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TEMPORAL VARIATIONS OF SUSPENDED SEDIMENT CONCENTRATION DURING PERIOD OF HIGH WATER STAGES IN THE LOWER COURSE OF THE OBRA RIVER (WESTERN POLAND)

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Keywords: Sediment concentration, hysteretic effect, the Obra River.

Abstract: Research concerning temporal variations of suspended sediment concentration during period of high water stages was done in the lower course of the Obra River near Międzyrzecz (Western Poland). The analysis regarding dependence of mean suspended sediment concentration and discharge allowed to determine the way of suspended sediment supply to the river bed during high water stages. It was supposed that exposures of glacial and fluvioglacial sediments in high concave banks could be an important factor influencing the amount of delivery of suspended material. Besides, normal hysteretic loops (oriented clockwise) were observed in cross-sections 4 and 5. That fact would suggest that transported material originates form the Obra River bed or its vicinity. The process of sediment accretion was observed on a fragment of drowned floodplain during high water stages. Collection of samples of freshly deposited sediment and grain size analysis allowed to illustrate the mechanism of forming floodplain sediments. It also was possible to draw near conditions of forming such sediments in the past.

INTRODUCTION

Considerable amount of sediment load is transported outside river basin area as suspended load. There are many factors, which influence the intensity of suspended sediment transport (meteorological factors, sediments present in a river basin, feature of hydrological regime). Both the effects and interactions between those factors cause sudden and irregular variations of suspended sediment concentration, which are very difficult to measure. These changes can be very swift especially during floods when suspended sediment concentration can increase rapidly [1]. The analysis of dependence between suspended sediment concentration and discharge provides particularly useful information concerning variations of sediment transport intensity. Besides, such dependence provides information about processes of erosion and transport in a river basin. Special attention is paid to hysteretic effect. In such case, the dependence "sediment concentration-discharge" takes the shape of a loop. Occurrence of hysteretic effect is joined with delivery and/or exhaustion of material, which is available to transport in a river bed [15]. Such reliance was investigated by many researchers with reference to postglacial [20] and mountain areas [8, 14, 15, 24, 30].

Hysteretic loops may be clockwise when material originates form the river bed or counterclockwise when material originates form more distant sources of supply. Besides, Seeger *et al.* [32] observed eight-shaped hysteretic loops. Such phenomenon was caused by a number of floods, which were following each other after long dry period, and was the effect of a sequence of clockwise and counter-clockwise partial floods [32]. It should be noted that this research referred to river basins of Mediterranean climate.

Research problem concerning temporal variations of intensity of suspended load transport during period of high water stages was investigated in the case of the lower course of the Obra River. The choice of research area was not accidental. The Obra is the biggest river in the area between the Warta River and the Odra River, which flows through the middle and western part of Wielkopolska lowland. Since the beginning of the 19th century, the Obra River bed has been subjected to intensive transformation. The following hydro technical works were done here:

- construction of channel systems in the upper course of the Obra River (within Warsaw-Berlin proglacial stream valley; Fig. 1, section 1);
- hydrotechnical works regarding to meander bends cutoffs (Fig. 1, section 3);
- construction of water dam near Bledzew village (Fig. 1, section 3).

Topographic maps edited in 1895 and 1934 illustrate such modifications [29].

Another important feature of the Obra River hydrological regime is existence of several lakes, which smooth amplitude of water stages, discharges and floods [3, 7, 9,]. The research work, whose results are presented here, was done in the lower course of the Obra River, 3.5 km north-west of Międzyrzecz (Western Poland) where hydrotechnical works were limited and had little influence on the river bed geometry.

Main research problem was to determine temporal variations of intensity of suspended load transport during period of high water stages. The following research tasks were done:

1. Analysis of variability of mean suspended sediment concentration in cross-sections of the river bed. Field data allowed to illustrate such variations during high water stages.
2. Characteristics of dependence between mean suspended sediment concentration and discharge. Particular attention was paid to hysteretic effect which occurred during high water stages in March 2002. On the basis of obtained results it was an attempt was made to initially determine sources of sediment supply to the river bed.
3. Analysis of flood sediment granulation, which was deposited on floodplain during high water stages period. Such study allowed to demonstrate the mechanism of accumulation processes, which influence vertical accretion of sediments on floodplain.

GEOGRAPHIC LOCATION OF THE OBRA RIVER VALLEY

Sources of the Obra River are situated at 145 m a.s.l. about 2.5 km from Obra Stara village, south of Jarocin. In its upper course, the Obra River flows trough Żerkow – Rydzyna proglacial stream valley [5, 22]. Between Wieszków and Kościan, and within Warsaw – Berlin proglacial stream valley (Fig. 1; section 1) the Obra River is seized in a system of channels.

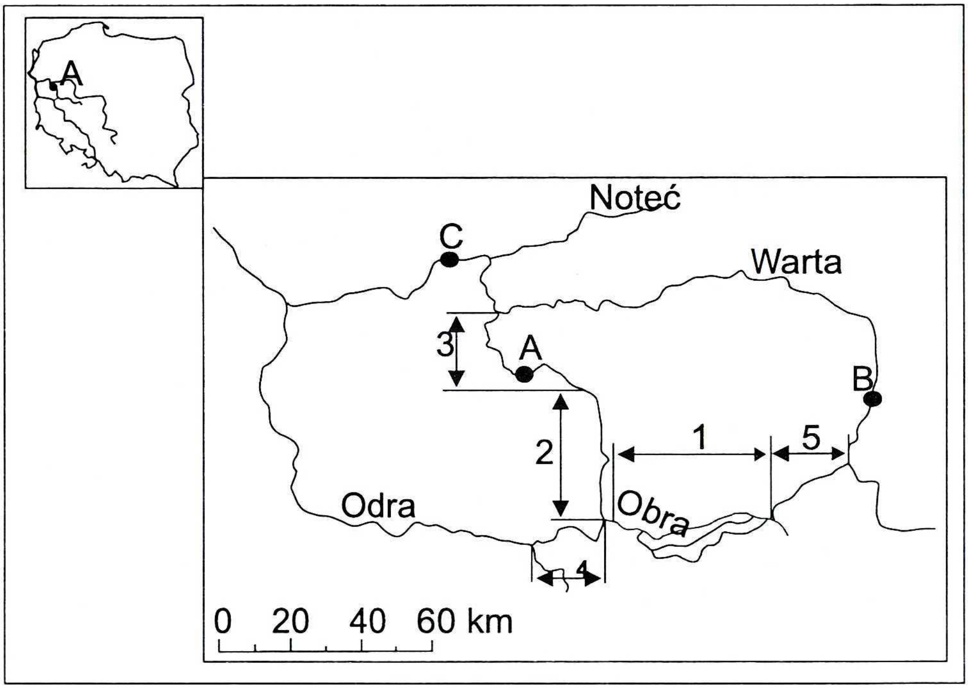

Fig. 1. The Obra River in its middle and lower course (Kościan – Skwierzyna); particular sections were distinguished according to Tomaszewski [36]: 1 – section Kościan – Kargowa (Warsaw – Berlin Pradolina), 2 – section Kargowa – Policko, 3 – section Policko – Skwierzyna, 4 – bifurcation of the Obra River (outlet to Odra near Cigacice), 5 – outlet to Warta (Mosiński channel). A – Międzyrzecz, B – Poznań, C – Zbąszyń

