Ecological flow estimation in Latvian – Lithuanian Transboundary river basins (ECOFLOW) LLI-249

REVIEW

OF HYDROPOWER PLANTS INFLUENCE ON WATER QUANTITY AND QUALITY IN LIELUPE RIVER BASIN DISTRICT

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Abbreviation

a.s.l.	Above sea level;
BOD_5	Biological Oxygen Demand;
BQE	Biological Quality Elements;
CEN	Comité Européen de Normalisation (French: European Committee for Standardization);
DSFI	Danish Stream Fauna Index;
EQR	Ecological Quality Ratio;
HAP-LV	Hydromorphological Assessment Protocol of Latvia;
HMWB	Heavily Modified Water Body;
HPP	Hydropower Plant;
LEGMC	Latvian Environment, Geology and Meteorology Centre;
LFI	Lithuanian Fish Index;
LIFE	Lotic-invertebrate Index for Flow Evaluation
LMI	Latvian National River Macroinvertebrate Index;
LRMI	Lithuanian River Macroinvertebrate Index;
LT	Lithuania;
LV	Latvia;
MIR	Latvian National River Macrophyte Index, modified version of Polish Macrophyte Index for Rivers;
MS	Meteorological Station;
RB	River Basin;
RBD	River Basin District;
RBMP	River Basin Management Plan;
RHI	River Hydromorphological Index;
UK	United Kingdom;
WB	Water Body;
WFD	Water Framework Directive;
WGS	Water Gauging Station

I. INTRODUCTION

River hydrological regime regulation can cause lower variability in flow and overall lower flow magnitudes in rivers downstream of dams. Flow velocity can be described as major driving force which affects all other processes and functions in streams. Low flows are associated with low oxygen level, temperature extremes, increased concentrations of contaminants and risk of eutrophication. Dams also reduce connectivity along the river length, which has implications for nutrient and sediment transport, as well as it can have effect on downstream trophic structure and function.

River continuity is a vital part of healthy ecosystem and dry periods, caused by natural or man-made alterations, may lead to irreparable damage of aquatic ecosystems. Fish fauna in particular is the most sensitive to hydrological alterations, mainly because of their inability to overcome artificial obstacles and getting to their feeding and spawning areas.

Evaluation of the impact of HPP dams and reservoirs on the ecological status of waters downstream is performed through targeted habitat surveys and simulations by MESOHABSIM. The MESOHABSIM software can help set minimum environmental flow recommendations and determine biological indicators suitable and sensitive enough to assess hydromorphological pressure.

II. LIELUPE RIVER BASIN DISTRICT

Lielupe River Basin District (Lielupe RBD) consists of Lielupe river basin entering the Gulf of Riga. Lielupe River basin comprises large river sub-basins such as Mūsa/Mūša, Mēmele/Nemunėlis, Svēte/Švėtė in Latvia and Lithuania, Iecava and Veciecava in Latvia as well as numerous medium large and small sub-basins entering the Lielupe River (Fig. 1). The total area of Lielupe RBD is 17 600 km^2, within Latvia – 8849 km^2.

The soils of Lielupe RBD were mainly formed on limnoglacial clay and sandy bedrock. The upper courses are characterized by sod-podzolic and pseudo-gley soils, while sod-gley and sod-podzolic gley soils prevail at lower reaches. Sod-calcareous soils and brown soils are the typical soils of the Zemgale Plain. Alluvial soils occur in river floodplains and peat soils are typical for swamps [1].

The terrain, climate and soils create favorable conditions for agricultural land use in Lielupe RBD. The proportion of agricultural land in Lielupe RBD within Lithuania is 71% and within Latvia – 52% [2]. However, agricultural activities usually contribute to diffuse loads of water pollution and agriculture is the main cause of dispersed pollution load in Latvia and Lithuania.

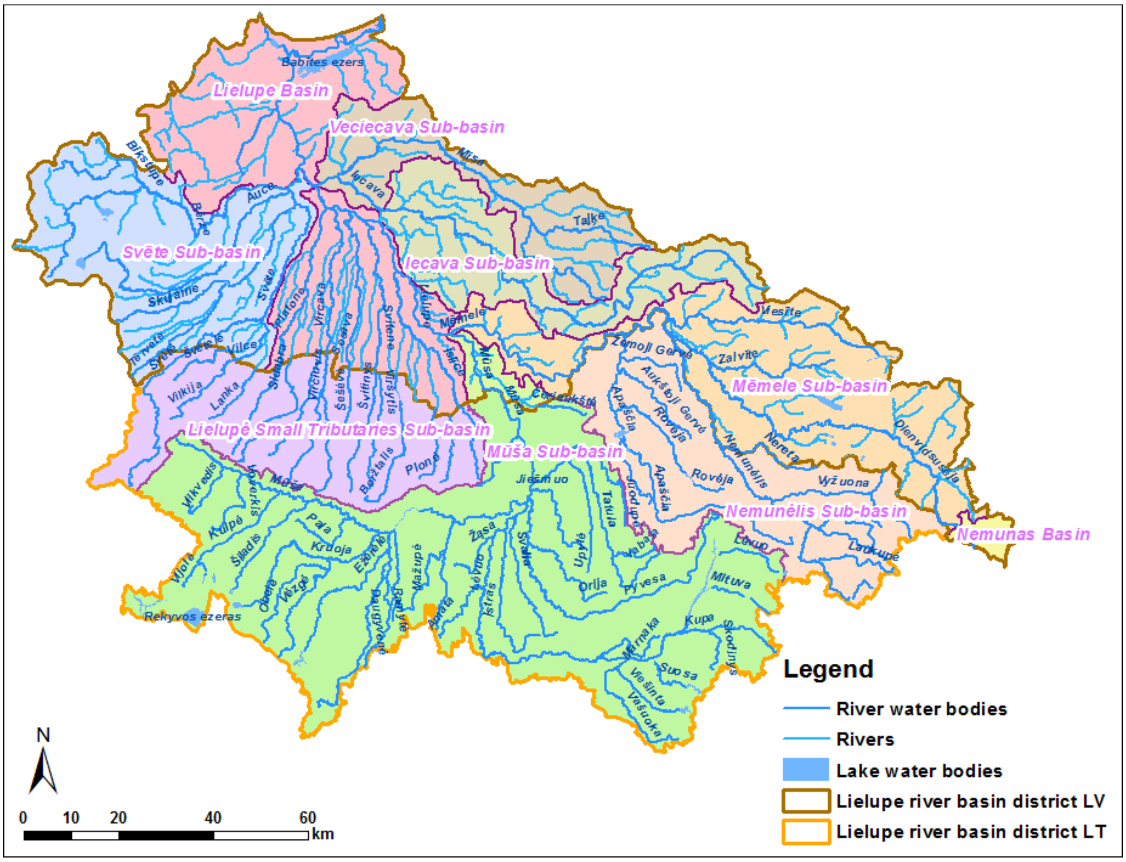

Figure 1. Lielupe River Basin District

2.1. TOPOGRAPHY AND HYDROGRAPHY OF LIELUPE RBD

2.1.1. Lithuania

The upper reach of Lielupe RBD is located in the north of Lithuania (Fig. 2). 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. The border between mentioned plains is clearly expressed by Linkuva Ridge (the average height 70-80 meters a.s.l.). The eastern and western borders of upper reach of Lielupe RBD are surrounded by West Aukštaičiai Plateau and East Žemaičiai Plateau respectively. The maximum height of these uplands up to 160 meters a.s.l.

In Lithuania the Lielupe RBD consists of the sub-basins of Mūša and Nemunėlis (Mēmele) rivers as well as Lielupe Small Tributaries. The Lielupe RBD covers the area of 8 938.3 km^2. The largest part of this area depends to the Muša River sub-basin (5 296.7 km^2). The area of sub-basins of the Nemunėlis River and Lielupe Small Tributaries are quite similar because they cover 1 892.0 km^2 and 1 749.6 km^2 respectively. The springs of all mentioned rivers are located in Lithuania.

The total length of the Mūša River is 157.3 km. A stretch of 133.1 km of the Mūša flows through the Lithuania territory. The source of this river located on the western edge of the Mūšos Tyrelis bog and 1.5 km southwest from the lake of Miknaičiai. The Mūša River has four tributaries (Lėvuo, Pyvesa, Tatula and Daugyvenė) longer than 60 km. Due to topographical configuration of the Mūša River sub-basin and Linkuva Ridge; almost all tributaries are left side. There are 7 lakes larger than 0.5 km^2. In general the percentage of lakes consists of 0.5%, while bogs and swamps occupy 5.1%. The forests cover 14.1% of the Mūša River sub-basin. The average bed slope of Mūša River is 0.047%, which makes this river one of the calmest rivers in Lithuania. The density of network of the rivers longer than 3 km is 0.73 km/km^2.

The total length of the Nemunėlis (Mēmele) River is 199.3 km. A stretch of 80.7 km from its springs flows in Lithuania, meanwhile the river segment of 79.4 km coincides with the Lithuanian-Latvian border and only 39.2 km of this river are situated in Latvia. The Nemunėlis River flows from the lake of Lūšna, which located in Šventoji Plateau (up to 160 meters a.s.l.). The topographical conditions of the Nemunėlis River sub-basin cause the average bed slope of 0.07% as well as 0.12 % in the border zone). There are 4 lakes larger than 0.5 km^2 the basin and whole lake percentage is 0.4%. The density of network of the rivers longer than 3 km is 0.75 km/km^2 and in total the Nemunėlis River sub-basin comprises 165 rivers longer than 3 km. The longest and the largest tributaries of the Nemunėlis River are the rivers of Apaščia (90.7 km) and Vyžuona (34.1 km).

The sub-basin of Lielupe Small Tributaries comprises the upper parts of the catchments of the left side tributaries of the Lielupe River. Except the Švėtė River, the all small tributaries of the Lielupe River rise at the northern foot of the Linkuva Ridge and flow over Zemgale Plain. Consequently, the major part of Lielupe Small Tributaries are artificially regulated. The average bed slope varies between 0.066% (the Yslikis River) and 0.176% (the Platonis River). This sub-basin relates to its drained fertile and cultivated land, which occupies nearly the whole sub-basin. There are no lakes in this part of the Lielupe RBD, except the several artificial ponds. The density of the network of the rivers longer than 3 km is dense enough and totals to 0.81 km/km^2.

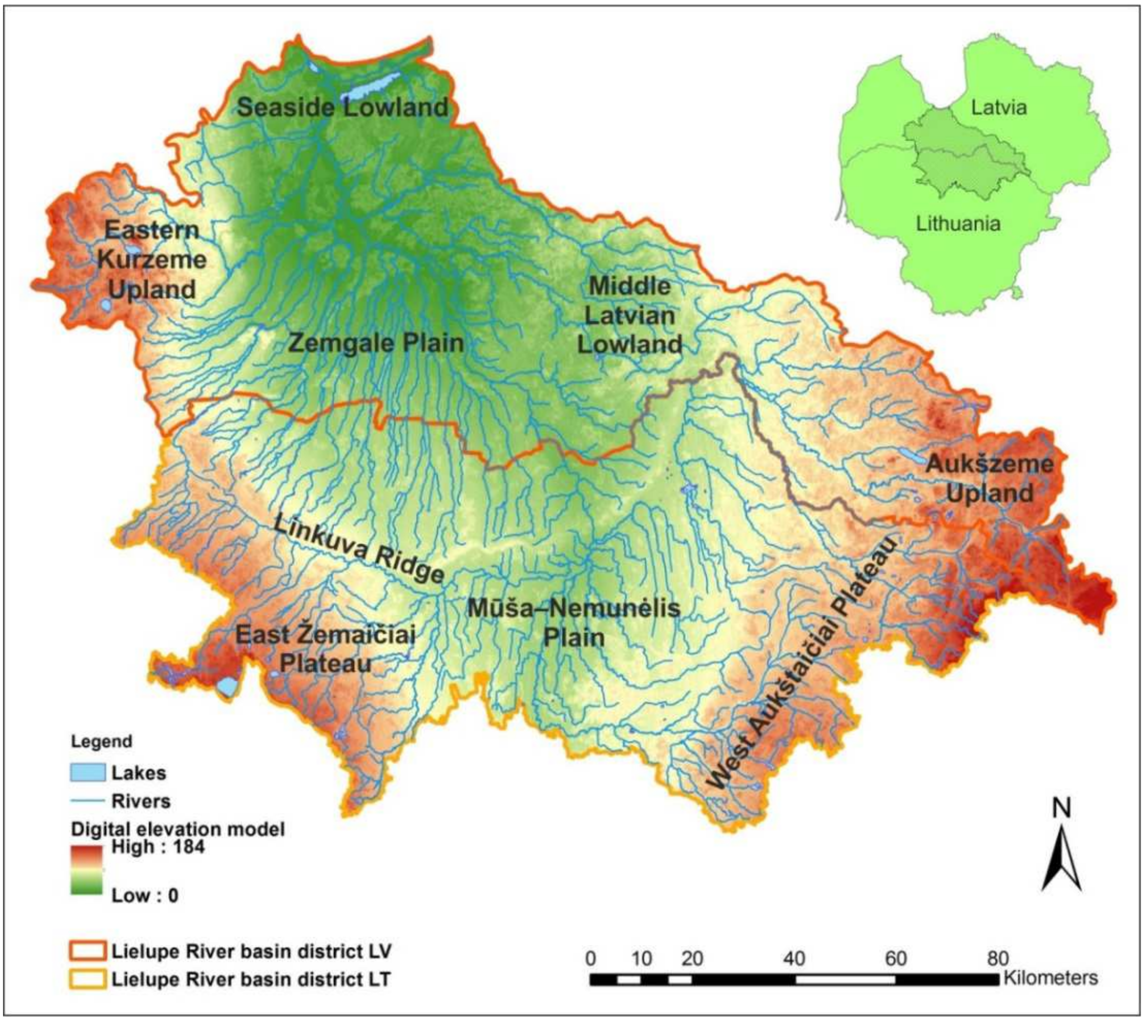

Figure 2. Topography and hydrography of Lielupe RBD

2.1.2. Latvia

Lielupe RBD is located in the central part of Latvia. The largest part of Lielupe River basin is situated in the Middle Latvian Lowland and lower course of the Lielupe River is occupied by the Seaside Lowland. The altitude fluctuations in Lielupe River basin are negligible; 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 RBD and the Augšzeme Upland in the southeastern part, where elevations reach up to 150 meters a.s.l. (Fig. 2).

The Lielupe River begins at the confluence of the Mēmele and Mūsa rivers near Bauska town. For the upper part of its course, the river flows through a dolomite valley with a few small rapids, until it reaches Mežotne village, where it widens and deepens over flat Zemgale Plain. The Lielupe River flows parallel to the coastline of the Gulf of Riga at its lower reaches; the city of Jūrmala stretches for almost 30 km between the river and the sea. Eventually the Lielupe flows into the Gulf of Riga, while the Buļļupe Branch (at 1.4 km from Lielupe river mouth) flows towards the Daugava River to the northeast.

