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Estimation of Combined Sewer Overflow Discharge From the City of Malmö

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The function of combined sewer overflows (CSO) from both a quantitative and a qualitative point of view is often little known in the Nordic communities. Since large pollution loads are discharged from urban areas by CSO, it is important to consider this problem when rehabilitation plans are established.

A study aiming at the estimation of yearly volumes of CSO and yearly quantities of pollution load from CSO has been carried out in the city of Malmö, Sweden. The CSO discharges into four different types of receiving waters: the channel, the harbour, the Sege River and the Öresund. Registration of frequency, duration and water volume was made at about 30 weirs at different time periods.

Storm Water Management Model (SWMM) was used both to simulate single SCO events and for continuous simulation. The results from these simulations were compared with actual measurements.

The total pollution load was estimated from mean concentration of pollutants from more than 100 samples taken at different weirs and CSO events.

Through analysis of the occurrence of CSO in time and space, a program of priorities for the rehabilitation of the CSO-system was established.

Introduction

Combined sewer overflows (CSO) are generally the least known parts of the sewer system. This can be a serious situation since the pollution load from combined sewer systems may constitute a major part of the total pollution load from urban areas. In order to map and to control this type of pollution discharge, each community in Sweden is obliged by the agencies for environmental natural resources to supply a rehabilitation plan for the entire sewer system.

In this context the Department of Water Resources Engineering, the University of Lund, was engaged in a study of the yearly volumes of water and the pollution load caused by CSO from the city of Malmö. The study was to be used as a substratum for a rehabilitation plan for the sewer system. Through analysis of the occurrence of CSO in both time and space it was possible to determine the need of measures to reduce CSO volumes and the order of priority for reduction in different parts of the sewer system. In this respect it was necessary to consider the amount of pollution in the receiving waters, and the present and future use of the recipients. Furthermore inexpensive methods were suggested for the reduction of CSO volumes.

General Methodology of CSO Studies in Connection with Rehabilitation Plans

The work with the rehabilitation plan starts from a CSO point of view, with a preliminary study describing the present situation. This study may contain:

- the location and the type of CSO
- observed CSO events
- observed inconveniences in connection with the CSO
- receiving water data

The location of the CSO is determined by studying construction plans together with field studies. Observed CSO events and inconveniences give an overview of where immediate problems like clogging, gasification, leakage etc. are to be found.

When formulating a program of priorities in a rehabilitation plan it is necessary to consider the CSO discharge in relation to existing receiving water conditions together with the present and the future use.

The preliminary study indicates where more detailed studies should be performed.

Investigated Area

The city of Malmö is the third largest city in Sweden, with a population of about 230,000 inhabitants. The sewer network is divided into six sewerage areas (see Fig. 1).

The older parts of the city are drained by a combined sewer system where CSO discharge occurs during heavy rainfall when interceptor capacities are exceeded.

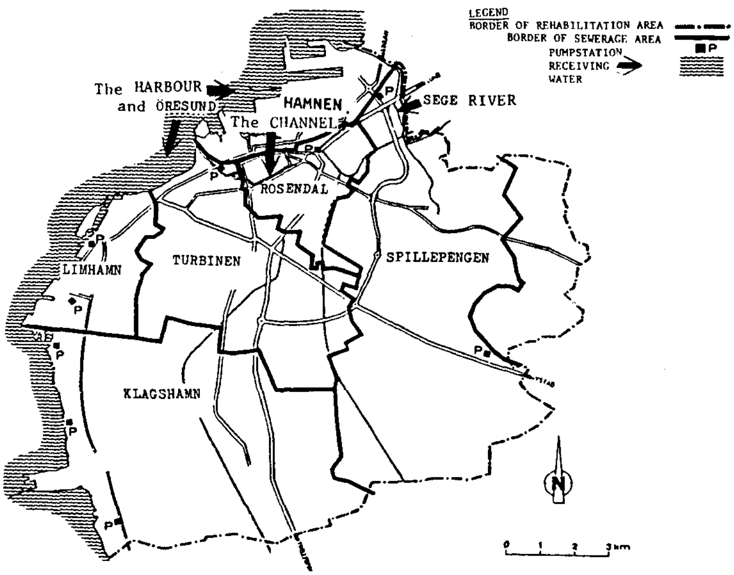


Fig. 1. Main sewerage areas and receiving waters in the city of Malmö.

