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The Laka Lake

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Abstract: The main aim was to establish the precise altitude of the Laka Lake and to draw its ground plan and bathymetric map. Geographic position and morphometric characteristics of catchment area of this smallest Šumava lake are also described. Differently from the other Šumava lakes, the Laka Lake is interesting by its relatively intensive silting processes.

Keywords: bathymetric map, the Laka Lake, the Šumava Mountains

1. Position and name of the lake

The Laka Lake is situated at the north-eastern slope of the Debrník Mountain (1336 m a.s.l.) known also under the name of Plesná Mountain – this name is given for instance by the tourist map 1 : 50 000. The name of the mountain is derived from the Slavonic root "debr" that means deep valley. The data on the altitude of the lake level differ. For the first time F. Hochstetter established it as 1065 m in 1856 on the basis of its own measurement. In 1878, the Military Institute of Geography in Vienna proceeded to a new mapping there – the maps 1 : 75 000 and 1 : 25 000 give its altitude as 1096 m a.s.l. The lake is also mentioned by the forest map of the local Hohenzollern estate (Karte der Forstverwaltungsbezirke 1 : 33 120) where its altitude is indicated as 1080 m a.s.l. The Základní vodohospodářská mapa ČSR 1 : 50 000 made out on the basis of the Základní mapa ČSSR gives the altitude of 1085 m a.s.l. (Sheet 22–23 Kašperské Hory). The tourist map Šumava – Povydří 1 : 50 000 gives the altitude of the lake as 1085.6 m a.s.l. The Základní mapa ČSSR 1 : 10 000 does not directly give the altitude of the lake, but according to it the lake is situated between the contour lines 1085 and 1090 m. Because of the mentioned differences, one of the aims of our research was to determine the exact altitude of the lake with the help of the levelling order from a fixed point of known altitude. The precise geographical localization of the lake was determined already by Švambera (1913) as 49°6'30"of north latitude and 13°19'36" of east longitude. With the help of the GPS pocket apparatus, the following geographical co-ordinates of the lake were determined: 49°6'44"of north latitude and 13°19'45"of east longitude.

The name of Laka appears for the first time on the Kreybich map from the year 1831. When the stable cadastre was being compiled in 1837, the planar dimensions of the lake were indicated for the first time. The lake is called here Laka See. An older special map (Spezialkarte v. Böhmen 1 : 144 000) brings already the lake drawn with its contours corresponding to the scale of the map.

In literature and on maps, the following names of the lake have progressively appeared: Laka or Lakka, also Lackensee or Laccensee, in Czech literature it was also called Pleso, Mlacké jezero Lake or Mláka.

2. Geographical particularities of the Laka Lake

Differently from the other Šumava lakes, the Laka Lake basin is not situated immediately below the foot of the lake wall. The linear distance of the Debrník Mountain top and the bank line of the lake is 1240 m, the relative height of the lake wall with respect to the surface level is 250 m. The lake has the shape of a relatively regular rectangle and is oriented from SSW to NNE. The dam of the lake runs approximately perpendicularly to the outflow and is of artificial origin. The owner of the estate Kryštof Abel built it approximately in 1730 in view to increase the quantity of water in the lake. As indicated by Švambera (1912), the dam of the lake was entirely reconstructed in 1888. The elevated dam of the lake helped then to increase the water flow in brooks and in the canal when floating timber. The lake used to have a smaller area than today which is proved by many stumps on the grounds of the lake.

V. Švambera mentions a great quantity of trout he saw in the lake. According to the district forest officer Weiss, every year some 400 to 500 trouts were fished away from the lake without any visible decrease of the number of fish. Because of the progressive acidifying of the accumulated water, the fish disappeared from the lake probably already in the 1950's. Today no fish live in the lake although an attempt to reintroduce the trout was made in 1960 (Veselý, 1994).

The Laka Lake makes the impression of an agreeable park lake. On its banks there are larger rock blocks that nevertheless do not reach the dimensions of those at the other lakes. A particularity of the lake is a considerable intensity of silting processes. This is connected with a low depth of the lake basin and with the occurrence of many islands that are floating or are attached to the ground and the position of which is changing with time. This is also due to the fact that Laka is the only Šumava lake where a typical cirque has not developed. Both affluents coming to it from the SSE contribute to its silting. This is the most important during summer storm flushes and during spring melting of the snow from a relatively large water catchement area of the lake. The southern part of the lake has been slowly changing into a swamp with progressing spruce vegetation.

3. History of the research on the Laka Lake

F. Bayberger initiated the research on the Šumava lakes as soon as in 1886. Ten years later, P. Wagner started with complex bathymetry of the Šumava lakes (with the exception of the Malé Javorské jezero Lake, where V. Švambera did the first explorations). Among other authors, let us mention A. Frejlach (1898), author of the first bathymetric map of the Plešné jezero Lake, as well as the papers by A. Frič (1871), Vávra and Reissinger on the Černé and Čertovo jezero Lakes (1898 and 1931). Prior to these research works, individual guides gave isolated figures mostly concerning the depth of the lakes that were however not always reliable.

In September 1903, Professor Václav Švambera, founder of the Institute of Geography of the Charles University started with his research on the Šumava lakes, iniciated by frequent and contradictory reports of researchers. In the 1906 – 1909, Švambera, together with 17 students carried through a complex research on Šumava lakes, during which he drew precise maps of all lakes of a scale 1 : 1 000 and with the help of a sounding apparatus, did 3075 deep measurements in 79 profiles. Further on he proceeded to make 717 measurements of water temperature in vertical column and in the same time determined the colour and transparency of lake water.

The history of the research on the Laka Lake is not long. Because of its size and depth, the lake did not draw so much attention as the other Šumava lakes. The most precise information about the lake is given in the papers by P. Wagner and V. Švambera.

The area of the lake is for the first time indicated in the stable cadastre and that 4 morgen and 1465 square klafter, which is 2.8294 ha. Different authors give different areas: Willkom (1878) 7 morgen, Möchel (1878) 12 ha, Průvodce po království Českém by Řivnáč (1882) 3.5 ha, the guide by Detter (1906) 3 ha, Wagner (1897) 2.5317 ha, Švambera (1912) 2.7840 ha.

The depth conditions were mentioned for the first time by A. Frič (1871) who assessed the greatest depth as being 8 to 10 feet (2.4 – 3 m), in 1878 Möchel gave an incredible depth of 20 m, the guide by Detter (1906) gives an equally fantastic average depth of 16 m.

3.1. Research by P. Wagner

Dr. Paul Wagner carried out his research on the Laka Lake in 1896. It was exactly at the time when almost the whole lake was discharged of water because of over fishing of trout. Water remained only in the area of the greatest depth and the depth of the "puddle" was only 0.9 m. Wagner had thus the unique opportunity to examine the major part of the ground. He writes that the lake is largely filled by mud and the usually floating islands are sitting on the ground. With the help of a 3.6 m long stick he tested the depth of the deposits and he stuck the whole stick into the mud without reaching the solid surface. He supposed therefore that the lake was getting silted relatively quickly. This was confirmed also by a local fisher who was in charge of the lake. He asserted that 1 m of mud gets deposited on the bottom during ten years, so that the deposits must be from time to time artificially removed. The interest of the inhabitants of Hůrka was to have the greatest quantity of water retained in the lake because the water was taken away by canals to manufactures. The results of Wagner's research on the Šumava lakes are given in Table 1.

