Pol. J. Environ. Stud. Vol. 20, No. 5 (2011), 1193-1201

Original Research

Floodplain Forest Technical and Monitoring Solutions for Protection of the Uroczysko Warta Floodplain Forest

Bogusław Kamiński[1]*, Antoni T. Miler[1], Bernard Okoński[1]***, Sylwester Grajewski[1]****, Krzysztof Schwartz[2]*****

[1]Department of Forest Engineering, Poznań University of Life Sciences, Mazowiecka 41, 60-623 Poznań Poland
[2]Jarocin State Forest Division

Received: 27 October 2010
Accepted: 5 April 2011

Abstract

Big river floodplain forests are the richest yet most highly diminished and endangered forest ecosystems. Water engineering projects conducted on rivers and in river valleys, land use changes, and deforestation have contributed to these ecosystems' degradation. Less than 10% of the natural forest floodplain area in Poland is currently covered by floodplain forests. Uroczysko Warta forest is one of the best preserved and largest natural floodplain forests in Poland, located in the Warta River Valley (the Oder River Basin). Damming of the Warta (Jeziorsko Reservoir) has changed the river regime and flooding patterns downstream (reduced flooding area and decreased flooding frequency), initiating floodplain forest disintegration. In response, a protection project has been undertaken in Uroczysko Warta. The project employs a system of water engineering constructions (flashboard gates, river sills, and culverts with flap check valves). The water engineering system is supposed to improve and reestablish hydrological conditions similar to the natural and stop disintegration processes occurring in floodplain forests. The paper presents technical solutions implemented for protection of Uroczysko Warta floodplain forests, the initial results after implementation of the project and research perspectives aimed at assessment of hydrological restoration effectiveness.

Keywords: floodplain forests, hydrological regime changes, floodplain forest protection technical solutions

Introduction

Floodplain forests are the most complex and richest forest ecosystems in Poland. The potential vegetation cover of Poland includes almost in 9% of floodplain forests, yet site types corresponding to floodplain forest vegetation occupy as little as 0.7% of the area, including floodplain forests at 0.2% [1].

A large, coherent area of well-preserved floodplain forests is to be protected in the network Nautra2000 – SAC Lasy Żerkowsko-Czeszewskie PLH300053 (site of community importance) [2]. The first description of Lasy Czeszewskie floodplain forest was performed in the 1930s [3], shortly after the area was recognized as an important sanctuary of river valley ecosystems. Flora and descriptions

*e-mail: bkamin@up.poznan.pl
**e-mail: amiler@up.poznan.pl
***e-mail: okonski@up.poznan.pl
****e-mail: sylgraj@up.poznan.pl
*****e-mail: k.schwartz@poznan.lasy.gov.pl

of plant communities followed [4]. The terrestrial plant communities of the area were also discussed in detailed analysis of terrestrial communities of the Warta River Valley [5].

A key natural factor supporting the sustainability and ecological processes in floodplain forests and non-forest natural ecosystems (such as oxbow lakes) is periodical flooding of the valley bottom. The disturbance of flooding pattern causes the degradation of floodplain forest sites, i.e. initiates transformation of oak-elm-ash floodplain forests (*Querco-Ulmetum minoris* Issler) into oak-hornbeam forests (*Carpinion betuli* Oberd.) in Central Europe and transformation processes of oxbow lakes into landed ecosystems. The most significant stress factors affecting floodplain ecosystems are the reduction of floodplain area by construction of flood embankments and changes of river hydrological regime caused by the construction of large water reservoirs [6, 7].

Protection of floodplain habitats is a complex issue requiring dedicated solutions. General strategies [8] and a range of monitoring methods have been developed [9]. Yet these procedures often have a guideline dimension. In most cases protection of floodplain ecosystems includes passive methods, monitoring of processes in ecosystems of floodplain areas caused by human activities or climate changes [10-14]. While solutions are sought in conflict between need of technical infrastructure utilization and fulfilling the floodplain environment protection goals [15], pragmatic needs are favored [16, 17]. The Water Framework Directive Regulations in Europe balance needs of the environment protection and requirements of the communities. Various mechanisms dedicated to large river valleys and river basin management have been introduced [18]. In effect, programs of floodplain ecosystem restoration, renaturization and protection [19, 20], or efforts to predict scenarios of floodplain environment changes are undertaken [21].

An important environmental issue raised in debate about natural habitat preservation in river valleys is implementation of effective protection methods of which active protection methods may be the right answer. The area of Uroczysko Warta Forest, due to the construction of Jeziorsko Reservoir and the hydrological regime of Warta River modulation downstream, is affected by the reduction of frequency and area of floods. The required ecological effect in Uroczysko Warta may be achieved through the application of relatively simple water engineering solutions that help reestablish hydrological conditions similar to the natural, as well as alter the storage volume of oxbow lakes. Groundwater level depths will then be more stable and reach lower levels below ground surface.

The technical solution for the protection of forests in Uroczysko Warta employs the buffer capacity alteration of local oxbow lakes, which can be effective in the periods of high water in the Warta and Lutynia Rivers. The concept for improving water storage in the floodplain forests of Uroczysko Warta is based on the premises described below. Oxbow lakes, due to spatial share and local hydrogeological conditions, may have a regulatory effect on water processes in the forest sites, while an additional amount of water is provided and storage capacity enhanced. An additional amount of water may be stored in oxbow lakes and natural dry channels (inactive oxbow lakes). The source of water supplied for additional storage will be high water, and floodwater preserved from quick return to the main river channel. Preventing the discharge of floodwater in the periods of overbank flow or higher water on the Warta River, allowing water transfers through the system of natural dry channels from the Lutynia River, may provide additional water storage volume. Such a system of providing additional water storage and employing storage capacity reserves copies natural hydrological processes occurring in ecosystems of the valley bottom floodplain forests, since the water does not stagnate, but is transferred into the ground and slowly filtrates horizontally in the direction of the main river channel.

