Guidelines for CleanStormWater best practices

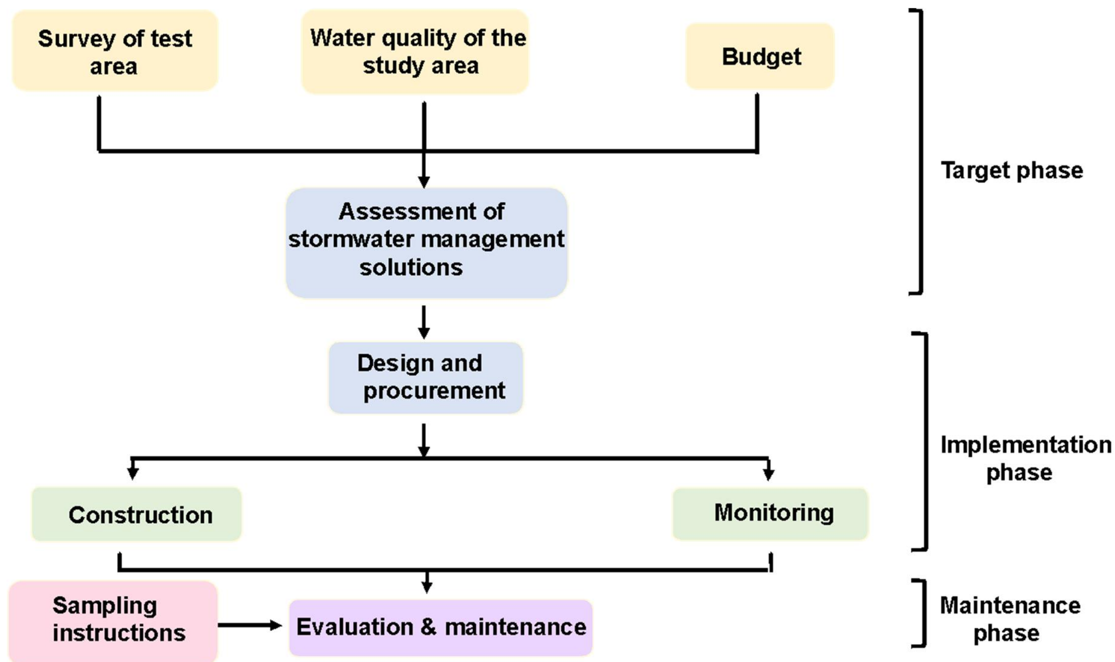
Stormwater management is becoming increasingly important for our society due to factors like urbanization and the increasing areas of surfaces impervious to rainwater that urbanization creates. Stormwater management may also become more relevant due to climate change and the potentially increasing volumes of annual rainfall. If left untreated stormwater can transport hazardous substances and environmental pollutants from urban environments into rivers, lakes and seas and thereby impose a significant risk for the water quality and the ecosystem.

One of the main objectives of the Interreg Central Baltic programme 2014-2020 project “Testing new stormwater treatment solutions for reduction of hazardous substances and toxins inflows into the Baltic Sea” (further - the CleanStormWater project) was to improve the stormwater management around the Baltic Sea by designing and piloting innovative stormwater treatment solutions for specific pilot sites - stormwater pollution hotspots.

Municipalities around the Baltic Sea lack sufficient knowledge and experience on the life cycle management and practical realization of stormwater treatment systems; thus, there is a risk that a significant part of the newly constructed systems will not function as expected. The CleanStormWater project team tested four methods relevant for the Baltic Sea region believes that stormwater technology solutions piloted within the present project can be successfully applied in many other cities, therefore we are proud to share with you our documented experience compiled in the present “Guidelines for Stormwater Treatment Solutions and e-monitoring” elaborated by the CleanStormWater project team.

These recommendations are primarily intended to assist other Baltic Sea communities in implementing stormwater treatment solutions for addressing and/or mitigating both urban stormwater quantity and quality issues. Be part of the solution and help to keep our water ways healthy.

The following procedures are involved in the construction and monitoring of stormwater treatment solutions. By clicking the text box, you will be redirected to the topic of your choice.



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Partners

VIIMSI VALD TALTECH RĪGA TURKU AMK KTH VETENSKAP OCH KONST

Associated partners

LIETO TURKU

Abbreviations:
Al- Aluminium
BOD-Biochemial oxygen demand (5 days)
Cd-Cadmium
COD- chemical oxygen demand
Cr- Chromium
Cu- Copper
DO- Dissolved oxygen
EC- Electrical Conductivity
Fe- Iron
Hg- Mercury
Ni- Nickel
N-tot- Total Nitrogen
ORP-Oxidation Reduction Potential
Pb- Lead
PO_{4}^{-}Phosphate
Ptot- Total Phosphorus
TDS- total dissolved solids
TOC-Total Organic Carbon
TSS- total suspended solids

I. Survey of test area

Stormwater management contributes to keeping streams, lakes, lawns and other green sites healthy by improving water quality. We started the project by thinking to minimize the surprises and mistakes by obtaining a detailed stormwater and drainage survey.

The little we do in our living area will have a significant impact in reducing the pollutants in waterways and to the Baltic Sea. The first step in developing stormwater management solutions for treating and monitoring stormwater was finding the appropriate site and technology. Here is an example of identifying the sites for piloting the stormwater treatment solutions and management in Estonia, Finland, Latvia and Sweden.

