Table 3.1. Grain-size composition of deposits in the area of the lakes Na Jazach.

Type of deposit	Grain sizes in %					
	above 2.5 mm	2.5–1.0 mm	1.0–0.5 mm	0.50–0.25 mm	0.25–0.10 mm	below 0.1 mm
Residual glacial deposits	24.0	12.1	37.0	23.8	2.3	0.8
Glacifluvial sands	0.2	2.7	38.2	41.4	9.9	0.6
Fluvial sands	0.4	0.9	12.3	48.5	19.7	12.2
Eolian sands	0.0	0.3	6.2	31.2	49.1	13.2

sional edge between the terraces. South of lakes Na Jazach the dune complexes are usually arcuate and reach to 12 m in height. At the southern and eastern margins of the meltwater depressions there are only singular small dune ridges stretching from NW to SE. Probably the dunes originally overlaid the dead ice, and because of that some of these dunes end abruptly at the edges of the lake basins. At the base of the dunes the layers of fossil soils and weathering zones are lacking. The dunes are built of fine sands (Tab. 3.1) containing locally fair amount of muscovite.

Melting of dead ice and formation of outwash took place after cessation of the eolian processes. Because of the lack of free surface runoff, marginal fragments of meltwater depressions played the role of reservoirs of limnic sedimentation. The plains related to this episode are covered with fine sands or silty sands with thin silty interbeddings (Fig. 3.1). These deposits exhibit an indistinct horizontal lamination (Kotarbiński & Urbaniak-Biernacka 1975).

Holocene deposits and forms

In the deeper meltwater depressions, limnic sedimentation started in the Bølling or Allerød and took place without major interruptions also at the beginning of the Holocene. However, in the eastern part of Lake Gościąż geomorphological and sedimentological changes occurred. In the borings located directly at the eastern shore, it was found that the limnic sediments accumulated around 11,800 ^{14}C BP became covered with a fine sand layer 4.4–6 m thick. The surface of the lake terrace there is adjacent to a landslide slope. Formation of the latter took place after deposition of the limnic sediments. The change in the shore morphology caused intensified sedimentation in the nearby part of the lake. The slopes and spring-niches at the southern shore of Lake Gościąż and at the springs of the Ruda stream are much younger. The 5–7 m steep scarp of the lake that incises the aquifer is subject to landslide processes. The beach is built of the sands transported towards the lake from numerous springs.

The Holocene limnic sediments of the present-day lakes Na Jazach consist of carbonate and carbonate-sulphide gyttjas. The latter are common in Lake Gościąż. The meltwater depressions occupied at present by the peatlands, are filled with carbonate gyttjas being up to 4 m thick. The peats overlying the gyttjas are 1.2–4 m thick. Swamp peats with *Phragmites* and wood peats predominate there. The peats of the transitional peatlands are 1.5–2 m thick and occur in the meltwater depressions located mainly on the northern side of the system of lakes Na Jazach. Lake Mrokowo is surrounded by moss peat.

When the activity of the Ruda stream began, the gyttjas became locally covered with deposits of the alluvial fans. These deposits consist of sands of various grain sizes and with plant detritus and chunks of charcoal.

3.2. BATHYMETRY AND MORPHOMETRY OF LAKE GOŚCIĄŻ

Zygmunt Churski

Lake Gościąż was sounded for the first time by Jaczynowski in 1925 (Lencewicz 1925). The depths were measured every 20 or 30 meters by means of a string with a weight. Distances between sounding points were marked on a rope extended on floats. Positions of transects were determined by geological compass. The water table of the lake during the measurements was at a level of 63.9 m a.s.l. As a result of this sounding the maximum depth was determined as 25.8 m, with the lake area as 46.9 ha. Moreover, Jaczynowski (1929) worked out the lake morphometry based on the established grid.

