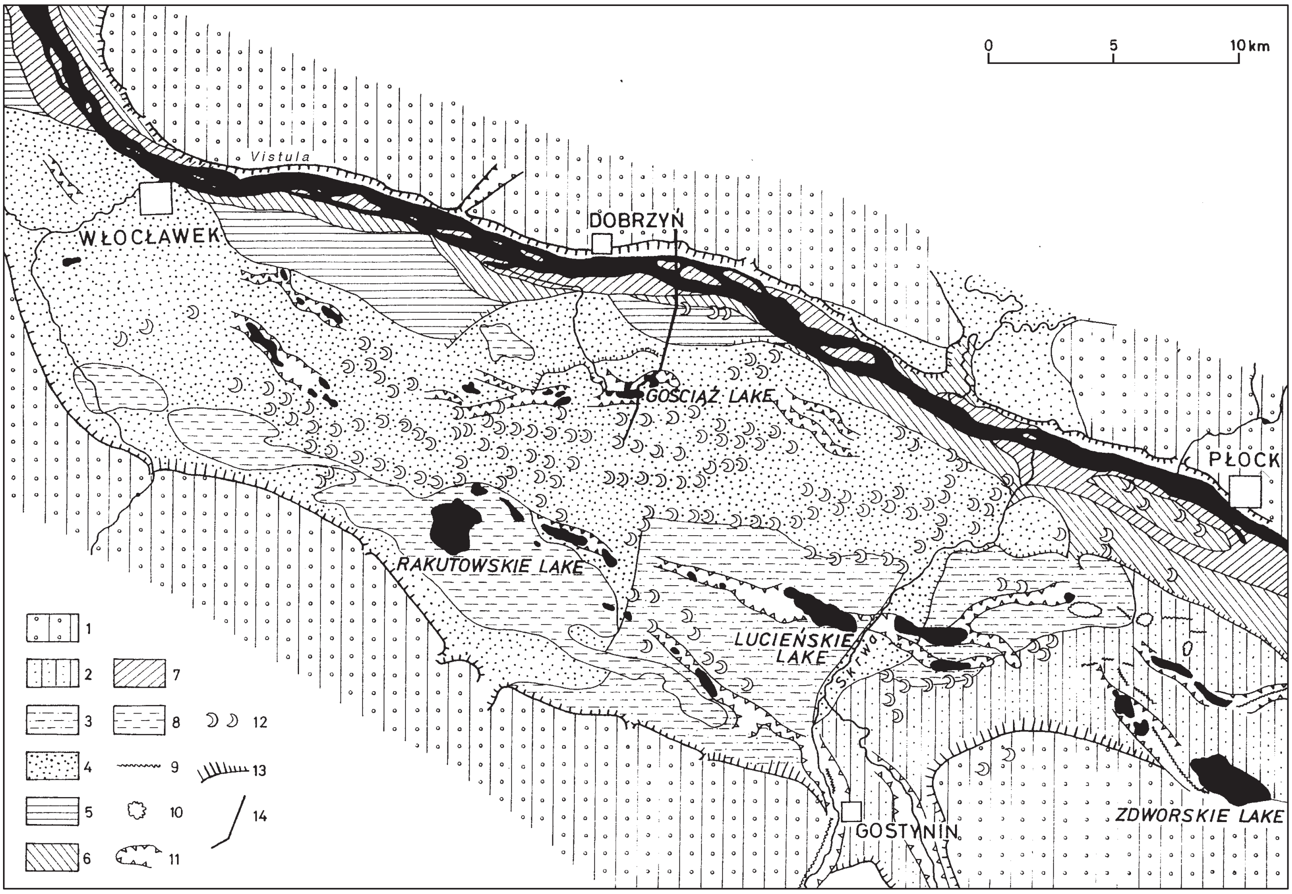

Fig. 2.7. Geomorphological map of the Płock Basin (compiled from: Baraniecka & Skompski 1978, Kopczyńska-Lamparska & Piwocka 1981, Skompski 1968, 1969, 1971, Starkel 1990, Wiśniewski 1976, 1987). 1 – morainic plateau, 2 – Ciechomice level originated due to deglaciation processes, 3 – glaciolimnic and glaciofluvial level 80–82 m a.s.l., 4 – glaciofluvial levels 62–77 m a.s.l., 5 – fluvial terrace III dated to the end of the Pomeranian phase, 6 – Late-Glacial fluvial terrace II, 7 – Holocene flood-plain (terrace I), 8 – lacustrine and swampy plains, 9 – eskers, 10 – kames, 11 – glacial channels, 12 – dunes, 13 – erosional edges, 14 – profile – see Fig. 2.5. Vistula river before the Włocławek dam construction is shown.

(9,620±300 ^{14}C BP – Florek et al. 1987). It corresponds to the terrace II (56–62 m a.s.l. – Starkel 1990) in the main part of the Płock Basin, previously described by Skompski (1961, 1969) as the Late-Glacial one. The end of the river sedimentation was documented also by the Preboreal age of the organic deposits covering the fluvial ones (Borówko-Dłużakowa 1961).

Holocene flood-plain (terrace I – 50–59 m a.s.l.), like the older two, is composed of sands with gravels in the lower part and muds in the upper part, with a total thickness up to 10 m. At present, following the Włocławek dam construction, terrace I has been inundated by the artificial lake waters.

