

## Chapter I

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### **Influence of morphogenesis and connecting with a river on a rate of oxbow lake evolution in young glacial river valleys**

#### INTRODUCTION

The oxbow lakes are water reservoirs being a sub-type of river lakes that are morphogenetically associated with the main river channel (CHOIŃSKI 1988). They are usually distinguished by semi-circle shape resulting from complex hydrodynamic processes (erosion-accumulation) in a river bed, that lead to bends and meanders formation. Against common opinion on boring semi-circle shapes and similarity of morphometric and biocenotic features, these reservoirs are characterized by extremely abundant diversity of shapes, dimensions, and hence reactions towards hydrological processes (CONSTANTINE, DUNNE 2008; HEIN et al. 2004; WEIHAUPT 1989).

The oxbow lakes, spreading on both sides of river beds, enrich the hydrographic and biocenotic structure of a valley (OBOLEWSKI et al. 2009; PENCZAK et al. 2005; VAN DEN BRINK et al. 1993) by accompanying numerous natural or anthropogenically transformed water ecosystems. Their value results from a wide spectrum of ecological benefits, including the help in water purification processes, flood control, habitat features for freshwater biocenoses, and landscape virtues (CABEZAS et al. 2009; MITSCH, GOSSELINK 2000).

The specificity of the origin, morphometry, and hydrodynamics of oxbow lakes indicate that they should be considered as a type of aqueous ecosystems differing from postglacial lakes that are common in young-glacial landscape. At comparisons of oxbow lakes with postglacial ones, following attributes resulting from below features should be taken into account:

- **genesis.** The oxbow lake's genesis is associated with a slow meander migration down the river valley and enhancing of its curvature till both arms connection and cutting off the river. Davis (1903) and Tower (1904) were the first who documented and described in details the oxbow lake genesis. The effect of a screw-type water flow due to the presence of any obstacle (e.g. a rock resistant to washing out) is the main reason for river bed bending and free meanders formation. Then, one of the river-side (concave) gets eroded, and materials accumulate on the other side (convex) that is situated down the river course. An oblong sandbar is formed at convex embankment that makes the waters are directed to opposite (concave) one

and its erosion. Movement of the river bed slantwise forward is due to the resultant of a force directed in accordance to the river flow direction and a force directed according to transverse currents acting within a bed. That process lasts until the meander neck is broken, effect of which is shortening the river course, i.e. “renewal” and its slope increase. During the stage of meander's cutting off of the main river-bed, its bottom arm remains connected with the main bed for a longer time. Closing the bottom arm with alluvial material is the beginning of oxbow lake separated from from the river. A gradual filling the reservoir with mineral and organic material occurs, and subsequently the oxbow lake becomes a land habitat (VAN DER VALK 1981).

Due to massive hydrotechnical practices, e.g. straightening out the river-beds, semi-circle hollows are present at the place of former meanders. Such formed river lakes are an important element of river valley landscape, also in Poland. In the case of young rivers, their number is usually greater than that of natural reservoirs (river Drwęca valley below Drwęckie lake – Photo 1).

- **distribution.** The oxbow lakes can be found in regions with sufficient humidity ensuring formation of river network (i.e. from 200-250 mm in moderate climate to 750-1000 mm in warm climate). They are distributed in band-like pattern along with meandering river-beds, though they are most numerous in South America, where that genetic type of lakes dominates. Melack (1984) reported that there are 8 000 oxbow lakes (i.e. more than total number of lakes in Poland) in Amazon river valley (Solimoes), 2 300 in Orinoco river valley in Venezuela, and at least 1 500 in river Sepik-Ramu valley in Papua New Guinea (VYVERNAM 1994). Under moderate climate conditions, oxbow lakes are less numerous objects as compared to postglacial lakes (LEWIS et al. 2000). In Poland, their share in total lakes number (>1ha) is estimated for about 8% (KONDRACKI 1988). When considering oxbow lakes with surface area from 0.25 to 1 ha, the percentage is much higher. Oxbow lakes are most abundantly met along middle fragments of main Polish rivers. According to Michalczyk et al. (2002), there are 708 oxbow lakes (at least of 0.25 ha area) in river Bug valley. In valleys of major rivers (Vistula, Warta, Oder), oxbow lakes bear their regional names such as: *buzysko*, *warcisko*, *wiślisko*, or *odrzysko*, etc.

- **forms.** Shape and bathymetric traits of oxbow lakes are the most important elements that distinguish them from another genesis lakes. Morphometric parameters of oxbow lakes apparently underline their potamic origin (Photo 2). The morphometric arrangement usually makes a single, apparently-shaped bend, although older forms have complex structure reflecting the dynamics of fluvial processes.



Photo 1. Fragment of the Drwęca river bed beneath Drwęckie lake straightened in 30s of the 20th century with visible cut off meanders (photo by K. Glińska-Lewczuk)

The oxbow lakes are characterized by small width as compared to their length. The bed width and amplitude of a former meander (present oxbow lake) is a resultant of the flow rate intensity, dependence of which is described with exponential function by Leopold and Wolman (1957); see Table 1.

