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A Monte-Carlo based method for the identification of potential sewer mining locations

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Who is who…

DESSIN

DEMONSTRATE ECOSYSTEM SERVICES ENABLING INNOVATION IN THE WATER SECTOR

www.dessin-project.eu

Sewer Mining Pilot (Athens)

EYDAP Athens Water Supply and Sewerage Company, Greece (CASE)

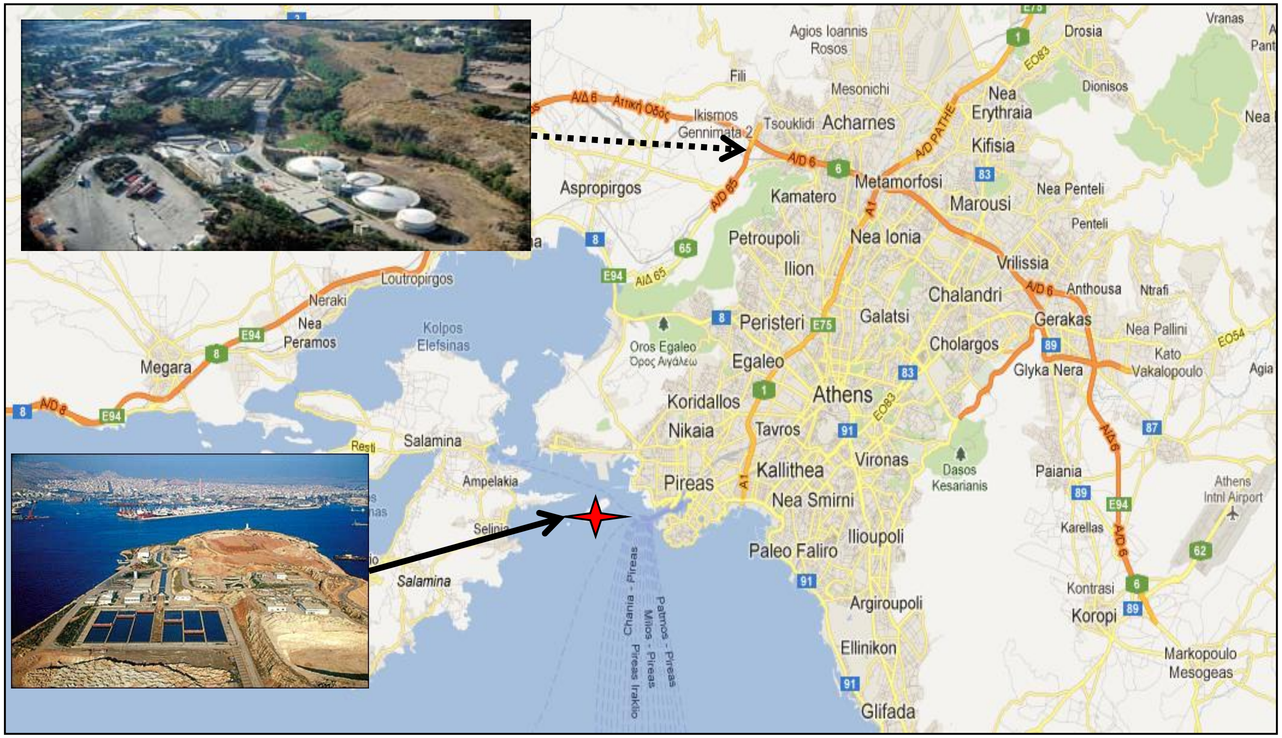
NTUA, National Technical University of Athens (RTD)

CHEMiTEC Water & Environmental Technologies, Greece (SME)

TELINT RTD Consultancy Services, UK (SME)

Context

- Athens has suffered rapid urbanisation resulting in **few urban green spaces**
- **Reuse**, but at what **scale**?
- Need for innovative management options and technologies for reuse needed to irrigate (primarily) green urban areas (incl. devastated peri-urban forests).



