Interreg Latvija–Lietuva
European Regional Development Fund
EUROPEAN UNION

Joint management of Latvian – Lithuanian trans-boundary river and lake water bodies (TRANSWAT) LLI-533

REPORT ON ILZU (GARAIS)/ILGE LAKE ECOSYSTEM HEALTH ASSESSMENT

2022

TABLE OF CONTENTS

ABBREVIATIONS

Chl-a	chlorophyll-a
CPUE	catch per unit of effort
d.w.	dry weight
EQR	ecological quality ratio
LHS	lake habitat survey
LLMI	Lithuanian Lake Macroinvertebrate Index
LLMMI	Latvian Lake Macroinvertebrate Multimetric Index
QEs	quality elements
TN	total nitrogen
TP	total phosphorus
WFD	Water Framework Directive
WWTP	wastewater treatment plant
EPA	Environmental Protection Agency
RBMP	River basin management plans

J. Demidko (red.) (2022)

Autoru saraksts alfabētiskā secībā:
Arsauska I., Čičendajeva M., Bikše, J., Demidko, J., Dimante-Deimantoviča I., Grīnberga L., Jēkabsone J., Kokorīte I., Koļcova, T., Križickis E., Medne R., Ozoliņš D., Retike, I., Skuja, A., Virbickas, T.

This document has been produced with the financial assistance of the European Union. The contents of this document are the sole responsibility of Latvian Environment, Geology and Meteorology Centre and can under no circumstances be regarded as reflecting the position of the European Union.

1. INTRODUCTION

There are 65% of lake water bodies in Latvia that do not reach at least good ecological status as required by the Water Framework Directive (WFD). One of such lakes is the Lake Ilzu (Garais)/Ilge which is considered as a risk water body in Latvia. Prior to the start of the TRANSWAT project, this lake was not designated as a water body in Lithuania. Therefore, no monitoring and analysis of pressures from the Lithuanian part of the lake has been previously carried out.

In water bodies where ecological quality is not sufficient, measures should be taken to reduce anthropogenic pressures from the whole lake or river basin, including catchments of upstream water bodies.

In order to assess the Lake Ilzu (Garais)/Ilge ecological status and main impacts, a concept of lake ecosystem health was applied within the project LLI-533 TRANSWAT. Lake ecosystem health assessment can be considered as a holistic approach which uses both quantitative and qualitative information available for a lake body and the whole catchment area. During the project, information on environmental conditions in the lake catchment (e.g., catchment geology, topography, climate and hydrology) was collected. Hydrogeological conditions and the role of groundwater in lake feeding were analysed, which is often not considered in other studies and river basin management plans. To estimate anthropogenic pressures and elaborate programme of measures for Lake Ilzu (Garais)/Ilge, land-use data, nutrient loads and sources as well as other potential impacts were analysed. Data on biological quality elements indicating the ecological status of the lake is presented.

II LAKE CATCHMENT CHARACTERISTICS

2.1. Topography

The Lake Ilzu (Garais) / Ilge belongs to the Mēmele/Nemunelis River Basin that is one of two big sub-basins of the Lielupe River Basin. The upper reach of the Lielupe River basin is located in the north of Lithuania (Fig. 2.1.1). The largest part of this area consists of Mūša-Nemunėlis Plain where average height fluctuates from 40 to 60 meters above sea level (a.s.l.) and of Zemgale Plain with fluctuation of 30-50 meters a.s.l.

In Latvia the largest part of the Lielupe River basin is situated in the Middle Latvian Lowland, and the elevation downstream from Jelgava city is normally less than 10 meters above sea level (a.s.l.). Exceptions are the Eastern Kurzeme Upland in the most western part of Lielupe River basin and the Augšzeme Upland in the southeastern part, where elevations reach up to 150 meters a.s.l. The Lake Ilzu (Garais) / Ilge is located here, in the Augšzeme Upland (Fig.2.1.1).

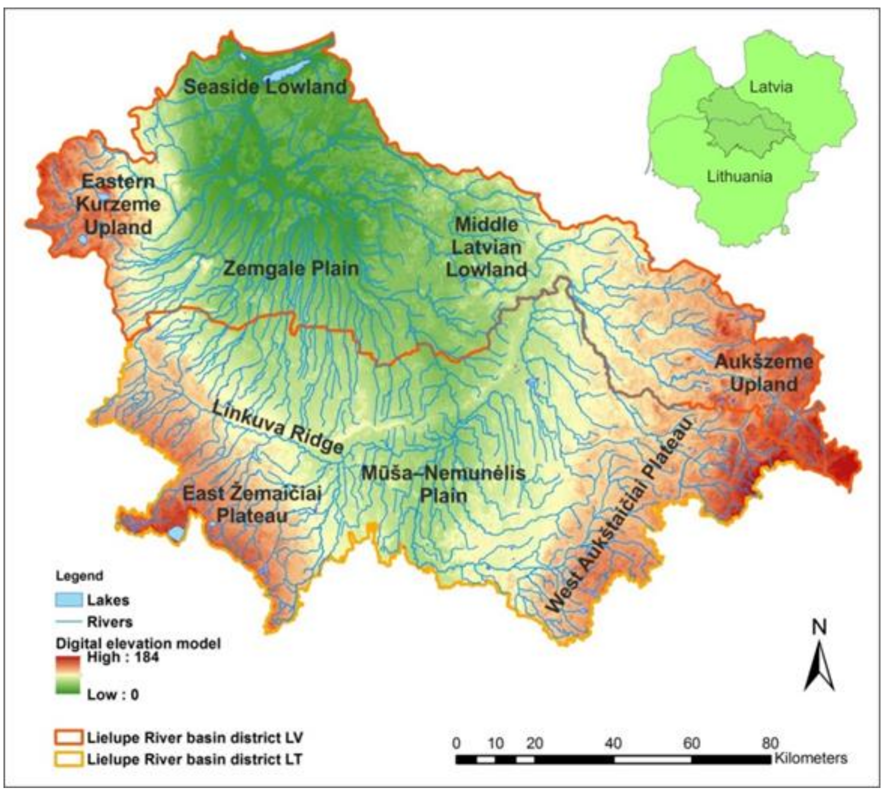

Figure 2.1.1. Topography and hydrography of Lielupe River basin (ECOFLOW Project, 2017).

According to the "Watershed model for the Lake Ilzu (Garais) / Ilge" report the catchment area of the lake is 8.72 km^2, out of which 5.04 km^2 is located in Latvia and 3.68 km^2 - in Lithuania Fig. 2.1.2).

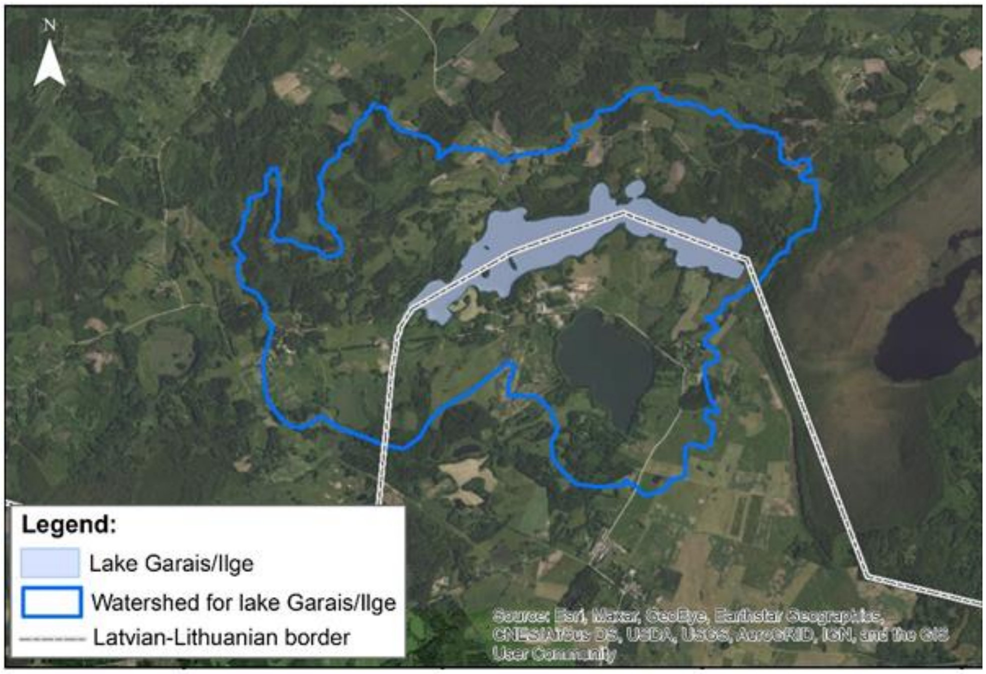

Figure 2.1.2. Ilzu (Garais)/Ilge Lake catchment area (LEGMC, 2021).

2.2. Climate, hydrology and hydrography

Climate in the Eastern part of the Lielupe River basin can be characterized as a tr ansitional between mild Western European and continental Eastern European climate. The Baltic Sea has an impact on the climate here, however from west to east, the sea has less and less influence on climatic conditions.

Annual air temperature in the territory of the Lake Ilzu (Garais)/Ilge is 6.3 ºC (Biržai MS). Average air temperature in February (the coldest month of the year) is -4.3 °C, while average air temperature in July (the warmest month of the year) reaches 16.8 °C.

The annual amount of precipitation is about 670 mm (Zilani MS).

The Lake Ilzu (Garais)/Ilge is a drainage lake with small inflow from the drainage channel in Latvian territory and outflow to Lithuanian territory. Specific water discharge in a lake basin is about 7 L*sec/km^2.

The Lake Ilzu (Garais)/Ilge is a shallow lake with a maximum depth of 3.6 m and an average depth of 2.4 m. In most parts of the lake, the depth is more than 0.5 m. Lake's water volume at water level 97.3 m (a.s.l.) is 2.1 mln m3.

2.3. Land use

The land cover/land use analysis is primarily based on CORINE Land Cover data (Fig. 2.3.1). The main types of land use in the catchment area of Lake Ilzu (Garais)/Ilge are forest lands (broad-leaf forests, mixed tree forests and transitional forests/shrubberies) and surface areas of two lakes, which together comprise about 53.8% of the total catchment area. Agricultural lands with significant areas of natural vegetation cover 37.2% of the total area. Of the remaining 9%, pastures make up 6.6% and non-irrigated arable lands – 2.4% of the total catchment area. More detailed information on land use is available in the Report "Conceptual model of surface – groundwater interaction" (2022).

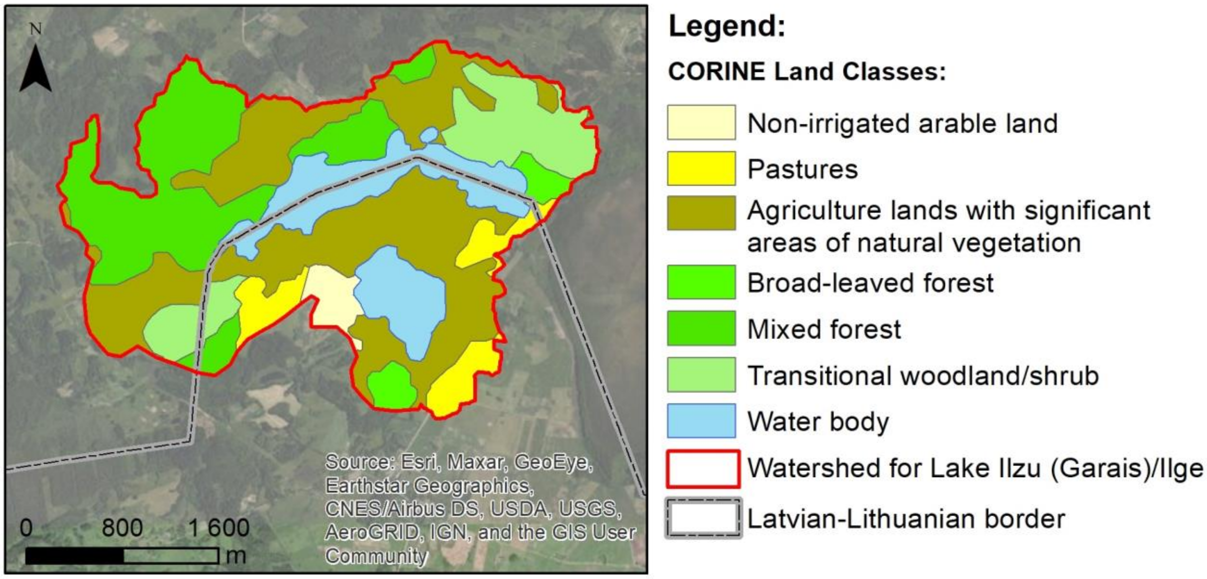

Figure 2.3.1. Land use types in the catchment of Ilzu (Garais)/Ilge Lake.