Table 1  
Empirical dependencies between meander dimensions in alluvial river valleys according to Leopold and Wolman (1957)

Length of meander in relation to river-bed width	Amplitude in relation to river-bed width	Length of meander in relation to curvature radius
$\lambda = 6.6 w^{0.99}$	$A = 2.7w^{1.1}$	$\lambda = 4.7 r_m^{0.98}$

Unlike other lake types, oxbow lakes usually have no isles, steps, nor bays. These reservoirs have usually smooth bottom with deeper sites at the place of former depressions. Mean depths are associated with morphometric and hydraulic

conditions of a river. The oxbow lake's bottom is made of sediments with a structure corresponding to conditions the river worked at the moment of cutting off the main stream. The bottom is covered with organic matter layer, the thickness, level and rate of mineralization of which depends on hydrodynamic conditions in a reservoir. The quicker time of a horizontal water exchange, the slower sediment increase, namely organic ones, and moderate and coarse-grain material dominates.



Photo 2. Example of naturally formed oxbow lakes and river wetlands in the middle Drwęca river above the town of Brodnica (photo by K. Glińska-Lewczuk)

• **catchment supply.** Dependence of river's hydrologic regimes is a unique for oxbow lakes as compared to other genetic types of lakes. Hydrological processes are the key in controlling the productivity and development of these ecosystems. Amounts, manners, and ways of supply determine the changes of chemical forms of particular components and the way of their internal circulation mainly due to exchange at the boundary of aquatic environment and bottom sediments, bio-sorption, as well as supply of components from a catchment. The alimentation area of oxbow lakes, as similar as other fluvial wetlands, is characterized by complex supplying system, from which water can penetrate to an oxbow lake through many ways: from out of a valley - due to intra-cover and surface wash-out, runoff from below the slopes, and resulting from washing out with alluvial and river waters (BORNETTE et al. 1998).

The period of water refreshment by periodical spates, is important in hydrology of river lakes. Moreover, as compared to other natural lake types, they differ with high water level amplitudes met also in dam reservoirs. Oxbow lakes, that are rarely flooded or flooded by well-filtered waters, may have relatively longer life-time than those frequently flooded (BORNETTE et al. 1994; PIÉGAY et al. 2001). Oxbow lakes

have usually no surface supply; however, objects that were formed due to hydrotechnical works often function as matter receivers from drainage systems (Photo 1, GLIŃSKA-LEWCZUK 2005).

• **contamination loads.** River lakes, both those with natural and anthropogenic genesis, being at advanced evolution stage, are seen as important bio-geochemical barriers in a landscape (GLIŃSKA-LEWCZUK 2005; VAN DEN BRINK, VAN DER VELDE 1994). Their ability to retain nutrient loads in oxbow lake water varies in time and results from a great diversity of ways, manners, and sources of their supplying (GLIŃSKA-LEWCZUK 2005, 2009). Comparing to other genetic types of lakes, oxbow lakes are characterized by larger loads of lithosphere-origin chemicals and nutrients. It is in part associated with small dimensions of the basin as compared to the catchment area, as well as relatively long shore-line contact with a land, from where chemicals are washed out to the oxbow lake's aqueous environment.

Increasing interests in ecology of riverside ecosystems led to the development of method and theories that found their application in almost all climatic zones and hydrological regimes. Resulting from applying new theories, e.g. *flood pulse concept* (JUNK et al. 1989), *flow pulse concept*, (TOCKNER et al. 2000), *river continuum concept* (WARD et al. 2001), recent years brought considerable change in perception of a relation between river and river-dependent aqueous ecosystems. Unlike riverside ecosystems localized in wide valleys of tropical zone, that are characterized by a simple hydrological regime and apparent differences of physicochemical parameters of water during floods and low water levels, oxbow lakes in moderate climate with complex hydrological regime, are of less predictable character. Dynamics of water physicochemical properties in oxbow lakes of moderate climate undergoes the natural processes, despite of frequently dramatic man's intrusion into the water circulation.

The present research aimed at identifying factors that shape the oxbow lake evolution rate in young-glacial river valleys in northern Poland. Assuming that oxbow lakes are the centers where chemicals migrating through a valley, are accumulated, made efforts to search such features that might be used in ecological models being at present a basis for any environmental analysis. A set of earlier study results upon these biotopes related to the associations between abiotic habitat factors vs. their biocenoses character, was a background for discussed issues.

Surface morphometric traits of 112 oxbow lakes localized within three young-glacial river valleys (Fig. 1), including river Łyna (60), Drwęca (31), and Ślupia (21), were characterized on a base of topographic maps 1:10 000 along with aerial pictures PHARE 1:26 000. Based on morphometric measurements of objects made in accordance to methodology described by Glińska-Lewczuk et al. (2004), the bathygraphic plans of 23 reservoirs considered as representative for young-glacial valleys, were made. The selection of study object resulted from the following premises:

1. Oxbow lakes represent typical for Middle-European Lowland, bend lakes with continuously or temporarily constant water level, formed near meandering river-beds, the genesis of which is associated with Vistulian glaciation at its Poznań and Pomeranian phases;

2. Water reservoirs are a fragment of former river bend or meander formed both due to natural erosion-accumulation processes and hydrotechnical practices consisting in river-bed straightening;
3. These reservoirs are not separated from the active river-bed with barriers in a form of anti-flood embankments;
4. Oxbow lakes function in river valleys with complex hydrological regime, for which the multi-year runoff non-uniformity coefficient ( $c_v$ ) is 0.35-0.45;
5. Analysis takes into account the reservoirs localized along river-beds with similar flow rates  $Q_{avr}$  amounting to about 10-20 m<sup>3</sup>/s.