2.3. PRESENT-DAY CLIMATIC CONDITIONS OF THE LAKE GOŚCIĄŻ REGION

Gabriel Wójcik & Rajmund Przybylak

Lake Gościąż lies in the centre of the forested Płock Basin at the height of 64.3 m a.s.l. and about 20 km SSE from Włocławek. The lake is surrounded by a forest that stretches in a close belt 10–15 km wide and about 55 km long along the left bank of Vistula River from Płock on the SE to Lubań on the NW. Climatically, this region belongs to the Land of Great Valleys (according to Romer 1949) and to the VII or central province in the agro-climatic classification of Gumiński (1948).

The present-day climatic conditions of the Gościąż region are discussed on the basis of data from nearby stations. The nearest station with all the needed basic meteorological elements is in Płock. Data from this station for the period 1951–1989 have been used for the description of temperature and precipitation. Directions and velocity of wind have been analysed with data from the decade 1951–1960 (Atlas Klimatyczny Polski 1971). Tables 2.1 and 2.4 contain mean (m) as well as the lowest (Nm) and the highest (Nw) values for long periods. The last two characteristics describe the range of changes of air temperature and precipitation at Płock over the period 1951–1989. The spatial distribution of precipitation of the lake area and its state in recent years (1981–1989) is described on the basis of data from Baruchowo, Brześć Kujawski, Duninów, Olganowo, Płock, and Włocławek.