Current status

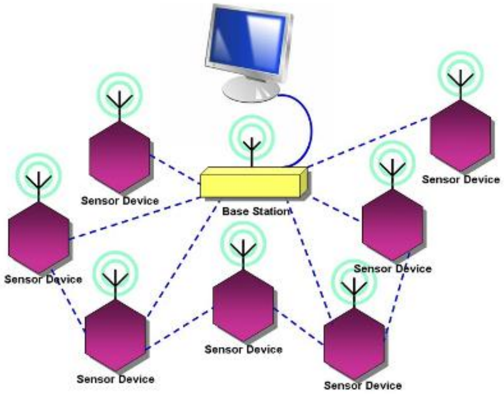
- Main WWTP in an **island** (Psytalleia)
- Increased energy costs for transp.
- Peri-urban forests devastated by fires
- Water scarcity

Enter Sewer Mining…

The Athens Pilot brings together two emerging technologies:

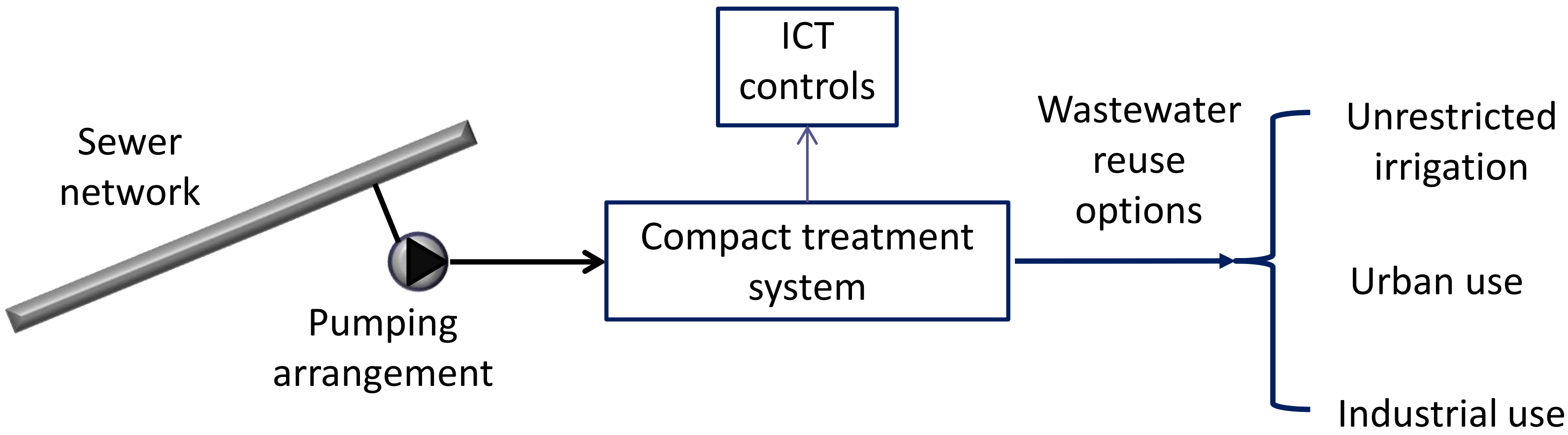
Fully **automated packaged treatment plants** featuring membrane based, small footprint, sewer mining technologies that allow **direct mining of sewage** from the network, close to the **point-of-use** with minimum infrastructure required and low transportation costs for the effluent

Distributed **low energy sensor networks coupled with distributed ICT** intelligence (e.g. Advanced Metering and Monitoring Infrastructure, AMIs) innovative in terms of data fusion (b) data communication (c) interoperability and (d) mobile solutions for **remotely controlling and operating** the distributed infrastructure (against stringent performance criteria, incl. health and water quality standards)



Main concept

The following general concept was developed as a basis of applications of the proposed solution:



Benefits to be explored

Benefits

Case Athens is an opportunity to:

- **Increase reuse efficiency** with treatment at the point of use
- **Decrease transaction costs** compared to "centralised" reuse (licensing / footprint / local communities)
- **Increase % of reused water** within the highly constrained urban environment
- **Improve urban quality of life** through improved ecosystem services and;
- Create **new market for SMEs** that can provide this service to, e.g. local municipalities

A win-win scenario → SMEs will sell raw sewage using the existing centralised sewerage network of the water company and water companies will be able to sell untreated sewage, while also minimise the load to their centralised treatment facilities.

