Project „Water bodies without borders" (EstLat 66)

ACTION PLAN

Pressures and impacts on water quality, economical analysis and programme of measures

February 2020

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Abbreviations

EC – European Commission
EE – Estonia
EELIS – Estonian Nature Information System
EstModel – Estonian software for modeling nutrient loads
GES – good ecological status
GIS – geographic information systems
HPP – hydropower plant
HYMO – hydro-morphology
in/km^2 – inhabitants per square kilometer
LSU – livestock units
LV - Latvia
MCA – multi-criteria assessment
N, N_{tot} – nitrogen, total nitrogen
NRT – nature resource tax
P, P_{tot} – phosphorus, total phosphorus
PoM – programme of measures
RBD – River Basin District
RBMP – River Basin Management Plan
WB – water body
WBWB – project “Water Bodies Without Borders”
WFD – Water Framework Directive
WWTP – wastewater treatment plant

Introduction

According to the Water Framework Directive 2000/60/EC the member states of the European Union have taken obligation to achieve and to maintain good ecological status for all water bodies.

If the status of water body isn’t at least good, there is a need to implement measures to improve the status. These measures can be administrative, technical, advisory and also investigative. Currently the second period of water management plans are in progress (2015-2021). Existing measures are those that have been implemented, are in process of implementation or are planned in the current water management period. The water bodies failing to achieve good ecological status with the existing measures need additional or supplementary measures for improvement.

At the beginning of “Water bodies without borders” project the project area was selected with the aim to analyse, compare and assess quality of transboundary water bodies. Pressure assessment, economic analysis and ecological quality assessment were carried out to elaborate adequate measures for improvement of ecological quality of water bodies.

Project area includes all of the Salaca/Salatsi river basin in Latvia and Estonia, all of the Gauja/Koiva river basin in Estonia and part of Gauja/Koiva river basin affected by transboundary processes in Latvia. Additionally, some water bodies outside of Gauja/Koiva and Salaca/Salatsi river basins were included, to cover the whole transboundary area.

This document describes the pressures and impacts on water bodies, economical analysis and evaluation of additional measures. Based on these analysis water body scale measures for achieving good status are proposed. Also the results of ecological flow estimation for Vaidava River and experience with small-scale filtration system are given.

1. General description of project area

Project area is located in two countries - Latvia and Estonia, covering whole Salaca/Salatsi river basin, part of Gauja/Koiva river basin and other smaller parts of smaller transboundary basins (Figure 1). Total area of project territory is 7336 km^2 (5657 km^2 in Latvia, 1679 km^2 in Estonia). In project area there are in total 109 water bodies, 63 water bodies on Latvian side (52 river water bodies (WBs) and 11 lake WBs) and 46 water bodies on Estonian side (37 river WBs, 9 lake WBs), of which 18 are transboundary (EELV1010 Atse/Acupīte_1, EELV1001 Gauja_8/Koiva_1, EELV2002 Läteteperä/Akaviņa, EELV1015 Pedeli_1/Pedele_1, LVEE1016 Pedele_2/Pedeli_2, EELV2001 Pedetsi/Pededze_1, LVEE1003 Peļļupīte/Peeli, EELV1004 Peetri/Melnupe_2, EELV1011 Penuoja/Kolkupīte, EELV1012 Puupe/Pužupe, LVEE1005 Pērļupīte/Pärlijõgi_1, EELV1013 Raamatu/Ramata, EELV1014 Ruhja/Rūja_1, EELV1006 Ujuste/Kaičupe, EELV1007 Vaidva_1/Vaidava_1, LVEE1008 Vaidava_2/Vaidva_2, EELV1017 Õhne_2/Omuļupe, EELV1009 Murati järv/Muratu Ezers).

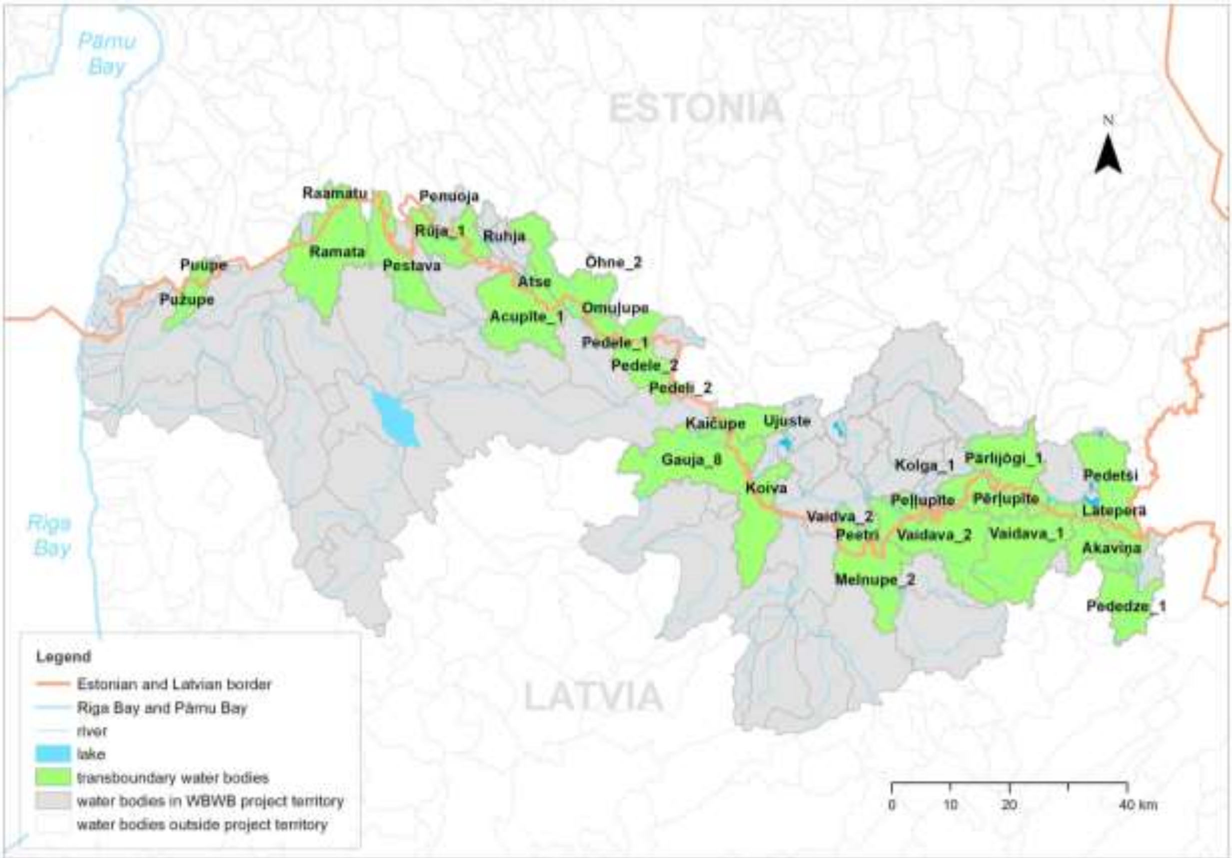

***Figure 1**. Project area and transboundary water bodies*

Most of the project area is covered by forests (64.3%) and agricultural lands (30.9%). Various protected areas are located within the Gauja/Koiva river basin, such as Gauja National Park, Veclaicene Protected Landscape Area, Ziemeļgauja (North-Gauja) Protected Landscape Area, Karula National Park and Haanja Nature Park. In the Estonian side of Koiva river basin, about

22% of the area is under nature conservation (including nature conservation areas and limited-conservation areas).

In the project territory there are 90 wastewater effluents in total (21 in Estonian part and 69 in Latvian part of project territory), most of which are municipal wastewater discharges for agglomerations with population equivalent (PE) under 2000, and only in Latvian side there are 5 agglomerations with PE above 2000 (Valka, Aloja, Mazsalaca, Rūjiena, Alūksne). Within the project territory on Latvian side one contaminated site of 1st category is registred, 262 potentially contaminated sites (2nd category) and 11 sites that are not contaminated (3rd category), however there are no significant pressures from contaminated sites on water quality. On Estonian side no contaminated sites are identified within the project area.

On the Estonian side of the project territory there are 213 livestock buildings (buildings for livestock, manure and silo storages, etc), total amount of 4129 livestock units (LSU) - 1.07 LSU per hectare in the project area. On the Latvian side of the project territory there are 1691 livestock farms with 37543 LSU and average density of 0.066 LSU per hectare. Total amount of livestock farms since 2000 has significantly decreased (about 5 times), however the livestock units during the time have increased, thus indicating intensification of livestock farming.

In the project area in Estonia there are altogether 56 man-made dams, including 1 small hydro-power plant (Vastse-Roosa). Dams in Estonian side of project territory are usually located in tributaries, which are not priority habitats for fish and therefore do not affect the status of water bodies. However, the dams of Pärlijõgi, Saarlasõ, Vastse-Roosa, Ala-Raudsepa, Sänna-Mäeveski, Sänna-Alaveski ja Koorküla Veskijärve are located in water bodies with suitable habitats for salmonidae fish species. Dams of Pärlijõgi, Saarlasõ and Koorküla Veskijärve don't have fish passes. The Environmental Board of Estonia has given the permit for special use of water (hereinafter water permit) to 32 dams, 11 dams do not require water permit (the natural level of a watercourse is raised by up to one meter) and 13 dams don't have water permit despite it being a mandatory requirement. In addition, there are 210 beaver nests on water bodies of Estonian side of project area, which means there is a negative impact from beaver dams as well.

In accordance with existing information there are 80 man-made dams and other obstacles on Latvian side of the project area, 10 of which are used by hydropower plants (HPPs). Mostly dams are located on small tributaries, but two transboundary water bodies (G317 Pedele_2 and G235 Vaidava_2) both have 2 HPPs on the main stream without any working fish pass (there is one fish pass constructed on "Karva" HPP on Vaidava river, however, it doesn't operate properly).

Table 1 provides the main socioeconomic figures characterising the project area, and Figure 2 a map with water bodies (WBs) of the project area and administrative units (parishes and cities for Latvia, counties and cities for Estonia) which are considered for the socioeconomic estimates.

Table 1. *Estimated number of inhabitants, companies and employed persons in the project area. (Source: Estimates developed as part of the project. The estimation approach and input data are described in the detailed report of the project on the economic analysis)*

Indicators	**Estimates for the project area**			**Input data and estimation approach**
	For Latvia	**For Estonia**	**TOTAL**	
Number of inhabitants	50 897	12 442	**63 339**	For Latvia: Input data from the OCMA (data on 01.2019, for selected parishes and cities). Estimate for the project area based on proportion of territory of administrative units which belongs to the project area. For Estonia: Input data from the Estonian Statistics (geographical information system (GIS) map layer).
Number of companies	4 299	1029	**5 328**	For Latvia: Input data from CSB (data for 2017, for selected parishes and cities).* For Estonia: Input data from Estonian Statistics 2018 for Võru and Valga county. For both countries – estimate for the project area based on proportion of territory of administrative units which belongs to the project area.
Number of employed persons	14 921	5780	**20 701**	

* Note. There is uncertainty in the CSB data on number of employed persons since they are accounted according to location (administrative unit) of legal address of a company which can differ from administrative unit where employees are actually located. The actual number of employed persons in the administrative units of the project area could rather be larger than accounted in the statistical data.

Around 80% of the estimated inhabitants and companies and around 70% of the employed persons are located in the Latvian part of the project area.

12 442 inhabitants are estimated living in the Estonian part of the project area. There are 1029 companies employing 5780 people. Average population density is 7.4 inhabitants/km^2, which is much lower than the average in Estonia overall (29.8 in/km^2).

50 897 inhabitants are estimated living in the Latvian part of the project area. Population density in the Latvian part is 9.0 in/km^2, which is similar as in the Estonian part and considerably lower than the average in Latvia overall (30 in/km^2). There are 4299 companies employing 14 921 persons in the Latvian part of the project area.

The estimated number of inhabitants, companies and employed persons in the project area is based on data from the Central Statistical Bureau of Latvia and the Office of Citizenship and Migration Affairs for Latvia and Estonian Statistics (data for 2016-2019) for Estonia. For Latvia the socioeconomic data were calculated for the project area based on proportion of territory of administrative units which belongs to the project area. For Estonia the number of inhabitants for the project area is estimated based on data of the Statistics Estonia (public databases, data for 2016) where GIS map layer is provided with distribution of inhabitants by their place of residence (number of people living in each 1 km^2). Similar approach was used as in Latvia for estimating the number of companies and employed persons in the project area.

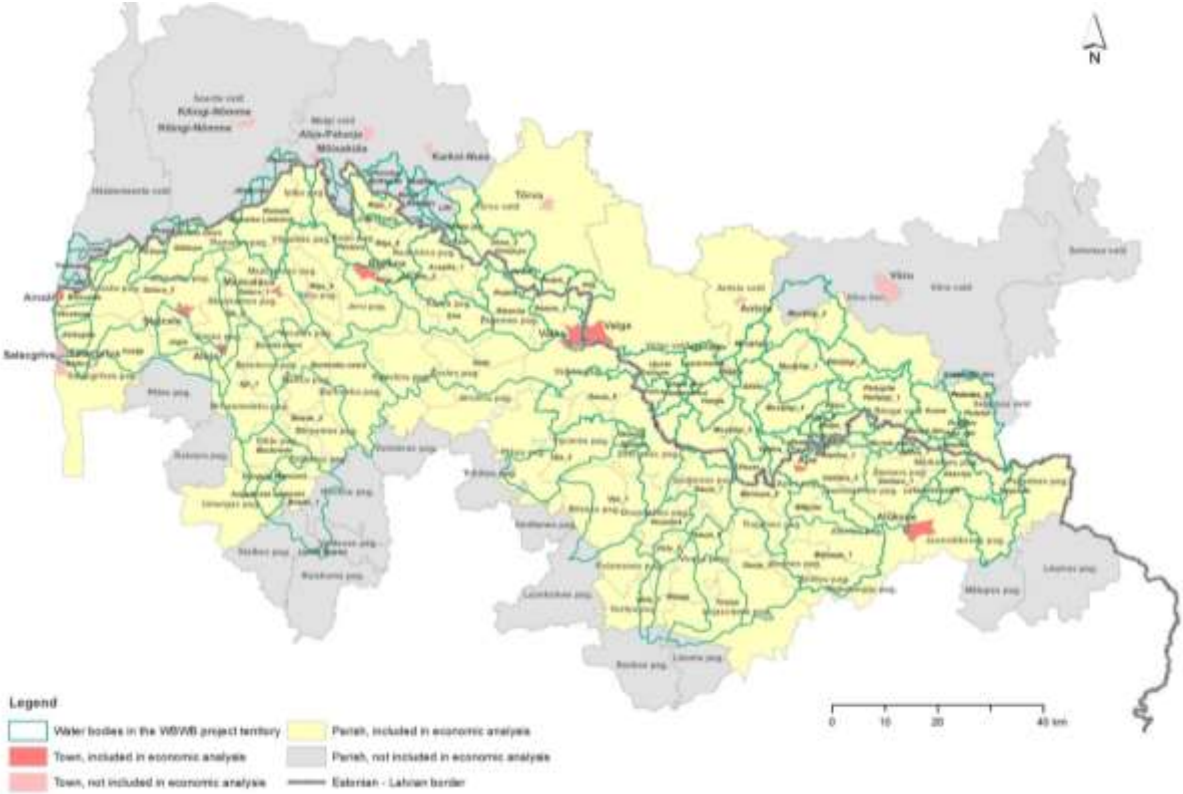

Figure 2. *Map of water bodies and administrative units in the project area included in the economic analysis. (Source: LEGMC.)*

**Note. Yellow colour denotes the parishes and bright red colour denotes the cities that are included in the economic analysis (according to the approach described earlier). The parishes marked with grey and the cities marked with light red are excluded from the economic analysis.*

2. Pressure and impact analysis

The Water Framework Directive 2000/60/EC (WFD) requires the identification of significant pressures from point and diffuse pollution sources, modifications of flow regimes through abstractions or regulation and morphological alterations, as well as any other pressures. ‘Significant’ means that the pressure contributes to an impact that may result in failing to meet the WFD objectives of having at least good status. In some cases, pressures from several drivers, e.g. nutrient runoff from agriculture and municipal wastewater treatment plants, may in combination become significant.

Within the project Water Bodies Without Borders (WBWB) project area several pressure types were identified and analysed, taking into account assessments done in national river basin management plans that are in force for period 2016-2021, as well as updated information on quality and pressures. In pressure and impact analysis point and diffuse pollution sources, hydro-morphological alterations and water quantity were assessed in a relation to water quality.

After pressure and impact analysis it was determined that 25% of WBs are significantly impacted - 23 WBs on Latvian side and 4 WBs on Estonian side (Table 2, 3), including 4 transboundary water bodies (EELV1004 *Peetri/Melnupe_2*, EELV1007 *Vaidva_1/Vaidava_1*, LVEE1008 *Vaidava_2/Vaidva_2*, LVEE1016 *Pedele_2/Pedeli_2*).

Table 2. *Latvian water bodies failing good ecological status (GES) due to significant pressures.*

WB Code	**Trans-boundary WB code**	**WB Name**	**Point source pollution**		**Diffuse pollution**		**Hydro-morphological alterations**					**Internal load**
			Nutrient pollution from point source	**Point source - non IED plants**	**Nutrient pollution - agriculture**	**Nutrient pollution - forestry**	**Drainage - agriculture**	**Drainage - forestry**	**Dams, barriers, locks – hydro-power**	**Dams, barriers, locks - industry**	**Dams, barriers, locks - unknown**	**Historical pollution**
E203		Lake Salainis				x						
E204		Lake Lūkumīša				x						
E225		Lake Burtnieka			x							x
E228		Lake Lielais Bauzis			x							
G229		Vija_1			x	x		x				
G233	EELV1004	Melnupe_2 / Peetri			x							
G234		Melnupe_1			x		x					
G235	LVEE1008	Vaidava_2 / Vaidva_2			x				x			
G241		Gauja_6			x	x						
G242		Vizla_2					x					
G301		Salaca_2			x	x				x		
G303SP		Salaca_3			x							
G304		Iģe_1			x			x				
G306		Salaca_1					x				x	
G308		Jogla		x	x							
G310		Rūja_4					x	x				
G313		Rūja_2					x					
G315		Ķire					x					

WB Code	Trans-boundary WB code	WB Name	Point source pollution		Diffuse pollution		Hydro-morphological alterations					Internal l oad
			Nutrient pollution from point source	Point source - non IED plants	Nutrient pollution - agriculture	Nutrient pollution - forestry	Drainage - agriculture	Drainage - forestry	Dams, barriers, locks – hydro-power	Dams, barriers, locks - industry	Dams, barriers, locks - unknown	Historical pollution
G317	LVEE1016	Pedele_2 / Pedeli_2							x			
G320		Acupīte_2					x					
G322		Briede_1			x				x		x	
G325		Blusupīte			x			x				
G334	EELV1007	Vaidava_1 / Vaidva_1	x									

Table 3. *Estonian water bodies failing GES due to significant pressures.*

WB Code	Trans-boundary WB code	WB Name	Point source pollution		Diffuse pollution		Hydro-morphological alterations					Internal load
			Nutrient pollution from point source	Point source - non IED plants	Nutrient pollution - agriculture	Nutrient pollution - forestry	Drainage - agriculture	Drainage - forestry	Dams, barriers, locks - hydropower	Dams, barriers, locks - industry	Dams, barriers, locks - unknown	Historical pollution
2133700_1		Lake Köstrejärv	x		x							x
2155200_1		Lake Pullijärv										x
2136600_1		Lake Aheru										x
2136000_1		Lake Ähijärv										x
2155500_1		Lake Hino										x
2144700_1		Lake Kirikumäe										x
1155700_1	LVEE1005	Pärlijõgi_1									x	
1155700_2		Pärlijõgi_2									x	
1158000_1	EELV1007	Vaidava_1							x			
1158000_2	LVEE1008	Vaidava_2							x			
1012100_2	LVEE1016	Pedele_2 / Pedeli_2									x	

2.1. Point source pollution analysis

Point source pollution is a single identifiable source of water pollution as effluents of wastewater treatment plants (municipal, industrial) or other sources that can be easily identified. Within this project data on WWTPs and contaminated sites was analysed to assess the potential impact of point source pollution on water quality.

It was established that impact from point source pollution is significant only on Latvian side of project territory, and there are 2 water bodies affected - EELV1007 *Vaidva_1/Vaidava_1* (on Latvian side G334 *Vaidava_1*) and G308 *Jogla* (due to wastewater effluents) (Figure 3).

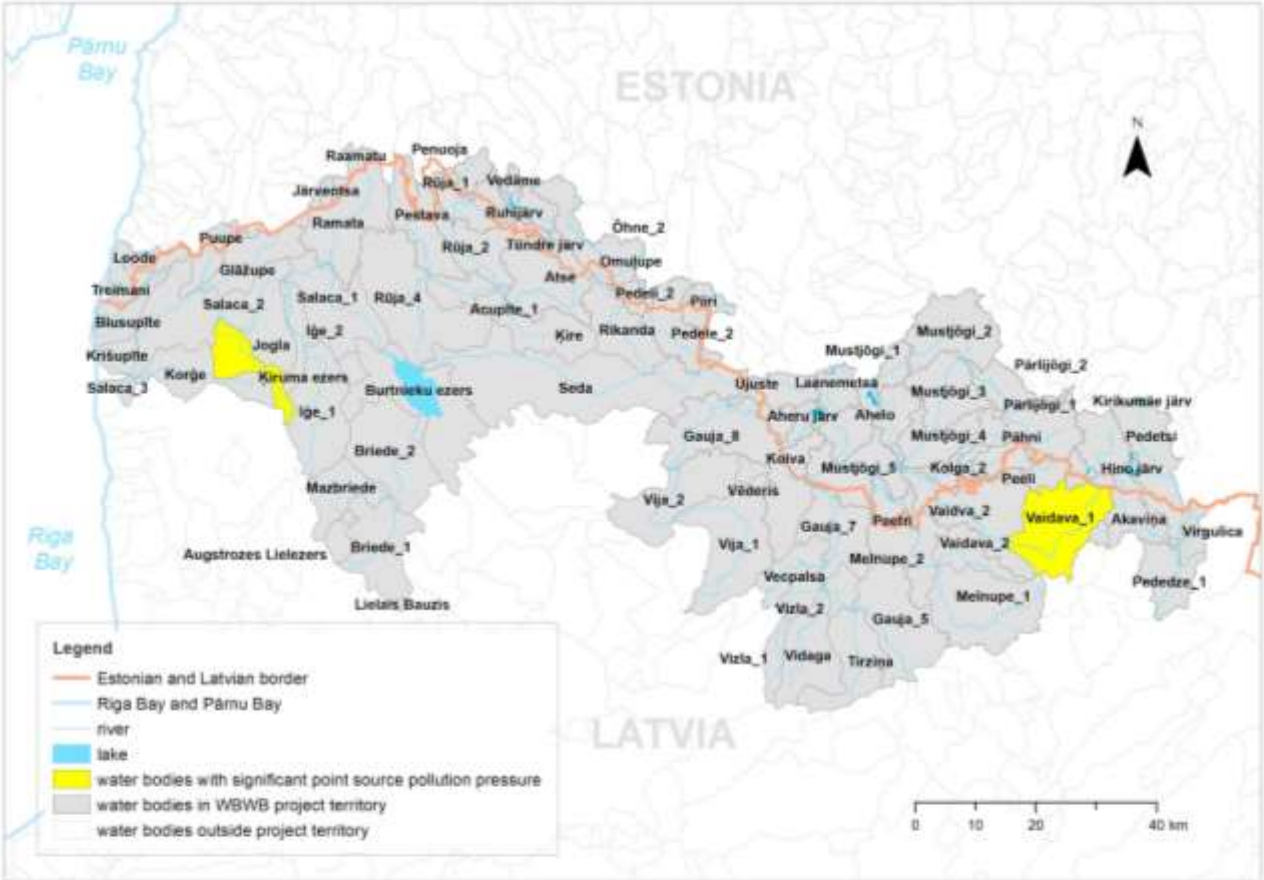

Figure 3. *Water bodies with significant pressures due to point source pollution*

Wastewater effluents

In Latvian part of project area there are 69 wastewater treatment plants registered in State statistical database "Water-2" in 2017. Most of them (55) are municipal wastewater treatment plants (WWTP). Five WWTPs serve population equivalent of above 2000 (Valka, Aloja, Mazsalaca, Rūjiena, Alūksne), other treatment plants serve agglomerations with population equivalent below 2000. The rest of wastewater treatment plants are either industrial or independent (for example, schools, landfill polygons, hospitals etc.). Activated sludge is mostly used by WWTPs in the project area, ensuring biological treatment of wastewaters.