Characteristics of Uroczysko Warta Forest

The Uroczysko Warta forest covers the active and inactive floodplain terrace on the left bank of the Warta River (from 332 to 337.5 km of its course). The forest is located between the Lutynia and the Warta Rivers at the confluence section of (from 0 to 3.2 km) (Figs. 1 and 2). The area is located in the central part of Wielkopolska Plain (a part of the North European Plain) and the mid-section of the Warta River at 52º08'12"N and 17º30'35"E (the Oder River right-side tributary).

Jarocin Forest Division administers the area. The total area of Uroczysko Warta forest is 772.44 ha, of which the forested area comprises 634.99 ha. Non-forest vegetation cover is composed of meadows, oxbow lakes, and marshes. Alluvial soils prevail (82.2%), brown and gray podzolic soils (9.3% and 5.7%) also occur. Brown podzolic soils and grey brown podzolic soils cover inactive floodplain. Ground gley soils, brown soils, gley soils, podzolic epigleic soils, alluvial muck soils, forest black earths, and initial soils are also found in small amounts [22].

Climatic conditions prevailing over the analyzed area and the Warta River Basin are relatively disadvantageous as far as the support of flooding conditions is considered.

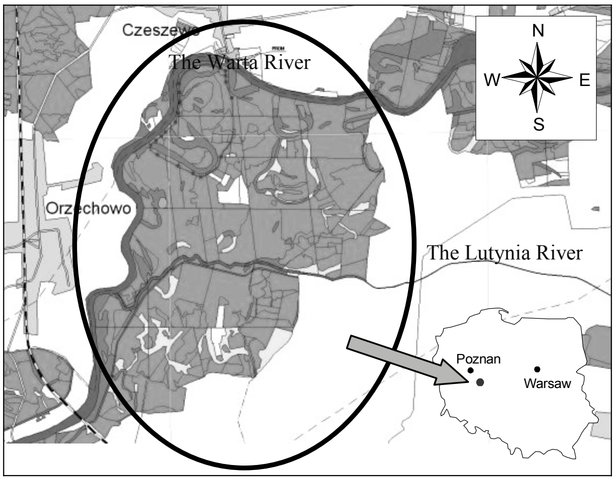

Fig. 1. Location of Uroczysko Warta [24].

Relatively low precipitation, high evapotranspiration, and small share of snowpack in the winter period over the river basin destimulate the frequency and extent of floods. For example, annual mean precipitation observed at the nearest rainfall measurement station located in Nowa Wieś Podgórna for 1951 to 2000 was relatively low and variable (546 mm mean annual precipitation). Once every 10 years annual precipitation falls below 400 mm, and a cyclicity is observed in the sequence of wet and dry annual periods [23].

There are 10 active oxbow lakes of the Warta River (starting from the east: Musiółka, Czapla, Szaniec, Łojewo, Mała Starucha, Podkowa, Wielka Starucha, Kierzek, Zaskrzęcie, and Dębiński Rów), as well as several inactive channels (overgrown troughs) that are remnants left after landed oxbow lakes. The eastern part of Uroczysko Warta occupies Czeszewski Las Nature Reserve of 222.62 ha (Fig. 2). The entire investigated area is located within Żerkowsko-Czeszewski Landscape Park, area 15,640 ha [24].

The Uroczysko Warta forest area is a mosaic of oak-hornbeam forests and oak-elm-ash floodplain forests, with a high share of older stands, located on the active and inactive terrace of the Warta River, with preserved oxbow lakes and characteristic natural vegetation (Fig. 3a). Non-forest vegetation cover consists of the following species: reed canary grass (*Phalaridetum arundinaceae*), wood sweet grass (*Glycerietum maximae*), iris (*Iridetum pseudacori*), and sedge rushes (*Caricetum*), as well as fragments of meadows related in terms of their floristic composition to cnidium meadows (*Cnidion dubii*) – vegetation typical for the valley bottom of big river floodplains. A part of the reserve is regularly flooded by the Warta River during the early spring high water periods. Floodplain forests in Uroczysko Warta, together with forests extending along the Warta River downstream (to Dębno Natural Reserve) constitute one of the largest and best preserved floodplain forest areas in the Wielkopolska Region and Poland. Field maple (*Acer campestre* L.) is regular component of the forest stand composition. The substantial population of white poplar (*Populus alba* L.) is also represented, and native black poplar (*Populus nigra* L.) can also be found in the area. Cork-forming elm (*Ulmus minor var. suberosa* Rehder) and field maple (*Acer campestre* L. 'suberosa') are characteristic of the area. A characteristic feature of the forest age composition is the large proportion of old oak (*Quercus robur* L.) stands (age classes VIII and IX, i.e. 140-180 years), as well as a high number of ash stands of age class IV (60-80 years). The area holds numerous old trees, of which 77 are monument trees (39 common oaks, with the thickest being 620 cm in circumference) [24].

The flora is typical for well-preserved floodplain forests, oxbow lakes, and river bank margins. A rich flora of vascular plants, including rare and valuable species, comprises over 600 taxa. In Czeszewo Forest a total of 75 nesting or probably nesting birds were recorded [25]. The number of bird species should be considered as high judging by the relatively small area of the investigated area (5 km^2).