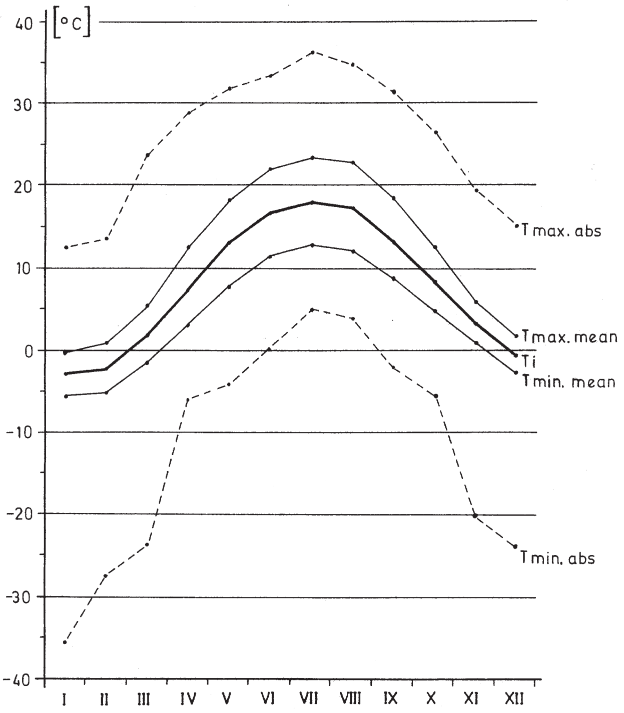

Fig. 2.8. Annual courses of selected thermic parameters at Płock over the period 1951–1989.

This region has the lowest precipitation in the entire Poland (Ostromęcki 1948, Wiszniewski & Chełchowski 1975, Tarajkowska 1982, Kożuchowski 1985, Paszyński & Niedźwiedź 1991 and others).

Air temperature

The monthly long-term mean temperatures (Ti) range from –2.8°C in January to 18.1°C in July, with the annual mean of 7.9°C (Tab. 2.1, Fig. 2.8). The annual temperature range is 20.9°C. The winter months (XII, I, II), as usually in central Poland, have average temperatures lower than 0°C. However, in particular years negative mean monthly air temperatures can also occur in November (when winter comes early) and in March (when winter is long and severe or comes very late). On the other hand, in some years the mean temperatures of winter months can reach positive values. The annual course of temperature (Fig. 2.8) is asymmetric: the first half-year (I–VI) is colder than the second one (VII–XII), and their average temperatures are 5.8°C and 10.0°C respectively.

The monthly mean temperatures show large fluctuations from year to year (Tab. 2.1). The temperatures of the cool half-year (X–III) have wide oscillations, and the biggest ones appear in January. The average for this month ranged from –12.7°C (in 1987) to +3.1°C (in 1975), with –2.8°C as the long-term average. In the warm half-year (IV–IX) the variability of temperature is smaller, and it is the smallest in August, when the monthly mean ranged from 15.1°C (in 1987) to 20.2°C (in 1951), with 17.4°C as average. The annual mean ranged from 6.2°C in the coldest (1987) to 9.4°C in the warmest year (1975), with the long-term average as 7.9°C.

The lowest (Nm) absolute monthly minimum air temperatures (Tmin abs.) ranged from –35.6°C in January (this is also absolute annual minimum air temperature) to 5.1°C in July. Negative absolute minima occur in 9 months (from IX to V), and this means that in the analysed period (1951–1980) only in three months (VI, VII and VIII) the frost never occurred.

The highest (Nw) absolute monthly maximum air

Table 2.1. Monthly and annual values of selected thermic parameters at Płock over the period 1951–1989.

Parameter \ Month		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Annual
	m	-2.8	-2.3	1.8	7.6	13.4	16.9	18.1	17.4	13.3	8.4	3.3	-0.2	7.9
Ti	Nm	-12.7	-11.1	-3.3	4.7	9.4	14.2	14.7	15.1	10.9	6.2	-1.2	-8.0	6.2
	Nw	3.1	3.9	5.7	10.5	15.9	20.4	21.6	20.2	16.2	11.5	6.7	4.4	9.4
	m	-5.5	-5.2	-1.6	3.0	7.8	11.5	12.9	12.3	8.9	4.8	1.0	-2.6	3.9
Tmin	Nm	-18.2	-14.2	-6.8	0.4	3.9	9.2	10.7	10.2	6.3	0.0	-4.0	-11.2	-2.5
mean	Nw	1.1	1.6	2.5	6.0	10.3	15.8	16.6	14.0	12.3	8.0	4.4	1.4	5.5
	m	-0.2	0.7	5.7	12.7	18.6	22.2	23.5	23.0	18.6	12.8	5.9	1.8	12.1
Tmax	Nm	-8.3	-6.9	0.4	8.2	14.3	19.0	19.4	20.1	14.5	9.4	1.3	-5.3	10.1
mean	Nw	5.2	7.0	10.3	16.2	21.9	26.0	27.4	26.4	22.8	16.2	9.2	5.3	13.8
	m	-16.4	-14.7	-10.0	-3.0	0.6	4.9	7.8	6.9	1.6	-2.4	-6.3	-12.4	-3.6
Tmin	Nm	-35.6	-27.7	-23.7	-5.8	-4.3	0.3	5.1	3.9	-2.2	-5.2	-20.2	-23.8	-35.6
abs.*	Nw	-3.6	-3.4	-2.5	0.1	5.4	9.0	10.6	9.8	4.4	2.7	-1.0	-3.6	10.6
	m	6.1	7.4	15.6	17.1	26.8	30.2	31.0	30.2	27.3	20.9	12.9	8.3	19.5
Tmax	Nm	0.6	-1.0	4.8	15.4	20.7	25.7	24.5	25.4	21.1	13.6	7.6	0.6	-1.0
abs.*	Nw	11.2	13.4	23.8	29.1	32.1	33.6	36.6	35.0	31.6	26.7	19.5	15.4	36.6

