Augmented Resilience of Water Distribution Systems following Severe Abnormal Events

Olivier Piller, Fereshte Sedehizade, Thomas Bernard, Mathias Braun, Nicolas Cheifetz, Jochen Deuerlein, Martin Wagner, Emmanuel Lapébie, Iris Trick, Jean-Marc Weber, et al.

RESIWATER

INNOVATIVE SECURE SENSOR NETWORKS AND MODEL-BASED ASSESSMENT TOOLS FOR INCREASED RESILIENCE OF WATER INFRASTRUCTURES

Augmented Resilience of Water Distribution Systems following Severe Abnormal Events

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Federal Ministry of Education and Research

O. Piller, F. Sedehizade, T. Bernard, M. Braun, N. Cheifetz, J. Deuerlein, M. Wagner, E. Lapébie, I. Trick, JM Weber, and C. Werey

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Water Distribution Networks are Large Interconnected Complex Systems

Introduction

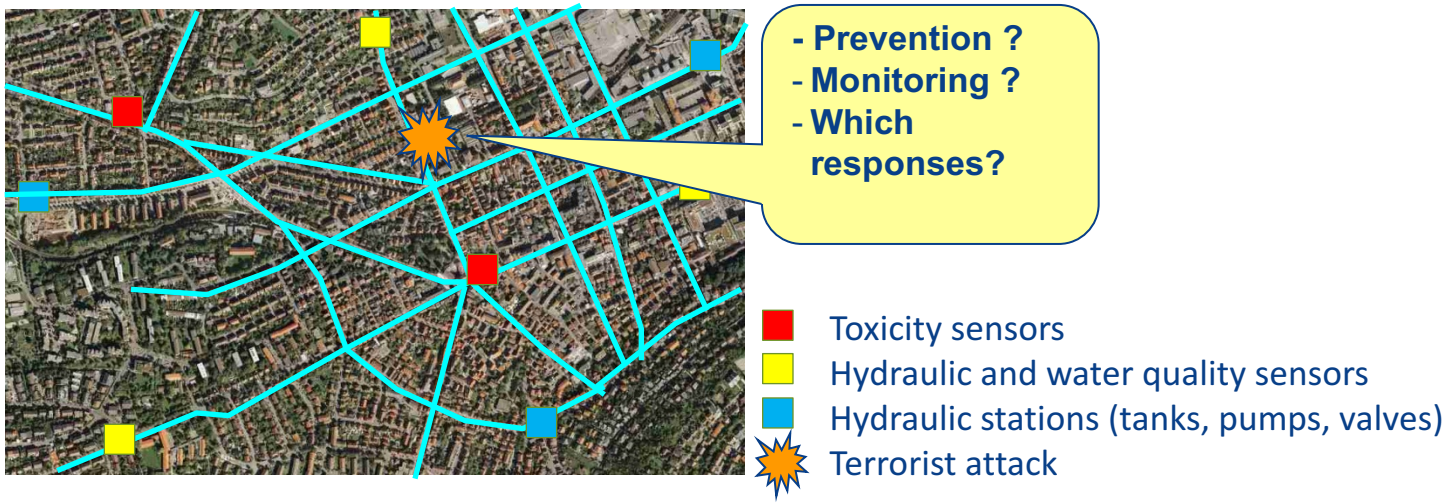
CRITICAL INFRASTRUCTURE PROTECTION

Drinking water distribution networks are exposed to natural or human-made disasters:

Terrorist attacks, cascade effects, major industrial accidents or natural disasters…

Not only are contaminant warning systems important, but so is water utility preparation, maintenance, training…

