Dynamic Pollutant Modelling in Halmstad Sewer System as an Input to a WWTP model and CSO Regulation.

Claes Hernebring *, Ole Mark**, Lars Ohlsson***
* DHI Sweden, Box 126, S-581 02 Linköping, Sweden
**Danish Hydraulic Institute, Agern Allé, DK-2970 Hørsholm, Denmark
*** The Municipality of Halmstad, Västra Strandens reningsverk, Småbåtsg 2, S-302 38 Halmstad, Sweden

ABSTRACT

In this paper the background for the practical application of an ICS (Integrated Catchment Simulator) is described, comprising of a MOUSE model for the sewer system and STOAT for the wastewater treatment plant (WWTP). Problems encountered in that context are discussed, as well as the implication of some necessary simplifications

Introduction

In Halmstad, Sweden, great efforts have been made during the 1990's to improve the functionality of the sewer system and the wastewater treatment plant. The wastewater treatment plant is reconstructed to meet increased nutrient removal demands. A five-year rehabilitation plan for the sewer system is under completion, where the measures mainly are motivated by the aim to reduce the combined sewer overflow volumes and to minimise the risk of local flooding. It was soon realised that an integrated use of storage volumes at the wastewater treatment plant and within the sewer system would improve the general conditions for the treatment at the plant. To implement this strategy a real time control system was introduced by installing controllable weirs and flow control devices in the main sewer.

Description of Halmstad WWTP catchment

Halmstad WWTP Vastra Stranden receives wastewater from about 100 000 p.e. with a total catchment area of 26 km^2 . The sewer system is partly combined, with the connected impervious area (170 ha) mainly concentrated to the central parts of the city. Most of the CSO are concentrated within the main interceptor along the River Nissan.

The design of the WWTP is based on a line with high treatment efficiency, but with limited flow capacity, combined with an open equalisation tank of 6 000 m^3 for peak flows. The storage volume includes pre-precipitation. Before the outlet to the recipient all sewage will pass through polishing ponds. The design was supported by computer simulation studies of the activated sludge process.