Forests cover about 38% and swamps 10% of total area of Lielupe RBD. Forests are very unevenly distributed in Lielupe RBD, while large moss bogs are found in the north of the city of Jelgava including both banks of the Lielupe River. Lakes cover less than 1% of Lielupe RBD.

Lielupe RBD is characterized by relatively dense network of small rivers. Many rivers are potamal-type rivers with current speed of up to 0.5-1.0 m/s. The largest river is Lielupe (the second largest river in Latvia after Daugava); its length is 119 km. Except for Lielupe river basin, there are 5 river sub-basins with catchment area >1000 km^2 in Latvia: Mēmele (2110 km^2), Dienvidsusēja (1210 km^2), Iecava with Velnagrāvis (1166 km^2), Veciecava (1006 km^2), and Svēte (1951 km^2) [3]. The Mūsa River also belongs to a large river type (5320 km^2) but its catchment area within Latvian territory is only 151.5 km^2. There are 8 rivers longer than 100 km and 1 lake larger than 10 km^2 (Babīte Lake).

The Lielupe river bed is much lower than average Baltic Sea level over a length of 100 km upstream from the mouth. Lielupe river gradient is only 0.1 m/km; the average density of river network is 0.40-0.45 km/km^2. Many rivers in Lielupe RBD (Iecava, Misa, Bērze, Auce, Džūkste, etc.) are artificially regulated [4].

2.2. CLIMATE AND HYDROLOGICAL REGIME

2.2.1. Lithuania

Lithuanian climate can be characterized as a transitional between mild Western European and continental Eastern European climate. The Baltic sea has an impact on the climate of country. However from west to east, the sea has less and less influence on climatic conditions. The Lielupė RBD is located in the northeastern part of Lithuania. The climate of this territory gets more features of the continental climate.

Annual air temperature in Lielupė RBD is 6.4 ºC (Šiauliai MS) and 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.

Annual amount of precipitation in Lielupė RBD (650 mm/year) is lower than average amount of Lithuanian territory (695 mm/year; 1981-2010). Amount of precipitation in Lielupė RBD varies from 550 mm/year for the Western part to 700 mm/year for the Eastern part of district. Average annual number of days with snow cover in Lielupė RBD is from 80 to 90.

The largest karst areas in Lithuania are in Lielupė RBD. In the northern part of this district where the Upper Devonian period gypsum and dolomite lay under thin cover of Quaternary deposits, karst processes develop. Hydrological regime of rivers of this district is closely related to the karst phenomenon which directly affects annual runoff distribution.

The natural hydrological regime in the rivers of Lielupė RBD is characterized by high spring flood, summer drought, autumn and winter rainfall floods which are not intensive (Fig. 3). In the rivers of Lielupe RBD spring (March-April) runoff accounts for an average 51 %, summer (May-August) – 14 %, and the autumn-winter season (September-February) – 35 % of the annual runoff.

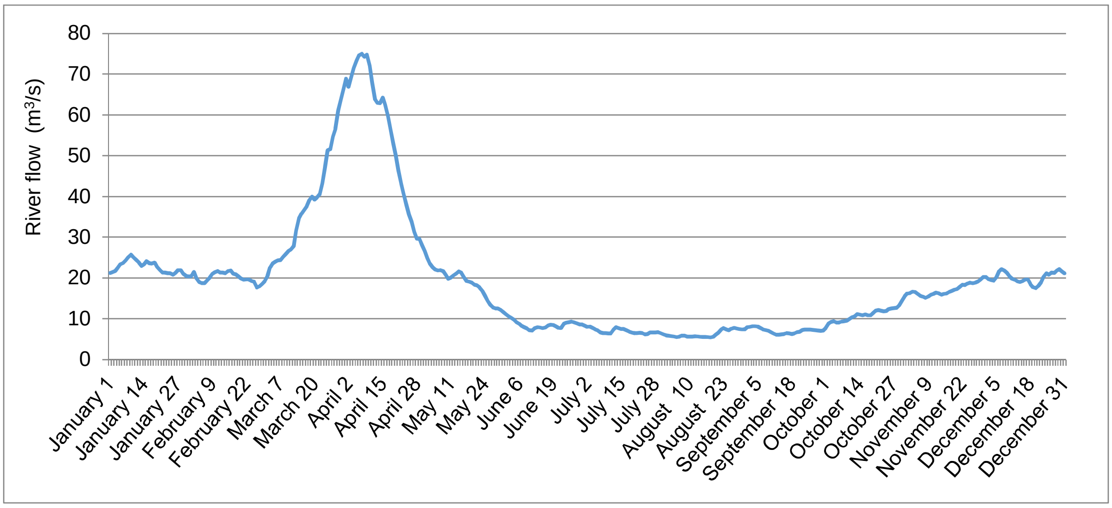

Figure 3. Hydrograph over multiple years (1959-2015) of the Nemunėlis River at Tabokinė WGS

Long-term annual water runoff in the rivers of Lielupė RBD is on average 6.0 l/sec·km², and it varies from 4.5 l/sec·km² in the Mūša River – Ustukiai water gauging station (WGS) to 7.4 l/sec·km² in the Nemunėlis River – Tabokinė WGS (Table 1, Annex I).

The spring flood season in the rivers of Lielupė RBD usually begins in the second half of March (from 14 to 24 days), and mostly ends in late April. Average duration of spring flood is 41 days. It varies from 33 days (in the Daugyvenė River – Meilūnai WGS) to 55 days (in the Mūša River – Raudonpamūšis WGS). The part of spring flood in the annual water runoff is about 51 %.

The average runoff of the most dry 30-day summer period in Lielupė RBD is very low. The hydro modules reach 1.0-1.3 l/sec·km² in the Nemunėlis River basin, while in the Mūša River basin - 0.2-0.7 l/sec·km². The lowest runoff of the most dry 30-day summer period (0.1-0.3 l/sec·km²) is in the rivers Yslikis and Švėtė which are a small tributaries of the Lielupe River (Table 1, Annex I).

The snow melting water forms the largest part of the annual rivers runoff. It varies from 42% in Nemunėlis River basin to 50% in Mūša River basin. Part of groundwater in river feeding is low: from 11% (in Mūša River headwaters) to 20 % in the Lėvuo River.

The duration of ice cover in the rivers of Lielupė RBD varies in large scale. An initial ice cover forms in December and usually breaks up in April. However, over the last years the rivers of Lielupė RBD did not freeze annually. Some rivers freeze up only occasionally during periods of unusual cold winters.

2.2.2. Latvia

Kurzeme Upland is a natural barrier that protects Lielupe RBD against moist Maritime Polar air masses from the North Atlantic. Therefore, the central part of Lielupe RBD is characterized by the least amount of annual precipitation and higher air temperatures within Latvian territory. Average amount of precipitation varies from 550-600 mm per year in the Zemgale Plain to 700 mm per year in the eastern part of Lielupe RBD. The monthly average air temperature is -5.0 °C in January and 17.0-18.0 °C in July. Average annual duration of snow cover is 99 days on the right bank and 88 days on the left bank of the Lielupe River.

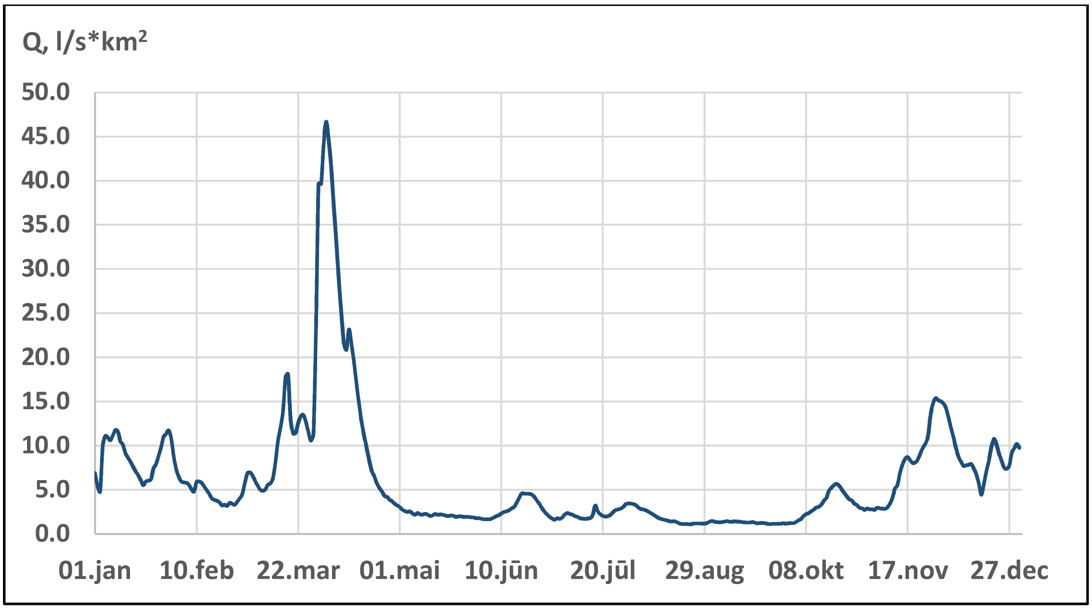

Figure 4. Hydrograph, Lielupe nearby Mežotne, 2009

Hydrological regime is characterized by high spring flood, summer-autumn rainfall floods, summer drought and winter low flow period interrupted by thaws (Fig. 4). Long-term annual water runoff of the Lielupe River is 6.1 l/sec*km^2 in average. In wet years water runoff increases up to 13.2 l/sec*km^2 but in dry years runoff is reduced up to 2.5 l/sec*km^2.

The spring flood usually starts in early March and lasts 63 days in average. The spring flood peaks in the beginning of the third decade of March. River alimentation during the spring flood includes snow melting and rainfall waters (42% of the annual water runoff in Lielupe RBD).

30-days low flow period is observed from the middle of the first decade of August till the beginning of September. The average water runoff during low flow period is less than 1.0 l/sec*km^2.

The groundwater in annual water runoff formation is about 5% and rain waters 53%.

Ice phenomena in rivers usually appear at the end of November. River freeze-up occurs in the third decade of December. The duration of ice cover on the Lielupe River is 94 days, on the tributaries – 79 days in average. Ice phenomena period continues till the third decade of March. Almost every year the movement of ice on rivers is accompanied by ice jams and a rapid rise in water levels.

2.3. RIVER HYDRO-MORPHOLOGY, PRESSURES AND CLASSIFICATION

2.3.1. Lithuania

The main hydromorphological parameters of the Lielupė RBD are presented in Table 1. According to available data (in Lielupė RBD), an average riverbed depth of the Mūša and Nemunėlis is 0.9 m, the Lėvuo – 0.7 m and the Apaščia – 0.6 m. An average riverbed width of the Mūša is 18.1 m, the Nemunėlis – 17.2 m, the Lėvuo – 15.6 m and the Apaščia – 13.1 m. The slopes of different river segments in the Lielupė RBD range from 0.14 to 1.53‰.

Table 1. Hydromorphological parameters of Lielupė RBD (Lithuanian part)

Catchment	River	Distance from the mouth, km	Segment length, km	Slope, ‰	Average depth of the riverbed, m	Average width of the riverbed, m
Muša	Lėvuo	0	13.5	0.630	0.8	16.2
	Lėvuo	13.5	12.9	0.566	0.8	15.8
	Lėvuo	26.4	10.7	0.327	0.8	17.2
	Lėvuo	47.6	3.6	0.333	0.8	16.9
	Lėvuo	51.2	5.5	0.655	0.7	14.8
	Lėvuo	56.7	11.9	0.311	0.8	17.0
	Lėvuo	68.6	12.8	0.477	0.7	15.2
	Lėvuo	81.4	12	0.417	0.6	14.4
	Lėvuo	93.4	1.1	0.455	0.6	13.4
	Mūša	149.3	4.9	0.163	1.8	30.3
	Mūša	159.6	5.9	0.136	1.8	31.3
	Mūša	168.9	2.1	0.714	1.2	20.8
	Mūša	171	5.9	0.864	0.9	16.8
	Mūša	176.9	8.9	0.494	1.0	18.6
	Mūša	192.5	6.6	0.727	0.8	16.5
	Mūša	199.1	12.8	0.891	0.8	15.5
	Mūša	211.9	2.4	0.292	0.8	17.3
	Mūša	224.5	5.8	0.483	0.6	13.4
	Mūša	230.3	10.1	0.713	0.5	12.3
Lielupė Small Tributaries	Apaščia	0	3.6	1.528	0.5	11.9
	Apaščia	3.6	2.6	1.192	0.6	12.4
	Apaščia	6.2	3.8	0.500	0.6	14.3
	Apaščia	16.7	4.7	0.404	0.6	13.9
Nemunėlis	Nemunėlis	60.1	11.5	0.730	1.1	20.2
	Nemunėlis	71.6	11.4	0.904	1.0	18.8
	Nemunėlis	83	10.4	1.154	0.7	13.7
	Nemunėlis	93.4	11.4	0.430	0.8	16.5
	Nemunėlis	116.2	22.8	0.329	0.8	16.6

The rivers in Lithuania are classified into 5 types according to two main criteria: catchment area and a slope of the riverbed (Table 2) (Concerning the Order of the Minister of Environment No. D1-256 of 23 May 2005; Concerning the Changes of Approval of the Description of Types of Surface Water Bodies; List of the Standard Indicators for Surface Water Quality Elements and List of the

Standard Indicators for Artificial, Heavily Modified and Risk Water Bodies; https://www.e-tar.lt/portal/lt/legalAct/TAR.77637555FA37).

Table 2. Typology of rivers in the Venta RBD (by Lielupė RBMP, 2015)

Factors	Type				
	1	2	3	4	5
Absolute height, m	<200				
Geological	Calcareous				
Catchment area, km^2	<100	100–1000		>1000	
Bed slope, m/km	–	<0.7	>0.7	<0.3	>0.3

Environmental Protection Agency (EPA) of Republic of Lithuania grouped rivers of Lielupė RBD according to the river typology presented in Table 2. As can be seen from Table 3 and Figure 5, water bodies of all five types can be found in Lithuanian part of Lielupė RBD. Water bodies of type 1 and 3 dominate in basins of the Muša, the Lielupė and the Nemunėlis, whereas water bodies of type 4 and 5 are characteristic only for the Lielupė Basin, since these water bodies must have the catchment area of at least 1000 km^2 according to the typology (Table 2).

Table 3. Number and length of river water bodies of different types in the Lielupė RBD (by Lielupė RBMP, 2015).