The reservoirs were selected due to their genetic, geomorphologic, and hydrologic similarity. Geometric characterization of meanders, such as wave length, amplitude, and size is similar to their oxbow lakes, which indicates in geological meaning, that oxbow lakes are relatively young. Furthermore, for comparing purposes, results from planimetrics measurements of oxbow lakes situated in old-glacial river valleys, were also used. Analyzed objects were divided into three groups according to hydrodynamic typology (GLIŃSKA-LEWCZUK 2009) based on a criterion of oxbow lake with river connection way: open (lotic), semi-open (semi-lotic), and closed (lentic). Hydrological data (characteristic water levels and 2nd-order flow rates) used in the present survey originate from Hydrological Annals IMGW 1951-1970.

## **OUTLINE OF YOUNG-GLACIAL RIVER NETWORK EVOLUTION VS. OXBOW LAKES PRESENCE IN THE LANDSCAPE OF NORTHERN POLAND**

Current sculpture of young-glacial areas in northern Poland is a consequence of the environmental changes rhythm resulting from glacial-interglacial cycle occurrence, i.e. climatic changes that appeared within hundreds thousands years, namely during the youngest Pleistocene stage – Vistulian glaciation. The changes exerted the influence on a present shape of river valleys, namely during Leszno phase determining the maximum of Vistulian glaciation range in western Poland (about 20 000 years BP) and Poznań phase (about 18 800 years BP), that delimits the maximum range of an ice sheet head along the line from river Vistula valley, Dobrzyńskie Lakes, through Masuria (BŁASZKIEWICZ 1998; DROZDOWSKI, BERGLUND 1976).

