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SEWAGE SYSTEM MANAGEMENT STRATEGY TO REDUCE RAIN WATER POLLUTION OVERFLOWS. THE CASE OF A WATER STORM BASIN IN NANCY

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ABSTRACT

Since 1991, European Legislation on the urban treatment of waste water requires local authorities to take into consideration the treatment of polluted water transported by the sewage network both during dry and wet weather. The sewage system of Nancy, and of the majority of the larger European urban centres, are of the combined sewer network type. It conveys a mixture of wastewater and storm water, and it is connected to a limited capacity sewage treatment plant. This limited capacity conduce to consider new practices for the treatment of the wet weather flows.
A new management strategy of the sewage system of Nancy has been developed in order to reduce rain water pollution overflows into the Meurthe river. This new management strategy, optimising the use of existing infrastructures, is named global pollution/flood management strategy. The word global refers as well as the system in its totality (rainfall forecasting and sewer network from collect to treatment plant) and the double objective : to conciliate flood risk management and the reduction of pollution overflows into the natural environment. This paper presents a first application project of this management strategy by the Metropolitan Authority of Nancy to regulate an existing underground storm basin aimed at protecting an urban area against flooding.

KEYWORDS

SEWAGE SYSTEM, MANAGEMENT STRATEGY, REAL TIME CONTROL, STORMWATER, STORAGE, POLLUTION

INTRODUCTION

The International Water Centre of Nancy (NANCIE) initiated 15 years ago a working group on the automated management of sewage systems. This consortium (industrialists, research centres, public authorities) has worked on quantitative management aspects and has, in accordance with the European Directive, enlarged its actions by adding the qualitative aspects (rainwater decontamination).

The present project has been undertaken by the above mentioned group within the Life Programmme, the financial European instrument for Environment (DGXII), created to help and promote demonstration projects.

GENERAL SITUATION

The sewage systems of the majority of the larger European urban centres are of the combined sewer network type (designed to convey a mixture of wastewater and storm water) connected to limited capacity sewage treatment plants which are often unable to cope with heavy rainfall events. Besides, the fact that city surfaces are becoming more and more impermeable has led to the construction of significant sewer and storage infrastructures for storm drainage to avoid or limit flood.

The European Directive n° 91/271 of May 21 1991 on the Urban Treatment Waste Water now obliges local authorities to consider the treatment of polluted waters transported by the sewage system both during the dry and rainy weather, excluding exceptional rainfall. Existing storage and treatment facilities are often largely undersized in relation to this objective and therefore necessitate the construction of new infrastructures similar to existing projects found in Denmark and Germany. If new investments are necessary, they must be made under conditions which are economically acceptable to local authorities. It is sounder under these conditions to make the best use of existing infrastructure through the optimization of their management by means of appropriate measuring and monitoring techniques. Here lies the aim of this project.

In order to deal with the problem of floods, the Metropolitan Authority of Greater Nancy, has constructed over the past two decades detention basins with a total storage capacity of 170 000 m^3 of which 95 000 m^3 are in underground basins. At present, these underground basins are used during heavy rainfall to limit flow peaks which cause overflow of the sewage system. They are filled only when the flow peak exceeds a critical threshold (figure 1). In order to have a maximum reserve of storage capacity available, the basins are not filled for lesser flows during normal rains. For the same reason, the basins are evacuated as quickly as possible after each rain. These options are the source of numerous polluting overflows into the river downstream the sewage system.

The aim is to transform the management of the existing underground basins so as to limit rain water pollution overflows into the Meurthe river that passes through Nancy. This new management strategy which takes into account environmental considerations, must not however undermine this initial function of the basins to protect against floods. The validity of this approach will be demonstrated with this LIFE project in its first application to one of the underground detention basins, the Gentilly Basin which has a storage capacity of 12 000 m^3.

This new global pollution/flood management system will permit the basin to be filled right from the start of a rain event so as to limit storm overflows into the natural environment during rainfall. At the end of each rain, the water will continue to be stored in the basin and its drainage optimised to limit polluting overflows.Much of the sewage water pollution is linked to suspended solids which can be decanted easily. A few hours of storage allows for the concentration of solids and attached substances in the lower layer of the water in the basin. The upper layer effluent which is thus sufficiently purified through settling can then be drained into the river. One can also opt for a slow drainage to a pollution control facility: a waste water treatment plant, or later to a special-purpose storm drainage treatment basin planned for construction in a few years time.