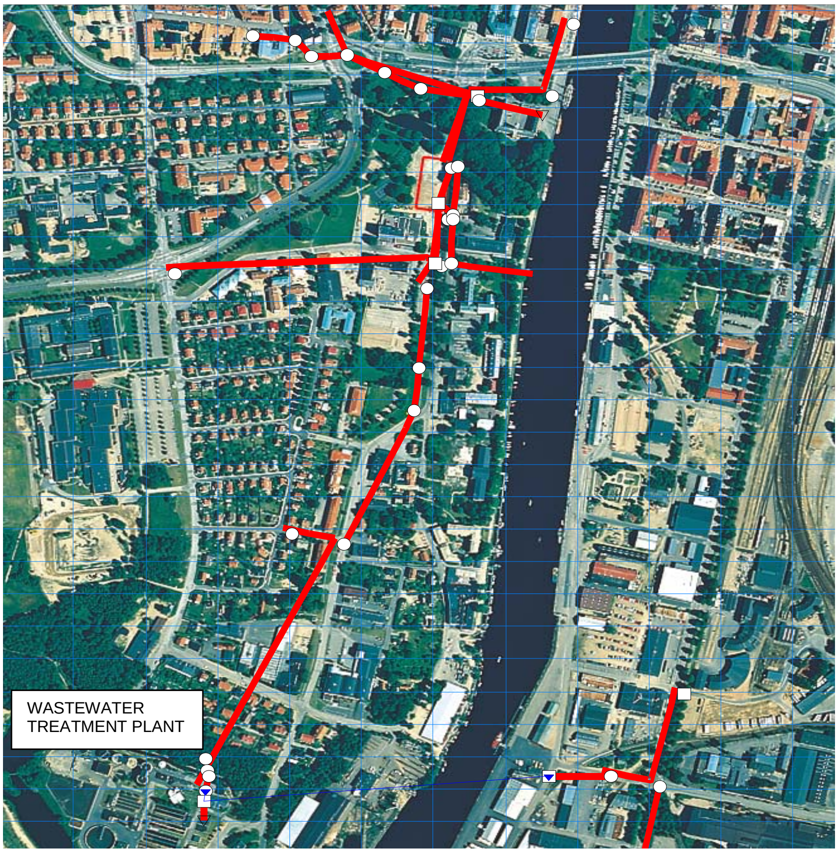


Figure 1 Overview of Halmstad sewer system

The present outlet standard formulation comprises enhanced conditions concerning the nitrogen and phosphorus removal efficiency. 0.4 mg total P/l is demanded as a maximum limit for the annual mean value and for nitrogen outlet target values depending on the quarter of the year: 14, 10, 6 and 10 mg total N/l, respectively (quarter 1-4). The requirements should be met including untreated or partly treated storage by-pass volumes occurring from the equalisation tank at the treatment plant, measured at the outlet of the polishing ponds. This may be a difficult task, mainly depending on the high P-removal efficiency demanded.

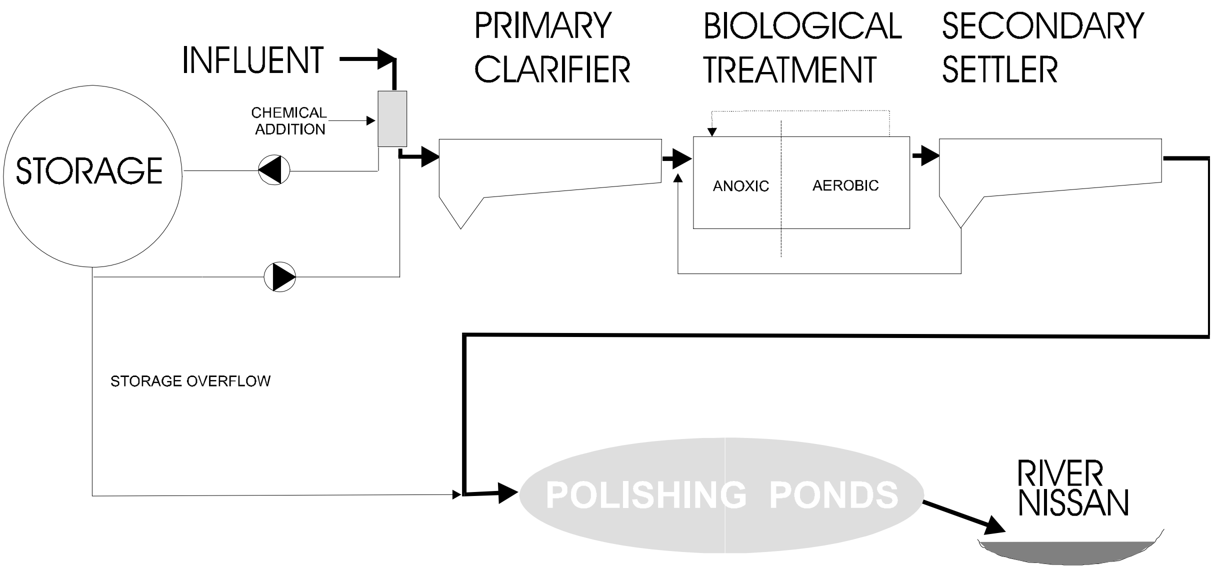


Figure 2 Halmstad wastewater treatment plant flow scheme

In Halmstad sewer system an integrated utilisation of the covered equalisation tank in the sewer system and the open equalisation tank at the wastewater treatment plant is performed by using movable weirs and flow regulation equipment in the main sewer adjacent to the storage volume.

The main purpose of the RTC actions is to bring as much wastewater as possible through the full treatment line of the WWTP, without causing unacceptable overflow volumes neither from the sewer system nor from the storage at the WWTP. This is expressed in a control strategy implying: “When the WWTP storage is getting full, then the gate at the storage tank “Vallgraven” decreases the outlet flow to the main collector”. This continues up to a certain degree of filling of the storage tank when the control strategy is changed: “The outlet flow gate is opened because flow by-pass at the WWTP is preferred compared to CSO volumes from the sewer system”. Further, a CSO weir at the storage tank is regulated in such a way that overflow is avoided as long as possible, but when an overflow is inevitable, the weir is lowered to permit a rapid discharge of overflow water to minimise the risk of upstream flooding. The details of the strategy are described elsewhere[1].