After initiation of the studies on the deposits of Lake Gościąż, which required precise determination of sounding coordinates, new measurements were undertaken in order to obtain an up-to-date and a very detailed grid of the lake and its surrounding. Toruń Military Unit No. 1440 under the supervision of Lt. J. Ciuba, M. E., performed bathymetric (echosounding) and topographic measurements, which allowed for working out a new plan (Fig. 3.2).

Application of echosounding and modern surveying techniques enables precise positioning of sites of sounding and levelling as well as for precise determination of depths from water table to the surface of the bottom deposits. When a weighted line (sounding line) is used, its submergence into the upper layer of lake deposits, even down to 0.5 m, has to be taken into consideration. Moreover, Jaczynowski's measurements of 1925 did not include large parts of the lake. Thus, a new plan was necessary.

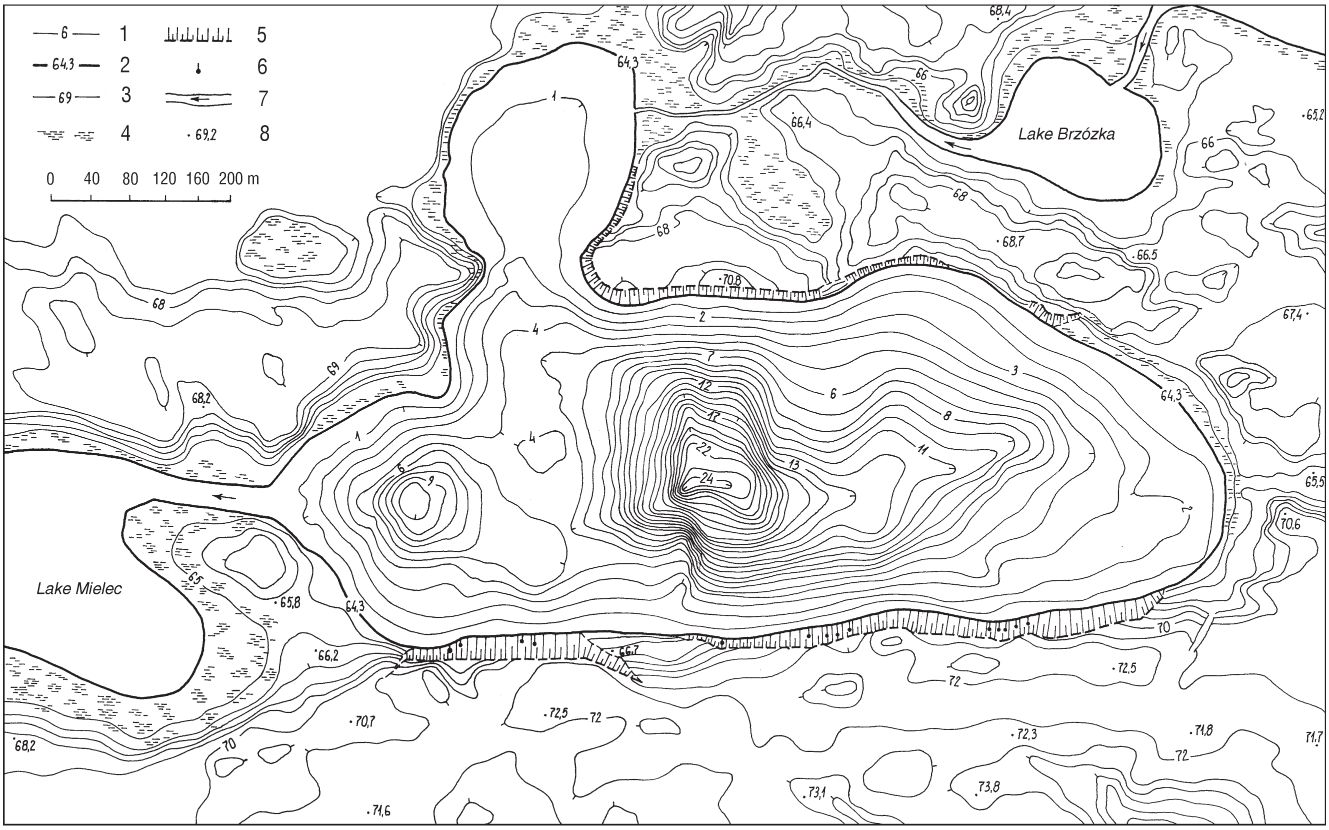

Fig. 3.2. Bathymetric plan of Lake Gościąż. 1 – isobaths, 2 – shoreline, 3 – contour lines, 4 – wetlands, 5 – scarps, 6 – springs, 7 – streams, 8 – elevation in m a.s.l.

The plan with isobaths and contour lines every 1 m provides a detailed picture of relief of the bottom and surroundings of the lake. In the relief of the lake basin there are two distinct deep hollows, with steep western slopes and gentle eastern ones. Asymmetry also extends to the basin slopes above the lake. The southern slope of the lake is steep, with well-defined landslides and underwater landslide lobes. On the other hand, the northern slope is much lower and more gentle. Large contrast also is apparent between the relief of the bottom and surroundings of the lake due to different origin of these units.

When analysing the present plan of the lake bottom one should bear in mind that the lake basin has been filled with lacustrine deposits. The sediment cores and cross-sections in which primary bottom is included (Więckowski 1993) show that the initial outline of the lake bottom is only partially preserved in the present relief of the lake. Despite the fact that the deposits are several meters thick (up to 20 m), two well-defined deep hollows remained in the central and western parts. These hollows have existed since the lake formation and provide evidence of calm sedimentation. On the other hand, the hollows have been neither preserved in the northern bay (Tobyłka) nor in the eastern part, where sedimentation was intensified due to the stream flowing from Lake Brzózka to Lake Mielec as well as due to landslide processes.

