43rd IAH International Congress “Groundwater and society: 60 years of IAH”

Urban groundwater model of Bucharest city, Romania

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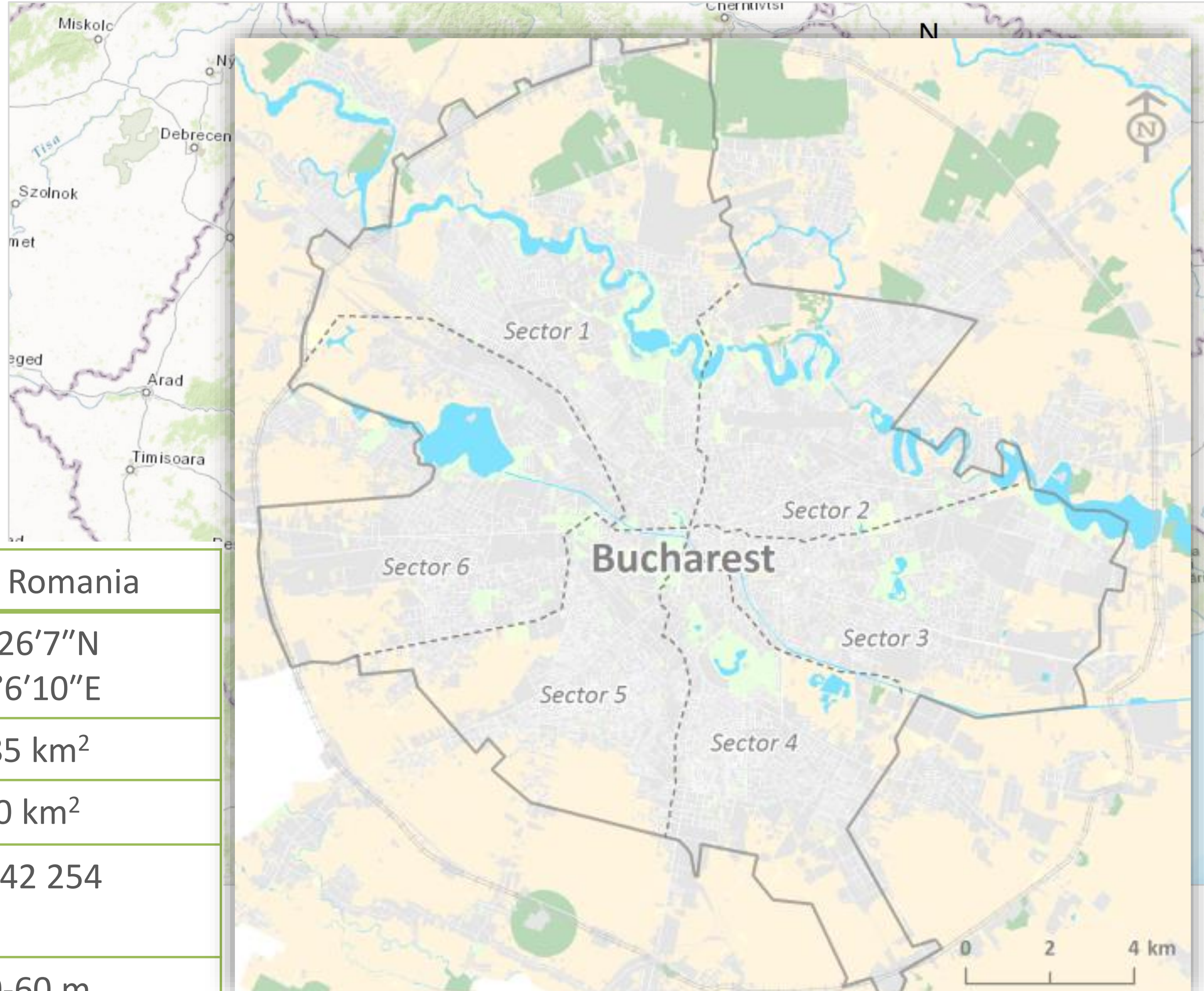
N°abstract 1526

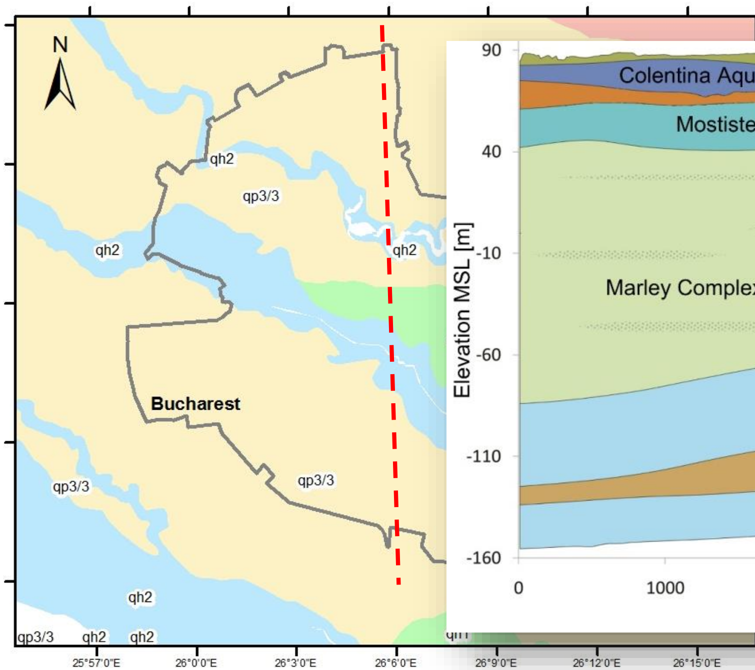
Bucharest City

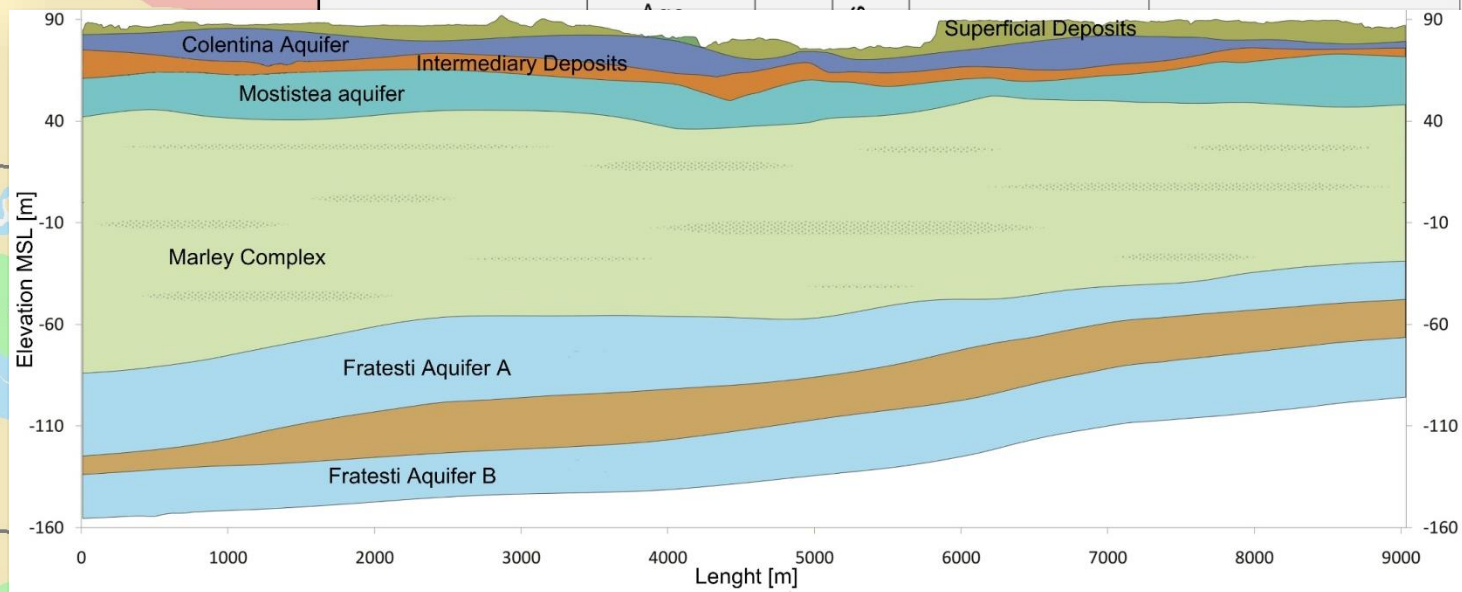


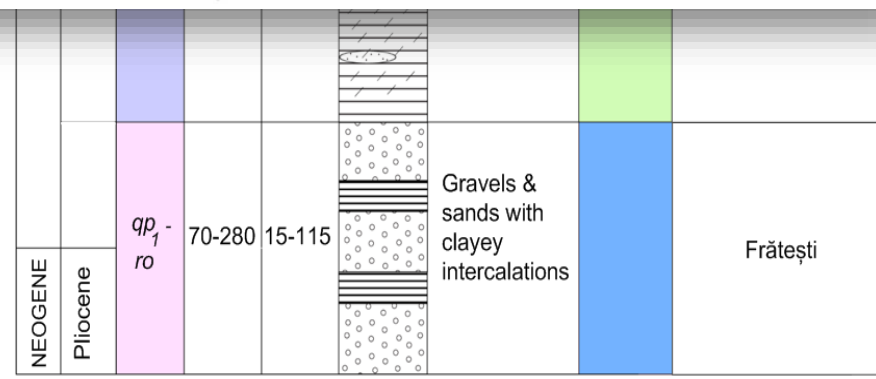
Location	SE of Romania
Coordinates	44°26′7″N 26°6′10″E
Surface	285 km^2
Green surface	20 km^2
Population (2011)	1 942 254
Altitude (MSL)	90-60 m
Administrative subdivisions	6 subunits

