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# MELIORACJE I INŻYNIERIA ŚRODOWISKA

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# VARIATION OF GROUND-WATER LEVELS IN THE CATCHMENT OF THE MIDFIELD POND LOCATED AT GNIEZNO LAKELAND

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ABSTRACT. In the paper are presented results of researches on ground-water level variation carried out in the catchment of a midfield pond. The significant influence of weather conditions and topography of area on shaping of depth of ground-water levels were proved. During a wet hydrological year groundwater levels were more varied that during a year with an average amount of precipitation. During a wet year also a strong influence of the midfield pond on ground-water levels was observed.

**Key words:** hydrology, groundwater, midfield pond

## Introduction

Groundwater levels are an important factor, which could be useful in describing water regime in soils on areas with high relief. Prior to this time, the results of researches carried out on such areas showed big variation of the depth of groundwater, effected mainly by meteorological conditions and diverse area topography (**Kostrzewa et al.** 1994, **Szafrański** 1988, 1993). In local area depressions often occurred soil sinking and very shallow groundwater levels. At the same time in the upper layer of soils, located higher in area relief, often occurred water deficiencies. Also the relationships between water levels in midfield ponds and levels of groundwater in areas nearby ponds often are emphasised (**Hall** 1976, **Kosturkiewicz** and **Fiedler** 1993, **Winter** 1986). Detailed recognition of moulding of water depth in midfield ponds as well as groundwater levels is necessary for the

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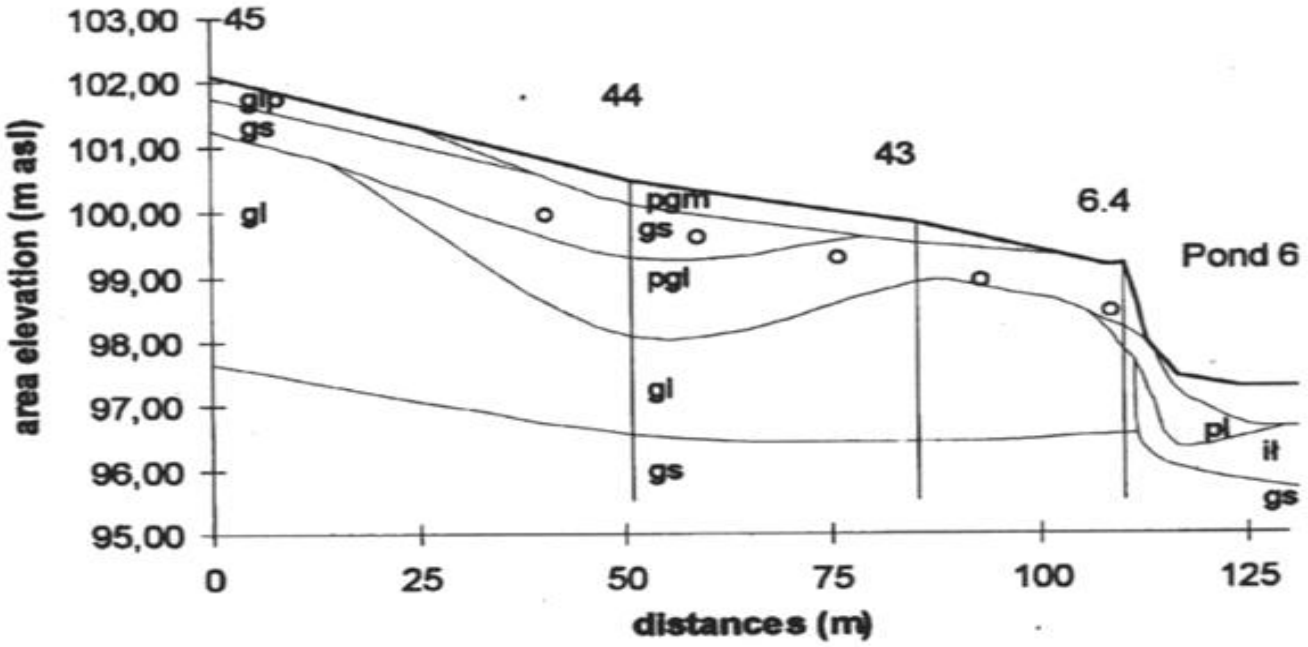