Within Warsaw-Berlin proglacial stream valley the Obra River is divided into three channels: North, Middle and South. Artificial outlet to the Warta River (Mosina channel) is situated near Mosina village (Fig. 1; section 5). Natural outlets are located within Warsaw – Berlin proglacial stream valley near Cigacice village (to the Odra River; Fig. 1; section 4) and near Skwierzyna village (to the Warta River). In the following section the Obra River turns north and flows through Nowotomyski outwash plain (Fig. 1; section 2). There are many lakes (Chobienickie, Grójeckie, Nowowiejskie, Zbąszyńskie, Lutol, Młyńskie and Wielkie lake) situated in the course of the river, within this section of the valley. In the following section, between Rybojady and Policko villages, the pattern of the Obra River bed is close to rectilinear. This is the effect of hydro technical works in the past. The process of artificial straightening of the river bed is presented on topographic maps from 1895 and 1934 [29].

RESEARCH AREA

Research concerning temporal variations of suspended sediment concentration was done in the lower course of the Obra River which is situated within the Depression of Obra (Fig. 1; section 3). This is a concave form of landscape spreading from north-west to south-east, which originates from pre-Pleistocene depression shaped before last glaciation's period [21]. The Depression of Obra consists of three stagnant water basins which are filled with clays, silts and very fine sands [4]. Detailed research regarding geology, geomorphology and surface waters of this area is presented in the publication edited by M. Żurawski [10].

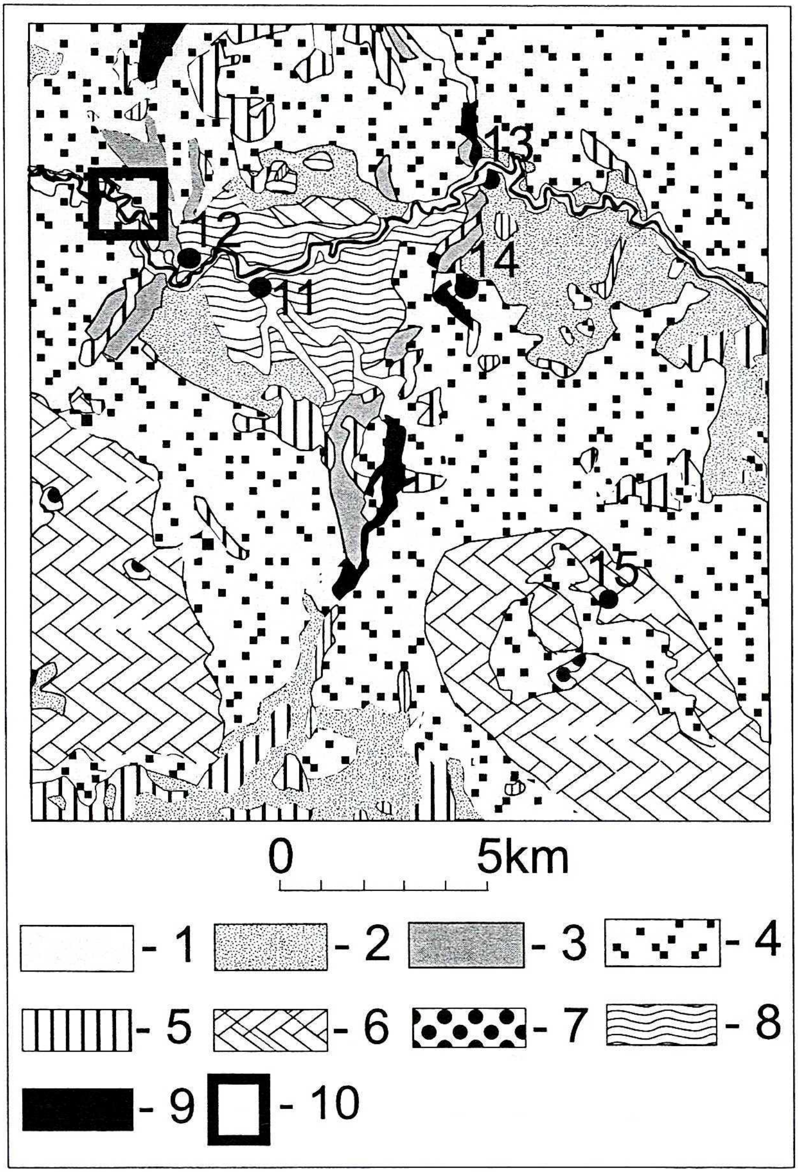

Fig. 2. Surface sediments geologic map; localization Świebodzin [27, 37]: 1 – river sands, silts and gravels (Holocene), 2 – river sands, silts and gravels (Północnopolskie glacial period, Pomeranian phase), 3 – sands and gravels in eskers, 4 – fluvioglacial sands and gravels (Północnopolskie glacial period, Poznańsko-Dobrzyńska phase), 5 – peats (Holocene), 6 – basal till or its residuum, 7 – sands, gravel and boulders of terminal moraines, 8 – lacustrine silts, sands and loams, 9 – rivers and lakes, 10 – detailed research area. Main towns and villages: 11 – Międzyrzecz, 12 – Św. Wojciech, 13 – Żółwin, 14 – Bobowicko, 15 – Bukowiec

Detailed research was done in 1 km long and 70–150 m wide section of the Obra River valley which is situated about 3 km from Międzyrzecz near Św. Wojciech village (Fig. 2 and 3). The river formed here distinct meander bends (Fig. 3). The valley is deep and narrow here – concave banks are steep and high (7–10 m above the valley floor). The Obra River shaped its valley in glacial sediments: glacial till and fluvioglacial fine sands, which can be seen in a few exposures within high river banks. Glacial till is also positioned beneath alluvial sediments of the Obra River valley.

