Reduction of Combined Sewer Discharges in Germany: Planning Methodology for Implementing RTC in the AOI-Project

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I. Introduction

Urban Drainage Systems (**UDS**) and Treatment Plants (**TP**) are main sources of water pollution. Their pollutant discharges therefore constitute an important parameter of evaluation of a **UDS** and its sanitation needs. Each local government can issue its own technical regulations concerning the required level of environmental protection. National unity, however, is to a great extent guaranteed, because the regulations basically refer to technical reports (called Working Sheets), which are published by a single organization of experts. These experts define the German state-of-the-art in the transport and cleansing of waste and combined waters. This paper focuses on the reduction of Combined Sewage Discharges (**CSD**) in **UDS**. The present planning methodology, as described in Working Sheet **WS128**, will be discussed and criticized. A methodology is proposed, which makes it possible to develop and verify unconventional sanitation solutions (*i.e.* implementation of Real Time Control Systems or **RTC** systems) on the basis of numerical simulations.

II. Reduction of Combined Sewage of UDS

II.1 General Planning Principles

Different solutions can theoretically be implemented to reduce the **CSD** of **UDS**:

- <u>(partially) redefining the function of the existing combined **UDS**</u>
  "*All rainwater as fast as possible into the canalization*" has now been abandoned in favor of a more "ecological" principle that stipulates that unpolluted rainwater be stored and utilized or be infiltrated. Such "conceptional" measures, when applied systematically in an urban catchment, significantly reduce the rainwater inflows and therefore the amount of **CSD**.

- <u>increasing the transport/storage capacity of **UDS** upstream from a **TP**</u>
  The planner can also decide to increase the storage capacity in critical parts (construction of retention basins at the outlet of subcatchments) or increase the transport capacity of collectors (in order to distribute the water quantities better among storage units).

- <u>exploiting existing transport/storage capacity by means of **RTC**</u>
  If there is storage/transport capacity that can not completely be activated without external control devices (like pumps or weirs) and/or if the catchment size is considerable (the rainfall spatial distribution is not uniform), a **RTC** system should be envisaged.

In most cases, the optimal way to upgrade an existing **UDS** will probably be a combination of the different design approaches. Such optimization, however, requires an exhaustive analysis of the **UDS**'s behavior through numerical simulations, which is not considered a state-of-the-art process. Today, planners normally rely almost exclusively on the standard simplified methodology described in **WS128**.

II.2 Conventional Upgrading Approach Based on WS128

The general objective of planning according to **WS128** is "to reduce pollutant emissions of Combined Systems as far as possible while taking financial constraints into account." **WS128** formulates corresponding technical requirements and proposes a planning methodology, the characteristics of which are briefly described below.

- The yearly total emission of Biochemical Oxygen Demand (**BOD** in kg/an) is the main criterion for evaluating **UDS** discharges. **BOD** constitutes a global parameter of organic pollution, which directly and rapidly affects the ecological balance of receiving waters. Enhancement measures in **UDS**, according to **WS128**, aim at limiting the **BOD** emission to an acceptable level, the value of which does not depend explicitly on the state of the receiving waters (evaluation according to the so-called emission principle).

- The planning methodology is based on a "constructional" approach. The explicit objective of the calculation steps in **WS128** is to determine the required storage capacity of existing **UDS**, which is supposed to insure the fulfillment of the emission requirements.

N.B..: In case environmental protection must satisfy higher standards, the "emission principle" is replaced by the "immission principle," which explicitly examines the influence of pollutant loads on the biochemical state of the receiving waters (*i.e.*, fluctuation of oxygen concentration, nutrient concentration,...). This paper deals only with the normal planning case based on the emission principle.

The basic equation of **WS128** expresses in mathematical terms the aim that *a combined sewage system not discharge more pollutants into the receiving waters than an equivalent separate system.*

$$VQ_r . e_0 . c_e + VQ_r (1- e_0) . c_k < VQ_r . c_r \qquad \text{(Eq. 1)}$$

VQ_r mean amount of rainwater in a year (m^3)
e_0 mean proportion of rainwater that is discharged (-)
c_e mean pollutant concentration of discharged combined sewage (mg/l)
c_k mean pollutant concentration at the outlet of the TP (mg/l)
c_r mean pollutant concentration of the rainwater (mg/l)

