REPORT ON WATER QUALITY RESULTS

Output 3.2 of Interreg Baltic Sea Region project NOAH

Protecting Baltic Sea from untreated wastewater spillages during flood events in urban areas

Sisällys

1 Introduction

NOAH project's Work package 3: Taking control and ensuring prevention focuses on decreasing spillages of untreated wastewater from urban drainage network to the Baltic Sea by enhancing capacity of water utilities responsible for urban drainage system operation. For that, WP3 experimented and introduced new solutions in drainage system operation not widely used before in urban conditions. The idea was to install on-line sensors (measurement stations) and actuators (gates) into the existing system to utilize the capacity of the pipeline to accumulate excessive flows and thus avoid combined sewer overflows to the natural waters. In some cases, adjustments in the operation of the existing facilities (pumping stations) was also helpful to achieve this target.

The procurement and installation of investments were procured in six NOAH pilot areas (Rakvere, Haapsalu, Jurmala, Ogre, Liepaja, Słupsk) with a combined sewer system. Söderhamn and Pori were selected as reference pilot sites, where no installations were made, but which were monitored e.g. water sampling. All the pilot areas are situated in different regional conditions in 5 different countries. This was needed to eventually generalize the results and make them applicable for whole BS region regardless of the local regulations and environmental conditions.

First activity of WP3 was data acquisition from pilot UDS systems in 6 partner towns and utilities (A3.1). The aim of the activity was to collect necessary information about the existing urban drainage system (UDS) in order to detect combined sewer overflows (CSO) and treatment plant bypasses (WWTPBP) that can be controlled by implementing real time control in A3.3. This activity serves as an input provider for the next activities in WP3.

Herein is the intermediate report (O3.2) on pilot areas, undertaken actions, faced challenges, and found solutions. The report includes the following information about 6 pilot sites:

1) Drawings and technical information about selected CSO-s and WWTPBP-s (Chapter 2)

2) Blueprints of existing water quality measurements and measurement plan (Chapter 3 and 4)

3) Water quality analysis procedure (Chapter 4)

4) Water quality analysis results before and after pilot investment (A3.4) (Chapter 5)

5) Results of water quality modelling after pilot implementation of extreme weather layer in A2.4. (Chapter 6)

6) Guideline for following water quality sampling and modelling procedure in any urban area in BS region. This section will be eventually added into project handbook (A4.3) (Chapter 7)

For further progress in WP3 the report was used as an input for compilation of Real Time Control (RTC) algorithms for urban drainage system (UDS) – as the main objective of these routines was to minimize the degradation of water quality (by avoiding untreated wastewater spillages from CSO-s and WWTPBP-s). Therefore O3.2 was base to the main activity of investments (A3.4) and from there to the main investments output in WP3 (O3.4).

The final report (O3.2) on undertaken actions, faced deficiencies and final solutions was published at the end of period 5 (30.6.2021).

2 Descriptions of the pilot areas

2.1 Haapsalu

Haapsalu is a town on West Estonia's Baltic coast, located in an oasis typical of the north-west coast of Estonia. The town's coastline length is 18 km and the area 10.6 km². A total of 67 % of the town area is covered with greenery (parks, recreational areas etc.). Due to the coastline length and ground elevation, the city is open to seawater flooding. Old drainage systems, bottlenecks in pipelines and incomplete information on the town's drainage system were contributing to rainwater flooding. The pilot area was divided into two, corresponding to actual stormwater system catchment areas.

The stormwater systems were mapped, and water samples were taken from stormwater outflows. The old depreciated dam of the wetland, which was the buffer for rainwater outflow before the sea, was replaced with a new automatic weirwall (Smart Weirwall System). The system consists of a moveable gate and two sensors, installed into a new manhole. Implementing Real-Time Control (RTC) can (1) prevent seawater backflow in case the sea level rises higher than level in the wetland (= flood protection), (2) ensure sufficient retention time of the urban stormwater in the wetland before letting the water to the sea (= water treatment).

2.1.1 System description

The stormwater system in Haapsalu is managed by Haapsalu City Government. Sewage and stormwater systems are separate. The pilot area is located at the south part of Haapsalu, corresponding to actual stormwater system catchment areas. Due to the coastline length and ground elevation, the city is open to seawater flooding. Old drainage systems, bottlenecks in pipelines and overall incomplete information on the town's drainage system are contributing to rainwater flooding.

Stormwater outflow is a wetland that is a buffer before reaching the sea. The wetland is surrounded by a dam designed to protect seawater inflows into stormwater systems. The dam has 2 manually closable weirs that are in a very poor condition and release seawater to the wetland, which places a burden on stormwater systems. The NOAH project aim was to replace the existing depreciated concealment system with a new automatic weirwall system. The location of the pilot area is indicated by a blue circle in the Figure 1.

Figure 1. Aerial Photo of Haapsalu with pilot area (blue) and outfall of the stormwater system (red).

2.1.2 Description of selected solutions

There were no existing control, actuators, sensors or SCADA system in use before. The implemented location of the RTC is at the new automatic weirwall system. The system consists of moveable gate and two sensors situated at the opposite sides of the gate. All the equipment was installed into a new manhole that replaced the existing obsolete gate. Local street-lighting control system was used to host the remote control and monitoring environment.

The effect of the solution was, that it keeps the water level in the downstream lagoon low during the high water tables in the Haapsalu bay or in extreme rainfall events, which leads to reduced sewer overflows in the city.

2.2 Rakvere

Rakvere is a municipality in northern Estonia, 20 km south of the Gulf of Finland of the Baltic Sea. There are two waterbodies in Rakvere, Soolikaoja creek and Tobia mainditch. The Tobia mainditch flows down to the Soolikaoja creek, the Soolikaoja flows down to river Selja and the river flows to the Baltic sea. The Tobia mainditch catchment area is 31,8 km^2 and the Soolikaoja catchment area 122,1 km^2. The selected pilot area of about 1 km^2 is located in the middle of the town. According to the climate scenarios, this area has the highest flood risk.

Storm Water Management Model (SWMM) of the area was created, calibrated and validated based on measurements made on the site. Movable weir with Real-Time Control (RTC) was installed for the Soolikaoja creek to reduce flooding in the downstream city by using the storage capacity in an upstream lake. The construction works of the system was completed by the end of 2020. Extreme Weather Layer (EWL) as a planning tool for more flood resilient urban space is the second outcome of the modelling. It was implemented with a dynamic feature allowing the municipality to create maps for flood risk for different development scenarios and climate projections.

2.2.1 System description

Rakvere pilot catchment with an area of 177 ha has a fully separate stormwater system built with several outflows to Soolikaoja stream (both stream and tunnel). Soolikaoja is a natural stream passing the town and has been enclosed to 1.2 m wide tunnel in the central part of the town. There are no pumping stations and automatically adjustable actuators in the system. Upstream part of Soolikaoja takes stormwater from two residential areas and some roads. There are several static overflow weirs on the stream before water ends up in Süsta pond with an area of 7000 m^2 and depth of ca 1.5m. Inflow from Soolikaoja streams to the pond varies between ca 10 – 1000 m^3/h (it is highly dependent on the precipitation and snowmelt). Figure 2 shows a map and images from the catchment.

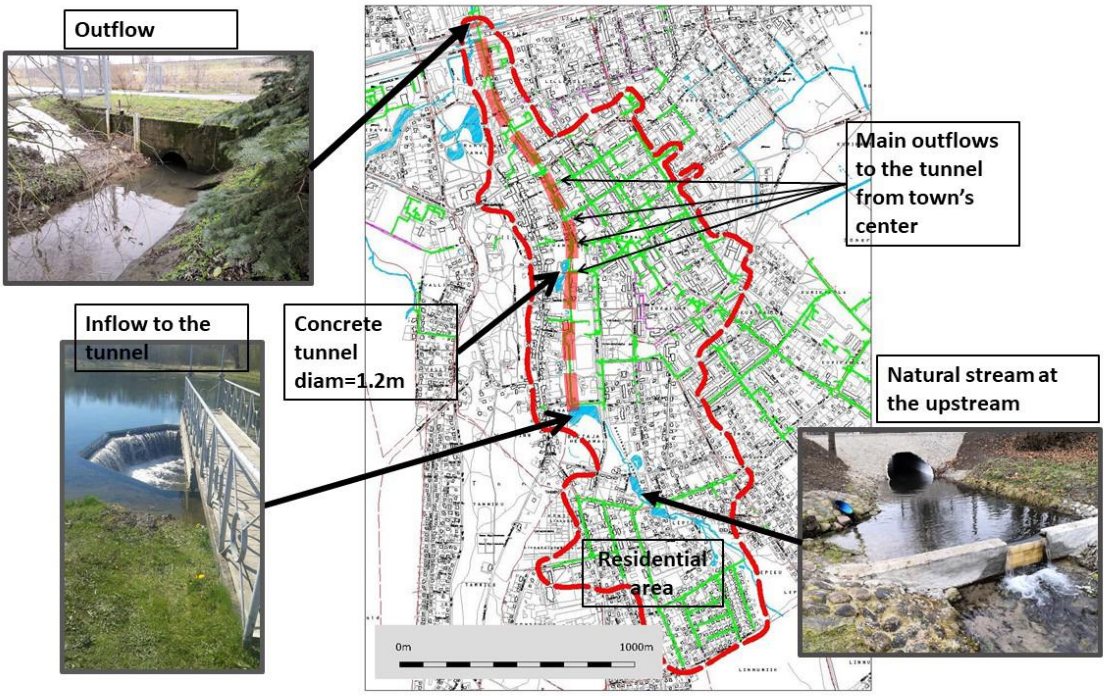

Figure 2. Images of water infrastructure and a map of the catchment.

The outlet from the Süsta pond is a weir and since the water from this, flows through the limited capacity stretch in the center of the city it can worsen problems with flooding.

There is hexagonal overflow well at the southern part of pond from where water enters to Soolikaoja tunnel. The tunnel has length of 1.7 km and diameter of 1.2 m, construction material is concrete. There is substantial accumulation of sediments in some sections of the tunnel. Four main stormwater collectors situated at the centre of the town are directing the water to this tunnel. After 1.7 km water will continue flowing in natural ditch leading to the Baltic Sea. Water level in the ditch + sediments are dictating the outfall elevation.

2.2.2 Description of selected solutions

The scope of the RTC setup in the Rakvere pilot was to reduce flooding in the downstream city by using the storage capacity in the upstream lake. The RTC setup in the Rakvere pilot was done by installing a movable weir (Smart Weirwall System) that can raise its weir crest based on a signal from a sensor in the city and thus providing 30 cm of additional depth in the lake.

The effect of selected solution is reduced downstream flooding and risk of pollution spillages from wastewater system during flood events.

2.3 Pori

Pori is a town on the south-west coast of Finland, located about 10 kilometers from the Gulf of Bothnia on the estuary of the Kokemäenjoki river. The NOAH pilot area is Suntinoja ditch catchment area from where water exits into the Kokemäenjoki river, which is the 4th largest waterbody catchment area in Finland. The catchment area consists of fields, forests and an urban residential area. The ground surface is flat, which increases drainage problems and stormwater and snowmelt flood threat. Besides the risk to property, flooding increases contaminant and nutrient migration into the Baltic Sea. The Suntinoja ditch was originally designed for drainage of agricultural areas, so its capacity may not be enough in heavy rainfall situations, and it may begin to flood residential areas through stormwater drains.

Main ditches of the area were mapped, and calibration measurements were carried out by the city of Pori. Storm Water management model (SWMM) was created for the area. The modelling determines the effects of different types of heavy rain events and can be used to examine the impact of residential construction on Suntinoja's capacity. Water sampling was conducted to analyze the quality of the stormwater and for modelling it in different flood situations. No actual Real-Time Control (RTC) installations were made since the outflow from the system is not restricted as the outlet pump has large capacity, and since the system performs similarly in terms of flooding throughout the city. The actual problem is more linked to the water level in the surrounding ditches and the related risk of flooding. Pori is not implementing technical innovations in the NOAH project but as stormwater samples have been taken the pilot area will be described and the samples assessed.

2.3.1 System description

The city of Pori (Finland) is located close to a river which maximum water level frequently is higher than the outlets of the drainage system, in which case the stormwater from the city need to be pumped into the river. Figure 3 shows an aerial photo of the city.

Figure 3. Areal photo of Pori (Googlemaps).

The SWMM model of the Pori pilot area was skeletonized so that only pipes with D>200 mm and the related manholes were included. The main reason for that was the data availability. Most of the pipes with smaller diameters (and the related manholes) did not have any elevation data in the GIS.

The model results from an extreme rain event, see Figure 4, indicates that the current system has a rather uniform performance, since the magnitude of the surcharging flows are more or less the same throughout the city. Some individual nodes do have significant high surcharging flows than the average but there are no areas that stand out as more flood prone than others.

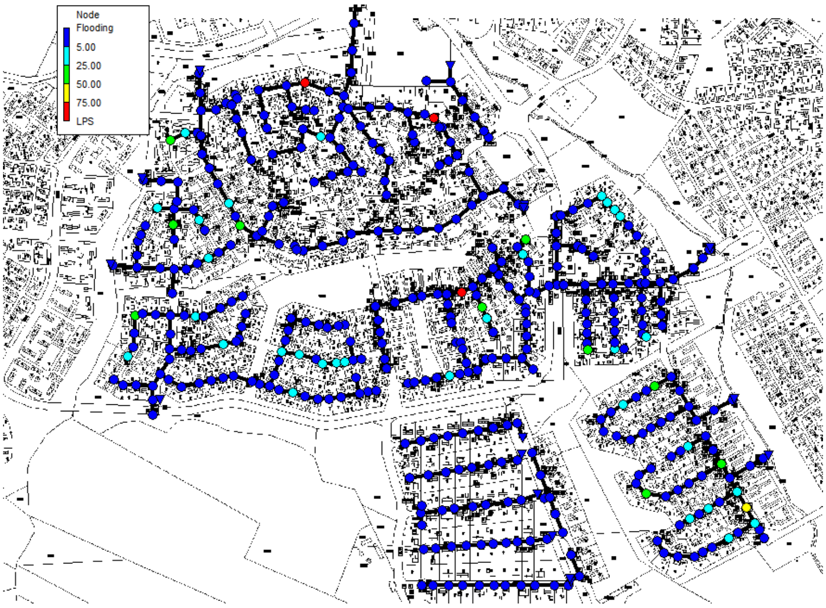

Figure 4. SWMM model result showing the flow from surcharging nodes for an extreme rainfall event.

2.3.2 Description of potential solutions

There were no existing actuators in the pilot area, just one pump that was not included in the model. Due to elevation differences near one outlet, water from the UDS is directed to a tank and then pumped to the surrounding ditch. The pump and tank were not included in the model as it was assumed that the capacity of the pumping station is larger than the outflow from the UDS.

Since the outflow from the system is not restricted due to the large capacity of the pump at that outlet, and since the system performs similar in terms of flooding throughout the city there is not much control potential. The actual problem is more linked to the water level in the surrounding ditches and the related flooding risk, which cannot be solved by RTC.

2.4 Jurmala

Jurmala is situated on the southernmost shore of the Gulf of Riga, by the drainage basin of the Lielupe river. The pilot area consists mainly of forested areas and low-rise residential buildings, landscape can be characterized as rather flat. Roofs constitute around 9.5 % and paved roads up to 14 % of the total catchment area. The rainfall collection system is a separate sewer system with several sanitary sewer connections from households. Run-off is conveyed by gravity pipelines and roadside ditches. System discharges into the Lielupe river. For NOAH, three sections of the area have been chosen as pilot sites. The sections are actual storm water catchments, chosen to study the city area evenly.

Storm Water Management Model (SWMM) was created for the area. Through modelling, Real-Time Control (RTC) was implemented by transforming a node (joining point of pipeline and ditch) into a pumping station to see the changes in the system discharge during dry weather and during rainfall. The main investment in Jurmala was an automatic hydrological station (AHS). The purpose of AHS was to develop a better process control and management system in regard to the city's storm water and waste water system as well as their potential interaction, especially during rain events. This includes not only the modelling but also precipitation, storm water level and waste water flow measurements as well as storm water sampling.

Miera street is located in the Eastern part of Jūrmala, Latvia (see Figure 5). The pilot area consists mainly of forested areas and low-rise residential buildings. Landscape can be characterized as rather flat since invert elevations of the highest point in the system and the outfall differ by 3.08 m (distance between the points 1.4 km). Roofs constitute around 9.5 % of the total catchment area. Paved roads add up to 14 % of the total catchment area.

Figure 5. Miera catchment location and discharge point.

2.4.1 *Description of selected solutions*

Pump was installed at the outlet from a part of the storm water system where the dry weather flow is particularly polluted. The pumping is controlled so that the dry weather flow is transported to the sanitary sewer system but the much cleaner water during rain events is allowed to flow to the recipient.

The effect of selected solution is expected to be reduction in nutrient load to the recipient.

2.5 Liepaja

Liepaja is located in western Latvia, between the Baltic Sea and the lake of Liepaja. For NOAH, Tebras street catchment basin with a separate storm sewer was chosen for detailed inventory. The area of the catchment basin is approximately 19 ha. Low-rise residential buildings mostly occupy the area, impervious surfaces consist of roofs (42 %) and paved roads are (8 % of total area). The stormwater sewer outlet of the catchment discharged water into the Lake of Liepaja. There was a problem related to backflow from the lake with water standing still all the way from the outfall to the pump.

Hydraulic model of the Tebras street catchment basin was developed to (a) clarify how the sewer functions under different circumstances, (b) examine whether it is possible to add new connections to this catchment basin in the future, (c) understand the quality of water drained from the catchment basin, (d) examine the possibility of using project partner experience from Haapsalu in application of a smart weir wall system or usage of a tidal check valve, which would allow stormwater flow only in one direction. Additional pilot activities were performed in the northern part of Liepaja nearby Tosmare lake. This part of the city is enclosed by Cietokšņa channel. There was a plan to install two water level sensors in Cietokšņa channel, as the territories around the channel are potential flood areas and sensors are needed to indicate water level rise in the channel. The main problem was that the Cietokšņa canal outlet into the Baltic Sea was clogged and the adjacent areas were flooded.

2.5.1 *System description*

The Tebras street catchment in Liepaja (Latvia) is a paved street area with low rise residential buildings (Figure 6). The area in orange is also a low rise residential area, but it is paved with gravel and no gullies. The area is fairly flat and the outfall is connected to the lake.

There is a problem with backflow from the lake from the outfall to the pump with water standing still all the way to the pump. There are areas planned to be connected to the catchment which are shown in the first picture and there is doubt about the system’s capacity to take in such connections.