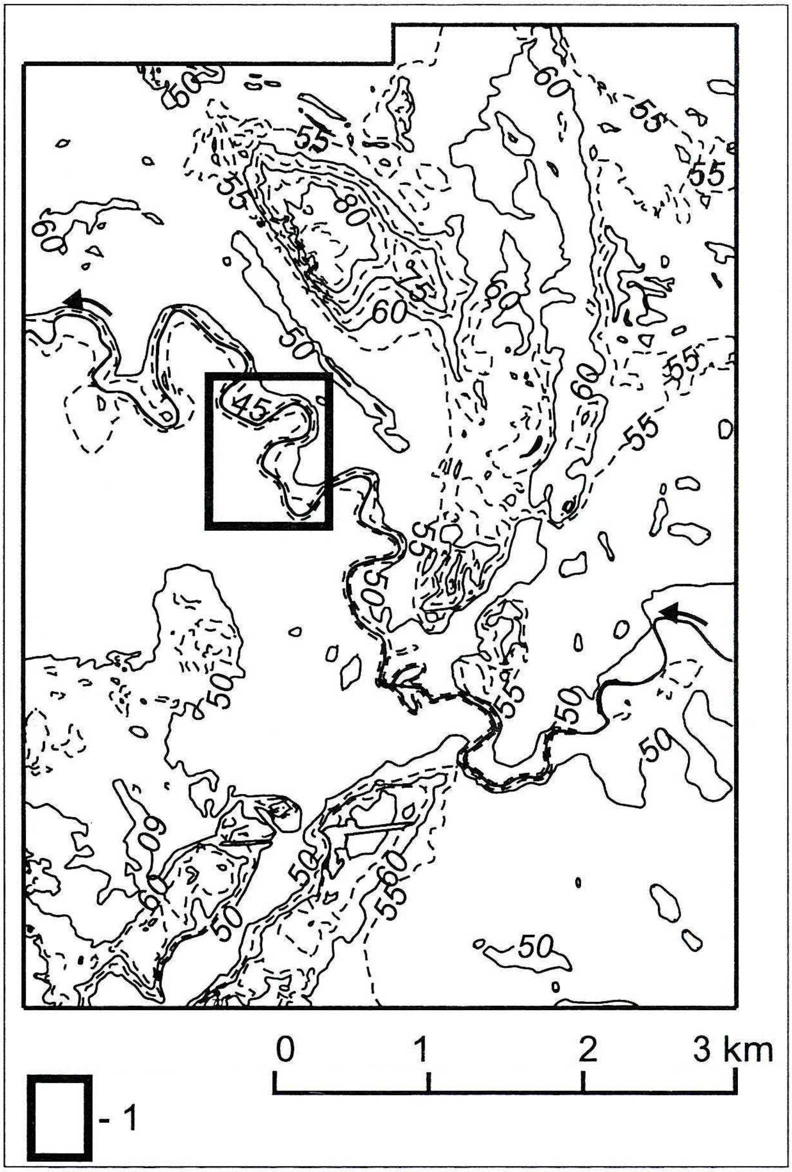

Fig. 3. Hypsometric map of research area and its neighborhood: 1 – detailed research area

DIRECT METHODS OF MEASUREMENT OF INTENSITY OF SUSPENDED LOAD TRANSPORT

Before demonstrating research methods used during field surveys in the Obra River bed, a short review concerning direct methods of measurement of suspended load transport intensity is presented in this chapter. The review regards selected Polish and foreign measurement methods used in such kind of studies.

Basic device, which is used in taking water samples, is bottle batometer of Polish Hydro-Meteorological Institute [28]. According to instructions of PIHM, water samples for determining suspended sediment concentration should be taken from the depths of 0.2 h, 0.4 h, and 0.8 h (h – river depth) [28]. Beside batometers, there are another devices which make possible to determine suspended sediment concentration using acoustic features of water which alter depending on changes of sediment concentration (*Acoustical Sand Transport Profiler*: [19]; *2D Ultrasonic Sand Transport Meter*: [12]). In this method, measurement of changes of frequency and dispersion of ultrasonic waves is used. On this basis, suspended sediment concentration and velocity of sediment particles is determined [12]. To estimate changes of suspended sediment concentration, optical methods are also used (*OPCON Optical Concentration Meter* and *Silt Monitor*: [12]). Another method is based on a measurement of changes of dielectric properties of sediment-water mixture [12, 38]. Those features are subjected to changes because of different concentrations of sand material in water. The measurement is done using sensors equipped with dielectric material. However, experiments done with mixtures of various concentrations of sand material showed that considerable measurement errors occur at high concentrations (exceeding 70%), flow velocity over 2 m s^{-1} and salinity over 2% [38]. On the other hand, the measurement results obtained at low flow velocity and low concentrations remained in linear dependence with sand material concentrations used in experiment [38].

CALCULATION METHODS

Suspended sediment concentration in water samples taken during field research is used to determine intensity of suspended sediment transport. The concentration is calculated by using weight method [6]. Intensity of suspended load transport is estimated by integration of width and depth of flow velocity area and sediment concentration area [2]:

$$S_s = \int_0^B \int_0^h vPdxdy$$

where: S_s – intensity of suspended load transport [g s^{-1}],
v – flow velocity [m s^{-1}],
P – sediment concentration [g m^{-3}].

Intensity of suspended load transport can also be calculated due to reliance: sediment concentration – discharge, on the basis of field measurements data. Although, such method is much less precise because of the lack of precise dependence between these two variables [2].

There are many models described in hydrological literature, which can be used to determine intensity of suspended sediment transport. One of them assumes differences in granulation of suspended material by dividing sediment mixture into a number of grain-

-size classes [30]. The model also includes exchange between material transported as bed-load and suspended load [30]. It should be noted that the authors verified this formula in regard to the Yangtze River of discharge 40 000 $m^3 s^{-1}$. There is no such demonstration with reference to smaller rivers. Another model, STAND (Sediment-Transport-Associated Nutrient Dynamics) [39], also assumes division of suspended load into particular grain size fractions. The model has a three-level structure. The first two levels regard hydraulics of open channel flow (described using St. Venant's equations) and sediment transport rate determined on the basis of first model's level calculations and field data [39]. The third one allows to demonstrate variability of nutrient concentration in a river bed as a function of nutrient transport as well as adsorption/desorption of nutrients to suspended sediment [39]. The authors applied this model relating to the section of a river valley, which was "closed" with water-gauges with accessible data concerning discharges, sediment transport rates, changes of river bed configuration and granulation of transported sediment. However, there is no reference to the river valleys where water-gauges or other monitoring stations are not present.