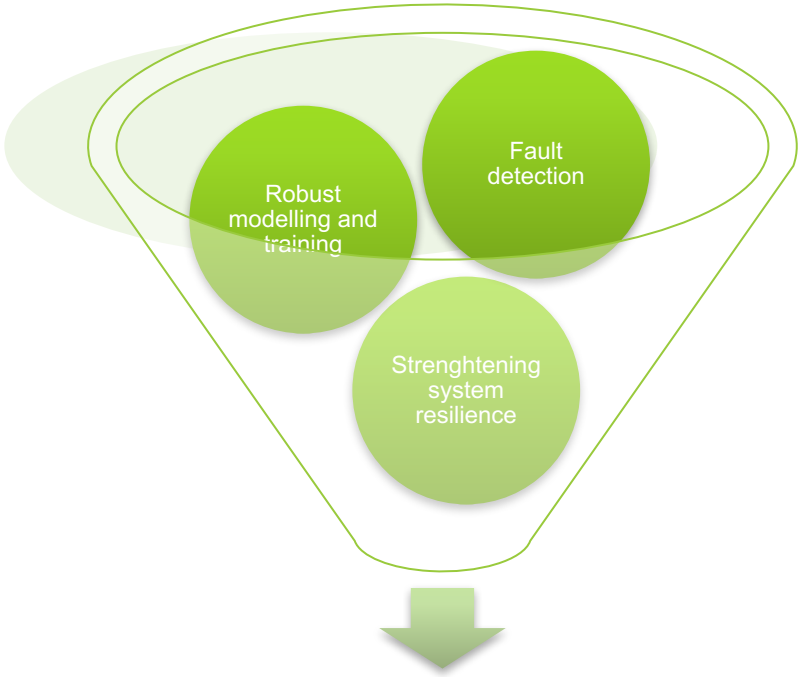
The detection of faults and the capacity to return quickly to a normal state after failures and interruption of services are essential for water utilities.



Introduction

OBJECTIVE

Prepare water utilities to crisis management by improving the system resilience with respect to 3 specific case studies: system failure, water quality deterioration and cascade effects between water, energy and IT infrastructures.



1. Project consortium and work plan
2. The resilience framework
3. High-performance sensors
4. Self-learning Monitoring System
5. Robust hydraulic simulation tools and training simulator
6. Main conclusions

Project consortium and work plan

PARTNERS (JULY 2015 – JUNE 2018)

End-users

Berliner Wasserbetriebe (BWB, Germany)

Eurométropole de Strasbourg (EMS, France)

Veolia Eau d'Ile-de-France (VEDIF, France)

Engineering Consulting Company

3S Consult GmbH (Germany)

Laboratories and Research Centers

Irstea (France)

Engees GESTE and ICUBE (France)

DVGW-Technologiezentrum Wasser TZW (Germany)

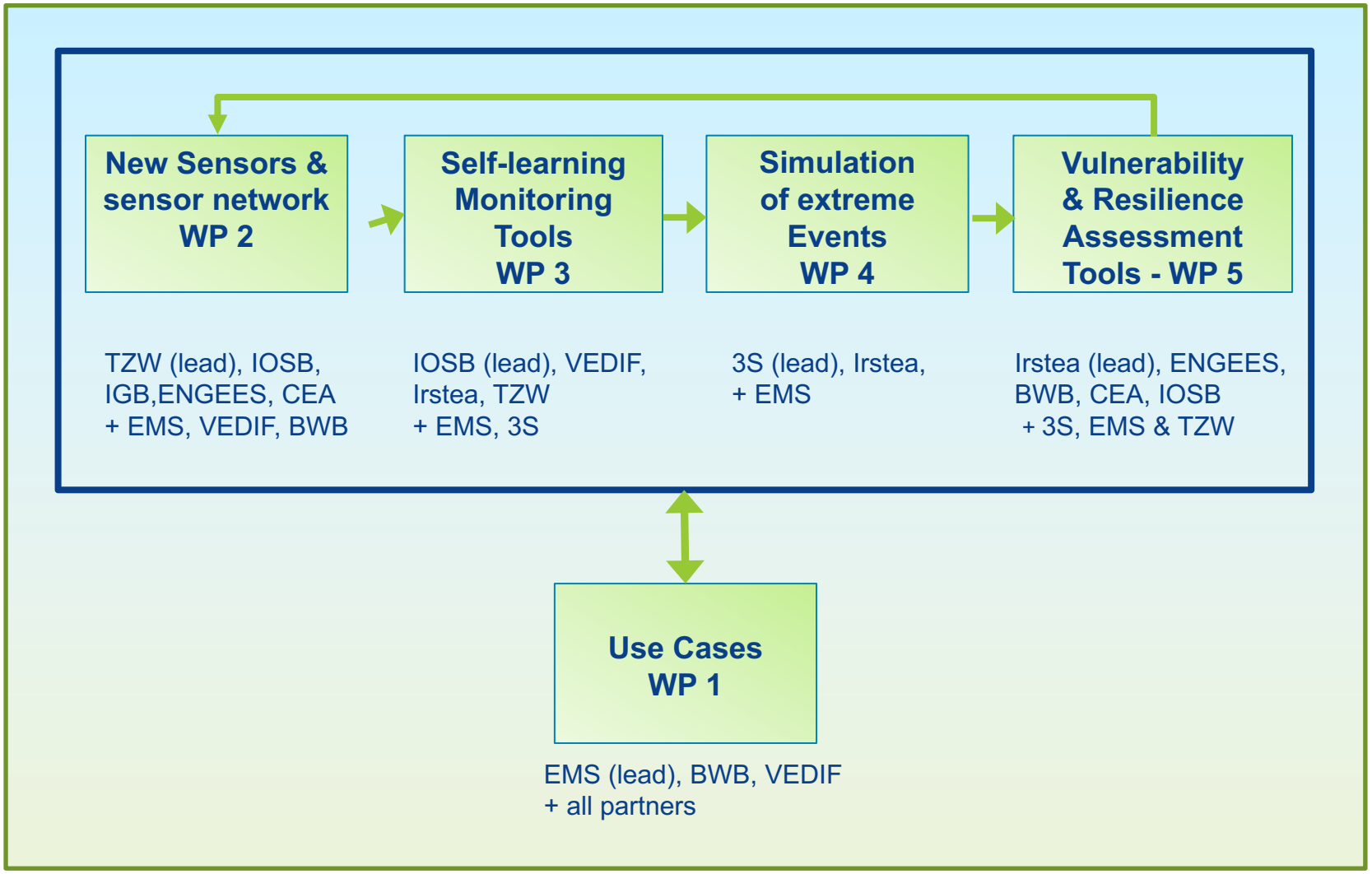
Fraunhofer Institute IOSB (Germany)

