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Field monitoring in the Upper Basin of the Biebrza Wetlands (Poland)

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INTRODUCTION

In the framework of bilateral scientific and technical cooperation between Flemish and Polish universities, a research project "Environmental river catchment by natural or artificial wetlands" is conducted in the Biebrza River basin in Northeast Poland. The project is aimed at the development of methods to increase the use and the efficiency of the wetland areas itself and the potential development of artificial areas with similar impact. When dealing with artificially created wetlands, the first questions to be answered concern the location for implementation, the dimensioning and the kind of vegetation to be used.

The location of wetlands is highly conditioned by the presence of groundwater seepage and a shallow groundwater table, which are maintained and regulated by local hydrogeological conditions. The identification of these groundwater systems is essential in understanding the wetland presence and characteristics. Further, the important impact of the surface water flow system on the functionality of the wetland will also be investigated in the project.

THE BIEBRZA WETLANDS

The Biebrza wetlands, situated in the northeastern part of Poland, have been studied for decades by Polish natural scientists and since nineties also by scientists from other countries. English versions of the most important papers, describing the environmental conditions in the valley, are compiled by Okruszko & Wassen (1994).

According to the geomorphologic description, the Biebrza Valley is an extensive depression formed during the last glaciation. It is filled with several thick deposits of fluvioglacial sands and then covered by different types of organic soils. The Biebrza Valley is usually divided into three subbasins (Zurek, 1984), using a relation of the higher order morphologic features, such as ancient and young morainic plateaus, glacier outwash plains, and river flood terraces. The three subbasins are identified respectively as: the *Upper Basin*, with the Augustow outwash, reaching from the springs of the Biebrza River to the mouth of the Netta River; the *Middle Basin*, covering the area from the Netta River to the mouth of Rudzki Channel; and the *Lower Basin*, situated in the southern part of the valley up to the alluvial cone of the Narew River (Fig. 1).

The *Upper Basin* is relatively long (40 km) and narrow (2–3 km), with basin-lake widenings in its middle part and in the transition zone to the Middle Basin. The flood plain is filled with thick deposits of peat (usually from 2 to 5 m), partly underlain by a gyttja layer (from 1 to 4 m). Together with a 10 m deep sandy gravel bed they form a single aquifer. The valley intensively drains the surrounding plateau and the outwash plain into the river. The slopes of the river (see Table 1) are the highest in the upper part of the valley (from the springs to the Niedzwiedzica Creek) and then lower in the downstream part. The flow conditions of this section of the river are characterized by a gauge station in Sztabin (see Table 2). The peatlands are mostly fed by the groundwater.

The *Middle Basin,* the biggest of the three, is 40 km long and 20 km wide. It forms a vast, very flat depression paludified by surface waters of the Biebrza River and its tributaries (flowing from the Lake District), and by groundwater from two aquifers. The main direction of the water flow is from the north to the south with the exception of the Biebrza River. The diversity of the hydrological feeding is reflected by the variety of hydrogenic soils. In the flood plain, the peat has a medium thickness (1 to 3 m) and occurs in several varieties, with dominance of reed swamp, tall sedge and alder peat. The river bed slope varies. It is steeper in the upper and very small in the lower part of the basin (see Table 1). The surface water conditions are characterized by gauge stations in Dolistowo, Goniadz, and Osowiec (Table 2). The main tributary to the Biebrza River, the Netta River, almost doubles the amount of water in the system, what significantly changes the characteristics of the river valley (spring floods predominate in forming the riparian wetlands). The second most important tributary, the Rudzki Channel, joins the Biebrza River on the edge of the Lower Basin.

The *Lower Basin* forms a wide channel (12 to 15 km) with a total traject length of 30 km. The flood plain comprises flat peatlands and a mud zone of 2 km along the river border. The hydrological feeding is mixed, however surface waters predominate. Direct water runoff from the surroundings is blocked by an alluvial ridge deposited by the Narew River. The slopes are relatively low, causing the regular, long-lasting floods during the snow-melting period. The eastern part of the basin is fed by groundwater flowing from the surrounding plateau. The floodplain is filled with up to 2 meters deep alder and osier peat. Close to the river, mud covers homogenous layers of fine sand. Surface water conditions are characterized by a gauge station in Burzyn.