The problem of variability of suspended sediment transport in unsteady flow conditions was investigated by de Sutter *et al.* [33]. The authors' experiment showed that suspended sediment concentration measured by turbidity sensors differs distinctly from concentration values estimated using formulae of van Rijn [33] and Verbanck [33]. Similar results were obtained with reference to mixed sediments transport in sewers [34]. On the basis of the experiment's results, the authors proposed a model, which can estimate sediment concentration more precisely, in agreement with direct measurements [33]. However, the model was applied to laboratory experiments with no reference to natural river bed.

Artificial Neuron Networks MLP (multi-layer perceptrons) [11] were also applied to determine changes of intensity of suspended sediment transport. According to the author, such model allows to simulate non-linear character of such changes. Although, Cigizoglu [11] notes that calculation errors, which do not exceed 20%, can occur in the case of rapid changeability of suspended load transport rate.

Another research regarding suspended sediment granulation showed that in the middle course of the Yellow River there is reliance between sediment grain size and such variables as precipitation, sort of sediments in a river basin and wind activity [18]. It was observed that suspended material is relatively coarse at low water stages and during flood events. Finer deposits appear at high water stages [18]. Sukhodolov *et al.* [35] investigated variability of suspended sediment concentration and deposition of fine material in a groyne field. The authors noted that sediment concentration in bank zone can be about 17% greater because of waves induced by ships. Accumulated sediment is being resuspended and then redeposited [35]. The authors also point that the factors, which are often ignored (wind activity and ship passage near a groyne field), can significantly change flow velocities and sedimentation conditions within bank zones [35].

RESEARCH METHODS USED IN THE STUDY CONCERNING THE LOWER COURSE OF THE OBRA RIVER

Hydrological measurements in the Obra River bed were done in the period from 2nd February 2002 till 4th April 2003. Special attention was paid to the period of high water stages (2nd February – 4th April 2002). Five river bed cross-sections (divided into 1 m wide subsections) were marked (Fig. 4). Flow velocity was measured with hydrometric current meter. Altogether, twelve hydrological surveys were done. Besides, tachometric measurement of detailed research area was done to analyze river bed geometry (Fig. 4). According to instructions of Polish Hydro-Meteorological Institute [28] flow velocity measurements should be done in near bed zone and at depths of 0.2 h, 0.4 h, and 0.8 h (h – river bed depth) and close to water surface when river depth exceeds 0.6 m. The amount of measurements done in the Obra River bed was greater than mentioned above because of assigning those surveys to establish dependence between flow velocity variables and bed-load transport rate in river bed cross-section [26]. Flow velocity was measured in all subsections (within delimited cross-sections) at 0.1, 0.5, 1.0, 1.5, 2.0, 2.5 and 3.0 m distance from the river bottom as well as near water surface.

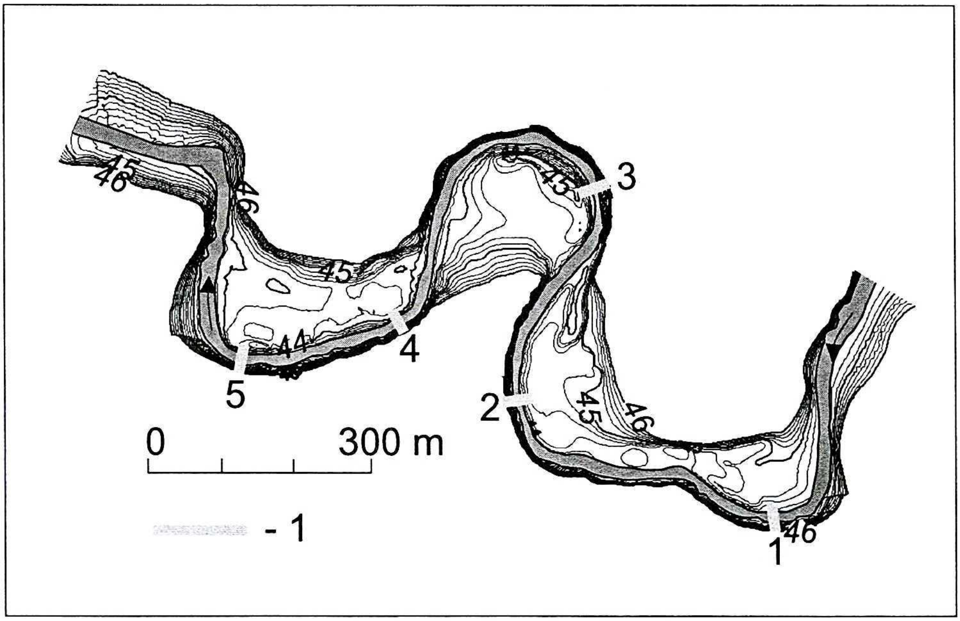

Fig. 4. Location of river bed cross-sections (1)

During each of hydrologic surveys, water stage was measured at Polish Hydro-Meteorological Institute water-gauge in Międzyrzecz, which is located at 42.8 km distance from the Obra River mouth and closes 2116 km^2 surface of the Obra River-basin. It should be noted that systematic hydrological observations ended at the water-gauge in 1992. The closest gauges, where such surveys are still done, are situated in Zbąszyń (40 km upstream of research area) and Bledzew (20 km downstream) village.

During field research, 800 water samples were collected to determine the amount of suspended material, which was done in laboratory using weight method [6]. Mean suspended sediment concentration in particular cross-sections was determined using the RIVER program [25], which uses spline approximation function [23]. On the basis of the calculations of the spline function, a region of the distribution of flow velocities in channel cross-section is obtained. The cutting of the region with planes perpendicular to the channel cross-section in any hydrometric vertical makes it possible to plot velocity profiles. For each velocity profile a mean flow velocity can be computed [25]. Similar results were achieved in reference to suspended sediments by applying to the program suspended sediment concentration as independent variable.

Besides, 30 samples of freshly deposited floodplain sediment were gathered to analyze its granulation. The samples were collected in the vicinity of cross-sections no. 1, 2 and 3, where such sediment covered the greatest floodplain surface. Grain-size analyses (using sieve method) and hydrometer analyses (Casagrande's method, Prószyński's modification) were done for all collected samples to determine statistical granulation coefficients: mean diameter, standard deviation, kurtosis and skewness. The coefficients were calculated using method of moments [16].

