SAMBA Reference Manual

1 Objective

SAMBA is a simple model for calculation of discharges from combined sewer overflows. (The name is derived from the first letters in the Danish sequence: Simple runoff model for calculation of discharge from overflows). The model has been created specifically to give statistical parameters, with which to characterise the properties of combined sewer overflows.

The basic concept behind the SAMBA-model is to facilitate calculation of large sewer networks with long time series of rainfall data as input to the calculation. The load on the environment can be expressed in statistical terms. There are two essential cases to deal with:

The annual load is of concern in case of discharge of pollutants which accumulate in the receiving water. The annual load can be described by an average value and the variation from year to year around the average. This approach is applicable to discharges of the nutrients: nitrogen and phosphorus, because they accumulate to cause eutrophication through excess algae blooms. Non-degradable organics and heavy metals are often in the same category. It is of little relevance whether the discharge comes as a constant flow or whether it comes as few heavy discharges. The long term accumulation is the same.

The other extreme is the abrupt load of a pollutant, the effect of which lasts as long as the event and a little longer. In such cases it is the statistics on the individual event that counts, not the time average over extended periods.

The result of the calculation is extreme statistics on the mass of pollutant discharged pr. event. This is applicable to oxygen depletion caused by discharge of BOD to rivers, because the depletion lasts as long as the event and not much longer. The same applies to discharges of acute toxicity, like discharge of ammonia, which is very toxic to fish. The result of the calculation is expressed as the return period for the load in a single event exceeding x kg of the pollutant in question.

The results of the two different approaches are illustrated in Section 5 of this manual.

2 The Basic Approach

A detailed description of the methods of calculation is given in the MOUSE documentation. Detailed documentation of the scientific principles and the background for the development of the model is given in the literature, specifically the PhD-thesis by N. B. Johansen: "Discharge to Receiving Waters from Sewer Systems During Rain", Department of Environmental Engineering, Technical University of Denmark (1985). The development was made as part of a project for the Council of Greater Copenhagen.

The rain input to the model is a long series of individual rainfall records. The more years that are covered, the better the reliability of the statistics becomes on the load on the receiving water. With respect to accumulating pollutants it is recommended to use no less than ten years with a continuous record of rains larger than a critical rain depth. For calculations in Denmark 33 full years of rain record involve 1571 individual rains larger than 3 mm from the city of Odense, on the island of Funen. The name of the file is: ODE1571. With respect to pollutants having acute effects only the most heavy rains of the record may be used as input. For Denmark such files are available. ODE100 contains the 100 most intense rain events from the city of Odense over a 46 year period. Correspondingly, GEN106 contains the most intense 106 rains from the city of Gentofte, a suburb north of Copenhagen. These are just examples which can be used as a test in the beginning. Later, such series have to be produced locally, regionally or nationally.

In order to use the statistical approach by running a very large number of rains through the calculations it is a requirement that the runoff model be simplified. Otherwise the time of calculation will be too long for practical application. This can be carried out by using a modified time-area approach without sacrificing calculation accuracy compared with a kinematic wave simulation of the runoff process. The fundamental principle of the time-area approach is that standard unit hydrographs from each subcatchment are translated from one point to the other with the velocity of the water in the pipe and summarized at all junctions. The fundamental simplification is that a big catchment can be described by a single unit hydrograph or time-area curve. The principle is illustrated in Figure 1 and is well known from any textbook on hydrology. The significant advantage is that the time-area approach involves the principle of superposition (addition and multiplication) which works orders of magnitude faster than iterations and numerical solution algorithms to differential equations.

Individual time-area curves can entered via SAMBA. If this has not been done, then the time area curves are generated automatically for each catchment. In the traditional approach, where the time-area curve is used for design, the translation is always done at the speed corresponding to full pipe flow. This approach will lead to overestimation of the flow at small rain events, where the pipes are partly filled and the velocities smaller. In the modified approach used in SAMBA-versions greater than 1.3, the translation is done at the kinematic velocity of partial filling. In this way the properties of the time-area approach is combined with the properties of the kinematic wave approach.

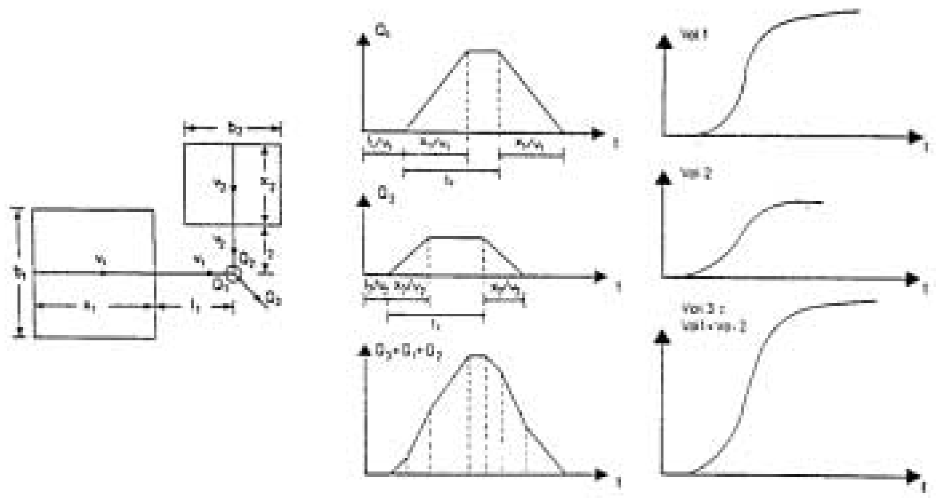


Figure 1 *Hydrographs from two rectangular catchments determined by the time area model.*

Accordingly, the SAMBA-model is characterised by the same limitations as the kinematic wave approach. This involves the following essential limitations:

- o The flow in a pipe is governed by the slope and the partial filling of the cross-section. Non-uniform flow is not accounted for.
- o The water cannot run backwards. A direction of flow is connected to every pipe, which cannot be changed.
- o Surcharging can be calculated with rough approximation only, which can turn out to be **unrealistic**.