Besides the two main tributaries, the Netta River and the Rudzki Channel, the Biebrza River receives its water from a couple of smaller streams. Their characteristics are given in Table 2 and Table 3.

FIELD MONITORING IN THE BIEBRZA RIVER BASIN

Intensive field measurement campaigns are set up to collect input data for further hydro-logical modelling of the wetland area. In-situ registrations in the Biebrza River basin also reveal some fundamental features of the natural ecosystem of the wetland. Until now, two field measurement campaigns have been developed in the area, in September 1999 (autumn) and May 2000 (spring), respectively. Unfortunately, both of them have been performed under similar dry conditions. Basically, the field measurements concer-ned two fields of interest: (a) surface water flow, and (b) groundwater flow.

Surface water data collection

In the field measurement campaigns, the collection of surface water data took place in the Upper Basin and the Middle Basin. Surface water flows were recorded in several, discrete cross-sections along the Biebrza River and its main tributaries (Fig. 2). Measurements of surface water levels and channel shapes were performed by assessment of a general geodetic levelling. For discharge measurements, a variety of velocity meters and level gauges was used: (a) an OTT propeller, an one-dimensional electromechanical current meter; (b) an OTT Nautilus 2000, an one-dimensional electromagnetic current meter; and (c) a Valenport 802, a two-dimensional electromagnetic current meter.

Traject lengths of the river sections between consecutive cross-sections have been calculated using new digital topographical maps in 1 : 10 000 scale in ArcView GIS. Based on the respective, local altitudes of surface water levels in the cross-sections of the recorded spots, associated surface water slopes in the river segments have been calculated, leading to an initial estimation of friction characteristics of the river channel (Table 4).

These field data help to develop and calibrate a proper numerical model for the surface water flow in the Biebrza River. Nevertheless, for a good and reliable reconstruction of the hydraulic flow condition fluctuations related to different water level and flow regimes in the river basin, additional field measurement campaigns under high water level conditions have to be elaborated in the (near) future.

Groundwater data collection

In the first field measurement campaign, in September 1999, about 50 groundwater level measurement sites were selected all over the Upper Basin. The measurement sites are all local house wells, with a typical diameter of about 1 m. With GPS equipment X, Y and Z coordinates of these wells were determined (Fig. 3). Measured groundwater depths ranged from 1 to 18 m. It is expected that these groundwater level measurements depict the baseflow conditions of the aquifer, since during several weeks before the observations in September 1999 no precipitation had been recorded. In the second field measurement campaign, in May 2000, the groundwater level measurements were repeated. The levels appeared to be close to the levels of September 1999. On average the level in May 2000 was even slightly lower. Fig. 4 and Fig. 5 give an overview of the recorded heads in the catchment.

During the May 2000 measurement campaign, hydrochemical characteristics were determined at 37 wells by analysing 10 parameters: temperature, electrical conductivity, pH, $O_{2(aq)}$, Cl, total alkalinity, HCO_3, PO_4, NO_3, and NH_4. The hydrochemical characteristics of the groundwater will be used to establish a relation between the groundwater flow path through the aquifer and the mineralogy of the aquifer. This information is essential in understanding the feeding mechanism of the natural wetlands and the impact on the overall water quality.

HYDROLOGICAL MODELLING

Surface water model

Three computer programs will be used to solve the surface water modelling problems as a part of the project realisation. For water flow analysis in the main river channel the computer programs ACCESSUS (Verhoeven *et al.*, 1996) and UNET (HEC, 2000) will be used. These programs solve the de Saint-Venant equations in a one-dimensional version to describe both steady and unsteady open-channel flow. The quasi two-dimensional model UNET is able to include off-channel and overbank storage areas in the calculation. A full two-dimensional hydrodynamic model much better describes a combined flow, both in the main river channel and over the floodplain. Therefore, for higher (flood) flows, the two-dimensional hydrodynamic model RMA2 will be used (SSG, 1998). The RMA2 software uses a two-dimensional Reynolds expression of the Navier-Stokes equations to analyse turbulent flow and can be applied both under steady and unsteady conditions. Moreover, RMA2 has capabilities for simulating wetting and drying events. To prepare a spatial database as an input file for the proper water flow modelling of the wetland area, a digital terrain model (DTM) of the local topography and a map of vegetation types in the floodplain is prepared based on actual topographic maps and field observations.