It should be mentioned that the share of agricultural lands such as pastures and non-irrigated arable lands, that can have a substantial impact on quality of groundwater and surface water is less than 20 % of the Lake Ilzu (Garais) catchment. These lands are mainly located in territories with low and moderate vulnerability to groundwater pollution. In turn, agricultural pressure is more intensive in the Lithuanian part of the catchment area.

Analysis of long-term changes in land use suggest that the anthropogenic pressure has decreased during the last 18 years (Table 2.3.1). The biggest changes are observed on the class of non-irrigated arable lands. Its area decreased by more than 100 ha. However, other land-use classes, such as pastures, lands principally occupied by agriculture, with significant areas of natural vegetation, broad-leaved forests, mixed forests and transitional woodlands/shrubs, have given the increase.

Table 2.3.1. Changes of CORINE Land Cover area in Lake Ilzu basin.

Class name	**Area by years, ha**			
	2000	**2006**	**2012**	**2018**
Non-irrigated arable land	129.9	79.4	20.6	20.6
Pastures	48.9	58.0	58.2	58.1
Complex cultivation patterns	3.4	0	0	0
Agriculture lands with significant areas of natural vegetation	287.3	320.4	326.4	324.1

Broad-leaved forest	12.7	24.2	24.5	24.3
Mixed forest	208.3	195.6	228.3	210.1
Transitional woodland/shrub	52.6	66.7	86.1	103.4
Water body	128.5	127.4	127.4	131.0

It should be mentioned that total area of pastures and non-irrigated arable land in the Lake Ilzu (Garais)/Ilge catchment has decreased from 178.8 to 78.7 ha. However, during the last 6 years it remained stable. Visualization of land-use changes is presented in Figure 2.3.2.

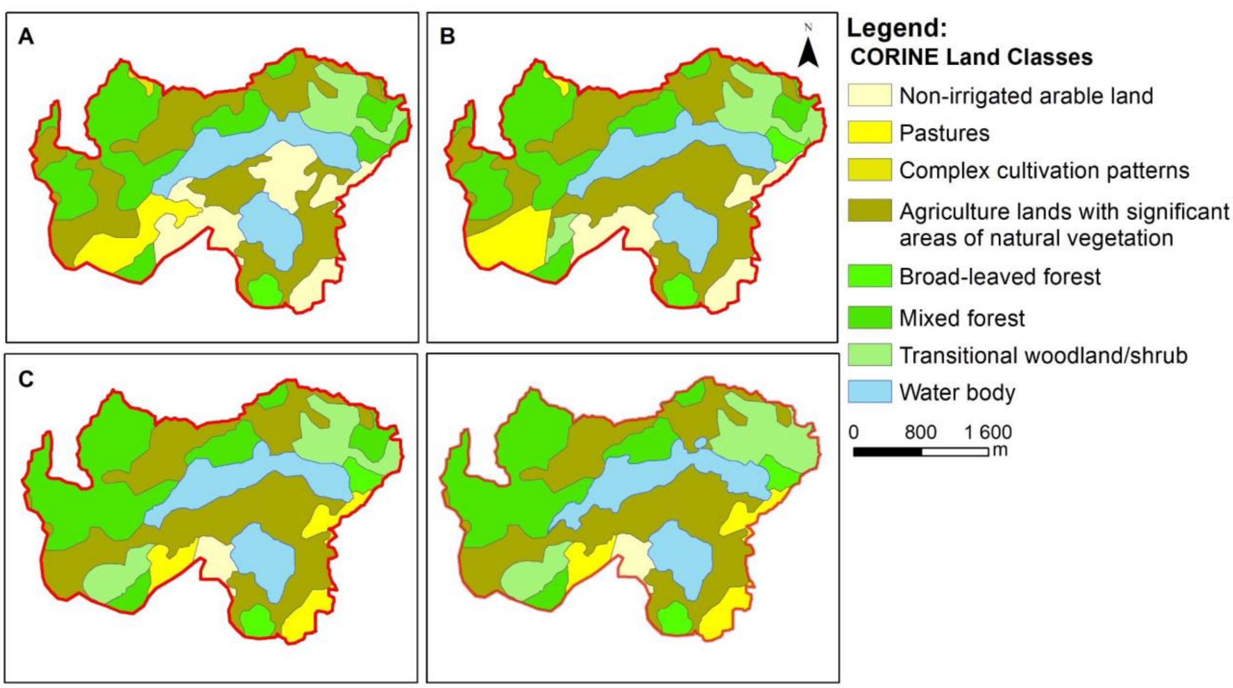

Figure 2.3.2. CORINE Land Cover data changes of Ilzu (Garais)/Ilge lake (A - year 2000, B - year 2006, C - year 2012, year – 2018)

III LAKE WATER ECOLOGICAL QUALITY

3.1. Biological indicators

3.1.1. Phytoplankton

Phytoplankton samples were collected twice during vegetation season - in May and August. Minor seasonal variations were observed and phytoplankton EQR index value varied from 0.59 indicating a moderate quality to 0.80 indicating a good quality. Annual average quality is good in Latvia and moderate in Lithuania (Table 3.1.1.1). Chlorophyll-a concentrations varied from 11.9 µg/L to 35 µg/L indicating moderate to poor quality class. It leads a very low water transparency (Fig. 3.1.1.1.1).

Table 3.1.1.1.1. Ecological quality of Lake Ilzu (Garais) by phytoplankton

Latvia		Lithuania	
Quality assessment	**EQR**	**Quality assessment**	**EQR**
Good	0.70	Moderate	0.48

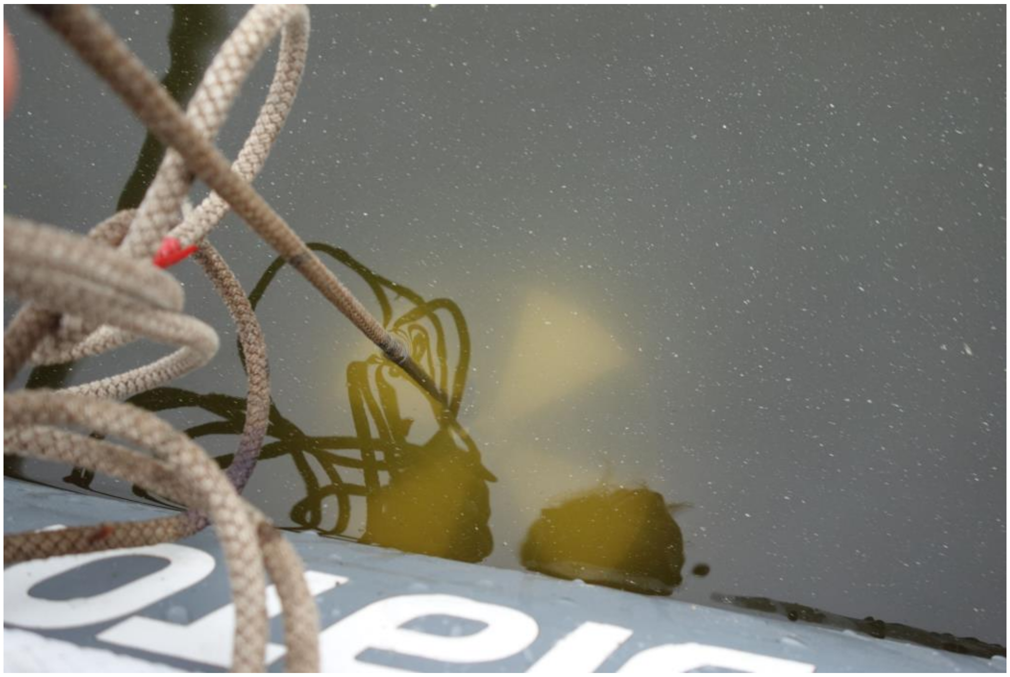

Figure 3.1.1.1.1. Observation of low water transparency in May (photo: L.Grīnberga)

3.1.2. Macrophytes

Assessment of macrophyte species abundance and diversity was carried out in August 2021 in the Latvian part of Lake Ilzu (Garais). Species abundance and colonization depth of submerged macrophytes was estimated in three transects, as well occurrence of all macrophyte species

around the perimeter was fixed. The abundance of macrophytes was estimated using a 7-point scale, where 1 – very rare (<1%), 2 – rare (1-3%), 3 – quite rare (2-10%), 4 – frequent (10-25%), 5 – common (25-50%), 6 – abundant (50-75%), 7 - very abundant (75-100%).
Diversity of macrophyte species in Lake Ilzu (Garais) is low. In total, only 18 species are found (Table 3.1.2.1.).

Table 3.1.2.1. Composition and abundance of macrophyte species in Lake Ilzu (Garais).

Species	**Transect 1**	**Transect 2**	**Transect 3**	**Perimeter**
Acorus calamus				x
Carex rostrata				x
Ceratophyllum demersum		4	3	x
Cicuta virosa				x
Eleocharis palustris				x
Equisetum fluviatile	3			x
Lycopus europaeus				x
Lythrum salicaria				x
Nuphar lutea	5	5		x
Phragmites australis	2	4	5	x
Polygonum amphibium			4	x
Potamogeton lucens				x
Potamogeton natans	4	2		x
Potamogeton perfoliatus				x
Scirpus lacustris				x
Thelypteris palustris				x
Typha latifolia	4			x
Utricularia vulgaris				x
Bottom	Stones, gravel	Mud	Stones, gravel	

Figure 3.1.2.2. Floating-leaved and emerged species are characteristic for Lake Ilzu (Garais), without submerged macrophyte stands

Dominating species in Lake Ilzu (Garias) are *Phragmites australis, Nuphar lutea, Potamogeton natans, Ceratophyllum demersum*. Emergent macrophytes dominate in the species composition (61% of all species), and only 3 submerged species are found. Growth of macrophytes is limited by low water transparency caused by high algae production (Fig. 3.1.2.2).

Figure 3.1.2.3. One of the dominating macrophyte species (Ceratophyllum demersum) demonstrates low water transparency (photo: L. Grīnberga)

Macrophytes indicate poor ecological quality in Lake Ilzu (Garais) according to Latvian methodology, and moderate quality according to Lithuanian methodology (Table 3.1.2.3). The main factors indicating lower quality - colonization depth of submerged macrophytes is only 1.3 m, charophytes are absent in the lake (although the habitat is appropriate - the lake Ilzu (Garais) is a hard-water shallow lake), *Potamogeton* and other submerged macrophyte species occur very rare. One of the dominating species - *Ceratophyllum demersum* is an indicator of eutrophic waters (Fig. 3.1.2.3).

Table 3.1.2.3. Ecological status of Lake Ilzu (Garais) by macrophytes

Latvia		**Lithuania**	
Quality assessment	**EQR**	**Quality assessment**	**EQR**
Poor	0.4	Moderate	0.25

Eutrophication and high phytoplankton production significantly impact species richness of submerged macrophytes. The low light availability in turbid lakes decreases maximum depth distribution and macrophyte-covered area (Jeppesen et al., 2000).

3.1.3. Macrozoobenthos

In the Latvian part of Lake Ilzu, sampling of benthic macroinvertebrates was carried out in May and October 2021. Both seasons the samples were taken at 3 sampling stations using a hand-net from the shallow littoral zone (Fig. 3.1.3.1). At each sampling station 5 replicates in proportion of present micro-habitats were taken and merged into one sample. Samples were preserved in 70 % ethanol. Sample processing and identification level of macroinvertebrate taxa was carried out according to the methodology described by Skuja and Ozoliņš (2016).

Spring: Abundance and number of taxa was higher at 1st and 3rd sampling site. At all sampling sites the most abundant taxa were Chironomidae larvae, common was mayfly *Caenis horaria* (at 2nd and 3rd site also *Cloeon dipterum*) and water mites Hydrachnidia. At the 1st site high abundance in the benthic invertebrate community was composed of crustaceans: amphipod *Gammarus lacustris* and isopod *Asellus aquaticus*.