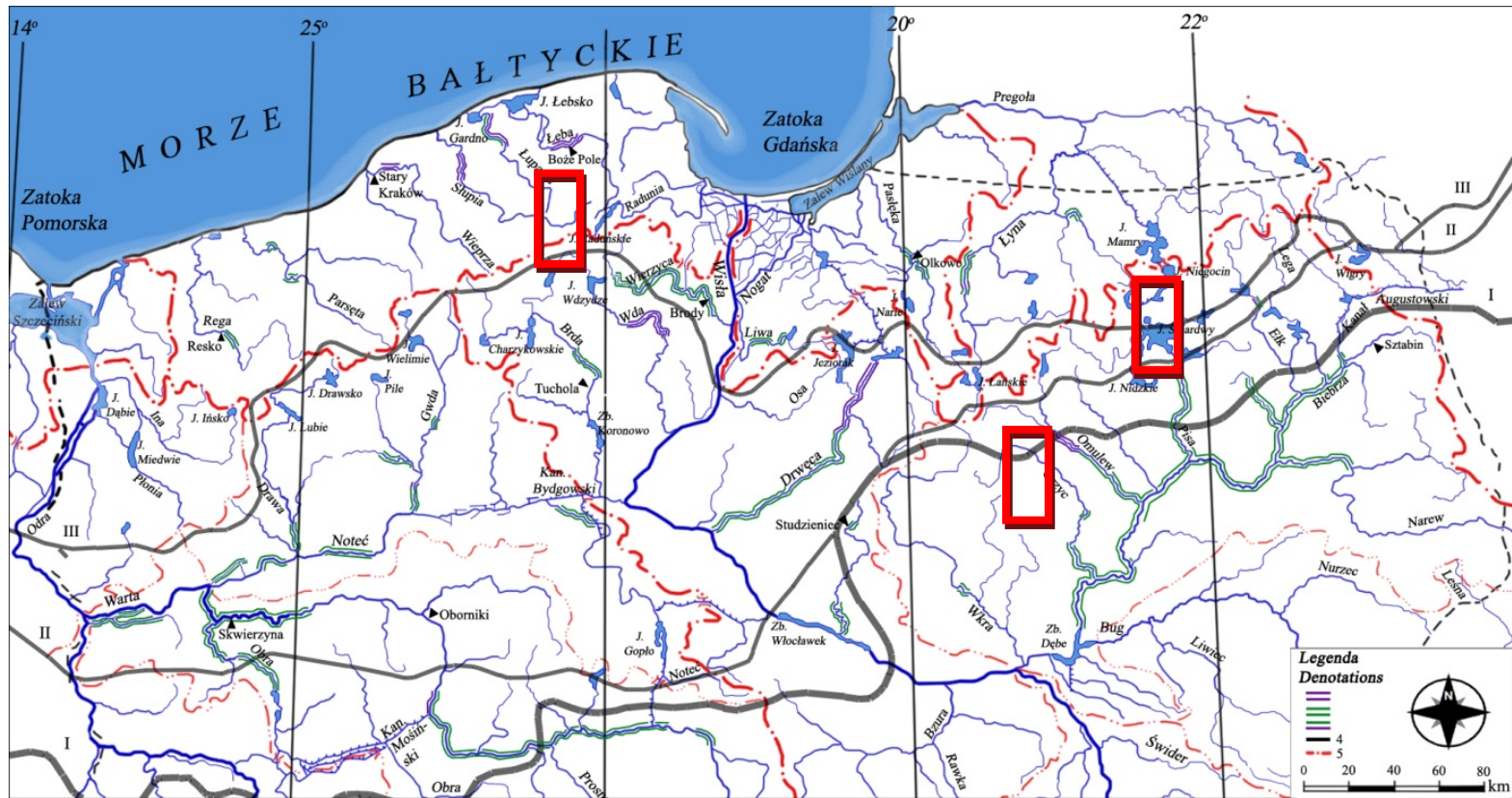


Fig. 1. Location of floodplain lakes of natural and anthropogenic origin, along main River courses of N Poland on the background of the reaches of the last glaciation (Vistulian) phases. Denotations: 1 – floodplain lakes being a result of hydrotechnical works; 2 – floodplain lakes of natural origin, only; 3 – river sections with floodplain lakes of both origins; 4 – the reach of glaciation phases: I – Leszczyńska phase, II – Poznańska phase, III – Pomeranian phase. Red rectangulars show the study sites.

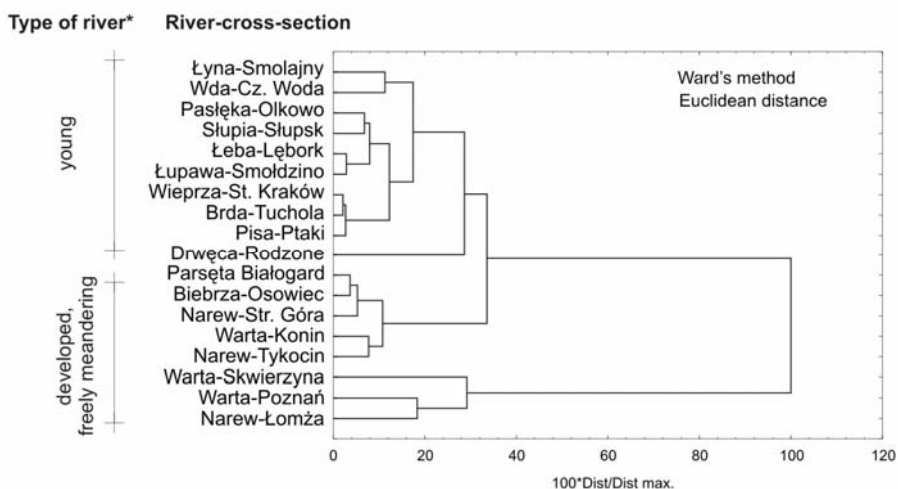


Fig. 2. Similarity of chosen postglacial Polish rivers in terms of channel morphometry and floodplain lakes morphometry parameters versus hydrological data. The groups were distinguished based on the Ward's method using Euclidean distances. \*Type of a river channel according to FALKOWSKI (1971).

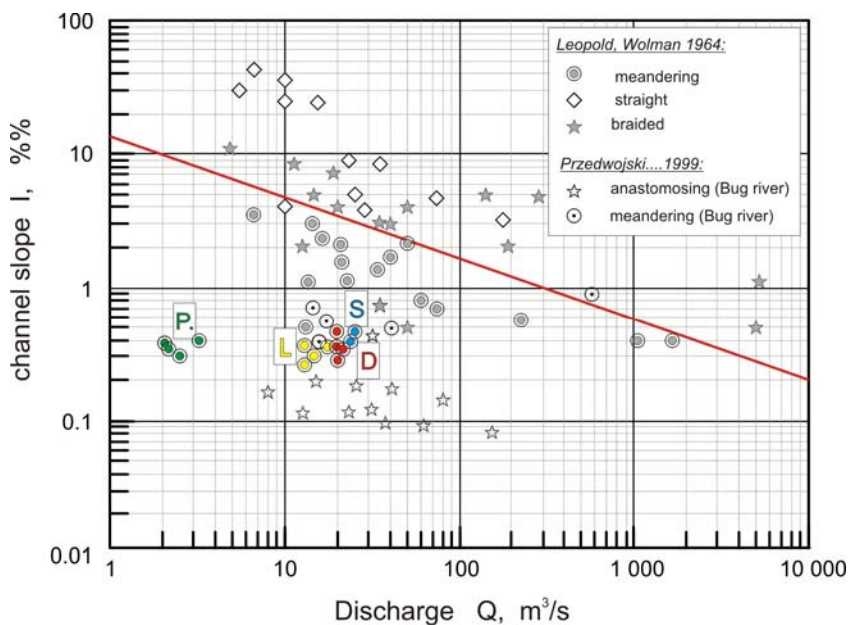


Fig. 3. Types of channel patterns on the background of channel slope and discharge (modified after LEOPOLD, WOLMAN 1957 and PRZEDWOJSKI 1999). The letters: P, S, D, L indicate meandering sections of Pasłęka, Słupia, Drwęca, Łyna rivers, respectively



During the gradual ice sheet disappearance, two important positions of its head appeared – Pomeranian phase (about 16 200 years BP) and Gardzieńska phase (14 500 years BP), though the former was limited with the river lobes on Pomerania (e.g. Oder lobe) and Masuria (e.g. Łyna lobe).

