

Project STORM – Wastewater Discharge During Rain Events

During rainy periods, only some of the waste water runs through treatment plants. In combined sewer systems, the excess flow is discharged directly or, after some simple treatment, into surface waters. Until recently, planning for these overflow structures has been based on unspecific problem criteria and empirical methods. In order to improve water protection and cost efficiency, environmental factors and uncertainty assessments will increasingly become incorporated into the planning and decision-making processes.

There is rarely another problem that is similar in complexity and that exhibits dynamic and stochastic like that of the discharge of sewage into surface waters during rain events. This is especially true for the rainfall runoff from towns and villages, because in urbanized areas, the majority of the rain

water cannot infiltrate the soil and so has to be removed through the sewer system. In the combined sewer system, which represents the majority of systems in Switzerland, rainfall runoff mixes with domestic and industrial sewage, is treated in the wastewater treatment plant, and is subsequently

discharged into streams and lakes. During intense rain events, the treatment plants are not able to process the entire discharge of waste water. This is because the treatment plants are, for various reasons, designed to treat no more than twice the water flow occurring during dry weather (= equivalent

Locality of manifestation/problem and potential effects	Potential causes	Examples of possible measures		
		in urban areas	in urban drainage	in the stream or lake
Urban area, sewer system				
Frequent and long-lasting combined sewage overflow	Infiltration and minimally contaminated water in combined sewer systems	Separate collection of rainfall runoff, soil infiltration	Reduce collection of clean water	
Frequent and long-lasting combined sewage overflow	Malfuction of the overflow structures		Adjustment of the outflow regulation	
Streams and lakes				
Aesthetic impacts: affecting well-being of humans	Discharge of gross pollutants (toilet articles, etc.), odors, dyes	Retention of domestic or industrial waste water	Screens /sieves	
Colmation of the stream bed: oxygen deficit in the stream bed and in the interstitial spaces of the hyporheic zone	Solids in waste water, discharge of easily degradable particulate contaminants	Reduction of deposits in the sewer system	Removal, treatment (e.g., sedimentation, vortex separators), optimization of operation	
Public health: increased infection risk	Discharge of bacteria, pathogens		Relocation of discharge point, storage, real time control	Warning, temporary ban on bathing
Hydraulic impact: drifting or elimination of organisms	Sediment transport and high flow velocity caused by sewer discharge	Unsealing, utilization of rain water, retention, infiltration	Relocation of discharge point, storage, real time control	Profile modifications, substrate improvements (creation of refuge space)
Acute problems (toxicity, NH ₃ , O ₂): damage to or elimination of organisms	Discharge of toxic compounds, unnaturally low water levels, high pH values, high temperature in streams	Storage of domestic or industrial waste water	Relocation of discharge point, storage, real time control, treatment	Shading by trees and other plants, improvements of the hydraulic regime
Eutrophication: damage to organisms	Input of nutrients	Source control	Storage, real time control	Shading by trees and other plants
Chronic toxicity: damage to organisms	Input of heavy metals, pesticides, hormonally active compounds, etc.	Source control	Treatment (e.g., soil filters, phys.-chem. treatment, wastewater treatment plant)	

Tab. 1: Relationships between problems caused by wastewater discharge during rain events, the nature of these problems, and possible remedies. This table shows some selected examples.



Possible remedies (from left to right): rotating brush – sieve with cleaning spiral blades – screen – underground combined sewage overflow tank – above ground combined sewage overflow tank, integrated into the landscape (bottom).

to rainfall runoff during weak rain events). During intense rain events then, a fraction of the combined sewage is discharged directly into surface waters, mostly without any kind of treatment.