In 2017 pollution loads from point sources in Latvian project area were equal to 129.7 t of suspended solids, 42.3 t of total nitrogen (N_{tot}), 5.7 t of total phosphorus (P_{tot}) Organic pollution load from point sources was equal to 105.7 t of biochemical oxygen demand (BOD_5), 491.9 t of chemical oxygen demand (COD). *FyrisNP* tool was used for catchment-scale modelling of source apportioned gross and net transport of nitrogen (N) and phosphorus (P), using available data for a period of 18 years (2000 - 2017). It was established that during this period of 18 years total nutrient loads for Gauja river basin equal to 48.4 t P_{tot} and 284.8 t N_{tot}. Nutrient pollution loads for the same period in the whole Salaca/Salatsi river basin equal to 80.3 t P_{tot} and 382.1 t N_{tot}.

In Estonian part of project area there are 20 wastewater plants registered according to the Estonian Nature Information System (EELIS) database. All of the WWTPs serve population equivalent under 2000. Most of them are municipal wastewater treatment plants. Three WWTPs are used by peat production industry and are mostly used to treat rainwater. Total organic pollutant load in 2017 was equal to 0.852 t of biochemical oxygen demand (BOD_7), 2.8 t of chemical oxygen demand (COD), 1.24 t of total suspended solids (TSS), 0.1 t of total P per year and 1.77 t of total N per year. Main processes used in wastewater treatment are sedimentation basins with active sludge, ensuring biological treatment of wastewaters. There is no water body with significant pressure due to wastewater effluent in Estonian part of the project area.

Significance of criteria for point source pollution assessment were discussed between Latvian and Estonian experts, and no common approach was elaborated, however, the approach in each country is fully acceptable and comparable. Significant pressure according to WFD CIS Guidance No.3 (Common Implementation Strategy for the Water Framework Directive (2000/60/EC). Guidance document No.3 “Analysis of Pressures and Impacts”, 2003) states that the pressure contributes to an impact that may result in the failing of the objective to reach GES.

To assess the significance of wastewater effluents on water quality, statistical analysis was used and threshold values were calculated (taking into account average water discharge and load of pollutants) - similar approach was used also in previous Gauja river basin management plan for period 2016-2021. Additionally, trends of polluting substance loads during the period were analysed.

According to methodology on assessment of significant pressures, it was estimated that two WBs (EELV1007 *Vaidva_1/Vaidava_1* (on Latvian side G334 *Vaidava_1*) and G308 *Jogla*) are impacted by wastewater effluents.

High amounts of nutrients and suspended solids are released by centralized municipal wastewater system (Alūksne city) into transboundary river WB **EELV1007 *Vaidva_1/Vaidava_1*** (on Latvian side - G334 *Vaidava_1*), as well as high amounts of organic matter, as indicated by biochemical oxygen demand (BOD_5) and chemical oxygen demand (COD). The amounts have been stable during the analysed period of years, no decrease has been observed. Throughout the observed period concentrations of total N and total P in effluent are mostly above 15 mg/l and 2 mg/l, respectively. According to permit (No.MA14IB0025) issued by State Environmental Service for nutrients no limits are set. Monitoring of WWTP effluent is carried out 4 times per year.

Significant impact due to industrial wastewaters affects WB G308 Jogla (Ltd. “Aloja-Starkelsen” - manufacturer of potato starch) - high amounts of N_{tot}, suspended solids, as well as large amounts of organic matter are released into Jogla river (as indicated by high BOD5 and COD). Polluting loads have been stable throughout the years, however some higher concentrations of N_{tot} or suspended solids in effluent have been observed for a few years, but limits set in permit issues by State Environmental Service (No.VA13IB00018) were not exceeded as there are no limits set for nutrients in the permit. Production of potato starch is seasonal – higher concentrations of nutrients and suspended solids are observed only in autumn. Improvements in industrial processes have been implemented in the recent years, decreasing the amount of water used in production of potato starch.

Contaminated sites

On Latvian side the methodology for assessment of significant pressures due to contaminated sites is the same as in current Gauja river basin management plan (2016-2021). According to methodology if at least 3 contaminated sites of 1st category are located in the water body catchment area, it is considered a significant pressure. In Latvia contaminated and potentially contaminated sites are classified into three categories: 1st category - contaminated sites (data about concentrations of polluting substances is available), 2nd category - potentially contaminated sites (there is no data about concentrations of pollutants), 3rd category - not contaminated sites (results of analyses indicate that there is no pollution). Second parameter for assessing pressures from contaminated sites as significant - if the pollution has spread and polluting substances from contaminated sites of 1st category have entered deeper aquifers.

Within the project territory on Latvian side there is one contaminated site of 1st category (in WB LVEE1016 Pedele_2/Pedeli_2 (name of WB on Latvian side G317 Pedele_2) - gasoline station in Valka city), 262 potentially contaminated sites (2nd category; most of them - fertilizer and pesticide storages, gasoline stations and old landfills) and 11 sites that are not contaminated (3rd category). After carrying out assessment for the project territory it was determined that no significant pressures due to contaminated sites are present.

In Estonian part of the project area no contaminated sites are registered, therefore there are no significant pressures due to contaminated sites.

2.2. Diffuse source pollution analysis

Total area of project territory is 7336 km^2 (5657 km^2 in Latvia, 1679 km^2 in Estonia), and most of the area is covered by forests (64.3%) and agricultural lands (30.9%). In Estonian part of project territory percentage of forest lands is higher than in Latvia. Percentage of agricultural lands is slightly higher in Latvia. However, the impact of these differences on pressure distribution is not great. Type of land use can be used as an indicator of pressures present in the catchment, and serves as an integral part of the pressure assessment. Agricultural areas (arable lands) are usually defined as most significant areas for anthropogenic nutrient runoff, and forest areas - as natural areas where anthropogenic nutrient runoff occurs due to clear-cutting or drainage. It is important to determine anthropogenic pressures and loads in order to select appropriate measures to improve ecological status of water bodies. Main sources of diffuse nutrient pollution are agricultural areas, animal husbandry and forestry. Agricultural areas, especially arable lands where fertilizers are applied, account for the greatest nutrient runoff. Pastures are classified as natural areas, but impact from animal husbandry can be present. Since 64.3% of project territory is covered by forests – accordingly, greatest part of total nutrient load is runoff from forest lands. Runoff from forest areas is generally considered a natural load, except if forest areas are impacted by human activities, such as drainage and clear-cuts.

To assess the amounts and impact of diffuse source nutrient pollution, usually different modelling tools are used - from very simple mass balance calculation tools to more advanced modeling tools. For nutrient pressure analysis in project area in Latvian territory *FyrisNP* modeling tool was used and for Estonian territory *EstModel* was used. Detailed information about *EstModel* can be found in Annex 1. Detailed information about *FyrisNP* can be found in Annex 2.

Graphs below (Figure 4a and 4b) show modelling results - N and P load distributions by sectors in the modelled Latvian part of project territory for the period from 2000 to 2017.

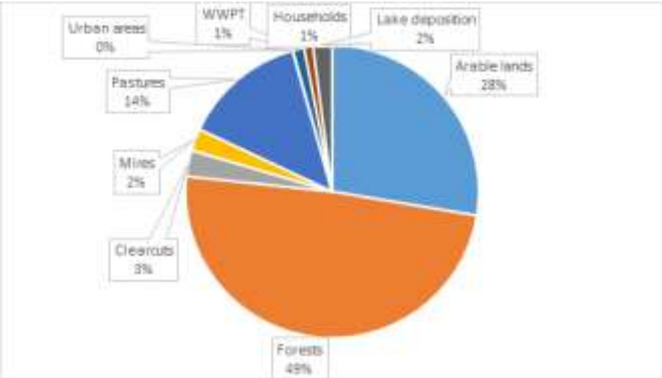

Figure 4a. *Nitrogen load distribution by sectors in Latvian project area 2000 - 2017.*

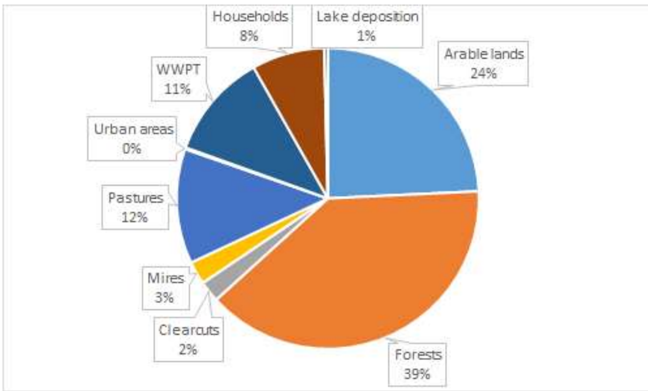

Figure 4b. *Phosphorus load distribution by sectors in Latvian project area 2000 - 2017.*

Graphs below (Figure 5a and 5b) show modelling results - N and P load distributions by sectors in 2017 in the Gauja/Koiva river basin part in Estonia.

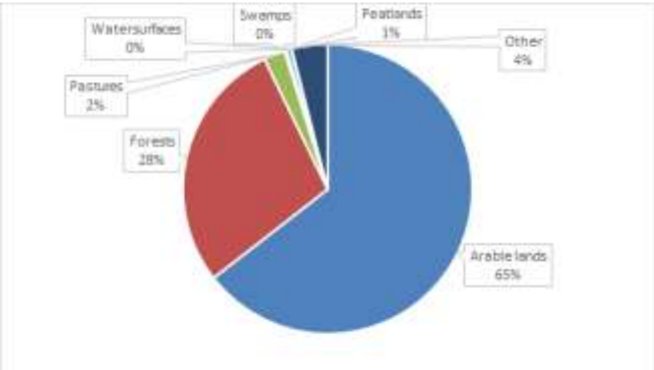

Figure 5a. *N load distribution by sectors in Gauja/Koiva river basin in Estonia in 2017.*

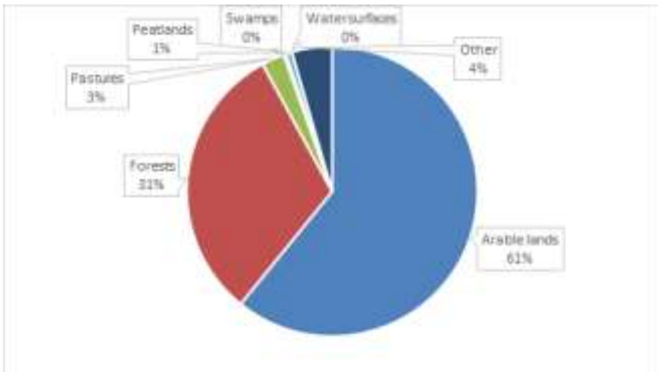

Figure 5b. *P load distribution by sectors in Gauja/Koiva river basin in Estonian water bodies in 2017.*

Results indicate differences within the results obtained. Although in Estonian part of project territory the percentage of forests is higher and percentage of agricultural lands is lower than in Latvia, the distribution of load sources indicates higher loads from agricultural lands in Estonia, while main source of nutrient loads in Latvia are forest lands. These differences have occurred due to the differences in modelling tools used by both countries as well as methodologies and input data used in model. For example, in Latvian territory a higher amount of nutrients come from pastures than in Estonian territory, and this can be due to Latvian approach to distribute animal units evenly across all arable lands (as manure from farms) and pastures (grazing). *EstModel* has still some technical issues and therefore the results are not final. The calculation coefficients still need adjusting but considering the timescale of the project, there was no time to wait longer. So the differences may also come from the fact that *EstModel* may need adjusting.

Based on modelled N concentrations 28 water bodies in the Koiva river basin district were in the good and high status class and only 2 water bodies were in the moderate status class. Based on P concentrations 12 water bodies in the Koiva river basin district were in the high status class, 5 in the good, 7 in the moderate, 4 in the poor and 1 water body was in the bad status class.

Modelling results indicated that significantly higher concentrations of nutrients in Estonian side of project territory were from agricultural land, however, forestry also plays an important role in the nutrient content. In other areas the proportion of natural concentration in the total concentration of nutrients was predominant.

Despite the differences, pressure and impact assessment methodologies allowed to identify significant sectors impacting the quality of water bodies due to nutrient runoff. 14% of all WBs in project territory are significantly impacted by diffuse source pollution, all of which (15 WBs) are located in the Latvian side of project territory (Figure 6). Detailed description of the main diffuse pressure sectors - agriculture, forestry and animal husbandry can be found in the following subsections.

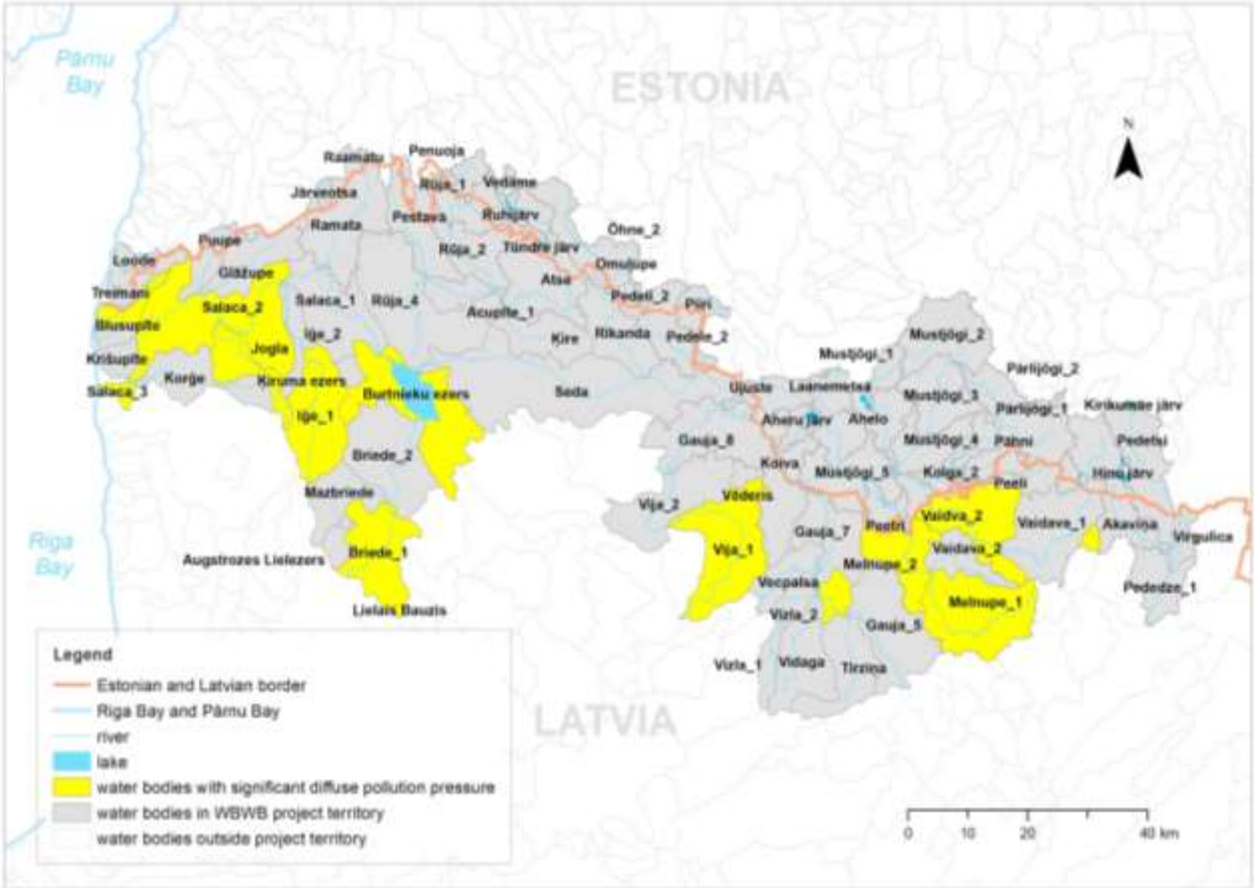

Figure 6. *Water bodies with significant pressures due to diffuse source pollution*

Hydro-morphological alterations in forest and agricultural areas in many cases impact the biological quality elements in rivers and lakes, and in project territory impact on biota is identified as significant in many water bodies. The pressures are analyzed in the subsection on hydro-morphological alterations.

2.2.1. Forestry

50.6% of the Latvian project territory is covered with forests, of which 16.8% are altered with drainage systems (calculations are based on estimation of several forest types typically drained) and 13.8% are clear-cuts. Forestry as main driver for nutrient drainage causing failure of GES in 5 water bodies on Latvian side (E203, E204, G229, G241, G301), drawing up 4.6% percent of the total number of water bodies in the project area. No water bodies in Estonian side are failing GES due to forestry.

According to modelling results for 18 year period (2000 - 2017) for Latvian part most part of N load originates from forest areas - 1876.5 t in 2017 (in Salaca river basin - in 20 WBs out of 30, and in Gauja river basin - in 22 out of 23 WBs as well as in the 3 WBs included in project territory, but outside Gauja and Salaca river basins). Similar is the situation with P loads – in most WBs greatest amounts of P originates from forest areas - 147.4 t in 2017 (in Salaca river basin - in 14 WBs out of 30, in Gauja river basin territory - 22 out of 23 WBs and in all 3 WBs from Daugava river basin included in project territory). It should be noted that these proportions combine both natural and anthropogenic loads of nutrient runoff.

As the clear-cut areas in the project area on the Latvian side are small, accounting for not more than 6.9% of the total N load in each water body from the clear-cut areas and not more than 6.7% of the total P load in each water body come from the clear-cut areas. For the whole Latvian part of the project territory it was calculated that N load in 2017 originating from clear-cuts was 110.2 t and P load originating from clear cuts was 7.4 t.

For Estonian part it was calculated that N load in 2017 from clear-cutting areas was 313.5 t, therefore it is assessed as an important source of N. Clear-cutting is an important source of P as well - P load was 13 t in 2017 (Figure 7).

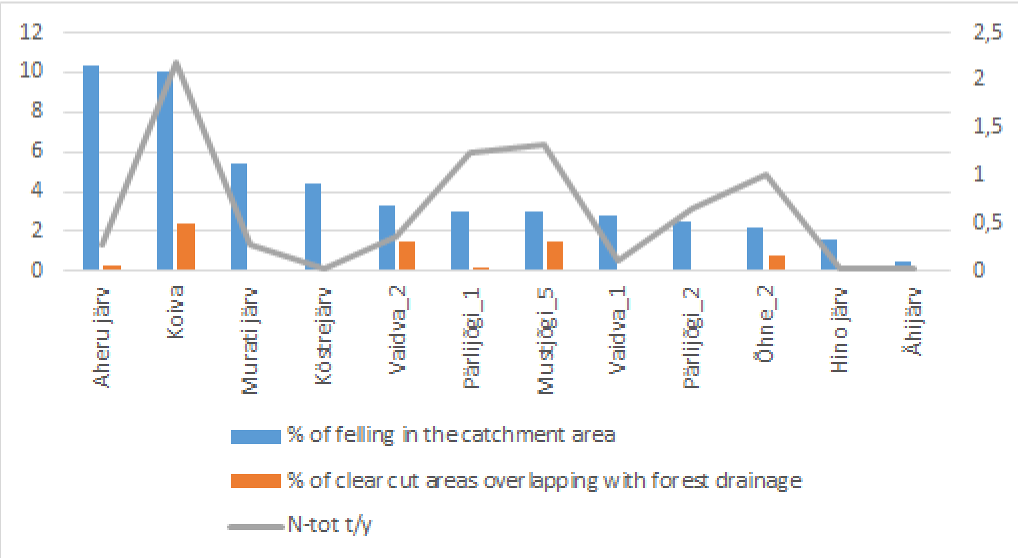

Figure 7. *N_{tot} load from felled area in Estonia.*

2.2.2. Agriculture

According to *Corine Land Cover* 2018 data, almost 21.6% of Salaca river basin area in Latvian project territory is used for agriculture as arable lands and 12.3% as pastures. 11.3% of all Gauja river basin water bodies included in project area are arable lands and 18.7% are pasture lands. After analysing land *Corine land cover* land use data for years 2018 and 2012, slight increase in arable land area proportion and slight decrease in pasture land area proportion is observed. According to the *Corine Land Cover* 2018 data almost 22% of the project area on Estonian side is arable land and 4.5% are pasture lands. Land cover data shows that there have been no significant changes in land use since 2013.

After the pressure analysis it was determined that diffuse pollution due to agricultural runoff is significant in 13 water bodies in Latvian part of project territory (12% of the total project territory) and there are no WBs in Estonian part of project territory with significant pressures from diffuse pollution sources.

Nitrogen

According to the pressure analysis and calculations for Estonian part, most of the N load comes from arable lands. Highest N load is in Mustjõgi water bodies. According to calculations, the N load from the arable land in Estonian territory of the project area in 2017 was 616.8 t. The load from pastures was significantly lower, 24.7 t.

According to calculations for the Latvian side, the N load from the arable land in the Latvian par of project territory in 2017 was 1030.7 t and N load from the pasture lands in 2017 was 541.8 t. According to modelling results for 18 year period (2000 - 2017) runoff from arable lands was the main N source in 9 WBs for the 30 modelled WBs within the Salaca river basin in WBs within the Gauja and Daugava river basins runoff from arable lands was not the main N source.