Type	Mūša Basin		Nemunėlis Basin		Lielupė Small Tributaries Basin		Lielupė RBD	
	Number of water bodies	Length of water bodies, km	Number of water bodies	Length of water bodies, km	Number of water bodies	Length of water bodies, km	Number of water bodies	Length of water bodies, km
1	63.0	614.3	15.0	137.6	21.0	239.1	99.0	991.0
2	4.0	115.8	6.0	210.2	1.0	5.4	11.0	331.4
3	10.0	139.4	1.0	8.9	2.0	31.0	13.0	179.3
4	1.0	16.9	0.0	0.0	0.0	0.0	1.0	16.9
5	3.0	129.9	1.0	20.6	0.0	0.0	4.0	150.5
Total	81.0	1016.3	23.0	377.3	24.0	275.5	128.0	1669.1

Ecological status of Lithuanian rivers is evaluated according to the hydromorphological quality elements: hydrological regime (water runoff volume and dynamics), river continuity and morphological conditions (bank and riverbed structure; runoff amount and character; condition of riparian vegetation; soil composition). River ecological status is characterized according to the quality of hydromorphological elements and is expressed by the river hydromorphological index (RHMI). There are three classes of hydro-morphological quality: very good, good, and worse than good (Table 4).

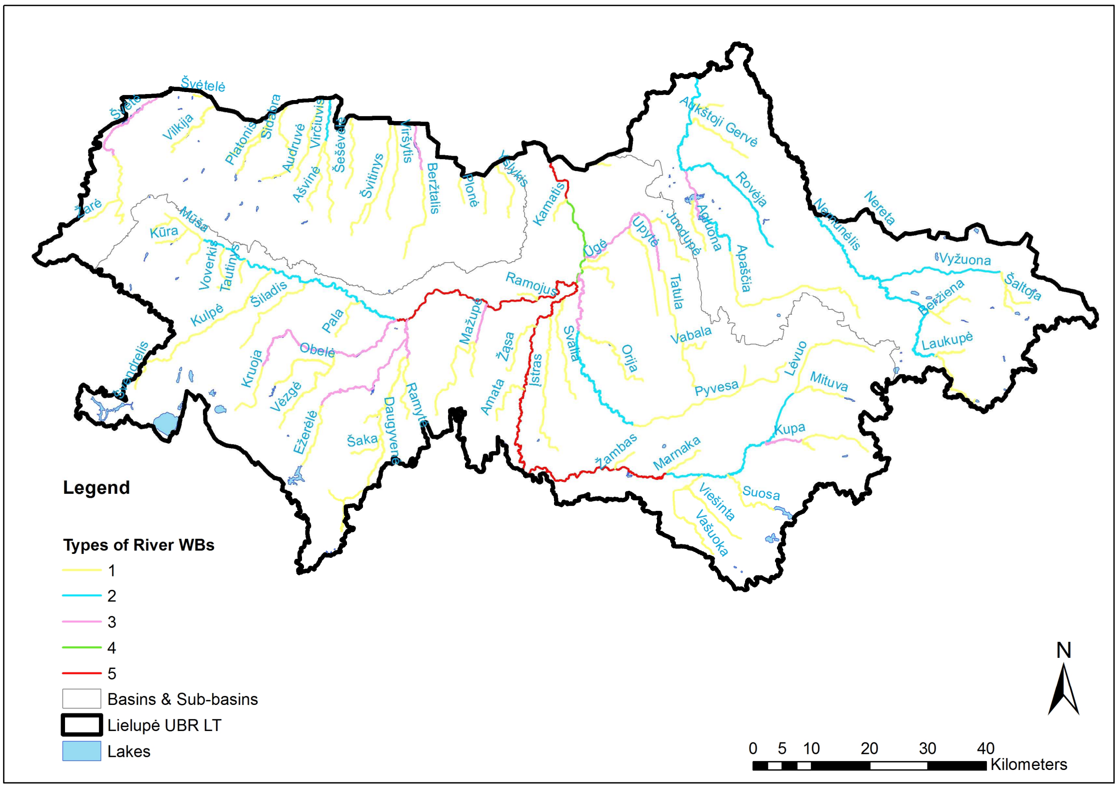

Figure 5. Types of river water bodies in the Lielupė RBD (prepared according to Lithuanian EPA data)

Table 4. River ecological status class based on the hydrological regime, river continuity and morphological conditions (by https://www.e-tar.lt/portal/lt/legalAct/81bef6e05df711e693cf945f20391699).

<table>
<tr><th colspan="3" rowspan="2">Quality element</th><th rowspan="2">Index</th><th rowspan="2">River type</th><th colspan="3">River ecological status according to hydromorphological criteria</th></tr>
<tr><th>Very good</th><th>Good</th><th>Worse than good</th></tr>
<tr><td>Hydrological regime</td><td>Water runoff volume and dynamics</td><td>Runoff amount and character</td><td rowspan="5">RHMI</td><td rowspan="5">1-5</td><td rowspan="5">1.00-0.91</td><td rowspan="5">0.90-0.80</td><td rowspan="5"><0.80</td></tr>
<tr><td colspan="3">River Continuity</td></tr>
<tr><td rowspan="3">Morphological conditions</td><td rowspan="3">Bank and riverbed structure</td><td>Character of the riverbed</td></tr>
<tr><td>Condition of riparian vegetation</td></tr>
<tr><td>Soil composition</td></tr>
</table>

RHMI is calculated according to the Lithuanian Minister of Environment approved methodology (the Order of the Minister of Environment of the Republic of Lithuania No. D1-210 of 12 April 2007 “Concerning the Changes of Approval of the Methodology for Assessment of the State of Surface Water Bodies”) (https://www.e-tar.lt/portal/lt/legalAct/81bef6e05df711e693cf945f20391699). The studies of evaluation of RHMI for Lielupė river basin district have not been fully completed; therefore, the results are not yet published.

Identification of main pressures

Hydropower impact

The negative effects of HPP dams on ecosystem are: fragmenting the continuity of river, altering the natural flow fluctuations, altering water quality and modifying channel morphology and bed structure by increasing siltation upstream and erosion downstream.

Hydropower dams damage the ecological integrity and stability of river ecosystem. They block fish migration from lower river reaches to the upper ones.

The blocked movement of fishes together with changed habitat and physicochemical conditions of streams may be the reason of decreased number of fish species, converting lotic habitats to lentic, etc.

Altered natural water level regime downstream changes the whole hydrological regime of a river. Especially high water level fluctuations (i.e. hydropeaking) occur downstream from the HPPs, which are operating only a few hours per day. Upstream from the impoundment river floodplain is usually flooded and, as a consequence, river bank erosion begins.

In the Lielupė RBD are only 5 HPPs (Figure 6, Annex I, Table 4). Only Dvariukai HPP ($Q_{Installed}/Q_{Perennial}$ = 1.16) and Žiobiskis HPP ($Q_{Installed}/Q_{Perennial}$ = 1.3) have a significant impact, because they are located in the segment of the Mūša and Vingerinė rivers, which have water quality problems. These water bodies are presented in Figure 6.

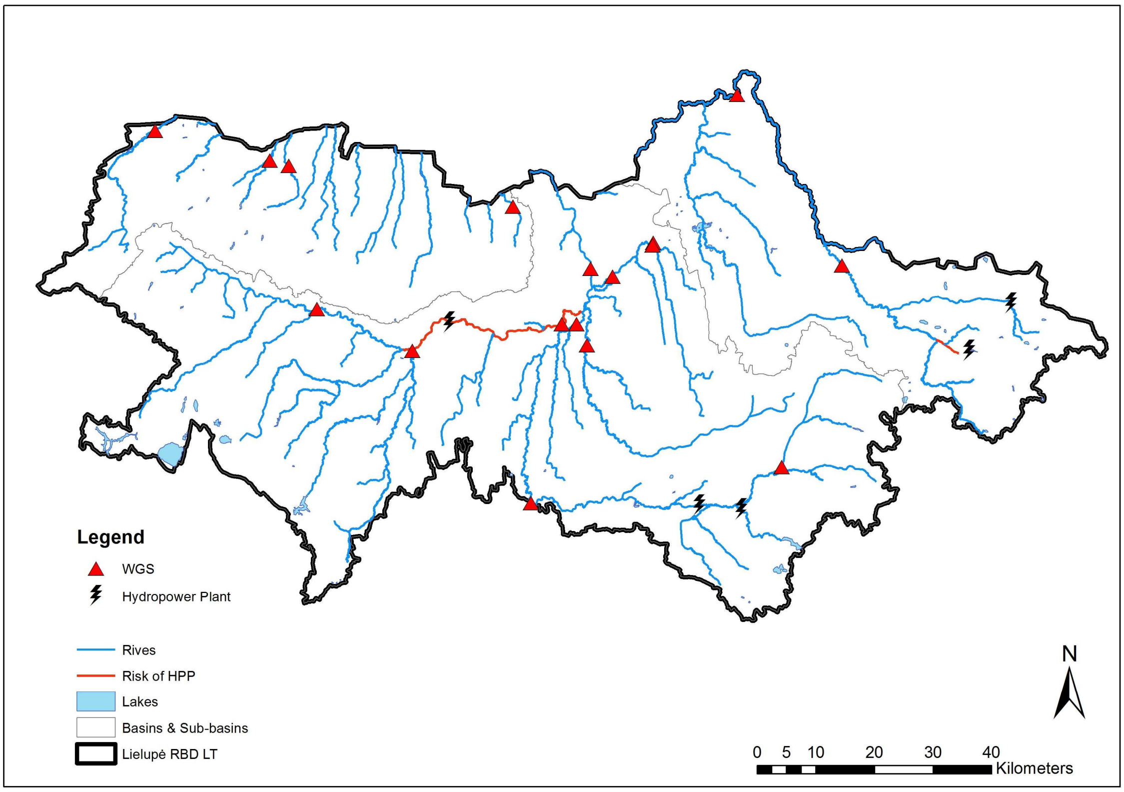

Figure 6. Water bodies, assigned to a risk group due to impact of HPP (Lithuanian part)

Significant impact of river straightening

Regulation of river beds result in morphological changes, which are assessed using the criterion K3:

$$K_3 = \frac{\sum L_{reg}}{L_u}$$

where ΣL_{reg} is the aggregated length of regulated river stretches, km; L_u is the total length of the river.

When $K_3 \leq 20\%$, morphological changes in the riverbed are minimum, and anthropogenic transformations do not have any significant impact thereon. When this value is exceeded by up to 10%, morphological changes are assumed to be small; when the exceedance is up to 30% – changes are medium; when 30-100% – changes are significant; and when the value is exceeded by more than 100% – morphological changes are considered to be very significant. The length of river stretches designated as HMWB and water bodies at risk due to a significant impact of straightening is given in Table 5.

Table 5. Length of river stretches and number of water bodies suffering from a significant impact of straightening (by Lielupė RBMP, 2015).

Catchment	Length of straightened river beds, km	Length of rivers designated as HMWB due to straightening, km	Amount of rivers designated as HMWB due to straightening	Length of rivers designated as WB at risk due to straightening, km	Amount of rivers designated as WB at risk due to straightening
Lielupė Small Tributaries	231.4	205.8	18.0	25.6	3.0
Mūša	453.0	403.8	39.0	49.2	10.0
Nemunėlis	110.1	103.6	8.0	6.5	2.0
Total in Lielupė RBD	794.5	713.2	65.0	81.4	15.0

Drainage reclamation

The purpose of drainage reclamation is to regulate the moisture regime of the soil thus providing favourable conditions for plants. Lithuania is situated in the zone of surplus humidity therefore ditches were dug and drainage systems were constructed to remove this surplus from cultivated land. Reclaimed area in the Lielupė RBD is given in Table 6.

Table 6. Reclaimed area in the Venta RBD

Basin	Total reclaimed area, ha	Share of the total reclaimed area in the basin area, %	Bad condition part of drained areas, %	Drained area, ha
Lielupė Small Tributaries	134119.6	76.6	6.32	128254.5
Mūša	336233.2	63.5	7.78	322849.7
Nemunėlis	95007.56	50	11.7	89539.83

Systematised information on river hydromorphology and the main pressures is necessary in further study, when case studies from Lithuanian part will be selected for more detailed investigation.

2.3.2. Latvia

The types of rivers in Lielupe RBD as well as in the whole Latvian territory have been specified, using System B of the European Community. Size of the catchment area and mean water slope are used as the main factors in rivers typology.

According to the height above sea level (<200 m), geographical longitude and latitude all river water bodies of Lielupe RBD have been divided in one class, because significant ecological differences between rivers have not been observed in Latvia due to such indicators.

Riverbeds in Lielupe RBD are mainly of carbonatic origin, therefore, one class – rivers with carbonate bed – has been singled out in typology.

Rivers in Latvia are classified into 6 types according to two main criteria: catchment area and mean water slope [5] (Table 7).

Table 7. Typology of rivers in Latvia

No.	Catchment area	Mean water slope	Type	Characterisation of the type
1.1.	Small (< 100 km^2)	Large (> 1.0 m/km)	Small ritral-type river	The river is shallow, the speed of the current exceeds 0.2 m/s. The substrate of the bed is formed by sand and gravel
1.2.	Small (< 100 km^2)	Small (< 1.0 m/km)	Small potamal-type river	The river is shallow, the speed of the current is less than 0.2 m/s. The substrate of the bed is formed by sand covered in detritus of organic origin and silt
1.3.	Medium large (100–1000 km^2)	Large (> 1.0 m/km)	Medium ritral-type river	The river is medium deep, the speed of the current exceeds 0.2 m/s. The substrate of the bed is formed by boulders, cobbles, sand and gravel
1.4.	Medium large (100–1000 km^2)	Small (< 1.0 m/km)	Medium potamal-type river	The river is medium deep, the speed of the current is less than 0.2 m/s. The substrate of the bed is formed by gravel, sand covered in detritus of organic origin and silt
1.5.	Large (> 1000 km^2)	Large (> 1.0 m/km)	Large ritral-type river	The river is deep, the speed of the current exceeds 0.2 m/s. The substrate of the bed is formed by sand, gravel and rocks
1.6.	Large (> 1000 km^2)	Small (< 1.0 m/km)	Large potamal-type river	The river is deep, the speed of the current is less than 0.2 m/s. The substrate of the bed is formed by sand covered in detritus of organic origin and silt

In accordance with the second Cycle RBMPs (2015), in Lielupe RBD within Latvian territory there are 1 water body classified as a river of the first type, 7 water bodies classified as rivers of the third type, 16 water bodies - as rivers of the fourth type and 8 water bodies - as rivers of the sixth type (Fig. 7, Table 8). Rivers of the second and fifth types are not designated as water bodies in Lielupe RBD. The revision of existing water bodies is in progress now, taking into account rivers regulation by HPPs, polders and other obstacles.