Protecting Surface Waters from Sewage Discharge

One possible strategy for protecting surface waters from receiving sewage discharge during rainy periods is to collect the rainfall runoff separately; such a separate sewer system would then only discharge rainfall runoff into streams and lakes. At first glance, this solution appears to make sense, although it is not without its problems. Rainfall runoff originating in urbanized areas is usually more or less polluted, with roofs and streets serving as the main sources of contaminants. It is, therefore, more common that combined sewer systems are supplemented by overflow tanks [1]. These tanks can temporarily store the combined sewage overflow before it is fed into the treatment plants. The main advantage is that this prevents many negative

impacts on surface waters by solid waste (toilet paper, tissues, toilet articles), which are highly problematic for esthetic and public health reasons (Tab. 1) and can remain visible for months. Thus far, Switzerland has invested 2 billion CHF into the construction and operation of such overflow tanks. In separate sewer systems, rainfall runoff is normally not treated in any way. Many surface waters are, therefore, still receiving polluted rainfall runoff, either from separate or from combined sewer systems. In the mid-term, we should anticipate additional investments of approximately the same order of magnitude as that which has been spent until now.

Since the overall goals remain optimization of water protection and the most efficient use of available financial resources, we need to plan for dealing with rainfall runoff drainage issues according to new criteria. This task is the focus of the project “STORM – Wastewater Discharge During Rain Events”, a joint undertaking by the Swiss Agency for the Environment, Forests and Landscape (SAEFL), the Swiss Water Pollution Control

Association (VSA), and EAWAG. This article summarizes some early results.

New Principles in the Planning Process

Immission-oriented approach: Until now, the general approach has been to consider rainfall runoff discharge from an emissions standpoint; that is, the main concern is about the pollutant types and loads that are discharged from sewer systems into surface waters. The conditions and specific properties of the receiving streams or lakes are considered only at a very rudimentary level. We propose to shift any future planning – as far as our knowledge allows us – towards an immission-oriented approach (see box), where we take the characteristics of the specific stream or lake into consideration.

Tailored solutions based on effect prognosis: Unfortunately, past solutions for wastewater drainage during wet weather were not evaluated for their environmental effects. It is, therefore, difficult to assess how effectively aquatic communities are being pro-

Type of water body	Aesthetics	Public health (pathogens)	Temperature	Mechanical and hydraulic stress	Chemical parameters			
					Ammonia ¹	TSS ²	Nutrients	Other compounds ³
Spring	Yes	No	Yes	Yes	Yes	Yes	No	Currently no reliable information available
Small lowland stream	Yes	No	Yes	Yes	Yes	Yes	No	
Small stream in lower Alps	Yes	No	Yes	Yes	Yes	Yes	No	
Large lowland stream	Yes	Yes	Possibly ⁴	Possibly ⁴	Yes	Yes	No	
Large stream in lower Alps	Yes	Yes	Possibly ⁴	Possibly ⁴	Yes	No	No	
Larger streams	Yes	Yes	No	No	No	No	Yes	
Small lake (pond)	Yes	Yes	No	No	No	Yes	Yes	
Large lake	Yes	Yes	No	No	No	Yes	Yes	

¹ Acute toxicity due to ammonia

² TSS = total suspended solids

³ e.g., hormonally active compounds, aromatic and polychlorinated hydrocarbons, etc.

⁴ According to problem identification

Tab. 2: Relevance of specific problem areas in wastewater discharge from combined sewer systems and the discharge of rainfall runoff from separate sewer systems. An entry of “No” indicates that that particular aspect is not relevant for the corresponding water type; for example, public health aspects are not relevant in small streams since humans do not normally use these streams for bathing.

