Ref. Ares(2026)6066120 - 15/06/2026

THESEUS

Hub4Circularity

A First of a kind Hub for circularity demonstrator for Attica and peripheral regions

Grant Agreement No 101178059

D7.2 Decentralised Water Reuse v1

Work Package: 07 Water Symbiotic Flows

LEAD BENEFICIARY:

ETHNICON METSOVION POLYTECHNION (NTUA)

Document Sheet

Project acronym	**Theseus**
Project full title	A First of a kind Hub for circularity demonstrator for Attica and peripheral regions
Programme	Horizon Europe
Topic	HORIZON-CL4-2024-TWIN-TRANSITION-01-38
Type of Action	HORIZON Innovation Actions
Grant Agreement	101178059
Start day	1 December 2024
Duration	60 months

LEGAL NOTICE
Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or European Health and Digital Executive Agency (HADEA). Neither the European Union nor the granting authority can be held responsible for them.

©Theseus Consortium, 2026
Reproduction is authorised provided the source is acknowledged.

Funded by the European Union

This project has received funding from the European Union Horizon Research and Innovation programme under grant agreement No 101178059

Document Information

Deliverable number	D7.2
Deliverable name	Decentralized Water Reuse v1
Lead beneficiary	NTUA
WP	WP7
Related task(s)	Task 7.2
Type	R- Document, report
Reviewers	EYDAP
Delivery date	31.05.2026
Main author(s)	Klio Monokrousou (NTUA), Maria Peteinaki (NTUA), Philippos Goumas (NTUA), Zois Gravanis (NTUA), Argyro Plevri (NTUA), Tilemachos Kolokythas (EYDAP), Theodora Paramana (EYDAP), Nikiforos Klosteridis (EYDAP), Stelios Samios (EYDAP), Stavros Stathakis (EYDAP), Konstantinos Zozolos (EYDAP), Kolikoniaris Petros (EYDAP)
Contributor(s)	-
Acknowledgements	-

Dissemination level

PU	**Public**	**X**
SEN	Sensitive, limited under the conditions of the Grant Agreement	
Classified R-UE/EU-R	EU RESTRICTED under the Commission Decision No2015/444	
Classified C-UE/EU-C	EU CONFIDENTIAL under the Commission Decision No2015/444	
Classified S-UE/EU-S	EU SECRET under the Commission Decision No2015/444	

Funded by the European Union

This project has received funding from the European Union Horizon Research and Innovation programme under grant agreement No 101178059

Document history

Version	Date	Changes	Reviewer/Contributor
V0.1	18.05.2026	First complete version	All
V0.2	29.05.2026	Internal Review	Theodora Paramana (EYDAP) Nikiforos Klosteridis (EYDAP)
V1.0	14.06.2026	Final version	Babis Manousiadis (ICCS)

Funded by the European Union

This project has received funding from the European Union Horizon Research and Innovation programme under grant agreement No 101178059

Publishable summary

The objective of Deliverable D7.2, developed within the framework of the THESEUS project – A First of a kind Hub for circularity demonstrator for Attica and peripheral regions – is to present the design, development and initial implementation of decentralised water reuse solutions in an urban environment. The deliverable focuses on the valorisation of two locally available water resources: treated wastewater recovered through Sewer Mining and harvested rainwater collected from building surfaces.

The report examines two complementary decentralised water reuse pathways. The first concerns the design and planned deployment of a Sewer Mining system in a highly urbanised area of Athens, at Klonaridis-Fix Park. The system is designed to abstract wastewater from the existing sewerage network, treat it locally through a compact treatment configuration, and reuse the reclaimed water for the irrigation of urban green spaces. This approach builds on experience from existing Sewer Mining applications operating at Goudi Park and in the Municipality of Markopoulo in Attica, developed in the context of previous projects, and seeks to demonstrate the potential of decentralised wastewater reuse in dense urban settings.

The second decentralised water reuse solution refers to the integration of rainwater harvesting systems (RWHS) in buildings, with an initial demonstration at the 21st Primary School of Athens “Lela Karagianni” at the city of Athens. At the particular school site, two separate but interconnected systems have been designed and started to be implemented: (a) one for the collection of rainwater from a surface area of the rooftop, storing it locally and reusing it for irrigation of new plants and herbs for the greening of the school terrace; and (b) the another system through harvesting rainwater from photovoltaic panel surfaces already installed in the terrace, to be sent with gravity and stored in the back yard of the school for irrigation of another garden that will be installed. The harvested rainwater supports greening of school yards and spaces, as well as educational activities and school community engagement. In parallel, composters are installed in the back yard to treat school biowaste and convert it into compost, so as to directly use it for the plants and herbs, to promote nutrient recycling.

The research focuses on the design of these decentralised water reuse systems, starting from the site selection and the technical requirements for implementation, as well as to the various permits procedures, stakeholder engagement, construction needs and specifications as well as the initial implementation challenges. The analysis highlights the importance of adapting each solution to local conditions and particularities, and ensures that the solutions are generic and transferable to other urban areas.

The deliverable also demonstrates that decentralised water reuse solutions can provide benefits beyond reducing potable water consumption for non-potable uses. As a demonstration system implemented in a visible public or educational space, it can serve as a living laboratory that promotes awareness, environmental education and citizen engagement towards climate adaptation practices. This is particularly relevant in Mediterranean urban regions such as Attica, where water scarcity and droughts are becoming more frequent and more extreme and pose pressure on freshwater resources.

Funded by the European Union

This project has received funding from the European Union Horizon Research and Innovation programme under grant agreement No 101178059

The report also identifies key challenges and limitations that affect the deployment of such systems in real world urban spaces. These include technical integration with existing infrastructure, permitting and procedural aspects, early engagement of the local communities and end users, planning of operational and maintenance challenges, so as to achieve the better adaptation and integration with the maximum social acceptance of the interventions. Addressing these challenges requires early stakeholder involvement, clear allocation of responsibilities, appropriate monitoring and a supportive regulatory framework.

Overall, Deliverable D7.2 confirms the potential of integrated, decentralised and circular water-resource management in Attica. By combining Sewer Mining and Rainwater Harvesting, the THESEUS project demonstrates practical pathways for reducing pressure on freshwater resources, supporting urban greening, strengthening adaptive capacity to climate change and promoting the wider transition towards circular and resilient cities.

Funded by the European Union

This project has received funding from the European Union Horizon Research and Innovation programme under grant agreement No 101178059

Contents

1. Introduction 14
1.1 Background and context 14
1.2 Purpose of the deliverable 15
1.3 Scope and structure of the report 15
Section A. Sewer Mining for decentralised water reuse 17
2. Sewer Mining as a distributed water reuse solution 17
2.1 Concept and objectives 17
2.2 System architecture 17
3. Study area description and selection criteria 19
3.1 Site overview 19
3.2 Data collection, inspections and site assessment 20
3.2.1 Inspection of sewerage network infrastructure 23
3.2.2 Land ownership and land use compatibility 24
3.2.3 Compatibility with existing utility networks 24
3.3 Site assessment and selection criteria 26
4. Sewer Mining system design and technical specifications 27
4.1 Overview and objectives 27
4.2 Overall system architecture 28
4.3 Wastewater Pumping Station 30
4.3.1 Introduction and scope 30
4.3.2 Pumping station characteristics – Type of pumping units 31
4.3.3 Hydraulic design parameters 32
4.3.4 Total dynamic head of the pumping units 32
4.3.5 Selected pumping units 35
4.3.6 Pumping station pipes– Hydraulic fittings – Other 35
4.3.7 Electrical issues – Power supply 36
4.4 Main system architecture and technical specifications 38
4.4.1 Main treatment unit 39
4.4.2 Machine room and auxiliary systems 40
4.4.3 Quality characteristics of produced water 43

Funded by the European Union

This project has received funding from the European Union Horizon Research and Innovation programme under grant agreement No 101178059

5. Urban integration and landscape 44
5.1 Historical background and integration into the urban fabric *44*
5.2 Landscape and spatial design considerations *48*
6. Stakeholder engagement and co-creation processes 51
6.1 Introduction *51*
6.2 Stakeholder mapping *51*
6.3 Engagement processes *52*
7. Challenges, risks and mitigation measures 53
7.1 Technical and operational challenges *53*
7.2 Stakeholder engagement and social acceptance *53*
7.3 Procedural and administrative constrains *53*
7.4 Next steps *54*
8. Regulatory framework and permitting 55
9. Replicability and upscaling potential 56
9.1 Transferability to other urban areas *56*
9.2 Guidelines for replication *56*
9.3 Upscaling potential *57*
10. Conclusions on the Sewer Mining intervention 58
Section B. Raienwater Harvesting decentralised solutions 59
11. Rainwater harvesting solutions 59
11.1 Planning *59*
11.1.1 Licensing and compliance *61*
11.2 Rainwater harvesting system Design *62*
11.2.1 Baseline Site Conditions *62*
11.2.2 Components sizing *63*
11.2.3 Final Designs *71*
11.3 Implementation *74*
11.3.1 Installation of the systems *74*
11.3.2 Planting *79*
12. Conclusions and next steps on the rainwater harvesting system 82
13. Overall conclusions and final remarks 83

Funded by the European Union

This project has received funding from the European Union Horizon Research and Innovation programme under grant agreement No 101178059

References 84
Annexes 85
Annex I. Excerpts from the Hellenic National Cadastre 85
Annex II. Site land use – Extract from the Government Gazette 290/2-4-1992/D 86
Annex III. Response from the Ministry of Environment and Energy on the permitting of the pilot project of the sewer mining system 88
Annex IV. National Technical University of Athens decision of signing a programmatic Agreement with the City of Athens 89

Funded by the European Union

This project has received funding from the European Union Horizon Research and Innovation programme under grant agreement No 101178059

List of Figures

Figure 1 Sewer Mining configuration design 18
Figure 2 Overview of the site in Klonaridis-Fix Park, Patisia at the City of Athens 19
Figure 3 Overview of the current status of the parcel highlighting the areas for installing the SM system 21
Figure 4 Views of unstructured form of the parcel without landscaping, vegetation, or recreational functions 22
Figure 5 View of the manhole of the sewerage network that was inspected during the technical assessment of the site 23
Figure 6 Electrical power supply network and manholes (site plan) 25
Figure 7 Topographic layout of the decentralised Sewer Mining water recovery unit within the selected site at Klonaridis-Fix Park 27
Figure 8 Sewer Mining system architecture 29
Figure 8 Pumping Station drawing - Section and Plan View 38
Figure 10 Overview of the main Sewer Mining architecture 38
Figure 11 Existing pipeline to which the unit is connected (Pumping station and raw wastewater pipeline) – Plan view 39
Figure 12 Plan View of the Sewer Mining treatment unit 40
Figure 13 Machine room container - Plan View 41
Figure 14 PLC System of the SM configuration 43
Figure 15 Overview of the Klonaridis-Fix urban park and the Klonaridis Villa 44
Figure 16 Design of the factory, showing the villa on the right 45
Figure 17 The historic preserved Klonaridis-Fix Villa 46
Figure 18 Sewer Mining configuration siting in the parcel plot to irrigated Klonaridis-Fix Park 47
Figure 19 Design of integrated interventions – Sewer Mining configuration and urban microforest initiative 48
Figure 20 Conceptual infographic representation of the combined interventions 50
Figure 21 Top view of the school and the neighbourhood 60
Figure 22 Front view of the school 61
Figure 23 View of Primary School “Lela Karagianni” rooftop 63
Figure 24 Primary School “Lela Karagianni”: School rear courtyard 63
Figure 25 Schematic flow chart of the rooftop rainwater harvesting and reuse system (System 1), illustrating rainfall collection from the rooftop catchment, temporary storage in the rooftop storage unit, and distribution through irrigation lines to the rooftop planters. 64
Figure 26 Schematic flow chart of the rear-courtyard rainwater harvesting and reuse system (System 2), illustrating rainfall collection from the rooftop photovoltaic surfaces, conveyance through gutters and downpipes to the rear-courtyard storage tanks, and distribution through irrigation lines to the rear-courtyard planting areas 64
Figure 27 Monthly rainfall distribution (mm) for 2024, based on data from the Patision meteorological station of the National Observatory of Athens. 65
Figure 28 Rainwater collection area on the rooftop (highlighted in yellow) 66
Figure 29 PV surfaces on the school rooftop proposed for rainwater collection 67
Figure 30 Layout of the rainwater harvesting and reuse system on the rooftop of the 21st Primary School of Athens. 71

Funded by the European Union

This project has received funding from the European Union Horizon Research and Innovation programme under grant agreement No 101178059

Figure 31 Layout of the rainwater harvesting and reuse system in the rear courtyard of the 21st Primary School of Athens 72
Figure 32 Conceptual infographic overview of the two rooftop RWHS (system 1) and rear courtyard RWHS (system 2) 72
Figure 33 Completion of the rooftop preparation phase for both the rainwater collection area and the area designated for green interventions (system 1) 75
Figure 34 Installation of the safety wooden fence in the rooftop planting designated area (system 1) 75
Figure 35 View of the completed wooden fence in the rooftop planting area (system 1) 75
Figure 36 Installation of rainwater collection pipes in the PV (system 2) 76
Figure 37 Conveyance pipework installed to route the collected runoff from the PV to the rear courtyard 76
Figure 38 Rear courtyard system (system 2): Completion of the installation of gutters from the PV panel surfaces and hydraulic interconnection with the water storage tanks in the rear courtyard. 77
Figure 39 Rainwater storage tanks – Rear courtyard (system 2) 77
Figure 40 Completion of the planter construction phase for rooftop RWHS (system 1) 78
Figure 41 Promotional poster for the THESEUS “Rainwater workshop at 21st Primary School of Athens “Lela Karagianni”, held on Thursday 26/02/2026 at 10:00 a.m., highlighting the educational planting activities and the use of harvested rainwater for rooftop greening. 79
Figure 42 Rooftop planting activity for the RWHS (System 1) at the 21st Primary School of Athens “Lela Karagianni”, with students participating in the planting of the rooftop planters under the guidance of NTUA and school representatives 80
Figure 43 Educational workshop activities accompanying the rooftop planting event, including interactive, game-based plant identification and “adoption” tasks to familiarise student0073 with the planted species and basic plant care/irrigation practices. 81

List of Tables

Table 1 Data for the calculation of the dynamic head of the pump at the nominal flow 33
Table 2 Description of main discharge pipeline losses 33
Table 3 Pumping station losses 34
Table 4 Planting proposal for the rear courtyard garden (System 2) 69
Table 5 Planting proposal for roof garden (System 1) 70
Table 6 Summary of key parameters of Rooftop RWHS (System 1) 73
Table 7 Summary of key parameters of rear-courtyard RWHS (System 2) 73

Funded by the European Union

This project has received funding from the European Union Horizon Research and Innovation programme under grant agreement No 101178059

Abbreviations

Abbreviations	Full name
AISI	American Iron and Steel Institute
DN	Nominal pipe size (Diamètre Nominal)
EYDAP	Athens Water Supply and Sewerage Company
E/M	Electromechanical
FL	Float Switches
KAEK	Cadastral Code
LID	Low Impact Development
MCC	Motor Control Center
MBR	Membrane Bioreactor
MLSS	Mixed Liquor Suspended Solids
MWL	Minimum water level
NBS	Nature-Based Solutions
NTUA	National Technical University of Athens
HDPE	High-density polyethylene
pH	potential of hydrogen
PLC	Programmable logic controller
PN	Nominal Pressure
PV	Photovoltaic
PVC	Polyvinyl chloride
RWH	Rainwater Harvesting
RWHS	Rainwater Harvesting Systems
SM	Sewer Mining
SuDS	Sustainable Drainage Systems
UF	Ultrafiltration

Funded by the European Union

This project has received funding from the European Union Horizon Research and Innovation programme under grant agreement No 101178059

UV	Ultraviolet radiation
WSUD	Water Sensitive Urban Design
WWTPs	Wastewater Treatment Plants
Φ	Diameter of millimeters

Funded by the European Union

This project has received funding from the European Union Horizon Research and Innovation programme under grant agreement No 101178059

1. Introduction

1.1 Background and context

The water resources in the urban environment are under pressure due to the combined impacts of the climate change, and the increasing water consumption due to urbanisation and population growth. In particular, droughts events have become more frequent and intense, especially in Mediterranean regions, posing significant water scarcity risk on the already limited water resources. Furthermore, a temporal inconsistency between water availability and water demand is observed over the annual cycle, resulting in lack of resilience and in a reduction of capacity to respond to periods of water stress. Therefore, there is an urgent need to reduce the use of potable water for non-potable applications and turn into a more resilient and adaptive urban water management practices and solutions.

The current trend is to move away from a conventional linear approach, which assumes that resources are abundant, available and cheap to dispose of and embrace circular economy principles and technological innovation. In parallel, there is a shift towards more decentralised and flexible solutions that can increase local water availability and reduce pressure on freshwater resources. Decentralised water reuse systems enable water to be collected, treated, stored, and reused close to the point of demand. To reduce dependence on potable water supplies and centralised systems, a transition towards a more circular, resilient and sustainable approach to water management is promoted.

Under this concept, two key decentralised water reuse approaches are investigated, designed and implemented within the THESEUS project: Sewer Mining (SM) and Rainwater Harvesting (RWH).

First, Sewer Mining is an innovative wastewater recycling technology that transforms waste into a valuable resource, enhancing the circularity of urban environments and supports a sustainable transition to address projected climate change. The core idea behind this pioneering technology is to install treatment plants where the demand lies and where the resource is already available, given that wastewater exists everywhere throughout a city. Specifically, wastewater is extracted from local sewers, is treated directly on-site and either reused immediately at the point of demand or stored for later use. This system enables the production of reclaimed water suitable for non-potable uses, such as irrigation of urban green spaces, street cleaning, or other municipal applications. By providing an alternative local water source, Sewer Mining can significantly reduce the use of potable water for non-potable applications and reduce the pressure on freshwater resources.

The second water reuse system is based on rainwater harvesting practices and involves the collection, storage, and reuse of rainwater from rooftops and other impermeable surfaces. It has been designed to be implemented at a school setting, and provides an opportunity to engage the students, teachers and the wider school community, as well as raise awareness on circular water management and water reuse practices. Moreover, this approach enhances local water recovery and reduces demand for potable water for non-potable purposes, such as irrigation or toilet flushing, contributing to more efficient and sustainable use of water resources.

Funded by the European Union

This project has received funding from the European Union Horizon Research and Innovation programme under grant agreement No 101178059

Both systems support integrated and circular urban water management as they promote local water reuse enhance greening of a city, and improve the overall sustainability of urban environments. Their combined application may offer further potential additional benefits and support cities become more resilient to drought and water scarcity.

In addition to these benefits, decentralised water reuse systems such as Sewer Mining and Rainwater Harvesting also provide significant social and educational value. When implemented in visible real-world applications that are accessible to citizens, they can serve as living laboratories that raise awareness on water scarcity, climate change, and sustainable water resource management. The demonstration of such systems, these concepts become more tangible and easier for the local communities to understand, and help bridge the gap between technical innovation and everyday urban life.

As a final aspect, the early involvement of local communities, schools, municipal stakeholders, and end users throughout the implementation process can be proven to be quite valuable both for the design and the implementation phase as well as the acceptance and integration of the interventions. Especially in urban areas affected by drought and water scarcity, such systems can serve as practical demonstration projects also to be expanded and adopted to other areas, and embrace a more strategic transition towards climate adaptation measures and practices.

1.2 Purpose of the deliverable

This deliverable, developed within the THESEUS project, presents the design, analysis, and assessment of decentralised water reuse solutions within an urban environment. It focuses on the technical design and specifications of the systems components as well as the broader procedural and social engagement aspects for enabling their successful integration.

The primary objective of this report is to present the full design of the proposed solutions, from the initial concept to practical implementation. This includes the design of the systems, the identification and assessment of suitable sites for installation, as well as the integration of the interventions within the surrounding context.

A key aspect of the deliverable is the systematic consideration of non-technical dimensions that are essential for the realisation of such projects. These include stakeholder engagement, which play a critical role in facilitating public acceptance, as well as collaboration with technical services. Also, the analyses of regulatory and administrative conditions that influence project feasibility were explored.

1.3 Scope and structure of the report

This report provides a thorough examination for the design and implementation of decentralised water reuse systems within the urban environment, with particular emphasis on sewer mining and rainwater harvesting solutions.

Funded by the European Union

This project has received funding from the European Union Horizon Research and Innovation programme under grant agreement No 101178059

The scope of the report includes the definition and analysis of solutions as innovative, distributed approaches to water management and reuse, and highlights their objectives, systems architecture, and expected outcomes. It further presents the methodology that was adopted to identify and assess suitable locations, based on technical, environmental, and social criteria.

In addition, the report presents the design of the proposed solutions, including their main components, along with their technical specifications. Furthermore, the performance requirements, the quality characteristics of the recovered water are examined, to ensure compliance with the applicable standards for the particular applications.

Beyond the technical dimension, further other aspects are thoroughly examined, including stakeholder identification and mapping, engagement targeted interactions and co-creation practices in order to support public acceptance and long-term sustainability.

Furthermore, the report investigates potential risks and barriers associated with the implementation of decentralised water reuse systems. A dedicated section is also included on the regulatory framework and permitting procedures governing such interventions.

Finally, the report explores the potential for replication and upscaling of the proposed solutions in other urban areas. It provides guidance on transferability, and proposes a set of recommendations to support a wider more strategic adoption of decentralised water reuse interventions.

Funded by the European Union

This project has received funding from the European Union Horizon Research and Innovation programme under grant agreement No 101178059

Section A. Sewer Mining for decentralised water reuse

2. Sewer Mining as a distributed water reuse solution

2.1 Concept and objectives

Sewer mining (SM) is an innovative decentralized water reuse system that transforms urban wastewater into a valuable resource, contributing to circular water management. By recovering water directly from the sewer network and treating at point of demand, SM systems reduce dependence on potable water for non-potable water reuse and promote more a sustainable transition to address droughts and water scarcity issues in the Mediterranean regions.

The main concept of the SM system is to install small scale, decentralised treatment plants where the demand lies and where the resource is always available, beneath every part of a city. Specifically, wastewater is extracted from the local sewage network, treated directly on-site, and either reused directly at the point of demand or is stored for later use. The technology is gaining popularity due to its efficiency in treatment and its limited space requirements for installation.

The current research explores the implementation of sewer mining technology in a real-world setting, in the densely urbanized areas of the Athens City centre that face space constraints, promoting the use of potable water for the irrigation needs of parks and urban green areas that are vulnerable to drought and water scarcity due to urban heat islands and heatwaves. Furthermore, these solutions alleviate pressures on existing sewage treatment facilities. Consequently, leveraging the latent potential of sewage as a valuable resource beneath city streets emerges as a highly effective strategy for enhancing urban resilience to climate change.

Thus, one of the main objectives of this task is to:

- Design, build and deploy a Sewer Mining (SM) unit tapping into the Athens Water Utility network for reusing water at the point of demand for irrigation and for climate proofing against droughts.
- Integrate the technology into local needs, opportunities and limitations.
- Enhance stakeholders' engagement in co-creating new climate change adaptation services around the 'new' water resource.

2.2 System architecture

The main concept of this innovative technology is that, to alleviate local pressures on water resources, instead of having treatment taking place only at the Wastewater Treatment Plants (WWTPs) and building networks to transport recycled water back into the city, the possibility of moving the treatment closer to the point of demand is explored as an alternative.

For delivering this purpose, a flexible, scalable and replicable wastewater treatment system has been conceptualised to be implemented in this drought-prone Mediterranean area, in the city center of Athens, serving as the ideal setting to demonstrate the potential of circularity in densely urban environments, as well as the effectiveness and adaptability of this solution.

Funded by the European Union

This project has received funding from the European Union Horizon Research and Innovation programme under grant agreement No 101178059

In particular, the process involved extracting sewage from a local urban network drain pipe using pumps to fill a subsurface buffer tank (Figure 1). The collected wastewater was then treated on-site using a membrane bioreactor (MBR) unit and a UV disinfection component, producing high-quality reclaimed water suitable for irrigation, aquifer recharge and other urban uses (street washing, fire protection, etc.).

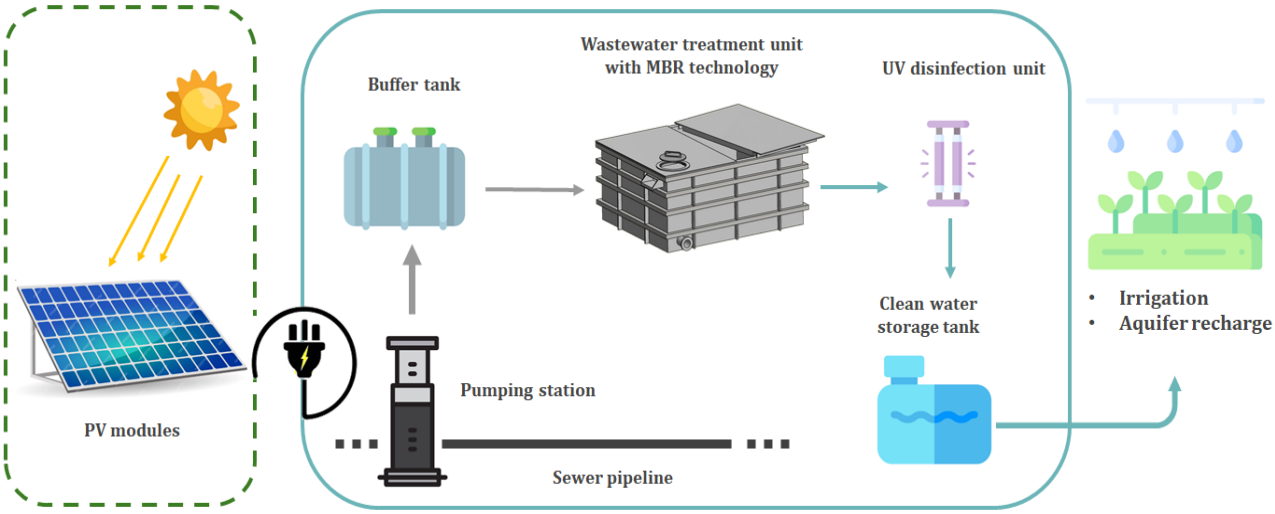


Figure 1 Sewer Mining configuration design

The process can be outlined as follows:

- Two pumps will extract wastewater alternately from the network at a depth of about 3-4m.
- The raw wastewater will be transferred to a series of tanks within a container, where treatment takes place using MBR membrane technology, followed by biological treatment and disinfection with ultraviolet (UV) radiation.
- High quality water will be produced for irrigation with an average capacity of 24 m^3/day

The capacity of the system is flexible as it can be adjusted according to the water needs of each area and the respective period. The entire process is designed to be closely monitored remotely through a local PLC system integrated in a Digital Twin platform, enabling real-time data flow and visual representation of the system's performance. Further to the online monitoring, laboratory tests will be conducted for a series of parameters to ensure dedicated monitoring and cross-validation of the produced water for reuse.