The highest taxonomic diversity was characteristic for caddisfly Trichoptera larvae (14 taxa). The most abundant were Limnephilidae larvae; less significant role in community was characteristic for case-less Trichoptera, e.g. Polycentropodidae, *Ecnomus tenellus* etc.

Autumn: Similarly, also in autumn season abundance and number of taxa was higher at 1st and 3rd sampling sites and compared to spring season - higher at all sites. Chironomids were the most abundant taxa. Higher diversity was found at the 1st site. From crustaceans, isopods *Asellus aquaticus* were dominant, with high abundance at 1st site; amphipods *Gammarus pulex* were common at 1st and 3rd site, but abundance was low. Unlike the spring season, high abundance was characteristic for damselflies (Odonata) Coenagrionidae larvae, especially at 1st site. The highest taxonomic diversity also was characteristic for caddisfly Trichoptera larvae (12 taxa); Limnephilidae were the most abundant.

Ecological quality. The average values from all sampling stations were calculated in order to assess the ecological quality. The Lake Ilzu in spring and autumn seasons is at good status (Table 3.1.3.1) according to the LLMMI (Skuja and Ozoliņš, 2016) and LLMI (Šidagytė et al. 2013).

Table 3.1.3.1. Ecological status of Lake Ilzu (Garais) by macroinvertebrates

	Latvia		Lithuania	
	Quality assessment	**EQR**	**Quality assessment**	**EQR**
May 2021	Good	0.67	Good	0.52
October 2021	Good	0.66	Good	0.64

Figure 3.1.3.1. Sampling of benthic macroinvertebrates in the Lake Ilzu (Garais) (photo: L.Grīnberga)

3.1.4. Fishes

In the Lithuanian part of the lake, fish surveys were carried out at the end of August 2021 according to the procedure described in the report on methodology of lake ecosystem health assessment (Retiķe et al. 2021). The catch in the lake was standardized to catch per unit of effort (CPUE) per a set of 4 nets (for a total length of 20 m of each of the segments with different mesh sizes).

In total, 9 fish species were recorded in the lake during the fish survey. Data on catches of different fish species in segments of nets of different mesh sizes are presented in Table 3.1.4.1. Catches are dominated by roach, accounting for 68.8% of the total number of fish and 47.8% of the total biomass. The number of small roach individuals is especially high, their catch in only a 14 mm segment of the nets accounts for more than half of all fish caught (55.4% of the total number of fish). Among other fish species, only bream is more numerous, accounting for 16% of all individuals and 27.9% of the total biomass in the catch per unit of effort (Table 3.1.4.2). The rest of the fish species are much less numerous and make up only 14.8% of the total number of fish and 24.3% of the total biomass. The total number of fish per CPUE is 462.3 ind., the total biomass is 15.43 kg.

Lake Ilzu (Garais)/Ilgė is shallow (BIOR, 2021) and polymictic, therefore the ecological status of the lake was assessed based on the fish metrics used in the Lithuanian fish-based assessment system for this type of lakes (LT lake type 1; for more details see Retiķe et al., 2021). The metrics, their reference and measured values, ecological quality ratio (EQR) values, fish index value and the corresponding ecological status class are shown in Table 3.1.4.3. Two of the four metrics used in the system indicate a significant alteration of the structure and composition of the lake's fish assemblage. The relative abundance of piscivorous perch is extremely low, although under reference conditions this species should be one of the dominant species in polymictic lakes. This may be the reason for the unnaturally high abundance of small roach in Lake Ilzu (Garais)/Ilgė. The relative biomass of benthivorous fish species is not too high and still meets the criteria for good ecological status, but one species (white bream) was absent from the catch. However, the total number of obligatory species only slightly deviates from reference conditions, therefore the lake still has potential for recovery. According to the Lithuanian lake fish index, the ecological status of the lake is moderate, but close to the boundary of moderate/poor status.

Table 3.1.4.1. Species composition of fish, number (N, ind.) and biomass (B, g) of different fish species in the catch per unit of effort using a set of four multi-mesh gillnets in Lake Ilzu (Garais)/ Ilgė. The total length of each segment of different mesh size is 20 m.

Species	**Metric**	**Mesh size, mm**								
		14	18	22	25	30	40	50	60	**Total**
Bream	N, ind.	6	26		26	17	1	1		**77**
(Abramis brama)	B, g	72	945		1464	1342	109	367		**4299**
Bleak	N, ind.	6								**6**
(Alburnus alburnus)	B, g	101								**101**
Crucian carp	N, ind.								0.3	**0.3**
(Carassius carassius)	B, g								128	**128**
Gibel carp	N, ind.							1		**1**
(Carassius gibelio)	B, g							502		**502**
Pike	N, ind.						1	1		**2**
(Esox lucius)	B, g						664	842		**1506**
Ruff	N, ind.	22	4	1						**27**
(Gymnocephalus cernua)	B, g	281	82	19						**382**
Perch	N, ind.	6		1			1			**8**
(Perca fluviatilis)	B, g	83		100			308			**491**

Roach	N, ind.	256	52	4	3	1	1			**317**
(Rutilus rutilus)	B, g	4852	1651	234	243	154	247			**7381**
Rudd	N, ind.	12	9	3						**24**
(Scardinius erythrophthalmus)	B, g	239	261	144						**644**
	N, ind.	**308**	**91**	**9**	**29**	**18**	**4**	**3**	**0.3**	**462.3**
Total	**B, g**	**5628**	**2939**	**497**	**1707**	**1496**	**1328**	**1711**	**128**	**15434**

Table 3.1.4.2. Proportion of abundance (N%) and biomass (B%) of different fish species in the CPUE with a set of four multi-mesh gillnets in Lake Garais/Ilgė

Species		**N%**	**B%**
Bream	*(Abramis brama)*	16.7	27.9
Bleak	(Alburnus alburnus)	1.3	0.7
Crucian carp	*(Carassius carassius)*	0.1	0.8
Gibel carp	*(Carassius gibelio)*	0.2	3.3
Pike	*(Esox lucius)*	0.4	9.8
Ruff	*(Gymnocephalus cernua)*	5.8	2.5
Perch	*(Perca fluviatilis)*	1.7	3.2
Roach	*(Rutilus rutilus)*	68.6	47.8
Rudd	*(Scardinius erythrophthalmus)*	5.2	4.2

Table 3.1.4.3. Reference and measured values of fish metrics that are used in the Lithuanian fish-based method for assessing the ecological status of polymictic lakes, EQR values of metrics, fish index value and the corresponding class of ecological status of Lake Ilzu (Garais)/Ilgė

Fish metric (Polymictic lakes)	**Reference value**	**Measured value**	**Metric EQR***	**Fish index***
White bream (B%)	≤1.5 (>0)	0	0	0.39
Benthivorous species (B%)	≤10 (>0)	30.3	0.66	

Perch (N%)	≥30	1.7	0.06	
Obligatory species (number)	6	5	0.83	

*Green-good status class, yellow-moderate, red-bad

Based on the results of the analysis of potential anthropogenic pressures in the territory of Lithuania, the lake is likely to have previously suffered from pollution from point sources. Since 2019, Lithuania has banned the discharge of water from wastewater treatment plants into lakes. The economic entity was denied permission to discharge wastewater from the treatment plant into the catchment area of Lake Ilzu (Garais)/Ilgė. It is likely that this will have a positive impact on the ecological status of the lake in the long term.

In the Latvian part of the lake, fish surveys were carried out at the end of August 2021. For lake ecosystem health assessment, sampling of fish was performed with three different mesh-sized gillnets ranging from 20 mm to 35 mm knot to knot which are 30 m long (in total, 270 m). For fish diversity assessment additional fishing gears: beach seine (mesh size 5 mm), gillnets and trammel nets (8, 13, 14, 15, 18, 40, 45, 50, 60 and 70 mm) were used.

In total, 12 fish species were recorded in the lake during the fish survey: belica *Leucaspius delineatus*, bleak *Alburnus alburnus*, bream *Abramis brama*, crucian carp *Carassius carassius*, gudgeon *Gobio gobio*, perch *Perca fluviatilis*, Prussian carp *Carassius gibelio*, roach *Rutilus rutilus*, rudd *Scardinius erythrophthalmus*, ruffe *Gymnocephalus cernua*, spined loach *Cobitis taenia* and tench *Tinca tinca*.

From them 5 in gillnets (20-35 mm) which were used for lake ecosystem health assessment: bream, perch, roach, rudd and ruffe (Table 3.1.4.4).

Table 3.1.4.4. Number of fish species, individuals and their weight from fish surveys in Latvia

Species	Individuals	Weight (g)
Bream	427	24397
Perch	28	5083
Roach	75	5839
Ruffe	1	28
Rudd	8	406
Total	539	35753

In the Latvian part of the lake the relative abundance of piscivorous perch is relatively low (only 14% of total fish weight) and the abundance of bream is unnaturally high (68%).

Roach average weight (78 g) is low, but weight per unit of effort (2.1 kg) not particularly high (Table 3.1.4.5).

Table 3.1.4.5. EQR for different metrics according to Latvian assessment method

Metric	Wpue (kg)	Bream/RoachW%	PerchW%	RoachWavg (g)
Value	2.1	84	15	78
EQR	0.63	0.12	0.25	0.31

EQR calculated using a combination of all four metrics is 0.35. That means the lake has a poor/bad ecological status based on Latvian Lake Fish Index. Secchi depth (26.08.2021) was relatively low – 0.9 m, indicating a poor quality.

3.1.5. Zooplankton

The greatest total zooplankton abundance in Lake Ilzu (Garais)/Ilge was observed in May, both in the surface layer (1560 ind/L) and throughout the water column (626 ind/L). It gradually decreased in August (surface 516 ind/L, column 383 ind/L) and was even lower in October (surface 132 ind/L, column 279 ind/L). Rotifers were dominant only in spring while later in August and October cladocerans and copepods were more abundant. All together 10 rotifer and 31 small crustacean species were found both in zooplankton and littoral zone (Table 3.1.5.1). Of those in zooplankton samples, there were 10 rotifer and 12 small crustaceans species (7 Cladocera and 5 Copepoda). The dominant and most frequent species among zooplankton were:

- *Daphnia cucullata* (common in Latvia, known from eutrophic lakes and ponds with high fish predation pressure, planktonic species);
- *Bosmina (Eubosmina) coregoni thersites* (known from this region of Latvia before, characteristics for mesotrophic-eutrophic lakes);
- *Chydorus sphaericus* (very common, widely distributed and highly adaptive species from different kind and trophy gradient water bodies);
- *Eudiaptomus graciloides* (common, widely distributed species);
- *Mesocyclops leuckarti* (common, inhabiting large variety of water bodies)
- *Thermocyclops oithonoides* (widely distributed species whose abundance increases with the trophy increase).

In the littoral part, dominant species were:

- *Ceriodaphnia pulchella* and *Eucyclops macrurus* (both are widely distributed).

As to rotifers, *Keratella cochlearis, K. quadrata*, *Polyarthra* sp. and *Kellicottia* sp. were among most abundant species in the plankton and are known as widely distributed and common species (Bledzki and Rybak, 2016). Moreover, three first species apart from *Kellicottia* sp. are known to show positive correlation with total phosphorus (Čeirāns, 2007). Cyclopoida nauplii were more present in the upper water layer and less common throughout the water column. Of large species *Cyclops vicinus* and *Leptodora kindti* were found, both in the upper water layer and in the water column. As suggested by Zettler and Carter (1986), reduced transparency in turbid waters may favour large zooplankton species protecting from fish predators seeking visually.

Despite rather poor ecological status, the species richness is comparable to those lakes with good or moderate ecological conditions, most likely total phosphorus level has not reached that level when decline of zooplankton species richness starts.

