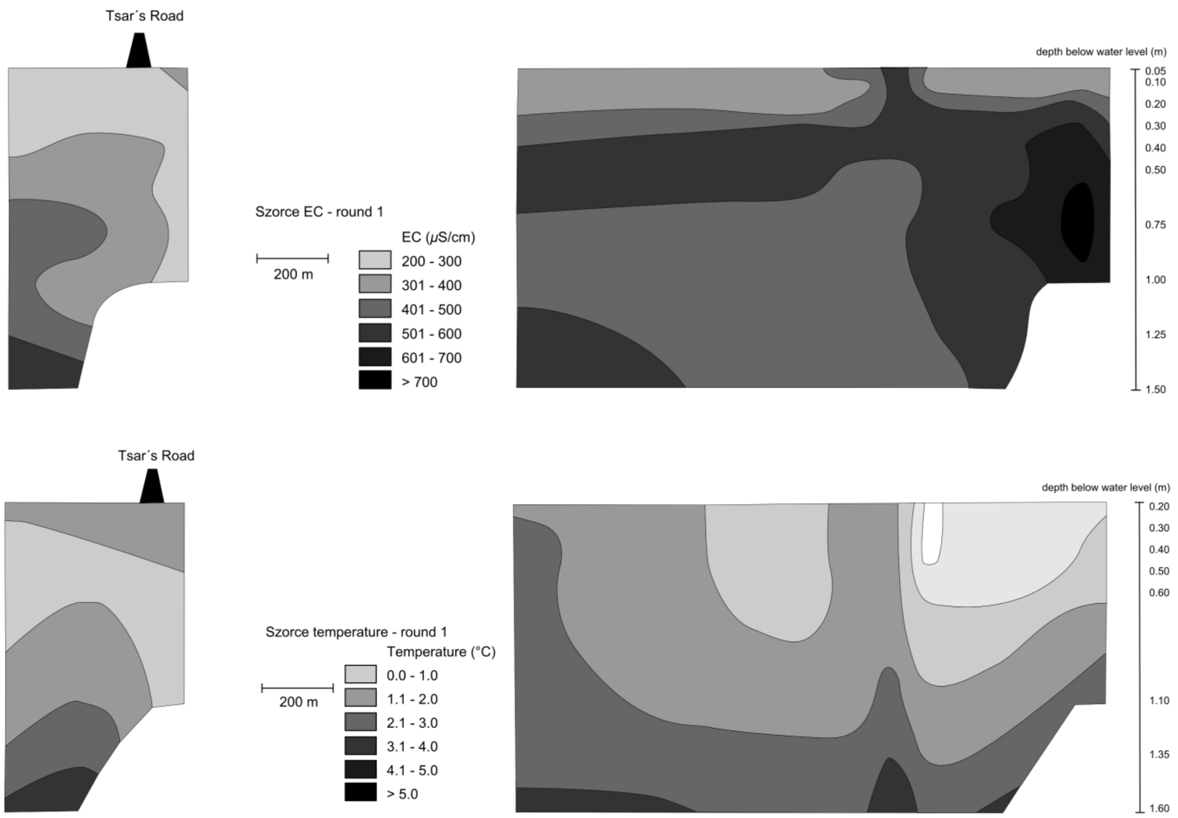

Fig. 29. Cross-section of transect Szorce (round 1) with interpolated EC (μS/cm) and temperature (°C). The transect is split up in two parts because of the large distance between sampling points in the middle reach.

Locations where water samples, EC and temperature cross-sections indicated groundwater discharge are narrow and cover only about 50-100 m of the transect. A section of low EC (Olszowa Droga, Barwik and Gugny) or high EC (Szorce) extends upwards in sampling moment 2 in all cross-sections which indicates the start of a process of upflowing water.

For most locations, groundwater bears very little similarity to surface water. Groundwater of all sampling points combined is significantly higher in terms of EC, alkalinity, pH, calcium, magnesium, lithium, bromide, iron, phosphate and inorganic nitrogen ($p \leq 0.05$). This is most pronounced in the river water zone of Olszowa Droga, and also in Szorce and Barwik where local or regional groundwater discharges, which subsequently flows towards the river over the surface and in the shallow subsurface. This water type is different from the water in the peat. Water on the surface downstream of discharge locations is similar to groundwater at discharge locations. At the Gugny transect groundwater samples are more similar to surface water samples, and higher EC and alkalinity indicate a mixing water type between groundwater and rainwater.

Table 8. Comparison of the hydrochemistry method and the temperature profile method in identification of groundwater discharge. Presence of upwelling groundwater is given for each sampling round at sampling points for the four sampled transects in the Biebrza Lower Basin. Method A is the temperature profile method; method B is surface water sampling and EC profile method.

	round 1		round 2		round 3		round 4	
	method		method		method		method	
Sampling points	A	B	A	B	A	B	A	B
Olszowa Droga								
606	x							
601	x							
Barwik								
402	x	x	x	x	x	x	x	x
407	x	x	x	x	x	x	x	x
Gugny								
101	x	x		x		x		x
111	x	x		x		x		x
102	x							
114		x	x	x	x	x		x
105		x	x	x	x	x		x
Szorce								
501	x	x		x		x		x
506	x	x		x		x		x
503	x	x	x	x	x	x		x
510	x	x	x	x	x	x		x
511	x	x	x	x	x	x		x

Temperature cross-sections have increased soil temperatures in the deeper soil at the following locations (see also Table 8; Fig. 26, 27, 28 and 29):

- Olszowa Droga (round 1: point 606, 601),
- Gugny (round 1: point 101, 111, 102; round 2 and 3: point 114, 105),
- Barwik (all rounds: point 402, 407),
- Szorce (round 1: point 501, 506, 503, 510, 511; round 2 and 3: point 503, 510, 511).

These locations corresponded to the following locations where water samples and EC profiles indicate groundwater discharge:

- Olszowa Droga (not observed in water samples or EC profiles),
- Gugny (all rounds: point 101, 111, 114, 105),
- Barwik (all rounds: point 402, 407),
- Szorce (all rounds: point 501, 506, 503, 510, 511).

In round 1, temperature profiles indicated groundwater discharge at all locations where EC profiles and surface and groundwater also indicated groundwater discharge, except for two points where regional groundwater flowed upwards in the deeper soil (Gugny: 114, 105). In Olszowa Droga, EC profiles and water samples did not show the upwelling of groundwater that was evident from the temperature profiles. Round 2 and 3 are similar when the two methods are compared. In Gugny and Szorce, temperature profiles do not show discharge anymore for points close to the dune or moraine. Over time, the temperature profiles are less able to capture the groundwater discharge still evident from water samples and EC profiles. Notably in round 4, where only in Barwik do temperature profiles still correctly predict groundwater discharge.

However, although EC profiles indicated groundwater to reach the surface in most cases, temperature cross-sections could not show whether heating actually reached the surface or not.

6. Discussion

The objectives of this study were to determine dynamics in water quality during spring flooding in a temperate floodplain at different scales. Annually repeated sampling gave insight in between-year variation, repeated small scale sampling over a period of four weeks gave insight in small scale, short-term variation. First, the different water types will be discussed on the basis of the 2012 research, followed by a discussion of temperature profiles and sampling scale and uncertainty in the results. Then, between-year dynamics in water quality will be discussed, followed by a discussion of the dynamics during flooding.

6.1 Hydrological interpretation of water type zones (spring 2012)

6.1.1 River water

The river water zone was only found in one transect, where it did not cover the entire transect and bordered a rainwater zone. The difference between the two zones was pronounced and the gradient from river water to rainwater occurred over a distance of less than 50 m. A sharp border with no mixing was also observed for other reaches in the Biebrza Lower Basin (Chormański et al. 2011).

Many lowland rivers similar to the Biebrza with high water stages every spring have a negative water quality (Van Den Brink et al. 1996). When these rivers flood their floodplains (if present), polluted river water enters the floodplain ecosystem. To prevent the floodplain from being flooded with river water, the presence of a body of other water type turns out to be essential. This water originates from snowmelt, precipitation and discharging groundwater. Management practices in restoration projects along lowland rivers that aim at restoring typical nutrient-poor species-rich fen vegetation, should ensure the existence of a) discharging nutrient-poor groundwater or b) clean atmospheric water in the floodplain.

Over time, the border between river water and rainwater shifted riverwards, but not more than 100 m. The shift occurred in sampling round 3, after a period of rain. It probably indicated an extension of the rainwater zone due to runoff from the adjacent river dune covered marginal valley terrace remains and the extension of local groundwater systems. The extension of local groundwater systems was also observed for valley meadows (Grootjans et al. 1988). After the rain period, the river zone was again wider and the border receded back to the old position.

6.1.2 Rainwater

A rainwater zone was found in all transects. The rainwater zone had low pollutant concentrations. Of the pollution variables, chloride is environmentally inert and not taken up by organisms and one of the least reactive solutes (Van Wirdum 1990, Younger 2007). Low chloride concentrations therefore are a robust indicator for clean rainwater. When chloride concentrations are lowered over time, this is a sign of input of chloride-poor water from precipitation or chloride-poor runoff or groundwater discharge. Lower concentrations measured in round 3 are probably the result of dilution with rainwater as was also observed before for the Biebrza fens (De Mars, Wassen & Olde Venterink 1997) and in other mires (Wassen et al. 1990b, Van Wirdum 1990, Wassen et al. 1990a). The diluted rainwater lens extended up to a larger depth after periods of extreme precipitation. However, even while the precipitation before sampling round 3 could not be characterized as extreme, dilution effects on the rainwater zone were still significant and comparable to earlier findings (De Mars, Wassen & Olde Venterink 1997).

Van Wirdum (1990) did extensive research on temperature profiles in mires. It was found that vegetation with a structure that covers the surface inhibits warming of the surface, serving as an insulating blanket. For the Biebrza fens, at Barwik and Gugny, zones with lower temperatures in the shallow soil also corresponded to locations where vegetation with long leaves covered the soil and shallow surface water. This can partly explain the lower temperatures in Gugny and Barwik; however hydrochemistry and EC profiles did actually indicate relatively mineral-poor rainwater.

6.1.3 Groundwater

Local and regional groundwater

Local groundwater sampled close to the river dune in Olszowa Droga and Barwik could not be significantly differentiated from rainwater. Separation of local groundwater and rainwater has been a problem in earlier studies as well due to mixing of ground- and rainwater (Chormański et al. 2011) and similarity of groundwater and rainwater close to the river dunes. Similarity results from a) the river dunes having a lower calcium content than the moraines, 0.134 +/- 0.327 versus 5.416 +/- 7.342 mg g^{-1} dry wt (Wassen et al. 1996), and b) local groundwater having a much shorter throughflow time compared to regional groundwater. Layers of sedimentary loam close to the river (Wassen et al. 1992) probably result in calcium rich groundwater closer to the river. If sedimentary loam causes high calcium concentrations also closer to the river at Gugny cannot be verified, but groundwater samples and EC profiles here indicate an extremely alkaline water type and temperature profiles indicated probable upwelling of groundwater.

Groundwater discharge at Szorce

On the basis of earlier research additional evidence was found for groundwater discharge zones during the 2012 flood. The groundwater discharge location at Szorce (2.2 km) where unpolluted, alkaline water was found in the surface water corresponded to the same location where this water type was found for 1987, 1990 and 1992 in both spring and summer (Appendix A: Table A, B) and where a loamy gyttja layer was found (De Mars, Wassen & Olde Venterink 1997). Analogously, on the western side of the Tsar's Road, previous research indicated groundwater discharge (Wassen et al. 1992), confirming the spring 2012 findings.

Hydrological windows

The soil and surface water was frozen during the orienting sampling campaign and partly during the first sampling round for Barwik, Gugny and Szorce. Even in the river water zone, the submerged peat was frozen. This must have prevented infiltration of river water into the soil and could be one of the reasons explaining the stratigraphy found in the river water zone of Olszowa Droga where surface water and groundwater were significantly different. Beumer et al. (Beumer et al. 2007, 2008) found the same stratigraphy during flooding in lowland brooks in the Netherlands. However, locally 'windows' were found in Barwik, Gugny and Szorce where the soil was not frozen and where a higher EC was found in the surface water, corresponding with locations of higher temperature in the deeper soil. It is here that groundwater reaches the surface (Jarek Chormański, personal communication, February 1, 2012). The width of these groundwater discharge zones is rather small: less than 100 m in Barwik and Szorce, although the groundwater signal in the surface water covers a much larger area. Small discharge zones (< 100 m) were also found close to the dune in summer 1987 and 1990 for Olszowa Droga (De Mars, Wassen & Olde Venterink 1997).

If conducting water sampling when the soil is still frozen, caution should be taken with the location of the samples because of the presence of hydrological windows in the frozen soil where warmer groundwater 'breaks' through the frozen layer. An orienting sampling campaign at fine scale and visual recognition of melted water on the frozen surface can show the possible presence of these windows. When the distribution of water types at floodplain scale needs to be determined, preferably, transects with extreme variation in the surface water quality resulting from hydrological windows should be omitted. The local variation is difficult to capture in a water sampling campaign and may hamper correct assignment of water type.

Throughflow mire

Surface EC decreased at the discharge location in Barwik. This indicated influence of precipitation, melting ice or discharging mineral-poor groundwater. However, the temperature profile showed warmer soil temperatures, indicating discharge of groundwater. Downstream of the discharge location, EC values increased over time, indicating an increasing influence of water being richer in minerals than the present water. EC profiles of the transect confirmed discharge and flow of mineral-poor local groundwater at the surface and in the shallow soil. The significant differences in hydrochemistry between the surface water and the groundwater in the zone downstream of the discharge location and the similarity of groundwater and surface water at the discharge location prove the throughflow hypothesis to be correct.

The above shows that a groundwater signal in the surface water does not necessarily indicates groundwater discharge. Groundwater can discharge at a location upstream and flow downstream on the surface or in the shallow soil (van Loon et al. 2009). Even in de Lower Basin, which is characterized as inundation mire (Zurek 1984), zones in Barwik and Szorce show signs of a throughflow mire. Especially in Barwik this was not expected, as this transect is located close to the river. This also raises questions on the previously identified spatial distributions by Chormański et al. (2011). They should not be interpreted as hydrological processes, but water types. Most probably, the zone identified as covered with groundwater does not correspond with the zone where groundwater actually discharges. It seems that correct identification of the source of the surface water is only possible when groundwater samples or temperature measurements at specific moments (see section below) are included.

The implication of throughflow for vegetation is that calcareous groundwater covers a much larger area than only the area where it discharges (van Loon et al. 2009). This results in a higher cover of plant species that require nutrient-poor, calcareous conditions. Nowadays, the hydrology of fen plant communities is often altered through the cutting off of groundwater flow towards discharge areas by extraction in recharge areas and faster drainage of exfiltrated groundwater areas though lowering of the groundwater table (van Loon et al. 2009). When the drainage of exfiltrated groundwater is reduced, the throughflow mechanism provides hopeful conditions for restoration of low-productive fen systems.

6.1.4 Use of temperature profiles

Temperature profiles can serve as an additional technique to determine the river water zone and groundwater discharge zones. Within the river water zone, much higher temperatures were measured than in the bordering rainwater zone. Furthermore, temperature profiles showed locations where warmer groundwater flowed in upward direction. However, temperature profiles could not show whether this groundwater actually reached the surface or not (except for Szorce where very clear surface water warming was observed). But when warmer temperatures in the soil are observed in a vertical pattern, resulting from upwelling groundwater, one can probably assume this water also reaches the surface in the upwelling location.

It should be noted that previous research (Appendix A: Table A, B, Wassen et al. 1992, 2003) confirms the locations where temperature observations indicate groundwater discharge.

Temperature profiles provided additional proof for groundwater discharge, but come with a disadvantage. The sensor used needs time to adjust to the warmer or cooler temperature in the soil.

When the method is used in future research, a much faster sensor is needed. Temperature profiles did not provide additional proof when surface water samples clearly indicated water type. The method should be used preferably only in cases where there is doubt about the water type determined on the basis of surface water samples.

6.1.5 About uncertainty and sampling timing

Dynamics in biochemical processes

Sampling at higher resolution reduces uncertainty. For organic compounds, a small sampling interval (sub-daily, Bowes 2011) is required to fully estimate concentration changes for nutrients in relation to storm events and internal riverine nutrient dynamics. It is recognized that diurnal fluctuations in biochemical cycles such as those of dissolved O_2 and pH have altering effects on the concentration and speciation of dissolved gases, organic and inorganic carbon, trace elements, nutrients and suspended particles (Nimick, Gammons & Parker 2011). Therefore, measured concentrations of nutrients and compounds associated with biochemical processes must be interpreted with caution as they can be result of processes that are under strong diurnal variation. This is also clear from the data: nutrients (NO_2^-, NO_3^-, NH_4^+, K^+) and biochemically associated variables (pH, PO_4^{3-}, SO_4^{2-}, Fe^{2+}) show the largest variability over space and time.

Sampling moment

It is clear now that sampling scale and frequency should be tailored to the research questions. Sampling scale was not sufficient to accurately determine the distribution of water types in the Biebrza Lower Basin for all previous years except 2002. Only for Olszowa Droga and Szorce were sufficient samples available to distinguish water type zones. The sampling density of the spring 2012 sampling was high enough to distinguish water type zones.

In the rainwater zone, over time groundwater influence was seen to increase, altering the water quality. Therefore, repeated sampling turned out to be essential here in contrast to the river water zone where water quality remained relatively constant.

For the rainwater and groundwater zones, variation over the course of four weeks was of the same order as variation between years, showing that different values can be measured for the same flood event. If all years are sampled at the flood peak, but one year is sampled two weeks later but still during a high water stage, concentrations can be much lower. In this case, the year sampled later would seem different, while the difference only results from the difference in sample moment. The same hydrological moment (e.g. exact peak) should be taken to compare years.

The borders between the zones did not shift substantially. This means that the sampling moment has no influence on the determination of the border location. However, the river water - rainwater border did shift. When a high precision is needed for the location of this border, repeated sampling during the flood event is essential.

Furthermore, because of the large river floodplain and catchment size, hysteresis takes place at a temporal and spatial scale. The water level responded with a delay to the precipitation; it did not rise immediately, but only after some days when runoff in the whole catchment had gathered in the Biebrza river and increased water level. A second example is probably observed in local groundwater. Groundwater flow did get stronger and expanded at the cost of rainwater present on the surface a few days after the precipitation period. This inhibits an accurate attribution of water quality signals to precipitation and flooding (Robson et al. 1993), although a relatively successful attempt is made in the current master thesis.