The insect fauna is also rich, including numerous species typical for old forest stands. A quarter of the recorded taxa of long-horn beetles (*Cerambycidae*) are the indicators of natural and primeval forests and require habitats provided by the presence of huge, old trees and a unique microclimate formed by mature forest stands.

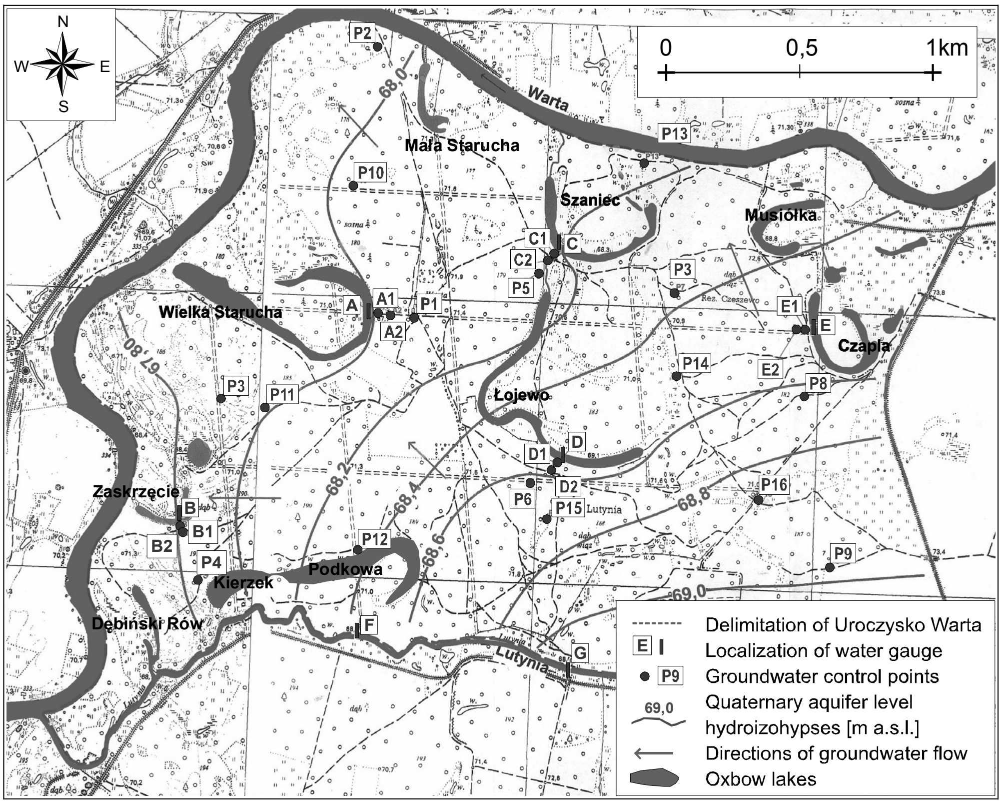

Fig. 2. Plan of Uroczysko Warta Forest [28].

According to the archive forest management plan for the period from 1989 to 1998, Czeszewo Reserve before enlargement covered a fragment of floodplain forest of 26.37 ha. Oak-elm-ash floodplain forest (*Ficario-Ulmetum campestris*) was identified. Forest stands are dominated by the oldest common oak (aged from 150 to 180 years) with uneven-aged ash (*Fraxinus excelsior* L.), lime (*Tilia cordata* Mill.), hornbeam (*Carpinus betulus* L.), and field maple tree admixture. The disintegration processes of forest stands were indicated. These processes are marked by reduction of stand density as a result of dying out of elm (*Ulmus minor* Mill., *Ulmus laevis* Pall.) and ash – the main forest species in this type of vegetation.

The reserve was enlarged up to an area of 222.62 ha and the name was changed to the Czeszewski Las Reserve in 2004. According to the current protection plan for Czeszewski Las Reserve, the objective of the reserve protection was to preserve the natural forests and oxbow lakes in the valley area of the Warta River. Special emphasis was put to the protection of floodplain site conditions, providing floodwater for the floodplain ecosystems with the simultaneous preservation of meadow patches to support the biodiversity of flora and fauna.

After finishing the initial project in 2006, the second stage followed. Supplementary research and expert analyses were completed in order to work out optimal technical solutions. Founding of the supplementary project was provided by a grant won from the EcoFound (EkoFundusz) Foundation. The planned project is titled "Protection of floodplain ecosystems of Uroczysko Warta Forest in Żerkowsko-Czeszewski Landscape Park – the second stage," and was scheduled for technical implementation 2009 to 2010. Dedicated technical solutions were selected in order to enlarge the environmental intervention area to neighboring floodplain areas of Dębno and Warta Forests. Altogether, the area under environmental intervention covered 1500 ha. The supplementary water system is composed of 3 conversed flap valve culverts (Fig. 3b). The reconstruction of flap valve culverts included the addition at the top of embankment flashboard gates for control of water overflow. Other technical elements of the system form 2 damming new-constructed sills and a rebuilt river sill on the Lutynia River (originally built in 2005, Fig. 3c). Transfer of stored water between oxbow lakes and the main river channel was provided by a system of dry channels created in landed oxbow lakes, which form a sequence of linear depressions. These depressions were connected, if necessary, by ditches to form a coherent water transfer system. The dry channels are provided with additional regulating flashboard gates for the control of stored water outflow.

a)

b) c)

