HYDRAULIC NUMERICAL MODELS APPLIED TO THE BRUSSELS SEWER SYSTEM (BELGIUM) 
AND COMPARISON WITH TELEMETRIC DATA

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ABSTRACT

This paper deals with some hydraulic problems encountered in the Brussels sewer system (Belgium) which hydraulic behaviour is complex. Discharges cannot always be determined with rating curves. A telemetry network combined with a set of hydraulic numerical models provide real time information about the state of the system. An important tool becomes available in view of the design and operation of the future treatment plant and adapted sewer system.

INTRODUCTION

The management of large combined urban drainage systems requires two types of infrastructure: a sewer system collecting domestic and industrial wastewaters and surface runoff from the catchment; a water treatment plant and controlled overflow structures to minimize the pollution of the receiving surface waters.

The city of Brussels drains an area of about 40 km² to the river Zenne without any water treatment. This river has a low average discharge of 6 m³/s and crosses the city in an underground pipe with very mild slopes. In the area under investigation (Brussels North), wastewater is directed to a main collector almost parallel to the river Zenne. The hydraulic behaviour of the system is very complex due to interactions of the main sewer, characterized by mild slopes, and some steep sloping tributaries.

It is aimed to set up a modern and fully equipped real time management system with following objectives:

1. Economical and efficient management of the sewer system.
2. Reduction of inundation risks.
4. Optimisation of the management of the future water treatment plant.

The water quality aspects are studied by a team of the Université Libre de Bruxelles (U.L.B.). Quality parameters are surveyed by the telemetry network [1].

Even if investigations were carried out in the past [2], there is still a lack of a consistent hydrological database. Extensions of the raingauges network, as well as use of telemetry and radar will be considered.

The installation in 1985 of an experimental telemetric network with on-line water level and velocity registrations made a systematic hydraulic study of the sewer system possible.

This paper presents the use of hydraulic numerical models in order to verify and validate field data, to get a better understanding of the behaviour of the sewer network and to help define future strategies for the water management and treatment problem of Brussels North.
DATA ACQUISITION

1. Geometric data

The sewer system is old and was modified quite often by several different authorities, coordination lacking most of the time. Maps do not represent always the actual situation and new surveys are required in order to obtain the necessary and sufficiently accurate data. Numerical modelling is one of the means to identify the reaches where geometric data should be checked. Computations allow error identification like wrong gauge altitudes, erroneous transverse geometry, obstructions inducing local head losses.

2. Hydraulic data

2.1. Telemetry network

Twenty level gauging stations are installed in the sewer system. Most are pressure probes but in some locations ultrasonic sensors are used. The water levels are recorded with varying sampling periods, function of the level change rate. In two important sections, surface velocities are continuously recorded. The currentmeter was first based on a paddle-wheel sensor [3]. Since 1989, an electromagnetic velocity sensor is used successfully. The teletransmission network contains a 12 km long cable fixed at the ceiling of the main sewer, four sub-stations and a central computer located near the outlet of the collector in the Zenne river. The operation of several years has shown that a regular maintenance and calibration of the sensors is necessary, but the actual idea is to optimize the maintenance procedure by checking the sensors on-line using different methods (visual verification, modelling, correlations etc...).

2.2. Direct in situ gauging

2.2.1. Dry weather flow gauging

Direct measurements are performed in the sewer system during dry weather periods in order to calibrate local hydraulic structures and sensors, to determine local head losses and roughness coefficients and to set up stage-discharge relationships. They are also used to validate parameters of non uniform or non stationary numerical models.

2.2.2. Storm flow gauging

The extrapolation of stage-discharge relationships for flood conditions is hazardous and direct measurements are desirable. As the sewer system becomes inaccessible, alternative gauging techniques must be used. The Laboratory of Hydrology, having experience with tracer techniques in rivers, is trying to apply these to sewers.

DATA PROCESSING

Data recorded on-line from the telemetry network represent at this moment about ten megabytes per year. They are transferred monthly to an off-line database on a P.C. (Compaq Deskpro 386). Water levels, velocities, geometry of different sewers and technical parameters of the sensors are stored in the database. An on-line data structure will be implemented on the central computer of the telemetric network. The present database serves multiple purposes:
1. Verification and validation of data:

Presently, verification of the hydraulic data is performed by visual observation using graphical tools connected to the database. In this way it is possible to identify errors such as break down of the computer, malfunction, drift or shift of sensors (Fig.1).

Validation of data is possible to a certain extend with the aid of simple numerical hydraulic models. For example, errors due to wrong (re-)positioning of probes can be revealed. In the operational phase, automatic filtering techniques would be applied.