About 50 overflows are located in the combined sewer system of which 30 were instrumented during the study.

Four different kinds of receiving waters may be distinguished (see Fig. 1),

- the Sege river
- the channel
- the harbour
- the Öresund

Each of these recipients has a different level of susceptibility to pollution release and recreational values.

The Sege river, situated in the outskirts of the city, partly in an industrial area, is of low recreational importance and is already heavily polluted. The pollution situation in the river cannot be improved without intercommunal agreement.

The channel, in the middle of the city, has quite the opposite value. Canoeing and walking along the channels are popular leisure activities.

The harbour is polluted by industries and boat traffic, which reduces the relative effect of the CSO discharge. The harbour basins also function as sediment traps.

The Öresund represents a large receiving water which is not seriously affected by CSO discharge. However, discharge of pollutants into the Öresund is an international problem where restriction about discharge from industries, waste water treatment plants and agricultural areas must be of first order priority.

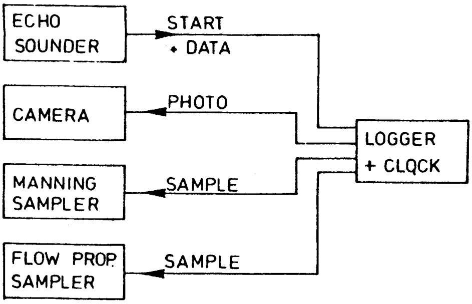


Fig. 2. Scheme of measuring unit at the main stations.

Instrumentation

Two basically different types of quantitative measuring methods were used at the 30 locations in the combined sewer system:

- Measurement of CSO-frequency
- Registrations of water levels

The measurements were used for two purposes i.e. to compare different calculation methods and to calibrate the computer model SWMM.

In addition, two locations were equipped, as described in Fig. 2, for more extensive measurements during CSO-events.

An echo-sounder activated the measuring equipment at the beginning of a CSO event. All measuring data and corresponding sampling times were automatically registered by a minilogger and stored on tape for later computer processing. A camera was pointed at the weir crest which has a fixed water level scale, and a picture was taken every 15 seconds. The water level fluctuations and the functioning of the weir during a CSO event could thus be studied on film. Both a discrete quality sampler and a flow-proportional sample were connected to the measuring unit. The quality measurements were used to estimate the pollution load, (Hogland et al. 1984).

Estimation of CSO Discharge

Both simple hand calculation methods and computer modelling were used to estimate CSO discharge for a comparison with actual measurements. The results of the hand calculations and the description of the different calculation methods can be found in Hogland et al. (1983; 1984).

Two main types of computer simulation techniques can be distinguished in accordance with the rainfall data.

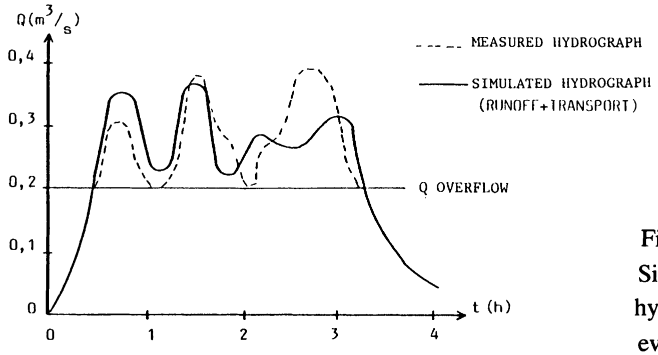


Fig. 3.
Simulated and measured CSO hydrograph for a single rainfall event.

Single Event Simulation

In single event simulation only one rainfall event within the catchment is analysed with a high accuracy. Fig. 3 shows the result of a simulation made with this technique. The measured overflow hydrograph is compared with the results of the simulation.

The difference between simulated and measured CSO volume for this event was about 5%. Generally single event simulation agrees with actual measurements after sufficient calibration. However, for a series of rainfall events this technique becomes too costly and complicated. When calculating yearly volumes of CSO, continuous simulation is accordingly a more efficient alternative.