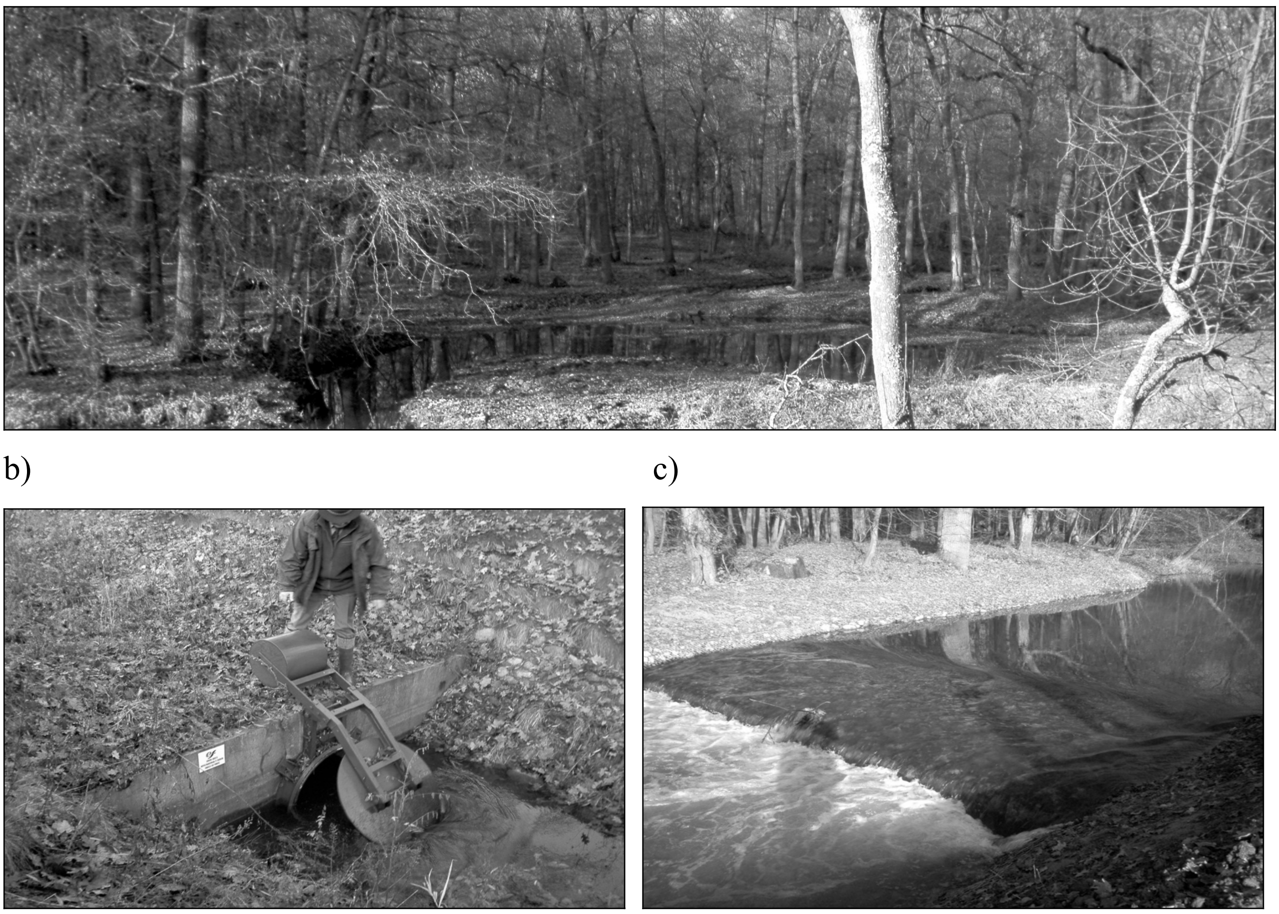

Fig. 3. The floodplain forests in Uroczysko Warta Forest (a), culvert with a flap check valve (b), damming sill (c).

Methods

The assessment of the hydrologic effect was based on the analysis of diurnal discharge values and was calculated utilizing data from the Poznań gauging station for the period 1822 to 1997. The Poznań gauging station is located at 244 km of the Warta River and covers a catchment area of ca 25,000 km^2.

The system of hydrologic monitoring was introduced in Uroczysko Warta Forest in 2008. Both the surface and groundwater are intended to be monitored for assessment of interactions between hydrologic processes and the ecological processes of floodplain ecosystems. Installation of the groundwater monitoring system was preceded by selection of drilling locations according to identified terrain relief and geologic condition variability. Altogether, 26 hydrologic borehole locations were selected over the entire investigated area, and the drillings ranged in depth from 4 to 26 m below ground surface (Fig. 2) [26]. Hydrological borehole distribution will allow groundwater dynamics analysis, which may be performed across geologic transects and for separate points placed at the local depressions and upper ground. Automatic piezometers were placed in hydrologic boreholes. Monitoring data have been recorded since 2009. The surface water measuring system consists of 7 staff gauges placed at oxbow lakes and the Lutynia River.