Transgressions and regressions of a last ice-sheet that covered about 30% of Polish territory brought significant changes in river network organization. On lowlands at the beginning of the late Vistulian (the oldest dryas), rivers had tendency to built-up the valley bottoms, which was invoked by difficulties in an infiltration due to existing permafrost in subsoil and the lack of blocking the runoff by insufficiently developed plants (KOZARSKI 1983). Rivers formed channel beds that “wandered” across carried sediments, in abundantly transported material. When warming up came during inter-stadial glaciation, the plant development reduced the denudation and runoff rates. Therefore, it made better organization of river network and utilization of energy from flowing rivers to cut off the deposited cover at valley bottoms. Mentioned author supposed that majority of rivers in late glacial changed the bed development from straight to meander type. Traces in a form of paleo-meanders (the older the closer valley bottom edge are localized), are of the longest curvature radius and larger flow rate. A meander in river Proсна floodplain from late glaciation can be counted as the oldest identified object of that type (KOZARSKI 1983). Decreasing, although not uniform trend in river flow rate change, has been observed since late Vistulian till present. That is expressed with forming smaller and smaller paleo-meanders or up-to-date active oxbow lakes. The meander beds with large radii of curvature were the effects of a free bed development, decreased bottom transport, and slight slopes, which was proven by detailed research, including upon river Warta valley near Śrem (KOZARSKI 1983) and Tworzykowo (BORZYSZKOWSKI 1971).

Along with the Vistulian ending, warming period (Holocene) came, when forest communities were completely developed, water circulation slowed down, and geochemical processes associated with a mankind appearance became more important. Development of river network in Holocene made that up-to-date endorheic regions got incorporated into the surface runoff system (FALKOWSKI 1971; KOUTANIEMI, RACHOCKI 1981). According to these Authors, it was possible due to connecting the lake gutters with valley fragments. Hence, young-glacial valleys are at present polygenetic and the sculpture of the following sections of a given valley is often extremely distinct.

Since the recession of the last ice-sheet, young-glacial rivers reached the level of almost contemporary bottom and lateral river-bed development processes prevailed in the Holocene evolution. Spatial diverse of that evolution resulted from different types of river-bed development. According to FALKOWSKI (1971), the river-bed development type, river's reaction towards climatic changes, and plant cover depends on the river and its valley type. His theory is based on a division of rivers into three types differing in their reaction to climate changes at the turn of Pleistocene and Holocene: (i) young river type, (ii) free river type, and (iii) restricted river type.

The young-glacial rivers in northern Poland are of young character. They are characterized by insufficiently formed valleys (usually one level of accumulation

terrace and one erosion-accumulation level). Most of these rivers valleys are polygenetic and flow alternately through melting troughs, post-glacial gutters, and flat valley wide areas, changing their character from the gorge, turbulent, with fast stream into calm and slow. The diagram illustrating the similarity of morphometric features of rivers and accompanying oxbow lakes apparently indicates two river groups: young vs. free ones (Fig. 2).

The river-bed development type is determined by its susceptibility to erosion depending on water flow rate, alluvia type, and plant coverage (CITTERIO, PIEGAY 2000). Therefore, the young-glacial rivers are of twisting or meandering character usually within fragments of flat valley areas where short plants (meadows, pastures) favor the lateral erosion. These river-bed sections, with slopes between 0.3 and 0.6 ‰, favor meandering and oxbow lakes forming under conditions of young-glacial landscape (Fig. 3). However, to cut off the meander neck, the main river-bed should migrate due to intensified lateral erosion. Lower rates of flowing water reduce the erosion rate and tendency to cut off the meander neck.

Holocene history of river valleys development in Poland and changes within the hydrographic network is associated not only with climatic and geologic factors, but also man's economic activity. The former is significant in transforming the river valley environment, including young-glacial ones. Long intrusion of a man, mainly due to massive de-forestation since Neolithic Age and rainfall increase, led to a considerable revival of erosion processes. Massive regulation of twisted rivers performed since the second half of 19th century caused that majority of river-beds got indented into the valley bottoms due to larger slopes, and moreover the number of artificially cut off meanders significantly increased. However, at present they are important element of a river valley landscape and their ecological value matches up to natural ecosystems, hence they are considered as valuable aqueous ecosystems and ranked on NATURA 2000 listed encoded with 3150. Regions of river valleys with natural oxbow lakes formed with no man intervention are few in a young-glacial landscape.