Continuous Simulation

For the studied area in Malmö about 600 rainfall events were used as model input. The computed series of flows was routed through a simple hydraulic model of the overflow in order to obtain the corresponding CSO volumes. This methodology is described in Fig. 4.

Extensive calibration runs were performed in order to attain good agreement with actual measured volumes.

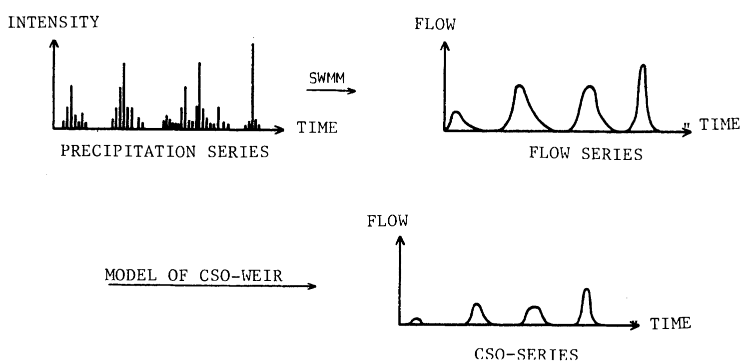
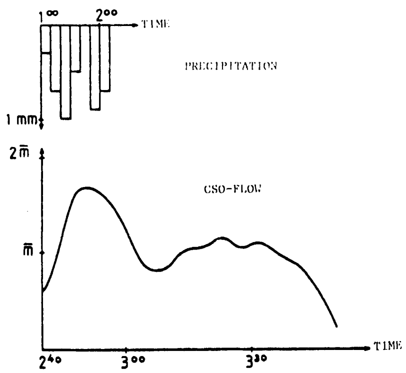


Fig. 4. Continuous simulation of CSO volumes.



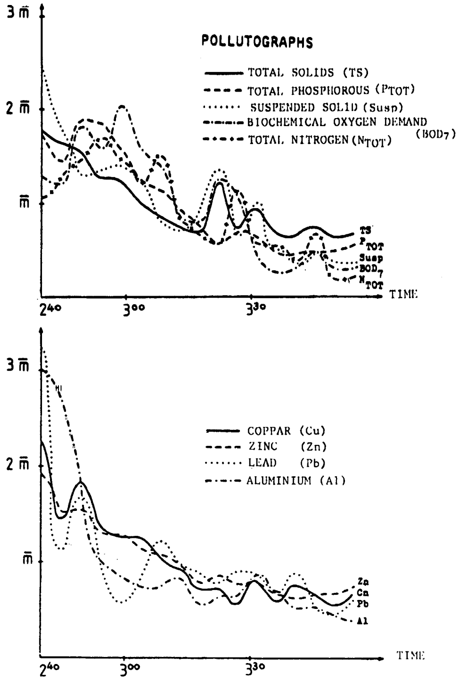


Fig. 5. Pollutographs measured during a CSO event, m̄ = mean.

Mass Transport Calculation

On the basis of quality measurements, standard values of pollution concentration representative for each sewerage area were determined. The pollution load from each area was calculated by multiplying the CSO volumes by the standard concentrations of pollutants (see Table 1).

In reality the pollution concentration of the CSO discharge varies during the

Table 1 – Standard values of concentration for different CSO pollutants and sewerage areas in Malmö.

	Unit: mg/l									
	BOD_7	SS	P_{TOT}	N_{TOT}	COD_{Cr}	Cu	Zn	Pb	Cd	Cr
Limhamn										
CSO at Ekonomigatan	85	280	2.7	9.8	480	0.25	0.42	0.14	0.085	0.014
The rest of Limhamn	25	75	1.1	3.3	160	0.07	0.14	0.02	0.005	0.010
Hamnen	20	110	0.9	5.2	160	0.17	0.34	0.10	0.005	0.010
Spillepengen, Rosendal and Turbinen	60	210	2.1	7.5	160	0.22	0.38	0.12	0.005	0.013