Bucharest geology

- Bucharest lies on Quaternary sedimentary deposits;







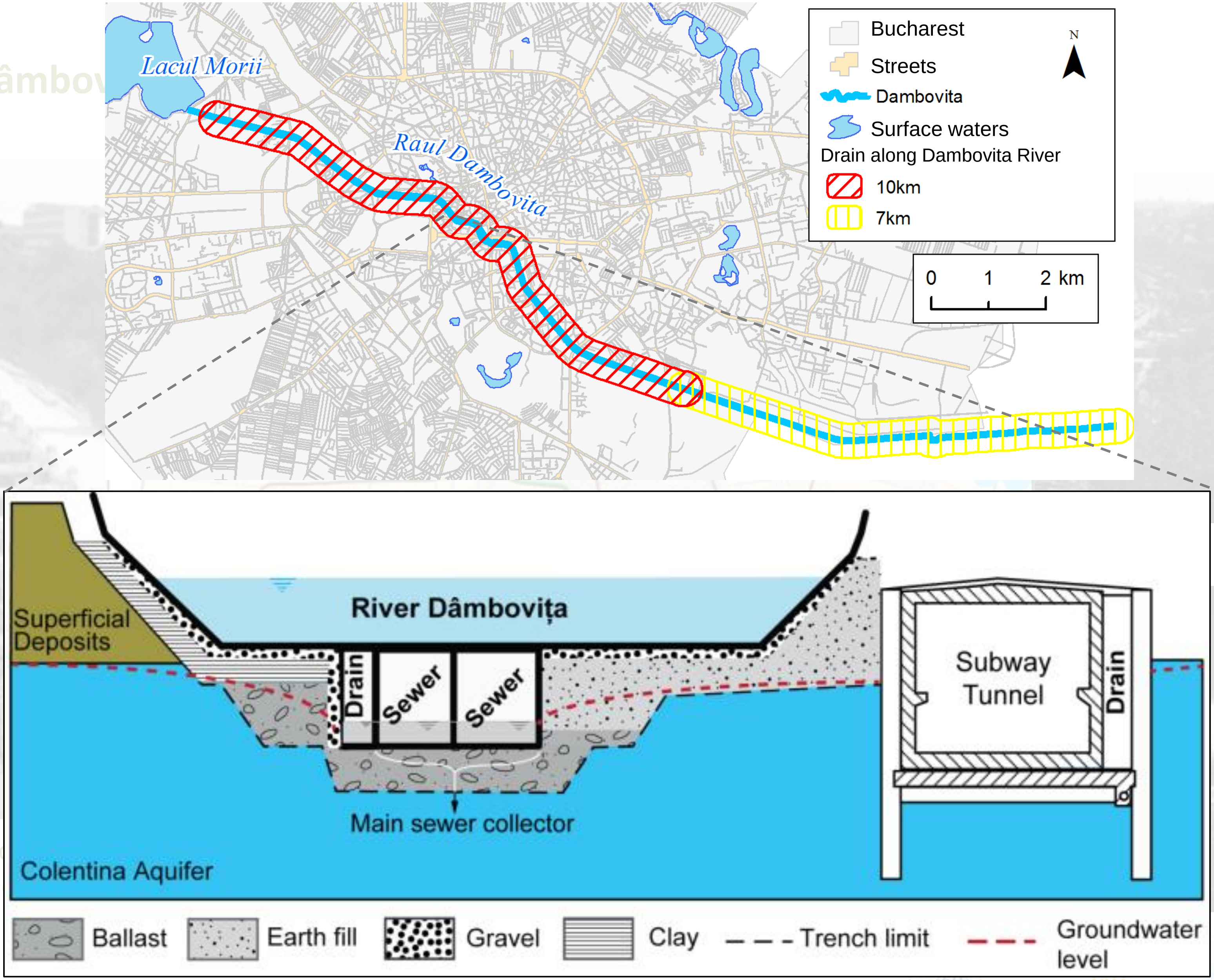
Bucharest Hydrogeology

3 Sedimentary aquifer units:

- **Shallow aquifer** "Colentina" interacting with urban infrastructure
- **Medium depth aquifer** "Mostistea"
- **Deep aquifer** "Fratesti" made of 3 subunits: A, B & C

Bucharest - Hydrogeological problems

River Dâmbov



Earthworks

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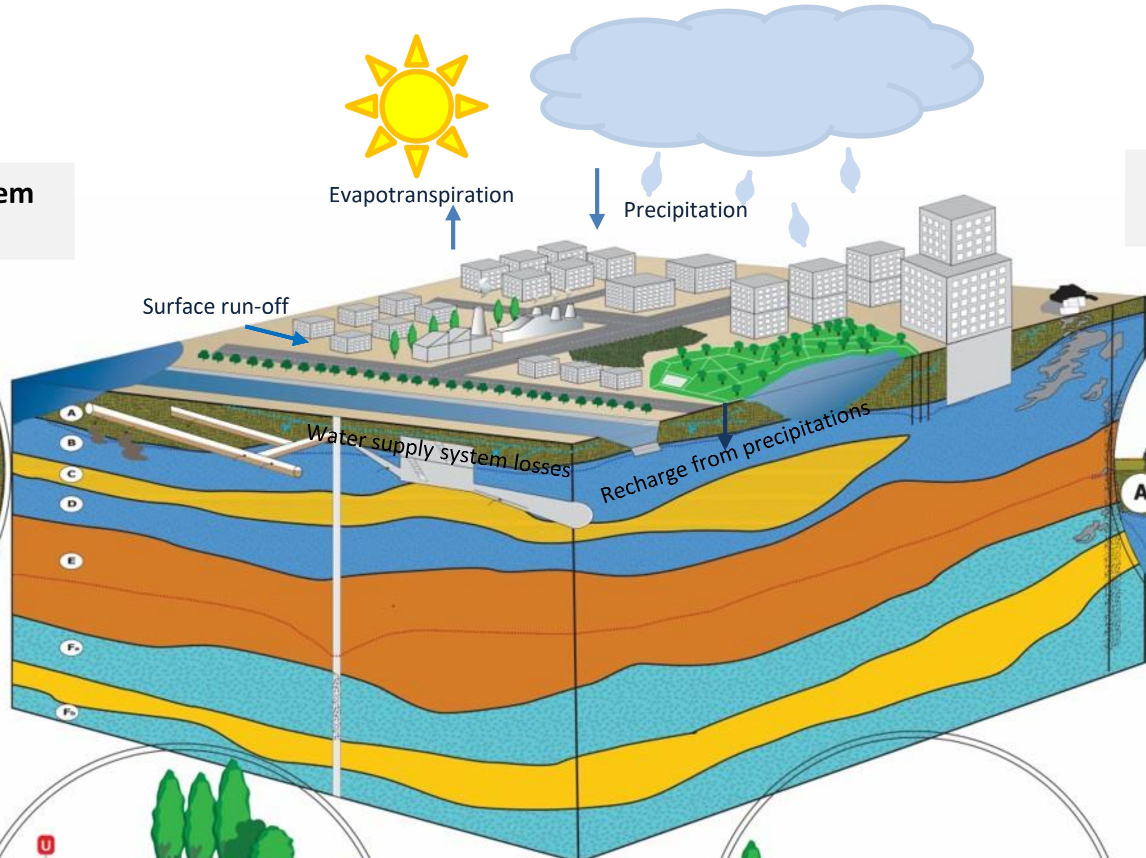
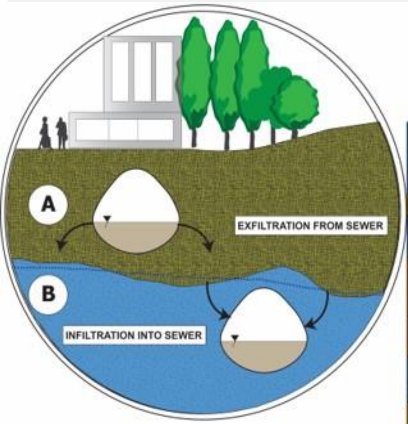
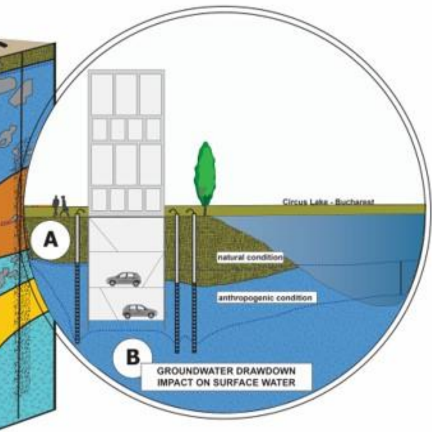
Bucharest - Urban hydrogeological conceptual model