6.2 Dynamics in hydrochemistry

6.2.1 Dynamics over years (2001-2012)

Meteorological conditions before and during the analyzed floods of 2001-2012 were clearly related to discharge hydrographs. Years with a large snow cover had high peak discharges (2002, 2005 and 2010). Years where snow cover was absent or only very short, had low peak discharges (2001 and 2012). 2006 had a very long snow cover, but a very dry and cold spring with little precipitation caused low peak discharge. Precipitation before and during flooding made the flood peak more pronounced (2002 and 2004).

River water and rainwater

The extent of the river water and rainwater zone varied depending on flood magnitude, amount of snow present before thawing and precipitation during and before the flood peak. In years with high peak discharges the river flooded the total breadth of the floodplain at Olszowa Droga (2002 and 2010). A zone with rainwater or local groundwater was present within the floodplain in years with low peak discharges (2004, 2006 and 2012). A sharp border was found in 2002 and 2012, while a gradual border was found in 2001 and 2004. The exact cause of the presence or absence of a sharp border could not be found. Furthermore, there is a point in the transect beyond which river water always covers the surface, independent of peak discharge. In the zone before this point variation is substantial and cover with river water in some years alternates with cover with rainwater. There is a good correlation with vegetation distribution maps, zones which are covered with river water every spring have different vegetation types than zones which are only incidentally covered with river water (Chormański et al. 2011). Extreme conditions have a more pronounced effect on vegetation development than the average conditions (De Mars, Wassen & Olde Venterink 1997). In this light, even sub-annual flooding with river water is detrimental for vegetation development. However, it could be that vegetation is able to recover from extreme conditions when flooding with river water alternates with flooding with other water types for some years. This hypothesis deserves further research.

Rainwater and groundwater

Where a mixture of rainwater and groundwater is present, water quality seems to depend strongly on the amount of snow present before thawing and precipitation during and before the moment of sampling. When snow cover was higher before spring thaw (2005), or extreme precipitation occurred before or during the moment of sampling (2002) a larger proportion of rainwater was present, seen in lower concentrations of solutes in the surface water. Variability between years is highest in the zone close to the dune or moraine, because of a strong groundwater signal being diluted or groundwater discharge blocked off more or less by rainwater or snowmelt water, depending on meteorological conditions.

A groundwater zone was not always observed and also not along the entire valley margin in the northern part of the Biebrza Lower Basin (Chormański et al. 2011). Because groundwater exfiltration only started after melting of the peat soil, this research suggests that the moment of sampling plays a detrimental role. When possible groundwater zones are sampled when the soil is still frozen only rainwater or river water will be sampled here. Furthermore the amount of rainwater present (depth of rainwater lens) on the surface water also plays a major role in the ability of groundwater to reach the surface water. These are all possible causes of the observed variation in rainwater and groundwater zones.

6.2.2 Dynamics during the flooding period (spring 2012)

Dynamics in water type borders

Over the course of four weeks, the borders of the identified river water, rainwater and groundwater zones stayed in between the sampling points where they were identified for the first round. The only exceptions were the border between river water and rainwater at Olszowa Droga and the groundwater discharge zone at Barwik. This indicated that the zones were horizontally stable.

The extent of rainwater zone appears not to depend on the amount of snow present before thawing, but on flood magnitude. In 2001, snow cover was absent and there was no extreme precipitation before or during the flood. However, albeit little snowmelt-/rainwater present, the river did not cover the entire transect at Olszowa Droga and a rainwater zone was still present.

The flood pulse concept that presumes river water to cover the entire floodplain was already criticized by Chormanski et al. (2011). The findings of the current research confirm the basis of critique that a floodplain can be covered with other water types than only river water during flooding. The current research even shows that the location of the border is not static during flooding and that dynamics in water quality play an important role during flooding. It should be noted that the findings only apply to comparable lowland rivers and fen systems. Rivers and floodplains with different settings such as the absence of groundwater discharge at the valley margin will probably show a much larger influence of river water during flooding. If these floodplains are the subject of restoration, extensive research into the hydrology is essential.

Dynamics within water types

Over time, river water showed the most variation, probably because of hydrological (e.g. runoff) and chemical (e.g. pollution release) processes in the large upstream catchment. Water level in the river zone correlated less with water level at Osowiec than expected. This probably results from the much wider floodplain at Olszowa Droga than at Osowiec. When more water runs down the Biebrza river during a peak in discharge, the increase in water level over a width of 50 m at Osowiec will be much more pronounced than over the floodplain width at Olszowa Droga (width of river water zone approximately 2 km).

Rainwater zones showed variation as well, resulting from a) the chemistry altering effect of groundwater discharge, and b) concentration or dilution of the surface water during periods of respectively drought or precipitation. How pronounced the rainwater zone is in values depends on the amount of snow present before thawing and precipitation during flooding. When there is less snow, groundwater influence is larger and the rainwater zone resembles more a diluted groundwater zone. When there is a large snow cover, groundwater hardly reaches the surface, resulting in rainwater being only slightly enriched with minerals from the groundwater.

Groundwater zones were stable in water quality and width of the discharge zone. The stability in water quality probably results from the very homogeneous flow of water with a constant discharge rate. The stability in width of the discharge zone results from the hydrologic window that is ‘paired’ to the infiltration location. Groundwater flow discharging at certain location will probably not easily discharge at a different location. Water level in the rain- and groundwater zones had no relation with river water level at Osowiec because they were not linked hydrologically.

De Mars, Wassen & Olde Venterink (1997) indicated dynamics in water quality to be a major determinant for vegetation. As it seems now that the range of dynamics during flooding can be of the same order of magnitude as the range over a year and very high concentrations of iron, sulphate, phosphate and pollutants were observed during flooding, the water quality during flooding should get much more attention in research of water quality of fen systems. In addition, the fact that plant species are much more sensitive to extreme than average conditions (Jarvie et al. 2001) and that these extreme conditions are indeed present during flooding, also shows that more attention is needed on the water quality during flooding.

Restoration projects can learn from these findings. A thorough analysis of the effects of dynamics in flooding and water quality in the proposed restored wetland is essential to predict vegetation distribution. When projects are aimed at restoration of specific conditions (e.g. a nutrient-poor species-rich environment) the distribution of water types needs to be predicted during different hydrological conditions (e.g. dry, wet, flooding, precipitation during flooding, heavy precipitation during low water level introducing pollution via runoff) to accurately predict hydrochemistry and consequently possible vegetation distribution.

7. Conclusions

7.1 Water types

Zones flooded with river water, rain- or snowmelt water or groundwater are identified using hydrochemistry of the surface water and shallow groundwater, EC profiles of the peat soil up to 1.50 m depth and temperature profiles of the peat soil up to 1.60 m.

River water can be identified easily using hydrochemistry. EC and temperature profiles only provide additional evidence and EC profiles and groundwater hydrochemistry show no exchange between surface water and groundwater. Because of the negative water quality of river water, management practices that aim at restoring nutrient-poor fen vegetation in floodplains should ensure the presence of other water types within the floodplain. This body of other water type can block the inflow of river water in these reaches.

Rain- and snowmelt water zones are more difficult to identify because hydrochemistry shows mixing with groundwater. Temperature profiles indicating standing water provide additional evidence for zones where no warming occurs resulting from deeper groundwater or inflowing warmer surface.

Identification of groundwater zones is problematic with the use of only surface water chemistry. Local groundwater is very similar to rainwater. With the use of EC and temperature profiles of the soil, zones with upwelling groundwater can be identified. However, it remains questionable if conclusions for the water type of the surface water can be drawn from the upwelling signal in the deeper peat.

Surprisingly, location where groundwater is sampled not always correspond to locations where groundwater actually discharges. The concept of ‘throughflow mire’ in contrast to ‘inundation mire’ is also applicable for a significant part of the Biebrza Lower Basin, even during flooded conditions. The throughflow mechanism provides hopeful conditions for the restoration of nutrient-poor fen vegetation when drainage of exfiltrated groundwater is reduced, not only in ombrotrophic systems such as the Biebrza Lower Basin, but also in lowland fen systems such as the Lower Basin and comparable river valley fens.

7.2 Dynamics

The first hypothesis that small scale dynamics and temporal dynamics relate strongly to flood magnitude and atmospheric conditions before and during the sampling campaign can be accepted. Years with much snow or above average precipitation before or during the flooding have a river water zone that extends further into the floodplain. Variation between years is most pronounced in the river water zone and in groundwater discharge zones. In these zones, more or less dilution with snowmelt or rain water takes place. Furthermore, frozen soil can prevent groundwater from reaching the surface water.

For the spring 2012 sampling campaign, precipitation causes significant drop in concentrations in the third sampling round and extension of the rainwater zone at the cost of river water. Increasing discharge in sampling round 4 causes again extension of the river water zone. Drier conditions result in concentration of surface water in round 4. The identified zones are horizontally stable during the flood event. This means that sampling moment does not matter for identification of the location of the borders. However, because temporal variation is substantial in all zones, the moment of sampling does matter when water quality is compared between years for the same location.

The second hypothesis that addition of temperature and EC cross-sections of the transects adds considerably to system understanding can also be accepted. In zones where mixing is seen in the surface and for which determination is uncertain, temperature and EC profiles of the soil indicate hydrological processes within the deeper soil, leading to identification of causes of observed surface hydrochemistry. This reduces uncertainty in determination of the water types. Therewith, water type zones and borders between zones can be distinguished more clearly. For future research, a much faster, multi-level temperature sensor is preferred to reduce sampling time.

The research presented here shows that a water type distribution can only apply for the specific year the water sampling was done. Water type distribution relates strongly to meteorological and atmospheric conditions before and at the time of water sampling. Furthermore, because of sharp borders and presence of mixing zones determination of water type zones can only be successful if sampling is done on a small scale, with sampling distance depending on EC gradients observed.

Acknowledgements

Now that I have finalized the written part of my research, I think back on all the people that made this research possible and have had confidence in the progress and process. It gives me great pleasure in acknowledging the support of Prof. Hab. Dr. Tomasz Okruszko and his colleagues at the Warsaw University of Life Sciences. Especially Mateusz Grygoruk and Dr. Ignacy Kardel should be thanked for their help in the research which was the basis of this thesis. Mateusz introduced me to the Biebrza Lower Basin and looked after me and was always there when I needed help. Ignacy provided assistance before departure to the research area and analyzed the water samples.

Robert Michalowski made the piezometers. I would like to thank him for the time and effort he put in a creative solution to inhibit surface water from flowing into the filter.

Dr. Jarosław Chormański should be named for introducing me to the possible research locations, providing general information about the Biebrza Lower Basin and discussing my proposal before departure to Poland.

In the field, I would like to thank my Erasmus colleagues Matthieu Taymans and Florentin Dumas who helped me out during the first sampling round in the freezing cold.

Lastly, I consider it an honor to have received the trust and support from Prof. Dr. Martin Wassen from Utrecht University who has offered me the possibility to carry out this research. He pulled me back when I went into the wrong direction during analysis of the results. Discussing the results was extremely helpful in the process of analyzing the findings. It was a delight to spend some days with him in the Biebrza and getting to know the history and (fairy)tales of the region and all the research that preceded my research.

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Appendix A

Table A. Water samples taken at Szorce transect at a depth of 10 cm below the water surface on April 20, 1992. GWS = water level in cm below ground level; negative values indicate water abvoe the surfacein cm. EC in μS/cm, pH in (-), all other values in mg/l.

Location	Plot	xcoor	ycoor	GWS	EC	pH	Cl	SO_4	Ca	Mg	Na	K	Fe	Si
C01	C01	679337	839786	2.0	456	7.13	8.50	11.78	72.93	11.96	3.88	0.91	0.17	6.01
C01	C01B	679316	839782	2.0	358	7.32	6.47	11.38	75.16	12.36	4.00	0.75	0.13	5.78
C02	C02	679249	839768	-1.0	277	7.16	6.11	9.75	52.91	9.22	3.30	0.37		5.71
C03	C03	679188	839755	-3.0	299	7.44	6.68	12.81	58.42	10.21	3.49	0.64	0.06	4.80
C04	C04	679067	839687	-3.0	290	7.40	6.17	11.44	56.82	10.03	3.27	0.31	0.11	3.79
C05*	C05	678766	839517	-1.0	233	6.74	2.88	2.54	35.56	7.05	2.91	0.59	4.14	3.95
C06	C06	678499	839366	-3.0	257	7.22	5.18	8.54	47.82	8.44	2.75	0.46	0.05	3.79
C07	C07	678118	839151	-1.0	222	7.17	5.21	9.14	39.99	7.65	2.81	0.21		2.75
C08	C08	677931	839045	-3.0	220	7.27	4.52	9.39	41.62	8.06	2.99	0.29	0.04	2.84
C09	C09	677617	838868	-8.0	222	7.35	5.24	7.60	39.34	7.75	3.46	1.18	0.05	3.98
C11	C11	677276	838676	-14.0	200	7.14	5.22	8.46	36.06	7.12	3.58	0.36	0.06	4.47
C12	C12	677138	838598	-11.0	200	7.04	4.75	7.33	35.21	7.05	2.91		0.05	5.04
C13	C13	676978	838427	-19.0	195	7.08	4.74	7.08	34.06	6.94	3.13	0.20	0.04	5.47
C14**	C14	676840	838279	-6.0	162	7.10	5.05	10.02	27.25	5.75	2.77	0.42	0.08	5.62
C15**	C15	676717	838149	-7.0	170	7.03	4.75	5.58	28.22	6.07	2.55	0.17	0.10	5.45
C16**	C16	676625	838050	0.0	182	7.00	4.80	5.18	30.80	6.68	2.64		0.08	5.61

* Location with water type differing from spatial trend riverwards. Water low in pollutants, high in Fe.
** Samples taken at the western side of the Tsars's Road.

Table B. Water quality of samples taken at location C05 for summer 1987, summer 1990 and summer 1992. GWS = water level in cm below ground level. EC in μS/cm, pH in (-), all other values in mg/l.

Date	GWS	EC	pH	Cl	HCO_3	SO_4	Ca	Mg	Na	K	Fe	Si
870700	3.0	345	7.50		256.10	2.60	70.00	14.50	3.20	0.44	3.96	4.44
900805	8.0		6.76	7.07	249.49	3.39	115.15	16.19	9.89	0.80	2.32	2.15
920710	31.0	418	6.87	2.47	305.00	0.95	74.88	11.18	6.98	0.92	0.92	9.72

Appendix B

Table A. EC and pH values measured during the orienting sampling campaign of 14.03.2012 to 24.03.2012.

Transect	IDPOINT	UTM_x	UTM_y	EC	PH
Gugny	10001	605622	5912328	202	6,81
Gugny	10002	605594	5912325	89	6,74
Gugny	10003	605421	5912258	760	6,80
Gugny	10004	605347	5912255	550	7,15
Gugny	10005	605288	5912259	626	7,17
Gugny	10006	605217	5912252	558	7,49
Gugny	10007	605104	5912269	487	7,71
Gugny	10008	605010	5912263	370	7,76
Gugny	10009	604919	5912226	410	7,76
Gugny	10010	604823	5912230	422	7,70
Gugny	10011	604737	5912223	381	7,75
Gugny	10012	604644	5912223	395	7,71
Gugny	10013	604597	5912231	394	7,71
Gugny	10014	604516	5912244	387	7,64
Gugny	10015	604470	5912254	395	7,75
Gugny	10016	604390	5912276	283	7,69
Gugny	10017	604318	5912276	418	7,61
Gugny	10018	604221	5912290	441	7,55
Gugny	10019	604107	5912302	422	7,59
Gugny	10020	602628	5912597	253	7,35
Gugny	10021	602499	5912524	320	7,33
Gugny	10022	602424	5912520	315	7,38
Gugny	10023	602347	5912516	385	7,37
Gugny	10024	602261	5912557	332	7,42
Gugny	10025	602191	5912625	342	7,51
Gugny	10026	601907	5912778	330	7,15
Gugny	10027	601760	5912675	325	7,27
Gugny	10028	601898	5912652	303	0,00
Gugny	10029	602091	5912561	290	0,00
Gugny	10030	602186	5912555	307	0,00
Gugny	10031	602721	5912567	348	7,06
Gugny	10032	602805	5912522	405	7,45
Gugny	10033	602898	5912511	435	7,66
Gugny	10034	603026	5912491	390	7,79
Gugny	10035	603117	5912492	380	7,80
Gugny	10036	603237	5912512	420	7,89
Gugny	10037	603321	5912496	439	7,71
Gugny	10038	603430	5912469	415	7,75
Gugny	10039	603521	5912457	403	7,68
Gugny	10040	603625	5912423	428	7,55
Gugny	10041	603720	5912394	436	7,55

Gugny	10042	603840	5912375	435	7,46
Gugny	10043	603938	5912361	450	7,47
Gugny	10043	604028	5912319	452	7,46
Gugny	10044	604351	5912276	462	
Gugny	10045	604397	5912279	472	
Gugny	10045	604501	5912260	458	
Gugny	10046	604592	5912242	436	
Gugny	10047	604783	5912237	375	
Gugny	10048	604840	5912238	310	
Gugny	10049	604898	5912247	302	
Gugny	10050	604960	5912244	306	
Gugny	10051	605062	5912253	350	
Gugny	10052	605217	5912267	430	
Gugny	10053	605317	5912279	630	
Gugny	10054	605337	5912283	505	
Gugny	10055	605354	5912288	642	
Gugny	10056	605375	5912294	495	
Gugny	10057	605397	5912302	515	
Gugny	10058	605422	5912304	520	
Gugny	10059	605450	5912283	695	
Gugny	10060	605461	5912278	810	
Grobla Honczarowska	20001	606617	5908409	332	7,58
Grobla Honczarowska	20002	606502	5908367	691	7,44
Grobla Honczarowska	20003	606396	5908318	768	7,95
Grobla Honczarowska	20004	606310	5908292	646	7,74
Grobla Honczarowska	20005	606198	5908244	636	7,71
Grobla Honczarowska	20006	606082	5908230	582	7,74
Grobla Honczarowska	20007	605954	5908217	385	7,40
Grobla Honczarowska	20008	605954	5908217	683	7,00
Grobla Honczarowska	20009	605954	5908217	363	7,60
Grobla Honczarowska	20010	604228	5907645	320	7,60
Grobla Honczarowska	20011	605817	5908209	663	7,32
Grobla Honczarowska	20012	605685	5908240	983	7,05
Grobla Honczarowska	20013	605683	5908245	586	7,33
Grobla Honczarowska	20014	605565	5908210	652	6,96
Grobla Honczarowska	20015	605455	5908170	636	6,88
Grobla Honczarowska	20016	605317	5908114	636	7,11
Grobla Honczarowska	20017	605210	5908031	572	7,27
Grobla Honczarowska	20018	605089	5907933	880	7,00
Grobla Honczarowska	20019	604977	5907848	564	7,21
Grobla Honczarowska	20020	604827	5907787	523	7,00
Grobla Honczarowska	20021	604622	5907741	545	7,28
Grobla Honczarowska	20022	604396	5907683	624	7,11
Grobla Honczarowska	20023	604301	5907662	223	7,52
Grobla Honczarowska	20024	604163	5907604	242	7,16
Grobla Honczarowska	20025	604105	5907579	112	6,75