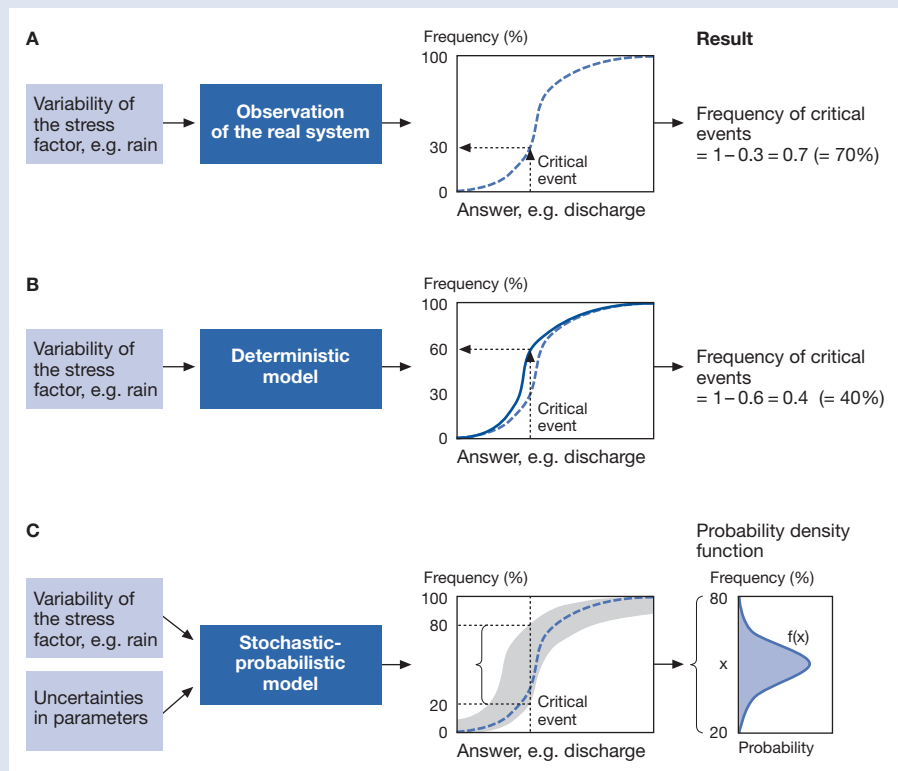


Fig. 1: Planning tools for estimating the probability of critical events during rain events. Critical events are defined by predetermined requirements; exceeding a certain discharge where sediment transport begins would be an example for such a critical event.

A: The frequency of critical events is determined from observations on real systems. Dashed line = cumulative frequency curve for the observed event. For comparison, this curve is also plotted in B and C.
B: The frequency of critical events is calculated in a deterministic model where variability in rainfall is included in the model calculations. Due to uncertainties that were not included in the calculations, reality (A) and the calculated curve are not identical.
C: The new stochastic-probabilistic model can calculate the probability of a certain frequency of critical events. The computer calculation incorporates rainfall variability as well as uncertainties in other parameters. The frequency with which critical events occur lies in a certain range, between 20% and 80% in the example shown here. All values for x = frequency of critical event enter the probability density function $x = f(x)$.

tected from negative effects of wastewater discharge by the currently existing overflow tanks, particularly during critical periods. For this reason, we recommend that any future plan be accompanied by a detailed prognosis enumerating the specific effects of the plan. This should allow us to devise tailored solutions that take into account all specific and local conditions.

Consideration of planning uncertainties:

Whenever a system like urban drainage is to be represented by a model, simplifying assumptions have to be made. These assumptions give rise to a number of uncertainties. Since the water itself is also described by a number of parameters that must be considered in the planning process, this creates additional uncertainties. Some of these assumptions or uncertainties are:

- The model structure: Is the model accurate enough to represent the system? Are the calculated demands for water discharge during rain events reasonable and realistic?
- Empirically determined model parameters (e.g., pollutant concentrations, temperature, etc.) are subject to measurement errors.

- Certain model parameters exhibit a high degree of variability (e.g., precipitation intensity, duration and frequency, flow rate in streams).

These uncertainties have to be identified during the effect prognosis, which is accomplished with the use of stochastic-probabilistic modeling (Fig. 1). Uncertainties can either be accepted, or the planning can

yield a step by step solution. This means that initially a limited amount of money is invested in smaller measures which are then tested for a certain amount of time. Experiences from this phase feedback into the effect prognosis, leading to a more refined and optimized solution. This approach is obviously closely linked to financial resources.

The Immission Oriented Approach

In contrast to the emission approach, which only takes into account the pollutants that are being discharged with the combined sewer overflow and storm water, the immission approach represents an integrated way of analyzing the problem and considers any type of impact as well as properties of the receiving water body. Relevant parameters are those that allow the assessment of stream conditions during critical periods:

- the type of impact (Tab. 1);
- the intensity of the impact, e.g., pollutant concentrations (chemical), concentrations of pathogens (public health), temperature changes (physical), and discharge or sweeping force (mechanical);
- the duration of the impact;
- the frequency of events;
- seasonal restrictions or deviations;
- characteristic properties of the stream or lake being affected (Tab. 2), e.g., type of water body (spring, lowland stream, lake), properties (discharge, nutrient concentrations, species diversity), condition (natural/modified, sensitive/non-sensitive).