Table 1: Basic data on the Šumava lakes – results of measurements by P. Wagner in 1896 (in Wagner, P., 1897, modified)

Lake	Černé	Čertovo	Plešné	Prášilské	Laka	Velké Javorské	Malé Javorské	Roklanské
Area (ha)	18.4135	9.7157	6.055	3.5757	2.5317	4.3245	2.4525	3.7485
Maximal depth (m)	40	36	18.5	15.6	4	15	6?	13.5
Average depth (m)	17	14.7	6.9	6	2	6.1	3	4.4
Volume (km^3)	3.24	1.43	0.42	0.22	0.05	0.27	0.06	0.16
Surface (m a.s.l.)	1008	1030	1090	1079	1096	934	925	1050
Top of the lake wall (m)	1343	1343	1378	1314	1346	1345	1391	1300
Height of the lake wall (m)	335	313	288	235	250	411	456	396
Length of the lake (m)	662	432	435	290	374	441	165	285
Width of the lake (m)	465	260	176	175	86	144	135	195
Orientation	E	E	NE	E	NE	E	N	SE

3.2. Research by V. Švambera

Prof. Václav Švambera carried out his measurements from 22 to 26 July 1907, then he visited the lake on 27 August 1908 and in 1910 he examined in detail its neighbourhood. During his first visit he found that in 1906 mud had been cleaned away from the lake and at that occasion he measured the greatest depth of the lake – 3.9 m near the outflow. His calculation of average depth (1.4 m) does not correspond to that established by P. Wagner (2 m). Further on, the measured the water temperature (in the whole water column, in the affluents as well as at the outflow from the lake) and determined the transparency and the colouring of the water. He did not inquire into the lake water chemistry. The results of his measurements are given in Table 2.

Table 2: Basic data on the Šumava lakes – research results by V. Švambera from 1907 (in Švambera, V., 1939, modified)

Lake	Černé	Čertovo	Plešné	Prášilské	Laka
Area (ha)	18.4302	10.3318	7.4845	3.7200	2.7840
Maximal depth (m)	39.8	37	18.3	14.9	3.9
Average depth (m)	15.61	17.93	8.24	7.36	1.43
Catchment Area (km^2)	1.286	0.875	0.666	0.524	1.346
Volume (m^3)	2 878 000	1 852 378	617 081	274 047	40 000
Surface (m a.s.l.)	1008	1030	1090	1079	1096
Position below the mountain	Jezerní hora	Jezerní hora	Plechý	Poledník	Plesná
Altitude (m)	1343	1343	1378	1314	1346
Situated in the catchment area of	Úhlava	Regen	Vltava	Otava	Otava

4. Catchment area of the lake

4.1. Geographic position and morphometric characteristics of the catchment area

The Laka Lake is situated in the catchment area of the Jezerní Brook, right affluent of the Křemelná River. The catchment area of the lake itself is considered to be the largest of all the Šumava lakes. It is elongated in the SSW-NNE direction. The southern and the south-eastern watershed line runs on the ridge between the Debrník (1336 m a.s.l.) and the Ždánidla Mountains (1308 m a.s.l.), while nearly the whole catchment area spreads northwards from that ridge.

All cartometric measurements were done on four sheets of the basic map 1 : 10 000 (22-33-06, 22-33-10, 21-44-10, 21-44-15). Four methods in total were used for determination of the mean altitude of the catchement area of the lake. The first two methods are based on calculated mean altitudes of identically large areal parts of the given territory. They are substituted into the following formulas: $v = 0.5\ (X + N)$, $\underline{v} = 0.4\ X + 0.6\ N$, where $\underline{X}$ is the altitude of the highest and $\underline{N}$ is the altitude of the lowest point of the field. The further method is based on division of the catchment area into 25 m contour line belts. The mean altitude is then calculated with the help of the formula: $v = \Sigma(v\ .\ p)/P$, where $\underline{v}$ is the altitude of the centres of the belts, p is their area and P is the catchment area. The last method supposes measuring of contour lines lengths that are substituted into the formula by A. Steiner: $v = \Sigma(v.L)/\Sigma L$, where $\underline{L}$ is the length of the contour line and $\underline{v}$ is its altitude. The resulting mean altitude – 1186.50 m a.s.l.m. – was established as arithmetical average of all four measurements.

The mean inclination of the lake catchment area was determined by a formula by Penck:

$$tg\beta=(V/P)\partial[(O1+O2)/2],$$

where: ß is the angle of mean inclination, $\underline{V}$ is the height difference of contour lines, $\underline{P}$ is the area of the contour line belt and $\underline{O_1}$, $\underline{O_2}$ are the lengths of contour lines. In this way the mean inclination of individual contour line belts is calculated at first and the mean inclination of the catchment area is then determined as the average of inclinations of all belts. According to our calculations it is 12°06'. The smallest inclination is in the highest and in the lowest part of the catchment area. The greatest inclination is between the contour lines 1150 and 1300 m.

Table 3: Basic shape characteristics of the lake catchment area (measured on maps 1 : 10 000)

Catchment area	P = 1.020025 km^2
Total length of the water shed line	r = 4.10 km
Coefficient of the development of the water shed line	K = r/P = 4.0195
Total length of affluents	d = 1.35 km
Length of the main valley line	L = 0.65 km
Mean width of the catchment area	š = P/L = 1.569
Coefficient of the elongation of the catchment area	š/L = 2.414
Characteristics of the catchment area	P/L^2 = 2.414
Area of the lake (determined with the help of a map)	P_j = 0.027 km^2
Part of the lake on the catchment area	P_j/P = 0.0265
Mean altitude of the catchment area	1186.50 m
Mean inclination of the catchment area	12°06'

Table 4: Morphometric characteristics of the catchment area of the lake (measured on maps 1 : 10 000)

Contour line (m a.s.l.)	Length of contour lines (km)	Altitudinal span of the belt (m a.s.l.)	Area of the belt (km^2)	Mean inclination of the belt (°)	Part of the catchment area (%)
1083	0.00	1083–1087	0.0270	3°13'	2.65
1087	0.76	1087–1100	0.0548	11°44'	5.37
1100	0.99	1100–1125	0.1209	13°16'	11.85
1125	1.29	1125–1150	0.1507	13°02'	14.77
1150	1.50	1150–1175	0.1242	16°54'	12.17
1175	1.52	1175–1200	0.1400	14°19'	13.72
1200	1.34	1200–1225	0.1565	10°25'	15.34
1225	0.96	1225–1250	0.0770	15°52'	7.55
1250	0.79	1250–1275	0.0600	16°22'	5.88
1275	0.62	1275–1300	0.0425	16°23'	4.17
1300	0.38	1300–1325	0.0400	11°28'	3.92
1325	0.27	1325–1336	0.0268	3°10'	2.63

4.2. Geological structure of the lake catchment area

The western part of the lake catchment area consists of biotitic and sillimanite-biotitic migmatized para-gneiss, locally with quartzite. In the area of the spring of the left affluent, there is an outcrop of biotitic granodiorite. The eastern part of the lake catchment area is very diversified from the geological point of view. The largest area is taken up by cordierite-biotite migmatite of non-bulit type locally with muscovite. In the summit part of the Ždánidla Mountain there are outcrops of fine-grained to medium-grained biotitic granite and muscovite-biotitic granite with an adjacent belt of medium-grained to coarse-grained porphyric biotitic granite (of Weinsberg type). In lower positions of the eastern part of the catchment area there occur quartzite and quartzitic gneiss, locally with positions of erlans, leptynite, further on chlorite-muscovitic slate gneiss (locally slate and phylitic slate) with garnet and quartz lenses, locally with biotite and sillimatite. In the near neighbourhood of the lake there are diluvial and diluvial solifluction sediments mainly loam-sandy and loam-stony. In the neighbourhood of the Jezerní potok Brook there are fluvial sandy loams, loamy sands and gravels. The lake catchment area is crossed by two presumed faults that are nevertheless covered by younger sediments. Both faults meet immediately below the lake to form one that continues via Hůrky to Zhůří. The principal fault is oriented to the north, the shorter fault before the junction is oriented to the NNW.