* – for the period 1951–1980
m – mean, Nm – the lowest, Nw – the highest

Table 2.2. Average dates of beginning and end of thermic seasons and their mean duration at Płock over the period 1951–1980 (B – beginning, E – end, N – number of days, P – percent of the year, T – air temperature).

Season	Criterion	Date		Duration		Mean
		B	E	N	P	T
Winter	$T_i \leq 0^oC$	11 XII	8 III	88	24.1	–3.5
Early Spring	$0^oC < T_i \leq 5^oC$	9 III	1 IV	24	6.6	2.5
Spring	$5^oC < T_i \leq 15^oC$	2 IV	31 V	60	16.4	10.3
Summer	$T_i > 15^oC$	1 VI	9 IX	101	27.7	17.9
Autumn	$5^oC < T_i \leq 15^oC$	10 IX	10 XI	62	17.0	9.9
Late Autumn	$0^oC < T_i \leq 5^oC$	11 XI	10 XII	30	8.2	2.5
Vegetative period	$T_i \geq 5^oC$	2 IV	10 XI	223	61.1	12.4

temperatures (Tmax abs.) in the year ranged from 11.2°C in January to 36.6°C in July (this is also the absolute annual maximum air temperature) in the 30-year period 1951–1980. This means that during the whole year, including winter, advections of warm air appear with temperature considerably higher than 0°C. The absolute annual amplitude of air temperature is 72.2°C.

Similarly the fluctuations (differences of Nw and Nm) of the other thermic parameters (Tmin mean and Tmax mean) are the biggest in winter and the smallest in summer.

For the duration of ice cover as well as of biological processes in the lake, selected intervals of daily average temperature are important for they correspond in the best way to thermic seasons (Tab. 2.2).

Summer and winter are the longest seasons in the region, and the transitional seasons, i.e. early spring and late autumn, are the shortest. The climatic seasons have great fluctuations from year to year with regard to the length, mean temperature, and the number of proper and not proper days (i.e. the days that fulfill or do not fulfill the thermic criterion for the given season). This is illustrated for Płock by the length of winter, which ranged from 13 days (1956/1957) to 125 days (1957/1958), with 88 days as average (Tab. 2.2). The mean temperature of the warmest winter is –0.9°C (1974/1975) and of the coldest one is –6.9°C (1955/1956), with –3.5°C as average. Summer is the longest season, ranging from 56 days (1978) to 140 days (1963) with 101 days as average. The mean temperature ranged from 15.9°C (1980) to 19.9°C (1951), with 17.9°C as average. The vegetation period, which includes spring, summer, and autumn, ranged from 185 days (1955) to 245 days (1951), with 223 days as average (61.1% of the year).