Identifying the site for stormwater treatment solutions and management

Estonia

Viimsi demo site 2 – trash screen

Viimsi municipality started by looking for a catchment that is primarily urban, and would therefore be most likely to be affected by pollutants. The Municipality anticipated that human activities like transportation would cause urban watersheds to be the most polluted. The large watershed in the center of Viimsi was later determined to be the best candidate for the stormwater treatment system construction. The analysis of the watershed area revealed that there are roughly three sub-catchments, each of which has distinct treatment requirements. The first sub-watershed was found to have an issue with nutrients, the second was found to have a problem with trash, and the third was found to pose risk to the water quality due to the potential future development. In Viimsi, the entire catchment area had been granted an environmental permit, which regulates the discharge of stormwater to the Baltic Sea. This permit also mandates the municipality to collect stormwater samples to collect at the discharge point by the sea every three months in order to track stormwater quality.

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Finland

Catchment area of the Turku pilot consists of a road area (left). Location of the stormwater treatment solution prior to building (right).

Catchment area of the Lieto pilot consists of an industrial area (left). Location of the stormwater treatment solution prior to building (right).

The following site characteristics were considered when choosing the pilot sites:

- If the land use of the pilot catchments poses a high risk for the stormwater quality. (High trafficked area or industrial activity).
- If the size of the catchment areas enables stormwater treatment by constructing nature-based stormwater treatment solutions.
- If the pilot area lots are owned by associated partner municipalities.

Latvia

Lucavsala island (left) and selected pilot site at the bank of Dugava (right)

The pilot sites were selected in consultation with the responsible municipal departments - the Traffic Department and the Housing and Environment Department of Riga city who were also involved in the project working group. The following considerations were taken into account: the views of the responsible departments; spatial planning; the nature of the site (intensity of use, etc.); land ownership.

Riga initially nominated two potential pilot sites - *Lucavsala* and *Zakusala*. *Lucavsala* was chosen due to its intensive use, the area has heavy traffic, and the stormwater is drained from the road and the bridge. Accordingly, Lucavsala was considered to have the highest pollution risks.

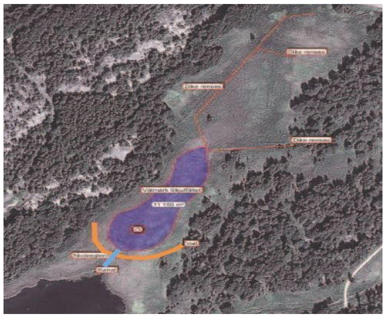
Sweden
Södra Fladen

Constructed wetland site in Södra Fladen

Freshwater comes into the wetland from a 250 hectare forest area. Flowing under the main road and through a 1 km ditch passing an equestrian facility and entering the first step into the wetland, which is a phosphorus pond. Water flows into the next step where nitrogen removal processes take action. Finally, the water reaches the Baltic Sea. A survey of the land area was conducted to find a suitable place for constructing the wetland. The bottom sea area consists of gravel sands 2 meters below the surface followed by clay soil (30-40cm depth). A pond was constructed based on the vegetation and sea level.
The size of the wetland is 3 hectares and the landowner is the Haninge Municipality and the construction was completed in March 2015.

Byviken

Construction of the wooden gate (left) used to regulate the water flow (right).



The drawing was created together with the constructor.

The length of the embankment was decided based on incoming water from main ditches, ground gradient and surrounding levels. The height of the embankment is a combination of ground gradient and water levels (normal and maximum).

The freshwater catchment area is a military practice field of approximately 300 hectares. The construction slows down the speed of the water into the pond shown in the figure above. In the next step a small island further slows the speed of water before it flows out to the Baltic Sea.

The size of the wetland is 1,5 hectares and the landowner is Fortifikationsverket. Construction was completed in November 2021.

Gruvbyn

Depicted the foot path to the wetland (left) and the wetland (right).

The water catchment area is 200 hectares of forest where the freshwater flows through a 3 km ditch to reach the wetland. This is the smallest of the three wetlands on Utö. In the proximity there are 1000-year-old iron mines that are not in use today. The size of the wetland is 0,5 hectares and the landowner is Skärgårdsstiftelsen and a private owner. Construction was completed in April 2021.

II. Stormwater quality and regulations

This section provides an overview of the stormwater quality in the pilot areas of Estonia, Finland, Latvia and Sweden (test bed) to highlight the importance of stormwater treatment solutions and water quality management. It also provides insight about national and regional regulations on stormwater quality.

1. Stormwater quality

Estonia

Stormwater samples were taken from four points within the catchment in the period of June - September. The following parameters were analyzed from the samples: TSS, EC, turbidity, TDS, pH, DO, ORP, Ntot, Ptot, Cd, Cr, Cu, Pb, Ni, Zn, Hg, Al, Fe, TOC, cations, anions, *Escherichia coli* and Enterococci. During this period, it was possible to collect 6 samples, the samples were collected during both dry (3) and wet (3) weather.

Although the analysed samples did not indicate exceedance of nutrients or heavy metals, they indicated that there is a consistent microbiological contamination (reflected in high levels of *Escherichia coli* and Enterococci) and a sporadic pollution input (reflected in elevated EC/TDS and iron, aluminium, chlorine concentration). These substances are not regulated in the Estonian legislation but the measurements do give an indication of the "normal" magnitude of concentrations, which are occasionally significantly exceeded.

It must be noted that the collected data is significantly affected by the timing of sample collection. The sample collection was outsourced to a contractor and a single grab sample was taken during each event from each individual location, thus the first flush, which is the primary source of particle bound pollutants, such as heavy metals and nutrients (phosphorus), may be reduced.

Finland

Prior to making final decisions on stormwater treatment solutions, water samples were collected from both pilot sites. Turbidity, TSS, electric conductivity, pH, Ntot, Ptot, PO4, Cd, Cr, Cu, Pb, Ni, Zn, and Hg were all measured in the samples. The water quality at the sites fluctuated over short time periods. Both sites had elevated concentrations of solids, phosphorus, and heavy metals, especially zinc.

