Design and analysis of an urban retention pond database

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Conception et analyse d'une base de données sur les bassins de retenue d'eau pluviale

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RESUME

Lors de la création des villes nouvelles en région Ile de France dans les années 70, les bassins de retenue en eau ont été abondamment utilisés pour contrôler l'évacuation des eaux pluviales. Toutefois, en raison de leur nombre, la connaissance du comportement de ces bassins reste limitée, ce qui constitue une faiblesse pour leur gestion optimale.

Ce texte présente une base de donnée relative à ces bassins en eau. Elle rassemble toutes les informations disponibles relatives à leur conception, leur fonctionnement, la qualité de leurs eaux et leur entretien. L'objectif de cette base de données est d'améliorer la connaissance de ces plans d'eau et ultérieurement d'aider à leur gestion.

Les données de 55 bassins sont actuellement rentrées dans la base de données. A partir de ces données, on peut estimer un potentiel de dépollution élevé. Par ailleurs, des relations significatives entre la qualité des eaux et l'occupation du bassin versant ont été mises en évidence.

ABSTRACT

In conjunction with the urban development in the Ile-de-France region numerous retention ponds were created in the seventies. Because of their number the knowledge concerning the behaviour of these ponds remains quite scarce and it is a weakness for their optimal management.

This paper presents a database related to retention ponds in the Ile-de-France region, which gathers all the available data concerning their design, their behaviour in their catchment, their water quality and their maintenance. The objective of this database is precisely to improve their knowledge and to finally help in their management.

Data from 55 ponds are presently included in the database. From these data it is possible to infer a high pollution retention potential of the ponds. Despite the heterogeneity of the monitoring strategies, significant relations between the water quality in the ponds and the occupation of the catchment were established.

KEYWORDS

Database, retention ponds, Ile-de-France, quality

1 INTRODUCTION

1.1 Retention ponds in the Ile-de-France Region

The Ile-de-France region was created as an administrative entity in the middle of the sixties. It includes the city of Paris as well as eight other Departments located around Paris (12000 km^2). 11 millions inhabitants are living in Ile-de-France – 20% of the total French population -and the density of the population is decreasing from the centre of Paris to the peripheral zones but remains very high with an average of about 900 inhabitants/km^2. The population is quite stable with an increase rate of 0.25%/year over the last decade.

In order to equilibrate the development of the various parts of the region, and especially to avoid an increase of the population density in the old urbanised areas, it was decided in 1965 to create 5 new urban areas, called “villes nouvelles” (Figure 1). In 1993 700 000 inhabitants were living in these new urban areas located 20 to 40 km away from the centre of Paris.