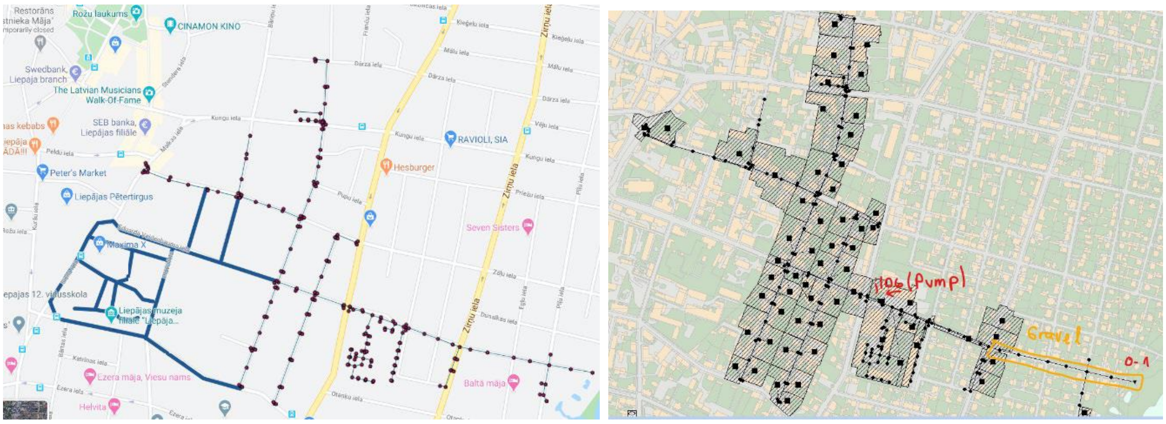

Figure 6. (Left) Map of the area. The blue lines indicate streets and pipes in the new area that might be connected to the existing system. (Right) Image of the SWMM model of the existing system. The pumping station is indicated with a hand written "Pump" and the outlet is just below the "0-1" annotation.

2.5.2 Description of selected solutions

A tidal gate and a pump were installed at the outlet to prevent sea water from backing up into the drainage system. The gate to control the inflow from a newly connected area was not recommended. The potential effect of the pilot change is a less negative effect of high tide in the recipient.

2.6 Ogre

Ogre is located alongside the Ogre river approximately 50 km from the Baltic Sea coastline. The pilot area of Ogre has been selected due to its significant flood problem and estimated future challenges caused by climate change. The focus is on the Loka street neighborhood, which has developed from a low swampy meadow. The surface water run-off has been organized with a network of open ditches along the streets, draining into the Ogre river. Due to intensive detached housing construction, part of the ditches has been arbitrarily filled or the culvert elevation marks have been misaligned. This has led to a loss of functionality of the existing drainage network. To control surface run-off, the municipality must provide rainwater drainage from the street and adjacent areas by creating a single network. Therefore, the municipality has started the gradual construction of a rain drainage piping system, which NOAH installations support.

Storm Water Management Model (SWMM) was created for the area. Measurements of the Ogre riverbed upwards from Daugava river water reservoir will be performed (including measurement data processing and cartographic material preparation). Sensory locations as well as the technical design of the Automated Hydrological Stations (AHS) were identified and evaluated. Three automated hydrological stations with a non-return tidal gate and a pump were constructed and installed.

2.6.1 System description

The city of Ogre is situated in Latvia close to the river Ogre (Figure 7and Figure 8).

Figure 7. Areal picture of the catchment.

Figure 8. Data of the system and a birds view of the SWMM model.

The stormwater system of the pilot area drains to the river. The biggest problem for this pilot site is that when the water level in the river rises due to ice blockages in the spring, the outlet from the stormwater can become blocked, which causes flooded basements due to stormwater that cannot be drained to the river, or due to river water that runs backwards through the drainage system.

2.6.2 Description of selected solutions

Sensors were placed only for water level measurements in Ogre river. There are no control systems in the stormwater system, except for one flap gate ("C" on Figure 9).

Figure 9. The outlets from the system.

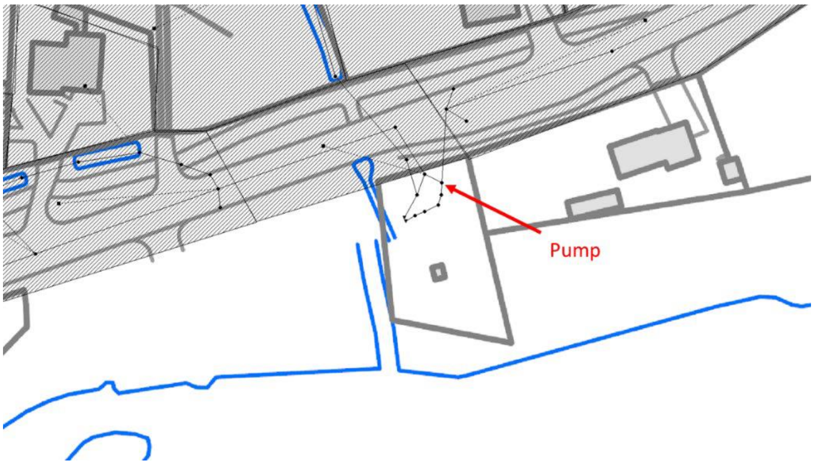

Figure 10. Suitable location of a pump.

As the biggest problem for this pilot site is when water level rises in Ogre river (caused by ice blocking in the spring), the pump could be used to pump floodwater from rainwater sewerage system to the riverside, in such a way ensuring floodwater pumping out of the basements of inhabitants, who are connected to the drainage system (Figure 10).

2.7 Słupsk

Słupsk is situated in northern Poland, about 20 km from the Baltic Sea coast, on the Slupia river. The pilot area covers the entire city (22 km^2). The Słupsk sewer system includes 2 % of combined sewer pipes which drain 7 % of the analyzed area. Even though the share of combined sewer system is small, approximately 30 % of the total flow originates from the stormwater entering the sewer system via unsealed manholes and pipes. This poses a risk to the wastewater treatment plant (WWTP) and to the Slupia River, which is the recipient of overflows. The modelled network has one main outflow from which the wastewater and storm water is pumped to the WWTP. The excess which cannot be pumped is stored in the retention tank upstream the pump or discharged to the Slupia River.

Storm Water Management Model (SWMM) was created for the area. To collect data, precipitation meters (rain gauges) with an automatic data archiving system and remote transmission were installed in six locations in the city. In addition, devices for measuring the level of filling of the main sewage channels were installed in 12 locations. In order to improve on the flooding issues in the city, there is a need for retaining and delaying water upstream of the affected areas. A Real-Time Control (RTC) scheme with a detention volume has the potential to do this by controlling the outflow from the basin based on downstream water level sensors in the vulnerable areas.

2.7.1 System description

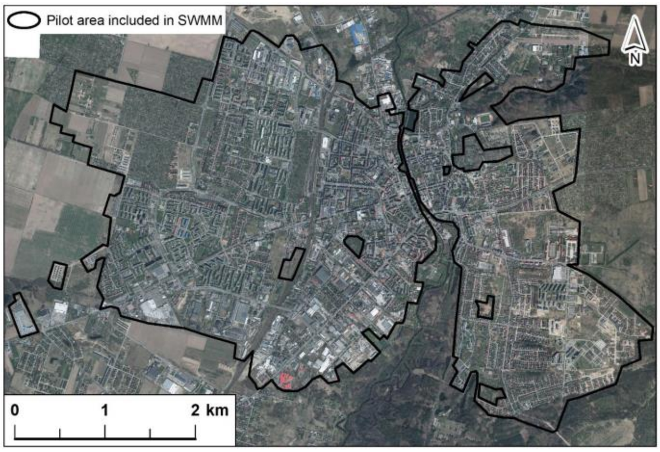

Figure 11. Aerial Photo of pilot area

The pilot area network model covers the entire city of Słupsk (22 km^2) and is presented in Figure 11 and Figure 12. The model consists of 5608 pipe sections and 5511 nodes (junctions). The sewer system includes 2 % of combined sewer pipes only which drain 7 % of the analysed area. Even though the share of combined sewer system is small, approximately 30 % of the total flow originates from the storm water entering the sewer system via unsealed manholes and pipes. Such contribution poses a risk to the wastewater treatment plant (WWTP) and to the Słupia River, which is a recipient of overflows. The modelled network has one main outflow from which the wastewater and storm water is pumped to the WWTP. The excess which cannot be pumped is stored in the retention tank upstream the pump or discharged to the Słupia River. The total capacity of the tank is 493 m^3, however the retention capacity of the system (tank + main pipes) is nearly 2000 m^3. The modelled network is presented below.

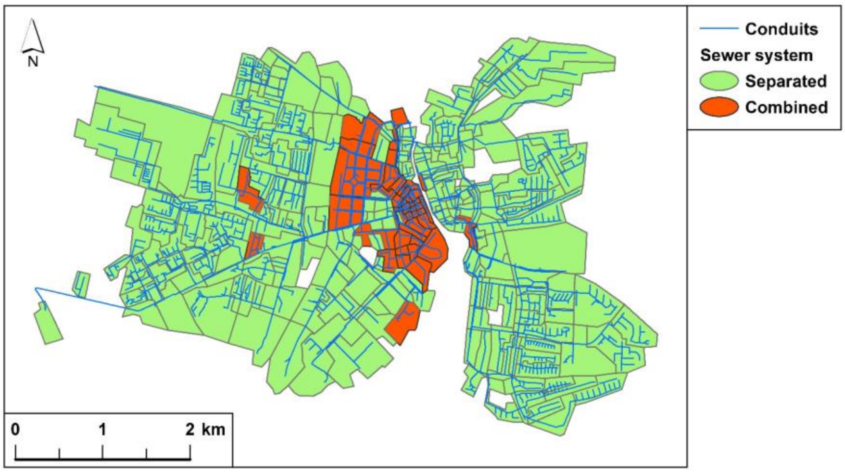

Figure 12. Conduits and catchments simulated in the Słupsk pilot area using SWMM

2.7.2 Description of selected solutions

The total volume of wastewater and storm water pumped out of the analysed area is monitored in the main pumping station with a temporal resolution of 10 minutes. The data is available online for the Słupsk Water Supply, however, for the external use (e.g. for the modelling purposes) can be exported periodically only.

There are also twelve wastewater/stormwater level sensors and six rain gauges installed in the pilot area in December 2019 as a part of the NOAH project. Both types of monitoring devices operate with a temporal resolution of 10 minutes and transmit data once a day. One of level sensors is installed in the sewer overflow just before the outlet of the analysed area – in the storage tank upstream the main pumping station.

There are three locations indicated by the Słupsk Water Supply as prone to flooding during heavy rainfalls. These locations and the closest SWMM nodes are presented in Figure 13-15.

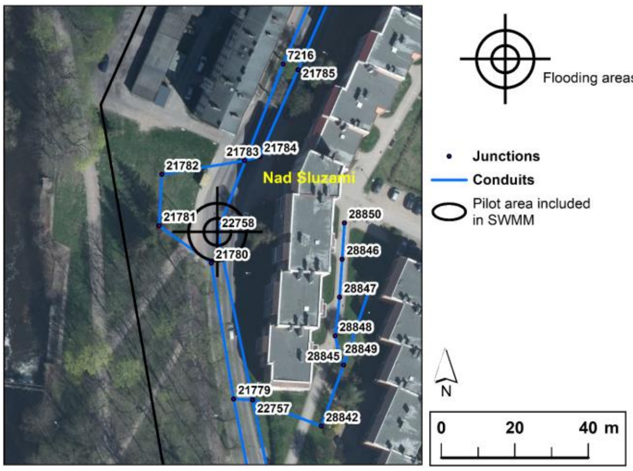

Figure 13. Location [1]: Nad Śluzami Str. (SWMM node 22758)

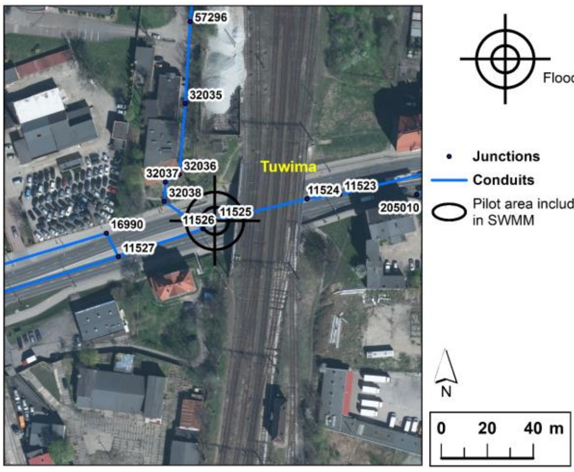

Figure 14. Location [2]: Tuwima Str. under the railroad overpass (SWMM node 11525)

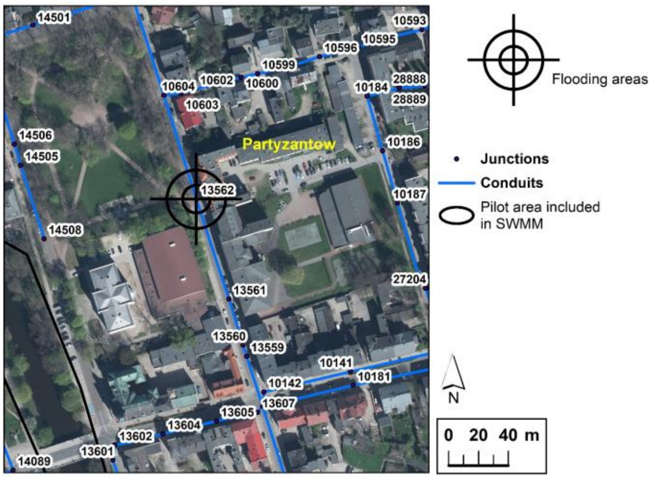

Figure 15. Location [3]: Partyzantów Str. along a school and a park (SWMM node 13562)

These locations may serve as virtual sensors which will control actuators (orifices) upstream. According to the information provided by the Słupsk Water Supply there is no sufficient capacity of the sewer system upstream these locations to retain the excessive water during periods of flooding. Therefore, there is a need of additional retention capacity in a form of tanks, or preferably low impact development solutions which allow to store storm water before it enters the sewer system.

2.8 Söderhamn

Söderhamn is a coastal municipality located in the bay of Söderhamn, at the outlet of Söderala river. The pilot area was chosen because the central parts of Söderhamn are most severely affected when a heavy rainfall occurs. In addition, some densification of the area is expected to happen with new buildings, changes in park areas and streets. The Söderhamn pilot area consists of 11 sub-catchments. Four of them have outlets to a natural stream and the rest to the narrow bay of the Baltic Sea, most of them submerged. The stormwater from e.g. roofs is still directed to the sewer system and therefore there are several combined sewer overflow (CSO) structures. These CSOs are equipped with backflow valves to avoid seawater entering the sewer.

Storm Water management model (SWMM) is created for the area and calibrated on the basis of flow measurements. Extreme Weather Layer (EWL) as a planning tool to create more flood resilient urban space is the main outcome of the modelling. Flood risk maps for different climate scenarios will be embedded to the municipality’s urban planning procedure. This allows urban planners to evaluate the impact of any development plan on climate resilience.

Söderhamn pilot area consists of 11 sub-catchments (Figure 16 and 17). Four of these have outlets to the natural stream and the rest to the narrow bay of the Baltic Sea. The outlets to the bay are typically submerged. The stormwater from some areas such as roofs are still connected to sewer system and therefore there are several CSO overflow structures in the system. These CSOs are equipped with backflow valves to avoid seawater entering to the sewer. Ground slope is quite steep towards the stream/bay with a height difference of approximately 10 meters, see Figure 16. Söderhamn is not implementing technical innovations in the NOAH project but as stormwater samples have been taken the pilot area will be described and the samples assessed.

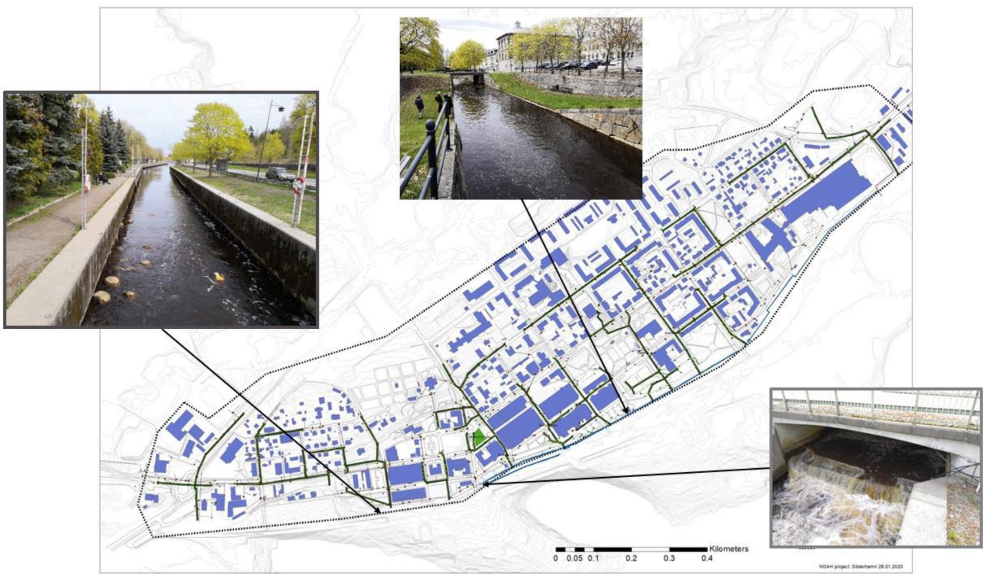

Figure 16. Height map of the pilot site and some photos of water infrastructure.

2.8.1 Description of potential solutions

The main pumping station of the wastewater system in the pilot area is equipped with remote control system. There are no actuators and sensors installed to separate stormwater system (Figure 17).

Figure 17. System description and picture of SWMM model.

There is not much RTC potential in the system as the ground slope is very steep and stormwater system has enough capacity because of several outlets. As a result, water flows quickly to the bay. There are problems related to sea level rise – which will be focused in NOAH in terms of urban planning improvement (see the blue areas on the Figure 18).

A possibility for RTC could be to protect the blue areas with dyke and then control the pumping/opening gates according to sea level elevations and precipitation. This is, however, more a dimensioning issue than a control issue.

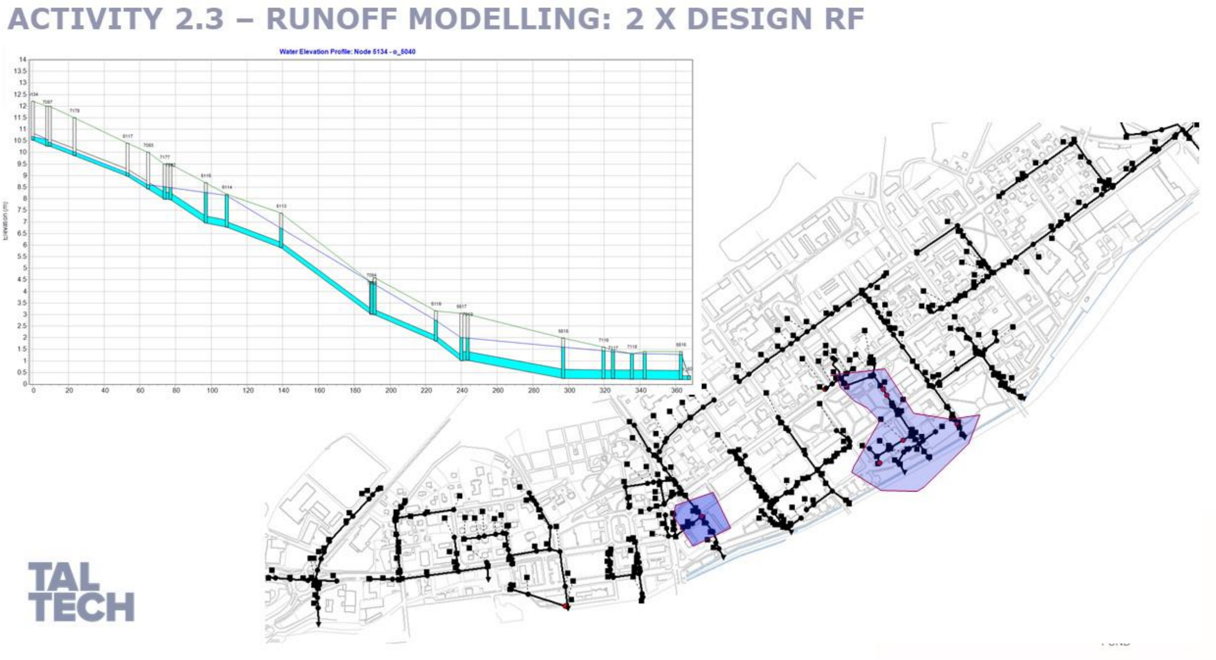

Figure 18. Areas negatively affected by sea level rise (blue areas on the map).