2. Link with hydraulic models:

The link of the database with the hydraulic models is an important help for the real time management of the sewer system. Presently, tests are carried out to check the applicability domain of several models.

NUMERICAL HYDRAULIC MODELLING

The future management of the sewer system and treatment plant will probably be based on on-line information about water quantity and quality. The hydraulic information will have to be obtained to a large extend by the use of hydraulic models, as the applicability (and usefulness) of rainfall-runoff models can only be expected after several years of experiments. In the following approach, the behaviour of the sewer system is analyzed locally by dividing it in a number of clusters which all contain at least two level gauging stations. For each cluster, three different numerical hydraulic models have been used:

1. Stationary uniform flow model

In most of the cases, this approach is not relevant due to backwater or local effects (confluences, geometry changes etc...). The discharges obtained do not fit the observations and are presented only for comparison.
2. Stationary gradually varied flow model

Since this model takes into account backwater effects, the agreement between observed and computed discharges is good for dry-weather flow conditions.

3. Dynamic flow model

Dynamic effects are taken into account in this model solving the full set of De Saint Venant equations. The observed up- and downstream water levels in a cluster are introduced as boundary conditions in the model.

The benefit using described models is lies on several levels:
- Automatic data file preparation through a direct link with the data base.
- Speed up of the existing algorithms for stationary flow models using a hydraulic approach: by comparing up- and downstream water levels and checking the applicability domain, essential information can be obtained without any computation (Fig.2).

![Diagram of applicability domains](image)

Fig.2: Domains of applicability of stationary flow models. (main sewer Brussels, 4.4m height, mild slopes)

- Feedback in quality control of measurements or occurrence of peculiar flow phenomena: works in the sewer system which were not reported properly, malfunction of the telemetry network, effects of hydraulic structures, changes in hydraulic regime, etc.
- Besides the evaluation of dry weather conditions, storm events are also analyzed by the models, making possible to identify problem areas and to treat them on a local scale.

In a second stage, modelling techniques will be used to simulate scenarios on a more general scale, using "global" models [4]. They can be related to extreme events (e.g. exceptional storms) or to future changes in the configuration of the sewer system (e.g. construction of retention basins). Results will be incorporated in the analysis of management strategies.

RESULTS AND DISCUSSION

1. Dry weather flow simulations
The discussed models were calibrated and used to determine dry weather flow discharges. Results were compared with telemetry flow data (Fig.3).
Fig. 3: comparing models and measurements for dry weather flow discharges

From the given example, the results show that there is little difference in the use of gradually varied flow or dynamic flow models, mainly due to the almost stationary character of the dry weather flow. Discharges obtained from the uniform flow model were overestimated because of backwater effects.

2. Track down of sensor malfunctioning
The example relates to a station where the absolute level of the sensor was wrong. Models applied to the data obtained from the telemetry network indicated reversed flow which was very unlikely (Fig.4). An in situ verification identified a shift of one of the sensors.

Fig. 4: an example of track down of sensor malfunction

3. Storm weather flow
The calibration of a model in extreme flood conditions is very difficult due to the lack of reliable field data and because of dynamic effects. Results presented were obtained from a gauging station near the outlet, submitted to strong backwater effects of the river Zenne. The station was therefore equipped with automatic level and velocity sensors. Direct in situ gauging were performed with the velocity-area method and a comparison was made with telemetric data and model results (Fig.5).
**MAIN SEWER BRUSSELS: FLOOD 27/06/89**

**COMPARISON NUMERICAL MODELS - MEASUREMENTS**

![Graph showing comparison of model results, telemetric data and in situ gauging](image)

**Fig. 5**: Comparison of model results, telemetric data and in situ gauging

The results show a good agreement between the gradually varied flow model and gauging results. Evidently the uniform flow model does not fit.

**CONCLUSIONS**

The telemetry network of Brussels North has proven to provide valuable and reliable information on the hydraulic behaviour of a large sewer system. Part of the instrumentation problem has been solved for dry-weather as well as for flood conditions. Off-line direct gauging are performed as a necessary complement for calibration. In this way, a reliable database becomes available for numerical model simulations. The verification and validation of the data from the telemetry network requires tools such as a.o. the graphical presentations of data time series or the application of numerical models. The database and the related tools are an absolute necessity for the future real time management of the sewer system and treatment plant.

Models applied on a "local" or "global" base are necessary to understand the hydraulic behaviour of the system. Real time management strategies could be partly based on the use of local hydraulic models. It is not yet clear if rainfall-runoff modelling could increase the efficiency of the real time operation. The development of expert systems is now considered to optimize the know-how acquired from telemetric or in situ data acquisition systems on one hand, and from the understanding of the sewer system hydraulics through modelling and observations on the other hand.

**REFERENCES**

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