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SEWERAGE SYSTEM DEVELOPING

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Abstract

Design and operation of gravity sewer systems can be divided into:

- combined,
- separated,
- mixed sewer systems. In the traditional planning and operating systems there were no functional connections between:
- sewer systems,
- wastewater treatment plant and the
- receiving water body.

Keywords: Sewerage, runoff, rainwater storage, storage basin.

Introduction

They operated as 'black boxes' and the input-output connection was basically inadequate. The planning of hydraulic and organic loading of wastewater treatment plant, the loading capacity of the receiving water body and the self-purification of the receiving waters was approximative. This attitude was due to the lack of theoretical basis.

The traditional planning and operational viewpoint supposes permanent even flow, so the Chezy hydraulic theory is used. The dimensioning of the collection and transport of the rainwater is based on the 'rational calculation method', while the loading capacity of the receiving water body is dimensioned on the basis of the 'dilution theory'. Therefore, there is no hydraulic and pollution loading, which is optimal for the sewer system, the receiving water body and the wastewater treatment plant at the same time.

In the modern attitudes that include runoff control,

- the method of collection and transport in the sewer system,
- the runoff conditions in the network

are organized and optimized from the point of view of the receiving water body and the wastewater treatment plant as well. In this attitude the technical – economic optimalization of the system is essential.

Classifying of Sewer Systems

The introduction of pressure and vacuum sewer systems has provided several options and the importance of economic and operational optimization has increased. *Fig. 1* shows a characteristic mixed sewer system, while in *Fig. 2* a pressure sewer system can be seen.

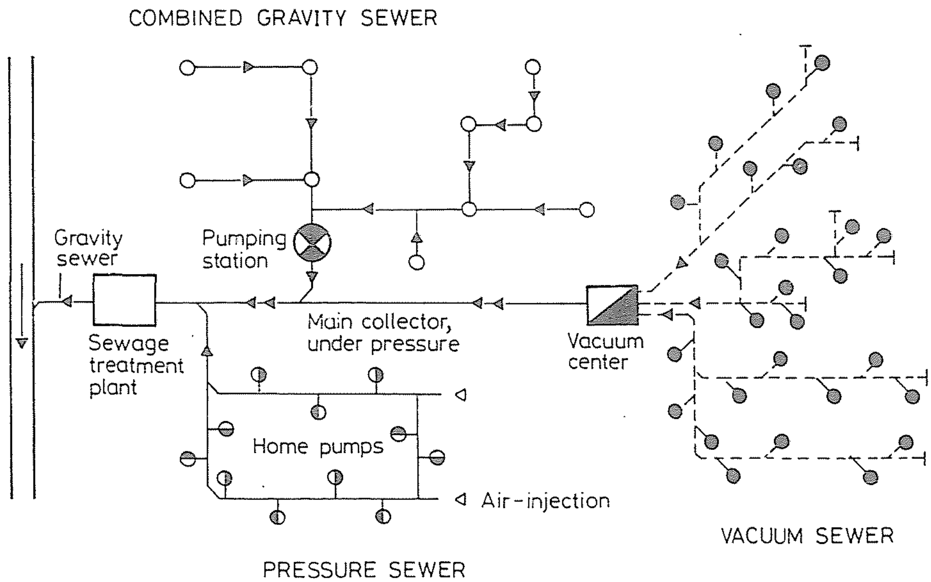

Fig. 1. A characteristic mixed-system sever network

Fig. 3 shows the types of sewer systems and their possible combinations.

Establishment of mixed systems — in the case of medium and large systems — will probably become more important. With spreading and reconstruction of combined system a vacuum or/and pressure sewer system should be joined to the existing network in many cases to collect the wastewater from the suburbs.

Rainwater Runoff Model

The Storm Water Management Model (SWMM) is a deterministic, spatially distributed model for the calculation of runoff from urban areas.

The *input* consists of time series of rainfall data and a set of parameters describing the physical properties of the catchment.