The combination of steep gradients and little storage volume in the system makes it difficult to achieve much with RTC. If additional storage was build upstream in the catchment, then RTC could be used to control the emptying of this storage based on downstream conditions. While RTC can improve the utilization of upstream storage volumes, it does not change the overall cost-benefit analysis of implementing basins that much. In a well-run utility like Söderhamn such storage would already have been added to the system if it was worth the investment. This more than indicates that it is not worth implementing even though RTC should be used to control the emptying of the storages.

3 Water quality measurements

The most common contaminants in stormwater are solids, nutrients, metals, chloride, and oils and fats, and some other organic compounds, such as polycyclic aromatic hydrocarbons (PAHs) and pesticides. In addition, stormwater often contains high amounts of intestinal bacteria. Substances that endanger the quality of groundwater and occur in stormwater include e.g. pesticides, anti-slip agents and methyl tertiary butyl ether (MTBE). At its best, stormwater management is based on local observational data collected on stormwater quality, but extensive measurement studies involving numerous contaminants often lack resources. Fairly good information on stormwater quality can be obtained by monitoring the amount of solids transported, as solids are generally considered to be the most important parameter for stormwater quality. Many of the adverse water effects of stormwater are either directly or indirectly related to the transport of solids and the contaminants they contain. The solid as such clouds the water and accumulates in networks and stormwater storage structures. In addition, contaminants, such as phosphorus and metals, are carried with the stormwater when bound to the solid. On a case-by-case basis, it is necessary to determine several different contaminants from stormwater. The substances to be analysed should be selected on the basis of the land use of the area and the activities located on it. For example, numerous chemicals are used and stored in industrial areas, in which case the assessment of the risks associated with stormwater may in practice require site-specific assessments before the actual measurement of stormwater quality.

3.1 Sources of emissions

Harmful substances end up in stormwater, e.g. dry and wet deposition, traffic exhaust fumes, corrosion of vehicles and building materials, wear of road materials and anti-slip agents. The omission of lead from fuels has led to the use of MTBE in large quantities as a petrol additive. MTBE is very harmful to groundwater due to its low taste and odour threshold. MTBE is transported e.g. from exhaust gases highly water-soluble storm water

The assessment of the total amount of substance leached from the catchment area during the load and run-off event, ie the run-off, requires not only the concentration but also information on the run-off formed during the monitoring period. High concentrations can occur with very low rainfall or melting cycles. In this case, however, the amount of stormwater and the leaching of substances during the event remain small. On the other hand, during heavy and prolonged rains, the concentrations of the substance may be very low, but the leaching may be multiple compared to the leaching caused by the light rains. Concentration is therefore not a sufficient measure of the effects of stormwater quality, but a reliable assessment requires a long-term review of pollutant-specific leaching - for example for a year - on a catchment scale. In addition to land use, the quality of stormwater is affected by a number of different factors, such as the season, rainfall and rainfall intensity, the physical characteristics of the catchment area and the length of the pre-drainage dry season. The amount of impermeable surfaces affects the amount of material leaching, especially as less water can be infiltrated. The areas with a high percentage of impervious surface can be expected to generate higher contaminant loads than areas with lower percentage of impervious surface, especially during the summer.

The pollution in urban areas is derived from different sources. Many pollutants enter the urban catchments as wet and dry deposition. Others are released from various parts of the catchments due to corrosion processes and as waste of construction, renovation and demolition works. A considerable amount of pollutants is generated in the urban catchments, mainly by vehicular traffic. The mass flow of these pollutants can be evaluated by the formulation of a simple mass balance in urban catchments including input, permanent and temporary storage, controlled and uncontrolled losses, and output. combustion exhausts, leakages, and abrasion products from vehicles (tire wear, brake linings) or roads (pavement wear). In fact, a complex mixture of pollutants is generated. It is well known that combustion exhausts contribute to the urban atmosphere significant amounts of carbon monoxide, NOx, lead and polycyclic aromatic hydrocarbons (PAH). Actually, lead emissions in Europe are of minor importance if compared to NOx emissions, which may be responsible for at least a part of the forest degradation.

Leakages of fuels, motor oils, and lubricants are spilled everywhere on roads, but they are concentrated at parking lots and near traffic lights. They are partly volatized (degraded with time), when exposed to strong heat (absorption of sun-light on dark-coloured pavements).

The amount of abrasion products from tires in urban catchments depends on the volume of traffic, the distribution of traffic lights, the road conditions, and the driving habits. According to different brands, the composition of tire materials varies significantly. Considering moderate driving, the average rate of tire wear is approximately 80 mg/vehicle km.

Brake emissions are closely related to traffic volume, rush-hour effects, traffic light distribution, and to a considerable extend, to driving habits. Brake lining compounds contain a complex mixture of heavy metals and phenolic binders. While 10-20 % of abrasive materials are brake entrained, the rest is emitted in the form of gaseous or particulate materials. In general, abrasive particulate matter of brake linings has a particle size of less than 10µm.

3.2 Chemical characteristics

3.2.1 pH

Description: The pH of natural waters is a measure of the acid-base equilibrium achieved by the various dissolved compounds, salts, and gases. Specifically, pH is the measure of the amount of free hydrogen ions in water. A pH of 7 is considered to be neutral. Acidity increases as pH values decrease, and alkalinity increases as pH values increase. Most natural waters have a pH between 7-7.5. Changes in pH affect the toxicity of many compounds found in water.

Effects on Watershed / Health: The pH of water affects the solubility of many toxic and nutritive chemicals which affects the availability of these substances to aquatic organisms. High alkaline waters can be unpalatable and cause gastrointestinal discomfort.

3.2.2 Conductivity

Description: Conductivity is a measure of the ability of water to pass an electrical current. Conductivity in water is affected by the presence of inorganic dissolved solids such as chloride, nitrate, sulphate, and phosphate anions (ions that carry a negative charge) or sodium, magnesium, calcium, iron, and aluminium cations (ions that carry a positive charge).

Natural Sources: Native Geology

Human-caused Sources: Industrial Discharges, Failing Sewage Systems

Effects on Watershed / Health: Conductivity outside normal ranges may not support certain fish or macroinvertebrate species.

3.2.3 Biochemical Oxygen Demand (BOD)

Description: Biochemical Oxygen Demand (BOD) measures the amount of oxygen consumed by microorganisms when decomposing organic matter in water under aerobic conditions.

Natural Sources: Leaves and Woody Debris, Dead Plants and Animals, and Animal Manure

Human-caused Sources: Effluents from Pulp and Paper Mills, Wastewater Treatment Plants, Feedlots, and Food-Processing plants; Failing Septic Systems; and Urban Stormwater Runoff

Effects on Watershed / Health: BOD directly affects the amount of dissolved oxygen in rivers and streams. The greater the BOD, the more rapidly oxygen is depleted in the stream. This means less oxygen is available to higher forms of aquatic life. The consequences of high BOD are the same as those for low dissolved oxygen: aquatic organisms become stressed, suffocate, and die.

3.2.4 Total Suspended Solids (TSS)

Description: Total Suspended Solids (TSS) is a term used to describe the amount of organic and inorganic particulate matter suspended in water. TSS is also related to turbidity.

Natural Sources: Erosion, Seasonal Changes in Algae Population

Human-caused Sources: Land Development

Effects on Watershed / Health: High TSS concentrations interfere with recreational uses and the aesthetic enjoyment of water. They also can have negative impacts on fish and aquatic life in many ways including, preventing the successful development of fish eggs and larvae, modifying natural migrations, reducing the amount of food available, and by reducing growth rates and disease resistance or causing death. TSS can also impact invertebrate populations and decrease dissolved oxygen levels if the material is organic.

How to Correct: Limit land disturbing activities. Use proper sediment and erosion controls. Sweep sediments from paved surfaces to prevent them from entering storm drains.

3.2.5 Dissolved Oxygen

Description: Dissolved oxygen (DO) is the amount of oxygen present within the water and is necessary for the respiration of aquatic organisms such as fish. The stream system both produces and consumes oxygen. It gains oxygen from the atmosphere and from plants as a result of photosynthesis. Running water, because of its churning, dissolves more oxygen than still water, such as that in a reservoir behind a dam. Respiration by aquatic animals, decomposition, and various chemical reactions consume oxygen. DO levels fluctuate seasonally and over a 24-hour period. They vary with water temperature and altitude. Cold water holds more oxygen than warm water and water holds less oxygen at higher altitudes.

Effects on Watershed / Health: Low dissolved oxygen levels are not adequate to support aquatic life and can lead to fish kills.

How to Correct: Decrease the amount of oxygen consuming nutrients entering the water. Aerate water to increase dissolved oxygen levels by mixing colder water with warm surface water. Decrease activities which raise the temperature of the water.

3.2.6 Ammonia

Description: Ammonia is a nutrient that contains nitrogen and hydrogen. Its chemical formula is NH_3 in the un-ionized state and NH^{4+} in the ionized form. Total ammonia is the sum of both NH_3 and NH^{4+}. Total ammonia is what is measured analytically in water.

Natural Sources: the decomposition or breakdown of organic waste matter, gas exchange with the atmosphere, forest fires, animal and human waste, and nitrogen fixation processes.

Human-caused Sources: Fertilizers, Failing Septic Systems, Waste Water Treatment Plant (WWTP) Discharges, Pet Waste, Livestock and Farm Animals, Industrial Discharges.

Effects on Watershed / Health: Natural factors that can affect the concentration of ammonia include: algal growth, decay of plant or animal material, and fecal matter. Other aspects of nitrogen cycling can also affect the amount of ammonia present. Ammonia can also come from domestic, industrial or agricultural pollution, primarily from fertilizers, organic matter or fecal matter. Together with phosphorus, nitrates in excess amounts can accelerate eutrophication, causing dramatic increases in aquatic plant growth and changes in the types of plants and animals that live in the stream. This, in turn, affects dissolved oxygen, temperature, and other indicators. Excess nitrates can cause hypoxia (low levels of dissolved oxygen) and can become toxic to warm-blooded animals at higher concentrations (10 mg/l or higher) under certain conditions. The natural level of ammonia or nitrate in surface water is typically low (less than 1 mg/l); in the effluent of wastewater treatment plants, it can range up to 30 mg/l.

How to Correct: Do not over fertilize lawns or over water to the point of runoff. Do not dump grass clippings, leaves, or other yard debris near streams or rivers. Pick up and dispose of pet waste properly.

3.2.7 Nitrites and Nitrates

Description: Nitrates are a form of nitrogen, which is found in several different forms in terrestrial and aquatic ecosystems. These forms of nitrogen include ammonia (NH_3), nitrates (NO_3), and nitrites (NO_2). Nitrates are essential plant nutrients, but in excess amounts they can cause significant water quality problems.

Natural Sources: Leaves and Woody Debris, Dead Plants and Animals, and Animal Manure

Human-caused Sources: Fertilizers, Failing Septic Systems, Waste Water Treatment Plant (WWTP) Discharges, Pet Waste, Livestock and Farm Animals, Industrial Discharges

Effects on Watershed / Health: Together with phosphorus, nitrates in excess amounts can accelerate eutrophication, causing dramatic increases in aquatic plant growth and changes in the types of plants and animals that live in the stream. This, in turn, affects dissolved oxygen, temperature, and other indicators. Excess nitrates can cause hypoxia (low levels of dissolved oxygen) and can become toxic to warm-blooded animals at higher concentrations (10 mg/l or higher) under certain conditions. The natural level of ammonia or nitrate in surface water is typically low (less than 1 mg/l); in the effluent of wastewater treatment plants, it can range up to 30 mg/l.

How to Correct: Do not over fertilize lawns or over water to the point of runoff. Do not dump grass clippings, leaves, or other yard debris near streams or rivers. Pick up and dispose of pet waste properly.

3.2.8 Total Kjeldahl Nitrogen

Description: Total Kjeldahl Nitrogen is the total amount of organic nitrogen and ammonia nitrogen present in water.

Natural Sources: Decaying Plant Debris, Wildlife

Human-caused Sources: Fertilizers, Failing Septic Systems, Waste Water Treatment Plant (WWTP) Discharges, Pet Waste, Livestock and Farm Animals

Effects on Watershed / Health: Excessive concentrations of nutrients can overstimulate aquatic plant and algae which can lead to depletion of dissolved oxygen levels in the water.

How to Correct: Do not over fertilize lawns or over water to the point of runoff. Do not dump grass clippings, leaves, or other yard debris near streams or rivers. Pick up and dispose of pet waste properly.

3.2.9 Dissolved Phosphorus

Description: Phosphorus is a nutrient, along with nitrogen, necessary for the growth of algae and other plants. It aids in photosynthesis and usually is found in low levels in surface waters.

Natural Sources: Soil and Rocks

Human-caused Sources: Fertilizers, Failing Septic Systems, Waste Water Treatment Plant (WWTP) Discharges, Pet Waste, Livestock and Farm Animals, Disturbed Land Areas, Drained Wetlands, and Commercial Cleaning Preparations

Effects on Watershed / Health: Since phosphorus is the nutrient in short supply in most fresh waters, even a modest increase in phosphorus can, under the right conditions, set off a whole chain of undesirable events in a stream including accelerated plant growth, algae blooms, low dissolved oxygen, and the death of certain fish, invertebrates, and other aquatic animals.

How to Correct: Do not over fertilize lawns or over water to the point of runoff. Do not dump grass clippings, leaves, or other yard debris near streams or rivers. Pick up and dispose of pet waste properly.

3.2.10 Total Phosphorus

Description: Phosphorus is a nutrient, along with nitrogen, necessary for the growth of algae and other plants. It aids in photosynthesis and usually is found in low levels in surface waters.

Natural Sources: Soil and Rocks

Human-caused Sources: Fertilizers, Failing Septic Systems, Waste Water Treatment Plant (WWTP) Discharges, Pet Waste, Livestock and Farm Animals, Disturbed Land Areas, Drained Wetlands, and Commercial Cleaning Preparations

Effects on Watershed / Health: Since phosphorus is the nutrient in short supply in most fresh waters, even a modest increase in phosphorus can, under the right conditions, set off a whole chain of undesirable events in a stream including accelerated plant growth, algae blooms, low dissolved oxygen, and the death of certain fish, invertebrates, and other aquatic animals.

How to Correct: Do not over fertilize lawns or over water to the point of runoff. Do not dump grass clippings, leaves, or other yard debris near streams or rivers. Pick up and dispose of pet waste properly.

3.2.11 Lead

Description: Lead is a metal element widely used in industry.

Natural Sources: Lead is an element often found in very low concentrations in the natural environment.

Human-caused Sources: Batteries, Gasoline, Paint, Caulking, Rubber, and Plastics

Effects on Watershed / Health: Heavy metals cause a variety of problems including interfering with vitamin uptake, neurological disorders, and disruption of renal function. These problems result from chronic and cumulative exposure. Lead causes a variety of neurological disorders in humans, particularly inhibiting brain cell development in children. It also prevents the uptake of iron in the body leading to anemia.

3.2.12 Cadmium

Description: Cadmium is a metal element widely used in industry and often found in industrial waste discharges.

Natural Sources: Cadmium is an element often found in very low concentrations in the natural environment.

Human-caused Sources: Widely used in industrial processes.

Effects on Watershed / Health: Heavy metals cause a variety of problems including interfering with vitamin uptake, neurological disorders, and disruption of renal function. These problems result from chronic and cumulative exposure. Cadmium is a cumulative toxicant that replaces zinc in the body; it is toxic to both humans and fish.

How to Correct: Dispose of industrial by-products appropriately.

3.2.13 Copper

Description: Copper is a metal element widely used in industry.

Natural Sources: Copper is an element often found in very low concentrations in the natural environment.

Human-caused Sources: Metal Plating, Electrical Equipment, Pesticides, Paint Additives, and Wood Preservatives.

Effects on Watershed / Health: Heavy metals cause a variety of problems including interfering with vitamin uptake, neurological disorders, and disruption of renal function. These problems result from chronic and cumulative exposure.

How to Correct: Dispose of industrial by-products appropriately. Do not over fertilize lawns or over water to the point of runoff.

3.2.14 Zinc

Description: Zinc is an essential element in trace amounts for plants and animals; it is involved in healing and other biological processes.

Natural Sources: Mineral deposits in the soil.

Human-caused Sources: Metal and other Manufacturing Industries, Fertilizers, Household Products, Pharmaceuticals

Effects on Watershed / Health: Zinc toxicity is not generally a problem, but heavy metals cause a variety of problems including interfering with vitamin uptake, neurological disorders, and disruption of renal function. These problems result from chronic and cumulative exposure.

How to Correct: Sweep grounds of industrial facilities and parking areas. Paint galvanized metal surfaces to prevent zinc coatings from being washed by rain.

3.2.15 Fecal Coliform

Description: Bacteria found in the digestive systems of warm blooded organisms

Natural Sources: Human, Wildlife, and Livestock Waste

Human-caused Sources: Pet Waste, Failing Septic Systems, Sanitary Sewer Overflows, Animal Feeding Operations

Effects on Watershed / Health: Fecal coliform does not pose a health threat but serves as an indicator for bacteria that can cause illness in humans and aquatic life. High bacteria levels can limit the uses of water for swimming or contaminate drinking water in groundwater wells.

How to Correct: Pick up pet waste. Ensure proper functioning of septic systems. Connect to municipal sewers.

3.2.16 Fecal Streptococci

Description: Fecal Streptococci is a bacteria commonly found in human and animal feces that is used as an indicator of possible sewage contamination.

Natural Sources: Human, Wildlife, and Livestock Waste

Human-caused Sources: Pet Waste, Failing Septic Systems, Sanitary Sewer Overflows, Animal Feeding Operations

Effects on Watershed / Health: Fecal streptococci do not pose a health threat but serve as an indicator for bacteria that can cause illness in humans and aquatic life. High bacteria levels can limit the uses of water for swimming or contaminate drinking water in groundwater wells.

How to Correct: Pick up pet waste. Ensure proper functioning of septic systems. Connect to municipal sewers.

3.2.17 Oil and Grease

Description: Oil and Grease is a non-definitive description of organic compounds that include oils derived from animals, vegetables, and petroleum.

Natural Sources: Petroleum

Human-caused Sources: Automotive Oils, Cooking Oils

Effects on Watershed / Health: Petroleum based oils can be acutely lethal to many aquatic organisms as evidenced by the aftermaths of many petroleum (oil and fuel) spills. Chronic exposure to oils can also affect feeding and reproductive processes in aquatic organisms. Oil and Grease also cause a human public health concern by 1) decreasing the supply of edible aquatic species, 2) increasing the possibility of ingesting carcinogenic elements that have bio-accumulated in the organisms tissues, and 3) through direct contact with known carcinogens found in oil. Oils of animal or vegetable origin are generally nontoxic to humans and aquatic life. Floating oils of any origin on surface waters cause a variety of harmful effects to waterfowl, fish, and invertebrate species and create poor aesthetics on water surfaces and shorelines.