Groundwater Hydrogeological Monitoring Cross-Sections

In all, 5 measurement sections were established. Each section consists of a gauging staff for surface water dynamics observations and 2 piezometers – at different distances from the gauging staff location. Two gauging staffs were also installed on the Lutynia River. The sections were assigned for all the active oxbow lakes for which technical solutions were planned. The sections were marked with consecutive letters and were located on the following oxbow lakes: Wielka Starucha – section A, Zaskrzęcie – section B, Szaniec – section C, and Łojewo – section D. One section was prepared on a passive oxbow lake called Czapla – section E. Altogether, 10 hydrogeological boreholes were drilled in the section system. Each hydrogeological bore was drilled by utilization of the dry method in a single column of steel drilling shelter pipes (ϕ168 mm) reaching the bottom of each borehole. The shelter pipes were retracted after installation of filters. The pipe screen tubes installed for the quaternary aquifer layers were PVC-U, DN 100 (ϕ113 mm) 3 m long perforated casing. Pipe stability was secured by 1.4-2.0 mm gravel fraction fill. Elements of each hydrogelogical cross-section were arranged in collinear mode. Each gauging staff was installed on steel poles placed 1-2 meters from the oxbow/river bank. The surface water observations may be performed with 0.5 cm measuring accuracy.

Auxiliary Groundwater Hydrogeological Monitoring Points

There were 7 groundwater monitoring borehole points marked P10 to P16 placed in local depressions of terrain surface, all the points below altitude 70 m above sea level (a.s.l.) The hydrogeological boreholes on higher ground, marked P1 to P9, were placed at the area never submerged by floodwater during flood periods. The methods employed for preparing these boreholes were similar to the method used for setting the cross-section boreholes. The hydrogeological boreholes marked P2 to P9 reached a depth not exceeding 7.0 m below ground surface (b.g.s.), but the borehole marked P1 was drilled up to 26.5 m b.g.s., the bottom of Quaternary sediments layer (Fig. 2). After soil sample collection, the boreholes were filled with drilled out soil up to 15 m b.g.s., with preservation of the geological layer natural sequence.

Groundwater level dynamics is measured automatically. Each borehole is equipped with an automatic recorder of groundwater level depth changes of DIVER type programmed for recording measurements every 3 hours. Surface water changes are observed weekly. It was recommended that a hydrologic monitoring report should be prepared every 2-3 years. The reports should include maps of groundwater hydroisopleths for low, average, and high water levels, conclusions regarding floodplain ecosystems current state and recommendations for forest and water management activities. In addition, water quality monitoring should be performed every 2-3 years. Basic physicochemical water analyses are recommended, including monitoring of parameters such as color, pH, total hardness, oxidability, iron, manganese, chlorides, sulfates, nitrites and nitrates, and mineralization (TDS).

Water Level in Oxbow Lakes and Deadwood Volume

Research on oxbow lake level changes and deadwood volume dynamics was carried out in 1991-2006. The forest data inventoried by the Jarocin Forest Division and hydrometric data for the Warta River (the Nowa Wieś Gauging Station, 5 km upstream from the research area) were utilized. The relations between the Warta River and oxbow levels were identified to determine the beginning and end of a period of oxbow lake water level rise.

Results

Effect of Jeziorsko Reservoir on the Warta River Flow Regime

The Jeziorsko reservoir of total water volume capacity of 203 million m^3, located in the middle course of the Warta River, has been operational since 1987. The reservoir has a significant impact on the Warta River flow regime.

Runoff of the Warta has a relatively high stationary pattern as far as mean annual values are considered. During the period of the reservoir operation, mainly under average meteorological conditions except for 1997, the daily river flows were significantly reduced. The reduction of variability of daily flows caused a significant decrease of the maximum diurnal flow values. Mean standard deviation of daily discharge for the period preceding reservoir construction of 1822-87 (166 years in total) was 75.3 $m^3 \cdot s^{-1}$, while the respective standard deviation for the 10-year period of reservoir operation decreased to 38.8 $m^3 \cdot s^{-1}$. Furthermore, the mean low discharge increased from 32.1 to 39.5 $m^3 \cdot s^{-1}$ and the mean high discharge decreased from 449 to 201 $m^3 \cdot s^{-1}$ (significant at the 0.05 level). The above described changes in flow pattern caused by river regime modulation are presented in Figs. 4a, b. The effect of changes in flow at Poznań Gauging Station is a result of water management activities – holding or releasing of stored water at the reservoir. Storage capacity of Jeziorsko Reservoir has a flattening effect on the flood flows down the Warta River course. The effect of floodwater impact reduction was particularly evident during the summer flood of 1997 in Poznań [27].

Monitoring of Surface Water and Groundwater

Groundwater monitoring of the upper Quaternary aquifer level for the period 27 March 2009 to 5 May 2010 showed that groundwater level depths ranged from 0.90 to 3.97 m b.g.s. at the beginning, and -0.05 to 3.06 m b.g.s at the closing date of the monitoring period. The amplitude of the measurement periods for total number of 26 monitoring points ranged from 0.35 m to 1.98 m (Table 1). The surface water observations performed on the gauging staffs were presented in Table 2.

Out of 26 piezometers, 24 were operational throughout the entire investigated period. During the initial stage of measurements only 11 piezometers returned required reliability of measurements. The analysis of monitoring data enabled noticing two periods of groundwater level rising. The first period started ca on 27 June 2009 with two maximums reached on 16 and 22 July. The second period started on 12 October and lasted to 23 February. At the end of this period the rising of groundwater level occurred (average rise 1 m per week) (Fig. 5). Groundwater level reached two maxima – the first on 6 March and the second on 5 April 2010. The highest amplitudes of groundwater level depth occurred at Szaniec oxbow lake, and the lowest at Czapla oxbow lake (Fig. 2).