This solution allows for creating a series of gardens around the SM technology by using the recycled water for irrigation, such as the ones created in the Goudi Athens Nursery and the Markopoulo Urban Gardens.

Funded by the European Union

This project has received funding from the European Union Horizon Research and Innovation programme under grant agreement No 101178059

3. Study area description and selection criteria

3.1 Site overview

The Klonaridis-Fix Park is located in the densely built 5th Municipal District of the City of Athens, in the wider area of Patisia, one of the most populated and socially diverse parts of the capital (Figure 2). The neighbourhood is characterised by intense urban activity, a multicultural population, mixed residential and commercial land uses, and limited availability of public open spaces. As a result, urban green areas such as Klonaridis-Fix Park is of great environmental and social significance, serving as everyday gathering spaces for residents, schools, families, and local communities.

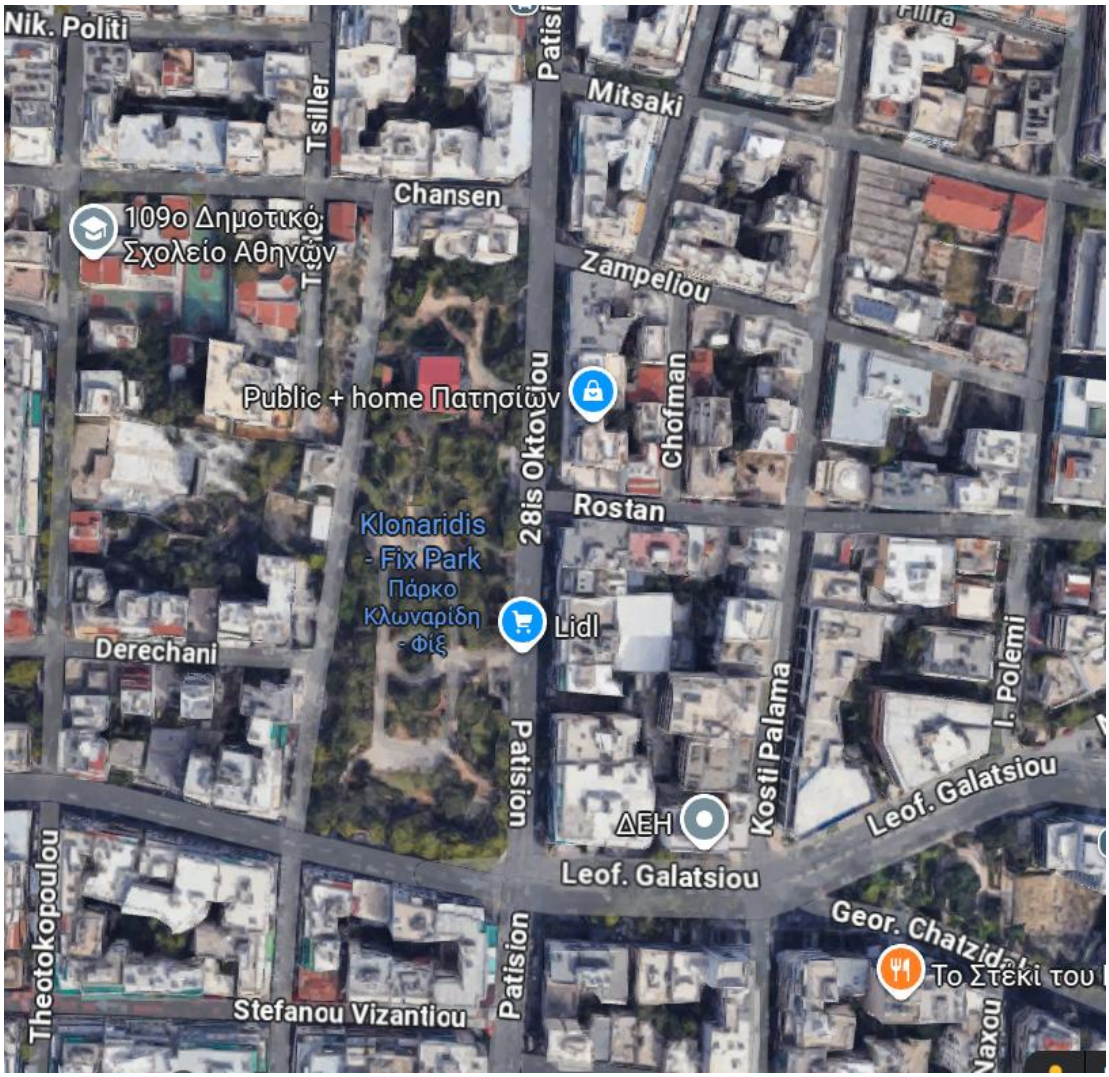


Figure 2 Overview of the site in Klonaridis-Fix Park, Patisia at the City of Athens
Source: Google maps (https://maps.app.goo.gl/zPnMfFYtKXEw4cu36)

Funded by the European Union

This project has received funding from the European Union Horizon Research and Innovation programme under grant agreement No 101178059

The particular area is a typical dense district of Athens, characterised by a compact buildings setting, a high proportion of paved and impermeable surfaces, with limited vegetation and open green spaces. For this reason, during the summer months, the area experiences high temperatures and increased thermal discomfort, along with adverse effects of urban heat islands and heatwaves. Therefore, the local park acts as a significant cooling and recreational space that improves the microclimate, air quality, and thermal stress.

Furthermore, Athens faces increasing drought periods and water scarcity issues due to climate change and high water demand for non-potable uses. To maintain the urban green under such conditions requires substantial water volumes, especially during the summer period. Currently, the irrigation needs of Klonaridis–Fix Park, which are about 20m^3/day, and are fully covered through the potable water supply network operated by EYDAP. The use of freshwater for irrigation purposes comes at a significant environmental and economic cost.

In addition, the particular dense urban district produces constant volumes of wastewater conveyed through the sewer network that passes beneath the park at a close distance. Despite its potential value, this alternative water resource remains largely unleveraged. The direct proximity of the sewerage network, along with the constant water demand for the irrigation of the park, makes the site suitable for such an application.

The implementation of a Sewer Mining system at Klonaridis-Fix Park could enable the local extraction, treatment, and reuse of wastewater for irrigation purposes, significantly reducing dependence on potable water for non-potable uses. Furthermore, the site offers strong demonstration value both to the local residents and the visitors as it constitutes a visible and accessible urban green space within the dense urban environment.

Overall, the Klonaridis–Fix Park represents a highly strategic pilot location for demonstrating decentralised water reuse solutions within a dense Mediterranean urban environment. Its characteristics reflect many of the challenges increasingly faced by cities across Southern Europe, including water scarcity, heat stress and lack of green space, making it an ideal case study for testing and promoting circular water management systems in an urban environment.

3.2 Data collection, inspections and site assessment

As part of the preparatory phase for developing the Sewer Mining system at Klonaridis-Fix Park, a dedicated site investigation and assessment was carried out. This investigation focused on an adjacent undeveloped municipal parcel directly connected to the park area, bearing Cadastral Code (KAEK) 050090725022 as shown in Figure 3. An excerpt from the Hellenic National Cadastre is provided in Annex I.

Funded by the European Union

This project has received funding from the European Union Horizon Research and Innovation programme under grant agreement No 101178059

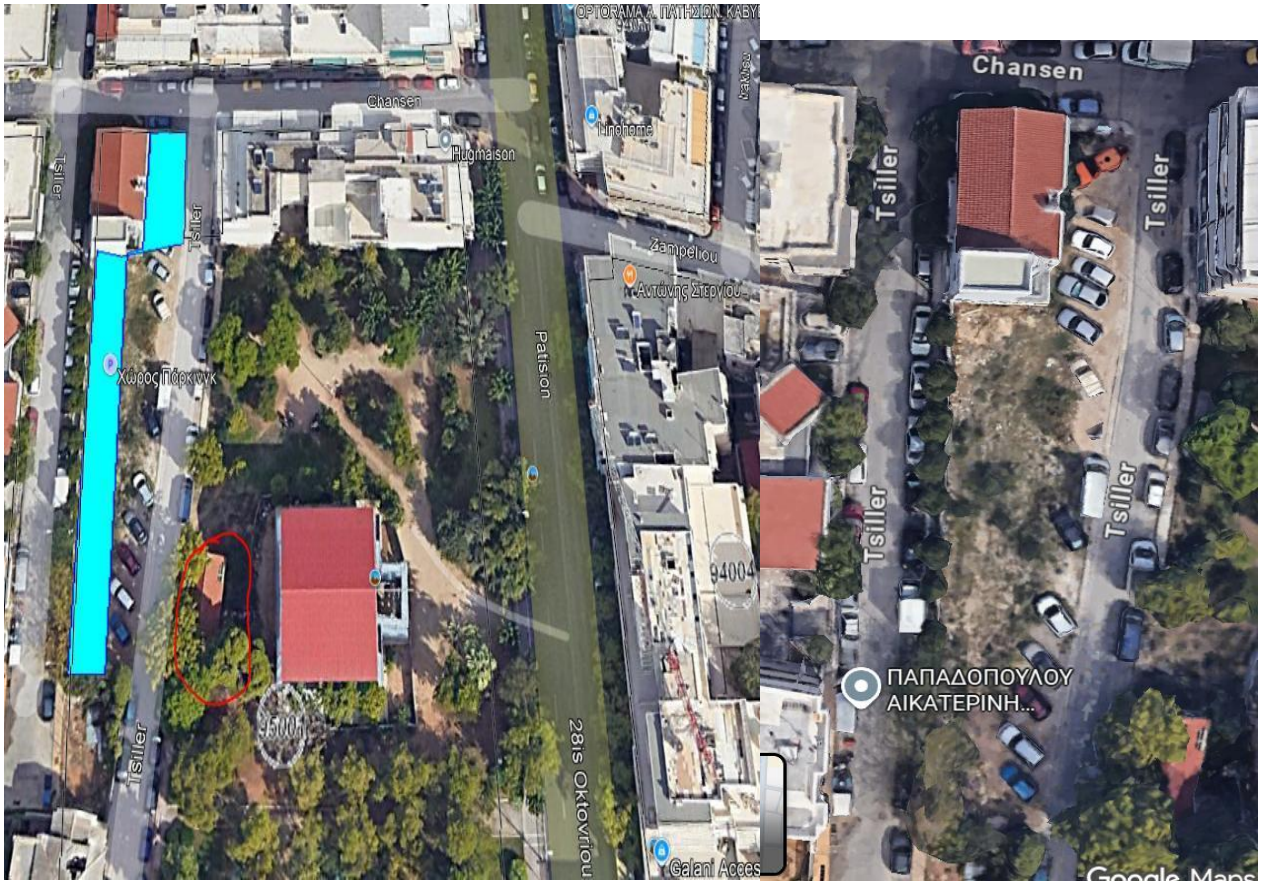


Figure 3 Overview of the current status of the parcel highlighting the areas for installing the SM system

The examined parcel is located at the edge and in immediate proximity to the park, at the Hansen and Tsiller streets intersection and very close to the existing sewerage network. The site currently remains unused and unstructured, without landscaping, vegetation, or recreational functions, and is informally used for temporary parking of a limited number of vehicles, approximately 8-10 cars (Figure 4). Due to its inactive use, strategic location, and direct connection with the park's irrigation needs, the area was identified as a highly suitable candidate for accommodating the proposed SM facility with minimal disturbance to existing public activities and green areas.

Funded by the European Union

This project has received funding from the European Union Horizon Research and Innovation programme under grant agreement No 101178059







Figure 4 Views of unstructured form of the parcel without landscaping, vegetation, or recreational functions

Funded by the European Union

This project has received funding from the European Union Horizon Research and Innovation programme under grant agreement No 101178059

Within this context, a comprehensive technical and environmental assessment was performed to evaluate the feasibility of integrating the proposed system within this dense urban environment. The investigation aimed to determine whether the site satisfies the necessary technical, spatial, procedural, and operational requirements for implementing a sewer mining water reuse solution.

3.2.1 Inspection of sewerage network infrastructure

Particular emphasis was placed on assessing the nearby sewer infrastructure, given its critical importance for the operation of the Sewer Mining system. An existing sewage manhole of the EYDAP sewer network, located at the Hansen and Tsiller crossing, directly adjacent to the proposed installation site, was opened and inspected several times throughout the design phase (Figure 5).



Figure 5 View of the manhole of the sewerage network that was inspected during the technical assessment of the site

During the inspection, the internal condition of the sewer structure was examined, wastewater samples were collected, and detailed measurements of the manhole geometry and depth were carried out in order to document its structural and hydraulic characteristics.

The close proximity of the sewer network to the park constitutes a particularly advantageous site-specific characteristic, as it allows wastewater extraction and conveyance to take place with limited intervention requirements and reduced construction complexity within the dense urban setting.

Overall, the investigation confirmed that the sewer network in the area is technically suitable for integration with the proposed SM system. No critical structural deficiencies, hydraulic limitations, or operational incompatibilities were identified that could hinder the implementation of the facility.

Funded by the European Union

This project has received funding from the European Union Horizon Research and Innovation programme under grant agreement No 101178059

3.2.2 Land ownership and land use compatibility

A detailed investigation on the ownership of the parcel was also conducted. Based on official documentation provided by the Department of Municipal Property of the City of Athens, ownership of the land was confirmed to belong to the Municipality of Athens (Contract No. 8202/2010).

In parallel, the applicable land use designation was examined in relation to the proposed intervention. According to Government Gazette 290/2-4-1992/D (Annex II), the specific area is classified as urban green space, a designation compatible with the installation of public utility and environmental infrastructure, subject to compliance with the relevant planning and environmental regulations.

More specifically, the proposed Sewer Mining water recovery system falls within the category of permitted infrastructure installations in open urban green spaces, according to Article 7 of Presidential Decree 59/2018 (Government Gazette A' 114/2018) and Joint Ministerial Decision 18485/26-4-2017 (Government Gazette B' 1412). These provisions explicitly allow:

- The construction of utility infrastructure networks and installations of public benefit, including their associated components (both above-ground and underground) - Case A (48.2) – Installations (a)
- The installation of desalination units and other water treatment systems for the supply of municipal networks, together with the accompanying works required for their full operation - Case B (48.2) – Installations (f)

This assessment confirms that the ownership status, designated land use, and applicable regulatory framework are fully compatible with the proposed implementation of the Sewer Mining facility within the specific urban context of Klonaridis-Fix Park.

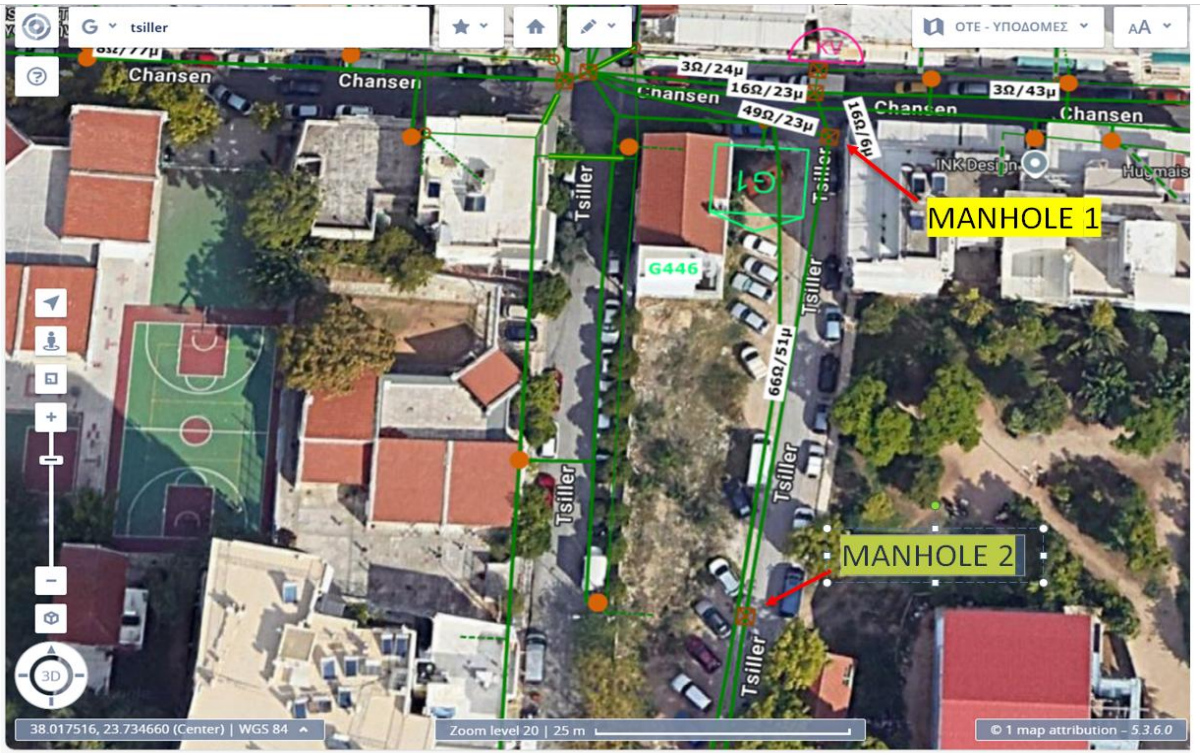
3.2.3 Compatibility with existing utility networks

Due to the dense urban environment surrounding Klonaridis-Fix Park, extensive coordination and on-site inspections were carried out regarding existing underground utility networks. The assessment included the electrical power supply network (Figure 6), natural gas infrastructure, telecommunications systems, and optical fibre installations located within the proposed intervention area.

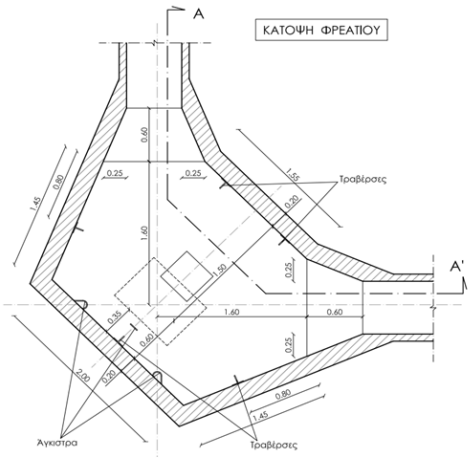
The purpose of this investigation was to identify potential spatial conflicts or other technical constraints that could affect the implementation of the SM unit. The assessment concluded that no major incompatibilities or physical interferences exist between the proposed installation and the surrounding utility infrastructure. Sufficient spatial clearance and operational separation can be maintained, allowing the SM system to be integrated safely and effectively within the existing urban environment.

Funded by the European Union

This project has received funding from the European Union Horizon Research and Innovation programme under grant agreement No 101178059



MANHOLE 1



MANHOLE 2

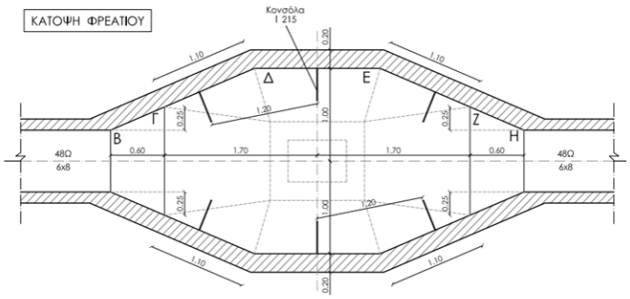


Figure 6 Electrical power supply network and manholes (site plan)

Overall, the site assessment confirmed that the selected parcel presents favourable case for implementing the Sewer Mining system, based on technical, spatial, and ownership aspects.

Funded by the European Union

This project has received funding from the European Union Horizon Research and Innovation programme under grant agreement No 101178059

3.3 Site assessment and selection criteria

The selected site, located on the municipal parcel at the crossing of Tsiller and Hansen streets, adjacent to Klonaridis-Fix Park, presents a combination of characteristics that make it suitable for installing the proposed Sewer Mining (SM) facility.

The parcel is an undeveloped urban space with no landscaping. Part of the site is current used as a small parking area that facilitates a limited number of vehicles. Due to its low environmental and recreational value, the site offers an opportunity for redevelopment through the implementation of sustainable circular water solutions for irrigation of the nearby park, while minimising interference with existing green space activities.

The location is easily accessible with regard to construction works, the installation of equipment, and future operation and maintenance activities. In addition, its direct proximity to the existing sewerage network represents a major advantage, as it facilitates the implementation of the SM system and reduces the need for extensive interventions within a complex urban setting.

The preliminary technical assessment indicates that the surrounding urban infrastructure can support the proposed installations, as no spatial conflicts were identified with underground utilities, such as power supply, telecommunications, natural gas, or optical fiber networks.

Furthermore, the site satisfies the basic criteria required for the installation of a SM unit, including sufficient space for the containers and the complementary installations (storage tanks, pumping station, etc.). The geometry and capacity of the adjacent sewer infrastructure were found to be compatible with the proposed system, ensuring hydraulic and operational feasibility.

In terms of land use, the selected site is located within an area designated as urban green space. However, the specific section chosen for the intervention is currently not planted, unmaintained and of limited environmental and aesthetic value. The proposed intervention is therefore considered compatible with the particular area, complies with regulatory requirements, and provides an opportunity to improve the site's environmental quality.

Finally, regarding legal and administrative considerations, the ownership of the parcel has been confirmed as belonging to the City of Athens. This ensures clear responsibility of the Municipality and facilitates coordination, permitting procedures, and future implementation activities. The assessment of the applicable planning and regulatory framework also confirmed that the installation of the Sewer Mining system is legally permissible within the specific land-use designation.

Overall, based on the combined evaluation of technical feasibility, infrastructure compatibility, spatial adequacy, environmental considerations, and legal permissibility, the selected site is considered highly suitable for the implementation of the Sewer Mining pilot application within the framework of the project.

Funded by the European Union

This project has received funding from the European Union Horizon Research and Innovation programme under grant agreement No 101178059

4. Sewer Mining system design and technical specifications

4.1 Overview and objectives

The pilot project concerns the design and installation of a decentralized water recovery and reuse system based on Sewer Mining (SM) technology, with a nominal treatment capacity of 24 m^3 per day. The system is intended to supply reclaimed water for the irrigation needs of Klonaridis-Fix Park, replacing the current use of potable water from the central water distribution network of the city (Figure 7).

The proposed SM unit has been designed as a compact and modular installation, specifically adapted to the spatial constraints of the selected urban site. The system incorporates automated operation, remote monitoring and control functions, enabling continuous supervision, early fault detection, operational flexibility and minimisation of need for on-site intervention.

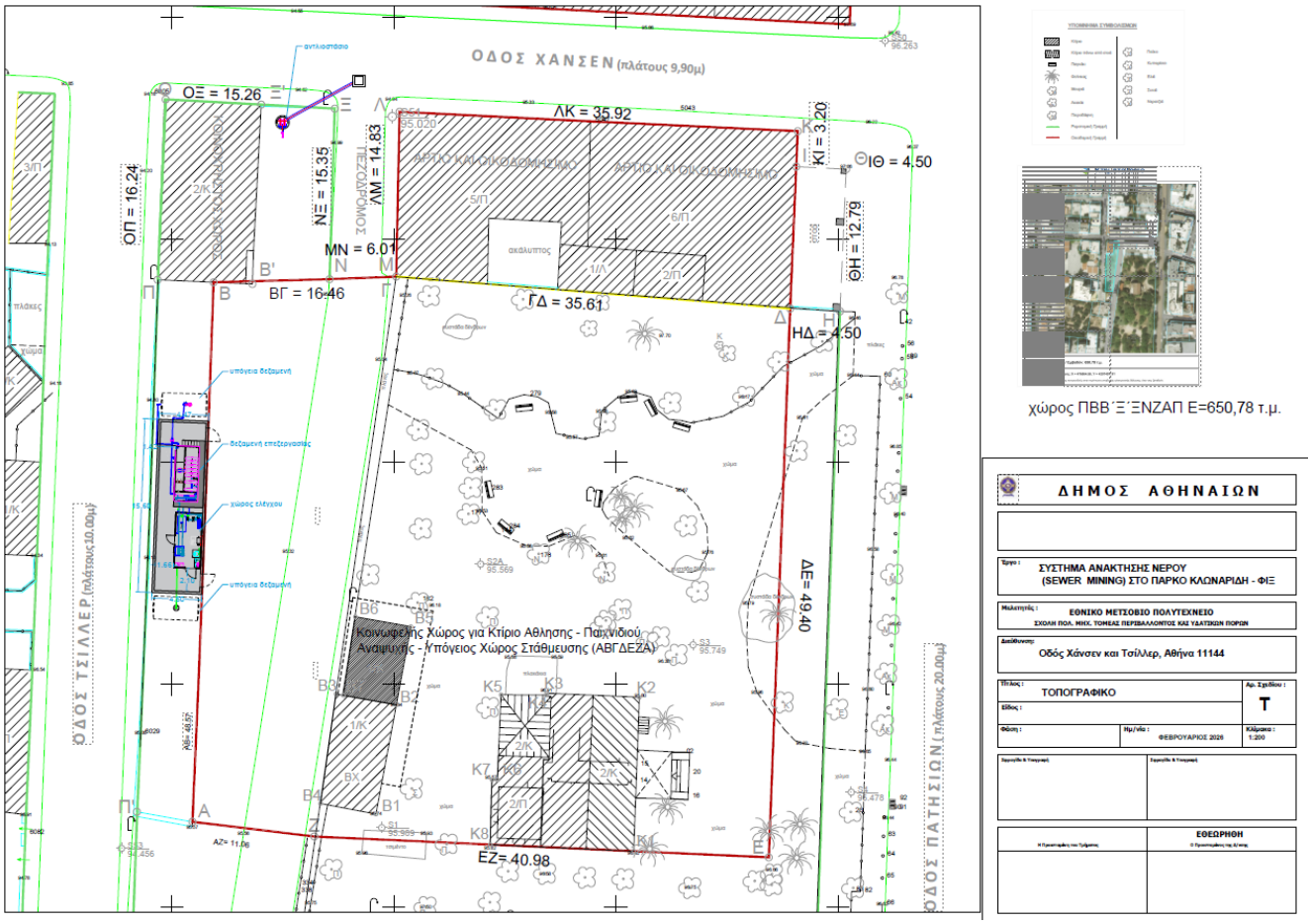


Figure 7 Topographic layout of the decentralised Sewer Mining water recovery unit within the selected site at Klonaridis-Fix Park

The treatment process is based on Membrane Bioreactor (MBR) technology and consists of a multi-stage configuration comprising advanced pre-treatment, biological treatment, membrane filtration, and ultraviolet (UV) disinfection. This configuration ensures the production of high-quality reclaimed water

Funded by the European Union

This project has received funding from the European Union Horizon Research and Innovation programme under grant agreement No 101178059

suitable for non-potable urban reuse applications, particularly irrigation of urban green spaces, in compliance with applicable European and national water reuse requirements.