How to Correct: Properly dispose of used motor oil at a recycling center. Install grease traps to prevent oil and grease from entering wastewater streams.

4 Water quality analysis procedure

NOAH project aims to protect the Baltic Sea from untreated wastewater spillages during flood events in urban areas. For this purpose, passive and active methods like holistic urban planning, real time control of urban drainage systems and raising stakeholder awareness are harnessed.

For that, WP3 will experiment and introduce new solutions in drainage system operation not widely used before in urban conditions. The idea is to install on-line sensors (measurement stations) and actuators (gates) into the existing system to utilize the capacity of the pipeline to accumulate excessive flows and thus avoid combined sewer overflows to the natural waters. In some cases, adjustments in the operation of the existing facilities (pumping stations) is also helpful to achieve this target. In combination of these activities and for the calibration of the hydraulic models establishing the EWL the municipalities are taking samples for water quality assessment. Due to delays in bidding for contract for sampling and analysis and to the situation with the covid-19 there has been a delay in sampling after technical innovations have been implemented there are still some samples analysed but not yet assessed.

4.1 Methods for sampling and water quality assessment

At all pilot sites the characteristics of the spillages are determined using either grab samples or flow or time proportional sampling. The flow proportional sample will be mixed into one sample and can be considered as describing one event and the concentrations of the analytes will be presented as an Event Mean Concentration (EMC). Different physical and chemical parameters are determined, and they were selected using workshops in the NOAH project and through literature studies (for example Ericsson et al. 2007, Viklander et al. 2018). The analytical methods recommended is presented in Table 1 (Priority 1) and also other Priorities in Appendix 1. Slightly different methods have been used depending upon municipal budget constraints and analytical contracts and they are presented in Appendix 2 (Latvia) and Appendix 3 (Poland). A detailed description of potential stormwater pollutants is presented in chapter 3 in this report. The different water quality parameters monitored are classified into 7 groups of parameters (Table 2);

1) Routine parameters including parameters such as pH and hardness which influence the bioavailability of metals and metalloids, electrical conductivity which is a measure of the amount of ions in a sample. Total Suspended Solids (SS) is an estimate of the amount of particles in a sample and it can also be used as a correlate for other pollutants such as heavy metals because many metals bind to particulate matter.
2) Organic sum parameters are measured in order to determine the amount of oxygen depleting substances in the samples. The ratio of BOD/COD can be used to determine the amount of persistent organic compounds where lower values indicate a larger proportion of persistent organic compounds.
3) Eutrophying substances. Nitrogen and phosphorous are plant growth limiting substances in aquatic ecosystems. Depending upon the area of the Baltic Sea one or both substances can be growth limiting. Nitrogen is considered the growth limiting substance in Baltic Proper, in coastal areas south of Bothnian Bay both nitrogen and phosphorus limiting occurs while phosphorous is limiting growth in inland water.

4) Heavy metals, metals and half metals. In this group several well-known pollutants commonly occurring in storm water are measured including Cd, Cu, Ni, Pb, Zn.
5) Organic micropollutants. In this group various organic micropollutants and/or groups of micropollutants such as polyaromatic hydrocarbons (PAH), PCB, PFAS are listed as well as microplastics.
6) Bacterial contamination of fecal origin is determined using membrane filtration.
7) Oil measured as an oil-index.

The water quality assessment may be conducted according to five different methods by comparing the analytical results to limit values derived from different legislations and types of water representing treated wastewater, surface water, stormwater data from the stormwater database in StormTac, guideline values for stormwater in Gothenburg, Sweden and water quality parameters for stormwater in Estonia. The selection of assessment methods depends on the interest of the municipalities, the type of spillages and the type of recipient (freshwater or coastal and transitional zones). If different national limits have been set by Baltic Sea Region countries the lowest limit has been selected for the assessment. In this report assessments have been made according to method 3.

1) Effluents from wastewater treatment plants. Limit values have been collected from the Urban Wastewater Directive 91/272/EC (updated 1st of January 2014). If no limit value is stated in the Directive but a national limit in one or several of the NOAH member states has been issued the lowest value has been used, representing the most stringent condition. The limit values used in the assessment is presented in Table 3.
2) Environmental Quality Standards (EQS) listed in the Directive on priority substances 2013/39/EU amending the Water Framework Directive 2000/60/EC and the Directive on environmental quality standards in the field of water policy 2008/105/EC. The EQS for "other water" has been used in the assessment and both the EQS for Annual Average (AA) and the Maximum Admissible Concentration (MAC) have been used. According to the Directive member states may derive EQS for other priority substances. When available, EQS from NOAH member states and Lithuania have been used for coastal and/or transitional water. If more than one nation has derived an EQS for a priority pollutant the lowest value has been used, representing the most stringent condition. For several metals the EQS is derived taking the dissolved phase (bioavailable form). In the assessment natural background concentration of elements have not been considered. In the assessment of fecal bacteria, the assessment has been made according to the Bathing Water Directive 2006/7/EC (updated 1st of January 2014). The limit values used in the assessment are presented in Table 4.
3) The interval (min-max) of water quality parameters listed in the Storm Tac database is presented in Table 5. The values in the database are derived from international studies from the 1990s and forward. The database can be accessed at http://www.stormtac.com/. Values for similar type of land use as for catchment used in building the EWL has been used.
4) The guideline values for discharge to the stormwater network and recipients in the city of Gothenburg (Göteborgs stad 2020). The guideline values are set according to environmental quality standards in recipients in inland water and becomes discharge limits when legal decision has been made. They are valid for temporary and continuous discharges as well as

small or large effluents. They are not intended for use for municipal or household wastewater nor for the cleaning of boats in cleaning stations (Table 6).

5) Water quality parameters for stormwater outlets in Estonia according to the Estonian Water Act presented in Table 7.

Table 1. Analytical methods recommended.

Analyte	Sample pretreatment	Standard Methods
pH	no filtration	EN ISO 10523:2012
Temperature	no filtration	EN ISO 10523:2012
Electrical conductivity	no filtration	EN 27888:1993
BOD7	no filtration	EN 1899-1:1998 or EN 1899-2:1998
Suspended solids	method includes filtration	EN 872:2005
Dissolved oxygen	no filtration, sample treatment on field	EN 25813:1993
Dissolved organic carbon (DOC)	filtration needed	EN 1484:1997
Total organic carbon (TOC)		EN 1484:1997
Ammonia nitrogen	filtration needed	EN ISO 11732:2005, ISO 7150-1: 1984
Sum of nitrate and nitrite nitrogen	filtration needed	EN ISO 13395:1996, EN ISO 10304-1:2009
Total nitrogen	no filtration	EN ISO 11905-1:1998
Phosphate phosphorous	filtration needed	EN ISO 6878:2004, EN ISO 10304-1:2009, EN ISO 15681-1 and -2:2004
Total phosphorus	no filtration	EN ISO 6878:2004, EN ISO 15681-1 and -2:2004
Metals and other elements obtained by the same method of analysis: Al, As, B, Ca, Cd, Cr, Cu, Fe, K, Mg, Mn, Na, Ni, P, Pb, S, Si, Zn	filtration needed	EN ISO 11885:2009
Coliformic bacteria	no filtration	EN ISO 9308-1:2014 or EN ISO 9308-2:2014
Oil Index		ISO 9377-2

The sampling guidances applied are:
Water quality - Sampling - Part 2: Guidance on sampling techniques (EN ISO 5667-2:1991) and Water quality - Sampling for microbiological analysis (ISO 19458:2006): EN ISO 19458:2006

Table 2. Measured physical and chemical characteristics. For a detailed description of stormwater pollutants see chapter 3 in this report.

Parameter	Comments
Routine parameters	
pH	Influence the bioavailability of metals.
Temperature	
Hardness	Calculated from Ca+Mg below. Influence bioavailability of metals.
Electrical conductivity	The amount of ions in a sample
Total Suspended Solids	Many micropollutants including trace element often occur in particulate form in stormwater
Eutrophying substances	
BOD_7	Biological Oxygen Demand,
Dissolved Organic Carbon (DOC)	Influence the bioavailability of metals.
Total Organic Carbon (TOC)	Replace COD, % of DOC as TOC will be calculated
Total phosphorus	Eutrophying substance in inland areas and coastal zones
$P\text{-}PO_4$	Amount of TP that is bioavailable
Total Nitrogen	Eutrophying substance in coastal zones and the sea
Ammonium nitrogen	Unionized ammonia, a very toxic molecule to fish if not measured it will be calculated
Sum of nitrate and nitrite nitrogen	
Organic N	Will be calculated from TN, ammonium-nitrogen and the sum of nitrate and nitrite nitrogen
Half-metals, metals and metalloids	
Boron (B)	
Phosphorus (P)	
Sulphur (S)	
Potassium (K)	
Calcium (Ca)	Ca+Mg is used to calculate hardness
Magnesium (Mg)	
Aluminum (Al)	
Iron (Fe)	
Copper (Cu)	Common pollutant in stormwater
Zink (Zn) and its compounds	Common pollutant in stormwater
Manganese (Mn)	

Sodium (Na)	
Silicon (Si)	
Lead (Pb)	Common pollutant in stormwater
Cadmium (Cd) and its compounds	Common pollutant in stormwater Depends on hardness
Chromium (Cr)	Common pollutant in stormwater
Nickel (Ni) and its compounds	Common pollutant in stormwater
Arsenic (As)	
Organic micropollutants	
Polyaromatic hydrocarbons	
MTBE	Odour threshold in water of 15 µg/l (WHO)
Microorganisms (cfu/100 ml)	
Enumeration of Escherichia coli and coliform bacteria	Indicators of fecal contamination are monitored
Oil	
Oil index	May cause odour in raw drinking water oil may also clog respiratory organs in aquatic organisms

[1] *The bioavailable fraction is used for nickel and lead since 2013(2013/39/EU)*

[2] *EQS on total concentration used up to 2013*

[3] *No EQS derived in EU, value used for water quality assessment in Sweden for coastal waters and transition zones (HVMFS 2019:25)*

Table 3. Water quality parameters – the most stringent condition for effluents from WWTP to the Baltic Sea using Legislation and EU 91/271/EEC (2014) and national guidelines.

Parameter	**Reduction or PNEC (EQS)**		**Comments**
	Value	**Reference**	
Routine parameters			
pH	6.5-8.5	Lithuania	Influence the bioavailability of metals.
Temperature	Not regulated		
Hardness	Not regulated		Calculated from Ca+Mg below. Influence bioavailability of metals.
Total Suspended Solids	<35 mg/l	EU	For WWTP with more than 10 000 pe
Organic sum parameters			
BOD5	25 mg/l	EU	
COD_{Cr}	125 mg/l	EU	
Dissolved Organic Carbon (DOC)		Not regulated	
Total Organic Carbon (TOC)		Not regulated	Can replace BOD according to Directive
Eutrophying substances (mg/l)			
Total phosphorus (TP)	1 mg/l	EU	For WWTP with more than 100 000 pe
$P\text{-}PO_4$		Not regulated	Amount of TP that is bioavailable
Total Nitrogen (TN)	10 mg/l	EU	For WWRTP with more than 100 000 pe
Ammonium nitrogen	5 mg/l	Lithuania	
Sum of nitrate and nitrite nitrogen		Not regulated	
Organic N	Not regulated		Calculated
Half-metals, metals and metalloids			
Aluminium (Al)	0.5 mg/l	Lithuania	
Iron (Fe)	10 mg/l	Poland	
Microorganisms (cfu/100 ml)			
Enumeration of Escherichia coli and coliform bacteria	Not regulated for WWTP	Not regulated	(Indicator of faecal contamination monitored in Latvia, for abstraction of drinking water 50 000 coliforms /100 ml)
Oil			
Oil index	Not regulated		

Table 4. Water quality parameters – the most stringent condition in surface water in the Baltic Sea. Legislation: According to WFD and EQS Directive, classification according to ¨other water¨ if no special regulation for transitional waters and coastal areas has been derived.

Parameters	**Limit value**		**Comments**
	Value	**Reference**	
Routine parameters			
pH		Not regulated	Influence the bioavailability of metals.
Temperature	Not applicable		
Hardness		Not regulated	Calculated from Ca+Mg below. Influence bioavailability of metals.
Electrical conductivity		Not regulated	
Suspended Solids		Not regulated	≤ 25 mg/l (guideline value) Latvia sensitive areas (fish), not considered here
Organic sum parameters			
BOD5/7		Not regulated	
Dissolved Organic Carbon (DOC)		Not regulated	Influence the bioavailability of metals.
Total Organic Carbon (TOC)		Not regulated	Replace COD
Eutrophying substances (mg/l)			
Total phosphorus	0.1-0.14	Lithuania	
Phosphate-P		Not regulated	Amount of TP that is bioavailable
Total Nitrogen	3 mg/l	Estonia, Lithuania	Lower values in Latvia for sensitive areas (fish), not used her
Ammonia-N (NH_4-N)	<0.2 mg/l	Lithuania	Lower values in Latvia for sensitive areas (fish), not used here
Nitrite-N	<2.3 mg/l	Lithuania	
Sum of nitrate and nitrite nitrogen		Not regulated	Values exist for Latvia for sensitive areas (fish), not used here.
Half-metals, metals and metalloids (µg/l)			
Ag (Silver)	0.2 (AA) 1.2 (MAC)	Denmark	Not regulated in EQS Directive AA and MAC ARA
As (Arsenic)	0.55 (AA), 1.1 (MAC)	Sweden	Coastal waters and transition zones Not regulated in EQS Directive Denmark has similar values AA-ARA
B (Boron)	94 (AA), tot20 000 2080 (MAC)	Denmark	Not regulated in EQS Directive, AA- ARA
Ba (Barium)	5.8 (AA) 145 (MAC)	Denmark	Not regulated in the EQS Directive, AA-ARA
Cd (Cadmium and its compounds)	0.2 (AA) ≤0.45-1,5 (MAC)	EQS	Depends on hardness ($CaCO_3$)
Cr (Chromium)	VI: 3.4 (AA), 17 (MAC) III: 3.4 (AA) 124 (MAC)	Denmark	Not regulated in EQS Directive

	Tot conc: AA – 3.4	Sweden	
Co (Cobalt)	0.28 (AA) 34 (MAC)	Denmark	Not regulated in EQS Directive, AA-ARA
Cu (Copper)	tot 4.9 (AA) tot. 4.9 (MAC)	Denmark	Not regulated in EQS Directive AA and MAC ARA (Sweden has a general value of 1.45 for Baltic Sea bioavailable fraction this has not been considered here).
Hg (Mercury)	0.07 (MAC)	EU	
Mb (Molybdenum)	6.7 (AA) 587 (MAC)	Denmark	Not regulated in EQS Directive, AA-ARA
Mn (Manganese)	150 (AA) 420 (MAC)	Denmark	Not regulated in EQS Directive AA and MAC ARA
Ni (Nickel and its compounds)	8.6 (AA) 34 (MAC)	EU	
Pb (Lead)	1.3 (AA) 14 (MAC)	EU	
Sb (Antimony)	11.3 (AA) 177 (MAC)	Denmark	Not regulated in EQS Directive
Se (Selenium)	0.08 (AA) 31 (MAC)	Denmark	Not regulated in EQS Directive AA and MAC ARA
Sn (Tin)	0.2 (AA) 20 (MAC)	Denmark	Not regulated in EQS Directive
Sr (Strontium)	2100 (AA) 5530 (MAC)	Denmark	Not regulated in EQS Directive AA and MAC ARA
Th (Thallium)	0.048 (AA) 57.8 (MAC)	Denmark	Not regulated in EQS Directive AA and MAC ARA
V (Vanadium)	4.1 (AA) 57.8 (MAC)	Denmark	Not regulated in EQS Directive, AA-ARA
Zn (Zinc)	7.8 (AA) 8.4 (MAC) 1.1 (AA)	Denmark Sweden coastal areas and transition zones	Not regulated in EQS Directive, AA-ARA, MAC ARA Not considered in evaluation here.
Organic micropollutants (µg/l)			
Anthracene	O.1 (AA) 0.1 (MAC)	EU	
Benzene	8 (AA) 50 (MAC)	EU	
Fluoranthene	0.0063 (AA) 0.12 (MAC)	EU	
Naphthalene	2 (AA) 130 (MAC)	EU	
NP	0.3 (AA) 2.0 (MAC)	EU	
Benzo(a)pyrene	0.00017 (AA) 0.027 (MAC)	EU	
Benzo(b)fluoranthene	AA – not determined 0.017 (MAC)	EU	

Benzo(k)fluoranthene	AA – not determined 0.017 (MAC)	EU	
Benso(g,h,i)perylen	AA – not determined 0.00082 (MAC)	EU	
TBT	0,0002 (AA) 0.0015 (MAC)	EU	
Faecal bacteria (cfu/100 ml)			
Enumeration of Escherichia coli and coliform bacteria	E. coli: 500 cfu/100 ml Faecal Enterococcus: 200 cfu/100 ml	EU	EU Bathing Water Directive, 2006/7/EC (2014) Assessment made for good quality for coastal and transitional waters Indicator of faecal contamination monitored Faecal enterococcus has replaced faecal coliforms as it is supposed to show higher correlation with human pathogens in sewage than faecal coliforms.
Oil (µg/l)			
Oil index	Not regulated Not used		Latvia <1.0 mg/l for abstraction of surface water for human consumption Gothenburg, stormwater to very sensitive recipient 1 mg/l

Table 5. The interval (min-max) of water quality parameters listed in the Storm Tac database for similar land uses as in catchments studied in this project.

Parameter	**min-max**	**Parameter**	**min-max**
Routine parameters		Half-metals, metals and metalloids (µg/l)	
pH		Ag (Silver)	
Temperature		Al (Aluminium)	
Hardness		As (Arsenic)	
Electrical conductivity (ms/m)		B (Boron)	
Alkalinity (mg/l)	28	Ba (Barium)	
Suspended Solids (mg/l)	24-333	Ca (Calcium)	
Organic sum parameters		Cd (Cadmium and its compounds)	0.30-1.32
COD_{Cr}	19-203	Cr (Chromium)	2.0-43
BOD5/7	2.0-24.4	Co (Cobalt)	
Dissolved Organic Carbon (DOC)	3.5-21	Cu (Copper)	11-162
Total Organic Carbon (TOC)	5-92.9	Fe (iron)	1188-4718
Eutrophying substances (mg/l)		Hg (Mercury)	0.012-0.245
Total phosphorus	0.12-0.524	K (Potassium)	
Phosphate-P		Mb (Molybdenum)	
Total Nitrogen	1.2-4.5	Mg (Magnesium)	
Unionized ammonia nitrogen (NH_3-N)		Mn (Manganese)	
Ammonia-N (NH_4-N)	0.5-0.8	Na (Sodium)	
Nitrite-N		Ni (Nickel and its compounds)	2.0-30
Nitrate-N		Pb (Lead)	3.0-113
Sum of nitrate and nitrite nitrogen		Sb (Antimony)	
Organic N		Se (Selenium)	
Organic micropollutants (µg/l)		Si (Silicon)	
PAH (USEPA sum 16)	0(0.07)-11.1	Sn (Tin)	
Nonylphenol	0.15-2.8	Sr (Strontium)	
DEHP	0.5-10	Th (Thallium)	
PCB (7)		V (Vanadium)	
TBT	0.0016-0.064	Zn (Zinc)	9-1170
Microorganisms (cfu/100 ml)		Oil (µg/l)	
E.coli	700-5000	Oil index	100-3843
Fecal coliforms	0(1700)-12000		

Table 6. Limit values for discharges to the city of Gothenburg to stormwater networks and recipients.