The hydrology on catchment surfaces is computed only by a description consisting of an initial loss and a runoff coefficient from impermeable surfaces, and by the hydrological reduction factor.

Each catchment is thus described only by time-area curves (corresponding to unity hydrographs) in a downstream point, a calculation point (see below). This simplification is illustrated in Figure 2.

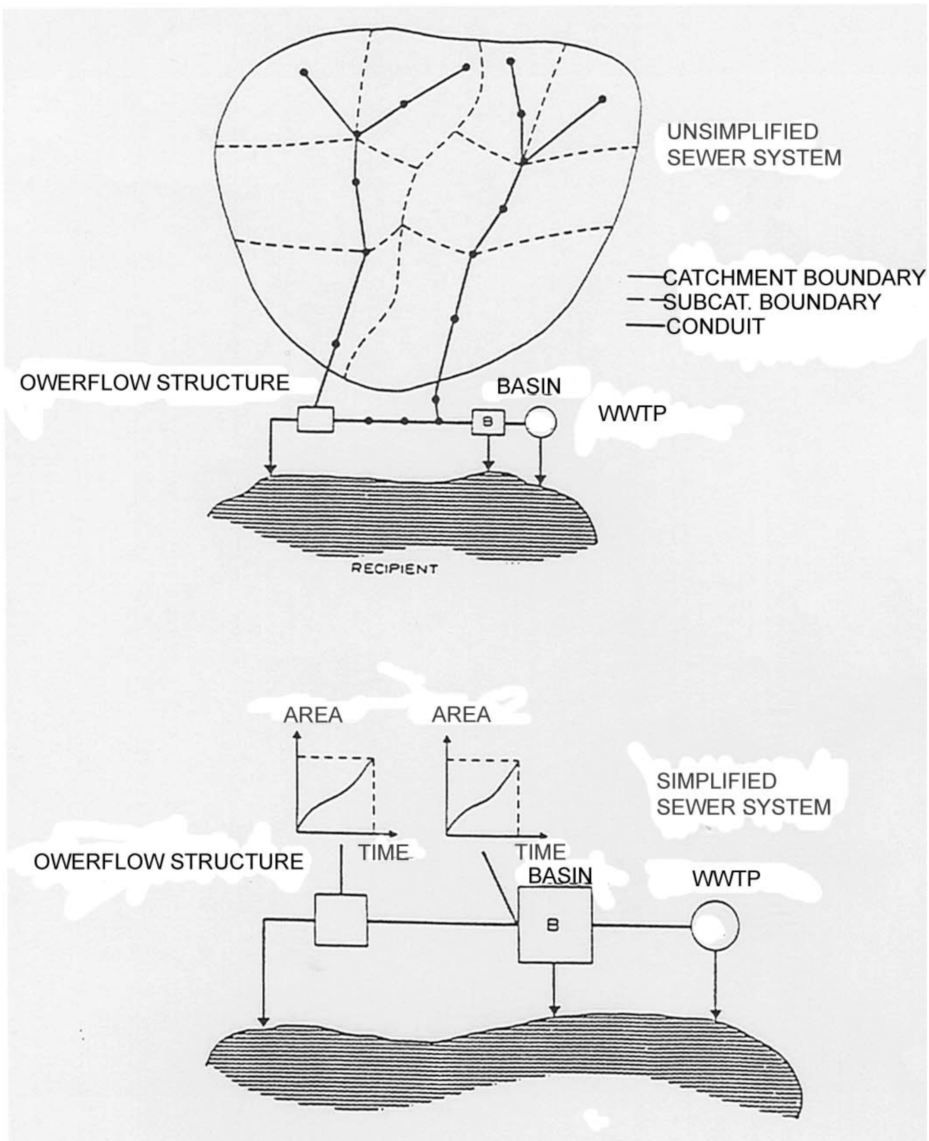


Figure 2 *An example of simplification of a catchment for the SAMBA computation. The pipes are reduced to interception pipes and the catchments for the individual weir are represented by a time area curve only. This can either be entered by the user or SAMBA will generate it automatically.*

Time-area curves are calculated for selected rain intensities in accordance with the partial fillings for the actual intensity. This is illustrated in Figure 3.

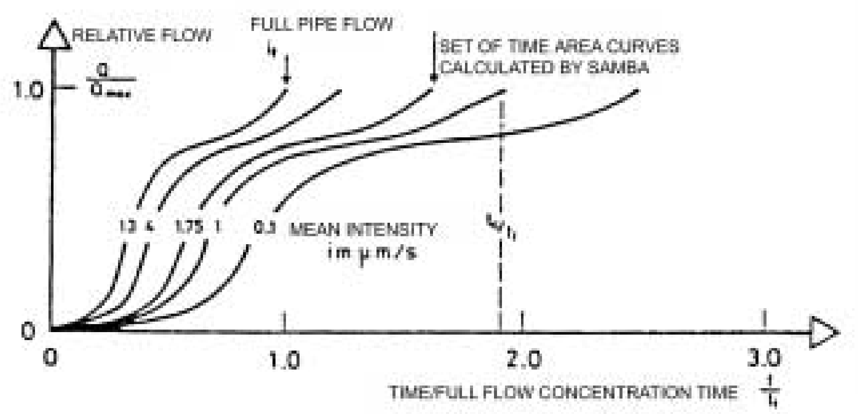


Figure 3 *In the modified time area method different time area curves are used, corresponding to different partly filling curves, which again correspond to different rain intensities.*