Table 3.1.5.1. Zooplankton species abundance of the Lake Ilzu (Garais) / Ilge in 2021 from May to October

Sampling date	19.05	09.08	12.10	19.05	09.08	12.10	19.05	09.08	12.10
Sample type (1 - littoral 2 - surface, 3 - vertical)	2	2	2	3	3	3	1	1	1
liters	1	1	1	1	1	1	1	1	1
TOTAL (Rotifera+Cladocera+Copepoda)	**1560**	**516**	**132**	**626**	**384**	**279**	**83**	**1291**	**79**
Rotifera	**1260**	**88**	**26**	**525**	**38**	**6**	**0**	**30**	**0**
Asplanchna sp. Goose	92	0	0	9	0	0	0	0	0
Brachionus Pallas	4	44	1	0	19	0	0	15	0
Platyias Harring	12	0	0	0	0	0	0	0	0
Keratella cochlearis (Goose)	216	0	5	277	6	0	0	0	0
Keratella quadrata (O.F.M.)	504	0	3	226	0	0	0	0	0
Kellicottia Ahlstrom	176	0	0	13	0	0	0	0	0
Conochilus Ehrenberg	56	0	9	0	0	4	0	0	0
Polyarthra sp. Ehrenberg	200	36	5	0	6	2	0	8	0
Trichocerca sp. Lamarck	0	8	2	0	6	0	0	8	0
Filinia Bory de St. Vincent	0	0	1	0	0	0	0	0	0
Cladocera	**40**	**196**	**34**	**19**	**119**	**134**	**30**	**1215**	**68**
Diaphanosoma brachyurum (Liév.)T	0	16	0	0	13	0	0	15	0
Sida crystallina (O.F.M.)	0	0	0	0	0	0	0	8	0
Ceriodaphnia pulchella Sars	0	0	0	3	0	6	19	15	0
Ceriodaphnia quadrangula (O.F.M.)	0	0	0	0	0	0	0	0	0
Daphnia cucullata Sars	0	52	7	3	44	75	0	8	4
Scapholeberis mucronata (O.F.M.)	0	0	0	0	0	0	0	23	0
Bosmina (Eubosmina) coregoni thersites Poppe	0	4	26	0	6	51	0	0	4

Bosmina (Bosmina) longirostris (O.F.M.)	8	0	0	9	0	0	0	1117	0
Acroperus angustatus Sars	0	0	0	0	0	0	0	0	4
Acroperus harpae (Baird)	0	0	0	0	0	0	4	8	0
Alona rectangula Sars	0	0	0	0	0	2	0	0	49
Alonella nana Baird	0	0	0	0	0	0	8	0	0
Camptocercus lilljeborgi Schoedler	0	0	0	0	0	0	0	0	0
Chydorus sphaericus (O.F.M.)	32	124	1	3	57	0	0	23	0
Rhynchotalona falcata Sars	0	0	0	0	0	0	0	0	0
Monospilus dispar Sars	0	0	0	0	0	0	0	0	0
Disparalona rostrata Koch	0	0	0	0	0	0	0	0	0
Pleuroxus truncatus (O.F.M.)	0	0	0	0	0	0	0	0	0
Leydigia leydigi Schoedler	0	0	0	0	0	0	0	0	0
Pleuroxus trigonellus O.F.M.	0	0	0	0	0	0	0	0	4
Polyphemus pediculus (Leuck.)	0	0	0	0	0	0	0	0	4
Leptodora kindti Focke	0	0	0	0	0	0	0	0	0
Copepoda	**260**	**232**	**72**	**82**	**226**	**140**	**53**	**45**	**11**
Calanoida	**0**	**16**	**3**	**3**	**0**	**26**	**0**	**8**	**0**
Eudiaptomus graciloides (Lillj.)	0	4	2	3	0	19	0	0	0
cal naup	0	12	1	0	0	8	0	8	0
cal cop	0	0	0	0	0	0	0	0	0
Cyclopoida	**260**	**216**	**69**	**79**	**226**	**113**	**53**	**38**	**11**
Cyclops vicinus Uljanin	4	0	1	0	0	6	0	0	0
Acanthocyclops sp.	0	0	0	0	0	0	0	0	0
Eucyclops macrurus (Sars)	0	0	0	0	0	0	23	0	4
Eucyclops serrulatus (Fisch.)	0	0	0	0	0	0	8	0	0
Megacyclops viridis (Jurine)	0	0	0	0	0	0	0	0	0
Mesocyclops leuckarti (Claus)	0	0	2	0	19	9	4	0	8
Thermocyclops oithonoides Sars	0	24	0	0	75	15	0	8	0

Thermocyclops crassus Fisch.	0	8	0	0	38	0	0	0	0
cycl naup	224	132	44	44	25	34	8	23	0
cyc cop	32	52	22	35	69	49	11	8	0

3.2. Physico-chemical indicators

Assessment of ecological quality based on supportive physico-chemical indicators according to the WFD is currently the most widely used method for evaluation of lake ecosystem quality and status. In Latvia, annual average TP and TN concentrations as well as summer season average Secchi depth values are used for assessment of ecological quality in lake type L5. Annual average values of TP, TN and Secchi depth are used in Lithuania.

According to Latvian methodology, TP concentration of the Lake Ilzu (Garais) / Ilge corresponds to good ecological quality, but TN concentration and Secchi depth measurement values indicate moderate ecological quality. Lithuanian methodology assesses the lake as in high status based on TP concentration, in good status according to TN, and moderate according to transparency. It should be noted that only summer season measurements of transparency were available for the assessment. Based on the WFD principle “one-out, all-out”, the overall physico-chemical quality of the lake is estimated as moderate in both countries (Table 3.2.1).

Table 3.2.1. Ecological quality assessment based on physico-chemical indicators according to Latvian and Lithuanian methodology (color scheme as for the EU WFD: blue - high, green - good, yellow - moderate, orange - poor, and red - bad ecological quality)

Latvia		**Lithuania**	
parameter	**average value**	**parameter**	**average value**
TP, mg/L	0.033	TP, mg/L	0.033
TN, mg/L	1.14	TN, mg/L	1.14
Secchi depth, m	1.10	Secchi depth, m	1.10
TOTAL	**moderate**	**TOTAL**	**moderate**

Although Lake Ilzu (Garais) / Ilge is not included in the list of priority salmonid and cyprinid waters (Cabinet Regulation No.118, adopted 2002), the suitability of the lake for cyprinid fish communities can be assessed.

Yearly average concentrations of almost all measured parameters important for fish life do not exceed the guideline and limit values. Exceptions are ammonium and free ammonia concentrations which exceed guideline values (Table 3.2.2). The highest observed values (1.55 and 0.84 mg NH_4^+/L) of individual measurements of ammonium concentration were exceeding limit values for cyprinid fish waters in January and February 2021, but un-ionized NH_3 concentration (0.035 mg NH_3/L) exceeded the limit value only in January 2021.

Table 3.2.2. Suitability of Lake Ilzu (Garais) / Ilge for cyprinid fish life (guideline and limit values as given in the LR Cabinet Regulation No.118, adopted 2002). N/A: not measured

Parameter	Measurement value	Guideline value	Limit value
Ammonium, mg/l NH_4^+	0.35	≤ 0.16	≤ 0.78
BOD5, mg/l O_2	2.8	≤ 4.0	
Dissolved oxygen, mg/l O_2	8.2 (minimum)	50 % > 8 100 % > 5	50 % > 8
Ammonia, mg/l NH_3	0.006	≤ 0.005	≤ 0.025
Nitrites, mg/l NO_2^-	0.014	0.03	
pH	8.06		6-9
Suspended solids, mg/l	N/A	≤25	

Lake Ilzu (Garais)/Ilge is a shallow lake with an average depth of 2.4 m and maximum depth of only 3.6 m. It means that the lake is polymictic and no stable hypolimnion is observed. Due to mixing of the water layer, no oxygen deficiency is observed.
In order to assess the possible inflow of nutrients and organic matter to the Lake Ilzu (Garais)/Ilge, two ditches in Latvian part of the catchment were sampled by the LEGMC experts in winter and summer season. Ditch No.1 was dry during sampling in July. TN concentration was only slightly elevated in both ditches in January 2021. Ditch No.2 is a potential source of TP to the lake (Table 3.2.3.) as well as of easily degradable organic matter in winter. Water quality of inflowing streams within the Lithuanian part of the catchment was not assessed during this project, although there is some evidence that a stream outflowing from Lake Apvalasai might be an important source of nutrients to Lake Ilzu (Garais)/Ilge. Economic activities are quite intensive on Lithuanian shore of the lake, but there are no wastewater treatment plants that exceed the volume of wastewater discharged, which triggers the obligation to register the treatment plants in Lithuanian EPA and to monitor the quality of the wastewater (information provided by Lithuanian EPA). However, this does not mean that unauthorised or illegally connected sewage discharges and the discharges from WWTPs which are not obliged to be registered in the databases of the Environmental Protection Agency are not present in Lithuanian part of the lake's catchment. Therefore, it is planned in Lithuania's 3rd RBMPs to inventory the outlets into the lake and its tributaries, as well as in the vicinity of the lake, in order to determine whether there are any discharges of wastewater into the lake.

Table 3.2.3. Concentration of nutrients and indicators of organic matter in two inflowing ditches

Parameter	Ditch No 1	Ditch No 2	Ditch No 2
date	25.01.2021	25.01.2021	21.07.2021

P_{tot}, mg/L	0.065	0.390	0.380
$P\text{-}PO_4^{3-}$, mg/L	0.015	0.064	0.097
N_{tot}, mg/L	2.1	2.1	1.13
$N\text{-}NO_3^-$, mg/L	0.051	0.36	0.26
$N\text{-}NH_4^+$, mg/L	0.77	0.2	0.26
BOD5, mg/L	2.4	4.2	1.63
Total organic carbon, mg/L	29	27	7.1

Analysis of **lake sediment quality** and properties is often overlooked in lake studies and monitoring. One of the most important features of sediments is the content of organic matter (in % of organic matter). Sedimentary organic matter in lakes is generally derived from in-lake sources (e.g., due to decay of phytoplankton, macrophytes) and terrestrial sources (e.g., input from organic-rich soils, peat, shoreline vegetation). The formation of organic-rich deposits is favored by increased primary productivity, high sedimentation rate, low water dynamics, restricted input of inorganic particles and oxygen deficiency (Woszczyk et al. 2011). The content of organic matter has a huge impact on biogeochemical processes in a lake ecosystem and is a potential indicator of lake ecosystem health. Organic matter may constitute a source of nutrients to lake ecosystem components, impact oxygen conditions in hypolimnion or near sediment-water boundary layer, as a result of transformations, it may have a significant effect on the mobility, bioavailability and toxicity of trace elements and micropollutants (e.g. Chen and Hur 2015). Sediment analysis reveals that Lake Ilzu (Garais)/ Ilge sediments have a high content of organic matter (40.01 to 40.58% by weight of dry mass) if compared to average value of all five studied transboundary lakes (Table 3.2.4). Organic matter content in 18 priority salmon fish lakes comprised 4.3 - 46.2%. Only in eutrophic Lake Zosna, organic matter content was higher than 40% (Jankevica et al. 2012). Higher carbon content (%), if compared to other transboundary lakes, is due to the presence of organic matter as the share of carbonates is comparatively lower (Table 3.2.4).

Nitrogen content in Lake Ilzu (Garais)/ Ilge sediments is 1.97-1.98% by weight of dry mass, and it is 1.6 times higher than average in the five transboundary lakes (Table 3.2.4).

Table 3.2.4. Sediment quality of Lake Ilzu (Garais) / Ilge

Sampling site	**organic matter, %**	**carbonates, %**	**mineral matter, %**	**N, %**	**C, %**
L.Ilzu (Garais), E side, deeper part	40.01	3.49	56.50	1.97	22.66

L.Ilzu (Garais), W side, near islands	40.58	2.64	56.78	1.98	23.33
AVERAGE in 5 transboundary lakes	28.57	5.04	66.39	1.23	16.24

Lake sediments usually are considered as a net sink for phosphorus, but surface sediment can also store a large fraction of mobile or bioavailable P. The amount of mobile P in the surface sediment is an important parameter for assessment of internal loading and the subsequent export of P from lake sediments (Rydin 2000). P fractions in sediments are measured using different sequential extraction schemes. The fractionation procedures are based on the differential solubilities of the various inorganic P forms in various extracts. During this study, a modified extraction scheme by Psenner et al. (1984) was used. Following P fractions were analysed (Psenner et al. 1984; Rydin 2000):

- NH_4Cl-P in general represents inorganic phosphorus in porewater, loosely bound P, and in hard-water lakes, also $CaCO_3$-associated P;
- $NaHCO_3$/ Na_2S_2O4-P fraction extracted by these solutions is sensitive to redox conditions;
- NaOH-P in general represents P exchangeable with OH^-, mainly aluminium;
- HCl-P fraction is sensitive to low pH, e.g., P bound in apatites;
- residual-P is the difference between total P concentration and concentration of all above-mentioned P fractions. Residual P fraction consists of both inert inorganic P and organic fraction that was not extracted in previous steps (organic fraction may become bioavailable during mineralisation of organic matter).