Table 2.3. Comparison of annual sums of precipitation for the stations located around Lake Gościąż over the period 1981–1989.

Station \ Year	1981	1982	1983	1984	1985	1986	1987	1988	1989	1981–1989
Baruchowo	588.8	427.1	550.7	459.4	574.9	455.5	695.1	554.4	345.0	516.8
Brześć K.	563.9	271.4	374.9	415.0	503.3	379.3	490.5	378.2	356.0	414.7
Duninów	701.5	414.3	508.5	534.8	–	587.8	526.0	521.2	405.0	524.9
Olganowo	617.9	402.0	500.9	589.9	574.8	450.3	577.3	469.1	338.0	502.2
Płock	569.6	384.7	460.3	501.4	494.5	474.1	592.9	467.7	368.9	479.3
Włocławek	626.2	334.2	494.6	458.8	574.8	468.7	585.7	506.2	364.0	490.4
Regional mean	611.3	372.3	481.6	493.2	544.5	469.3	577.9	482.8	362.7	488.0

Table 2.4. Monthly and annual sums of atmospheric precipitation (in mm) at Płock* over the period 1951–1989 (m – mean, Nm – the lowest, Nw – the highest, v – variability coefficient, σ – standard deviation).

Parameter \ Month	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Annual
m	29.7	25.6	29.6	31.5	52.9	66.1	82.5	61.5	42.9	35.7	42.0	39.8	539.8
Nm	6	2	7	2	14	16	27	4	4	.	14	4	366
Nw	65	69	57	102	178	149	216	162	118	137	197	92	819
v %	45	57	42	62	61	45	52	53	65	76	53	52	19
σ	13.2	14.9	12.5	19.5	32.0	29.7	42.9	32.6	28.2	26.7	21.9	20.8	103.1

* Data for the period 1951–1980 are taken from the station Płock-Radziwie and for the last years from the station Płock-Trzepowo

Atmospheric precipitation

The Kujawy region, where Lake Gościąż lies, is one of the areas with the lowest precipitation in Poland. Kożuchowski (1985) found that the average annual total precipitation in 1891–1980 did not exceed 550 mm. These results are confirmed by the data from the stations located around Lake Gościąż (Tab. 2.3). The average annual totals for the years 1981–1989 are low, ranging from 414.7 mm at Brześć Kujawski to 524.9 mm at Duninów, and the average from 6 stations is 488.0 mm.

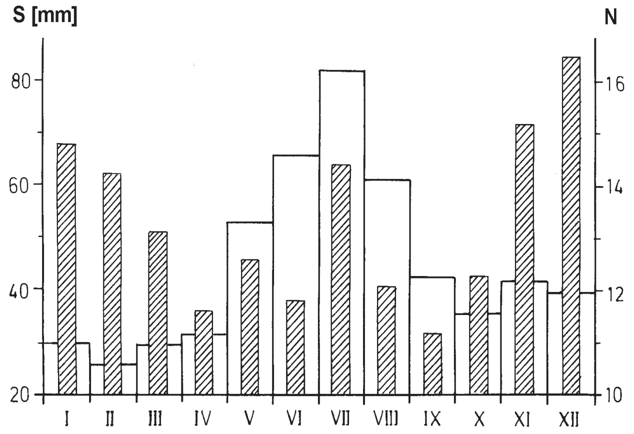

Fig. 2.9. Mean monthly precipitation sums (S – open bars) over the period 1951–1989 and mean monthly number of days (N – hatched bars) with precipitation ≥0.1 mm at Płock over the period 1951–1980.

The mean annual course of precipitation for Płock (Tab. 2.4, Fig. 2.9) shows minima in February (25.6 mm) and October (35.7 mm) and maxima in July (82.5 mm) and November (42.0 mm). Precipitation in the warm half of the year (IV–IX) equals 337.4 mm (63% of the yearly sum), in the cold half of the year 202.4 mm (37% of the yearly sum). The long-term variability of precipitation is illustrated by the lowest and highest monthly sums from the period 1951–1989 as well as the variability coefficients and standard deviations (Tab. 2.4). The sums of precipitation in the cold season are more stable than the sums in the warm part of the year.