Phosphorus

According to the pressure analysis and calculations for Estonian part, most of the P load comes from arable land. As with N load, the largest part of P load is in the Mustjõgi water bodies, as most of the agricultural land in the Estonian project area is located in the catchments of the Mustjõgi water bodies. *EstModel* estimated that in 2017, the P load of arable land on the Estonian territory in the project area was 22.8 t. The load on pastures was significantly lower, 1.04 t.

According to calculations for Latvian side, the P load from the arable land in the Latvian part of project territory in 2017 was 31.9 t and P load from the pasture lands in 2017 was 42.4 t. Modelling results from 18 year period indicated that runoff from arable lands (and in one case - pastures) was the main P source in 10 WBs (7 of them - failing GES) from 30 WBs within the Salaca river basin, however in WBs within the Gauja and Daugava river basins runoff from the arable lands was not as the main P source.

2.2.3. Animal husbandry

At the beginning of 2018 on Latvian side of project area 1691 farms with total of 37543 LSU are registered. Most of these farms are small-scale, where the sum of livestock units is below 10 LSU - in 63% of all farms registered (8% of all LSU in project territory). There are 78 large farms (where LSU>100), which are located in 26 WBs, 1-7 farms within WB. The average density is 0.066 LSU per hectare (6.6 LSU/km^2) in the project area. Total amount of farms since 2000 has significantly decreased (about 5 times), however the livestock units have increased, thus indicating intensification of livestock farming.

According to geospatial distribution of livestock farms and LSU density on arable land, in the WB E225 Burtnieka lake the pressure by livestock farming is potentially significant - there are 5 large farms located in the water body territory (LSU>100). In 3 WBs - G312 Rūja, G320 Acupīte and G334 Vaidava there is higher LSU density than on average in project territory.

On Estonian side there are in total 213 livestock buildings with 4129 LSU. In Estonia, like in Latvia, most of the farms are small-scale, where sum of livestock units is below 10 LSU - 57% of all farms registered in project territory. There are 6 large farms (LSU>100), which are located in 5 WBs. The average density of LSU is 0,036 LSU per hectare (3.6 LSU/km^2). According to map analysis the share of cultivated land and the location of livestock buildings, livestock farming can be considered as a potentially significant pressure throughout the Mustjõgi river basin. Arable land covers 75% of the river catchment area, with a total of 1679 LSU. The average density (3.6 LSU / km^2) is no higher than in project area. There are 2 large farms (LSU>100) in the WB Mustjõgi_4. In addition there are 3 other WBs where LSU density is higher than on average in project territory: Lake Hino (2155500_1), Raamatu (1153000_1), Lake Ähijärv (2136000_1).

2.2.4 Diffuse pressure from residents not connected to public sewerage system

In Estonian project area the average population density is 7.4 in/km^2, which is much lower than average in Estonia. The emissions from inhabitants that aren´t connected to centralized sewage networks is low. There are 5500 people that are not connected to public sewerage system in the Estonian project area. The nutrient load in 2017 was 1.2 t of N. However, these pressures are not significant and do not cause failure of GES.

Similar situation is observed in Latvia - in Latvian part of project territory the average density of inhabitants is much lower than in the country on average - only 9 in/km^2. Also part of inhabitants aren’t connected to centralized sewage networks, and, according to modelling results, nutrient runoff from households is 1% of total N load and 8% of total P load in this territory during the 18 year period. N and P amounts in 2017 from households not connected to the centralized sewage system were 33.8 t and 10.8 t.

2.2.5 Non-channeled rainwater

Non-channeled overflow comes from rainwater overflow where the load can’t be estimated as a point load without more accurate data. The load is based on hard-surfaced road areas. The total area of hard-surface roads in the project area is 22.4% and annual loads in 2017 were 3.3 t N and 0.53 t P. These pressures are not significant and do not cause failure of GES.

In Latvian part of project territory runoff from urban areas was also taken into account, however, the share of nutrient runoff from these territories was calculated as insignificant.

2.3. Hydro-morphological alterations

An assessment of hydro-morphological alterations has been done on the basis of hydro-morphological (HYMO) monitoring provided by LEGMC in the Gauja and Daugava River Basin Districts (RBDs) since 2013. Hydro-morphological quality assessment elements include morphological and hydrological elements as well as river continuity.

The main HYMO pressures in the project area (Figure 8) are:

- land drainage in agricultural area and in forests that causes, as changes in the river morphology (reduction of length of river bed), as hydrological regime;
- water regulations by HPPs and sluices which cause significant changes in hydrological regime of river;
- dams for hydropower production and other water use that interrupt the continuity of stream flow and create barriers for sediment transport and biota migration;
- seaport operation in Salaca river mouth is a combination of HYMO alterations (e.g. bed dredging, changes in sediment regime, bank stabilization, bank erosion).

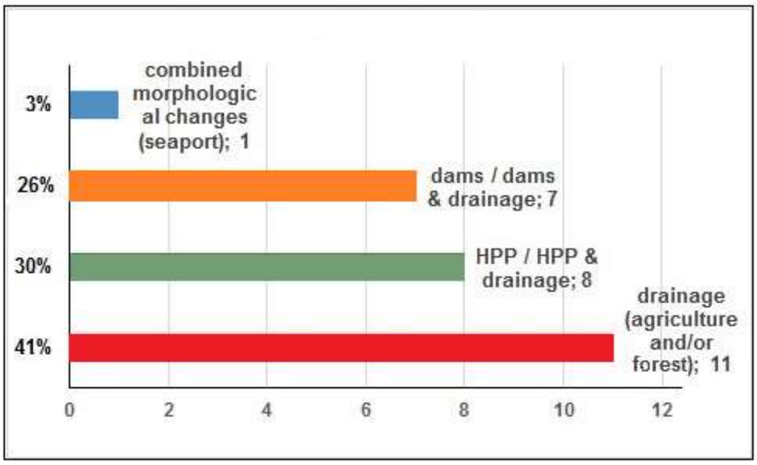

Figure 8. *HYMO pressures in water bodies under risk.*

In accordance with impact on water bodies' HYMO quality, all water bodies in the project area subdivided into 3 categories: referenced WBs without any alterations (45% of WBs), WBs under risk (41% of WBs) and WBs under significant risk not to meet the good quality (14% of WBs).

Among water bodies under HYMO risk and significant risk there are 14 that have direct or indirect impact on the ecological quality of water bodies in the project area. First of all, these are G303HM Salaca_3 with multiple pressures of "Salacgriva" seaport and G315HM Kire that is completely modified by Amelioration Company. Secondly, two transboundary water bodies G317 Pedele_2 and G235 Vaidava_2 that both have 2 HPPs in the stream without any working fish pass. Others 9 water bodies have modified river stretches and small dams in the main stream or in tributaries

(G229 Vija_1, G234 Melnupe_1, G242 Vizla_2, G301 Salaca_2, G306 Salaca_1, G304 Ige_1, G310 Ruja_4, G313 Ruja_2, G320 Acupite_2, G322 Briede_1 and G325 Blusupite).

An assessment of hydro-morphological alterations has been done on the basis of analysis of HYMO status that was provided by Estonian Environmental Agency in 2019. Hydro-morphological quality assessment elements include morphological and hydrological elements. Water bodies can be divided into three categories (Figure 9).

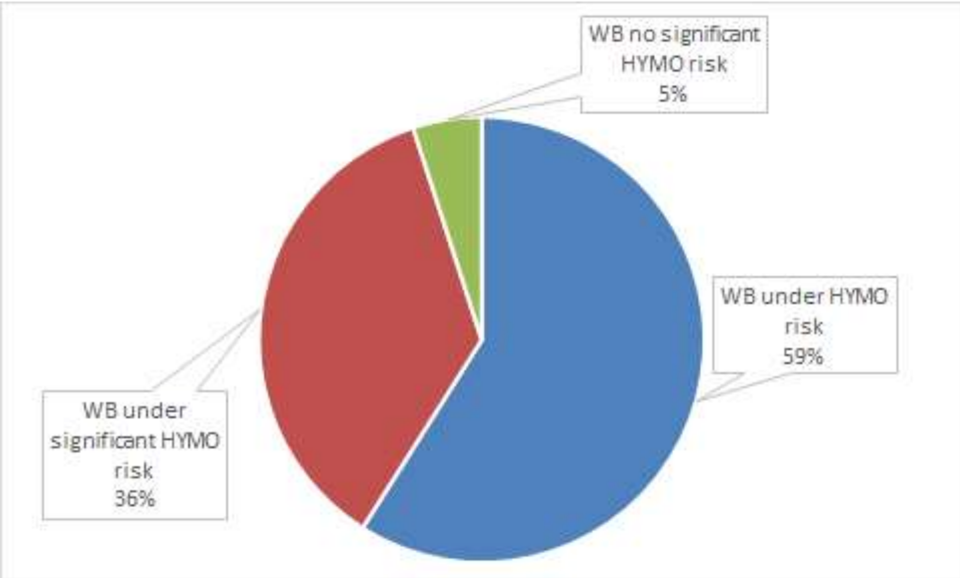

Figure 9. *Assessment of HYMO alterations in water bodies in the Estonian part of project area.*

In Estonian part of the project area the main HYMO pressures (Figure 10) are similar to Latvian:

- land drainage in agricultural area and in forests that cause, as changes in the river morphology (river bed shortening), as hydrological regime;
- water regulations by HPPs and dams that cause significant changes in the river hydrological regime;
- dams for hydropower production and other water use that interrupt the continuity of stream flow and create barriers for the sediment transport and fish migration.

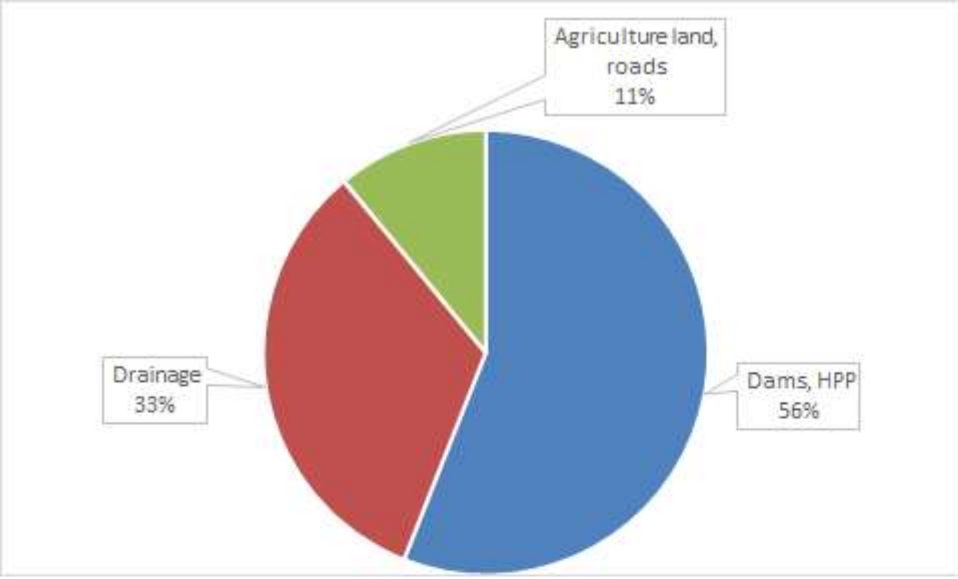

Figure 10. *HYMO pressures in water bodies under risk.*

In total there are 65 dams and 1 HPP in 24 river water bodies in the project area in Estonia. Of these, 15 are WB-s that are with HYMO risk and have 1 or more dams. Four of them are not obstacles for fish and 5 WB have 3-5 dams which are obstacles or difficult to overcome (Kolga_1, Kolga_2, Pärlijõgi_1, Pedeli_2, Õhne_2). There are 2 water bodies Pärlijõgi_2 and Vaidava_2 where fish passes have been built and therefore dams are not causing significant HYMO risk anymore.

There are 465.7 km^2 of drained areas in the Estonian project area and this makes up to 27% of the Estonian part of the project area. The length of the state-maintained recipients is 109 km. Most land improvement systems have been established more than 30 years ago and need to be maintained or reconstructed.

From WBs with HYMO risk, there are 9 water bodies of which more than 50% of the length of the body has been modified by land improvement.

During pressure assessment it was determined that 17 water bodies in the project area significantly impacted by hydro-morphological alterations - 14 WBs in Latvian part of project territory and 3 WBs in Estonian part of project territory (Figure 11).

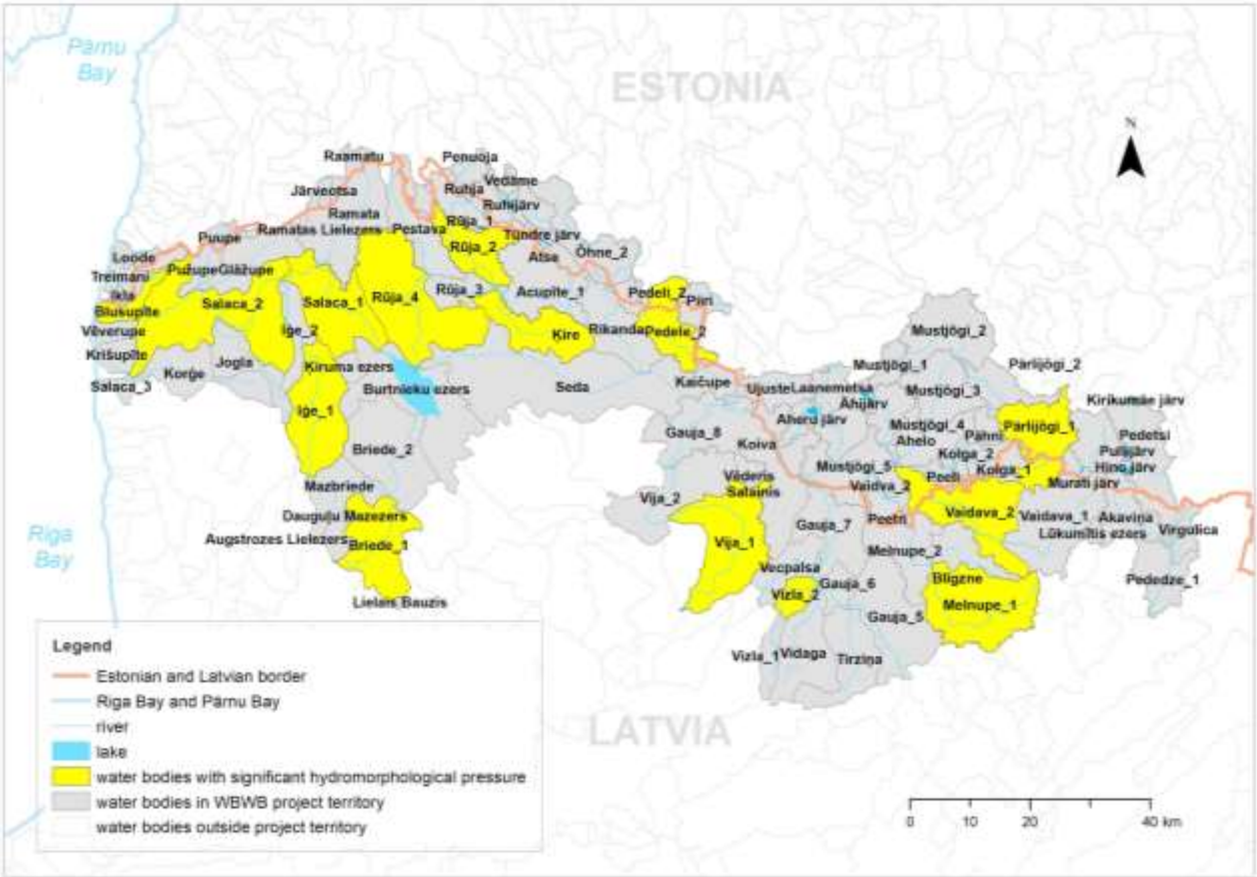

Figure 11. *Water bodies with significant pressures due to hydro-morphological alterations.*

2.4. Water abstraction

Water abstraction has been assessed as non-significant pressure in both countries. In project territory water abstraction doesn't cause deterioration of water quality or quantity. According to Latvian State statistical data base "Water-2" information in the project territory there are 52 water users that abstract water, and in total in 2017 abstracted water amount is 1 100 200 m^3.

According to EELIS, there were no water users abstracting water in 2017 on Estonian side of project territory.

2.5. Other pressures

Other pressures were not evaluated in detail within this project. Discussions about the concentrations of pharmaceuticals in water, potentially invasive species that may impact specific indicator species, pesticides, as well as other issues were discussed among project experts. It should be noted that in national river basin management plans these pressures should be taken into account during the pressure assessment process, especially in cases when water bodies are failing GES due to substances or invasive species impacting natural indicator species.

4. Defined environmental targets

4.1 Information about Estonia

According to the Water Framework Directive the objective initially was set to achieve good ecological status of water bodies by the year of 2015. In the previous water management plan (2010-2015), some water bodies were given exceptions, good status has to be achieved by the year of 2021.

In the current water management plan of 2015-2021 the objective of the 34 surface water bodies of the project area is set to achieve at least good ecological status by the year 2021 (including good ecological potential). For 7 water bodies the objective is moderate status by the year of 2021 (including moderate ecological potential), it means the water bodies were given an exception. Exceptions are given, because improvement of status is achieved in stages, some exceed the time limit (4/1), finishing of the corrections is expensive (4/2) and/or it’s because of the unsuitable natural conditions (4/3).

Comparing the compilation of the first water management plan to the compilation of the second water management plan the knowledge about the status of water bodies has improved, because more monitoring and research has been carried out. Therefore there is more information to rely on when assessing the status. At the same time it has been revealed, that the status of the water bodies have changed for better and also for worse.

According to the interim assessment in 2019 there are 32 surface water bodies in good status, so for those water bodies, the objective for the year of 2021 is already achieved (Table 4). Among them there are water bodies given an exception and to which the objective of achievement of good status was extended to 2021 or 2027. Those are, for example, Treimani, Hargla, Õhne_2, Ruhja, Peeli, Mustjõgi_2. Regardless of the exception, for all water bodies the objective is achieved according to the interim assessment of 2018. From former single Kolga water body two new water bodies were delineated – (Kolga_1 and Kolga _2). Järveotsa and Läteperä water bodies were added as well. There is no previous information or status assessment for them.

Table 4. *Surface water bodies in the project area with status objective set for 2021 is already achieved by 2019. Exeption reasons: improvement of status is achieved in stages, some exceed the time limit (4/1), finishing of the corrections is expensive (4/2) and/or it's because of the unsuitable natural conditions (4/3).*

Code of WB	WB name	Status 2013	Objective 2015 reached	Updated postponed objective	Updated exception reason	Status 2018 / Objective 2021
1157400_1	Ahelo	good	yes	-	-	good
1157600_1	Kuura	good	yes	-	-	good
1154600_1	Laanemetsa	good	yes	-	-	good
1154800_1	Mustjõgi_1	good	yes	-	-	good
1154800_3	Mustjõgi_3	good	yes	-	-	good
1154800_4	Mustjõgi_4	good	yes	-	-	good
1159700_1	Pedetsi	good	yes	-	-	good
1160200_1	Punaoja	good	yes	-	-	good
1154300_1	Ujuste	good	yes	-	-	good
1154000_1	Atse	good	yes	-	-	good
1012100_1	Pedeli_1	good	yes	-	-	good
1153200_1	Penuoja	good	yes	-	-	good
1152700_1	Puupe	good	yes	-	-	good
1153000_1	Raamatu	good	yes	-	-	good
1153400_1	Lilli	good	yes	-	-	good
1153300_1	Vedäme	good	yes	-	-	good
2099300_1	Ruhijärv	good	yes	-	-	good
2114800_1	Tündre järv	good	yes	-	-	good
1152300_1	Loode	good	yes	-	-	good
1012600_1	Piiri	good	yes	-	-	good
1152500_1	Treimani	moderate	no	2021	4/1, 4/2	good
1159300_1	Hargla	moderate	no	2021	4/1	good
1013700_2	Õhne_2	moderate	no	2021	4/1	good
1153600_1	Ruhja	moderate	no	2027	4/1	good
1158100_1	Peeli	moderate	no	2021	4/1	good
1154800_2	Mustjõgi_2	moderate	yes	2021	4/1, 4/2, 4/3	good
1152900_1	Järveotsa	-	-	-	-	good
1158400_1	Kolga_1	-	-	-	-	good
1158400_2	Kolga_2	-	-	-	-	good
1159704_1	Läteperä	-	-	-	-	good

According to the interim assessment of 2019 there are 9 water bodies that are in moderate status and 5 water bodies that are in poor status (Table 5). Among them there are 6 lakes and 8 rivers.

The changes in the status of the lakes are slow, because of the lake's internal load. The assessments of the status depend greatly on the weather of given year. There are 10 lakes in the project area, of which 6 lakes are in poor status. The reasons for poor status for lakes are inner nutrient load and eutrophication, for some lakes, the reasons are unclear. Historical reasons for poor status are lowering the water level and historical nutrient loads. Internal nutrient loads are the main pressure, since external loads have significantly decreased in the last decades. Further reduction of pressures is complicated and the remediation of lakes may require extensive investments.

For rivers the moderate status is caused by damming, which prevents free migration of aquatic biota. Many rivers are located in Natura 2000 area, where there is also need to ensure the passage of fish, both upstream and downstream of a dam, to achieve good ecological status. In the years 2012-2015 there were 5 fish passes that were constructed on the dams of salmonidae river water bodies, which is a part of achievement of good ecological status. During the project fish expert conducted on-site inspections, according to which the fish passes of Vastse-Roosa, Sänna-Alaveski, Sänna-Mäeveski and Ala-Raudsepa need additional improvements. Currently fish passes are difficult to pass for some/most of the fish - they are functionally impaired and don’t fully serve the purpose.

For some surface water bodies the river basin specific pollutants exceed the applicable limit values (for instance barium, bromodiphenyl ether). The sources and reasons for these river basin specific pollutants are unknown.

The time limit for the achievement of a water protection objective provided in the Water Framework Directive may be extended for two periods, unless the objective related to the water body cannot be achieved by that time due to natural conditions. In that case the good status has to be achieved by the year 2027.

Table 5. Surface water bodies in the project area, which status objective for 2021 is not achieved.