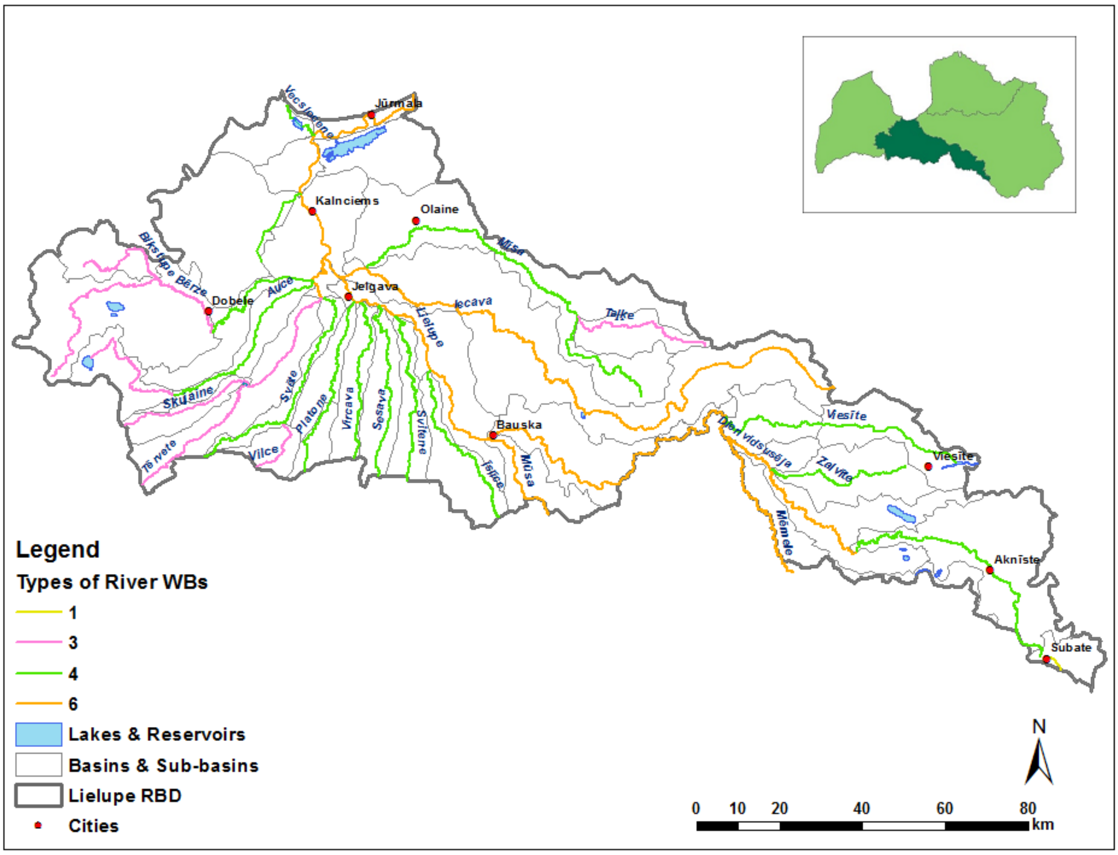

Figure 7. Types of river water bodies in Lielupe RBD within Latvian territory (by Lielupe RBMP, 2015)

Table 8. Number and length of river water bodies of different types in Lielupe RBD within Latvian territory

Type	Lielupe RBD	
	Number of water bodies	Length of water bodies, km
1	1	3.7
2	0	0
3	7	310.7
4	16	698.2
5	0	0
6	8	498.4
Total	**32**	**1510.9**

Hydro-morphological monitoring in Lielupe RBD as well as in the whole Latvian territory was started in 2013. Till 2016 morphological, river continuity and hydrological conditions have been surveyed in 27 river water bodies from 32 designated in Lielupe RBD. For the rest hydro-morphological quality assessment has been done by expert judgment using land and water use information as well as historical hydrological data.

HAP-LV method on the base of Hydro-morphological Protocol of the Slovak Republic is used for the assessment of WB's hydro-morphological quality in Lielupe RBD. This method covers three main components: hydrological regime, river continuity and river morphology.

Two first components will be described below in item 2.4. River morphology is assessed by 4 groups of parameters, where each is targeting different aspects of the morphological structure of a river or a stream:

- Channel plan form parameters (channel sinuosity, channel type and channel shortening);
- In-stream parameters (river bed elements, bed substrates, variation in river width, flow types, large woody debris and artificial bed features);
- Bank and riparian zone structures (riparian vegetation, bank stabilization and bank profile);
- Floodplain structure (flooded area and natural vegetation).

All parameters are assessed with scores from 1 (natural or near-natural conditions) to 5 (severely modified conditions). For each group of parameters, the average score is calculated. Finally, the worse score determines the Hydro-morphological quality of a water body.

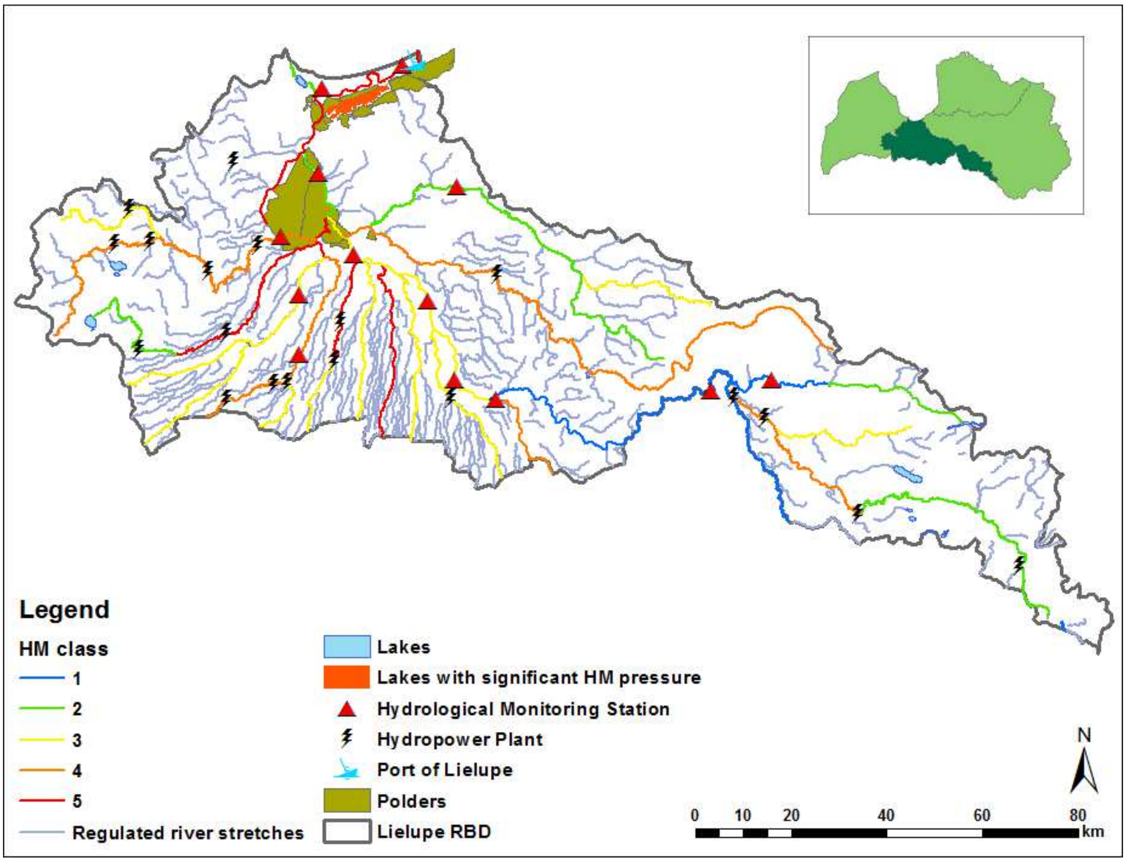

Figure 8. Main hydro-morphological pressures in Lielupe RBD

As a monitoring result, 4 main hydro-morphological pressures in Lielupe RBD (Fig. 8) were identified:

- River drainage and water regulations (deepening of river bed, shortening or changing of bank profile);
- Hydropower plants (barrier to fish and sediment migration, hydrological regime regulation);
- Polders (flood protected dams, water pumping);
- Multiple morphological pressures (port location in Lielupe river mouth as well as combination of many anthropogenic pressures within a water body).

Significant hydro-morphological impact within Lielupe RBD is identified in 9 river water bodies and 1 lake water body (28% and 11% of the total number), of which

6 river water bodies and 1 lake water body have been designated as heavily modified water bodies.

The port of Lielupe is located in a water body *Lielupe* L100SP and is considered as a significant pressure in 6.4 km long stretch between river mouth and railway bridge nearby the city of Jūrmala due to regular river dredging. In addition, there are 6 polders covering more than 20% of total area of river water body *Lielupe* L100SP, as well as 7 polders covering 20% of Babīte Lake catchment area (within lake water body E032SP).

Historical changes in flow regime have occurred in the lower course of the Lielupe River. According to hydrological calculations, about 1/3 of Lielupe runoff flows into the Babīte Lake (a lake of the lagoon type) through the Gāte Branch during spring flood. The Varkaļi Channel that was dug in 1988 flows out of the Babīte Lake in order to reduce maximum flow rate in Lielupe nearby the city of Jūrmala.

Polders have significant hydro-morphological impact on 3 river water bodies - *Lielupe* L100SP, *Svēte* L108SP, *By-pass channel of Vecbērze polder* L106SP, and 1 lake water body - *Babīte Lake* E032SP.

Small hydropower plants (>2) are also considered as a significant hydro-morphological pressure in 3 river water bodies within Lielupe RBD - *Bērze* L111, *Svēte* L123, *Dienvidsusēja* L166. Assessment of influence of small hydropower plants will be described in item 2.4.

According to water regulation data, there are 298 straightened rivers in Lielupe RBD. From total length 3792 km of Lielupe basin rivers, 2988.7 km (79%) belong to straightened (regulated) river stretches located in 23 water bodies (72% of the total number).

As hydro-morphological quality assessment result for Lielupe RBD, a total of 12 river water bodies out of 32 (38%) have been classified with poor and bad hydro-morphological conditions. Hydro-morphological status has been set as moderate for 11 (34%) and good for 6 river water bodies (19%). Only 3 river water bodies (9%) have been classified at high status (no pressures identified) (Table 9).

Table 9. Hydro-morphological quality of water bodies in Lielupe RBD

Quality (Class)	Identified anthropogenic pressures	Number of water bodies
5	Seaports (multiple use)	1
	Polders with area >10% of water body area	2
	Length of drained stretches 100% of water body length	1
	Multiple pressures	2
4	>2 HPPs along a water body (no fish pass)	3
	1 HPP nearby LV-LT border	1
	Multiple pressures	2
3	Length of drained stretches >50% of water body length	4
	Significant morphological changes	2
	Multiple pressures	5
2	Drained stretches of tributaries	6
1	No pressures, reference conditions	3

Detailed information of water body's quality class depending on anthropogenic pressures can be found in Annex I, Table 3.

2.4. ASSESSMENT OF INFLUENCE OF HYDROPOWER PLANTS ON WATER QUANTITY

2.4.1. Lithuania

5 small hydropower plants were constructed on the rivers of Lielupė RBD (Fig. 6; Annex I, Table 4). 3 HPPs are located in the Mūša River basin and 2 HPPs in the Nemunėlis River basin. The largest HPP (installed capacity 494 kW) was constructed on the Mūša River. Currently streamflow is monitored only in 2 rivers, Mūša (2 WGS) and its largest tributary Lėvuo (2 WGS) where the HPPs are constructed.

Usually small HPPs are operated with little water storage capacity relative to the volume of flow in the river, resulting in only minor alterations to flow regimes. However, larger hydropower dams with considerable reservoir storage capacity are able to capture high water flows and store them for later use. This can result in lowered spring flood peak downstream hydropower dam (Fig. 9).

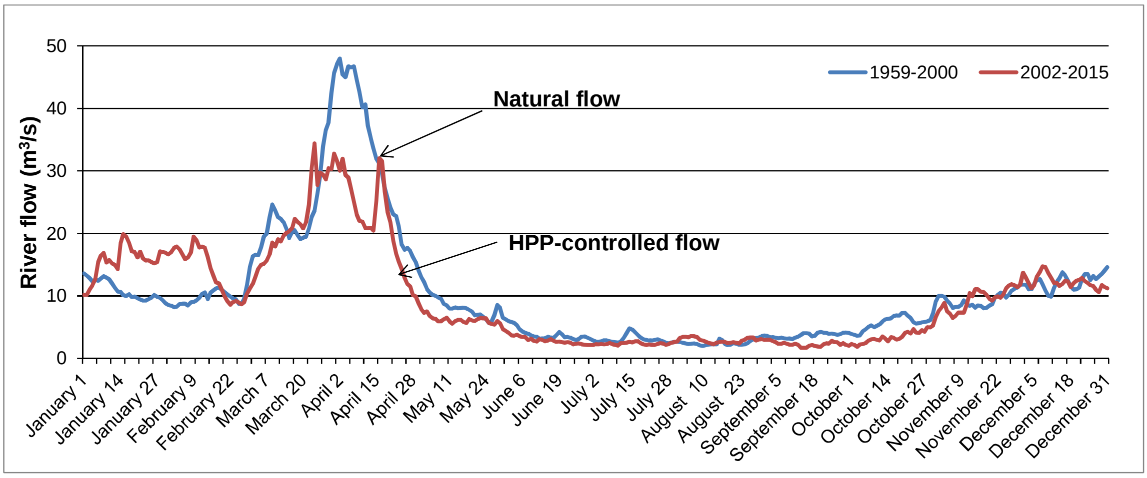

Figure 9. Hydrographs of Mūša River – Ustukiai WGS (downstream of Dvariukai HPP) for the natural flow period (1959–2000) and HPP-controlled flow (2002–2015)

Fig. 9 shows that during winter, stream flow in the river is higher after the construction of HPP. Meanwhile spring stream flow has a tendency to decrease. In the second half of the year, natural flow and HPP-controlled flow were usually changeable. These changes in streamflow are fixed during last period

The reason for the river streamflow changes during last period may be not only the influence of the power plant, but also the impact of climate change.

2.4.2. Latvia

19 hydropower plants are located in 12 water bodies and on 9 rivers (Fig. 8; Annex I, Table 5). One regulated river (Džūkste) is not identified as a separate water body but hydro-morphological monitoring on the river stretch downstream of a hydropower plant was carried out in 2015.

Two components of HAP-LV are used in the assessment of HPPs impact on water quantity and quality – “river continuity” parameter and “hydrological regime” group of parameters.

River continuity parameter shows the impact of barriers on fish and sediment migration along the river. In presence of barriers in streams, this parameter is critical for the assessment of the water body hydromorphological quality.

Guidance standard on determining the degree of modification of river hydromorphology is used for the assessment of this quality element (Table 10).