Downstream the network will reach a structure of relevance to the calculations: a basin, an overflow, a pumping station and/or an interceptor which leads the water further down the system to other structures or to an outlet (which is likely to be the inlet to a treatment plant). The whole catchment is thus divided into few subcatchments draining to a structure, where the water is either stored, conveyed to another structure via an interceptor or discharged from an overflow, if the capacity of the basin or the interceptor is exceeded. The simplified system is illustrated on Figure 2.

The SAMBA-programme works in three stages:

1. The first stage, called the reduction module (import menu), does the simplification of the network. The programme performs a systematic analysis of the systems. The analysis involves an analysis of how all elements in the systems are logically connected. In case there are inconsistencies or the system cannot fit the concepts required for the SAMBA-model, there will be error messages or warnings on the screen. The programme performs a reduction of the information to fit the SAMBA-model and all other information is deleted.

2. In the second stage the actual calculations are performed. From the allocated raindata file the data for each individual rain in the time series are read in the sequence in which they are listed in the database. The calculated discharges from outlets and from overflow structures are temporarily stored in a new file

on the disk in the sequence in which they are generated.

3. The third stage performs the statistical calculations on the temporarily stored data. The results are stored on the disk in new files, which are called when plots and tables are generated. This stage is performed automatically at the end of the simulation (2).

3 Basic Definitions

The SAMBA-model uses a number of terms which are important to understand. They will be explained in the following:

Calculation points

A calculation point is a position in the network, where at least one of the following functions are performed:

- o Division of flow
- o Constriction with an overflow, without a basin
- o Constriction with a basin and an overflow
- o Outlet

By <u>division of flow</u> is meant a structure in which the flow can be conveyed in two directions. The discharge from the structure can be routed through two different pipe downstream from the structure. The division is done proportionally with the capacity of the downstream pipes.

A <u>constriction</u> is a limitation of the flow. In practice such a constriction can take several forms: A pipe with a limited capacity, a water brake, a pumping station. The common feature is that the flow has a maximum that cannot be exceeded.

A <u>constricting pipe</u> is a pipe just downstream a calculation point, for which an overflow function has been defined. Due to local conditions, like increased water level in the overflow chamber or increased water level downstream, the maximum flow can be allocated specifically. This is done within SAMBA and the values are stored in the *.cap file. This file can be reread during the next import. If this maximum flow is not allocated, the programme selects the capacity of the downstream pipe automatically - and a warning is highlighted.

A <u>water brake</u> is characterized by a maximum flow. Flow less than the maximum is conveyed on to the next calculation point. Flow in excess is carried over the overflow.

A pumping station is correspondingly characterised by its maximum flow capacity. Flow less than the maximum is conveyed on to the next calculation point. Flow in excess is carried over the overflow.

A basin is simply a structure, which has a maximum storage capacity.

An overflow is simply a structure that conveys excess flow to the receiving water or to another point in the system. These are called external and internal overflows, respectively.

An overflow without a basin gives rise to overflow when the flow to the calculation point exceeds the maximum capacity.

An overflow with a basin gives rise to overflow, when both the flow capacity of the constriction and the storage capacity are exceeded. This is illustrated on Figure 4.

An outlet is a structure, that creates the downstream termination of the network. For the benefit of the logic of the system it is required to establish an identified outlet. This calculation point together with the direction of slope gives the unique orientation of the network in the reduction module (import menu). If an outlet is missing the programme gives an error message.

Details regarding the hydraulic description of the function of the pipes and structures and the transport of pollutants in the system can be found in the programme documentation.

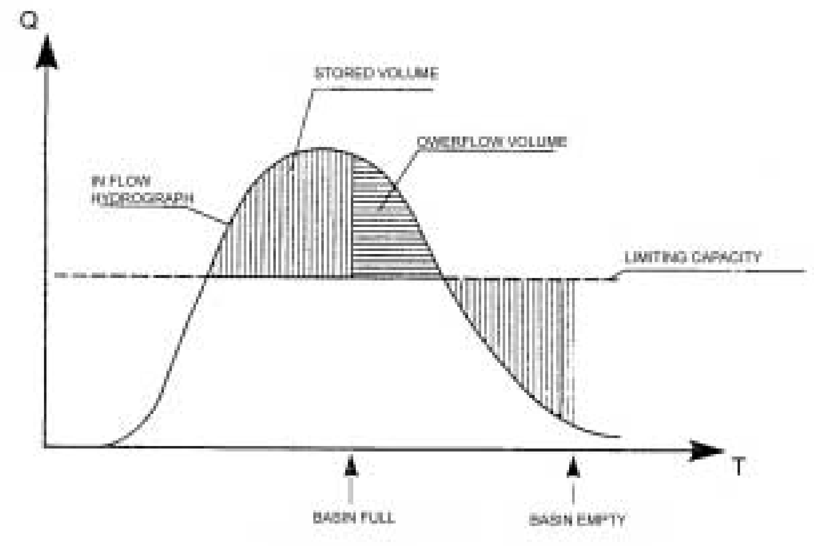


Figure 4 *An illustration of holding the water in a basin with a constriction pipe.*

Subcatchments

A subcatchment is everything upstream of a calculation point: surfaces, gully pots, pipes and manholes. The whole subcatchment is reduced in the set-up module to a contributing area and time-area curves, as illustrated in Figure 3.