Modelling of pollutant transport in the sewer system

MouseTRAP is used to describe the transport of pollutants in the sewer system and STOAT for description of the processes at the WWTP. A sampling programme has been carried out in the sewer system for validation of the advection-dispersion model. This included short term sampling during rainfall and dry weather conditions as well as long term sampling/validation (composite daily samples during one year). A tracer measurement programme has also been carried out to serve as a basis for simulations of the transport mechanisms in the sewer.

Results from dry weather sampling in the sewer system are illustrated by figure 3, where 1-h diurnal analyses of soluble phosphorus are shown.

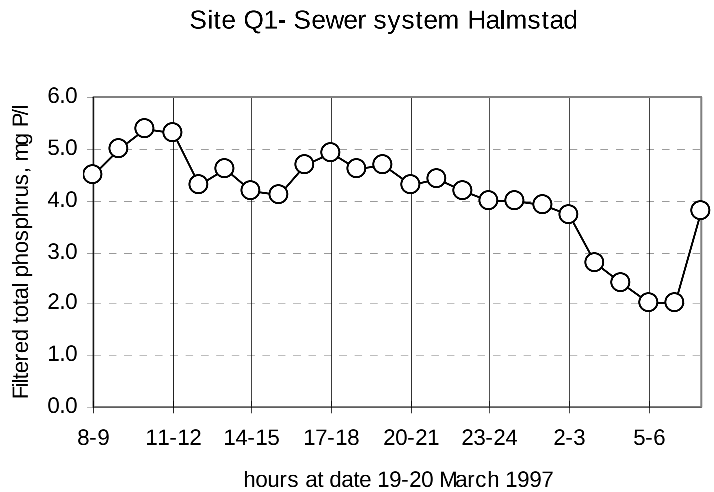


Figure 3 Example of analyses from 1-h diurnal dry weather sampling in Halmstad sewer system.

[1] Hernebring C. Ohlsson L., Andréasson M. and Gustafsson L-G. (1997): *Integrated Operation of the Treatment Plant and the Sewer System in Halmstad, Sweden.* EWRA Conference on Operational Water Management, Copenhagen, Denmark. Proceedings, Balkema, Rotterdam. pp. 427-432.

By the sampling procedure the distribution of pollutants within the sewer could be established. Hereby the main pollution source is supposed to be the domestic foul sewage, but other important point sources, such as industrial discharges, will then also be included. In figure 4 is shown the distribution of the total daily pollution load divided into the three main trunk sewers to the treatment plant. Here, “conductivity” is not really a “pollutant”. It was used as an indicator for the transport of relative amounts of dissolved substances, and could thereby serve as a tracer for foul sewage.

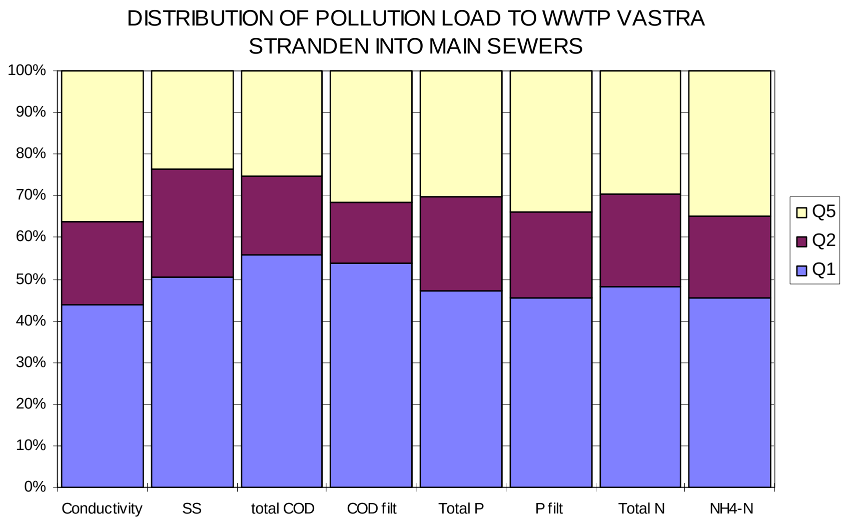


Figure 4 Distribution of the total daily mass of different components from the three main sewers to Vastra Stranden Treatment Plant, Halmstad, based on sewer dry weather sampling.