The main difficulty of this project resides in the modification of the current management of the basin and the flood risk this entails. Since the Gentilly basin is meant to protect an urban district close to the centre of town, such a risk cannot be taken. This problem is solved in an innovative way through the use of a global pollution/flood management strategy integrating (figure 2) :

- a real-time exploitation of regional weather radar images to forecast the development of rain events;
- a new system of continuous measurement of the pollution levels in sewages systems to know the exact state of the water stored in the basin and notably to control the evolution of its settling during storage.
- when a big storage capacity is needed, the possibility of quickly evacuating the sufficiently decanted upper layer water at the cost of slight polluting discharges into the natural environment;
- a global sewage system management model permitting the reconciliation of the objectives of pollution control and the basin's initial function of protecting against flood.

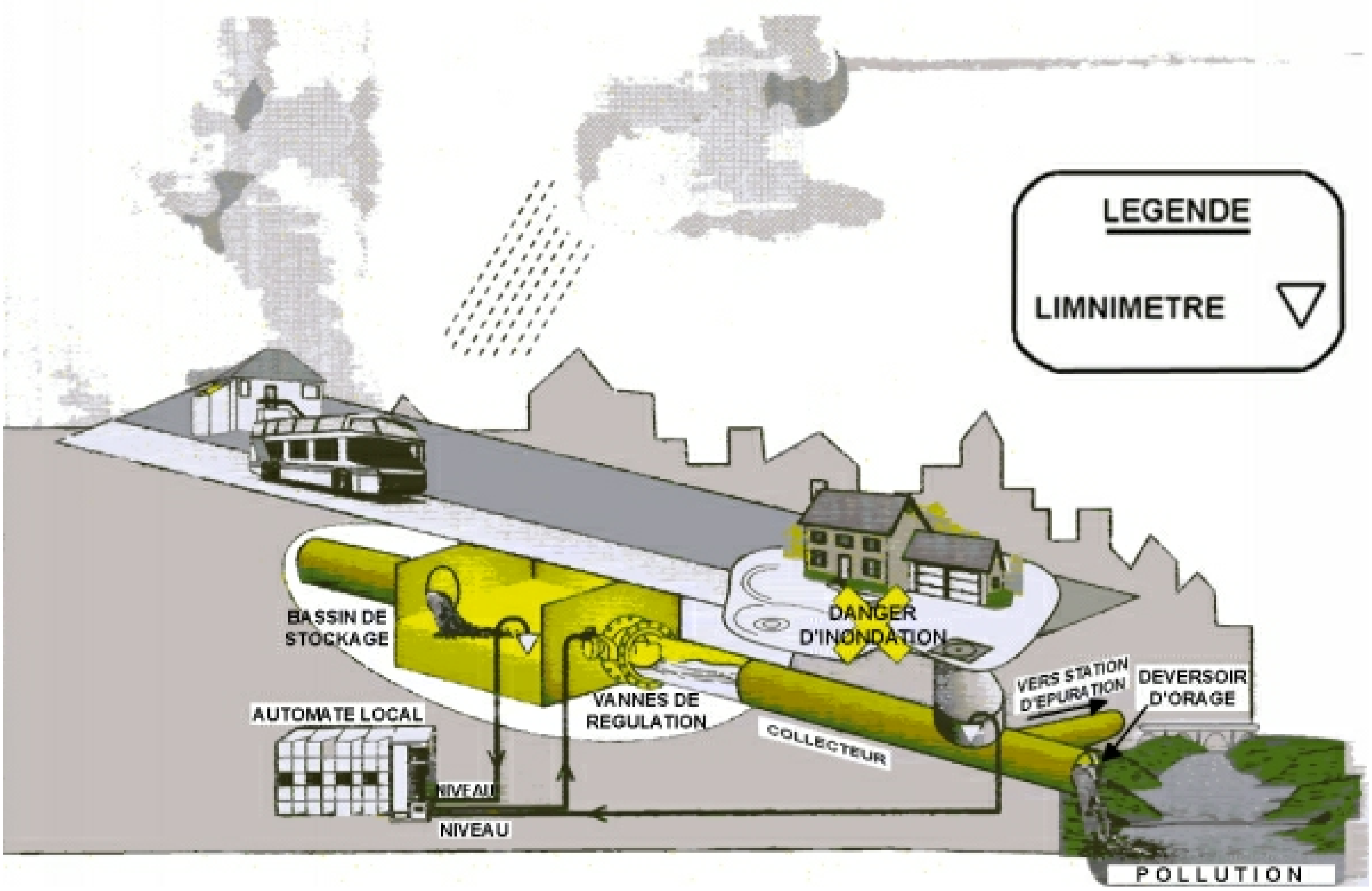


Figure 1. Diagram presenting the old management of the portion of the sewage system included in the project The regulation of the basin to prevent flood depends uniquely on the height of the water in the basin and in the network downstream.

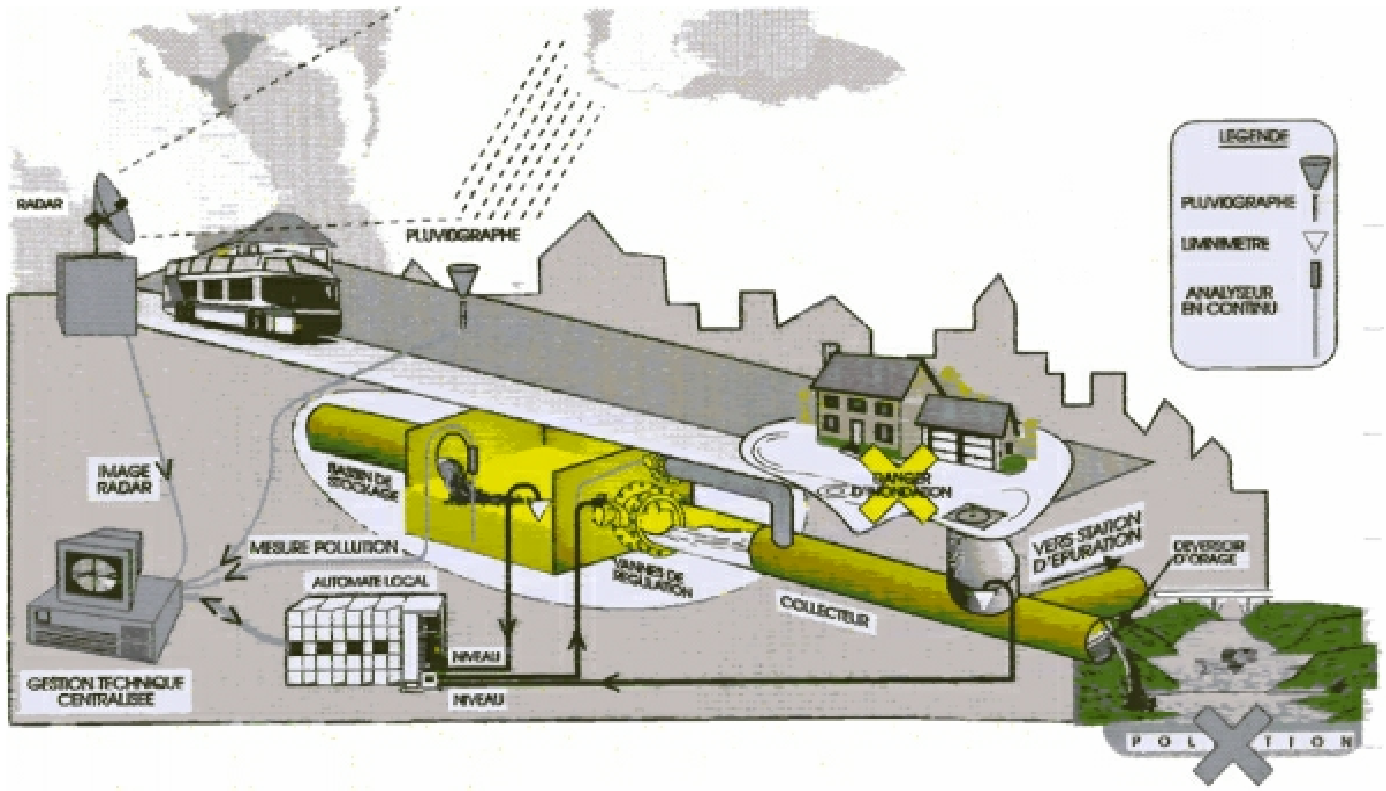


Figure 2. Diagram presenting the new global management of the portion of the sewage system included in the project. The regulation takes into account the function of pollution control.