Latvia

Stormwater analysis was performed in the pilot area to measure the following parameters: Zn; Cr; Ptot; Ntot; Pb; Cu; TSS; Ph; BOD5; COD; Petroleum products of hydrocarbons index; synthetic surfactants (SVAVanj). Although heavy metals and other parameters have been identified in the stormwater samples, only the TSS value has been exceeding the value set by the binding regulations.

Sweden

During this project, parameters such as nitrate-N, ammonia, phosphorus, heavy metals and polyaromatic hydrocarbons were analyzed and monitored to evaluate the efficiency of the constructed wetland systems. The elevated concentration of heavy metals in one of the wetlands might be due to differences in land use.

2. National and regional regulations on stormwater quality

Estonia

The requirements for stormwater handling, monitoring, discharge, and control in Estonia are outlined in the Estonian Water Act, and the regulations are developed by the Estonian Ministry of the Environment. The ministry is also in charge of determining the permissible threshold values, and the Estonian Environmental Board is in charge of ensuring that they are followed. When dealing with stormwater, the Water Act states that preference should be given to solutions that allow stormwater to be handled at the source, thereby preventing potential stormwater contamination downstream. In addition, discharged stormwater must meet the permissible pollutant concentration threshold values established by the Estonian Ministry of the Environment or the threshold values assigned through water or integrated permits. Stormwater management by infiltration or conveyance is prohibited in areas where a water protection zone or a maintenance zone of a water intake has been established. There are also some restrictions and exemptions for stormwater management in Estonia:

It is permissible to direct stormwater to the outlet as long as the water quality criteria are below threshold values set by the Estonian Ministry of Environment.

Using infiltration as a stormwater management strategy is only permitted in the areas where the highest groundwater table is at least 1.2 meters below the infiltration bed.

For combined sewers, the regulations indicate that combined sewer overflows (CSO) may be activated only if the stormwater-to-sewage ratio is 4:1. Adherence to such ratio should be ensured by appropriate design and construction of overflows. Because the use of CSO is an exemption, the water quality is not monitored in this case.

When it comes to stormwater quality, Viimsi municipality follows given environmental permission and limits set by the ministry of environment 24.07.2019 regulations number 28.

Finland
In Finland, there are no quality thresholds for pollutant concentrations in stormwater at the outlets. The Government Decree on Substances Dangerous and Harmful to the Aquatic Environment establishes environmental quality standards for surface water bodies and coastal sea areas. These thresholds, however, do not directly apply to stormwater or smaller bodies of water such as brooks and ditches.

Latvia
Currently, there are no separate regulations in Riga City Municipality for stormwater quality issues, however, the municipal binding regulations No.17 “Composition of wastewater discharged into the sewerage system in the City of Riga” among other issues apply to stormwater quality, as well as the binding regulations No.39 “Binding regulations for the operation, use and protection of the centralized water supply and sewerage system of the City of Riga” state that the service provider is the company rendering public water management services, its obligations include drainage of wastewater, in turn wastewater is defined as only the runoff stormwater which is drained into the city’s sewerage system. These regulations also provide that stormwater drainage systems are not included in the balance sheet of the service provider.

Most relevant from the national level:

The Cabinet of Ministers Regulations No. 34 “On Discharge of Polluting Substances into Water” classifies run-off stormwater as wastewater and provides requirements in relation to polluting substances in wastewaters.

Cabinet of Ministers Regulations No. 327 on Latvian Construction Standard LBN 223-15 “Sewerage Constructions” sets the methodology for calculating the amount of stormwater to be drained into domestic sewerage systems, as well as provides technical requirements for designing stormwater sewerage systems.

LTD CLEANTECH LATVIA (Group of companies offering solutions for sustainable and smart cities, regions and industries) has developed useful documents in the field of stormwater treatment, for example, “Methodological guidelines for stormwater treatment in typical situations: design guidelines for sustainable stormwater management solutions”.

Within the framework of the Interreg BSR project “BSR WATER” the Baltic Smart Water HUB has been established, which gathers the best examples of stormwater treatment in the BSR. On the platform it is possible to get in touch with the stormwater experts from all BSR countries, as well as to register as the stormwater expert. Link to the platform: https://www.balticwaterhub.net/

Sweden

In Sweden, the flow rate of small, and medium-sized rains, that transport large amounts of pollution, are generally used as a basis for the dimensioning of stormwater filtering structures. There are currently no national standards for stormwater quality but the Swedish Environmental Agency has outlined the water quality thresholds for various water bodies (Naturvårdsverket, 2008).

The threshold values differ for different waterbodies, based on their size and geographic location in the country (North/South). Some municipalities in Sweden, such as Stockholm and Gothenburg, have developed and self-imposed stormwater pollution guidelines (Alm et al., 2010; Göteborgs Stad, 2017). The Gothenburg guidelines are much stricter and have higher demands than Stockholm guidelines and they do not differentiate according to the receiving waterbody or the origins of the stormwater.

Handbook from Trafikverket (2015, p.147) provides a check list for maintenance and care needed for different kind of stormwater management solutions.

Budget - approximate

The cost for construction and management of a stormwater treatment solutions is crucial in determining the feasibility of implementing the ideas. In this section, we provide an estimate of the approximate cost for some of the treatment technologies and maintenance. The cost referred herein is based on our experiences gained during the CleanStormWater project by constructing pilot sites in Estonia, Finland, Latvia and Sweden (test bed) as well as e-monitoring systems for stormwater management.