Details regarding the description of hydrology and the hydraulics of the subcatchments are available in the SAMBA-documentation.

Special pipes

After the simplification of the system there are only two types of pipes remaining:

Outlet pipes
Interceptors

The outlet pipe is simply the pipe that connects the outlet with an upstream calculation point.

An interceptor is simply a pipe that connects two calculation points upstream of the outlet pipe.

These pipes are illustrated on Figure 2. No other pipes are of relevance to the calculation, because all other pipes are adequately included in the time-area curve for each subcatchment.

The special pipes run partially filled as long as the flow does not exceed the capacity and as long as no water is stored in basins upstream. As soon as the capacity of the constriction is exceeded and there is water stored in a basin upstream the interceptor will be full. The water is carried to the next calculation point with the full pipe flow velocity.

Sources and transportation of pollutants

The SAMBA-model operates with three sources of pollution:

Domestic wastewater
Industrial wastewater
Runoff

Domestic wastewater is wastewater produced from normal habitation. Industrial wastewater is discharged at specific points and can be specified individually. Runoff is the water in excess of the regular wastewater. This corresponds in quantity to the rain input. The pollution assigned to the runoff represents all other sources of pollution than the domestic and the industrial with which the runoff is mixed. The runoff concentration represents the pollution derived from the surfaces plus the pollution derived from erosion of the deposits in the pipe during the rain event. The runoff concentration is an event mean concentration calculated from mass balance of the volumes and concentrations of the three different types of water.

This approach is based on the concept that it is the total quantity of pollution discharged pr. event that counts. This is valid for both the accumulating pollutants and the pollutants with accute effects. The temporal distribution is of little importance to the ultimate effect in the receiving water. The statistical properties of the concentrations and mass flow give rise to selection of the event mean concentration as an adequate parameter with which to describe the discharge of pollution.

The resulting calculation at a calculation point describes that the three wastewaters are mixed in each time-step according to flow and concentration. It is this mixture that is carried forward in the interceptor and over the overflow structure at calculation points.

The SAMBA-model can take sedimentation in account in the pipes, structures or basins. The quantity of pollution that enters the network during a whole rain event is exactly equal to the quantity that leaves the network, either via overflow to the surroundings, or/and via outlets, or/and is sedimented in the basins

4 Network Simplification.

The unique feature of the SAMBA-model is the way in which the network is simplified. This is the feature that makes the statistical treatment of lengthy rain series possible. It is essential to understand the simplifications, which are made in the reduction module (import menu), and the adaptations, which are required in the catchment data input.

Figure 5 shows a number of symbols, which are convenient to use for the description of the system. There are symbols for the following uniquely defined structures:

Subcatchments, calculation points, special pipes, the treatment plant and the environment.