Analyses of the sediment cores provide evidence for the existence of five definite deep hollows at the initial phase of the lake development (Więckowski 1993). The maximum depth of the lake was at the site of the present deepest spot and reached ca. 44 m. Thus, morphometric data presented below refer to the present bottom relief, which preserved the original outline in the central part only.

The plan provides evidence that Lake Gościąż occupied much larger area and was confluent with the neighbouring lakes. A higher elevation of the original water table is evidenced by wetlands in the vicinity of lakes and by the fragments of preserved terraces, which are well-defined east of the lake.

The morphometric data of the lake are as follows:

Area (A)	41.7 ha
Maximum length (L)	1168 m
Maximum width (B)	735 m
Mean width (A/B)	357.2 m
Elongation (L/B)	1.59
Volume (V)	$2\,073 \cdot 10^3$ m^3
Maximum depth (D_{max})	24 m
Mean depth (V/A)	4.97 m
Relative depth ($D_{max}/\sqrt{A}$)	0.04
Depth index (D_{mean}/D_{max})	0.21
Shore line length (S)	3 452 m
Development of shore line	1.51

Elevation of water table	64.3 m a.s.l.
Mean bottom gradient	4°29'
Mean gradient of the slope from the isobath of 16 m to 24 m	11°21'

The comparison of the above data with the corresponding parameters of Jaczynowski (Lencewicz 1925) proves that the lake area is now smaller by ca. 5 ha and shallower by ca. 2 m. The change in the area can result from permanent overgrowing of the lake. The difference in the depths can be partly attributed to the low accuracy of earlier measurements.

Analysis of morphometric data shows that Lake Gościąż can be assigned to the medium-sized lakes of the Gostynińskie Lake District. It is the second deepest lake in the region (after Lake Białe). If the original basin (without lake deposits) were considered, however, Lake Gościąż would be the deepest one in the region (44 m). Lake Gościąż is also unique with respect to gradient of the slopes. Although the average bottom gradient (4°29') can be accepted as a high mean value, the gradient of the deep hole, below 16 m, reaches 11°21', which is an extreme value rarely encountered. The average gradients of other lakes vary from 2° to 5°. Moreover, relative depth (ratio of maximum depth to the square root of the area) of Lake Gościąż is 0.04, a rather large value as well. This value allows comparison of vertical and horizontal dimensions of the lake basin, and is more characteristic for cirque than for lowland lakes.