Upscale opportunities

Deployment in the east coast of Attica for:

- Urban green
- Reduced water treatment cost
- Reused water withdrawal to avoid saltwater intrusion

Map of Attica, Greece

Identification of potential locations for sewer mining units: A Monte-Carlo approach

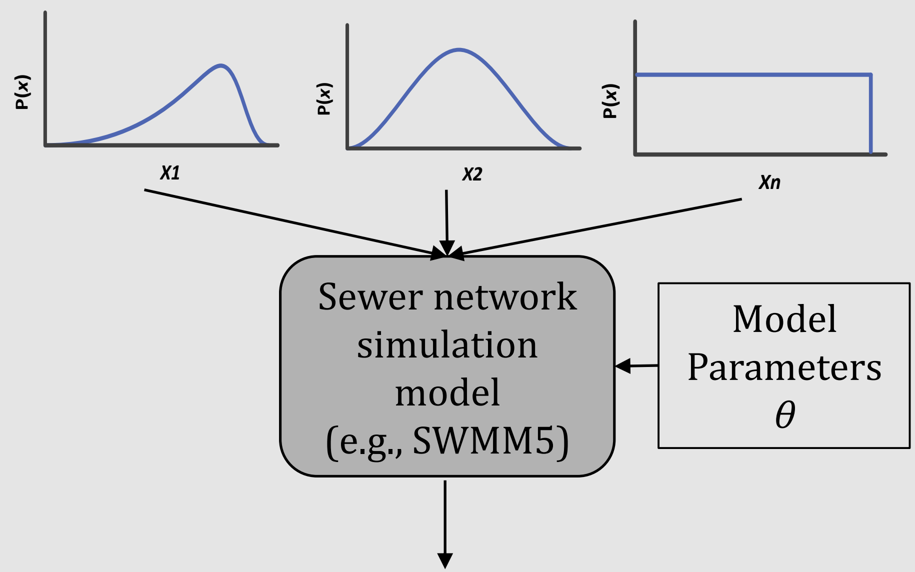
Step 1: Spatial data pre-processing

Identification of:

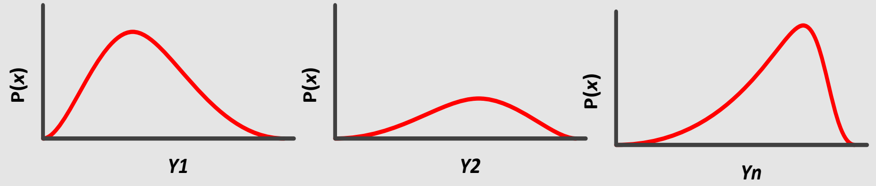
1. Sewage network topology and assets (e.g., manholes, pipes)
2. Hydraulic characteristics (e.g., pipe diameter, slope)
3. Land uses (areas that will benefit from sewer mining – e.g., parks)
   - Locate neighborhood sewer network components (e.g., nodes)

Step 2: Monte-Carlo Simulation

Inputs: Uncertain parameters X (e.g., Variation coefficients of wastewater discharge , BOD_5 loading).