Code of WB; tranboundary WB code	WB name	Status 2013	Objective 2015	Objective 2015 reached	Postponed objective in 2010	Reason for exception in 2010	Updated postponed objective	Updated exception reason	Status 2018	Objective 2021
2136600_1	Aheru järv	good	good	yes	-	-	-	-	moderate	good
2155500_1	Hino järv	good	good	yes	-	-	-	-	moderate	good
2144700_1	Kirikumäe järv	moderate	good	no	-	-	2027	4/1, 4/3	moderate	good
1154200_1; EELV1001	Koiva	good	good	yes	-	-	-	-	bad	good
2133700_1	Köstrejärv	moderate	good	no	-	-	2021	4/1, 4/3	bad	good
2155900_1; EELV1009	Murati järv	moderate	good	no	-	-	2021	4/1	bad	good
1154800_5	Mustjõgi_5	very good	good	yes	-	-	-	-	bad	very good
2155200_1	Pullijärv	moderate	moderate	yes	2021	4/1, 4/2	2027	4/1, 4/3	bad	moderate
1155700_1; LVEE1005	Pärlijõgi_1	moderate	good	no	-	-	2021	4/1	bad	good
1155700_2	Pärlijõgi_2	good	good	yes	-	-	-	-	moderate	good
1158000_1; EELV1007	Vaidva_1	moderate	moderate	yes	2021	4/1, 4/2, 4/3	2021	4/1, 4/2, 4/3	moderate	good
1158000_2; LVEE1008	Vaidva_2	good	good	yes	-	-	-	-	moderate	good
2136000_1	Ähijärv	good	good	yes	-	-	-	-	moderate	good
1012100_2; LVEE1016	Pedeli_2	good	good	yes	-	-	-	-	moderate	good
1158700_1	Peetri	very good	very good	yes	-	-	-	-	good	very good

4.2 Information about Latvia

On Latvian side of the project area there are 63 surface water bodies, including 11 lake water bodies and 52 river water bodies (Figure 12). 60 water bodies belong to Gauja RBD and 3 water bodies - to Daugava RBD.

More than half (60%) of the water bodies have good ecological quality, 38% water bodies have moderate ecological quality and only one water body (Lake Burtnieks) is in poor ecological quality.

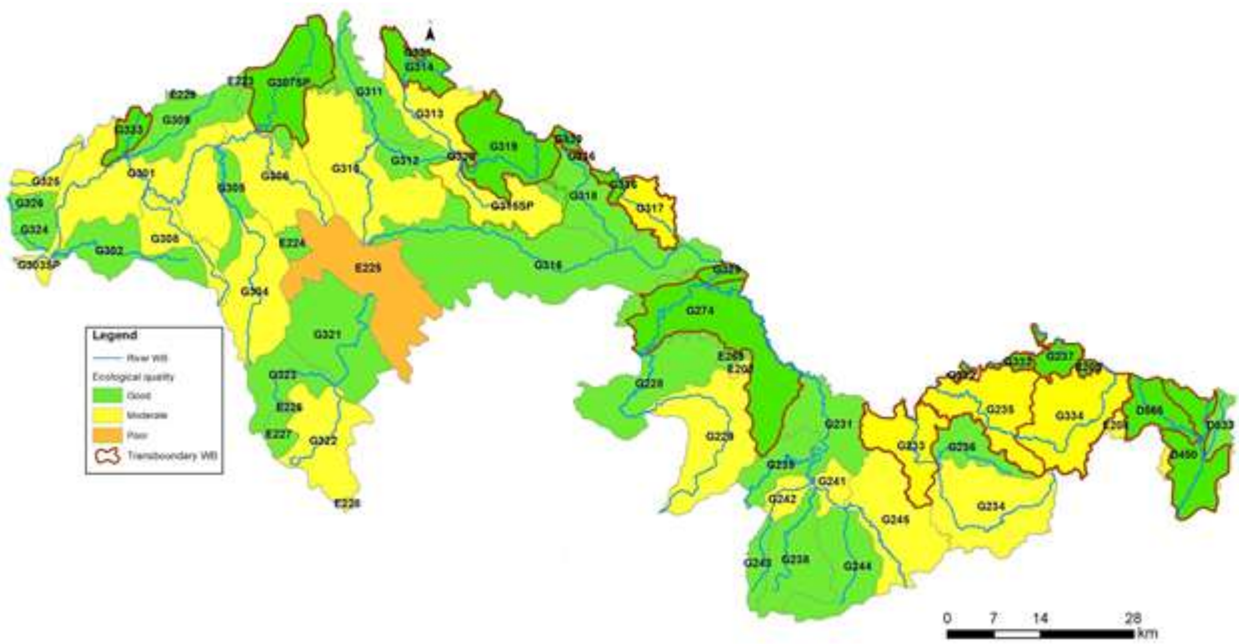

Figure 12. *Map of ecological quality in water bodies of the project area.*

In current Gauja and Daugava river basin management plans (2015-2021) the objective for 31 surface water bodies in the project area is set to be in good status by the year of 2021. For two water bodies (Lake Burtnieks and River Salaca (G306)) exceptions were applied. According to the latest results, 18 water bodies are in good ecological quality and thereby 60% of water bodies have reached the good ecological quality objective.

Comparing to second river basin management plans, the quality has improved in 8 water bodies. For 5 water bodies ecological quality has decreased and for 18 water bodies it has not changed. Most of the changes have occurred due to implementation of better assessment methodology and improvements in monitoring. For example, Latvia has developed macroinvertebrate method especially for dystrophic humic lakes. Integration of hydro-morphological alterations as a criteria for status assessment has been improved, especially impact of HPPs and other dams on river continuity.

5. Economic analysis of water use and possible measures to support planning of the programme of measures

The economic analysis aims to provide socioeconomic information and assessments relevant for planning and decision making on effective measures for achieving environmental targets of water bodies. It includes:

1. **Analysis of water use and users**, which aims to provide relevant socioeconomic information to support assessing costs of water use and socioeconomic impacts of additional measures to achieve environmental targets of water bodies.

2. **Assessment of the costs caused by water use and their recovery**, which analyses what are the costs of water use causing degradation of the water environment and who and to what extent is paying for these costs. This is analysed for significant water uses – those which create significant pressures causing failure of good ecological status for water bodies in the project area. The analysis serves basis for proposing the necessary policy actions to improve recovery of these costs according to the "cost recovery principle" and "polluter-pays-principle".

3. **Economic evaluation of additional measures** for achieving environmental targets, which includes assessment of costs of the measures, their cost-effectiveness, analysis of other socioeconomic impacts of the measures. The results are used to provide recommendations on the most socioeconomically effective additional measures to achieve environmental targets for the WBs failing GES.

5.1. Economic analysis of water use and users

The economic analysis started with identifying significant water uses and pressures related to them in the project area to which the relevant policy requirements and principles apply. Those water uses are considered as "significant" which create significant pressure causing failure of GES for WBs. Assessment of the significance of the pressures comes from the pressures and impact analysis prepared as part of the project.

The significant water uses considered in the economic analysis are listed in Table 6. For the Latvian part of the project area, water uses related to agriculture, forestry, small HPPs and dams/obstacles on rivers with other or no use impact significantly several to large number of WBs. There are few other uses which cause failure of GES in 1 WB each. For the Estonian part four water uses are significant, however majority of them impacts only one WB each except the dams/obstacles on rivers with other or no use which impact 4 WBs.

Table 6. *A list of significant water uses and users for the project area. (Source: Based on analysis as part of the project.) * Information source: Pressures' and status' assessment prepared as part of the project.*

Water users	Water uses	Significant pressures due to the water use	Significance for LATVIA No of surface WBs failing GES*	Significance for ESTONIA No of surface WBs failing GES*
Agriculture	Pollution run-off from agricultural lands (mainly arable land and manure storage sites)	Diffuse pollution of nutrients	13 WBs	Do not cause significant pressures
	Drainage for agriculture (by polders, regulation of water regime, straightening of rivers, drainage ditches etc.)	Hydro-morphological pressure	7 WBs	Do not cause significant pressures
Forestry	Pollution run-off from clear-cutting and drained forest areas	Diffuse pollution of nutrients	5 WBs	Do not cause significant pressures
	Drainage of forest lands	Hydro-morphological pressure	4 WBs	Do not cause significant pressures
Various users (e.g. recreation, roads) or no users	Dams/obstacles on rivers with various uses or no use	Hydro-morphological pressure	3 WBs with 8 obstacles creating significant pressure	4 WB
Small hydro-power plants (HPPs)	Use of water flow for energy production (involving dam, turbine, water flow fluctuations, storage pond/reservoir, etc.)	Hydro-morphological pressure / Hydrological pressure (quantity, water flow regime)	3 WBs (due to operation of 5 HPPs).	1 WB (due to Vastse-Roosa dam)
Households, Industry, Other	Wastewater discharging from centralised sewage systems	Point source pollution of nutrients	1 WB (due to Alūksne city)	1 WB (due to Köstrejärv)
Industry	Wastewater discharging from individual sewage systems	Point source pollution of nutrients	1 WB (due to SIA "ALOJA-STARKELSEN").	Do not cause significant pressures
No user (historical)	Accumulated (past) pollution in WB	Nutrient pollution in sediments	1 WB, past pollution in sediments (Burtnieku lake).	1 WB, past pollution in sediments (Köstrejärv).

Joint quantitative socioeconomic indicators were agreed for each significant user taking into account information needs for further economic assessments and availability of data for applying the indicators. The socioeconomic significance of the water users is characterised in Table 7. It aims to show socioeconomic significance of the water use and users for the economy and welfare in the area. Moreover, it provides relevant data and estimates for further economic assessments – for analysing cost recovery of water use and socioeconomic impacts of additional measures for achieving environmental targets.

Table 7. *Socioeconomic characterisation of significant water users in the project area. (Source: Estimates developed as part of the project. The estimation approach and input data are described in the detailed report of the project on the economic analysis.)*

<table>
<tr><th rowspan="2">Water users (sectors/ activities)</th><th rowspan="2">Applied socioeconomic indicators</th><th colspan="2">Estimates for the project area</th></tr>
<tr><th>for the LATVIAN part</th><th>for the ESTONIAN part</th></tr>
<tr><td>Agriculture</td><td>1. Number of companies
2. Number of employed persons
3. Turnover per year
4. Profit / Losses per year</td><td>1549 companies.
2703 employed persons.
Turnover 38.4-38.7 milj EUR per year.
Profit 5.35-5.38 milj EUR per year</td><td rowspan="2">437 companies together in agriculture and forestry sectors.
1270 employed persons together in agriculture and forestry sectors.
Turnover 123.2 milj EUR per year together in agriculture and forestry sectors.</td></tr>
<tr><td>Forestry</td><td>1. Number of companies
2. Number of employed persons
3. Turnover per year
4. Profit / Losses per year</td><td>349 companies.
657 employed persons.
Turnover 18.3-18.4 milj per year.
Profit 0.58-0.59 milj per year.</td></tr>
<tr><td>Users/ owners of dams/ obstacles (with various or no use)</td><td>1. Number of dams/obstacles causing failure of GES
2. Number of owners of these dams/ obstacles</td><td>8 dams/ obstacles causing significant pressure in 3 WBs (17 obstacles overall in these 3 WBs)
11 owners related to these 8 obstacles (28 owners related to all 17 obstacles)</td><td>11 dams causing failure of GES in 4 WBs.</td></tr>
<tr><td>Small hydro-power plants (HPPs)</td><td>1. Number of small HPPs in the project area
2. Their revenues from the produced energy</td><td>10 HHPs
Revenues 0.69 milj EUR per year (average from 2016-2018 data).</td><td>1 HHP.
Revenues 1735 EUR per year (average from 2016-2018 data).</td></tr>
<tr><td>Households</td><td>1. Number of inhabitants served with centralised water services
2. Mean disposal income of inhabitants per person per month</td><td>24 700 inhabitants in the project area, from those 5486 in the Aluksne city.
Disposal income 361 EUR in the project area, 308 in the Aluksne county (489 EUR in Latvia on average).</td><td>10 300 inhabitants in the project area, from those 7250 in the Valga City.
Disposal income 584 EUR in the project area (655 EUR in Estonia on average).</td></tr>
</table>

5.2. Assessment of costs caused by water use and their recovery

Aim of the assessment, commonly called as cost recovery assessment, is to support implementation of the following principles:

- Cost recovery principle to ensure that users of "water services" cover adequately costs of these "water services" (including, financial, environmental and resource costs).
- "Polluters-pay-principle" (PPP) which guides on how the costs of water use should be covered among water users, i.e. that the users provide adequate contribution into covering their created costs based on their role in causing these costs.

According to the WFD requirements the actions towards implementing the named principles shall be reported in the River Basin Management Plans (RBMPs) and specific measures need to be included in the programs of measures.

5.2.1. Approach for the cost recovery assessment

The cost recovery assessment needs to address range of methodological issues – from defining "water services" and other "significant water uses", assessment of recovery of their costs, analysis of the current pricing instruments via which the costs are recovered, assessing socioeconomic effects of the cost recovery of "water services" where relevant. Approach and results of the cost recovery assessment are described in the detailed report of the project on the economic analysis.

The cost recovery assessment is closely linked with the pressures and WBs status assessments, which provide basis for identifying "water services" and other "significant water uses" to be included in the assessment, as well indication on presence of the "environmental costs" due to water use.

Two types of water uses are distinguished for the assessment – "water services" and (other) "significant water uses". According to definitions in the WFD Article 2, the **"water services"** means all services which provide, for households, public institutions or any economic activity: (i) abstraction, impoundment, storage, treatment and distribution of surface water or groundwater; (ii) wastewater collection and treatment facilities which subsequently discharge into surface water. Users of the "water services" must cover adequately costs of these "water services", including, financial, environmental and resource costs[1]. Other water uses, if they cause failure of GES in WBs, are defined as **"significant water uses"**. There is a need for policy instruments (i.e. additional measures for reducing pressures) to ensure that these uses give adequate contribution into reaching environmental targets in the affected WBs according to PPP.

A list of "water services" and "significant water uses" for the project area is provided in Table 8. For the "water services" relevant costs of water use include "financial costs" of using the service and "environmental costs", which capture negative impact from the water use. For the "significant water uses" only the "environmental costs" are analysed. Relevance of the "environmental costs" in the project area is characterised in the table with the number of WBs failing GES due to each "water service" and "significant water use".

[1] The "financial costs" include all the costs of providing and administering the service. The "environmental costs" are the costs of damage caused by water uses to the water environment and ecosystems and those who are using them. The "resource costs" are not significant in the project area since there is sufficient water availability for all water uses. Thus, they were not included in the analysis.

Table 8. *The list of "water services" (WS) and "significant water uses" (SWU) for the project area. (Source: Based on analysis as part of the project.)*
** No of WBs failing GES due to each water use is provided in parenthesis. Note that the same WB can be affected by multiple significant pressures.*
*** Since there are no WBs where the given "water service" creates significant pressure, it is assumed that there are no un-covered "environmental costs". Hence only "financial cost" recovery is analysed.*

Water uses	Their created significant pressures	LAT*	EST*
Centralised sewage services	Point source pollution of nutrients	WS (1)	WS (1)
Individual sewage discharge by households		WS (0)**	WS (0)**
Individual wastewater discharge by agriculture		WS (0)**	WS (0)**
Individual water (self) abstraction by industry		WS (0)**	WS (0)**
Individual (self) wastewater discharge by industry	point source pollution of nutrients	WS (1)	WS (0)**
Individual excess water discharging related to mining	pressure on surface water quality (suspended matters)	WS (0)**	Not relevant
Individual wastewater discharge by waste management (disposal) sites	point source pollution of hazardous substances	WS (0)**	Not relevant
Water use for energy production in small HPPs (involving water storage)	hydro-morphological pressures	WS (3)	SWU (1)
Dams/obstacles with various or no uses	hydro-morphological pressures	SWU (3)	SWU (4)
Pollution run-off from agricultural lands	diffuse nutrient pollution	SWU (13)	Not relevant
Pollution run-off from clear-cutting and drained forest areas	diffuse nutrient pollution	SWU (5)	Not relevant
Drainage for agriculture	hydro-morphological pressures	SWU (7)	Not relevant
Drainage for forestry	hydro-morphological pressures	SWU (4)	Not relevant
Accumulated (past) pollution in WB	nutrient pollution in sediments	SWU (1)	SWU (1)

5.2.2. Summary on the cost recovery assessment for the project area

Summary on assessment of the cost recovery level for the **"water services"** is presented in Table 9. It can be concluded concerning the "water services":

- They cover their "financial costs" of water use, except the centralised "water services" where the cost recovery rate varies considerably depending on the settlement – it is in range of 78-101% for Latvia (not assessed for all settlements), including 101% for the Aluksne city, and 87% for the largest settlement in the Estonian part (the Valga municipality).

- In the Estonian part only the "centralised water services" create "environmental costs" (in 1 WB). Nature Resource Tax (NRT) is paid for covering the environmental damage, thus the "environmental costs" are covered (at least) partly.

- In the Latvian part 3 out of the 8 "water services" create "environmental costs" in single or few WBs. They pay NRT aimed to cover the environmental damage. However, the NRT payments are rather small and do not cover the "environmental costs".

Summary on qualitative assessment of the cost recovery level for the **“significant water uses”** is presented in Table 10. It can be concluded concerning all “significant water uses” that their created “environmental costs” are not covered. In the Estonian part, three water uses cause “environmental costs” in single or several WBs[2] and there are no current pricing instruments for covering these costs. In the Latvian part, four water uses cause such costs in considerable number of WBs. There is the current pricing instrument only for compensating damage to fish resources. But no pricing instruments for covering other environmental damage costs.

[2] Note that the water use for electricity production in small HPPs is considered as “water use”, not “water service” in Estonia, while it is considered as the “water service” in Latvia.

Table 9. *Summary on the cost recovery assessment for the "water services" in the project area. (Source: Based on analysis as part of the project. The assessment approach and input data are described in the detailed report of the project on the economic analysis.)*

<table>
<tr><th rowspan="2">"Water services"</th><th colspan="2">Financial costs and their recovery</th><th colspan="2">Environmental costs (EC) and their recovery</th><th colspan="2">Cost recovery level, including EC</th></tr>
<tr><th>For LATVIAN part</th><th>For ESTONIAN part</th><th>For LATVIAN part</th><th>For ESTONIAN part</th><th>For LATVIAN part</th><th>For ESTONIAN part</th></tr>
<tr><td>Centralised water supply and sewage services</td><td>Financial cost recovery 78-101% (depending on settlement).
101% for Aluksne city.</td><td>Financial cost recovery 87% for Valga city.</td><td>Cause EC in 1 WB – due to WW discharges of Aluksne city (NRT payment around 1200 EUR per year).</td><td>Cause external EC in 1 WB – due to WW discharges of Köstrejärv (NRT payment 18 325 EUR in 2017).</td><td>Partial financial cost recovery (depending on settlement).
EC (for 1 WB) are covered partly.</td><td>Partial financial cost recovery.
EC (for 1 WB) are largely covered.</td></tr>
<tr><td>Individual sewage by households</td><td colspan="2">Covered</td><td colspan="2">No "environmental costs" due to this water use</td><td colspan="2">Costs are fully covered.</td></tr>
<tr><td>Individual water supply by industry</td><td colspan="2">Covered</td><td colspan="2">No "environmental costs" due to this water use</td><td colspan="2">Costs are fully covered.</td></tr>
<tr><td>Individual wastewater discharging by industry</td><td colspan="2">Covered</td><td>Cause EC in 1 WB due to WW of a single company.
NRT payment by this company around 270 EUR per year</td><td>No "environmental costs" due to this water use</td><td>Financial costs are covered.
EC are not covered in 1 WB.</td><td>Costs are fully covered.</td></tr>
<tr><td>Individual wastewater discharging by agriculture</td><td colspan="2">Covered (but possible use of subsidies)</td><td colspan="2">No "environmental costs" due to this water use</td><td colspan="2">Costs are fully covered.</td></tr>
<tr><td>Individual excess water discharging by mining</td><td>Covered</td><td>Not relevant for the Estonian part.</td><td>No "environmental costs" due to this water use</td><td>Not relevant for the Estonian part.</td><td>Costs are fully covered.</td><td>Not relevant for the Estonian part.</td></tr>
<tr><td>Individual wastewater discharging by waste</td><td>Covered (but possible use of subsidies)</td><td>Not relevant for the Estonian part.</td><td>No "environmental costs" due to this water use</td><td>Not relevant for the Estonian part.</td><td>Costs are fully covered.</td><td>Not relevant for the Estonian part.</td></tr>
</table>

"Water services"	Financial costs and their recovery		Environmental costs (EC) and their recovery		Cost recovery level, including EC	
	For LATVIAN part	For ESTONIAN part	For LATVIAN part	For ESTONIAN part	For LATVIAN part	For ESTONIAN part
management (landfills)						
Water use for energy production in small HPPs	Covered (but public financial support is available which is covered by end users of electricity).	*Not defined as "waters service", analysed as "significant water use".*	Cause EC in 3 WBs. NRT paid by all (10) HPPs in the project area – around 25000 EUR per year.	*Not defined as "waters service", analysed as "significant water use".*	**Financial costs are covered.** **EC are covered (at least) partly.**	*Not defined as "waters service", analysed as "significant water use".*

Table 10. *Summary on the cost recovery assessment for "significant water uses" in the project area. (Source: Based on analysis as part of the project. The assessment approach and input data are described in the detailed report of the project on the economic analysis.)*

"Significant water uses"	**"Environmental cost" recovery description**		**Proposed instruments for improving the "environmental cost" recovery**
	For the LATVIAN part	**For the ESTONIAN part**	
Water use for energy production in small HPPs*	(Treated and assessed as the "water service" – see the previous table).	Creates "environmental costs" (in 1 WB). No current instruments for covering these costs. ⇨ **EC are not covered.**	Implementation of additional measures proposed in the program of measures to achieve environmental targets in the affected WBs.
Dams/ obstacles on rivers with various or no use	Creates "environmental costs" (in 3 WBs). No current instruments for covering these costs. ⇨ **EC are not covered.**	Creates "environmental costs" (in 4 WBs). No current instruments for covering these costs. ⇨ **EC are not covered.**	
Pollution run-off from agricultural lands, clear-cutting and drained forest areas	Creates "environmental costs" (in 13 WBs due to agriculture and 5 WBs due to forestry). No current instruments for covering these costs. ⇨ **EC are not covered.**	Do not create "environmental costs".	**For Latvia only:** Implementation of additional measures proposed in the program of measures to achieve environmental targets in the affected WBs.
Drainage for agriculture and forest lands	Creates "environmental costs" (in 7 WBs due to agriculture and 4 WBs due to forestry). The current pricing instrument addresses only damage to fish resources. No data about the paid amounts. ⇨ **EC are not covered.**	Do not create "environmental costs".	
Accumulated (past) nutrient pollution in sediments	Creates "environmental costs" (in 1 WB). No current instruments for covering these costs. ⇨ **EC are not covered.**	Creates "environmental costs" (in 1 WB). No current instruments for covering these costs. ⇨ **EC are not covered.**	Implementation of additional measures proposed in the program of measures to achieve environmental targets in the affected WBs.

* The small HPPs in Latvia are not analysed here since their water use is defined as "water service" in Latvia. They pay NRT (as an instrument for covering the "environmental costs"). See the previous table on the "water services".

5.2.3. Recommendations for improving the cost recovery level

Recommendations concerning the “water services”

There is no full “financial costs” recovery for centralised “water services”. The “financial costs” recovery can be improved by increasing tariffs paid for the services by users. According to international recommendations payments for the centralised “water services” should not exceed 3% of households’ disposal income. The estimated share of the payment for the centralised water supply and sewage services in households' disposal income is below 3% on average in the project area. But it exceeds the 3% threshold for lower households’ income groups. It limits possibility for increasing the tariffs. At the same time, the share of the payment for the centralised “water services” differs across settlements, like also the “financial costs” recovery level. Hence, each settlements needs to be evaluated individually – whether there is full recovery of the “financial costs” and whether tariffs can be increased without exceeding the 3% threshold, or there are any compensation mechanisms for low income households to make the tariffs affordable.