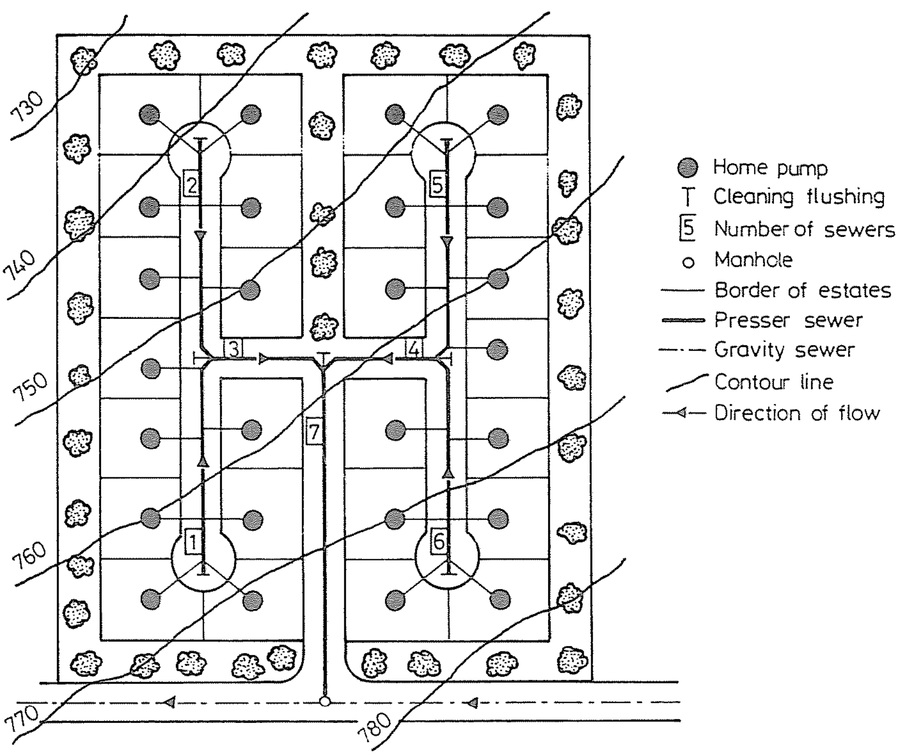

Fig. 2. Pressure sever system

The *output* consists of time series of runoff data or any other point of the catchment.

The *rainfall input* can be geographically divided at the outlet point.

The rainwater runoff model can be divided into four main 'blocks' which can be run separately or combined with each other (*Fig. 4*).

The *runoff block* generates surface runoff.

The *transport block* carries and combines the outputs from the runoff block (runoff hydrographs from the subcatchment) through the sewer system. Dry-weather flow and infiltration into the sewer system may be optionally generated using the transport block.

The *storage/treatment block* characterises the effects of control devices upon flow and quality.

The *receiving waters block* consists of hydrographs and pollutographs.

The figure shows that in the future the planning and operation of modern sewer systems can be realized by complex interventions on the catchment and in the drainage network, based on rainwater management.

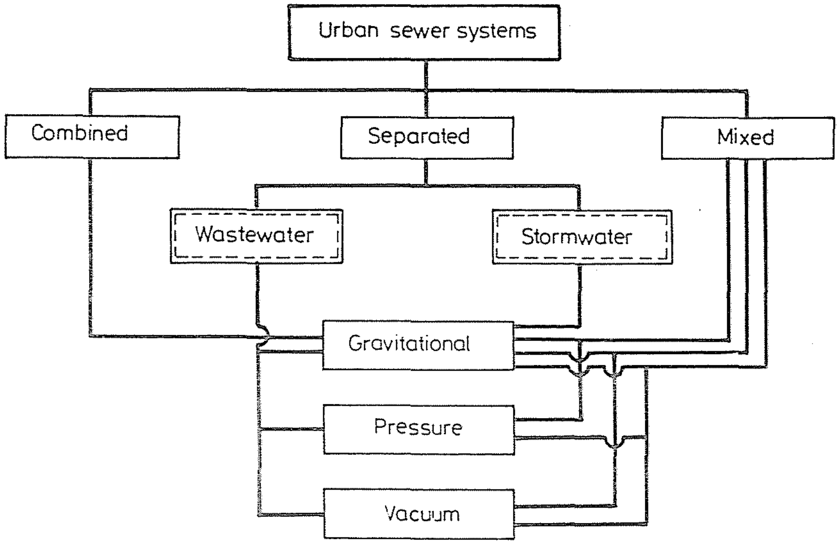

Fig. 3. Types of sewer system and their combinations

In most cases a final solution is to plant several small facilities for:

- storage,
- infiltration or,
- water holding back.