4. 3. Geomorphological mapping of glacial relics

The most intensive erosion activities of glaciers in the Šumava Mountains occurred in the positions exposed to the north to east, where lake cirques were deepened in the most favourable localities. In localities where cirques were not deepened, imperfect cirque-shaped slope formation appeared (embryos or caroids). The most favourable routes for glacier movements were the slopes egalizing the steps between the piedmontane plateaux and the strongly lowering summits and ridges.

The morphometry and the depth of the lake basins are therefore bound to the morphology of the landscape before glaciation. The Plešné, Malé Javorské, Velké Javorské, Roklanské, Stará jímka and Laka Lakes are situated in rather large and plain relics of piedmontane plateaux, the articulation of which into valleys has not much progressed. Their basins are elongated and small in comparison to the area of the whole firn region and the total quantity of firn. The Prášilské, Černé and Čertovo jezero Lakes are deepened into a narrow plateau relic, the articulation of which into valleys has much progressed. Their shape is rather round and they are relatively very deep. The greatest depths are registered at the lake walls or nearer to the centre of the lake (Pelíšek, 1978).

During our geomorphological mapping we were trying to find the relics of the moraine damming the lake basin. However the anthropogenous impact of the neighbourhood of the lake is today so high that we failed to discover this moraine. A military building was constructed on one side of the supposed moraine. It was demolished after the year 1989. On the left bank of the lake, a canal was deepened to feed the canal. The most visible is therefore the final moraine, locally up to 10 m high. The lake brook flows perpendicularly to it. The moraine is covered by considerably dense vegetation that makes a larger view difficult. We did not succeed to precisely localize and map the other retreat stages of the moraine.

In the lake wall at about 1200 m, there are three steps formed probably during the retreat stage of glaciation. In the place of a granite rock outcrop, the inclination of the wall gets sensibly greater. These outcrops are surrounded by bloc debris. The material is then transported to lower parts of the wall by erosion and gravitation processes. The in this way constituted thicker slope debris cause slighter inclinations in the lower part of the wall.

4. 4. Hydrography of the lake catchment area

The Laka Lake is fed by two permanent and one occasional affluents. The right affluent (when looking to the lake dam) has its source at about 1170 m a.s.l. and is approximately 550 m long. The left affluent of the lake is formed by confluence of two smaller brooks at 1135 m a.s.l. The total length of both brooks is 800 m. The left affluent has a more rapid course with a greater inclination. In the period of spring melting there are in the source area many smaller brooks that form both affluents. The occasional affluent feeds the lake either during strong spring melting or after heavy rains. Its origin is partly anthropogenous, because the water flowing down the slope meets a cutting of a way with deep tracks. In one place water leaves the tracks and flows down to the lake. Because of a considerable inclination in the area of the occasional affluent, this one largely participates at the silting of the lake by a highly coarse-grained material.

The outflow from the lake is no more regulated by a sluice as it used to be in the past when the lake was used for pisciculture and the accumulated water also fed an artificial canal that is up to now well preserved. At first it passes through the moraine relief, then cuts into the Debrník slope and after 2.1 km mouths into the Drozdí Brook. The water from that canal was used in glass works in Nová Hůrka and for hydraulic drive of different machines. It was also used for floating timber. Although the canal is well preserved, water flows there only in one third of its length (1.3 km of the canal being without water). At the time of our field work water flew out of the lake over an overflow from accumulated logs. Later on the outflow of the lake was regulated in a way not to allow any manipulation with the water level as it occurred for instance in summer 1998. The lake brook draining the lake mouths after 7.0 km into the Křemelná River.

4. 5. Snow conditions

The Laka Lake catchment area is one of the richest rainfall regions of Czechia. The average rainfall measured by the neighbouring stations records some 1300 mm of precipitation fall annually in the lake catchment area. To determine the precise rainfall, it would be necessary to install a totalizator in the lake catchment area.

During our research carried out during two winter periods 1997/98 and 1998/99, the durability and the thickness of snow cover in the catchment area and on the frozen surface of the lake were observed. Our aim was to determine the water equivalent of snow cover with respect to the altitude and also to calculate the water reserves accumulated in the snow cover during winter. The snow column was taken at approximately each 20 height metres with the help of a volumetric cylinder, its height was measured and its water equivalent established (see Table 5).

The first snow appeared by the end of October, the first more durable snow cover was laying from the beginning of November. With several exceptions, snow cover laid during the whole winter. It was melting dependent on the quantity of snow and of spring temperatures from the end of March to the beginning of May. The maximal height of 2.9 m was reached in February 1999 immediately under the Debrník summit.

Table 5: Snow measurements

	altitude (m)	1085	1088	1100	1120	1140	1160	1180	1200	1230	1250	1280	1300	1330
10 Feb. 1998	Snow height (mm)	330	600	660	280	370	560	500	850	390	570	760	680	440
	Water equivalent (mm)	71.3	112	148	61.1	76.4	127	125	183	78.9	153	178	168	127
1 March 1998	Snow height (mm)	100	120	350	450	450	430	320	490	450	560	390	580	650
	Water equivalent (mm)	19	21	74,6	91	95	87	71,3	114	100	132	71	131	166
1 March 1999	Snow height (mm)	1450	1300	1800	2100	2150	2290	2380	2400	2530	2740	2800	2750	2810
	Water equivalent (mm)	374	342	423	611	616	636	671	679	714	801	839	805	845
21 March 1999	Snow height (mm)	800	1400	1600	1570	1655	1740	1920	1570	1835	1880	1940	2130	2200
	Water equivalent (mm)	146	201	377	359	402	485	563	364	546	594	623	658	662

5. Morphographic conditions of the lake

5.1. Determination of water level altitude

As is has been already said in the beginning of this article different literature sources give very various data on the water level altitude. For that reason we decided to determine the water level altitude with the help of leveling order.

As a basis for determination of the altitude of the lake we used the leveling point situated at about 2 km from the lake on an afforested slope southwards from the road Nová Hůrka – Železná Ruda. It is the point No. 40, Vlčí jámy, the position of which is given by the geodetic co-ordinates y = 837 576.57, x = 1 138 378.86 and the altitude Bpv = 1 178.24 m. The levelling order was done on 22 November 1997 the water gauge indicated 47 cm. When taking into consideration oscillations of the lake water level during the year up to the level of 97 cm at the water gauge, the measured altitude approaches 1085 m, indicated by the Základní vodohospodářská mapa. The level of 47 cm at the water gauge of the lake corresponds to the beginning of winter when the water level is the lowest.

5.2 Survey of the lake's ground plan

The most favourable days were chosen for ground plan measurements – the 22nd and 23rd November 1997. A 7 cm thick ice layer, not yet covered by snow, covered the lake. The measurements could be thus done directly on the surface of the lake and the mistakes that could arise when measuring on steep slopes could be thus avoided. Another advantage was that the bank line of the lake was clearly limited by ice cover.