Table 10. Classification of River Continuity (Water quality - Guidance standard on determining the degree of modification on river hydromorphology [6])

High class (near-natural)	Good class (slightly modified)	Moderate class (moderately modified)	Poor class (extensively modified)	Bad class (severely modified)
Continuity of the river is not disturbed by human activities (any dams).	Artificial structures are present, but having only minor effects on migration of aquatic organisms and sediment transport.	Artificial structures are present, but having moderate effects on migration of aquatic organisms and sediment transport (dam has a fish pass).	Artificial structures having a great effect on migration of aquatic organisms and sediment transport (few species are able to pass a dam, but almost all sediment is retained behind a dam).	Artificial structures are having a great effect on migration of aquatic organisms and sediment transport (all sediment is retained behind a dam, or presence a large dam with height of 15 m or with height from 5 to 15 m and a reservoir capacity of more than 3 mil m^3).

Hydrological regime parameters are used to evaluate the effect of artificial impacts on the hydrological regime in the sampling site and indirectly on aquatic ecosystem. The hydrological quality is assessed by 4 parameters:

- change in mean flow,
- change in low flow,
- change in water level range,
- impact of artificial frequent flow fluctuations.

An impact of only 2 small HPPs on river hydrological regime can be determined by analyzing of hydrological data due to limited number of hydrological monitoring stations in Lielupe RBD (Fig. 8). Therefore, the expert judgment, partly on the base of existing long-term hydrological observations, is used in the assessment of HPP impact on water quantity.

Figure 10 shows water level fluctuations of the Bērze River compared to water level of the Tērvete River over 3 months period. These fluctuations of Bērze River flow are related to operations of HPP Bērze, which is located 6 km upstream from a hydrological monitoring station Baloži.

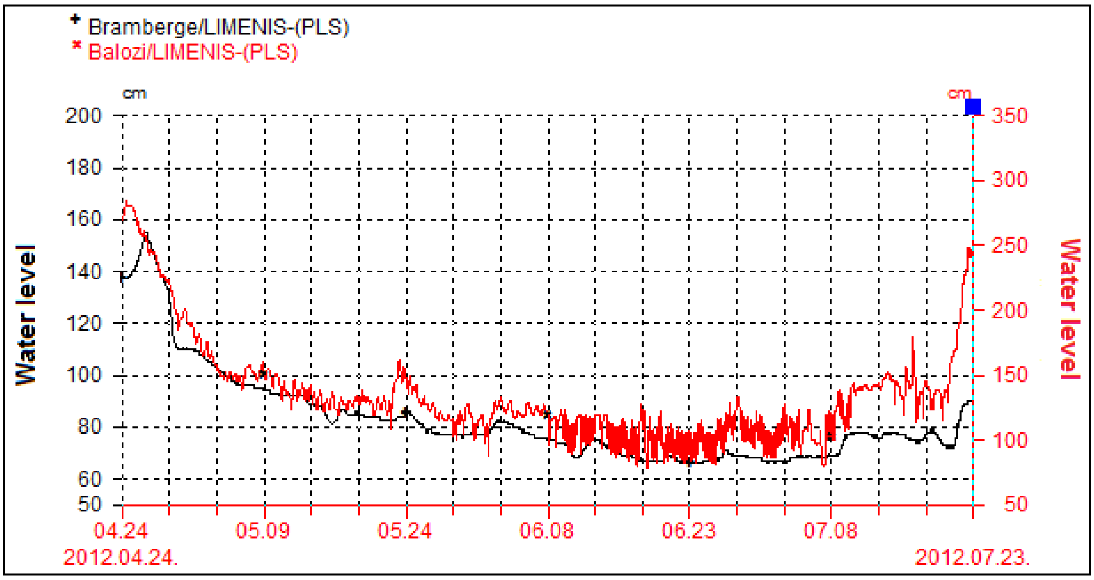

Figure 10. Bērze River water level downstream of HPP Bērze (in red) vs. Tērvete River water level nearby Bramberģe (in black)

Some HPPs may have an influence on the downstream reach of a river even at larger distances. For example, there are 3 hydropower plants in upper reaches of the Svēte River and one of them is located 9.5 km upstream from a hydrological monitoring station Ūziņi. As it can be seen in Figure 11, water level fluctuations caused by operations of a hydropower plant, are typical not only for low flow period (July 4th – August 2nd) but also for the end of spring flood period (mid-March – mid-April).

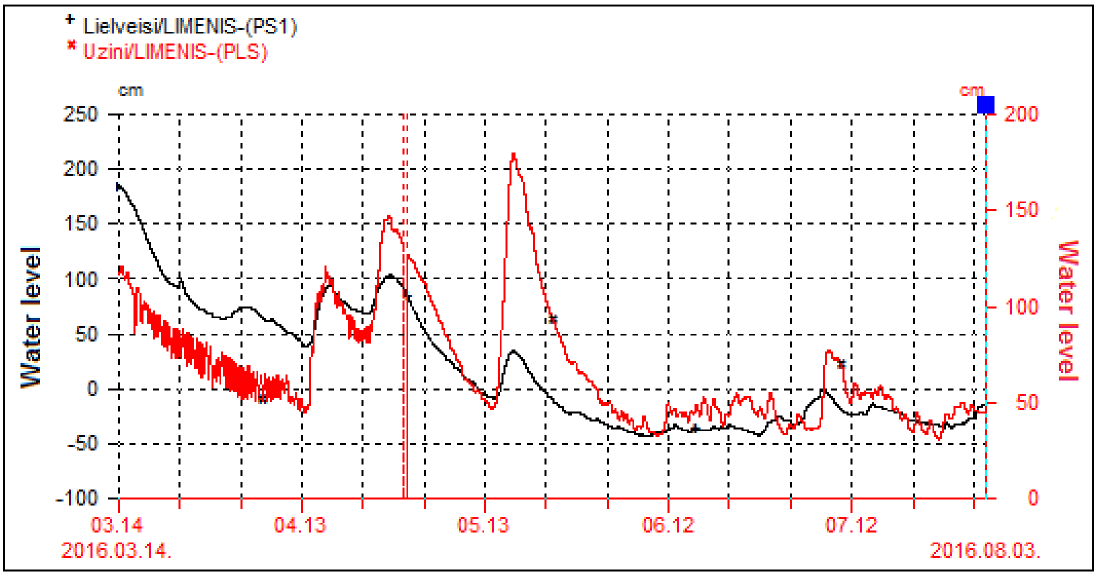

Figure 11. Svēte River water level nearby Ūziņi (in red) vs. Misa River water level nearby Lielveisi (in black)

Analysis of water flow data on the water bodies shows decreasing of water runoff during summer season even below 95% low flow. For example, the long-term hydrograph of Bērze River nearby Baloži, downstream of HPP Bērze shows not only the peaking but extended low flow period from mid-August till the beginning of November, as well (Fig. 12). Moreover, 4 HPPs are located on the Bērze River upstream of Baloži hydrological monitoring station. Therefore, the impact seems to be significant due to operations of the HPPs.

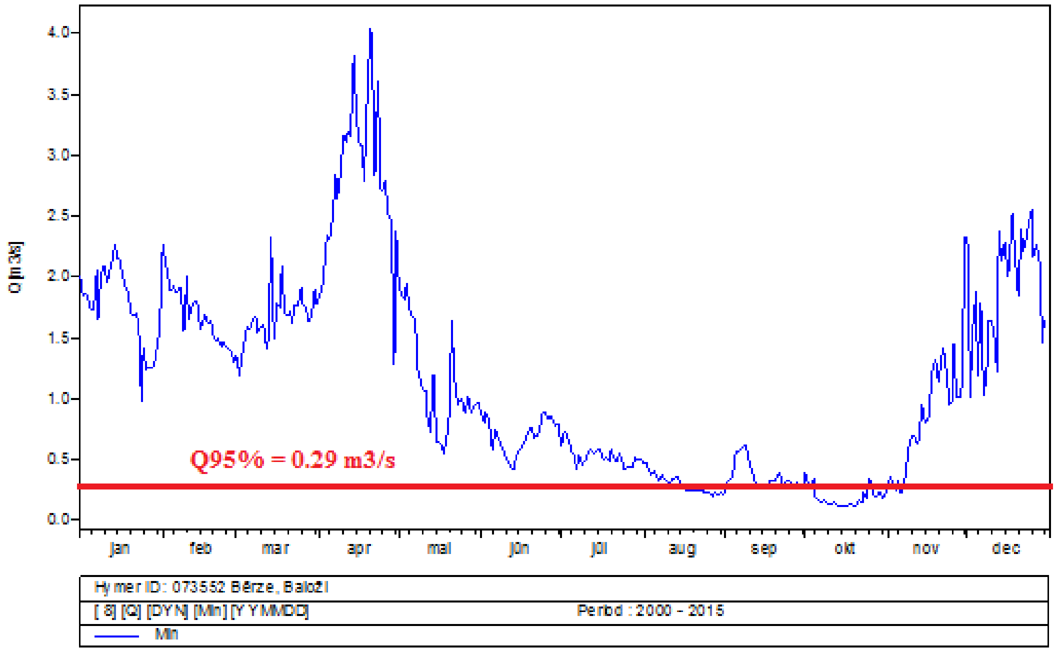

Figure 12. Hydrograph of the Bērze River nearby Baloži, downstream of HPP Bērze for period 2000–2015 in comparison with water discharge of 95% probability

Analyzing daily maximum and daily minimum discharges of the Bērze River nearby Baloži from 2004 to 2015, the duration curve for the hydropeaking ratios Q_{max}/Q_{min} shows that a hydropeaking ratio 1:3 up to 1:5 reaches about 0.5% of the time whereas a hydropeaking ratio >1:5 is an exceptional event that occurs in average once or twice over a ten years period. However, timing of hydropeaking events may be rather crucial in some years. For example, hydrograph of the Bērze River nearby Baloži for 30-days low flow period of 2015 shows that a hydropeaking ratio 1:3 up to 1:5 is typical for even 40% of the time (Fig. 13).

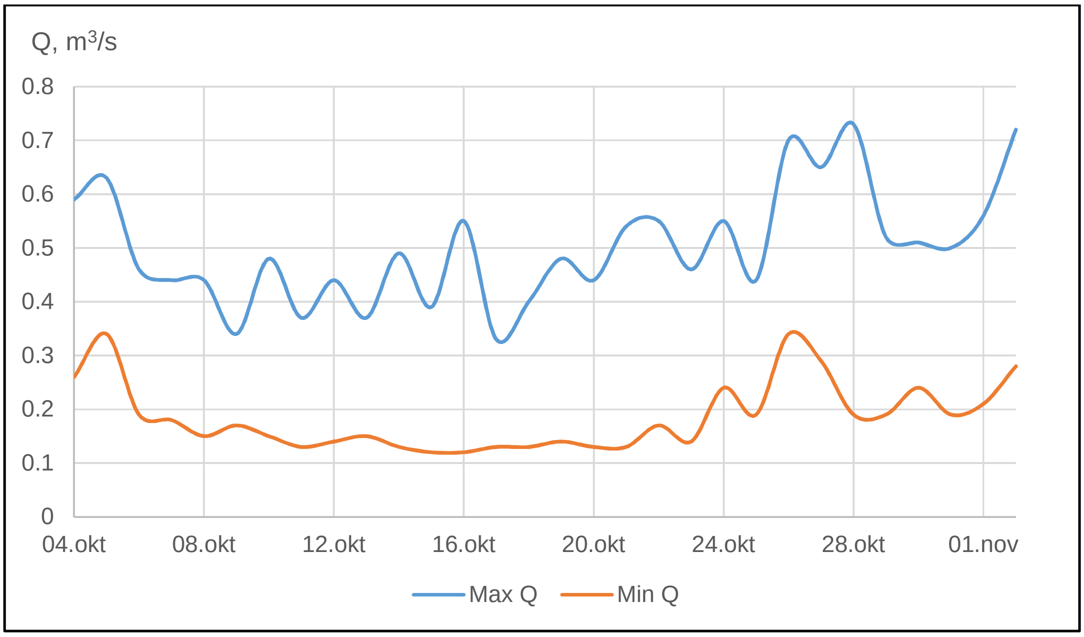

Figure 13. The duration curve for hydropeaking ratios during 30-days low flow period of 2015 (Hydrographs of the Bērze River nearby Baloži)

The Dienvidsusēja River (right tributary of the Mēmele River) also has 4 small HPPs. Despite lack of hydrological data, it is clear that at least one of them (HPP of Nereta) operates in accumulation mode. Significant changes in the lower pool of this HPP occur when turbines are switched on, especially during low flow period, taking into account water level rise up to one meter and even more due to rapidly increased flow rates in reservoir. Riverbanks are washed out by high water level downstream of the HPP on a quite long river stretch [7].

However, it must be noted that changes in river hydrological regime as well as hydromorphological alterations not always can be the only factors which affect natural habitat structure. Moreover, limited number of the existing hydrological monitoring stations does not allow evaluating the influence of HPPs on aquatic ecosystems.

2.5. RELATIONSHIPS BETWEEN BIOLOGICAL QUALITY AND MORPHOLOCICAL ALTERATIONS

2.5.1. Lithuania

Macroinvertebrates and fish metrics are commonly used for assessment of deviations in river water quality and hydromorphological conditions. Lithuanian River Macroinvertebrate Index (LRMI) and Lithuanian Fish Index (LFI) are officially approved and intercalibrated methods for assessment of ecological status of rivers in Lithuania [8]. These indices integrate macroinvertebrate and fish metrics, sensitive to various types of environmental perturbations, including hydromorphological ones.

As it was already mentioned in chapter 2.5 of Venta RBD report on relationships between biological quality and morphological alterations in Lithuanian part of Venta RBD, an impact of hydromophological perturbations on aquatic community status can be correctly assessed only in case that there is no other significant pressures (e.g. pollution). In addition, data on fish and macroinvertebrate metrics at reference conditions should also be present as a basis for assessing the deviation. Due to intense economic activities, reference status river sites are absent in the Lielupe river basin district, mainly due to the impact of diffused pollution coming from agricultural lands and due to straightening of river channels for land reclamation purposes. Therefore, there are only few river sites at good ecological status are left in the Lithuanian part of the Lielupe RBD [9] (Fig. 14).