Groundwater model

For the Upper Basin, a transient state groundwater flow model will be set up. The MODFLOW modelling code (Harbaugh & McDonald, 1996) as implemented in GMS version 3.0 will be used. The groundwater seepage to the natural wetlands will be simulated, within the MODFLOW model, by way of the DRAIN or SEEPAGE Package (Batelaan & De Smedt, 1998).

Aquifer characteristics are obtained from geological and hydrogeological maps and drilling records. Topography is an important boundary condition in the estimation of groundwater discharge to the wetlands. Therefore, a digitization of the elevation contours of the 1 : 25 000 scale maps is performed. Arc/Info GIS is used for the digitization and creation of an Upper Basin digital terrain model (DTM). Recharge to the groundwater system will be determined by way of the semi-physically based distributed water balance model WetSpass (Batelaan *et al.*, 1996). Distributed rainfall, potential evapotranspiration, soil and landuse data are gathered for modelling the recharge in the Upper Basin. The landuse map is created on basis of multi-temporal classification of satelite (LANDSAT TM) images.

The calibration of the model will be done by means of the head measurements from the field measurement campaigns as well as other obtained water table measurements. The calibration will also be done using river discharge time series of the gauge station in Sztabin at the outlet of the Upper Basin.

CONCLUSIONS

The reported field measurements form part of a general international (bilateral) research project on the potential use of wetlands as a means of environmental river basin sanitation. A proper understanding of both surface water and groundwater flow characteristics in the valley, based on an intensive in-situ registration of all relevant parameters, will lead in a first step to an operational mathematical tool for managing the integrated water resources of the Biebrza wetlands. In addition it will lead also to fundamental knowledge of the water quality improvements induced by the typical ecosystem in this reference wetland.

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TABLES

Table 1. Water surface slopes on particular reaches of the Biebrza River (Park Protection Plan, 2000)

Reach	Length [km]	Slope [‰]			Basin
		max.	average	min.	
Springs – mouth of Niedzwiedzica	14.0	13.0	2.97	0.60	Upper
Mouth of Niedzwiedzica - Sztabin	48.3	0.20	0.08	0.04	Upper
Sztabin – mouth of Brzozówka	26.9	0.45	0.25	0.20	Middle
Mouth of Brzozówka – Osowiec	30.1	0.09	0.07	0.05	Middle
Osowiec – mouth into Narew River	51.3	0.22	0.13	0.11	Lower

Table 2. The average flow (SSQ) and mean spatial outflow (SSq) for the Biebrza River and its main tributaries (Park Protection Plan, 2000).

River	Gauge station	*A* [km^2] Associated basin area	*SSQ* 1971-1995 [m^3/s]	*SSq* 1971-1995 [$l/(s \cdot km^2)$]
Biebrza	Sztabin	846.0	5.27	6.23
	Dabowo	2322.4	14.0	6.03
	Stare Dolistowo	3064.2	17.3*	5.65
	Osowiec	4365.1	26.6	6.09
	Burzyn	6900.4	39.2	5.68
Sidra	Harasimowicze	263.9	1.40*	5.30
Jastrzebianka	Jastrzebna	75.2	0.46*	6.12
Netta	Bialobrzegi	980.6	6.12*	6.24
Brzozówka	Karpowicze	649.8	3.53	5.43
Jegrznia	Wolnawiec	851.5	5.67*	6.66
Rudzki Chanel	Przechody	1452.5	11.1	7.64
Wissa	Czachy	487.8	2.77	5.68

Table 3. River reach length and associated basin area of the Biebrza River and its main tributaries (Park Protection Plan, 2000).