Most solutions regulate and decrease the quantity and/or the peak of runoff.

The technical-economical and environmental optimization of complicated processes connected to the task solution can be achieved only by suitable mathematical models.

To establish a control system it is essential to define the most important *network-elements* first (*Fig. 5*).

The storage element represents a subnetwork with storage capacity. The subnetwork consists of one or two detention reservoirs, overflow elements and short connecting sewers. The dynamic equation governing the elements' behaviour is:

$$V_i(k+1) = V_i(k) + T[q_{in}(k) - q_i(k) - s_i(k)],$$

$$i = 1, \dots, n_\nu,$$

in which :

- T discrete time period,

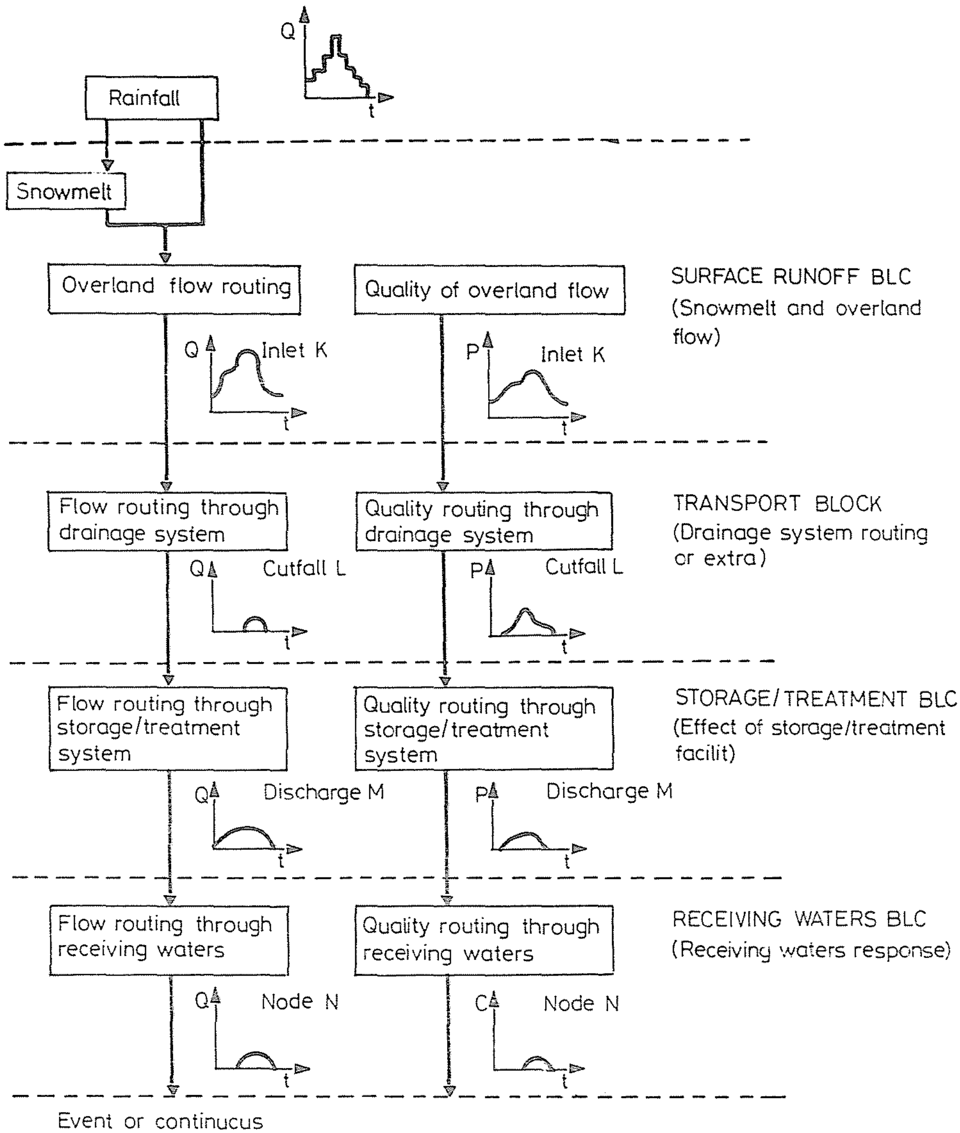

Fig. 4. Overview of the stormwater management model

– q_i and s_i control variables which should be selected from an admissible control region:

$$0 \leq q_i(k) \leq q_{i,\max},$$
$$0 \leq s_i(k) \leq s_{i,\max}.$$

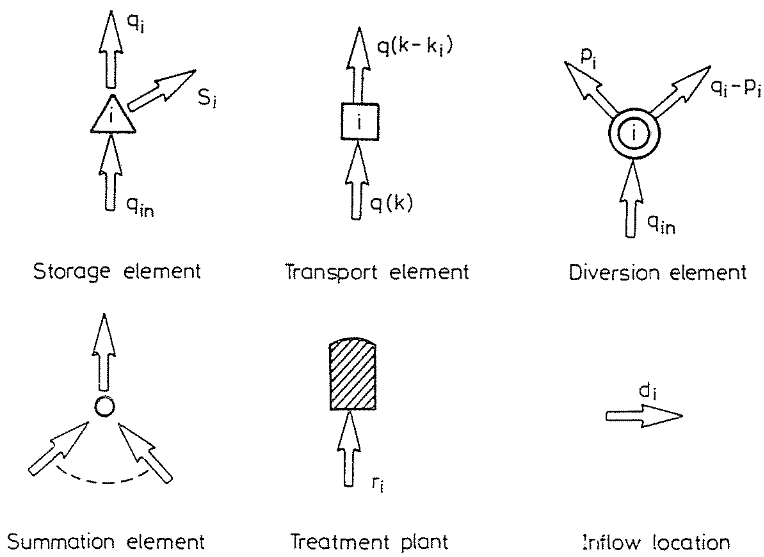

Fig. 5. Elements of the simplified network

The state variables V_i should not exceed the subnetwork's capacity:

$$0 \leq V_i(k) \leq V_{i,\max}.$$

The transport element represents a long sewer trunk and is a delay element with delay k_i where $i = 1, \ldots, n$.

The *diversion element* represents a subnetwork without storage capacity. The inflow q_{in} to the diversion element is divided into two outflows p_i and $q_{in} - p_i$. The admissible control region for the control variable p_i is given by

$$0 \leq p_i(k) \leq \min\left[p_{i,\max}; q_{in}(k)\right] \qquad i = 1, \ldots, n_p.$$

Summation element: several inflows are summed up to a unique outflow. *Treatment plant:* its inflow is denoted by r_i, $i = 1, \ldots, n$, and is selected from an admissible control region:

$$0 \leq r_i(k) \leq r_{i,\max}.$$

Inflow location: these are locations of external inflows: $d_i(k)$ where $i = 1, \ldots, n_d$, the trajectories of which are assumed to be known.

The efficient — economically satisfying — automatic control strategies of the combined sewer systems are based on the temporary hold back of stormwater in storage basins and therefore on the drastic reduction of the overflow.