Fig. 1. Section of midfield pond 6 catchments (pl – loose sand, pgl – light loamy sand, pgm – heavy loamy sand, gl – light loam, glp – silty light loam, gs – medium loam, ił – clay, o – drain pipes)

Ryc. 1. Przekrój przez zlewnię oczka 6 (pl – piasek luźny, pgl – piasek gliniasty lekki, pgm – piasek gliniasty mocny, gl – glina lekka, glp – glina lekka pylasta, gs – glina średnia, o – sączki drenarskie)

evaluation of land reclamation needs. It will also make estimating water resources in pond catchments possible (**Kosturkiewicz** et **al.** 1997).

## Methods

In the paper are presented results of field investigations and researches carried out in the Mokronosy Experimental Station, located at Gniezno Lakeland (52°53'N, 17°28'E). Detailed analyses of water levels in the pond and groundwater levels were made for the catchment of the midfield pond 6, with area 2.06 ha, for hydrological years 1987/88 and 1994/95. Field investigations included measurements of water levels in the pond and depth of groundwater levels in four observation wells located in the pond catchment (Fig. 1). Well 6.4 is located near the pond bank, at the foot of the slope. In the soil cover of this area occurred browned black earth (Typic Endoaquolls) built from light medium sand, in a shallow layer on top of sandy loam, changing at the depth of 250 cm into medium-heavy loam. The other wells are located in soil lessives (Typic Hapludalfs), which are built from heavy medium sand and sandy loam that lies on medium-heavy loam. Wells 43

and 44 are located in the lower and middle parts of slope, respectively. Well 45 is located on the top of the slope. Measurements of depth of ground water were done in five day periods. During spring snow melting, when rapid changes of ground water happened, measurements were done every day. Results of researches were used for statistical analysis and for drawing up histograms and distribution function of water levels. The depth of water in the pond 6 and groundwater in the observation wells were grouped in ranges of 10 cm. Lacking data were supplemented by interpolation between measurements.

The analysis of weather conditions based on precipitation measurements, in Hellmann's rain gauge, done in Experimental Station Mokronosy and on data got from IMGW meteorological station Gniezno.

## Results

In both chosen for analysis hydrological years 1987/88 and 1994/95 in the pond were observed free water surface. These hydrological years had different meteorological conditions (Fig. 2). The year 1987/88, in which atmospheric precipitation was 596 mm, and significantly exceeded mean yearly precipitation that was equal 457 mm, can be considered a wet year. Wet was the winter half-year (November-April) with the sum of precipitation exceeding multi-year mean for this period by 93 mm, as well as summer half-year (May-October) with the sum of precipitation exceeding mean by 40 mm. Probabilities of occurrence of such sums of precipitation in the described half-years were one year in 25 and 6 years periods, respectively. On the other hand, the hydrological year 1994/95, with sum of precipitation 497 mm, can be considered an average year.

Mean yearly groundwater levels in the pond 6 catchment observed in the wet year 1987/88 were 94 cm beneath soil surface in the well 6.4 down to 201 cm in well 45 (Tab. 1). These water levels were closer to area surface than groundwater levels observed in year 1994/95 by 55 cm in well 6.4 located close to pond. In wells 43 and 44, located on the slope, those differences were 77 cm and 101 cm, and in well 45 located on top of the slope reached 154 cm. Also the water levels in the pond 6 were much higher. Mean depth of water in the pond in this year was equal to 120 cm and was by 86 cm higher that in year 1994/95. With shallower groundwater, depth to water level had considerably greater ranges of amplitudes than in year 1994/95. Average amplitude of groundwater levels in four observation wells in year 1987/88 was 141 cm and was two times greater than in year 1994/95. Also calculated standard deviations showed up significantly greater variation of groundwater levels during the wet year than during an average year. For all wells, except for well 6.4 located near the pond edge, these values were much higher in year 1987/88 that in year 1994/95. Interesting is also the comparison between mean water levels and medians (Tab. 1). For a wet year these values were almost the same. During a year with an average sum of precipitation, the median is lower