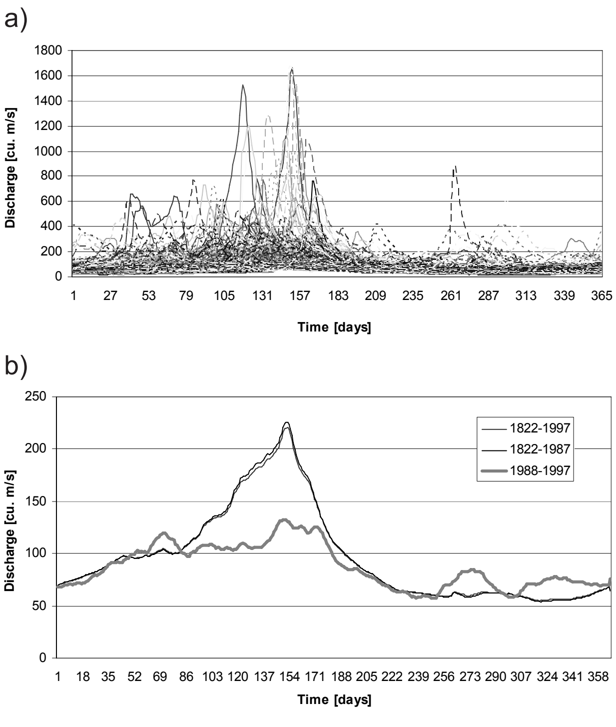

Fig. 4. a) Time series of daily mean of the Warta River discharges at Poznań in the period 1822-97. b) Time series for periods: 1822-97, 1822-87, and 1988-97 of averaging at individual days of the Warta River discharges at Poznań.

Water Level in Oxbow Lakes and Deadwood Volume

It was indicated during research in 1991-2006 that a decrease of period length of water level rise in oxbow lakes is inversely proportional to the volume of deadwood (r=057, p=0.07, Fig. 6).

Discussion

Jeziorsko Reservoir, constructed 23 years ago, significantly modulates the Warta River flow regimes downstream. For example, the reservoir modulates river flow pattern and causes the reduction of area and frequency of river valley flooding in Uroczysko Warta Forest.

Active protection methods undertaken in Uroczysko Warta that employ simple technical solutions (flashboard gates, sills, culverts with flap check valves) are supposed to emulate natural hydrologic processes at the river valley bottom. However, river floods cause vertical recharge of groundwater, the implemented solution bases on horizontal groundwater movement in soil due to a rise of water level in oxbow lakes and storing water in dry channels. It can be assumed that groundwater levels in the area will gain lower level below ground surface for longer periods during the vegetative period in effect.

The technical scheme of active protection was financed by the EcoFund Foudation (EkoFundusz), an organization established in 1992 by the Ministry of Finance for providing grants financed from converted Polish foreign debt resources (debt-for-environment swap founds) dedicated to funding projects related to environmental protection.

The results of water processes mitigation cannot be assessed more firmly at this stage. Thus, the effect of simulation and reestablishment of natural hydrological regime typical for floodplain forests should be assessed in the course of prospective research. Water level dynamics analysis is the basis for water regime assessment. The groundwater dynamics and oxbow lake level monitoring

Table 1. Results of hydrogeological observations of groundwater.

No.	H_t [m a.s.l.]	No. of piezometer	No. of DIVER	Measurements on 27 March 2009		Measurements of 5 May 2010	
				h_{ZWG} [m b.g.s]	H_{ZWG} [m a.s.l.]	h_{ZWG} [m b.g.s.]	H_{ZWG} [m a.s.l.]
1	71.013	A1	C6644	2.60	68.41	1.63	69.38
2	70.781	A2	C6665	2.50	68.28	1.41	69.37
3	70.994	B1	C7010	2.83	68.16	2.59	68.40
4	71.008	B2	D4788	2.89	68.12	2.54	68.47
5	69.983	C1	D4758	1.39	68.59	0.22	69.76
6	70.430	C2	C6649	1.88	68.55	1.00	69.43
7	72.104	D1	C7013	3.44	68.66	2.53	69.57
8	72.228	D2	C6990	3.62	68.61	2.61	69.62
9	71.712	E1	C6026	1.87	69.84	1.95	69.76
10	71.727	E2	C6081	2.89	68.84	1.98	69.75
11	72.274	P1	C6628	3.89	68.38	2.80	69.47
12	71.163	P2	C6630	2.69	68.47	2.47	68.69
13	71.469	P3	D2393	2.54	68.93	2.89	68.58
14	70.953	P4	D4793	2.67	68.28	2.39	68.56
15	71.796	P5	D4754	3.25	68.55	2.35	69.45
16	72.550	P6	C7001	3.91	68.64	2.99	69.56
17	72.531	P7	D4741	3.85	68.68	3.06	69.47
18	71.145	P8	C6054	2.14	69.01	1.29	69.86
19	72.109	P9	C6024	2.79	69.32	2.11	70.00
20	69.191	P10	D4818	0.90	68.29	-0.05	69.24
21	69.908	P11	D4813	1.75	68.16	0.85	69.06
22	70.998	P12	C6652	2.72	68.28	2.01	68.99
23	71.212	P13	D4753	3.97	67.24	2.05	69.16
24	70.302	P14	C6977	1.43	68.87	0.65	69.65
25	70.653	P15	C6996	2.00	68.65	1.01	69.64
26	70.655	P16	C6057	1.79	68.87	0.76	69.90

H_t – altitude of terrain of piezometer [m a.s.l.]
H_{ZWG} – altitude of groundwater level [m a.s.l.]
h_{ZWG} – depth of groundwater level [m b.g.s.]

Table 2. Results of surface water observations (XII 2008).