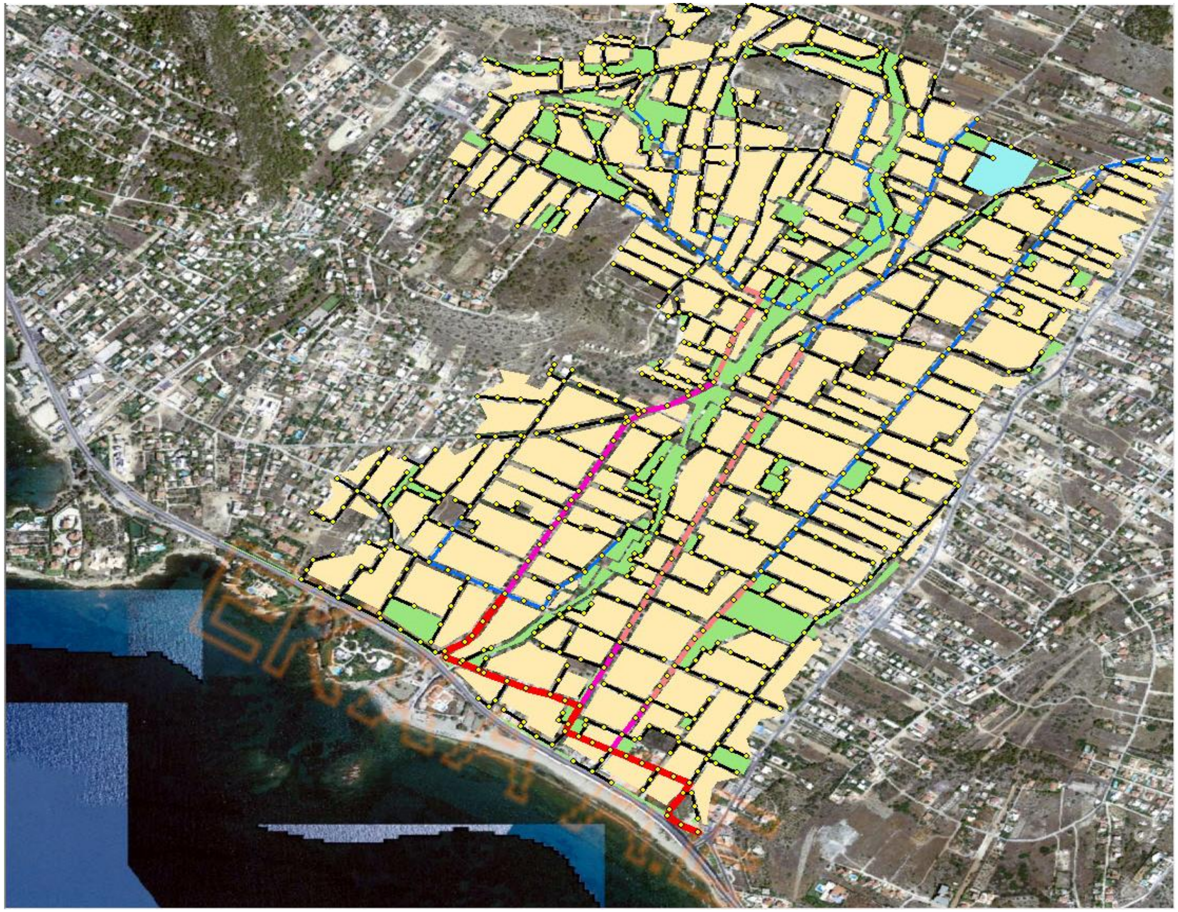
Outputs: Quantities of interest (e.g., concentration of BOD_5 at each pipe).



Step 3: Results post-processing

- Calculate metrics (e.g., utility functions, risk functions) & perform multi-criteria analysis
- Location(s) selection