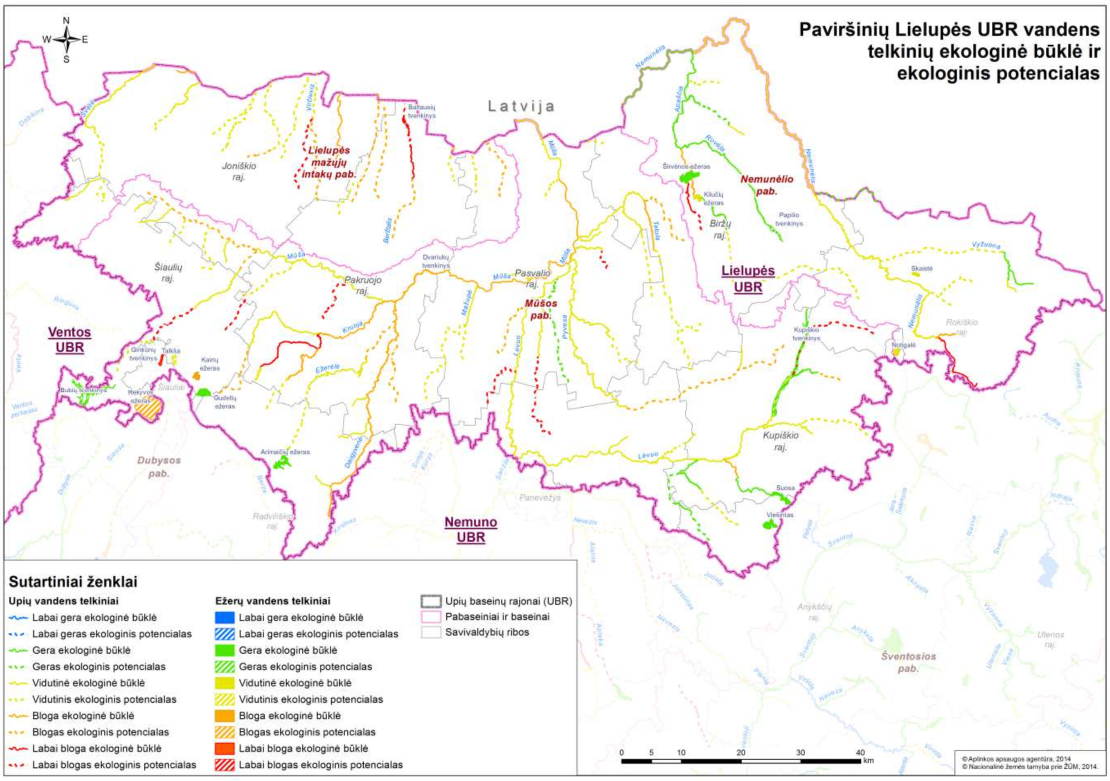

Figure 14. Ecological status and ecological potential of surface water bodies in the Lielupe RBD (segmented lines/polygons denote heavily modified water bodies; water bodies of good ecological status/potential are indicated in green, moderate in yellow, poor in brown, and bad in red) (Lielupės UBRVP, 2015).

The Lielupe RBD borders the Nemunas RBD, and there are no substantial differences in climatic or hydrological characteristics which could lead to very specific natural characteristics of the rivers (and hence in the structure and composition of aquatic communities). There are no differences in the characteristics of aquatic communities between the rivers of the same type and the same ecological status. This was confirmed by analysis of the monitoring data and fieldwork results [9]. Therefore, the impact of changes in river hydromorphology on LRMI and LFI should be of the similar character, as it was established based on analysis of sites, studied in the Nemunas RBD, and described in chapter 2.5 in Venta RBD report on Lithuanian part of the catchment.

There are 4 hydropower plants installed on the rivers in Lithuanian part of Lielupe RBD (Fig. 15). Two of them (Dvariukai HPP on Mūša River and Žiobiškio HPP on small river Vingerinė) are considered to have a significant impact on the ecological status of the river stretches below these HPP‘s (Lielupės UBRVP, 2015). Therefore, these river stretches are monitored periodically within the frame of State monitoring network.

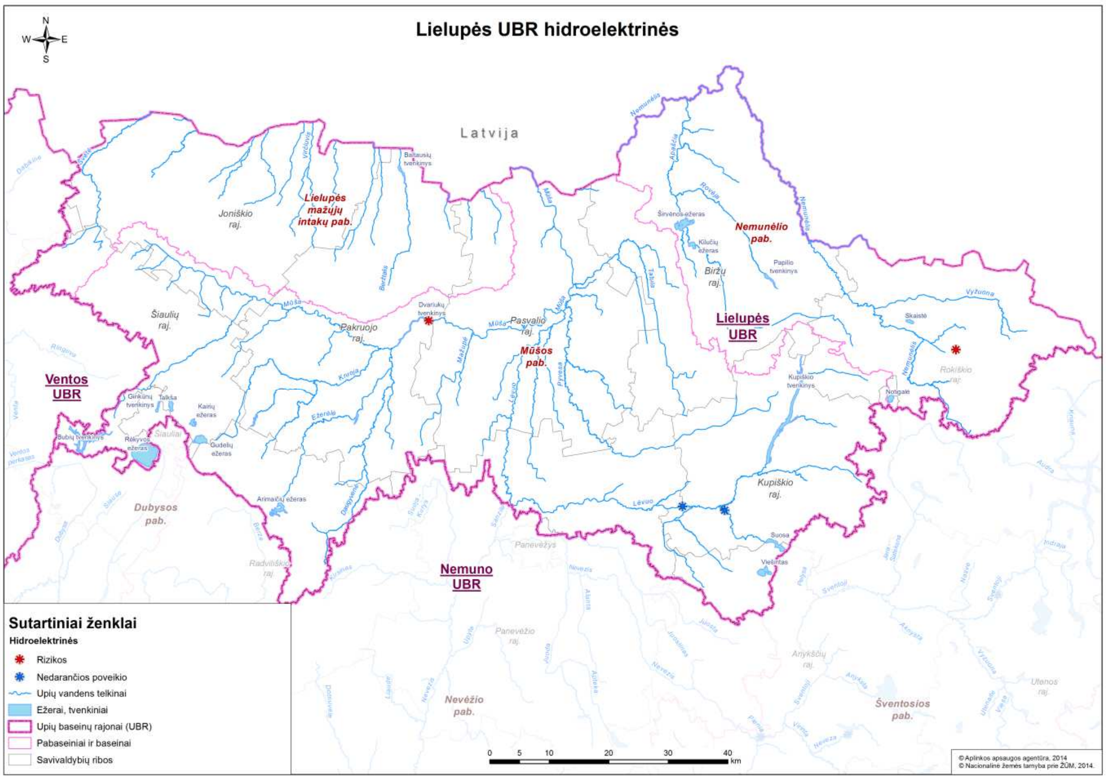

Figure 15. Hydropower plants installed on the rivers in Lithuanian part of Lielupe RBD (hydropower plants, considered to have a significant negative impact are indicated in red) (Lielupės UBRVP, 2015).

Since all hydropower plants in Lithuanian part of the Lielupe RBD are situated in the rivers, suffering from pollution, it is not possible to separate clearly the impact of hydrological alterations from the impact of other pressures. Analysis conducted on Lithuanian river fish monitoring data of 2011-2013 years has disclosed, that multiple pressures have stronger negative impact on fish community status compared with an impact of a certain single pressure [10]. The status of fish communities in the river stretches suffering from both HPP and pollution impacts is twice worse compared with that in the rivers with HPP pressure alone, and 1.5 times worse compared with the status in the river stretches where pollution is the only pressure (Fig. 16). The same is valid for straightened river stretches.

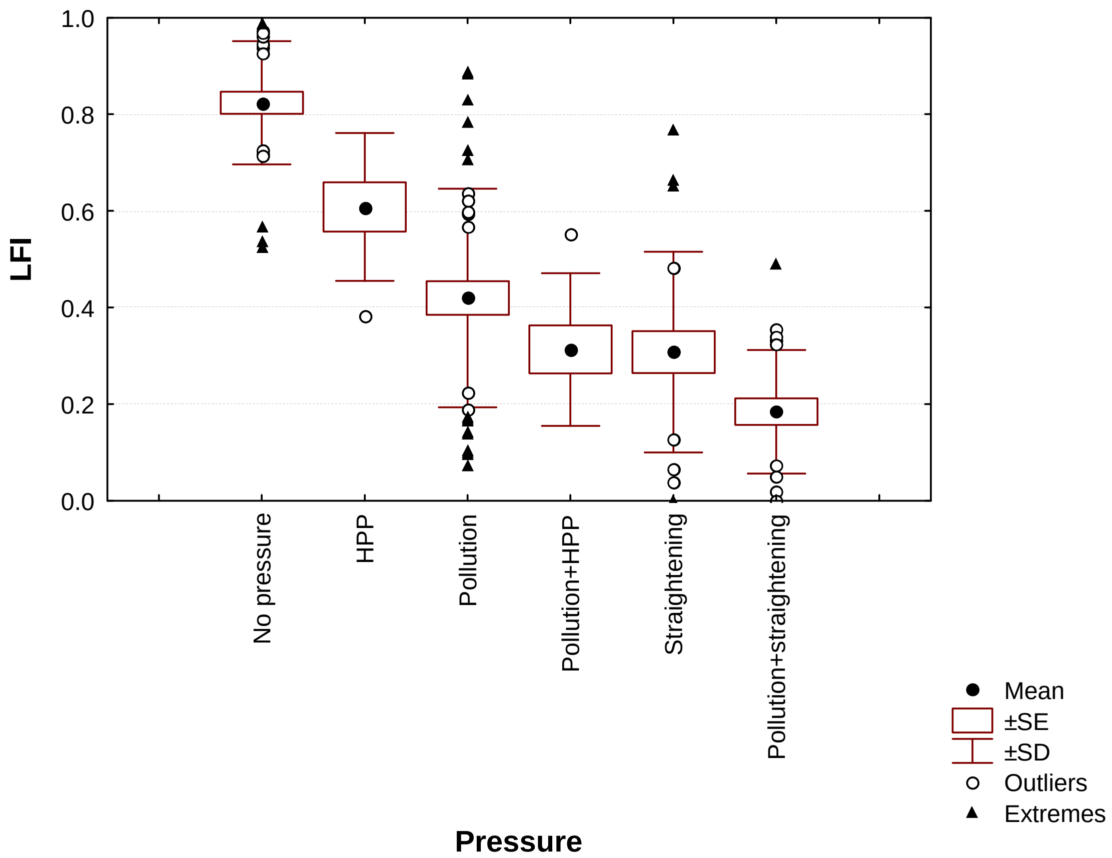

Figure 16. LFI scores in the rivers sites, differing in human pressure type.

Monitoring data shows that similar tendencies are present in the river stretches while only BDS7 slightly exceeds good/moderate threshold (3.3 mgO2 l-1). Meanwhile, poor fish community status in the river stretch below Žiobiškis HPP in 2014 corresponds to poor status according to concentrations of phosphates and total phosphorus. It seems that different pressures strengthen or hide each other's impact on fish community. However, it is not possible to identify the proportions of impacts, generated by different pressures in a certain river site. Application of proper hydromorphological assessment methodology can partly solve this problem via establishment of the extent of deviation of hydromorphological metrics from reference conditions.

Table 11. Values of general physicochemical elements and biological indices measured in the river stretches below HPP dams in Lielupe RBD (source: official State monitoring data).

Metric	Mūša River below Dvariukai HPP	Vingerinė River below Žiobiškio HPP	
Sampling date	*2013*	*2010*	*2014*
O_2 (mg0_2 l^{-1})	8.23	8.06	8.3
BDS_7 (mg l^{-1})	1.23	3.75	2.6
NH_4-N (mg l^{-1})	0.04	0.1	0.053
NO_3-N (mg l^{-1})	2.16	0.65	1.685
N total (mg l^{-1})	3.03	2.45	1.94
PO_4-P (mg l^{-1})	0.083	0.061	0.359
P total (mg l^{-1})	0.108	0.073	0.353
LRMI (EQR)	0.57	0.5	-
LFI (EQR)	**0.34**	**0.41**	**0.31**

2.5.2. Latvia

With aquatic habitats we understand in-stream composition of macrophytes and bed substrate which creates suitable environment for different aquatic organisms. Hydrological regime (stream velocity, available water) is the main force which determines aquatic habitat structure and its suitability for different life stages of flora and fauna.

Benthic macroinvertebrates and macrophytes were used as indicators to detect links between hydromorphological alterations caused by hydropower plants and biological quality elements. Both, macroinvertebrate and macrophyte indices were calculated according to newly intercalibrated methods (available at https://circabc.europa.eu/webdav/CircaBC/env/wfd/Library/working_groups/ecological_status/). Other biological quality elements (BQE), such as fish and phytobenthos, were not available.

Besides national macroinvertebrate index LMI and its subindices (Average Score Per Taxa, Danish Stream Fauna Index), Lotic-invertebrate Index for Flow Evaluation LIFE [11], in Guidance Document No. 31 [12] mentioned as potentially suitable and to be developed method, was tested for streams in Lielupe RBD. LIFE score, developed in UK, was used to estimate how hydrological pressure affects benthic macroinvertebrates.

In total, HPP are installed on 8 rivers (designated as water bodies) which can possibly affect 11 surface water and biological monitoring stations in Latvia. Other HPP are on rivers which are not designed as water bodies and therefore no monitoring has been done. Only 3 monitoring stations in Lielupe RBD are located up to 5 km from nearest HPP, four stations are located 5-10 km from nearest HPP (Fig. 17). Both water quality monitoring stations on river Dienvidsusēja are located very close to HPP or even its impoundment which significantly alters flow regime and may cause degradation of in-stream environment and habitats. It also affects interpretation and quality of monitoring results.

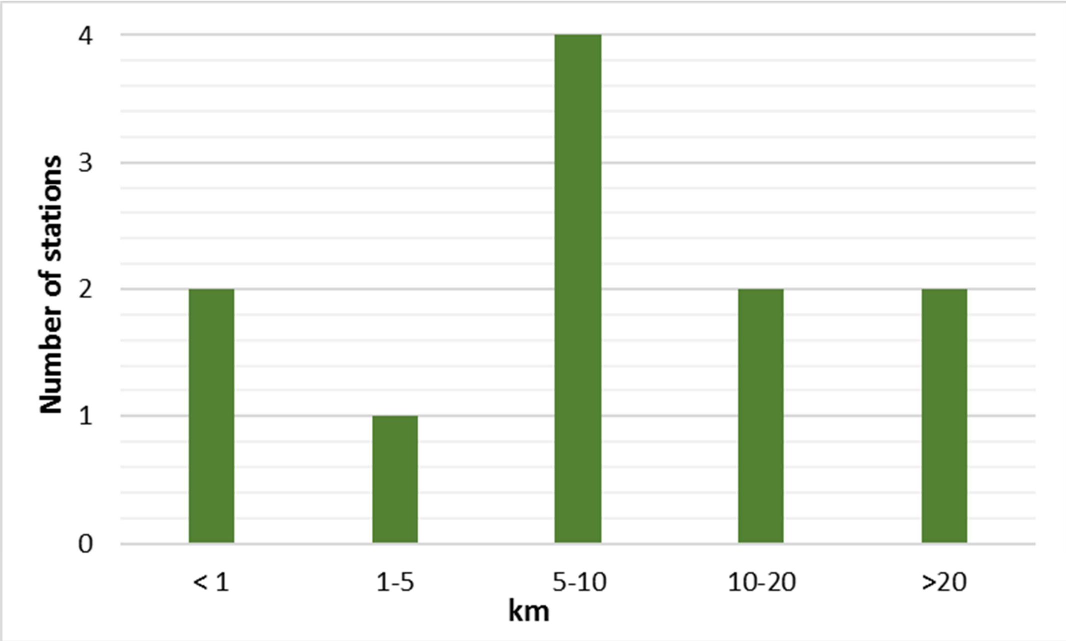

Figure 17. Distance between monitoring stations and HPP in Lielupe RBD (when HPP was located between two monitoring stations, shortest distance was taken into account)

As mentioned in chapter 2.5 in Venta RBD report, DSFI was selected as best indicator of hydromorphological degradation degree, because it revealed strongest relationships between distance from HPP and the biological data of nearest surface water monitoring station. Due to natural reasons (low slopes and small catchments), relatively low number of HPP are installed in Lielupe RBD. As central part of Lielupe River catchment is strongly affected by agricultural activities, it is hard to separate nutrient pollution/ morphological alterations from hydrological pressure caused by HPP operations. Four small HPPs are installed on Dienvidsusēja River which have significant impact on benthic macroinvertebrates (Fig. 18) because stretches with good water chemical quality have only moderate macroinvertebrate quality. Four small HPPs are installed also on Bērze River, but no biological impact can be determined because all monitoring stations are located too far from HPPs (nearest is 6.5 km downstream from dam).