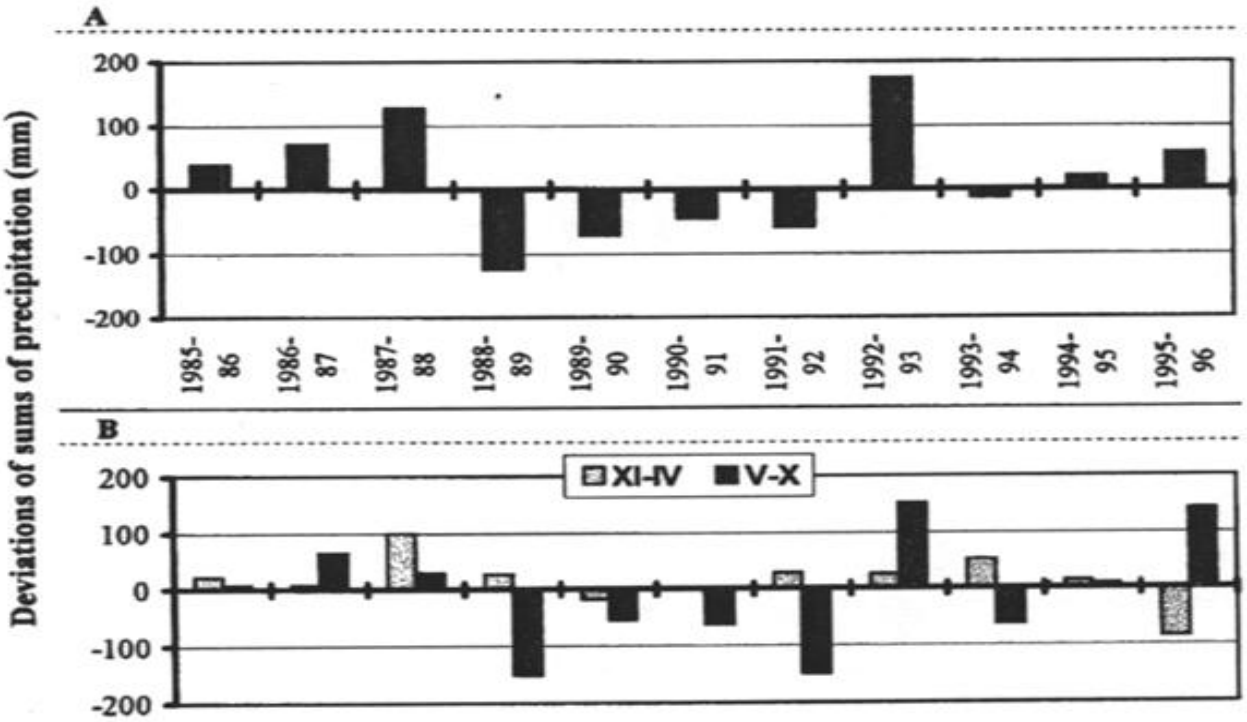


Fig. 2. Deviations of year (A) and half-year (B) sums of precipitation from multi-year average measured at Mokronosy for hydrological years from 1985/86 to 1995/96
Ryc. 2. Odchylenia sum opadów rocznych (A) i półrocznych (B) dla posterunku opadowego Mokronosy od średnich z wielolecia dla lat hydrologicznych 1985/86-1995/96

by 2 to 12 cm, 8 cm on average, than the mean groundwater level. It showed that in an average year prevailed deeper water levels than mean ones. In a wet year, times of duration of water levels deeper and shallower than average were similar.