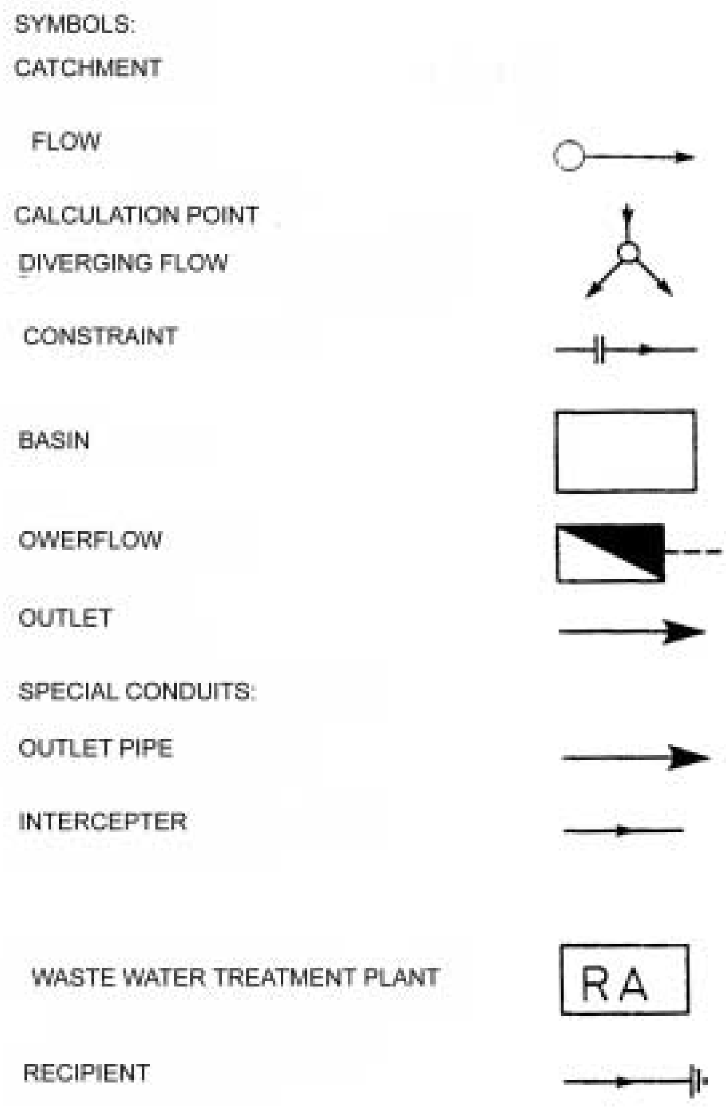


Figure 5 *Symbols used at system simplification.*

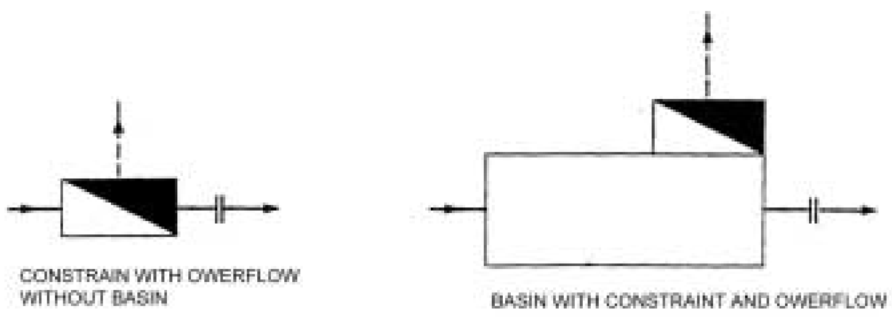


Figure 6 *Symbols for overflow and basin with overflow.*

Figure 6 shows the two ways in which a construction, an overflow and a basin can be combined.

Figure 7 is a simple example of a system involving all types of elements: Subcatchment, division, overflow, basin, interceptor, outlet, purification plant and receiving water. This is the way in which the system has to be interpreted. In most cases this simplification is performed automatically in the reduction module (import menu), but in certain cases it is required to adapt the system to fit the approach. That may apply to special combinations of structures in relation to overflows and basins, see the documentation.

Under all circumstances it is recommended to understand the simplifications and to check the display with respect to the number of catchments, calculation points and outlets.

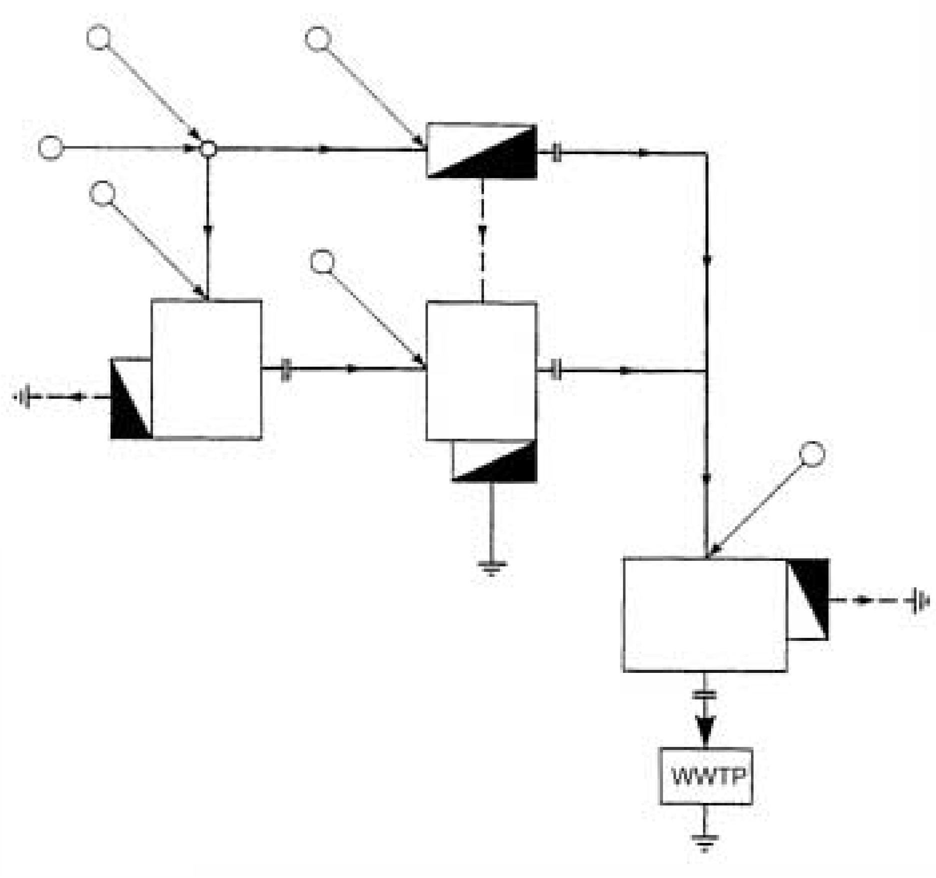


Figure 7 *An example of a simplified sewer net with 6 catchments, 1 outlet and 5 calculation points (1 ramification point, 1 overflow without basin, 1 basin without overflow and 2 basins with overflow, one overflow is internal).*

5 Statistical Handling of Overflow Data

The SAMBA-calculation generates datasets with the primary results of the calculation on the disk. The dataset contains information on: water volume, mass transport, max. flow and duration of overflow for each overflow structure. From this sequence of information the statistic module generates chronological variation and variation within the year and statistics on extreme values.

Chronological and Annual Variations

On the basis of the historical rainseries over the selected period of years chronological series are produced for the chosen parameters. For each year all overflows are summed up for the periods of the year chosen. There are the following choices: all year, summer and winter and any month of the year. The average value and the standard variation between years are calculated on an arithmetic basis. An example is shown on Figure 8.

From the primary data the variation within the year is calculated. The result can be given as a table or as a plot, an example is given in Figure 9. From all the yearly loads the average and the standard variation for a month is calculated and shown.