Concentration of total phosphorus and its speciation forms in mg/kg dry weight sediments is presented in Table 3.2.5., and proportion of P forms is shown in Figure 3.2.1. Concentration of total P and its forms in Lake Ilzu (Garais)/Ilge is in general similar to that in other studied transboundary lakes. The largest fraction is the residual P, which comprises about 85% of total P content in the Lake Ilzu (Garais)/Ilge sediments. Considering the very high content of organic matter in the lake sediments (Table 3.2.4), a substantial amount of residual P possibly can be attributed to organic P. Due to microbial degradation, organic P is a potential source of dissolved reactive phosphorus to the lake, especially, in anoxic conditions, thus promoting eutrophication (Rydin 2000; Ahlgren et al., 2011). Content of the residual P fraction in this lake is higher if compared to that in other Latvian lakes (40-72%; Jankēvica et al. 2012). The share of other easily available P fractions (NH_4Cl-P and $NaHCO_3$/ Na_2S_2O4-P) is small (Fig. 3.2.1). Study by Jankēvica et al. (2012) shows that a share of NH_4Cl-P accounted for less than 0.35% of total P and that of oxred sensitive P species varied from 0.9 – 15.6% of total P content.

Table 3.2.5. Concentration (mg/kg d.w.) of phosphorus speciation forms in Lake Ilzu (Garais)/ Ilge sediments in August 2021

Sampling site	Ptot, mg/kg	NH_4Cl-P, mg/kg	$NaHCO_3$/ Na_2S_2O4-P, mg/kg	NaOH-P, mg/kg	HCl-P, mg/kg	residual-P, mg/kg
L.Ilzu (Garais), E side, deeper part	1197	2.09	49	61	62	1023
L.Ilzu (Garais), W	1030	1.08	47	53	55	875

side, near islands						
AVERAGE in 5 transboundary lakes	1032	1.54	50	106	68	806

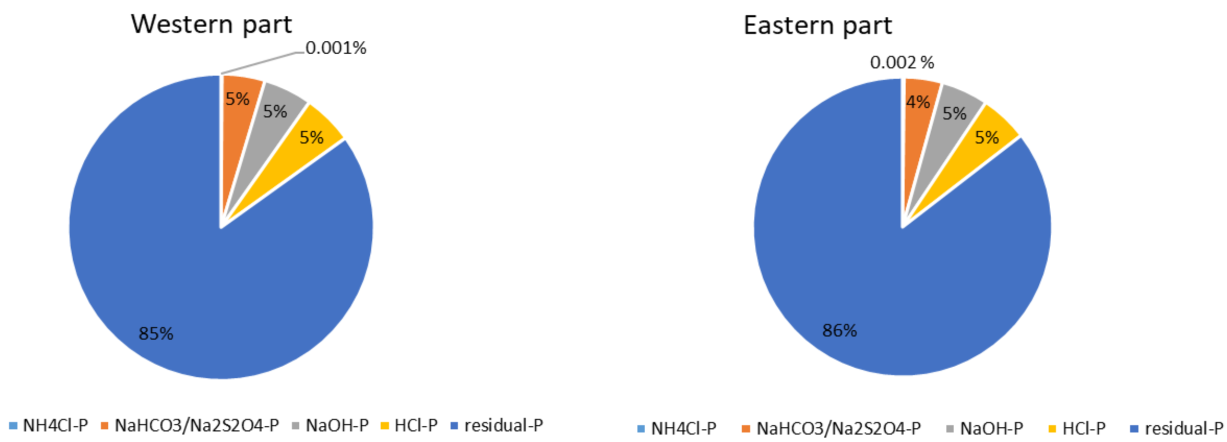

Figure 3.2.1. Proportion of phosphorus fractions in Lake Ilzu (Garais)/ Ilge sediments

3.3. Indicators of Lake Hydromorphological Character

The Water Framework Directive (WFD) requires physical features of surface waters to be considered when assessing ‘ecological status’ and refers to these features as hydromorphological. The physical character of a lake is defined by its morphometry (size and shape) and by its hydrological regime, both of which are contingent on the landscape setting of the lake-catchment system and its environmental history (CEN, 2011). The Lake Habitat Survey (LHS), as a method for describing and evaluating hydromorphological characteristics of the lakes and reservoirs, was adopted in Latvia in 2014.

Water level data analysis has been made, taking into consideration data logger installation in Lake Ilzu (Garais)/Ilge at the end of March 2021. It is clear that the short period of water level measurements cannot be enough to characterize the hydrological regime of the lake and should be increased to at least 10-years period. Therefore, data series of a hydrological monitoring station ‘Viesite River, nearby Sudrabkalni’ for the period 2008-2021 (in 2008 the station was restored after interrupted observations from 1994 to 2007) were used as an analogue for calculation of water levels in the lake (Fig. 3.3.1.). The monitoring station is located approximately 40 km northwest of Lake Ilzu (Garais)/Ilge catchment boundary. The catchment area of the Viesite River (nearby Sudrabkalni) is large in comparison with total catchment area of the Lake Ilzu (Garais) /Ilge (323 km^2 against 8.72 km^2) but depends upon water level and flow regime upstream and outflow from Viesite Lake (at Viesite River source). The Viesite River, as well as the Ilzu (Garais)/Ilge Lake belong to a large Mēmele/Nemunelis River basin. The Viesite River is a right-bank tributary of Mēmele/Nemunelis River. The correlation coefficient of measured water level data series from a monitoring station 'Viesite River, nearby Sudrabkalni' and a logger in the Lake Ilzu (Garais)/Ilge is quite high and equals to 0.78.

It should be emphasized that there is no possible to find more lakes – analogues with the similar catchment area and flow regime within the Lielupe River basin due to lack of monitoring data.

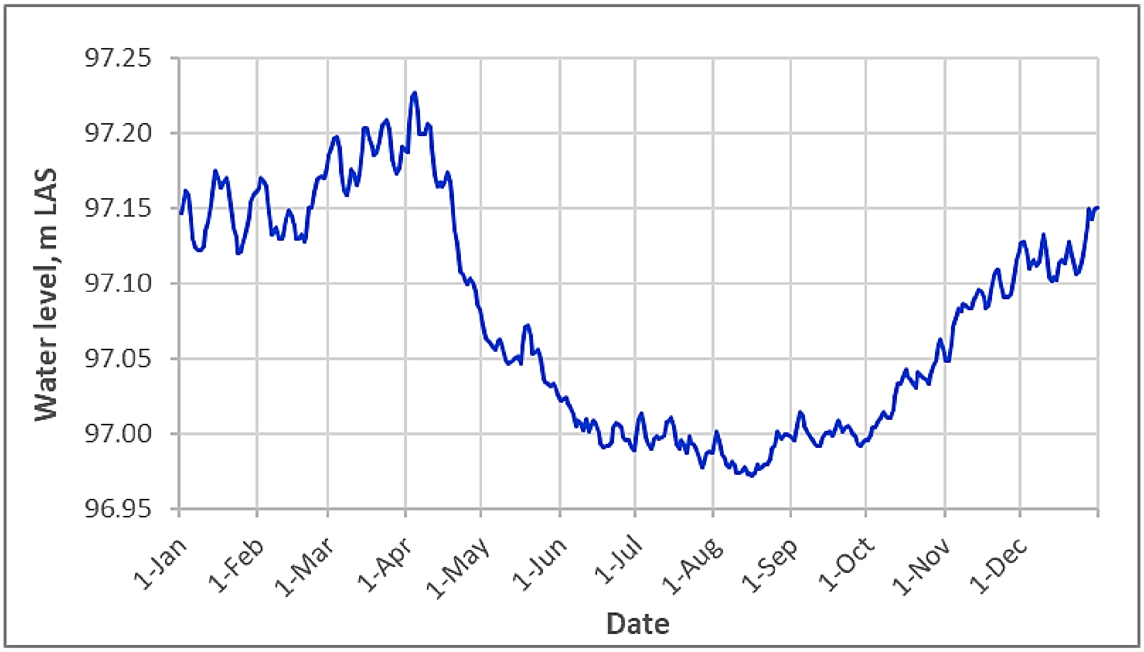

Figure 3.3.1. Calculated daily water level fluctuations in the Ilzu (Garais)/Ilge Lake for the period 2008-2021

The 14-years period hydrological regime of Lake Ilzu (Garais)/Ilge catchment can be characterized by the spring flood, summer low flow period and autumn – winter rainfall floods. At the lake's maximum filling period, the highest water levels are observed from early March until mid-April, on average. The low flow period usually lasts from the beginning of June until late September followed by frequent rains causing gradual water level rising during autumn and winter seasons.

The long-term (14-years period) water level range in the Lake Ilzu (Garais)/Ilge reaches 98 cm. Maximum water level (97.83 m Latvian normal height system or LAS) is calculated for the lake during spring flood of 2010, minimum water level (96.85 m LAS) was observed on 27th July 2021. 14-years mean water level in the lake is 97.08 m LAS.

The Lake Ilzu (Garais)/Ilge is a natural lake without significant water level alterations caused by unnatural factors. Drainage (amelioration) systems are located in the northern part and occupy only about 0.5% of the total lake catchment. There are other hydrological structures (e.g. dams, sluices, impoundments) found neither on the inflowing streams nor on the outflowing river. Thus, the Lake Ilzu (Garais)/Ilge corresponds to a lake waterbody in referenced hydrological condition or at high status.

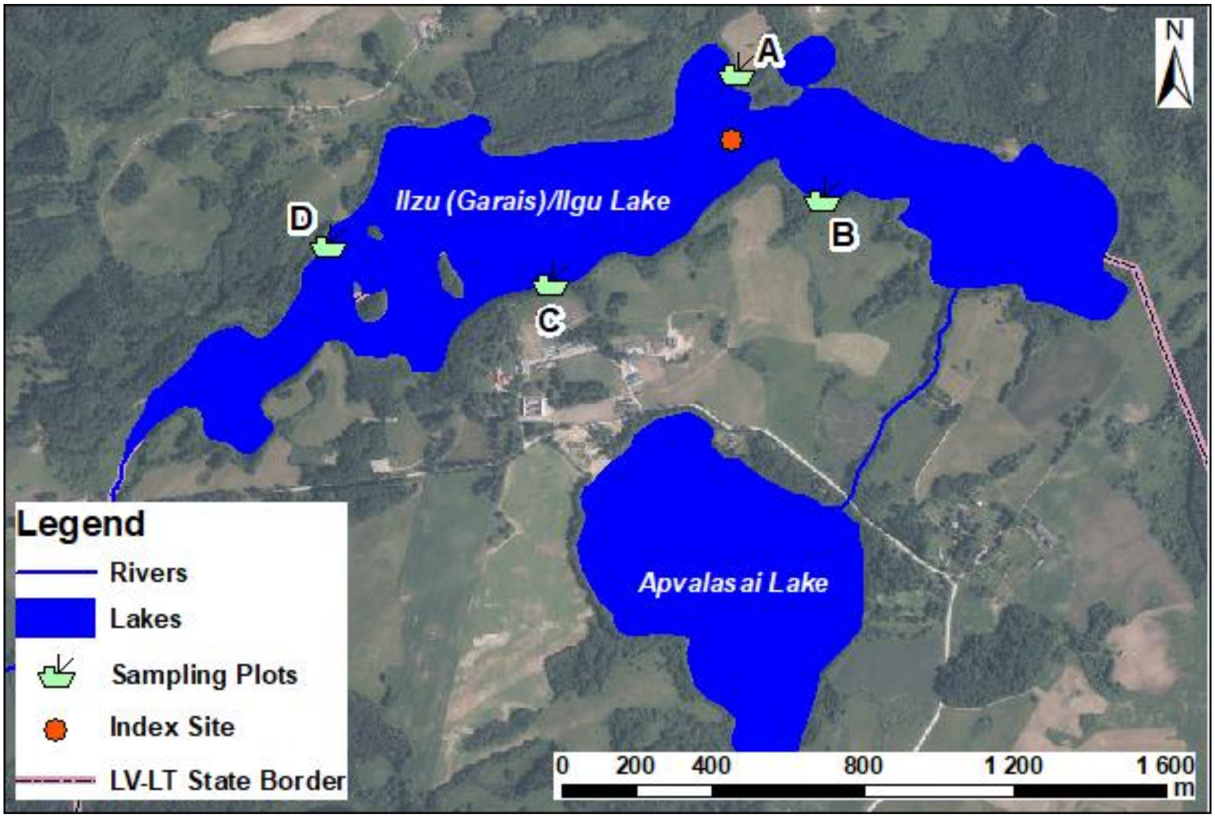

Figure 3.3.2. Selected Hab-Plots around the Ilzu (Garais)/Ilge Lake perimeter and measured in-lake Index Site within field survey (29 August 2014)

The LHS for the Lake Ilzu (Garais)/Ilge was carried out by boat in the late summer of 2014. Four sampling plots or Hab-Plots (A, B, C, D) evenly spaced around the lake, were selected in order to record detailed habitat characteristics in the shore, riparian and littoral zones (Fig. 3.3.2).