Considerable differences in water levels fluctuations during analysed years were also visible during the analysis of frequency of occurrence of water levels in the pond and of groundwater levels. Occurrences of water levels counted in intervals of 10 cm were used for drawing histograms presented in Figures 3, 4 and 5. In analysed years, distribution of water levels in the midfield pond is similar to normal distribution (Fig. 3). Groundwater levels in the catchment of pond 6 had different distributions. In wet year 1987/88 (Fig. 4), groundwater levels had distribution more even than in average year 1994/95 (Fig. 5), when lower water levels predominated clearly. In year 1987/88 the exception to the above rule were observed for groundwater levels in the well 6.4 located in the lowest part of slope, close to the pond. Distribution of these water levels is similar to the distribution of water levels in pond 6. This situation indicates that water levels in the pond strongly influenced groundwater levels in areas surrounding the pond. In the hydrological year 1987/88, when water levels in the pond were high, water seeped through the pond bank and established a relationship between groundwater levels and water levels in pond. This relation did not take place in year 1994/95 which was a result of

Table 1

**Characteristics of water levels in the midfield pond 6 and depth of groundwater levels in observation wells 6.4, 43, 44 and 45 located in the pond's catchment in hydrological years 1987/88 and 1994/95 (cm)**
**Charakterystyki stanów wody w śródpolnym oczku wodnym 6 i głębokości zalegania wód gruntowych w studzienkach 6.4, 43, 44 i 45 położonych w zlewni tego oczka w latach hydrologicznych 1987/88 i 1994/95 (cm)**

| | Pond – Oczko | | | | |
|---|---|---|---|---|---|
| | 6 | 6.4 | 43 | 44 | 45 |
| | Hydrological year 1987/88 – Rok hydrologiczny 1987/88 | | | | |
| Minimum water level<br>Stan minimalny | 86 | 59 | 50 | 84 | 66 |
| Mean water level<br>Stan średni | 120 | 94 | 136 | 155 | 201 |
| Median<br>Mediana | 123 | 93 | 137 | 156 | 202 |
| Maximum water level<br>Stan maksymalny | 152 | 132 | 190 | 209 | 292 |
| Amplitude<br>Amplituda | 66 | 73 | 140 | 125 | 226 |
| Standard deviation<br>Odchylenie standardowe | 18.1 | 19.5 | 37.8 | 38.2 | 63.0 |
| | Hydrological year 1994/95 – Rok hydrologiczny 1994/95 | | | | |
| Minimum water level<br>Stan minimalny | 6 | 100 | 165 | 231 | 296 |
| Mean water level<br>Stan średni | 34 | 149 | 213 | 256 | 355 |
| Median<br>Mediana | 35 | 157 | 222 | 258 | 367 |
| Maximum water level<br>Stan maksymalny | 63 | 179 | 239 | 275 | 388 |
| Amplitude<br>Amplituda | 57 | 79 | 74 | 44 | 92 |
| Standard deviation<br>Odchylenie standardowe | 14.0 | 22.3 | 20.9 | 13.4 | 28.4 |

very low water levels and a lack of water exchange between the pond and groundwater. For this year, distribution of water levels in well 6.4 resembles distribution of groundwater levels in the other observation wells. During wet year 1987/88, as well as during average year 1994/95, groundwater levels in wells 43, 44 and 45, which were located in the higher parts of slope, had maximum of frequency in the lower intervals of water levels. Moreover, these maximums were clearly lower in the wet year than in the average one. In well 43, located in the lower part of the slope, the greatest size of class equal to 79 days had interval 180-189 cm, while in