The polygon order was led in a way to have the sides of the polygon situated the closest possible to the bank line of the lake. In this way the possible inaccuracies when leading perpendiculars to individual sides of the polygon could be minimalized. The traced polygon had 19 pieces in total. The position of two of them was then fixed because we used them as bases for our bathymetrical measurements. The results of measurements of angles and lengths of the polygon sides are given in the master thesis of M. Šobr (1999). The total length of the polygon sides was 846.5 m, the measurements being done at 311 perpendiculars in total. One perpendicular comes then to 2.72 m of length. On terms of measured values in the relief, the ground plan of the lake 1:500 was drawn. With the help of this plan and of two methods (planimetric and square network), the area of the lake was determined as being 2.57705 ha, the islands of deposits covering 0.220125 ha.

5. 3. Bathymetrical measurements and morphometrical characteristics of the lake basin

Václav Švambera, Professor of Geography at Charles University, did the first detailed measurements of the depths of the Laka Lake in the period of 25 to 27 July 1907. Our measurement of 4 of June 1999 was thus done ninety-two years later. The water gauge indicated on the day 99 cm, which means that the lake surface was at 1084.8765 m a.s.l.

Our bathymetric research was done by the classical way with using kevral fibre with marked measuring points situated at a distance of 5 m. Because of frequent occurrence of water plants covering at many places the ground and occurring frequently in the whole vertical water column, it was not possible to use the acoustical depth gauge (echolot). Exactly for that reason we had to use a calibrated bar to measure the depths, and that despite of the attitude of the Šumava National Park Administration. The argumentation of the National Park management that our measurements will damage the ground bottom sediments seem very incompetent as during the last hundred years the sediments were several times artificially removed from the Laka Lake. The first depth profile was based on the points of the polygon side 1 – 2. They were fixed on the bank during the precedent surveying of the lake's ground plan. The individual crosswise profiles were then measured at 10 m intervals. In total, 563 point measurements of depths were done at 36 profiles. There is thus one measurement for an area of 45.8 m2, or 218 depth measurements in total for one hectare.

Measuring of areas of individual depth steps and of lengths of individual depth lines was then done on the bathymetric map of the lake (see Fig. 1) of the original scale 1:500. On the basis of the results of cartometric measurements, the following morphometric characteristics of the lake basin were calculated:

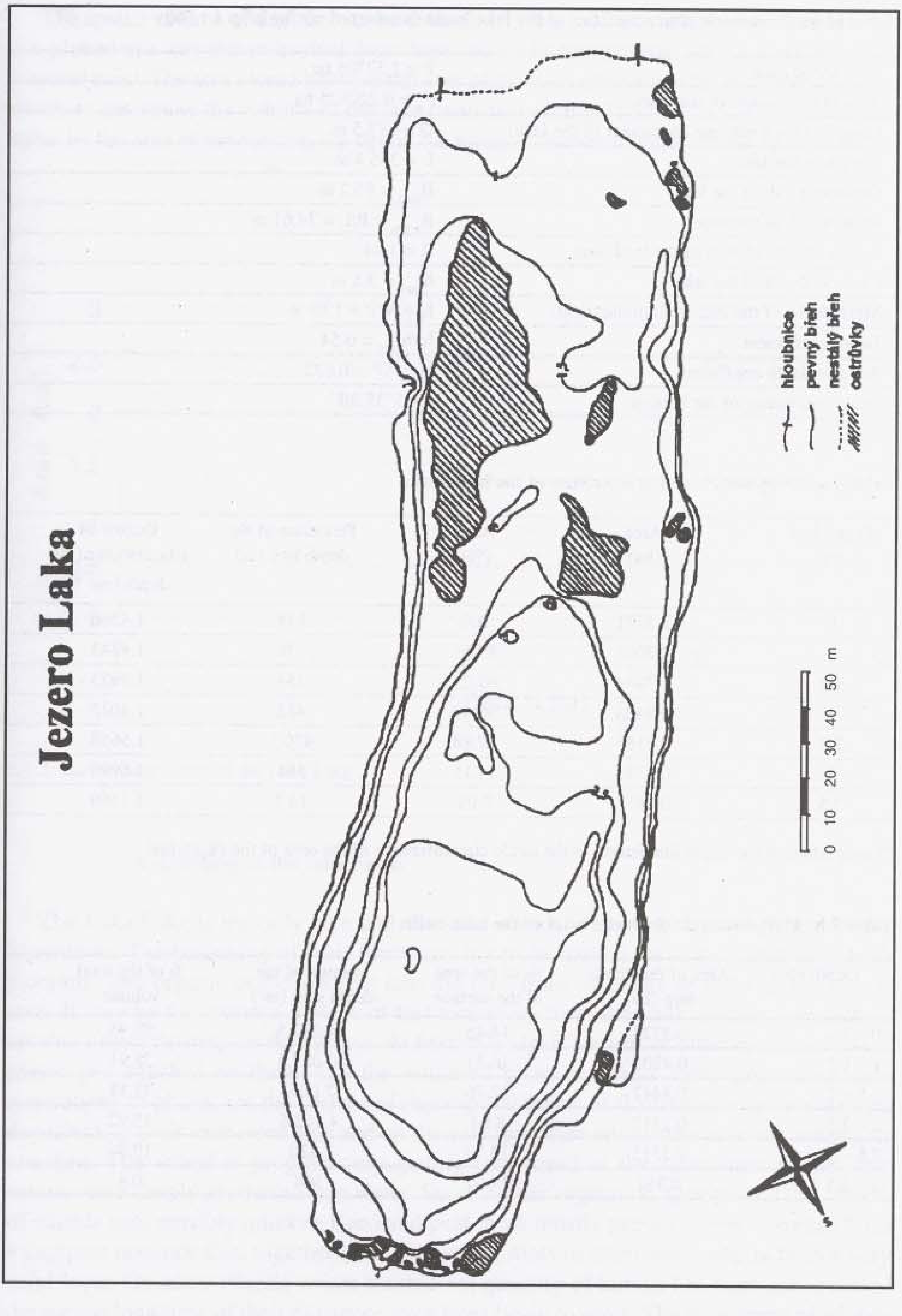

Fig. 1: Bathymetric map of the Laka Lake

Table 6: Basic numeric characteristics of the lake basin (measured on the map 1 : 500)

Area of the lake	P = 2.57705 ha
Area of the islands of deposits	P_o = 0.220125 ha
Length of the bank line (perimeter of the lake)	O = 817.5 m
Length of the lake	L = 345.4 m
Greatest width of the lake	B_{max} = 95.2 m
Mean width of the lake	$B_{prùm}$ = P/L = 74.61 m
Degree of articulation of the bank line	R = 1.44
Greatest depth of the lake	h_{max} = 3.5 m
Mean depth of the lake (volumometrical)	h_s = V/P = 1.89 m
Depth coefficient	h_s/h_{max} = 0.54
Relative depth coefficient	$h_{max}/\sqrt{P}$ = 0.022
Mean inclination of the bottom	I = 3°35'20"

Table 7 a: Morphometric characteristics of the lake basin

Depth line (m)	Area (ha)	Area (%)	Perimeter of the depth line (m)	Degree of articulation of the depth line *)
0	2.5771	100	818	1.4366
1	2.2047	85.55	776	1.4743
1.5	1.7844	69.25	754	1.5923
2	0.9403	36.49	482	1.4022
2.5	0.7186	27.88	470.5	1.5658
3	0.3633	14.11	361	1.6896
3.5	0.0013	0.05	14.5	1.1569

*) proportion of the depth line length to the circle circumference of the area of the depth line

Table 7 b: Morphometric characteristics of the lake basin

Depth step	Area of the depth step (ha)	% of the area of the surface	Volume of the depth step (m^3)	% of the total volume
0 – 1	0.3724	14.45	24 082.5	93.45
1 – 1.5	0.4203	16.31	10 027.5	38.91
1.5 – 2	0.8442	32.76	7 005	27.18
2 – 2.5	0.2217	8.64	4 102.5	15.92
2.5 – 3	0.3553	13.79	2 820	10.94
3 – 3.5	0.362	14.05	104	0.4

The spatial volume of the lake can be determined from the bathymetric curve (see Fig. 2). It is plotted in a way that individual depth lines (on the horizontal axis) are adjoined their area (vertical axis). The area closed between the axes of the co-ordinates and the bathymetric curve serves to determine the volume of the lake basin as reaching 48 817.5 m3. If we divide this value by the area of the surface, we obtain the mean (volumetric) depth of the lake – 1.89 m.