Fraunhofer institute IGB (Germany)

CEA DAM (France)

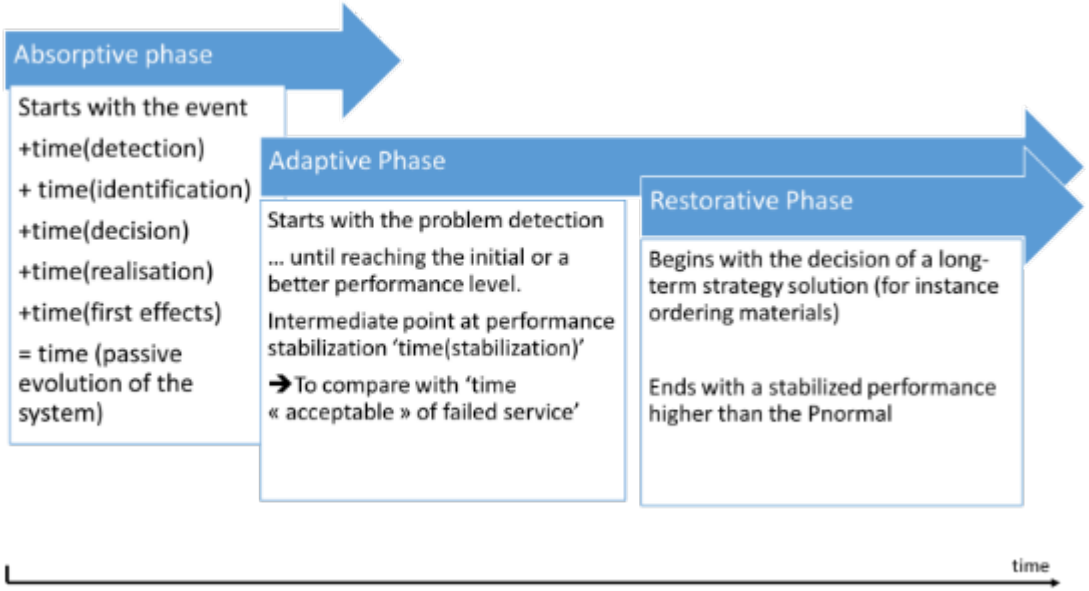
Project consortium and work plan

SCIENTIFIC AND TECHNICAL PROGRAM



WP5: The resilience framework

THREE RESILIENCE COMPONENTS



Timeline for the three resilience phases in the ResiWater project

VULNERABILITY and RESILIENCE signatures are assessed on a simple three-level scale:

☺ 😐 ☹

The resilience framework

END USERS CASE STUDIES

Case Studies Berlin:

1. Cut off of two waterworks by a regional power cut
2. Contamination (non-pathogen bacteria)
3. Cyber attack at control systems (stuxnet)