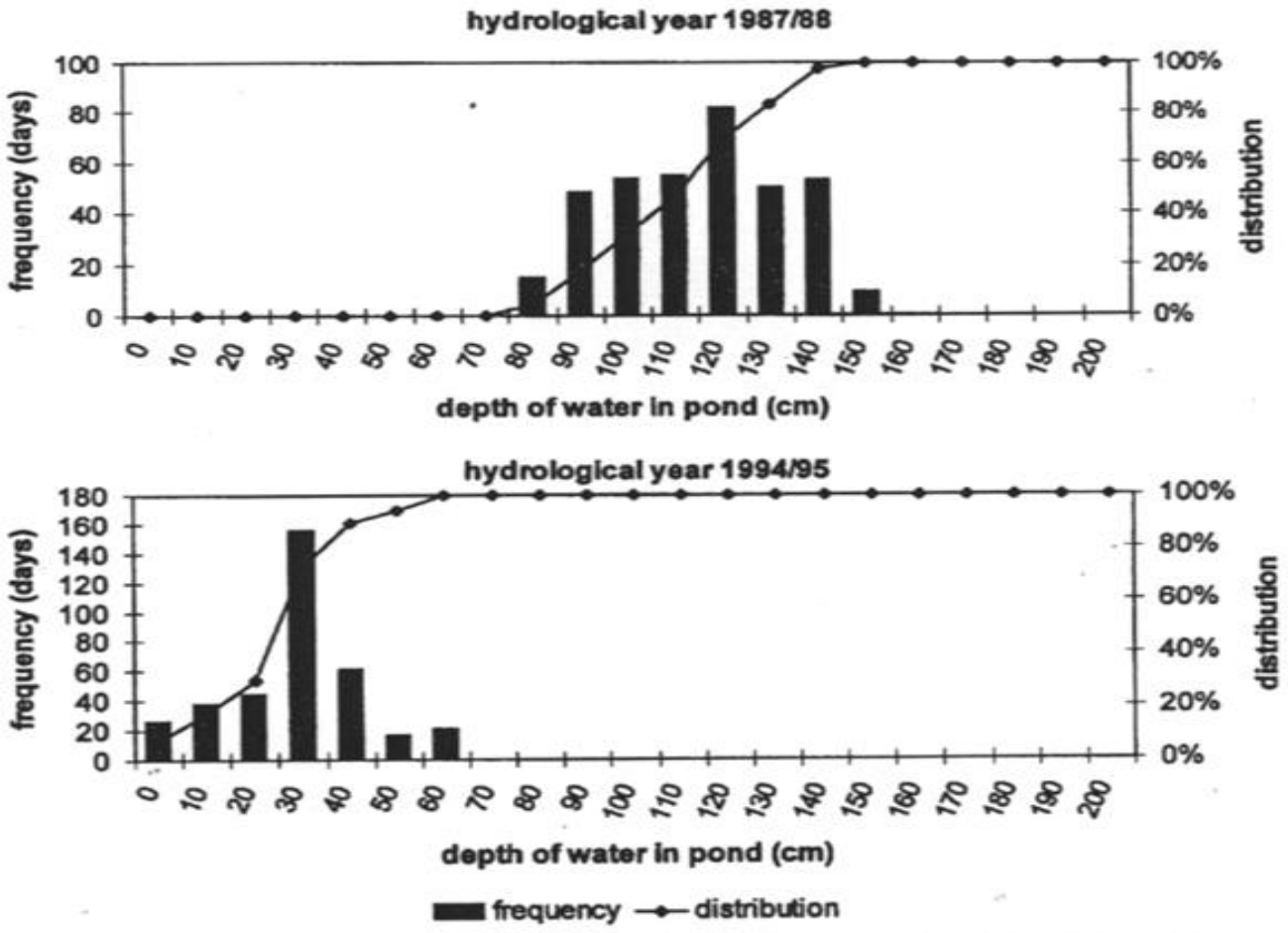


Fig. 3. Histograms and distribution of depth of water in pond 6 in hydrological years 1987/88 and 1994/95