In Płock the annual total precipitation ranged from 366 mm in 1951 (67.8% of the long-term average) to 819 mm in 1970 (151% of the long-term average) (Tabs 2.4, 2.5). In Table 2.5 the annual sums of precipitation are presented with the definition of the separate years ac-

Table 2.5. Annual sums of precipitation at Płock in comparison with the mean annual sum for the period 1951–1989.

Year	Annual sums		Classification of the year acc. to Kaczorowska (1962)
	mm	%	
1951	366	67.8	very dry
1952	598	110.7	humid
1953	444	82.2	dry
1954	498	92.2	average
1955	528	97.8	"
1956	494	91.5	"
1957	572	105.9	"
1958	538	99.6	"
1959	379	70.2	very dry
1960	704	130.4	very humid
1961	566	104.8	average
1962	595	110.2	"
1963	423	78.3	dry
1964	422	78.1	"
1965	651	120.6	humid
1966	669	123.9	"
1967	720	133.3	very humid
1968	507	93.9	average
1969	519	96.1	"
1970	819	151.7	extremely humid
1971	471	87.2	dry
1972	649	120.2	humid
1973	582	107.8	average
1974	619	114.6	humid
1975	482	89.3	dry
1976	495	91.2	average
1977	682	126.3	very humid
1978	662	122.6	humid
1979	561	103.9	average
1980	539	99.8	"
1981	570	105.6	"
1982	385	71.3	very dry
1983	460	85.2	dry
1984	501	92.8	average
1985	494	91.5	"
1986	474	87.8	dry
1987	593	109.8	average
1988	468	86.7	dry
1989	369	68.3	very dry
1951–1989	540	100.0	average

Table 2.6. Monthly and annual means of the number of days with precipitation ≥0.1, ≥1.0, and ≥10.0 mm at Płock-Radziwie over the period 1951–1980.

Month / Precipitation	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Annual
≥ 0.1	14.8	14.2	13.1	11.6	12.6	11.8	14.4	12.2	11.2	12.3	15.2	16.5	159.9
≥ 1.0	8.2	7.6	7.7	7.6	8.8	8.9	10.8	8.8	8.1	7.8	9.1	9.6	103.3
≥ 10.0	0.2	0.2	0.4	0.6	1.4	2.0	2.6	2.1	1.1	0.7	0.7	0.5	12.5

cording to the classification of Kaczorowska (1962). In the analysed period there were 4 very dry years (1951, 1989, 1959 and 1982), 8 dry, 17 average, 6 humid, 3 very humid years (1967, 1960, and 1977), and 1 extremely humid year (1970).

The frequency of days with different precipitation values in Płock in the period 1951–1980 is given in Table 2.6. The number of days with precipitation (≥0.1 mm) ranged from 11.2 (IX) to 16.5 (XII), with 160 days as the annual average. In the yearly course there are 3 minima (in IX, IV and VI) and 3 maxima (in XII, VII and V) of frequency. The mean number of days with moderate precipitation (≥1.0 mm) is 103 and with high precipitation (≥10.0 mm) is 12.5. Moderate precipitation appears with almost equal frequency during the year. High precipitation appears most frequently in summer (2.6 in July) and least frequently in winter (in January and February once in 5 years).

Directions and velocity of wind

The anemologic relations, following the average long-term distribution of pressure, are modified in the Płock Basin by the latitudinal direction of Vistula River valley. Therefore in Płock the western winds are the most frequent (24.9%), together with the SW winds (14.2%) and NW winds (8.7%), so the winds with western component make up almost the half of the frequencies (Fig. 2.10). Winds from NE (3.9%) and N (4.2%) are the least frequent. The frequency of calm is high (15.7%), and near the lake even higher because of the surrounding forest.

