Estimate combined sewer overflows in real-time at a city scale: Case Helsinki

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INTRODUCTION

HOW COULD WE ESTIMATE COMBINED SEWER OVERFLOWS ANYWHERE IN THE SEWER SYSTEM IN REAL-TIME?

BACKGROUND: Helsinki Region Environmental Services Authority (HSY), Finland, is a joint municipal assembly providing waste management and water services for 1.2 million people in the Helsinki metropolitan area and operates the largest WWTPs in Nordic countries. Uniquely, HSY uses only model-based simulations to estimate the quantity and quality of Combined Sewer Overflows (CSO) from the network into the Baltic Sea. HSY reports the results to the Environmental Authority quarterly as part of their environmental permit.

CHALLENGE: HSY's earlier hydraulic models could not provide valuable results and analysis at the system level due to the extensive and detailed sewer system. A new approach was needed. A critical goal was to develop an efficient, flexible, and highly automated modeling process to improve quality and save the modeler's time while enabling more detailed data analytics.

SOLUTION: HSY adopted a modern modeling platform to achieve a more cost-effective and holistic system analysis. The results demonstrate an advanced way to analyze, report, and prepare for combined sewer overflows (CSO) anywhere in the combined sewer system. By the end of 2022, Fluidit will develop the model to support real-time CSO simulations that will be used to give timely health and safety warnings to the residents should CSOs occur.

METHODS

OVERVIEW:
HSY adopted the model-based Fluidit Storm simulation platform in 2020. HSY and Fluidit co-developed a detailed combined sewer system model. The hydraulic pipe network model and the hydrological catchment processes are fully integrated into **Fluidit Storm** software using the **Open Water Analytics** (OWA) Stormwater Management Model (**SWMM**) methodologies. The model also simulates 2D surface flooding using the **CAFLOOD** simulator. A summary of the critical details of the model is presented in Figure 1.

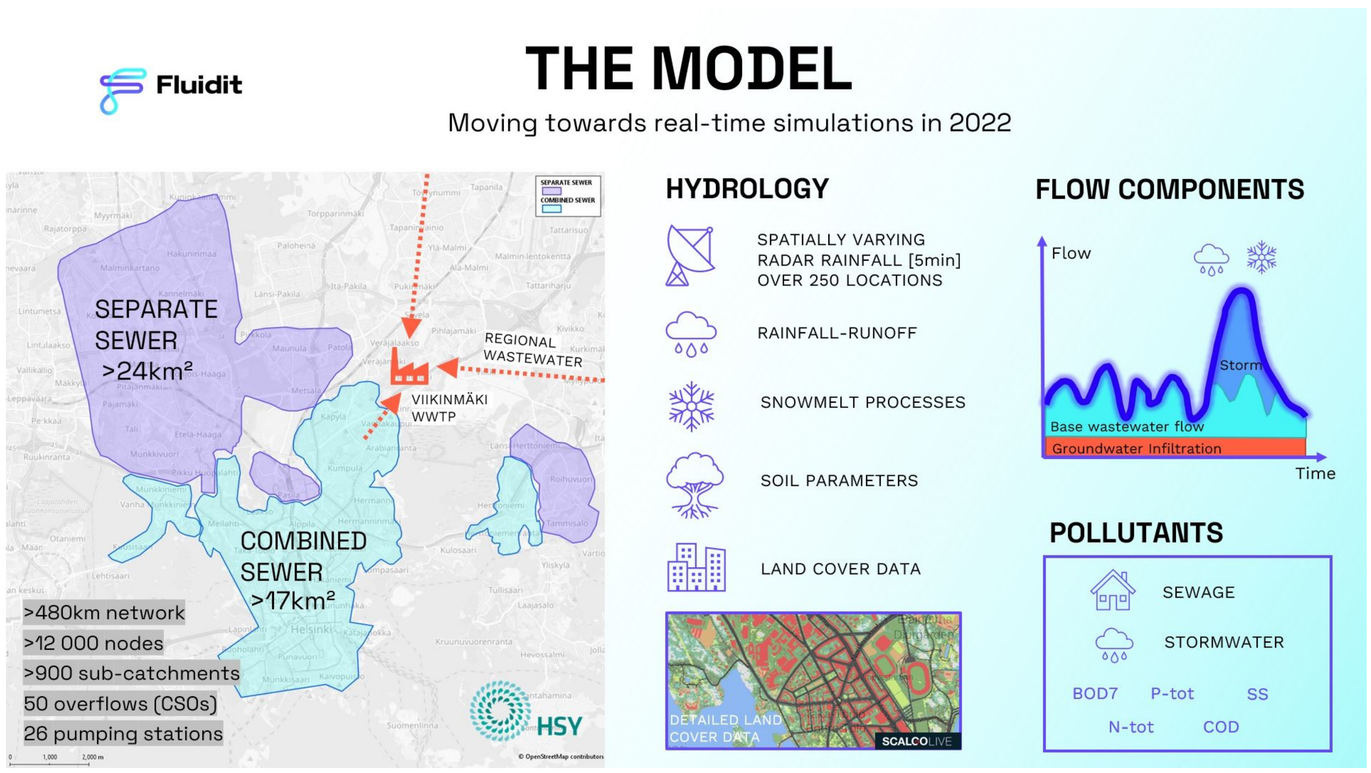

Figure 1 – Overview of the model details and methodologies (source: Fluidit Ltd)

Hydrology:
The hydrological catchment processes are simulated in great detail to enable comprehensive simulations in all seasons. For example, the model is required to respond accurately to high-intensity rainfall events in summer and varying snow melt conditions that cause a significant increase in combined sewer flow rates in spring.