The individual “water services” cover fully their “financial costs” overall.

The “water services” create the “environmental costs” in 1 WB in the Estonian part and 5 WBs in the Latvian part of the project area (due to centralised “water services” of single settlements/cities in both countries, individual wastewater discharging by industry (an individual company) and water use for energy production in small HPPs (caused by 5 HPPs) in the Latvian part). These water users pay NRT, which is the current pricing instrument for compensating the “environmental costs”. However, on the Latvian side, the estimated NRT payments are rather small to be seen covering the created “environmental costs”. There are two policy instruments for covering these costs if new instruments are not introduced – increasing payments via the NRT (increasing NRT rates), and/or implementing additional measures (and financing their costs) for reducing the pressures. NRT is a national pricing instrument hence increasing the NRT rates would impact all respective water users nationally. Since the cost recovery problem is relevant in rather few WBs, local solutions could be preferred. Hence, the implementation of additional measures by the users for reducing their created pressures and allowing achievement of GES in the affected WBs is the recommended instrument for improving the “environmental costs” recovery level and implementing the PPP.

It should be noted concerning the centralised “water services” that the additional measures can include not only improving the wastewater treatment systems for reducing the nutrient pollution amounts discharged in the WBs. They can include also measures taken by the users of the centralised sewage services (e.g. households, industries, other companies and institutions) for reducing nutrient pollution amounts reaching their sewage.

Recommendations concerning the "significant water uses"

There are several WB in the Estonian part and considerable number of WBs in the Latvian part where the "significant water uses" create "environmental costs". There are no current pricing instruments for covering these costs. The current policy instrument relates to implementation of measures by users and financing their costs according to the mandatory requirements for environmental protection prescribed by the national regulations. However, the failure of GES for range of WBs shows that these measures are not sufficient to be the "environmental costs" covered. Introducing new pricing instruments would impact all respective water users nationally since the pricing instruments should be introduced nationally to secure equal conditions and requirements for water users. Also, establishing new pricing instruments for the most of the given water uses would be complex (and also costly) process. Local solutions (policy instruments) could be more appropriate. Hence, the implementation of additional measures by the users for reducing their created pressures and allowing achievement of GES in the affected WBs is the proposed instrument for improving the "environmental costs" recovery level according to the "polluters pay principle".

5.3. Economic evaluation of additional measures for achieving environmental targets

For the WBs failing GES additional measures need to be implemented to reduce significant pressures and ensure achievement of GES. Since various alternative measures are available for this purpose, the economic evaluation of possible additional measures aims to support their prioritisation and selection of the most socioeconomically efficient and acceptable measures.

The water uses and pressures creating significant pressures and failure of GES in both countries are described in chapter 5.1. Possible additional measures were identified to address the significant pressures and water uses causing the failure of GES. The measures must be technically feasible and cost-effective, but also relevant socioeconomic impacts of their implementation should be considered. The evaluation approach should consider all these aspects to support effectively the planning of measures.

Possible approach for the evaluation of additional measures was discussed among the project partners who represent also relevant institutions in Latvia and Estonia involved in the River Basin Management Planning. It was agreed that similar evaluation approach could be applied in both countries concerning common pressures and water uses which cause failure of GES of WBs in both countries. Most relevant of such common pressures and water uses (causing failure of GES for the largest number of WBs) are hydro-morphological pressures from dams/obstacles in rivers with various uses (including small HPPs) or no use. There were no specific methodologies applied previously for the RBMP in the countries concerning the economic evaluation of additional measures for such pressures and uses. A **multi-criteria**

analysis (MCA) approach was proposed since it was seen appropriate for the analysed pressures and measures and also practically applicable taking into account available information and resources. It was also seen relevant that the used approach and prepared assessments would be transferrable to other areas providing possibility to use them in the countries for the RBMP overall (not only concerning the trans-boundary WBs).

The multi-criteria analysis (MCA) approach allows simultaneous assessment of various relevant impacts in one methodological framework, where the applied criteria cover all relevant impacts.

The MCA approach was applied to the following cases of WBs (pressures and water uses):

1. dams used by small HPPs creating hydro-morphological pressures,
2. obstacles/impoundments with other/no use creating hydro-morphological pressure,
3. lakes with accumulated past nutrient pollution in sediments.

Possible additional measures were assessed with the MCA on general scale without connecting them to concrete WBs[3]. This assessment aims to support general prioritisation of the measures and to provide detailed information on relevant impacts and range of their magnitude. This information was used afterwards to guide selection of additional measures for concrete WBs (failing GES) in the project area.

Range of WBs fails GES in the Latvian part of the project area due to nutrient pollution from agriculture and forestry and hydro-morphological pressures from drainage for these activities. Since there is large number of possible additional measures to reduce these pressures, the evaluation of such measures should focus primarily on assessing their effectiveness and costs and finding the most cost-effective measures for achieving the environmental targets. Therefore the cost-effectiveness analysis of measures was conducted in Latvia to support development of measures for these pressures. Due to limitations of the study, the analysis was conducted based on an example of a selected WB G308 Jogla, which fails GES due to elevated P load coming as diffuse pollution from agriculture (arable land). The evaluation results can be used also for other WBs failing GES due to elevated P load. The costs assessments for the analysed measures can be used also for the cost-effectiveness analysis of these measures in light of nutrient pollution reduction.

The next chapters provide summary results on the evaluation of possible additional measures conducted as part of the project – starting with the results based on MCA approach and ending

[3] Except for lakes where the assessment partly addresses the WB failing GES – the Burtnieku lake in the Latvian part of the project area (which is particular lake due its size and specific environmental conditions) and the Köstrejärv lake in the Estonian part of the project area. The developed assessments can be attributed to similar lakes overall, however estimation of costs of the measures required taking into account specific characteristics of a lake. Detailed approaches and assessments, as well as their transferability are explained in respective chapters of the report.

with the cost-effectiveness analysis results for Latvia. Full results of the evaluation of additional measures are provided in the detailed report of the project on the economic analysis.

5.3.1. Additional measures included in the evaluation with the MCA

The additional measures included in the assessment are listed in Table 11. They were identified based on knowledge of the project's experts. The main principles for identifying possible measures were that they address the pressure causing failure of GES and are technically feasible. All the measures are technically feasible in principle. However their application for concrete WBs needs further analysis taking into account local conditions and selecting appropriate technical solutions (e.g. type of fish pass). This can be considered when developing the program of measures – when analysing and selecting measures on the WB scale (for each concrete WB failing GES).

It should be noted concerning the measures for dams used by small HPPs that the measures M2 and M3 have very limited applicability in Latvia since they can be implemented only in cases with an existing fish pass. But such cases are rare in Latvia (only 1 dam with a small HPP has an existing fish pass out of 5 such cases creating significant pressure in the project area). Hence, the measures M1 and M4-M8 were the main alternatives for the evaluation. Similar note applies also to Estonia where the measure M4 for dams used by small HPPs and other obstacles/impoundments has limited applicability since this can be implemented only in case where there is an existing fish pass, hence the main alternatives for the evaluation are M1-M3.

As can be seen from the table, there are differences between the countries concerning measures included in the analysis – some measures were not considered in Estonia since they were seen having limited effectiveness or applicability.

Table 11. *The additional measures included in the evaluation with the MCA approach. Similar measures analysed in both countries are marked with light green colour.*

Additional measures analysed for Latvia	Additional measures analysed for Estonia
Additional measures for dams used by small HPPs for energy production creating hydro-morphological pressures	
M1 Building of a fish pass	M1 Building of a fish pass
M2 Reconstruction or improvement of an existing fish pass	M2 Demolishing a dam
M3 Maintenance of an existing fish pass	M3 Environmentally friendly turbine
M4 Environmentally friendly turbine	*M4 Improvement of an existing fish pass*
M5 Implementation of ecological flow	
M6 Demolishing a dam	
M7 Permanently lowering a dam	
M8 Opening migration way during spawning period	
Additional measures for obstacles/impoundments with other/no use creating hydro-morphological pressure	

Additional measures analysed for Latvia	Additional measures analysed for Estonia
M1 Building of a fish pass	M1 Building of a fish pass
M2 Demolishing a dam	M2 Opening migration way during spawning period
M3 Opening migration way during spawning period (if a dam with sluice)	M3 Demolishing a dam
	M4 Improvement of an existing fish pass
Additional measures for lakes with accumulated past nutrient pollution in sediments*	
M1 Sediment dredging	M1 Sediment dredging
M2 Removal of macrophytes	M2 Removal of macrophytes
M3 Immobilization of phosphorus using chemical treatment	M3 Biomanipulation
M4 Artificial aeration and mixing	M4 Complex methods (sediment dredging and macrophytes removal)
M5 Biomanipulation	
M6 Hypolimnetic withdrawal	
M7 Artificial floating wetlands	

* Note for Estonian: For all restoration options concerning lakes with accumulated nutrient pollution in sediments, proper limnological investigations should be conducted, especially on external and internal loading, buffer capacity of a lake to that loading, inventory of biota, evaluation of the main factors influencing functioning efficiency of a lake.

5.3.2. Approach for the evaluation of additional measures with the MCA

With the MCA approach measures are assessed applying **criteria**, which aim to cover relevant impacts of the measures. Criteria identified as relevant for the evaluation and applied in the assessment are listed in Table 12. The assessments for the criteria are prepared using **assessment categories**. Table 12 provides also the used categories and related **scores**. Summary assessment is calculated for each measure by summing up scores from the individual criteria. The summary scores of measures can be compared, and they can be used for prioritisation of measures. In general, the larger is the summary score, the higher is the priority.

Table 12. *The list of criteria, assessment categories and related scores applied in the MCA of additional measures.*

Criteria	Assessment categories	Scores
1. Effectiveness of a measure	No effect Low effect Moderate effect High effect	0 1 2 3
2. Certainty of the Effectiveness assessment	- Low certainty Moderate certainty High certainty	0 1 2 3
3. Negative adverse environmental impacts from implementing a measure	High impact Moderate impact Low impacts No impact	0 1 2 3
4. Costs of a measure	- High costs Moderate costs Low costs	0 1 2 3
5. Constraints/obstacles of implementation of a measure (institutional, legal, financial)	High constraints Moderate constraints Low constraints No constraints	0 1 2 3

Three criteria are included covering relevant **environmental impacts of the measures**: C1 Effectiveness of a measure, C2 Certainty of the Effectiveness assessment and C3 Negative adverse environmental impacts. The effectiveness assessment (Criterion 1) evaluates whether and to what extent a measure improves the state and reduces the gap to GES. The certainty of the effectiveness assessment (Criterion 2) shows confidence of the effectiveness assessment (that a measure would deliver the expected effect). The negative adverse environmental impacts (Criterion 3) cover any negative environmental side impacts on the WB or wider environment from implementing a measure. The assessments of measures for these criteria were developed based on expert opinion of the environmental experts of the project for each country.

The effectiveness of measures (under Criterion 1) was assessed applying environmental state parameters which are used also for assessing status of WBs (Table 13). The effectiveness assessment (assigning the category and score) was prepared for each state parameter separately. Where more than one parameter is used, the summary effectiveness score was calculated in two ways – as an average score of all parameters' scores and as a summary score by summing up individual scores of each parameter.

As can be seen from the table, there are some differences regarding these parameters used for the assessment in Latvia and Estonia. They reflect differences and relevance of various state parameters for assessing status of WBs in each country.

Table 13. *Environmental state parameters used for assessing the effectiveness of the additional measures.*

Full information about the assessment approach is provided in the detailed report of the project on the economic analysis.

<table>
<tr><th rowspan="2">Water uses and pressures causing failure of GES</th><th colspan="2">Environmental state parameters used for assessing effectiveness of the measures</th></tr>
<tr><th>for Latvia</th><th>for Estonia</th></tr>
<tr><td>dams used by small HPPs for energy production creating hydro-morphological pressures</td><td>P1 Obstacle for fish migration, disruption of river continuity (as indicator under WFD).
• Presence of obstacle for fish migrating (Yes/No).
• Length (km) of river or area (km^2) of river catchment opened for fish migration.
P2 Rapid Habitat areas (riverbed). Size of habitat areas (ha or m2, or m) with suitable (rapid) conditions (hydro-morphological conditions of the habitats).
P3 Ecological flow (enough water in a river during different fish bio-periods).</td><td>P1 Obstacle for fish migration, disruption of river continuity (as indicator under WFD). Presence of obstacle for fish migrating (Yes/No).
P2 Hydro-morphological quality of river.
P3 Improvement of fish index.
P4 Objectives of Habitats directive. Whether it improves the status or not.</td></tr>
<tr><td>obstacles/impoundments with other/no use creating hydro-morphological pressure</td><td>P1 Obstacle for fish migration, disruption of river continuity (as indicator under WFD).
• Presence of obstacle for fish (Yes/No).
• Improvement of fish index.
• Length (km) of river or area (km^2) of river catchment opened for fish migration.
P2 Habitat areas (riverbed). Size of habitat areas (ha or m2) with suitable conditions (hydro-morphological conditions of the habitats).</td><td>P1 Obstacle for fish migration, disruption of river continuity (as indicator under WFD). Presence of obstacle for fish (Yes/No).
P2 Hydro-morphological quality of river.
P3 Improvement of fish index.
P4 Objectives of Habitats directive. Whether it improves the status or not.</td></tr>
<tr><td>lakes with accumulated past nutrient pollution in sediments</td><td>P1 Phosphorus amount (concentration) in water</td><td>P1 Macrophytes. Improvement in macrophytes status.
P2 Macroinvertebrates. Improvement in macroinvertebrates status.
P3 Fish. Improvement in fish status.</td></tr>
</table>

Assessment of the **costs of measures** (under Criterion 4) included the following steps (for each measure): (i) identifying and describing relevant types of the costs; (ii) developing quantitative estimates for each type of the costs; (iii) calculating total costs of a measure (as annualised costs per year); (iv) estimating financing need for the planning period 6 years (2022-2027) for implementing a measure; (v) estimating costs as a share of a implementers’ revenues/budget (%); (vi) performing sensitivity analysis of the calculated costs to incorporate variation and uncertainty in the costs’ estimate; (vii) assigning the qualitative assessment category (high, moderate, low costs) based on the share of the costs in revenues/budget.

All relevant types of the costs were considered and assessed for each measure, including (i) direct financial costs of a measure (investment costs, yearly operation and maintenance costs, other direct costs); (ii) “opportunity costs” (foregone/lost revenues) for an actor who implements a measure; (iii) “induced costs” – costs due to implementing a measure to other actors than the one who implements the measure.

Total costs for each measure were estimated quantitatively. For the measures applied to small HPPs, the costs were afterwards estimated as a share of yearly revenues of a HPP. For other measures, different approaches were used in the countries. In Latvia the costs were estimated as a share of yearly municipal budget while in Estonia the costs were estimated as a share of an average yearly budget of the Environmental Investments Centre’s (EIC) water management programme.

The costs are classified as low/moderate/high costs according to an approach as presented in the Tables 14 and 15. In this way the costs are linked to financial capacity of actors to implement a measure (called also as “affordability” of the costs).

Table 14. *Interpretation of the qualitative costs' categories (and scores) for measures applied to small HPPs.*

Costs' category	Interpretation of the category	Costs as a share (%) of yearly HPP revenues
Low (3)	The costs are affordable, an actor could cover the costs with own funding.	< 1% of revenues
Moderate (2)	The costs are hardly affordable, some public financial support would be recommended to facilitate implementation of a measure.	1-1.5% of revenues
High (1)	The costs are not affordable, public funding would be needed for financing implementation of a measure.	> 1.5% of revenues

Table 15. *Interpretation of the qualitative costs' categories (and scores) for other measures.*

** For Latvia: the costs as a share of a yearly municipal budget. For Estonia: the costs as a share of a yearly EIC budget of water programme.*

Costs' category	Interpretation of the category	Costs as a share (%) of yearly budget*
Low (3)	The costs are affordable, an actor could cover the costs with own funding.	< 0.5% of a budget
Moderate (2)	The costs are hardly affordable, some public financial support would be recommended to facilitate implementation of a measure.	0.5-1% of a budget
High (1)	The costs are not affordable, public funding would be needed for financing implementation of a measure.	> 1% of a budget

Assessment of **constraints/obstacles of implementation** of a measure (under Criterion 5) involved identifying relevant types of the constraints/obstacles for each analysed measure and their assessment using the qualitative categories (and scores) based on expert opinion of the project's experts. All relevant types of the constraints were considered (institutional, legal and financial).

5.3.3. The evaluation results concerning measures for dams used by small HPPs creating hydro-morphological pressures

Tables 16 and 17 provide summary assessment for the analysed measures for dams used by small HPPs for each country. The measures are ordered in the tables starting with the measure with the highest summary score. However this ordering should not be taken as strict ranking because the assessment approach is rather rough to be used for strict ranking.

Table 16. *Summary on the assessment for LATVIA for the analysed additional measures for dams used by small HPPs creating hydro-morphological pressures. (Source: Assessments prepared as part of the project. The assessment approach and results are described in the detailed report of the project on the economic analysis.)*

** Using Sum of all (3) parameters' scores for the Effectiveness assessment. ** These measures are treated separately because of the limited applicability hence in most cases they would not provide solution for achieving GES.*

The analysed additional measures	C1 Effectiveness*	C2 Certainty	C3 Negative impact	C4 Costs	C5 Constraints	Total
M6 Demolishing a dam	9	High (3)	Moderate-High (0.5)	Low-High (2)	High (0)	**14.5**
M5 Implementation of ecological flow	6	Moderate (2)	No impact (3)	Moderate-High (1.5)	Low-Moderate (1.5)	**14.0**
M4 Environmentally friendly turbine	1.5	Moderate-High (2.5)	No impact (3)	High (1)	Moderate (1)	**9.0**
M1 Building of a fish pass	4.5	Moderate (2)	Moderate (1)	High (1)	High (0)	**8.5**
M7 Permanently lowering a dam	2	Low-Moderate (1.5)	Low-Moderate (1.5)	High (1)	High (0)	**6.0**
M8 Opening migration way during spawning period	3	Low-Moderate (1.5)	Moderate (1)	High (1)	High (0)	**6.5**
*M3 Maintenance of an existing fish pass***	*4.5*	*Moderate (2)*	*No impact (3)*	*Moderate-High (1.5)*	*Low/No (2.5)*	***13.5***
*M2 Reconstruction or improvement of an existing fish pass***	*4.5*	*Moderate (2)*	*Moderate (1)*	*High (1)*	*Moderate (1)*	***9.5***

Table 17. *Summary on the assessment for ESTONIA for the analysed additional measures for dams used by small HPPs creating hydro-morphological pressures**.** (Source: Assessments prepared as part of the project. The assessment approach and results are described in the detailed report of the project on the economic analysis.)*

** Using Sum of all (4) parameters' scores for the Effectiveness assessment.*

The analysed additional measures	C1 Effectiveness*	C2 Certainty	C3 Negative impact	C4 Costs	C5 Constraints	Total
M2 Demolishing a dam	11.5	High (3)	Low (2)	High (1)	Moderate-High (0.5)	**18**
M4 Improvement of an existing fish pass	7	Moderate (2)	Low (2)	High (1)	Low (2)	**14**
M1 Building of a fish pass	8	Moderate (2)	Low (2)	High (1)	Moderate (1)	**14**
M3 Environmentally friendly turbines	5.5	Moderate (2)	Low (2)	High (1)	Moderate (1)	**11.5**

Conclusions for Latvia:

- The measures M7 and M8 are not proposed further as options due to their low effectiveness, uncertainty in the effectiveness assessment and high costs.
- The only measure which fully eliminates the problem for all state parameters is the measures *M6 Demolishing a dam*. Other measures give positive effect concerning part of state parameters only.
- For small size (revenue) HPP public financial support would be needed for implementing any of the measures. Hence it would be more sustainable to stop the operation of such HPP and to demolish a dam.
- Demolishing a dam could be low cost option if the opportunity costs need to be compensated based on cadastral value of properties. It could still be affordable if compensating foregone revenues from electrical energy production assuming low-moderate compensation. The costs become high if large production value would need to be compensated (e.g. if there is a small HPP with large production).
- Removing a dam is the highest priority option where it is suitable and no large energy production is involved/possible. Otherwise other measures must be considered, but a set of measures could be needed to ensure achievement of GES (for instance, a fish pass and ecological flow implementation). It would increase the costs, hence public financial support would be necessary even for HPPs with relatively large production.
- For moderate and large size small HPPs affordability of the costs depends on actual costs of the measures and size of a HPP (production and revenues) in each concrete case. Estimates for each concrete case should be developed when elaborating the program of measures on WB scale.

Conclusions for Estonia:

- Demolishing a dam and giving up electricity production is always the most effective measure to open fish migration route and to protect aquatic biota. Also it is usually cheaper than to construct a fish pass. Hence this measure should be treated as preferred measure. Only when demolishing a dam is not feasible due to socioeconomic reasons, the construction of fish pass is reasonable.
- The installation of a fish-friendly turbine instead of a non-friendly turbine is an extra measure to protect fish when continuing electricity generation at a dam is indispensable.

The collected information and prepared assessments were used and developed further when analysing and selecting measures for concrete WBs failing GES due to this water use in the project area.

5.3.4. The evaluation results concerning measures for obstacles with other or no use creating hydro-morphological pressures

Tables 18 and 19 provide summary assessment for the analysed measures for obstacles/impoundment on rivers for each country. The measures are ordered in the tables starting with the measure with the highest summary score. However this ordering should not be taken as strict ranking because the assessment approach is rather rough to be used for strict ranking.

Table 18. *Summary on the assessment for LATVIA for the analysed additional measures for obstacles/impoundments creating hydro-morphological pressures. (Source: Assessments prepared as part of the project. The assessment approach and results are described in the detailed report of the project on the economic analysis.)*

** Using Sum of all (2) parameters' scores for the Effectiveness assessment.*

The analysed additional measures	C1 Effectiveness*	C2 Certainty	C3 Negative impact	C4 Costs	C5 Constraints	Total
M2 Demolishing a dam	6	High (3)	Moderate (1)	Low-High (2)	High (0)	**12.0**
M1 Building of a fish pass	4	Moderate (2)	Moderate (1)	Low-Moderate (2.5)	Moderate (1)	**10.5**
M3 Opening migration way during spawning period	3.5	Low-Moderate (1.5)	Moderate (1)	Low (3)	Moderate (1)	**10.0**

Table 19. *Summary on the assessment for ESTONIA for the analysed additional measures for obstacles/impoundments creating hydro-morphological pressures. (Source: Assessments prepared as part of the project. The assessment approach and results are described in the detailed report of the project on the economic analysis.)*

** Using Sum of all (4) parameters' scores for the Effectiveness assessment.*

	C1 Effectiveness*	C2 Certainty	C3 Negative impact	C4 Costs	C5 Constraints	Total
M3 Demolishing a dam	9	High (3)	Low (2)	High (1)	Moderate-High (0.5)	**15.5**
M4 Improvement of an existing fish pass	7	Moderate (2)	Low (2)	Low (3)	Moderate (1)	**15**
M1 Building of a fish pass	8	Moderate (2)	Low (2)	High (1)	Moderate (1)	**14**
M2 Opening migration way during spawning period	4.5	Low (1)	High (0)	Low (3)	Moderate (1)	**9.5**

Conclusions for Latvia:

- The only measure which fully eliminates the problem for both relevant state parameters is the measure *M6 Demolishing a dam*, it has also high certainty of the effectiveness assessment, and the negative environmental effect is expected to be temporal. Other measures give only partial achievement of GES.