The mixed wastewater is purified during the storage in the basin. After the rainy period the basins should be emptied in order to enable it to receive the stormwater of the next period. The hydraulic theory of the storage is shown in *Fig 6.*

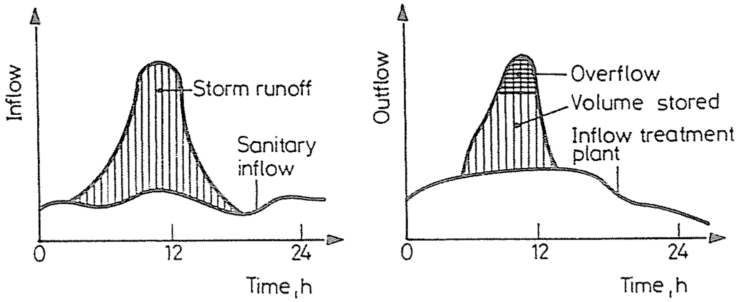

Fig. 6. Theory of storage system for overflow reduction

Flow Equalization in the Sewer System

The technical configuration of a storage facility is depending on local conditions (*Fig 7*).

1. Storage facilities at the place of appearance of storm runoff.
   1.1. The infiltration facility collects the rainwater without having outflow. The aim is to drain all the incoming water.
   1.2. Installing a preliminary control system to the storm runoff system, permits also a temporary storage (for example on the top of isolated plain roof and in parking places).
   1.3. The storm runoff can be retained locally in natural channels and in open lakes. 'Dry' lakes infiltrate water only in the storm period. 'Wet' lakes infiltrate water continuously because they collect ordinary rain as well.
2. The possible ways of flow equalization in the sewer network may be the following:
   2.1. Storages series connection, which can be realized in two ways:
   – using the unutilized capacity of the sewer,
   – establishing extra volumes for storage.
   The main characteristic of storages in series connection is that in combined systems the stored, mixed wastewater, while in sep-

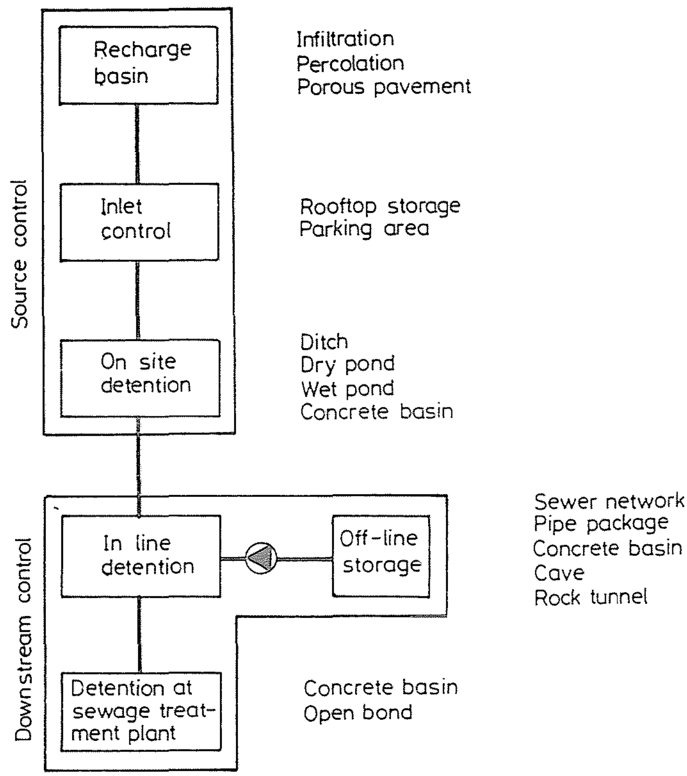

Fig. 7. Scheme of how flow equalization basins can be systematized according to their technical configuration and their location in the sewer system

arated systems the stored rainwater get in a direct connection with the transported mixed wastewater or rainwater.
Let's have a concrete storage basin as an example. Such a basin stores the stormwater periodically, and passes it regulated to the channel until it becomes empty. For economic reasons it is not suitable for heavy storm runoff.

2.2. In the case of *parallel connections* of storages a certain part of the mixed wastewater can be removed from the sewage system by overflow. So there is no connection between the stored and the transported wastewater. The overflowing mixed wastewater can be stored for shorter or longer period of time in the storage basin, then it is returned to the channel usually by pumps.