## **MORPHOMETRIC ANALYSIS OF OXBOW LAKES IN YOUNG-GLACIAL RIVER VALLEYS OF NORTHERN POLAND**

Oxbow lakes selected for study are localized in middle sections of young-glacial river valleys. Integral part of each consists of diverse and rich hydrographic system that is formed by numerous natural or artificial elements such as concave and convex embankments, oxbow lakes, near-shore sandbanks, flood and over-flood terraces, as well as drainage ditches. The common feature of these ecosystems is a strong dependence on river's activity.

Appearing the meandering river-beds and forming the oxbow lakes result from hydrological processes with particular parameters. Fluctuations of water level with amplitude about 2 m and different time of the floodplain inundations are attributes of meandering rivers on studied area (Table 2).

Table 2

Chosen characteristics of the studied rivers (Łyna, Drwęca and Słupia) along their meandering sections

Parameter	Unit	River – gauge		
		Łyna Smolajny	Drwęca Rodzone	Słupia Słupsk
River length (from outlet)	km	172.0	126.7	31.6
Catchment area	km <sup>2</sup>	2 290	2 725	1 450
Mean annual discharge	m <sup>3</sup> /s	14.7	11.2	15.0
Flood water of probability 10% HQ <sub>10%</sub>	m <sup>3</sup> /s	50.5	46.1	49.0
Low water of probability 10% LQ <sub>10%</sub>	m <sup>3</sup> /s	4.49	4.5	6.02
Mean annual low discharge SNQ	m <sup>3</sup> /s	6.45	6.3	7.45
Variability coefficient <i>cv</i>	-	0.439	0.442	0.450
Water level amplitude	cm	207	191	171
Average channel slope	m/km	0.32	0.30	0.18
Average floodplain width	m	372	618	315
River channel sinuosity	After straightening	1.36	1.66	1.21
	Before straightening	1.82	2.40	2.13
Average number of oxbows per 1 km of the floodplain length	number/1 km	3	10	4

Surveyed oxbow lakes are characterized by simple structure composed of a single arch with characteristic horseshoe-like shape (Fig. 4). All reservoirs have constantly or almost constantly remained water surface. Studied oxbow lakes are reservoirs with diverse morphometric conditions. Their lengths are from 61 to 1229 m with domination of 400-600 m, which makes up 52 % of all objects. General shape of oxbow lakes is determined by a single well-developed bend of *S*-curvature about 4.3, although there are also both reservoirs almost parallel to a river-bed (*S* = 1.1), and those with strongly varied shapes (*S* = 13.2). The most diverse shape is represented by the youngest oxbow lakes that were formed due to river regulation. Water surface areas of surveyed reservoirs – at mean water levels – amounted from 0.12 to 2.64 ha, while their capacities from 0.64 up to 25.30 thousand cubic m. Morphometric parameters of the oxbow lake troughs vary through the year, but those changes are individual for each reservoir. Steep and tall embankments make changes of water surface more difficult. Resulting from the water surface area oscillations, the water capacity differences in an oxbow lake may be almost 4-fold, whereas those of the surface only 1.9-fold.

Length and geometry of upper connection may also indicate the sedimentation rate within an oxbow lake. Longer connections of the upper arm are associated with

larger impact of reciprocal currents and faster sediment deposition (PIÉGAY et al. 2001). The angle between connection and the axis of a main river-bed also significantly affects the rate of material deposition; e.g. former beds of river channels are more parallel to the main river axis than typical cut off bends of meanders, thus they are better washed through with river water. Therefore, cut off river meanders have potentially longer lifetime than cut off channels of brook rivers, because they are more isolated from a river-bed. Relatively longer, afforested alluvial closing of oxbow lakes make the flood flow rate slower and reduce the efficiency of sediments wash out from an oxbow lake (PIÉGAY et al. 2001), whereas shorter, closings allow for flood waters to supply an oxbow lake and wash out the accumulated material (BORNETTE et al. 1994). Therefore, these closings may function as buffers between an oxbow lake and a river, being at the same time a trap for sediments before they get into the aquatic zone of a former river-bed fragment along with the flood waters.

The morphometric system of oxbow lakes in post-lake river valleys is usually determined by one apparently shaped bend, while older objects have complex structure reflecting the dynamics of fluvial processes (Fig. 5).

Older forms are made of many overlapping bends with sharp age differences. Despite of river meanders and oxbow lakes recall circle arches, FLOREK (1978); LEOPOLD, WOLMAN (1957) and WEIHAUPT (1989) underlined that they do not project typical curvatures of general geometric shapes. Nevertheless, some repeating schemes can be noted on a base of geologically old and young rivers analyses. Shapes of older oxbow lakes are complex and irregular, while these localized in young-glacial river valleys are usually straight and formed by a single apparent arch. The way of arrangement of complex forms, i.e. made of two or more connected bends, is governed by a rule: the nearer contemporary river-bed, the smaller arches of younger meanders.