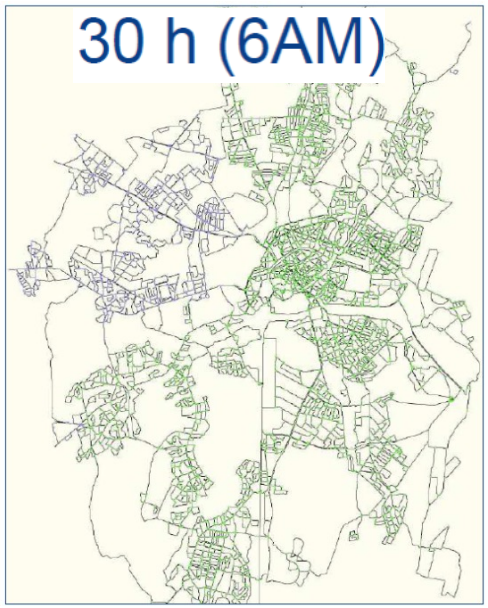
Case Studies Strasbourg:

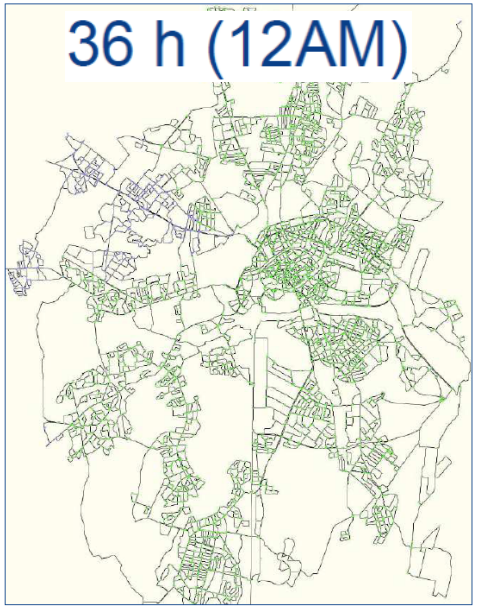
1. Main production unit stopped by major flood event
2. Water quality degradation by intentional network contamination
3. IT attack: power plant stopped, event masked by false data

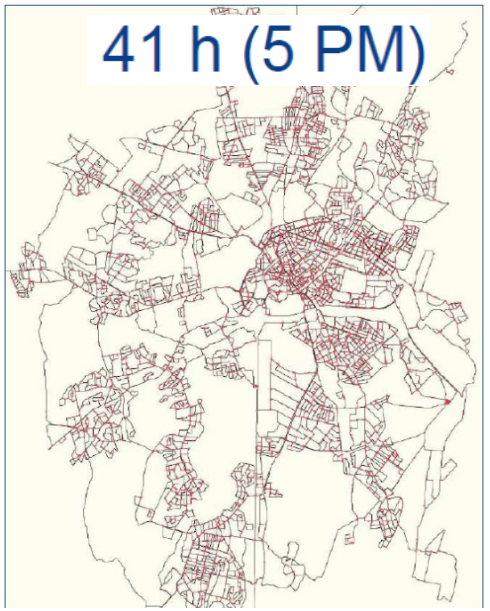
Case Studies VEDIF (Paris):

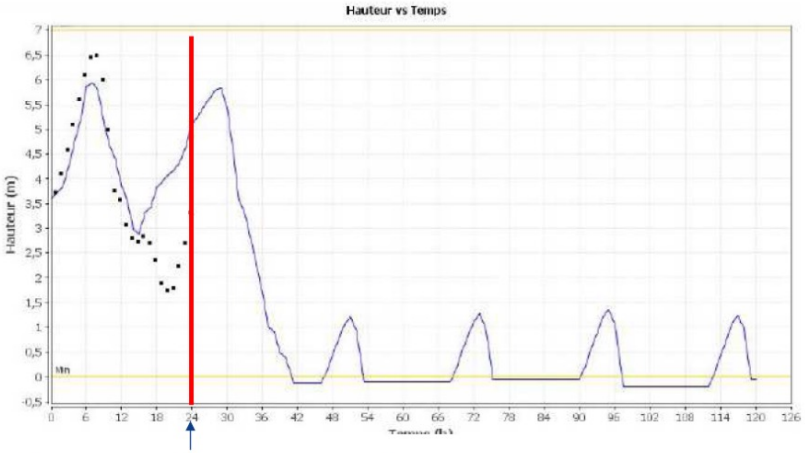
1. Fire Hydrants operation in “Street Pooling” situation;
2. Terrorist attack on network in the situation of a major International Event
3. Centennial Flood
4. Above Centennial Flood – Establishment of the major crisis emergency plan