Hydraulics:
The hydraulic 1D simulations use the SWMM Dynamic Wave method to include complex hydraulic phenomena such as surcharge and backflow. Various hydraulic flow components and pollutants are included in the hydraulic simulations to quantify pollutant discharges due to overflows. To plan more targeted CSO mitigation measures, the model can distinguish and quantify the sewage and stormwater components of the combined sewer flow.

Measurements:
The simulated results and direct flow measurements taken at critical locations were compared over a two-year-long period from 2019-2020. Flow measurements were available from up to 19 pumping stations providing sufficient means for model calibration. Any gaps in the measurement data were filled in with synthetic time-series generated based on average sewage flow rates, the Rainfall-Derived Inflow and Infiltration (RDII), and the groundwater flow estimates.

Real-time simulations:
The real-time simulations use Fluidit Storm's inbuilt capabilities that facilitate a direct connection to the Neuroflux system, a data analytics and visualization platform adopted by HSY. Repetitive hydraulic simulations are performed hourly using initial conditions adjusted with the most recent flow rate data sourced automatically from pumping stations. Simulated overflow results are available for viewing and analysis minutes after each simulation.

RESULTS

Adopting a more robust modeling platform for the CSO analysis and reporting has proven clear benefits to HSY:

1. Detailed simulations can now be performed for extended periods.
2. Understanding problem areas and interactions in the sewer system has improved.
3. Hydraulic results are available anywhere in the system at any given time.
4. Automated post-processing of results has saved a significant amount of modeler's time.
5. Visual dashboards have facilitated more accessible review and communication of results.
6. The modeling platform is purpose-built to accommodate real-time simulations.

Examples of results for an overflow location are shown in Figure 2.

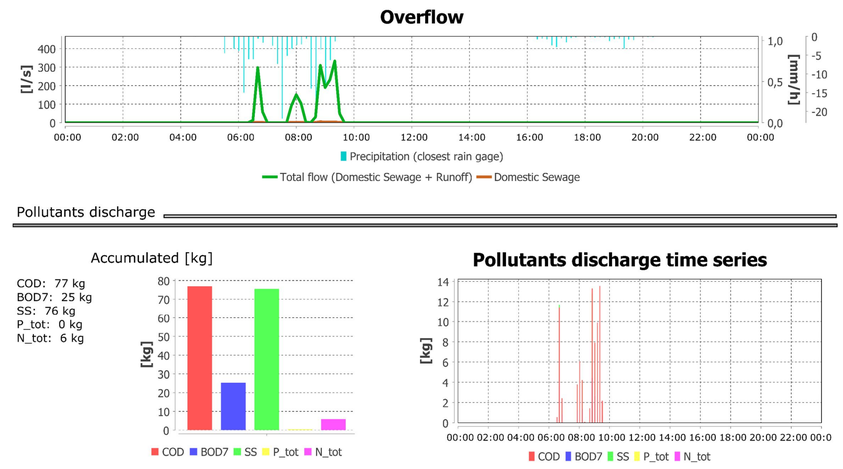

Figure 2 – Examples of overflow summary results for a storm event (source: Fluidit Ltd)

DISCUSSION

The new model has been in operational use since early 2021. The model has proven to provide a great platform to assess the network behavior, plan future investments, and communicate the actions required.

As with any modeling activity, proving the model's accuracy can be challenging. At HSY, the model performance is evaluated using flow measurements taken at strategic pumping stations across the network. While these are not the exact overflow locations, pumping stations provide a well-coordinated and high-quality reference point for assessing the overall simulation accuracy. Notably, a suitable IT infrastructure is already in place to support online-modeling systems.

While simulations are not as accurate as direct flow measurements, simulations provide consistent, safe, cost-effective overflow estimates across the whole network. Simulations can also accommodate extreme flow conditions where direct flow measurements often fail.

CONCLUSIONS

HSY's real-time combined sewer model provides critical insights into what happened in the sewer system in the past hours and days. Crucially, real-time analysis enables timely warnings of CSO events to the public, unlike when overflows were reported months afterward.

The new model provides robust scenario analysis to investigate what could happen in the future and plan actions for operational challenges and emergencies. It also helps to design cost-effective investments and develop resilient sewer systems for future conditions.

References:
[1] Björninen, H., Sänkiaho, L. 2021. Conference Presentation, NORDIWA 2021 (online)
[2] Data System: Helsinki Region Environmental Services Authority, 2020-2022, Network Information system and flow measurements 2020-2022.

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