No.	Gauging staff	Observation value [m]	Altitude of surface water level [m a.s.l.]
1	A	0.6	68.00
2	B	0.3	67.79
3	C	0.4	68.28
4	D	0.3	68.46
5	E	-	-
6	F	0.4	68.45
7	G	0.6	69.21

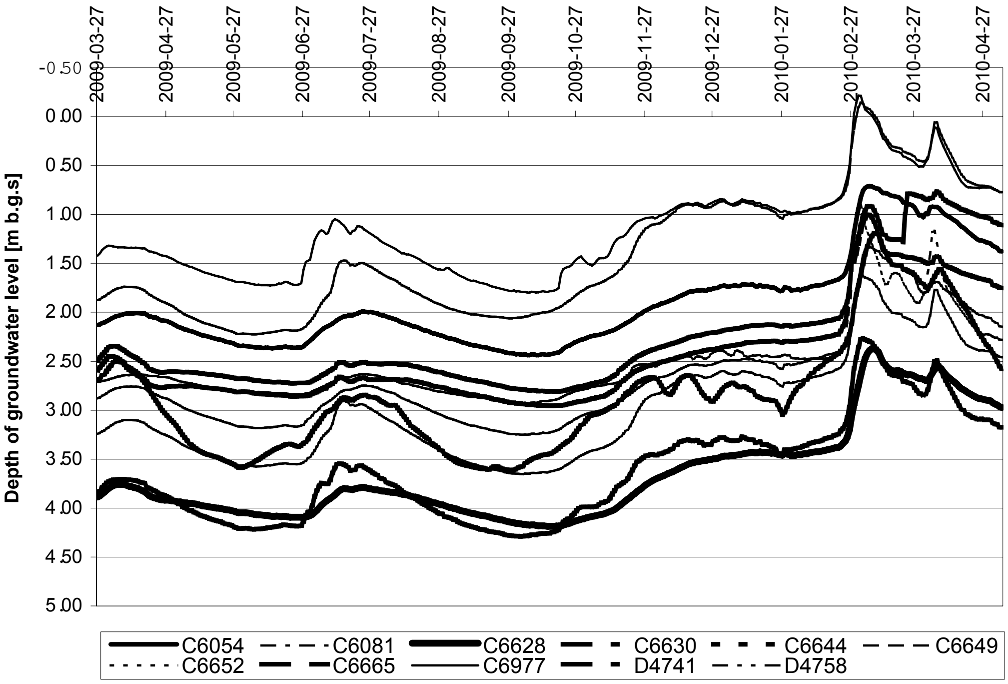

Fig. 5. Groundwater level depth at 11 piezometers for the period 27 March 2009 to 5 May 2010.

system was implemented for this purpose. Effectiveness assessment of the implemented active protection system of the floodplain forests in Uroczysko Warta, apart from hydrologic monitoring, should also cover the monitoring of ecosystems and ecological processes occurring in the ecosystems, e.g. deadwood dynamics, vegetation changes, and tree increment analysis. So far, it was indicated that deadwood volume dynamics for the period 1991-2006 depend on oxbow lake water level dynamics (inversely proportional dependence). The relatively short period of hydrologic monitoring does not enable us to make a more firm assessment of technical solution effectiveness. The research project related to identification of long-term hydrologic and meteorological regimes impact on tree increment for forest floodplain vegetation in Uroczysko Warta has already been started. The project is aimed at providing ecohydrological background to process governing tree growth of floodplain forests and thus may help explain the effects caused by an implemented hydrological restoration system on river valley floodplain forests.

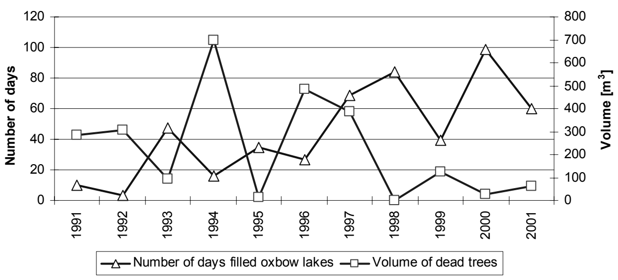

Fig. 6. Annual volume of deadwood and the period of water level rise in oxbow lakes.

Conclusions

1. Jeziorsko Reservoir impacts extensively the area and frequency of flooding of Uroczysko Warta.
2. The implemented system of active protection of Uroczysko Warta floodplain forests employs simple water engineering constructions (flashboard gates, sills, culverts with flap check valves) to emulate natural flooding regimes that occur periodically.
3. The firm assessment of hydrological restoration system capability to emulate floodplain natural hydrological processes is yet to be proved.
4. The assessment of implemented protection solution effectiveness in Uroczysko Warta requires long-term monitoring of floodplain forests and ecological processes, particularly forest stand vitality.
5. It was already indicated that deadwood volume is destimulated by the length of oxbow lake water level rise period.

References

1. DANIELEWICZ W. A forests and an afforestation of river valleys – economic meaning as well as the part in protection of natural environment. Advances of Agricultural Sciences Problem Issues Polish Academy of Sciences, **1993** [In Polish].
2. JANYSZEK S., KASPROWICZ M. Nature 2000. Standard form. **2009** [In Polish].
3. WODZICZKO A. Forest reserve in Czeszewo by the Warta River. Nature Conservation, Kraków, **4**, 131, **1924** [In Polish].