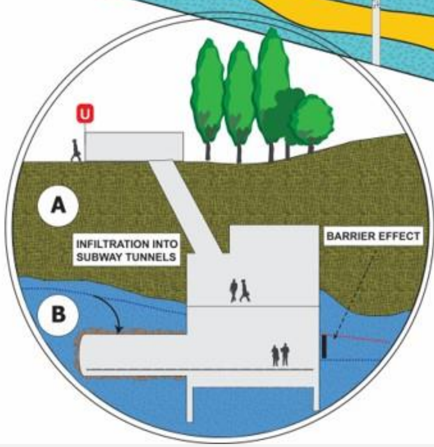


Groundwater - sewer system interaction

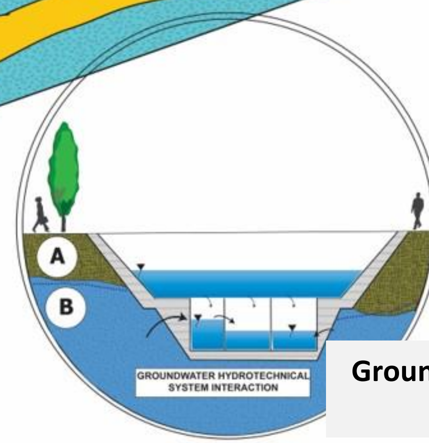


Dewatering impact





Groundwater – subsurface infrastructure interaction



Groundwater – channelized River interaction

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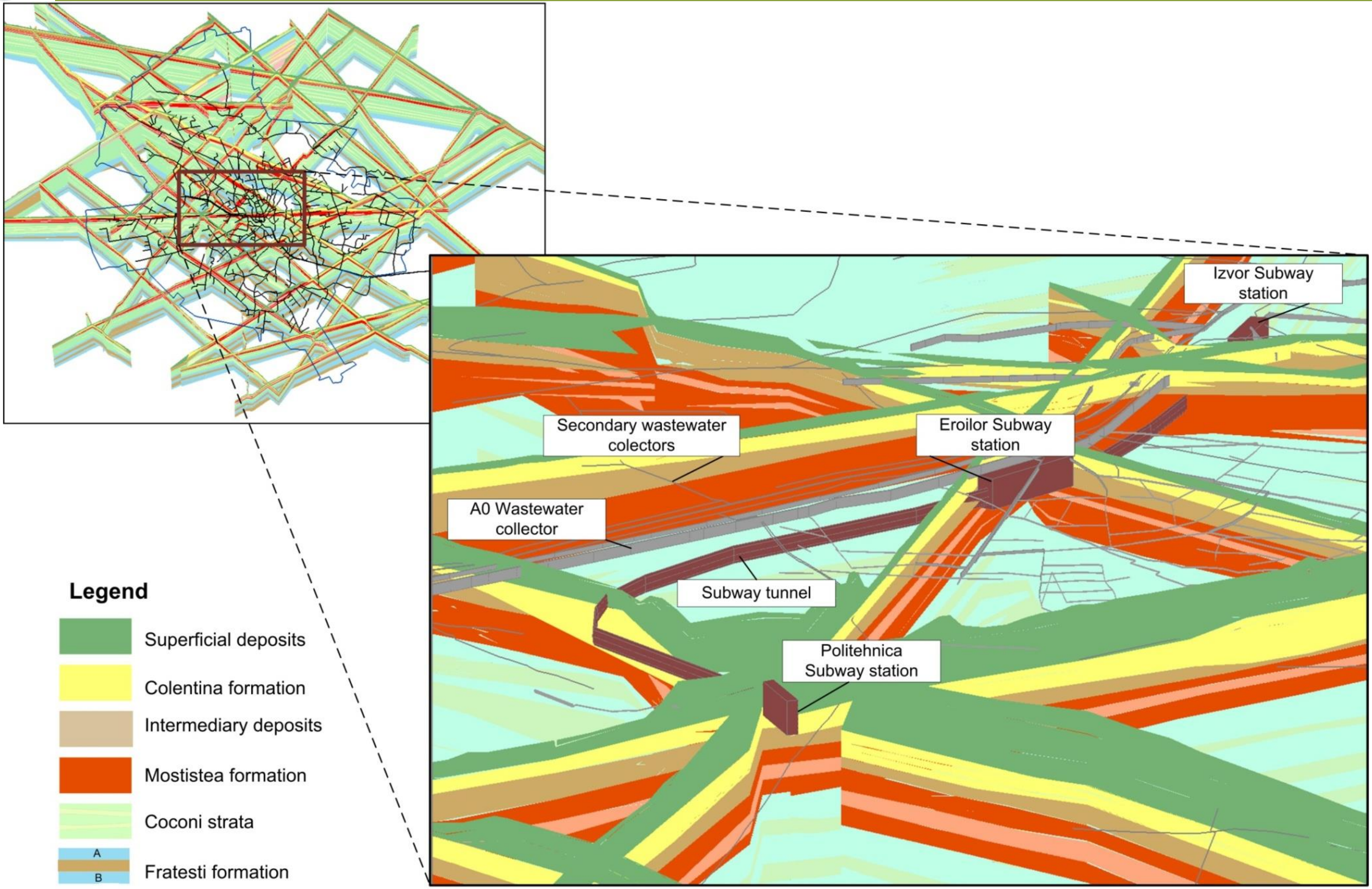
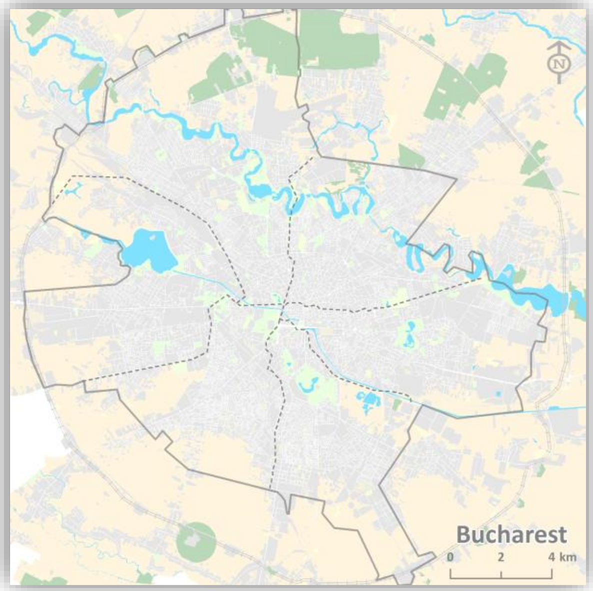
Bucharest - 3D Geological Model



Hydrogeological model - key elements



Urban coverage

Total area: 285 km^2:
Constructed area : 70%
Green urban area : 30%

Surface water bodies

Unlined surface water bodies:
- Lakes along Colentina Riv. course
- Lakes in Parks
- Wetland: Vacaresti

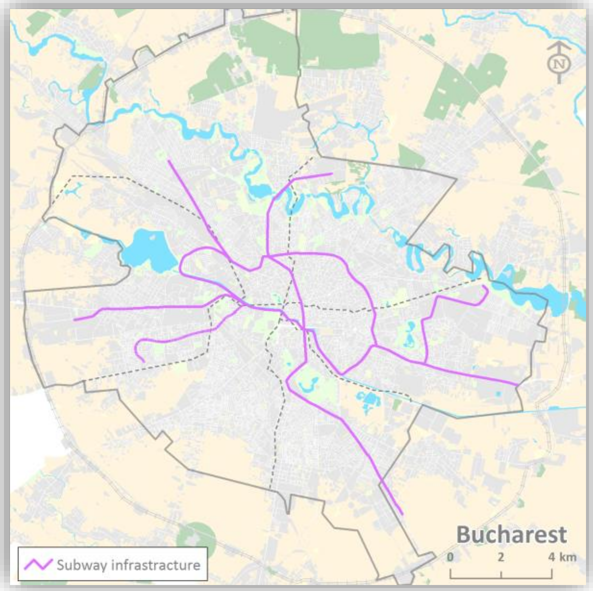
Channelized River:
- Dambovita River

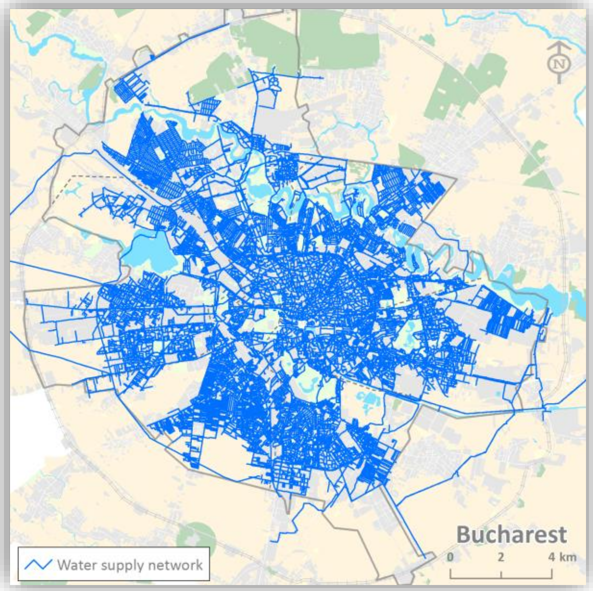
Drainage system under channelized river:

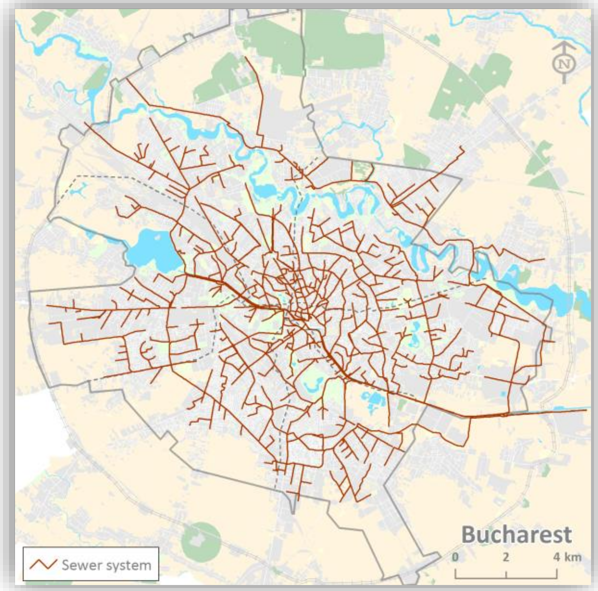
- Total length: 17 km

- Function:
Drain groundwater flow rates initially discharged by Dambovita Riv. before the channelizing works