- The costs of all measures could be affordable overall even for small budget counties. Demolishing a dam could be low cost option if the opportunity costs need to be compensated based on cadastral value of properties or assuming low to moderate compensation of the foregone revenues.

- It can be concluded overall that removing a dam is the highest priority option and should be applied where technically suitable. Where it is not the case other measures must be considered but possibility of achievement of GES needs to be evaluated carefully.

Conclusions for Estonia:

- The best option would be to demolish a dam. If it is not possible due to socioeconomic or legal reasons, effectively working fish pass should be constructed. If the fish pass is already constructed but does not work effectively, the problem should be eliminated if possible.

- The measure M2 can be a solution only in exceptional cases and it, most likely, would not be sustainable for long. Probability of achieving GES is low with implementing this measure only.

The collected information and prepared assessments were used and developed further when analysing and selecting measures for concrete WBs failing GES due to this water use in the project area.

5.3.5. The evaluation results concerning measures for lakes with accumulated nutrient pollution in sediments

Tables 20 and 21 provide summary assessment for the analysed measures for lakes for each country. The measures are ordered in the tables starting with the measure with the highest summary score. However this ordering should not be taken as strict ranking because the assessment approach is rather rough to be used for strict ranking.

__Table 20.__ Summary on the assessment for LATVIA for the analysed additional measures for lakes with accumulated nutrient pollution. (Source: Assessments prepared as part of the project. The assessment approach and results are described in the detailed report of the project on the economic analysis.)

The analysed additional measures	C1 Effectiveness	C2 Certainty	C3 Negative impact	C4 Costs	C5 Constraints	Total
M2 Removal of macrophytes	Low (1)	High (3)	Low (2)	Low (3)	No-Low (2.5)	**11.5**
M5 Biomanipulation	Moderate (2)	Moderate-High (2.5)	Low-Moderate (1.5)	Moderate-High (1.5)	Moderate (1)	**8.5**
M7 Artificial floating wetlands	Low (1)	Moderate (2)	No impact (3)	High (1)	Low-Moderate (1.5)	**8.5**
M1 Sediment dredging	High (3)	High (3)	Moderate (1)	High (1)	High (0)	**8**
M3 Immobilization of phosphorus using chemical treatment	Moderate-High (2.5)	Moderate (2)	Moderate (1)	High (1)	High (0)	**6.5**
M6 Hypolimnetic withdrawal	Moderate (2)	Moderate (2)	Moderate (1)	High (1)	High (0)	**6**
M4 Artificial aeration and mixing	Low-Moderate (1.5)	Low-Moderate (1.5)	Moderate (1)	High (1)	High (0)	**5**

__Table 21.__ Summary on the assessment for ESTONIA for the analysed additional measures for obstacles/impoundments creating hydro-morphological pressures. (Source: Assessments prepared as part of the project. The assessment approach and results are described in the detailed report of the project on the economic analysis.)

** Using Sum of all (3) parameters' scores for the Effectiveness assessment.*

	C1 Effectiveness*	C2 Certainty	C3 Negative impact	C4 Costs	C5 Constraints	Total
M4 Complex method (sediment dredging and macrophytes removal)	9	High (3)	Low (2)	High-Moderate (1.5)	Moderate (1)	**16.5**
M1 Sediment dredging	8	High (3)	Low (2)	High-Moderate (1.5)	Moderate (1)	**15.5**
M2 Removal of macrophytes	6	Low (1)	Low (2)	Low (3)	Low (2)	**14**
M3 Biomanipulation	5	Low (1)	Low (2)	Low (3)	Low (2)	**13**

Conclusions for Latvia:

- The measures M3, M4, M6 and M7 were not proposed further as options due to their limited effectiveness in combination with uncertainty in the effectiveness assessment and high costs.

- Taking into account the effectiveness, only the *M1 Sediment dredging* could ensure achievement of GES, but it has very high costs (in particular, if considering such a large lake as the Burtnieku lake). All other measures might bring partial achievement of GES. The next best measure is M5 with "moderate" effectiveness and quite high certainty of this assessment, besides rather low negative adverse impacts. The measure M2 cannot be considered as realistic option for achieving GES due to its low effectiveness.

- The measures, which should be investigated further, are *M5 Biomanipulation, M1 Sediment dredging* and *M2 Macrophyte removal* in combination, as there is no single measure that would provide achievement of GES with affordable costs. Assuming the Burtnieku lake with its large size, the costs for the highly effective measure M1 would be too high. The measure M5 could be to some extent affordable but there is uncertainty whether it alone would provide achievement of GES. The measure M2 can be considered due to its low costs but the achieved state improvement would be very limited. The main criteria which need further investigation are the effectiveness – whether the measures would ensure achievement of GES, and costs since the prepared assessments are rather rough. Further investigations are needed to assess possible combined effect of measures.

- The costs are expected to be high, in particular for such large lake as the Burtnieku lake, and public financial support would be needed for implementing measures. Hence, also further studies could be suggested to look for additional (not considered in this analysis) possible measures for addressing the given environmental problem.

Conclusions for Estonia:

- The best option would be the measure M4 due to its high effectiveness. The measures M2 and M3 alone might not allow achieving GES.

- Since implementation of all measures is very much dependent on specific WB (e.g. m^3 of sediments to be removed or ha of macrophytes to be cut), the cost can vary considerably. Hence, water body specific assessments need to be developed for each concrete case.

5.3.6. The evaluation of additional measures for agriculture (for Latvia only)

Scope and general approach of the analysis

Range of WBs fails GES in the Latvian part of the project area due to nutrient pollution from agriculture and forestry and hydro-morphological pressures from drainage for these activities. The largest number of these WBs fails GES due to **diffuse nutrient pollution from agriculture** (from crop farming). Due to limitation of the study the analysis was focused on evaluating possible additional measures for this pressure and source/activity.

There is large number of possible additional measures to reduce diffuse nutrient pollution from agriculture. The evaluation should support identifying and selecting the most cost-effective measures for achieving nutrient load reduction targets. Hence, the **cost-effectiveness analysis (CEA)** is the most appropriate tool to support the prioritisation and selection of the measures. The CEA involves assessing effectiveness and costs of the measures and estimating cost-effectiveness of each measure. The measures with higher effectiveness and lower costs are more cost-effective. The CEA can help finding the least cost way for achieving the environmental objectives.

To serve the given purpose quantitative analysis would be preferable. The more quantitative CEA is aimed, the more detailed and quantitative information is needed about the current nutrient pollution load, applicability, effect and costs of the measures. Due to limited information for the project area and limitations of the study, the analysis was conducted **based on an example of a selected WB failing GES due to the given pressure – G308 Jogla.**

Although the assessment was conducted on the basis of a selected WB, it aims to provide generalised assessment of cost-effectiveness of the measures, which could be applicable to other WBs also and support the RBMP. Running similar analysis for few other selected WBs could allow verifying outcome of the given assessment to provide general prioritisation of the measures (based on their cost-effectiveness). This information could be used afterwards to guide selection of additional measures for concrete WBs (failing GES) when planning the program of measures.

The developed methodology can be used also for evaluating measures concerning other pressures from agriculture and forestry.

Additional measures included in the evaluation

The additional measures included in the assessment are listed below. They have been identified based on knowledge of the project's experts. The main principles for identifying possible measures were that they address the pressure causing failure of GES and are technically feasible. The technical feasibility was considered based on experience in the project's countries with implementing such measures, information from existing studies in the countries, as well as literature. All the measures are technically feasible in principle. However their application for concrete WBs needs further analysis taking into account local conditions. This can be considered in the next step of developing the program of measures – when analysing and selecting measures on the WB scale (for each concrete WB failing GES).

Possible additional measures for reducing diffuse nutrient pollution from agriculture (crop farming), which were initially identified for the analysis:

M1 Artificial (constructed) wetlands (groundwater)
M2 Artificial (constructed) wetlands (surface)
M3 Controlled drainage
M4 Buffer bars
M5 Using of nitrogen stabilizers when applying nitrogen
M6 Post-crops sowing after harvest / middle crops sowing (intermediate crops), catch crops
M7 Sedimentation basins / traps
M8 Crop rotation in arable land
M9 Spreading of fertilizers at certain distances from waters
M10 Winter green areas (stubble fields)
M11 Agricultural liming
M12 Energy crops
M13 Straw application in the field before winter sowing
M14 Preparation of fertiliser management plans or improving of basic fertiliser management plans.

Approach for assessing effectiveness of the measures

The assessment approach has been developed (in 2014) and applied (in 2016) for the CEA of marine protection measures in Latvia, also has been applied for the second RBMPs in Estonia.

The effectiveness assessment consists of **3 elements, which are combined** for estimating the total effectiveness of a measure.

1) Effect of a measure in terms of load reduction from the source. Such assessment is done for each measure. It is not WB-specific but general assessment for a measure as such.

The used assessment scale and categories:

> 1 – "low" effect, a measure gives < 5% reduction of load from the source,
> 2 – "moderate" effect, a measure gives 5-15 % reduction of load from the source,
> 3 – "high" effect, a measure gives 15-30 % reduction of load from the source,
> 4 – "very high" effect, a measure gives > 30 % reduction of load from the source.

2) Relative significance of the activities' created pressure, which, in general, shows relative contribution of each activity causing the particular pressure into the total pressure on all WBs

failing GES due to this pressure. In the given analysis, which is based on a selected WB, the total nutrient load on the selected WB is taken as the total pressure. The used assessment categories are presented in Table 22.

3) Significance of scale of the activities' created pressure, which characterises extent of impact of the activities' created pressure in terms of number of WBs failing GES due to the given pressure. The used assessment categories are presented in Table 22.

The assessments for the elements 2 and 3 are not measure specific, they are developed for the analysed pressure and relevant activities contributing into this pressure. Hence they are the same for all measures addressing the same pressure and activity (e.g. contribution of the agriculture into the total nutrient load).

Assessments with the categories can be derived based on expert judgement. In our case, nutrient modelling data are used for the element 2 (for the selected WB) and pressure and status assessment results (on WBs failing GES due to various pressures in the project area) are used for the element 3.

Table 22. *Description of the assessment scale for assessing the significance of activities' caused pressures. (Source: LHEI, AKTiiVS (2014).[4])*
** In the given analysis total nutrient load on the analysed WB (G308 Jogla) is taken as the total pressure.*

Scale	Categories	Description of the categories for SIGNIFICANCE OF PRESSURE (Effectiveness element 2)	Description of the categories for SIGNIFICANCE OF SCALE of pressure (Effectiveness element 3)
1	**Low significance**	Activity makes **< 20 %** of the total pressure on all WBs failing GES*	Pressure from activity impacts **< 5 %** of the WBs failing GES due to given pressure
2	**Moderate significance**	Activity makes **20-30 %** of the total pressure on all WBs failing GES*	Pressure from activity impacts **5 -20 %** of the WBs failing GES due to given pressure
3	**High significance**	Activity makes **30-50 %** of the total pressure on all WBs failing GES*	Pressure from activity impacts **20-60 %** of the WBs failing GES due to given pressure
4	**Very high significance**	Activity makes **> 50 %** of the total pressure on all WBs failing GES*	Pressure from activity impacts **> 60 %** of the WBs failing GES due to given pressure

Summary effectiveness assessment for each measure is calculated by multiplying scores of each element, and interpreting the summary points according to the following categories, where the effectiveness is:

1 – "very low" = if total points range from 1 to 5,
2 – "low" = if total points range from 6 to 10,
3 – "moderate" = if total points range from 11 to 20,
4 – "high" = if total points range from 21 to 30,
5 – "very high" = if total points range above 30.

4 LHEI, AKTiiVS (2014) Report for a project financed by the Latvian Environment Protection Fund "Feasibility study for developing program of measures for achieving GES". Available in Latvian (at http://www.lhei.lv/attachments/article/133/Projekti-Prieksizpete_JSD_PP_Nosleguma%20atskaite_20141222_gala.pdf).

Approach for assessing costs of the measures

A measure can involve the following categories of the costs:

1. direct financial costs of a measure (investment, e.g. construction, costs; yearly operation and maintenance costs; other direct costs e.g. costs of a construction project and permit);
2. "opportunity costs" (foregone/lost revenues) for an actor who implements a measure and for the local economy – some measures create such costs due to lost production (e.g. in the measures application area for wetlands and buffer bars) or due to reduced yield in the measure application area (e.g. for *M9 Spreading of fertilizers at certain distances from waters*);[5]
3. administrative costs (e.g. for controlling implementation of a measure) – might be relevant for some of the measures, but could not be estimated quantitatively, hence are not included.

The measures can give also economic gains (e.g. due to improving soil fertility, increasing yield), but also these could not be estimated qualitatively, therefore are not included. The exception is the measure *M12 Energy crops* where the revenues from selling the harvest are estimated and the costs of this measure are calculated as net costs (revenues minus costs).

It was concluded overall that the main cost types are covered by the developed quantitative estimates, and the provided estimates could be seen reliable for the cost-effectiveness analysis and prioritisation of the measures.

Assessment of the costs for each measure included the following steps:

- identifying and describing relevant types of the costs (related to the categories above),
- developing quantitative estimates for each type of the costs,
- calculating total costs of a measure (as annualised costs per year),
- estimating costs as a share of a implementers' revenues (%),
- performing a sensitivity analysis of the calculated costs to incorporate variation and uncertainty in the costs' estimate,
- assigning the qualitative assessment category (from "very high" to "very low" costs) based on the share of the costs in the revenues.

Total costs for each measure are estimated quantitatively. To incorporate variation and uncertainty in the costs a "sensitivity analysis" was performed. Relevant input parameters (the ones impacting the calculated total costs most significantly) are identified and cost interval is calculated (with the range of values for the relevant input parameters).

[5] The „opportunity costs" are estimated based on the data about turnover and profit of crop farming (using CSB data and calculations) and application area of a measure.

The quantitative costs are calculated as a share of yearly turnover of the crop farming in the project area (since the analysed measures address diffuse nutrient pollution load from arable land). Various CSB data are used to estimate the turnover of the crop farming in the project area and in the analysed WB G308 Jogla.

The costs are classified as low/moderate/high costs according to an approach as presented in Table 23. In this way the costs are linked to financial capacity of actors to implement a measure (called also as "affordability" of the costs). The applied affordability threshold (for high costs) is 1.5 % of turnover. This threshold was set based on expert opinion of the project's experts, taking into account also practice in other EU countries[6] and similar national assessments for the marine protection policy in Latvia.

Table 23. *Interpretation of the qualitative costs' categories (and scores).*

Costs' category	Interpretation of the category	Costs as a share (%) of yearly turnover
Very low (5)	The costs are affordable, an actor could cover the costs with own funding.	< 0.5 % of turnover
Low (4)		0.5-1 % of turnover
Moderate (3)	The costs are hardly affordable, some public financial support would be recommended to facilitate implementation of a measure.	1-1.5 % of turnover
High (2)	The costs are not affordable, public funding would be needed for financing implementation of a measure.	**1.5**-2 % of turnover
Very high (1)		> 2 % of turnover

Approach for assessing cost-effectiveness of the measures

The cost-effectiveness of measures allows comparing measures and selecting the most cost-effective ones for achieving the environmental objectives (for the required P load reduction in the analysed case). The cost-effectiveness of each measure is assessed combing the assessments on their effectiveness and costs according to the approach as presented in Table 24. The cost-effectiveness is assessed in the scale from 1 "very low" (red cells in the table) to 5 "very high" (dark green cells in the table). The given approach has been developed and applied in Latvia for evaluating the marine protection measures. Also has been applied for the 2nd RBMPs in Estonia.

Table 24. *Approach for estimating cost-effectiveness of additional measures based on the assessed effectiveness and costs. (Source: AKTiiVS, LHEI (2016) „Sociālekonomiskais novērtējums papildus pasākumiem laba jūras vides stāvokļa panākšanai", LVAF finansēta projekta atskaite.)*

Cost categories	**Effectiveness categories**				
	5 very high	**4 high**	**3 moderate**	**2 low**	**1 very low**
1 very high	**3**	**3**	**2**	**1**	**1**
2 high	**3**	**3**	**3**	**2**	**1**
3 moderate	**4**	**4**	**3**	**2**	**2**
4 low	**5**	**4**	**3**	**3**	**3**
5 very low	**5**	**5**	**4**	**3**	**3**

[6] European Commission (2014) *"Addressing affordability concerns in WFD implementation. Resource document for the WG Economics."* Version from October 2014.

In addition a **cost-effectiveness coefficient** is calculated for each measure based on the effectiveness and costs' categories (scores). It is calculated diving the costs' score by the effectiveness' score, where the costs scores are changed from 1 being "very low" costs to 5 being "very high" costs. It can take value from 0.2 to 5 – the lower is the coefficient, the better is the cost-effectiveness.

The developed quantitative estimates for the effectiveness and costs of the measures allowed also calculating **quantitative cost-effectiveness ratio** for each measure – as EUR per 1 kg of reduced P load.

All these assessments are used to demonstrate capacity of various approaches to support prioritisation of measures for developing the program of measures.

Assessment results on the cost-effectiveness of measures for phosphorus load reduction

The WB G308 Jogla, which is used as the test case in this assessment, fails GES due to elevated P load.[7] Therefore the effectiveness of the measures was assessed in light of their capacity to reduce P load. Only measures which give P load reduction are included.[8] Note that the measures' effectiveness for reducing N load can differ, thus the given assessment can be used only for assessing cost-effectiveness of the measures concerning P load.

For quantitative estimation of the effectiveness and costs, application area for each measure was estimated. It was necessary to compile the cost estimates, and it also allowed estimating capacity of each measure to provide achievement of the required P load reduction for the WB (45.8 kg of P per year). The results show that part of measures would not serve the required P load reduction if implemented alone (M8, M9, M10 and M12). This is due to their low effectiveness and, hence, large area necessary for application (larger than available in the WB). Therefore these measures are not proposed as options for the program of measures.

Table 25 provides the assessment result on the cost-effectiveness of the analysed measures. The assessment with the qualitative cost-effectiveness categories is provided as the first. It applies 5 categories from "very low" to "very high", combining the effectiveness and costs' assessments. It shows that majority of measures has "moderate" cost-effectiveness, except *M12 Energy crops* with "high" cost-effectiveness due to zero (net) costs and *M9 Spreading of fertilizers at certain distances from waters* with "moderate-high" cost-effectiveness due to

[7] Current P load from agriculture in the WB – 245 kg/year; allowed P load to comply with GES – 199.2 kg/year; load reduction target – 45.8 kg/year. (Source: nutrient modelling results by LEGMC.)
[8] The measures M5, M6, M13 and M14 from the initial list were excluded since they do not provide P load reduction.

relatively good effectiveness and low costs. But both measures have rather limited capacity for achieving the required load reduction, like it is also for the measures M8 and M12.

Table 25 includes also the calculated CE coefficient (the costs assessment score divided by the effectiveness assessment score). It allows slightly more differentiated assessment supporting better prioritisation of the measures based on their cost-effectiveness. As can be seen, the coefficient varies for all the measures with the same "moderate" cost-effectiveness category (from 0.9 for M7 till 1.25 for M8 and M10).

The last columns of Table 25 include fully quantitative cost-effectiveness assessment, which shows the estimated costs per 1 unit of the reduced P load (EUR/1 P kg). The measures are ranked in the table according to this result – starting with the most cost-effective measure (with the least costs per 1 reduced P kg, using the mid of the interval).

Due to the low cost-effectiveness the measures M1, M8 and M10 are not proposed as potential options. Also M12 and M9 could be seen as "second best" options (or not considered at all) – they have rather low effectiveness giving limited capacity to provide achievement of the required P load reduction.

Table 25. *Assessment on the cost-effectiveness of additional measures for P load reduction. (Source: Estimates developed as part of the project.)*

[1] Assessment using 5 categories from "very low" (1) to "very high" (5) cost-effectiveness (combining the effectiveness and costs' assessments).
[2] Calculated dividing the costs category (score) by the effectiveness category (score), where the costs score is changed from 1 being "very low" costs to 5 being "very high" costs. The coefficient can take value from 0.2 to 5. The lower it is, the better is the cost-effectiveness of a measure.
[3] Calculated dividing the estimated costs (EUR) by the delivered P load reduction (kg/year).
** These measures have limited capacity to provide achievement of the required P load reduction (due to their relatively low effectiveness). Hence they are not proposed as options for the WB scale analysis. Some of them have also the worst cost-effectiveness for P load reduction.*

	Cost-effectiveness assessment		**Yearly costs EUR per 1 kg of P reduction[3]**		
	Category[1]	**CE coefficient[2]**	**Lower**	**Upper**	**Middle**
M7 Sedimentation basins / traps	Moderate (3)	**0.90**	50	69	**59**
M4 Buffer bars	Moderate (3)	**1**	84	106	**95**
M2 Artificial (constructed) wetlands (surface)	Moderate (3)	**1**	83	227	**155**
M3 Controlled drainage	Moderate (3)	**1**	88	258	**173**
M11 Agricultural liming	Moderate (3)	**1**	384	460	**422**
*M12 Energy crops**	*High (4)*	***0.3***	*0*	*0*	***0***
*M9 Spreading of fertilizers at certain distances from waters**	*Moderate-High (3.5)*	***0.88***	*98*	*195*	***146***
M1 Artificial (constructed) wetlands (groundwater)	*Moderate (3)*	***1***	*546*	*1714*	***1130***
*M8 Crop rotation in arable land**	*Moderate (3)*	***1.25***	*1952*	*1952*	***1952***
*M10 Winter green areas (stubble fields)**	*Moderate (3)*	***1.25***	*777*	*4507*	***2642***

The results clearly demonstrate that the more quantitative is the cost-effectiveness assessment, the better results serve the prioritisation of measures for selecting the most cost-effective set of additional measures for WBs failing GES.

The given results can be used for WBs failing GES due to P pollution (they cannot be used concerning N since the measures' effectiveness and, hence, the cost-effectiveness differs for N). The prioritised list of the measures can be applied for selecting measures on WB scale when developing the program of measures – for the analysed WB G308 Jogla, but also for other WBs in the project area where the P load from agriculture (diffuse pollution from crop farming) needs to be reduced for achieving GES. When working on the WB scale, the primary issue to be analysed in possible application of the measures taking into account local conditions and also current application of a measures (which reduces applicability). The overall principle to guide the selection is to start with the most cost-effective measures and apply them as much as possible to achieve the required load reduction.