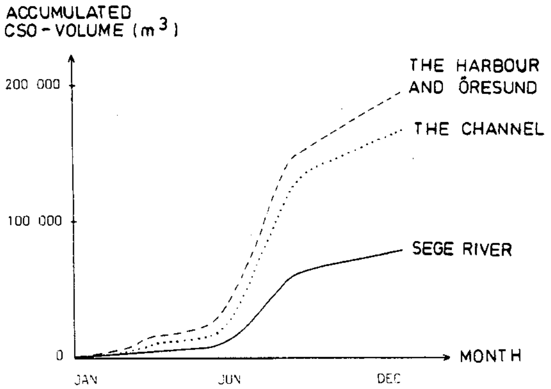


Fig. 6.
Average distribution of CSO volumes during a normal year for the receiving waters in Malmö.

event. The fluctuations depend mainly on rainfall intensity and the amount of pollutants accumulated in the sewer system and on urban surfaces during the preceding dry weather period. Fig. 5 shows an example of the variation in concentration for different pollutants during a CSO event.

Discussion

The distribution of CSO volumes during a normal year for the different types of receiving waters in Malmö is illustrated in Fig. 6.

In Table 2 the total pollution loads to the receiving waters are shown.

The yearly pollution load is used to estimate the long term effects on the quality of the receiving waters. Short-term effects like shock loading must be studied in connection with single CSO events. Measurements in Malmö showed that CSO events are most frequent during the period June to September (about 70% of the total volume). In the smaller receiving waters (river Sege) this period is often the most sensitive from a pollutional point of view due to low receiving water flow with little dilution of the polluted discharge. It is possible to estimate the short-term effects by comparing the maximum pollution concentration in the CSO discharge during an event with the receiving water conditions.

In this context the CSO discharge flow and the present concentration of pollu-

Table 2 – Total yearly pollution load to the different receiving waters for Malmö. Unit: kg/year

Receiving water	BOD_7	SS	P_{TOT}	N_{TOT}	COD_{CR}	Cu	Zn	Pb	Cd	Cr
The harbour and Öresund	6.800	24.000	270	980	43.000	25	48	12	<3.0	2.1
The channel	9.600	34.000	340	1.200	26.000	35	61	19	<0.8	2.1
The Sege river	4.800	17.000	170	600	13.000	18	30	10	<0.4	1.0

Table 3 – Maximum of pollution concentration in CSO discharge in Malmö, (mg/1).

SS	TS	VS	BOD_7	P_{TOT}	N_{TOT}	COD_{Cr}	Termo coli*	Cu	Zn	Pb	Cr	Cd	Al
750	910	620	250	9.0	29	2000	160	0.57	0.92	0.36	0.15	2.2	8.7

* 1000 st/100 ml

tants in the receiving water are taken into consideration. Table 3 shows the maximum pollution concentration in CSO discharge from all sampling events measured in Malmö during 1982.

In general pollution discharge with a high dilution rate into less sensitive receiving waters may be allowed for.

Sometimes simple and less costly measures can improve the CSO situation. Example of such methods which were suggested in connection with the rehabilitation plan in Malmö are:

- Improvement of maintenance and increasing the height of weir crests
- Outlet sewers to be used as retention storages
- Redistribution of the flow conditions in the sewer network
- Increasing the capacity of contracted sewers, jets and pumping stations
- Disconnection of storm water pipes from the combined sewer system

Sludge pumping of storages and sediment traps in the sewer system are also beneficial to CSO-quality.

References

Hogland, W., Berndtsson, R., and Larson, M. (1983) Combined Sewer Overflow in Malmö – yearly overflow volumes and pollution load and suggestions for reduction of combined sewer overflow, Report No 3079, Department of Water Resources Engineering, Lund Institute of Technology/University of Lund, Lund (in Swedish).

Hogland, W., Berndtsson, R., and Larson, M. (1984) Estimation of Quality and Pollution Load of Combined Sewer Overflow Discharge, Third International Conference on Urban Storm Drainage, June 4-8, 1984, Göteborg.

Hogland, W., Berndtsson, R., and Larson, M. (1984) Combined Sewer Overflow, Rehabilitation, Construction and Function and Calculation of Overflow Volumes and Pollution Load, Report, Department of Water Resources Engineering, Lund Institute of Technology/University of Lund, Lund (in Swedish, in press).

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