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.

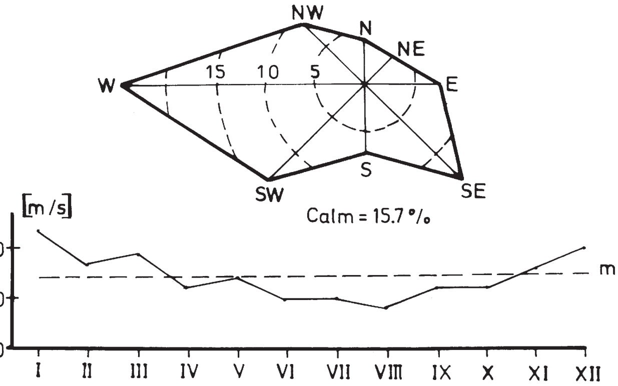

Fig. 2.10. Frequency of occurrence of wind directions and calms (%) as well as the annual course of wind velocity (m/s) at Płock over the period 1951–1960.

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

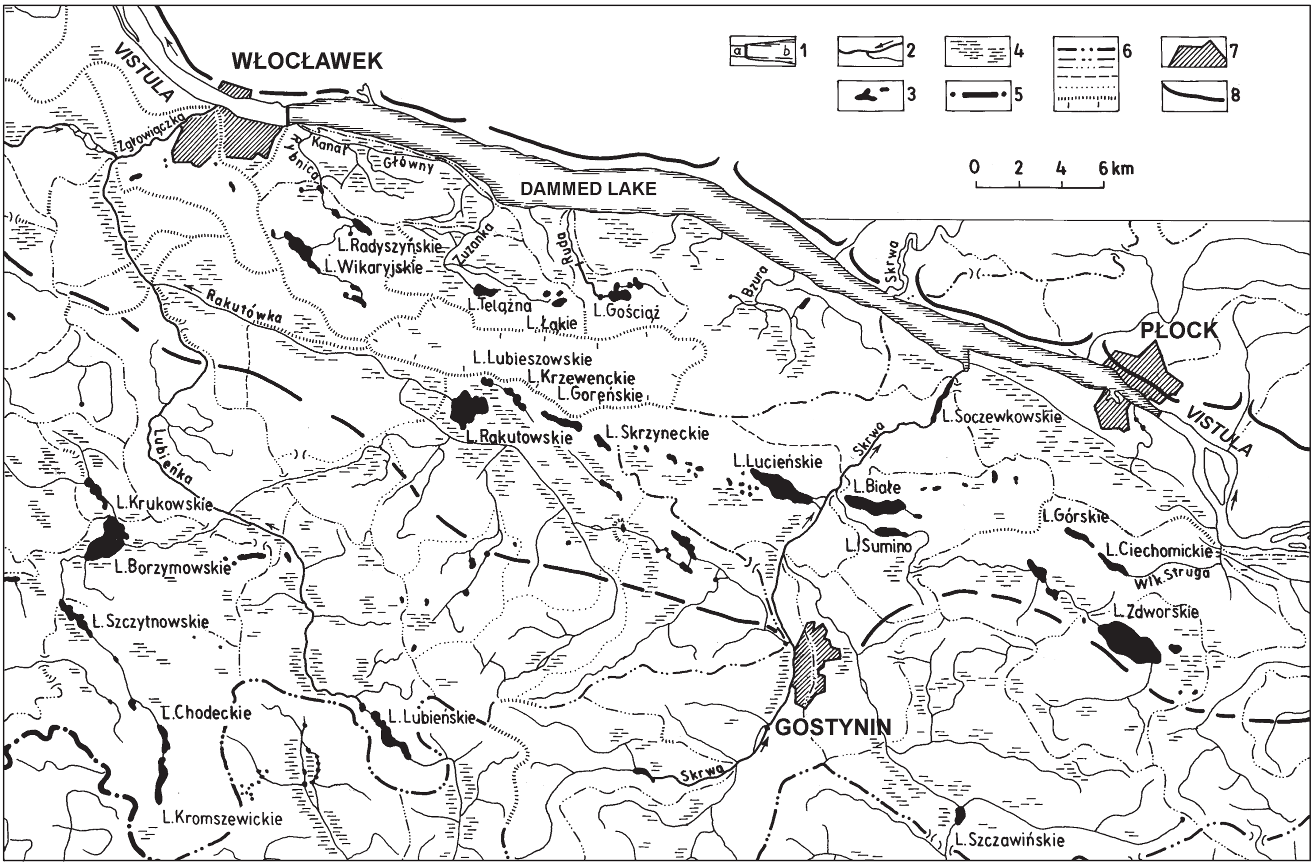

Fig. 2.11. Hydrological map of the Płock Basin. 1 – (a) Vistula River, (b) reservoir, 2 – streams, 3 – lakes, 4 – bogs, 5 – Vistula – Odra watershed, 6 – watersheds of lower order, 7 – towns, 8 – scarp of morainic plateau.