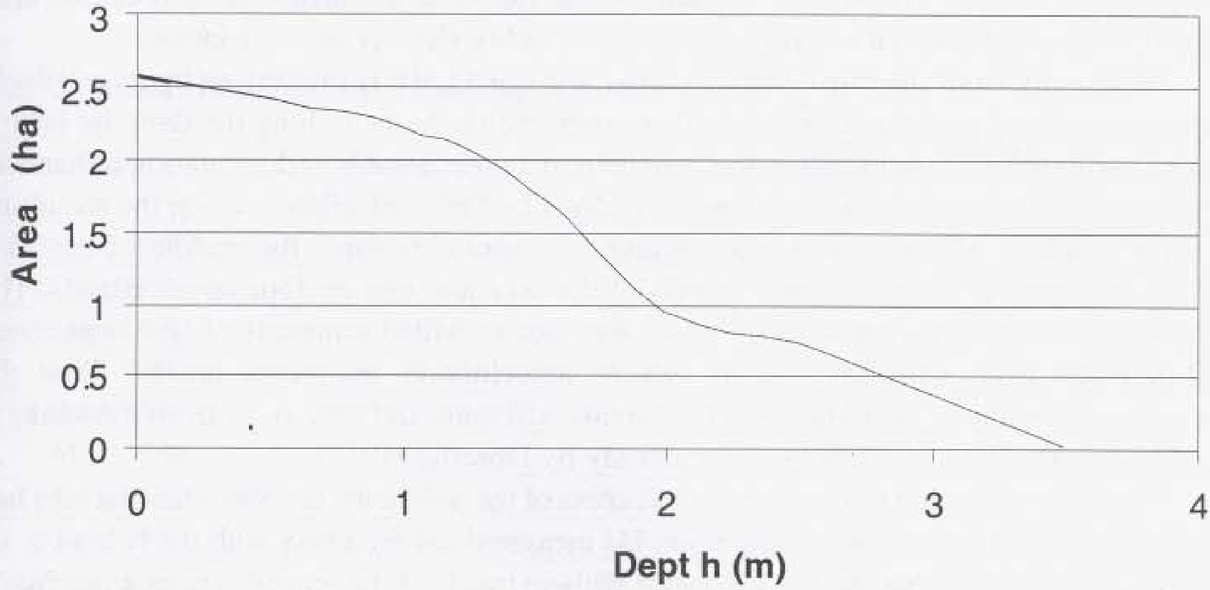

Fig 2: Bathymetric curve of the Laka Lake

5. 4. Silting of the lake basin

The Laka Lake is the only lake with floating islands at the Czech side of the Šumava Mountains. The beginning of their formation has to be looked for in the material of both inorganic and organic origin coming into the lake from its banks or from its catchment area. It may be for instance a piece of turf torn away from the bank, a stem, a branch or another object floating on the surface. At first only algae, mosses or other species of lower plants get attached to them. On the withered plant remnants there grow then new generations of plants. On the surface of those initial forms of floating islands air dust gets deposited, at their immersed side and on their margins fine silt dispersed in the water gets attached. The island is progressively getting larger and in the same time thicker that means more deeply immersed into water. Soon, higher vegetation appears and the growth of islands gets sensibly quicker. Reed and peat moss mostly prevail. Reed rhizomes form a compact network that, together with humus and roots of other water plants form a very solid layer. On some islands where a sufficient quantity of humus has been accumulated during the long time of their existence even trees begin to grow. The movement of islands is generally influenced by increase and decrease of the quantity of water in the lake and mainly by the direction and force of wind. Floating islands have usually only a short life. In fact when their dimensions and mainly their mass increase they sit down on the ground or get attached to the bank and help to fill the lake basin.

At present there are on the Laka Lake three large and twenty small islands, some of them entirely adjacent. The total surface of the islands is 0.220125 ha, that is 8.54% of the area of the lake. The largest one has the surface of 1580.75 m^2 and is situated closely to the eastern bank of the lake. It is firmly adjacent to the ground and remains in the same place. It has been there probably for more than hundred years – in fact, on the map by Švambera, it is smaller but situated nearly in the same place. The other islands are mostly adjacent to shallow places near the dam of the lake or at the lake wall as it can be seen from the ground plan. In summer, cotton grass richly flowers on the islands.

Differently from the other Šumava lakes, the Laka Lake is interesting by its relatively intensive silting processes. In its southern part and in the belt along the dam the lake is very shallow. Two brooks filling the lake help to a considerable sedimentation dynamism of the lake. At the southern bank there is a larger belt of bank alluvia. From the mouthing of the two lake affluents, two belts of lake bars spread towards the middle of the lake. They are parallel to the lengthwise axis of the lake and end by four larger islands. The silting of the basin is in a sensibly lesser way due to wilted remnants of lake organisms. Differently from eutrophic basins, where autochthone sediments prevail, here the allochthone material brought down by the lake affluents and torn away from the banks is prevalent. This hypothesis was given already by Dosedla (1962).

Wagner was the first to examine the thickness of the sediments in 1896 when the lake had been discharged because of fishing trout. He measured the thickness with the help of a 3.8 m bar. He stuck it whole into the sediments without touching the ground. The administration of the Šumava National Park did not allow us to collect the sediments as we might "damage the stratigraphy of lake sediments". By the end of 1980's, the lake sediments were collected by a team of VÚV and ÚÚG Prague in view to establish the quantity of organochlore pollutants in the Šumava lakes. According to that research the sediments of the Laka lake contained 18.6% of organic substances (mass percentage, Nondek et al., 1989).

6. Hydrologic regime of the lake

The flows were measured from November 1997 to May 1999 at both main affluents and at the outflow from the lake. In the rear part of the lake a water level gauge was installed and the altitude of nul reading was determined at it. Simultaneously with each measurement of the flow, the level of the water gauge was registered to make a graph of dependence of the flow quantity of water of the Jezerní Brook on the level of the water gauge of the lake. It should enable to determine the level of outflow of the water from the lake even if we had not a hydrometric propeller to measure the flow.

The graph of outflow oscillation shows low levels of flow always at the end of winter period in February and March (before the beginning of spring melting) and during summer months from July to September. A sensible increase of outflow is evident during spring snow melting in April. While the period of spring increased flows was relatively short in 1998, in 1999 the increased outflow from the lake was evident still during the whole month of May. It was due to great quantities of snow accumulated in the lake catchment area during the winter 98/99.