Large relative depth of similar order of magnitude has been recorded in the case of Lake Dzielno (0.042) and Lake Kocioł (0.082) (see Churski, Chapter 2.4). For comparison, the relative depth of Lake Zdworskie is 0.003 and that of Lake Rakutowskie 0.0013 (Jaczynowski 1929).

It should be emphasized that the present plan can constitute background for tracing further changes in depth, area, and shore line. In order to make such surveying possible, a network of benchmarks corresponding to the present-day topographic framework was established at the lake.

3.3. HYDROLOGY AND SEDIMENTATION CONDITIONS IN LAKE GOŚCIĄŻ

Zygmunt Churski & Włodzimierz Marszelewski

Lake Gościąż is located in the Vistula River valley and belongs to the drainage basin of the Ruda, which is the left tributary of the Vistula. The topographic catchment of Lake Gościąż occupies an area of ca. 588 ha, including the Lake Gościąż area of 41.7 ha, i.e. 7.1% (Fig. 3.3). The highest site in the lake drainage basin is located on the watershed in the southern part of the catchment (97.5 m a.s.l.), while the lowest point occurs where the Ruda flows out of the lake (64.3 m a.s.l.). The absolute difference in elevation reaches 33.2 m. The surface of the lake drainage area reveals a slope from SE to NW and therefore controls directions of surface and groundwater drainage. Directions of groundwater flow have been determined on the basis of groundwater contour lines (Fig. 3.3). Surface deposits of the drainage basin are mainly highly permeable loose sands. Almost the entire area of the drainage basins is covered with forest.

Maximum depth of the lake at the period of its formation was 44 m. At present the lake basin is half-filled with nearly 20 m of sediments. Mean rate of accumulation is more than 1 mm per year. Regarding that the lake occurs in flat, forested terrain and that no large river enters it, this rate is large. The nature of the deposits provides evidence of continuous sedimentation (Goslar, Chapter 6), which indicates permanent water supply to the lake and exceptional regularity of seasonal changes in thermal regime and water dynamics.

In order to describe the lake hydrology as well as its thermal regime and water dynamics, systematic field studies (in monthly intervals) were performed in 1990–1993. Hydrogeological, hydrological, and limnological investigations have been organized to elucidate lake stability and formation of laminated deposits.

The field studies, lasting only three years, were attempted to explain conditions of water supply to the lake and their seasonal and multi-year stability, as well as to explain variability in water level, thermal conditions, and chemistry of lake water and to gain insight into water balance and water regime in the lake catchment. Particular emphasis was placed on the contribution of groundwater to the lake budget. In order to determine conditions at the contact of groundwater and lake water, geoelectrical measurements were performed at 40 spots along 4 meridional and parallel transects on each side of the lake. The layout of gauging spots allowed the study of aquifers in the direct vicinity of the lake, and evaluation of possibilities of water supply to the lake from deeper aquifers. The measurements were taken by vertical electroresistance sounding method in the symmetric scheme of Schlumberger. Power line separations AB/2 were of 120 to 200 m, which facilitated penetration to a depth of ca. 70 m. The network of measurement sites is presented in Fig. 3.3.

The main stream in the drainage basin of Lake Gościąż is the Ruda stream, which flows out from swamps in the trough upstream of Lake Wierzchoń, ca. 2.7 km upstream from Lake Gościąż. The Ruda flows through four lakes (Wierzchoń (Jazy), Brzózka, Gościąż, and Mielec) and discharges into the Włocławek Reservoir. The Ruda is 9 km long. In its middle course it is dammed by a weir ca. 3 m high, which is also a water discharge gauging site. The backwater affects the upper course of the Ruda, including Lake Gościąż itself. Despite the damming some seasonal variability in water level