The dry weather sampling was carried out at four sites at the same time, at the three main sewers before, and at the inlet to the treatment plant. Consequently, the sum of the pollutant masses in the sewers should equal to what was found at the treatment plant. That was not the case, as can be seen in figure 5.

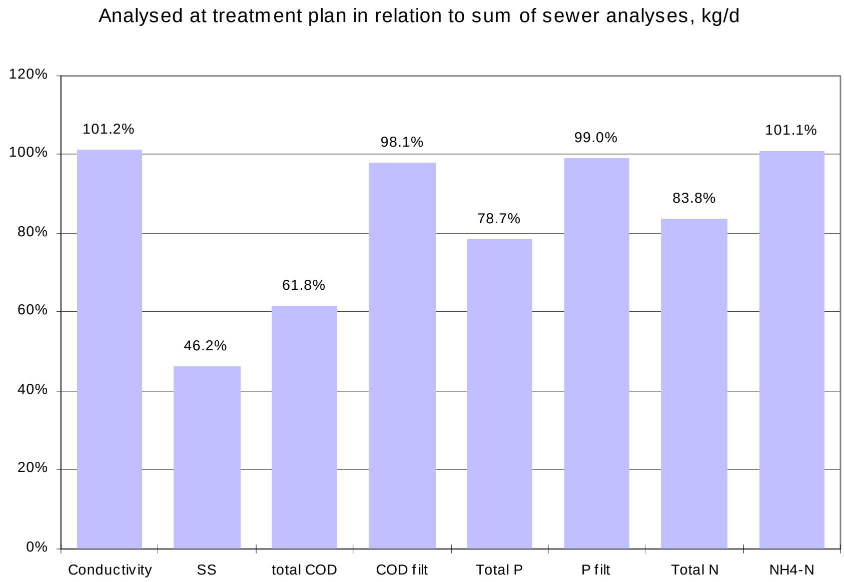


Figure 5 Recovery in the sample point at the wastewater treatment plant of the sum of total daily analysed mass in the sewer system.

All soluble substances in figure 5 were recovered very close to 100 %, which indicate good quality of flow measurements and analyses. The particulate matter, however, represents a severe problem. Only 50-80% of those components, to a varying degree containing particles, was found in the composite sampling point.

It was found out that the most likely cause for that phenomenon was that the sampling point at the treatment plant was situated after the inlet movable screens with rather fine openings. During dry weather flow and if operated that way, they are capable of removing substantial amounts of suspended matter. That later represented a modelling problem just at the boundary between the sewer system and the treatment plant. It was decided to ignore the effects of the screens, because at wet weather conditions (more important to describe) the removal efficiency of particles is not expected to be so extremely high.

Sampling in the sewer system and at the treatment plant was also carried out during wet weather conditions. Some examples are given below of analyses compared with MouseTRAP simulations. The input to these simulations consists of the diurnal variation of the dry weather flow concentration with the industrial loads included. The results can be seen in figure 6. The most straightforward simulation is the one for ammonia, which can be considered as a quasi-conservative pollutant, not influenced by the presence of sediment in the sewers. This has resulted in very good results. The results obtained by the simulation of phosphorous are also relatively good. The simulation of COD is not satisfactory yet. This may be due to the fact that at present the total COD is simulated with the same transport mechanism as dissolved pollutants and sediments may contribute as particulate COD in the total COD load. Hence, the water quality model has to be somewhat modified in the near future.