strongly perched. The upper Miocene aquifer occurs at the interface of the Pliocene deposits and stabilizes close to the surface of the ground. The deeper Miocene waters, have characteristics of artesian waters, and their table stabilizes several meters above the ground surface. The presence of these aquifers is confirmed by geoelectric measurements made in 1992 and 1993. The groundwaters described above can contribute to numerous lakes as well as to streams in trough-like depressions. These waters follow the course of the Vistula valley.

Lake Gościąż, in its initial phase, was fed by both the Pleistocene and Tertiary waters. The entire lake basin was on the route of this groundwater flow. At present, after the filling of Lake Gościąż with deposits, contribution of the Pleistocene waters is dominant. However, the supply of Tertiary waters is also possible because the Pliocene layer, which is glacitectonically transformed, does not form a tight barrier to strongly perched waters occurring mainly in the Miocene deposits.

Two zones can be distinguished in the surface runoff of the Płock Basin. The internal zone is drained by four tiny streams which directly discharge into the Vistula reservoir or to the Kanał Główny. These streams are: Rybnica, draining lakes Wójtowskie, Wikaryjskie, and Radyszyńskie; Zuzanka, outflowing from Lake Telążna; Ruda, draining the Lake Gościąż catchment; and Bzura, draining the wetlands near the reservoir. These streams are also fed by groundwaters draining the area in the central part of the basin with no surface runoff (Fig. 2.11).

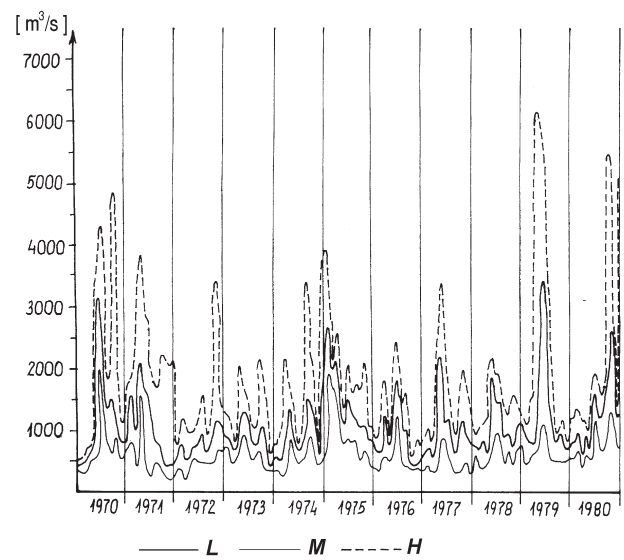

Fig. 2.12. Course of the mean monthly discharges of Vistula at Włocławek (source: Institute of Meteorology and Water Management). L – low flow, M – moderate flow, H – high flow.

Table 2.7. Basic morphometric data on the lakes of the Płock Basin (after Choiński 1992 and Jaczynowski 1929).