Degree of connecting the floodplain lakes with a river plays a key role in their habitats shaping. The factor affects the evolution rate of every river reservoir regardless of the climatic zone it occurs (TOCKNER et al. 1999). French scientists Cloud Amoros and Gudrun Bornette developed the theory of hydrological connection influence on matter, energy, and biotic elements exchange on a base of surveys within rivers Rodan, Rein, and Danube catchments (AMOROS, ROUX 1988; AMOROS 2001; AMOROS, BORNETTE 2002; BORNETTE et al. 1998) and found the dependences between water quality, biotic elements of river lake environments vs. water surface dynamics in a valley. Their study results were confirmed by GLIŃSKA-LEWCZUK (2002, 2005, 2009), who reported that connecting with a river ensures the light and oxygen conditions that favor the biodiversity in aqueous ecosystems localized in post-glacial river valleys (Photo 3). In each of studied objects, at limited hydrological connection of an oxbow lake with a river or lack of such connection, the intra-reservoir (autochthonic) supplying system dominates, while outer delivery of organic matter and nutrients is present only during high floods (flooding the valley bottom) or probable supplying through drainage ditches.

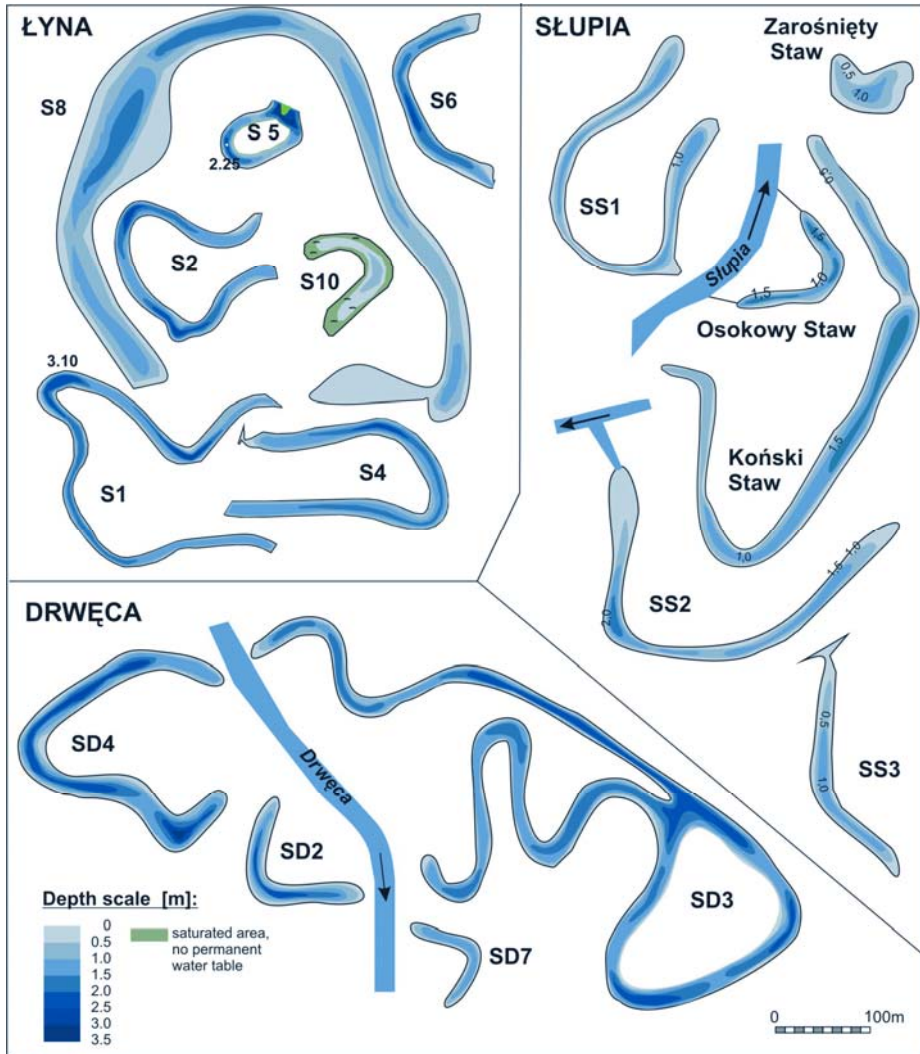


Fig. 4. Bathymetry plans of chosen floodplain lakes along the Drwęca, Łyna and Słupia rivers

Hydrological connection between oxbow lake and river is also one of the principle factors influencing on oxbow lake's evolution rate. Natural development of these ecosystems consisting in the change of aquatic environment into land one, should be attributed to filling their bowls with flood sediments and organic matter (PIÉGAY et al. 2001). Periodical river floods are general phenomenon, due to which the sediments are introduced into the oxbow lake. Therefore, the flood frequency and the quantity of a load carried by waters is a key for sedimentation rate. Both during and after cutting off, the bed gets gradually transformed from potamic to apotamic environment (Photo. 4). Subsequently, it is more and more out of contact with river water, which results from the lowering the erosion basis or river-bed migration

within a valley in opposite direction than a given oxbow lake (WARD, STANFORD 1995).