EMS (1): Main production unit stopped by major flood event









Polygone plant stopped

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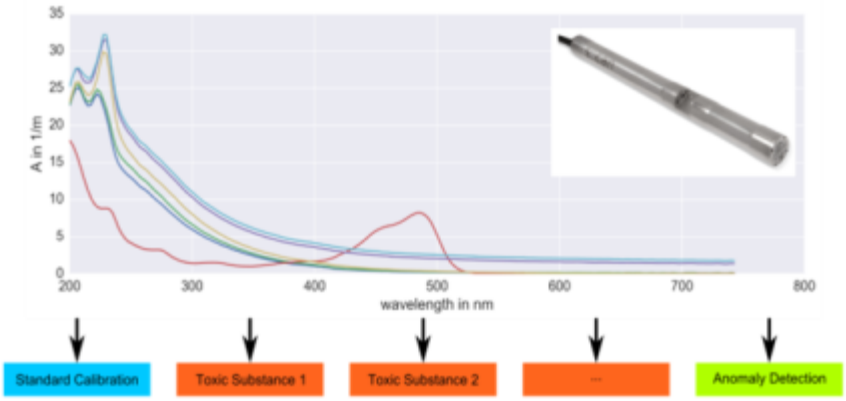
WP 2: High-performance sensors

3 NEW SENSORS

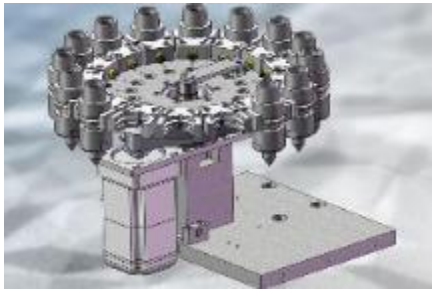
Investigation and partly development of new sensors for online-Monitoring

- Biological Sensor system « AquaBioTox »
- Spectroscopic sensors
- Low-Cost through-flow measurement system

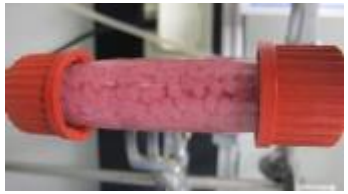
Development of a concept for integrated and secure sensor networks



Spetroscopic Sensors



Revolving cartridge system for several biological reactors



Red colonies of the biosensors cultivated on agar medium

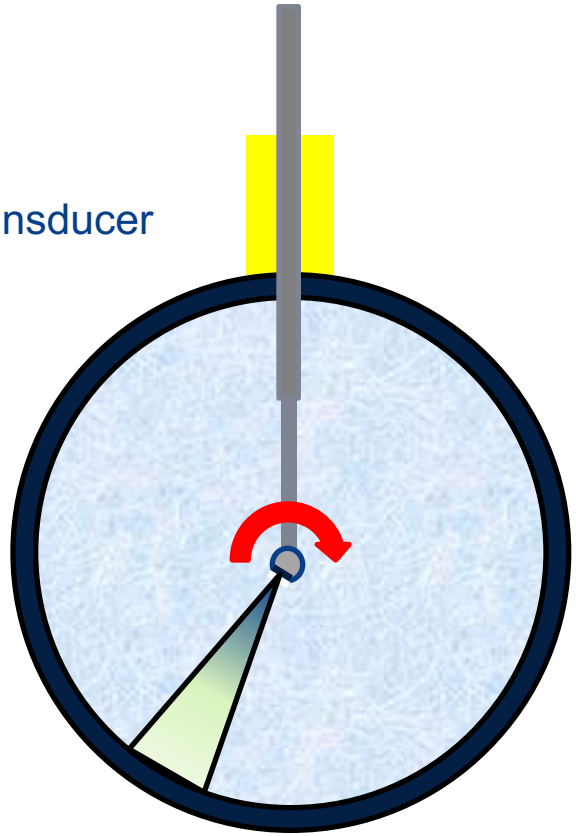
Low-Cost through-flow measurement system