The installation and the optimisation of the new management strategy has been subdivided into four major actions as presented hereafter.

TECHNICAL ACTIONS OF THE PROJECT

Action 1. The development of a meteorological surveillance to anticipate the evolution of rain events

As with a great number of European towns, Nancy and its region are covered by a radar of the national meteorological forecasting network which monitors the evolution of rainfall. Every five minutes, the Centralised Technical Management Department of the Metropolitan Authority of Nancy receives images from this radar.

A specific system for processing these images has been developed (Faure D. and Auchet P., 1997). A first phase of treatment establish a mapping of the rainfall intensities and follow its evolution with time. The rainfalls estimated from the radar data and those supplied by the Urban Community rain gauge network are compared in real-time for the supervision of the radar calibration (Faure D. and Auchet P., 1996).

A second phase of the processing consists of forecasting the evolution of the rain over agglomeration. A study has been carried out for estimate the limits of the radar rainfall forecasting for the management of the sewage system of Nancy, in particular the Gentilly storm water tank (Faure D. et al, 1999). The results have conduce to imagine a adapted sewage system management strategy using radar data to limit the risks in the Life project. This strategy, based on predefined scenarios, helps to estimate :

- the eventuality of imminent rain over the Urban Community;
- the time that an approaching rain can take to reach the agglomeration;
- if maximum rainfall rates on the agglomeration are already over or still to come;
- if the rain event is due to stop soon or is likely to continue for many more hours;
- the type of rain corresponding to a particular type of sewage risk which can be derived from the Urban Community's databank.
- the chances of another rain event taking place shortly after the prevailing one is over.

The preceding points are essential for the project. Indeed, deciding to fill the basin from the beginning of rain events or storing the water after its stop entails flood risk. This risk is linked with the partial loss in the storage capacity of the basin purposely designed initially only to limit the maximum flow peak. Very short-range forecasting with the radar allows dealing with this risk through management decision (such as rapid evacuation of the basin) before the situation becomes critical.

Similarly, short-range forecasting allows a significant reduction of the safety margin (increasing the proportion of the basin that can be filled) thereby helping to increase in a considerable way the number of rains that can be treated for pollution removal.

Action 2. Study of the evolution of the pollution level during settling phase of the water stored in the basin

The urban flood risk management is accentuated by the need to include pollution control considerations. Such a commitment cannot be made without being sure that the new regulation of the basin will be effective and produce maximum yield as regards the treatment of pollution.

An efficient pollution removal action of the basin can be obtained by taking advantage of the settling of water during its storage and this by evacuating the basin through the top (draining away of the upper layer water) and by a continuous control of the quality of the stored water. This control is necessary because it is difficult to determine, once and for all, the time needed to purify a layer of water of a given thickness. Moreover, a second rain occurring during settling can cause partial re-homogenisation of the layer which is already purified.

To monitor the evolution of settling, a floating basement has been placed in the basin equipped with 3 automatic sampling and various sensors : 2 turbidimeters and 2 multi-parameters sensors (NH4+, PH, temperature conductivity, turbidity, redox potential, dissolved oxygène). This permitted to perform analyses at different depths in the basin to characterise the exact state of the water at any moment and provide a vertical profile of the pollution. The results obtained for several rain events (figure 3) show that an upper layer which is purified sufficiently through settling can be released into the river rapidly after the rain (at the cost of very slight polluting overflow into the river) while continuing with settling on the lower layer (Pilloy, 1998). Such a gradual evacuation permits a rapid recovery of a significant storage capacity in the basin without reducing the efficiency of the pollution removal process.