Such theoretical set of additional measures for G308 Jogla is provided in Table 26. But note that real applicability of each measure for the given WB is not analysed. Hence this result is just for illustrating the approach. The analysed measures with the lowest cost-effectiveness are not included in the list (M1, M8, M10). Also the measure *M12 Energy crops* is not proposed – although it has very good cost-effectiveness ratio, it has very limited capacity to provide load reduction.

For the given WB, even the first measure *M7 Sedimentation basins* could be sufficient for achieving the required P load reduction. If there are limitations in technical applicability of this measure in reality, also *M4 Buffer bars* can be considered in addition. Most likely there would be no need for other additional measures.

Table 26. *Illustration on selecting additional measures for the program of measures for WB G308 Jogla.*

[1] Nutrient modelling results (LEGMC).
[2] Assuming maximal (theoretical) application of the measures (real applicability is not analysed).

Required P load reduction for G308 Jogla, kg/year[1]	**45.8 kg**	
The proposed additional measures – RANKED starting with the most cost-effective measure	**The achieved P load reduction by each single measure (kg/year)[2]**	**Comments in relation to measures' selection for the program of measures**
M7 Sedimentation basins / traps	73.5	Top 1 measure. Also positive multiple effect (on suspended solids reduction, hydro-morphological quality elements)
M4 Buffer bars	73.5	Top 2 measures. Also positive multiple effect (on suspended solids reduction).
M9 Spreading of fertilizers at certain distances from waters	-	*Not proposed since it overlaps with the M4 Buffer bars, but implemented alone would not allow achieving the load reduction target.*
M2 Artificial (constructed) wetlands (surface)	147	No need for these measures since the required load reduction most likely could be achievable with the first measures in the list.
M3 Controlled drainage	122.5	
M11 Agricultural liming	55	

6. Programme of Measures

The measures in the current river basin management plans program of measures are divided in three groups and planned for each water body failing GES:

1. **basic measures**, which implementation is ensured by regulatory requirements for specific sectors and apply for all water bodies;
2. **national additional measures** which also apply to all water bodies but not included in the legislation;
3. **additional (also supplementary) measures**, which are defined for certain water bodies to improve the quality of the particular water bodies.

Chapters 6.1 and 6.2 give an overview about implementing measures and improving status for Estonian and Latvian water bodies in the project area.

It has to be noted that implementing measures creates assumption that the status of water bodies can and may improve. The change in status can take several years in nature, before the improvement reflects in the monitoring results. Therefore the proposed additional measures would have to be implemented during the next 4-5 years so the changes would reflect also in monitoring results before 2027. Some measures are already long overdue and have to be dealt with immediately. E.g opening migration routes for fish in salmonid rivers had a deadline of the 1 January in 2013 in Estonia.

Overview of measures is given in Annex 3.

6.1 Measures so far in Estonia

In the current water management period, there are altogether 128 measures planned for surface water bodies in project area. Since project area is forested area in the provincial area near state border, there are no basic measures for water bodies in project area. The 128 measures named are national additional and additional measures.

Thirty of planned measures in the current programme of measures (PoM) are implemented. Implementation is not necessary for 10 measures due to alteration in legislation. For 6 measures the implementation is in progress. As of the end of year 2018 the remaining 82 measures are not implemented. Some of these 82 measures are precaution measures for WBs in good status and the main aim is to keep the good status.

Status of some water bodies has been assessed worse, so the measures from the current PoM are not relevant for improving status. Also the knowledge and information about WBs has improved since the current PoM was compiled. So for some water bodies we already knew that additional measures are needed.

As there are already 32 water bodies which have reached their good status, the measures in current PoM are not a priority anymore and we have to deal with WBs which have been assessed worse.

The measures of current river basin management plan PoM are implemented through 2 year action plans. For every two year period a set of measures are under greater attention. There is overview of implemented measures compiled after every year. Information about implemented measures in project area about WBs that are not in good status is given in annex 3.

6.2 Measures so far in Latvia

In the current water management period 97 basic measures are outlined in Latvian RBMP. Basic measures include general requirements for bathing water quality, drinking water, use of sewage sludge, wastewater treatment, environmental impact assessment, reduction of nitrate pollution from agricultural activities, protection of surface water bodies and groundwater against pollution caused by plant protection products, preservation of biodiversity; protection of wild birds, protection of marine waters, prevention of accidents involving dangerous substances, protection of water resources. These activities are performed continuously, thus there are no measurable categories as “implemented” or “not implemented” available.

In the current water management period there are 30 national additional measures - the same for all water bodies in Latvia, except for Daugava RBD there are 31 national additional measure proposed. National additional measures include public educational activities, the need of various studies and evaluations to mitigate the impact of hydrological and morphological alterations of waters, as well as for improvement of regulatory enactments and planning documents, the need for different evaluations to develop future river basin management plans, and the need to improve access to information on water resources and their status. In the program of measures due dates for implementation of measures are set. Unfortunately, there are some measures which are already overdue, however, there are also some measures which, although the implementation deadline has expired, are still being implemented.

For water bodies is failing to achieve good ecological quality through implementation of basic and national measures, supplementary measures are needed. In the project area on Latvian side from 22 water bodies out of 63 in current Water management plans additional measures are proposed. There are some water bodies with more than one additional measure proposed, for example, Lake Burtnieks (E225) and River Salaca (G303SP). Only a few additional measures have been or are in a process of implementation, but it should be noted that public information on the implementation activities is not always easily available, so there might be some measures implemented even if there is no public information about them.

6.3 Additional measures on water body scale

Various measures should be selected and applied to achieve good ecological status and decrease the impact of pressures. Selection of measures on water body scale is based on results of economic analysis (*reference technical document*) as well as evaluation of feasibility for each measure – applicability, constraints, potential to reach good ecological status. After selection of either a single measure or a set of measures is proposed.

Measures to mitigate significant pressures causing failure of GES were proposed. Summary about additional measures in the project area is found also in Annex 3.

6.3.1 Estonia

In addition to measures in the current water management plan there is evaluated the need for additional measures to improve the status. The measures were developed to reduce the pressure of water bodies which are in bad, poor or moderate status. The measure is effective when it's targeted directly to improve bad, poor or moderate status. To find effective additional measures, economical evaluation of measures was conducted, which is outlined in Chapter 5.

As a result of the economic evaluation, there are proposed measures, which improve the status of surface water bodies. The economic evaluation was based on generalized data about pressures and their reduction measures. Since the economic analysis doesn't take into account the site-specific circumstances of every problem and measure, then the possibility of implementing measures and suitable solutions will be under evaluation with environmental impact assessment, the procedure for the environmental permit or with similar process.

There aren't additional measures developed for all water bodies, which status is bad, poor or moderate. For some water bodies there is no information what causes bad, poor or moderate status, monitoring data is episodic or there is no data at all. In these cases it is not possible to find measures to improve the status of the water body and it is necessary to conduct analysis to evaluate internal and external load or to find the source of pollution.

There are three different kind of pressures causing failure of GES for 5 water bodies in Estonian side. Table 27 gives an overview on pressures, water bodies and measures analysed in economic evaluation.

__Table 27.__ Overview on pressures, water bodies and measures analysed in economic evaluation.

Pressure	WB	Measures analysed
Hydro-morphological changes due to small-scale hydropower plants:	Vaidva_2	• Building of a fish pass • Demolishing a dam • Environmentally friendly turbine • Improvement of an existing fish pass
Hydro-morphological changes due to other dams and obstacles:	Pärlijõgi_1 Pärlijõgi_2 Pedeli_2	• Building of a fish pass • Opening migration way during spawning period • Demolishing a dam • Improvement of an existing fish pass
Accumulated nutrient pollution in lakes:	Köstrejärv	• Sediment dredging • Removal of macrophytes • Biomanipulation • Complex methods (sediment dredging and macrophytes removal)

Vaidava_2 is the only water body affected by small HPPs causing hydro-morphological pressures. There is an existing dam, hydropower plant and fish pass which is in need of improvements. The best measure from the economic evaluation of measures was M4 Improvement of an existing fish pass. Also M3 Environmentally friendly turbines will have a positive effect on the status of fish. Detailed information about dams and fish passes on Estonian side project area is presented in separate document *Overview on dams and fish passes in Koiva Water Bodies Without Borders project area in Estonia.*

Pärlijõgi_1, Pärlijõgi_2 and Vaidava_2 water bodies are according to the Minister of the Environment 15.06.2004 regulation no 73 “The list of spawning areas or habitats of salmon, brown trout, salmon trout or grayling” protected water bodies where it is obligatory to find solutions to ensure the migration of fish if there are dams in these water bodies.

There are dams without fish passes in Pärlijõgi_1. The best measure from the economic evaluation of measures was M2 Demolishing a dam. There are also Natura 2000 objectives concerning Pärlijõgi_1 since it is Natura 2000 habitat. Demolishing dams helps to achieve Natura 2000 objectives in the best possible way.

On Pärlijõgi_2 dams fish passes were constructed in 2012 and 2015. According to the surveys conducted in project area, all of these fish passes are in need of repair and improvements. The best measure from the analysis was M4 Improvement of an existing fish pass.

Pedeli_2 water body is not a salmon river and opening of migration routes is not obligatory. Nevertheless, the best measure to reduce impact from damming is to demolish dams - it is maintenance free and the most sustainable solution. Also building of a fish pass minimizes negative impact but it comes with maintenance costs. The choice whether to open migration routes has to be made based on expert opinion or results of environmental impact assessment.

Status of Õhne_2 water body is assessed as good. During the project, Õhne river dams and fish passes were checked. It was found out that the existing fish pass of Tõrva dam is in need of improvements. The monitoring point of Õhne_2 is downstream from Tõrva dam. So status of Õhne_2 may have been assessed as good inaccurately.

There are measures for lakes analysed only for Lake Köstrejärv, since enough information is available about this lake. The best measure for Lake Köstrejärv would be M4 Complex method, which means sediment dredging and macrophyte cutting and removal.

Table 28. gives an overview on additional measures on water body scale.

Table 28. *Overview of selection of new measures on water body scale for Estonia.*

Water body	**Measure**
Purpose: to reduce impact of hydro-morphological changes due to small-scale hydropower plants	
Vaidva_2 1158000_2	Improvement of an existing fish pass
	Environmentally friendly turbine
Purpose: to reduce impact of hydro-morphological changes due to other dams and obstacles	
Pärlijõgi_1 1155700_1	Demolishing a dam
Pärlijõgi_2 1155700_2	Improvement of an existing fish pass
Pedeli_2 1012100_2	Demolishing a dam or building of a fish pass
Purpose: to reduce impact of internal nutrient loading in lakes with accumulated nutrient pollution	
Köstrejärv 2133700_1	Complex method – Sediment dredging and macrophytes cutting and removal

As said before there are more water bodies with moderate or poor status but the exact reason for failing GES in not known. There are lakes that are not reaching GES – Aheru, Hino, Ähijärv and Pullijärv. Currently, there is not enough knowledge to select specific measures for these lakes. To select measures, limnological studies about inner and outer loads impacting the lake and its buffer capacity etc. are needed. Ecological status studies for Lake Pullijärv and Lake Ähijärv are in progress and therefore the results cannot be outlined here yet. There is also a need to conduct limnological studies for Lake Aheru and Lake Hino to propose measures for status improvement.

The study for Lake Kirikumäe was completed at the end of 2019. The status of Lake Kirikumäe is at the border between good and moderate. The lake is on the edge of its ecological tolerance and therefore additional anthropogenic pressures must be eliminated within the catchment of the water body.

Koiva, Mustjõgi_5 and Lake Murati water bodies' ecological status is good but chemical status is bad. There is no information about source of contaminants in the catchment area, it is necessary to conduct re-monitoring to find out if the concentration of pollutants exceeding the threshold is persistent. After re-monitoring there would be enough information to make a decision if there is a need to conduct a study to clarify the source of contaminants and to assess measures.

In the proceedings of relevant regulation, there has been made additional proposal about Ikla water body not to delineate it as a water body. According to experts and locals Ikla water body is small and was straightened in the past, it was excavated in the past on the Latvian side and water has been partially misdirected. The water body is waterless in the Estonian side and it's not reasonable to consider Ikla as a water body.

Estonian side of the project area is sparsely populated and the pollution load incurred in the Soviet era is significantly reduced. Still, there are many lakes which are sensitive to pressures and therefore there is a need to assess the impact of planned activities to the water quality before carrying out the activities. Thus, raising environmental awareness has an important role and it is reasonable to compose relevant information materials or to plan trainings.

6.3.2. Latvia

From the 63 water bodies in Latvian project area 24 which are failing GES - 20 river water bodies (including 4 transboundary river water bodies) and 4 lake water bodies. Appropriate additional measures were applied according to the pressures affecting the water body. Various measures to reduce impact of hydro-morphological alterations in rivers, to address accumulated nutrient pollution in lakes, and measures to reduce the impact of agriculture, forestry and land reclamation on water bodies were considered. As there are no water bodies in Estonian project area failing GES due to the impact of agriculture or forestry, measures targeting these sectors were considered only on Latvian side. Following the assessment of the cost-effectiveness appropriate measures were selected on water body scale (Table 29). Selection of measures on WB scale is based on results of economic analysis as well as evaluation of feasibility for each measure – applicability, constraints, potential to reach good ecological status. After selection either a single measure or a set of measures were proposed.

Selection of measures for lakes with accumulated nutrient pollution.

Internal nutrient load plays a significant role in lake ecology. Majority of P reserves in lakes are usually stored in bottom sediments, therefore P resuspension from sediments into the water column can act as a driving force for eutrophication processes and have greatly negative impact on the ecological quality of the lake. If external pollution sources are reduced or eliminated, lakes with accumulated nutrient pollution may still fail to reach good ecological quality due to internal recirculation of nutrients. There are two lake water bodies on Latvian side of project territory with accumulated nutrient pollution - Lake **Burtnieku (E225)** and Lake **Lielais Bauzis (E228)**. Various measures exist to address the issue, seven were analysed within the project:

1. Sediment dredging – removal of sediments form lake bed.
2. Biomanipulation – targeted fishing of cyprinid fish species.
3. Removal of macrophytes – harvesting and removing mocrophytes from lake, especially common reed (*Phragmites australis*) with the aim to remove nutrients with the plant biomass.
4. Immobilization of P using chemical treatments – application of various aluminium and calcium based chemical compounds to immobilise sediment P by turning P in the upper layer of sediments into insoluble, non-bioavailable forms.
5. Artificial aeration and mixing – oxygenation of lake by either injecting oxygen / air into the hypolimnion, or mixing lake water colum to bring hypoxic bottom waters to the surface.
6. Hypolimnetic withdrawal – suctioning and removing nutrient rich hypolimnetic water from the lake.
7. Floating treatment wetlands – artificial wetland islands with nutrient demanding plant species planted on them. Nutrients are removed from the lake during plant growth, plants are harvested after.

Majority of these measures can only be expected to be effective when external nutrient sources are not causing significant pressures on the lake, therefore measures that prevent external nutrient pollution (such as diffuse source pollution) need to be implemented prior to addressing internal lake nutrient loads. Three measures are proposed currently for improvement of the lake Burtnieka ecological quality - sediment dredging, macrophyte mowing and biomanipulation. Calculations were done to determine amounts of N and P possible to remove from the lake using biomanipulation and macrophyte removal, but the measures are not sufficient on their own in reduction of nutrient loads to reach good ecological status. Detailed limnological studies are needed with focus on in-lake distribution of nutrient pollution in sediments, sediment nutrient release and analysis of internal nutrient load. These lake studies would help to determine the most appropriate combination of measures for lake restoration.

Rivers with hydro-morphological pressures from small scale hydroelectric power plant dams.

On Latvian side of project territory three water bodies were identified, where main pressures causing failing GES are hydro-morphological changes from small HPP's: **G235 Vaidava_2** ("Karva" HPP, "Grūbe" HPP), **G317 Pedele_2** ("Dzirnavnieku" HPP, "Kalndzirnavu" HPP), **G322 Briede_1** ("Kārlīšu dzirnavu" HPP). A list of measures was proposed for mitigating negative impacts of hydro-morphological pressures from small HPPs. Measures then were compared in their efficiency in regards to achievement of good ecological quality. The parameters for evaluation include river continuity, fish migration and habitat areas, and ecological flow. Eight measures were initially proposed for small HPP's:

1. building of a fish pass;
2. reconstruction or improvement of an existing fish pass;
4. maintenance of an existing fish pass;
5. environmentally friendly turbine;
6. implementation of ecological flow (assessment and implementation);
7. demolishing a dam used for energy production;
8. permanently lowering the dam;
9. opening migration way during spawning period.

Second and third measures were proposed specifically for cases where fish pass exists already, but it is not functioning (one case – Karva HPP on Vaidava_2).

Rivers with hydro-morphological pressures from dams.

In Latvian project area there are three river WBs where hydro-morphological pressures are caused by dams – **G306 Salaca_1**, **G301 Salaca_1**, **G322 Briede_1.** A list of measures was proposed for mitigating negative effects of dams on WB ecological quality:

1. Demolishing the obstacle
2. Building of fish pass
3. Reconstruction or improvement of an existing fish pass
4. Maintenance of existing fish pass
5. Opening migration way during spawning period

There are some historically constructed dams with no current use in the Latvian project area - the only measure proposed for those dams is demolishing. For other dams that are used for economic or recreational purposes building a fish pass is considered as the second measure, if demolishing the dam is not possible due to the restraints, however demolishing the dam is the priority measure as it is the most effective for achieving all the parameters of GES in rivers with hydro-morphological pressures from dams.

Table 29. *Overview of selection of new measures on water body scale for Latvia*

Water body	Obstacle and measure / combination of measures
Purpose: to reduce impact of hydro-morphological changes due to small-scale hydropower plants	
Water body	Obstacle and measure / combination of measures
Vaidava_2 G235	*“Karva” HPP* - demolishing a dam *or* implementation of ecological flow + reconstruction / improvement and maintenance of existing fish pass.
	“Grūbe” HPP - implementation of ecological flow + building a fish pass.*
Pedele_2 G317	*“Dzirnavnieku” HPP* - demolishing dam *or* implementation of ecological flow + building a fish pass.
	“Kalndzirnavu” HPP - demolishing dam *or* implementation of ecological flow + building a fish pass.
Briede_1 G322	*“Kārlīšu” HPP* - demolishing dam *or* implementation of ecological flow + building a fish pass.
	“Sviluma” impoundment lake - demolishing a dam *or* building a fish pass.
	Impoundment lake on river Briede - demolishing a dam.
Purpose: to reduce impact of hydro-morphological changes due to other dams and obstacles	
Water body	Obstacle and measure / combination of measures
Salaca_1 G306	*Impoundment lake on river Nātrene “Ķāvu dzirnavezers”* - demolishing a dam or building a fish pass.
	Impoundment lake on river Lāčupīte “Grūbes dzirnavas/ Grūbes dzirnavu ezers” - demolishing a dam or building a fish pass.
	Impoundment lake on river Lāčupīte (2) - demolishing a dam.
Salaca_2 G301	*Impoundment lake on river Puršena (1)* - demolishing a dam.
	Impoundment lake on river Puršena (2) - demolishing a dam.
	Staicele dam on river Salaca - demolishing a dam *or* building a fish pass
Purpose: to reduce impact of internal nutrient loading in lakes with accumulated nutrient pollution	
Water body	Measure / measure combination
Burtnieka lake E225	Complex method - sediment dredging, biomanipulation and removal of macrophytes. Detailed lake studies are needed to determine the most appropriate combination of these measures.

Lielais Bauzis lake E228	Complex method - sediment dredging, biomanipulation, artificial treatment wetlands. Detailed lake studies are needed to determine the most appropriate combination of these measures.
Purpose: To reduce the impact of agriculture / reduce nutrient leaching (due to plant cultivation)	
Water bodies	Proposed measures to consider when developing basin management plans for the next period
Burtnieku ezers E225 Lielais Bauzis E228 Vija_1 G229 Melnupe_2 G233** Melnupe_1 G234 Vaidava_2 G235 Gauja_6 G241 Salaca_2 G301 Salaca_3 G303SP Iģe_1 G304 Jogla G308 Briede_1 G322 Blusupīte G325	• Artificial (constructed) groundwater wetlands • Artificial (constructed) surface wetlands • Controlled drainage • Buffer bars • Using of nitrogen stabilizers when applying nitrogen • Post-crops sowing after harvest / middle crops sowing (intermediate crops), catch crops • Sedimentation basins / traps • Crop rotation in arable land • Spreading of fertilizers at certain distances from waters • Using legumes in grasslands • Winter green areas (stubble fields) • Agricultural liming • Energy crops • Straw application in the field before winter sowing • Preparation of fertiliser management plans or improving of basic fertiliser management plans
Purpose: to reduce impact of forestry / reduce nutrient leaching (due to tree felling)	
Water bodies	Proposed measures to consider when developing basin management plans for the next period
Salainis E203 Lūkumīša ezers E204 Vija_1 G229 Gauja_6 G241 Salaca_2 G301	• Controlled drainage • Buffer bars • Sedimentation basins / traps
Purpose: to reduce the effects of reclamation in arable and/or forest lands	
Water bodies	Proposed measures to consider when developing basin management plans for the next period
Vija_1 G229 Iģe_1 G304 Blusupīte G325 Melnupe_1 G234 Vizla_2 G242 Salaca_1 G306 Rūja_4 G310 Rūja_2 G313 Ķire G315 Acupīte_2 G320	• Controlled drainage • Sedimentation basins / traps • Phosphorus filters • Stacks of stones • Meandering • Two-stage drainage ditches

*Additional evaluation is needed to determine whether building a fish pass would be a suitable measure for “Grūbe” HPP, as the power plant is constructed on an existing geological object - a dolomite platform, which might be a natural obstacle for fish migration.

**According to the latest monitoring data, the quality of the Melnupe_2 is rated as moderate, but this is questionable due to the fact that the monitoring station is located in a location that is unlikely to objectively represent the quality of the entire waterbody. The proposed measure is therefore linked to the choice of site for the monitoring station.

7. Practical results of measures

7.1. Ecological flow estimation for Vaidava River

Water quantity and hydrological regime have a critical role in the quality of aquatic ecosystems, including available habitat areas. According to EEA, about 40% of European water bodies are affected by hydro-morphological degradation, including habitat alterations. In the context of WFD environmental flow is “a hydrological regime consistent with the achievement of the environmental objectives of the WFD in natural surface water bodies” (CIS guidance document No. 31).

On Latvian side of trans-boundary water body Vaidava_2 (G235) two HPPs are located: “Karva” HPP (installed capacity: 480 kW, head: 11 m, turbine flow: 0.2-5.5 m3/sec, ecological flow: 0.94 m3/sec) and Grube HPP (installed capacity: 250 kW, head: 6 m, turbine flow: 5.0 m3/sec, ecological flow: 0.57 m3/sec). The water body G235 hydro-morphological quality is assessed as “bad” and ecological quality as “moderate”.