Parameter	**Guideline value**[1]
Routine parameters	
pH	6,5-9[2]
Suspended Solids (mg/l)	25[2]
Organic sum parameters	
Total Organic Carbon (TOC) (mg/l)	12[3]
Eutrophying substances	
Total phosphorus (TP) (mg/l)	0.050[3,4]
Total nitrogen (TN) (µg/l)	1250[3,4]
Half-metals, metals and metalloids (µg/l)[4]	
As (Arsenic)	16[2,5]
Cd (Cadmium and its compounds)	0,9[2,5]
Cr (Chromium)	7[2]
Cu (Copper)	10
Hg (Mercury)	0.07[2,5]
Ni (Nickel and its compounds)	68[2,5]
Pb (Lead)	28[2,5]
Zn (Zinc)	30[2]
Organic micropollutants (µg/l)	
Benzo (a) pyrene indicator of PAH	0.27[3]
Benzene	50[3]
Methyl-t-butyl ether (MTBE)	2600 µg/l[3] 500 µg/l within water protection area in Göta älv 15 µg/l close to raw drinking water intake (approx. 1-2 km upstream)
Polychlorinated biphenyls (PCB)	0.014[3]
Perfluoroalkyl substances (PFAS)	0,09[3]
Tributhyltin (TBT)	0.0015[3]
Trichlorethylene	10[3]
Oil (µg/l)	
Oil index	1000 µg/l 500 µg/l within water protection area in Göta älv 100 µg/l close to raw drinking water intake (approx. 1-2 km upstream)

[1] *becomes a limit value after legal decision on discharge*
[2] *mandatory to monitor*
[3] *depends on discharge and discharge point*
[4] *mandatory for continuous discharges*
[5] *total concentration assuming that 50 % occurs in dissolved form*

Table 7. Water quality parameters for stormwater outlets in Estonia according to the Estonian Water Act.

Pollution parameters	**Limit value (mg/l or reduction)**	
	Value mg/l	**Reduction %**
BOD7	15	80
COD	125	75
Total phosphorus	1	80
Total Nitrogen	45	30
Suspended Solids	40	
monophenols	0.1	75
phenols	15	70
Oil index	5	
pH	6-9	

5 Water quality analysis results before and after pilot investment

5.1 Results – Water Quality Assessment

Detailed assessment has been completed using assessment method 3 for samples presented in Table 8.

Table 8. Samples assessed.

Country (municipality)	Sampling method	Sampling time	Sampling sites	Expected type of effluent
Estonia (Haapsalu)	Automatic, time regulated Grab sample	Mar, Dec 2020 wet weather May 2021 wet weather and after rain	1 (Pilot site 1)	Stormwater
Estonia (Rakvere)	Automatic, time regulated	Mar, Nov 2020 wet weather	1	Stormwater
Finland (Pori)	Manual sample	Sep 2020 wet weather	3 (Suntinoja) 3 Pervonoja 3 Lattomerenoja 1 Rainwater	Stormwater
Latvia (Jurmala)	Manual sample	Aug 2019 wet weather Sep 2019 dry weather Oct & Nov 2020	1 (Miera street) 2020: Ditari, Melluzi, Kauguri	Stormwater
Latvia (Liepaja)	Manual sample	Aug 2019 dry weather Sep 2019 (after rain) Mar 2021	1 (Pumping station manhole on Tebras street)	Stormwater
Latvia (Ogre)	Manual sample	Aug 2019 dry weather Oct 2019 wet weather Feb, Mar, Apr 2021	1 (manhole at the end of catchment)[1]	Stormwater 2021: snowmelt
Poland (Słupsk)	Composite sample taken with an automatic sampler except for sample in July 2020	Dec 2019, May 2020 wet weather Jun 2020 Dry weather July 2020 heavy rain Oct, Nov 2020 wet weather	4 (Kanał ul. E. Orzeszkowej-site 1, Kanał ul. Mickiewicza-site 2, Kanał Nad Śluzami-ul. Wiejska-site 3) 2 Rainwater	Untreated waste water mixed with stormwater and rainwater
Sweden (Söderhamn)	Composite sample taken with an automatic sampler	Jun 2020 wet weather Oct 2020 wet weather	1 (manhole, Snörböle 1:28)	Stormwater

[1] there are two pipes at the outlet during dry weather only the right-hand pipe was sampled

The samples have been taken using different sampling methods depending upon municipal budget constraints and availability. In all cases the whole or part of the catchment for building the hydraulic model has been sampled. According to project plan Söderhamn and Pori will not install technical innovations in the NOAH project.

As stated above also contracts with analytical laboratories and municipal budget constraints have led to the analyses of different number of substances and number of samples taken. In Poland and Latvia also slightly different methods of analyses has been made but all analyses have been made using ISO/EN or national standards. All municipals have measurement of a few routine parameters such as pH and suspended solids as well as organic sum parameters and the nutrients total phosphorus and total nitrogen.

Below a short description of sampling sites and the characteristics of the sampled water is presented for each pilot site.

5.2 Haapsalu, Estonia

The sampling site in Haapsalu is shown in Figure 19. Three samples, each consisting of several subsamples during rain events have been assessed and the assessment on average concentrations is presented in Table 8). Only a few parameters have been analysed. measured parameters are within interval previously observed for stormwater (StormTac 2019), Table 9.

Table 9. Parameters above, within or below interval in samples from Haapsalu as presented for similar land use types in StormTac database (2019).

Level	Sample 1, March 2020	Sample 2, December 2020	Sample 3, May 2021
Above interval			
Within interval	SS, COD, TN, TP	SS,COD, BOD, TN,TP	SS, COD, BOD, TN, TP
Below interval			

Figure 19. Sampling site in Haapsalu.

5.2.1.1 Rakvere, Estonia

The sampling site in Rakvere is shown in Figure 20. Two time-weighted samples representing subsamples taken every fifth minute during a rain event have been assessed and the assessment based upon average values is presented in Table 10. The sampe was collected from the outlet of the main stormwater collector – Soolikaoja. Only a few parameters have been analysed. Higher values are recorded in the beginning of the sampling period in the sample taken 2019 indicating a first flush that might have started earlier than the sampling period. Most parameters measured are low except for total nitrogen. Levels of measured parameters are below interval previously observed in stormwater except for total nitrogen which is above interval (StormTac 2019).

Table 10. Parameters above, within or below interval in samples from Rakvere as presented for similar land use types in StormTac database (2019).

Level	Sample 1 (2019)	Sample 2 (2020)
Above interval	TN	TN
Within interval		SS, BOD, COD, TP
Below interval	SS, BOD, COD, TP	

The second sampling was conducted in November 2020. The sample assessed is representing 12 subsamples taken every fifth minute during an hour during a rain event. At the results are shown that all other parameters measured were within interval except the total nitrogen.

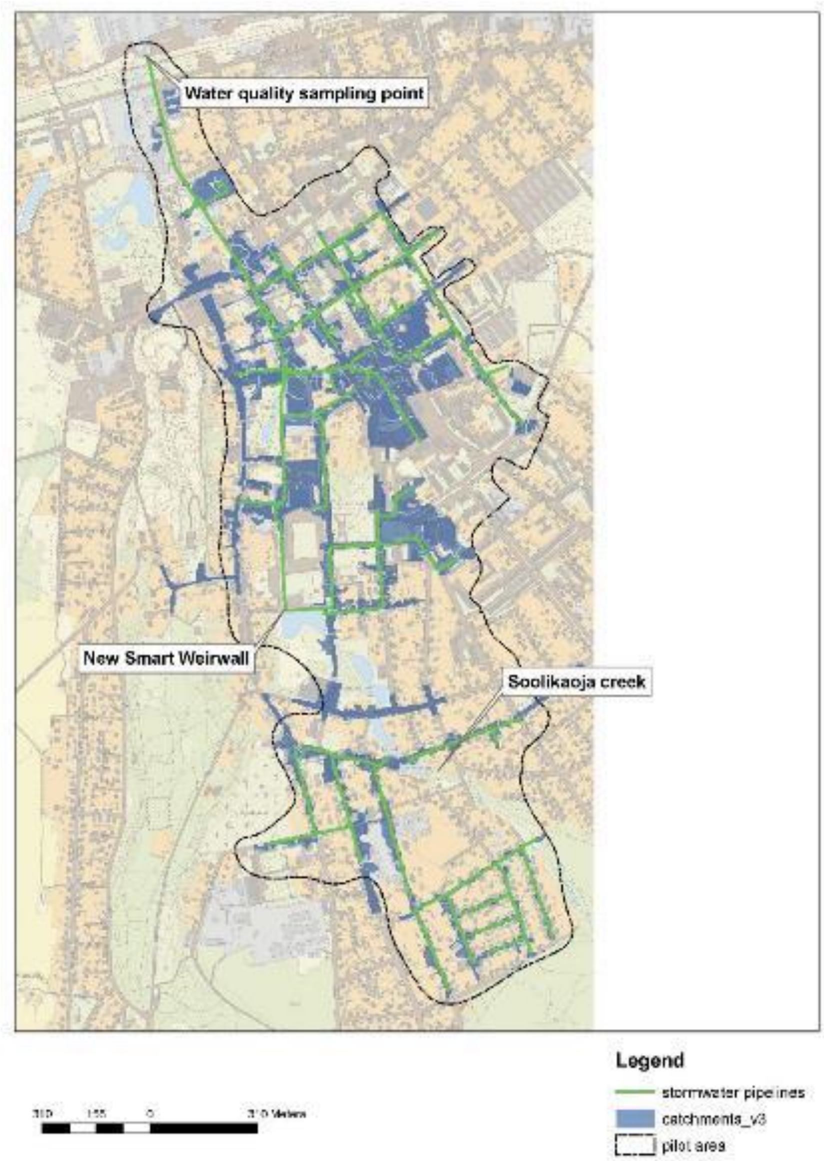

Figure 20. Sampling site in Rakvere, Estonia.

5.3 Pori, Finland

The sampling sites in Pori is shown in Figure 21. Three samples have been taken in Suntinoja catchment during a rain event in September 2020. They were taken with one-hour intervals starting 1 h after the rain had begun. The sample is expected to be stormwater and the samples were taken from the end of the catchment area where the outflow is to the stream, Suitinoja, then it flows to the ditch (Lattomerenoja) which flows into a river. Rainwater was sampled at the same time. The characteristics of water as assessed using data from the StormTac database is presented in Table 11. The samples contained low amounts of pollutants and for example nutrients, organic sum parameters and SS was low. The samples have very similar characteristics.

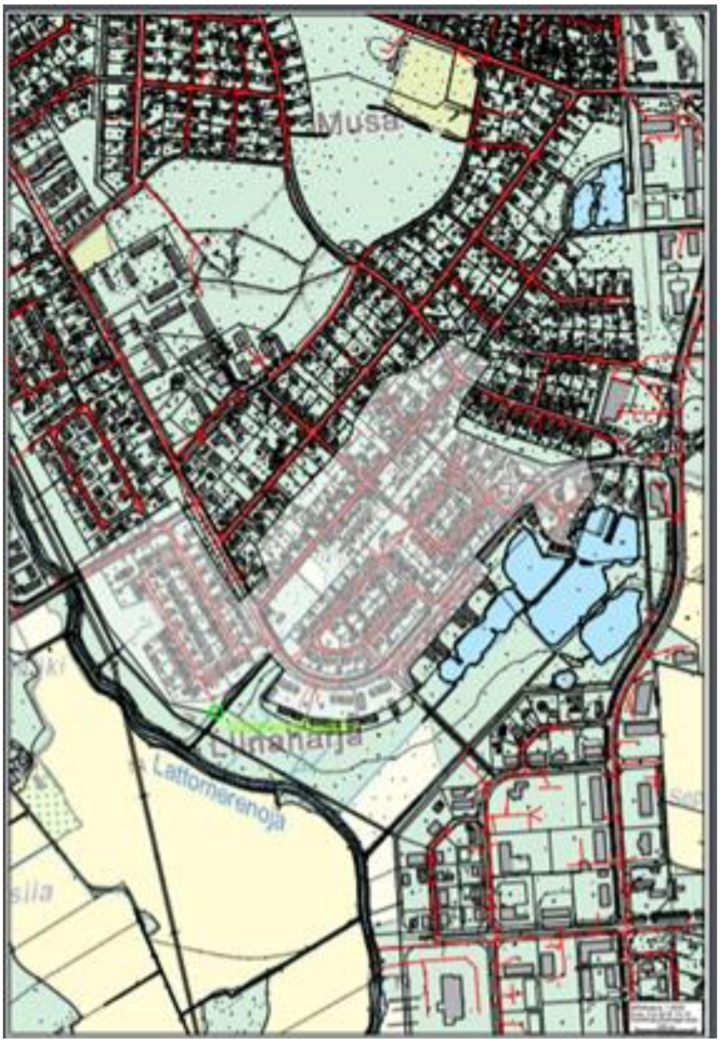

Figure 21. Sampling site in the Suntinoja catchment in Pori, Finland.

Table 11. Parameters above, within or below interval in samples from Pori as presented for similar land use types in StormTac database (2019)

	Sample 1,2000	Sample 2,2000	Sample 3, 2000
Above interval	none	none	none
Within interval	Ammonium-N, TN, TP, Cd, Ni, Zn, coliforms	Ammonium-N, TN, TP, Cd, Ni, Zn, coliforms	Ammonium-N, TN, TP, Cd, Ni, Zn, coliforms
Below interval	SS, BOD, DOC, TOC, Cr, Cu, oil index	SS, BOD, DOC, TOC, Cr, Cu, Fe, oil index	SS, BOD, DOC, TOC, Cr, Cu, Fe, oil index
	Fe, Pb	Pb	Pb

5.4 Jurmala, Latvia

The sampling site in Jurmala is shown in Figure 22. The first sample was taken August 2019 from Drintari (C) during a rain event and the second sample was taken during dry weather in September 2019. In October 2020 manual grab sample was taken from Drintari during a rain event and with autosampler from Melluži (B), but only 1 bottle was analysed, and it can be seen to as grab sample. In November 2020 sampling was done with autosampler during a rain event in Kauguri (A). The analysed sample was composite sample including 4 subsamples collected with 7 minutes intervals. The characteristics of water as assessed using data from the StormTac database is presented in Table 12. The second sample taken during the dry period has more parameters above the interval generally recorded for similar land use types in the database. Values for routine organic sum parameters and nutrients was also higher in the sample during dry weather except for BOD. Both samples in 2019 have low concentrations of suspended solids as well as low concentrations of some metals commonly occurring in stormwater (Cd, Cu, Ni, Pb). Faecal contamination in the dry weather sample is indicated. In 2020 ammonium-N values were above interval in Melluži and Kauguri, but the value was below interval in Drintari. Amount of coliforms and total N and P values were above the interval in Drintari and Kauguri. Also in Drintari and Melluži concentration of Zinc was found to be above the interval, but within the interval in Kauguri.

Table 12. Parameters above, within or below interval in samples from Jurmala as presented for similar land use types in StormTac database (2019).

Level	Drintari dry weather (sample 2, 2019)	Drintari wet weather (sample 1, 2019)	Drintari wet weather 2020	Melluži wet weather 2020	Kauguri wet weather 2020
Above interval	DOC, ammonium-N, TN, TP, E. coli, coliforms	ammonium-N, TN, TP	TOC, TN, TP, Zn, coliforms	ammonium-N, Zn	ammonium-N, TN, TP, coliforms
Within interval	BOD, TOC, Cr, Fe, oil index *Fe is within or below interval*	BOD, DOC, TOC, Cr, Fe, Ni, Zn, *E. coli*, coliforms, oil index	SS, COD, BOD5, DOC, TOC, Fe	COD, BOD5, DOC, TOC, TN, TP	COD, BOD5, DOC, TOC, Zn
Below interval	SS, Cd, Cu, Ni, Pb	SS, Cd, Cu, Pb	ammonium-N, Cd, oil index	SS, coliforms, Cu, Fe	SS, Cu, Fe,

Figure 22. Sampling sites in Jurmala. Latvia.

5.5 Liepaja, Latvia

The sampling site in Liepaja is shown in Figure 23. The first sample was taken in September 2019 during dry weather and the second sample was taken just after a rain event in October 2019. Third sampling was in March 2021. The characteristics of water as assessed using data from the StormTac database is presented in Table 13. The sample taken during wet weather had higher SS, conductivity, and faecal indicators but lower concentrations of TP, and TN than the sample taken during dry weather. The wet weather sample also had concentration of some metals commonly occurring in stormwater (Cd, Cu, Ni, Pb). In 2020 only suspended solids and total phosphorus values were above the interval.

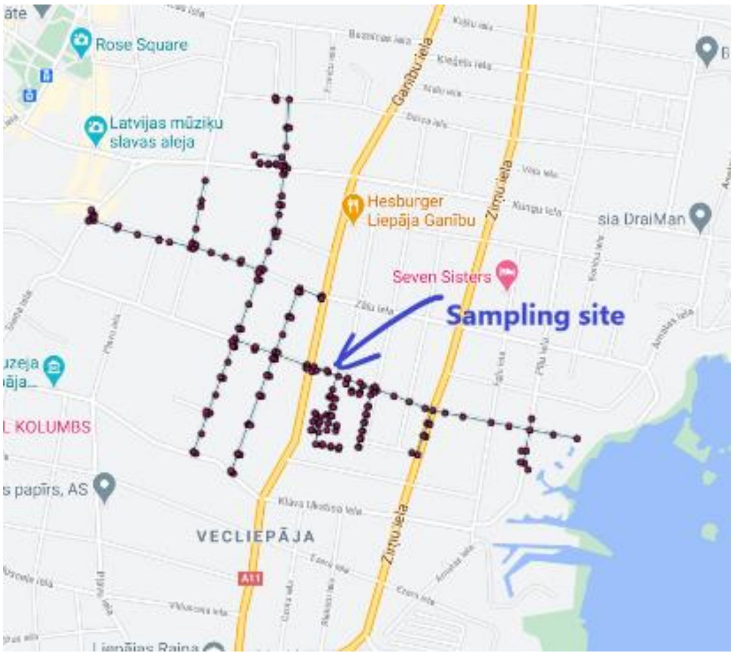

Figure 23. Sampling site in Liepaja, Latvia.

Table 13. Parameters above, within or below interval in samples from Liepaja as presented for similar land use types in StormTac database (2019). Parameters in italics have higher detection limits than the lowest value in the interval.

Level	dry weather (sample 1) 2019	wet weather (sample 2) 2019	wet weather (sample 3) 2021
Above interval	TN, TP, coliforms	TP, E.coli and coliforms	SS and P tot
Within interval	BOD, DOC, TOC, E. coli Cr, Zn, and oil index within or below	SS, BOD, TN, Cr, Cu, Fe, Ni, Zn Oil index within or below	BOD5,DOC,TOC,N tot, Cd, Cr, Cu, Ni and coliforms
Below interval	SS, ammonium-N, Cd, Cu, Fe, Ni Pb	TOC, ammonium-N, Cd, Pb	Fe and E.coli

5.6 Ogre, Latvia

The sampling site in Ogre is shown in Figure 24. The first grab sample was taken in August 2019 during dry weather and the second grab sample was taken just after a rain event in October 2019. The characteristics of water as assessed using data from the StormTac database is presented in . The sample taken during wet weather had higher conductivity and higher levels of SS. It also had higher level of TP but lower levels of TN than the sample taken during dry weather. The wet weather sample also had concentration of some metals commonly occurring in stormwater (Cd, Cu, Ni, Pb, Zn) than the sample taken under dry weather.