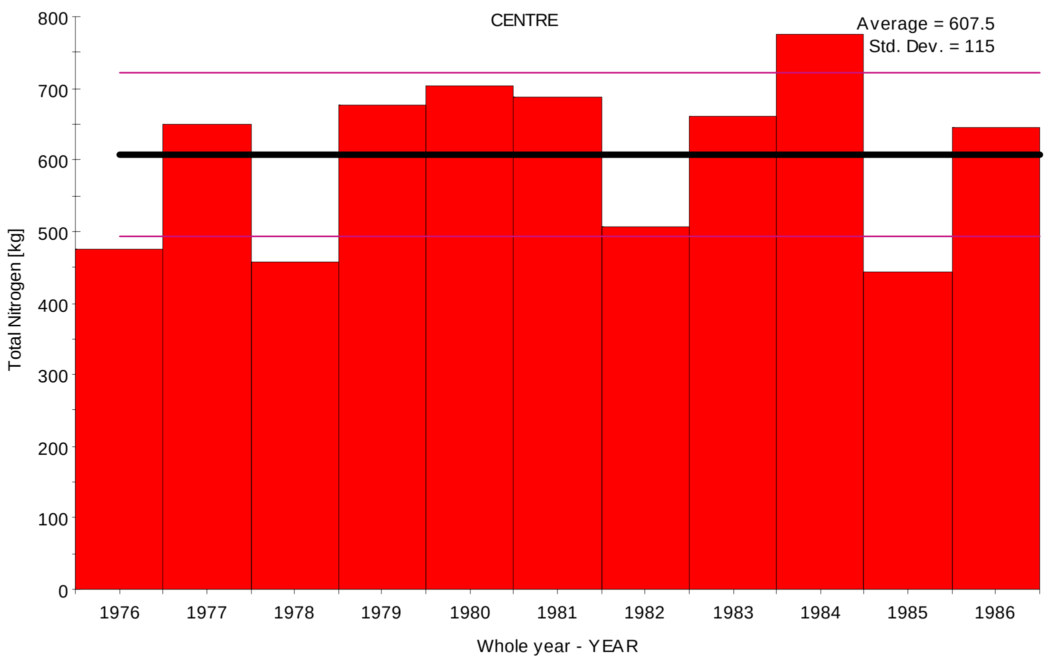


Figure 8 *An example of chronological variation.*

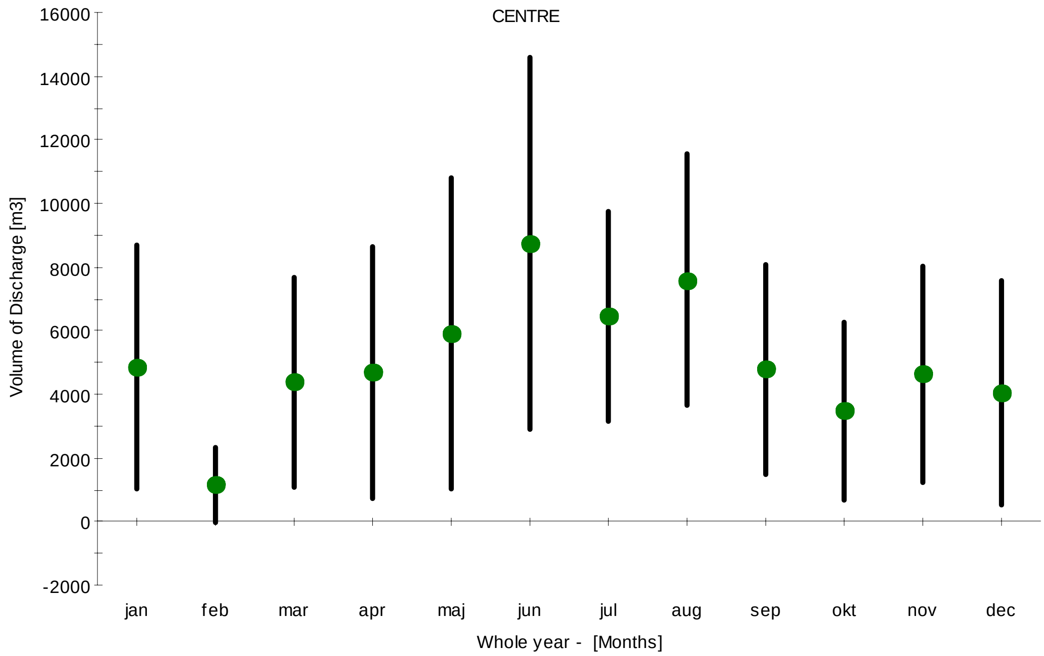


Figure 9 *An example of year variation.*

Extreme values

Each overflow event is ranked for the parameter in question, the biggest value first, the second biggest next and so on. The return period allocated to each figure is calculated by the figure T = N/M, where M is the rank and N is the number of years in the rain series. The statistics can be calculated for selected periods of the year (full year, summer, winter and individual month).