No.	Name of lake	Area in ha	Max. depth in m	Volume in m^3 $\times 10^3$
1	Górskie (Ciechomskie Wlk.)	43.1	5.5	1 261
2	Ciechomskie (Grabińskie)	41.9	6.8	1 833
3	Łąckie Wielkie	61.2	7.0	2 335
4	Łąckie Małe	25.0	2.0	250
5	Zdworskie	352.8	5.4	8 045
6	Sęděń	14.2	4.4	399
7	Jeziorce	4.6	3.1	91
8	In Sęděń Wielki	3.0	1.5	25
9	Białe	150.2	31.3	14 885
10	Drzesińskie	13.8	2.1	175
11	Lubaty	9.5	2.4	123
12	E of Lubaty	5.1	1.5	40
13	Lucieńskie	203.3	20.0	17 016
14	Sęděń Mały	6.0	2.5	65
15	In Sęděń Mały	3.7	1.0	35
16	Sumino	35.6	7.0	1 235
17	Czarne (E of Nagodowo D)	4.2	4.0	90
18	Czarne (W of Goreń)	4.8	3.0	70
19	Czarne	8.8	7.0	320
20	Radziszewskie	8.5	2.9	125
21	Goreńskie	55.3	6.1	1 672
22	Gościąż (Gąsak)	13.9	2.1	175
23	Kocioł	4.1	16.6	250
24	Krzewenckie	38.1	7.6	1 674
25	Lubiechowskie	16.8	4.0	459
26	Popówek	5.2	4.0	105
27	Przytomno	36.6	9.0	1 760
28	Rakutowskie	300.5	2.8	3 228
29	Skrzyneckie	29.2	10.3	1 775
30	Trzebowskie	10.7	2.0	155
31	Zuzinowskie	10.5	6.4	280
32	Żłoby	26.8	0.4	40
33	Łuba	12.5	–	–
34	Grzywno	4.3	4.5	85
35	Czarne (S of Glinki)	4.8	6.5	151
36	Czarne (near Radyszyn)	3.0	4.0	81
37	Dziemionek	2.4	1.8	36
38	Jedwabno	3.9	2.2	45
39	Łąkie	5.8	6.0	160
40	Radyszyn	31.1	10.9	1 456
41	Rybnica	7.6	4.6	173
42	Widoń	13.8	3.6	184
43	Wikaryjskie	65.9	13.6	2 750
44	Wójtowskie N	10.6	6.5	334
45	Wójtowskie SE Duże	20.6	8.0	633
46	Wójtowskie SW Małe	9.2	8.5	356
47	Chrapka	5.6	1.0	65
48	Dzielno	2.9	7.2	85
49	Łąkie	14.8	2.8	340
50	Święte	4.1	4.6	83
51	Telążna	25.6	2.7	342
52	Brzózka	3.1	1.3	18
53	**Gościąż** (na Jazach)	41.7	24.0	2 073
54	Mielec	6.9	1.5	40
55	Wierzchoń (na Jazach)	15.3	1.7	131

The outer zone, adjacent to the upland, is drained by two large streams in troughs that collect waters from the upland margin as well. The largest one Rakutówka, departs near Gostynin and flows westward to Zgłowiączka. Its upper course was the tributary of Skrwa until the mid-19th century. The Skrwa drains the eastern part of the area and discharges into Vistula near Płock.

The Płock Basin is known for numerous lakes. According to Marszelewski (1993) there are 55 lakes larger than 1 ha here (see Tab. 2.7; Fig. 2.13). These glacial lakes use troughs or meltwater depressions, and many of them are nearly overgrown.

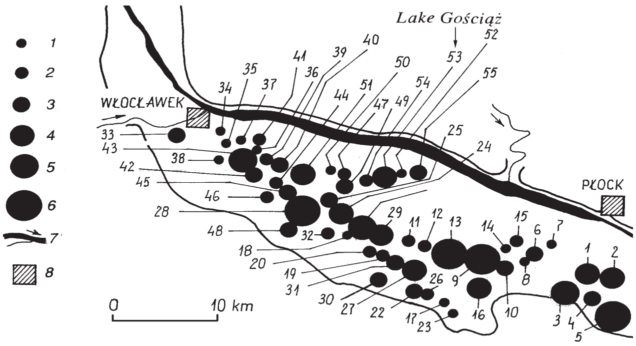

Fig. 2.13. Sizes of lakes in the Płock Basin (after Marszelewski 1993). 1–6 areas of lakes presented in Tab. 2.7 (1: 1–5 ha; 2: 5–10 ha; 3: 10–25 ha; 4: 25–50 ha; 5: 50–100 ha; 6: 100–400 ha), 7 – rivers, 8 – towns.

Both the streams and lakes are mainly fed by groundwaters, which control the regime, temperature, and chemistry of waters. This situation results from position of surface waters in the Vistula valley.

The water level of lakes and streams is subject to seasonal oscillations, which varied in a narrow range under natural conditions due to overwhelming contribution of groundwaters. At present, however, the annual oscillations reach up to 1 m because of the canalization. In summer of 1994 the water level of numerous lakes was lowered by 1 m when compared with the average values.

Numerous wetlands and peatbogs also occur in the areas as remnants of the gradually disappearing lakes. They are mainly fed by groundwaters and occur around lakes, at the bottoms of meltwater depressions, and in the vicinity of the Włocławek Reservoir. Like lakes these mires significantly contribute to water circulation and are habitats of unique swamp vegetation.

The river network has been changed due to land reclamation, artificial drainage, and recreational and tourist management of lakes. Most dangerous and threatening is the increase in pollution of surface and groundwater, mainly associated with location of resorts and lack of adequate sewage-treatment plants. These factors are particularly harmful because numerous tiny lakes and swamps are very sensitive due to weak water exchange.