Figure 24. Sampling sites in Ogre, Latvia. Samples taken from the manhole is indicated with the purple circle.

In 2021, samples were taken in February, March and April from both the outflow (ditch runoff) and the manholes (mainly road runoff). According the results the snowmelt sample taken from the outflow had elevated concentrations of total nitrogen, E.coli and coliforms. Samples taken during the wet weather including snowmelt snow contained ammonium nitrogen above the limit value. Rainwater samples alone contained total nitrogen above the limit value (Table 14).

Table 14. Parameters above, within or below interval in samples from Ogre as presented for similar land use types in StormTac database (2019). Parameters in italics have higher detection limits than the lowest value in the interval.

Level	**dry weather (sample 1)[1] 2019**	**wet weather (sample 2)[2] 2019**	**wet weather, snowmelt runoff, ditch O1 (sample 3) 2021**	**wet weather, snowmelt runoff, road M1 (sample 4) 2021**
Above interval	ammonium-N, TN	TN	Tot N, E.coli and coliforms	
Within interval	coliforms, Cr, Zn	SS, BOD, TP, Cr, Cu, Ni, coliforms	BOD5, DOC, TOC, Tot P, Cr and Zn	BOD5, TOC, Cr, TN, E.coli coliforms and TP
Below interval	BOD, SS, TP, Cd, Cu, Fe, Ni, Pb, oil index, E.coli	DOC, TOC, ammonium-N, Cd, Fe, Pb, Zn, oil index, E.coli	SS, Cd, *Fe, Ni, Pb* and Cu	DOC, Cu, Ni, oil index and Pb, SS

Level	**wet weather, snowmelt & rain runoff, ditch O2 (sample 5) 2021**	**wet weather, snowmelt & rain runoff, road M2 (sample 6) 2021**	**wet weather, rain runoff, ditch O3 (sample 7) 2021**	**wet weather, snowmelt & rain runoff, road M3 (sample 8) 2021**
Above interval	ammonium-N, TN	ammonium-N, SS, Fe	TN	TN
Within interval	BOD, DOC,TOC, TP, Cr,Ni,SS, E.coli and coliforms	BOD, DOC,TOC, TP, Cr, E.coli and coliforms, TN	BOD, TP, Cr, E.coli and coliforms	BOD and Cr
Below interval	Fe, Zn Cu and oil index, Pb	Cu, *Cd, Ni, Pb*	Cu, Fe, Ni, Zn, oil index	TP, Cu, Fe, Ni, E.coli and coliforms

[1] only right-hand pipe has been sampled

[2] both pipes were sampled and mixed 50/50.

5.7 Słupsk, Poland

The three sampling sites are shown in Figure 25. Six composite samples taken with an automatic sampler have been collected from three different canals leading into the wastewater treatment plant in Słupsk. It is expected that the water is a mix of untreated wastewater, stormwater and rainwater as the samples were taken during rain events. The first samples were taken in

December 2019 and the second samples were taken in May 2020. Rainwater was also sampled at the same time. The characteristics of sampled water as assessed using data from the StormTac database is presented in Table 15. The concentration of nutrients and organic sum parameters were often more than 10 x higher than the maximum value. Coliform bacteria also occurred in very high numbers. Several of the measured parameters were also several times higher than guideline values for effluents from wastewater treatment plants (Appendix 3) and consequently the samples resemble untreated wastewater with a possible mix of stormwater rather than stormwater.

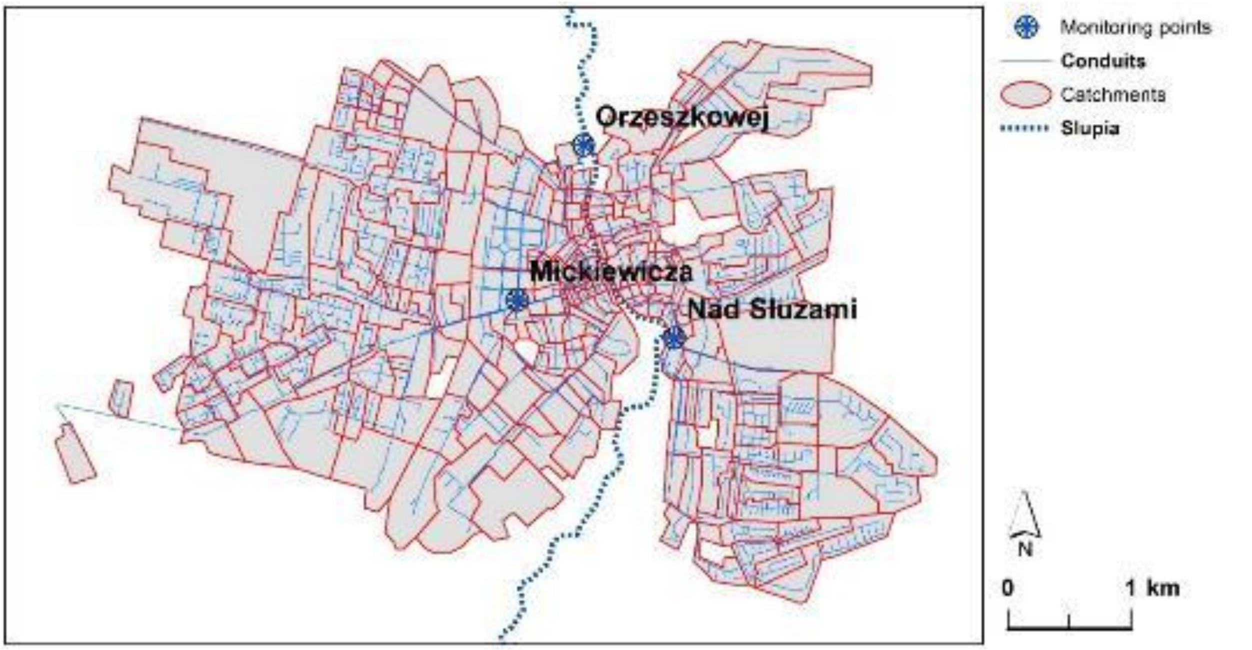

Figure 25. The area for the three sampling sites in Słupsk, Poland, Orzeszkowej, Mickiewicza and Nad Sluami.

Table 15. Parameters above, within or below interval in samples from Słupsk as presented for similar land use types in StormTac database (2019). Parameters in italics have higher detection limits than the lowest value in the interval.

Site	Orzeszkowej street						
	Sample 1[1]	Sample 2[1]	Sample 3[2]	Sample 4[2]	Sample 5[2,3]	Sample 6[2]	Sample 7[1]
	Dec 2019	May 2020	June 2020	July 2020	June 2020	Oct 2020	Nov 2020
Above interval	BOD, DOC, TN, ammonium-N, TP, coliforms	SS, BOD, DOC, TOC, TN, ammonium-N, TP,	COD, TN, TP, ammonium-N	COD, TN, TP, ammonium-N	SS, COD, TN, TP, ammonium-N	SS, COD, TN, TP, ammonium-N	BOD, SS, DOC, TOC, TN, ammonium-N, TP, coliforms
Within interval	SS, TOC, oil index, Cr, Cu, Ni, Pb, Zn	Zn, oil index, Cr, Cu, Ni, Pb	SS	SS			Cr, Cu, Ni, Pb, Zn
Below interval	Fe	Cd, Fe					Fe
Site	Mickiewicza street						
	Sample 1[1]	Sample 2[1]	Sample 3[2]	Sample 4[2]	Sample 5[2,3]	Sample 6[2]	Sample 7[1]
	Dec 2019	May 2020	June 2020	June 2020	June 2020	Oct 2020	Nov 2020
Above interval	BOD, DOC, TN, ammonium-N, TP, coliforms	BOD, DOC, TN, ammonium-N, TP, coliforms	SS, COD, TN, TP, ammonium-N	SS, COD, TN, TP, ammonium-N	SS, COD, TN, TP, ammonium-N	SS, COD, TN, TP, ammonium-N	BOD, DOC, TOC, TN, ammonium-N, TP, coliforms
Within interval	SS, TOC, Cu, oil index, Cr, Cu, Ni, Pb, Zn	SS, TOC, Cu, Zn, oil index, Cr, Ni, Pb					SS, Cr, Cu, Ni, Pb, Zn, oil index
Below interval	Fe	Fe					Fe
Site	Nad Śluzami/Wiejska street						
	Sample 1[1]	Sample 2[1]	Sample 3[2]	Sample 4[2,]	Sample 5[2,3]	Sample 6[2]	Sample 7[1]
		May 2020	June 2020	June 2020	June 2020	Oct 2020	Nov 2020
Above interval	SS, BOD, DOC, TN, ammonium-N, TP, coliforms	BOD, DOC, TOC, TN, ammonium-N, TP, coliforms	SS, COD, TN, TP, ammonium-N	SS, COD, TN, TP, ammonium-N	SS, COD, TN, TP, ammonium-N	SS, COD, TN, TP, ammonium-N	BOD, SS, DOC, TOC, TN, ammonium-N, TP, coliforms
Within interval	TOC, Cu, oil index, Cr, Ni, Pb, Zn	SS, Fe, oil index, Cr, Cu, Ni, Pb, Zn					Cr, Cu, Ni, Pb, Zn, oil index
Below interval	Fe						

[1] priority list 1 substances analysed, detection limit for Cd is higher than max value in interval AND assessment is therefore not possible
[2] reduced number of parameters analysed
[3] grab sample taken same day as sample 3

In 2020 samples 3 were almost exclusively municipal sewage, taking during the dry period. Samples 4 were raw sewage including stormwater, sampled during the rain event with heavy rainfall. Samplings 3 and 4 were taken with an autosampler (mixed subsample).

Samples 5 were grab samples taken during the rain event with moderate rainfall. Samples 6 were taken during the rain event with moderate rainfall with an autosampler. Samples 5 and 6 were raw sewage including rainwater.

5.8 Söderhamn, Sweden

The sample was taken with an automatic sampler in June 2020 during a rain event and the sample is expected to be stormwater. It was taken in a manhole Snarböle 1:28 close to the city center. The characteristics of water as assessed using data from the StormTac database is presented in Table 16. Most parameters were within interval of stormwater a few parameters were below.

Table 16. Parameters above, within or below interval in samples from Söderhamn as presented for similar land use types in StormTac database (2019)

Level	Sample 1, 2019	Sample 2, 2020
Above interval	none	
Within interval	SS, BOD, Pb, Zn Ammonium-N, TP, Fe, Cu, Ni, oil index	Al, As, Pb, BOD7, P, Fe, Cu, Ni, Zn, PAHtot, SS
Below interval	DOC, TOC, Cd, Hg, TBT	Cd, Hg, DOC, TOC, TBT, oil index

6 Results of water quality modelling after pilot implementation of extreme weather layer -lessons learned

6.1 Adding Water Quality to the model

In order to assess the impact of the solution in terms of reduced pollution to the recipient, it is necessary to add a water quality parameter to the SWMM model. In Jurmala pilot case was chosen to do this by adding the virtual substance “Stuff” to all dry weather flow with a concentration of 50 mg/l (corresponding to typical concentrations of ammonia in wastewater). Since phosphorous and COD can be modelled in the same way for smaller systems like this with little time for reactions and setting, the water quality results can be used to give an indication of the relative savings of pollutant loads.

The effect of the solution was tested using the Riga rainfall data for the entire year of 2019. A plot of the flows in and out of the node with the pump for the period day 130-135 in the simulation is shown in Figure 26. The concentration in the water standing in the belly sag slowly increases towards that of the waste water of 50 mg/l. As soon as it starts to rain the concentration drops as the cleaner stormwater fills the system. The magnitude of the pumping flow is so small that it is barely visible on the plot but none the less this pumping catches the vast majority of the pollutant load for longer periods of time.

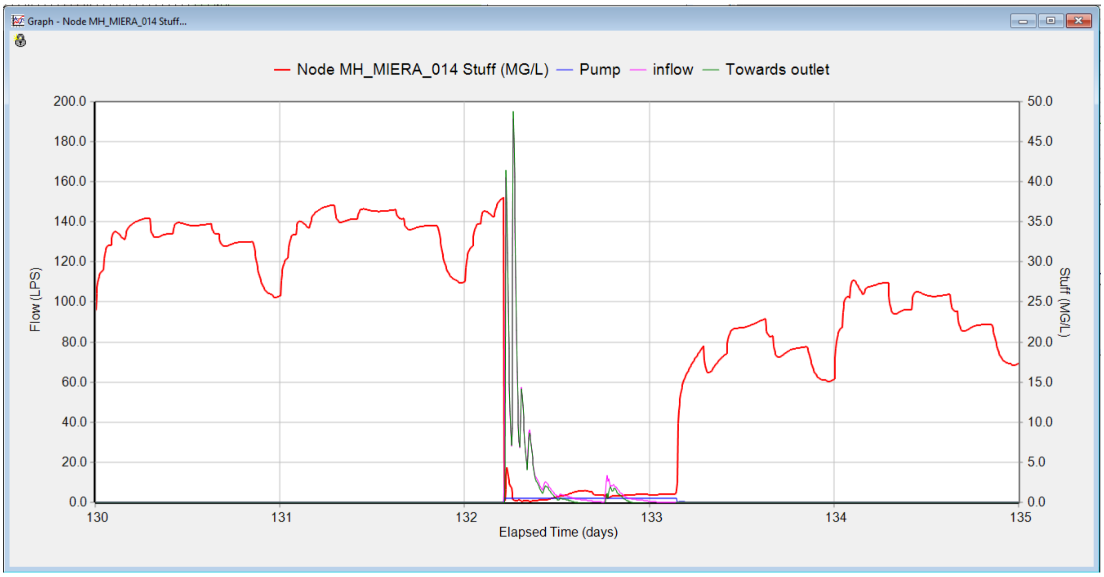

Figure 26. Flows in and out of the node with the pump and the pollutant concentration in the node in a five day period with a rainfall event in the middle.

The summary statistics from SWMM with and without the proposed solution can be seen in Figure 27. It shows that the total pollutant load trough the outlet to the recipient (outfall O-1) is 159,5 kg while the corresponding number after implementing the pumping solution is down to 46,9 kg, which is a reduction of 71 %.

Summary Results

Topic: Outfall Loading — Click a column header to sort the column.

Outfall Node	Flow Freq. Pcnt.	Avg. Flow LPS	Max. Flow LPS	Total Volume 10^6 ltr	Total Stuff kg
O-1	97.73	6.40	952.69	113.021	159.501
O-2	0.12	97.79	1131.18	0.945	0.000

Summary Results

Topic: Outfall Loading — Click a column header to sort the column.

Outfall Node	Flow Freq. Pcnt.	Avg. Flow LPS	Max. Flow LPS	Total Volume 10^6 ltr	Total Stuff kg
O-1	20.04	27.94	953.33	95.631	46.913
O-2	0.12	97.47	1129.71	0.943	0.000
1	98.39	0.58	2.00	17.471	104.925

Figure 27. Result summary for 2019 with (bottom) and without (top) the proposed solution. Outfall node “1” is the virtual outlet that represent the connection to the sanitary sewer.

Comparing the result of SWMM model to the results of water quality analysis

Results from Jurmala in 2019 and 2020 was analysed according to the Gothenburg values. Those values which were above the guideline values were taken to further analysis. Those were TOC, ammonium-N, total N and total P. The results of the analyses were compared by calculating the percentage change from the 2019 dry sample to the 2019 and 2020 wet samples and by comparing the wet samples of the years with each other.

The results indicated that in 2019 the dry sample vales of TOC, ammonium-N, total N and total P were reduced on average by 40 % compared to wet sample 2019. When comparing wet samples 9019 to 2020, it was found that the mean reduction in concentrations was 60 %. The result of the 2020 wet sample was 74 % lower than the result of the 2019 dry sample (Figure 28). This result is in line with modelling value. Further research is needed to evaluate the findings.

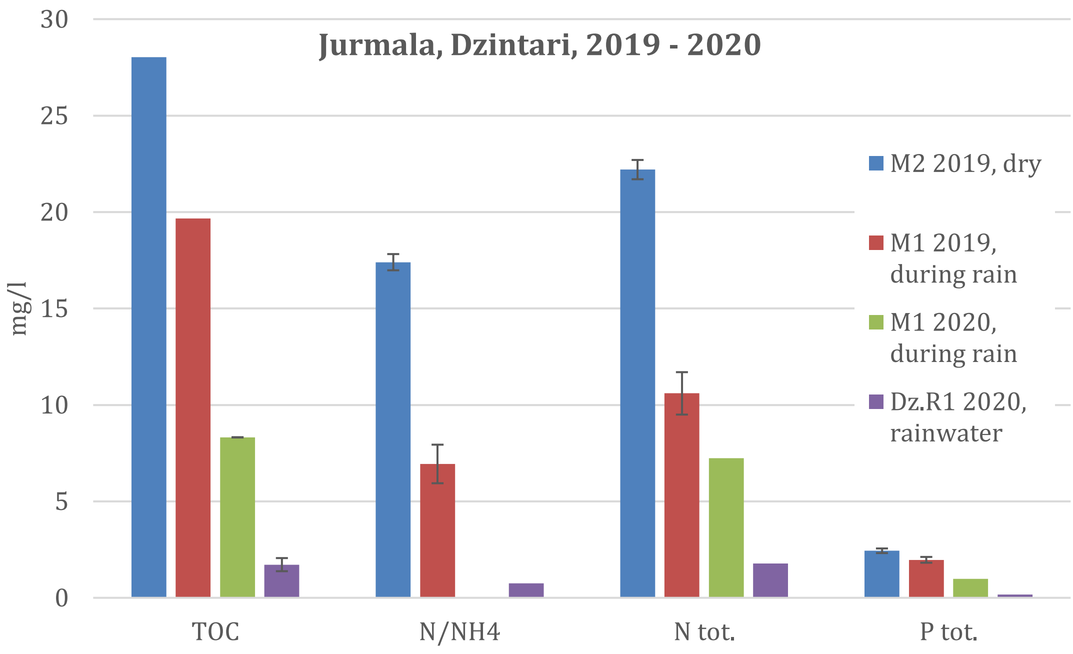

Figure 28. TOC, ammonium-N, total N and total P values from Jurmala 2019-2020.

6.2 Lessons learned

Municipalities were asked about their experiences of the process of sampling and analysis. The questions were:

1) What is your experience about getting the equipment in place for sampling?

2) What is your experience of taking the samples, where you able to take representative samples (dry weather, wet weather (rain of short duration and/or heavy/long duration), rain water samples?

3) What is your experience in choosing the right parameters to analyse for the quality assessment (was our priority list 1 used and if not why not?

4) Did you experience any problems in storage and transport of the samples?

5) Was it difficult to interpret the result of the water quality assessment in the O3.2. report?

6) What would you do differently today if you have repeated the process?

7) Additional remarks etc.

The answers are listed below by each municipality:

6.2.1 Haapsalu

1) What is your experience with getting the equipment in place for sampling?

The procurement about getting stormwater quality samples started not very smoothly. At the beginning there was difficulties to get right automatic sampler and the operator, who would run it. Also the prices were too high but with the help of TalTech we managed to get right operator with necessary equipment for the satisfactory price.

2) What is your experience of taking the samples, where you able to take representative samples (dry weather, wet weather (rain of short duration and/or heavy/long duration), rainwater samples?