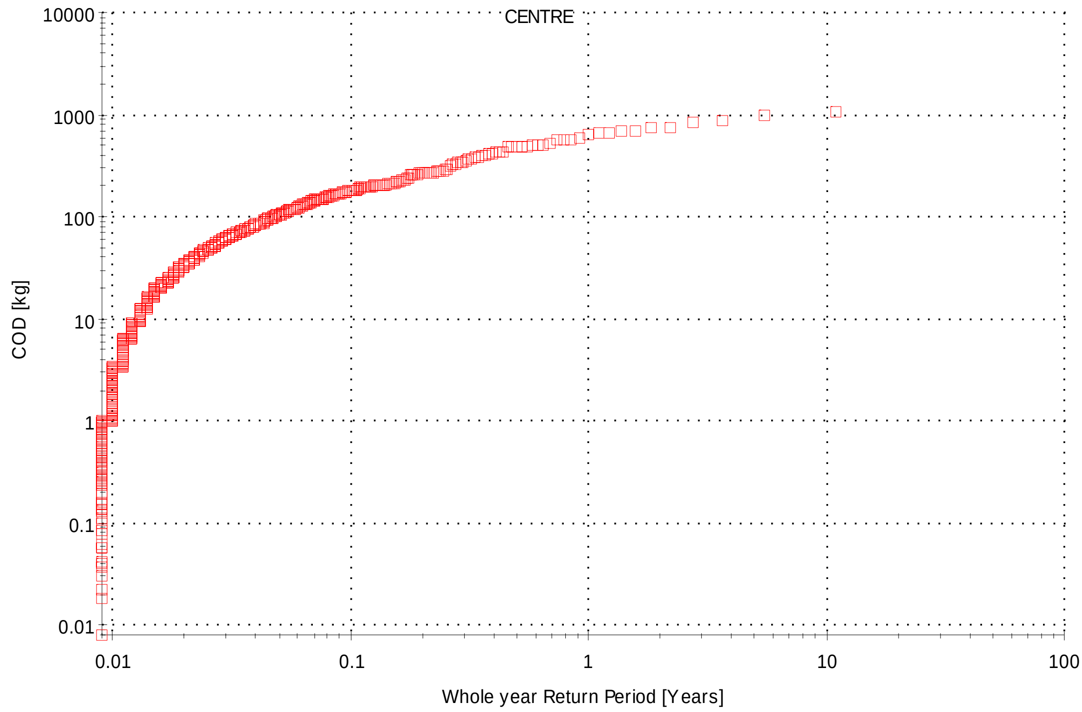


Figure 10 *An example of statistics for extreme values.*

6 Hydrology

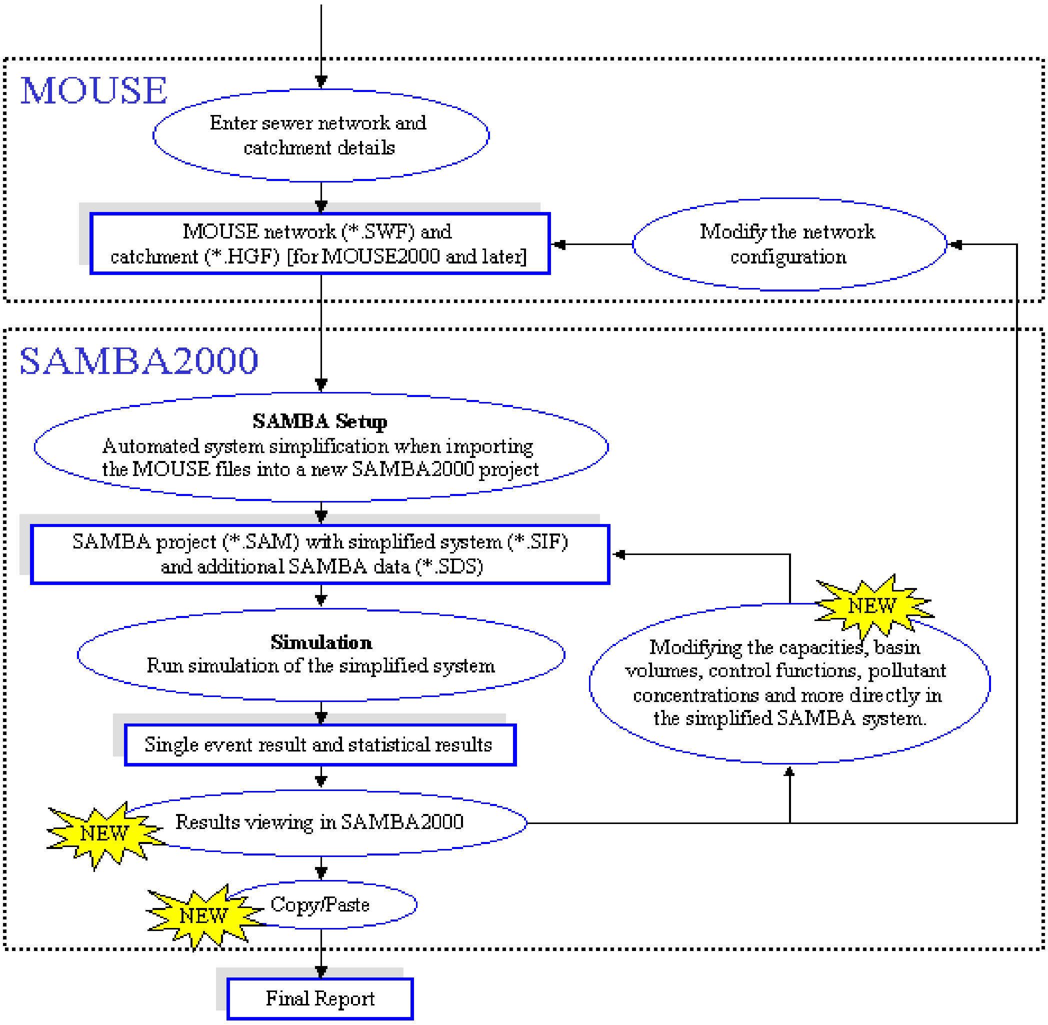
Reference is made to standard data, in which the total area of each catchment is written and where the fraction of paved area is written. For the hydrological model level B (see MOUSE user guide) the paved area is regarded to be the sum of the impermeable areas together with 50% of the semipervious areas.