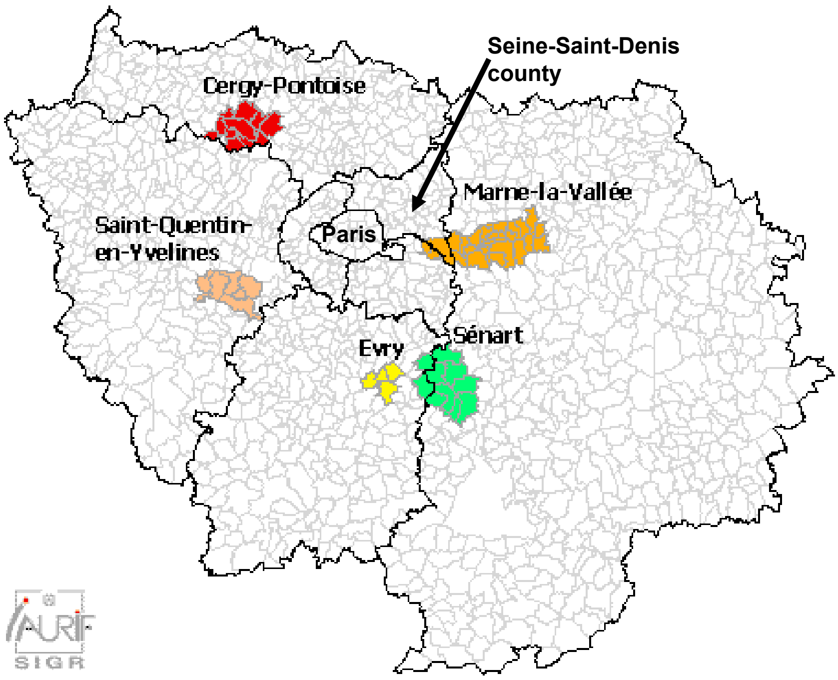

Figure 1 Ile-de-France region and the 5 “villes nouvelles” (IAURIF SIGR map)

Management of rain water was a major issue in the design of these “villes nouvelles”. As the basic principle of the “villes nouvelles” was to develop less densely populated areas, most of them have been located in the less urbanised upper parts of the catchments of the tributaries of the main rivers (Seine, Marne and Oise rivers), but far from these rivers which constitute the final natural receiving system of runoff water.

The use of a classical drainage system, based on the old paradigm stating that rain water should be drained as quickly as possible from the catchment to the receiving system would have led to a financial dead end because of the required size of the pipes, and to a major impact on the receiving system because peak runoff water flow values would have had the same order of magnitude as the river flow.

Thus it was decided to design numerous retention ponds along the previous hydrographic network of the small tributaries in order to reduce drastically peak flows as well as suppress most of the pipes or at least reduce their diameter. Moreover, from an urbanistic point of view, these retention ponds were used, especially during the first phases of the construction of these “villes nouvelles”, as structuring elements of the new urban areas. They are now not only hydraulic equipment but also water mirrors in the city, highly appreciated by the population.

30 to 40 years after their construction, if their design rules are well established and reported (Azzout et.al., 1994, STU , 1994), the knowledge concerning the behaviour of these retention ponds remains very limited. Depending on local management strategies, very different water quality monitoring plans have been applied. Moreover, the available data relative to these ponds are distributed in numerous places and it is very difficult to gain a global overview of the applied management strategies and their results. In order to improve this situation, which is a real weakness, a database was designed to gather the available information.

In a first step this database was designed for a scientific purpose. In a second step, its transfer to managers of retention ponds is a further objective. For this reason it contents deals mostly with scientific aspects but management is also taken into account.

This paper presents successively a description of the database, a description of its content and a first analysis of the gathered information.

2 CONSTRUCTION OF THE DATABASE

This database aims at serving a similar purpose as the US National stormwater BMP database[1] (ASCE & EPA, 2002), but focussed only on retention ponds. It was developed with MS Access 97™ and consists in 55 interconnected tables which cover the following aspects: i) Design of the retention pond, ii) the connected catchments, iii) The retention pond and its environment, iv) The water and sediment v) The ecological quality vi) The management.

On this basis, it is theoretically possible to explore relations between the catchment and the quality of the pond, as well as the influence of the pond on the quality of the downstream parts of the drainage system, that is the downstream retention ponds and the small rivers which connect them.

2.1 Design of the retention pond

This part of the database gathers all the information related to the design of the retention pond : location, geometrical and topographical data, design methodology and criteria, especially the return period for which the pond was designed.

2.2 The retention pond inside its catchment

In order to be able to analyse the data related to the water quality, it seems necessary to describe in the database not only the retention pond itself but also the various catchments which are connected to it. Five land uses are taken into account:

[1] “to provide a data exchange tool that permits characterisation of ponds upon their measured performances, using the same protocols fos measurements and reporting information”

Individual housing, collective housing, individual-collective housing, transport and public equipment and professional activities. While a larger number (up to 100 categories) of land use descriptors is often considered in catchment description and available in the regional GIS, it was decided in a first approach to limit drastically the number of categories in order to be consistent with the number of ponds in the database. The temporal evolution of land use is a major difficulty in the maintenance of the database. In the first version of the database, it was decided only to consider the most recent description of land use. Obviously other topographical information like area, slope, form coefficient is also take into account.