HYDROLOGICAL REGIME OF THE LOWER COURSE OF THE OBRA RIVER

"Hydrological regime is defined as forming of river discharge under the influence of river basin environment. This is the reaction of river caused by climate factors and physico-geographical features of river basin. Discharge regime shows temporal structure of river discharge within twenty-four hour's, monthly and annual cycle." [17].

Hydrological characteristics of the lower course of the Obra River were based on variability of water stages at Międzyrzecz water-gauge in hydrologic years 1964–1992. It should be noted that no discharge measurements were done at Międzyrzecz water-gauge. The closest water-gauges with such data are located in Zbąszyń and Bledzew. However, there was no possibility to determine the dependence of water stages in reference to these gauges

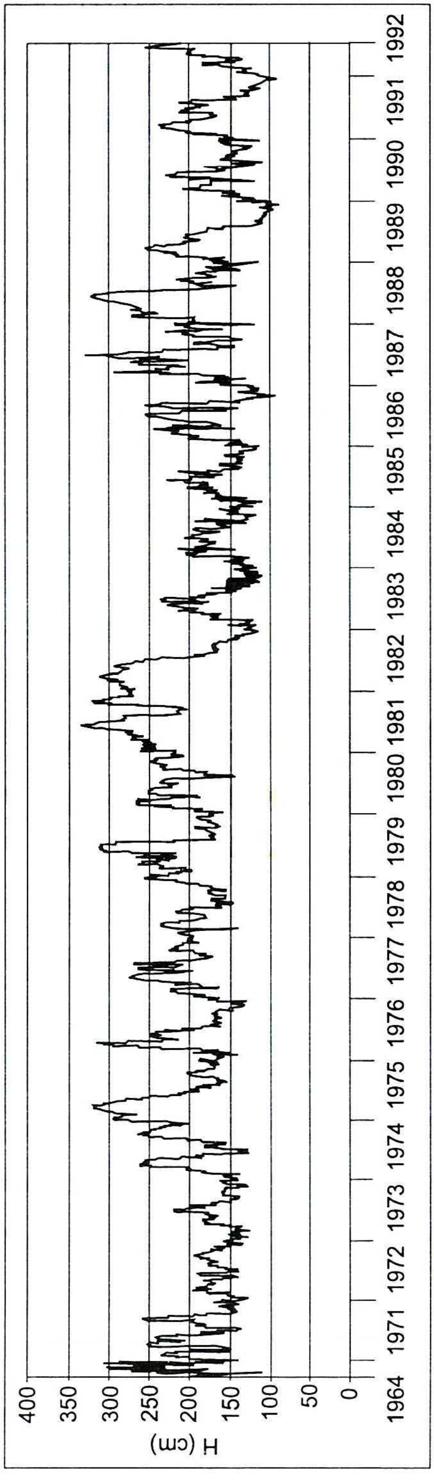

Fig. 5. Changes of water stages (H) in Międzyrzecz water-gauge – years 1964–1992

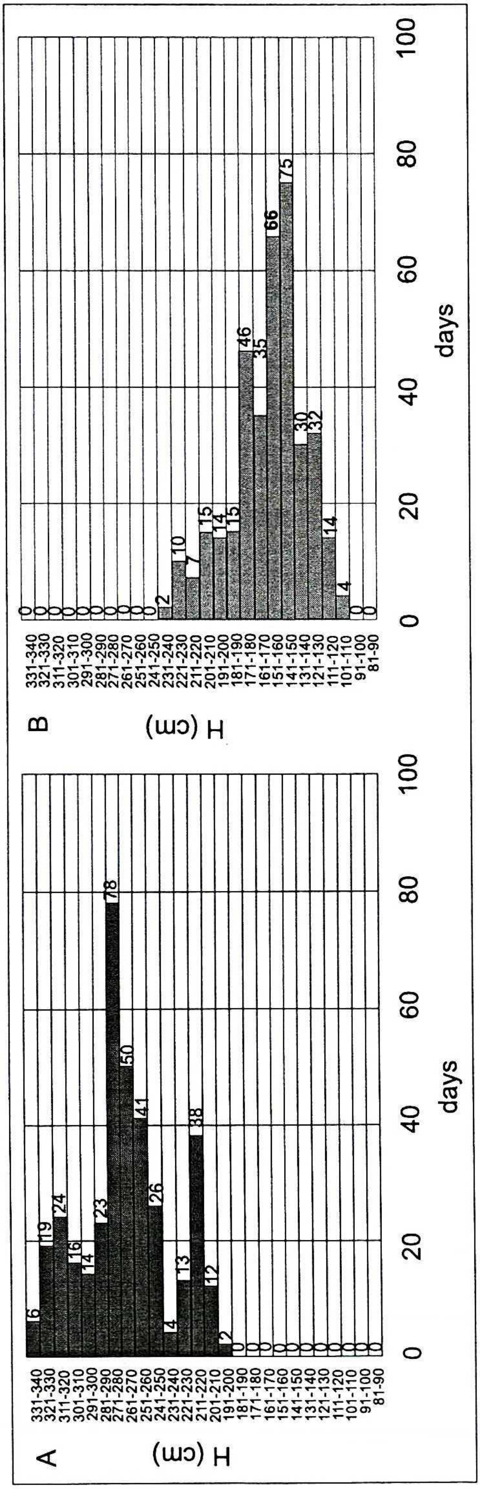

Fig. 6. Frequency of water stages (H) in chosen wet (1981; A) and dry (1990; B) hydrological year

because of hydro technical constructions (sluice gates) and damming up water near the Obra outflow from the Zbąszyń lake, and because of water dam in Bledzew.

In the case of the Obra River, the amplitude of water stages is regular (Fig. 5). Within the analyzed period, floods and high water stages occurred mainly in winter and early spring months (February – April). The highest noted water levels exceeded 300 cm. Low water stages were frequent in summer and autumn months (minimum: 81 cm in October 1989). During summer period, floods were caused by precipitation. They were of short duration in comparison with spring floods, which were caused by snow melt out. Figs. 6A and 6B show diagrams, which include number of days with particular level of water stage. During "wet" hydrological year (1981), water stages were most frequent within interval 271–280 cm (Fig. 6A) and in "dry" hydrological year (1990) – within interval 141–150 cm (Fig. 6B). The highest observed water level in 1981 was 340 cm (Fig. 6A) and in 1990 – only 240 cm (Fig. 6B).