The use of membrane technology ensures efficient and consistent treatment resulting in the production of high quality water. It also provides resilience against fluctuations of incoming water quality characteristics, which is particularly important in dynamic urban sewer environments. The overall system has been designed to achieve a high level of operational reliability while maintaining a limited physical footprint, allowing integration within the selected municipal parcel adjacent to the park without disruption to surrounding urban activities.

Particular attention has been given to minimising visual impact, noise emissions and odour generation due to the proximity of residential areas, schools, and public recreational spaces. The facility also includes a dedicated machine room container housing the electromechanical equipment, pumps, electrical panels, automation systems, telemetry equipment, and auxiliary infrastructure necessary for operation and maintenance. Air-conditioning systems are integrated to ensure suitable operating conditions and protection of the installed equipment.

All components of the SM system will be supplied and installed as a fully integrated unit in accordance with the project technical specifications, operational requirements, and relevant environmental and safety standards.

The pilot installation on municipal land adjacent to Klonaridis–Fix Park within the 5th Municipal District of Athens (Figure 7) will be implemented under the scientific and technical coordination of the National Technical University of Athens (NTUA), in collaboration with EYDAP and the City of Athens. A Programmatic Agreement has been prepared to define the responsibilities of the involved parties and regulate the use of the site (Annex IV).

4.2 Overall system architecture

A detailed presentation of the system architecture, treatment stages, operational parameters, and technical specifications is provided in the following sections. In Figure 8, an illustration of the system architecture is provided.

The treatment process consists of a sequence of interconnected biological and physical treatment stages to ensure effective wastewater purification and safe water reuse.

Initially, raw wastewater is directed to a buffer tank connected to a denitrification tank, where anaerobic microorganisms convert nitrates into nitrogen gas, which is naturally released from the system. A mechanical mixer is installed to ensure adequate homogenisation and maintain biomass in suspension.

The wastewater subsequently flows into the aeration tank, where aerobic microorganisms oxidise reduced nitrogen compounds, primarily ammonia, into nitrates. Dissolved oxygen levels are maintained through continuous aeration using diffusers, ensuring optimal conditions for biological activity.

Funded by the European Union

This project has received funding from the European Union Horizon Research and Innovation programme under grant agreement No 101178059

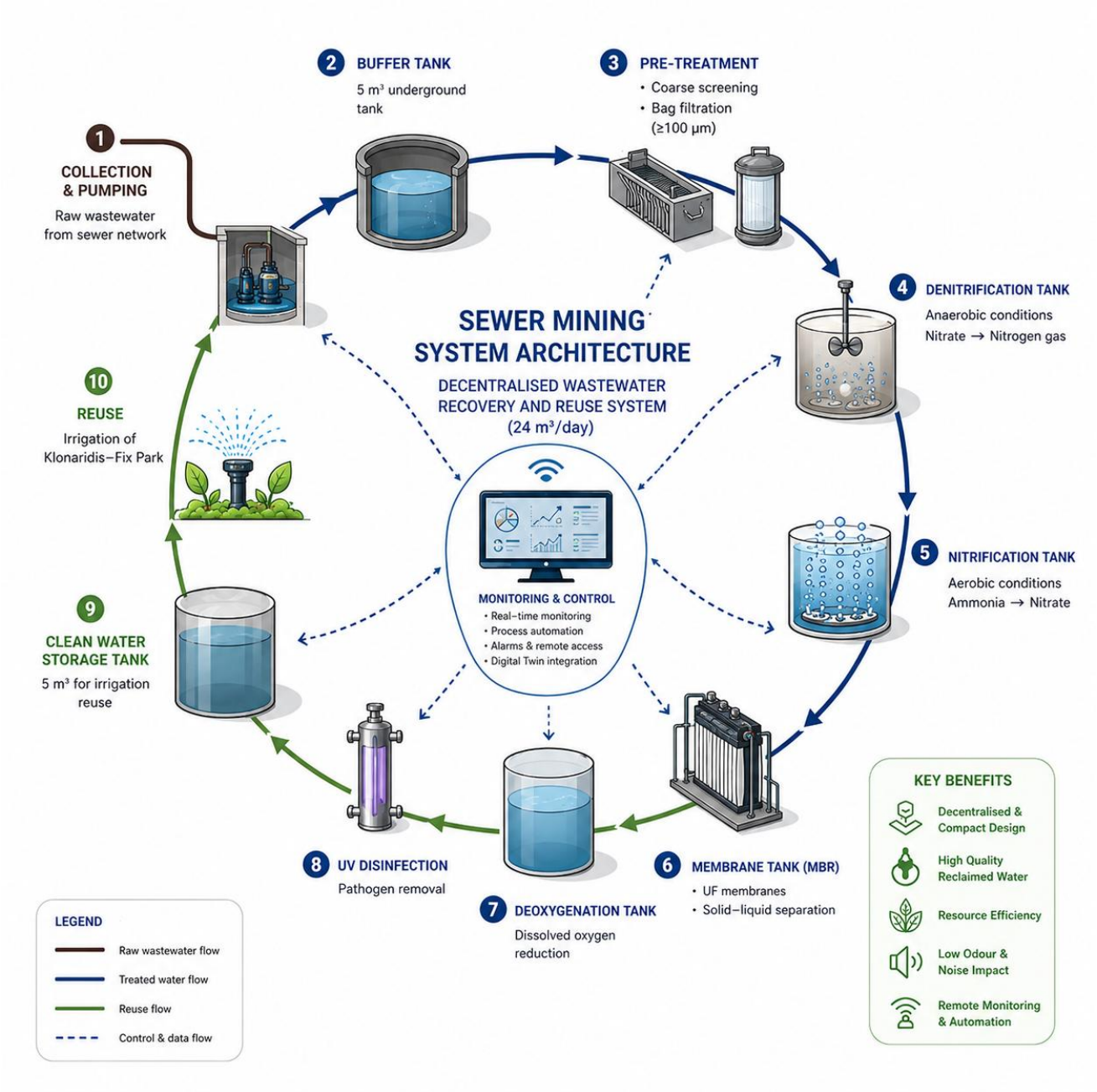


Figure 8 Sewer Mining system architecture

Following biological treatment, the mixed liquor is conveyed to a membrane tank for advanced solid–liquid separation through membrane filtration, where the filtration remains are deposited into the sewage network. The permeate is then subjected to ultraviolet (UV) disinfection to eliminate remaining pathogens before being transferred to a storage tank for reuse in irrigation applications. No additional treatment

Funded by the European Union

This project has received funding from the European Union Horizon Research and Innovation programme under grant agreement No 101178059

chemicals are introduced during the main biological process, thereby minimising the potential generation of secondary contaminants.

4.3 Wastewater Pumping Station

4.3.1 Introduction and scope

This section presents the design study and technical specifications for the supply and installation of a prefabricated wastewater pumping station, through which raw urban wastewater will be supplied to the sewer mining treatment system.

The pumping station will receive wastewater from the gravity sewer network running along Hansen Street. More specifically, wastewater will be abstracted from the existing manhole located at the junction of Hansen and Tsiller streets through a stub pipe to which the prefabricated pumping station will be connected.

The total scope of work includes the following: the prefabricated pumping station will be connected to the existing stub pipe to be installed by EYDAP. This pipe has a diameter of Φ200 and is made of PVC. The supplier of the pumping station will provide at least 8 m of PVC Φ200, 6 atm pipe and a suitable Φ200 coupling (zipo-type) and any bends that may be required due to the final siting of the pumping station, for the connection to the EYDAP pipe. The new wastewater pumping station will be of prefabricated type and will be equipped with two wastewater pumps (one of which is a stand-by). The pumping station will discharge into a 5 m^3 plastic tank near the installation that will treat the pumped wastewater.

More specifically, the electromechanical (E/M) equipment of the pumping station includes:

- The prefabricated well of the pumping station
- The pumping units
- The discharge piping up to the receiving tank
- The hydraulic fittings, isolation valves, non-return valves, etc.
- The low-voltage electrical panel and the automation & control system
- Complete electrical installations for the drives
- Various auxiliary instruments and equipment necessary for the smooth and uninterrupted operation of the pumping station (float switches or level switches).

The pumping station will have a Φ200 inlet stub for its feed and a Φ90 stub for the future connection to a deodorisation unit, should this be required. The positions of the stubs are shown in the design drawings. The supplier is also obliged to supply and install approximately 30 m of high-density polyethylene (HDPE) Φ90, 10 atm rising main, as well as four 90° bends of the same class and diameter as the rising main. The bends shall be glued (welded) type.

Overall, the supply scope for the pumping station includes the following:

Funded by the European Union

This project has received funding from the European Union Horizon Research and Innovation programme under grant agreement No 101178059

1. Supply, transport and installation of one complete prefabricated P/S of capacity as described herein and in the accompanying technical specifications. The prefabricated pumping station will be equipped with 2 (1+1R) pumps (one main and one stand-by).

2. Supply and installation of a feed pipe PVC Φ200, 6 atm, with a length of approximately 8 m, for the connection of the pumping station to the gravity stub pipe of EYDAP. Supply and installation of a suitable connection fitting (zipo or another type approved by EYDAP), including any bends, or other components required for the connection.

3. Supply and installation of a HDPE Φ90 rising main (10 atm), for the connection of the pumping station to the buffer tank of the wastewater treatment unit. The scope includes four welded bends of the same diameter, material and pressure class as the rising main are included for the construction of the network.

4. Excavation of the required trench for the installation of the pumping station and associated pipework.

5. Contraction of a concrete foundation of a minimum thickness of 10 cm thickness, at the bottom of the trench to support the prefabricated pumping station. The dimensions of the slab will be determinined by the manufacturer of the pumping station.

6. Backfilling and compaction of the excavation in accordance with the manufacturer's instructions for the pumping station.

4.3.2 Pumping station characteristics – Type of pumping units

The design and selection of the pumps were based on the operational requirements of the wastewater treatment installation. The treatment unit has a capacity of 24 m^3/day, which corresponds to an average flow rate of approximately 1 m^3/h. However, this flow is considered excessively low. For the efficient operation of the pumping station, a design flow of at least 18 m^3/h is selected, on the basis of which the pumps will be selected.

The flow rate of the pumping station is considerably greater than the required capacity of the treatment installation. This is done in order to use a discharge pipeline of acceptable internal diameter (HDPE Φ90, 10 atm pipe) and to achieve a velocity above the self-cleaning velocity. This design also facilitates the selection of pumps with a more satisfactory free passage of solids and higher efficiency. Furthermore, no operational problem is expected, since the pumps will discharge into a 5 m^3 tank, which will function as a balancing tank.

In summary, the pumping units have been selected after taking into account that:

(a) The operation of the pumping station will be automatic and, in order to simplify the automation system, the pumping units will be of the same size and characteristics.

(b) The main discharge pipeline used for the conveyance of wastewater should not have minimum nominal diameter of DN 80 or Φ90, to reduce the risk of clogging and ensure reliable and constant operation of the system.

Funded by the European Union

This project has received funding from the European Union Horizon Research and Innovation programme under grant agreement No 101178059

On the basis of the above, one pumping station will be equipped with one duty pump and one standby pump.

4.3.3 Hydraulic design parameters

According to the data of the study (flows, elevations), the level setting of the wet well and the MWL (minimum water level, suction), the pumping data shown in the table below are derived:

Pumping station Flow Rate	l/s	5,00
	m^3/h	18,00
Number of Pumping Units	pcs	2
Nominal Flow Rate per Pump	m^3/h	18
Min. Water Level – MWL (suction)		-3,35
Max. Water Level – MWL		-2,90
Discharge Level		0,00
Geodetic Head (Hgeo)	m	3,35
Length of Discharge Pipeline	m	30,00
Discharge Pipeline Material		HDPE,10atm
Nominal Diameter of Discharge Pipeline	DN or Φ	Φ90

The diameter of the prefabricated well of the pumping station is the responsibility of the manufacturer of the system.

4.3.4 Total dynamic head of the pumping units

Total Dynamic Head of Nominal Flow Rate

The pumping station will discharge into a plastic tank with a capacity of 5 m^3, located at the wastewater treatment installation. Inside the prefabricated pumping, the pumps will be able to operate without interruption down to the minimum pumping level, which is defined at the level of the pump head.

For the calculation of the total dynamic head of the pumps at the nominal flow rate, the geodetic head, the frictional losses along the main discharge pipeline, and the local frictional losses of the pumping station are required. The geodetic head is calculated as the difference between the maximum discharge level and the minimum suction level. The losses in the main discharge pipeline were calculated using the COLEBROOK formula for a roughness of 0.10, while for the pipes inside the pumping stations (stainless-steel construction material) for a roughness of 1. The total losses for each pumping station are presented in the tables below.

A safety margin is added to the sum of the losses, and in this way the total dynamic head H_o for the nominal flow rate Q_o of the pumps is calculated.

Funded by the European Union

This project has received funding from the European Union Horizon Research and Innovation programme under grant agreement No 101178059

Below, all the data for the calculation of the dynamic head of the pump at the nominal flow are given.

Table 1 Data for the calculation of the dynamic head of the pump at the nominal flow

PUMP DESIGN FLOW RATE	m^3/h	18.0
	m^3/s	0.005
NUMBER OF INSTALLED PUMPS	pcs	2
NUMBER OF PUMPS IN OPERATION	pcs	1
TOTAL PUMPING STATION FLOW RATE	m^3/h	18.0
PUMPING STATION LEVEL H1 (minimum)	m	-3.35
PUMPING STATION LEVEL (maximum)	m	-2.90
DISCHARGE LEVEL H2 (maximum)	m	0.00
GEODETIC HEAD Hgeo (H2-H1)	m	3.35

Table 2 Description of main discharge pipeline losses

DESCRIPTION (MAIN DISCHARGE PIPELINE LOSSES)			
FLOW RATE	Q	m^3/h	18.0
		m^3/s	0.005
PIPELINE MATERIAL			HDPE, 10 atm
ROUGHNESS COEFFICIENT	k	mm	0.10
NOMINAL PIPE DIAMETER	DN (or Φ)		Φ90
INTERNAL DIAMETER	D	mm	79.20
VELOCITY	U	m/s	1.02
TEMPERATURE OF PUMPED LIQUID	T	°C	20
KINEMATIC VISCOSITY OF WASTEWATER	v	m^2/s	1.01
REYNOLDS NUMBER	Re	-	79,626
FRICTION FACTOR	λ	-	0.02348
PRESSURE LOSS	J	m/m	0.01558
PIPE LENGTH	L	m	30.00
TOTAL LINEAR LOSSES	**Hvid**	m	**0.47**

Local losses are taken as 5% of linear losses

Funded by the European Union

This project has received funding from the European Union Horizon Research and Innovation programme under grant agreement No 101178059

LOCAL LOSSES OF INDIVIDUAL FITTINGS	**Hζ**	m	**0.02**
TOTAL LINEAR AND LOCAL LOSSES (Hvid + Hζ)	**H'tot**	m	**0.49**

Likewise, for a stainless-steel pipe DN65, which is the discharge pipeline of the pump inside the P/S, and for a length of approximately ~4 m, the linear losses are calculated at 0,60 m (the losses of local fittings such as gate valves, elbows, tees, etc., are also included).

Table 3 Pumping station losses

PUMPING STATION LOSSES				
			PUMP DISCHARGE PIPE	**MANIFOLD PIPE**
PIPELINE MATERIAL			INOX AISI 304	INOX AISI 304
ROUGHNESS COEFFICIENT k (mm)	k	mm	1,00	1,00
NOMINAL PIPE DIAMETER DN (or Φ)	DN (ή Φ)		DN 65	DN 65
INTERNAL DIAMETER D (mm)	D	mm	70,00	70,00
VELOCITY U (m/s)	U	m/s	1,30	1,30
TEMPERATURE T (°C)	T	^{O}C	20	20
KINEMATIC VISCOSITY ν (m²/s)	ν	m2/sec	1,01	1,01
REYNOLDS NUMBER Re (-)	Re	-	90.091	90.091
FRICTION FACTOR λ (-)	λ	-	0,04342	0,04342
PRESSURE LOSS J (m/m)	J	m/m	0,05341	0,05341
PIPE LENGTH L (m)	L	m	4,0	0,5
LINEAR LOSSES OF PUMP DISCHARGE PIPE Hvid (m)	**Hvid**	m	**0,214**	**0,027**

PUMPING STATION FITTING LOSSES	**ζ**	**Τεμ**	**Τεμ**
90° Elbow	0,40	1	1
45° Elbow	0,30	0	0
30° Elbow	0,20	0	0
Inlet	0,50	1	0
Outlet	1,00	0	1
Gate valve	0,18	1	0
Ball check valve	0,60	1	0
Reducer / Expander	0,20	1	0
Tee	0,60	0	1
Σ_{ζ}		**1,88**	**2**

Funded by the European Union

This project has received funding from the European Union Horizon Research and Innovation programme under grant agreement No 101178059

LOCAL LOSSES OF PUMPING STATION Hζ (m)	**$H_ζ$**	m	**0,16**	**0,17**

From the above calculations, and taking into account a safety margin of approximately 43 cm, it follows that the total dynamic head at the nominal flow rate of the pump is approximately 4.855 m.

TOTAL LOSSES	m	Htot	4.42
SAFETY MARGIN	m		0.43
TOTAL DYNAMIC HEAD	m	**Ho**	**4.85**

Consequently, the selected pump will have the following characteristics:

NOMINAL FLOW RATE OF PUMP	**m^3/h**	**Q**	**18**
TOTAL DYNAMIC HEAD	**m**	**Ho**	**4.85**

4.3.5 Selected pumping units

In the previous paragraph the total dynamic head of the pump was calculated and its characteristics are stated. Due to the fact that the required characteristics of the pump are not part of a standard series, it is acceptable to achieve these characteristics with the use of an inverter. The candidate Contractor must submit an operating curve of the pump on which the Hz is noted, which in no case shall be less than 30 Hz.

The pumps will be of the submersible type with a specific impeller (NON-CLOGGING – single-channel or multi-channel, or VORTEX type).

The above pumps are designed to be coupled to four-pole electric motors (1500 rpm). Due to the fact that the flow rates are small in relation to the required dynamic head, motors with higher speeds (up to 2,900 rpm) are also permitted.

The electric motors will be vertical, three-phase, induction, squirrel-cage, and their starting, rotation regulation and stopping will be performed via a suitable inverter.

4.3.6 Pumping station pipes– Hydraulic fittings – Other

The discharge pipelines of the pumps and the collector pipe will be of stainless steel of a quality of at least AISI 304. The cross-section of the discharge pipelines of the pumps will not be smaller than DN65. The connection between the stainless-steel collector and the main discharge pipeline in each pumping station will be made with a suitable cast-iron flanged coupling.

Likewise, the flanges, bolts and nuts will be entirely of stainless steel AISI 304. The pipe supports located inside the wet well will be of stainless steel of the same quality as the pipes.

On each pump discharge pipe, a ball-type non-return valve and a manual gate valve with elastic seal will be installed. The hydraulic fittings and flanges will be of class at least PN10.

Funded by the European Union

This project has received funding from the European Union Horizon Research and Innovation programme under grant agreement No 101178059

Likewise, the pump lifting guide rails and the lifting chains will be stainless steel AISI 304.

4.3.7 Electrical issues – Power supply

The prefabricated pumping station will be accompanied by a complete electrical panel containing all the necessary motor circuits as well as the automatic operation and control systems. The panel will contain all the necessary switching equipment, the speed controllers, the necessary protective devices, voltage indicators, etc. The electrical panel will be suitable for outdoor installation; it will be of the pillar type and will be powered from the electrical distribution panel of the wastewater treatment installation.

The control panel shall be supplied by the manufacturer of the prefabricated pumping station and will constitute an integral part of the pumping station configuration. An electrical panel from a different manufacturer is not acceptable to ensure full compatibility, responsibility, and system integration.

General

The operation of the pumping station will be automatic and will take place without the continuous presence of operators for operational handling.

For each consumer there will be the possibility of AUTO – MANUAL operation. In MANUAL operation the equipment will be controlled by an operator, while in AUTO operation it will be controlled by the automation system.

Control system

A local automation, monitoring and alarm system will be installed for the control of the operation of the pumping station. The automation, measurement and signalling systems shall enable the automatic operation of the pumping unit, while ensuring the safe and reliable performance of the installation. In the event of abnormal operating conditions (e.g. motor overload, undesired levels, etc.), it will provide an indication of the situation that prevails at any given moment by means of suitable signals (audible signalling is proposed) and protect the installation from damage or abnormal operation conditions.

Restoration of the normal operation of the unit, after the action of a protection-safety device, will take place only after intervention by the personnel.

The signals on the panel will be visual.

The basic purpose of the system is to be able to ensure the smooth conveyance of the wastewater entering the collection tank, by means of starting and stopping of the pumps, as described above.

The regulation of the operation of the pumping station will be carried out on the basis of the level inside the wet well and inside the tank into which it discharges. The pumps will operate on a cyclical alternation basis in order to ensure their uniform wear.

A total of 4 float switches will be installed. The float switches will be installed as follows:

- FL-01: installed in the pumping station wet well. Indication of the minimum water level (MWL) of the pumping station. Stop pump; protection against dry operation.

Funded by the European Union

This project has received funding from the European Union Horizon Research and Innovation programme under grant agreement No 101178059

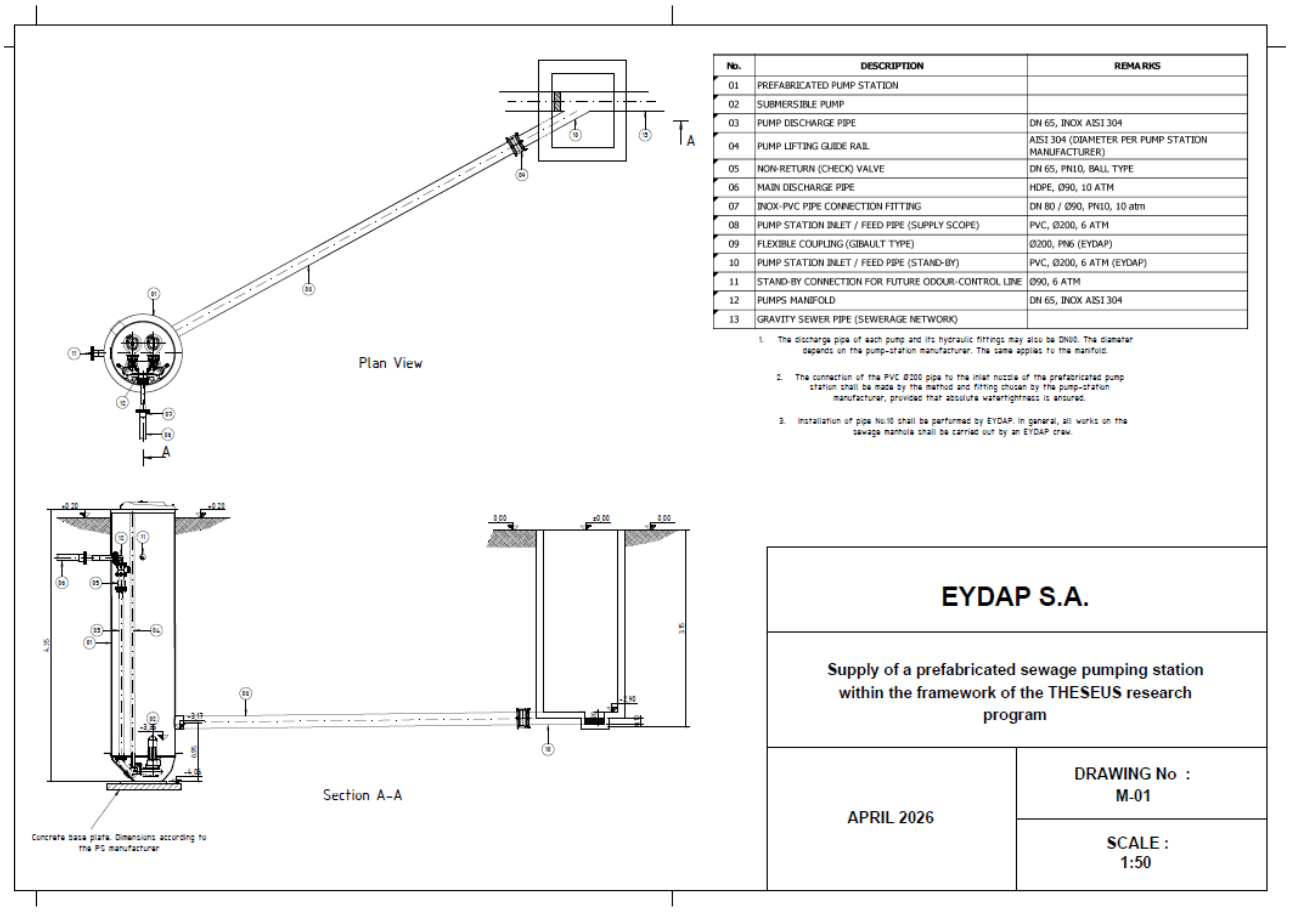
- FL-02: installed in the pumping station wet well. Indication of the maximum water level (MWL) of the pumping station (installed ~5 cm below the level of the feed pipe). Start pump.
- FL-03: installed inside the tank into which the pumping station discharges. Indication of the lowest liquid level in the tank. Command for the feeding of the tank from the pumping station.
- FL-04: installed inside the tank into which the pumping station discharges. Indication of the highest liquid level in the tank. Command for stopping the operation of the pumping station.