Grobla Honczarowska	20026	604102	5907576	114	6,40
Grobla Honczarowska	20027	604005	5907496	496	7,34
Grobla Honczarowska	20028	603845	5907490	293	7,20
Grobla Honczarowska	20029	603813	5907464	473	7,28
Grobla Honczarowska	20030	603688	5907367	498	7,29
Grobla Honczarowska	20031	603568	5907356	506	7,09
Grobla Honczarowska	20032	603322	5907245	469	7,37
Grobla Honczarowska	20033	603192	5907183	480	7,24
Grobla Honczarowska	20034	603050	5907121	454	7,24
Grobla Honczarowska	20035	602893	5907039	475	7,11
Grobla Honczarowska	20036	602749	5906931	405	7,40
Grobla Honczarowska	20037	602540	5906775	274	7,18
Grobla Honczarowska	20038	602395	5906795	430	7,18
Grobla Honczarowska	20039	602222	5906871	384	7,02
Grobla Honczarowska	20040	602010	5906866	795	7,00
Grobla Honczarowska	20041	601393	5906978	540	7,50
Grobla Honczarowska	20042	601265	5906974	507	7,26
Grobla Honczarowska	20043	601130	5906954	721	7,02
Grobla Honczarowska	20044	601106	5907003	181	7,12
Olzowa Droga	30001	604447	5921232	420	7,16
Olzowa Droga	30002	604337	5921229	307	7,17
Olzowa Droga	30003	604187	5921222	288	7,28
Olzowa Droga	30004	604048	5921208	388	7,19
Olzowa Droga	30005	604397	5921246	305	7,15
Olzowa Droga	30006	604439	5921211	298	7,10
Olzowa Droga	30007	604374	5921212	275	6,98
Olzowa Droga	30008	604296	5921212	305	6,65
Olzowa Droga	30009	604223	5921205	360	6,65
Olzowa Droga	30010	604156	5921187	243	7,16
Olzowa Droga	30011	604092	5921191	300	7,15
Olzowa Droga	30012	604024	5921184	355	7,36
Olzowa Droga	30013	603961	5921178	372	7,32
Olzowa Droga	30014	603902	5921164	361	7,47
Olzowa Droga	30015	603839	5921179	352	7,40
Olzowa Droga	30016	603858	5921212	341	7,44
Olzowa Droga	30017	603885	5921214	355	7,42
Olzowa Droga	30018	603936	5921222	370	7,49
Olzowa Droga	30019	603996	5921231	363	7,50
Olzowa Droga	30020	604066	5921228	360	7,50
Olzowa Droga	30021	604134	5921231	300	7,53
Olzowa Droga	30022	604172	5921232	274	7,57
Olzowa Droga	30023	604204	5921234	225	7,37
Olzowa Droga	30024	604279	5921231	244	7,37
Olzowa Droga	30025	604319	5921237	274	7,32
Olzowa Droga	30026	604366	5921242	306	7,07
Olzowa Droga	30027	604396	5921243	316	7,02

Barwik	40001	604106	5914836	275	7,17
Barwik	40002	604022	5914788	436	7,37
Barwik	40003	603921	5914744	335	7,17
Barwik	40004	603785	5914664	400	7,41
Barwik	40005	603657	5914592	410	7,45
Barwik	40006	604109	5914835	588	7,14
Barwik	40007	604060	5914813	445	7,28
Barwik	40008	603970	5914748	590	7,06
Barwik	40009	603858	5914682	460	6,92
Barwik	40010	603708	5914611	415	7,23
Barwik	40011	603545	5914511	388	7,29
Barwik	40012	603462	5914449	405	7,35
Barwik	40013	603363	5914407	376	7,35
Barwik	40014	603277	5914373	397	7,33
Barwik	40015	603174	5914319	409	7,33
Barwik	40016	603097	5914254	452	7,41
Barwik	40017	602968	5914213	404	7,38
Barwik	40018	602894	5914193	489	7,25
Barwik	40020	602502	5913860	440	7,20
Barwik	40021	602456	5913754	352	7,28
Barwik	40022	602495	5913695	317	7,18
Barwik	40023	602546	5913617	374	7,46
Barwik	40024	602630	5913585	597	7,18
Barwik	40025	602698	5913479	706	7,40
Barwik	40026	602780	5913413	590	7,10
Barwik	40027	602894	5913232	685	7,10
Barwik	40028	602877	5913002	1050	7,25
Barwik	40029	602789	5912873	440	7,35
Barwik	40030	602632	5912973	220	7,60
Barwik	41001	604152	5914864	598	7,22
Barwik	41002	604095	5914839	649	7,41
Barwik	41003	603980	5914768	422	7,21
Barwik	41004	603848	5914678	395	7,09
Szorce	50002	607437	5905524	233	6,83
Szorce	50003	607491	5905587	222	6,90
Szorce	50004	607576	5905650	232	6,83
Szorce	50005	607648	5905718	205	6,88
Szorce	50006	607424	5905457	127	6,91
Szorce	50007	607484	5905519	221	6,91
Szorce	50008	607530	5905598	235	6,96
Szorce	50009	607603	5905665	264	6,95
Szorce	50010	607722	5905717	239	6,97
Szorce	50011	607812	5905782	235	7,00
Szorce	50012	607886	5905825	241	7,04
Szorce	50013	607957	5905872	195	7,08
Szorce	50014	608019	5905923	236	7,18

Szorce	50015	608099	5905965	250	7,21
Szorce	50016	608178	5906013	252	7,14
Szorce	50017	608262	5906064	269	7,09
Szorce	50018	608348	5906123	305	7,27
Szorce	50019	608426	5906177	297	7,20
Szorce	50020	608511	5906241	335	7,37
Szorce	50021	608587	5906319	346	7,27
Szorce	50022	608677	5906382	286	7,26
Szorce	50023	608758	5906442	338	7,32
Szorce	50024	608850	5906490	370	7,29
Szorce	50025	608931	5906545	395	7,13
Szorce	50026	609003	5906591	385	7,28
Szorce	50027	609081	5906620	480	7,05
Szorce	50028	609162	5906676	604	7,28
Szorce	50029	609261	5906724	300	7,16
Szorce	50030	609349	5906764	310	7,30
Szorce	50031	609418	5906821	338	7,38
Szorce	50032	609482	5906880	338	7,45
Szorce	50033	609567	5906927	320	7,30
Szorce	50034	609641	5906976	290	7,40
Szorce	50035	609698	5907016	312	7,25
Szorce	50036	609722	5907016	410	7,10
Olszowa Droga	60001	604364	5921272	258	6,58
Olszowa Droga	60002	604327	5921332	242	7,07
Olszowa Droga	60003	604297	5921381	253	7,23
Olszowa Droga	60004	604280	5921408	269	7,21
Olszowa Droga	60005	604259	5921453	329	7,28
Olszowa Droga	60006	604229	5921494	374	7,32
Olszowa Droga	60007	604194	5921531	377	7,36
Olszowa Droga	60008	604167	5921560	365	7,38
Olszowa Droga	60009	604141	5921605	368	7,56
Olszowa Droga	60010	604114	5921642	378	7,48
Olszowa Droga	60011	604064	5921649	385	7,52
Olszowa Droga	60012	604008	5921685	390	7,50
Olszowa Droga	60013	603976	5921737	417	7,48
Olszowa Droga	60014	603931	5921793	430	7,47
Dluka Luka	70001	607361	5905411	210	7,16
Dluka Luka	70002	607319	5905397	210	7,33
Dluka Luka	70003	607270	5905373	205	7,37
Dluka Luka	70004	607220	5905342	210	7,38
Dluka Luka	70005	607179	5905321	205	7,38
Dluka Luka	70006	607133	5905295	201	7,35
Dluka Luka	70007	607086	5905269	196	7,29
Dluka Luka	70008	607043	5905246	197	7,31
Dluka Luka	70009	606975	5905204	200	7,24
Dluka Luka	70010	606889	5905189	197	7,36

Dluka Luka	70011	606793	5905136	175	7,32
Dluka Luka	70012	606705	5905094	175	7,15
Dluka Luka	70013	606618	5905051	154	7,22
Dluka Luka	70014	606530	5905019	157	7,21
Dluka Luka	70015	606440	5904994	145	7,36
Dluka Luka	70016	606343	5904972	167	6,78

Table B.1. Discharge and water level at Osowiec (highway bridge).

Date	Discharge [m3/]	Water level [cm]
11-2-2012	28	
12-2-2012	26	
13-2-2012	24	
14-2-2012	23	
15-2-2012	22	
16-2-2012	21	
17-2-2012	20	
18-2-2012	19	
19-2-2012	19	
20-2-2012	18	
21-2-2012	17	
22-2-2012	17	
23-2-2012	19	
24-2-2012	25	
25-2-2012	32	
26-2-2012	36	
27-2-2012	42	
28-2-2012	44	
29-2-2012	45	
1-3-2012	46	
2-3-2012	47	
3-3-2012	44	
4-3-2012	44	
5-3-2012	44	
6-3-2012	43	
7-3-2012	43	
8-3-2012	43	
9-3-2012	42	
10-3-2012	42	
11-3-2012	43	
12-3-2012	44	
13-3-2012	45	
14-3-2012	44	
15-3-2012	43	
16-3-2012	43	
17-3-2012	42	
18-3-2012	41	
19-3-2012	40	381,3
20-3-2012	40	381,0
21-3-2012	40	381,0
22-3-2012	41	382,0

Date	Discharge [m3/]	Water level [cm]
23-3-2012	41	382,0
24-3-2012	41	382,0
25-3-2012	40	380,9
26-3-2012	40	381,0
27-3-2012	40	381,0
28-3-2012	40	381,0
29-3-2012	40	380,0
30-3-2012	39	379,0
31-3-2012	39	379,0
1-4-2012	39	378,3
2-4-2012	39	377,9
3-4-2012	39	378,0
4-4-2012	39	378,7
5-4-2012	40	380,0
6-4-2012	40	380,0
7-4-2012	39	379,3
8-4-2012	39	378,6
9-4-2012	39	378,0
10-4-2012	38	377,0
11-4-2012	37	375,7
12-4-2012	36	373,7
13-4-2012	35	371,9
14-4-2012	35	371,0
15-4-2012	35	370,0
16-4-2012	34	369,0
17-4-2012	34	369,0
18-4-2012	35	370,0
19-4-2012	35	370,8
20-4-2012	36	372,5
21-4-2012	37	374,7
22-4-2012	38	376,0
23-4-2012	38	376,9
24-4-2012	39	378,0
25-4-2012	39	379,0
26-4-2012	39	379,0
27-4-2012	39	378,5
28-4-2012	38	377,7
30-4-2012	37	374,2
1-5-2012	35	371,0
2-5-2012	33	367,3
3-5-2012	32	365,1

Table B.2. Discharge and water level at Burzyn.

Date	Discharge [m3/s]	Water level [cm]
11-2-2012	27	
12-2-2012		
13-2-2012		
14-2-2012		
15-2-2012	32	
16-2-2012	32	
17-2-2012	32	
18-2-2012	32	
19-2-2012	32	
20-2-2012	32	
21-2-2012	31	
22-2-2012	31	
23-2-2012	33	
24-2-2012	52	
25-2-2012	51	
26-2-2012	58	
27-2-2012	55	
28-2-2012	59	
29-2-2012	69	
1-3-2012	58	
2-3-2012	60	
3-3-2012	65	
4-3-2012	68	
5-3-2012	69	
6-3-2012	69	
7-3-2012	67	
8-3-2012	66	
9-3-2012	64	
10-3-2012	62	
11-3-2012	62	
12-3-2012	62	
13-3-2012	63	
14-3-2012	62	
15-3-2012	61	
16-3-2012	62	
17-3-2012	63	
18-3-2012	63	
19-3-2012	62	312,4
20-3-2012	62	312,0
21-3-2012	61	311,0
22-3-2012	61	311,0

Date	Discharge [m3/s]	Water level [cm]
23-3-2012	59	309,7
24-3-2012	59	309,0
25-3-2012	57	307,1
26-3-2012	57	307,0
27-3-2012	56	306,0
28-3-2012	56	306,0
29-3-2012	56	305,0
30-3-2012	55	304,0
31-3-2012	55	304,0
1-4-2012	55	304,0
2-4-2012	55	304,0
3-4-2012	55	304,5
4-4-2012	55	304,7
5-4-2012	56	305,0
6-4-2012	56	305,0
7-4-2012	56	305,0
8-4-2012	55	304,1
9-4-2012	55	303,8
10-4-2012	54	303,0
11-4-2012	53	302,0
12-4-2012	52	301,0
13-4-2012	52	300,0
14-4-2012	51	299,8
15-4-2012	51	299,0
16-4-2012	51	299,0
17-4-2012	54	302,7
18-4-2012	54	303,0
19-4-2012	54	303,2
20-4-2012	55	304,0
21-4-2012	55	304,0
22-4-2012	55	304,0
23-4-2012	55	304,0
24-4-2012	55	304,0
25-4-2012	54	303,1
26-4-2012	54	303,0
27-4-2012	54	302,5
28-4-2012	53	301,1
30-4-2012	52	300,4
1-5-2012	51	299,3
2-5-2012	51	298,2
3-5-2012	50	297,5

Table C. Water depth [cm] for sampling points with piezometers installed. Readings are given for each sampling round separately. Sampling dates for round 1 are 31.03.2012 (Olszowa Droga), 03.04.2012 (Gugny and Szorce) and 05.04.2012 (Barwik). Other sampling dates are 09.04.2012 (round 2), 15.04.2012 (round 3) and 23.04.2012 (round 4).

	waterdepth			
round	round 1	round 2	round 3	round 4
sampling point				
Olszowa Droga				
601	6,4	6,2	8,0	6,2
602	13,4	13,6	12,6	12,3
603	19,6	19,2	18,2	18,8
604	32,4	32,0	30,8	31,4
605	42,8	42,2	40,4	41,2
Barwik				
401	21,7	19,2	21,6	20,6
402	11,4	10,4	12,0	10,4
403	17,2	15,4	16,2	15,6
404	22,2	22,0	22,0	24,2
405	26,4	25,6	26,2	28,6
Gugny				
101	6,0	5,0	5,4	5,0
102	6,4	6,4	6,4	6,4
103	7,0	7,8	7,4	7,4
104	8,8	8,2	7,4	10,0
105	25,4	26,2	24,6	28,4
Szorce				
501	11,4	12,9	13,0	13,6
502	11,2	12,0	11,8	11,2
503	10,0	10,0	11,0	10,4
504	7,4	7,8	8,0	9,0
505	24,0	23,6	23,0	26,8
510	14,6	14,8	15,4	17,0

Table D.1. Temperature (°C) and EC (μS/cm) profiles of Olszowa Droga (round 1). Temperature readings are from 20 to 160 cm below the water surface, EC readings are from 10 to 150 cm below the water surface. Water depths shown in Table C. All dates are from 2012.

Sampling point	606	601	607	602	608	603	609	604	610	605
Date	31-mrt	31-mrt	31-mrt	31-mrt	31-mrt	31-mrt	31-mrt	31-mrt	31-mrt	31-mrt
Depth [cm]	Temperature [°C]									
20		0,4	2,8	0,8	0,0	2,1	1,3	2,2	3,0	2,4
30	0,9	-0,2	2,4	0,8	-0,2	2,1	1,8	1,5	2,5	2,4
40	1,4	-0,4	2,1	0,6	-0,5	1,4	2,1	-0,6	2,4	2,4
50	1,8	-0,6	2,2	0,3	-0,7	1,2	2,0	-0,7	2,0	2,3
60	1,9	-0,3	2,7	-0,7	-1,3	1,3	1,7	0,6	1,0	2,1
85	1,9	0,0	1,0	-0,9	-0,6	0,7	1,5	1,0	0,4	1,9
110	3,0	1,3	0,7	-0,6	0,0	1,2	0,5	1,3	-0,3	-0,1
135				0,9	0,7					
150										
160	3,9	3,0	0,3				0,6	1,3	0,1	-0,1
Depth [cm]	EC [μS/cm]									
10		204	315	301	309	289	383	437	465	481
20	305	217	340	387	360	284	376	435	468	475
30	329	285	387	415	459	317	367	409	437	410
40	372	328	390	438	435	336	400	475	364	515
50	328	272	333	391	436	360	445	476	535	689
75	258	230	243	265	307	218	305	390	667	646
100	262	205	240	289	309	148	279	294	477	559
125				271	267					
140										
150	290	257	233				308	281	419	488

Table D.2. Temperature (°C) and EC (μS/cm) profiles of Olszowa Droga (round 2). Temperature readings are from 20 to 160 cm below the water surface, EC readings are from 10 to 150 cm below the water surface. Water depths shown in Table C. All dates are from 2012.

Sampling point	606	601	607	602	608	603	609	604	610	605
Date	13-apr	13-apr	13-apr	13-apr	13-apr	13-apr	13-apr	13-apr	13-apr	13-apr
Depth [cm]	Temperature [°C]									
20	5,9	4,2	7,6	7,3	9,5	9,1	10,4	11,0	10,8	10,4
30	5,0	3,1	6,8	6,1	8,3	8,1	9,5	10,8	10,8	10,2
40	3,9	2,8	6,0	5,1	7,0	7,0	8,1	9,1	10,2	10,2
50	3,6	2,8	5,2	4,5	6,0	6,2	6,8	7,9	8,2	8,2
60	3,7	3,1	4,9	4,4	5,6	5,5	5,8	6,6	7,0	6,8
85	4,1	4,3	5,1	4,6	5,4	5,5	5,5	5,6	5,5	5,5
110	4,9	5,3	5,5	5,2	5,7	5,8	5,5	5,6	5,1	5,1
135										
150				6,0	6,2					
160	6,5	6,9	6,6				6,2	6,1	5,4	5,2
Depth [cm]	EC [μS/cm]									
10	205	248	323	282	279	301	406	485	481	507
20	255	297	366	383	329	302	388	475	472	456
30	310	383	369	344	407	251	359	492	471	477
40	340	376	386	327	255	249	363	454	374	640
50	249	306	308	353	360	198	348	505	476	698
75	234	217	241	242	246	205	283	323	543	607
100	214	202	275	247	280	202	254	265	454	519
125										
140				173	271					
150	279	267	260				280	258	450	498

Table D.3. Temperature (°C) and EC (μS/cm) profiles of Olszowa Droga (round 1). Temperature readings are from 20 to 160 cm below the water surface, EC readings are from 10 to 150 cm below the water surface. Water depths shown in Table C. All dates are from 2012.