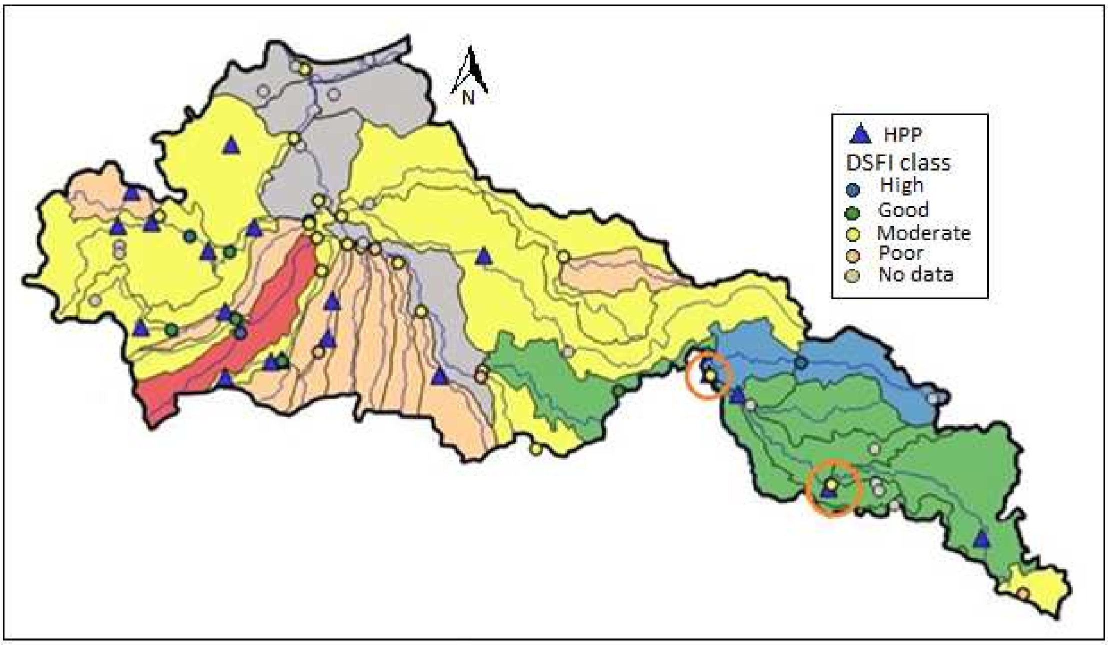

Figure 18. Surface water biological and hydrochemical quality in Lielupe RBD (catchments are colored after their hydrochemical quality class)

In rivers without any hydrological impact, distribution between macroinvertebrates preferring fast (LIFE groups I and II) and slow flows (LIFE groups III, IV, V) are very similar (Table 12). When HPP is located downstream from monitoring station, amount of LIFE group IV significantly increases, indicating that habitats are changed from riffles/flowing water to stagnant flow which may be caused by lack of water downstream from the dam. If biological monitoring station is located more than 7 km from nearest HPP, no impact on biological quality elements can be assessed.

Table 12. LIFE score distribution in sites with various hydrological impact in Lielupe RBD

HPP location	I	II	III	IV	V
No HPP	1.6	36.0	2.4	33.1	0.1
< 7 km	0.0	24.1	1.2	55.3	0.0
> 7 km	2.1	28.4	0.9	24.5	0.0
Downstream from MS	0.0	24.1	1.2	55.3	0.0

As it can be seen in Figure 19, LIFE scores can be used as sensitive enough indicators to assess hydrological pressure impact on benthic macroinvertebrates. Distribution of fast and slow/no flow preferring species are significantly different in river sites with and without HPP.

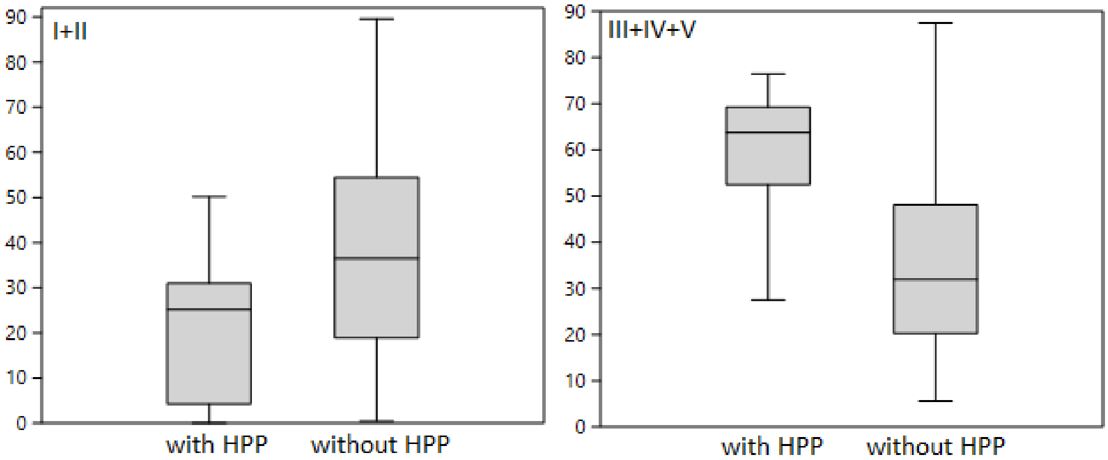

Figure 19. LIFE score distribution (%) in sites with and without hydroelectric power plants in Lielupe RBD

Latvian macrophyte MIR index did not demonstrate any significant response to hydrological alterations caused by HPP (Fig. 20), also number of species did not show any difference between impacted and unimpacted streams. Used plant index was developed to assess eutrophication as main pressure, also natural environmental factors (bed substrate, shading) are more important to macrophytes. Mean macroinvertebrate index LMI values were significantly higher in streams without hydroelectric power plants. It must be taken into account that newly developed macroinvertebrate index shows relatively low values even in close to natural streams and results must be carefully interpreted.

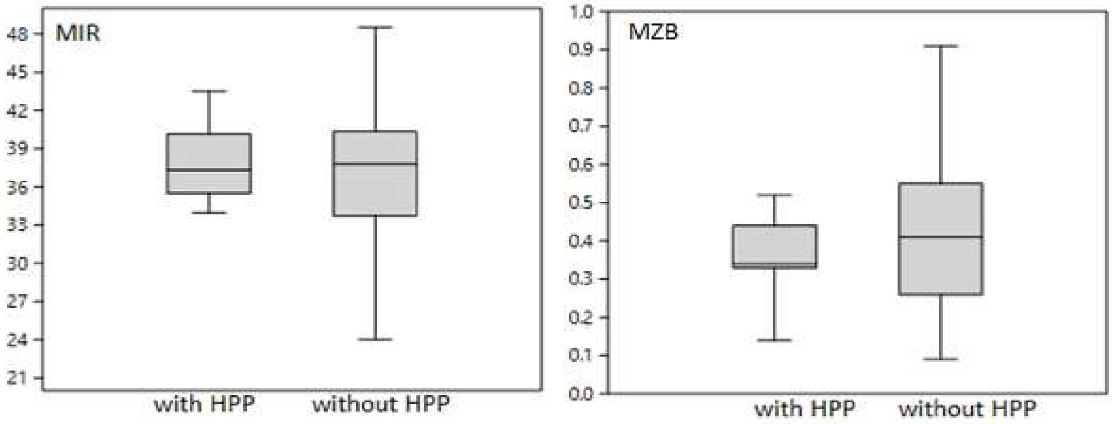

Figure 20. The variation of macrophyte (MIR) and macroinvertebrate (mzb) indices in studied streams with and without HPP in Lielupe RBD

Similarly to Venta RBD, chemical quality in hydrologically impacted sites in Lielupe RBD was lower (Fig. 21), probably because of substance accumulation above dams. As Lielupe RBD can be characterized with highest agriculture intensity in Latvia, Ptot revealed great concentration variation even in unimpacted rivers. Once again it must be noted that it is hard to separate multiple pressures acting within the same river segment (diffuse/point source pollution, land use and hydromorphological pressure).

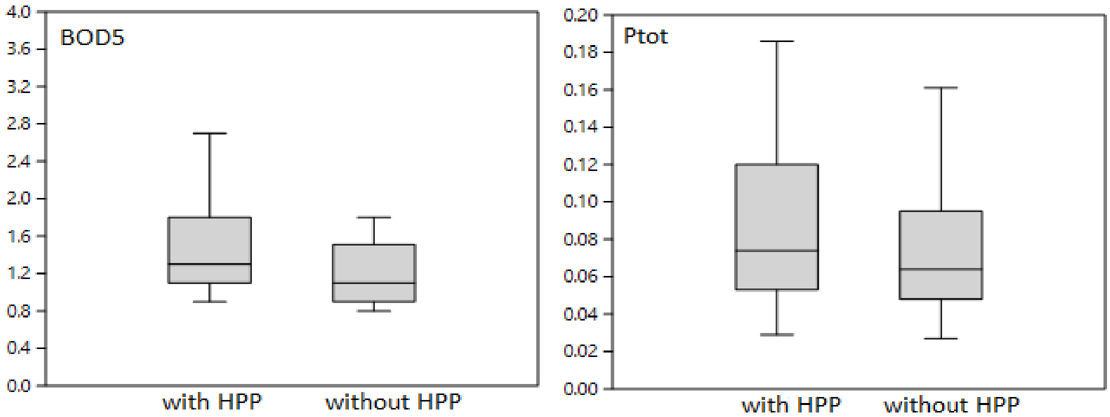

Figure 21. Variation of BOD5 and Ptot in streams with different hydrological pressure intensity in Lielupe RBD

HPP as migratory barriers. About 75% of river water bodies within Lielupe RBD belongs to slow flowing potamal rivers which explain relatively low density of hydroelectric power plants. All rivers within Lielupe RBD which are designated as Priority Fish Waters belongs to *cyprinid fish* waters. HPP have significant impact on fish communities because upstream dams are artificial obstacles which interrupts natural migratory routes and several fish species can't reach upstream catchments which affects their life cycle (breeding, feeding). In total, ~ 37.9 % of river catchments in Lielupe RBD are inaccessible for migratory fish due to currently operating HPP (Fig. 22), mostly in Dienvidsusēja and Bērze river catchments. When former mill ponds (with or without sluice) with are taken into account, 40.1 % of Lielupe RBD are inaccessible for migratory fishes. It must be noted that this map (Fig. 22) is only theorethical and river continuity disruption must be checked by experienced ichthyologists.

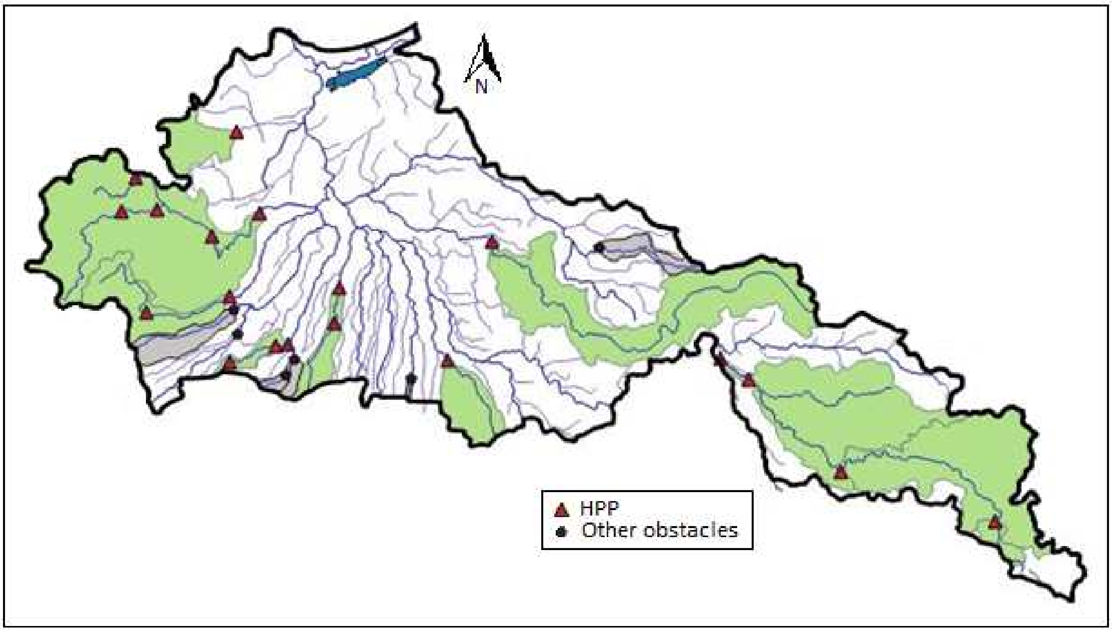

Figure 22. Areas inaccessible for migratory fishes in Lielupe RBD due to operating HPP (green catchments) and other artificial obstacles (grey)

III. CONCLUSIONS

Biological quality elements and their indices used in Latvian routine monitoring are not sensitive enough to assess habitat degradation and any kind of hydrological alterations. All biological quality metrics used in current Latvian state surface monitoring programme detects eutrophication as major pressure. LIFE index described in this review, clearly shows that benthic macroinvertebrates are strongly affected by flow modifications and hydrological indices must be developed to assess HPP impact on biological communities.

Results of analysis of Lithuanian river fish monitoring data demonstrate that fish metrics are sensitive to both water quality and hydromorphological alterations. However, it is not possible to identify the proportions of impacts of different pressures that act together. Application of proper hydromorphological assessment methodology can partly solve this problem via establishment of the extent of deviation of hydromorphological metrics from reference conditions.