In connection with the catchment description, the description of the inlet equipment is also included in the database, and especially the various pre-treatment devices (oil chambers, grit and silt chambers, …).

2.3 The retention pond and the hydrosystem

The description of the catchment connected to a retention pond is necessary but not sufficient. Such a pond is actually a part of an hydrosystem and it is necessary to describe at least roughly this hydrosystem in order to be able to analyse the respective impacts of the pond on the hydrosystem and of the hydrosystem on the pond. Particularly, on areas where retention ponds have been implemented intensively, it is highly probable that several of them are on the same drainage system and interact, on both hydraulic and water quality aspects.

Thus it is necessary to describe in the database the environment of a retention pond, that is i) its position inside the catchment of the drainage system it is connected with, and more precisely ii) the hydraulic connection between the pond and the drainage system.

When several ponds are inside the same drainage system *i.e.* their waters will finally join and reach the receiving system together, it is assumed that these ponds form a "cluster" of ponds of the same hydrosystem. This hydrosystem is described following the Strahler order procedure (Strahler, 1957), which enables the definition of homogeneous branches of the drainage system with a growing order from the upper parts to the outlet of the catchment. If several ponds are situated on a branch, their position along this branch from upstream to downstream is include in the database following an incremental index.

Moreover several types of connection between a pond and the hydrosystem are possible. As the type of connection may have consequences on the hydraulic and ecological behaviour of the pond, it has to be included in the database. Five types of connection were identified in a first approach (Figure 2).

2.4 Water, sediment, ecological quality

Usual water and sediment quality parameters are included in the database[2]. Concerning the ecological quality of the pond, both aquatic and terrestrial ecosystems have to be taken into account. For each ecosystem both quantitative and qualitative (abundance indicators) variables may be potentially entered in the database. Despite the fact that in most ponds only one sampling point is used, it is allowed in the database to consider several sampling points if necessary as well as several sampling depths.

[2] Temp., pH, Cond., O_2, BOD, N-forms, P-forms, heavy metals, …

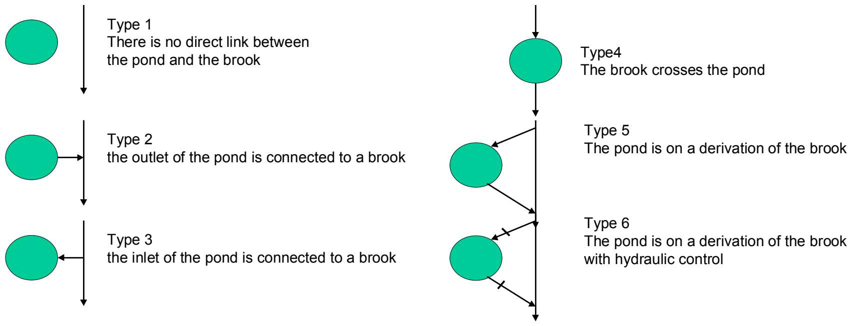

Figure 2 various types of connection between a pond and a brook taken into account in the database

2.5 Management of the retention pond

The management of a retention pond is a very wide subject. In the database we consider the description of the regular and exceptional maintenance of both the pond itself and the related equipment. Regular maintenance includes the production of indicators of hydraulic performance and water quality.

Dysfunctions of the pond that are observed are also included in this part of the database. It includes chronic dysfunctions like impact of wrong connections or accidental ones like pollution caused by traffic accidents.

Other aspects like the various social uses of ponds are also included in the management part of the database.

3 CONTENT OF THE DATABASE

Data from 55 ponds located in three areas in the Ile-de-France region are presently included in the database. 24 are located in the Ville Nouvelle of Saint Quentin en Yvelines, in the western part of Paris (Figure1), 26 are located in the central part of the Ville Nouvelle of Marne la Vallée. The 5 remaining ponds are located in the Seine-Saint-Denis county, in the North-Eastern part of the Ile-de-France region.