Sampling point	606	601	607	602	608	603	609	604	610	605
Date	19-apr	19-apr	19-apr	19-apr	19-apr	19-apr	19-apr	19-apr	19-apr	19-apr
Depth [cm]	Temperature [°C]									
20	6,6	6,2	8,0	7,4	8,3	8,4	8,4	8,9	8,8	9,7
30	6,4	5,8	7,6	7,1	8,1	8,5	8,8	9,3	9,1	9,8
40	5,9	5,6	6,8	6,7	7,6	8,2	8,7	9,5	9,3	9,6
50	5,6	5,1	6,5	6,2	7,2	7,8	8,0	9,0	9,0	9,8
60	5,4	5,0	6,1	5,8	6,8	7,4	7,2	8,3	8,0	8,5
85	5,3	5,1	5,9	5,6	6,4	5,9	6,5	7,3	7,1	7,7
110	5,5	5,6	5,9	5,5	6,2	6,4	6,2	6,3	6,0	6,3
135					6,2		6,0	6,0	5,6	5,8
150										
160	6,6	6,5	6,6	5,8			6,3	6,3	5,7	5,6
Depth [cm]	EC [μS/cm]									
10	215	224	240	241	232	222	289	417	434	445
20	294	209	310	263	308	232	309	445	459	465
30	269	231	260	263	318	213	351	436	449	446
40	320	277	296	334	412	198	405	401	437	489
50	343	286	324	403	429	190	372	468	379	631
75	266	273	307	364	344	206	371	527	616	698
100	232	208	259	254	262	210	272	324	622	646
125	225	209	257	197	276	155	261	287	487	525
140				244	115		281	366	419	478
150										

Table D.4. Temperature (°C) and EC (μS/cm) profiles of Olszowa Droga (round 4). Temperature readings are from 20 to 160 cm below the water surface, EC readings are from 10 to 150 cm below the water surface. Water depths shown in Table C. All dates are from 2012.

Sampling point	606	601	607	602	608	603	609	604	610	605
Date	31-mrt	31-mrt	31-mrt	31-mrt	31-mrt	31-mrt	31-mrt	31-mrt	31-mrt	31-mrt
Depth [cm]	Temperature [°C]									
20	10,3	9,3	11,3	11,2	13,5	17,1	17,9	20,4	19,5	18,9
30	9,1	8,1	10,2	10,3	12,0	12,5	14,5	19,0	18,6	18,5
40	8,0	7,2	9,2	9,2	10,6	11,0	12,5	14,8	14,3	15,0
50	7,3	6,6	8,2	8,2	9,5	10,0	10,5	12,5	12,2	13,0
60	6,9	6,1	7,5	7,5	8,6	9,1	9,5	11,0	10,5	11,0
85	6,4	5,7	6,7	6,7	7,5	8,1	7,9	9,0	8,5	9,0
110	6,4	5,8	6,5	6,3	7,0	7,1	7,0	7,5	7,1	7,2
135	6,6	6,2	6,5	6,3	6,9		6,6	6,5		
150										
160	6,9	6,9	6,9				6,6	6,7	6,5	6,4
Depth [cm]	EC [μS/cm]									
10	228	253	266	228	268	281	350	414	420	426
20	260	224	308	244	306	319	406	382	480	498
30	267	320	340	360	325	282	402	468	478	474
40	336	387	354	429	401	245	429	409	407	438
50	319	382	389	402	369	257	354	448	266	474
75	292	264	350	372	375	242	376	431	538	667
100	239	221	285	249	259	220	281	348	576	692
125	243	212	291	162	285	89	248	286	479	535
140				207	146		264	323		503
150										

Table D.5. Temperature (°C) and EC (μS/cm) profiles of Barwik (round 1). Temperature readings are from 20 to 160 cm below the water surface, EC readings are from 10 to 150 cm below the water surface. Water depths shown in Table C. All dates are from 2012.

Sampling point	401	406	402	407	403	408	404	409	405
Date	7-apr	7-apr	7-apr	7-apr	7-apr	7-apr	7-apr	7-apr	7-apr
Depth [cm]	Temperature [°C]								
20	4,1	3,1	2,0	2,1	0,8	2,4	1,5	2,9	3,3
30	3,5	2,4	1,9	1,8	0,8	2,1	1,3	1,8	3,0
40	2,8	2,2	2,0	1,9	0,9	2,0	1,2	1,4	3,0
50	2,5	2,2	2,1	2,0	1,1	1,9	1,3	1,3	2,9
60	2,5	2,2	2,4	2,4	1,4	2,0	1,5	1,4	2,9
85	2,7	3,0	3,4	3,4	2,4	2,5	2,2	2,3	3,2
110	3,5	3,8	4,4	4,3	3,3	3,3	3,5	3,4	
135		5,0					4,7		
150	5,0							4,8	
160			6,4	6,0	5,0	5,1			
Depth [cm]	EC [μS/cm]								
10	513	788	432	399	313	344	314	338	447
20	447	798	462	429	409	365	371	350	336
30	450	776	389	422	463	386	491	480	373
40	467	722	378	417	451	368	475	578	430
50	471	655	328	375	449	319	478	510	526
75	495	584	406	398	487	444	548	481	483
100	583	516	374	391	435	460	619	520	
125		528					329		
140	495							510	
150			425	347	447	435			

Table D.6. Temperature (°C) and EC (μS/cm) profiles of Barwik (round 2). Temperature readings are from 20 to 160 cm below the water surface, EC readings are from 10 to 150 cm below the water surface. Water depths shown in Table C. All dates are from 2012.

Sampling point	401	406	402	407	403	408	404	409	405
Date	13-apr	13-apr	13-apr	13-apr	13-apr	13-apr	13-apr	13-apr	13-apr
Depth [cm]	Temperature [°C]								
20	8,0	4,4	2,4	4,1	1,4	2,5	4,2	5,5	7,3
30	5,4	3,3	1,8	3,5	0,9	2,0	3,2	4,6	7,1
40	4,4	2,2	1,9	3,1	0,9	1,6	2,7	4,0	5,6
50	3,4	2,1	2,0	3,0	1,0	1,6	2,4	3,0	5,0
60	3,4	2,2	2,5	3,3	1,4	1,7	2,2	3,0	4,2
85	3,2	2,8	3,4	3,9	2,3	2,4	2,9	3,1	3,9
110	3,4	3,7	4,5	4,7	3,2	3,3	3,9	3,8	
135	4,6		5,5			4,2	4,8	4,9	
150									
160		5,6		6,0	5,1				
Depth [cm]	EC [μS/cm]								
10	592	553	309	331	316	394	354	378	476
20	522	664	359	340	412	450	406	378	462
30	551	598	373	385	401	487	462	516	353
40	586	544	346	370	354	494	493	540	470
50	606	439	350	368	329	461	509	522	501
75	602	501	421	397	475	501	497	445	323
100	578	533	404	383	442	486	539	521	
125	598		384			536	212	321	
140									
150		599		333	470				

Table D.7. Temperature (°C) and EC (μS/cm) profiles of Barwik (round 3). Temperature readings are from 20 to 160 cm below the water surface, EC readings are from 10 to 150 cm below the water surface. Water depths shown in Table C. All dates are from 2012.

Sampling point	401	406	402	407	403	408	404	409	405
Date	23-apr	23-apr	23-apr	23-apr	23-apr	23-apr	23-apr	23-apr	23-apr
Depth [cm]	Temperature [°C]								
20	10,2	8,8	7,1	6,7	6,5	7,4	8,3	9,5	
30	9,7	8,3	6,6	6,2	6,1	7,2	8,0	9,4	
40	8,3	7,1	5,5	5,6	5,5	6,3	7,3	8,2	
50	7,3	6,2	4,8	5,1	4,6	5,1	5,8	7,2	
60	6,6	5,2	4,5	4,5	3,8	4,5	5,0	6,2	
85	5,4	4,5	4,4	4,3	3,4	3,8	4,3	5,2	
110	4,7	4,3	4,7	4,4	3,5	3,9	4,3	4,6	
135	4,8	4,8	5,4	5,2	4,2	4,2	4,6	4,9	
150									
160		5,5		5,6	4,9	5,1			
Depth [cm]	EC [μS/cm]								
10	529	737	439	421	343	398	474	406	
20	524	655	352	383	445	449	388	404	
30	540	704	335	302	492	482	371	428	
40	553	680	332	306	470	481	375	464	
50	515	590	327	355	412	441	443	494	
75	569	569	386	391	464	480	517	436	
100	560	511	384	333	389	465	616	442	
125		507	389	386	488	519	489	502	
140									
150	637	534		349	449	428			

Table D.8. Temperature (°C) and EC (μS/cm) profiles of Barwik (round 4). Temperature readings are from 20 to 160 cm below the water surface, EC readings are from 10 to 150 cm below the water surface. Water depths shown in Table C. All dates are from 2012.

Sampling point	401	406	402	407	403	408	404	409	405
Date	28-apr	28-apr	28-apr	28-apr	28-apr	28-apr	28-apr	28-apr	28-apr
Depth [cm]	Temperature [°C]								
20	15,5	13,3	10,3	9,0	9,3	9,5	10,5	12,2	15,3
30	13,0	10,6	8,5	7,2	7,7	8,5	8,5	10,5	14,0
40	10,5	8,8	7,2	6,0	6,4	7,0	6,8	9,2	11,5
50	8,8	7,5	6,3	5,3	5,5	6,3	5,8	8,0	10,0
60	7,8	6,7	5,7	4,8	4,9	5,5	5,3	7,0	8,5
85	6,6	5,5	5,3	4,5	4,5	4,7	4,4	6,0	6,0
110	5,5	5,0	5,4	4,7	4,3	4,5	4,4	5,5	
135	5,0	5,1	5,8	5,2		4,7	4,6	5,1	
150									
160		5,5		5,9					
Depth [cm]	EC [μS/cm]								
10	487	489	380	400	370	474	429	474	540
20	556	490	444	371	383	462	388	392	492
30	533	463	401	363	396	463	394	431	404
40	506	459	386	365	395	428	442	463	398
50	491	513	347	347	351	366	490	468	404
75	537	565	386	381	403	472	578	408	410
100	525	519	372	376	425	460	545	455	
125	539	557	394	352		480	474	414	
140									
150		555		349					

Table D.9. Temperature (°C) and EC (μS/cm) profiles of Gugny (round 1). Temperature readings are from 20 to 160 cm below the water surface, EC readings are from 10 to 150 cm below the water surface. Water depths shown in Table C. All dates are from 2012.

Sampling point	101	111	102	112	103	113	104	115	105
Date	6-apr	6-apr	6-apr	6-apr	6-apr	6-apr	6-apr	6-apr	6-apr
Depth [cm]	Temperature [°C]								
20	4,5	4,4	3,7	2,5	1,8	1,3	2,2	4,1	3,6
30	4,5	4,1	3,7	1,8	1,6	1,4	2,1	3,0	3,5
40	4,6	4,1	3,8	1,9	1,6	1,3	2,1	2,7	3,1
50	4,8	4,2	4,0	2,1	1,6	1,3	2,1	2,7	2,9
60	5,0	4,4	4,1		1,7	1,4	2,1	2,7	3,0
85	5,4				2,2	2,1	2,7	3,2	3,3
110					3,1	2,9	3,5	4,0	4,0
135					3,6		4,8		5,0
150								5,6	
160						5,1			
Depth [cm]	EC [μS/cm]								
10	549	903	661	361	347	353	460	562	484
20	359	855	667	421	371	364	445	822	537
30	277	761	574	565	330	456	396	761	698
40	250	683	459	568	356	565	395	804	776
50	267	596	383		347	553	370	695	710
75	354				395	646	496	661	888
100					400	677	579	664	828
125					164		254		631
140								512	
150						628			

Table D.10. Temperature (°C) and EC (μS/cm) profiles of Gugny (round 2). Temperature readings are from 20 to 160 cm below the water surface, EC readings are from 10 to 150 cm below the water surface. Water depths shown in Table C. All dates are from 2012.

Sampling point	101	111	102	112	103	113	104	115	105
Date	12-apr	12-apr	12-apr	12-apr	12-apr	12-apr	12-apr	12-apr	12-apr
Depth [cm]	Temperature [°C]								
20	5,6	4,9	4,5	3,4	4,0	0,2	2,4	4,7	5,3
30	5,7	4,4	4,2	2,8	3,0	0,4	1,3	4,7	4,4
40	5,2	4,3	4,1	2,5	2,4	0,6	1,1	4,1	3,6
50	5,0	4,3	4,2	2,6	2,1	0,8	1,1	3,8	3,3
60	5,1	4,4	4,3		2,1	1,2	1,4	3,7	3,4
85	5,4				2,5	2,3	2,4	4,0	3,6
110					3,2	3,2	3,4		4,3
135							4,5		5,2
150								5,9	
160						5,3			
Depth [cm]	EC [μS/cm]								
10	1097	973	680	407	371	435	471	671	481
20	973	873	568	492	356	479	400	798	564
30	746	749	559	525	276	640	432	773	637
40	677	686	386	432	303	722	477	791	767
50	607	655	194		299	804	482	698	843
75	386				393	831	568	607	891
100					391	743	543		695
125							205		516
140								528	
150						655			

Table D.11. Temperature (°C) and EC (μS/cm) profiles of Gugny (round 3). Temperature readings are from 20 to 160 cm below the water surface, EC readings are from 10 to 150 cm below the water surface. Water depths shown in Table C. All dates are from 2012.

Sampling point	101	111	102	112	103	113	104	115	105
Date	20-apr	20-apr	20-apr	20-apr	20-apr	20-apr	20-apr	20-apr	20-apr
Depth [cm]	Temperature [°C]								
20	8,6	7,4	6,7	7,0	7,4	4,0	6,8	8,3	8,6
30	8,1	7,0	6,3	6,0	6,5	0,8	5,5	7,4	7,6
40	7,6	6,4	5,9	5,0	5,7	0,8	4,5	6,6	6,8
50	7,1	6,0	5,6	4,4	5,2	0,9	3,7	5,9	5,8
60	6,6	5,6	5,4		4,5	1,1	3,2	5,3	5,2
85	6,3				3,8	1,7	3,1	4,8	4,8
110					3,7	2,6	3,6	4,8	4,7
135						3,6			
150									
160						4,7	4,6	5,9	5,5
Depth [cm]	EC [μS/cm]								
10	743	816	631	412	424	436	474	553	444
20	1197	988	798	436	385	558	410	740	646
30	788	861	553	510	292	540	407	782	728
40	634	785	512	554	305	613	430	770	807
50	554	661	411		315	667	425	716	801
75	324				397	722	495	683	855
100					290	725	530	683	746
125						677			607
140							180		
150						575		481	

Table D.12. Temperature (°C) and EC (μS/cm) profiles of Gugny (round 4). Temperature readings are from 20 to 160 cm below the water surface, EC readings are from 10 to 150 cm below the water surface. Water depths shown in Table C. All dates are from 2012.

Sampling point	101	111	102	112	103	113	104	115	105
Date	26-apr	26-apr	26-apr	26-apr	26-apr	26-apr	26-apr	26-apr	26-apr
Depth [cm]	Temperature [°C]								
20	9,9	8,5	8,0	8,0	8,0	7,4	8,5	10,8	10,7
30	9,3	8,1	7,4	6,8	7,7	6,6	8,2	9,6	9,7
40	8,6	7,4	6,8	5,8	7,3	5,7	7,4	8,4	8,7
50	8,0	6,8	6,4	5,4	6,6	5,0	6,8	7,8	7,8
60	7,6	6,5			6,0	4,1	6,1	7,0	7,3
85	6,8				4,8	3,3	5,1	6,1	6,2
110					4,1	3,3	4,8	5,7	5,7
135					4,2	3,9	5,0	5,8	5,6
150									
160						4,7		6,2	6,0
Depth [cm]	EC [μS/cm]								
10	746	876	861	511	441	395	513	583	532
20	825	813	658	553	420	455	433	785	481
30	520	692	616	616	345	625	382	773	746
40	459	603	490	448	345	640	412	798	822
50	449	546			325	534	381	664	773
75	403				360	625	524	625	885
100					391	677	550	596	849
125					180	661	220	586	655
140									
150						643		521	232

Table D.13. Temperature (°C) and EC (μS/cm) profiles of Szorce (round 1). Temperature readings are from 20 to 160 cm below the water surface, EC readings are from 10 to 150 cm below the water surface. Water depths shown in Table C. All dates are from 2012.

Sampling point	501	506	502	507	503	508	504	509	505	511	510
Date	6-apr	6-apr	6-apr	6-apr	6-apr	6-apr	6-apr	6-apr	6-apr	6-apr	6-apr
Depth [cm]	Temperature [°C]										
20	1,9	1,8	1,4	1,0	3,5	3,8	2,4	3,9	4,1	3,3	3,4
30	2,2	1,9	1,4	0,9	3,3	3,7	2,4	4,2	3,5	3,2	2,9
40	2,4	2,0	1,4	1,0	3,3	3,7	2,2	4,3	3,3	2,9	2,6
50	2,6	2,1	1,5	1,1	3,3	3,7	2,2	4,2	3,0	3,0	2,4
60	2,9	2,4	1,8	1,4	3,4	3,7	2,3	4,2	2,6	3,0	2,3
85	3,6	3,4	2,5	2,2	3,6	3,7	2,8	4,2	2,4	3,3	2,6
110	4,7	4,4	3,4	3,1	4,3	3,7	3,5	4,3	2,7	4,0	3,5
135											
150											
160			5,1	4,7	5,6	4,7	4,9	5,1		5,5	5,4
Depth [cm]	EC [μS/cm]										
10	367	386	329	320	504	363	334	316	314	255	231
20	419	507	454	501	500	409	373	373	238	294	250
30	504	601	580	541	537	483	526	486	266	289	225
40	566	646	589	546	532	547	548	500	293	338	286
50	616	695	578	519	461	445	568	562	283	353	367
75	637	782	610	546	506	464	450	483	292	417	422
100	628	661	525	546	448	484	495	483	247	382	413
125											
140											
150			553	468	389	533	422	580		534	574

Table D.14. Temperature (°C) and EC (μS/cm) profiles of Szorce (round 2). Temperature readings are from 20 to 160 cm below the water surface, EC readings are from 10 to 150 cm below the water surface. Water depths shown in Table C. All dates are from 2012.