Hydrologic regime of the Obra River can be described as "snow-rain supplied" with one maximum and one minimum water stage period during hydrologic year, which is in agreement with opinion of Dynowska [13]. According to the author, hydrologic regime of the Obra River is reckoned among temperate group of regimes with spring flood and with groundwater and precipitation supply [13]. However, it is important to note that some years within analyzed period were featured with long duration high water stages. Such events were caused by high precipitation not only in spring but also during summer and autumn months. Hydrological year 1981 is one of the examples (Fig. 5). In the case of “dry” hydrological years, long duration periods of low water stages, which lasted unceasingly from spring to the following year’s winter months, could be observed (years 1983, 1984 and 1985; Fig. 5). Another important factor is several lakes situated in the river course, which influence the lowering of water stages amplitude [3, 9]. Byczkowski [7] noted that influence of such factor is marked by stability of discharges, which is caused by lowered magnitude of culminant discharges, extended duration of floods and increased level of low water stages.

During hydrological surveys’ period, (2nd February 2002 – 4th April 2003) the highest water stages were observed in the spring (12 March 2002: 284 cm, 20 March: 292 cm and 4 April: 277 cm) and late autumn (27 November 2002: 278 cm), with maximum discharge 10 $m^3 s^{-1}$ (Fig. 7B). There were long lasting low water stages during summer period (3 July and 30 July 2002: 154 cm) with discharge below 2 $m^3 s^{-1}$ (Fig. 7B). The highest discharges were also noted in spring and were caused by precipitation. The highest water levels were caused by precipitation and were accompanied with maximum discharges (14 March 2002: 9.32 $m^3 s^{-1}$, 21 March: 9.71 $m^3 s^{-1}$ and 5 April: 10.01 $m^3 s^{-1}$).

TEMPORAL VARIATIONS OF MEAN SUSPENDED SEDIMENT CONCENTRATION DURING PERIOD OF HIGH WATER STAGES

Froehlich’s research [14] showed that during flood events maximum sediment concentration occurs before culmination of discharge. However, the author observed that in some cases both those peak values appear simultaneously. Such situation may be caused by complex mechanism of fine sediment supply to transport in a river bed [14]. Another reason may be differentiation of rainfall intensity in particular

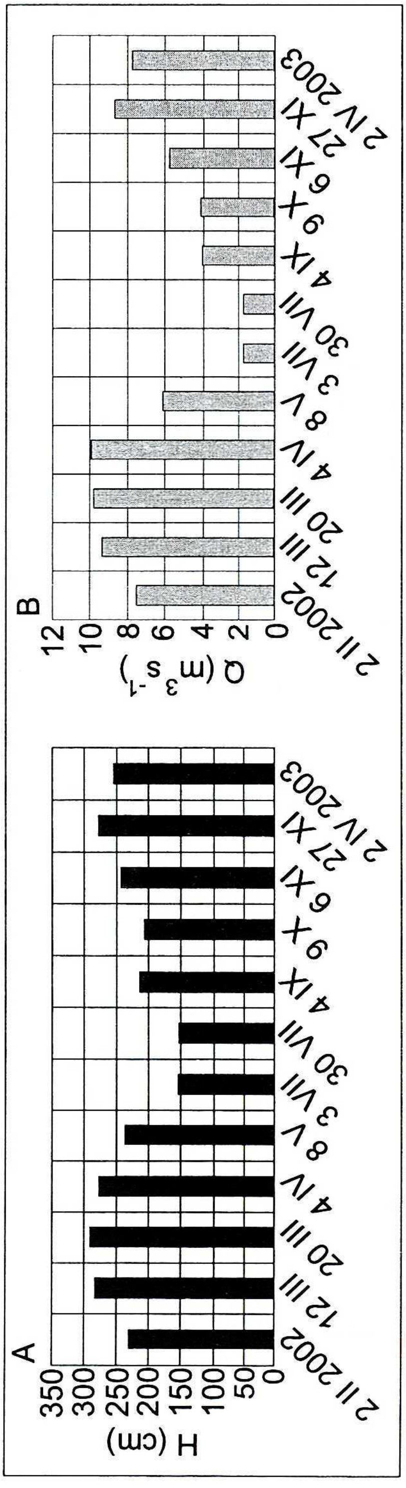

Fig. 7. Water stage (H) and discharge (Q) changes during field research period (2nd February 2002 – 4th April 2003)

regions of a river-basin and mass movement processes [15]. Besides, the author noted that temporal variations of intensity of suspended sediment transport can be dependent on rapid increase of discharge, which depends on precipitation intensity or ablation of snow cover [14]. Results of field research concerning the lower course of the Obra River are in agreement with Froehlich's observations; during high water stages period maximum sediment concentration occurred simultaneously with maximum discharge. Such situation was observed in cross-sections no. 1, 2 and 3, in April 2002 (Fig. 8A2, 8B and 8C2). Mean suspended sediment concentration increased to a maximum of 19.65 mg dm^{-3} in cross-section 3 (Fig. 8C1). At the same time, discharge increased to its maximum value during the hydrological survey (10.01 $m^3 s^{-1}$; Fig. 7B). The increase of sediment concentration appeared in the first phase of water stage subsidence. Such situation might be caused by sediment delivery process from riverbank slopes. Cross-section no 1 was located in the vicinity of high concave bank subjected to intensive lateral erosion. Distinct traces of landslides are present in this place. This is the place where sediment supply from riverbank slopes to the Obra River bed could be particularly simple. In the case of cross-section 3, another high concave bank with clearly visible traces of landslides in the vicinity of the cross-section could be the source of sediment delivery to the river bed.

Temporal variations of suspended sediment concentration in cross-sections 4 and 5 were of another character (Fig. 8D2 and 8E2). First, during period of high water stages, distinct increase of sediment concentration was noted (14^{th} March, cross-section 4: 16.15 mg dm^{-3}; Fig. 8D1). Then, in April 2002, a decrease of concentration value was observed (Fig. 8D1 and 8E1). It was mentioned above that maximum discharge was noted during hydrological survey in April 2002. In the two discussed cross-sections, hysteretic effect occurred as normal hysteretic loops (Fig. 8D2 and 8E2). It is supposed then that transported material was of autochthonous origin (originated from the river bed and its nearest vicinity) [20]. The authors of research, which regarded to the Parsęta river basin [20], pointed that this kind of sediment supply can be related to surface runoff.