The first measurement went fine. We hit the right rainy weather in early spring period, so the samples quality were sufficient. The second measurement didn't went fine compared to first measurement. The weather were dryer and we hit December month, when roads were also recently salted and with too low stormwater flowrate the results quality were poor.

3) What is your experience in choosing the right parameters to analyse for the quality assessment (was our priority list 1 used and if not why not)?

We decided with TalTech to measure 6 parameters: pH, suspended solids, BOD7, total nitrogen, total phosphorus and COD. Otherwise the quality measurement procurement price would have been too high.

4) Did you experience any problems in the storage and transport of the samples?

No problems.

6). *Was it difficult to interpret the result of the water quality assessment in the O3.2. report*? TalTech helped us with the interpretation.

7). *Additional remarks*

No

6.2.2 Pori

1) What is your experience about getting the equipment in place for sampling?

The installation of the measurement equipment was quite straight forward with only minor issues. We had some difficulties in securing the equipment so no one would be tempted to disturb or steal it. There were also some issues with the installation of the other measurer as the manhole we wanted to install it to, could not fit the installer into it for the instalment, so we had to move the location a bit.

The biggest difficulty with the measurement equipment was actually finding a place that rented them and had the exact ones we needed.

2) *What is your experience of taking the samples, where you able to take representative samples (dry weather, wet weather (rain of short duration and/or heavy/long duration), rain water samples?*

In the first round of samples, we took samples during rain events. We tried to take our samples during a heavy rain event after a dry period to be able to account the first flush-affect. This did not work as well as we planned. None of the rain events during which we took our samples was ideal. This was mostly due to the laboratories opening hours and the pressure to get any samples done.

We also took Water Quality samples during our measurements. One of the water samples was taken during a dry period and the rest were taken during rain events (one every 30 min after the beginning of the rain).

3) *What is your experience in choosing the right parameters to analyze for the quality assessment (was our priority list 1 used and if not why not?)*

We used the priority list 1 as we decided our parameters with Luke. Due to this, choosing our parameters was quite straightforward for us.

4) *Did you experience any problems in storage and transport of the samples?*

We had some issues with the laboratories as they were open only till Thursday afternoon. This meant that all the samples had to be taken Monday to Thursday before 16:00 o'clock. Unfortunately, the weather does not follow time schedules and we had to do some adjustments.

5) *Was it difficult to interpret the result of the water quality assessment in the O3.2. report?*

Not really, we had a lot of help from Luke and the results did not have anything too surprising or unexplainable.

6) *What would you do differently today if you have repeated the process?*
We would research into automatic sampling tools and equipment and other possible measuring tools, and research if they are any methods samples can be preserved for longer periods of time after sampling. It is also difficult to predict the exact time of the rain event, and to be able to be there with all the equipment. Automatic equipment could help with these issues.

7) Additional remarks etc.

-

6.2.3 Jurmala

1) What is your experience about getting the equipment in place for sampling?

In 2020 we moved the automatic sampler from one manhole to another (three manholes all together). Despite the prior measurements of the manholes, two manholes were difficult to place the equipment inside and extract afterwards. Purely practically. Lesson learned is to take in account not only dimensions of the equipment but also a space for the worker who will most likely operate inside the manhole because not all pre-installation operations can be done outside the manhole.

2) What is your experience of taking the samples, where you able to take representative samples (dry weather, wet weather (rain of short duration and/or heavy/long duration), rainwater samples?

We were asked by laboratories not to bring in samples on Fridays, but sometimes the conditions we needed (heavy rainfall) happened on Thursday night, Friday or Saturday. So certain samples (one or two) could gave been delivered after 24h had passed since sampler took the sample. This year we are waiting for the perfect conditions – rainfall between Monday – Thursday morning.

Also operating the automatic sampler requires practice and sometimes assistance from the producer. Which, in our opinion, is a normal process of learning.

3) What is your experience in choosing the right parameters to analyse for the quality assessment (was our priority list 1 used and if not why not)?

All parameters listed in Priority 1 list were analyzed.

4) Did you experience any problems in the storage and transport of the samples?

No difficulties.

5) Was it difficult to interpret the result of the water quality assessment in the O3.2. report?

No difficulties.

6) What would you do differently today if you have repeated the process?

Main lessons learned are the ones described in 1) and 2).

7) Additional remarks etc.

-

6.2.4 Ogre

1) What is your experience with getting the equipment in place for sampling?

As we did manual grab-sampling, there were no difficulties getting the equipment to the sampling place. The only complication was getting the manhole opened, but there were always some helpful colleagues for that.

We also had portable measuring equipment for samples of this spring to measure pH, t, EC, and dissolved oxygen on site.

2) What is your experience of taking the samples, where you able to take representative samples (dry weather, wet weather (rain of short duration and/or heavy/long duration), rainwater samples?

We took one dry-weather sample in 2019 (consists of multistore-housing foundation drainage groundwater) and one rain sample this spring. As for representative samples – we did not perform sampling in the most representative way, as it would require an autosampler. In total there is a drainage sample from 7 rain events, resulting in a total of 13 samples (6 were collected from outfall, conveying mostly ditch water, collected over single-family housing area; other 7 samples were collected from the manhole close to outfall, just before inflow into sedimentation-treatment manholes).

3) What is your experience in choosing the right parameters to analyse for the quality assessment (was our priority list 1 used and if not why not)?

For analysis priority list 1 was used with recommended pre-treatment; however, for a future sampling of drainage water (in Latvia), it might be slightly changed (see file attached). Additionally, it would be interesting to see if there is pollution present from other priority lists.

4) Did you experience any problems in the storage and transport of the samples?

It was necessary to take samples Monday – Thursday in the first half of a day to submit them for analysis to the laboratory during working hours. However, sometimes samples were taken on the evening of the previous day. Until submission samples were stored at outdoors air temperature.

5) Was it difficult to interpret the result of the water quality assessment in the O3.2. report?

For the assessment the values from the report were taken:
Table1 - WWWTP effluent comparison,
Table2 - Surface-water comparison,
Table3 - Stormwater comparison,
Table6 - Gothenburg values.

6) What would you do differently today if you have repeated the process?

To take samples that are more representative, an automatic sampler with a proportional volume-sampling algorithm would be beneficial. For the sampling of pure rainwater, a well-designed system is needed, so the sample could be collected during smaller rainfalls and it would be contamination-proof, as it was impossible to collect a contamination-free sample for us by now.

7) Additional remarks etc.

-

6.2.5 Słupsk

Stormwater quality tests were carried out independently by the laboratory of Słupsk Water Supply and laboratory of GUT's Department of Water and Wastewater Technology. The analyses, although performed on different dates, complement each other and provide full information on the quality of stormwater in combined sewage system of the pilot site in Słupsk.

	Question	Gdansk University of Technology	Laboratory of Słupsk Water Supply Company
1	*What is your experience about getting the equipment in place for sampling?*	Not applicable – samples were collected by the qualified employee of Słupsk Water Supply	• Location of sampling points: manholes in the middle of a busy street → the need to stop the traffic • Collection of 3 samples (where each is a representative mixed subsample) in different places at or near the same time (a need to deploy and operate 3 autosamplers) • the need to involve more employees
2	*What is your experience of taking the samples, where you able to take representative samples (dry weather, wet weather (rain of short duration and/or heavy/long duration), rain water samples)?*	• **Research planning:** regular monitoring is very difficult to plan and predict, thus is dependent on external/natural factors; it requires time-flexibility of the research personnel • **Sampling procedure:** not applicable – samples were collected by the qualified employee of Słupsk Water Supply	• Nuisance sampling in rain • Difficulty in planning the sampling and testing campaigns - due to the variability of the weather • Location of sampling points: manholes in the middle of a busy street → the need to stop the traffic • The lack of separate manholes for rainwater makes it difficult to obtain a complex representative sample • Often insufficient rainfall intensity during sampling campaign (within 1 hour for sampling) Due to the above: sometimes the only possible solution was to take grab samples.
3	*What is your experience in choosing the right parameters to analyse for the quality assessment (was our priority list 1 used and if not why not?*	• **The list of determinations seems to be too extensive**, which makes the research as a whole very time-consuming. In the case of regular monitoring, it is better to limit the tests to a few parameters. GUT decided to choose 10 physico-chemical parameters from priority 1 and follow them in regular analyses of stormwater quality • Moreover, the research material is very specific to process (generally, stormwater is characterized by a high concentration of suspensions e.g. sometimes it took several hours to determine the TSS in one sample) – time-consuming procedure • On the other hand, the sewage system in Słupsk is a combined sewage system.	The Słupsk Water Supply company's laboratory conducts tests of all parameters from priority 1

		Therefore, in the event of a heavy rainfall, the emergency/storm overflows transport a mixture of sewage and rainwater to the receiver (ground or surface water). **It is therefore reasonable to assume a wider range of control parameters than for pure rainwater.**	
4	*Did you experience any problems in storage and transport of the samples?*	• Inconvenience in transporting samples to the GUT laboratory in Gdansk due to the significant distance from Słupsk • Samples for prority 3 and 4 tests had to be frozen, which required special protective measures during transport	Due to the short distance from the laboratory premises to the collection points, there were no problems with the transport and storage of samples
5	*Was it difficult to interpret the result of the water quality assessment in the O3.2. report?*	First of all, it should be taken into account that in case of Słupsk pilot site the samples were collected from combined sewage system (were a mixture of sewage and stormwater) and therefore, the results of typical quality parameters were sometimes extremely different from the other pilot sites. As a consequence – it was really difficult to compare them with results obtained by other Project Partners or to relate them to the UE standards and guidelines.	Not applicable - the analysis of the results is carried out mainly by the Gdansk University of Technology
6	*What would you do differently today if you have repeated the process?*	Based on GUT experience – it would be better to plan a less extensive but regular monitoring (only few selected parameters), which would be also much more useful in modelling	No remarks
7	*Additional remarks etc.*	It should be mentioned that according to the Polish law only two parameters of stormwater quality are limited: TSS not higher than 100 mg/L and petroleum hydrocarbons in amounts not exceeding 15 mg/L. Only these two parameters are taken as a reference and required for monitoring. While stormwater runoff is a mixture of substances (even hazardous). That’s why stormwater runoff should be treated as a sewage (not as a pure water). It is consistent with the approach represented by Halmstad University that as many parameters as possible should be monitored.	No remarks

6.2.6 Söderhamn

1. *What is your experience about getting the equipment in place for sampling?*

Since we have used a specially borrowed sampling equipment at the moment, it must be placed in place when a downpour is expected, which has caused problems.

2. *What is your experience of taking the samples, where you able to take representative samples (dry weather, wet weather (rain of short duration and/or heavy/long duration), rain*
.
We have succeeded reasonably in two tests but made a number of unsuccessful attempts.

3. *What is your experience in choosing the right parameters to analyse for the quality assessment (was our priority list 1 used and if not why not?*

It was used but we also added from other lists.

4. *Did you experience any problems in storage and transport of the samples?*

Once the sample was taken, the rest worked well.

5. *Was it difficult to interpret the result of the water quality assessment in the O3.2. report?*

Yes the tables are many and long.

6. *What would you do differently today if you have repeated the process?*

We were going to procure a consultant who did the whole job.

7. *Additional remarks etc.*

No further remarks.

7 Guideline for following water quality sampling and modelling procedure in any urban area in BS region

These guidelines have been compiled by combining instructions from different official guidelines and international standards and supplementing them with practical advice from the 'lessons learned' in water sampling at the NOAH project pilot sites.

The first step is to make a comprehensive plan for stormwater quality monitoring. The plan requires information on the characteristics of the catchment area, background information of the amount of rainfall in different seasons and amount of stormwater flow. Knowledge of the area helps to determine the parameters to be measured, e.g. the ideal sampling method, locations, and time, and to assess the effect of the runoff of potential contaminants.

The cost of sampling can vary a lot depending on whether the purpose is to obtain a general idea of stormwater quality in the area or to measure only some critical elements. Parameters to sample should be chosen to be essential and significant based on the characteristics of an area. Timing the sampling, retention capacity and circumstances before a rain event should be considered. The selection of a sampling method and position and quantity of sampling locations are defined by the functionality of a location.

These instructions are advisory only, please follow primarily instructions from your municipality and/or laboratory.

7.1 Sampling

Stormwater sampling is usually taken by using grab sampling or composite sampling. In grab sampling all of the test material is collected at one time. So, a grab sample reflects performance only at the point in time that the sample was collected. The collection of a grab sample is also needed when analyzing substances that are unstable and should be analyzed as soon as possible (e.g., pH, temperature, dissolved oxygen or coliform bacteria).

Composite sampling consists of a collection of numerous individual discrete samples taken at regular intervals over a period of time. The analysis of this kind of sample (time-weighted), will therefore represent the average concentration during the collection period. At composite sampling is important to make sure that the parameter (or parameters) being measured is stable during the period of sampling and examination. Data derived from composite sampling should be considered a specific data type in databases so that this type of data is not confused with discrete samples. It should be borne in mind that composite samples are of little value in determining transient peak conditions.

The autosampler (especially combined with flow metering) is recommended for monitoring stormwater runoff when the use of it is possible. Depending of the site characteristics and available extra equipment; like electricity, or communication equipment; flow-weighted or time-weighted sampling (not recommended, see below) can be selected. Autosampler is practical for collection of flow-weighted samples from many sites or for sampling events that occur over an extended period of time. The rainfall to runoff data at the site is needed to assist in programming the autosampler. Sampling staff should ensure that “reverse flow”, which can occur from other parts of the system, does not produce contamination at the sampling point.

The weather information (temperatures and rainfall/weather data) at the time of sampling should be recorded. Changes in meteorological conditions can induce marked variations in water quality; such changes should be noted and allowance made for them when interpreting results. Also sampling programmes should be designed to take into account temperature variation over long or short periods, which can cause changes in the nature of the sample that can affect the effectiveness of equipment used for sampling.

The most common monitoring errors usually are improper sampling methodology, improper preservation, inadequate mixing during compositing and splitting, and excessive sample holding time. Because of that, it is recommended to conduct control checks during the actual sample collection to determine the performance of sample collection techniques. This can be done by using trip, field, temperature or equipment blank. Trip blanks are vial(s) filled at the laboratory with deionized water. The blank(s) follows the same handling and transport procedures as the samples collected during the event. The blank(s) functions as a check on sample contamination originating from sample transport, shipping and from site conditions. Field blanks are similar to trip blanks except they are prepared in the field with deionized water exactly as the sample(s) that are collected. A temperature blank is a small sample bottle filled with distilled water that is placed in each cooler prior to shipment. Collect an equipment/rinsate blank when using an automatic sampler or other non-dedicated equipment during the sampling process. The blank is a check of the equipment cleanliness. For automatic samplers, prepare blanks prior to collecting samples, by pumping deionized organic free water (rinsate) through the sampler and collecting the discharge purge water in a sample container for analysis for the constituents of concern. Also field duplicates, split samples etc. are good to conduct.

Pure rainfall is considered not to be significantly polluted, although this usually depends on the location, industrial density, traffic intensity, prevailing winds, season, previous dry periods, etc. The rain can acquire most of the particles and contaminants present in the atmosphere, such as solids, traces of heavy metals, pesticides, etc. This contamination increases during long dry periods and also depends on the surrounding environment. When monitoring stormwater flush to receiving waterbodies, its is recommended to analyze rainwater samples.

No single sampling study can satisfy all possible purposes. It is therefore important that specific sampling programmes are optimized for specific study purposes. Special care must be taken to notice a significant rain event, monitoring a good representation of a wide variety of storms, analysis of several rainfalls during different seasons, with different lengths of preceding dry periods, and even with different surrounding urban area conditions (residential, commercial or industrial areas, different traffic intensities, different land uses, etc.)

The samples should be taken according to the following ISO standards:

ISO 5667-1, Water quality – Sampling – Part 1: Guidance on the design of sampling programmes and sampling techniques

ISO 5667-2, Water quality – Sampling – Part 2: Guidance on sampling techniques

ISO 5667-3, Water quality – Sampling – Part 3: Guidance on the preservation and handling of water samples

Sampling and analyses of individual storm events

In order to determine the load of pollutants in an individual storm event the summation of load method can be used (Gulliver et al. 2010). For this purpose, it is not recommended to use grab samples or time weighted samples as sampling strategies. For flow weighted discrete samples i.e. samples collected using an automatic sampler during a complete rain event at a user-specified incremental volume of discharge (for example 1000, 2000 or 5000 l) equation 1 can be used to calculate total mass of pollutants.

$$M = V_T \frac{\sum_{i=1}^{n} C_i}{n} \qquad \text{(Equation 1)}$$

Where:
M = total mass of pollutant
V_T = total discharge volume
C_i =pollutant concentration in sample i
i = sample number
n = total number of samples collected

For flow-weighted composite samples (i.e. flow weighted discrete samples collected in one container) the pollutant concentration is assumed to represent the entire composite sample and by taking a representative sample from the flow-weighted composite sample for analyses equation 1 can be simplified and calculated according to Equation 2.

$$M = V_T C_C \qquad \text{(Equation 2)}$$

Where:
M=total mass of pollutant
V_T = total discharge volume (V_T=nV)
C_c = composite sample pollutant concentration in sample i

For short term monitoring the determination of Event Mean Concentration (EMC) can be calculated according to Equation 3.

$$EMC = \frac{\sum_{i=1}^{n} V_i C_i}{\sum_{i=1}^{n} V_i} \qquad \text{(Equation 3)}$$

Where:
EMC= event mean concentration
V_i = measured volume of stormwater which is represented by sample i

C_i = pollutant concentration in sample i
i = sample number
n = total number of samples collected

By comparing equation 1 (or 2) and 3 it is apparent that EMC can be calculated by dividing the mass (M) of pollutants obtained in Equation 1 (for discrete composite samples) or Equation 2 (for composite samples) and dividing it with the total amount of stormwater in the storm event.

CHECKLIST FOR SAMPLING

- Be ready to take the samples according to the sampling plan.
- Check the instructions to collect the samples from the laboratory. Each parameter has its own sampling, reservation and transportation procedure that must be followed to get the right results.
- Be ready to take all samples.
- Make sure you have all the proper bottles, field equipment and preservatives, such as ice or chemicals.
- Inform laboratory of incoming samples.
- Before going to the field make sure you have a proper sample identification system, how the samples will be referenced and recorded during collection at the field. Mark the date and time collected so the laboratory can determine if samples are being run within proper holding times. It's a good idea for samplers to keep a field notebook.
- The container shall be filled completely unless prescribed differently. If no preservatives are present in the bottle, then prerinsing the bottle may be advisable.
- Check the maximum holding time for each sample, instruction from the laboratory. Make sure that samples arrive at the laboratory in time and within temperature requirements.
- Check if there is a need for equipment cleaning/decontamination method at the field.
- Ready for transport logistics; samples have to deliver to laboratory as soon as possible, more information from the laboratory. Record the time between sampling and start of transport, transport time and starting time of analysis in the laboratory.
- Documentation: naming of sites and samples (name the samples so, that code can follow the sample all the time).
- Record GPS- coordinates of the sampling sites
- Check also if laboratory can use the proposed method for analyzing samples or if it is not possible, please record what method is used instead.

7.2 Parameters

It is recommended to analyze stormwater parameters in accordance with national or local discharge limits for stormwater. However, discharge limits for stormwater are usually lacking in the countries in the Baltic Sea Region and therefore it is recommended to consider monitoring stormwater pollutants which are listed in the EQS-Directive (2013(39/EU), a daughter directive to the Water Framework Directive. In addition, as several common stormwater pollutants are not listed in the EQS Directive, monitoring of additional parameters such as organic sum parameters, nutrients, suspended solids, trace elements and indicators of fecal contamination is recommended. In Table 17 a compilation of suitable parameters to monitor is presented. In the table guideline values for the assessment is also provided and for several of the parameters the guideline values have been obtained from the City of Gothenburg (*Göteborgs Stad, 2020. Riktlinjer och riktvärden för utsläpp av förorenat vatten till dagvattennät och recipient. R 2020:3, In Swedish*).