Hydrogeological model – key elements







Subway infrastructure

Number of lines: 4
Subway stations: 51
Average stations length : 135-175m
Average stations depth: 12m
Network length : 69.25km

Data from: www.metrorex.ro

Water Supply Network

4 Subsystems:
- Low pressure
- High pressure
- Water ducts
- Industrial waters

Total length: 2500 km
Average water transport: **6m³/s**

Data from: www.apanovabucuresti.ro

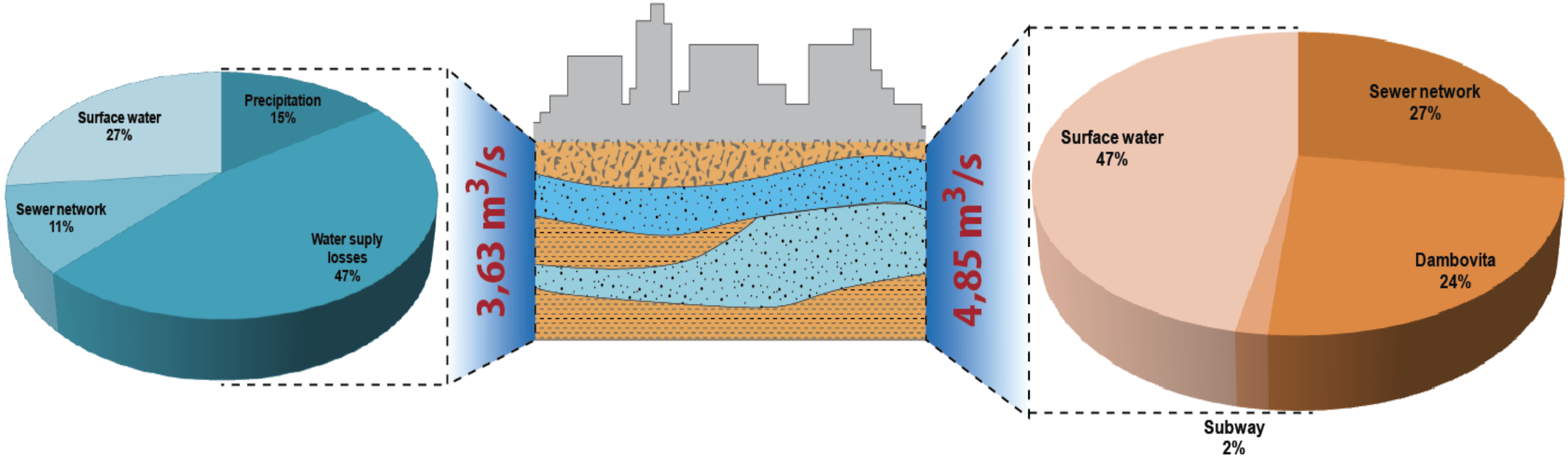
Sewer system

Type: combined
Total length: 2300 km
Average water transport: **9m³/s**

Data from: www.apanovabucuresti.ro

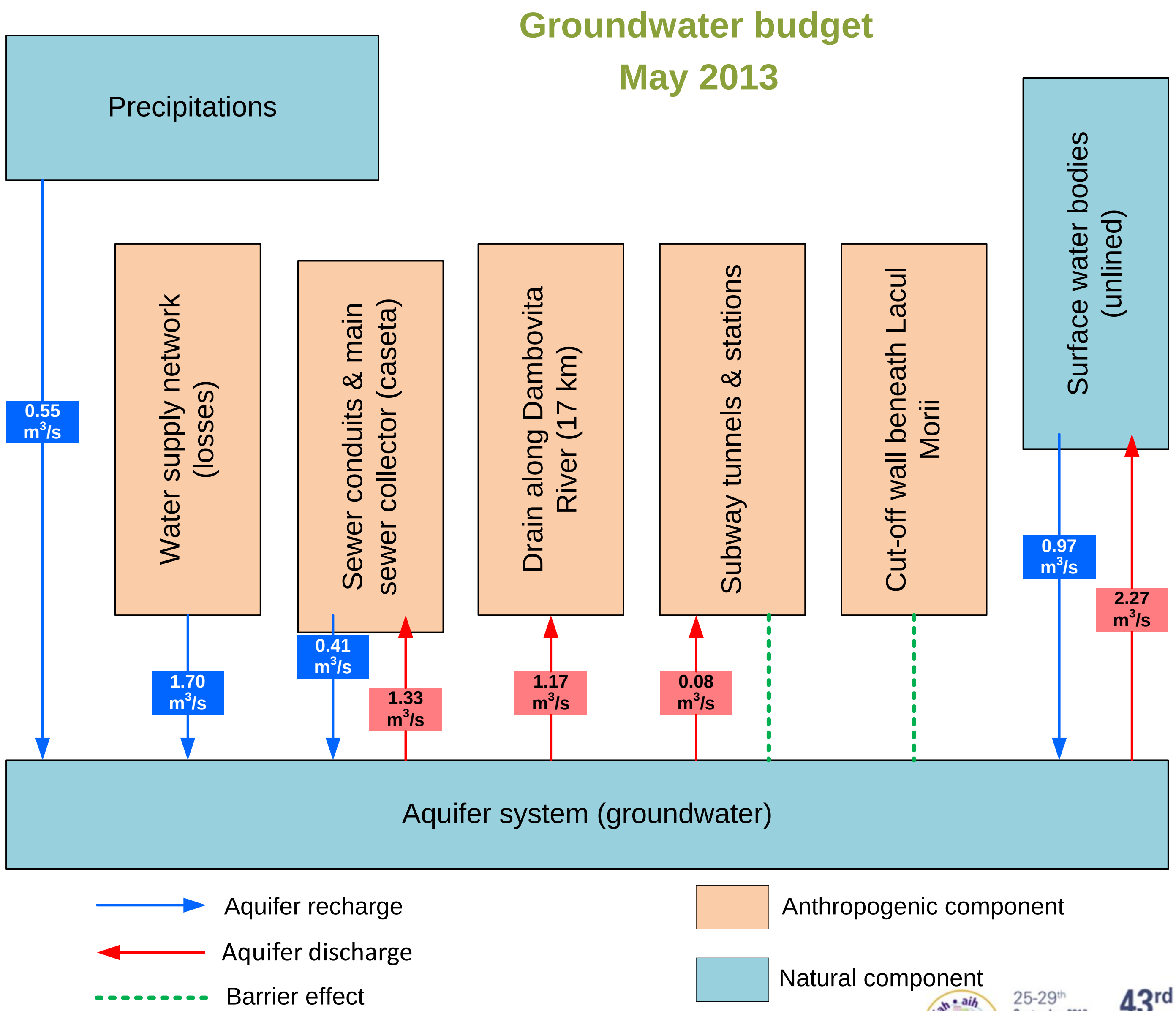
Hydrogeological model results

GROUNDWATER BUDGET



The total contribution of the groundwater infiltration into the sewer system registered at WWTP is 0.92m^3/s.