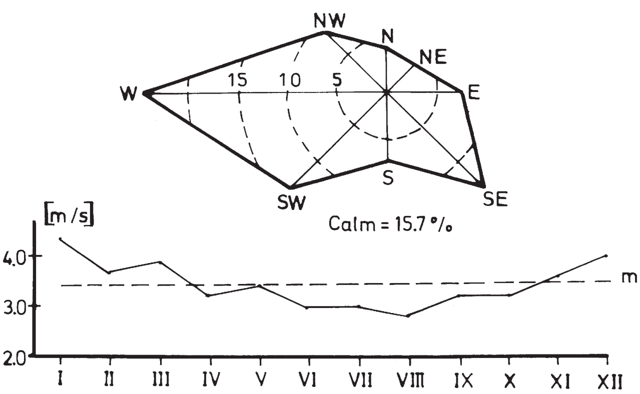

Fig. 2.10. Frequency of occurrence of wind directions and calms (%) as well as the annual course of wind velocity (m/s) at Płock over the period 1951–1960.

The annual course of the wind velocity is shown on the lower graph on Fig. 2.10. The monthly mean ranges from 2.8 m/s in August to 4.4 m/s in January, with 3.4 m/s as yearly average. The forest around Lake Gościąż reduces the wind velocities and, as a consequence, reduces water circulation in the lake.

2.4. HYDROLOGICAL CONDITIONS OF THE GOSTYNIŃSKIE LAKE DISTRICT

Zygmunt Churski

The Płock Basin, where Lake Gościąż is located, occurs in the Vistula River drainage basin, at the inter-basin area to be more specific (Fig. 2.11). Hydrological conditions of this area result from a complicated alimentation system, the latter being controlled by relief and river-network development after the retreat of the Vistulian ice-sheet. Due to the high water permeability of the surface deposits, the river-network is poorly developed. Excess water has an underground outflow. Few streams flow through postglacial depressions, which are occupied by partially overgrown lakes and wetlands.

The hydrographic axis of the Płock Basin is the Vistula River, which drains the adjacent areas during low-water periods and feeds the terrain below, mainly the flood terrace, during inundations.

Since 1969 the Vistula has been dammed, and water level has risen by ca. 10.5 m. The area of the water reservoir thus formed is 70.4 km^2. The reservoir is 58 km long, average ca. 1.2 km wide, and 2.4 km in maximum width. Due to the damming ca. 20 km^2 of the valley is flooded. The reservoir regime is controlled by power-plant operations. As the reservoir storage capacity is rather low, water level below the dam at Włocławek reflects the middle and upper Vistula regimes (Fig. 2.12).

Additional supply of water to the Płock Basin, which presently is a broad inter-basin area of the Włocławek Reservoir, originates from precipitation or from groundwater discharge from the upland to the Vistula valley.

Due to insufficient number of borings, groundwater in the Basin is not thoroughly studied. The borings available provide evidence for three distinct aquifers. Their character and position depends on the geological structure and lithology of particular strata (Adamiak et al. 1969).

The Pleistocene waters have been investigated best. They occur in the very permeable sand and gravel of the terraces of valleys and ice-marginal valleys (pradolinas). The water table oscillates from 1 to 4 m below the ground surface. In the case of this aquifer the water table is free. However, in some areas the water table is deeper and perched. Differentiation in perching is controlled by the depth. The perched waters most frequently occur at the contact between the Pleistocene deposits and Pliocene deposits transformed by glacitectonic processes.

The Pliocene waters usually occur in isolated pockets within clay matrices at depth of 20–30 m below the ground surface. Their pressure depends on the size of the pockets and the degree to which they are isolated from the Pleistocene waters. Pliocene waters in contact with the Miocene ones are characterized by larger perching.

The Miocene waters are most abundant and are