Ryc. 3. Histogramy i dystrybuanty stanów wody w śródpolnym oczku wodnym dla lat hydrologicznych 1987/88 i 1994/95

average year 1994/95 the greatest class size was 119 days and was observed in the interval 220-229 cm. Similar differences were observed also in case of wells 44 and 45. The influence of yearly moisture patterns on the occurrence of groundwater levels in lower intervals was also confirmed by their participation in the total number of observations. In wet year 1987/88, water levels in the two lowest intervals lasted in wells 43, 44 and 45 for 28%, 27% and 16% of the whole year, respectively, whereas in average hydrological year 1994/95 these values were equal to 55%, 42% and 44%, respectively. Analyses of results of researches show a great influence of meteorological conditions on groundwater pattern. In a wet year greater amounts of pluvial water supply groundwater, affecting greater fluctuations of groundwater levels, and keep them on a higher level, whereas in a year with the sum of precipitation closer to the multi-year average there is no clear supply of groundwater which affected smaller water level fluctuation and deeper water levels.

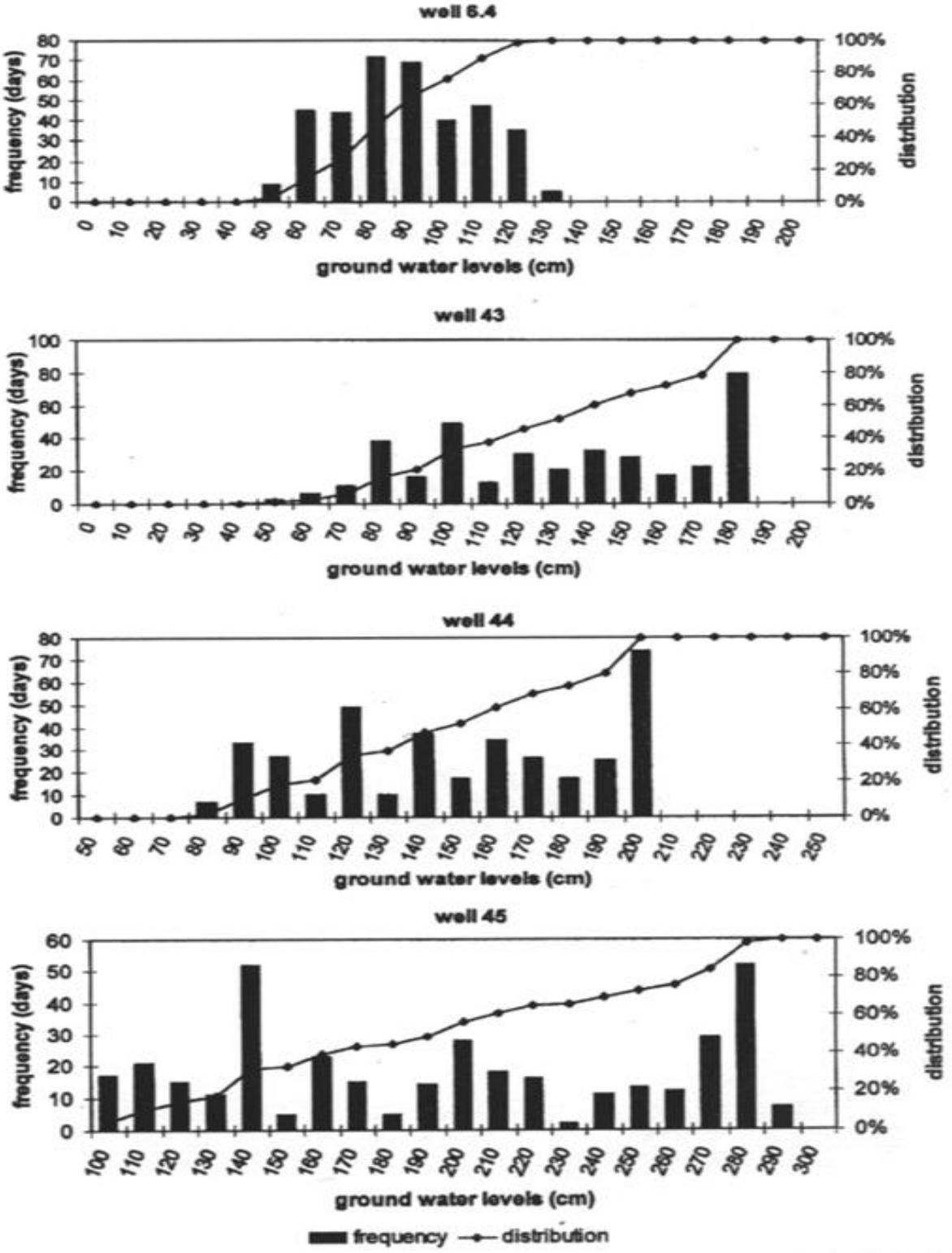


Fig. 4. Histograms and distribution of ground water levels in hydrological years 1987/88

Ryc. 4. Histogramy i dystrybuanty stanów wody gruntowej dla roku hydrologicznego 1987/88