Sampling point	501	506	502	507	503	508	504	509	505	511	510
Date	12-apr	12-apr	12-apr	12-apr	12-apr	12-apr	12-apr	12-apr	12-apr	12-apr	12-apr
Depth [cm]	Temperature [°C]										
20	5,5	3,1	4,3	3,1	5,6	5,2	4,2	6,8	8,3	7,5	7,0
30	4,6	2,0	3,3	2,4	4,8	4,6	3,5	5,9	6,5	5,2	5,8
40	3,8	2,0	2,7	2,1	4,2	4,0	3,4	5,2	5,2	4,1	4,7
50	3,6	2,1	2,6	2,1	4,0	3,9	3,0	4,8	4,3	3,4	3,9
60	3,6	2,6	2,6	2,1	3,9	3,9	3,1	4,6	3,9	3,3	3,5
85	4,1	3,3	3,0	2,8	4,0	3,9	3,3	4,6	3,4	3,3	3,5
110	4,8	4,5	3,5	3,3	4,3	4,2	3,7	4,6	3,2	3,8	4,0
135											
150											
160			5,0	4,9	5,4	5,1	5,0	5,2	4,2	5,3	5,6
Depth [cm]	EC [μS/cm]										
10	375	373	445	432	393	363	350	337	337	262	263
20	458	507	548	468	542	412	444	350	255	321	226
30	516	573	543	520	553	488	519	458	244	288	258
40	558	667	543	520	540	536	531	491	258	307	281
50	625	740	529	485	545	500	525	510	242	375	340
75	713	782	580	516	527	461	466	432	298	422	414
100	683	667	528	521	463	493	524	479	233	411	404
125											
140											
150			483	502	481	542	546	577	365	583	534

Table D.15. Temperature (°C) and EC (μS/cm) profiles of Szorce (round 3). Temperature readings are from 20 to 160 cm below the water surface, EC readings are from 10 to 150 cm below the water surface. Water depths shown in Table C. All dates are from 2012.

Sampling point	501	506	502	507	503	508	504	509	505	511	510
Date	21-apr	21-apr	21-apr	21-apr	21-apr	21-apr	21-apr	21-apr	21-apr	21-apr	21-apr
Depth [cm]	Temperature [°C]										
20	8,3	8,8	7,4	5,8	8,4	8,6	10,0		10,7	10,0	9,2
30	7,2	7,1	6,3	4,4	7,5	7,5	8,5		10,2	9,5	8,5
40	6,5	6,2	5,5	3,7	6,6	6,7	6,9		9,1	8,0	7,5
50	6,0	5,6	4,8	3,3	5,3	6,0	5,8		8,1	7,5	6,5
60	5,6	5,0	4,3		4,7	5,4	5,0		6,2	6,6	5,8
85	5,1	4,8	3,9	3,2	4,2	4,8	4,4		5,0	5,5	5,0
110		5,0	3,9	3,6	4,3	4,6	4,3		4,1	4,9	4,9
135				4,0	4,7	4,7	4,5		4,0		
150											
160			4,3	4,8	5,5	5,2	5,0		4,2	5,6	5,7
Depth [cm]	EC [μS/cm]										
10	404	462	507	419	444	329	362		326	293	251
20	508	559	604	525	525	404	404		293	269	262
30	553	649	587	539	531	468	435		195	289	295
40	619	716	574	531	504	480	522		148	262	302
50	619	707	542		507	495	562		232	305	406
75	622	746	628	513	518	441	477		318	404	390
100		661	465	519	404	471	513		293	388	379
125			478	462	444	490	519		282		
140											
150				432	457	522	531		355	571	541

Table D.16. Temperature (°C) and EC (μS/cm) profiles of Szorce (round 4). Temperature readings are from 20 to 160 cm below the water surface, EC readings are from 10 to 150 cm below the water surface. Water depths shown in Table C. All dates are from 2012.

Sampling point	501	506	502	507	503	508	504	509	505	511	510
Date	27-apr	27-apr	27-apr	27-apr	27-apr	27-apr	27-apr	27-apr	27-apr	27-apr	27-apr
Depth [cm]	Temperature [°C]										
20	9,6	9,5	9,1	7,0	9,3	10,1	9,4	11,4	13,2	13,0	13,0
30	8,6	8,5	8,1	6,2	8,3	9,0	8,2	9,9	11,2	10,5	10,6
40	7,8	7,8	6,5	5,5	7,6	8,2	7,4	8,9	10,2	9,3	9,6
50	7,0	6,9	5,6	4,8	6,8	7,4	6,6	8,2	9,0	8,3	8,5
60	6,4	6,3	4,9	4,6	6,3	6,7	6,0	7,5	8,2	7,4	7,6
85	6,0	5,6	4,4	4,3	5,6	5,9	5,1	6,5	6,5	6,4	6,5
110	5,7	5,4	4,2	4,2	5,4	5,4	4,7	5,8	5,4	5,7	5,6
135			4,5	4,6	5,5	5,4	4,8	5,6	4,7	5,6	5,6
150											
160				5,0	5,8	5,5	5,3	5,6	4,6	6,0	5,8
Depth [cm]	EC [μS/cm]										
10	483	497	413	371	563	427	397	314	376	311	329
20	447	572	559	413	559	425	440	345	307	277	291
30	507	582	552	453	558	505	519	492	299	284	253
40	570	677	572	501	504	536	556	562	269	311	264
50	605	704	577	507	526	493	530	569	286	347	333
75	704	740	616	509	526	454	479	485	280	378	410
100	698	655	495	510	454	484	485	451	235	383	363
125			494	481	453	505	539	525	263	482	516
140											
150				458	480	565	530	583	351	542	562

Table E. Water samples taken during the samplng campaign in the Biebrza lower basin.pointId corresponds to the sample location also shown in Fig. 22, 23, 24 and 25; round corresponds to the sampling round, depth correspond to the depth below the water level the sample was taken (1 = 5 cm below the water surface, 2 = 5 above the ground surface, 3 = 25 cm below the ground surface); EC in μS/cm; Alkalinity in mg HCO^{3}/l; other concentrations in mg/l.\

sampleNr	pointId	round	depth	Date	EC	pH	Alkalinity	F	Br	Cl	NO2	NO3	SO4	Li	Na	NH4	K	Mg	Ca	PO4	Fe	inorganic-N
101	110	1	1	03042012	690	6,80	427	0,295	0,077	12,7	0,000	0,341	1,74	0,001	7,7	0,29	1,88	21,9	114,3	0,576	2,527	0,30
102	101	1	1	03042012	915	7,32	397	0,342	0,136	7,0	0,000	0,000	1,87	0,017	5,2	0,95	1,15	13,1	101,9	0,249	3,324	0,74
103	101	1	3	03042012	625	6,67	360	0,000	0,129	5,6	0,000	0,000	172,22	0,131	3,3	1,10	0,22	10,3	85,6	0,900	36,854	0,85
104	111	1	1	03042012	599	7,14	348	0,202	0,000	7,6	0,000	0,000	77,22	0,089	6,1	0,02	0,16	13,9	90,5	0,096	5,754	0,02
105	102	1	1	03042012	664	7,64	323	0,218	0,000	4,7	0,618	0,000	22,29	0,039	5,9	0,23	0,13	14,2	84,7	0,118	2,089	0,37
106	102	1	3	03042012	755	6,89	421	0,000	0,000	2,9	0,465	0,000	10,32	0,024	4,9	1,69	0,38	20,4	111,7	0,163	1,324	1,45
107	112	1	1	03042012	402	7,20	238	0,151	0,000	3,0	0,602	0,048	6,75	0,022	4,2	0,05	0,16	10,6	49,6	0,000	0,470	0,23
108	103	1	1	03042012	466	7,40	250	0,204	0,016	3,3	0,786	0,017	36,82	0,040	5,3	0,04	0,28	16,0	60,6	0,112	0,037	0,27
109	103	1	3	03042012	420	7,25	238	0,182	0,018	3,3	0,726	0,030	19,94	0,027	5,2	0,04	0,36	14,5	54,6	0,000	0,943	0,26
110	113	1	1	03042012	424	7,39	238	0,197	0,024	2,9	0,633	0,015	6,29	0,006	5,0	0,00	0,27	14,7	56,2	0,015	0,425	0,20
111	104	1	1	03042012	544	7,47	305	0,237	0,053	5,2	0,785	0,014	14,92	0,016	7,5	0,00	1,23	22,9	67,7	0,008	0,026	0,24
112	104	1	3	03042012	585	7,03	305	0,418	0,027	5,3	0,386	0,000	8,19	0,011	8,1	1,34	1,19	22,1	75,6	0,980	2,265	1,16
113	114	1	1	03042012	491	7,23	287	0,238	0,103	6,0	0,595	0,033	19,44	0,015	7,3	0,00	1,32	22,6	63,8	0,018	0,500	0,19
114	115	1	1	03042012	555	7,49	336	0,277	0,028	7,1	0,487	0,023	13,03	0,008	7,5	0,01	1,43	25,3	70,7	0,008	0,077	0,16
115	105	1	1	03042012	530	7,35	287	0,254	0,038	8,1	0,348	0,008	10,72	0,006	6,9	0,01	1,90	23,3	66,4	0,009	0,033	0,12
116	105	1	3	03042012	1085	6,81	610	0,416	0,074	8,0	0,000	0,010	7,28	0,009	7,6	0,41	0,40	46,1	176,2	0,065	2,083	0,32
126	110	2	1	10042012	650	7,15	397	0,310	0,034	12,0	0,000	0,623	2,95	0,001	7,4	0,10	1,74	19,8	95,8	0,022	0,219	0,22
127	101	2	1	10042012	742	7,55	342	0,294	0,028	7,5	0,000	0,000	0,46	0,006	5,8	0,34	0,70	13,3	92,2	0,016	38,536	0,27
128	101	2	3	10042012	512	6,72	360	0,201	0,000	4,0	0,000	0,000	0,10	0,001	3,2	0,82	0,07	9,2	76,8	0,138	85,410	0,64
129	111	2	1	10042012	610	7,36	366	0,204	0,013	7,6	0,000	0,000	0,33	0,001	6,5	0,02	0,06	13,5	91,4	0,011	2,213	0,02
130	102	2	1	10042012	630	7,40	311	0,234	0,011	5,6	0,000	0,004	0,33	0,002	6,0	0,05	0,21	14,4	88,3	0,014	6,973	0,04
131	102	2	3	10042012	694	6,89	482	0,262	0,024	3,5	0,000	0,000	1,06	0,012	5,0	1,56	0,12	21,6	115,2	0,022	3,400	1,21
132	112	2	1	10042012	463	7,31	232	0,162	0,000	4,8	0,000	0,089	0,91	0,002	5,4	0,08	0,14	13,1	60,5	0,000	0,452	0,08
133	103	2	1	10042012	435	7,52	238	0,185	0,027	4,4	0,000	0,026	0,40	0,002	5,8	0,03	0,06	14,1	55,7	0,003	0,203	0,03
134	103	2	3	10042012	482	6,85	232	0,183	0,013	4,0	0,000	0,032	4,83	0,027	5,6	0,06	0,07	14,1	54,5	0,012	0,799	0,05
135	113	2	1	10042012	439	7,50	238	0,179	0,017	3,7	0,000	0,028	0,38	0,002	5,7	0,03	0,05	15,4	59,0	0,019	1,382	0,03
136	104	2	1	10042012	536	7,56	329	0,216	0,000	4,2	0,000	0,000	1,61	0,011	7,7	0,01	1,10	23,1	69,3	0,000	0,225	0,00
137	104	2	3	10042012	371	7,29	317	0,201	0,044	5,5	0,000	0,009	0,32	0,005	8,4	1,09	0,90	20,5	68,3	0,438	3,037	0,85

sampleNr	pointId	round	depth	Date	EC	pH	Alkalinity	F	Br	Cl	NO2	NO3	SO4	Li	Na	NH4	K	Mg	Ca	PO4	Fe	inorganic-N
138	114	2	1	10042012	502	7,46	275	0,211	0,000	5,0	0,000	0,000	0,71	0,003	7,2	0,03	1,25	21,8	62,6	0,045	0,518	0,02
139	115	2	1	10042012	575	7,48	354	0,235	0,044	7,3	0,000	0,033	2,37	0,004	8,1	0,06	1,23	27,4	76,6	0,013	0,095	0,05
140	105	2	1	10042012	489	7,38	262	0,233	0,000	8,9	0,000	0,020	3,95	0,003	7,1	0,04	1,73	22,8	65,3	0,002	0,407	0,04
141	105	2	3	10042012	1072	6,82	610	0,381	0,084	7,4	0,000	0,000	2,12	0,007	7,5	0,54	0,20	47,0	184,5	0,014	2,745	0,42
142	110	3	1	17042012	578	6,92	329	0,279	0,053	9,5	0,874	0,700	12,18	0,001	6,5	0,03	1,67	15,6	82,1	0,033	1,393	0,44
143	101	3	1	17042012	634	7,63	268	0,327	0,019	8,7	0,776	0,193	2,53	0,001	7,2	0,02	0,27	11,9	69,9	0,047	15,149	0,29
144	101	3	3	17042012	500	6,69	329	0,305	0,023	3,5	1,193	0,000	0,09	0,001	3,9	0,79	0,07	9,5	78,1	0,404	32,162	0,98
145	111	3	1	17042012	500	7,35	293	0,299	0,000	5,1	0,786	0,000	0,37	0,001	6,2	0,02	0,42	11,5	78,2	0,001	1,242	0,25
146	102	3	1	17042012	516	7,38	299	0,276	0,000	4,7	0,824	0,000	0,43	0,000	6,0	0,01	0,09	13,0	83,2	0,007	0,799	0,26
147	102	3	3	17042012	672	6,90	470	0,322	0,092	3,1	1,267	0,033	0,10	0,001	5,8	1,71	0,18	20,6	113,8	0,033	3,170	1,73
148	112	3	1	17042012	425	7,31	262	0,256	0,000	4,3	0,686	0,000	0,54	0,001	5,7	0,04	0,25	13,6	64,5	0,003	0,339	0,24
149	103	3	1	17042012	423	7,48	262	0,331	0,000	5,5	0,702	0,181	1,60	0,002	8,9	0,12	0,37	18,0	68,4	0,000	0,091	0,34
150	103	3	3	17042012	402	7,32	232	0,288	0,000	3,5	0,665	0,000	0,38	0,002	5,6	0,05	0,07	12,4	49,4	0,009	1,003	0,24
151	113	3	1	17042012	370	7,51	214	0,263	0,000	3,4	0,512	0,061	0,39	0,002	6,1	0,01	0,42	14,0	54,2	0,009	0,141	0,18
152	104	3	1	17042012	460	7,38	268	0,306	0,000	3,7	0,689	0,000	0,84	0,004	8,6	0,04	0,94	21,4	64,7	0,016	0,198	0,24
153	104	3	3	17042012	482	6,87	293	0,305	0,000	4,7	0,876	0,000	1,11	0,008	8,2	1,00	0,46	19,6	66,2	0,863	3,203	1,05
154	114	3	1	17042012	499	7,39	287	0,472	0,000	6,0	0,755	0,000	0,76	0,004	11,5	0,04	1,74	25,1	73,6	0,093	0,951	0,26
155	115	3	1	17042012	510	7,55	311	0,327	0,000	5,8	0,785	0,000	0,76	0,004	8,7	0,03	0,87	26,9	78,6	0,016	0,199	0,26
156	105	3	1	17042012	406	7,45	232	0,308	0,000	6,5	0,605	0,000	0,60	0,002	5,2	0,10	1,28	16,0	47,7	0,011	0,187	0,26
157	105	3	3	17042012	1035	6,88	610	0,494	0,096	7,5	0,000	0,000	1,40	0,003	7,6	0,53	0,09	45,4	178,3	0,005	3,460	0,41
158	110	4	1	24042012	700	7,25	421	0,396	0,022	9,3	1,087	0,453	1,12	0,001	5,6	0,26	0,64	15,5	85,3	0,062	14,783	0,64
159	101	4	1	24042012	914	7,31	464	0,335	0,026	5,7	0,944	0,013	0,23	0,002	6,1	1,10	1,62	16,3	123,2	0,002	3,432	1,14
160	101	4	3	24042012	440	6,60	287	0,324	0,000	3,5	0,813	0,000	0,07	0,002	3,8	0,86	0,07	9,8	81,3	0,000	3,275	0,92
161	111	4	1	24042012	563	7,32	354	0,347	0,000	5,0	0,767	0,000	0,16	0,001	6,0	0,10	0,08	13,7	109,7	0,000	1,827	0,31
162	102	4	1	24042012	555	7,49	348	0,320	0,000	3,9	0,879	0,017	0,20	0,001	6,1	0,08	0,18	14,9	97,6	0,000	3,668	0,34
163	102	4	3	24042012	627	6,92	433	0,343	0,011	2,6	1,095	0,015	0,07	0,001	5,6	1,93	0,18	22,1	125,4	0,000	3,087	1,83
164	112	4	1	24042012	454	7,40	262	0,234	0,000	3,3	0,696	0,033	6,85	0,001	6,0	0,25	0,09	15,5	79,4	0,031	0,824	0,42
165	103	4	1	24042012	440	7,59	275	0,215	0,000	2,1	0,671	0,065	0,18	0,002	7,0	0,16	0,10	19,5	77,9	0,006	0,400	0,34
166	103	4	3	24042012	431	7,33	244	0,334	0,000	2,0	0,593	0,013	0,13	0,002	7,0	0,11	0,06	19,5	79,9	0,014	2,061	0,27
167	113	4	1	24042012	381	7,53	244	0,317	0,000	2,9	0,812	0,013	0,14	0,001	6,6	0,07	0,07	16,7	66,1	0,000	0,165	0,30