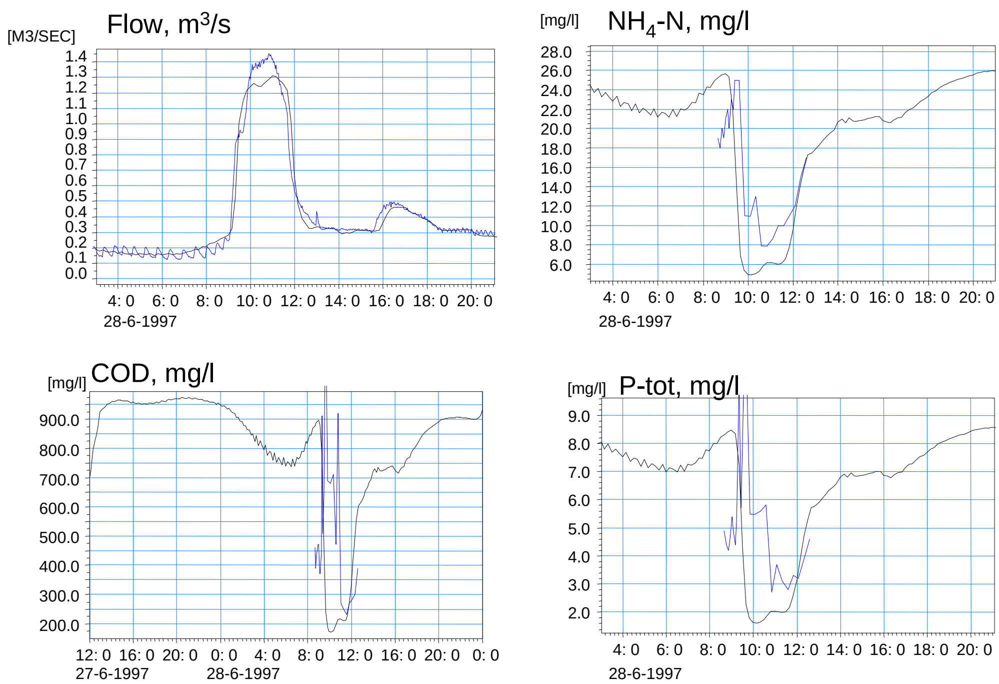


Figure 6 Examples of MOUSE HD/AD calculation results compared to measurements for the inflow to the WWTP in Halmstad.

Because there were time series available with analyses from the inlet to the wastewater treatment plant, it was decided to perform long-term verification simulations with the same input data as related above. The simulation period was the full year of 1998. The analyses consisted of composite 24-h samples (flow proportional) with the sampling frequency of each workday or one workday a week. To make the MouseTRAP simulation results comparable to the analyses, calculation results in this case were saved each 6th hour and weighted 24-h values were calculated. In the figures below the results are compared with available analyses for most of the year.

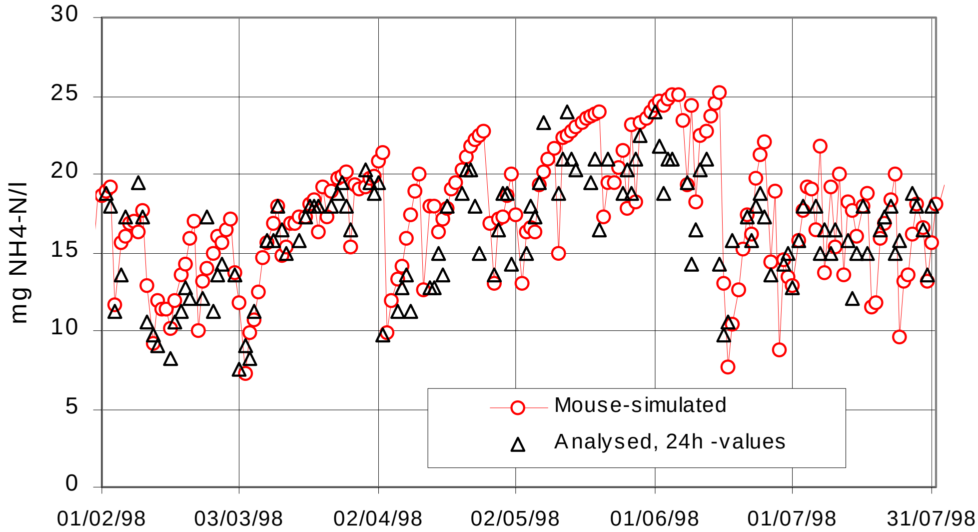


Figure 7 Simulated ammonium concentration in the inflow to Vastra Stranden WWTP, Halmstad, compared with analysed 24h values (each workday).