Estonia

The approximate budget for reconstructing Viimsi's stormwater treatment solutions and monitoring system is shown below. Extra work was carried out to reconstruct part of the pilot site (site 5), where the e-monitoring station was installed. The costs of the pilot sites shown below includes 20% VAT.

activities	costs (€)
project desgin	34560
construction at site 2	56292
construction at site 3	113112
constrcution at site 4	16429
constrcution at site 5	78126

Finland

In south-west Finland, two bioretention basins were built as part of the project. These nature-based solutions were created in order to provide new data on their efficiency in stormwater treatment. Due to the research purposes of the sites, certain structural modifications were required. As a result, the costs of the pilot sites are not fully representative of the costs of a bioretention pond built solely for stormwater management.

The Finnish pilot sites were completely funded by the project budget. Turku UAS project personnel completed pilot site mapping, flow calculations, planning, and installation tasks. These project costs are not comparable to market prices for the same services and thus are not presented. Other realized construction costs for the Turku and Lieto bioretention basins are shown in the table.

Content	Turku pilot (€)	Lieto pilot (€)
machine work	6300	5300
pipes, parts, tools	3700	6300
soil material	1600	7000
vegetation	400	1100
Total	12000	19700

Purchase costs for online flow and water quality monitoring devices similar to those used at the Lieto pilot site are estimated to be around 50,000 €. Sensor maintenance and calibration may incur additional costs.

Latvia

Stormwater monitoring at the Riga pilot site was conducted by manual sampling and testing the stormwater quality of the manhole in different weather conditions. A price survey was conducted. Procurement procedures that were carried out for the project development included geological survey, geodetic works, supervision and construction. A price survey was also conducted for the e-monitoring system and supervision of construction work.

Activities	costs (€)
overall monitoring of pilot site	12099
desiging project development	23474
e-moniroing system	10000
construction	112632
supervision of construction work	1803

Sweden
During this project, Utö constructed wetlands were used as a test bed for evaluating the efficiency of the stormwater treatment solutions. The Utö initiative raised funding to construct these three wetlands.

Content	Wetland 1 (Södra Fladen) (€)	Wetland 2 Byviken (€)	Wetland 3 Gruvbyn (€)
cost before construction			
geological survey/Mapping	5000	0	4000
procurement	3000	3000	3000
land and water use agreemen	0	0	2000
constructing pilot site			
machine work, transport	55000	60000	55000
pipes, parts, wooden gate	6000	6000	4000
stones	2000	2000	1000
vegetation	500	0	15000
project management	15000	15000	15000
cost after construction			
maintenance	5000	2000	2000

Other costs involved in the process
The cost of project management for the entire process from identification to implementation is approximately 15000€ per wetland.
The cost for maintenance is determined by how frequently the material is cut and removed from the wetland. Depending on the type of equipment is available.
it may costs approximately 2000€ per hectare

Financing
Södra Fladen 50% EU EMFF (European Maritime and Fisheries Fund), 25% Haninge Municipality and 25% LONA (Naturvårdsverket).
Byviken 100% Havs- och Vattenmyndigheten
Gruvbyn 90% LEADER Stockholmsbygd, 10% Initiativ Utö

Assessment of stormwater management solutions

The CleanStormWater project provided an opportunity to study the feasibility of implementing technological solutions and online monitoring systems for stormwater quality and quantity management. The solutions were tailored to the features of the catchment, such as size, land use, and human activities, for Estonia, Finland, Latvia and Sweden.

Estonia

The first sub-catchment was discovered to have a high nutrient concentration ; it was determined that the small pond at the end of the sub-catchment could be refurbished and used as part of the solution. The pond was supposed to be rebuilt in such a way that it improves water flow and sedimentation, preventing particles and associated contaminants from traveling downstream. The dissolved contaminants were also supposed to be treated by planting appropriate plant species. Unfortunately, due to budget constraints, this solution was omitted from the project's construction phase.

The second sub-catchment challenge is that trash from adjacent shopping mall waste bins enters the drainage ditch and clogs the underground stormwater pipe. If it does not clog the stormwater pipe and manages to pass through, it pollutes the Baltic Sea. To treat stormwater from the second test site, it was decided to design a smart trash screen that would catch a trash from the site and alert its managers when the grid needs cleaning .

The third sub-catchment is being used as a test site for an underground oil and grit separator, which has never been used in Estonia before. This solution was added to account for the potential effects of future developments on water quality in the area.

The fourth test site was selected based on two criteria: ease of construction and maximum catchment coverage. An existing ditch was chosen to reconstruct as far downstream as possible, so that it could treat the majority of runoff from upstream catchments and not to overcomplicate the process of construction.

Test site number 5 – not covered here because it is a monitoring station.

Finland

The research and promotion of sustainable nature-based solutions for stormwater management is important, as many municipalities lack experience and knowledge on practical realization of such systems. Stormwater filtering systems are considered promising solutions, as they alleviate both stormwater quantity and quality problems. In addition, bioretention basins have the potential to retain solids and heavy metals typically present in traffic area stormwaters.

Latvia

Two alternative technologies were offered for Riga. To make the choice of the preferred option, the following aspects were taken into account: maintenance and sensor installation options. The first alternative was The Screen basin approach, which is used in a water body and consists of a system of sieves and nets, and treatment is based on the principle of sedimentation through the sieve and later collection of accumulated particles.

The second option and the chosen solution was the Vertical hydrodynamic separator. Hydrodynamic separators are flow-through structures with a settling or separation unit to remove sediments and other pollutants that are widely present in stormwater. The separator was pre-fabricated from concrete .