River	Length [km]	Associated basin area [km^2]
Biebrza	170.6	7051.2
Sidra	32.8	298.6
Lebiedzianka	15.8	164.0
Netta	102.4	1336.1
Brzozówka	55.8	696.8
Jegrznia	110.6	1011.1
Rudzki Chanel	113.6	1524.5
Wissa	49.0	517.3
Kosodka	23.15	131.1

Table 4. The result of surface water measurements during both field campaigns in autumn 1999 and spring 2000.

River	Cross-section location	Cumulated Distance [m.]	Water level [m.a.s.l.]		Discharge [m3/s]		Velocity [m/s]	
			1999	2000	1999	2000	1999	2000
Biebrza	Lipsk	0	117.8	117.88	0.497	0.879	0.0406	0.052
	Ostrowie	17870	116.837	116.8	0.779		0.034	
	Sztabin	34890	115.131	115.3		1.153		0.108
	Jaglowo	54850	110.44	110.25	1.147	1.329	0.092	0.152
	Debowo	60750		109.23	3.636		0.103	0.144
	Dolistowo	67675	108.141	108.03	4.886	5.983	0.231	0.227
	upstream of Elk reach	78035	106.348	107.06		6.43		0.116
	Goniadz	87965	106.352	106.58	5.833	8.061	0.251	0.29
	Osowiec	95415	105.78	106.15	5.866	9.17	0.033	0.156
Rudzki Canal	Przechody	0	109.756	109.67	3.838	7.00	0.227	0.518
	Bialogrady	6285		107.93		6.88		0.440
	Osowiec	9285	107.167	107.29	3.598	6.88	0.340	0.507
Upper Biebrza	upstream of Sidra reach					0.244		0.130
Sidra					.	0.475		0.191
Brzozowka	Karpowicze					0.913		0.14
Augustowski Canal	Debowo					3.343		1.048
Jegrznia	Kuligi					+/-2.32		

FIGURE CAPTIONS

Figure 1. The Biebrza River basin (Northeast Poland).

Figure 2. Surface water flow registration.

Figure 3. Groundwater depth measurements.

Figure 4. Groundwater depth in the Upper Biebrza River Basin as measured in September 1999.

Figure 5. Groundwater depth in the Upper Biebrza River Basin as measured in May 2000.