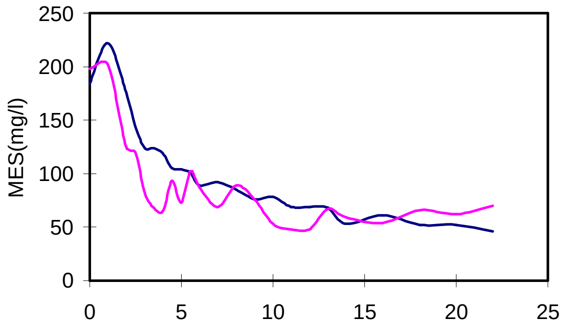


Figure 3. MES evolution during a 24h storage for two rain events (upper layer)

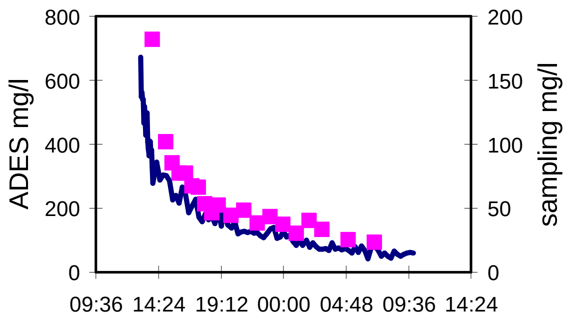


Figure 4. ADES measurement (solid line) and sampling laboratory analysis (squares) of MES the 29/04/97

The results equally show an increase of pollution levels after 15 hours of storage : for every rain event an increasing of the COD and $NH4^{+}$ is observed . Consequently, the retention time in the bassin should not exceed 15 hours.

A new type of continuous sensor for the monitoring of the quality of water stored in the basin has been tested. This instrument was developed specifically to measure the pollution of the wastewater in combined urban sewage systems. It periodically measures the temperature, the conductivity and the turbidity of the effluents and allows to derive the suspended sediment value and the COD value. Despite the fact that the general trend of MES and COD evolution was given by this instrument (figure 4), maintenance difficulties and limited quantitative measurement accuracy resulted in the replacement of this system by a set of two turbidimeters.

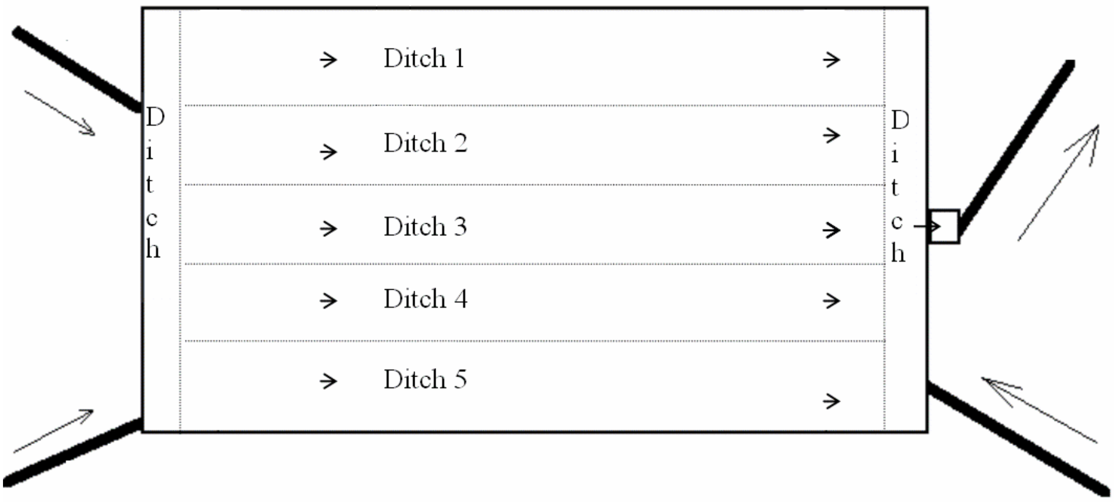
Action 3. Modification of the basin in order to improve the settling process

This action supplements the two ones. The basin is currently evacuated by its bottom and the form of its raft ensures the self-cleansing of the basin (figure 5).