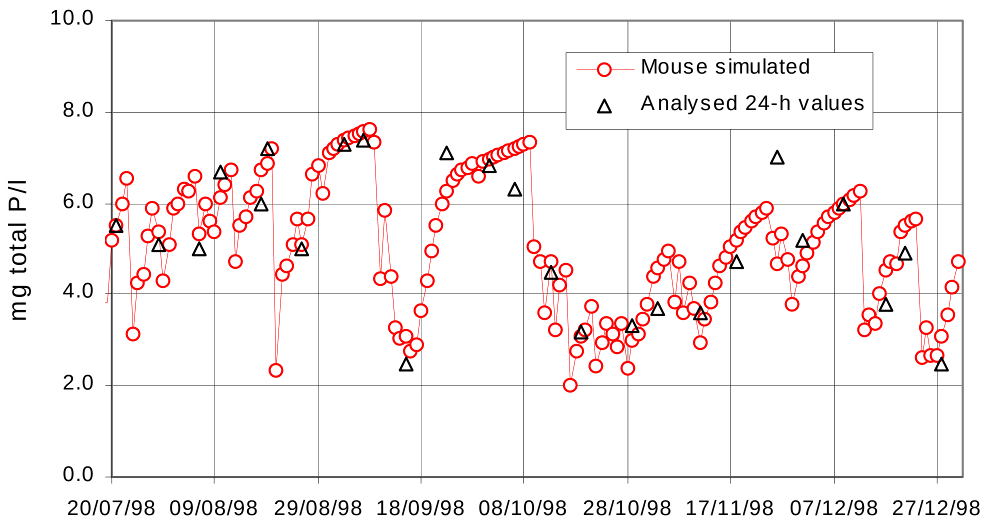


Figure 8 Simulated concentration of total phosphorus in the inflow to Vastra Stranden WWTP, Halmstad, compared with analysed 24h values (one workday each week).

In figure 9 below, all available analyses during 1998 are compared with the simulated values for the two components.

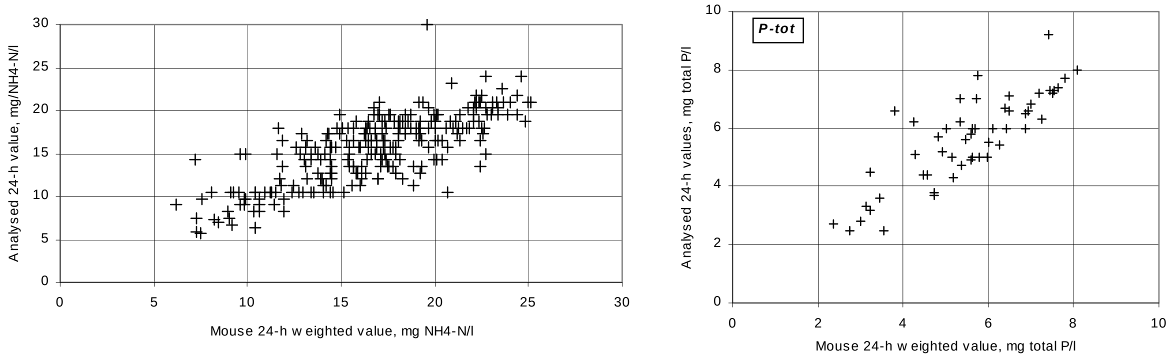


Figure 9 MouseTRAP simulated concentrations (horisontal axes) compared to all available 24-h sample analyses (vertical axes) during 1998 for, to the left: ammonium (each workday), to the right total phosphorus (one workday each week).

This simplified way of modelling it is not capable to describe extremely short-term (minutes) first-flush effects, caused by deposition/erosion of in-pipe sediments. Anyhow, it is evident that fundamental long-term (hours, days) pollutant concentration variations can be described reasonably well in that simplified manner.

A Stoat model for the treatment processes

An extensive sampling program has also been performed in order to calibrate the STOAT model for the wastewater treatment processes. In the study of different scenarios the Mouse and Stoat models are coupled together by means of the ICS-tool.