When preparing his master thesis, M. Šobr registered the course of the high-flood-water wave in the lake. On 28 October 1998, 8 cm of snow fallen on 26 October were laying in the neighbourhood of the lake. In the morning, the water gauge showed 84 cm. After 90 minutes of intensive raining, the lake surface reached its maximal level of 97 cm. In 1 hour and 30 minutes, more than 3350 m^3 of water had flown into the lake. The water level being so high, water was leaving the lake not only in the usual place, but it was rushing over the dam in several other places. It was not possible to precisely measure the flow, but it was estimated to reach more than 200 l/s.

Table 8: Measured flows and water conditions of the lake

Date	Water gauge indicating (cm)	Outflow w ($l.s^{-1}$)	Right affluent ($l.s^{-1}$)	Left affluent ($l.s^{-1}$)
10 Nov. 1997	48	22.26	8.02	8.04
22 Nov.1997	47	19.11	9.22	9.69
29 Dec.1997	61	36.1	9.26	14.7
10 Feb.1998*	57	19.6	9.85	10.2
1 March 1998	61	34.2	12.8	22.1
22 March 1998	65	38.37	21.72	17.1
5 April 1998	70	58.08	31.4	35.7
26 April 1998	60	32.75	17.42	22.01
10 May 1998	57	26.52	P	P
24 May 1998	55	26.28	10.63	13.62
4 June 1998	52.5	21.82	11.26	11.3
21 June 1998	57	22.38	12.35	11.76
7 Sept. 1998	62.5	36	-	-
17 Sept. 1998	84	92	-	-
9 Oct. 1998	57.5	25.3	14.11	12.09
23 Oct. 1998	59	29.61	16.61	15.17
28 Oct. 1998	84	92	-	-
28 Oct. 1998	97	200**	-	-
20 Dec. 1998	65	40	-	-
23 Jan. 1999	66	42	-	-
21 March 1999	S	21.04	S	S
2 April 1999	76	63.53	S	S
16 April 1999	78	70.79	S	S
7 May 1999	95	121.25	V	V

* measurements affected by ice cover, so it was not used for construction of the graph of dependence of the flow on the water gauge indication

** estimated level during the high-flood-water flow

P – not measured because of a defect of the propeller

S – not measured because of a high snow cover

V – not measured because of a too high flow (spiling of water outside the bed)

7. Sept. 98 – flows calculated from the measurement curve of the outflow

The measuring curve of the outflow (also consumption curve) enables to determine the flow especially under unfavourable natural conditions, when it is not possible to measure the flows directly for instance with the help of a hydrometric propeller. In that case it is possible to use the readings of water levels at the water measuring bar. The measuring curve should be nevertheless further precised by other measurements.

7. Physical properties of accumulated water

7.1. Water temperature

The water temperature was measured in the same place at the lake dam to limit the influence of the lake affluents. In the same days also water temperature of the affluents and at the outflow of the lake were measured. While during the period of water surface freezing the water temperature of the affluents is slightly higher, during the most of the year they cool the accumulated water of the lake.

Because of small depths and lengthwise elongation of the lake basin, the water in the lake mixes relatively well by the impact of the wind. This is proven also by relatively high temperatures of water at the surface in summer. The accumulated water largely influence also the temperature of lake outflow.

Table 9: Measured water temperatures at the lake surface, at the affluents, at the outflow (°C)

Date	Air	Surface of the lake	Outflow	Right affluent	Left affluent	Occasional affluent
29 Dec. 1997	0	0.5	2	1.8	1.5	
10 Feb. 1998	3.2	-0.2	1.9	1.3	1.1	
1 March 1998	-2.5	0	1.8	1	0.9	
22 March 1998	-2	0	1.2	1.1	1	
5 April 1998	6.2	2.3	2.2	1.5	1.2	
26 April 1998	18.2	8.3	8.1	5.7	5.4	
10 May 1998	14.5	13.1	10.6	7.1	7	
24 May 1998	7.5	12.9	9.1	4.5	4.4	
4 June 1998	18.5	16.7	15.4	10.9	11.2	
21 June 1998	21.6	14.8	12.7	8	8.9	
7 Aug. 1998	24.8	18.4	17.6	12.8	13.6	
7 Sept. 1998	16.5	12.5	11.5	8.8	9.5	
17Sept. 1998	8.5	8.2	7.1	6.5	6.5	7.2
9 Oct. 1998	13.6	8.5	7.8	6.6	6.9	
23 Oct.1998	10.3	7.1	6.7	5.1	5.2	
28 Oct. 1998	8.5	3.6	3.4	2.6	2.4	
20 Dec. 1998	-1	0	1.7			
16 April 1999	0.1	0	1.8			
7 May 1999	9.2	3.1	2.9	2.4	2.3	
21 May 1999	11.7	9.5	9.2	6.4	6.5	6.4

Because of its small depth the Laka Lake did not develop the classical summer stratification of temperatures. With the arrival of the frosty period the lake starts to freeze. The date of the first freezing is naturally different in different years, because it depends on the regime of air temperatures. We had the possibility to monitor in detail two winter periods 1997–98 and 1998-99.

The first winter period was not much snow abundant. The ice cover of the lake with a minimal isolation snow layer could reach a greater thickness of 42 cm. In the winter period 1997–98 the first ice appeared on the lake as soon as in the beginning of November (10 November) when nearly 30% of the lake was covered by ice up to 4 cm thick. The ice melted relatively quickly at the beginning of April 1998 while on 5 April it covered only the shadowed parts of the lake.

Table 10: Oscillation of the thickness of the ice cover during the winter 1997/1998

Date	10 Nov.	22 Nov.	29 Dec.	10 Feb.	1 March	22 March	5 April
Thickness (cm)	discontinuous	7	15	42	40	36	discontinuous

In winter 1998–1999 only the date of freezing and melting of the lake were registered. The thickness of the ice could not be regularly measured because a great quantity of snow was laying on the ice (80 to 120 cm during the most winter time). The first ice appeared again at the beginning of November, on 20 December it reached the thickness of 16 cm, on 23 January 28 cm. The ice cover started to melt at the beginning of April, and that at the lake affluents at first. In the middle of April however, the margin of lake froze again. Still as late as on 7 May 1999, some 60% of the surface of the lake were covered by ice. This late melting of the lake was due to a very thick snow cover that was disappearing only very slowly from the lake catchment and from the ice covered lake surface. In spite of the short monitoring period, it can be stated that the lake remains usually frozen 5 to 6 months of the year.

With the help of GT-2 thermometer we measured the water temperature in the vertical column of the lake in view to characterize all the seasonal stages of the thermic regime of the lake. The measurement of 28 October 1998 registered the period of autumn homothermy (see Fig. 3) when the temperature of the whole water column oscillated about the level of 4 °C at which the water has the highest density and the whole water mass gets intensively mixed. The beginning of summer stagnation was registered by the measurement of 21 May 1999, its more advanced stage then by the measurement of 4 June 1998. The water in the lake manifested signs of a direct temperature stratification but because of small depths we cannot speak about typically developed strata of epilimnium, metalimnium and hypolimnium (see also Fig. 3). The stage of winter stagnation was registered during the measurement of 10 February 1998. Under the 42 cm thick ice cover we registered a classical inverse strtification, while the water layer of the highest density with the temperature of about 4 °C was found already in the depth of 2.5 m.