Sweden
The constructed wetland system was chosen for the study site, Utö. It has one of the technologies to treat stormwater that was developed in the earlier study conducted by KTH master student project. The study focused on the ground water level, soil texture and sea water level.

Design and procurement

This section focuses on the design of stormwater treatment solutions including assessment of the catchment area (topography, geology, land use, as-built drawings of the existing stormwater system, etc.), storm sewers, streets, open channels, culverts and bridges. It begins with the layout of minor and major flow rates so that engineers can review the hydraulic grade line for runoff conditions.

The procurement is crucial to ensure that all services and assistance are acquired so that the pilot construction of stormwater treatment technology in the CleanStormWater project can proceed efficiently and successfully. The procurement planning will help in reducing the cost, increase transparency, improve planning vs performance and aid in future strategy.

1. Designing the treatment solution

Estonia
TalTech's knowledge, together with the experience of the Viimsi project team and design project consultants, was the primary "tool" employed in this project. Because of the work approach, the design changed several times throughout the process: initially, the design project creator drew out her proposal, and then the project team provided feedback.

Finland
The pilot structure design is based on literature references such as:

1. Woods B., Wilson S., Udale-Clarke H., Scott T., Ashley R., Kellagher R. 2015. The SuDS Manual. United Kingdom: CIRIA.
2. Illmann, S. Wilson, S. 2017. Guidance on the Construction of SuDS. United Kingdom: CIRIA.
3. Minnesota Pollution Control Agency. 2021. Design criteria for bioretention.

The catchment analysis with flow estimates were made using QGIS software, and detailed discharge measurements were made with the flowmeter in Avanti. The final drawings of the pilot sites were made with AutoCAD design software.

The design of the pilot structures has changed according to the additional information gained from the sites. The detailed location of the pipelines and cables as well as ground water conditions in the planned pilot areas disabled the use of originally planned pilot locations and created a need for minor changes in design of the solutions.

Latvia
Based on the specifications developed by technical partners of the CleanStormWater project, Riga city procured the service provider for elaboration of the technical design of the stormwater treatment solution through open public procurement procedure. During the design, regular meetings were held to monitor the process.

After choosing the exact stormwater treatment solution no changes were made. However, alternative sensors were adapted during construction, as the availability of the designed ones was limited during construction.

Sweden
The initial phase of the project is to identify the possibilities for the potential area for constructing the wetland. The construction of the wetland was adapted if the water carries a significant amount of nutrients and/or toxic substances into the wetland. For example, different areas in the wetland where vegetation is involved will help in reducing the contaminants.

The optimal design of the wetland is based on the water quality of the streams. The water quality in Utö determines two step treatment solutions. The first pond will collect phosphorus which will bind to the sediment. The second pond is expected to remove nitrogen by vegetation and microbial processes. before the water flows into the Baltic Sea.

2. Procurement and permission

Estonia
The procurement process was divided into the following steps.
Technical description
- procurement for design project
- signing the contract for design project
- creation of design project
- applying for construction permit once design project is completed
- procurement for constructor
- signing the contract for construction
- construction of demo sites
- applying for “use” permit.

For most of the aforementioned steps the process was quite fast, however, it took over 8 months for the completion of the design project and it took over 5 months for finalizing the construction works.

Three of our demo sites were not in municipality owned land. One was on state land and we had a servitude contract with the state. The other two were in private hands, and unfortunately the private owners ignored our requests. We therefore decided to exercise our right to reconstruct the pre-existing utility network that owners have to legally tolerate - this is something we rarely use.

The municipality adhered to national procurement legislation. The design project is the most crucial component of the procurement process for construction projects. Therefore, a thorough and comprehensive technical description is crucial. We adhered to Estonian law when obtaining authorization. Every landowner and the owners of the neighboring utility networks had to grant us permission. Unfortunately, some landowners chose to disregard us, so, as mentioned previously, the town decided to grant the building permission on the condition that an existing stormwater system would be rebuilt, and landowners would have to tolerate the historic stormwater system being rebuilt.

Finland

The procurement for the pilot site's construction works were executed according to national procurement legislation. Typically, it is recommended to reserve 1–3 months for the procurement and contracting of construction services. In this project, the procurement had to be repeated a couple of times, as the first two procurement processes received no compliant offers. Successful procurement was conducted when the requirements for the contractor were clearly presented, and the equipment and construction materials were not included in the call for tenders.

The permitting of the Lieto Avanti site was done by a cooperative contract with Lieto municipality. The siting permit for the stormwater treatment solution at the Turku site was granted via online service provided by the city of Turku. No permission fees were applied.

Latvia

In Latvia, there are clearly defined procedures for public procurement. Expert support (provided by TalTech in this case) was essential for the development of the technical specification. The selected pilot site contains a solid coverage of the engineering networks, which affects the number of institutions with which the design project should be coordinated. In order to speed up the process of verifying and coordinating the compliance with the issued technical regulations regarding the design project, the representatives of municipal departments who are involved in the process to approve the design project as the construction project, have been involved in the local working group of the CleanStormWater project.

Sweden

After the agreements have been signed with the land and water owners, the next phase is to submit an application for permission to construct the wetland. In most cases, permission is granted by the County Administrative Board. The handling time is up to 6 months. Parallel to this work is it is recommended that you start looking for funding to begin the construction.

Construction work and challenges

Constructing stormwater treatment solutions is not a simple task since it requires a large number of personnel with different disciplines. It often requires a range of managerial skills in project management, setting up the goals, communication, budgeting and scheduling. Below, you will find an overview of experiences and challenges encountered during the construction of the pilot stormwater treatment solutions in Estonia, Finland, Latvia and Sweden.