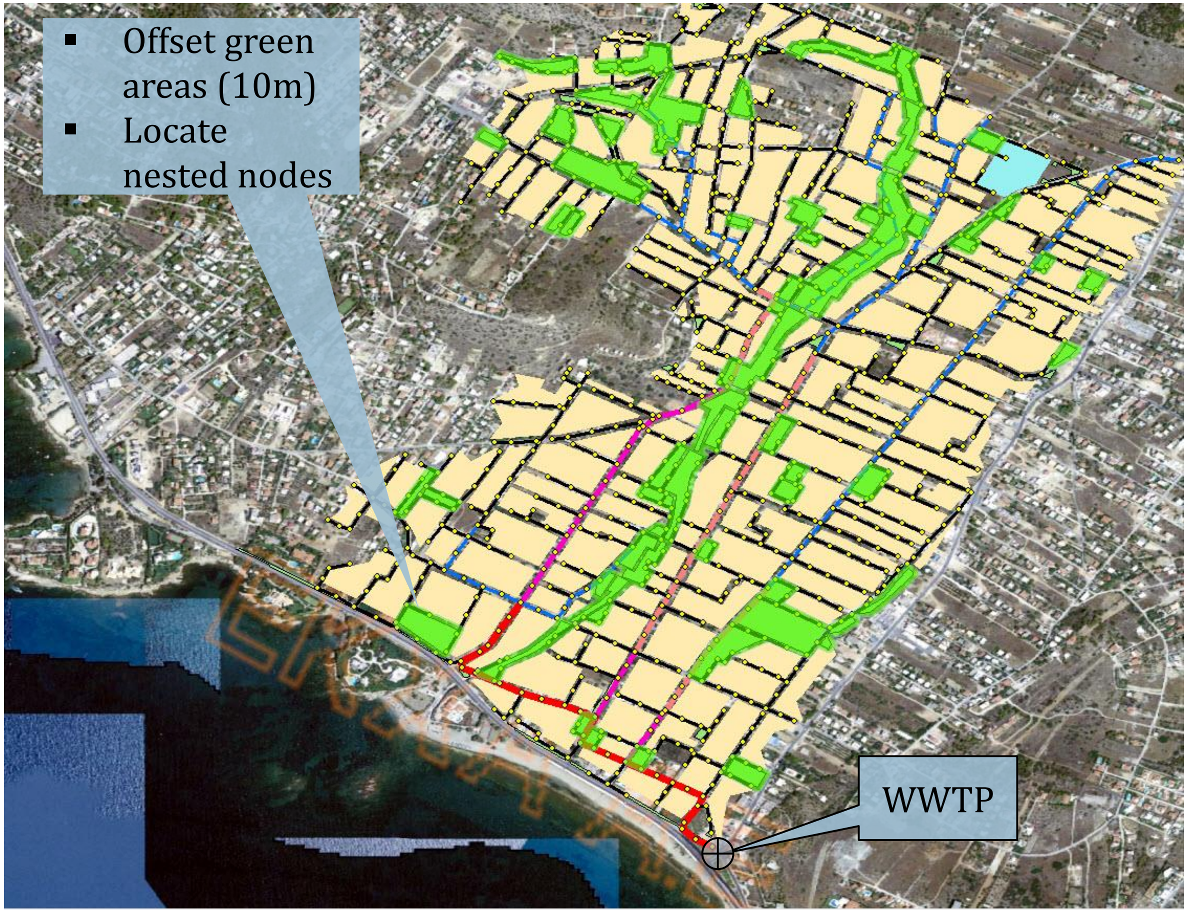
Step 1 (a): Spatial data pre-processing



Import:

1. Sewage network topology and assets (e.g., manholes, pipes)
2. Hydraulic characteristics (e.g., pipe diameter, slope)
3. Land uses (areas that will benefit from sewer mining – e.g., parks)
4. Other spatial data (e.g., aerial photo)

Step 1 (b): Spatial data pre-processing



Pre-process:

Why?

Identify land uses (areas that will benefit from sewer mining – e.g., green areas, parks)