4. MIELCARSKI C. Deciduous forests surrounding Czeszewo by the Warta River. Physiographic studies on the Western Poland, Poznań, B, **22**, 69, **1969** [In Polish].
5. BORYSIAK J. The structure of the alluvial land vegetation of the middle and lower course of the Warta River. Scientific Publisher Adam Mickiewicz University in Poznań, Biology Series, **52**, **1994** [In Polish].
6. CIEŚLA A. Effect of hydrotechnical constructions on the Oder river on the phytosociological diversity of riparian habitats in the Prawików forest. Forest Research Papers, **70**, (2), 161, **2009** [In Polish].
7. KUROWSKI J. K. Dynamic processes in forest communities caused by dehydration of forest sites. Forest Research Papers, **2**, 27, **2007** [In Polish].
8. ROHDE S., HOSTMANN M., PETER A., K.C. EWALD K. C. Room for rivers: An integrative search strategy for floodplain restoration. Landscape and Urban Planning, **78**, 50, **2006**.
9. SYRBE R.U, BASTIAN O., RÖDER M., JAMES P. A framework for monitoring landscape functions: The Saxon Academy Landscape Monitoring Approach (SALMA), exemplified by soil investigations in the Kleine Spree floodplain (Saxony, Germany). Landscape and Urban Planning, **79**, 190, **2007**.
10. GRECO S. E., FREMIER A. K., LARSEN E. W., PLANT R. E. A tool for tracking floodplain age land surface patterns on a large meandering river with applications for ecological planning and restoration design. Landscape and Urban Planning, **81**, 354, **2007**.
11. GREGER O. Special Role of Pioneer Crop in Stand Formation of Elbe River Valley. Forst Und Holz, **53**, (13), 412, **1998** [In German].
12. HAASE D., GLÄSER J. Determinants of floodplain forest development illustrated by the example of the floodplain forest in the District of Leipzig. Forest Ecology and Management, **258**, 887, **2009**.
13. KLIMO E., HAGER H. Eds. The floodplain forests in Europe: current and perspectives. European Forest Institute research report, 10. Koninklijke Brill NV, Leiden, **2001**.
14. KRAMER K., VREUGDENHIL S. J., VAN DER WERF D. C. Effects of flooding on the recruitment, damage and mortality of riparian tree species: A field and simulation study on the Rhine floodplain. Forest Ecology and Management, **255**, 3893, **2008**.
15. LARSEN E. W., GIRVETZ E. H., ALEXANDER K. FREMIER A. K. Landscape level planning in alluvial riparian floodplain ecosystems: Using geomorphic modeling to avoid conflicts between human infrastructure and habitat conservation. Landscape and Urban Planning, **79**, 338, **2007**.
16. BUIJS A. E. Public support for river restoration. A mixed-method study into local residents' support for and framing of river management and ecological restoration in the Dutch floodplains. Journal of Environmental Management, **90**, 2680, **2009**.
17. OSWALT S. N., KING S. L. Channelization and floodplain forests: Impacts of accelerated sedimentation and valley plug formation on floodplain forests of the Middle Fork Forked Deer River, Tennessee, USA. Forest Ecology and Management, **215**, 69, **2005**.
18. OLLERO A. Channel changes and floodplain management in the meandering middle Ebro River, Spain. Geomorphology, **117**, 247, **2010**.
19. KÜßNER R. Mortality patterns of Quercus, Tilia, and Fraxinus germinants in a floodplain forest on the river Elbe, Germany. Forest Ecology and Management, **173**, 37, **2003**.
20. KUPFER J. A., MEITZEN K. M., PIPKIN A. R. Hydrogeomorphic controls of early post-logging successional pathways in a southern floodplain forest. Forest Ecology and Management, **259**, 1880, **2010**.
21. MORADKHANI H., BAIRD R. G., SUSAN A. WHERRY S. A. Assessment of climate change impact on floodplain and hydrologic ecotones. Journal of Hydrology. **2010** [In press].
22. PAWLACZYK P., STAŃKO R., ZIELIŃSKI S., KOSIŃSKI Z., KUJAWA-PAWLACZYK J. Natural valorization as well as protection conception of the Uroczysko Warta Forest in the Jarocin Forest Division. Studio of Nature Protection – Club Naturalist. Świebodzin, **2002** [Typescript in Polish].
23. KOWALCZAK P., TERLECKI P., HAŃSKI A. Study – expert's report: optimum solution of water retention in oxbow lakes of the Uroczysko Warta on the Czeszewskie Forest area. Institute of Meteorology and Water Management, Dep. Poznań, **2006** [Typescript in Polish].
24. JAROCIN STATE FOREST DIVISION – Uroczysko Warta Forest. Study, editing by K. Schwartz, **2009** [Typescript in Polish].
25. BEDNORZ J., KUPCZYK M., KUŹNIAK S., WINIECKI A. Birds of the Wielkopolska. Fauna's monograph. Bogucki Scientific Publisher, Poznan, **2000** [In Polish].
26. PUŹNIAK J. Geological research project for planning of local surface water and groundwater monitoring for constructed surface water storage system on the oxbow lakes of the Uroczysko Warta in the area of Lasy Czeszewskie. Hydroconsult, Poznań, **2008** [Typescript in Polish].
27. MILER A. Water discharges of the Warta River in Poznan in 10-yearly period of the Jeziorsko Reservoir functioning against a background of water discharges in more than 150-yearly previous period. Scientific-Technical Conference: Exploitation and influence a large lowland reservoirs (on example of the Jeziorsko reservoir). Uniejów 20-21.05.1999, Publishing by Agricultural University, Poznan, **1999** [In Polish].
28. ZIELIŃSKI W., NIEMCZYŃSKI D. Geological report of ground and surface water local monitoring for existing retention system of surface water in oxbow lakes of the Uroczysko Warta on the Czeszewskie Forest area. GeKo, geology, consulting – Wrocław, **2008** [Typescript in Polish].