In Eq. 1 parameters c_e and e_0 are unknown and are evaluated with supplementary equations, which establish relationships between in- and outloads, as soon as all input values are given (*i.a.*, qualitative/quantitative characteristics of dry weather flows, of rainwater, of the **TP** outflow). As an example, the mean flow rate of **CSD** (Q_{re}) is a function of the impervious surface of the catchment (A_u), runoff lag-time (t_L) and capacity of the TP ($Q_m = Q_{r24} .+ Q_{t24}$).

$$Q_{re} = a_f . (3. A_u + 3,2\, Q_{r24}) \qquad \text{(Eq. 2)}$$

Q_{re} (l/s) mean flow rate of **CSD** during rainfall
Q_{r24} (l/s) mean flow rate of rainwater directed to the **TP** during rainfall
Q_{t24} (l/s) mean dry weather flow directed to the **TP** during rainfall
Q_{r24} (l/s) flow rate of rainwater, which is to be directed to the **TP**
a_f (-) reduction parameter, which depends on the runoff lag-time
A_u (ha) impervious surface of the catchment

WS128 gives no explanation of how Eq. 2 has been derived. It is probably the result of a statistical analysis of simulation and measurement data on "representative" catchments.

References to numerical simulation are avoided almost completely. According to the authors of **WS128**, numerical simulation lacks reliability, because its validity depends largely on the capability of planners to understand their model and adapt it to reality. In fact, distrust of engineers' (and water authorities') ability to manipulate complicated numerical tools properly in the design process is so great, that a strict interpretation of **WS128** forbids any direct evaluation of the discharge behavior of an existing **UDS**. In other words, *the acceptable emission level of a given **UDS** is defined as the emission level of a corresponding **UDS**, the total storage capacity of which amounts to the value calculated in **WS128***.

Both water authorities and planners have found advantages in the proposed methodology.

- Because the planners are given a narrow margin in their evaluation of input-parameters (*in situ* calibration) or the interpretation of the results, the water authorities expect a uniform level of environmental protection everywhere in Germany.
- For the planners, the calculation is quite simple and requires only a few steps.

As a consequence, many planners have only focused on increasing the storage capacity of **UDS**. The calculated storage capacity has often been directly interpreted as the required volume of retention basins to be built, so that many retention basins have already been, or are expected to be, constructed.

II.3 Critical Analysis of Conventional Planning

Construction of retention basins puts a high financial burden on local communities, since 1 m^3 of retention basin costs between DM 3,000 and DM 5,000. More and more **UDS** operators would be ready to implement alternative upgrading measures, if it can be shown that these measures would insure the same environmental protection level for less money. The more complex the **UDS** are, the more advantageous alternative upgrading measures become (especially when based on **RTC**). This is due to the following facts:

- A complex network system contains transport and storage capacities, which under normal conditions are not activated. Using this potential may be cheaper than increasing existing capacity.
- If a **UDS** drains a great catchment, it is improbable that the whole catchment will be loaded uniformly during a rainfall event, as is assumed in the simplified calculation.

Since comparison of design approaches is only possible with the help of numerical simulation, the central question is how to introduce numerical simulation. Unfortunately, the present version of **WS128** is of little use in establishing a more comprehensive way of planning.