1. Challenges in building the stormwater treatment solution and e-monitoring

Estonia

Constructed trash screens in demo sites 2 (Left) and 3 (Right)

The main challenge for the Municipality was to conduct the procurement and develop the project in such a way that it fit within the construction budget and that contractors could easily understand and implement it even in case the work scope is reduced. The Municipality's main concern was the competence of contractors because public procurement laws require that the lowest bid be accepted. We were fortunate in this case because the contractor was well-known to us, and the monitoring device subcontractor was also well-known for their expertise. The main challenge for the municipality throughout the construction phase was that we had never built anything like this before, and this was also a "first of its kind" project.

Finland

Construction of the Turku pilot site in December 2021 (top) and the ready bioretention basin in May 2022 (bottom right).

Installation of the filter medium (left) and watering of newly planted vegetation at the Lieto pilot (right).

To avoid challenges and surprises during the construction phase, thorough background research for the building site is essential. Background research should include an examination of the ground water level, the location of underground cables and pipelines in the area, and a soil quality investigation. When possible, avoid working in extreme weather conditions, such as when the temperature is well below freezing or when there is heavy rain. It is recommended to use the bypass or temporary dam if possible to ensure dry working conditions.

Latvia

Construction site where the vertical hydrodynamic separator is installed

Until now, sensor manufacturers' platforms have been used in Riga to display various types of sensor data. Along with the Clean StormWater project in Riga, the creation of a unified data platform will be launched. The municipal ICT services provider - Riga Municipal Agency “Riga Digital Agency” plans to synchronize the development of the platform with the e-monitoring platform developed in the project.

The availability of innovative stormwater treatment solutions in Latvia is limited, therefore the solution needs to be imported, which increases costs and takes extra time.

Sweden

Cleaning and material transport in the area for constructing the wetland

The three wetlands on Utö have different financiers and different land and water owners. The lowest common denominator is to start with an agreement with the owners. The agreement must include the right to implement the wetland solution and to maintain the solution. A detailed survey was carried out before planning and designing the constructed wetland.

2. Challenges in the construction phase

Estonia
The main challenge for the project team was a lack of experience in these types of construction projects. Another challenge was that the construction took place during the summer, when Viimsi and TalTech project members were on vacation. As a result, the team was unable to be as "hands on" with the project as they would have liked. Another issue was that the construction contractor had no knowledge of the plant species used. The main organizational challenge for Viimsi Municipality was the

construction of roads at the same time as the CleanStormWater test sites. This slowed the construction of the fourth test site.

Finland

Existing pipelines and cables next to the excavation area caused limitations in land use and routes for heavy machinery. Site visits with the contractor prior to construction and active communication with the excavator driver in the construction phase is recommended to ensure a smooth building process.

Latvia

There were no external obstacles during construction. The main obstacles are related to the quality of the builder's work. Based on this experience, the lessons learned in building innovative technology would be, it is critical to consult with the manufacturer before installing the equipment. Otherwise, the customer may ask the builder to provide the manufacturer's confirmation that the equipment has been properly installed as a mandatory requirement.

In the case of Riga, the most challenging aspect is to find contractors. The first procurement procedure ended without result. High groundwater levels at the selected pilot site may lead to further deviations in the construction process. In addition to this, the pilot site is located in a high traffic area, which might slow construction.

Sweden

Following the signing of the agreements, the next step is to submit an application for permission to build the wetland. In most cases, permission is granted by the County Administrative Board. The processing time can last up to 6 months. Parallel to this work, it is recommended that you begin looking for construction financing.

Drawings based on GPS tracking curves are created prior to construction. Almost every time the construction phase begins, some changes must be made due to GPS measurement errors. As a result, the project manager must be present on the construction site at all times.

3. Communication between builders, engineers and researchers

Estonia

The main issue was that the building contractor did not understand TalTech as a member of the Municipality's project team and did not directly include them in communications.

Finland

Before starting the actual building of the site, the working principles and reasons behind the planned structures needed to be communicated to the contractors.
Unexpected things may happen during the construction work and these things may require quick reactions and changes to the plans. A construction supervisor should be at the site all the time to monitor the work.

Latvia

In accordance with the concluded contract, construction meetings were organized every week, attended by the Riga municipality, the builder, the construction supervisor. The meetings were held as needed by the developer of the designing project and the developers of the e-monitoring system.

During the construction process, consultations with researchers were undertaken in addition to regular construction meetings in case of any unclear issues during the construction phase (regarding sensors).

Sweden

Despite the fact that the design and drawings were created and discussed in collaboration with engineers, some changes are always required during the construction phase. To avoid inaccuracies, the project management team must be present on-site during construction.

4. Supervision during construction

Estonia

The construction surveillance contractor had no past experience with similar projects, especially regarding monitoring equipment. We recommend that construction surveillance demonstrate their previous expertise and skill in order to participate in these sorts of projects.

Finland

Many of the construction contractors are not familiar with stormwater biofilters or other nature-based stormwater structures. It is important for the drawings of the structure to be clear and detailed enough. It would be also advisable to have at least one of the planners at the construction site in the beginning of the work.

Latvia

Latvian legislation sets the requirements for two-staged supervision of construction process: (1) construction supervision: professional and independent supervision of the construction work process in order to ensure high-quality and safe implementation of all planned construction works; and (2) author supervision: control performed by the developer of the construction project after the completion of the design work until the commissioning of the construction work in order to ensure the implementation of the construction works in accordance with the construction design. Supervision of the construction process must be performed by certified specialists. There is also a procedure for holding mandatory construction meetings, stipulating that representatives of all involved parties participate in these meetings, including the construction supervisor and the author's supervisor. Despite the established control, mistakes were made during the construction, which were later corrected.