Bucharest - Hydrogeological model results

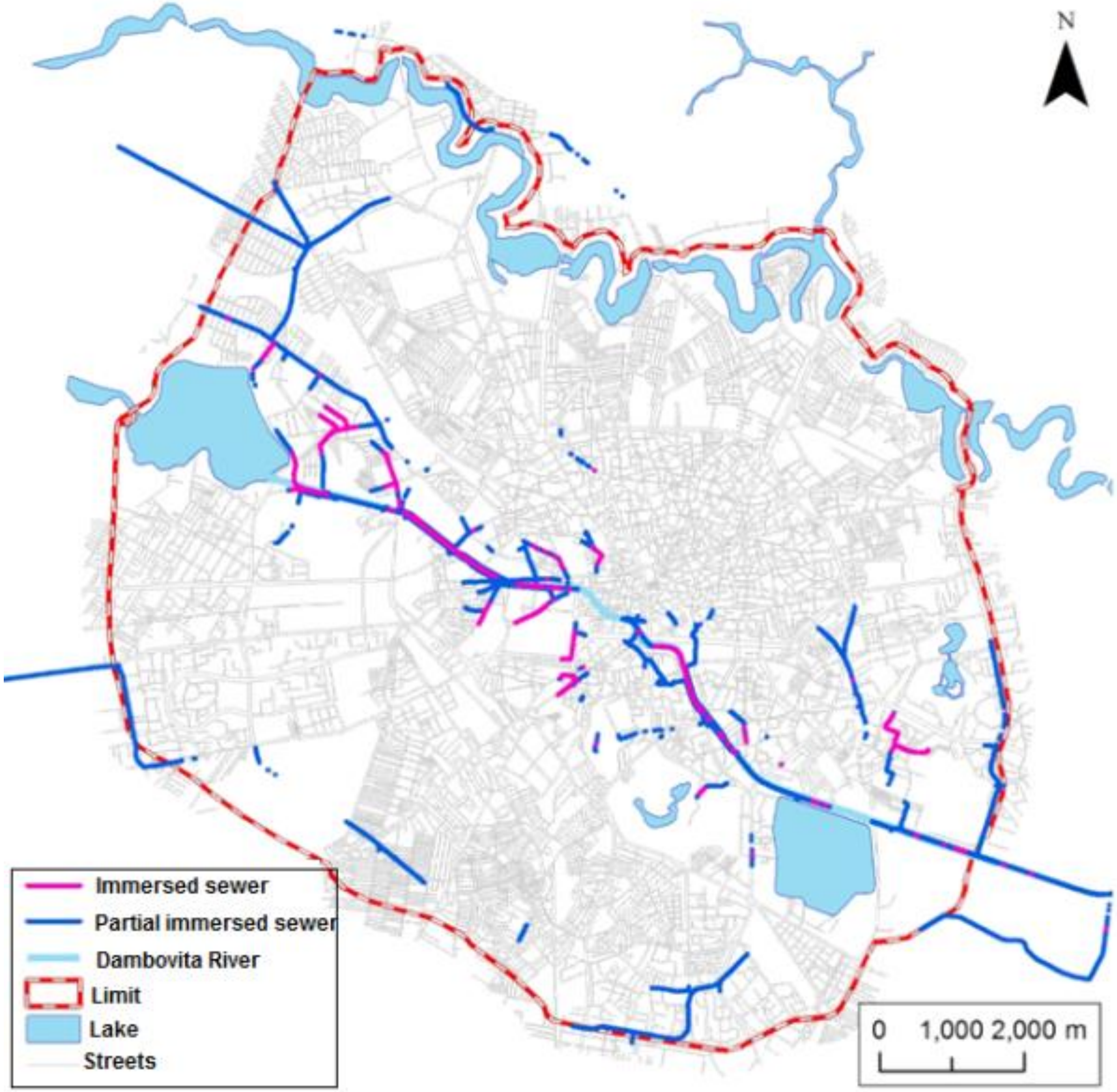


Bucharest - Hydrogeological model results

IMMERSED SEWER SEGMENTS

- **16.9km (3.5%)** of sewer conduits are **completely immersed** in groundwater
- **79.8km (16.5%)** of sewer conduits are **partially immersed** in groundwater

More than **20%** of the modeled sewer system is completely or partially immersed in groundwater

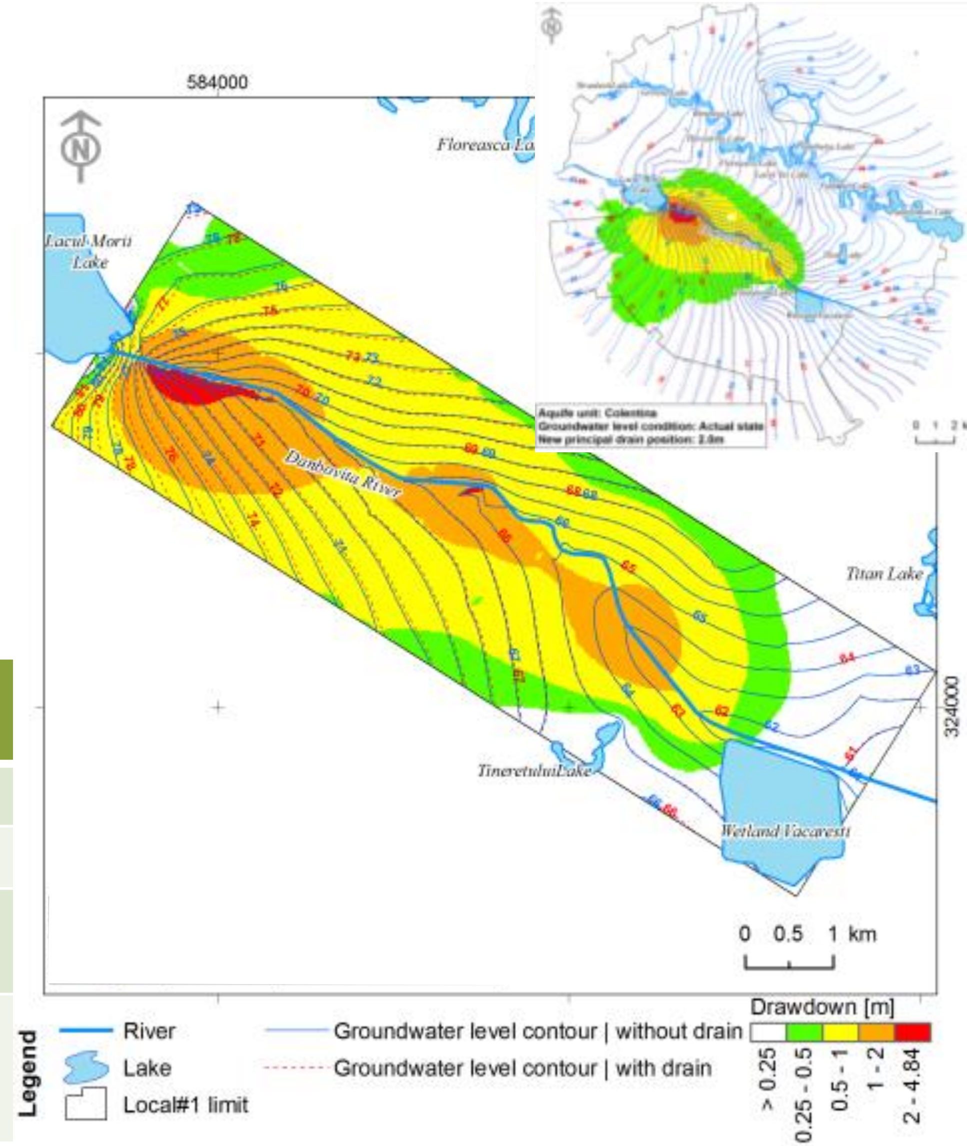


Bucharest – Urban hydrogeological solutions

Lowering groundwater level by constructing a new groundwater drainage system near sewer segments with major infiltration problems

→ Reduce infiltration into the sewer system but increase exfiltration (impact on groundwater quality), possible structure instability (subsidence, dif. settlements), etc.

Component	Groundwater recharge	Groundwater discharge
Water supply network	-	-
Sewer system	13% increase	35% decrease
Unlined surface water bodies	3% increase	2% decrease
Groundwater drainage system under Dambovita Riv.	-	18% decrease



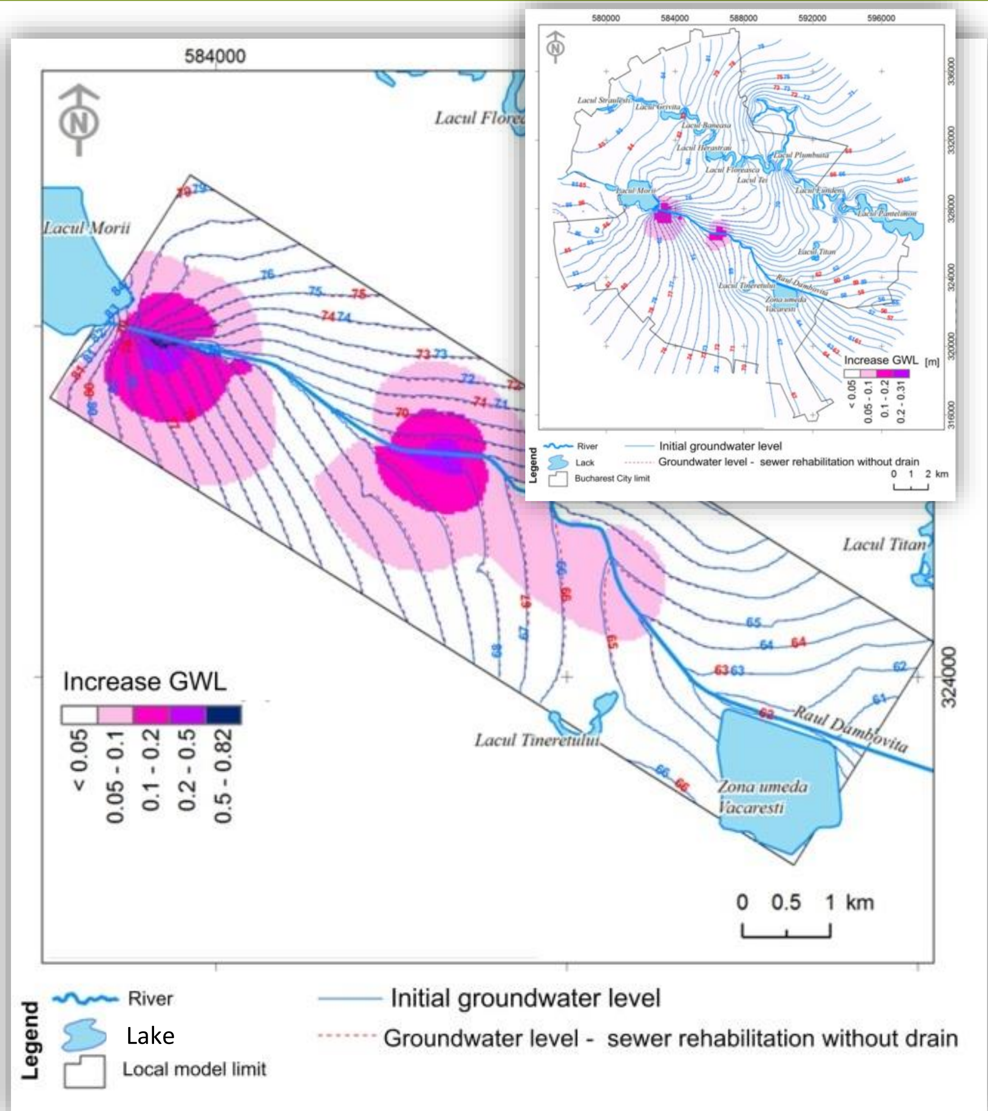
Bucharest – Urban hydrogeological solutions

Rehabilitate sewers with major infiltration problems (eliminate the associated sink)

→ Increase groundwater level

→ Increase infiltration and reduce exfiltration in un-rehabilitated sewers

→ Possible structure instability, etc..