sampleNr	pointId	round	depth	Date	EC	pH	Alkalinity	F	Br	Cl	NO2	NO3	SO4	Li	Na	NH4	K	Mg	Ca	PO4	Fe	inorganic-N
168	104	4	1	24042012	524	7,49	329	0,366	0,000	2,8	0,767	0,031	0,09	0,003	7,2	0,05	0,81	22,4	67,6	0,000	0,199	0,28
169	104	4	3	24042012	475	6,83	293	0,381	0,000	4,5	0,710	0,028	0,11	0,003	7,0	1,27	0,22	16,9	57,6	1,467	28,928	1,21
170	114	4	1	24042012	490	7,60	329	0,366	0,000	3,2	0,727	0,000	0,12	0,004	9,1	0,03	1,29	29,8	86,3	0,051	0,328	0,25
171	115	4	1	24042012	499	7,63	317	0,376	0,000	4,2	0,776	0,000	0,17	0,002	6,3	0,09	0,60	21,7	62,9	0,000	2,316	0,30
172	105	4	1	24042012	457	7,54	250	0,385	0,000	6,5	0,569	0,042	3,85	0,002	5,7	0,04	1,04	17,9	53,0	0,000	0,247	0,22
173	105	4	3	24042012	978	6,81	610	0,537	0,044	7,5	0,000	0,000	1,04	0,003	7,5	0,43	0,11	44,1	179,1	0,028	27,095	0,33
401	401	1	1	05042012	605	7,06	342	0,230	0,029	5,3	0,858	0,298	2,37	0,002	6,5	0,10	3,00	21,0	82,1	0,172	3,249	0,41
402	401	1	3	05042012	486	7,32	299	0,266	0,063	5,2	1,016	0,021	0,57	0,001	6,0	0,92	3,52	18,6	80,1	0,170	9,470	1,03
403	406	1	1	05042012	638	6,98	207	0,186	0,026	6,4	0,826	0,105	0,58	0,001	7,5	0,26	4,73	16,9	70,1	0,843	0,681	0,48
404	402	1	1	05042012	529	6,90	268	0,206	0,025	6,7	0,596	0,025	2,88	0,002	6,7	0,35	0,79	9,1	50,4	0,951	0,309	0,46
405	402	1	3	05042012	434	7,05	244	0,216	0,027	5,0	0,898	0,021	1,95	0,003	6,7	1,61	0,93	10,8	62,9	2,767	2,224	1,53
406	407	1	1	05042012	395	6,75	195	0,141	0,146	6,9	0,764	0,097	4,10	0,003	7,1	0,04	2,67	11,1	51,4	0,067	2,599	0,29
407	403	1	1	05042012	320	7,13	165	0,145	0,011	4,5	0,461	0,037	1,37	0,001	5,8	0,06	0,79	8,9	42,6	0,003	0,242	0,20
408	403	1	3	05042012	531	7,06	336	0,253	0,040	3,9	0,470	0,005	1,01	0,003	6,8	1,04	0,49	15,4	95,1	2,351	1,398	0,95
409	408	1	1	05042012	361	7,18	207	0,160	0,043	4,8	0,459	0,042	1,09	0,002	6,3	0,02	0,40	11,0	48,7	0,910	0,189	0,16
410	404	1	1	05042012	328	7,12	159	0,145	0,000	4,9	0,529	0,012	2,30	0,003	5,9	0,01	0,44	10,3	43,0	0,010	0,005	0,17
411	404	1	3	05042012	621	6,88	384	0,286	0,065	6,3	0,000	0,019	0,54	0,002	4,9	1,38	0,36	23,1	101,0	1,225	0,364	1,08
412	409	1	1	05042012	346	7,12	195	0,117	0,000	4,1	0,457	0,010	1,64	0,001	4,1	0,05	1,15	13,5	46,0	0,078	3,157	0,18
413	405	1	1	05042012	443	7,20	220	0,223	0,016	4,8	0,648	0,030	3,30	0,003	4,9	0,02	1,06	19,0	57,9	0,000	0,070	0,22
414	405	1	3	05042012	599	7,01	366	0,239	0,036	10,7	0,000	0,000	1,05	0,003	7,6	0,18	0,89	26,3	86,9	2,289	0,273	0,14
415	401	2	1	11042012	530	7,46	354	0,166	0,017	6,3	0,000	0,015	0,47	0,001	7,4	0,05	2,27	22,9	88,3	0,012	1,145	0,05
416	401	2	3	11042012	522	7,14	311	0,140	0,033	5,5	0,000	0,031	0,36	0,001	5,8	1,05	3,27	18,1	82,0	0,794	1,460	0,82
417	406	2	1	11042012	675	7,09	445	0,225	0,059	7,9	0,000	0,027	0,46	0,003	9,3	1,56	5,07	22,9	108,3	0,089	0,137	1,22
418	402	2	1	11042012	489	7,20	165	0,200	0,014	6,8	0,000	0,021	2,46	0,001	7,3	0,03	0,11	8,7	47,9	1,786	1,514	0,03
419	402	2	3	11042012	438	6,80	250	0,206	0,000	5,4	0,000	0,000	0,84	0,001	6,6	1,59	0,86	10,9	63,0	1,792	1,411	1,24
420	407	2	1	11042012	335	7,04	183	0,144	0,017	7,3	0,039	0,160	1,50	0,000	7,8	0,07	1,99	10,6	49,7	0,040	1,563	0,10
421	403	2	1	11042012	330	7,02	177	0,226	0,000	4,8	0,232	0,024	0,71	0,000	7,0	0,02	0,28	10,4	49,4	0,012	0,299	0,10
422	403	2	3	11042012	558	6,72	354	0,307	0,040	4,4	0,000	0,026	0,14	0,002	6,7	1,20	0,28	15,8	94,5	0,845	1,522	0,94
423	408	2	1	11042012	388	7,23	226	0,179	0,000	6,0	0,000	0,019	0,40	0,001	7,3	0,06	0,28	12,4	55,5	0,033	0,121	0,05
424	404	2	1	11042012	330	7,14	165	0,162	0,000	5,5	0,000	0,022	2,82	0,000	7,6	0,03	0,19	11,0	46,7	0,000	0,131	0,03

sampleNr	pointId	round	depth	Date	EC	pH	Alkalinity	F	Br	Cl	NO2	NO3	SO4	Li	Na	NH4	K	Mg	Ca	PO4	Fe	inorganic-N
425	404	2	3	11042012	627	6,56	354	0,237	0,081	6,7	0,000	0,000	0,21	0,002	5,0	1,62	0,07	23,9	103,4	2,330	41,370	1,26
426	409	2	1	11042012	346	7,16	195	0,138	0,000	5,1	0,000	0,000	1,46	0,001	5,4	0,03	0,71	13,0	46,8	0,018	0,272	0,02
427	405	2	1	11042012	451	7,17	268	0,170	0,000	5,6	0,000	0,000	1,77	0,000	6,3	0,01	0,52	22,0	70,2	0,008	0,195	0,01
428	405	2	2	11042012	452	7,12		0,165	0,000	5,7	0,000	0,036	4,66	0,001	5,1	0,08	0,52	18,1	56,2	0,005	0,726	0,07
429	405	2	3	11042012	595	6,68	366	0,188	0,055	10,4	0,000	0,000	0,74	0,004	7,8	0,43	0,42	25,4	86,2	1,126	3,127	0,33
430	401	3	1	18042012	492	7,36	323	0,262	0,000	5,4	0,796	0,000	1,53	0,003	6,0	0,03	1,70	18,2	73,7	0,019	0,938	0,26
431	401	3	3	18042012	545	7,17	329	0,231	0,030	5,5	0,876	0,040	0,33	0,001	7,0	1,18	3,26	18,7	86,9	1,300	15,770	1,19
432	406	3	1	18042012	448	7,23	311	0,323	0,000	6,7	0,957	0,070	0,82	0,003	8,5	0,67	4,04	20,6	87,6	0,038	2,311	0,82
433	402	3	1	18042012	358	7,19	201	0,306	0,057	5,8	0,537	0,055	1,09	0,002	7,4	0,18	0,51	9,7	57,1	0,243	11,265	0,31
434	402	3	3	18042012	425	6,95	250	0,331	0,012	5,8	0,847	0,046	0,73	0,001	8,0	1,75	1,00	11,6	67,7	2,221	3,082	1,63
435	407	3	1	18042012	370	6,86	183	0,216	0,000	6,2	0,599	0,049	1,19	0,002	7,8	0,13	2,49	12,5	58,4	0,104	3,140	0,29
436	403	3	1	18042012	301	7,10	153	0,283	0,009	5,6	0,454	0,052	0,61	0,001	7,6	0,09	0,66	9,1	45,9	0,017	0,513	0,22
437	403	3	3	18042012	538	6,83	342	0,339	0,026	4,3	0,857	0,032	0,59	0,004	6,9	1,29	0,20	15,9	98,4	1,229	13,201	1,27
438	408	3	1	18042012	315	7,27	183	0,276	0,000	4,5	0,468	0,017	0,48	0,001	6,8	0,08	0,39	10,6	49,1	0,030	0,379	0,21
439	404	3	1	18042012	364	7,23	195	0,218	0,000	5,4	0,550	0,021	0,54	0,001	6,5	0,09	0,22	12,6	51,1	0,014	0,216	0,24
440	404	3	3	18042012	593	6,68	366	0,345	0,033	7,6	0,959	0,050	0,24	0,002	6,0	1,80	0,17	23,5	99,6	3,413	3,396	1,71
441	409	3	1	18042012	294	7,05	153	0,148	0,000	5,0	0,412	0,018	0,96	0,001	5,9	0,10	0,81	11,9	44,9	0,040	0,955	0,21
442	405	3	1	18042012	384	7,36	244	0,247	0,053	5,3	0,578	0,056	1,15	0,002	6,2	0,08	0,86	17,6	58,4	0,009	0,135	0,25
443	405	3	2	18042012	407	7,17		0,196	0,000	6,8	0,660	0,062	4,08	0,001	6,0	0,15	0,91	18,0	58,8	0,084	0,882	0,33
444	405	3	3	18042012	527	6,83	372	0,256	0,027	9,6	0,852	0,019	0,67	0,003	7,9	0,46	0,66	24,9	83,1	0,945	3,662	0,62
445	401	4	1	25042012	550	7,35	360	0,343	0,021	5,1	0,796	0,000	0,08	0,001	8,0	0,02	1,75	25,5	105,9	0,945	1,613	0,26
446	401	4	3	25042012	515	7,26	342	0,272	0,019	5,4	0,837	0,014	0,13	0,001	5,7	1,11	2,57	17,9	84,4	1,197	3,470	1,12
447	406	4	1	25042012	1017	7,07	397	0,388	0,035	4,5	0,901	0,027	0,27	0,001	5,9	0,69	2,38	18,0	85,1	0,031	2,673	0,82
448	402	4	1	25042012	374	6,82	214	0,352	0,000	4,8	0,325	0,303	0,84	0,001	6,1	0,17	0,21	7,6	44,9	0,048	3,022	0,30
449	402	4	3	25042012	420	7,00	268	0,354	0,000	4,9	0,717	0,009	0,49	0,001	4,8	1,25	0,34	8,2	48,8	2,138	6,891	1,19
450	407	4	1	25042012	377	7,05	226	0,286	0,012	5,4	0,528	0,182	0,32	0,000	5,6	0,08	1,36	10,2	49,1	0,075	2,151	0,27
451	403	4	1	25042012	352	7,18	226	0,272	0,000	4,1	0,579	0,028	0,27	0,001	5,3	0,07	0,08	7,3	36,9	0,011	0,391	0,24
452	403	4	3	25042012	503	6,81	336	0,382	0,036	4,3	0,891	0,000	0,33	0,003	6,6	1,20	0,21	15,0	94,6	1,096	6,599	1,21
453	408	4	1	25042012	415	7,30	250	0,345	0,000	4,3	0,637	0,026	0,09	0,001	6,2	0,07	0,12	12,7	59,7	0,029	0,340	0,25
454	404	4	1	25042012	426	7,32	281	0,317	0,000	4,3	0,626	0,012	0,17	0,001	5,0	0,06	0,03	12,3	53,4	0,018	0,266	0,24

sampleNr	pointId	round	depth	Date	EC	pH	Alkalinity	F	Br	Cl	NO2	NO3	SO4	Li	Na	NH4	K	Mg	Ca	PO4	Fe	inorganic-N
455	404	4	3	25042012	554	6,69	397	0,374	0,033	8,4	0,803	0,041	0,37	0,001	4,3	1,51	0,07	15,9	69,3	3,507	28,749	1,43
456	409	4	1	25042012	405	7,23	244	0,285	0,000	4,4	0,609	0,014	0,44	0,001	4,3	0,03	0,16	11,8	45,5	0,021	0,445	0,21
457	405	4	1	25042012	438	7,34	305	0,293	0,000	3,8	0,727	0,024	0,47	0,001	3,5	0,03	0,49	13,6	48,5	0,007	0,328	0,25
458	405	4	2	25042012	441	7,17		0,295	0,000	3,7	0,723	0,000	1,58	0,003	6,4	0,11	0,44	22,2	78,4	0,021	1,172	0,31
459	405	4	3	25042012	517	6,83	360	0,335	0,030	8,5	0,821	0,023	0,84	0,003	7,3	0,59	0,77	24,1	82,4	0,842	3,900	0,71
501	501	1	1	03042012	390	7,13	220	0,140	0,000	5,5	0,577	0,274	11,02	0,003	3,3	0,04	2,20	17,9	46,6	0,016	0,169	0,27
502	501	1	3	03042012	698	6,60	415	0,239	0,040	8,4	0,000	0,010	0,62	0,003	4,4	0,07	0,81	29,1	102,4	0,122	0,489	0,06
503	506	1	1	03042012	390	7,18	195	0,146	0,000	5,3	0,611	0,916	11,50	0,011	3,3	0,04	1,69	18,2	45,8	0,005	0,005	0,42
504	502	1	1	03042012	405	7,33	195	0,149	0,000	6,1	0,551	0,472	9,14	0,011	3,8	0,07	1,83	19,8	48,3	0,015	0,000	0,33
505	502	1	3	03042012	747	6,65	464	0,000	0,035	8,7	0,000	0,020	1,55	0,011	5,2	1,14	1,13	39,6	106,6	1,931	0,754	0,89
506	507	1	1	03042012	392	7,25	226	0,131	0,000	6,4	0,554	0,063	6,91	0,002	3,4	0,04	2,43	20,2	45,4	0,013	0,034	0,22
507	503	1	1	03042012	539	7,01	311	0,169	0,027	3,6	0,971	0,000	0,40	0,003	3,2	0,04	2,18	31,4	66,0	0,022	4,388	0,33
508	503	1	3	03042012	750	6,68	488	0,211	0,000	2,5	0,000	0,011	0,39	0,005	4,9	0,23	5,23	50,1	100,1	0,185	11,255	0,18
509	508	1	1	03042012	472	7,17	275	0,180	0,012	5,6	0,736	0,022	0,31	0,002	3,1	0,05	2,37	26,0	59,9	0,012	0,113	0,27
510	504	1	1	03042012	389	7,14	207	0,114	0,000	6,0	0,625	0,032	5,56	0,000	2,9	0,02	1,84	19,1	42,4	1,678	0,115	0,21
511	504	1	3	03042012	433	6,71	232	0,000	0,012	6,2	0,839	0,032	3,27	0,002	4,0	0,05	1,88	19,4	54,5	0,000	0,258	0,30
512	509	1	1	03042012	323	7,30	165	0,160	0,000	6,5	0,571	0,011	2,33	0,001	3,5	0,03	1,35	17,7	40,0	0,006	0,000	0,20
513	505	1	1	03042012	315	7,18	177	0,134	0,018	5,4	0,389	0,000	5,28	0,002	3,0	0,01	1,55	17,9	33,9	0,015	0,000	0,13
514	505	1	2	03042012	315	7,18		0,130	0,000	5,8	0,499	0,047	5,38	0,001	3,3	0,09	1,75	18,3	33,0	0,000	0,000	0,23
515	505	1	3	03042012	320	6,73	183	0,167	0,020	5,3	0,680	0,000	2,33	0,001	3,3	0,44	2,41	19,7	35,3	0,980	0,000	0,55
516	511	1	1	03042012	241	7,15	128	0,123	0,027	4,5	0,316	0,000	3,67	0,001	2,5	0,04	1,50	14,0	25,7	0,015	0,000	0,12
517	510	1	1	03042012	251	7,22	122	0,118	0,000	4,7	0,371	0,000	3,32	0,002	2,8	0,03	1,43	15,0	26,9	0,005	0,000	0,13
518	510	1	3	03042012	268	6,44	128	0,132	0,015	5,8	0,584	0,000	1,22	0,002	3,3	0,02	1,37	15,5	28,7	0,076	0,318	0,20
519	511	2	1	10042012	270	7,15	140	0,155	0,000	5,0	0,000	0,000	3,23	0,001	2,7	0,04	1,20	14,7	25,4	0,007	0,035	0,03
520	510	2	1	10042012	260	7,10	140	0,126	0,000	5,3	0,000	0,000	3,63	0,000	3,4	0,03	1,45	17,4	32,3	0,005	0,053	0,02
521	510	2	3	10042012	292	6,64	165	0,157	0,000	6,4	0,000	0,027	3,49	0,015	3,4	0,03	0,97	17,1	32,5	0,081	0,681	0,03
522	501	2	1	10042012	425	7,05	226	0,171	0,000	8,8	0,000	0,241	15,65	0,003	5,6	0,08	1,69	21,1	50,4	0,003	0,103	0,11
523	501	2	3	10042012	642	6,64	445	0,228	0,034	7,9	0,000	0,012	5,73	0,034	4,7	0,11	0,25	34,0	104,0	0,012	1,173	0,09
524	506	2	1	10042012	426	7,13	226	0,162	0,000	7,3	0,000	0,031	15,58	0,002	4,1	0,06	1,32	23,1	54,9	0,002	0,094	0,05
525	502	2	1	10042012	415	7,37	201	0,168	0,017	7,2	0,000	0,302	14,86	0,001	4,1	0,03	1,32	23,2	55,7	0,000	0,033	0,09