The automatic operation of the pumping station will be carried out with simultaneous level monitoring in the wet well of the pumping station as well as in then discharge tank.

More specifically, the pump will receive a start signal from FL-03. Subsequently, provided the appropriate level (FL-02) is achieved, the pump will start. The stopping of the pump will take place exclusively from switches FL-01 and FL-04, irrespective of which of the two is activated first. At the next start, the stand-by pump will operate (cyclical alternation), in accordance with the start commands referred to above.

In this way, it is ensured that no overflow of the tank into which the pumping station discharges will occur and, at the same time, the pumps are protected from dry operation (below the upper part of the volute).

In Figure 9, the drawing of the pumping station design is illustrated.



No.	DESCRIPTION	REMARKS
01	PREFABRICATED PUMP STATION	
02	SUBMERSIBLE PUMP	
03	PUMP DISCHARGE PIPE	DN 65, INOX AISI 304
04	PUMP LIFTING GUIDE RAIL	AISI 304 (DIAMETER PER PUMP STATION MANUFACTURER)
05	NON-RETURN (CHECK) VALVE	DN 65, PN10, BALL TYPE
06	MAIN DISCHARGE PIPE	HDPE, Ø90, 10 ATM
07	INOX-PVC PIPE CONNECTION FITTING	DN 80 / Ø90, PN10, 10 atm
08	PUMP STATION INLET / FEED PIPE (SUPPLY SCOPE)	PVC, Ø200, 6 ATM
09	FLEXIBLE COUPLING (GIBAULT TYPE)	Ø200, PN6 (EYDAP)
10	PUMP STATION INLET / FEED PIPE (STAND-BY)	PVC, Ø200, 6 ATM (EYDAP)
11	STAND-BY CONNECTION FOR FUTURE ODOUR-CONTROL LINE	Ø90, 6 ATM
12	PUMPS MANIFOLD	DN 65, INOX AISI 304
13	GRAVITY SEWER PIPE (SEWERAGE NETWORK)	

1. The discharge pipe of each pump and its hydraulic fittings may also be DN80. The diameter depends on the pump-station manufacturer. The same applies to the manifold.
2. The connection of the PVC Ø200 pipe to the inlet nozzle of the prefabricated pump station shall be made by the method and fitting chosen by the pump-station manufacturer, provided that absolute watertightness is ensured.
3. Installation of pipe No.10 shall be performed by EYDAP. In general, all works on the sewage manhole shall be carried out by an EYDAP crew.

Funded by the European Union

This project has received funding from the European Union Horizon Research and Innovation programme under grant agreement No 101178059

Figure 9 Pumping Station drawing - Section and Plan View

It is noted that the automatic controller, its setting and the overall programming will be those of the manufacturer of the pumping station. The implementation of the automation will be carried out directly by the manufacturer of the pumping station, with the exception of the float switches FL-03 and FL-04, which will be installed by the Contractor. However, their functionality will be included in the automation programme.

If the manufacturer of the pumping station controls the level inside the pumping by means of an analogue level meter, this is acceptable and may replace the float switches FL-01 and FL-02.

4.4 Main system architecture and technical specifications

The overall Sewer Mining system architecture is illustrated in Figure 10 and the technical specifications of the main components are provided in the following section.

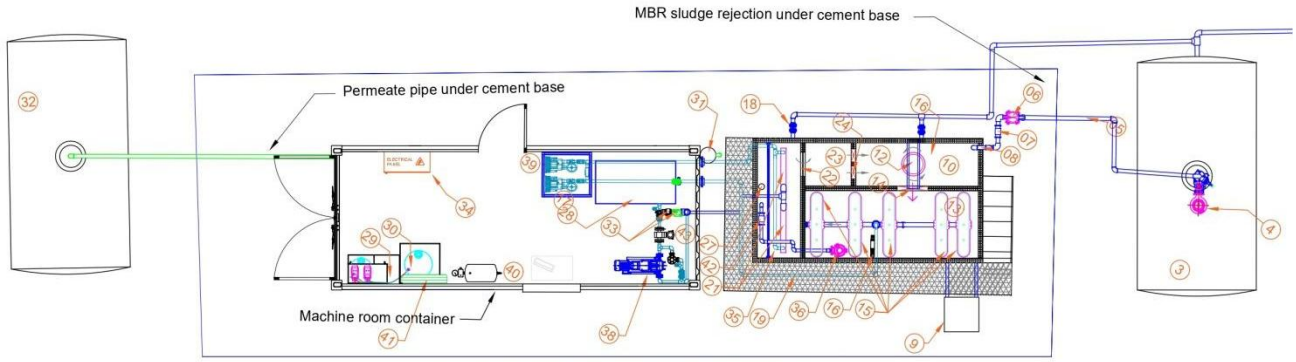


Figure 10 Overview of the main Sewer Mining architecture

Raw wastewater collected within the pumping station (Point 1, Figure 11) is conveyed via submersible pumps (Point 2, Figure 11), which will operate in alternating cycles to ensure uniform wear, to a 5 m³ underground buffer tank (Point 3, Figure 12).

Funded by the European Union

This project has received funding from the European Union Horizon Research and Innovation programme under grant agreement No 101178059

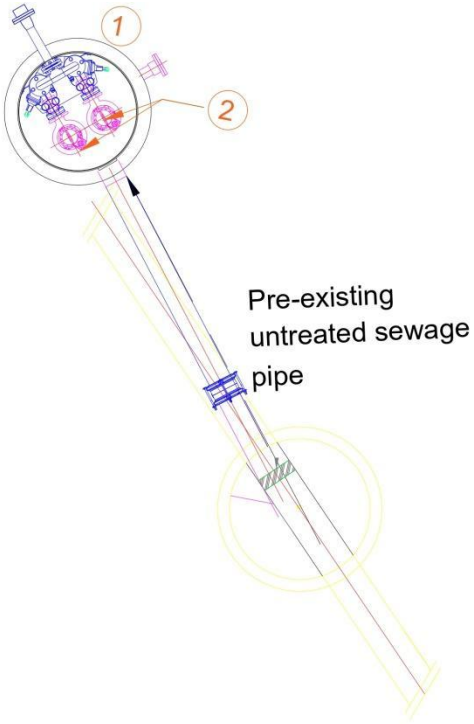


Figure 11 Existing pipeline to which the unit is connected
(Pumping station and raw wastewater pipeline) – Plan view

4.4.1 Main treatment unit

From the buffer tank, via the feed pump (Point 4, Figure 12), wastewater is transferred through a multi-stage mechanical pre-treatment system comprising:

- Coarse protective filtration;
- Bag filtration (≥100 µm particle removal).

Following pre-treatment, wastewater enters the biological treatment unit housed within the main treatment container.

Funded by the European Union

This project has received funding from the European Union Horizon Research and Innovation programme under grant agreement No 101178059

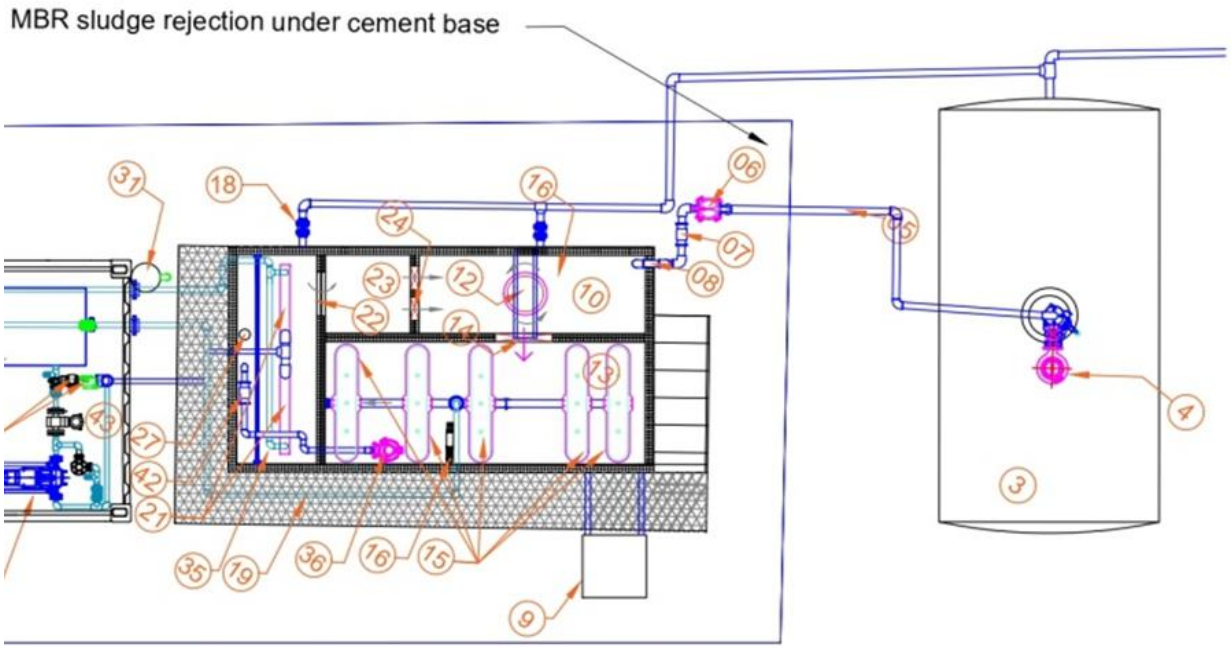


Figure 12 Plan View of the Sewer Mining treatment unit

After mechanical pre-treatment, the filtered wastewater will enter the main treatment unit (first container). From the outlet at its bottom, it will be conveyed to the denitrification tank (Point 10, Figure 12), where, with the aid of a mixer (Point 12, Figure 12), homogenization will be achieved and the suspension of anaerobic microorganisms will be ensured. Under oxygen-deficient conditions, these microorganisms convert nitrate ions into nitrogen gas, which will be naturally released from the system.

Next, through the bottom outlet, the treated wastewater is conveyed to the first nitrification tank (Point 13, Figure 12), which is equipped with aerators that supply the necessary air for biological treatment and aerobic nitrification.

After biological treatment, the wastewater is directed to the membrane tank (Point 35, Figure 12) via the corresponding feed pump (Point 36, Figure 12). The membrane tank contains immersed Ultrafiltration (UF) hollow-fiber membranes (Point 21, Figure 12), which separate clean water from the biological sludge.

The treated wastewater will then flow into the deoxygenation tank (Point 23, Figure 12), where the dissolved oxygen level will be reduced before entering the denitrification tank again (Point 12, Figure 12) through two bottom openings (Point 24, Figure 12). The deoxygenation tank will be fed by the overflow from the membrane tank, which will occur via an opening at the top of its wall (Point 22, Figure 12).

4.4.2 Machine room and auxiliary systems

The treatment container unit will be accompanied by a dedicated machine room, within which the required electromechanical equipment, automation panel, Monitor Control Center (MCC), and other elements will be installed. This container is illustrated in Figure 13 and its design dimensions are 6 m × 2.5 m × 2.9 m (L × W × H).

Funded by the European Union

This project has received funding from the European Union Horizon Research and Innovation programme under grant agreement No 101178059

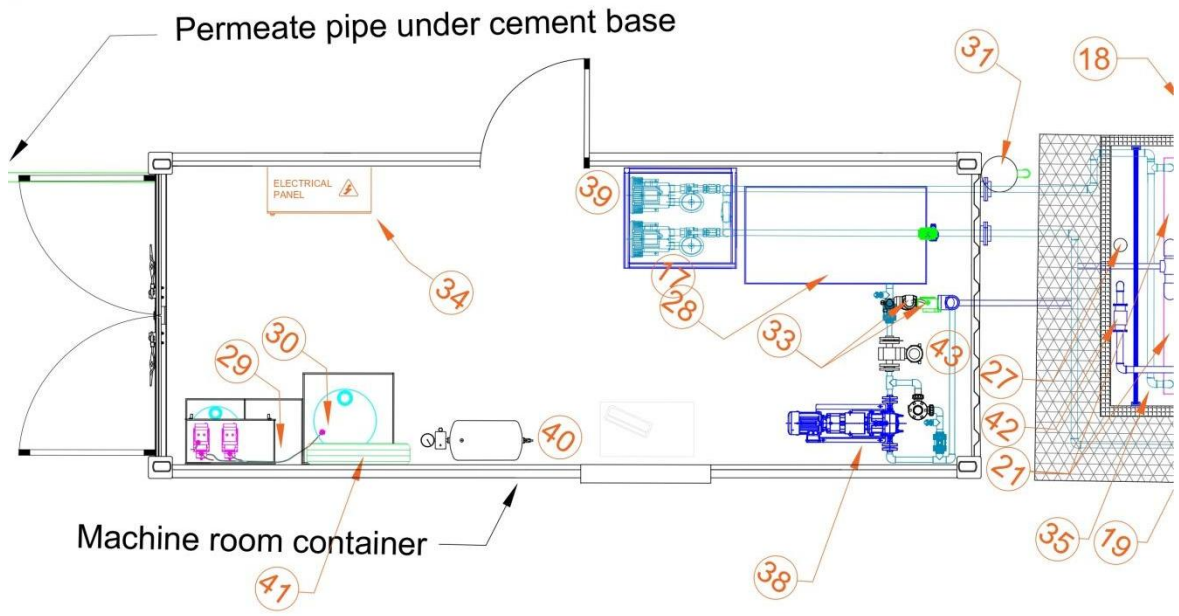


Figure 13 Machine room container - Plan View

Inside the machine room, there will be a temporary storage tank for the permeate produced by ultrafiltration membrane separation and membrane cleaning (Point 28, Figure 13), with a capacity of 500 L. This tank will temporarily store the permeate from the ultrafiltration membranes (Point 21, Figure 13), which will be used for backwashing the membranes. The tank will also include an overflow, which will allow permeate to flow by gravity to the UV disinfection system (Point 31, Figure 13), ensuring the proper radiation dose for disinfecting the final permeate before delivery to the final irrigation tank. The final treated permeate will then be directed to a clean water storage tank with a capacity of 5 m^3, intended for irrigation of urban green spaces.

Within the machine room, a lobed pump for permeate/backwash (Point 38, Figure 13) will be installed. This pump draws treated permeate from the hollow fiber membranes and, at regular intervals, pushes part of it back into the membranes to perform backwashing, preventing clogging. Additionally, a dosing pump (Point 30, Figure 13), with a 200 L storage tank and safety container, will be installed to supply citric acid for membrane cleaning.

The entire process is designed to be closely monitored through dedicated sensors, including tank level sensors, pH meters, Mixed Liquor Suspended Solids (MLSS) sensors, and dissolved oxygen probes. Automation will be achieved using pneumatically actuated valves, controlled by a programmable logic controller (PLC) system. Additionally, the local PLC system will be integrated into a Digital Twin platform, enabling real-time data flow and visual representation of the system's performance.

The system will be equipped with instruments for analogue level measurement based on hydrostatic pressure, with data recorded by the PLC, which will display the wastewater level digitally for each tank. Electromagnetic flow meters will be installed to measure the flow of raw wastewater feed, membrane tank feed, and permeate.

Funded by the European Union

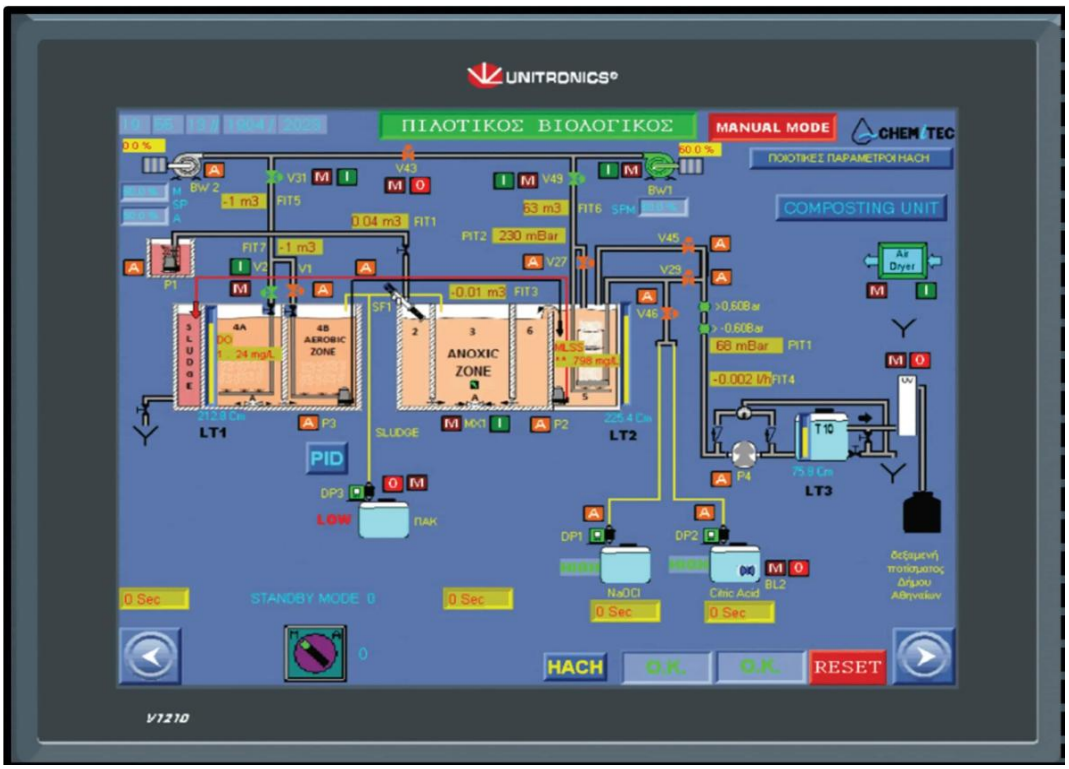
This project has received funding from the European Union Horizon Research and Innovation programme under grant agreement No 101178059

All instruments will be connected to a common controller for data collection, featuring a touch screen display for measuring dissolved oxygen in the second nitrification tank and the deoxygenation tank. Additional measurements include suspended solids in the denitrification and membrane tanks, pH in the membrane tank, turbidity in the permeate tank, and NO_2^-/NO_3^- concentrations in the nitrification and denitrification tanks.

The unit will have an MCC electrical control panel built to international safety standards, fully adapted to the functional requirements, automation, and control of the system, including the permeate/backwash pump, membrane feed pump, and aerators for the membranes and nitrification tank. The panel will include an integrated PLC for remote control and monitoring. The PLC, in combination with the instrument controller, will collect electrical signals to regulate, control, and automate the treatment processes.

The PLC will be programmed to automatically manage filtration, backwashing, chemical cleaning, and maintenance operations, ensuring the proper operation of the unit. It will also trigger alarms and stops of the unit if any equipment or membrane integrity are compromised, or if monitored parameters exceed safety limits.

Through the PLC, all instruments and electromechanical equipment will be monitored and controlled remotely in real time. End users will access the system via a password-protected interface, which allows direct viewing of the PLC screen and control of the electromechanical equipment, motors, and process stages.



Funded by the European Union

This project has received funding from the European Union Horizon Research and Innovation programme under grant agreement No 101178059

Figure 14 PLC System of the SM configuration

4.4.3 Quality characteristics of produced water

The entire process will be systematically monitored using specialized sensors, including tank level sensors, pH meters, mixed liquor suspended solids (MLSS) sensors, and dissolved oxygen probes. Automation will be achieved through pneumatically actuated valves, which are controlled by a Programmable Logic Controller (PLC) (Figure 14).

Additionally, the local PLC system will be integrated into a digital twin platform, enabling real-time data flow and visual representation of system performance.

Further to the online monitoring, laboratory tests are intended to be conducted for a series of parameters: Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD), Total Phosphorus (TP), Total Nitrogen (TN), Ammonium Nitrogen (NH_4^+-N^-), Nitrate Nitrogen (NO_3^--N), Total Coliforms (TC), Escherichia coli (E. coli), pH (measure of acidity or alkalinity), Electrical Conductivity (EC) (ion concentration in water indication), Dissolved Oxygen (DO), Transmembrane Pressure (TMP) used in membrane filtration systems.

These measurements will be initially scheduled to be taken every 2–3 days, then weekly, and finally biweekly, in order to enable targeted monitoring and cross-verification of the system performance.

Funded by the European Union

This project has received funding from the European Union Horizon Research and Innovation programme under grant agreement No 101178059

5. Urban integration and landscape

5.1 Historical background and integration into the urban fabric

The proposed Sewer Mining (SM) installation has been designed with particular consideration of its integration into the historical, architectural and social context of Klonaridis–Fix Park. The selected site is located within a municipal parcel adjacent to the preserved Klonaridis–Fix Villa and surrounded by residential buildings, educational facilities and public green spaces (Figure 15). Consequently, the intervention prioritises visual integration, minimisation of environmental disturbance and enhancement of the surrounding urban landscape.



Figure 15 Overview of the Klonaridis-Fix urban park and the Klonaridis Villa

The wider area is of significant historical value, as it originally formed part of the Klonaridis brewery and ice factory complex established in the early 20th century by the brothers Miltiades and Errikos Klonaridis (Figure 16). In the 1930s, the industrial facilities came into the possession of the Fix brewery company and continued operating until the closure of the business in 1982.

Funded by the European Union

This project has received funding from the European Union Horizon Research and Innovation programme under grant agreement No 101178059



Figure 16 Design of the factory, showing the villa on the right

Source: Athensvoice

At the centre of the site there is the preserved Klonaridis–Fix Villa (Figure 17), which served as the residence of the factory owners for much of the 20th century. The building is attributed to the architect Ernst Ziller and is estimated to have been constructed between late 19th century and 1902. Its architectural identity is characterised by symmetrical façades, a prominent portico, red-coloured surfaces and decorative diagonal brick detailing at first-floor level, elements that are representative of the architectural language of the period.

Following an auction in 1993, the site was acquired by the City of Athens. The former industrial buildings were subsequently demolished to allow for the creation of the present-day public park, while the villa was preserved and designated as a protected historical monument. After suffering fire damage in 2020, the building underwent emergency stabilisation and roof protection works; however, the broader restoration project has not yet been completed.

Funded by the European Union

This project has received funding from the European Union Horizon Research and Innovation programme under grant agreement No 101178059



Figure 17 The historic preserved Klonaridis-Fix Villa

Source: Mixanitouxronou

Given the historical and cultural importance of the site, the SM installation has been conceived as a discreet and landscape-integrated intervention rather than a conventional technical facility. The design approach seeks to combine infrastructural functionality with architectural sensitivity and public-space enhancement.

To achieve visual integration within the surrounding environment, a solid screening wall is proposed along the eastern side of the installation, shielding the unit from direct views from both the park and the historic villa (Figure 18). The wall's materiality and colour palette reference the lime-plastered surfaces of the adjacent building, reinforcing continuity with the existing architectural context. At the same time, the structure incorporates integrated seating facing the park and the villa, creating a small resting area for visitors. The wall may additionally serve as a surface for informational and educational material related to water reuse, circular water management and the Sewer Mining system.

The remaining sides of the installation will be enclosed using an upcycled timber framework constructed from reclaimed pallet planks. The timber elements are arranged in a herringbone pattern inspired by the decorative brick motifs of the historic villa, establishing a subtle architectural dialogue between the new intervention and the preserved building. The reuse of reclaimed timber also supports the sustainability objectives of the project.

The timber enclosure is designed to support climbing vegetation, enabling the infrastructure to gradually blend into the surrounding landscape over time. The upper section of the eastern partition bends slightly inwards, creating the visual impression of a lightweight canopy without fully enclosing the installation.

Particular attention has also been given to maintaining pedestrian permeability and accessibility throughout the site. Sufficient setback distances from adjacent pavements allow for the introduction of

Funded by the European Union

This project has received funding from the European Union Horizon Research and Innovation programme under grant agreement No 101178059

climbing and ornamental planting, while denser vegetation is proposed along the southern edge of the installation. The northern side remains more open in order to preserve pedestrian movement between the surrounding streets and the park (Figure 18).

Overall, the intervention aims not only to accommodate the technical requirements of the Sewer Mining system, but also to contribute positively to the environmental quality, identity and public character of the area.



Figure 18 Sewer Mining configuration siting in the parcel plot to irrigated Klonaridis-Fix Park

Funded by the European Union

This project has received funding from the European Union Horizon Research and Innovation programme under grant agreement No 101178059

5.2 Landscape and spatial design considerations

The selected location for the Sewer Mining unit was determined following consideration of both technical and spatial constraints. The site is positioned sufficiently close to the pumping station and sewer connection point to ensure hydraulic feasibility, while simultaneously maximising the distance from nearby residential buildings and the adjacent school located to the west.