Component	Groundwater recharge	Groundwater discharge
Water supply network	-	-
Sewer system	1% decrease	2% decrease
Unlined surface water bodies	<1% increase	<1% decrease
Groundwater drainage system under Dambovita Riv.	-	1% increase

Bucharest – Urban hydrogeological solutions

Rehabilitate defective sewer conduits AND construct a New drainage system near rehabilitated sewers

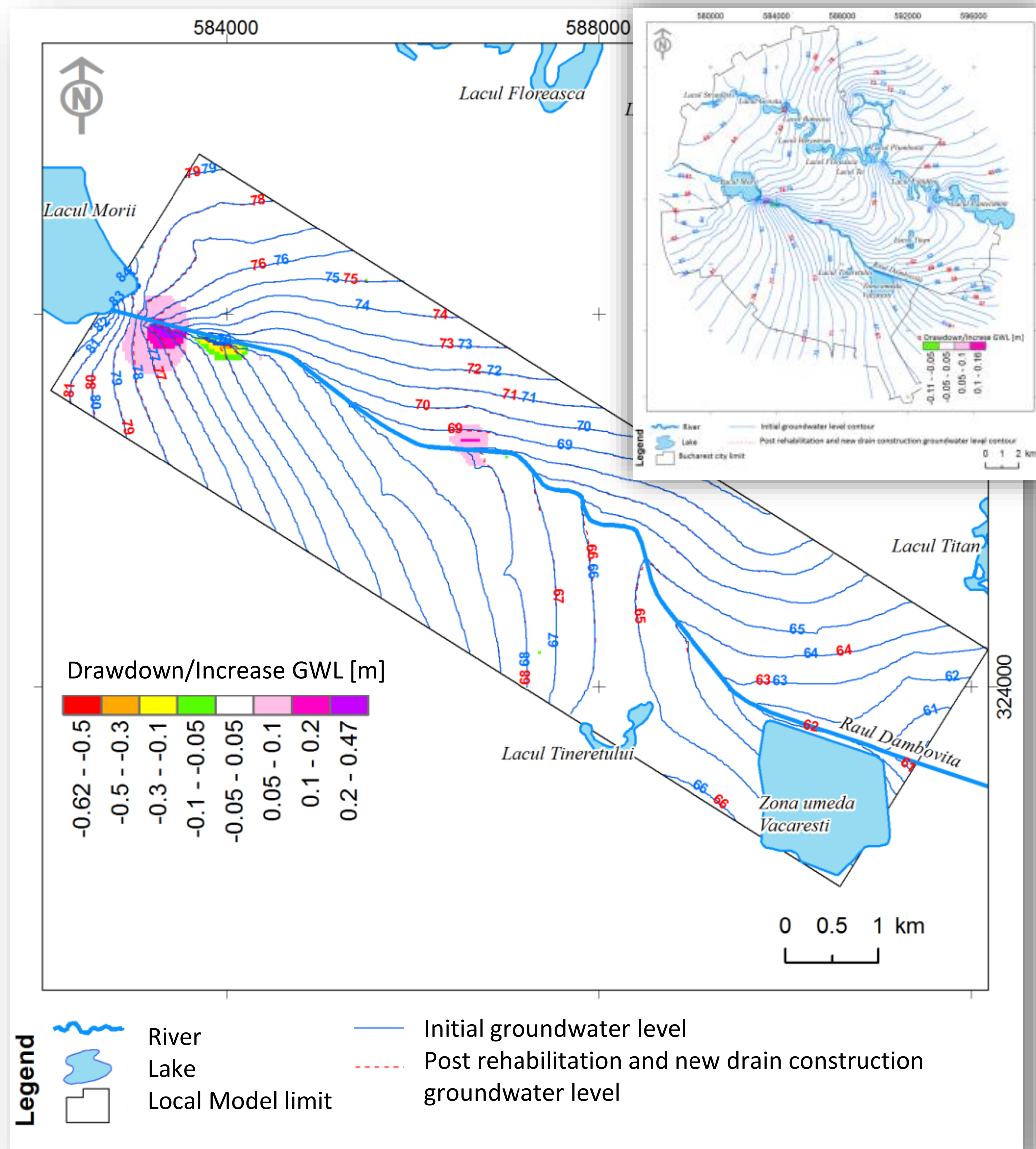
- Neutralize changes in groundwater after rehabilitation by installing a new drainage system
- Preserving groundwater level :

→ Reduced infiltration

→ Low impact on aquifer system

and interacting elements

Component	Groundwater recharge	Groundwater discharge
Water supply network	-	-
Sewer system	1% decrease	3% decrease
Unlined surface water bodies	0% neutralized	<1% decrease
Groundwater drainage system under Dambovita Riv.	-	0% neutralized



Conclusions

- Managing the aging process of infrastructure elements & developing new ones is an significant challenge in modern cities

- Tools and methodologies should allow the representation in three dimensions of the geological record heterogeneity and of its spatial distribution as well as the interaction between groundwater and the urban infrastructure.

- Hydrogeological models can provide a reliable process-based assessment to support subsurface urban planning.

- Integrated urban water management practices have to systematically be applied in modern cities

Bucharest - Solutions

Lowering groundwater level by reducing recharge from water supply network

- Losses from water supply network constitute an important groundwater recharge source in Bucharest
- Reducing the associate recharge (rehabilitating the water supply network)

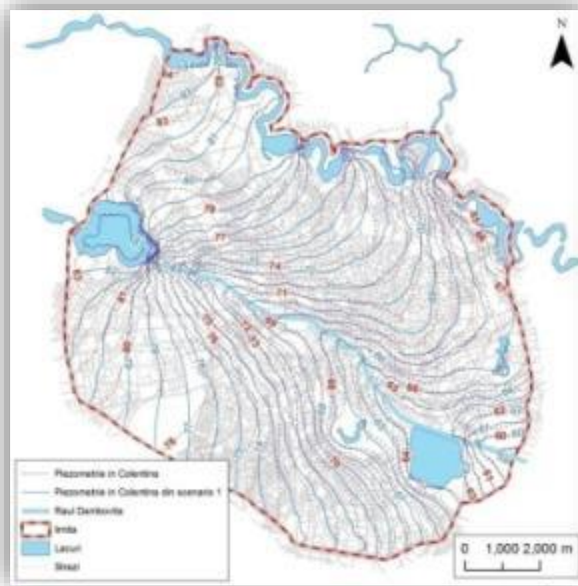
→ Lower groundwater level

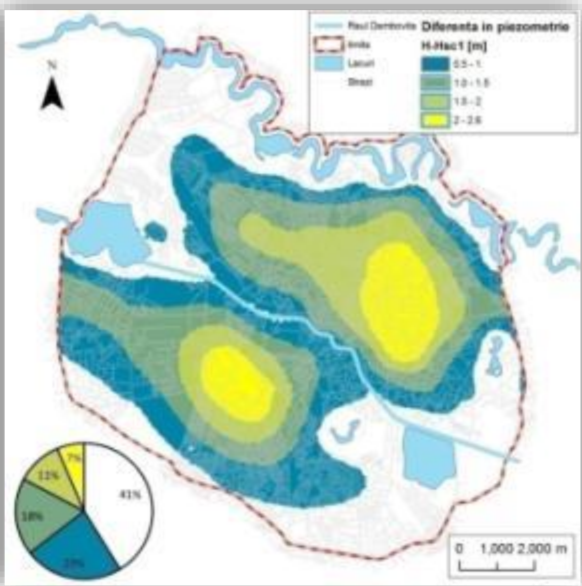
→ Reduce infiltration to the sewer system

→ Increase exfiltration (quality issue),

→ possible structure problems (subsidence), etc..