FIGURES

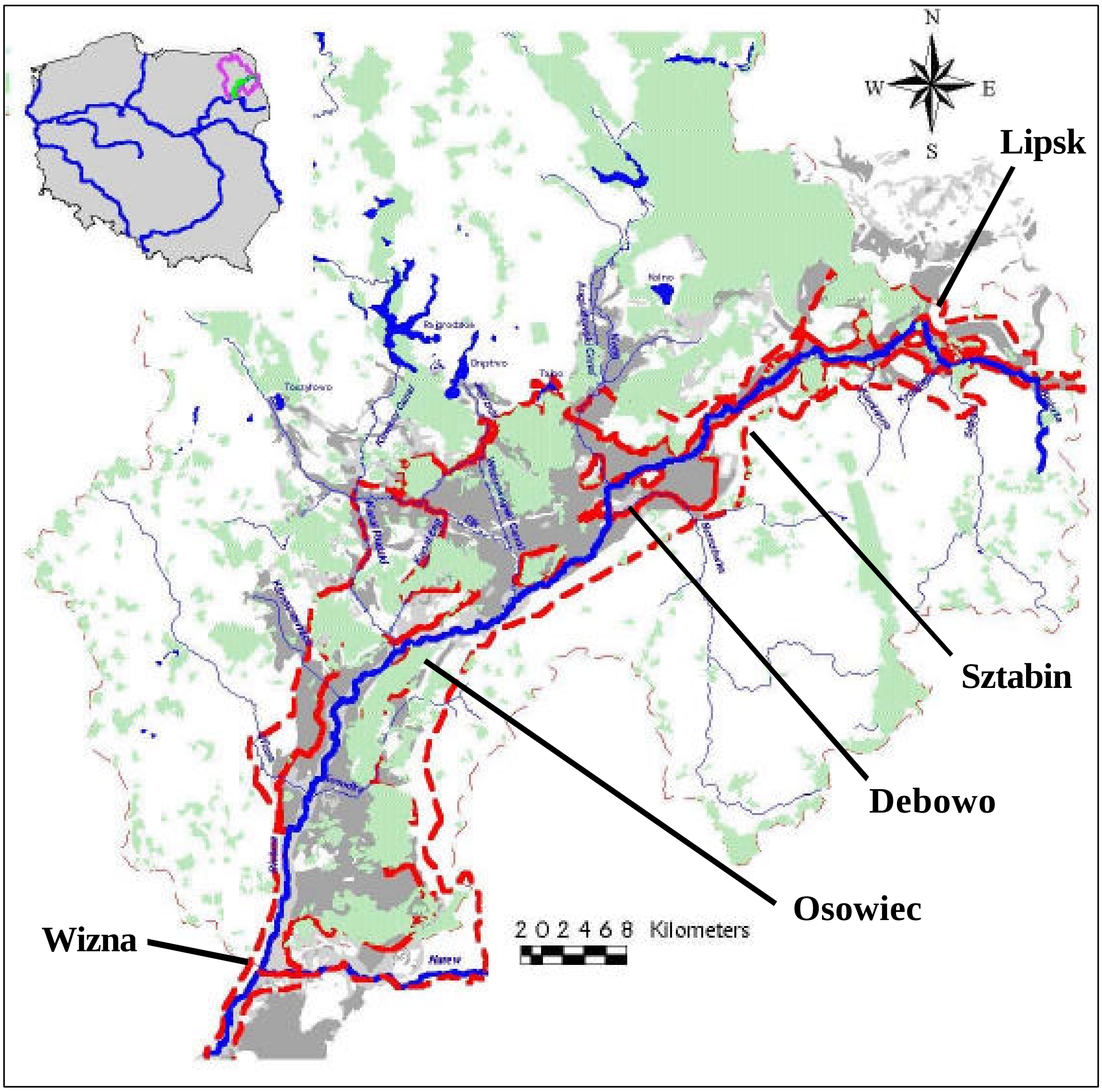


Figure 1.

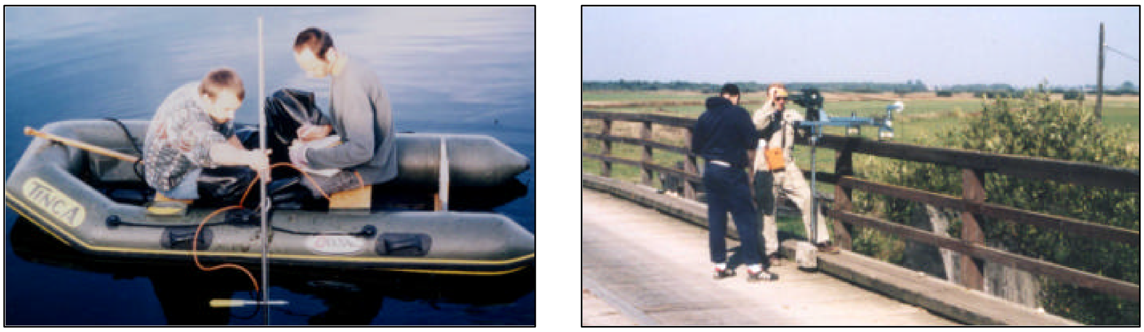


Figure 2.

Figure 3.