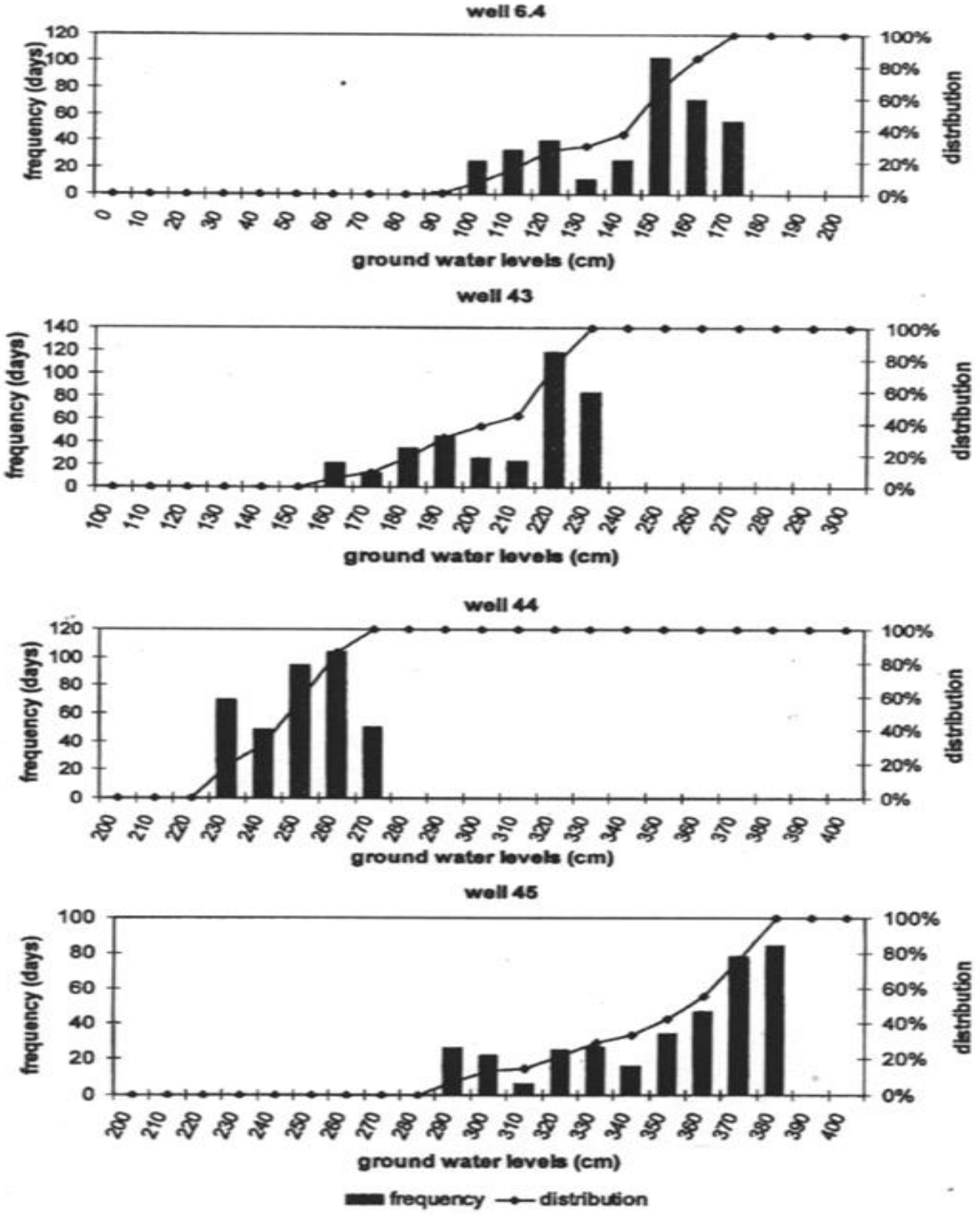


Fig. 5. Histograms and distribution of ground water levels in hydrological years 1994/95

Ryc. 5. Histogramy i dystrybuanty stanów wody gruntowej dla roku hydrologicznego 1994/95

Beside the estimation of variation of groundwater levels it is very important to determine the possibilities of occurrence of drainage outflows. This problem is particularly important in considering possibilities of retention in midfield pond drainage outflows from the pond's catchment. Estimation of time of duration and amount of the outflow make proper constructing of midfield ponds system possible, which in optimal way store drainage outflows (**Kosturkiewicz** et **al.** 1996). Possible time of duration of drainage outflows was established according to the distribution function of depth of groundwater levels (Fig. 4 and 5). We assumed that optimal depth of drainage for soil conditions of the catchment of pond 6 was 0.9 m. In wet hydrological year 1987/88, groundwater levels in wells 6.4, 43 and 44 rose above the assumed depth of drainage. In the well 6.4 located near the pond, water levels for 46% of year were above the depth of 90 cm. In the well 43, located in the lower part of the slope, this time took 16% of year. In well 44 located in the upper part of slope, water levels were above drainage depth for 2% of the year, whereas in the observation well 45, situated at the top of slope, groundwater levels during the whole year were below the depth of drainage. Also in average, according to the yearly sum of precipitation, hydrological year 1994/95, water levels in all observation wells described above were below the depth of drainage during the whole year.