sampleNr	pointId	round	depth	Date	EC	pH	Alkalinity	F	Br	Cl	NO2	NO3	SO4	Li	Na	NH4	K	Mg	Ca	PO4	Fe	inorganic-N
526	502	2	3	10042012	693	6,81	433	0,227	0,079	8,7	0,000	0,020	0,61	0,003	3,9	0,85	0,42	29,7	81,0	0,053	1,293	0,66
527	507	2	1	10042012	428	7,18	214	0,146	0,000	7,2	0,000	0,091	12,36	0,001	3,9	0,04	2,08	22,2	49,5	0,001	0,439	0,05
528	503	2	1	10042012	515	6,99	305	0,174	0,000	3,6	0,000	0,000	0,36	0,002	3,4	0,09	2,22	30,4	66,4	0,011	1,465	0,07
529	503	2	3	10042012	690	6,80	464	0,209	0,023	2,3	0,000	0,010	0,07	0,005	5,6	0,20	4,51	53,4	101,0	0,009	1,479	0,15
530	508	2	1	10042012	410	7,16	226	0,134	0,000	8,0	0,000	0,173	1,50	0,002	4,9	0,02	2,35	24,4	58,9	0,001	1,383	0,05
531	504	2	1	10042012	388	7,19	201	0,182	0,000	7,3	0,000	0,026	7,78	0,003	3,7	0,04	2,11	21,2	46,4	0,000	0,182	0,04
532	504	2	3	10042012	554	6,78	256	0,179	0,018	8,8	0,000	0,177	5,14	0,002	5,6	0,07	1,21	24,5	68,8	0,008	0,189	0,09
533	509	2	1	10042012	349	7,15	189	0,150	0,043	7,1	0,000	0,000	1,46	0,001	3,5	0,03	1,08	18,6	44,2	0,003	0,045	0,02
534	505	2	1	10042012	312	7,08	171	0,128	0,000	7,4	0,000	0,125	5,45	0,002	4,5	0,07	1,44	20,5	38,3	0,001	0,028	0,08
535	505	2	3	10042012	334	6,91	183	0,179	0,040	5,9	0,000	0,000	2,57	0,001	3,2	0,78	2,16	20,8	38,5	0,273	0,170	0,61
536	511	3	1	17042012	247	7,20	146	0,221	0,006	4,8	0,327	0,043	1,79	0,001	3,5	0,06	1,79	16,5	31,3	0,014	0,098	0,16
537	510	3	1	17042012	344	7,17	140	0,195	0,000	4,6	0,405	0,014	1,63	0,001	2,5	0,06	1,02	12,6	23,5	0,008	0,114	0,17
538	510	3	3	17042012	311	6,70	153	0,235	0,000	6,9	0,693	0,000	0,48	0,002	3,8	0,05	1,05	17,0	33,6	0,073	7,039	0,25
539	505	3	1	17042012	287	7,05	153	0,228	0,000	5,5	0,569	0,000	2,28	0,001	3,0	0,06	1,23	14,9	30,7	0,013	0,122	0,22
540	505	3	3	17042012	318	6,85	177	0,242	0,000	5,7	0,705	0,000	2,39	0,001	3,1	0,42	1,35	17,8	32,7	0,012	0,316	0,54
541	501	3	1	17042012	345	7,08	189	0,213	0,000	5,8	0,609	0,089	8,81	0,004	3,4	0,12	1,70	17,9	44,6	0,006	0,143	0,30
542	501	3	3	17042012	602	6,68	397	0,332	0,039	8,1	0,000	0,000	0,39	0,003	5,0	0,15	0,25	33,1	106,4	0,019	1,249	0,12
543	506	3	1	17042012	322	7,40	183	0,232	0,000	5,6	0,449	0,473	8,22	0,002	3,7	0,05	1,52	17,7	45,3	0,009	0,193	0,28
544	502	3	1	17042012	345	7,41	171	0,228	0,000	6,0	0,568	0,264	10,23	0,001	3,3	0,09	1,26	14,9	36,8	0,005	0,168	0,30
545	502	3	3	17042012	662	6,76	439	0,326	0,055	8,1	0,000	0,030	0,23	0,002	4,5	0,51	0,44	30,0	83,9	0,070	2,978	0,41
546	507	3	1	17042012	333	7,35	177	0,227	0,000	6,4	0,625	0,000	8,44	0,002	4,1	0,03	2,25	20,1	46,2	0,007	0,228	0,22
547	503	3	1	17042012	386	7,13	281	0,174	0,000	3,3	0,663	0,023	0,31	0,003	3,5	0,06	2,38	27,1	61,5	0,022	3,399	0,26
548	503	3	3	17042012	659	6,81	476	0,295	0,000	2,6	1,135	0,056	0,22	0,005	6,3	0,15	4,59	52,2	100,1	0,026	2,438	0,47
549	508	3	1	17042012	337	7,20	189	0,214	0,000	5,8	0,754	0,035	0,82	0,001	2,9	0,12	1,81	15,2	37,9	0,011	1,135	0,33
550	504	3	1	17042012	343	7,24	189	0,230	0,000	8,5	0,685	0,037	4,40	0,001	5,2	0,26	2,58	16,8	38,7	0,005	0,146	0,42
551	504	3	3	17042012	475	6,81	281	0,248	0,000	6,7	0,777	0,000	2,76	0,002	4,6	0,03	1,11	25,9	76,5	0,028	1,108	0,26
552	509	3	1	17042012	299	7,37	189	0,233	0,000	6,4	0,444	0,011	1,35	0,003	3,3	0,00	0,56	14,5	35,2	0,005	0,170	0,14
553	512	3	1	17042012	481	7,62	0	0,450	0,000	9,4	0,792	0,059	24,72	0,001	6,3	0,09	1,41	20,7	56,8	0,049	0,369	0,33
554	511	4	1	24042012	265	7,30	140	0,242	0,000	5,0	0,390	0,012	1,03	0,002	3,6	0,08	1,64	20,1	40,3	0,008	0,563	0,18
555	510	4	1	24042012	264	7,37	146	0,250	0,000	4,6	0,336	0,000	1,01	0,001	2,4	0,01	0,64	14,3	27,5	0,000	0,195	0,11

sampleNr	pointId	round	depth	Date	EC	pH	Alkalinity	F	Br	Cl	NO2	NO3	SO4	Li	Na	NH4	K	Mg	Ca	PO4	Fe	inorganic-N
556	510	4	3	24042012	321	6,53	165	0,284	0,000	5,9	0,500	0,000	0,58	0,001	2,6	0,02	0,37	13,6	27,0	0,027	5,816	0,17
557	505	4	1	24042012	331	7,18	183	0,270	0,000	5,9	0,541	0,000	2,39	0,001	2,8	0,04	0,64	16,3	32,3	0,003	0,056	0,20
558	505	4	3	24042012	320	6,78	195	0,307	0,000	5,4	0,545	0,037	2,51	0,001	2,3	0,14	0,15	14,1	26,7	0,005	0,234	0,28
559	501	4	1	24042012	459	6,99	244	0,216	0,000	5,5	0,399	0,009	3,67	0,002	4,7	0,15	1,63	25,8	66,3	0,000	0,148	0,24
560	501	4	3	24042012	596	6,64	415	0,363	0,015	7,2	0,851	0,000	0,32	0,002	4,1	0,05	0,16	27,1	88,2	0,014	2,473	0,30
561	506	4	1	24042012	382	7,12	232	0,294	0,000	5,6	0,524	0,035	5,71	0,003	3,0	0,02	0,79	16,9	41,3	0,023	0,106	0,18
562	502	4	1	24042012	390	7,33	232	0,286	0,000	5,9	0,658	0,032	6,30	0,002	3,8	0,02	0,60	19,8	49,0	0,000	0,097	0,22
563	502	4	3	24042012	650	6,70	458	0,356	0,060	6,6	1,034	0,008	0,32	0,002	4,2	0,21	0,15	30,7	86,8	0,060	2,756	0,48
564	507	4	1	24042012	377	7,30	207	0,291	0,000	6,5	0,525	0,014	5,18	0,001	3,3	0,04	0,25	17,6	40,6	0,000	0,101	0,19
565	503	4	1	24042012	545	7,32	317	0,281	0,035	3,0	0,700	0,000	0,10	0,002	1,8	0,02	0,96	18,9	44,9	0,040	12,175	0,23
566	503	4	3	24042012	635	6,86	452	0,346	0,019	1,7	0,748	0,000	0,12	0,003	3,5	0,06	2,80	31,0	56,6	0,009	9,820	0,27
567	508	4	1	24042012	431	7,15	268	0,273	0,000	5,8	0,604	0,000	0,19	0,002	3,5	0,08	2,49	23,9	62,4	0,001	3,295	0,24
568	504	4	1	24042012	373	7,19	220	0,351	0,000	6,1	0,772	0,000	2,31	0,002	3,0	0,00	0,51	18,0	55,9	0,000	0,139	0,24
568	504	4	3	24042012	471	6,80	299	0,287	0,000	6,5	0,533	0,000	4,76	0,001	2,7	0,04	1,08	15,7	36,7	0,003	3,783	0,19
569	509	4	1	24042012	303	7,12	226	0,272	0,000	5,5	0,417	0,000	0,66	0,001	3,0	0,09	0,70	15,2	37,4	0,000	0,152	0,20
601	606	1	1	31032012	229	6,15	88	0,082	0,000	9,5	0,427	0,032	2,54	0,001	4,6	0,07	1,68	6,0	25,9	0,011	0,136	0,19
602	607	1	1	31032012	298	6,98	146	0,089	0,049	7,5	0,471	0,017	1,23	0,001	5,3	0,16	1,94	9,3	37,2	0,003	0,207	0,28
603	602	1	1	31032012	245	6,86	116	0,115	0,000	3,7	0,388	0,016	2,05	0,001	3,4	0,05	0,66	8,7	32,1	0,008	0,174	0,16
604	608	1	1	31032012	304	7,08	140	0,103	0,000	6,2	0,462	0,015	3,44	0,001	3,5	0,05	1,21	10,6	36,3	0,002	0,025	0,19
605	603	1	1	31032012	279	7,11	137	0,104	0,000	5,8	0,386	0,023	3,52	0,001	4,4	0,09	1,38	10,9	36,5	0,001	0,025	0,19
606	603	1	2	31032012	255	6,85		0,112	0,000	5,9	0,124	0,044	3,75	0,001	4,3	0,09	1,55	9,9	34,1	0,000	0,897	0,12
607	609	1	1	31032012	392	7,19	201	0,112	0,000	7,3	0,612	0,007	10,96	0,002	6,3	0,10	2,25	16,4	49,9	0,005	0,020	0,27
608	604	1	1	31032012	440	7,31	232	0,127	0,000	8,0	0,675	0,016	13,62	0,002	6,5	0,08	2,48	18,6	53,6	0,006	0,004	0,27
609	604	1	2	31032012	395	6,99		0,127	0,000	8,2	0,588	0,000	13,72	0,002	6,4	0,04	2,53	17,7	51,3	0,007	0,731	0,21
610	610	1	1	31032012	457	7,28	262	0,198	0,000	8,2	0,656	0,012	15,02	0,002	6,6	0,04	2,87	19,3	55,5	0,000	0,040	0,23
611	610	1	3	02042012	425	7,05	268	0,159	0,000	8,5	0,639	0,013	15,39	0,002	7,2	0,03	2,90	20,6	58,9	0,000	1,174	0,22
612	605	1	1	02042012	471	7,26	265	0,125	0,007	9,0	0,684	0,011	16,66	0,003	7,2	0,01	2,91	20,6	58,4	0,003	0,348	0,22
613	605	1	2	02042012	440	7,14		0,138	0,000	8,7	0,381	0,000	20,27	0,010	6,9	0,01	2,94	20,1	56,9	0,008	0,912	0,12
614	601	1	3	02042012	286	6,55	153	0,059	0,049	6,4	0,732	0,021	4,30	0,009	4,2	0,76	0,63	8,2	38,7	0,165	0,896	0,82
615	602	1	3	02042012	370	6,36	195	0,115	0,034	6,7	0,000	0,000	1,66	0,004	4,8	0,21	0,83	13,0	58,7	0,391	0,390	0,16

sampleNr	pointId	round	depth	Date	EC	pH	Alkalinity	F	Br	Cl	NO2	NO3	SO4	Li	Na	NH4	K	Mg	Ca	PO4	Fe	inorganic-N
616	603	1	3	02042012	290	6,25	159	0,073	0,000	3,6	0,255	0,000	2,04	0,003	4,1	0,25	1,51	10,9	43,7	1,063	0,382	0,27
617	604	1	3	02042012	530	6,43	275	0,000	0,012	5,2	0,000	0,000	1,49	0,004	6,9	0,01	1,12	22,6	78,5	0,137	0,635	0,01
618	605	1	3	02042012	767	6,55	427	0,147	0,051	11,9	0,000	0,021	1,84	0,005	10,6	0,35	1,39	37,5	122,5	0,435	0,982	0,28
619	606	2	1	11042012	215	6,60	122	0,092	0,024	13,0	0,000	0,230	3,60	0,001	6,0	0,16	1,59	6,0	26,1	0,033	0,138	0,18
620	601	2	1	11042012	226	6,45	122	0,108	0,027	10,2	0,000	0,000	3,10	0,001	4,4	0,06	0,80	7,2	30,0	0,000	0,058	0,04
621	601	2	3	11042012	275	6,56	159	0,064	0,000	7,8	0,000	0,166	2,55	0,001	5,3	1,26	0,37	8,2	39,2	0,382	1,380	1,02
622	607	2	1	11042012	290	6,84	153	0,115	0,000	5,8	0,000	0,000	1,09	0,001	4,1	0,05	0,39	9,0	38,7	0,001	0,158	0,04
623	602	2	1	11042012	220	6,85	128	0,097	0,000	2,4	0,142	0,017	1,27	0,000	2,9	0,04	0,23	8,0	30,4	0,000	0,230	0,08
624	602	2	3	11042012	424	6,48	244	0,123	0,051	6,2	0,000	0,000	0,26	0,001	4,0	0,31	0,46	12,6	58,5	0,053	0,320	0,24
625	608	2	1	11042012	291	7,12	159	0,103	0,037	7,8	0,000	0,139	6,00	0,013	5,5	0,05	0,77	13,4	45,8	0,000	0,182	0,07
626	603	2	1	11042012	286	7,32	146	0,097	0,000	8,4	0,000	0,138	4,14	0,001	5,0	0,05	0,92	11,8	39,5	0,000	0,227	0,07
627	603	2	3	11042012	275	6,45	165	0,087	0,000	5,8	0,000	0,197	2,81	0,001	5,0	0,42	0,76	11,1	43,1	0,820	0,490	0,37
628	609	2	1	11042012	402	7,30	201	0,142	0,000	9,1	0,000	0,085	13,87	0,016	6,9	0,05	1,84	17,8	53,5	0,000	0,168	0,05
629	604	2	1	11042012	448	7,42	232	0,148	0,006	8,4	0,000	0,020	13,55	0,002	6,1	0,06	2,00	18,6	52,3	0,003	0,074	0,05
630	604	2	2	11042012	433	7,40		0,156	0,000	8,4	0,005	0,025	13,76	0,002	6,8	0,07	2,13	20,0	57,7	0,002	0,310	0,06
631	604	2	3	11042012	534	6,53	311	0,000	0,043	6,9	0,000	0,000	2,19	0,002	9,0	0,00	0,52	26,4	85,1	0,040	1,274	0,00
632	610	2	1	11042012	455	7,42	195	0,145	0,023	11,1	0,000	0,177	16,28	0,002	8,1	0,07	2,74	20,4	56,8	0,006	0,166	0,09
633	610	2	2	11042012	455	7,42		0,205	0,000	11,2	0,000	0,185	16,19	0,002	8,4	0,06	2,84	21,0	58,7	0,000	0,150	0,09
634	605	2	1	11042012	466	7,36	238	0,168	0,011	11,9	0,000	0,198	18,43	0,003	9,7	0,09	2,85	23,7	64,2	0,001	0,051	0,11
635	605	2	2	11042012	451	7,43		0,202	0,000	11,7	0,000	0,507	18,56	0,002	9,0	0,08	2,79	22,6	61,4	0,001	0,264	0,18
636	605	2	3	11042012	738	6,68	452	0,142	0,066	13,8	0,000	0,164	2,57	0,002	11,3	0,34	1,13	34,2	95,8	0,278	1,492	0,30
637	606	3	1	18042012	195	7,09	98	0,173	0,000	9,6	0,469	0,065	1,17	0,001	4,2	0,18	1,07	5,0	21,6	0,021	0,514	0,30
638	601	3	1	18042012	241	6,50	116	0,205	0,000	9,4	0,348	0,026	2,19	0,000	3,3	0,14	0,65	5,6	23,6	0,005	0,662	0,22
639	601	3	3	18042012	254	6,55	146	0,162	0,000	6,1	0,554	0,023	1,64	0,000	3,6	0,99	0,39	6,3	32,0	0,472	2,148	0,94
640	607	3	1	18042012	247	6,67	116	0,215	0,000	9,7	0,292	0,010	2,57	0,001	4,7	0,07	0,54	8,4	31,3	0,014	0,426	0,14
641	602	3	1	18042012	232	6,83	140	0,185	0,000	2,6	0,299	0,062	1,04	0,001	3,8	0,09	0,09	9,8	40,5	0,000	0,340	0,17
642	602	3	3	18042012	423	6,46	232	0,186	0,023	6,2	0,951	0,000	0,19	0,001	4,2	0,22	0,59	12,2	57,8	0,053	0,361	0,46
643	608	3	1	18042012	214	6,99	128	0,206	0,000	1,9	0,366	0,000	0,66	0,001	2,8	0,01	0,10	7,1	27,9	0,006	0,384	0,12
644	603	3	1	18042012	217	7,07	122	0,195	0,000	2,4	0,347	0,034	1,18	0,001	2,4	0,02	0,31	7,0	25,9	0,008	0,286	0,13
645	603	3	3	18042012	265	6,41	140	0,182	0,000	3,0	0,450	0,037	0,97	0,000	2,2	0,25	0,35	6,7	27,3	0,517	3,804	0,34