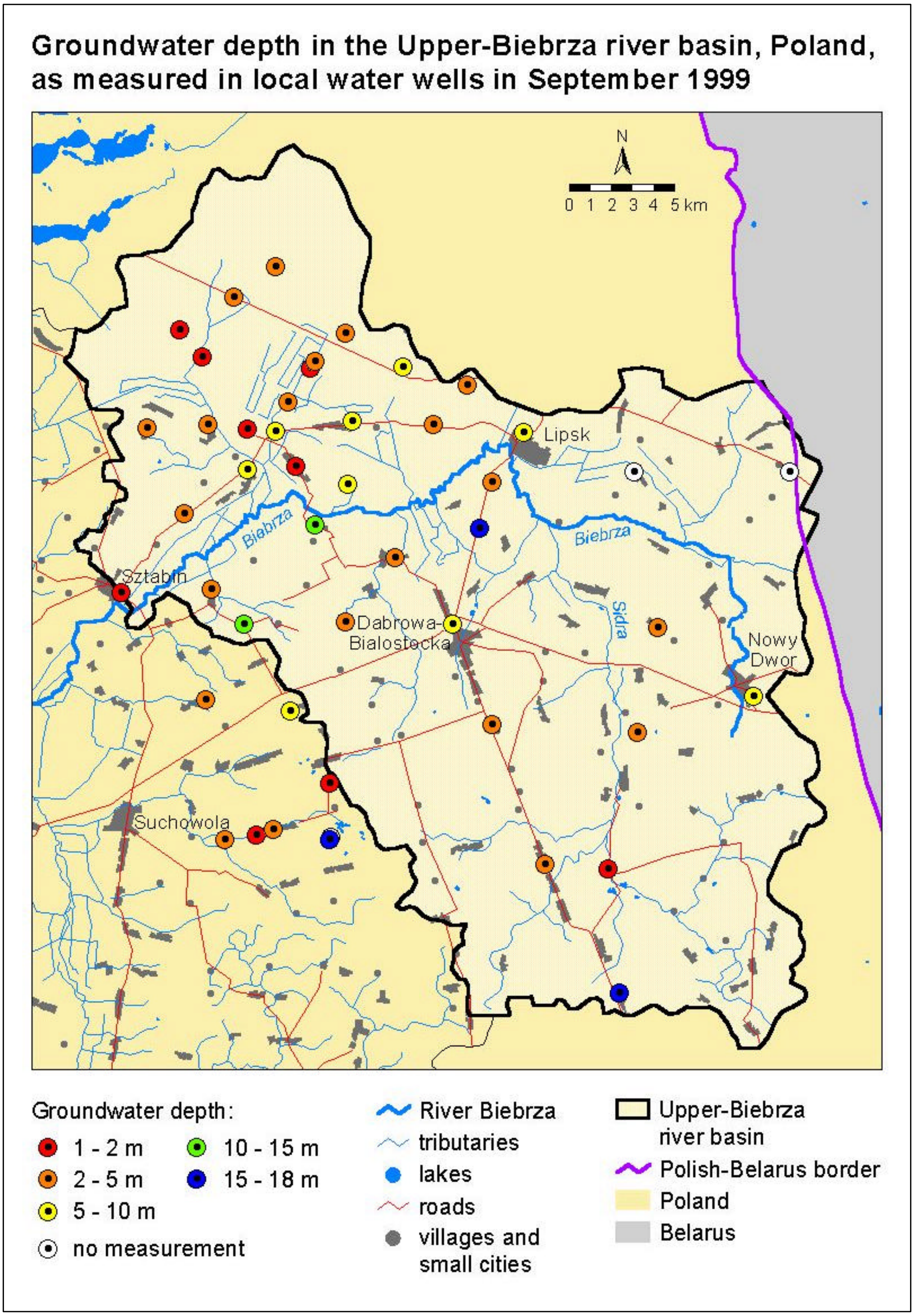
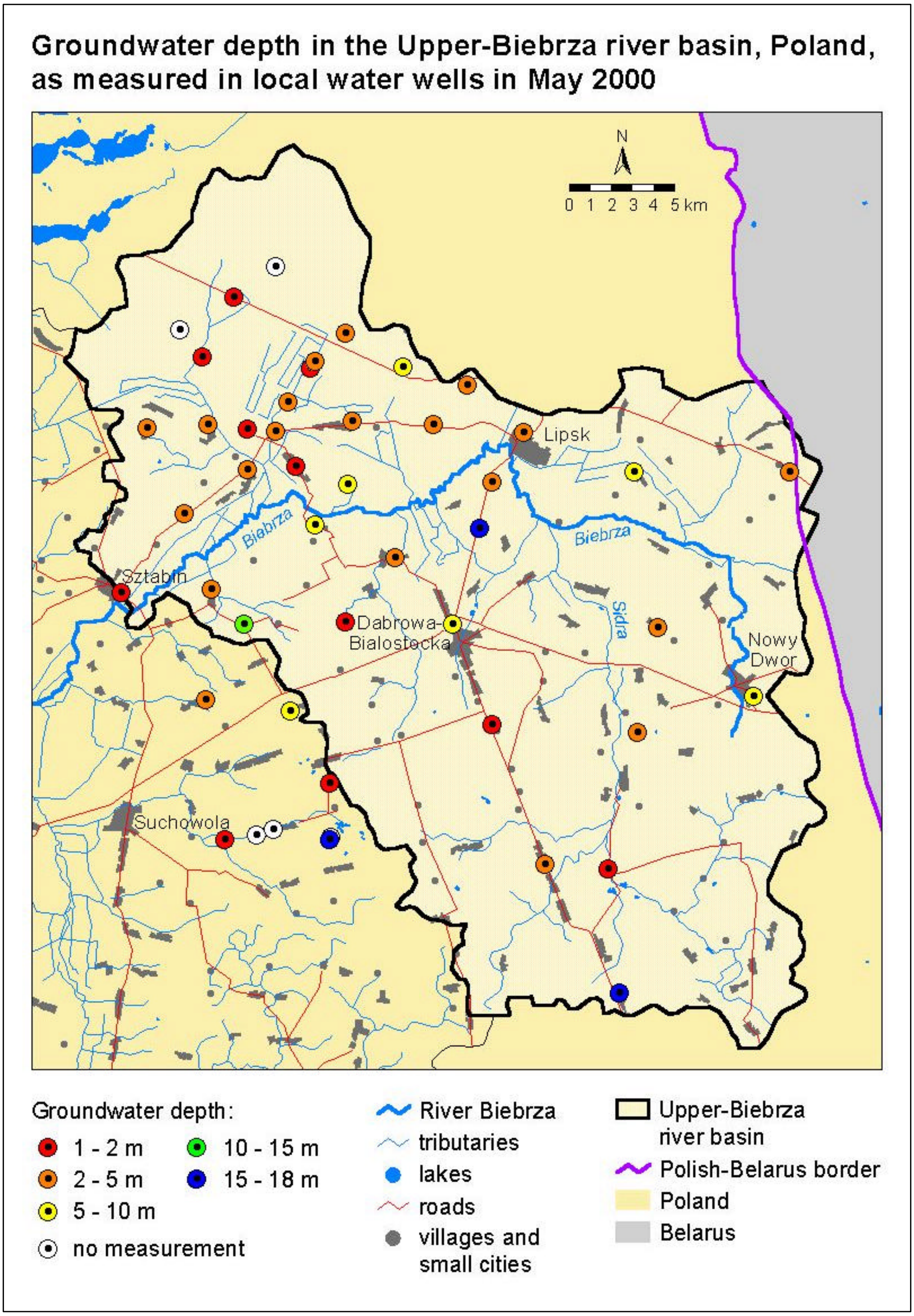

Groundwater depth in the Upper-Biebrza river basin, Poland, as measured in local water wells in September 1999
N
0 1 2 3 4 5 km
Lipsk
Biebrza
Biebrza
Sztabin
Dabrowa-
Bialostocka
Sidra
Nowy
Dwor
Suchowola
Groundwater depth:
1 - 2 m
2 - 5 m
5 - 10 m
10 - 15 m
15 - 18 m
no measurement
River Biebrza
tributaries
lakes
roads
villages and small cities
Upper-Biebrza river basin
Polish-Belarus border
Poland
Belarus

Figure 4.



Groundwater depth in the Upper-Biebrza river basin, Poland, as measured in local water wells in May 2000
N
0 1 2 3 4 5 km
Lipsk
Biebrza
Biebrza
Sztabin
Dabrowa-Bialostocka
Sidra
Nowy Dwor
Suchowola
Groundwater depth:
1 - 2 m
2 - 5 m
5 - 10 m
10 - 15 m
15 - 18 m
no measurement
River Biebrza
tributaries
lakes
roads
villages and small cities
Upper-Biebrza river basin
Polish-Belarus border
Poland
Belarus

Figure 5.