Sweden

Communication with people living in the area is important. Providing information pertaining to what is going to happen and when it will happen is a factor for success. One has to be onsite with the builders to make sure that the construction work is carried out as per the drawings and design.

Monitoring systems

It is critical to understand the performance of the stormwater treatment system in order to manage stormwater quality. This can be accomplished by installing e-monitoring devices that monitor water quality and flow in real time. Here are some examples of choosing appropriate e-monitoring systems and installing them in pilot treatment plants in Estonia, Finland, Latvia and Sweden.

Selecting an e-monitoring system for online water quality assessment

Estonia
Technical descriptions for sensors and the systems to which they would be connected were developed by Viimsi and TalTech. Suitable sensors had to be selected by the contractors. The project team's main concern was the price of sensors. For various substances the expense of the sensors make them impractical for long-term e-monitoring applications.

Finland
Turku UAS selected e-monitoring devices which were compatible with Turku UAS existing hardware and have been proven reliable in field conditions. The selected monitoring devices were also amongst some of the most used devices for water quality monitoring and discharge measurements in Finland.

Sampling wells have been installed in the inlet and outlet of the biofilter structures. The e-monitoring devices are installed into these wells, and they monitor the quality and quantity of the flow entering and leaving the system.

Latvia
Manual stormwater quality sampling was performed before selecting the parameters to be measured by the sensors. Consultations with technical partners of the CleanStormWater project (e.g., TalTech) were also held to take the final decision. Sampling wells have been installed before and after the treatment unit. A number of real-time sensors are set-up in the sampling wells and in the stormwater treatment unit to monitor the inflow and outflow stormwater quality and quantity.

The stormwater monitoring results are displayed via the e-monitoring system that is based on the ThingsBoard open-source IoT platform - an open-source IoT platform that enables rapid development, management, and scaling of IoT projects. The main features of the e-monitoring system designed for the Riga pilot are the following:

- collection and visualization of data from sensors;
- analysis of incoming telemetry and triggering alarms with complex event processing;
- design of dynamic and responsive dashboards and presentation of device or asset telemetry, and insights to users;
- enabling the use-case specific features using customizable rule chains.

Sweden
Manual sampling was performed to monitor stormwater quality in the constructed wetland. The efficiency of wetland for removing nutrients and heavy metals in Södra

Fladen from 2021. The sampling was performed in the constructed wetland located in the mining and military sites in 2022 when the construction was completed.

Sampling instructions

Monitoring stormwater quality is a challenge since it is not a continuous water flow system. The stormwater flow depends on the precipitation and rainfall intensity and snowmelt in the watershed area. When planning a sampling schedule, it is of utmost importance to know the area and flow of water. One good advice is to observe the area during a rain event, then all water flows will be shown and an idea of how to take the samples can be designed. In this case, where a treatment process is monitored it is very important to know where new flows attach to the semi-purified or purified stream as they can carry pollutants which will interfere with the measurements of the treatment process (1,2).

A sampling schedule is usually made up of quarterly sampling. There are certain guidelines for when to take samples, one is to only trace precipitation that has occurred within 24 hours before the rain event that is being sampled. The other one is that the sampling should be carried out within the first two hours of the rain event. For a rain event to count as a sampleable rain event, the rain intensity needs to be at least 2.54 mm in a 24-hour period. If a sampling has been done in a rain event with less than that intensity it can still be used, but further consideration in weather forecasts should be done. During the winter months when the precipitation is snow, the sample should be taken during a melt event which mimics the requirements for a rain event. [1, 2]

The volume of the sample depends on the number of parameters that need to be analyzed and the laboratory prerequisites. In the table below an example of the volumes that are needed is shown.

Table 1. Approximately volumes needed for different analysis and which vessel and waiting time that can be used [3].

Parameter	Vessel	Volume	Time between sampling and analysis
TSS	Glass, plastic, PTFE	150-1000 ml	48 h
Turbidity	Glass, plastic, PTFE	70-150 ml	48 h
Metals	Glass, plastic, PTFE	30-150 ml	48 h
Nutrients	Glass, plastic	250-500 ml	24 h (can be frozen)
TOC	Glass, plastic, PTFE	100-500 ml	As soon as possible
PAH	Glass	500-1000 ml	As soon as possible
pH	Glass, plastic, PTFE	50-70 ml	6 h
Conductivity	Glass, plastic	50-70 ml	24 h
Alkalinity	Plastic, PTFE	70-500 ml	24 h

Reference

1. How to do stormwater sampling, Washington state department of Ecology, 2002
https://www.oregon.gov/deq/FilterDocs/ph-WDOEStormwater.pdf

2. Industrial Stormwater monitor and sampling guide, EPA, 2009
https://www3.epa.gov/npdes/pubs/msgp_monitoring_guide.pdf

3. Kunskapssammanställning dagvattenkvalitet, svenskt vatten, 2019
https://www.svensktvatten.se/contentassets/f3d99ca8ce964851b9702d3dc85e4269/trvu-rrap-2019-02.pdf

Evaluation and maintenance

In addition to constructing the pilot stormwater treatment solutions, it is crucial to assess their impact on runoff, water logging prevention and reduction of pollutants. One of the objectives of this CleanStormWater project is to assess the feasibility of using e-monitoring solutions to evaluate the efficiency of treatment solutions as well as the challenges associated with maintaining the devices. In this section, an overview of e-monitoring devices is provided.

1. E-monitoring strategy of the treatment solution

Estonia
The contractor had to calibrate the devices according to the guidelines provided by the manufacturer. The accuracy of results had to be validated by an accredited laboratory.