During the field survey boat docks and footbridges were recorded only within one of four Hab-Plots. However this pressure regarding lake shore modification is not permanent and may be built in one place and disappear in another. Artificial structures like 'hard engineering' and 'soft engineering' were not recorded along the lake shore.

Large areas of total non-natural land-cover were recorded within 15 and 50 m for the Lake Ilzu (Garais)/Ilge expressed as extent of total shoreline length. This type of feature includes commercial activities, roads and railways, parks and gardens, litter, pastures and observed grazing, tilled land, orchards. Accordingly, these pressures exceed 50% of total lake shoreline length.

Less than 50% of Lake Ilzu (Garais)/Ilge shore is affected by erosion. However 50 - 70% of the lake area could be affected by deposition (excluding vegetated islands). These data are confirmed by recording sedimentation over natural substrate in the littoral zone within three Hab-Plots and by taking into consideration small average depth of the lake (2.4 m). The lake bottom consists mostly of gravel and sand covered by a thin layer of sand but in some places lake sediments are composed of silt and clay.

The Lake Ilzu (Garais)/Ilge is used mostly for recreational and management purposes: non-motor boat activities, angling from boat, angling from shore, fish cages, swimming, macrophyte control, powerlines. According to the latest orthophoto maps, about 70 m long and 2 m wide causeway as an in-lake barrier was built in the southwestern part (in Lithuania) in order to provide access from the lake shore to the one of three lake islands for visitors and tourists (Fig. 3.3.3).

Figure 3.3.3. The causeway to the island (photo: L.Grīnberga)

Data on the physico-chemical character of the Lake Ilzu (Garais)/Ilge was collected at the deepest point (Index Site). During the field survey by boat on August 29th, 2014 lake's maximum depth was 3.5 m. Dissolved oxygen levels were reduced from 10.2 mg/L at the surface of the lake to 9.7 mg/L at the deeper layers. The Secchi depth was only 0.8 m at the Index Site.

Analysis of natural and non-natural land-use information for Lake Ilzu (Garais)/Ilge catchment was made, taking into consideration CORINE Land Cover data of 2018 and data of 2020 from the Rural Support Service of Latvia. Forest lands comprise 38.9% of total catchment area, while 46.5% of the area is occupied by agricultural lands. As a significant catchment pressure, arable land occupies about 4.6%. Surface areas of Lakes (Ilzu (Garais)/Ilge and Apvalasai) comprise 14.6% of total catchment area.

Developed scoring system for hydromorphological alterations and pressures in the frame of the Lake Habitat Survey method illustrates that the difference of relevant scores for the Lake Ilzu (Garais)/Ilge and for a lake in reference conditions reaches 48%, i.e. 24 out of possible 50 scores when assuming the worst-case scenario (Table 3.3.1). That means the Lake Ilzu (Garais)/Ilge can be classified as a lake waterbody in moderate hydromorphological status (class 3).

Table 3.3.1. Scoring of hydromorphological indicators and characteristics of the impact for the Lake Ilzu (Garais)/Ilge

Hydromorphological Indicator	**Scores**	**Characteristics of the Impact**
Shore zone modification	2	Low risk of impact
Shore zone intensive use	6	High risk of impact
Hydrological regime	0	Un-impacted condition
Sediment regime	4	Moderate risk of impact
In-lake use	8	Severely impacted condition
Index Site condition	4	Moderate risk of impact
Catchment pressures	0	Un-impacted condition
Total	**24**	

IV HYDROGEOLOGICAL AND GEOLOGICAL CONDITIONS

4.1. Geomorphology, geology and hydrogeology

Geomorphologically, the Ilzu (Garais)/Ilge Lake (hereinafter – the lake) is located in the southern part of the Sēlija moraine hillside of the Augšzeme highland, on the border of Latvia and Lithuania. Sēlija moraine hillside is an interlining hillside, which was formed in the contact zone of the ice mass of two glacier tongues approximately 14’000 years ago. The territory of the catchment area of the lake is characterized by hilly relief, the highest point of which is Kapu Hill (145 m a.s.l.). In the rest of the territory, the altitude ranges from 97 m to 120 m a.s.l., and in only a small part of the territory vary between 120 m and 145 m a.s.l. (Conceptual model…, 2022).

In geological cross-section, there can be distinguished three main complexes: crystalline bedrock, pre-quaternary bedrock and quaternary deposits. Pre-quaternary sediments are from the Cambrian, Ordovic, Silurian and Devonian periods. Devonian stratum consists of terrigenous and carbonate sediments. Depth of quaternary sediments is variable throughout the Lake Ilzu (Garais) catchment . Quaternary deposits are mainly formed by the glacial sediments of the last glaciation (gQ_3ltv) – moraine sand and loam, as well as fluvioglacial (fQ_3ltv) sediments (sand and gravel). Outside the catchment area of the lake, limnoglacial (lgQ_3ltv) sand sediments and bog peat (bQ_4) sediments, which have formed after the last glaciation in the relief depressions, are also present (Fig. 4.1.1).

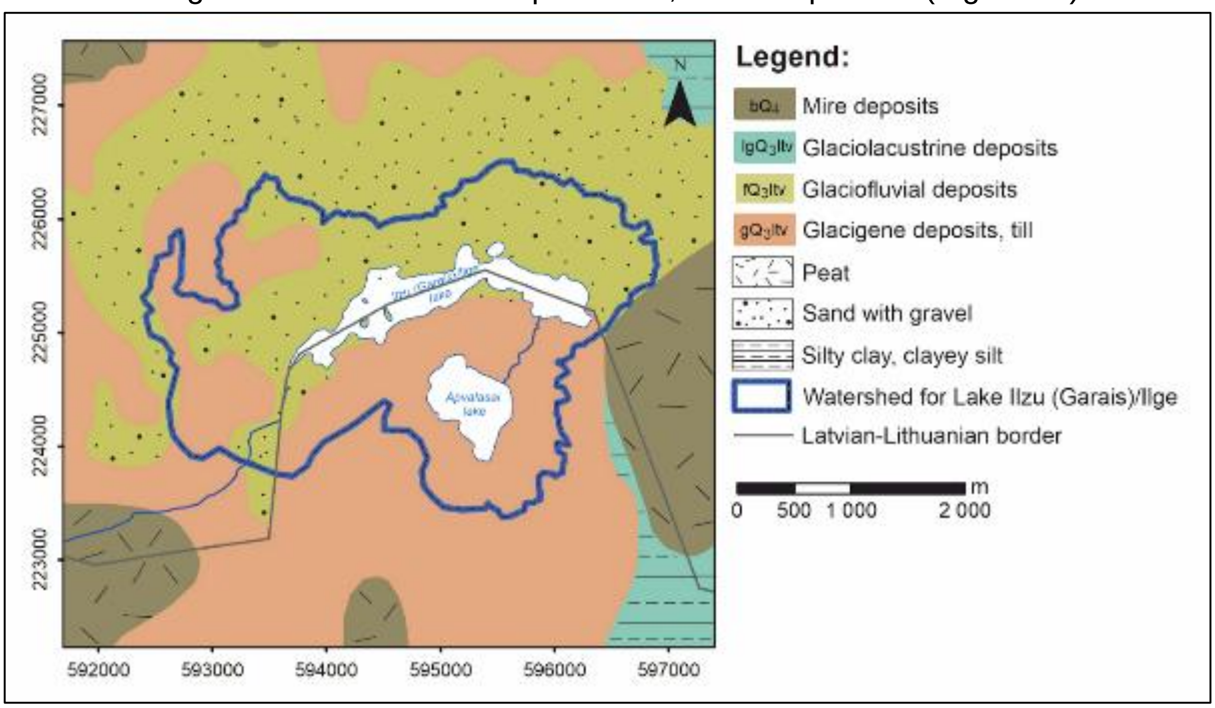

Figure 4.1.1. Prevalence of Quaternary sediments in the vicinity of the Ilzu (Garais)/Ilge Lake

The catchment area of the Ilzu (Garais)/Ilge Lake and the adjacent area is a part of the Baltic Artesian Basin, where the thickness of the active water exchange zone (up to the

Narva regional aquitard) is about 210-250 m. The active water exchange zone is separated from the slowed-down water exchange zone by the Narva (D2nr) regional aquitard which consists of water impermeable layers of aleurolite, marl, dolomite marl and clay layers with a thickness of about 120-125 m.

The active water exchange zone is formed by the quaternary sediments and pre-quaternary sediments from Upper Devonian and Middle Devonian period (Fig. 4.1.2). In the Lake Ilzu (Garais) catchment area following aquifers can be distinguished (Fig. 4.1.2):

- ➢ Quaternary aquifer (Q);
- ➢ Upper Devonian Pļaviņu aquifer (D_3pl). Not distributed in the catchment area of the lake and is identified only in the southwest part of the observed area with a small thickness (approx. 2-7 m);
- ➢ Upper Devonian Amatas aquifer (D_3am);
- ➢ Upper Devonian Gaujas aquifer D_3gj);
- ➢ Middle Devonian Burtnieku aquifer (D_2br);
- ➢ Middle Devonian Arukilas aquifer (D_2ar).

Despite the fact that the catchment area of the Ilzu (Garais)/Ilge Lake include five aquifers, it should be noted that only shallow groundwaters of the Quaternary aquifer has a direct hydraulic connection with the flake and it is the most important aquifer for the assessment of the lake. On the contrary, deeper groundwater of confined aquifers are not hydraulically connected to the lake, thus their contribution to the lake water budget is negligible (Fig. 4.1.4). Within this report, description of Quaternary groundwater is provided, but description of pre-quaternary aquifers are given in the report “Conceptual model of surface-groundwater interaction” (TRANSWAT project report, 2022).