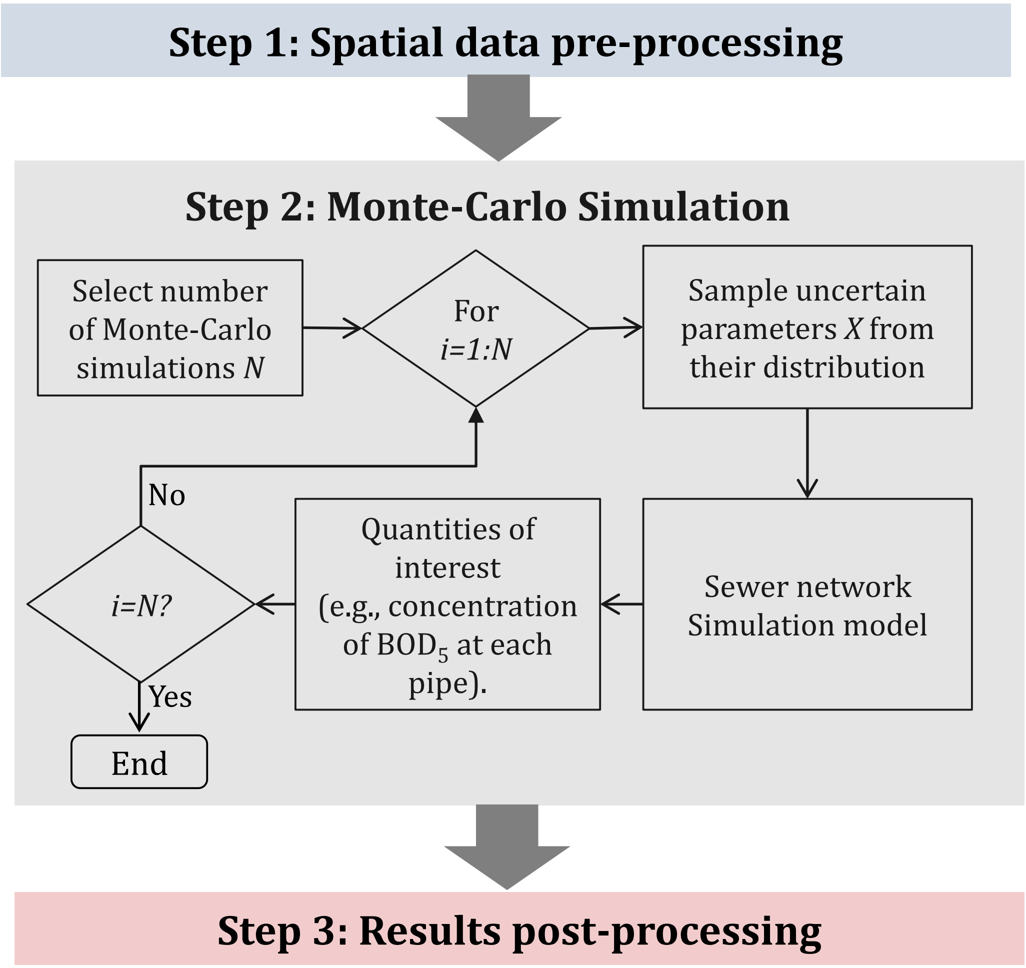
- Locate neighborhood sewer network components (e.g., nodes)

How?

- Add offset to green areas (e.g., 10m).
- Locate the nodes that are inside each offset area.
- Find the path from each “selected” node → Exit (e.g., WWTP).

This path is unique for each node due to the “collective nature” of sewer networks.

Step 2: Monte-Carlo Simulation



Why?

- The purpose of Monte-Carlo simulation is to propagate the uncertainties of input parameters to the outputs.
- Also, allow the use of probabilistic objective functions (metrics).

How?

- Identify uncertain parameters *X*
  - Daily and hourly variation coefficients of wastewater discharge
  - BOD_5 loading
- Identify output of interest
  - BOD_5 concentration of each pipe

Alternatives?

Similar, a scenario-based approach (instead or in conjunction with Monte-Carlo) could be employed (e.g., worst, middle, high conditions).

Next step?

- Define probabilistic objective functions (metrics).
- Post-process the results

Step 3: Results post-processing

Step 1: Spatial data pre-processing

Step 2: Monte-Carlo simulation

Step 3 (a) : Results post-processing

Metric Z originally proposed by von Bielecki & Schremmer, (1987) and Pomeroy, (1990) for a **single** pipe I in order to quantify the probability of H_2S build-up:

$$Z_i = \frac{0.3 \times 1.07^{T-20} \times [BOD_5]_i}{J_i^{0.5} \times Q_i^{1/3}} \times \frac{P_i}{B_i}$$

Where, i is the pipe index, T is the sewage temperature (°C), J is the pipe slope, Q is the discharge (m^3/s), P is the wetted perimeter of the pipe wall (m) and B the surface width (m) of the stream.