As noticed previously, the two first areas are recently urbanised areas where during wet weather, retention ponds aim mainly at reducing the peak flow. The last area was in the past a wide wetland. It was highly urbanised during the second part of the 20th century. As a consequence, during rain events numerous floods occurred in the lower parts of the county and the ponds have been implemented *a posteriori* for decreasing the floods occurrence.

3.1 Origin of the data

Data related to the ponds were obtained mostly from their managers. Surprisingly, if most of the available data were easy to gather, sometimes basic ones, especially those dealing with the design of the retention ponds, were very difficult to locate (design storm, calculation of the volume of storage, …). This is probably a consequence of the administrative organisation which was behind the creation of the "Villes nouvelles". In a first step an administrative public insitution was created. Its objective was the construction of the city itself. Then the responsibility of the management of the city was transferred to local authorities, and it is clear that many technical documents or information disappeared during this transfer or have been archived and are now difficult to access.

Data related to the catchments were obtained from the Ile-de-France Urbanism and Planning Institute (IAURIF), which developed a GIS over the entire Ile-de-France region (IAURIF, 2003). Watersheds were determined on the basis of the runoff water networks maps, and included as a new layer into the GIS. Intersection of this layer with the soil occupation layer allowed the determination of the various categories of land uses and their related area for all the catchments. The less detailed representation of land uses, which is available at different refinement levels in the GIS was in agreement with our objective of 6 types of uses.

Information related to the connection between the ponds and the drainage system were firstly determined from the available paper maps and confirmed through on-site visits.

Water, sediment and ecological quality data were collected by means of monitoring programmes. They were designed by the managers of the ponds and realised by environmental consulting companies or scientific university laboratories. They mostly aim at assessing the trophic level, the organic and bacteriologic pollution and the ecological behaviour of the ponds. Surprisingly, pollution removal efficiency is not an objective. As a consequence, data exist which describe the water quality of the pond but data related to the inlets or outlets of the ponds do not exist.

These programmes vary greatly from one place to another, depending on the local financial possibilities as well as on his strategic choices (yearly light monitoring or pluri annual heavy monitoring), and on the organisation in charge of the monitoring.

A consequence of this variability is the data high heterogeneity in time and space and in the numbers of parameters measured. Because of this heterogeneity, numerous physical-chemical parameters are included in the database (70) although the corresponding fields often remain empty when only basic parameters are measured.

Concerning ecological quality, the aquatic ecosystem is mostly qualitatively described in terms of presence or absence of certain species (fishes for instance) or in terms of abundance (phytoplankton). However in some cases a complete determination of species is available. The terrestrial ecosystem is only described very roughly. Unusual or protected species (birds, mammals, …) are reported eventually. However there is no systematic survey of the ecosystem either aquatic or terrestrial and the available related information is only very partial.

In many cases management related information is not available in a unique place. As numerous stakeholders are in charge of the management of the ponds, each of them keeps one part of the information. Moreover as quality insurance procedures are not generalised, very often regular management (and especially maintenance) activities are not summarised anywhere. However for exceptional events (dredging, accidental pollution, …) the local authority in charge of the pond is the main stakeholder and keeps the memory of such events. Cost related data are unreachable for many reasons. First of all, costs related to the regular maintenance of the ponds are often globalised for a group of ponds depending on a unique local authority and it is impossible to assess the cost related to a specific pond. Moreover, this maintenance is often sub-contracted to specialised firms and encompasses the maintenance of many parts of the drainage system.

4 ANALYSIS OF THE DATABASE

4.1 General information

The surface of the ponds varies from 0.3 to more than 20 ha, with a ratio between the catchment area and the pond area around 4%. This is quite a high value, indicating a potential high pollution removal efficiency above 80 % for suspended solids (Ellis, 1991). Thus despite the fact that no pollution removal efficiency monitoring was conducted, we can confidently consider that this objective is efficiently reached. This high value of the ratio pond/catchment indicates also that these ponds are very important in the urban landscape.