VARIABILITY OF GRANULATION OF ALLUVIAL SEDIMENTS DEPOSITED DURING HIGH WATER STAGES

During the period of high water stages, 3 cm thick sediment layer was accumulated within inundated fragment of floodplain (Fig. 9). Presumably, the material was subjected to transport mainly in suspension. This is suggested because of low flow velocities measured within flooded fragment of the valley floor, which slightly exceeded 0.1 $m s^{-1}$ in all cross-sections. After receding of flood waters, samples of freshly deposited material were collected near cross-sections 1, 2 and 3, where the deposits covered the biggest floodplain's surface. Mean diameter of the sediment varied from 2.3 phi to 2.5 phi near cross-section 1 (Fig. 9A). The value of MD (mean diameter) decreased together with increasing distance from the river bed. Coarser sediments were little more poorly sorted (SD = 1.1). Greater variations of grain size fractions were observed in case of cross-section 2 (MD = 2.2 phi at distance of 2 m from the river bed; MD = 2.7 phi at distance of 5 m) (Fig. 9B). Changes of sediment sorting were insignificant (SD = 0.7–0.9).

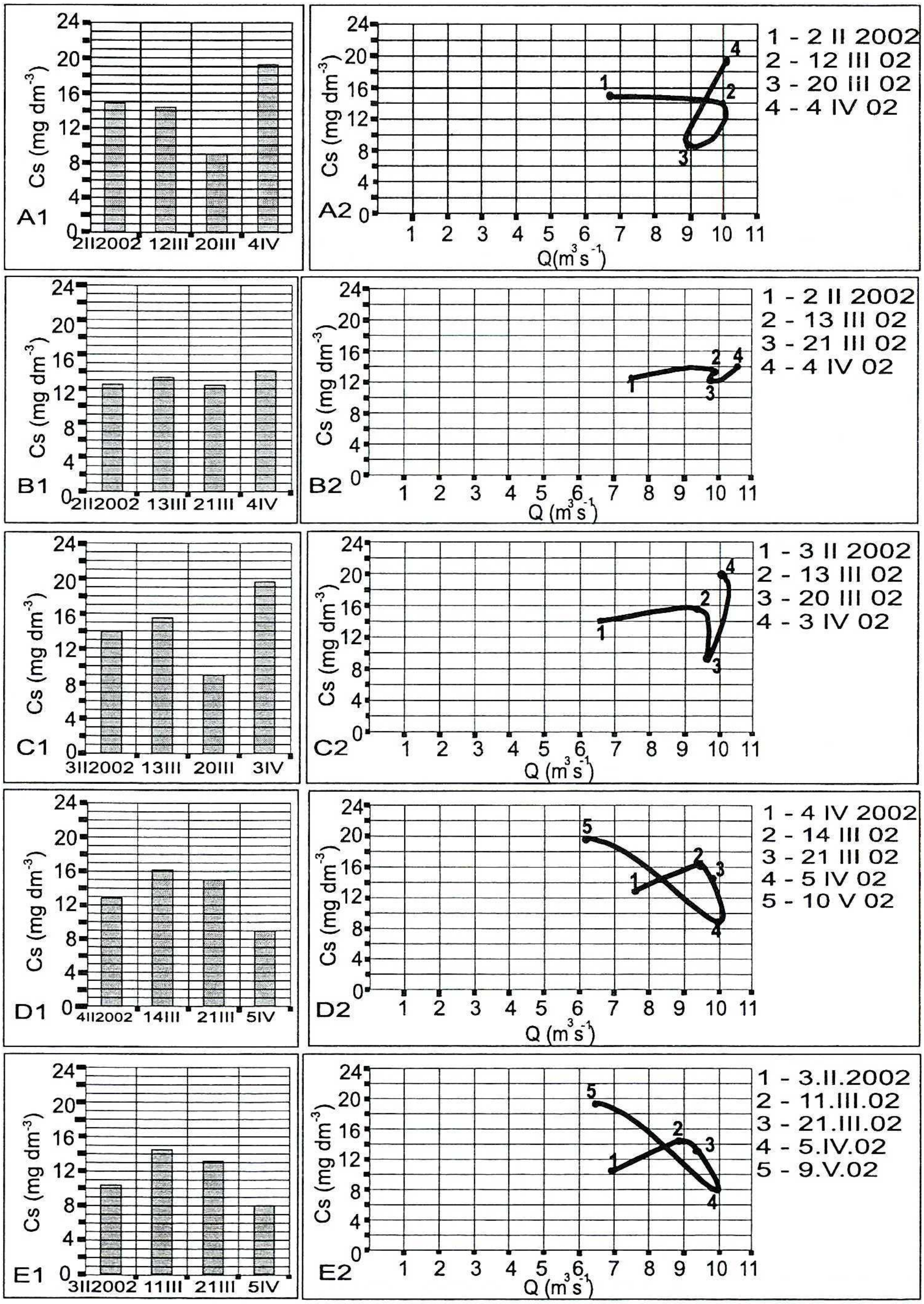

Fig. 8. Changes of suspended sediment concentration (Cs) and dependence between discharge (Q) and suspended sediment concentration (Cs) in the Obra River cross-sections during period of high water stages: A1, A2 – cross-section no 1, B1, B2 – cross-section no 2, C1, C2 – cross-section no 3, D1, D2 – cross-section no 4, E1, E2 – cross-section no 5