Input data

The mesohabitat simulation model (MesoHABSIM) was used for Karva and Grube HPP E-flow estimation. Model builds to predict the response of the aquatic fauna and flora to habitat changes. The types of mesohabitat are determined by their geomorphic (hydro-morphological) units (GUs), such as pools, riffles and rapids, substrate diversity and other hydrological characteristics. Vaidava River habitats were mapped during summer-autumn period of 2018 and 2019 in 4 water flow conditions: *min* (minimal) and *average* discharge *of low flow period*, water discharge *between low flow average* and *annual mean*, as well as water discharge *between annual mean* and *annual max (*maximum*)*.

Fish data were collected in 2018 within the same mesohabitats, where habitat surveys have been carried out. Data of every fish species and life stages are used to build a presence/absence and a presence/abundance model of fish. These data are used to develop mathematical models that describe which mesohabitats are used by fish more frequently. It gives the possibility to assess the availability of habitats at the different flow ranges.

Additionally, daily water flow series for normal (2015), wet (2016) and dry (2018) years in reference and altered conditions (upstream and downstream HPPs) have been created for river habitat modelling.

As a result, Habitat - Flow rating curves, Habitat Suitability (suitable, optimal, not suitable) maps, Habitat Time series and Integrity Indices have been calculated for each fish species of interest below Karva and Grube HPPs.

Modelling results & E-flow estimation

Habitat curves depending on flow rate, used for E-flow determination, were modelled for each fish species of interest (brown trout, stone loach, bullhead, etc.) that were pre-selected by fish expert. To establish the E-flow in the modelled river stretches, the Optimum flow (thereafter QOPTIMUM) should be chosen as a baseline. The QOPTIMUM is a flow value, at which the area of suitable habitat reaches its maximum, or continues to increase, depending solely on the surface area of the water. Herewith the maximum value of habitat area for juveniles is smaller than for adults and corresponds with smaller water discharge (Figure 13).

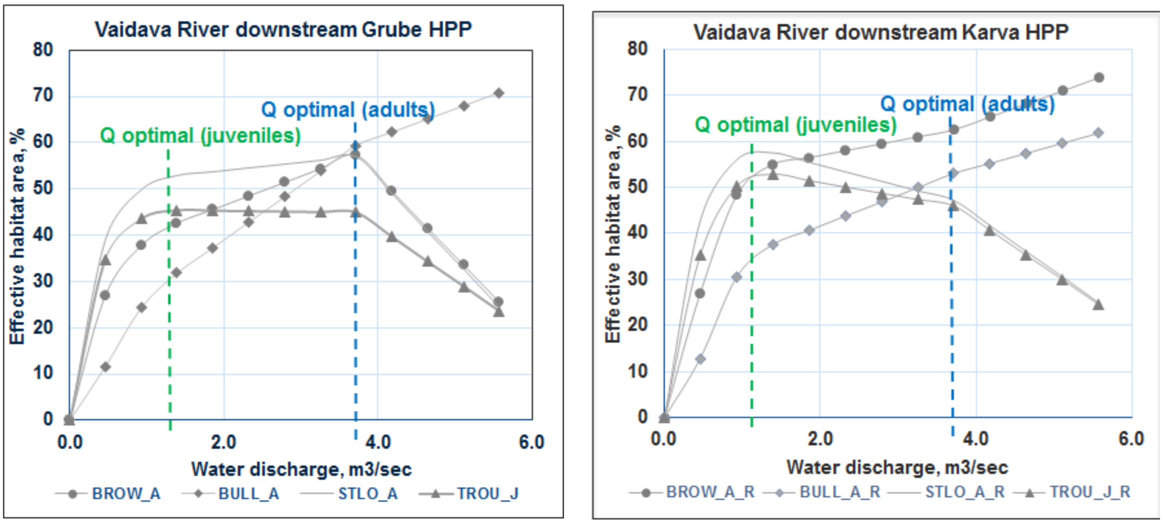

Figure 13. *Habitat-Flow rating curves of Vaidava River downstream HPPs (green arrow shows the optimal water discharge for juveniles and blue arrow – for adults).*

Consequently, it can be assumed that if the habitat area is the function of flow, then 0.6 of QOPTIMUM should guarantee at least good status of fish species of concern.

Table 30. *Estimated values of E-flow for adult and juvenile fish that should be provided by Karva and Grube HPP.*

E-flow estimation	**Karva HPP**	**Grube HPP**
QOPTIMUM (adult)*0.6	2.32	2.41
QOPTIMUM (juvenile)*0.6	0.66	0.71

Comparing of the E-flow values required by *Permissions of water resources use* are 0.57 m^3/sec for the Grube HPP and 0.94 m^3/sec for the Karva HPP, and these values are almost equal to the estimated E-flow for juveniles (Grube HPP) or even higher of it (Karva HPP). However, for adults these values are very low.

Conclusions

Modelling results shows close relationships between water flow and habitat availability as well as fish species presence/absence in hydrologically altered conditions.

Currently existing ecological flow for both HPPs of Vaidava River does not completely support the sustainability of Vaidava River aquatic ecosystems. It makes no sense that existing ecological flow for the downstream HPP is almost two times smaller than for the upstream HPP of the same river.

Project results show the necessity to provide the "ecological regime" in hydrologically regulated Vaidava River, and allow to estimate "winter E-flow" for salmonid fish spawning periods (from mid-October to May) and "summer E-flow" for growing of juveniles (from June to October).

8.2. Experience with small-scale filtration system

Lake Burtnieks is located in northeastern Latvia, in the administrative territory of Burtnieki County. Burtnieks is the fourth largest lake in Latvia with a total area of 39.01 km^2, its average depth is 2.2 m. The catchment area of the lake is 2250 km^2. The amount of water flowing into and out of Lake Burtnieks is ~ 0.487 km^3 and 0.485 km^3 per year.

The survey of the watercourses flowing into Lake Burtnieks was carried out on August 20, 2018. During the survey, water samples were taken to determine the nutrient content, the width and depth of the watercourse, its flow velocity, coastal overgrowth, land use in adjacent areas, and site availability for convenient filter construction.

Figure 14 shows the watercourses chosen for filter construction. These areas, around the watercourses, are active in economic activities (agriculture, animal husbandry, forestry), their size and stream speed are suitable for the installation and successful operation of the filters (small predicted runoff in spring floods) and have sufficient total P ($\geq$0.1 mg L-1).

Figure 14. *Locations of watercourses chosen for filter construction*

Filters installed in the ditches discharging into Burtnieks are 10 m long, 3 m wide and 1 m deep. A 50 m long water sedimentation basin is formed in front of the filter where suspended particles (mainly sand and organic matter) settles. This prevents rapid filter clogging.

The filter is made of moisture-resistant plywood at the ends of the structure, the geotextile filter bed, and 110 mm diameter perforated pipes for diffusing incoming water (Figure 15). The ends of the water distribution pipes are designed to be cleaned if necessary (Figure 16).

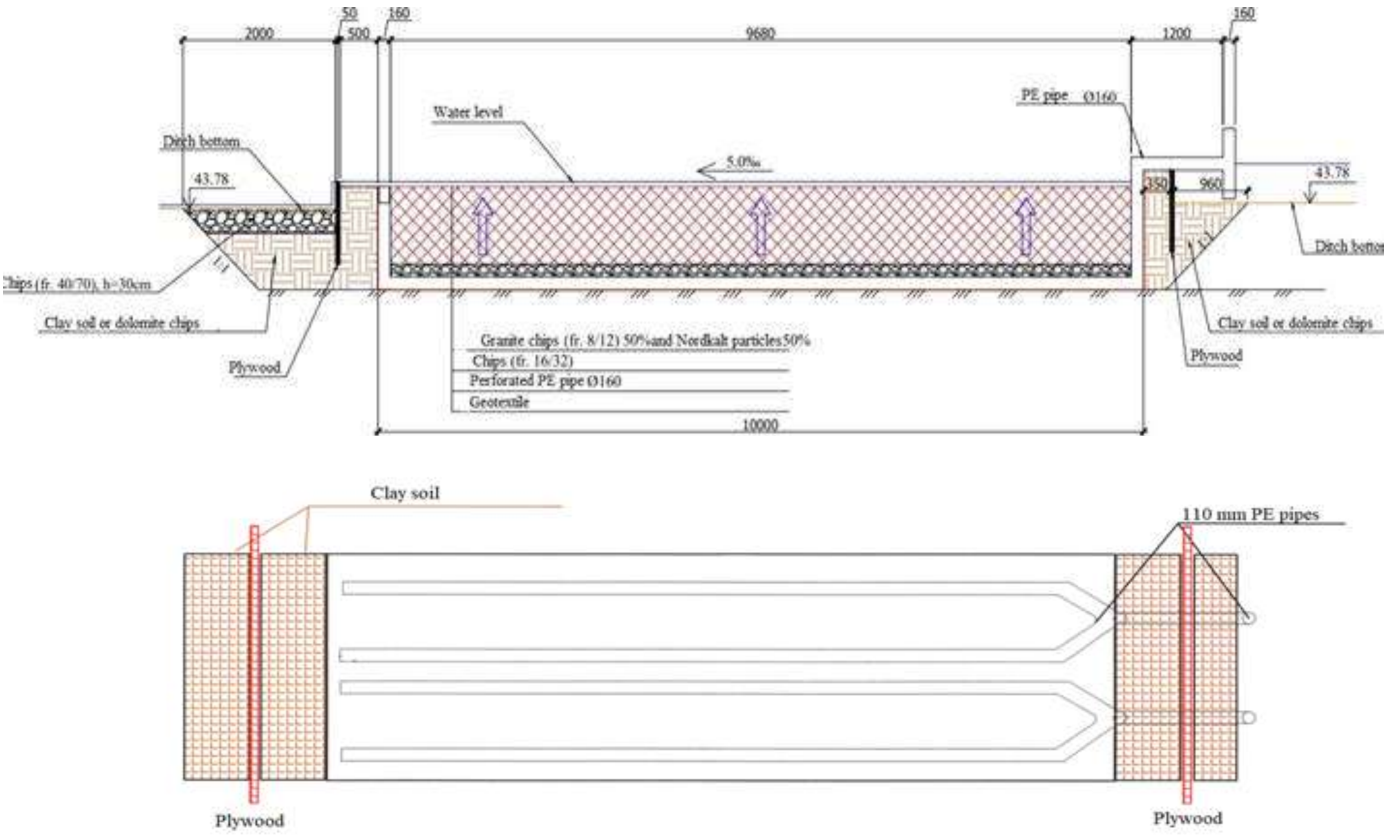

Figure 15. *Schematic representation of P filter. Top - side view, bottom - top view.*

The filter fill is calcium-containing material. All installed filters are filled with dolomite (CaMg (CO3) 2) chips. Two filters built in the ditch with the highest water flow rate, filled with 30 m^2 dolomite chips of 16 - 32 mm fraction. Filters built into ditches with lower water flow rate are filled with 12 - 16 mm fraction dolomite chips and 2 m^2 of Nordkalk ™ calcium hydroxide (Ca (OH) 2) granules added. After contact with the calcium P dissolved in water precipitates and forms and forms insoluble compound. The simplified P precipitation reaction is illustrated as follows:

$$5Ca^{2+} + 3PO_4^{3-} + OH^- \rightarrow Ca_5(PO_4)_3OH$$

Figure 16. *P filters on small ditches around Lake Burtnieks*

The effectiveness of the filters installed in the watercourses is assessed by sampling water before and after discharge into the filter. Concentrations of total N and P and their compounds (NO3, NO2, PO4) were determined in the water samples taken once a week starting December 13, 2019 for two months. The results obtained are shown in Figures 17. and 18. The results show the characteristics of filtration material impact on the reduction of P concentration.

For filter # 1 (Figure 17 - A), dolomite chips with a fraction of 16 - 32 mm are used, which provide faster water throughput and shorter contact time with the filtering material. Under heavy rainfall, there is also an overflow of ditch water which results in no water filtration.

For filter # 2 (Figure 17 - B), a mixture of dolomite chips (12 -16 mm) and calcium hydroxide granules were used. Figure 18. shows that the P concentration in the water discharged from the filter in six cases out of nine measurements is 15 - 85% lower than in the inflowing water.

The filter # 3 (Figure 17 - C) is filled with 12 - 16 mm fraction of dolomite chips. Also in this filter a decrease in P concentration was observed in six of the nine samples with a PO4 concentration reduction of 1.5 - 42%. However, this filter is impacted by water overflow which reduces the amount of precipitated P.

For filter # 4 (Figure 17 - D), dolomite chips of 16 - 32 mm fraction were used as the filter material, ensuring a smooth flow of water through the filter without overflow. In the case of heavy rainfall, the water filter structure didn’t function properly, resulting in no change or higher PO_4 concentration in the effluent than at the inlet.

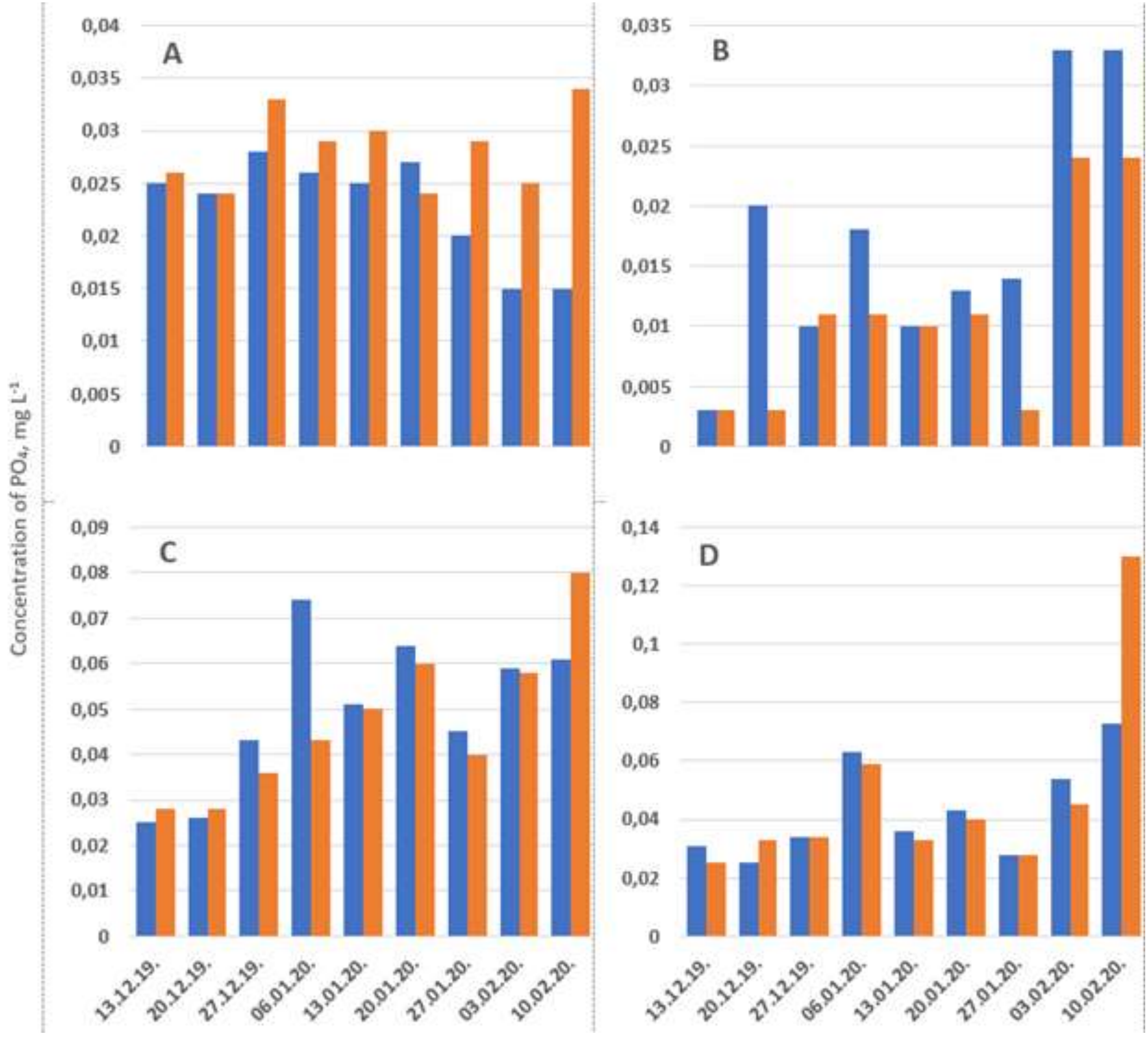

Figure 17. *Changes in PO_4 concentration. Blue - PO_4 concentration in water before entering the filter construction, orange - PO_4 in water after discharge of the filter structure. A - Filter # 1, B - Filter # 2, C - Filter # 3, D - Filter # 4.*

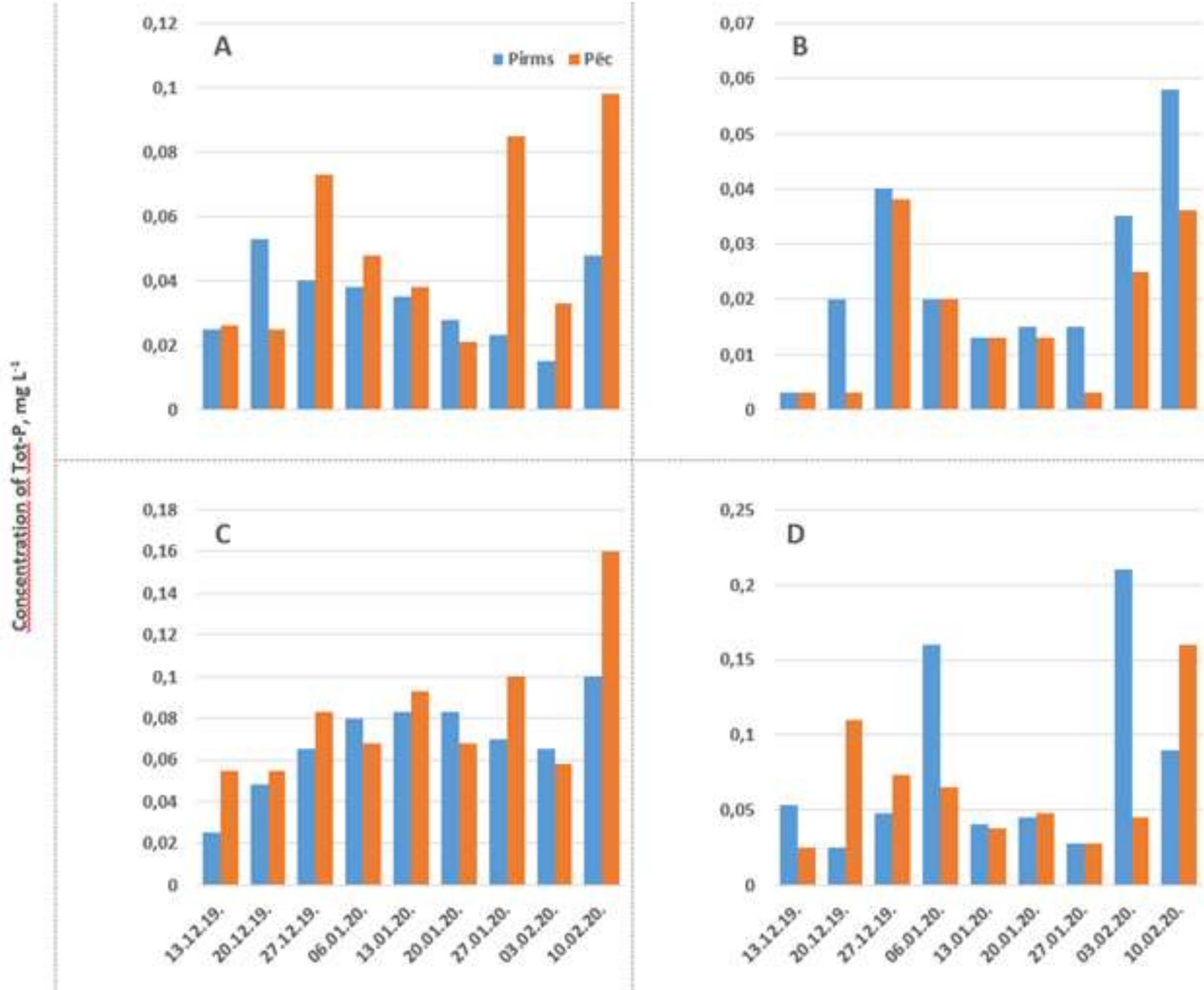

Figure 18. *Changes in total P (Tot-P) concentration. Blue - Tot-P concentration in water before entering the filter, orange - Tot-P content of the water at discharge from the filter structure. A - Filter # 1, B - Filter # 2, C - Filter # 3, D - Filter # 4.*

Conclusions

Effectiveness

Phosphate (PO_4) and total P concentrations were monitored to evaluate the effectiveness of the P filters in the ditches in the Lake Burtnieks catchment area. The concentrations of these forms of P were compared with water at the inlet to the filter design and with water at the outlet from the filter structure. The results obtained show that the efficiency of the filters is mainly influenced by the filtration material chosen.

The best results are provided by Filter # 2, whose filter material consists of a mixture of 12 - 16 mm fraction of dolomite chips and calcium hydroxide granules. This filtration material provides not only adsorption of P (dolomite) but also precipitation (calcium hydroxide). P reduction was also observed in Filter # 3, which used 12 to 16 m fraction of dolomite chips. However, due to regular water floods, the amount of adsorbed P is relatively small.

Filters # 1 and # 4 use dolomite chips of 16 - 32 mm fraction. These filters are less effective in reducing P than the other two. This is due to the rapid flow of water, which is facilitated by the coarse fraction of the filtration material. As a result, the contact time between water and dolomite is too short to absorb more P.

The performance of the filters was adversely affected by the heavy rainfalls, which caused extremely high water levels. As a result, water overflows were often observed in ditches with filter constructions. Under these conditions water is only partially filtered. Rainfall also facilitated the inflow of additional water into the filter structure directly from surrounding areas along the ditch slopes.

In order to be able to objectively evaluate the performance of the filters, it is necessary to continue monitoring for the rest of the year 2020. This would demonstrate the ability of filters to reduce P concentrations at low water flow rates and longer contact times between water and filtration material.

The total catchment area of the ditches selected for the construction of the filters is 14.39 km^2. It is 156 times smaller than the Burtnieks catchment area (2250 km^2). It can be concluded that the four watercourses discharging into Lake Burtnieks where P filters are installed account for less than 2.7% of the total P load of the three largest rivers discharging into the lake. Taking into account that the installed P filters do not work with 100% continuous efficiency (complete P removal from water), the resulting decrease in P load to Lake Burtnieks is no more than 2% of its total P load.

One of sources of Burtnieks P load is agriculture in the catchment area. In order to create a significant reduction in the P load to Lake Burtnieks, it is necessary to limit the use of P-containing fertilizers. The installation of P filters in all watercourses flowing into the lake is not possible due to different size, availability of suitable space and legal considerations. Therefore, these types of filters cannot serve as the primary and most effective solution for reducing P loads on Lake Burtnieks, but it is a good option to combine with other measures.