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ANNEX I

Table 1. Hydrological parameters in the rivers (WGS) of the Lielupė RBD within Lithuanian territory

No	River	WGS	Opened	Closed	Distance from the mouth, km	Drainage area, km²	Average discharge (Q), m³/s			30-day minimum discharge (Qmin 30), m³/s			Lowest daily discharge during the period of record, m³/s
							Multi-year average	Module, l/(s·km²)	Q95%	Multi-year average	Module, l/(s·km²)	Q95%	
1	Mūša	Miciūnai	1944-11-01	2000-03-15	118.3	792,2	4.20	5.3	1.66	0.75	0.95	0.14	
2	Mūša	Ustukiai	1957-09-01	works	56.1	2284	10.3	4.5	4.50	1.31	0.57	0.44	0.11
3	Mūša	Raudonpamūšis	1944-11-19	1957-08-15	42.5	5005	26.3	4.9		1.78	-	-	
4	Mūša	Žilpamūšis	2000-10-01	works	41.8	5006	21.6	4.3					0.94
5	Daugyvenė	Meilūnai	1951-10-01	1964	2.8	484.8	2.35	4.5		0.089	0.20	0.00	
6	Daugyvenė	Rimšoniai	2006-03-01	works	0.3	487.5	2.18	4.7					
7	Lėvuo	Kupiškis	1929-08-01 2006-03-01	2000-03-15 works	109.3	303.3	1.78	5.8	0.87	0.12	0.39	0.031	0.013
8	Lėvuo	Bernatoniai	1930-12-08 (1967-03-28)	works	47.2	1144	3.52	5.8	1.95	0.55	0.73	0.45	0.19
9	Lėvuo	Pasvalys	1930-02-01	2001-05-01	3.0	1625	6.46	5.8	3.23	1.11	0.88	0.69	
10	Įstras	Talačkoniai	1932-07-13 (1977-10-01)	2001-09-10	2.7	110	0.68	5.9	0.29	0.20	1.55	0.065	
11	Pyvesa	Žadeikiai	2006-03-01	works	11.5	442	2.70	6.1		0.24	0.63	0.11	
12	Tatula	Daudžgiriai	1961-10-01	1967-03-11	17.5	174.7	1.02	6.3		0.17	-	-	
13	Tatula	Trečionys	1961-10-01 (1993-01-01)	works	5.5	404.4	2.82	5.9	1.10	0.59	1.46	0.25	0.087
14	Smardonė	Likėnai	1994-01-01	works	2.3	7.9	0.26	31.9					0.06
15	Verdenė	Likėnai	1997-06-01	works	0.5	-	0.16	-					
16	Nemunėlis	Panemunėlis	1986-09-01	1992-12-31	184.1	47.7	0.34	6.9		0.068	-	-	
17	Nemunėlis	Panemunis	1935-11-01	1959-12-01	143	360	2.64	7.3	1.52	0.44	1.33	0.20	
18	Nemunėlis	Kvetkai	2006-03-01	works	125.0	751.8	5,76	7.7					
19	Nemunėlis	Rimšiai	1945-08-28	1986-08-31	118.1	877.2	5.93	6.8	3.26	1.15	1.31	0.45	
20	Nemunėlis	Tabokinė	1944-12-01	works	68.9	2744	20.2	7.4	10.2	2.95	1.10	1.2	0.23
21	Apaščia	Šimpeliškiai	1935-11-01	1959-04-01	37.9	276	1.51	5.8	0.58	0.062	-	-	

No	River	WGS	Opened	Closed	Distance from the mouth, km	Drainage area, km^2	Average discharge (Q), m³/s			30-day minimum discharge (Qmin 30), m³/s			Lowest daily discharge during the period of record, m³/s
							Multi-year average	Module, l/(s·km²)	Q95%	Multi-year average	Module, l/(s·km²)	Q95%	
22	Apaščia	Nausėdžiai	1994-08-01	1996-12-31	10.7	677	4.22						0.10
23	Agluona	Dirvonakiai	1959-07-22	1999-12-31	7.9	43.3	0.43	6.5	0.19	0.03	0.45	0.001	
24	Rovėja	Parovėja	1932-07-18	1946-07-16	10.5	150	1.31	7.0	0.52	0.056	-	-	
25	Yslikis	Kyburiai	1935-11-01 (1970-06-20)	works	47.0	70.0	0.34	4.7	0.093	0.006	0.07	0	0
26	Platonis	Vaineikiai	2006-03-01	works	43.5		0.60	5.0					
27	Sidabra	Šarkiai	2006-03-01	works	19.8	79.8	0.33	4.1					
28	Švėtė	Minčaičiai	1935-11-01	1960-07-01	82.6	206.2	1.53	5.4		0.043	0.27	0.019	
29	Švėtė	Žagarė	2011-11-12	works	74.2	230.6	1.15	5.0					

Table 2. Hydrological parameters of rivers in Lielupe RBD within Latvian territory

No	River	Monitoring station	Opened	Closed	Distance from the mouth, km	Drainage area km^2	Period of record	Average discharge (Q) m^3/s			30-day minimum discharge (Qmin 30) m^3/s			Lowest daily discharge for period of observations m^3/s
								Multi-year average	Module $l/(s\cdot km^2)$	Q95%	Multi-year average	Module $l/(s\cdot km^2)$	Q 95%	
1	Lielupe	Mežotne	17-06-1920	-	107	9390	1921-2015	57.0	6.06	30.8	9.50	1.18	3.61	2.51
2	Dienvidsu sēja	Elkšņi	26-11-1945	31-12-1987	73	517	1951-1987	3.45	6.67	1.73	0.64	1.24	0.28	0.20
3	Viesīte	Sudrabkalni	01-01-1958 01-12-2007	01-10-1993	15	313	1959-1992 2008-2015	2.48	7.92	1.40				
4	Mūsa	Bauska	07-01-1920	-	1.4	5320	1920-2015	25.1	4.71	13.0	3.35	0.63	1.03	0.79
5	Īslīce	Tiltsargi	10-09-1954	31-12-1987	22	330	1959-1987	1.47	4.44	0.33	0.037	0.11	0.0	0.0
6	Iecava	Dupši	01-11-1933	31-03-1995	66	519	1953-1994	3.71	7.14	2.16	0.92	1.77	0.27	0.26
7	Misa	Lielveisi	01-01-1951 01-01-2008	31-12-90	34	618	1952-1970 2008-2015	4.49	7.79	2.23	0.63	1.01	0.12	0.14
8	Svēte	Ūziņi	03-08-1926	-	45	632	1949-2015	2.71	4.35	2.49	0.42	0.66	0.06 3	0.050
9	Tērvete	Bramberģe	01-02-1984	-	14	330	1985-2015	1.84	5.59	1.04	0.24	0.72	0.05 2	0.040
10	Bērze	Baloži	15-03-1927	-	6	904	1960-2015	5.34	5.91	2.99	0.97	1.08	0.29	0.12
11	Auce	Brakšķi	27-12-1974	31-12-1990	5	291	1975-1987	1.90	6.52	0.87	039	2.19	0.054	0.019

Table 3. Hydro-morphological quality of water bodies in Lielupe RBD within Latvian territory

WB name	WB code	WB type	Substrate	Pressure	HM class
Lielupe	L100SP	R6	concrete, gravel, sand, mud	Lielupe port; polder' area 20% of WB; riverbank modification (reinforcement)	5
Vecslocene	L102	R4	bedrock, gravel, coarse debris, mud, peat	<30% of the total length of watercourses - water regulations	2
By-pass channel of Vecbērze polder	L106SP	R4	sand, mud, clay	Polder' area 21% of WB; >90% of WB' length - water regulations	5
Lielupe	L107	R6	bedrock, sand, mud	Water regulations in river network; morphological changes	2
Svēte	L108SP	R6	bedrock, sand, coarse debris, mud	Polder' area 31% of WB	5
Bērze	L109	R4	sand, mud	Bērzes HPP; >50% of the total length of watercourses - water regulations	4
Bērze	L111	R3	boulders, cobbles, gravel, sand, mud	Dobeles, Annenieku & Bikstu-Palejas HPPs; >30% of the total length of watercourses - water regulations	4
Bikstupe	L114	R3	boulders, cobbles, gravel, sand, mud	>50% of WB' length - water regulations; Bikstupes HPP	3
Auce	L117SP	R4	sand, mud	>50% of WB' length and >50% of the total length of watercourses - water regulations; Kroņauces HPP	5
Auce	L118	R3	cobbles, gravel, sand, mud	Water regulations in river network	2
Tērvete	L120	R3	bedrock, boulders, gravel, sand, mud	>50% of the total length of watercourses - water regulations; a dam	3
Skujaine	L121	R3	mud	>50% of the total length of watercourses - water regulations; a dam	3
Svēte	L123	R3	bedrock, boulders, cobbles, gravel, sand, mud	Gulbīšu, Lielberķenes & Mūrmuižas HPPs; water regulations in river network	4

WB name	WB code	WB type	Substrate	Pressure	HM class
Vilce	L124	R3	gravel, sand, mud	>50% of the total length of watercourses - water regulations; a dam	3
Iecava	L127	R6	bedrock, boulders, cobbles, gravel, sand, coarse debris, mud	>50% of the total length of watercourses - water regulations; Grienvaldes (Lejas) HPP; polders	4
Misa	L129	R4	mud, clay	>30% of the total length of watercourses - water regulations	2
Taļķe	L132	R3	sand, mud	>50% of the total length of watercourses - water regulations	3
Lielupe	L143	R6	bedrock, sand, mud	Water regulations in river network; morphological changes	3
Platone	L144SP	R4	cobbles, gravel, sand, clay	Ziedlejas & Viduskroģeres HPPs; >50% of WB' length and >50% of the total length of watercourses - water regulations	5
Platone	L146	R3	sand, mud	>50% of the total length of watercourses - water regulations	3
Vircava	L147	R4	mud, clay	>50% of the total length of watercourses - water regulations	3
Sesava	L148SP	R4	sand, mud, clay	100% of WB' length - water regulations	5
Svitene	L149	R3	cobbles, gravel, sand, mud, clay	>50% of the total length of watercourses - water regulations	3
Īslīce	L153	R4	gravel, sand, mud, clay	Rundāles HPP, >50% of the total length of watercourses - water regulations	3
Mēmele	L159	R6	bedrock, cobbles, gravel, sand, mud	<10% of the total length of watercourses - water regulations	1
Viesīte	L161	R3	cobbles, gravel, sand	none	1
Viesīte	L162	R4	cobbles, gravel, sand, mud	<30% of the total length of watercourses - water regulations	2

WB name	WB code	WB type	Substrate	Pressure	HM class
Zalvīte	L165	R4	cobbles, gravel, sand	>30% of the total length of watercourses - water regulations	3
Dienvidsusēja	L166	R6	sand, mud	Grīvnieku, Ērberģes & Neretas HPPs, >10% of the total length of watercourses - water regulations	4
Dienvidsusēja	L169	R3	cobbles, gravel, sand, mud	Gārsenes HPP, <30% of the total length of watercourses - water regulations	2
Mūsa	L176	R6	bedrock, cobbles, gravel	HPP in Lithuania nearby the border; lack of data	4
Kreuna basin	L178	R1	coarse debris, mud	none	1

Table 4. Small HPs in Lielupė RBD within Lithuanian territory

No	SHP name	River	Distance from the mouth, km	Basin area, km²	SHP commission-ning year	Head, m	Reservoir area, ha	Reservoir normal water level	Volume of reservoir, thousand m³	Installed capacity kW	Environmen-tal flow m³/s
1	Dvariūkai	Mūša	81.5	1927	2001	5.80	136.4	48.35	3050.0	494	0.380
2	Akmeniai	Lėvuo	85.6	873.6	1999	2.10	9.4	61.00	159.0	35	0.139
3	Stirniškiai	Suosa	1.6	95.3	1974	10.30	13.3	82.5	470.0	60	0.009
4	Žiobiškis	Vingerinė	6.5	31.9	1996	0.00	16.5	96.0	408.6	15	0.023
5	Juodupė	Vyžuona	23.8	96.8	2005	6.30	9.6	99.50	190.0	75	0.053

Table 5. Hydro-technical characteristics of Hydropower Plants in Lielupe RBD within Latvian territory

River	HPP	Distance from river mouth, km	Authority	WB code	Commissioning year	Turbine type*	Installed capacity, kW	Q, m^3/s	Reservoir area, km^2	Head, m
Džūkste	Mazkrāču	15.0	Džūkste	L106SP	1998	2F	90	0.16	0.161	5.0
Bērze	Bērzes	12.0	Bērze	L109	1996	2F+1K	60	0.2	0.098	5.8
Bērze	Dobeles	35.0	Dobele	L111	2002	3K	130	0.17	0.03	3.65
Bērze	Annenieku	61.0	Annenieki	L111	2002	2K	300	0.076	0.288	8.2
Bērze	Bikstu-Palejas	73.0	Biksti	L111	1999	1F+1K	120	0.031	0.113	4.0
Bikstupe	Bikstupes	12.0	Jaunpils	L114	2002	2K	100	0.05	0.124	5.1
Auce	Kroņauces	34.0	Tērvete	L117SP	2001	1K	90-125	0.003	0.172	5.8
Auce	Bēnes	59.0	Bēne	L118	2011	-	-	-	-	-
Svēte	Mūrmuižas	30.0	Vilce	L123	2002	1F+1K	150	0.08	0.091	4.9
Svēte	Lielberķenes	43.5	Vilce	L123	1999	1K	120	0.15	0.090	5.0
Svēte	Gulbīšu	52.0	Augstkalne	L123	2000	1K	125	0.04	0.147	5.0
Iecava	Grienvaldes (Lejas)	42.0	Iecava	L127	2001	1F+1K	200	0.182	0.051	2.4
Platone	Ziedlejas	36.0	Lielplatone	L144SP	2001	2K	165	0.008	0.352	3.9
Platone	Viduskroģeru	15.0	Platone	L144SP	2002	2K	240	0.046	0.29	3.4
Īslīce	Rundāles	18.0	Rundāle	L153	1999	2K	165	0.16	0.125	4.3
Dienvidsusēja	Grīvnieku	0.3	Mazzalve	L166	2002	2K	600	0.64	0.166	4.2
Dienvidsusēja	Ērberģes	10.0	Mazzalve	L166	1998	3K	174	1.37	0.058	2.5
Dienvidsusēja	Neretas	35.0	Nereta	L166	1999	2K	145	0.21	0.70	3.2
Dienvidsusēja	Gārsenes	99.0	Gārsene	L169	1999	1F	37	0.10	0.056	4.0

**Turbine types: F-Frensis, K-Kaplān, M-Mavel*