LIGHTER FLOW METER USE THE NETWORK PIPES

Method

Using an ultrasonic pulse

- Ultrasonic beam from a rotating (stepping motor) transducer
- Measuring distance between sensor and wall



Tasks

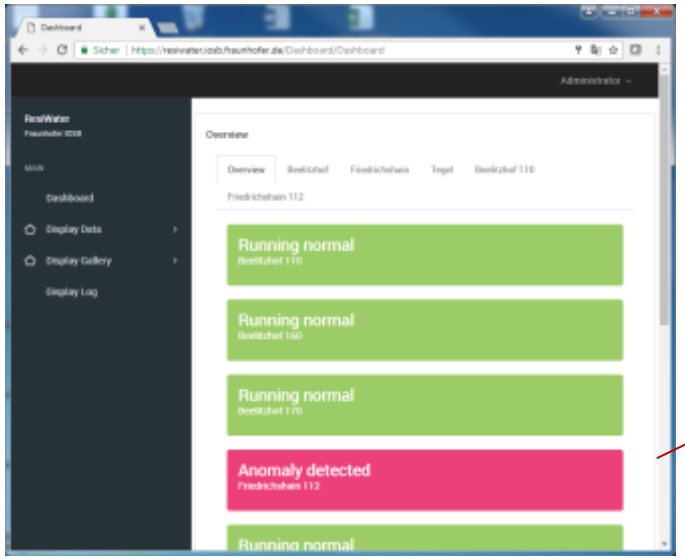
- Mobility of transducer
- Signal processing algorithm
- Area reconstruction algorithm
- Laboratory tests (Accuracy, resistance to pressure)
- Field tests (Strasbourg, …)

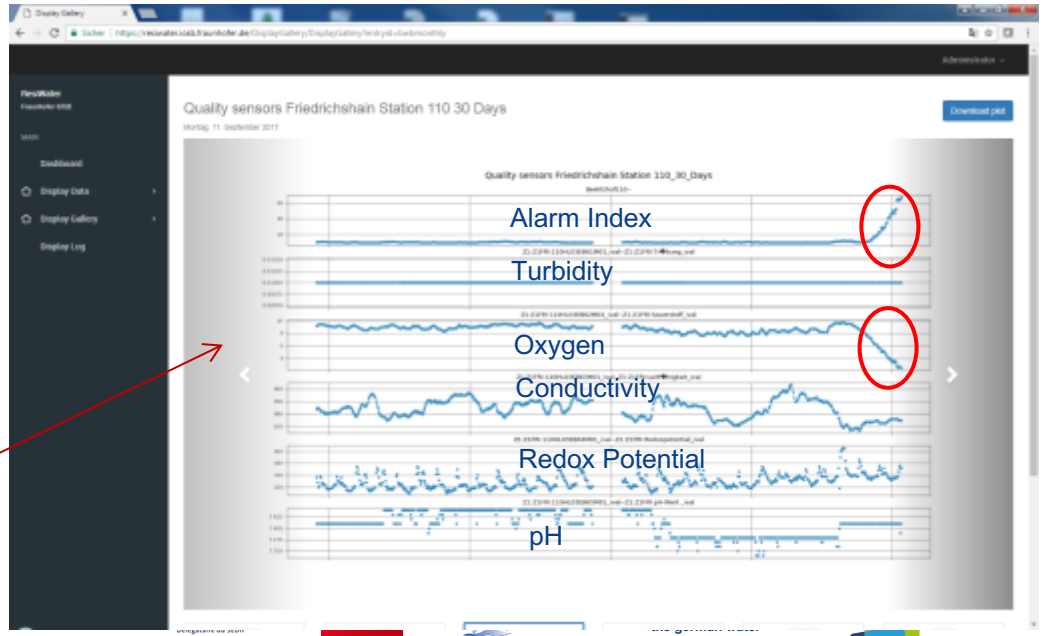
WP 3: Self-learning Monitoring System

EVENT DETECTION PLATFORM USING MACHINE LEARNING ALGORITHMS

Aim: Reliable and quick event detection in water distribution systems

- Plug-in software architecture for flexible data integration
- Web-based frontend for multi-user access
- Self-learning event detection algorithms