They have the same maximum depth, around 2 meters. This design option was decided to minimise the risk of hydrophyte growth within the ponds, which were supposed to decrease the site hydraulic efficiency. If this design strategy has consequences on the water quality of the pond because of an higher phytoplankton biomass production and suspended solids resuspension, it also reduces the risk of stratification and of hypolimnic deoxygenetion. However during spring and summer periods without complete mixing , which can last about 10 days, are encountered several times (ENPC 2003) .

Unfortunately no information related to the retention time is available. This is a direct consequence of the lack of monitoring of the pollution removal efficiency. Indirect calculations of the retention time based on rain estimates indicate that it may greatly vary between a few days and 2 to 3 months. This must have important consequences on the aquatic ecosystem.

The ponds are not independent but forming clusters of 5 to 10 ponds. For each cluster the upstream retention pond is of type 2 and receives its dry weather water from ground water which is transferred to downstream ponds. Other ponds are of type 4 (figure 2) and crossed by small pre-existing brooks. The Strahler order of a cluster is in most case 1, but may reach 3, which is a quite high value for rather small catchments. Derivative ponds (type 5 or type 6), which receive only wet weather flow, only exist in the Seine-Saint-Denis County, because of its very specific real time management system of runoff water.

4.2 The catchments.

On the basis of a hierarchical clustering analysis of the soil occupation of the catchments, 5 groups of catchments were identified: predominance of individual housing, predominance of collective housing, mixing of individual-collective housing, predominance of transport and public equipment and finally predominance of professional activities. This soil occupation is considered as an explanation factor of the water quality of the ponds.

4.3 The water quality.

The first result of the database concerning water quality is that data remain quite scarce, despite the monitoring programmes. Their cost and the absence of major water quality problems lead to as light as possible programmes, which do not enable deep analyses of the pond water quality. Two main sampling strategies were observed. For the Marne la Vallée ponds, one sample per year is analysed for every pond; however for the Saint-Quentin ponds, one survey is planned for each pond every 5 years and 3 samples are analysed in spring, summer and fall.

Despite this heterogeneity it is possible to draw some general trends concerning water quality on these ponds.

- *Sedimentation* : the risk of silting up is a major concern of the managers of the ponds. However, it seems to remain very reduced, with an approximate rate of 0.5cm/year.
- *Eutrophication* : All the ponds are eutrophic. The phosphorus level is over 0.1mg/l. Nitrogen (nitrates) exhibits strong variability, indicating either high primary production or denitrification activity. However, total Nitrogen is never a limiting factor of primary production.
- *Organic pollution*: because of the high primary production, BOD and COD do not properly describe the catchments organic pollution loading. Total coliforms are

much more efficient. Hierarchical clustering indicates a strong correlation between the bacteriological contamination and the groups of soil occupation, with a major impact of the collective housing and collective-individual housing groups. Ammonia, which also indicates wastewater contamination enables the detection of highly polluted ponds.

Concerning the ecological behaviour, some of them are protected because of their biotope. However the corresponding information in the database does not allow a deep analysis.

5 CONCLUSION

Retention ponds are very specific environmental objects. Because of their size, rather small, they are not considered in the Water Framework Directive (EU 2000) which only consider lakes and reservoirs over 50 ha. Because of their location in urban or sub-urban zones they are not considered as natural systems and are ignored by environmental scientists. At the scale of the local authority which is in charge of their management they are for some technicians hydraulic devices on the runoff water drainage systems. For other technicians they are landscape objects which enable a closed contact between the inhabitants and the water.

In this complex context it seems necessary to get a more global overview of the behaviour of these ponds. This is the main objective of this database and we think that the first partial results obtained in its analysis confirm the necessary investment in the development of such a tool. The recent observation of toxic algae in these ponds (Sarazin *et al.* 2002) is a supplementary reason to work in this direction.

6 ACKNOWLEDGMENTS

The authors thanks Eric Crommer who designed the first version of the database, the IAURIF and especially Cécile Mauclair and Jacky Poitevin for their help in the determination of the soil occupation at the catchment scale. The Agence de l'eau Seine Normandie is also gratefully acknowledged for its financial support.

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