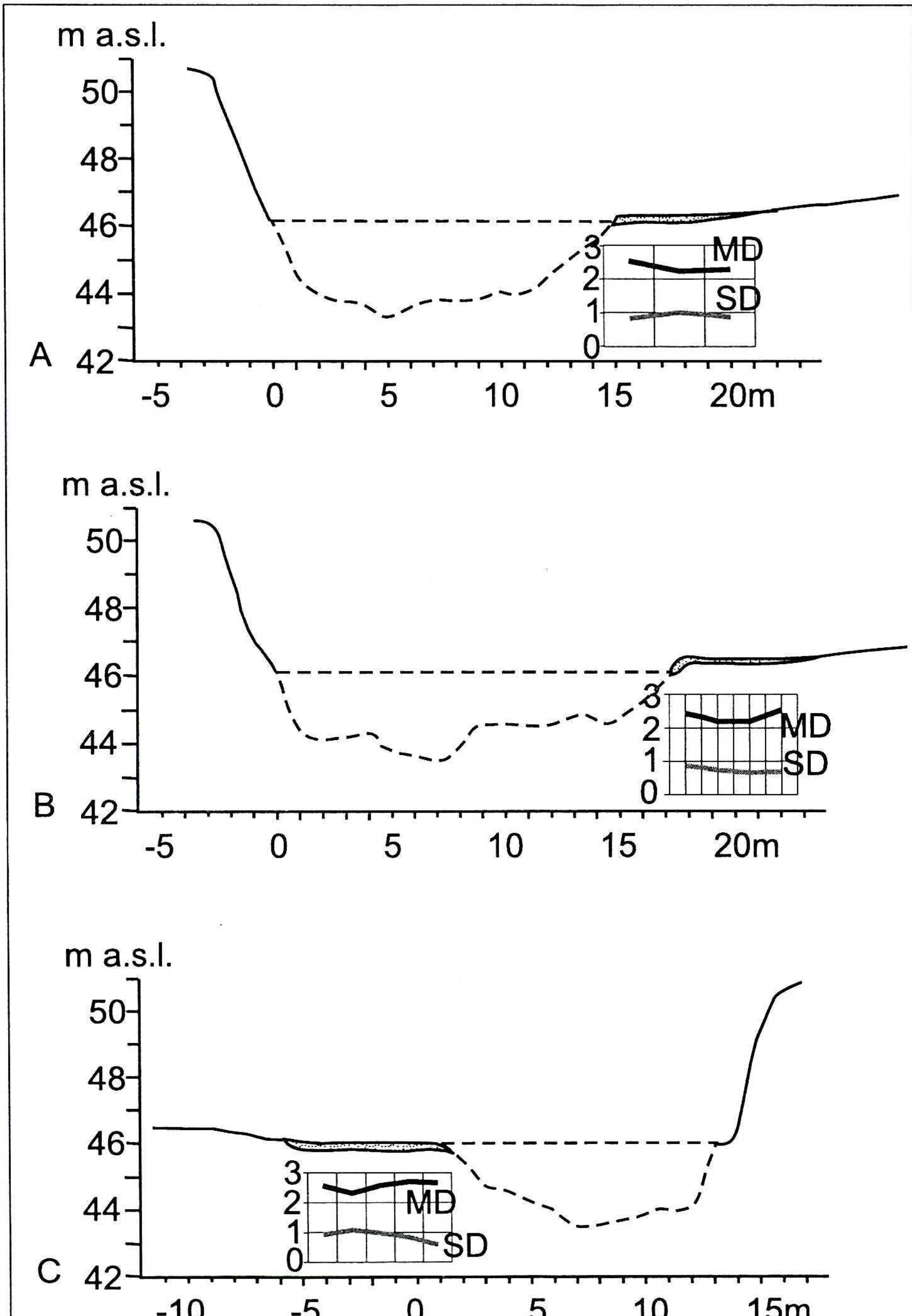

Fig. 9. Changes of granulation coefficients of flood sediments deposited on floodplain during period of high water stages: A – cross-section no 1 (8 May 2002), B – cross-section no 2(8 May 2002), C – cross-section no 3 (9 May 2002). MD – mean diameter (values in phi scale), SD – standard deviation

In the vicinity of cross-section 3 MD varied from 2.3 phi to 2.75 phi (Fig. 9C). The finest sediments were deposited directly near the river bed; slightly coarser material – at distance of 4 m. Similarly to cross-section 1, coarser material was more poorly sorted (SD = 1.2). Standard deviation parameter increased along with the distance from the river bed.

CONCLUSIONS

Observed variations of mean suspended sediment concentration and its reliance to discharge in particular cross-sections allowed to formulate the following conclusions:

1. Analysis of dependence between mean suspended sediment concentration and discharge allowed to preliminarily determine the way of sediment supply to the Obra River bed. In cross-sections 1, 2 and 3 suspended sediment originated from more distant sources of supply, first of all – from slope environment. Very important source could be the exposure of glacial and fluvioglacial sediments in high concave bank in the vicinity of cross-section 1. Traces of landslides were also visible near cross-section 3. In case of cross-sections 4 and 5, observed hysteretic effect suggested that transported material originated from the river bed and near bank zone.
2. Deposition process, which was observed within the floodplain during high water stages, may suggest that vertical accretion process is active in the case of the investigated section of the Obra River valley. It should be noted that during periods of higher water levels accumulation process could take place in the whole width of the valley floor. The maximum water level noted in the years 1971–1991 at Międzyrzecz water-gauge was 340 cm. The maximum water level, which was measured during field research, was 292 cm. A half of meter higher water level would cause inundation of greater part of the floodplain. Such flood event would cause process of sediment supply from more distant sources.
3. Observed deposition process within inundated fragment of the floodplain makes good illustration of forming lithofacies of floodplain sediments. Deposited floodplain sediment could be classified partly as lithofacies of flood sediments VA, which was distinguished by Rotnicki and Młynarczyk [31] (the finest accumulated material: MD = 2.5–2.7 phi) and partly as lithofacies of top part of point bar PBT [31] (accumulated sediment with MD = 2.2–2.5 phi including greater contribution of grain-size class 0.25–0.5 mm). The authors noted that mechanism of forming PBT lithofacies was joined with bankfull discharge as well as discharges, which are close to bankfull, and with deposition on point bar surface [31]. The names of lithofacies (VA, PBT) have been obtained from the study concerning lithological variability of alluvial sediments of the Prosna River valley [31].

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ZMIANY KONCENTRACJI MATERIAŁU ZAWIESZONEGO W DOLNYM ODCINKU OBRY W OKRESIE WYSTĘPOWANIA WYSOKICH STANÓW WODY

Badania nad zmianami koncentracji materiału zawieszonego w okresie występowania wysokich stanów wody przeprowadzono w dolnym odcinku rzeki Obry, w okolicach Międzyrzecza. Analiza związku pomiędzy średnią koncentracją materiału zawieszonego a przepływem umożliwiła wstępne określenie sposobu dostawy materiału do koryta rzecznego. Ważną rolę mogły tu pełnić odsłonięcia osadów glacjalnych i fluwioglacjalnych znajdujących się w wysokich brzegach wklęsłych koryta Obry. Ponadto na dwóch z pięciu badanych przekrojów pomiarowych zaobserwowano efekt histerezy o przebiegu normalnym, co świadczyłoby o autochtonicznym pochodzeniu transportowanego osadu. Ponadto zaobserwowano proces depozycji osadów na fragmencie równiny zalewowej w okresie występowania wysokich stanów wody. Podjęto w ten sposób próbę przedstawienia mechanizmu tworzenia się litofacji środowiska pozakorytowego. Pozwoliło to na przybliżenie warunków, w jakich osady powodziowe dna doliny Obry były kształtowane w przeszłości.