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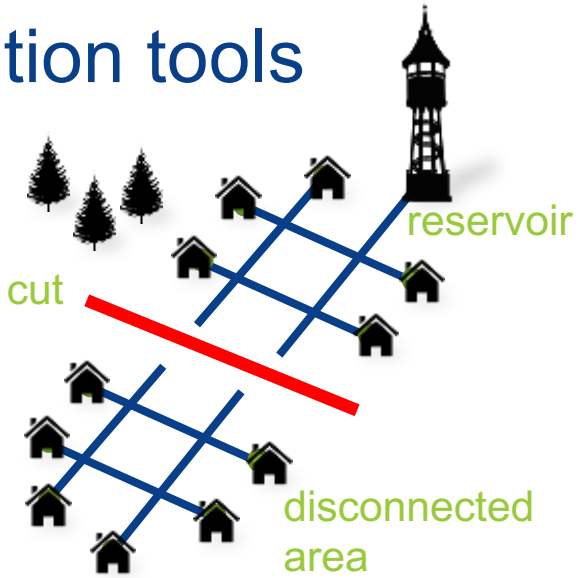
WP 4: Robust hydraulic simulation tools

AND TRAINING SIMULATOR

Extreme events may cause

- Decomposed systems
- Insufficient pressures
- Control system failures

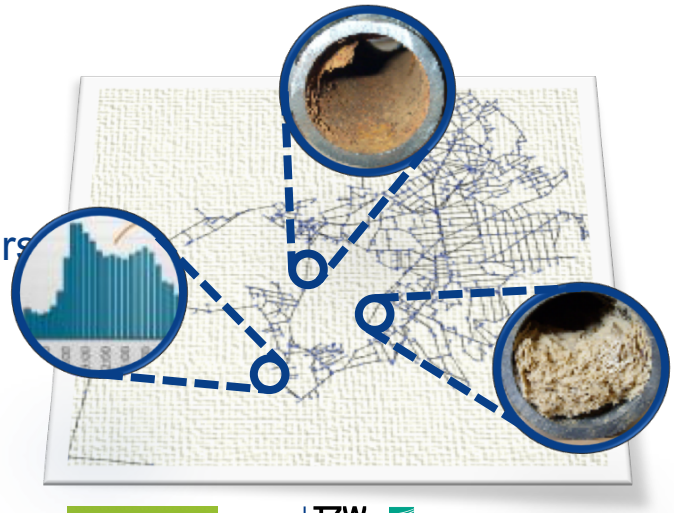


Objectives

- Development of robust solver
- Stable convergence for deficient systems
- Training simulator

Accompanying uncertainty analysis

- Complex network models with many parameters that are inherently uncertain
- How do Parameter Uncertainties influence the results of deterministic simulation?



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the german water center 3S Consult GmbH
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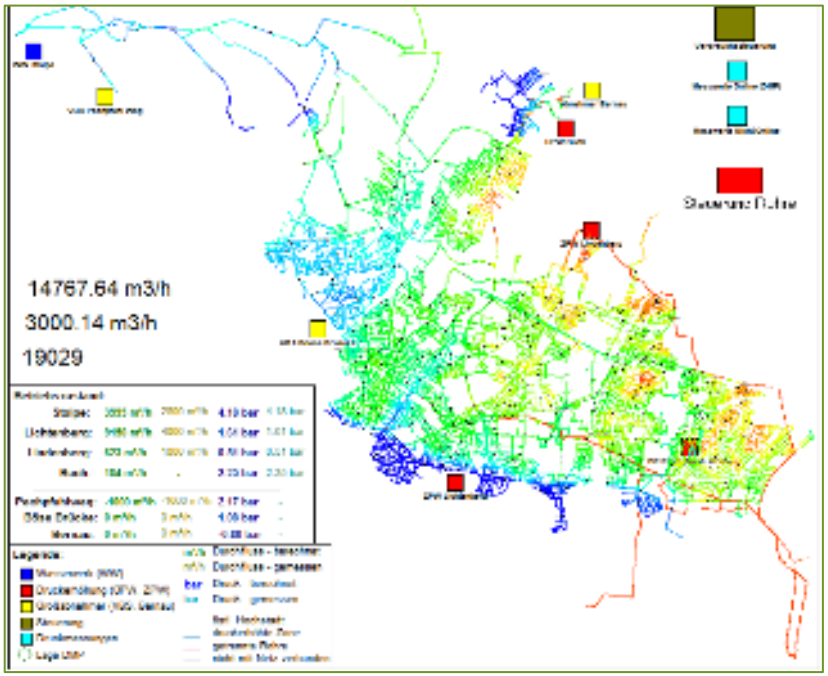
WP 4: Robust hydraulic simulation tools