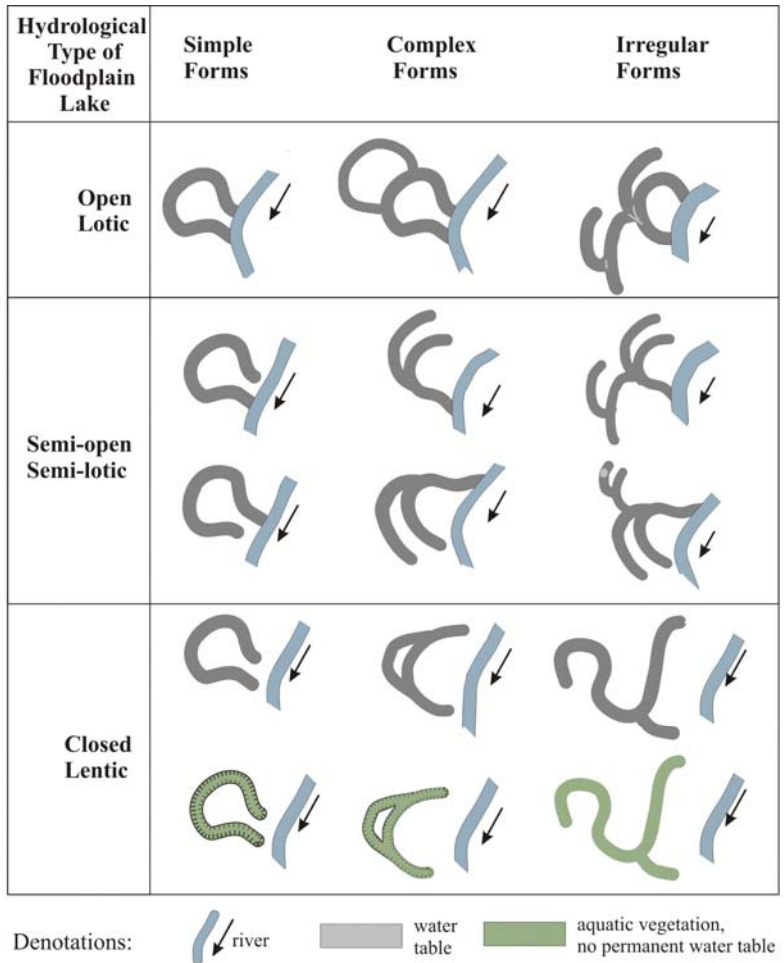


Fig. 5. Classification of floodplain lakes forms in relation to morphology and hydrological connectivity

Furthermore, development of the most distant water reservoirs is mainly under control of autogenic processes leading to a reservoir slow mudding and overgrowing (AMOROS 2001; WARD, STANFORD 1995; HEIN et al. 2004). However, it happens that river, when migrating within a valley, may restore earlier abandoned oxbow lake.



Photo 3. Examples of two nearby floodplain lakes differed by hydrological connectivity: upper photo – the view on hydrologically connected (open) Osokowy Staw (the Słupia River). Lower photo – a lentic habitat of Zarośnięty Staw (photos by K. Glińska-Lewczuk)



Photo 4. Examples of floodplain lakes at different stages of development. In the upper row semi-lotic lakes: S2 – Łyna and SS2 – Słupia; in the middle row – seasonally flooded lentic oxbows: Koński Staw – Słupia; S4 – Drwęca); in the lower row: lentic oxbows in the phase of overgrowing (S7 and S8 Łyna) (photos by K. Glińska-Lewczuk)

## SUMMARY

Features both of river and lake environments are characteristic for oxbow lake habitat. Reservoirs with similar genesis, but differing with water retention time, matter circulation ways, as well as the flora and fauna species composition functions altogether in a narrow band of a river valley (GLIŃSKA-LEWCZUK 2005, 2009). Hydrodynamic processes and the reservoir morphology are factors that shape quality of aqueous environment and are important for plant and animal species survival in oxbow lakes. They affect the evolution rate and determine the phytocenoses



development both within a reservoir, and a littoral. Morphometric differentiation, hydrological and biocenotic conditions in river lakes are very complex, which makes every object is characterized by its individual set of aqueous environment features and evolution pattern (CITTERIO, PIÉGAY 2000). Up-to-date observations (and studies in another climate zones) revealed that they are one of the fastest evolving among all other water reservoir types; they are the most geologically transient forms in a landscape, the age of which is at most hundred or tens of years. The highest rate of oxbow lake disappearance was observed in the case of artificially cut off lakes due to practices straightening the river-bed representing by rivers Łyna, Drwęca, and Śłupia, although the age of a given reservoir reflects its succession stage and is an important clue at determining the expectations from the reservoir's functions.

Shape of oxbow lakes is important for their functioning. The comparative analysis of river-bed morphology, oxbow lake shape, curvatures due to erosion-accumulation processes, in a view of hydrological and bio-geochemical studies within a single river valley, makes an opportunity to work out a procedure, on a base of which it would be possible to reconstruct the hydrographic network changed due to regulations (WARD et al. 2001). Monitoring the hydrological changes of aqueous ecosystems and chronology of river valley development, restoring former objects, land depressions, spots with elevated erosion activity, bottom level, and river-bed slopes, would explain the ecological systems of valley plants for purposes of planning and designing the reclamation practices.

## ACKNOWLEDGEMENTS

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