III. Upgrading a UDS by Implementing an RTC System

III.1 Description of the AOI-Project

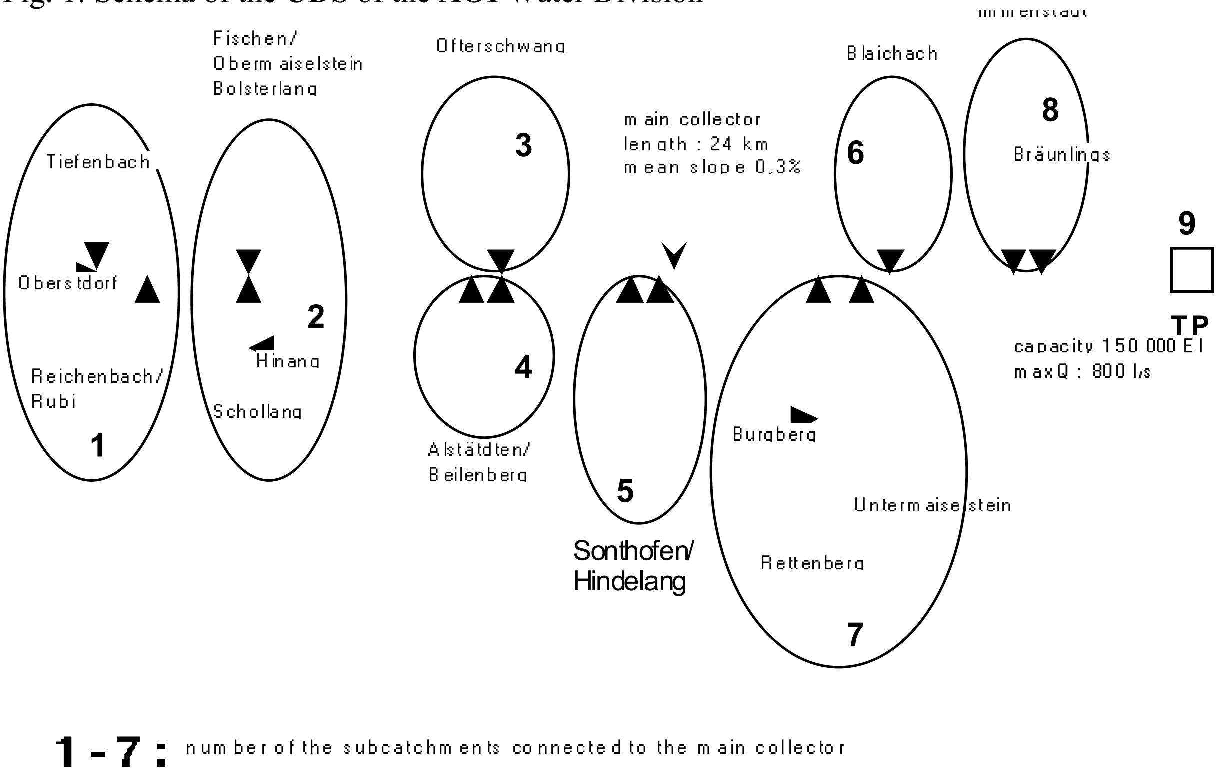
The German federal authorities are aware of the financial implications of present practices and support research projects that help develop and diffuse new planning methodologies. One of these projects is in South-West Bavaria, where the **AOI** Water Division intends to upgrade its network by implementing a **RTC** System of global control.

This **UDS** drains combined sewage of several communities into a **TP**. The whole catchment is 25 km long and 10-15 km wide. Each subcatchment has its own storage units. The main transport and storage capacity is contained in the main collector. At present, its storage capacity can be activated up to 10% (3500 m^3).

III.2 The Proposed Planning Approach in the AOI-Project

According to conventional planning, 40 storage units distributed throughout the system would be necessary. With **RTC**, however, only 33 storage units should suffice.

Fig. 1: Schema of the **UDS** of the **AOI** Water Division



To verify whether the level of environmental protection remains the same, the following path is proposed:

- Calculate the required storage capacity, according to **WS128,** for each subcatchment.
- With a calibrated hydrological model, calculate the amount of discharges. The calculated value is considered to be the required level of emission.
- With an hydrodynamic model, determine through iterated calculations the smallest storage volume that fulfills the requirements. In this case, it is assumed that the **UDS** is locally controlled (outflows from the storage units are constant values, *i.e.*, $Q_{ab} = 3\ Q_{t24}$)
- With an equivalent hydrodynamic model, simulate the same system assuming that the network is globally controlled (outflows vary depend on the current state in the **UDS**)

The methodology is based on a qualified use of simulation models, some of which are still to be developed in the course of the project. It is important to note the following points:

- The required emission level must be determined with an hydrological model, since **WS128** evaluates a total storage capacity (including activated storage in pipes) and hydrological models do not simulate storage effects in the pipes.
- The "real" storage capacity to be built should only be estimated with hydrodynamic models, because they do simulate the activation of existing storage potential in pipes. In some cases, retention basins that were dimensioned without considering the influence of pipes, have shown to be significantly oversized or at least do not work properly (the basins have never been filled up).

N.B..: The comparability between hydrological and hydrodynamic simulation is guaranteed, because both models will be calibrated on the basis of measurement data and a detailed description of the drainage network (The whole **UDS** is to be completely digitalized).

In the **AOI** research project, it is planned to implement a global control system. The control module will collect on-line data about the actual state of the **UDS** (water level in the storage units, flow rates at critical points, etc.) and also a simulated prediction of inflow values into the canalization. On this basis, it will estimate at every time step the new control values of the relevant weirs and pumps by performing an optimization. Only global control can ensure that the system will take full advantage of the existing capacity, especially when rainfall is not uniformly distributed on the catchment. In comparison with a locally controlled system, it is expected to reduce the total emission by 10-15 %.

References

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