A laboratory 1:20 scale-model was designed to establish the basin performance in pollutant removal (Dessez, 1998). Injection of solid particles was used, as also the retention time distributions using salt concentration measurement. Some different configurations in the design have been tested and necessary technical improvements have been suggested :

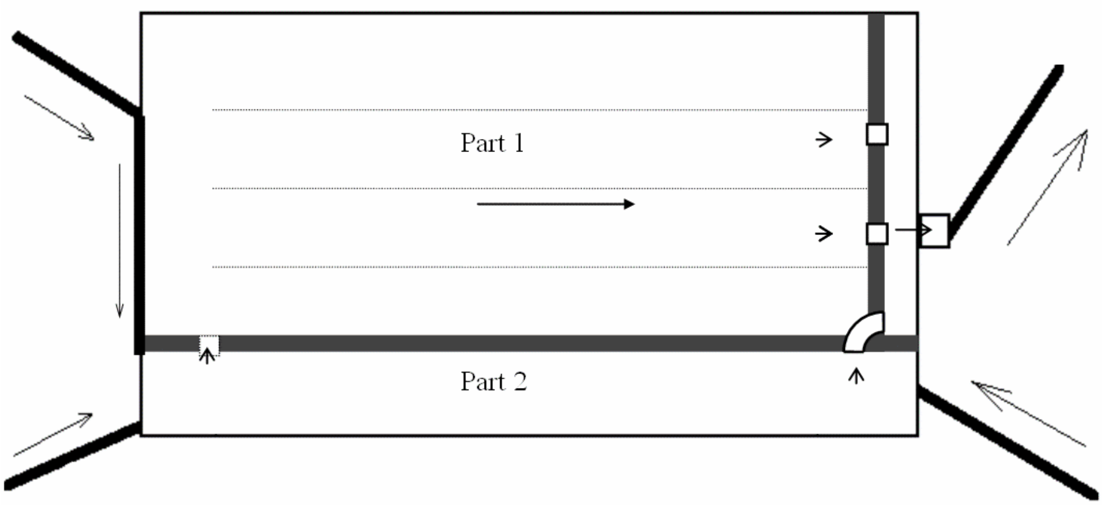
– to decrease water flow in the basin and to suppress the direct current between the downstream entrance and the exit, which constitutes the main objective
– To create an isolated volume dedicated to settling by raising a separation wall.
– To create an high, broad as possible, position exit.

Figure 5. The underground Gentilly storm water tank (initial configuration with 5 longitudinal ditchs)



The lesson of this experiment brought civil engineering works. The basin has been separate in two parts to reduce the hydraulic movements in the main volume (figure 6). The small part (Part 2) can also be use for water settling during moderate rain events (cumulative rainfall < 5 mm). Four automatics outlet valves have been placed at the top of the two basin parts to allow progressive evacuation of the clarified water through the top of the basin. Two bottom valves permit the rapid evacuation of the bottom polluted water toward the sewage treatment plant.

Figure 6. Separation of the basin in two parts



Action 4. Modelisation and validation of the management strategy

A mathematical modeling of the network depending up on this basin (Figure 7) bas been realised (Magne, 1999). This model take into consideration the two operating modes: protection against floods during heavy rain and pollution control during lighter rain.

The position of the drain valve of the basin corresponds to these two configurations. For protection against the floods, the valve position is adjusted according to a water level measurement in the main collector downstream of the basin. The position of the valve then obeys opening and closing algorithms. For the pollution removal operation, the valve is closed, and the water thus stored undergoes a settling. The cleaned water is then restored to the network. However, it was noted on the one hand a peak of concentration in TSS at the opening of the valve and, in a lower proportion, in the last drained cubic meters.

The aim of the modeling is to propose rules of management to obtain an optimal operation of the basin in terms of quantity and quality, by observing the impact of this management on the network. The mathematical model was created using the software HYDROWORKS, which is equipped with several modules: hydraulics, quality and real time control. First, the hydraulics and quality modules allowed the calibration and the validation of the mathematical model for several rain events with low precipitation. Then, the real time control module of the software was used to check the modeling of the valve management. Taking the algorithms of valve operation into account of this one, has shown a correct response of the model compared to the measured hydrographs of drainage for heavy rains.

The impact of management on the sewer system is currently studied with the same model. Basin improvements to ameliorate the quality of the tank drainage are taken into account in the simulations. It will be possible to generate theoretical drainage pollutant flows that will be used as input data in the model.