2.3. Detention at sewage treatment plants is possible in concrete storage basins or in open ponds.

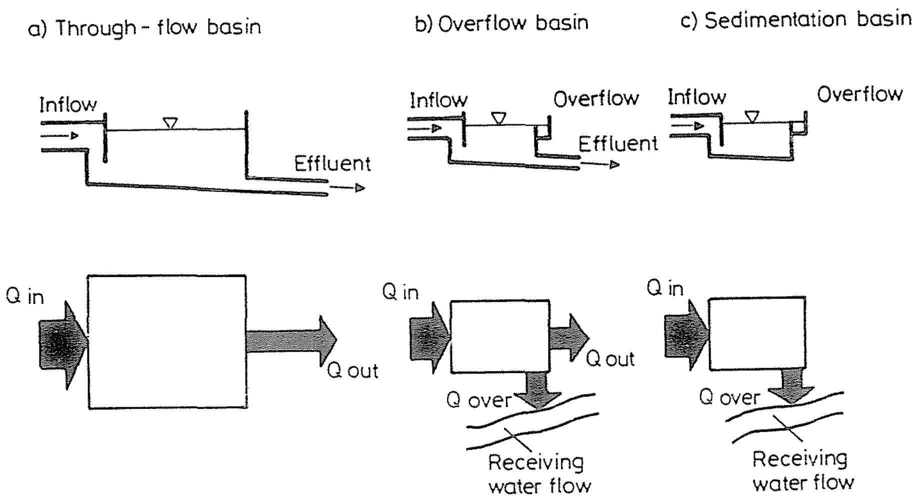

Fig. 8. Operation scheme of rainwater storages

Rainwater Storage in the Sewer System

The rainfall overflow units of combined sewer systems were replaced with rainwater (mixed wastewater) storages by enforcing of runoff control theory (*Fig 8 a–c*).

Therefore it became possible to decrease the yearly pollution loading of the receiving water flow. By determining the proper volume of the reservoirs, the yearly loading of the receiving water body can be reduced with one order of magnitude in comparison with the original volume.

The temporary storage of peak rainwater quantity, the equalization of mixed wastewater quantity and quality, and the releasing of the receiving water flow can be achieved by establishing of:

- retention,
- overflow,
- sedimentation storage basins and
- channel storage volumes.

A further reason of establishing rainwater storages is that the transport of the rare high rainfall quantities in the combined and separate sewer systems requires

- big channel cross-sections and
- high investment costs.

Application of Storage Facilities in Sewer Systems

Rainwater storages promote the following aims:

- the loading reduction of the sewerage system, the wastewater treatment plant and the receiving water body,
- the economical development of sewerage systems.

1. By installing storage basins the loading of the sewer system can be decreased without increasing the cross-section of the channels. For example: new built areas can be joined to an existing, nearly full-loaded sewer network usually without problems: the existing network can be loaded by the whole quantity of wastewater and a part of the rainwater (without peak-loading), if there are rainwater storage facilities in the system.

2. The overloading of the receiving water body can be decreased by installing a parallel overflow basin instead of a rain overflow at the same place (*Fig. 9*).

In this case the treatment effect of the storage on mixed wastewater and the effect of temporary storage stands out. During short but heavy rains the overflow does not work until the total volume of storage is utilized. During a longer/shorter heavy rainy period the mixed wastewater settles in the storage. The storage basin with overflow allows to reduce the loading of the sewerage system at that place too, where it was impossible by a simple rain overflow due to the overloading of the receiving water body.

If most rainwater flows to the wastewater treatment plant, the storage basin should be installed directly before the treatment plant.

3.*Fig. 9 a–b* show the application of rainwater overflow and sedimentation storage basin at the biological wastewater treatment plant.

The sediment storage basin (4) and the rainfall overflow (1) can be used for the daily equalization of the dry-period wastewater.