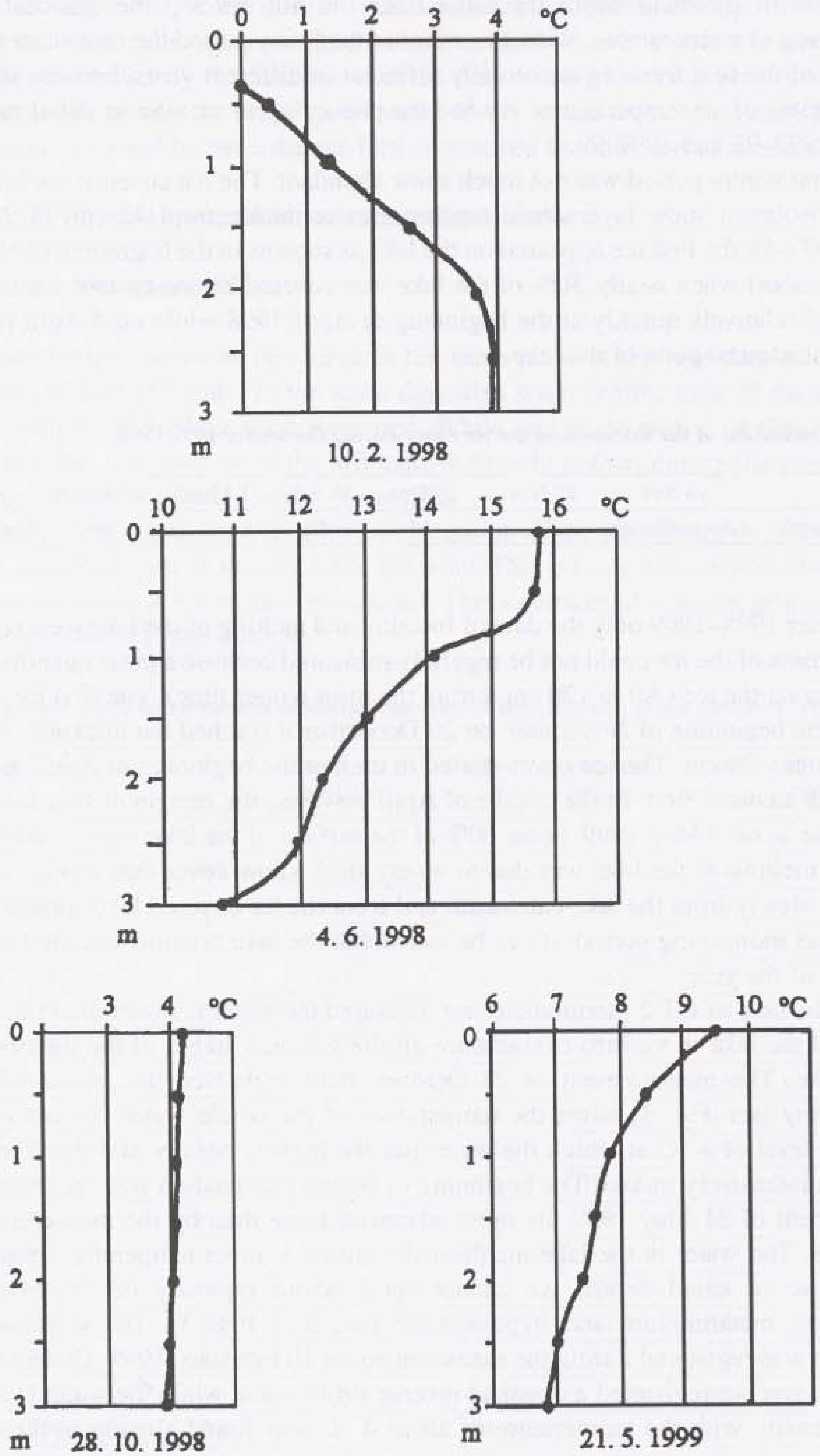

Fig 3: Temperature stratification

7.2. Colour and transparency of water

Colour and transparency of water are important characteristics of physical properties of accumulated water. They are very easily determinable and are closely connected with some indicators of basic chemical composition of water, mainly with the content of all dissolved and not dissolved matters.

To determine the transparency of water the Secchi disc is used – a white circular disc of a diameter of 30 cm hanging on a calibrated line. The disc is immersed into the depth on the limit of visibility, under which all the light reflected from the disc is absorbed by the water.

The Secchi disc helped also to determine the colour of lake water. For that purpose it is immersed into the half depth of the transparency and the colour of the water is examined against the white disc on the basis of comparison with the Ule-Forel scale. It is a system of 21 colour shades going from blue, via green, yellow to brown. The blue shades correspond to waters with minimal content of dissolved matters and suspended matters, that means little sustainable from the biological point of view – oligotrophic. On the contrary, brown shades correspond to waters with a high representation of dissolved and non dissolved matters, as it is typical for instance for waters of peat-bogs. Because of possible differences due to subjective evaluation of colours, each measurement was done at least by two people. Monitoring was done in all seasons (see Table 11).

The established values of transparency and colour of the water are little variable and not very dependent on the year cycle. We did not find any relation either with seasonal transport of non dissolved matters or with the cycle of biomass production. The main cause is probably again the little depth of the lake basin that does not enable any occurrence of significant seasonal differences.

Table 11: Transparency and colour of the lake water

Date of observation	Transparency (m)	Water colour
22 March 1998	2.5	16
4 June 1998	3	13
28 Oct. 1998	3	15
21 May 1999	3.2	12

The transparency and the colour of the water were determined also by Prof. Švambera and his assistants in the summer 1907. The transparency was 4 metres, the colour was, according to the Ule-Richter scale, equal to the degree 15.

8. Vegetation in the neighbourhood of the lake

The Laka Lake and its neighbourhood undoubtedly belong to valuable botanical localities of the Šumava Mountains. Differently from the Černé, Čertovo and Plešné lakes, in the cirque of this lake there are not developed subalpine belts. The neighbouring vegetation corresponds by its composition to the vegetation of the montane belt. In the whole catchment, there are neither denuded places without vegetation as consequence of avalanche trajectories, nor rock gardens. In the past, in the lower not wet positions there was mountain mixed forest – acidophile montane beech forests and related associations. Climax spruces forests covered the higher parts of the Debrník and the Ždánidla Mountains. In the saddle between the Debrník and the Ždánidla Mountains, there are remnants of these climax spruce forests. They of the so-called fern-type with frequent lady fern (*Athyrium*) (Skalický, Vaněček, 1970).

In wet places in the proximity of the lake, the vegetation of initially montane beech forests passes into belts of water-logged spruce forests. The nearest to the original composition of the forest are the segments along both affluents flowing from the south into the lake basin. Penetration of vegetation of montane acidophile beech forests, water-logged spruce forests, forest source areas, mountain brook alluvia and at the lake locally also several non-forest vegetations introduces a larger variety of floristic composition, although it does not reach by its abundance of flowers those of other Šumava cirques.

The flora of flowing and adjacent islands is poor in species. There prevail some species of sedges – *Carex nigra* and sporadically also *Carex pauciflora*. There occur brown bent grass (*Agrostis canina*), cotton grass (*Eriophorum angustifolium*), *Comarum palustre* and *Viola palustris*. On some islands, there were found small trees and shrubs of common spruce (*Picea abies*) and *Salix aurita*. On the largest island, there was a 2 m high spruce that however died. The smallest flowing islands are formed in the initial phase of silting by peat-mosses. Between the southern bank of the lake and the islands, there is a zone of shallows on fine sediments. They are colonized only by mannagrass (*Glyceria fluitan*), which is a species of mainly bank reed. In the bank sediments, it forms along both affluents a continuous belt in which it is also prevalent, but there is also *Carex rostrata*, and that its broad-leaved morphotype.