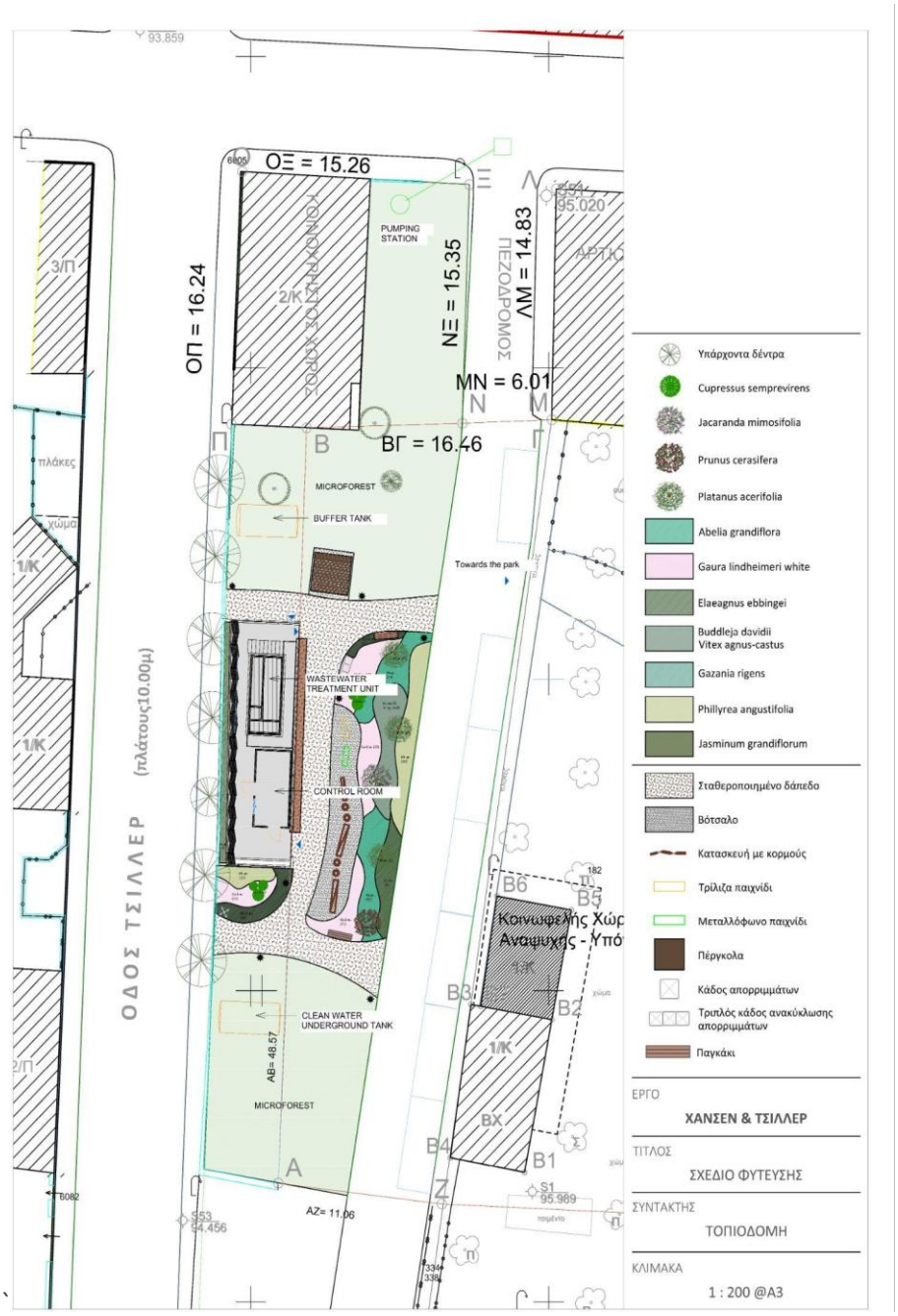


Figure 19 Design of integrated interventions – Sewer Mining configuration and urban microforest initiative

Funded by the European Union

This project has received funding from the European Union Horizon Research and Innovation programme under grant agreement No 101178059

The proposed intervention adopts an integrated landscape and ecological design approach, combining the Sewer Mining infrastructure with the development of a small-scale urban microforest initiative within the same municipal parcel (Figures 19 and 20). The overall concept seeks to demonstrate how decentralised urban water infrastructure can coexist with nature-based solutions and public open space improvements in dense urban environments.

The landscape design strategy extends beyond the immediate boundaries of the treatment unit enclosure and seeks to improve the overall spatial quality, environmental performance and accessibility of the surrounding public area.

The existing cement brick masonry wall currently located on the site will be demolished, and portions of the material may be reused within the new landscape and enclosure construction in order to minimise construction waste and support circular design principles. The intervention also aims to improve pedestrian permeability by opening the visual and physical connection between the school and the park.

In the eastern side of the installation, a small recreational area incorporating a simple playground and ornamental planting is proposed. Along the northern and southern edges of the site, dense micro-forest planting zones will be established in order to enhance biodiversity, improve microclimatic conditions, increase shading and thermal comfort, and strengthen the green character of the park.

The proposed microforest initiative will function for the greening of the undeveloped area through the support of the Sewer Mining system. The availability of reclaimed water produced creates opportunities for autonomous and sustainable irrigation of the new and existing planted areas, and enhance the resilience of the urban space by reducing the dependence on potable water for non-potable purposes.

A pergola structure that is integrated in the particular space will provide additional shading and a seating space for parents and children, playground users and park visitors. Together, these interventions contribute to the creation of a multifunctional public space that combines environmental sustainability, recreation and raising awareness.

The entire intervention will demonstrate how a decentralised urban water reuse system along with a greening intervention of the particular public open space can be integrated in a manner that enhance environmental quality, social engagement and urban resilience.

Funded by the European Union

This project has received funding from the European Union Horizon Research and Innovation programme under grant agreement No 101178059

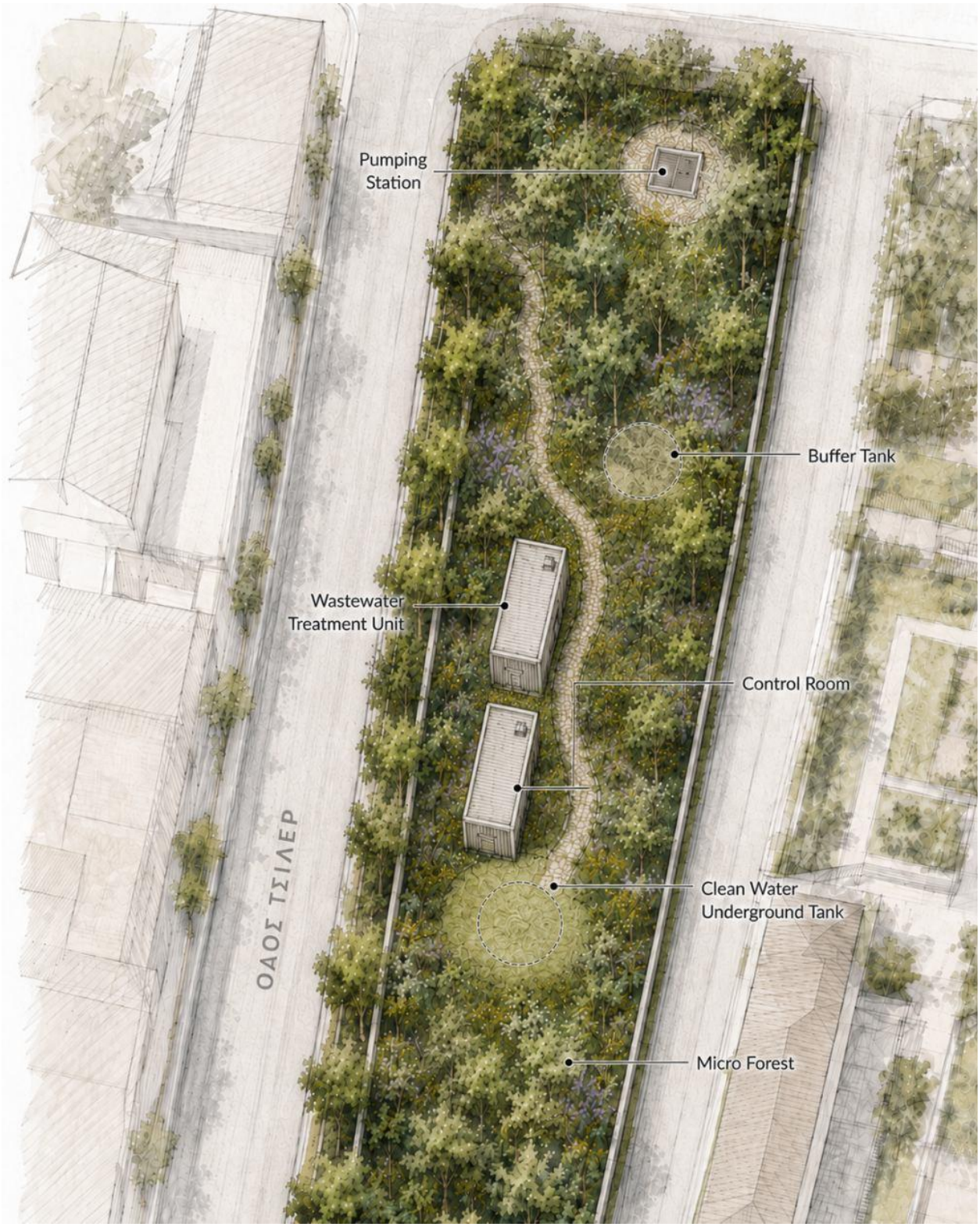


Figure 20 Conceptual infographic representation of the combined interventions (SM unit and micro-forest)

Funded by the European Union

This project has received funding from the European Union Horizon Research and Innovation programme under grant agreement No 101178059

6. Stakeholder engagement and co-creation processes

6.1 Introduction

The successful implementation of decentralised water reuse solutions, such as the Sewer Mining systems in real world dense urban environments, depends on technical capacity as well as on social acceptance and procedural coordination and efficiency. In this context, stakeholder engagement constitutes a key component of the process, to ensure that the proposed interventions are widely supported and tailored to local needs of the end users.

To support this, a structured engagement approach was followed that included a step-by-step engagement of the key stakeholders, including municipal authorities at a central and local level, local schools, and community representatives. Through a combination of site visits, technical discussions, and interactive meetings, the process aimed to increase transparency, to build trust, and enable co-creation of the final design of the solution.

This methodology was essential to alleviate potential concerns early in the process and to increase public acceptance. This way the local communities will be motivated to embrace these initiatives and support their efficient implementation. The engagement process is on-going and will continue to expand through more open and interactive activities involving the local community and end users.

6.2 Stakeholder mapping

The stakeholder mapping process identified a diverse set of actors at institutional, local, and community levels, all of whom are directly or indirectly involved or influenced by the project.

At the institutional level, key stakeholders include the City of Athens and in particular the Vice Mayor for Environment and Green Spaces as well as the Vice Mayor for Technical Services, Municipal Property and Digital Governance. Furthermore, several municipal departments and services were engaged in the design process of the interventions and their contribution was critical. In particular, the Division of Green Spaces and Urban Fauna, the Division of Road Works, Sewerage and Public Spaces, Division of Municipal Property, Legal Division, etc. These entities play a key role in decision-making and the permitting processes, and ensure alignment with urban planning and environmental policies. In addition, the Municipal Enterprise Develop Athens, being also a partner in the project, acts as an important coordinating body to support procedural matters.

At the local governance level, the president along with representatives of the 7th Municipal Community of Athens were informed. Also the local cultural association was informed on the interventions. Their participation ensures that neighbourhood-level priorities and concerns are adequately represented and integrated into the project design.

Finally, the adjacent schools and associations of parents, as key stakeholders, were informed and invited to participate in the process of design and later at the planting activities. Media representatives will also be

Funded by the European Union

This project has received funding from the European Union Horizon Research and Innovation programme under grant agreement No 101178059

engaged at a more mature level of the project design as indirect stakeholders, contributing to transparency and public communication.

6.3 Engagement processes

The stakeholder engagement process was carried out through a series of structured and iterative discussions, combining technical investigation with active consultation and dialogue. Multiple site visits (autopsies) were conducted, involving the project team, municipal representatives, and local stakeholders. These visits enabled a comprehensive understanding of the site conditions, including infrastructure networks, spatial characteristics, and interactions with the surrounding urban environment.

In parallel, data were systematically collected and analysed to support a technical efficient Sewer Mining facility that would integrate the development of the surrounding area (e.g. the creation of a microforest).

A series of meetings and interactive discussions were held with key stakeholders, including representatives from the City of Athens, Municipal Enterprise Develop Athens, the 7th Municipal Community, the local school, and the respective parent association. These engagements aimed to present the proposed interventions, gather feedback, and ensure transparency throughout the process.

Overall, the feedback was positive, with stakeholders expressing support for the project's objectives, particularly in relation to sustainable water management practices and the enhancement of urban green spaces. In addition, constructive comments were provided regarding the integration of the system within the park, the pathways, as well as additional elements to be included in the surrounding space. These inputs were recorded and integrated into the design.

Some stakeholders expressed interest to extend the intervention into a more integrated solution that would include the energy efficiency of the sewer mining unit through the installation of photovoltaic panels on the roof of the schools. This initiative would enable the production of renewable energy for both the SM operation and the school's own energy needs.

In addition, the school could benefit from rainwater harvesting through the same rooftop infrastructure, with collected water stored and reused for irrigating school gardens (as demonstrated in the corresponding THESEUS pilot, Task 7.2, Section B of the present report). This integrated approach would further enhance the efficient use of water, increase the resilience of the area and strengthen the demonstration nature of the intervention.

Based on the stakeholder feedback and interaction, a dedicated design was compiled that reflects not only technical work, but also the community needs and expectations as well as the municipal priorities for the recreation of the particular neighbourhood.

Funded by the European Union

This project has received funding from the European Union Horizon Research and Innovation programme under grant agreement No 101178059

7. Challenges, risks and mitigation measures

The Sewer Mining (SM) system within a dense urban environment involves a range of technical, procedural, and social risks that must be carefully identified and managed. This chapter outlines the main risks and barriers encountered during the design phase, along with the corresponding measures and actions that were taken to mitigate them.

7.1 Technical and operational challenges

At a technical level, the main challenges arise from the integration of a decentralised treatment unit within a dense and highly populated urban environment. These spatial limitations are addressed through a compact facility with a small footprint specifically designed for installation in restricted urban space.

The quantities and the quality of urban wastewater flows often vary, which can create issues in the system stability and performance. To address this matters sensors are installed within the configuration and alarm control systems are set to prevent such events. Furthermore, to ensure continuous operation of the system despite the variable flows, the coordinated use of buffer tanks is designed.

In addition, to comply with water reuse standards a real-time monitoring and quality assurance system is installed through the online use of a PLC system (see above). Also, the application of Membrane Bioreactor (MBR) technology combined with UV disinfection, enables continuous tracking of key operational parameters, early detection of unexpected events, and prompt response when needed.

7.2 Stakeholder engagement and social acceptance

As the interventions will be set within a public green space in Athens, public and community acceptance are key factors. Although decentralised water reuse technologies are recognised as sustainable solutions, concerns may arise related to the safe use of reclaimed water, potential odors, visual impact, etc.

To mitigate these risks, targeted stakeholder engagement activities were implemented at an early stage and will continue to be held throughout the implementation phase. As shown in Chapter 6, this approach has already contributed to a generally positive perception of the project.

7.3 Procedural and administrative constrains

In addition to technical and social dimensions, several procedural and administrative processes were considered. A formal Programming Agreement for the use of the selected site has been prepared and approved by the National Technical University of Athens (NTUA) and, following a series of consultations, is currently awaiting final approval by the City of Athens. The approval process is time consuming as a series of Divisions and Departments of the Municipality need to provide consultation and an opinion.

Funded by the European Union

This project has received funding from the European Union Horizon Research and Innovation programme under grant agreement No 101178059

In parallel, the tender documentation for the procurement of the Sewer Mining (SM) system equipment has been prepared by NTUA and is in the process of being published. Further, the technical specifications for the pumping station were prepared by EYDAP and will be used as the basis for the procurement to enable a smooth transition from design to implementation.

Despite this progress, delays in coordination among involved stakeholders and the complexity of administrative procedures may pose risks to the overall project timeline. Such challenges are common in multi-actor urban infrastructure projects and require continuous coordination, constant follow up of processes, and proactive management to avoid bottlenecks. In this context, it is crucial to initiate implementation activities as early as possible, particularly to prevent delays in the permitting processes. To avoid delays in these matters, it is important to interact, work closely, build trust, and coordinate the processes.

7.4 Next steps

The immediate next steps focus on advancing the project into the implementation phase. This includes the completion of the tendering process for the construction and installation of the SM system. Then, the execution of the works and the installation of the system will be performed. In parallel, stakeholder engagement and interaction with the local community will continue throughout the implementation of the project.

In parallel, potential synergies with other urban initiatives will be further explored. A key opportunity is the integration of photovoltaic (PV) systems on the roofs of a nearby school to partially cover the energy demand of the Sewer Mining unit, thereby strengthening the project's circularity, reducing its carbon footprint, as well as contributing to climate-neutral objectives and providing a synergetic result with other projects.

Furthermore, close coordination with the team responsible for the development of the micro-forest within the same parcel is essential to ensure a coherent plan for both interventions. This integrated approach will help maximise environmental, social, and functional benefits within the shared urban space.

Overall, the project is steadily transitioning from the design and preparatory phase to implementation, with continued emphasis on coordinated governance, technical readiness, and community integration.

Funded by the European Union

This project has received funding from the European Union Horizon Research and Innovation programme under grant agreement No 101178059

8. Regulatory framework and permitting

Regarding the site of the intervention, the street plan was defined by FEK 54 / 1938, FEK 204A / 1949, FEK 146 / 1954, FEK 208 / 1956, FEK 216 / 1959. FEK 727 / 1989, where the area of the plot is characterised as a green space, whereas FEK 290Δ / 1992 amends it, defining the limits of the different uses. FEK 421/1994 defines the plot as property of the municipality and the Villa as a monument.

The Ministerial Decision 145116/2011 defines the quality of the recovered water required so as to water a public place and according to Regulation (EU) 741/2020.

The sewer mining water recovery system is defined as a public service infrastructure that is under the law 4280/2014. Specifically, Law 4674/2020, art 11 par. 9 describes that such works for Municipalities don't require a building permit issued by the competent authority,

if all necessary studies are conducted;

"By way of derogation from the urban planning provisions, technical works and installations serving water supply and sewage, district heating of municipalities, irrigation of their areas, as well as the construction and operation of sanitary landfills (L.Y.T.A.) and Waste Transfer Stations are not subject to the terms and restrictions of these provisions and their construction does not require the issuance of a building permit by the competent authorities, provided that they are provided for by technical studies. [...] Any of the technical works and installations of this paragraph that have a large volume or height are carried out after obtaining an opinion from the competent Architectural Council".

So the permit requirements are:

- Permit by the Ministry of Environment – A decision is issued for implementing the solution for two years and then issue an Environmental Permit (Annex III)
- Operation permit according to national legislation,
- Reuse permit issued by Decentralised Administration of Attica Region, Directorate for Water
- Permit from the municipality (green spaces, technical services)
- Permit from the municipality (for the use of the parcel) – A Programmatic Agreement has been drafted, it is approved by NTUA, whereas it is awaiting approval by the City of Athens (Annex IV)
- Architectural Council of the Central Sector of Athens (for the establishment of the SM unit)
- Central Council for Modern Monuments (due to the vicinity to the historic preserved Klonaridis-Fix Villa)

Funded by the European Union

This project has received funding from the European Union Horizon Research and Innovation programme under grant agreement No 101178059

9. Replicability and upscaling potential

9.1 Transferability to other urban areas

Sewer Mining technology represents a flexible, scalable, and highly adaptable solution for decentralized wastewater treatment and reuse. Although it has been conceptualised and demonstrated within the dense, drought-prone Mediterranean context of Athens, its core principles make it highly transferable to a wide range of urban environments facing similar challenges.

In particular, cities characterised by water scarcity, high population density, ageing infrastructure, and limited space can significantly benefit from this approach. By enabling water reuse directly at the point of demand, Sewer Mining systems reduce dependency on potable water for irrigation purposes as well as on centralised infrastructure while improving overall the resilience and autonomy of the cities.

The concept is especially relevant for:

- Urban areas with seasonal water stress issues
- Cities seeking to maintain and expand green spaces
- Regions that implement water reuse master plans

Sewer Mining is a flexible, scalable and replicable water reuse system that has been conceptualised to be implemented in a dense area with water scarcity issues. The city centre of Athens, being a complex and dense environment, serves as the ideal setting to demonstrate the benefits of circularity and transferability of this approach to other urban contexts.

9.2 Guidelines for replication

The successful replication of Sewer Mining systems is based on technical, procedural, and social aspects that need to be considered and integrated in the proposed solution.

With regard to the technical issues, the design of a replication system should be grounded in a thorough understanding of the local conditions and particular limitations. This includes water demand, existing infrastructure, and spatial constraints. The connection with the sewage network through the pumping station should be investigated in detail in terms of proximity with the candidate space for the SM system as well as the quantity and quality of wastewater.

In addition, the regulatory framework could be a challenge as there is no existing roadmap of guidelines for implementing such solutions in an urban environment. In any case, there should be an alignment with water reuse regulations and permitting procedures. Close collaboration with local authorities and their technical departments is important to ensure that approvals for the system operation are granted and provided at an early stage.

Public acceptance is also a key factor for the successful implementation of replicated SM systems, especially in dense urban environments. A structured and ongoing engagement with stakeholders should

Funded by the European Union

This project has received funding from the European Union Horizon Research and Innovation programme under grant agreement No 101178059

be planned at an early stage based on the mapping of key actors and end users of the interventions. The potential stakeholders include municipalities, local organisations, and community groups, with whom the technical team should be transparent, build trust, and address any concern to ensure that solutions are well understood and supported.

Finally, existing demonstration projects can serve a valuable reference point for the replication similar systems in other areas. Site visits and study tours can be organised to allow cities, stakeholders and potential end users observe the technology in operation. Such initiative facilitate the exchange between cities and stakeholder so as the end users of the technology get a better perception of the visual impact and integration of the interventions in the urban space.

9.3 Upscaling potential

Sewer Mining, as a principle, redefines wastewater as a valuable resource rather than a waste. As a decentralised and circular water reuse solution, it provides to cities water availability at a local level where the demand exists. By installing a series of such technologies in a strategic coordinated manner, an upscaling approach is achieve to address water scarcity of a city

Beyond its technical contribution, the approach can support a broader shift towards more sustainable urban water management. It facilitates the use of circular economy practices, and reduces dependence on freshwater resources, so as to promote climate resilience at a city level.

For these reasons, a pilot Sewer Mining water reuse system can serve as a blueprint for an upscaled approach and contribute to more a more sustainable, adaptive, and resource efficient city.

Funded by the European Union

This project has received funding from the European Union Horizon Research and Innovation programme under grant agreement No 101178059

10. Conclusions on the Sewer Mining intervention

The Sewer Mining intervention developed under the THESEUS project demonstrates the feasibility of decentralised wastewater recovery and reuse in a dense urban environment. The selected demonstration site at Klonaridis-Fix Park provides a suitable urban setting that can test and showcase such solutions within urban real world environments.

The proposed treatment system, based on membrane bioreactor (MBR) technology and UV disinfection, is capable of producing high-quality reclaimed water suitable for irrigation and other non-potable urban uses. In addition, the integration of online monitoring and control through a PLC system connected to a digital twin platform further supports the reliability of the intervention.

The analysis also highlighted that the successful implementation of Sewer Mining systems depends not only on technological aspect, but also on procedural matters, permitting challenges, and social factors. These aspects are particularly important where interventions are implemented in public green spaces or in other sensitive areas in terms of culture, architecture, etc. The Sewer Mining technology is highly replicable and transferable to other urban areas that face water scarcity issues along with increased irrigation demand.

Overall, the Sewer Mining intervention constitutes a mature application of a circular urban water management system. It demonstrates how wastewater can be transformed from a waste flow into a local resource that supports urban greening and reduced dependence on freshwater resources. The next stages should focus on the permitting and procedural arrangements, the construction of the configuration and the installation and commissioning of the system. Finally, the system will be validated and its performance assessed, to support wider deployment of decentralised water reuse solutions in Attica and beyond.

Funded by the European Union

This project has received funding from the European Union Horizon Research and Innovation programme under grant agreement No 101178059

Section B. Raienwater Harvesting decentralised solutions

11. Rainwater harvesting solutions

Rainwater harvesting systems (RWHS) are a flexible and increasingly important water-management strategy that can address water scarcity, reduce urban flooding, enhance agricultural productivity, and provide decentralised access to water (Ali et al., 2025; de Winnaar et al., 2007; Selvinsimpson & Chen, 2022). Although rainwater harvesting has ancient origins, it is currently experiencing renewed interest as a decentralised approach that can reduce pressure on groundwater and municipal supply systems (Tahir et al., 2013). In the European context, RWHS are commonly framed within Sustainable Drainage Systems (SuDS) and broader green and blue–green infrastructure and Nature-Based Solutions (NBS) approaches, where they contribute to runoff retention, peak-flow attenuation, and fit-for-purpose non-potable reuse such as irrigation. Internationally, comparable concepts are addressed under frameworks such as Water Sensitive Urban Design (WSUD), Low Impact Development (LID), and Sponge City approaches, but in EU practice the SuDS, green infrastructure, and NBS framing is typically used to position RWHS within integrated urban water and climate-resilience strategies (Peker & İlhan, 2023). From a technical perspective, RWHS are best viewed as integrated systems comprising catchment, conveyance, storage, and controlled distribution, whose performance depends on local rainfall patterns, effective catchment area, storage capacity relative to demand, and operational rules such as demand-based irrigation and overflow management. When appropriately designed and operated, RWHS can provide both water-supply and stormwater-management benefits, supporting more resilient urban water systems.

Within THESEUS, rainwater harvesting systems (RWHS) are being developed in the Attica region to demonstrate the technical feasibility and multi-benefit value of decentralised harvesting in contrasting urban settings. The systems are being designed to capture and store rainwater and to enable safe local reuse, thereby reducing demand on potable supplies and improving resilience to seasonal water stress. Harvested rainwater is intended to be used primarily for irrigation purposes, including the irrigation of small-scale urban farming applications, demonstrating decentralised circularity through the coupled concepts of water reuse, nutrient recycling, and urban food production (with biowaste treated via composting and the produced compost applied as a soil additive). The scope of this chapter is to summarise the RWHS-related activities carried out during Months 1–18, structured across planning and licensing, design, and implementation.