e.g. 50% reduction of losses from water supply network

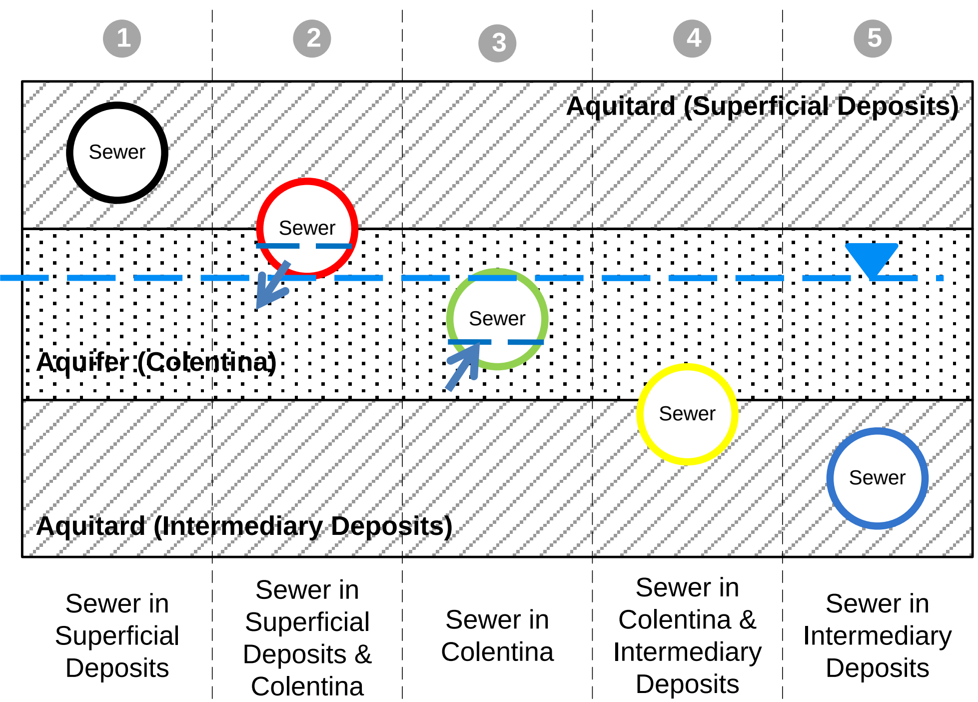


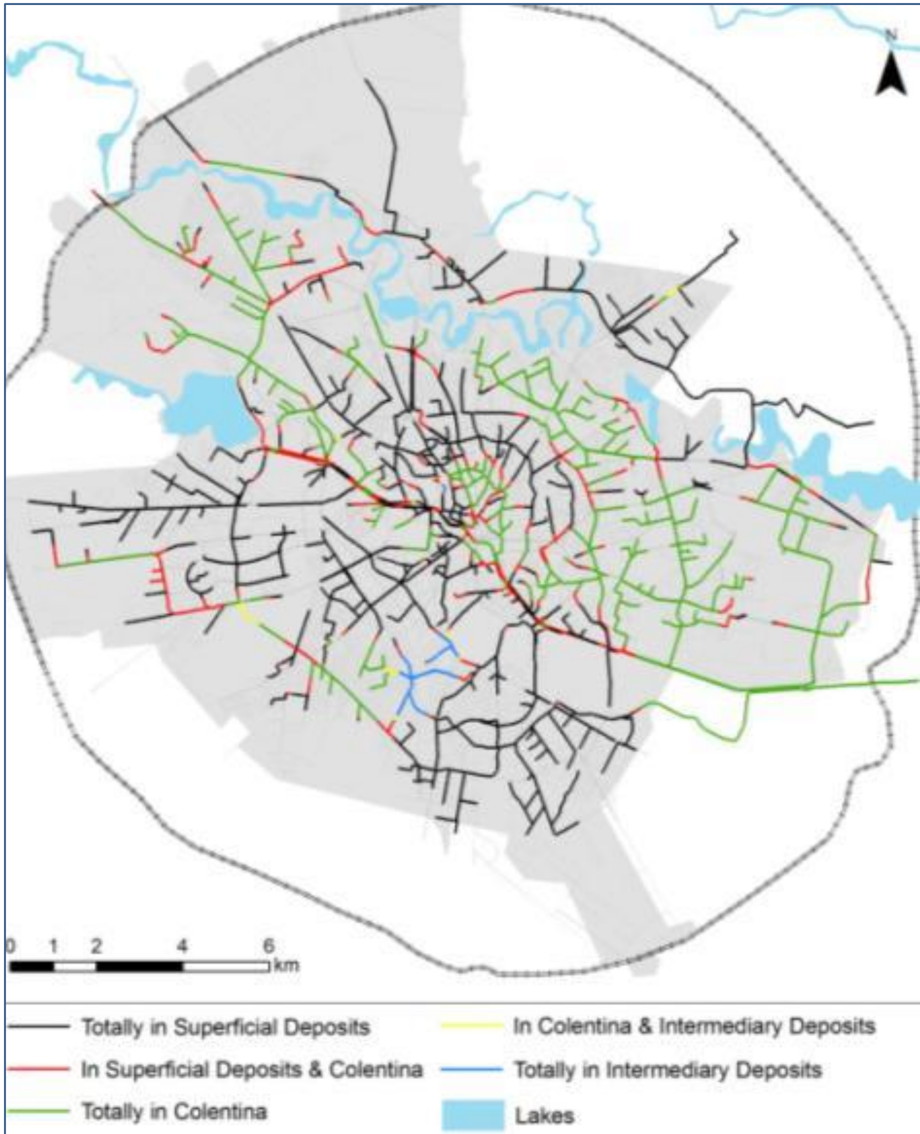


Component	Change in groundwater recharge	Change in groundwater discharge
Water supply network	50% decrease (rehabilitation)	-
Sewer system	14% increase	27% decrease
Unlined surface water bodies	29% increase	19% decrease
Groundwater drainage system beneath Dambovita Riv.	-	15% decrease

Geological model intersection with infrastructure elements

The position of the sewer conduits and their potential hydraulic connection with the aquifer strata



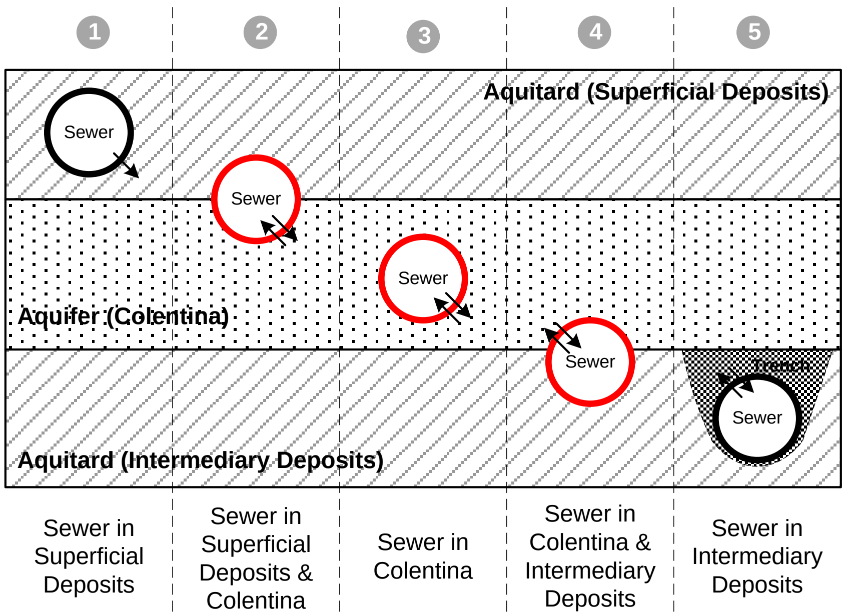


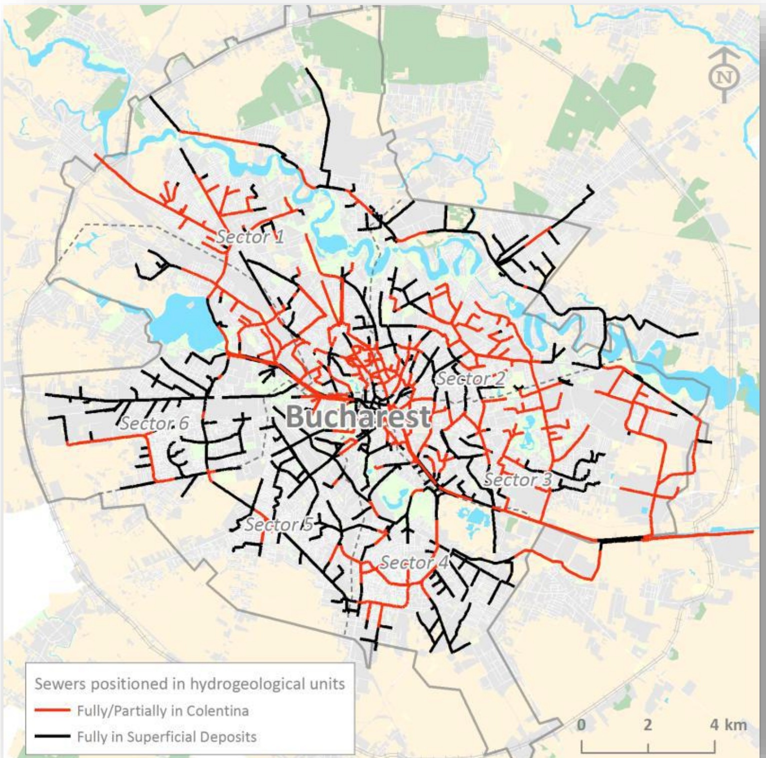
Data and approach

GROUNDWATER–SUBWAY INFRASTRUCTURE INTERACTION

Sewers modeling using **leakage factor approach under the following assumptions:**

- All sewers might have defects
- **Uniform distribution of defects along each sewer**
- Defect area is **proportional to sewer's wetted perimeter**
- Sewers in the Superficial Deposits are subjected to **exfiltrations**
- Sewers partially or totally in the aquifer unit Colentina can exhibit **infiltration or exfiltration**





Data and approach

GROUNDWATER–SUBWAY INFRASTRUCTURE INTERACTION

Sewers located above the aquifer unit

Exfiltration (leakeage) flow rates

$$Q_{exf} = K \cdot \frac{\Delta H}{B} \cdot \left(W_p \cdot L\right) \cdot \%_{leaks}$$

Qexf [m3/day] is the total exfiltration rate of the considered sewer segment having a length L [m] and a wetted perimeter Wp [m] generated with the water level in the sewer for the analyzed scenario, B [m] is the thickness of the clogging, K [m/day] is the hydraulic conductivity of the clogging layer, ΔH [m] is the hydraulic head difference between the water level in the sewer and the hydraulic head of the surrounding groundwater (taken to be null), and %leaks is the percentage of the leaky area from the total area generated by the wetted perimeter.