Modified Index Z of Pomeroy for a "**chain**" of pipes n:

$$Z_c = \sum_{i=1}^{n} a_i \times Z_i$$

Where, $a_i = L_i / L_{tot}$, L_i is the length of pipe i, and L_{tot} is the total length of pipes of chain n.

According to Pomeroy, (1990) if a pipe has $Z_i > 7500$ then there are high chances of H_2S formation which could lead to odour and corrosion problems.

Why?

The purpose of this step is to use metrics (e.g., utility functions, risk functions) that quantify the output of interest (in our case H_2S build-up) for **a chain of pipes** (node → exit node).

How?

- Employ a modified version of the "quasi-quantitative" indicator Z.
- Calculate the E[Z] for given reliability level (R>75%) for each path for each green area using the N simulation runs
- For each green area select the path with minimum E[Z].

Alternatives?

Similar, other metrics can be used that quantify the exact amount of H_2S in terms of mg/l.

Next step?

Multi-criteria analysis and selection of potential locations for sewer mining units.

Step 1: Spatial data pre-processing

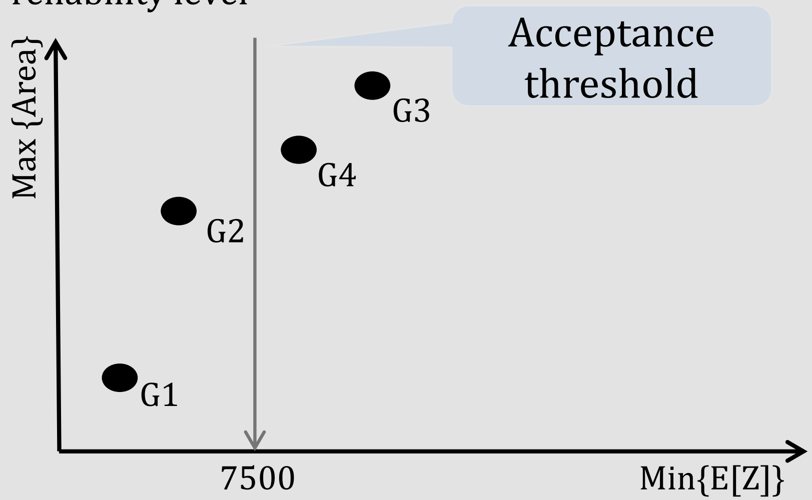
Step 2: Monte-Carlo simulation

Step 3 (a): Results post-processing

Step 3 (b): Identify the Pareto set (Max{Area}, Min{Z})

Based on the analysis:

- For each green area the optimal node for the SM placement is already found (step 3a).
- Fuse the information regarding H_2S build-up and green area water demand.
- Green area 1 and 2 are suitable for SM placement.
- Green area 1 and 2 were selected based on a desired reliability level



Why?

The purpose of this step is to use multi-criteria analysis in order to identify potential locations for sewer mining unit placement.

How?

- We have already calculated E[*Z*] for each node thus we can combine this information with:
- Information regarding the water demand in the areas of interest (green areas)
  - We select as rough indicator for water demand the area (m^2) of the park.

Alternatives?

Similar, the actual water demand of each area can be calculated if relevant information is available.