Installing a sediment storage basin (4) ensures the following advantages:

1. The stored mixed wastewater can be transported to the biological treatment basin after the heavy rain period.
2. The sudden sludge loading of the starting period of heavy rain can be retained and equalized more effectively.
3. The detention time in the preliminary settling tank can be decreased.
4. At the planning of a new sewer system, if a big quantity of rainwater must be transported for a long distance, the establishment of an overflow storage must be considered. For the establishing of storage basins those locations are primarily suitable, where:

- the part-catchment areas are connected to the rain catchments with long collecting channels,

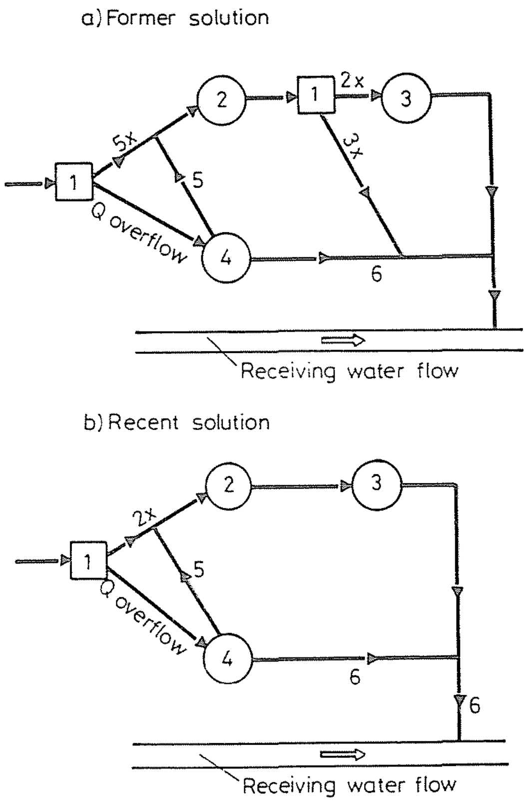

Fig. 9. Wastewater storage on biological treatment plant

Legend:

Insufficient solution	Appropiate solution
1 Stromwater overflow	4 Sedimentation storage
2 Presedimentation basin	5 Recirculation
3 Biological treatment	6 Overflow

- long main channel connects to the wastewater treatment plant to the catchment area.

Operation Algorithm of Storage Basin

By creating control concept for a local area of sewer system, the wastewater must be divided into such components which support the long-term utilizing of the storage basin concerning real runoff conditions.

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Therefore, the control algorithm consists of simple modules, which can be handled separately from one another, and can be considered as independent parameters.

The control of the storage channel or basin is based on the joint consideration of elements (*Fig 10,*) which adequately cover the whole information potential but not all of them are required to be known at the same time.

The real rain parameters derive from the hydrometric stations at certain times. When the measured parameters exceed a certain loading level, the rain forecasting model serves to estimate the next rain runoff.

Based on these estimated values the expected runoff wave can be produced with the help of the water catchment specific runoff model. The storage basin model takes into consideration the storage capacity and the hold back capacity of storages and other facilities. If there is enough data presented for the modelling of pollution concentration, the pollution loading can also be considered. The result of the controlled action is transformed into a numeric form.

Furthermore, with the help of suitable weighing factors some intentions can be specially emphasized. This quality function is the base of the optimal division of expecting runoff wave into components. By dividing the runoff time series, the parameters of the storage outflow can be calculated as well.

In the possession of the measured data the entire control algorithm should be repeated for the next time period.

Knowing rainfall parameters a forecasting model and a runoff transformation can be chosen. In the latter case such a model should be chosen which is easy to algorithm (*Fig 10*), reacts fast and needs small computer capacity. So the control can be realized along the whole sewerage system on the basis of dividing the sewerage system into sections.

The Infiltration of Stormwater

Control of the runoff of stormwater can be summarized as follows:

1. On the farthest point of the catchment, according to local conditions, stormwater should be infiltrated into the soil.