## Conclusions

1. Results of researches confirmed a large variation of water levels in the midfield pond and groundwater levels in the pond catchment. The variation was mainly affected by meteorological conditions.

2. In the wet year, groundwater levels show much greater range of fluctuations, whereas their distribution is more even than in a year with the sum of precipitation similar to the multi-year average. In the average year prevail water levels below the mean water level. In a wet year, the duration of water levels below and above mean was almost equal.

3. Water levels in the midfield pond have distribution similar to the normal distribution. In a wet hydrological year, the influence of the pond on the distribution of groundwater levels in the area surrounding the pond was also visible. Groundwater levels in soils located higher on the slope have different distributions of water levels.

4. In a wet year groundwater levels measured in the well located closest to the pond during 46% of year were above the depth of drainage. In observation wells lying higher in the area relief, these values were 16 and 2% of the year. In that year, in the well located on top of the slope, as well as in an average year in all the wells, groundwater levels were below the depth of drainage.

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## ZMIENNOŚĆ STANÓW WÓD GRUNTOWYCH W ZLEWNI ŚRÓDPOLNEGO OCZKA WODNEGO NA POJEZIERZU GNIEŹNIEŃSKIM

### Streszczenie

W pracy przedstawiono wyniki badań nad zmiennością stanów wód gruntowych, prowadzonych w zlewni śródpolnego oczka wodnego. Wykazano znaczący wpływ przebiegu warunków meteorologicznych oraz rzeźby terenu na kształtowanie się stanów wód. W roku mokrym stany wody gruntowej charakteryzowały się dużo większą zmiennością niż w roku średnim. W roku mokrym zaznaczyło się także silne oddziaływanie oczka na wody gruntowe w terenie przyległym.