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JEZERO LAKA

Résumé

Nejmenší šumavské jezero Laka se nachází na severovýchodním svahu Debrníka ve výši 1085 m n.m. Hráz jezera byla v průběhu 18. a opakovaně v 19. století uměle zvyšována. Hlavním důvodem byla zvýšená potřeba vody pro plavbu dřeva, výrobu skla a chov ryb.

První rozsáhlejší výzkum jezera uskutečnil koncem 19. století P. Wagner a po něm začátkem 20. století V. Švambera. Další komplexní fyzickogeografický výzkum prováděl asi o devadesát let později spoluautor tohoto příspěvku (Šobr 1999). Hlavním cílem bylo upřesnit nadmořskou výšku jezera, jeho plochu a vytvořit bathymetrickou mapu.

Jezero Laka má plochu 2,57705 ha, ostrovy zabírají 8,54% jeho plochy. Sběrná oblast jezera zaujímá plochu 102,0025 ha a její střední nadmořská výška dosahuje 1186,5 m n.m. Maximální hloubka jezera je 3,5 m, střední hloubka 1,89 m. Jezerní nádrž má objem 48 817,5 m^3. Nejhlubší oblast se nachází v blízkosti hráze.

Jezero Laka je intenzivně zanášeno především z oblasti jezerní stěny. Nejvíce sedimentů přichází v období jarního tání nebo během intenzivních dešťů, naopak nejnižší úroveň zanášení se projevuje na podzim a v zimě. Díky malé hloubce jezera nebyla registrována klasická letní teplotní stratifikace, i když zimní inverzní rozvrstvení teplot se projevilo. Významnou roli v hydrologickém režimu jezera hrají sněhové podmínky. Díky extrémním klimatickým podmínkám zimy 1998–1999 však nebylo možné provádět seriózní pozorování.

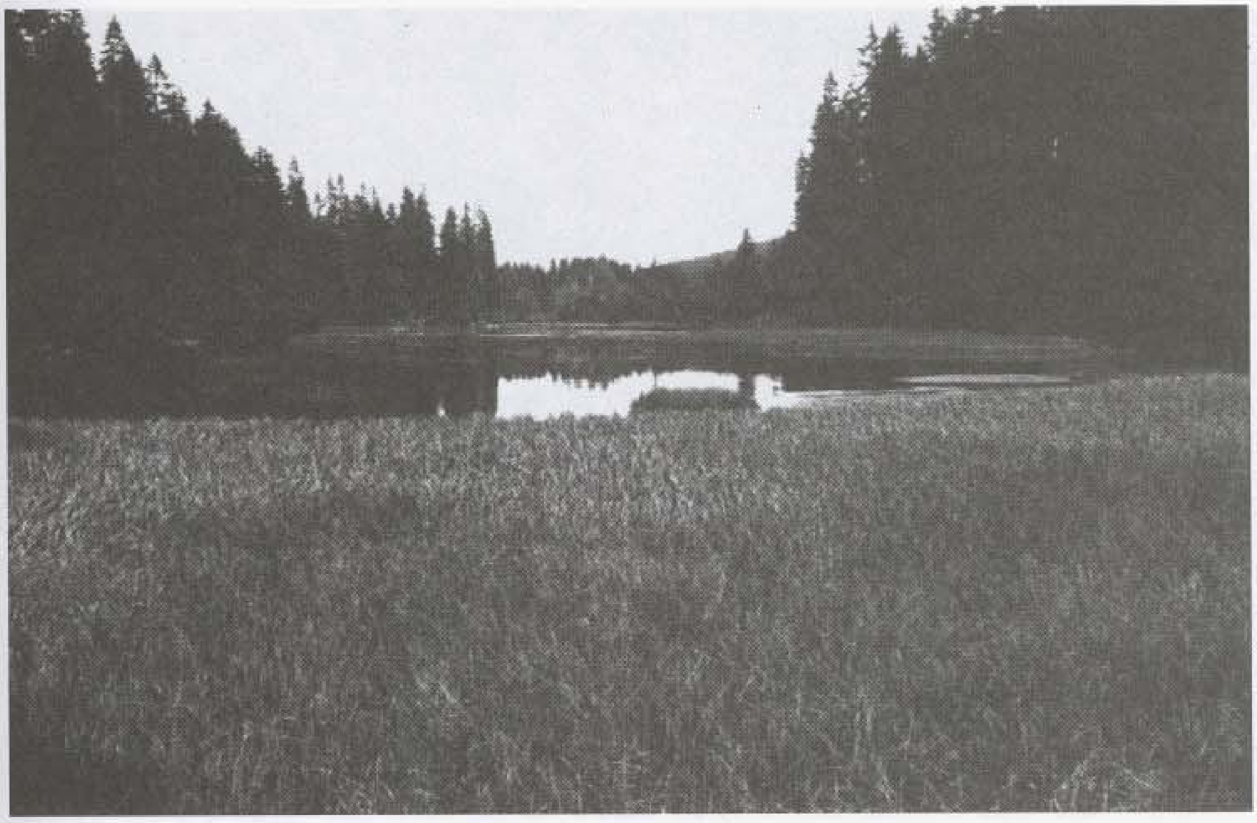

Photo 1: The Laka Lake

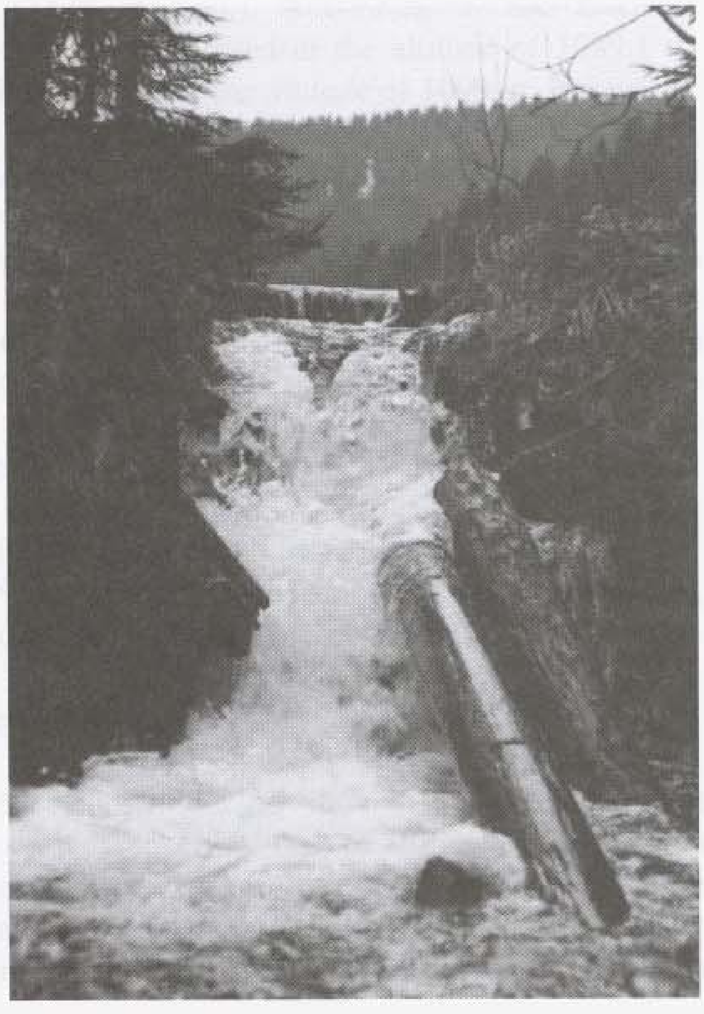

Photo 2: Outflow from the Laka Lake

Photo 3: Bathymetrical measurement