11.1 Planning

Upon the beginning of Task 7.2, NTUA initiated the process of identifying potential locations for system implementation, in line with the task scope. NTUA visited several schools in the Attica region that could potentially host rainwater harvesting systems. Following site visits and an initial feasibility screening, a school in the Municipality of Athens was selected, located in Kypseli. The selected school case is being developed as an urban demonstration at the 21st Primary School of Athens “Lela Karagianni”, located in the Kypseli area, within the central sector of the Municipality of Athens. The school operates in a densely built urban environment where green space and opportunities for nature-based infrastructure are limited. Figure 21 shows the top view of the school neighbourhood and Figure 22 the front view of the school. Importantly, the Theseus intervention will be embedded in a wider ecosystem of complementary initiatives

Funded by the European Union

This project has received funding from the European Union Horizon Research and Innovation programme under grant agreement No 101178059

already implemented (or planned) at the school. In particular, under the EU funded Ascend project, photovoltaic (PV) systems have been installed on the school rooftop through virtual net metering, supporting neighbourhood-scale progress towards climate neutrality. Within THESEUS, these photovoltaic surfaces could also be leveraged as rainwater collectors, enabling harvested rainwater reuse for irrigation of the school's green interventions. In addition, the Smart Cities project foresees the installation of an environmental monitoring station equipped with sensors for multiple parameters. The generated data could also support further optimisation of the rainwater reuse system for irrigation. Finally, the Cooling Havens initiative provides a digital twin platform that enables remote, real-time monitoring of the application, supporting early detection of malfunctions and continuous performance optimisation.

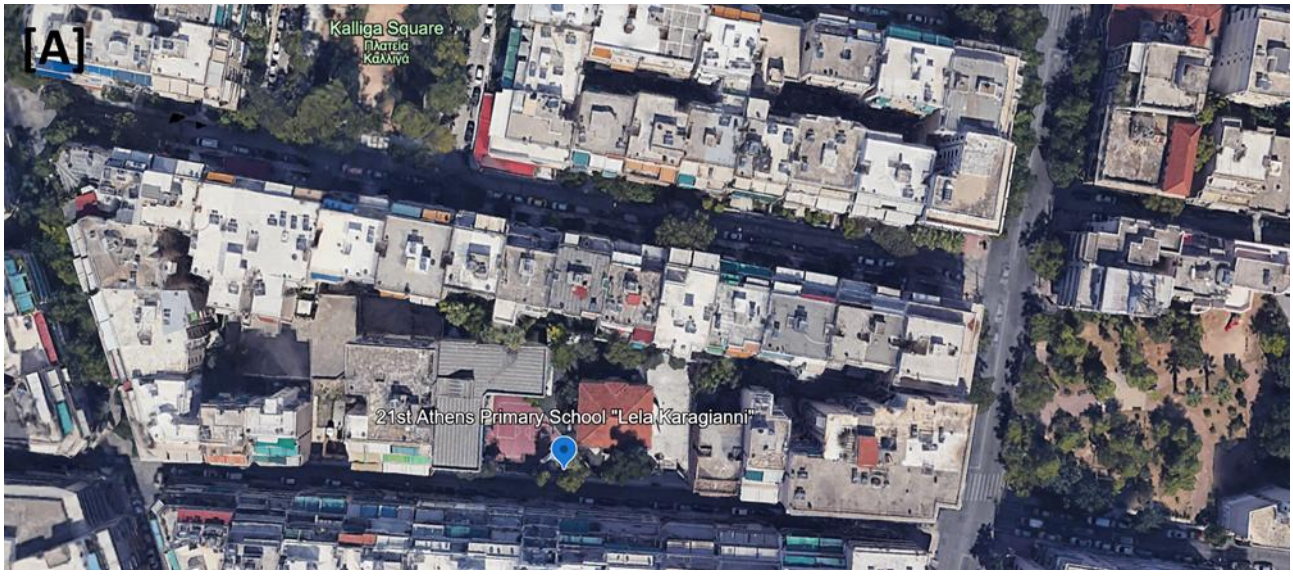


Figure 21 Top view of the school and the neighbourhood



Funded by the European Union

This project has received funding from the European Union Horizon Research and Innovation programme under grant agreement No 101178059

Figure 22 Front view of the school

In parallel, additional candidate sites are being explored to assess the integration of rainwater harvesting in other building typologies. In particular, the use of an office building is under consideration with the aim of collecting and reusing harvested rainwater primarily for on-site irrigation applications, including the potential irrigation of small-scale urban farming/green spaces.

11.1.1 Licensing and compliance

From a licensing and compliance perspective, early coordination was initiated with the relevant stakeholders (school administration and municipal services) to confirm access requirements, safety conditions, and compatibility with the building's operation. Structural adequacy was checked due to additional installation loads. Given that, part of the system will be installed on the rooftop and in accordance with the applicable legislation (FEK 350/2016 on interventions in existing buildings), a structural adequacy check is required to confirm the safety of the load-bearing structure. The check assesses the increase in base shear in the most unfavourable direction following the intervention, in order to determine whether a full structural study of the existing building is required, based on the general applicability criterion 1(2) of the same legislative framework. The assessment concluded that a full structural study was not required. Consequently, a targeted verification of the structural elements affected by the additional load was carried out in accordance with EN 1991 and EN 1992-1-1.

Following the structural adequacy check described above, and given that no requirement for a full structural study of the existing building was identified, it was considered necessary to define the conditions for safe access and use of the rooftop, which is planned to function as an accessible green area (roof garden) for educational and environmental activities. The use of the rooftop by people (students, staff, or visitors), in addition to the permanent loads from equipment and planting, constitutes an additional live load and falls under both structural safety requirements and fire-protection provisions applicable to areas of public gathering. In accordance with the relevant legislation (FEK 350/B/2016) and the Building Fire Protection Regulation (P.D. 41/2018), safe use of such spaces requires the determination of a maximum allowable number of users. Two scenarios were therefore examined, with the stricter criterion adopted for safety. Under Scenario 1 (structural capacity-based limit), the structural check indicates that the slab can accommodate up to 4.4 persons per m², assuming a conservative average user weight. Under Scenario 2 (fire-protection-based limit), the Building Fire Protection Regulation (P.D. 41/2018) applies an occupancy factor of 2 m² per person for public gathering areas such as an accessible rooftop/roof garden in an educational building. This requirement results in a clearly stricter limit than that derived from structural capacity. For safety, the stricter criterion (fire-protection-based) is adopted. For the total available roof garden area of 40 m², the maximum allowable number of users is therefore set at 20 persons. This value represents the maximum simultaneous occupancy of the configured rooftop area and ensures safe operation from both a structural safety and fire-protection perspective.

Funded by the European Union

This project has received funding from the European Union Horizon Research and Innovation programme under grant agreement No 101178059

11.2 Rainwater harvesting system Design

11.2.1 Baseline Site Conditions

A preliminary on-site technical inspection at 21 Primary school of Athens, “Lela Karagianni” was carried out by NTUA to identify the key boundary conditions influencing feasibility and design choices. The 21st Primary School of Athens “Lela Karagianni” is located in Kypseli, within a densely built urban environment where available green space and sustainable infrastructure are limited. The site does not include a dedicated rainwater harvesting or reuse system and roof runoff is managed through the existing drainage network and is ultimately discharged to the street. The roof drainage configuration conveys rainwater through downpipes (via balcony/interior sections) and directs runoff towards the front yard, where it enters ground-level manholes and then discharges by gravity to the street (Kyprou Street). As a result, rainwater is not retained on-site and is not currently utilised for irrigation or other non-potable purposes. From a rooftop geometry perspective, the roof slopes were observed to direct flow towards internal drainage points (towards the central areas of the roof), rather than towards the roof edges where planting interventions are planned. This constitutes a practical boundary condition for harvesting, as it affects where runoff can be intercepted and how collection elements must be integrated with the existing drainage arrangement. In addition, PV systems are already installed on the rooftop, providing an existing elevated surface area that can be leveraged as an alternative rainwater collection surface for the proposed reuse scheme.

Regarding the outdoor spaces, the school includes both a rooftop area and a rear courtyard. Baseline conditions indicate limited greenery in the school yards/external spaces, which contributes to increased thermal stress during summer months. The rear courtyard is therefore considered a suitable location for green interventions; however, due to the current drainage layout (runoff routed primarily to the front side), direct utilisation of existing downpipes for the rear courtyard is constrained and requires alternative collection and conveyance solutions. The school’s technical documentation (e.g., architectural, structural, and topographic drawings) was also available and reviewed to support the assessment. Figure 23 and Figure 24 present the school’s rooftop and rear courtyard, which were selected as suitable areas for the implementation of green interventions and the utilisation of rainwater through the installation of planters.

Funded by the European Union

This project has received funding from the European Union Horizon Research and Innovation programme under grant agreement No 101178059



Figure 23 View of Primary School “Lela Karagianni” rooftop



Figure 24 Primary School “Lela Karagianni”: School rear courtyard

11.2.2 Components sizing

The technical assessment defines two separate rainwater harvesting and reuse flows at the school, reflecting the site’s drainage layout and the distinct irrigation zones. The rooftop RWHS (System 1) serves the rooftop intervention area: runoff from a selected rooftop catchment is intercepted and routed to a dedicated rooftop storage unit, from which water is supplied via irrigation lines to the rooftop planters. The rear-courtyard RWHS (System 2) serves the rear courtyard: since the building downpipes discharge towards the front/street side and cannot be practically used to irrigate the rear yard, runoff is instead harvested from the rooftop PV surfaces, conveyed through gutter and downpipe elements to storage tanks installed in the rear courtyard, and then distributed via irrigation lines to the courtyard planting areas. This

Funded by the European Union

This project has received funding from the European Union Horizon Research and Innovation programme under grant agreement No 101178059

configuration enables modular operation and staged expansion, allowing the system to be progressively scaled and optimised based on observed irrigation needs and operational performance. The rooftop RWHS and the rear-courtyard RWHS are illustrated in Figure 25 and Figure 26, respectively.

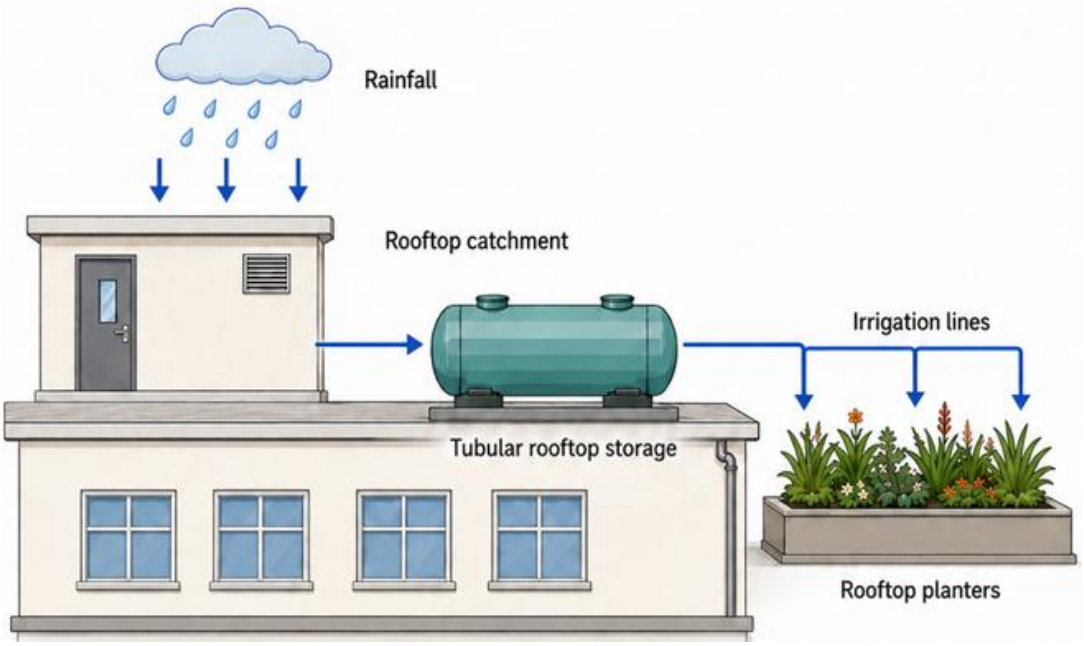


Figure 25 Schematic flow chart of the rooftop rainwater harvesting and reuse system (System 1), illustrating rainfall collection from the rooftop catchment, temporary storage in the rooftop storage unit, and distribution through irrigation lines to the rooftop planters.

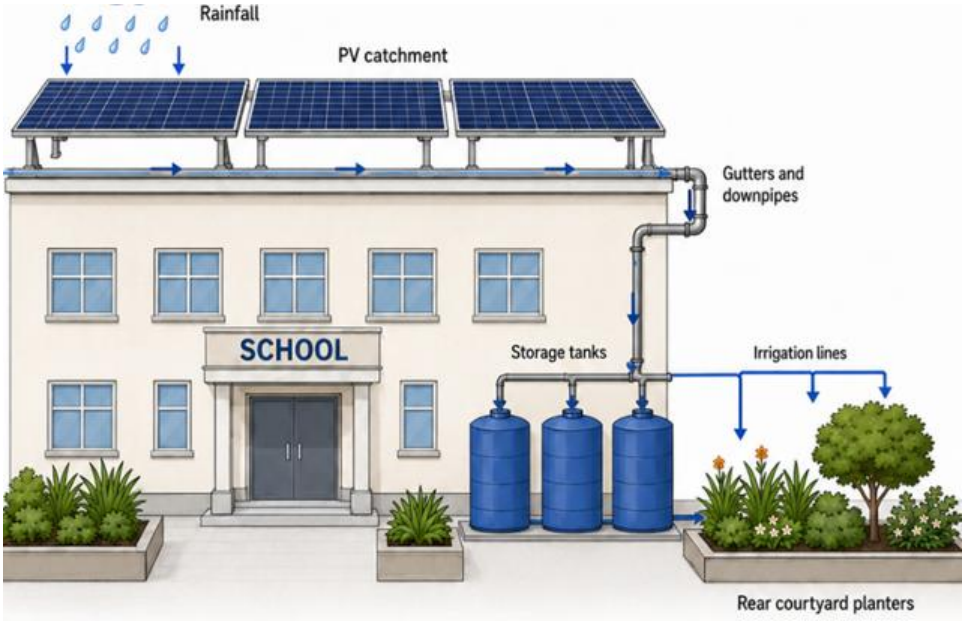


Figure 26 Schematic flow chart of the rear-courtyard rainwater harvesting and reuse system (System 2), illustrating rainfall collection from the rooftop photovoltaic surfaces, conveyance through gutters and downpipes to the rear-courtyard storage tanks, and distribution through irrigation lines to the rear-courtyard planting areas.

Funded by the European Union

This project has received funding from the European Union Horizon Research and Innovation programme under grant agreement No 101178059

Climatological/ rainfall data

A key component of the design phase was the establishment of a robust local design basis for estimating harvestable runoff and for the sizing of the main system components. To this end, precipitation data from the Patision meteorological station, located in close proximity to the site, were adopted as representative of local rainfall conditions. Based on the 2024 record (Figure 27), the annual precipitation was 387.9 mm, consistent with typical values reported for Athens (≈400 mm). Using locally representative rainfall data strengthens the reliability of yield estimates and reduces uncertainty compared with the use of generic regional averages.

PRECIPITATION (mm)

YR	MO	TOTAL	DEP. FROM NORM	MAX OBS. DAY	DATE	DAYS OF RAIN OVER .2	2	20
24	1	36.6	0.0	9.2	12	13	6	0
24	2	42.4	0.0	28.2	26	6	3	1
24	3	38.4	0.0	17.2	1	8	5	0
24	4	10.8	0.0	5.2	19	4	2	0
24	5	10.6	0.0	8.6	13	6	1	0
24	6	0.2	0.0	0.2	6	1	0	0
24	7	3.2	0.0	3.2	4	1	1	0
24	8	41.8	0.0	39.6	30	2	2	1
24	9	38.6	0.0	29.2	10	5	2	1
24	10	1.2	0.0	1.2	5	1	0	0
24	11	33.8	0.0	17.8	30	6	5	0
24	12	130.2	0.0	37.6	6	14	7	3
		387.9	0.0	39.6	AUG	67	34	6

Figure 27 Monthly rainfall distribution (mm) for 2024, based on data from the Patision meteorological station of the National Observatory of Athens.

Rainwater collection areas and storage

Two distinct catchment surfaces are envisaged for rainwater harvesting.

- For the rooftop RWHS (systems 1), a 27 m² area of the rooftop will be used as the rainwater collection surface, highlighted in yellow in Figure 28. This collection area corresponds to the roof slab of the building's stairwell, and its slope makes it well suited for rainwater collection. Based on the site's mean annual rainfall (387.9 mm) and assuming a runoff coefficient of 0.85, the estimated annual harvestable volume is approximately 8.9 m³.
- For the rear courtyard RWHS, where the building downpipes discharge towards the front part of the site and cannot be readily utilised, rainwater collection is planned from the surfaces of the PV systems installed under the EU Ascend project, with a total area of 93 m² (Figure 28). The corresponding estimate indicates a potential collection of approximately 30.7 m³ per year.

Funded by the European Union

This project has received funding from the European Union Horizon Research and Innovation programme under grant agreement No 101178059

Implementation will begin on a pilot basis at a smaller scale and will subsequently be expanded through the gradual connection of additional PV surfaces, with the aim of fully covering the irrigation needs of the rear courtyard. This phased approach is intended to maximise system performance and to match irrigation supply to actual plant water requirements, taking into account site-specific conditions (e.g., temperature, wind speed, evapotranspiration, solar exposure, shading). Overall system design will be dynamically optimised through monitoring and performance evaluation during operation.

For the rooftop RWHS (System 1), a compact storage solution was selected to match the limited available space and to minimise additional loads on the roof. Harvested runoff from the selected rooftop catchment is directed to a tubular (pipe-based) storage arrangement with an overall capacity of approximately 2 m^3. This configuration provides buffering for irrigation of rooftop planters, supports pilot operation and staged optimisation, and enables integration with a demand-based irrigation approach (e.g., irrigation triggered by soil-moisture thresholds) to prioritise efficient use of harvested water. For the rear-courtyard RWHS (System 2), storage is provided through modular tank-based buffering located within the rear courtyard. The system is designed for staged deployment: three storage tanks (1.5 m^3/storage tank) will be used, while three additional tanks are planned to be installed in a subsequent phase as collection is expanded to additional PV arrays (Figure 29). This staged storage strategy allows capacity to be increased in parallel with catchment coverage and based on observed irrigation demand, supporting robust irrigation supply for the rear-courtyard green areas while maintaining flexibility for operational optimisation.

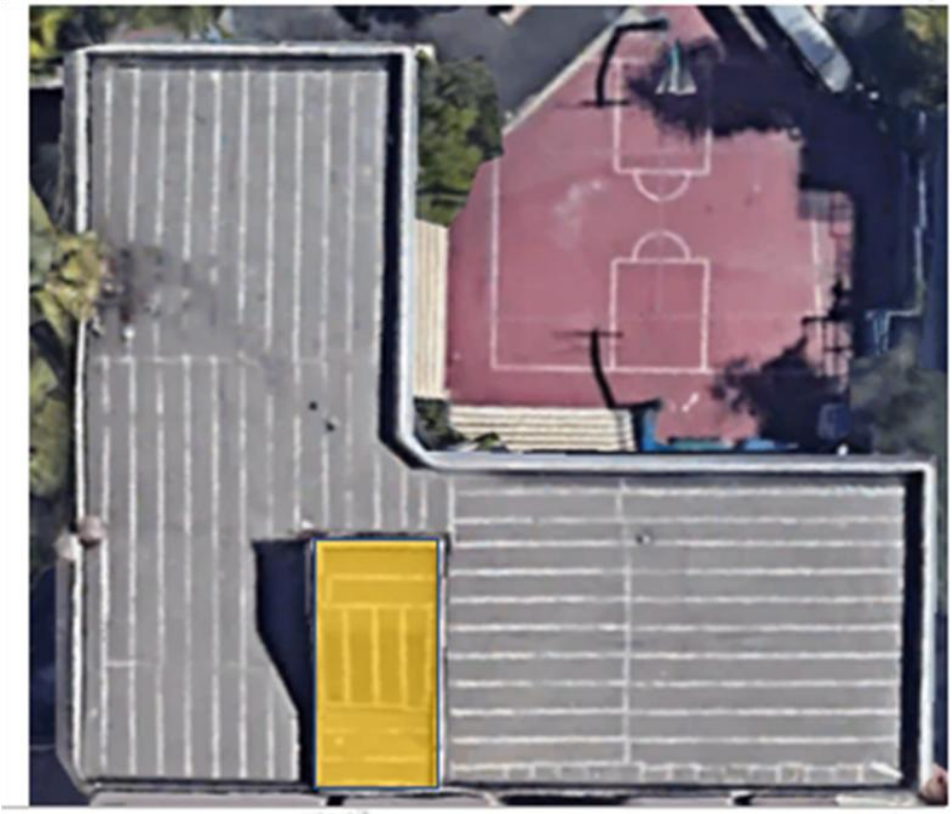


Figure 28 Rainwater collection area on the rooftop (highlighted in yellow)

Funded by the European Union

This project has received funding from the European Union Horizon Research and Innovation programme under grant agreement No 101178059



Figure 29 PV surfaces on the school rooftop proposed for rainwater collection

Monitoring, automation equipment and irrigation procedure

To maximise the performance of the two RWHS, real-time soil moisture sensors will be installed in the planting areas to enable demand-based irrigation. Irrigation will be triggered only when soil moisture drops below a predefined threshold. This approach minimises unnecessary use of harvested rainwater and prevents over-irrigation, thereby improving water-use efficiency and overall system performance.

Planting and soil selection

Species selection was based on their adaptability to local climatic conditions (Athens – Mediterranean climate), low irrigation and maintenance requirements, safety and educational value for children, and their suitability for ornamental and/or aromatic use. For the planting of the new green areas, the development of two distinct zones is proposed:

- Rear courtyard RWHS (System 2): Ornamental plant species were selected taking into account the rear courtyard's limited direct sunlight (shaded conditions), favouring species that are tolerant to low-light environments and have low water requirements (Table 4). These species are safe for children and provide both aesthetic and educational value, while some also have air-purifying properties. Indicative species include *Aspidistra elatior*, *Heuchera* spp., *Asplenium scolopendrium*, *Arbutus unedo*, and *Geranium phaeum*, among others. In addition, one of the planters will be allocated for vegetable cultivation (e.g., cabbages).

- Rooftop RWHS (System 1): The planting of aromatic species adapted to the Mediterranean climate and high solar exposure is foreseen (Table 5). These species have low water requirements, while they offer educational opportunities, as they can be linked to culinary, perfumery/aromatherapy, and medicinal uses. To strengthen the educational dimension, informative signs with "fun facts" for each plant will be installed. Indicative species include Salvia sclarea, Lavandula angustifolia, Rosmarinus officinalis, Origanum vulgare, Thymus vulgaris, and Crocus sativus, among others.

Funded by the European Union

This project has received funding from the European Union Horizon Research and Innovation programme under grant agreement No 101178059

For the planter beds, a lightweight growing medium was selected to ensure adequate water-holding capacity while maintaining drainage and limiting rooftop loads. In practice, the substrate used is a commercial peat-based potting soil enriched with zeolite, providing a balanced matrix for plant establishment and nutrient retention. According to the product specifications, the growing medium has a moisture content of approximately 40–60% and a near-neutral pH range (pH(H_2O) 6.5–7.5), supporting a broad range of ornamental and aromatic species. In addition to the base peat substrate, a small quantity of vermicompost will be incorporated as an organic amendment. Vermicompost is used as a supplementary input to enhance organic matter content and nutrient availability and to support overall substrate biological activity, while maintaining the lightweight character of the growing medium required for planting applications.