AND TRAINING SIMULATOR

Example: Large area with insufficient pressure after burst of trunk main



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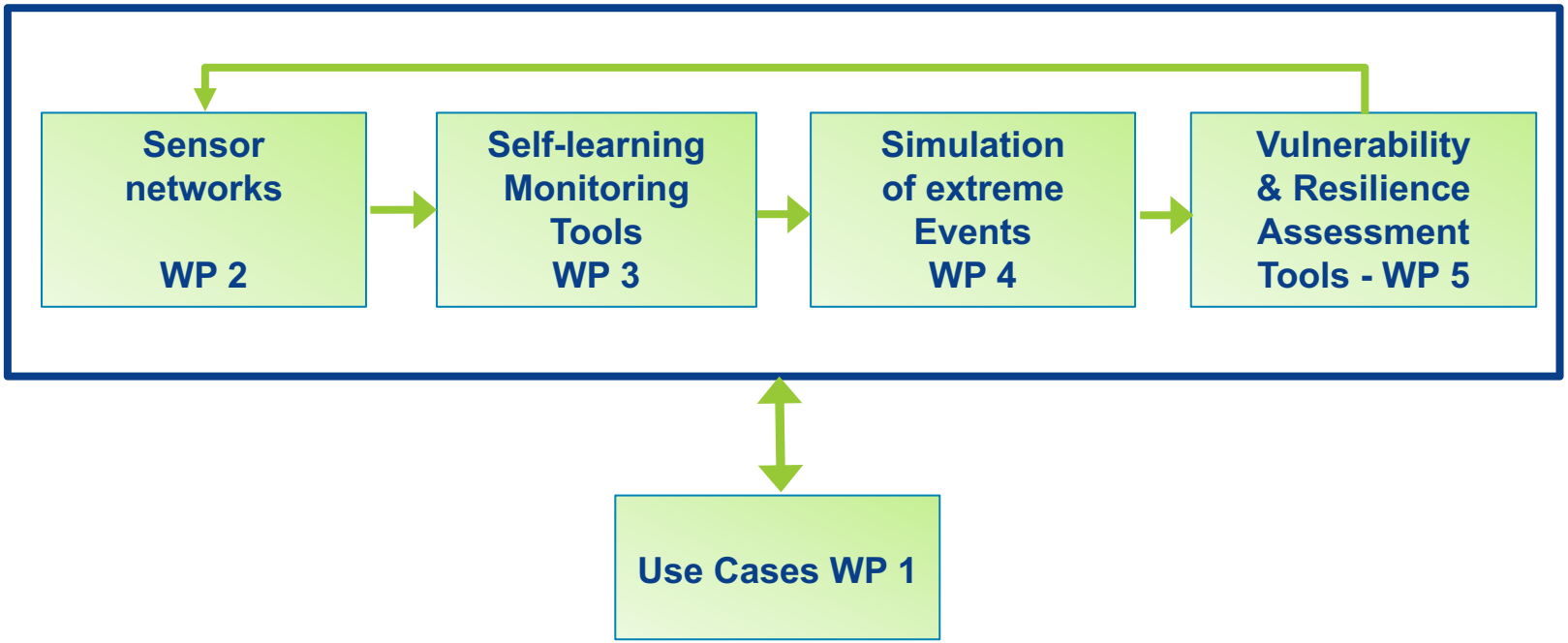
Conclusions

OBJECTIVE AND METHOD

Prepare water utilities to crisis management by improving the system resilience with respect to 3 specific case studies: system failure, water quality deterioration and cascade effects between water, energy and IT infrastructures.



Conclusions

MAIN RESULTS

✓An assessment method is adopted for the vulnerability and resilience assessments of the three project end users.

✓Three use cases per water utility: Collapse of WDS, Water Quality Deterioration and Cascade Events are specified in details.

✓New spectroscopic, biological sensors and a low-cost flow rate measurement system are under investigation in the project. They will be part of a broad and secure sensor network for monitoring the systems.

✓Other solutions were also studied in the project for the prevention and response of critical events.

- Robust modelling for training in presence of large disconnected network parts,
- Enhanced event detection by PCA and Gaussian mixture model (oscillating data and drifting sensor data)
- Economic evaluation by cost benefit analysis.

Thank you for your attention!
Any questions?

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