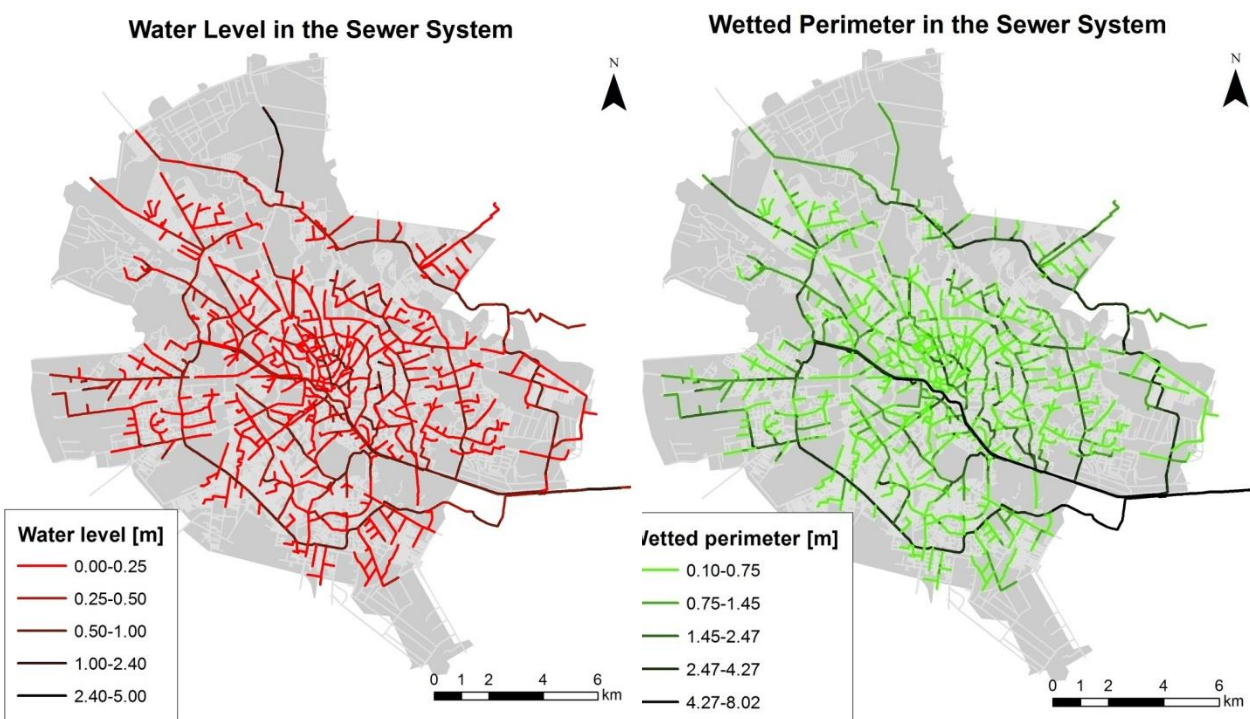
Sewer located partially or totally in the aquifer

Exchanged flow rates

$$Q = C \times \left[h - \max\left(H, Z_{SW}\right)\right] \times L$$

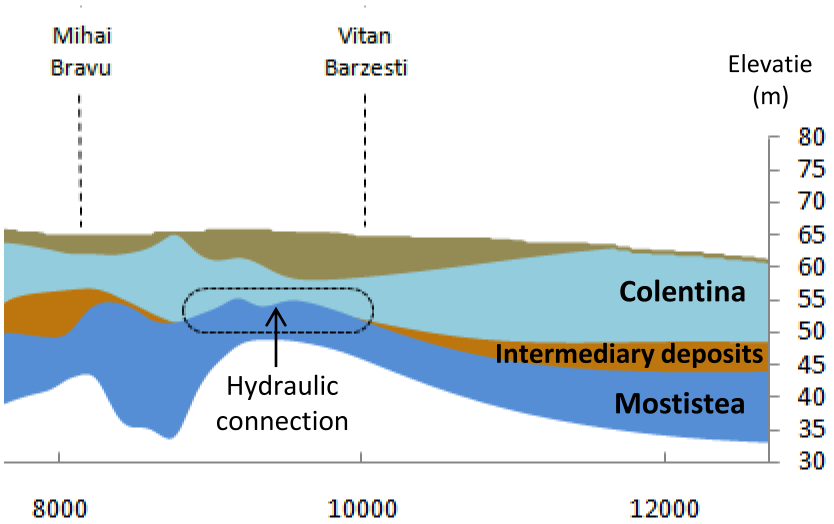
Where Q [L3/T] is the exchanged flow rate between the sewer conduit and the aquifer system; C [L2/T/L] is the sewer conduit conductance per unit of length; H [L] is the hydraulic head in the surrounding aquifer system; h [L] is the hydraulic head in the sewer; ZSW [L] is the elevation of the base of the sewer, and L [L] is the sewer length.

- Boundary condition: Cauchy
- *C values from inverse modeling*



Hydrogeological model

- **Steady state**
- **Pseudo -3D**

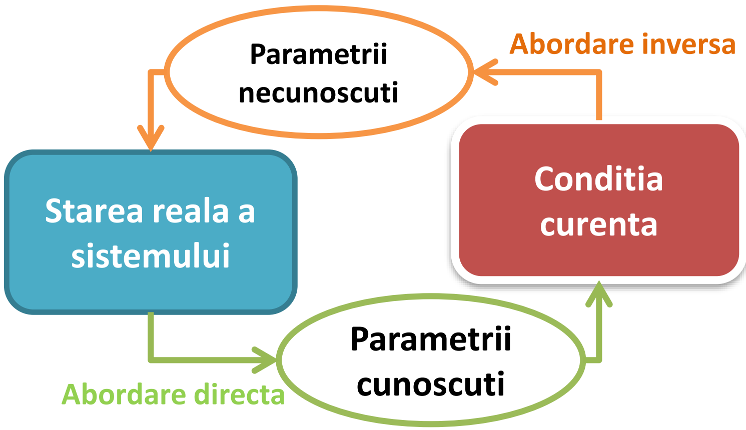


NUMERICAL METHOD

- **Finite differences -** MODFLOW, USGS (Harbaugh et al. 2000)

CALIBRATION TECHNIQUES

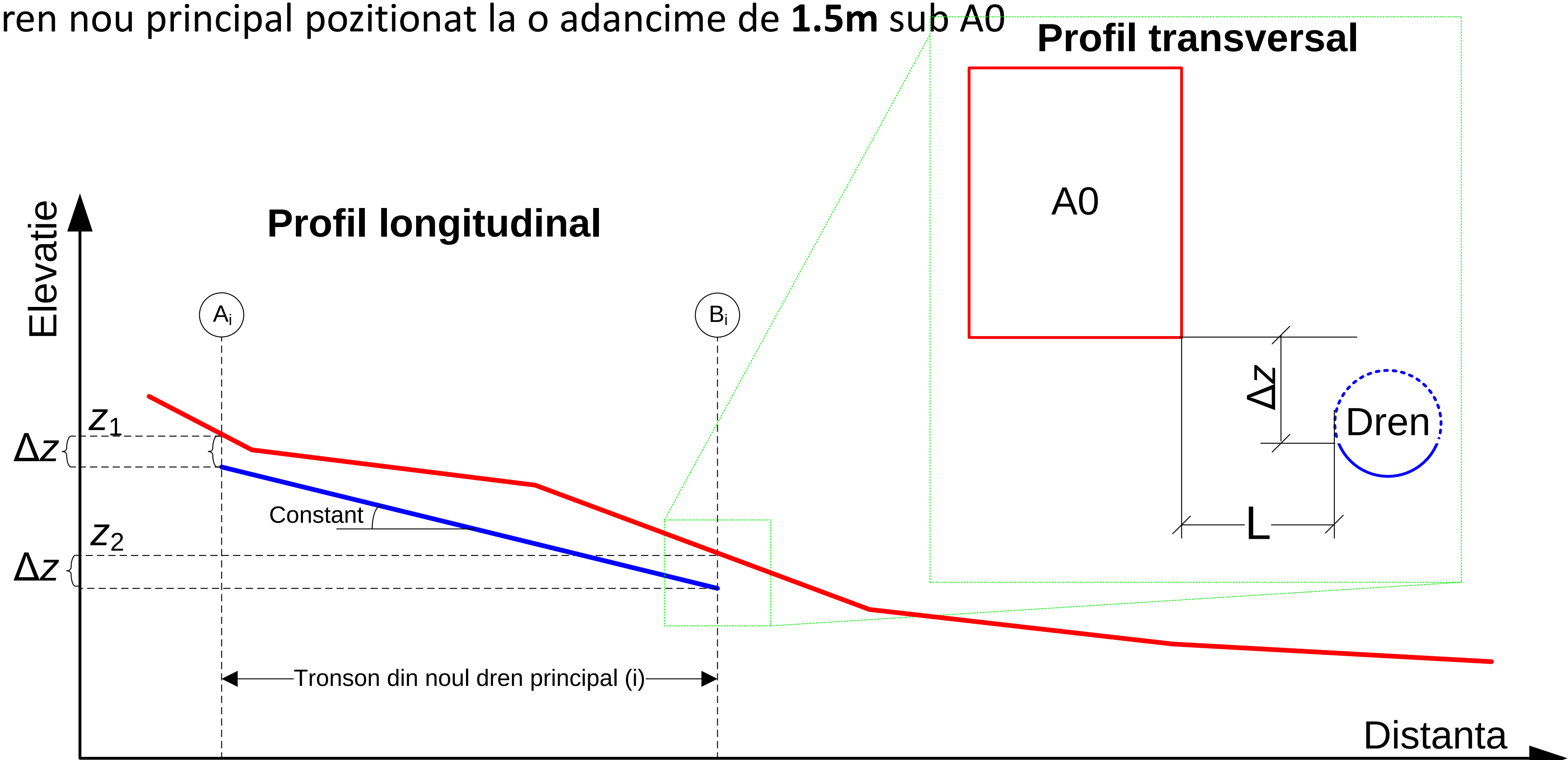
- Inverse modeling: sewer conductance values
- Pilot Points: aquifer hydraulic conductivity
- Inverse modelling: Leakage flowrates coming from sewer conduits located in the aquitard



Scenarii dezvoltate

SCENARII IN FUNCTIE DE POZITIA DRENULUI NOU

Dren nou principal pozitionat la o adancime de **1.5m** sub A0



Profil generic al colectorului A0

Tronson (i) din noul dren principal

A_i Extremitate a tronsonului (i) din noul dren principal

L: Distanta in plan dintre colectorul A0 si noul dren principal considerata ca fiind cea definita in studiul de fezabilitate