Planning of additional measures: Until now, planners have primarily considered combined sewage overflow tanks to deal with problems related to water pollution control during wet weather. There are, however, a range of other solutions that may be cheaper (Tab. 1) and should be considered as well. In order to promote these principles in the planning of new projects, STORM is aiming to provide the following tools:

- a compilation of the demands on wastewater discharge during rain events, based on requirements that also include characteristics of the surface water receiving the discharge;
- a methodical concept for the planning and design of specific measures;
- a computer model that can predict uncertainties contained in the planning process [2, 3].

With the help of these tools, it should become possible to formulate new guidelines for combined sewer overflow and stormwater discharge in Switzerland.

How Does the New Planning Concept Work?

We would now like to present a simple example to illustrate how these new principles can contribute to the planning process. Let us consider a small stream that is already

protected from wastewater discharge by an overflow tank; however, this tank is not large enough to prevent wastewater discharge even during moderate rain events. During minor rain events, the impact is primarily an increase in pollutants, while the hydraulic impact is the main problem during stronger rain events. During the general planning stage, we first identify the problems and document a need for remediation. Investigations reveal that the primary problems during discharge of the combined sewage are increased ammonia loads and higher sediment transport. According to VSA recommendations [4], this yields the following discharge requirements:

- the critical ammonia load may be exceeded only once in a 5 year period,
- the critical (sediment transporting) flow may be exceeded no more than 10 times per year.

For this example, we will model three different alternatives:

- Scenario 0 = status quo with a basin volume of 120 m³ and annual costs of 12 000 CHF.
- Scenario 1 with an expanded overflow basin of 520 m³ and annual costs of 29 000 CHF.
- Scenario 2 with an expanded overflow basin of 1320 m³ and annual costs of 47 000 CHF.

We are using a stochastic-probabilistic model. In order to assess uncertainties, model parameters are not represented (as is usual) by a single value, but by a range of values and a distribution function. For example, pH values range between 7.8 and 8.3 and exhibit a log-normal distribution; the discharge coefficient varies randomly and is equally distributed in the range of 80–120% of the expected value. With the exception of a small number of parameters, where more certain values are available, all parameters are described in this fashion. In preparation of the Monte Carlo simulation, random sets of parameters were selected, where the parameter values were chosen from within their predetermined range. For each set of

parameters, long-term simulations were calculated with the same 10-year rain series (Fig. 1).

The simulation showed that there is only a 48% probability that scenario 0 can fulfill the riverbed erosion requirement; even in scenario 2, this probability only increases to 60% (Fig. 2). The requirement of ammonia loads, however, can be satisfied with nearly 100% probability in scenario 2. These fairly well defined probabilities for meeting certain requirements provide an additional tool in the decision making process. Planners and decision makers can opt for a relatively expensive alternative, maximizing the probability for meeting the discharge requirements, but taking the risk of possible over-investment. Alternatively, they could choose a dynamic approach, i.e., make a lower investment by building a smaller basin, while conducting further investigations and thereby reducing uncertainties.

This example illustrates that the stochastic-probabilistic approach to the planning process requires a different kind of communication (e.g., in the handling of uncertainties) than the traditional planning process. While this approach yields better information, it is also more demanding of the participants.



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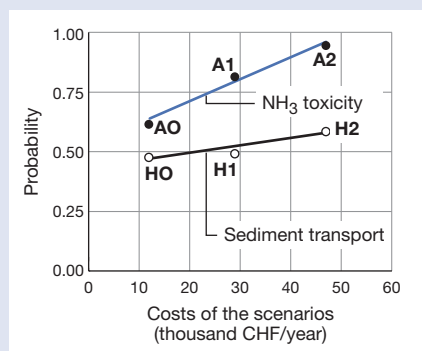


Fig. 2: Cost efficiency of different remedies (scenario 0 = status quo: A0/H0, scenario 1: A1/H1, scenario 2: A2/H2; for a detailed description of scenarios, see text). A: ammonia, H: hydraulic impact (sediment transport).

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