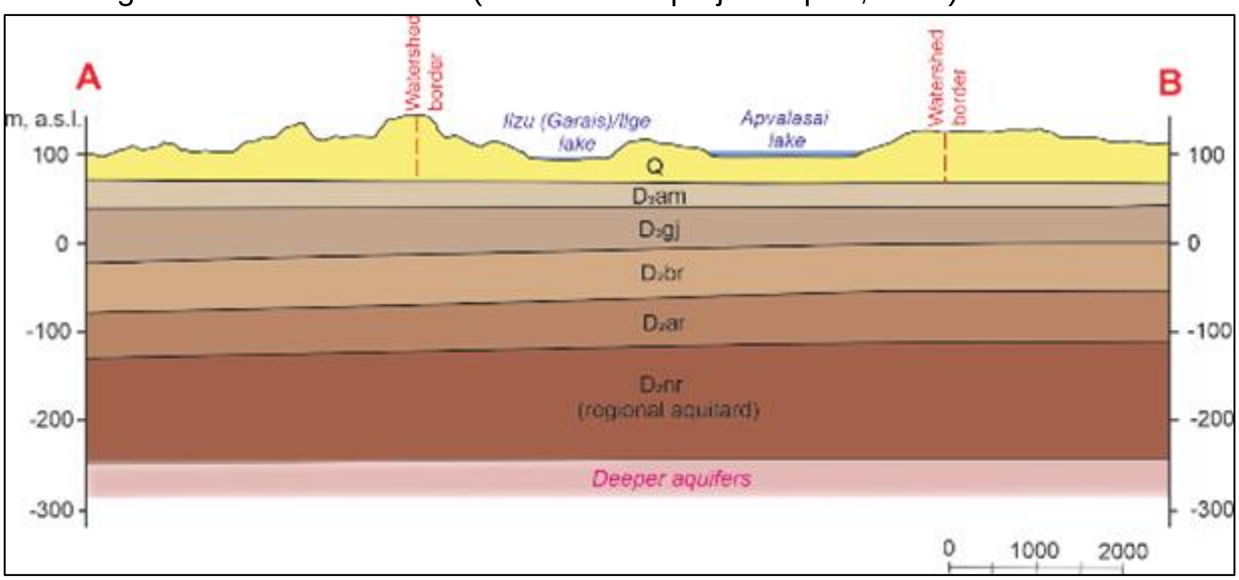

Figure 4.1.2. Schematic geological section along line A-B

The thickness of the Quaternary sediments in and around the catchment area of the lake varies mainly around 30-50 m, but in the southwest part of the area it decreases to 20 m, and in some elevations the thickness increases up to 70-80 m. Shallow groundwaters in the area are sporadic, associated with either sand and sand-gravel sediments above the moraine layer or with sand lenses in the moraine sediments. The thickness of aquiferous sediments usually ranges from 4 m to 10 m, and only some sections can reach a thickness of 20 m. Therefore, their use for water supply is limited and they can mainly be used only by the individual sector (dug wells) with limited resources. Depending on the terrain, the groundwater level can vary in different areas. In depressions, the groundwater level is 0.5-2.0 m below the ground surface, but in some hilly areas it can be as much as 10-20 m below the ground surface. Shallow groundwaters are vulnerable to surface pollution. Compared to confined groundwaters, shallow groundwaters have a lower amount of dissolved salts (mineralization) and hardness, but often have an increased concentration of organic matter and associated water colour. As there were no sampling and analysis of composition of groundwater, Quaternary deposits as well as detailed analysis on pollution extent within the Lake Ilzu (Garais), further description is based on literature review, which gives a preliminary information on chemical composition of Quaternary groundwater (Table 4.1.1). There is no information about possible pollutants in Quaternary groundwater.

Table 4.1.1. Concentrations of dominant ions in Quaternary groundwaters

HCO_3^-	SO_4^{2-}	Cl^-	Ca^{2+}	Mg^{2+}	Na+	K^+	Sum of ions
mg-eq L^{-1}							
4.92	0.31	0.2	3.9	1.5	0.18	0.04	11.04

The replenishment of shallow groundwater resources is mainly due to the infiltration of atmospheric precipitation. Its intensity depends on the amount of precipitation, surface runoff, the thickness of the aeration zone, sediment filtration properties, as well as other factors. Description of groundwater recharge conditions are summarized in Table 4.1.2. Part of shallow groundwaters infiltrates into the deer layers, replenishing the resources of the confined aquifers, while the rest drains into local depressions, river and stream valleys, lakes and drainage ditches. The regional shallow groundwater flow in the study area is directed to Lake Ilzu (Fig. 4.1.3).

Table 4.1.2. Characteristics of groundwater recharge

Sediments on Earth's surface	Specific yield, %	Thickness of unsaturated zone, m	Coefficient of filtration, m/d		Recharge rate, mm/year	
			min	max	max	min
Sand and gravel	0.05-0.15	2-5	0.1	50	340	75
Sandy loam, loam	0.01-0.06		$n*10^{-2}$	$n*10^{-5}$	80	40

Consequently, during periods when the shallow groundwaters levels are elevated as a result of prolonged high infiltration, the lake may replenish from the shallow groundwaters and its water level fluctuations due to external factors (sudden periods of drought) will be smaller. The total annual precipitation in the study area exceeds evaporation and infiltration is seasonal (it is clinical in nature and may vary from year to year, and there may be longer periods of change). On average, 15-20% of precipitation can infiltrate in shallow groundwaters.

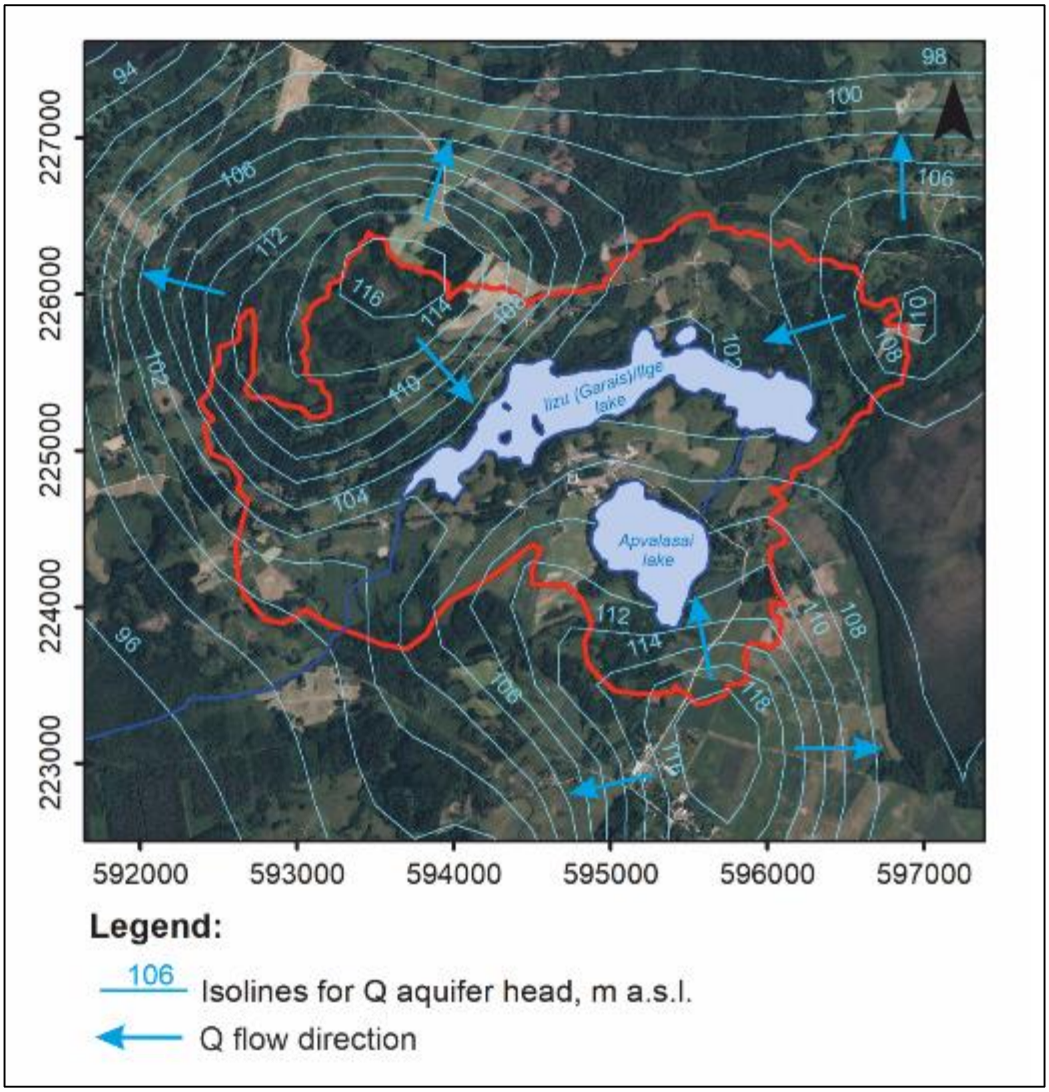

Figure 4.1.3. Regional shallow groundwater flow at the vicinity of the Lake Ilzu (Garais)/Ilge

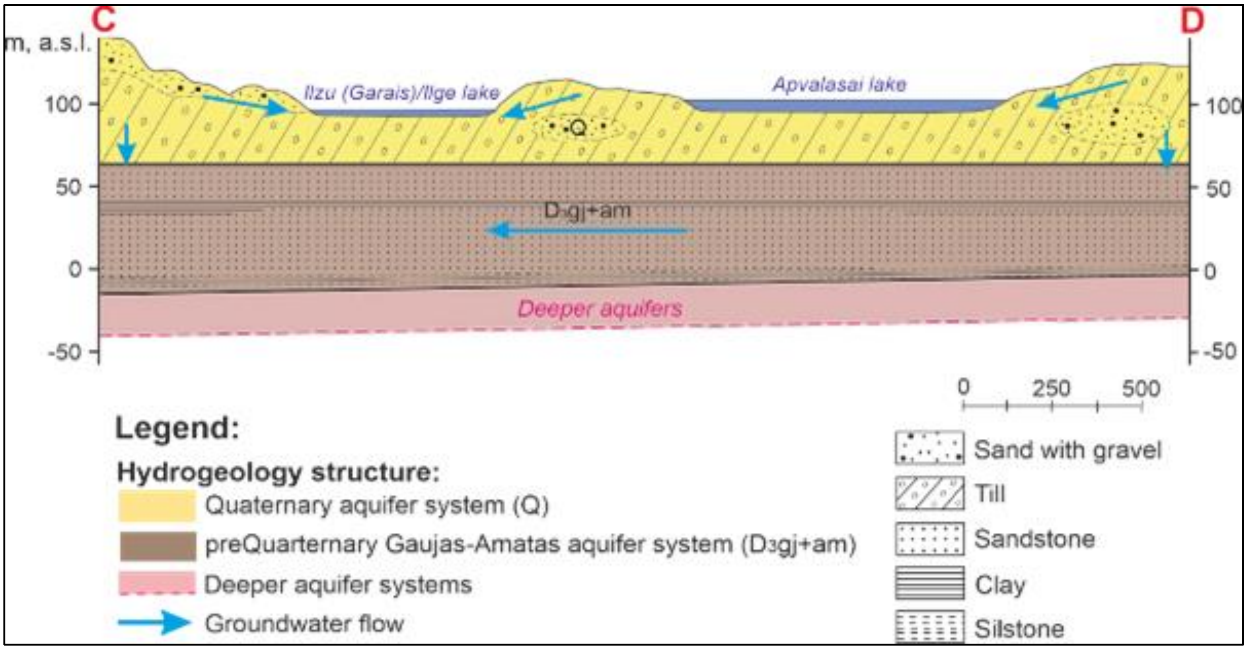

Figure 4.1.4. Schematic geological section along line C-D

Information on hydrogeological conditions in the Lake Ilzu (Garais) catchment was incomplete, the description was prepared based on the available materials at regional scale and currently available data. There is still a need for more in-depth assessment of the territory, based on data from hydrogeological surveys in the catchment of Lake Ilzu (Garais). In order to obtain more detailed and reliable data about the lake drainage basin, following tasks should be carried out:

- drilling of Quaternary sediments in order to define the full section of Quaternary deposits and the upper parts of the section;
- monolith samples to determine rock filtration properties;
- seasonal sampling of water and lab analysis of full spectrum of parameters, including dominant inorganic ions, nitrogen and phosphorus compounds, trace metals, organic compounds and other pollutants, that might be present in the environment taking into account the identified anthropogenic pressures in lake catchment;
- to ensure seasonal measurements of water levels;
- hydro-meteorological observations.

These data are needed for elaboration of a numerical model that could allow more precise estimations of the share of groundwater in total water balance of Lake Ilzu (Garais)/ Ilge.

4.2. Estimation of groundwater contribution to lakes water balance

Estimation of groundwater recharge to a dependent surface water body such as a lake is often a challenge for hydrogeologists because direct measurements are costly, time consuming and difficult to carry out (Retiķe et al., 2021). Within the TRANSWAT project, hydrogeological surveys were not carried out, and field works were aimed to analyse ecological and hydrochemical quality of the lake as well as to assess hydromorphological features.

In order to estimate the share of groundwater within the total water balance of the Lake Ilzu (Garais)/Ilge, information from the report “Review of existing hydro-morphological data and HPPs technical specification” (TRANSWAT project report, 2022) as well as discharge measurements in inflows and outflows were used. Taking into account that there are no monitoring stations in the vicinity of Lake Ilzu (Garais)/Ilge catchment, which data could be used for analysis of water level changes in Quaternary aquifer, simple calculations were used to estimate the share of groundwater in the lake water balance.