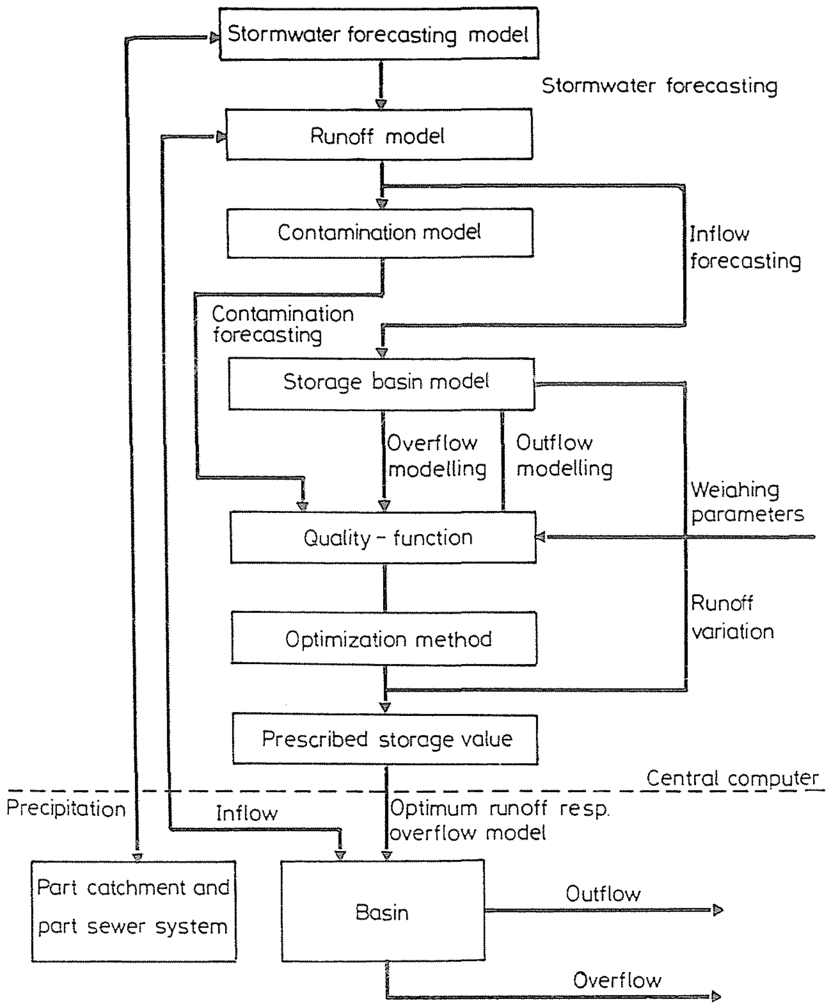

Fig. 10. Scheme of optimum control of series connection storage basins

2. If the infiltration capacity is not enough or there is no capacity at all, a direct percolation into a high-rate infiltration soil should be applied.
3. If this is not possible, runoff control storage must be established at appropriate places of the catchment or in the sewer network. The storage basin should be situated near to the source of rainfall.
4. In other cases the equalization must be realized at the wastewater or stormwater treatment plant.

5. Storage may be required at the receiving water body at the place of the output of the treated wastewater or stormwater.

Central and Decentralized Infiltration

Stormwater infiltration — if local circumstances make it possible — can be considered as an alternative solution for traditional sewer systems. Infiltration is specially important near to the covered area of the cities. The absence of the stormwater supply in the soil can cause the sinking of ground water level. This process is dangerous for the water household balance, for the water supply and can result in the depression of buildings, etc.

Concerning the theory of infiltration: on those estates, where the infiltration is possible, the stormwater loading of the combined sewers can be remarkably reduced at the place of source by applying infiltration instead of the surface collection of water. This solution reduces the investment costs of sewer systems because no overflow basins must be built. Infiltration can be used in the case of separated sewer system, too. It is especially advantageous for those systems, in which the stormwater must be transported into a receiving water body. For reducing the hydraulic loading of the sewer systems, a certain part of the estates is used for infiltration in several countries.

The quantity of wastewater can be remarkably decreased by infiltration of the rainwater in the covered areas. In the mentioned case some facilities of the sewer system, like storage basin, can be saved. The infiltration of rainwater promotes also the reduction of the loading of the receiving water body.

There are two types of infiltration:

1. Decentralized infiltration: — infiltration on the separated estates,
   — inside a group of estates.
2. Centralized infiltration: the water of a common rainwater sewer system of greater areas is infiltrated.

In the case of existing combined sewer systems the quantity of mixed wastewater can be decreased only with decentralized infiltration systems.

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