sampleNr	pointId	round	depth	Date	EC	pH	Alkalinity	F	Br	Cl	NO2	NO3	SO4	Li	Na	NH4	K	Mg	Ca	PO4	Fe	inorganic-N
646	609	3	1	18042012	289	7,14	153	0,181	0,000	5,7	0,551	0,065	2,43	0,000	2,8	0,13	0,73	8,4	29,1	0,001	0,270	0,28
647	604	3	1	18042012	405	7,32	226	0,232	0,000	7,8	0,590	0,025	8,01	0,001	5,9	0,07	1,68	14,8	42,2	0,005	0,239	0,24
648	604	3	2	18042012	395	6,93		0,221	0,000	7,9	0,712	0,039	7,71	0,002	7,3	0,21	2,45	20,0	58,0	0,090	0,219	0,39
649	604	3	3	18042012	518	6,58	299	0,000	0,030	3,8	0,798	0,000	0,73	0,001	5,1	0,00	0,34	18,2	65,4	0,047	3,409	0,24
650	610	3	1	18042012	431	7,34	232	0,237	0,000	8,4	0,599	0,000	9,21	0,002	7,6	0,07	2,22	22,2	63,4	0,006	0,327	0,24
651	610	3	2	18042012	425	7,23		0,195	0,000	9,1	0,831	0,069	10,31	0,001	4,9	0,05	1,50	13,6	38,7	0,015	0,360	0,31
652	605	3	1	18042012	444	7,33	238	0,180	0,000	8,8	0,710	0,025	11,44	0,002	7,0	0,14	1,39	20,7	57,4	0,016	0,255	0,33
653	605	3	2	18042012	428	7,17		0,173	0,016	8,9	0,655	0,032	12,07	0,002	7,8	0,06	3,46	22,7	63,2	0,032	1,128	0,26
654	605	3	3	18042012	688	6,70	452	0,267	0,054	11,5	0,000	0,045	1,63	0,002	8,5	0,19	1,14	26,6	93,2	0,355	1,443	0,16
655	606	4	1	25042012	207	6,61	110	0,241	0,000	7,1	0,301	0,000	0,53	0,001	4,6	0,14	0,56	6,6	29,9	0,052	0,252	0,20
656	601	4	1	25042012	246	6,76	128	0,176	0,000	7,8	0,396	0,027	1,45	0,001	4,4	0,16	0,07	9,2	41,8	0,008	1,841	0,25
657	601	4	3	25042012	235	6,50	140	0,134	0,022	4,8	0,212	0,033	1,61	0,001	2,8	0,84	0,13	5,8	29,1	0,367	2,371	0,72
658	607	4	1	25042012	254	6,86	153	0,244	0,000	3,6	0,350	0,006	0,44	0,001	2,6	0,05	0,01	6,4	29,3	0,008	0,250	0,14
659	602	4	1	25042012	246	7,06	146	0,235	0,000	1,6	0,290	0,000	0,46	0,001	2,6	0,07	0,22	8,2	29,4	0,000	0,255	0,14
660	602	4	3	25042012	428	6,49	256	0,268	0,031	5,7	0,871	0,000	0,58	0,001	3,8	0,45	0,34	11,9	63,1	0,065	3,906	0,62
661	608	4	1	25042012	240	7,04	140	0,161	0,000	2,6	0,170	0,000	0,77	0,000	2,2	0,09	0,26	7,0	27,6	0,006	0,245	0,12
662	603	4	1	25042012	289	7,14	177	0,233	0,000	3,7	0,471	0,000	1,03	0,001	3,0	0,04	0,52	11,4	41,4	0,000	0,217	0,18
663	603	4	3	25042012	263	6,49	159	0,213	0,000	2,4	0,418	0,025	1,12	0,001	3,0	0,23	0,52	9,9	49,7	0,242	3,599	0,31
664	609	4	1	25042012	349	7,17	201	0,252	0,000	5,1	0,440	0,000	1,80	0,002	4,7	0,03	1,54	15,7	51,1	0,107	0,217	0,16
665	604	4	1	25042012	420	7,27	244	0,266	0,000	7,5	0,712	0,000	4,82	0,001	4,9	0,01	0,19	15,4	44,1	0,007	0,339	0,23
666	604	4	2	25042012	408	7,28		0,257	0,000	7,3	0,609	0,000	4,77	0,002	4,7	0,06	0,37	14,6	41,1	0,049	22,686	0,24
667	604	4	3	25042012	500	6,63	342	0,278	0,000	3,7	0,770	0,015	0,56	0,002	4,5	0,00	0,12	15,5	55,6	0,006	0,367	0,24
668	610	4	1	25042012	429	7,31	256	0,307	0,000	8,3	0,637	0,712	6,99	0,002	3,9	0,01	0,32	11,9	33,8	0,000	0,136	0,37
669	610	4	2	25042012	428	7,28		0,292	0,000	8,3	0,647	0,000	7,06	0,003	7,7	0,12	1,68	23,3	65,2	0,000	0,266	0,29
670	605	4	1	25042012	439	7,28	256	0,304	0,000	8,6	0,688	0,000	9,58	0,002	4,8	0,05	0,47	14,8	40,6	0,068	0,133	0,25
671	605	4	2	25042012	436	7,25		0,305	0,000	8,7	0,706	0,000	9,73	0,002	5,1	0,07	1,74	15,1	42,2	0,027	0,279	0,27
672	605	4	3	25042012	664	6,76	458	0,335	0,037	11,0	0,000	0,008	1,00	0,002	8,6	0,21	0,98	28,3	99,4	0,148	11,169	0,16
801	991	1	1	05042012				0,167	0,011	9,9	0,111	3,107	26,29	0,003	6,4	0,10	1,82	23,5	65,7	0,064	2,014	0,81
902	992	2	1	11042012	475	7,61	250	0,153	0,000	8,9	0,000	2,041	21,35	0,005	7,1	0,06	2,57	22,2	63,2	0,012	0,836	0,51
903	991	2	1	11042012	540	7,32	287	0,209	0,048	9,0	0,040	2,145	25,81	0,003	7,4	0,22	2,05	27,5	78,2	0,078	2,750	0,67

sampleNr	pointId	round	depth	Date	EC	pH	Alkalinity	F	Br	Cl	NO2	NO3	SO4	Li	Na	NH4	K	Mg	Ca	PO4	Fe	inorganic-N
904	992	3	1	18042012	450	7,51	244	0,223	0,018	8,4	0,627	1,734	19,53	0,002	7,3	0,02	2,60	21,9	62,4	0,025	0,486	0,60
905	991	3	1	18042012	400	7,28	207	0,346	0,000	9,5	0,587	2,055	22,36	0,002	5,7	0,03	3,62	18,5	54,9	0,060	0,569	0,66
906	992	4	1	25042012	433	7,54	256	0,377	0,000	8,2	0,913	1,719	22,07	0,003	6,6	0,12	0,46	25,0	74,3	0,033	0,386	0,76
907	991	4	1	25042012	570	7,25	299	0,301	0,000	8,2	0,794	1,250	18,69	0,002	5,1	0,15	0,75	15,3	43,9	0,594	0,702	0,64

Table F.1. Olszowa Droga samples for the year 2001. EC in μS/cm, pH in (-), all other values in mg/l. Samples taken at 05.04.2001.

IdPoint	UTM_x	UTM_y	NH4	Ca	Cl	EC	Mg	NO3	PO4	K	pH	Na	SO4
9699	603806	5921725	0.000	70.2	12.8	449	13.0	1.36	0.20	3.44	7.94	8.24	41.33
9700	603849	5921661	0.000	71.1	12.6	456	13.0	0.45	0.00	0.00	7.80	8.10	42.99
9701	603919	5921586	0.000	75.0	12.7	463	13.4	0.00	0.47	3.14	7.89	7.73	46.51
9702	604000	5921476	0.000	66.3	9.7	447	11.2	0.00	0.16	0.00	7.60	6.92	58.37
9703	604048	5921417	0.000	67.9	9.4	435	11.4	0.00	0.17	0.00	7.62	6.85	70.87
9704	604161	5921346	0.000	81.9	14.6	462	12.7	0.00	0.38	0.00	7.45	7.08	53.87
9705	604314	5921260	0.235	71.1	18.2	435	9.5	0.00	0.35	0.00	7.18	8.02	18.39
9706	604442	5921251	0.326	61.3	10.6	386	5.7	10.90	0.20	0.00	5.96	6.37	125.97

Table F.2. Olszowa Droga samples for the year 2002. EC in μS/cm, pH in (-), all other values in mg/l. Samples taken at 23.02.2001.

IdPoint	UTM_x	UTM_y	Ca	Cl	EC	Mg	NO3	PO4	K	pH	Na	SO4
10066	603956	5921181	64.7	10.7	398	11.3	4.9	0.05	2.39	8.23	6.0	33.6
10067	604059	5921192	64.3	9.9	395	11.2	4.7	0.05	2.36	8.12	5.9	33.3
10068	604098	5921196	65.3	10.3	395	11.3	5.2	0.14	2.32	8.15	5.9	33.7
10069	604163	5921214	65.4	9.9	399	11.3	7.0	0.05	2.34	8.11	5.9	31.8
10070	604314	5921224	62.7	9.4	393	10.7	4.8	0.05	2.20	8.04	5.6	32.9
10071	604366	5921232	60.5	9.3	397	10.1	4.7	0.05	2.08	7.73	5.5	33.4
10072	604391	5921232	57.0	8.5	349	9.2	3.7	0.05	2.48	7.71	5.3	32.9
10073	604415	5921235	50.7	8.4	320	7.9	2.4	0.05	1.78	7.50	5.0	32.9
10074	604424	5921244	46.4	8.3	288	6.9	2.0	0.05	1.67	7.41	4.8	33.4
10075	604435	5921242	42.4	7.8	264	5.7	2.0	0.05	1.58	7.13	4.5	39.3
10076	604474	5921238	45.1	8.3	270	5.3	2.4	0.05	1.57	6.99	4.5	52.9
10077	604501	5921238	67.6	13.7	382	8.1	0.4	0.05	1.97	7.12	8.6	77.0
10172	604073	5921192	65.3	11.5	401	11.3	5.1	0.05	3.06	8.15	6.0	33.5
10173	603859	5921223	65.5	10.3	402	11.4	4.7	0.05	2.50	8.08	6.1	34.0
10174	603617	5921264	65.5	10.9	405	11.5	5.4	0.05	2.56	8.09	6.1	33.7
10175	603138	5921347	65.5	11.2	409	11.4	6.3	0.05	2.50	8.12	6.0	33.4
10176	602647	5921395	66.7	10.5	412	11.6	6.1	0.05	2.51	8.07	6.1	33.5
10177	602522	5921442	66.1	10.1	411	11.5	6.2	0.05	2.49	8.07	6.0	33.2

Table F.3. Olszowa Droga samples for the year 2004. EC in μS/cm, pH in (-), alkalinity in mg HCO^3/l, all other values in mg/l. Samples taken at 31.03.2004.

IdPoint	UTM_x	UTM_y	Alkalinity	NH4	Cl	EC	NO3	PO4	pH	TN	TOC
10375	604327	5921264	158.6	0.70	1.5	381	0.10	0.48	7.19	2.12	28.48
10378	604223	5921314	122.0	0.40	0.4	338	2.18	0.01	7.42	1.35	25.08
10381	604039	5921489	189.1	0.24	3.9	423	5.55	0.01	7.68	2.48	23.59
10382	604427	5921233	67.1	0.95	13.9	580	3.40	0.01	6.68	3.77	32.88
10384	603953	5921671	201.3	0.32	5.4	442	4.62	0.03	7.94	3.34	22.82
10385	604137	5921378	176.9	0.20	3.8	385	1.34	0.03	7.52	1.18	21.71
10425	603353	5922295	207.4	0.06	4.6	437	6.41	0.01	7.97	3.06	18.42

Table F.4. Olszowa Droga samples for the year 2006. EC in μS/cm, pH in (-), alkalinity in mg HCO^3/l, all other values in mg/l. Samples taken at 19.04.2006.

IdPoint	UTM_x	UTM_y	Alkalinity	NH4	Ca	Cl	EC	IC	Mg	NO3	K	pH	Na	SO4	TN	TOC
10487	604694	5921289	146.4	0.18		8.84	306	34.0	14.8	0.34	0.35	7.39	9.9	39.6	1.16	37.4
10673	603480	5921111	231.8	0.05	65.3	8.32	401	30.7	16.1	0.30	3.06	7.40	10.2	27.5	0.94	30.5
10674	602842	5921365	225.7	0.21	65.8	8.77	428	34.9	17.4	1.26	2.66	8.08	10.8	29.4	1.45	31.5
10675	602600	5921423	231.8	0.13	72.0	10.82	429	36.6	20.8	1.74	3.95	7.92	13.1	34.7	1.33	31.8

Table F.5. Olszowa Droga sample for the year 2010. EC in μS/cm, pH in (-), alkalinity in mg HCO^3/l, all other values in mg/l. Sample taken at 07.04.2010.

IDPOINT	UTM_x	UTM_y	Alkalinity	NH4	Ca	Cl	DOC	EC	F	IC	Li	Mg	NO3	NO2	PO4	K	pH	Na	SO4	TN
10918	604694	5921289	213.5	0.26	70.4	6.6	15.4	394	0.12	38.12	0.005	12.0	0.50	0.02	0.36	2.54	7.45	6.09	16.0	0.93

Table F.6. Szorce samples for the year 2001. EC in μS/cm, pH in (-), all other values in mg/l. Samples taken at 05.04.2001.

IdPoint	UTM_x	UTM_y	NH4	Ca	Cl	EC	Mg	PO4	K	pH	Na	SO4
9674	607121	5905337	0.00	29.4	7.5	222	7.7	0.00	0.71	6.61	4.55	39.0
9685	607362	5905418	0.00	51.0	10.4	330	10.1	0.29	0.00	6.67	5.63	30.2
9689	606883	5905270	0.00	27.5	3.7	197	7.4	0.12	0.76	6.75	4.23	25.6
9715	609584	5906869	0.30	85.4	9.1	443	15.0	0.00	1.15	6.97	5.06	54.1
9716	609494	5906832	0.22	77.2	9.1	406	13.9	0.00	0.00	7.28	4.69	61.7
9717	609225	5906671	0.19	66.5	6.6	370	14.4	0.19	0.00	7.09	6.17	28.0
9718	608668	5906359	0.33	59.4	7.1	310	11.4	0.00	0.00	7.10	4.18	52.6
9719	608317	5906155	0.37	51.8	6.7	259	10.3	0.00	0.00	7.27	4.22	46.6
9720	608169	5906055	0.27	51.1	5.9	282	10.1	0.00	0.00	7.24	3.80	44.3
9721	607844	5905862	0.25	43.2	4.8	241	8.6	0.00	0.00	7.18	3.40	36.0
9722	607592	5905716	0.30	41.2	5.5	234	8.5	0.00	0.00	7.23	3.82	33.8
9723	607457	5905604	0.45	34.6	8.1	200	8.4	0.00	0.00	7.09	4.57	34.4

Table F.7. Szorce samples for the year 2002. EC in μS/cm, pH in (-), all other values in mg/l. Samples taken at 23.02.2001.

IdPoint	UTM_x	UTM_y	Ca	Cl	EC	Mg	NO3	PO4	K	pH	Na	SO4
9752	607049	5905355	32.2	5.7	200	8.3	0.13	0.15	0.23	6.63	3.42	4.2
9787	609703	5907015	75.8	9.1	446	13.4	3.03	0.16	0.77	7.11	3.95	22.9
9802	607473	5905544	36.8	7.9	223	9.1	0.13	0.16	0.23	6.74	3.32	6.6
9803	607558	5905643	40.1	8.1	238	9.9	0.13	0.17	0.23	6.72	3.54	7.1
9804	607727	5905760	38.2	4.6	231	8.5	0.13	0.14	0.23	6.73	3.37	2.7
9805	608025	5905962	42.4	5.6	239	8.7	0.35	0.16	0.57	6.78	3.03	6.3
9806	608381	5906180	49.4	6.8	261	9.9	0.13	0.22	0.23	6.84	3.33	7.5
9810	608572	5906307	49.4	6.3	265	9.8	0.13	0.12	0.23	6.94	3.17	6.9
9811	608844	5906465	52.9	6.6	281	9.8	0.13	0.17	0.23	7.09	2.93	9.0
9812	609091	5906610	60.0	4.3	302	13.4	0.13	0.28	0.23	6.86	3.79	2.3
9813	609438	5906837	66.5	8.6	353	12.2	0.13	0.26	0.75	7.10	4.00	13.1
9814	609583	5906944	68.2	8.0	374	11.9	0.66	1.06	0.75	7.11	3.53	18.7
9815	609270	5906736	50.6	7.0	271	9.6	0.13	0.12	0.74	7.16	3.20	14.4
9902	607332	5905393	36.2	32.8	324	8.3	0.13	0.21	26.99	6.87	3.32	7.9

9903	607415	5905463	30.5	10.1	221	8.8	0.13	0.15	0.23	6.84	3.50	7.4

Table F.8. Szorce samples for the year 2004. EC in μS/cm, pH in (-), alkalinity in mg HCO^3/l, all other values in mg/l. Samples taken at 31.03.2004.

IdPoint	UTM_x	UTM_y	Alkalinity	NH4	Cl	EC	IC	NO3	PO4	pH	TN	TOC
10362	609644	5906985	213.5	0.26	3.3	420	30.4	3.32	0.03	7.67	1.53	25.3
10363	609357	5906792	152.5	0.26	2.6	356	28.1	3.41	0.03	7.33	1.57	28.4
10364	609036	5906603	109.8	0.37	0.1	288	25.0	2.75	0.15	7.10	1.47	27.0
10365	608849	5906489	128.1	0.18	0.8	292	25.7	3.13	0.04	7.01	1.36	27.5
10366	608564	5906313	122.0	0.20	1.2	321	26.0	2.21	0.58	6.90	1.05	26.7
10367	608478	5906282	122.0	0.29	0.6	289	24.9	2.51	0.06	6.81	1.28	28.0
10368	608217	5906096	115.9	0.40	0.7	271	24.8	1.51	0.02	6.95	1.05	28.0
10369	608112	5906033	140.3	0.32	2.6	302	27.4	1.73	0.02	6.84	1.03	27.0
10370	607843	5905852	115.9	0.40	1.2	270	25.9	1.88	0.34	6.74	1.19	26.5
10371	607557	5905653	109.8	0.47	2.1	274	25.1	1.00	0.17	7.30	0.96	25.7
10372	607250	5905405	359.9	0.65	5.2	566	35.1	2.20	0.05	7.18	1.62	31.1
10373	606898	5905279	122.0	0.55	2.1	240	24.4	0.72	0.02	6.29	0.95	25.6

Table F.9. Szorce samples for the year 2005. EC in μS/cm, pH in (-), alkalinity in mg HCO^3/l, all other values in mg/l. Samples taken at 08.04.2005.

IdPoint	UTM_x	UTM_y	Alkalinity	NH4	Ca	Cl	EC	Fl	IC	Mg	NO3	K	pH	Na	SO4	TN	TOC
10505	607490	5905472	183.0				265		55.6				7.37			0.70	14.29
10506	607490	5905472	366.0	0.58	36.2	3.9	518	0.077	124.6	7.2	0.21	0.40	7.50	3.08	2.82	1.20	82.45
10507	607490	5905472	195.2	0.14	23.5	3.6	292	0.080	70.8	4.1	0.11	0.26	6.53	2.72	1.71	1.03	25.41
10508	608481	5906288	183.0				270		63.7				7.53			1.73	28.71
10509	608297	5906155	183.0				260		61.0				7.46			1.26	53.42
10510	608102	5906038	183.0				271		58.8				7.47			0.77	18.18
10511	607855	5905873	152.5				263		55.0				7.28			0.78	42.84
10512	607720	5905775	158.6				260		52.2				7.46			0.68	14.69
10513	607585	5905684	189.1				214		56.7				7.35			0.83	43.38
10514	607232	5905352	457.5				608		165.4				6.98			0.83	93.64
10515	607232	5905352	128.1				184		37.1				7.52			0.65	32.05
10516	607037	5905233	134.2				217		41.5				7.44			0.80	16.32

10524	609700	5907026	237.9	356	82.1	7.48	2.15	56.45
10525	609637	5906969	262.3	366	83.2	7.60	1.35	17.66
10526	609526	5906922	225.7	314	73.2	7.48	1.17	56.93
10527	609341	5906792	237.9	353	84.4	7.56	1.52	21.20
10528	609199	5906699	280.6	379	99.4	7.53	1.04	64.58
10529	609010	5906574	237.9	332	82.4	7.45	1.08	20.45
10530	608856	5906482	244.0	315	74.4	7.48	1.17	55.56