Only the paved areas are taken into account. The hydrological reduction factor (sewer coefficient for areas below one) can be entered globally. The hydraulic reduction factor is set to 1,0 as a standard.

The initial loss has to be entered, usually in the order of 0.6 - 0.8 mm. It can be given only as a universal number for all catchments, which generally is a good approximation for paved areas. The initial losses thus established do not correspond to the other hydrologic data, or to the specially mentioned initial loss to hydrologic level A (see MOUSE user guide).

7 Procedure

SAMBA is a planning tool for combined sewer systems which uses a simpler calculation scheme than hydrodynamic models. The simple calculation scheme makes SAMBA suitable for the long term simulations needed for a statistical evaluation of discharges from combined sewer overflows.
The flow chart below shows the essential steps in working with SAMBA:



8 Practical Advice on Running the SAMBA Model

Degree of detail of the catchment description

Because of the simplified way the SAMBA model calculates, the user will not achieve a considerably better accuracy by entering detailed information of a catchment pipe after pipe, weir after weir. A simplified system based on main pipes, interceptors, overflow weirs/structures, basins and pumping stations is adequate.

Outlet capacity for weirs

It is recommended to enter the outlet discharge from overflow weirs as steady outlet capacity. Pumping stations can, in principle, very well be entered as overflow weirs with steady outlet capacity = maximum pumping output.

The steady outlet capacity for overflow weirs is determined as outlet capacity, when the overflow begins working. The capacities of the overflow weir could be determined by preceeding computations of the catchment with the dynamic pipe model.

SAMBA calculates with constant pumping output = maximum output for pumping stations with various pumping steps.

Weir volumes

The volume in a weir, that is available for storage before the overflow begins working, is calculated as the volume between bottom level and overflow level. The storage effect is not being taken into account for weirs for which no overflow has been entered.

SAMBA automatically calculates the volume in the pipenetwork upstream the structure. The volume is calculated as the pipe volume that lies under the overflow level of the structure and only up to the nearest upstream structures. In case the discharge to the outlet pipe occupies an essential part of this volume, this discharge volume contribution will not be subtracted. It is volountarily to use this facility. The user can say "yes" or "no" when starting a SAMBA computation.

A facility has been built-in to make it possible to see the main data the SAMBA model uses after importing MOUSE data. A print of this can be generated via the “book” button. It will show the calculated volumes and if "yes" has been entered to calculate on pipe volumes, then they can be read as well. It offers the possibility to say "no" to starting the SAMBA computation and to use the printed volumes to enter them separately as wished and then start it again.

Internal overflows

SAMBA is capable of computing internal overflows, where it occurs from one weir to another weir or structure in the system. However, the overflow may not be added to a point that lies upstream of the overflow weir.

SAMBA does not print out the results for internal overflows. Internal overflows directly from one overflow weir to another requires that a fictitious manhole is entered in between the two weirs.

Outlet capacity / wastewater flow

The mean 24 hour value of the wastewater influx to an overflow weir has to be less than the outlet capacity of the weir. If the mean 24 hour value of the wastewater influx is larger than the outlet capacity, there will be an error message, but if this value is only a bit larger than the wastewater, the user risks a computation that will take a long time.

Infiltration

In the present version, the SAMBA model does not take the infiltration into account, nor the additional discharge. In most cases it is most appropriate to include the infiltration in the wastewater influx. This can be carried out without loss of accuracy, if the user compensates for the too high wastewater discharge, by reducing the pollution concentrations in the wastewater.

First flush

The user has the possibility of entering that part of the total pollution load that is being transported to a structure with 50% of the total rain volume. Danish and international research indicates a tendency to transportation of more than 50% of the total pollution load runoff with the first 50% of the water runoff. There are however no investigations that unambiguously substantiate this effect and therefore can be a basis for the selection of a value. Therefore it is recommended only to use a value different from 50% as soon as local measurements are available that can establish another value. Note that the same percentage is used for all materials.

Sedimentation

The user has the possibility of entering whether to take sedimentation in structures in account for material. In supplementary data, the user can enter the amount of material that can**not** be sedimentated together with the amount of material that will be sedimentated after one hour respite. It is recommended only to use this facility when local measurements are available to determine these values.

User adjustment of the concentration level

The user can enter a relation between material concentration and the characteristic size of the individual rain events. There are no Danish or international investigations that unambiguously substantiate a relation between the concentration level for a certain material or one or more characteristic parameters for the rain event. However, there are measurement series available that indicate such a relation, but it cannot be generalized to application for other catchments than the one with actual measurements. This facility should therefore only be used when measurements for the actual catchment are available that can show such a relation.

Control

In the Standard SAMBA version 3.1 it is now possible to control the discharge capacity from a computational point based on the present volume in the same or in another computational point (reservoir + available pipe volume). The control is entered as a table with max. 18 corresponding values in Supplementary Data. The model interpolates, but it is exclusively up to the user to make sure that the table covers the relevant area. If, during the computation, a situation arises, in which the table does not describe the circumstances, the computation will stop with an error information of the type:

"Error in control function Qaflob (xxxxxxx) = f(yyyyyyy)
- volume (yyyyyyy) = zzzzz m3 is outside table".

where	xxxxxxx	is the name of the controlled structure
	yyyyyyy	is the name of the stucture, where measurements are taken
	zzzzz	is the calculated volume in the node where

measurements are taken.

The computation of the control functions is made **after** computation of the state of the whole system for the actual time step, and is consequently used for the next time step.