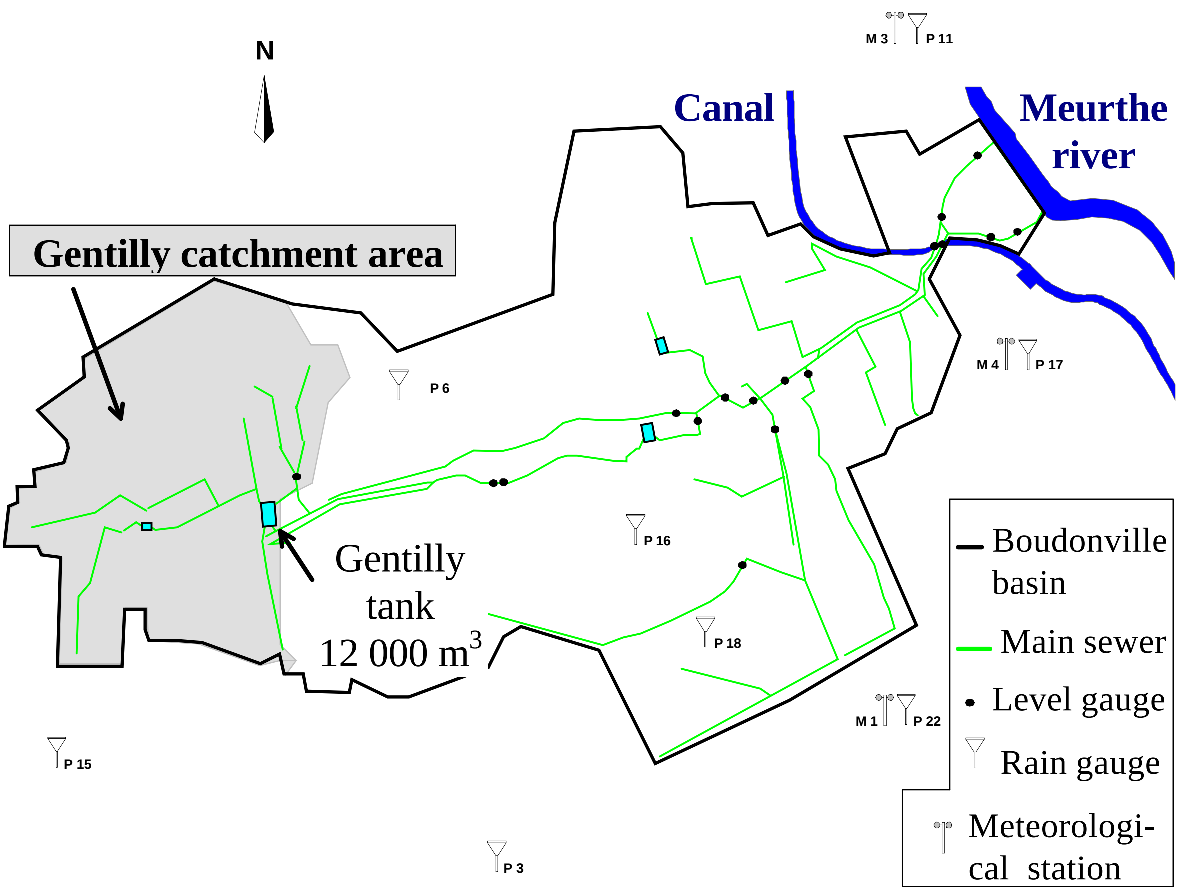


Figure 7: The Boudonville basin (6.6 km²) and the main sewer network

CONCLUSION

The results of this Life project demonstrate the feasibility of using existing retention infrastructures for new purposes of rainwater decontamination thereby reducing urban rain water treatment cost. These results have already been integrated into the recent conception and construction of a new retention basin in Nancy which can be used both for quantitative and qualitative management strategies.

In addition to this project the construction of an experimental rain water treatment basin has been planed, this operational resarch tool will allow to compare ten different physical-chemical treatment configurations to highlight the best technical solution for future construction.

The know-how developed by the consortium on automated sewer system management of Nancy can be transposed to major European cities using combined sewer networks.

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