Sample measuring station at demonstration site 5

Finland
E-monitoring is utilized for flow measurements in Turku and Lieto pilot sites. Water quality monitoring in Turku is based on water samples and for the Lieto Avanti pilot site online measurement is used.

The water quality sensors used at the Lieto pilot site are calibrated in the lab according to the manufacturer’s instructions. Stage-discharge curve is created for the pressure sensors used for flow calculations. The curve is developed from several on-site discharge measurements collected from different flow situations (low flow to flood stage).

The transmission unit for pressure data is taken out from the monitoring well during maintenance at the Turku pilot site.

Multiparameter water quality sonde at the Lieto pilot site.

Latvia

The constructed stormwater solution is an advanced vortex separator, a downstream defender used to meet a wide range of stormwater treatment objectives. Its wide treatment flow range, small footprint and low-profile make it a compact and economical solution for capturing nonpoint source pollution. The work assignment for the constructor foresees that the construction company shall provide detailed instructions for the maintenance of the built stormwater treatment solution, including its calibration.

Inside of the treatment solution with sensors, switchboard and controller

Sweden

Stormwater quality was monitored by manually collecting samples and analyzing them for nutrients, heavy metals and polyaromatic hydrocarbons. The sampling points marked were water ditches (1,2), sedimentation pond (3), after the sedimentation pond (4) and after the wetland (5).

Showing sampling points and sampling in Södra Fladen constructed wetland

2. Evaluation of the e-monitoring and treatment solutions

Estonia

E-monitoring at the Viimsi pilot sites is feasible and useful to have real-time information about major water quality parameters. The locations selected for e-monitoring are suitable for a variety of different monitoring devices, and during the design stage of the construction project, the requirements (e.g., flow rate, submergence of devices, etc.) of monitoring devices were taken into consideration.

Finland
Pilot structures are presumed to influence the loading of solids, heavy metals, and nutrients. Selected water quality monitoring equipment includes turbidity sensors, which can often be used as a surrogate for solids and other solid bound substances. Combined with the flow measurements, event mean concentrations and total loading can be calculated. As there are measuring devices deployed before and after the biofilter structure, it is possible to verify the difference between the inflow and outflow water quality and quantity.

Latvia

Prior to construction of the selected stormwater treatment solution, manual stormwater quality sampling was performed in the selected Riga pilot site. The constructed solution is used for the removal of TSS, floatable trash and petroleum products from stormwater runoff, being an optimal solution for such pollutant hotspots as the transport infrastructure junction and the public parking lot in the Riga pilot site. Oil, trash and other floating pollutants are captured and stored on the surface of the outer spiraling column. Low energy vortex motion directs sediment into the protected sump region. Only after following a long three-dimensional flow path is the treated stormwater discharged from the outlet pipe.

Maintenance ports at ground level provide access for easy inspection and clean-out of the stormwater treatment unit. A number of real-time sensors are installed in the sampling wells and in the stormwater treatment unit to monitor the inflow and outflow stormwater quality and quantity.

Sweden
The constructed wetland treatment solutions are expected to reduce the flow of solids, nutrients and heavy metals. The periodic sampling and analysis of the pollutants could provide data collection and evaluate the efficiency of the treatment solutions.

3. Planning for maintenance: delegation of responsibility
Estonia
According to the procurement, the contractor will be responsible for Maintenance of e-monitoring devices during the warranty period of 3 years. In this period the frequency of the cleaning of the sensors will be clarified. After the warranty period Viimsi municipality will take over the maintenance.

Finland
The water quality sensor deployed in Lieto has an internal wiper system that cleans the sensor heads before every measurement. However, the sensors need weekly manual cleaning. Pressure sensors have fewer maintenance needs, usually cleaning once or twice per year is sufficient. The data must be downloaded for backup purposes every two months.

Latvia
The Traffic Department of the City of Riga is responsible for the maintenance of the installed stormwater treatment solution. Based on the data collected by the e-monitoring system they are able to ensure the proper function of the stormwater

treatment solution. The maintenance guidelines were provided by the construction company and training was held for all parties involved.

Sweden
Before constructing the wetland, decide the organization that will be responsible for maintenance. It is highly recommended to write an agreement with stakeholders to finance the yearly maintenance work.

4. Availability of dataset, owners, storage
Estonia
Data will be automatically sent to Viimsi municipality's stormwater management system VAAL where it will be stored, the system also generates automatic alerts if any of the preset values are exceeded (for example differences in water levels at pilot site 2). Viimsi will own all data.

Finland
The dataset is owned by Turku UAS, and it is stored in cloud services

Latvia
The e-monitoring system provides online information about the need to clean the stormwater treatment solution from TSS and also collect data on flow rates, temperature and pH. The obtained data by the e-monitoring system is owned by the municipality.

Sweden
The dataset is collected and shared with Utö initiative and stored in cloud services.

5. Handling of wastes
Estonia
The second test location will generate solid waste . When a certain quantity of trash is collected, an automated e-monitoring system will forward the information to the municipality. Thereafter, municipality employees will have to collect and dispose of the trash collected from the unit.

Finland
The biofilter structure will generate plant waste when the structure is maintained. There can also be some other litter coming to the structure via the stormwater flow. It will be collected and recycled accordingly. In case, the filter medium has to be changed, the used filter medium can be utilized for landscaping purposes.

Latvia
The Traffic Department of the City of Riga is responsible for waste removal following the maintenance guidelines issued by the construction company. The e-monitoring system can inform the responsible employee via email when maintenance is needed.

Sweden
We start maintaining the constructed wetland every year in August and September. Taking the reed out of the wetlands by cutting and dragging it. Locate a location to store the items. Building a compost area is ideal for other applications.