Table 17. Guideline values for discharges to the city of Gothenburg to stormwater networks and recipients.

Parameter	**Guideline value[1]**
Routine parameters	
pH	6,5-9[2]
Suspended Solids (mg/l)	25[2]
Organic sum parameters	
Total Organic Carbon (TOC) (mg/l)	12[3]
Eutrophying substances (μg/l)	
Total phosphorus (TP)	0.050[3,4]
Total nitrogen (TN)	1250[3,4]
Half-metals, metals and metalloids (μg/l)[4]	
As (Arsenic)	16[2,5]
Cd (Cadmium and its compounds)	0,9[2,5]
Cr (Chromium)	7[2]
Cu (Copper)	10
Hg (Mercury)	0.07[2,5]
Ni (Nickel and its compounds)	68[2,5]
Pb (Lead)	28[2,5]
Zn (Zinc)	30[2]
Organic micropollutants (μg/l)	
Benzo (a) pyrene indicator of PAH	0.27[3]
Benzene	50[3]
Methyl-t-butyl ether (MTBE)	2600 μg/l[3] 500 μg/l within water protection area in Göta älv 15 μg/l close to raw drinking water intake (approx. 1-2 km upstream)
Polychlorinated biphenyls (PCB)	0.014[3]
Perfluoroalkyl substances (PFAS)	0,09[3]
Tributhyltin (TBT)	0.0015[3]
Trichlorethylene	10[3]
Oil (μg/l)	
Oil index	1000 μg/l 500 μg/l within water protection area in Göta älv

	100 µg/l close to raw drinking water intake (approx. 1-2 km upstream)
+ extra recommended parameters	
Ammonium nitrogen (mg/l)	<0.2
Microorganisms (cfu/100 ml)	
E.coli	700-5000
Fecal coliforms	0(1700)-12000

[1] *becomes a limit value after legal decision on discharge,* [2] *mandatory to monitor*
[3] *depends on discharge and discharge point,* [4] *mandatory for continuous discharges*
[5] *total concentration assuming that 50 % occurs in dissolved form*

Laboratory analysis

Samples are susceptible to changes which may take place between the time of sampling and the analysis of samples. In all cases, it is essential to take precautions to minimize these changes and to analyze the samples with a minimum of delay. During transportation samples shall be stored in a cooling device capable on maintaining a temperature of (5 ± 3) ^{0}C.

Remember always record GPS- information, date, time and temperature of the sampling event. Mark also sampling method (grab or autosampler; time or flow-weighted), when sample has arrived to the laboratory and when it is analyzed. Remember to check preservation instructions of each sample.

The material and the size of the bottle depends on the applied method/instrument (Check the instructions from your laboratory!).

Recommended suitable types of sample bottles for each analyze to be measured are presented in Table 18. The number of bottles required depends on their size and whether all the samples can be analyzed in the same laboratory or whether some samples have to be sent to another laboratory for analysis.

Table 18. Recommended maximum holding time, required preservative and the types of sample bottles for each analyze.

Analytical Parameter	Maximum Holding Time	Required Container Type	Required Preservative	Minimum Amount
pH	poor	plastic		100 ml
suspended solids		plastic		500-1000 ml
TOC		plastic		100 ml
total nitrogen	3 days	plastic		250 ml
total phosphorus	poor	plastic	1 ml 4 mol/l H2504 /100 ml sample	250 ml
half-metals: B	7 days	plastic		100 ml
metals: Al	7 days	plastic	1 ml 4 mol/I H2504 to 100 ml sample	250 ml

As	7 days	plastic	1 ml 35 % HNO_3 (suprapur) to 100 ml sample	250 ml
Cd, Cr, Cu, Ni, Pb, Zn	7 days	plastic	1 ml 35 % HNO_3 (suprapur) to 100 ml sample	100 ml/ each
Fe	7 days	plastic	1 ml 4 mol/l H2SO to 100 ml of sample	100 ml
B, Ca, K, Mg, Mn, Na, Pb, S, Si	7 days	plastic		100 ml/ each
metalloids		plastic		
Hg		borosilicate glass, quartz	25 ml 5% $KMnO_4$/l(Hg free) and 15 ml $HN0_3$ to 500ml of sample	500 ml
coliformic bacteria		sterile glass		
oil index		glass		
TBT, PAH, PCB, PFAS		glass Amber		
VOC		glass VOA		
benzene, MTBE, trichlorethylene		glass		
COD	7 days	plastic		250 ml

7.3 Analytical methods

The sampling guidances applied are:
Water quality - Sampling - Part 2: Guidance on sampling techniques (EN ISO 5667-2:1991) and Water quality - Sampling for microbiological analysis (ISO 19458:2006): EN ISO 19458:2006.

Table 19. Analytical methods recommended.

Analyte	Sample pretreatment	Standard Methods
pH	no filtration	EN ISO 10523:2012
Temperature	no filtration	EN ISO 10523:2012
Suspended solids	method includes filtration	EN 872:2005
Total organic carbon (TOC)		EN 1484:1997
Total nitrogen	no filtration	EN ISO 11905-1:1998
Total phosphorus	no filtration	EN ISO 6878:2004, EN ISO 15681-1 and -2:2004
Metals and other elements obtained by the same method of analysis: Al, **As**, B, Ca, **Cd**, **Cr**, **Cu**, Fe, K, Mg, Mn, Na, **Ni**, P, **Pb**, S, Si, **Zn**	filtration needed*	EN ISO 11885:2009
Hg	no filtration	ISO 17852:2006
Benzo (a) pyrene indicator of PAH	no filtration	ISO 28540:2011
Benzene	no filtration	ISO 11423-1:1997
Methyl-t-butyl ether (MTBE)	no filtration	ISO 11423-1:1997
Polychlorinated biphenyls (PCB)	no filtration	ISO 6468: 1996
Perfluoroalkyl substances (PFAS)	no filtration	ISO 21675: 2019
Tributhyltin (TBT)	no filtration	ISO 17353: 2004
Trichlorethylene	no filtration	ISO 11423-1:1997
Coliformic bacteria	no filtration	EN ISO 9308-1:2014 or EN ISO 9308-2:2014
Oil Index		ISO 9377-2: 2000

*Stormwater should be filtered if dissolved metals need to be analysed. A filter pore size 0,4 um to 0,45 um shall be used.

8 Conclusions

Drawings and technical information on selected pilot sites has been produced for Rakvere, Haapsalu, Jurmala, Ogre, Liepaja and Słupsk.

A description of major stormwater pollutants and their sources is presented.

A description of sampling procedure, analytical methods and assessment methods is produced and they have been used by the municipalities.

It has been a challenge for the municipalities to get an automatic sampler equipment installed for sampling. Lengthy and complicated procurement processes as well as the limited availability of the equipment resulted in delays of sampling or the municipalities opting for taking grab samples. Natural conditions such as long periods of ice and snow also generally prevented sampling during long periods. For example, in Söderhamn, the automatic sampler was rented on a long-term basis from Swedish Environmental Research Institute. For 8 months, from September 2019 to May 2020, it was not possible to sample a representative storm event as there was no rain or temperatures were below zero. In other municipalities automatic samplers where rented during a much shorter period of weeks and to catch a representative rain event during this time is difficult. For most municipalities and for many of the researchers it is also the first-time for sampling stormwater and therefore it has been a learning by doing process. Procurement processes and financial resources has also limited the number of samples taken and the number of parameters analysed in some cases. However, stormwater has been sampled and analysed several times in all municipalities. In total over 50 samples have been taken and the water quality assessed.

Analytical methods used have been slightly different in some cases than the recommended in the NOAH guideline, but sampling and analyses has been carried out using ISO/EN standards and the choice of method is not expected to significantly affect the results and all data obtained are considered reliable. Most municipalities have analysed the priority list 1 parameters as suggested in the guideline.

As there are no discharge limits for stormwater set at the EU level or national level in the Baltic Sea Region the municipalities have been provided with 5 different methods for assessing the water quality of the samples. The first one is based upon discharge limits for effluents from WWTPs, the second is based upon EQS set at the EU level or national level as specified under the EQS Directive (2013/39/EU) for coastal and transitional water. The third assessment method make use of the large database of stormwater pollutant concentration available in the StormTac database, the fourth method are guideline values for discharges to the stormwater sewers or freshwater recipients in Gothenburg, Sweden and the fifth method are water quality parameters for stormwater outlets in Estonia. The choice of assessment method depends on the type of water tested as well as the choice of recipient, the recipient being either coastal and transitional waters or freshwater. In this report StormTac data has been used for the assessment.

The assessment shows that water quality characteristics varies extensively from site to site but also with sampling date and weather conditions at a sampling site. The most contaminated water is coming from the untreated wastewater (CSO) from Słupsk which is a very different effluent than the water sampled in the other sites. Measured parameters for samples have been found to be above, within and below the interval for stormwater in the StormTac database. This is the case even if Słupsk samples are excluded from the assessment. Pollutant concentration above interval are sometimes found for the parameters TN, TP and/or indicator bacteria. It can indicate that the sample is contaminated by wastewater but other explanations can´t be excluded such as dry weather samples are taken in standing water in manhole containing residues.

Random sampling under a rain event using grab samples has been the sampling strategy in most municipalities and therefore event mean concentrations (EMC) and load calculations cannot be conducted. The possibility of comparing water quality before and after installation of monitoring equipment (passive technical innovations) is therefore also limited using the water quality data. Other methods for evaluating the reduced impact of the spillages to the BSR after installation of technical innovation should therefore be explored for example using the models.

The municipalities approach to take control over the spillages are govern by both the local conditions and municipal priority settings. The municipalities are therefore also choosing different technical innovations (Pori and Söderhamn are not installing technical innovations in the project) for the prevention of spillages. This is consequently also reflected in the type and number of samples that has been taken and assessed so far. During the reminder of the period efforts will be made to assess additional samples and evaluate how the technical innovations may improve the water quality in downstream recipients.

9 References

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10 Appendix

10.1 Appendix 1. Recommended analyses.

Analyte	Sample pretreatment	Standard Methods
Priority 1		
pH	no filtration	EN ISO 10523:2012
Temperature	no filtration	EN ISO 10523:2012
Electrical conductivity	no filtration	EN 27888:1993
BOD7	no filtration	EN 1899-1:1998 or EN 1899-2:1998
Suspended solids	method includes filtration	EN 872:2005
Dissolved oxygen	no filtration, sample treatment on field	EN 25813:1993
Dissolved organic carbon (DOC)	filtration needed	EN 1484:1997
Total organic carbon (TOC)		EN 1484:1997
Ammonia nitrogen	filtration needed	EN ISO 11732:2005, ISO 7150-1: 1984
Sum of nitrate and nitrite nitrogen	filtration needed	EN ISO 13395:1996, EN ISO 10304-1:2009
Total nitrogen	no filtration	EN ISO 11905-1:1998
Phosphate phosphorous	filtration needed	EN ISO 6878:2004, EN ISO 10304-1:2009, EN ISO 15681-1 and -2:2004
Total phosphorus	no filtration	EN ISO 6878:2004, EN ISO 15681-1 and -2:2004
Metals and other elements obtained by the same method of analysis: Al, As, B, Ca, Cd, Cr, Cu, Fe, K, Mg, Mn, Na, Ni, P, Pb, S, Si, Zn	filtration needed	EN ISO 11885:2009
Coliformic bacteria	no filtration	EN ISO 9308-1:2014 or EN ISO 9308-2:2014
Oil Index		ISO 9377-2

Priority 2		
Cas No, PAH		
56-55-3 Benzo (a) anthracene 205-99-2 Benzo (b) fluoranthene 207-08-9 Benzo (k) fluoranthene 50-32-8 Benzo (a) pyrene 193-39-5 Indeno (1,2,3-cd) pyrene 53-70-3 Dibenz (a, h) anthracene Sum of carcinogenic PAH 91-20-3 Naphthalene 208-96-8 Acenaphthylene 83-32-9 Acenaphthene 86-73-7 Fluorine 85-01-8 Phenanthrene 120-12-7 Anthracene 206-44-0 Fluoranthene 129-00-0 Pyrene 191-24-2 Benzo (g, h, i) perylene Total other PAH Total low molecular weight PAH Total PAH with medium molecular weight Total high molecular weight PAH		ISO 28540:2018
Priority 3		
VOC		ISO 11423-1:2011, ISO-EN 10301:1997
Methyl tert-butyl ether (MTBE)		included in VOC analyse
Benzene		included in VOC analyse
Priority 4		
Tributyltin (TBT)		
Microplastics		
Ftalater		

10.2 Appendix 2– Analytical methods used in Latvia

Sampling guidance applied:
Water quality - Sampling - Part 2: Guidance on sampling techniques (EN ISO 5667-2:1991)
Water quality - Sampling for microbiological analysis (ISO 19458:2006): EN ISO 19458:2006

Analyte	**Sample pretreatment**	**Standard Methods**	**Applied Standard Method**	**Notification (L-Liepāja, J-Jūrmala, O-Ogre; 1-sample 1, 2-sample 2, etc.)**
Priority 1				
pH	no filtration	EN ISO 10523:2012	LVS EN ISO 10523:2012	sensor (multimeter)
Temperature	no filtration	EN ISO 10523:2012	Determined simultaneously with pH and Electrical conductivity measurement	sensor (multimeter)
Electrical conductivity	no filtration	EN 27888:1993	LVS EN 27888:1993	sensor (multimeter)
BOD5	no filtration	EN 1899-1:1998 or EN 1899-2:1998	1) LVS EN 1899-2:1998 2) LVS EN 1899-1:1998	1) J1, J2, L2, O1, O2 2) L1
Suspended solids	method includes filtration	EN 872:2005	LVS EN 872:2005	J1, J2, L1, L2, O1, O2
Dissolved oxygen	no filtration, sample treatment on field	EN 25813:1993	LVS EN ISO 5814:2013	sensor (multimeter)
Dissolved organic carbon (DOC)	filtration needed	EN 1484:1997	LVS EN 1484:2000	
Total organic carbon (TOC)		EN 1484:1997	LVS EN 1484:2000	
Ammonia nitrogen	filtration needed	EN ISO 11732:2005, ISO 7150-1: 1984	1) LVS EN ISO 11732:2005 2) LVS ISO 7150-1:1984	1) J1, J2, L1, O1 2) L2, O2
Sum of nitrate and nitrite nitrogen	filtration needed	EN ISO 13395:1996, EN ISO 10304-1:2009	1) LVS EN ISO 13395:1996 (N/NO2, N/NO3) 2) LVS EN ISO 10304:2009 (N/NO2, N/NO3) 3) LVS EN ISO 10304:2009+AC2013 (NO2, NO3)	1) J1, O1 2) J2, L1, L2, O2 3) J2, L1, L2, O1, O2
Total nitrogen	no filtration	EN ISO 11905-1:1998	LVS EN ISO 11905-1:1998 LVS EN ISO 13395:1996	both J1, J2, L1, L2, O1, O2
Phosphate phosphorous	filtration needed	EN ISO 6878:2004, EN ISO 10304-1:2009, EN ISO 15681-1 and -2:2004	LVS EN ISO 15681-1:2005	J1, J2, L1, L2, O1, O2

Total phosphorus	no filtration	EN ISO 6878:2004, EN ISO 15681-1 and -2:2004	LVS EN ISO 15681-1:2005	J1, J2, L1, L2, O1, O2
Metals and other elements obtained by the same method of analysis: Al, As, B, Ca, Cd, Cr, Cu, Fe, K, Mg, Mn, Na, Ni, P, Pb, S, Si, Zn	filtration needed	EN ISO 11885:2009	1) Zn - LVS ISO 8288:1986 2) Pb, Cr, Cd, Ni, As - LVS EN ISO 15586:2003 3) K, Na, Ca, Mg - LVS EN ISO 14911:2000 4) Fe - Stand.Meth.3111B:2011 5) SO4 - LVS EN ISO 10304:2009+AC2013 6) Si - Stand. Meth.4500-SiO2:2011 7) Al - LVS EN ISO 10566:1994 8) B - LVS ISO 9390:1990 9) Mn - Stand.Meth.3111B:2011 10) P - LVS EN ISO 15681-1:2005 11) Cu - LVS EN ISO 15586:2003	1) J1, J2, L1, L2, O1, O2 2) J1, J2, L1, L2, O1, O2 3) J1, J2, L1, L2, O1, O2 4) J1, J2, L1, L2, O1, O2 5) J1, J2, L1, L2, O1, O2 6) J1, J2, L1, L2, O1, O2 7) J1, J2, L1, L2, O1, O2 8) J1, J2, L1, L2, O1, O2 9) J1, J2, L1, L2, O1, O2 10) J1, J2, L1, L2, O1, O2 11) J1, J2, L1, L2, O1, O2
Coliformic bacteria	no filtration	EN ISO 9308-1:2014 or EN ISO 9308-2:2014	LVS EN ISO 9308-2:2014	J1, J2, L1, L2, O1, O2
Oil Index		ISO 9377-2	LVS EN ISO 9377-2:2001	J1, J2, L1, L2, O1, O2
Cl			LVS EN ISO 10304:2009+AC2013	J2, L1, L2, O1, O2

10.3 Appendix 3 – Analytical methods used in Poland

Sampling guidance applied:

Water quality - Sampling - Part 2: Guidance on sampling techniques (PN-EN ISO 5667-10:1997)

Water quality - Sampling for microbiological analysis (PN-EN ISO 19458:2007)

Analyte	Sample pretreatment	Standard Methods	Applied Standard Method	Applied Measurement Techique
Priority 1				
pH	no filtration	EN ISO 10523:2012	PN-EN ISO 10523:2012	Metoda potencjometryczna
Temperature	no filtration	EN ISO 10523:2012	PN-77/C-04584	Metoda manualna
Electrical conductivity	no filtration	EN 27888:1993	PN-EN 27888:1999	Metoda konduktometryczna
BOD7	no filtration	EN 1899-1:1998 or EN 1899-2:1998	PN-EN 1899-1:2002 and PN-EN 1899-2:2002	Metoda elektrochemiczna
Suspended solids	method includes filtration	EN 872:2005	PN-EN 872:2007+Ap1:2007	Metoda wagowa
Dissolved oxygen	no filtration, sample treatment on field	EN 25813:1993	PN-EN ISO 5814:2013-04	Metoda elektrochemiczna
Dissolved organic carbon (DOC)	filtration needed	EN 1484:1997	CSN EN 1484	Metoda spektrofotometrii w zakresie podczerwieni
Total organic carbon (TOC)		EN 1484:1997	CSN EN 1484	Metoda spektrofotometrii w zakresie podczerwieni
Ammonia nitrogen	filtration needed	EN ISO 11732:2005, ISO 7150-1: 1984	PB-PBŚ-06 wyd. 2 z dnia 25.02.2009r.	Metoda spektrofotometryczna
Sum of nitrate and nitrite nitrogen	filtration needed	EN ISO 13395:1996, EN ISO 10304-1:2009	PB-PBŚ-03 wyd. 2 z dnia 25.02.2009r., PB-PBŚ-01 wyd. 2 z dnia 25.02.2009r.	Metoda spektrofotometryczna