Funded by the European Union

This project has received funding from the European Union Horizon Research and Innovation programme under grant agreement No 101178059

Table 4 Planting proposal for the rear courtyard garden (System 2)

Common name	Scientific name (Latin)	Shade / Light	Summer watering	Climate	Planting	Fertilisation	Pruning	Protection / Care	Pests	Properties
Aspidistra	*Aspidistra elatior*	Partial shade–Full shade	Once every 1–2 weeks	Broad / adaptable	Good drainage	Spring & summer: monthly	–	Avoid direct sun / wipe leaves occasionally	Mites / fungi	Ornamental
Heuchera	*Heuchera* spp.	Partial shade–Full shade	Once per week	Broad / adaptable	Good drainage	One complete application in spring	Remove dry leaves after winter	Avoid direct sun	Nematodes / fungi	Ornamental
Hart's-tongue fern	*Asplenium scolopendrium*	Partial shade–Full shade	Once per week	Broad / adaptable	Good drainage	One complete application in spring	Remove dry leaves after winter	Avoid direct sun	–	Ornamental / medicinal
Strawberry tree	*Arbutus unedo*	Partial shade	Once per week	Mediterranean	Good drainage	One complete application in spring	Optional	Protect from cold winds / frost	Borers / fungi	Ornamental / medicinal
Green lavender cotton	*Santolina rosmarinifolia*	Low–moderate light (reduced flowering)	Once per week	Mediterranean	Good drainage	One complete application in spring	Early autumn / with care	Protect from cold winds / frost	Aphids / fungi	Ornamental / aromatic
Geranium	*Geranium nodosum* or *Geranium phaeum*	Partial shade–Full shade	1–2 times per week	Mediterranean	Good drainage	Spring: monthly	Early autumn	–	Beetles / caterpillars / fungi	Ornamental
Oakleaf hydrangea	*Hydrangea quercisfolia*	Partial shade	1–2 times per week	Mediterranean	Good drainage	One complete application in spring	Early autumn	–	Aphids	Ornamental
Variegated oleaster	*Elaeagnus pungens* "Maculata"	Low–moderate light (reduced flowering)	1–2 times per week	Mediterranean	Good drainage	One complete application in spring	Optional	–	Fungi	Ornamental
Pink evening primrose	*Oenothera speciosa*	Low–moderate light (reduced flowering)	1–2 times per week	Mediterranean	Good drainage	One complete application in spring & summer	Optional	Protect from frost	–	Ornamental / groundcover
Mind-your-own-business	*Soleirolia soleirolii*	Partial shade–Full shade	1–2 times per week	Mediterranean	Good drainage	One complete application in spring	Frequent	Avoid direct sun	Aphids / fungi	Ornamental / groundcover

Table 5 Planting proposal for roof garden (System 1)

Proposal / Concept	Common name	No. of plants (for 2 planters)	Scientific name (Latin)	Sun / Light	Summer watering	Climate	Planting	Fertilisation	Pruning / Harvest	Protection / Care	Pests	Properties
Creation of an aromatic-plant garden with species well adapted to Mediterranean conditions and high solar exposure. The selected plants have low water requirements, they are safe for children, and provide educational value. They can be linked to culinary, aromatherapy/ perfumery, and medicinal uses. Informative signs with brief "fun facts" can be placed for each plant to strengthen the educational dimension.	Sage	5	Salvia sclarea	Full sun	Once per week	Mediterranean	Good drainage	One complete application in spring	Not required	Wind / severe cold → cover	Aphids / fungi	Aromatic / essential oil
	Cistus (rockrose)	5	Cistus creticus	Full sun	Once per week	Mediterranean	Good drainage	One complete application in spring	Not required	Wind / severe cold → cover	Aphids / mites / fungi	Medicinal
	Lavender	15	Lavandula angustifolia	Full sun	1–2 times per week	Mediterranean	Good drainage	One complete application in spring	Spring / with care	Wind / severe cold → cover	Fungi	Aromatic / essential oil
	Lavender (French lavender)	5	Lavandula dentata	Full sun	1–2 times per week	Mediterranean	Good drainage	One complete application in spring	Autumn / with care	Wind / severe cold → cover	Aphids / fungi	Aromatic / essential oil
	Rosemary	5	Rosmarinus officinalis	Partial –full sun	1–2 times per week	Mediterranean	Good drainage	One complete application in spring	Spring–summer / with care	Wind / severe cold → cover	Fungi	Aromatic / essential oil
	Oregano	10	Origanum vulgare	Full sun	Once per week	Mediterranean	Good drainage	One complete application in spring	Early autumn / with care	Wind / severe cold → cover	Aphids / fungi	Aromatic / essential oil
	Thyme	10	Thymus vulgaris	Full sun	1–2 times per week	Mediterranean	Good drainage	One complete application in spring	End of spring / late autumn	Wind / severe cold → cover	Fungi	Aromatic / essential oil
	Lemon thyme	10	Thymus citriodorus	Full sun	Once per week	Mediterranean	Good drainage	One complete application in spring	Early autumn	-	Fungi	Aromatic / essential oil
	Saffron crocus	20	Crocus sativus	Full sun	Once per week (as needed)	Mediterranean	Good drainage	One complete application in spring	Harvest (Sep–Oct)	-	Fungi (bulb rot)	Aromatic / culinary

Funded by the European Union

This project has received funding from the European Union Horizon Research and Innovation programme under grant agreement No 101178059

11.2.3 Final Designs

The final design of the RWHS demonstration at the 21st Primary School of Athens "Lela Karagianni" comprises two hydraulically independent rainwater harvesting and reuse systems, and the two distinct irrigation zones (rooftop and rear courtyard). The detailed technical configuration is documented through the AutoCAD layout drawings for the rooftop and rear-courtyard systems (Figure 30 and Figure 31), which define the placement of the main components (collection surfaces, conveyance alignments, storage locations, and irrigation routing) and provide the basis for implementation. The final configuration follows a staged implementation logic to support piloting and performance-based optimisation. The technical drawings depict the full set of interventions for each system, while the initial deployment focuses on an operational pilot configuration, with additional elements introduced progressively after evaluation of actual irrigation needs and system performance. Elements intended for later phases are indicated with dashed lines, reflecting that additional collection coverage and/or storage capacity will be gradually added following the initial operational period. For the rear courtyard, the installation of planters donated by the Municipality of Athens is foreseen, while any need for additional interventions or reinforcement of existing infrastructure will be assessed in a later phase based on operational experience.

To complement these technical drawings, a conceptual infographic overview (Figure 32) is included to communicate the two separate rainwater flow paths in a clear process-oriented manner. Finally, the key design parameters adopted for each system (catchment, estimated annual yield, storage type and location, end use, and monitoring/control approach) are consolidated in Table 6 and Table 7, providing a concise reference summary of the final design.

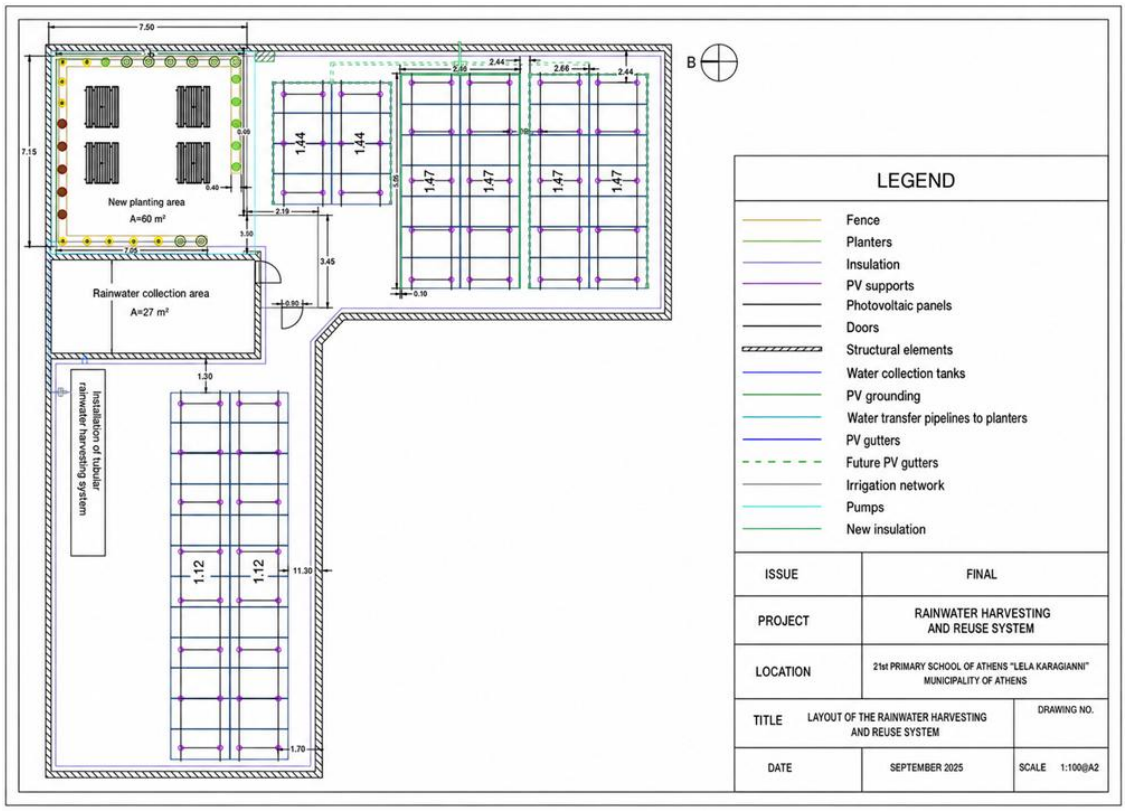


Figure 30 Layout of the rainwater harvesting and reuse system on the rooftop of the 21st Primary School of Athens.

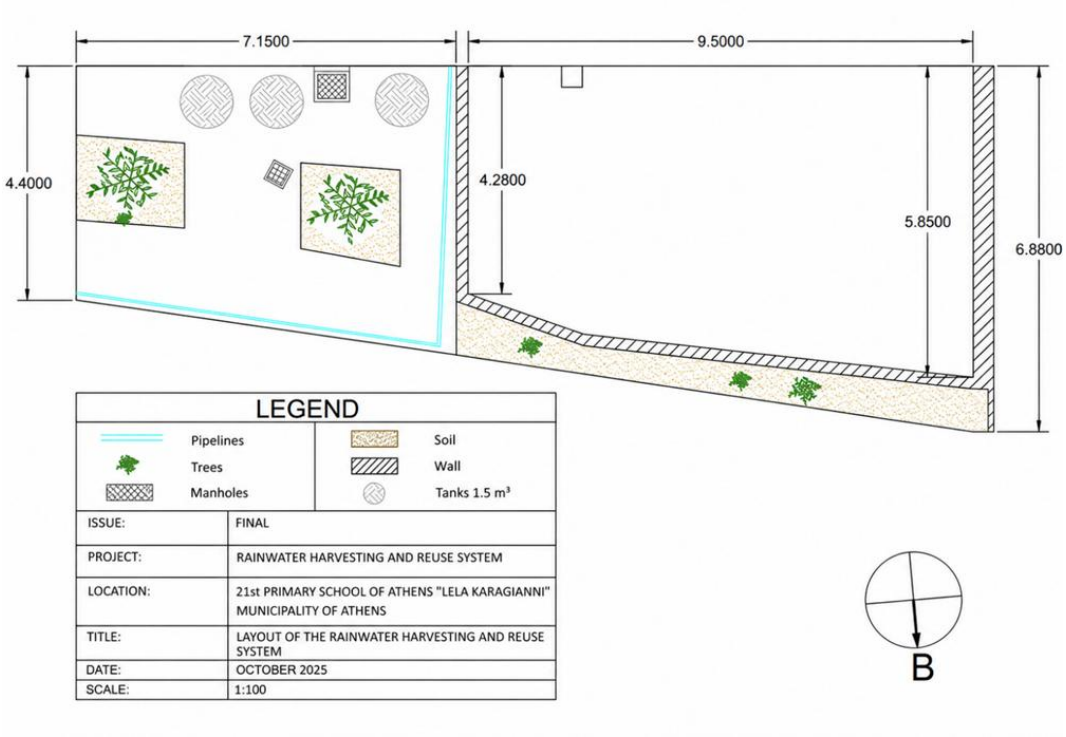


Figure 31 Layout of the rainwater harvesting and reuse system in the rear courtyard of the 21st Primary School of Athens

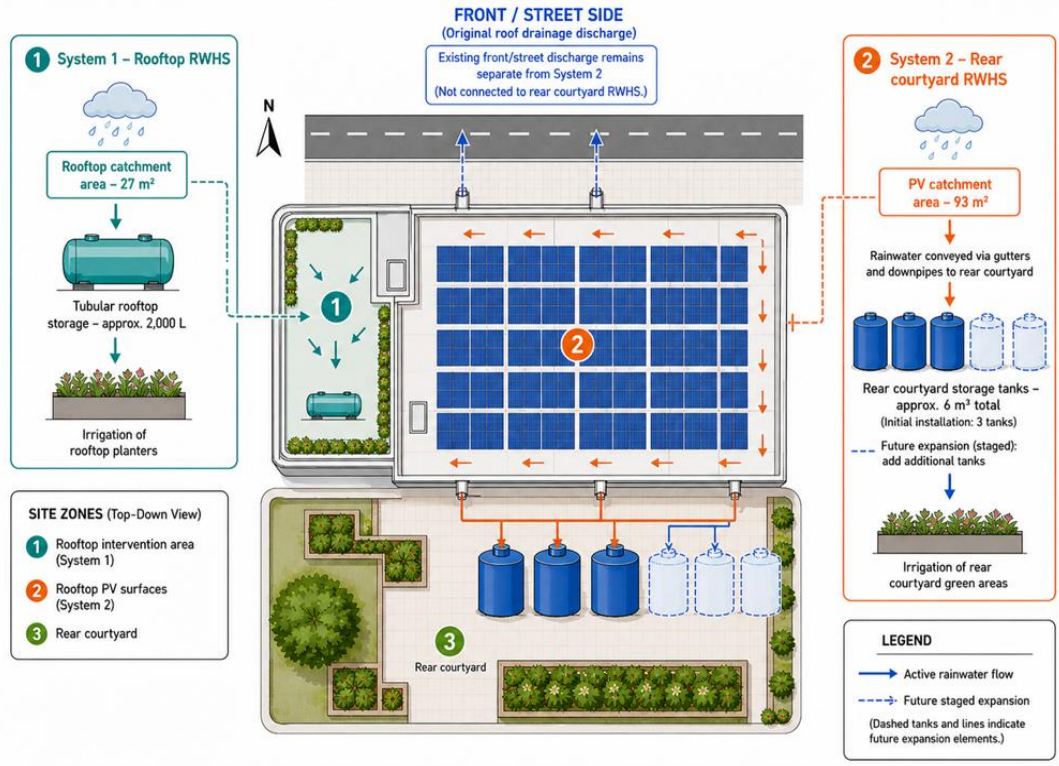


Figure 32 Conceptual infographic overview of the two rooftop RWHS (system 1) and rear courtyard RWHS (system 2)

Funded by the European Union

This project has received funding from the European Union Horizon Research and Innovation programme under grant agreement No 101178059

Table 6 Summary of key parameters of Rooftop RWHS (System 1)

Parameter	Value
System	Rooftop RWHS
Catchment	Rooftop (stairwell slab)
Catchment area	27 m²
Estimated annual yield	8.9 m³/y
Storage type	Tubular (pipe-based)
Storage volume	2.0 m³ (2,000 L)
Storage location	Rooftop
End use	Irrigation of rooftop planters
Monitoring/control	Soil moisture sensors (planned)

Table 7 Summary of key parameters of rear-courtyard RWHS (System 2)

Parameter	Value
System	Rear courtyard RWHS
Catchment	Rooftop PV surfaces
Catchment area	93 m²
Estimated annual yield	30.7 m³/y
Collection element/diameter	Open gutter/ 10cm
Storage type	Modular tanks
Storage volume	6.0 m³ total (3 tanks installed; +3 planned)
Storage location	Rear courtyard
End use	Irrigation of rear-courtyard planters/green areas
Monitoring/control	Soil moisture sensors (planned)

Funded by the European Union

This project has received funding from the European Union Horizon Research and Innovation programme under grant agreement No 101178059

11.3 Implementation

11.3.1 Installation of the systems

The individual implementation stages are summarised as follows:

- Site preparation (*Start: M8 – End: M13*): For the rooftop RHWS (System 1), the preparatory phase has already been completed and included waterproofing of the rooftop slab, removal works using high-pressure water jetting, repair of bituminous membranes and deteriorated plaster and repainting of walls (Figure 33). Furthermore, the rear courtyard area (System 2) was carefully clean using similar equipment.
- Installation of protective fencing (*Start: M10 – End: M 14*): In the rooftop RWHS planting area, procurement and installation of protective fencing on the rooftop have been completed, ensuring safe access and use of the area by students. Specifically, wooden slabs on metal frames were installed to isolate the area where planters will be placed. Figure 34 and Figure 35 shows the progress of the installation and the final arrangement of the wooden fence, respectively.
- Installation of hydraulic interconnections and storage tanks (*Start–End: M14*): For the rear-courtyard RWHS (System 2), the hydraulic interconnections required to convey harvested rainwater from the PV catchment surfaces to the storage area were installed. In particular, runoff interception on the PV arrays was implemented through the installation of open gutter-type (10 cm) collection elements placed along the lower edge of the PV panels (Figure 36), allowing rainwater draining from the panel surfaces to be captured and directed towards the collection points. The corresponding conveyance pipework was also installed to route the collected runoff from the PV collection elements to the rear courtyard (Figures 37 and 38), establishing the core flow path of System 2 (PV catchment → gutters/collectors → conveyance network → storage). At the current stage, three storage tanks have been installed in the rear courtyard, providing the initial storage capacity for piloting and operational testing (Figure 39). A further three tanks are planned to be added in subsequent phases, in parallel with the expansion of the PV collection system to additional PV arrays (i.e., installation of collection gutters on more panel rows), thereby increasing the effective catchment coverage and overall storage capacity in a staged manner.
- Construction of the rooftop planters (System 1) (Start: M12 – End: M14): This phase included the construction of planters for the rooftop RWHS (Figure 40), preparation of the rooftop garden area, and the planting of the aromatic species. The total volume of planting soil placed within the planters is 3.1 m^3, corresponding to approximately 1.6 tonnes under dry conditions. For safety and structural verification, the soil mass was also considered under fully saturated (rain-soaked) conditions, where it is conservatively estimated to increase to approximately 2.6 tonnes. The planters are constructed from natural wood and are arranged to enclose the rooftop garden. The total weight of the planter structures is approximately 0.6 tonnes. Consequently, the maximum combined mass of planters and soil under worst-case saturation conditions is estimated at approximately 3.2 tonnes.

Funded by the European Union

This project has received funding from the European Union Horizon Research and Innovation programme under grant agreement No 101178059



Figure 33 Completion of the rooftop preparation phase for both the rainwater collection area and the area designated for green interventions (system 1)



Figure 34 Installation of the safety wooden fence in the rooftop planting designated area (system 1)



Figure 35 View of the completed wooden fence in the rooftop planting area (system 1)

Funded by the European Union

This project has received funding from the European Union Horizon Research and Innovation programme under grant agreement No 101178059



Figure 36 Installation of rainwater collection pipes in the PV (system 2)



Figure 37 Conveyance pipework installed to route the collected runoff from the PV to the rear courtyard

Funded by the European Union

This project has received funding from the European Union Horizon Research and Innovation programme under grant agreement No 101178059

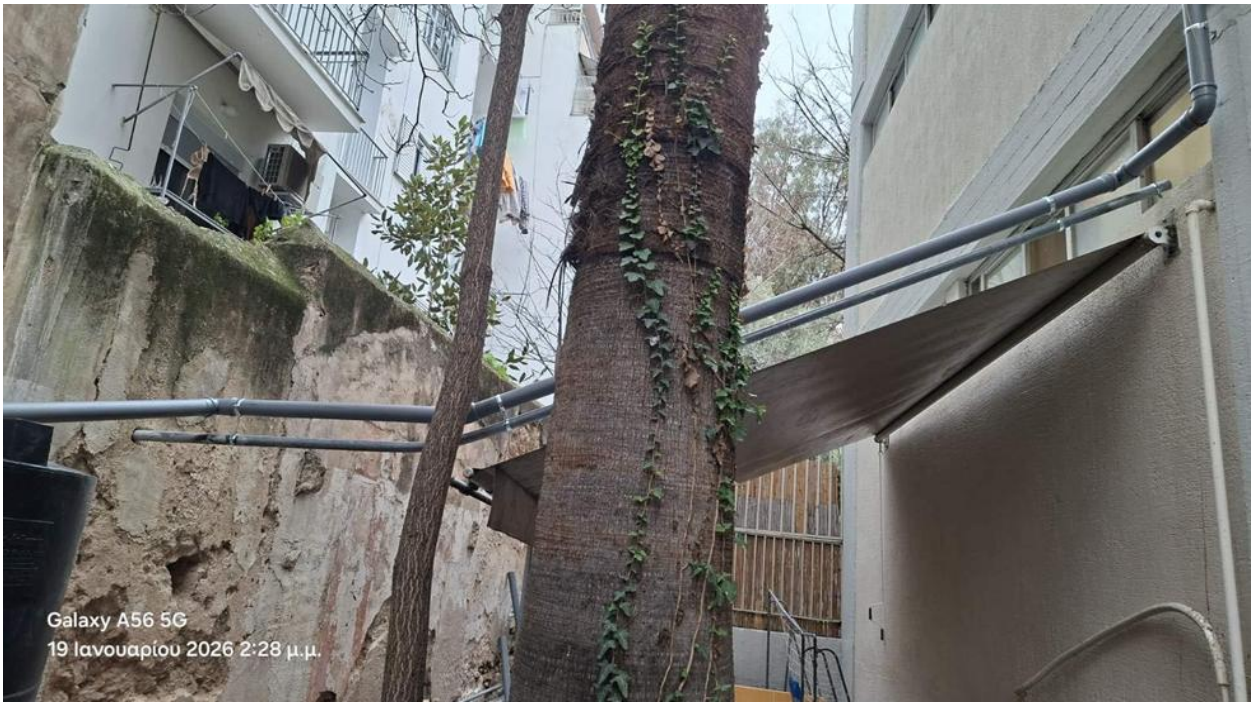


Figure 38 Rear courtyard system (system 2): Completion of the installation of gutters from the PV panel surfaces and hydraulic interconnection with the water storage tanks in the rear courtyard.



Figure 39 Rainwater storage tanks – Rear courtyard (system 2)

Funded by the European Union

This project has received funding from the European Union Horizon Research and Innovation programme under grant agreement No 101178059



Figure 40 Completion of the planter construction phase for rooftop RWHS (system 1)

Funded by the European Union

This project has received funding from the European Union Horizon Research and Innovation programme under grant agreement No 101178059

11.3.2 Planting

The planting of the rooftop RWHS (System 1) was initiated through a dedicated one-day participatory event hosted at the 21st Primary School of Athens “Lela Karagianni”, marking a key implementation milestone for the rooftop green interventions and the educational activation of the demonstration. The event was organised in the framework of the THESEUS project and formed part of the broader interventions for the creation of the RWHS. Prior to the activity, the intervention study package for the school, including the intervention study and the integrated structural adequacy documentation, was formally transmitted to the school and the Municipality of Athens, ensuring that implementation proceeded within an agreed technical and safety framework. The planting event itself was coordinated by NTUA with the support of representatives of the school, local communities, and the Municipality of Athens and was designed to combine practical implementation with structured, hands-on environmental education (Figure 41).

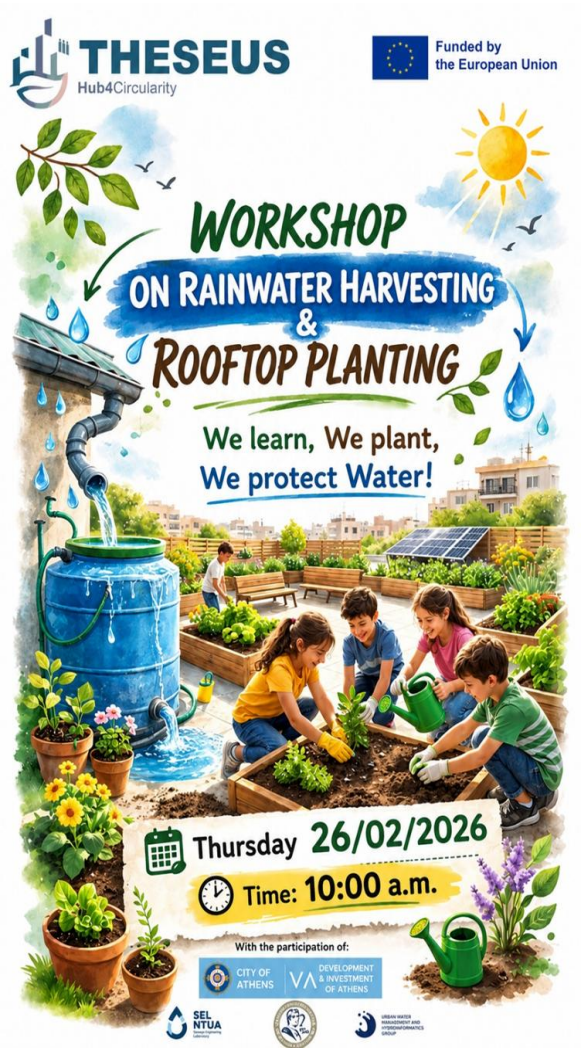


Figure 41 Promotional poster for the THESEUS “Rainwater workshop at 21st Primary School of Athens “Lela Karagianni”, held on Thursday 26/02/2026 at 10:00 a.m., highlighting the educational planting activities and the use of harvested rainwater for rooftop greening.

Funded by the European Union

This project has received funding from the European Union Horizon Research and Innovation programme under grant agreement No 101178059

During the event, students participated directly in planting activities associated with the rooftop green infrastructure supported by System 1 (Figure 42). The planting process was delivered in a supervised and age-appropriate manner, enabling students to engage with the rooftop space as a “living laboratory” for sustainable water management, urban greening, and circularity. To strengthen engagement and learning outcomes, the activity was structured around a creative, game-based format. An “adoption” approach was used, whereby each student or group of students planted and took responsibility for a specific species, reinforcing the concept of stewardship and follow-up care. In addition, an interactive plant-recognition/matching game was implemented, based on a “mission sheet” approach using key clues rather than photos. Pots were numbered and students were encouraged to observe, touch, and smell the plants and then match each numbered pot to the correct species name from a limited set of options (Figure 43). This format supported experiential learning and helped familiarise students with aromatic and horticultural species, while also introducing basic principles of plant care and irrigation needs (e.g., avoiding over-watering). Overall, the planting event served a dual purpose: (i) it supported the implementation of the rooftop planting interventions linked to the rooftop RWHS (System 1), and (ii) it strengthened the educational dimension of the demonstration by turning the concepts of rainwater harvesting, local reuse for irrigation, and responsible resource management into a tangible, participatory activity for students.



Figure 42 Rooftop planting activity for the RWHS (System 1) at the 21st Primary School of Athens “Lela Karagianni”, with students participating in the planting of the rooftop planters under the guidance of NTUA and school representatives

Funded by the European Union

This project has received funding from the European Union Horizon Research and Innovation programme under grant agreement No 101178059



Figure 43 Educational workshop activities accompanying the rooftop planting event, including interactive, game-based plant identification and “adoption” tasks to familiarise students with the planted species and basic plant care/irrigation practices.

Funded by the European Union

This project has received funding from the European Union Horizon Research and Innovation programme under grant agreement No 101178059

12. Conclusions and next steps on the rainwater harvesting system

With regard to the rainwater harvesting activities, during Months 1–18, the RWHS demonstration at the 21st Primary School of Athens “Lela Karagianni” progressed from site selection and feasibility screening to detailed design, licensing/compliance preparation, and initial implementation. The work established a complete concept for two complementary rainwater harvesting and reuse systems: System 1 serving rooftop greening through a dedicated rooftop catchment and storage solution, and System 2 serving the rear courtyard by harvesting runoff from PV surfaces and conveying it to modular storage in the courtyard for irrigation. Within the reporting period, key enabling works were completed, including rooftop preparation (waterproofing and surface restoration) and safety fencing for the rooftop intervention area, supporting safe educational use of the roof garden space. Furthermore, the core hydraulic pathway for System 2 (PV runoff interception via gutter-type collectors and conveyance to the rear courtyard) was installed, and initial storage capacity was deployed through the installation of three rear-courtyard tanks, enabling piloting and staged scaling. In parallel with the technical implementation, the demonstration incorporated a strong educational component. Rooftop planting activities for System 1 were initiated through a one-day participatory planting event with school students, delivered in a structured, game-based format (plant “adoption” and identification/matching tasks). This approach supported both implementation and engagement objectives by familiarising students with the planted species and basic plant care principles, and by linking the rooftop greening action to the broader logic of rainwater harvesting and local reuse for irrigation. Overall, the progress achieved to date provides a robust foundation for the commissioning and optimisation phase, including staged expansion of storage and catchment coverage and the introduction of monitoring-driven irrigation control.