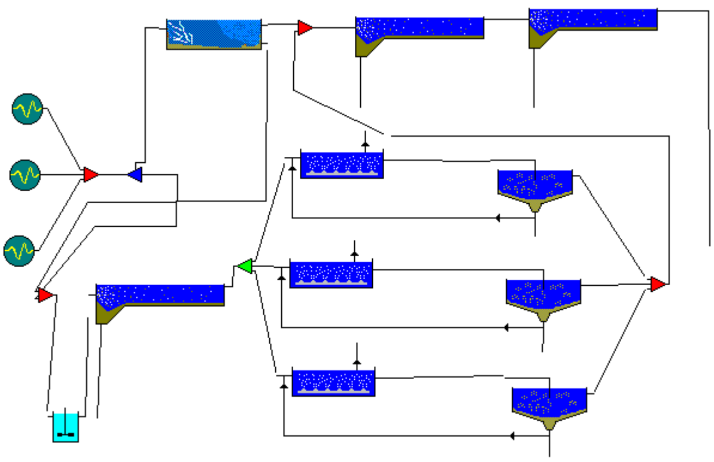
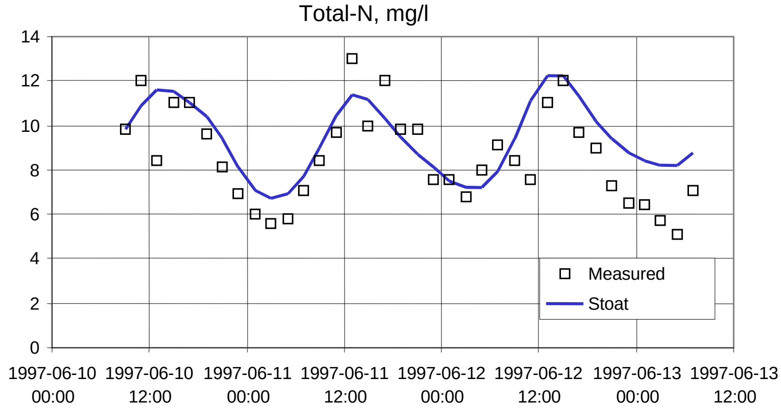


Figure 10 A Stoat model for Vastra Stranden WWTP with 3 sewer inflows, equalisation tank, chemical addition, pre settling, activated sludge treatment in 3 trains followed by polishing ponds.

In figure 11 below are some Stoat calibration results shown.



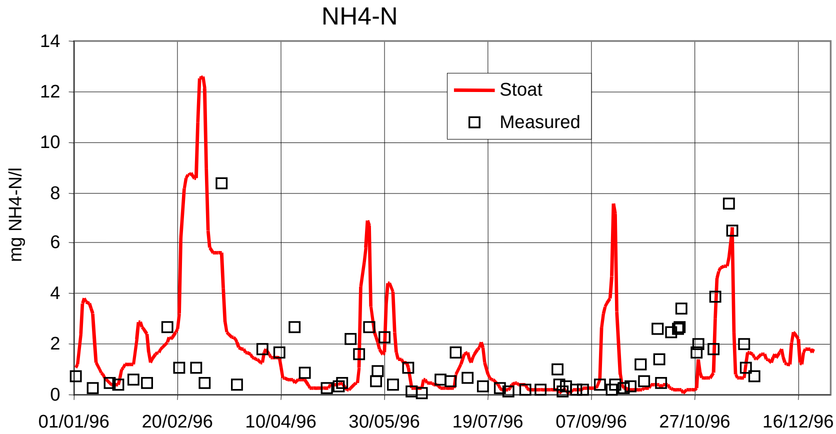


Figure 11 Examples of STOAT calibrations for the WWTP in Halmstad. Top: 3 days of simulation – 2-hour sampling frequency. Bottom: 1 year of simulation 24 hour sampling frequency.

Conclusions

With the ICS tool solutions will be evaluated which scenarios that are shown to meet existing standards by long-term model simulation. Besides “natural” changes of sewage quality affecting treatment and CSO impact, the effect of point sources within the sewer is studied. One example is operational measures to apply in the case of an accidental discharge of potentially harmful substances. Another issue is how to handle the discharge from a malting factory within the WWTP catchment. Its wastewater discharge represents a substantial portion of the total BOD load to the treatment plant and it is a potential valuable carbon source for the denitrification processes at the plant.

Processes and conditions in sewer system and wastewater treatment plants are highly dynamic and varying on different time scales. Dynamic modelling of the inflow and infiltration into the sewer system has shown to be extremely useful in finding cost-effective remedies to functional problems. The same reasoning is applicable when wastewater treatment processes are concerned. The use of integrated modelling as a planning tool and at the operational phases can be even more valuable to develop an effective composite use of existing resources in the sewer system and at the wastewater treatment plant.