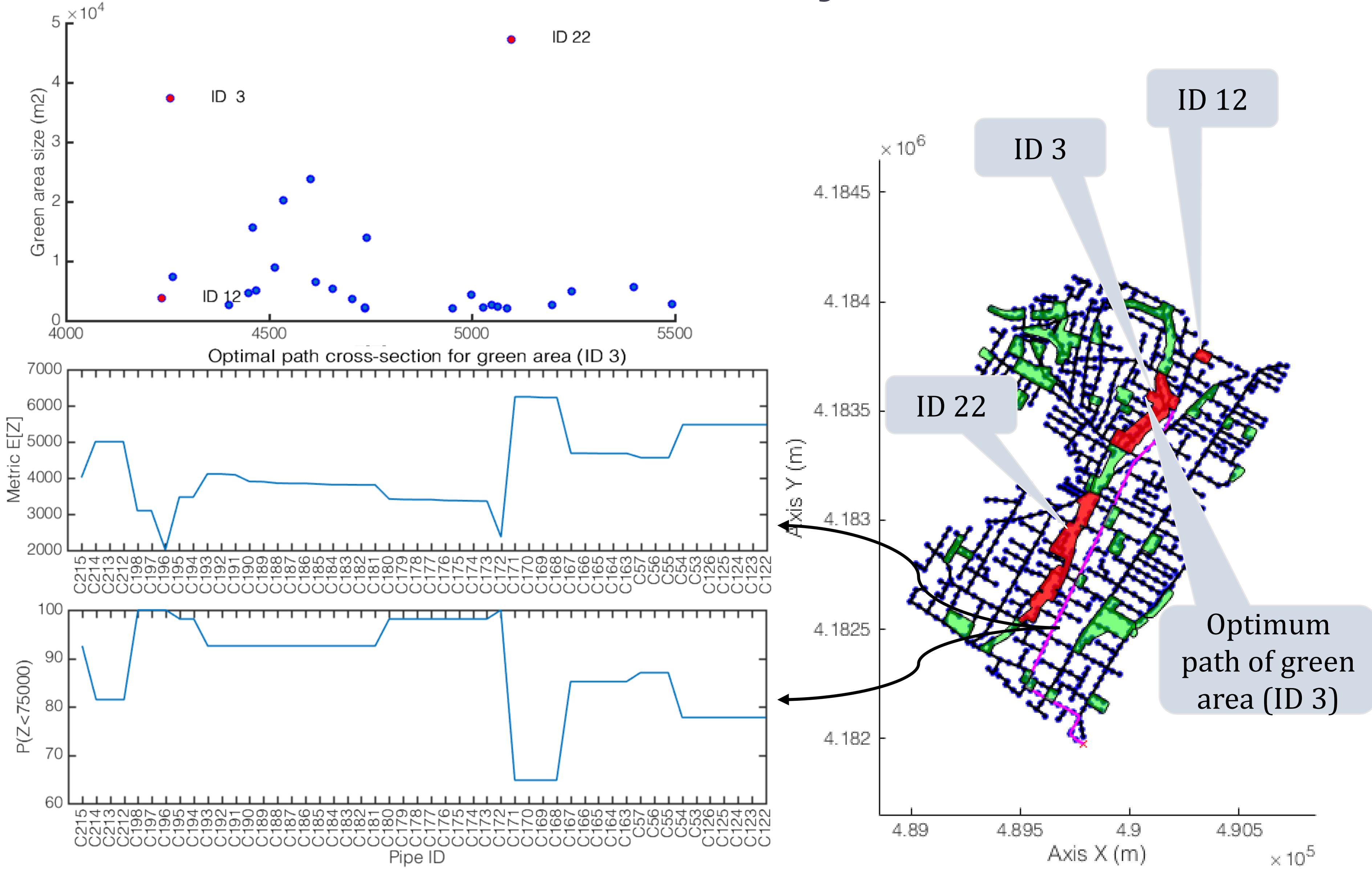
Also other metrics can be employed in

Next step?

- Selection of potential locations for sewer mining units.
- Further analysis and modelling of sewer mining unit for the selected locations.

Study area: Kalyvia Thorikou, Greece

Study area results: Kalyvia Thorikou



The GUI of Sewer Mining Placement Tool

Step 2: Setup Monte-Carlo Simulation

Step 1: Load spatial data and pre-processing

Step 3: Results post-processing

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Thank you!

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