The next steps will focus on completing the remaining components required for full system functionality and performance optimisation. For System 1 (rooftop RWHS), the planned actions include: (i) installation and commissioning of the rooftop storage unit (tubular storage arrangement) and the associated hydraulic connections required to support irrigation, and (ii) installation of soil moisture sensors in the rooftop planting areas to enable demand-based irrigation. For System 2 (rear courtyard RWHS), the next steps include the installation of the rear-courtyard green infrastructure, including placement of the donated planters, filling with the selected growing medium, planting of the selected species, and completion of the irrigation distribution pipelines required to supply the courtyard planting zones from the installed storage tanks. In parallel, the system will continue to follow a staged scaling approach: catchment coverage on additional PV arrays and storage capacity (additional tanks) will be expanded progressively following the initial piloting period, based on observed irrigation demand and operational performance. Furthermore, the composters already installed at the school will be used to produce compost from the green biomass generated from the two gardens. In addition to the above, NTUA will continue the screening and identification of additional candidate locations for RWHS implementation in Attica, in order to assess integration in other building typologies and expand the demonstration potential. This includes further evaluation of residential and non-residential buildings where harvested rainwater can be collected and reused primarily for on-site irrigation applications, including urban greening and, where feasible, small-scale urban farming uses.

Funded by the European Union

This project has received funding from the European Union Horizon Research and Innovation programme under grant agreement No 101178059

13. Overall conclusions and final remarks

Sections A and B jointly demonstrate that decentralised water reuse can play a significant role in the transition towards more circular, resilient and climate-adaptive urban water systems. Although the Sewer Mining system and Rainwater Harvesting are based on different water sources and are implemented at different scales, they share the same objective: the water recovery and reuse for non-potable applications at the point of demand, particularly for irrigation purposes and urban greening.

The Sewer Mining intervention demonstrates how wastewater can be recovered from the sewerage network, treated at a local level and reused for irrigating public green spaces. The Rainwater Harvesting intervention shows how rainwater collected from rooftops and photovoltaic panels can be captured and reused to support greening, awareness activities, and small-scale circular solutions. Together, these two approaches demonstrate the value of moving from linear water management approaches towards decentralised circular solutions that retain, recover and reuse water within the urban environment.

The work also confirms that the successful implementation of water systems depends on more aspects than their technical design, such as site selection, integration with the space, permitting procedures and stakeholder engagement. The two demonstrators therefore provide not only technical solutions, but also practical guidance on how such systems can be planned, implemented and integrated in actual urban conditions.

A common finding across both approaches is the aspect of visibility of the interventions and the active engagement of the public. By installing water reuse systems in parks, schools and other public settings, THESEUS creates opportunities for citizens, school communities, municipalities and technical stakeholders to directly experience and engage in circular water practices. This strengthens awareness of water related issues, such as water scarcity, climate adaptation and resource efficiency, while supporting broader acceptance of non-conventional water sources.

In conclusion, Sewer Mining and Rainwater Harvesting should be regarded as complementary components of an integrated urban water reuse strategy. Their combined implementation can reduce dependence on potable water, support green infrastructure, mitigate climate-related pressures, while the two presented interventions can create replicable models for other urban areas in Attica and beyond. The next phases of the project should focus on completing installation and commissioning, validating systems performance through monitoring, refining operational protocols and using the lessons learned to support wider replication and upscaling.

Funded by the European Union

This project has received funding from the European Union Horizon Research and Innovation programme under grant agreement No 101178059

References

Ali, S., Sang, Y.-F., Pilla, F., Singh, V. P., & Dilawar, A. (2025). Implementing urban rainwater harvesting systems: Multiple potential performances, barriers, challenges, solutions, and future perspectives. *Renewable and Sustainable Energy Reviews*, *218*, 115793. https://doi.org/10.1016/j.rser.2025.115793

de Winnaar, G., Jewitt, G. P. W., & Horan, M. (2007). A GIS-based approach for identifying potential runoff harvesting sites in the Thukela River basin, South Africa. *Physics and Chemistry of the Earth,* Parts A/B/C, 32(15–18), 1058–1067. https://doi.org/10.1016/j.pce.2007.07.009

Monokrousou, K., Makropoulos, C., Katsouras, G., Tsalas, N., Samios, S., Lytras, E., & Tsimnadis, K. (2025). Advancing Athens' circular economy: sewer mining for urban water reclamation. Urban Water Journal, 22(8), 987–996. https://doi.org/10.1080/1573062X.2024.2446520

Plevri A., Monokrousou K., Makropoulos C., Lioumis C., Tazes N., Lytras E., Samios S., Katsouras G. and Tsalas N., Sewer Mining as a Distributed Intervention for Water-Energy-Materials in the Circular Economy Suitable for Dense Urban Environments: A Real World Demonstration in the City of Athens, 2021. Water 2021, 13, 2764. https://doi.org/10.3390/w13192764

Peker, E., & İlhan, A. (2023). Catalysing the realisation of rainwater harvesting systems through participatory action research. *Habitat International*, *140*, 102927. https://doi.org/10.1016/j.habitatint.2023.102927

Selvinsimpson, S., & Chen, Y. (2022). Alternative sources of urban water supply and application of emerging materials in water treatment. In *Current Directions in Water Scarcity Research* (pp. 381–396). https://doi.org/10.1016/B978-0-323-91838-1.00025-7

Tahir, S., Adler, I., & Campos, L. (2013). Rainwater Recycling in Buildings. In *Water Efficiency in Buildings* (pp. 190–208). Wiley. https://doi.org/10.1002/9781118456613.ch11

Funded by the European Union

This project has received funding from the European Union Horizon Research and Innovation programme under grant agreement No 101178059

Annexes

Annex I. Excerpts from the Hellenic National Cadastre

Απόσπασμα Κτηματολογίου https://maps.ktimatologio.gr/?locale=e

Εκτύπωση

Κτηματολόγιο



ΚΑΕΚ: 050090725022 / Εμβαδόν: 650.78 τ.μ.

Συντεταγμένες κεντροειδούς: X = 476564.56, Y = 4207497.91

Πληκτρολογήστε τις συντεταγμένες κεντροειδούς στην περίπτωση υποβολής ηλεκτρονικής δήλωσης, όταν σας ζητηθούν.

Funded by the European Union

This project has received funding from the European Union Horizon Research and Innovation programme under grant agreement No 101178059

Κτηματολόγιο

govgr

ΤΗΛΕΦΩΝΙΚΗ ΕΞΥΠΗΡΕΤΗΣΗ
2106505600

ΕΛΛΗΝΙΚΟ ΚΤΗΜΑΤΟΛΟΓΙΟ
ΚΤΗΜΑΤΟΛΟΓΙΚΟ ΓΡΑΦΕΙΟ ΑΘΗΝΩΝ
ΝΟΜΟΣ: ΑΤΤΙΚΗΣ ΟΤΑ: ΑΘΗΝΑΙΩΝ
ΦΥΛΛΟ ΧΑΡΤΙΟΥ: 1:5000 4760-42060 / 1:1000 4760-42072
ΚΩΔΙΚΟΣ ΑΡΙΘΜΟΣ ΕΘΝΙΚΟΥ ΚΤΗΜΑΤΟΛΟΓΙΟΥ: 050090725022 / 0 / 0

Τα παραγόμενα αρχεία των αποσπασμάτων κτηματολογικής βάσης (περιγραφικής και χωρικής) δεν επέχουν θέση πιστοποιητικού για οποιαδήποτε νόμιμη χρήση, ούτε αποτελούν τίτλους των εγγεγραμμένων δικαιωμάτων και δεν δημιουργούν τεκμήριο γι' αυτά σύμφωνα με την υπ' αριθμ. 11206 ΕΞ 2021 Απόφαση Φορέα «Ελληνικό Κτηματολόγιο» (ΦΕΚ Β' 1539/15.4.2021).

ΑΠΟΣΠΑΣΜΑ ΧΩΡΙΚΗΣ ΒΑΣΗΣ



ΥΠΟΜΝΗΜΑ

ΚΛΙΜΑΚΑ 1 : 1000

- Όριο Δήμου ή Κοινότητας (πριν 01/01/1997)
- Όριο γεωτεμαχίου
- Όριο γεωτεμαχίου που αφορά το απόσπασμα
- Όριο αποκλειστικής χρήσης κάθετης ιδιοκτησίας
- Ζώνη δουλειάς

Εμβαδόν γεωτεμαχίου: 651 τ.μ.

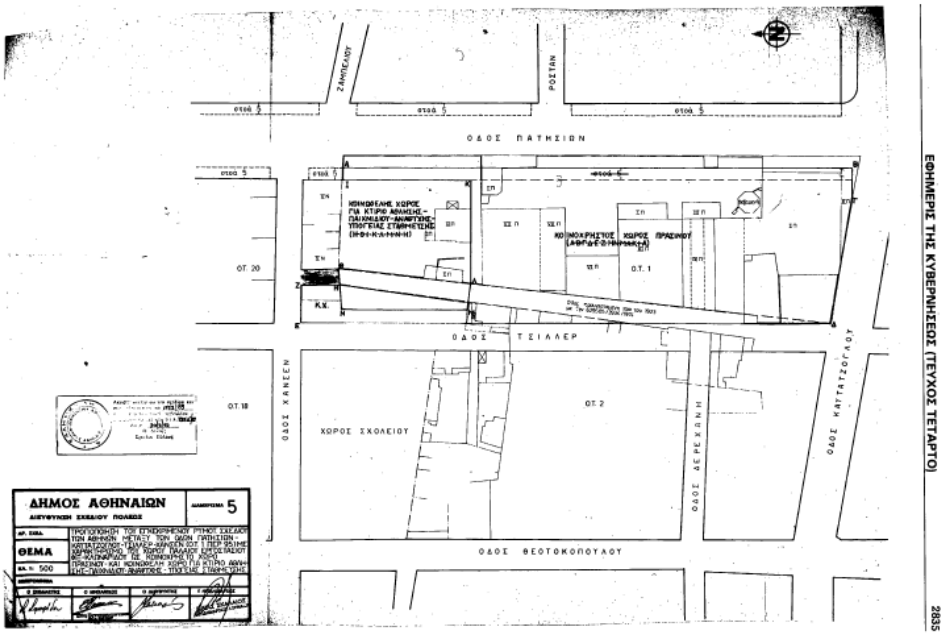
Ελληνικό Γεωδαιτικό Σύστημα Αναφοράς ΕΓΣΑ '87

ΗΜΕΡΟΜΗΝΙΑ ΜΕΤΑΠΤΩΣΗΣ: 16/09/2017 (ΥΑ.19779/2017, Β'/1763):

1. Διαφορές που προκύπτουν εκ της μετάπτωσης στην τιμή του εμβαδού των γεωτεμαχίων ειδικών εκτάσεων, τεκμαίρονται αποδεκτές σύμφωνα με τις τηρούμενες τεχνικές προδιαγραφές της διαδικασίας μετάπτωσης.

2. Διαφορές που προκύπτουν εκ της μετάπτωσης στην τιμή του εμβαδού των λοιπών γεωτεμαχίων, τεκμαίρονται αποδεκτές σύμφωνα με τις τηρούμενες τεχνικές προδιαγραφές της διαδικασίας μετάπτωσης και της εφαρμογής της στρογγυλοποίησης, οριζόμενες σε εύρος 0,01 τ.μ. όταν η στρογγυλοποίηση διενεργείται στο δεύτερο δεκαδικό στοιχείο, έως 1 τ.μ. όταν η στρογγυλοποίηση διενεργείται στο μέτρο.

Annex II. *Site land use – Extract from the Government Gazette 290/2-4-1992/D*



ΑΝΑΚΟΙΝΩΣΕΙΣ

(5)

Ειδοποίηση για την παρακατάθεση αποζημίωσης λόγω προσκύρωσης και απαλλοτρίωσης ακινήτων για ρυμοτομία στο Δήμο Ευόσμου Θεσσαλονίκης.

Γνωστοποιούμε ότι κατετέθη υπέρ των α) ΟΑΘ β) Δημ. Καλογερόπουλου και γ) Ελληνικού Δημοσίου ή παντός τρίτου δικαιούχου που θ' αναγνωρισθούν νόμιμα, στο ευρισκόμενο στη Θεσσαλονίκη γραφείο του ταμείου Παρακαταθηκών και Δανείων, η αποζημίωση από δρχ. δύο εκατομμύρια τριακόσιες εξήντα πέντε χιλιάδες οκτακόσιες εννιά (2.365.809) δραχμές που αφορά:

Την προσκύρωση και ρυμοτόμηση των τμημάτων με τα στοιχεία:

1) 1-2-3-4-1, εμβαδού σαράντα εφτά τετραγωνικών μέτρων και ενενήντα εκατοστών (47,90),

2) 4-6-5-4, εμβαδού τριάντα εκατοστών (0,30) του τετραγωνικού μέτρου,

3) 4-5-7-3-4, εμβαδού τεσσάρων (4) τετραγωνικών μέτρων,

4) 5-7-8-9-5 εμβαδού δέκα έξι (16) τετραγωνικών μέτρων και

5) 10-11-12-13-10, εμβαδού εκατόν πέντε τετραγωνικών μέτρων και ογδόντα εκατοστών (10,80), συνολικής προσκυρούμενης και ρυμοτομούμενης έκτασης από 121,10 τ.μ. και για ποσοστό 88,80% αυτής, δυνάμει του τοπογραφικού διαγράμματος που συνοδεύει την υπ' αριθ. 5947/90 πράξη προσκύρωσης και αναλογισμού αποζημίωσης λόγω ρυμοτομίας του Γραφείου πολεοδομίας Θεσ/νίκης, κυρωθείσης με την υπ' αριθμόν ΔΠ/ΤΑ οικ. 43324/4018/90 απόφαση του Νομάρχη Θεσσαλονίκης, όπως η αποζημίωση αυτή προσδιορίστηκε με την 293/1991 απόφαση του Μονομελούς Πρωτοδικείου Θεσσαλονίκης εκδοθέντος του αριθ. 499818/11.2.1992 γραμματίου συστάσεως παρακαταθήκης του Γραφείου Παρακαταθηκών και Δανείων στη Θεσσαλονίκη, το οποίο κατατέθηκε στην Συμβολαιογράφο Θεσσαλονίκης Χρυσούλα Μαλαχτάρη Τριανταφυλλίδου, Βασ. Ηρακλείου 26 Θεσσαλονίκη, που συντάχθηκε απ' αυτήν η υπ' αριθμόν 12.252/13.2.1992 πράξη κατάθεσης γραμματίου σύστασης παρακαταθήκης περί της κατ' αυτών τον τρόπο προσωρινώς καθορισθείσης και νομίμως κατατεθείσης αποζημίωσης.

Θεσσαλονίκη, 11 Μαρτίου 1992

Οι γνωστοποιούντες

ΓΕΩΡΓΙΟΣ ΔΑΛΓΚΙΤΣΗΣ ΔΗΜΗΤΡΙΟΣ ΑΡΒΑΝΙΤΟΠΟΥΛΟΣ

ΑΛΙΚΗ ΑΒΡΑΜΙΔΗ – ΜΕΛΕΣΙΔΗ

(Αριθ. δικλ. 9186363/11.3.92 του Δημοσίου Ταμείου Εισφ. Διχ. Θεσ/κης).

ΔΙΟΡΘΩΣΕΙΣ ΣΦΑΛΜΑΤΩΝ

(6)

Στην Π 2677/16.10.91 απόφαση Νομάρχη Λακωνίας, που δημοσιεύθηκε στο ΦΕΚ 870/28.11.91 (τ. Δ') διορθώνεται στο θέμα της απόφασης το εσφαλμένο «Επικύρωση της 2/91 πράξης αναλογισμού στα Ο.Τ. 6 και 141 σχεδίου πόλεως Σπάρτης» στο ορθό «Επικύρωση της 2/91 πράξεις αναλογισμού στο Ο.Τ. 137 του εγκεκριμένου ρυμοτομικού σχεδίου Σπάρτης».

(Από τη Νομαρχία Λακωνίας)

Funded by the European Union

This project has received funding from the European Union Horizon Research and Innovation programme under grant agreement No 101178059

Annex III. *Response from the Ministry of Environment and Energy on the permitting of the pilot project of the sewer mining system*

01.08.2025 15:17:10
ΑΚΡΙΒΕΣ ΑΝΤΙΓΡΑΦΟ
Υπογεγραμμένο
ΑΔΕ
Αντώνιος Κουλούρης

Α. Π.: ΥΠΕΝ/ΔΙΠΑ/82311/5197
Ημ/νία: 01/08/2026

ΕΛΛΗΝΙΚΗ ΔΗΜΟΚΡΑΤΙΑ
ΥΠΟΥΡΓΕΙΟ ΠΕΡΙΒΑΛΛΟΝΤΟΣ & ΕΝΕΡΓΕΙΑΣ
ΓΕΝΙΚΗ ΔΙΕΥΘΥΝΣΗ ΠΕΡΙΒΑΛΛΟΝΤΙΚΗΣ ΠΟΛΙΤΙΚΗΣ
ΔΙΕΥΘΥΝΣΗ ΠΕΡΙΒΑΛΛΟΝΤΙΚΗΣ ΑΔΕΙΟΔΟΤΗΣΗΣ
Τμήμα Β΄

Ταχ. Δ/νση : Λ. Αλεξάνδρας 11
Τ.Κ. : 114 73
Πληροφορίες : Ε. Ματζουράνη
Τηλέφωνο : 210 6417957
E-mail : e.matzourani@prv.ypeka.gr
sec. dipa@prv.ypeka.gr

ΠΡΟΣ: **ΕΥΔΑΠ**
ΔΙΕΥΘΥΝΣΗ ΣΤΡΑΤΗΓΙΚΗΣ & ΚΑΙΝΟΤΟΜΙΑΣ
Υπηρεσία Νέων Δραστηριοτήτων
e-mail: kdimitriou@evdap.gr
pblantzoni@evdap.gr

ΚΟΙΝ: **ΥΠΕΝ**
Γραφείο Προϊστάμενου Γενικής Διεύθυνσης Περιβαλλοντικής Πολιτικής

Θέμα: **Μη αναγκαιότητα περιβαλλοντικής αδειοδότησης για την πιλοτική λειτουργία τοπικών μονάδων παραγωγής ανακτημένου νερού για άρδευση – πυρόσβεση και λοιπές μη πόσιμες χρήσεις δημοσίων χώρων.**

Σχετ. :
1. Ο Ν. 4014/2011 (ΦΕΚ 209/Α΄), όπως έχει τροποποιηθεί και ισχύει.
2. Η ΥΑ ΥΠΕΝ/ΔΙΠΑ/17185/1069/2022 (ΦΕΚ 841/Β΄), όπως ισχύει.
3. Η ΚΥΑ 145116/2011 (ΦΕΚ 354/Β΄), όπως έχει τροποποιηθεί και ισχύει.
4. Το με Α.Π. 13573/22-07-2025 έγγραφό σας (ΥΠΕΝ/ΔΙΠΑ/82311/5197/23-07-2025).

Σε απάντηση του αιτήματος που υποβλήθηκε στη Υπηρεσία μας μέσω του 4ου σχετικού εγγράφου, στο πλαίσιο των αρμοδιοτήτων μας και σύμφωνα με τα στοιχεία που θέσατε στη διάθεσή μας, σας γνωρίζουμε τα εξής:

Οι περιγραφόμενες στο έγγραφο μονάδες παραγωγής ανακτημένου νερού μπορούν να θεωρηθούν πιλοτικές μονάδες, με την προϋπόθεση ημερήσιας δυναμικότητας έως 50m^3 και για μέγιστη περίοδο λειτουργίας τα δύο (2) έτη. Μετά το πέρας αυτού του διαστήματος θα πρέπει να ακολουθηθεί η διαδικασία περιβαλλοντικής αδειοδότησης, σύμφωνα με τις κείμενες διατάξεις. Επισημαίνεται ότι για το χρονικό διάστημα της πιλοτικής λειτουργίας, θα πρέπει να εξασφαλιστεί άδεια επαναχρησιμοποίησης επεξεργασμένων αστικών λυμάτων από τη Διεύθυνση Υδάτων της οικείας Αποκεντρωμένης Διοίκησης, κατ' εφαρμογή των διατάξεων της 3ης σχετικής ΚΥΑ.

Σε κάθε περίπτωση, κατά τη φάση κατασκευής και λειτουργίας των μονάδων θα πρέπει να ακολουθούνται οι πάγιες διατάξεις προστασίας του περιβάλλοντος, όπως π.χ. εκείνες που αφορούν στην προστασία του υδάτινου περιβάλλοντος και του εδάφους από ρύπανση, στη διαχείριση και τη σύννομη διάθεση στερεών και υγρών αποβλήτων, στον περιορισμό εκπομπών αέριων ρύπων, θορύβου κλπ.

Τα παραπάνω αφορούν αποκλειστικά το ζήτημα απαλλαγής από περιβαλλοντική αδειοδότηση των μονάδων του θέματος και δεν απαλλάσσουν τον φορέα του έργου, ή άλλους εμπλεκόμενους, από την υποχρέωση λήψης άλλων κατά περίπτωση ενδεχομένως απαραίτητων αδειών και εγκρίσεων.

Η ΠΡΟΪΣΤΑΜΕΝΗ ΤΗΣ ΔΙΕΥΘΥΝΣΗΣ

ΚΩΝΣΤΑΝΤΙΝΑ ΝΙΚΑ

Funded by the European Union

This project has received funding from the European Union Horizon Research and Innovation programme under grant agreement No 101178059

Annex IV. *National Technical University of Athens decision of signing a programmatic Agreement with the City of Athens*

ΕΘΝΙΚΟ ΜΕΤΣΟΒΙΟ ΠΟΛΥΤΕΧΝΕΙΟ

ΓΡΑΜΜΑΤΕΙΑ ΣΥΜΒΟΥΛΙΟΥ ΔΙΟΙΚΗΣΗΣ

Ηρώων Πολυτεχνείου 9, Πολυτεχνειούπολη Ζωγράφου 157 72 Αθήνα ☎ 210-772 1593, 1903 ✉ sd@mail.ntua.gr

ΑΠΟΦΑΣΗ 18ης/2025 ΣΥΝΕΔΡΙΑΣΗΣ ΤΟΥ ΣΥΜΒΟΥΛΙΟΥ ΔΙΟΙΚΗΣΗΣ
24.07.2025

ΘΕΜΑ 7.3: Έγκριση Σχεδίου Προγραμματικής Συμφωνίας με τον Δήμο Αθηναίων για παραχώρηση χώρου στο πλαίσιο του έργου με ΚΑ 63/2644 και Επιστημονικό Υπεύθυνο τον Καθ. Χρ. Μακρόπουλο

Ο εισηγητής Πρύτανης ΕΜΠ κ. Ιωάννης Κ. Χατζηγεωργίου, παρουσίασε την εισήγηση στα μέλη του Συμβουλίου Διοίκησης και ακολούθησε συζήτηση στο πλαίσιο της οποίας τέθηκαν ερωτήσεις και δόθηκαν διευκρινίσεις για τη δημιουργία ολοκληρωμένης άποψης επί του θέματος.

Το Συμβούλιο Διοίκησης, έχοντας υπόψη του:

α) την από 18.07.2025 εισήγηση του Προέδρου της Επιτροπής Ερευνών του ΕΛΚΕ ΕΜΠ, Καθ. Ε. Βαρβαρίγου,
β) την από 16.07.2025 απόφαση της Επιτροπής Ερευνών του ΕΛΚΕ ΕΜΠ, Θέμα 10.5 και
γ) τη συζήτηση που ακολούθησε και τις απόψεις και θέσεις που εκφράστηκαν,

αποφασίζει

την έγκριση του Σχεδίου Προγραμματικής Συμφωνίας με τον Δήμο Αθηναίων (σιτημμένο) για παραχώρηση αδιαμόρφωτου χώρου (εμβαδού 650,78τμ) πλησίον του Πάρκου Κλεισθένη - Φιξ στο πλαίσιο του έργου με τίτλο «Theseus: Προώθηση της καινοτομίας της κυκλικής οικονομίας στην Ελλάδα μέσω της βιομηχανικής-αστικής συμβίωσης για ένα βιώσιμο μέλλον» με ΚΑ 63/2644 και Επιστημονικό Υπεύθυνο τον Καθ. Χρ. Μακρόπουλο. Στόχος του εν λόγω έργου, που πραγματοποιείται από την αιγίδα της Ευρωπαϊκής Επιτροπής, είναι η ανάπτυξη ενός περιφερειακού κόμβου κυκλικότητας και καινοτομίας με την εφαρμογή και επικύρωση λύσεων αιχμής στους τομείς νερού, ενέργειας και υλικών, συμβάλλοντας στην κλιματική ουδετερότητα έως το 2050. Στην Ελλάδα, έχει επιλεγεί ο Δήμος Αθηναίων για την υλοποίηση του πιλοτικού έργου του Προγράμματος. Σκοπός της παρούσας σύμβασης είναι η συνεργασία των συμβαλλομένων μερών, με κοινό στόχο την εγκατάσταση και λειτουργία μονάδας επαναχρησιμοποίησης ανακυκλωμένου νερού (Sewer Mining) για την άρδευση χώρων πρασίνου του Δήμου, το οποίο επιδιώκει την εξυπηρέτηση σκοπών αποκλειστικά δημοσίου συμφέροντος.

.....

Η παρούσα Απόφαση υπεγράφη, κατά τη διάρκεια της Συνεδρίασης, σύμφωνα με τον πρωτότυπο πίνακα υπογραφών.

Αθήνα, 24/07/2025
Ο ΠΡΥΤΑΝΗΣ

Ιωάννης Κ. Χατζηγεωργίου
Καθηγητής

Funded by the European Union

This project has received funding from the European Union Horizon Research and Innovation programme under grant agreement No 101178059