Hydrological cycle follows the law of mass conservation means, that all inflows to the system are equal to all outflows if storage stays the same. It can be written as:

Inflow = Outflow ± changes in storage

For Lake Ilzu (Garais)/Ilge the most important inflow and outflow of the catchment area is precipitation and evapotranspiration, respectively. For the groundwater contribution estimation, ERA5-Land reanalysis data ranging from 1981 to 2018 is used to estimate average annual precipitation and evaporation (for more details see “Conceptual model of surface-groundwater interaction”; TRANSWAT, 2022). According to ERA5-Land data, annual precipitation rate at the territory of Lake Ilzu (Garais)/Ilge catchment is 787.1 mm, while evaporation accounts for 489.5 mm. Moreover, evaporation over the free lake surface is greater, reaching 673 mm (Fig. 4.2.1). Taking into account the catchment area of the lake (8.72 km^2) total inflow from precipitation is ~0.0069 km^3/year, while evaporation over land (catchment area (8.72 km^2) minus lake surface area (0.83 km^2)) accounts for ~0.0039 km^3/year and over lake surface (0.83 km^2) accounts for 0.00056 km^3/year.

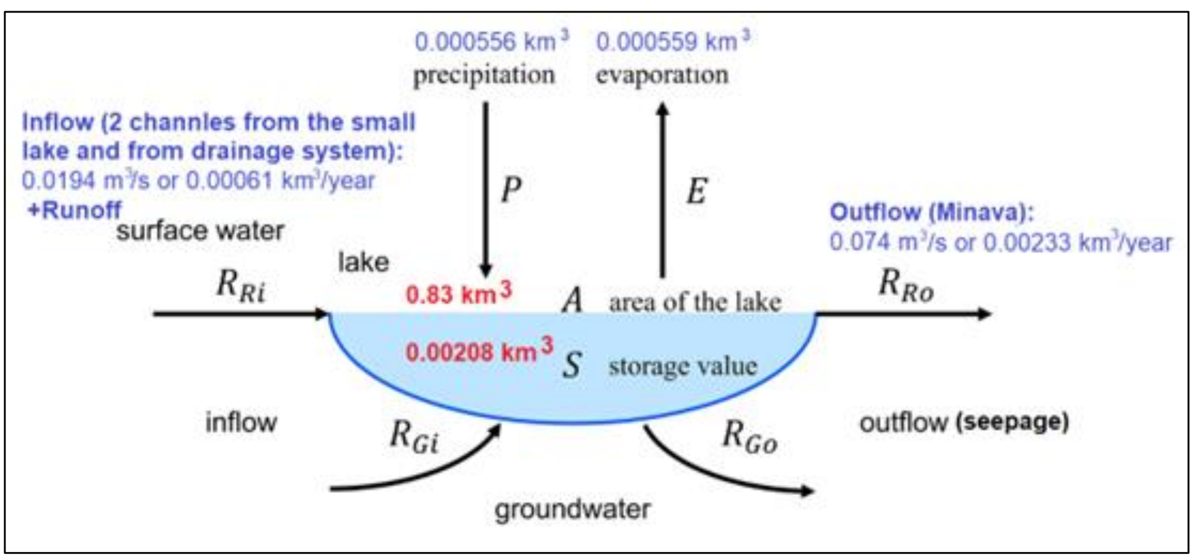

Figure 4.2.1. Schematic water balance of the Lake Ilzu (Garais)/Ilge

Field studies revealed that annual stream inflows into the lake accounts for 0.0194 m^3/s or 0.000612 km^3/year, while total stream outflow (river Minava) reaches 0.074 m^3/s or 0.002334 km^3/year ("Risk assessment of surface and groundwater interaction", TRANSWAT project report, 2022). While river Minava clearly leaves the hydrological system of the lake and represents outflow, the other streams which inflows into the lake Ilzu (Garais)/Ilge could be partly incorporated also within the precipitation inflow, therefore these inflow streams are not considered in the hydrological balance. All hydrological components of inflows and outflows are summarized in Table 4.2.1.

Table 4.2.1. Summary of hydrological components within the Lake Ilzu (Garais)/Ilge

Water balance	Volume, km^3/year	Total	Difference
Inflows			0.00011 km^3 or ~1.6%
Precipitation	0.00686	0.00686	
Outflow			
Evaporations over land	0.00386	0.00675	
Outflow by Minava river	0.00233		
Evaporations over the lake	0.00056		

The total difference between all inflows and outflows is 0.00011 km^3/year which accounts for ~1.6% of all outflows. This difference is rather small and basically indicates perfect hydrological balance. Uncertainties related to annual precipitation and evapotranspiration are hard to estimate, but most likely are much higher than the observed difference, since ERA5-Land is global reanalysis with a rather general estimation approach (for more details see "Conceptual model of surface-groundwater interaction"; TRANSWAT, 2022). As there is no obvious lack of inflows, regional groundwater contribution to the lake water balance is negligible for this lake, while shallow groundwater must likely play an important role by transporting precipitation within the watershed to the lake through soil and shallow unconfined aquifers.

VI HEALTH ASSESSMENT OF LAKE

6.1. Lake ecosystem health assessment by biological indicators

Summarizing the data obtained during research, the ecosystem health of the Lake Ilzu (Garais) is highly affected due to eutrophication. The worst quality is shown by macrophyte and zooplankton species composition and diversity. Low water transparency indicates moderate quality as well as limits the development of submerged macrophytes. Submerged macrophytes and phytoplankton absorb light in the water column, but the macrophytes take up nutrients from the sediment and thus will dominate over phytoplankton in less productive lakes (Brönmark & Hansson, 2010). Adversely in Lake Ilzu (Garais) the phytoplankton is the dominant group.

Macrophyte growth form (emergent, floating-leafed, free-floating and submerged) may influence their effects on lake-water quality. Macrophytes of different growth forms have different mechanisms for nutrient removal. Both submerged and emergent macrophytes had positive effects on water quality. In the lakes where macrophytes grow abundant, water transparency increases (Kosten et al., 2009). According to the alternative stable state theory, shallow lakes exist in a dynamic balance between the macrophyte-dominated clearwater state and the phytoplankton-dominated turbid water state. Macrophytes can maintain shallow lakes in the clear-water state through mechanisms that include nutrient competition, reduction of sediment resuspension and increasing refugia for herbivorous zooplankton (Scheffer et al., 1993).

6.2. Groundwater assessment as potential pressure on surface waters

Based on the available data on lake ecological and physico-chemical quality, it is concluded that the Lake Ilzu (Garais)/Ilge is a natural lake without significant water level alterations caused by unnatural factors and it corresponds to a lake waterbody in an un-impacted hydrological condition or at high status. Currently, the Lake Ilzu (Garais)/Ilge has a moderate ecological quality as shown by biological indicators. This is due to high nitrogen concentration and low water transparency. The reason for moderate ecological quality is high internal loading of nutrients due to legacy pollution, caused by discharge of untreated wastewater in former times. Nowadays discharge of wastewater is stopped and there are no known point-sources. Slight decrease of nutrient concentrations and possible recovery of the lake ecosystem can already be observed.

It can be concluded that groundwater inflow does not contribute to lake eutrophication processes. Groundwater vulnerability assessment and analysis of impacts of land use suggest that groundwater has no impact on lake ecological quality under present anthropogenic pressure. It means that detailed groundwater quantitative and quality assessment procedures are not necessary.

REFERENCES

Ahlgren, J., Reitzel, K., De Brabandere, H., Gogoll, A., Rydin, E. 2011. Release of organic P forms from lake sediments. *Water research*, *45*(2), 565-572.

Bledzki, L. A., Rybak, J. I. 2016. *Freshwater Crustacean Zooplankton of Europe: Cladocera & Copepoda (Calanoida, Cyclopoida) Key to species identification, with notes on ecology, distribution, methods and introduction to data analysis*. Springer.

Cabinet Regulation No. 118 (adopted 12.03. 2002) Regulations Regarding the Quality of Surface Waters and Groundwaters. Available: https://likumi.lv/ta/en/en/id/60829-regulations-regarding-the-quality-of-surface-waters-and-groundwaters.

Čeirāns, A. 2007. Zooplankton indicators of trophy in Latvian Lakes. Acta Universitas Latviensis, 723: 61-69.

Chen, M., Hur, J. (2015). Pre-treatments, characteristics, and biogeochemical dynamics of dissolved organic matter in sediments: A review. *Water Research*, *79*, 10-25.

Conceptual model of surface – groundwater interaction (2022) Project TRANSWAT LLI-533 report. Available: https://videscentrs.lvgmc.lv/files/Par_LVGMC/Projekti/Transwat/Transwat_atskaites/D.T.2.2.1_Conceptual%20model.pdf

Brönmark C., Hansson L. A. 2010. The Biology of Lakes and Ponds. Oxford University Press, New York, 285 p.

Jankēvica, M., Šīre, J., Kokorīte, I., & Kļaviņš, M. (2012). Assessment of the sediment chemical quality in salmonid lakes in Latvia. *Acta Biologica Universitatis Daugavpiliensis Supplement*, *3*, 36-49.

Jeppesen, E., J. Peder Jensen, M. Sondergaard, T. Lauridsen, F. Landkildehus. 2000. Trophic structure, species richness and biodiversity in Danish lakes: changes along a phosphorus gradient. Freshwater Biology 45:201–218.

Kosten, S., Lacerot G., Jeppesen, E., Motta, M.D., Nes, E.H., Mazzeo, N., Scheffer, M. 2009. Effects of submerged vegetation on water clarity across climates. – Ecosystems 12: 1117–1129.

Latvijas - Lietuvas ezeru kartogrāfija (Cartography of Latvian - Lithuanian transboundary lakes), BIOR, 2021. Available: https://bior.lv/lv/latvijas-lietuvas-parrobezu-ezeru-kartografija

Psenner R., Pucsko R., Sager M. 1984. Die Fraktionierung organischer und anorganischer Phosphorverbindungen von Sedimenten – Versuch einer Definition ökologisch wichtiger Fraktionen. Arch.Hydrobiol.Suppl., 70: 111-155

Retike, I., Akstinas, V., Bikše, J., Bruzgo, M., Demidko, J., Dimante-Deimantoviča, I., Grīnberga, L., Kokorīte, I., Koļcova, T., Medne, R., Ozoliņš, D., Rakauskas, V., Skuja, A., Steponėnas, A., Virbickas, T. 2021. Methodology of lake ecosystem health assessment. Project TRANSWAT LLI-533 report. Available: https://videscentrs.lvgmc.lv/files/Par_LVGMC/Projekti/Transwat/Transwat_atskaites/Methodology_lake_ekosystem_health_TRANSWAT_WP2.pdf

Review of Latvian – Lithuanian transboundary lakes residual time. 2022. Project TRANSWAT LLI-533 report. Available: https://videscentrs.lvgmc.lv/files/Par_LVGMC/Projekti/Transwat/Transwat_atskaites/Lake_residual%20time%20report.pdf

Risk assessment of surface and groundwater interaction. 2022. Project TRANSWAT LLI-533 report. Available: https://videscentrs.lvgmc.lv/files/Par_LVGMC/Projekti/Transwat/Transwat_atskaites/

Rydin, E. 2000. Potentially mobile phosphorus in Lake Erken sediment. *Water Research*, *34*(7), 2037-2042.

Scheffer, M., Hosper, S.H., Meijer, M.L., Moss, B., Jeppesen, E. 1993. Alternative equilibria in shallow lakes. – Trends Ecol. Evol. 8: 275–279.

Skuja, A., Ozoliņš, D. (2016). Fitting New Method—Latvian Lake Macroinvertebrate Multimetric Index (LLMMI) to Results of Central—Baltic Geographical Intercalibration Group (CB—GIG) Lake Benthic Macroinvertebrate Intercalibration. Report. Institute of Biology, University of Latvia: Salaspils, Latvia, p. 12.

Šidagytė E., Višinskienė G., Arbačiauskas K. 2013. Macroinvertebrate metrics and their integration for assessing the ecological status and biocontamination of Lithuanian lakes. *Limnologica*. 43(4), 308-318.

Water quality – Guidance standard on assessing the hydromorphological features of lakes, CEN. 2011. EN 16039:2011.

Woszczyk, M., Bechtel, A., Gratzer, R., Kotarba, M. J., Kokociński, M., Fiebig, J., Cieśliński, R. 2011. Composition and origin of organic matter in surface sediments of Lake Sarbsko: A highly eutrophic and shallow coastal lake (northern Poland). *Organic Geochemistry*, *42*(9), 1025-1038.

Zettler, E. R., Carter, J. C. 1986. Zooplankton community and species responses to a natural turbidity gradient in Lake Temiskaming, Ontario–Quebec. *Canadian journal of fisheries and aquatic sciences*, *43*(3), 665-673.