Paper Submitted for:
8th INTERNATIONAL CONFERENCE, URBAN STORM DRAINAGE
SYDNEY, AUSTRALIA, 30 August – 3 September 1999

INTEGRATED WASTEWATER MANAGEMENT - A EUROPEAN VISION FOR THE FUTURE

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ABSTRACT

The paper describes developments that are currently taking place towards the creation of a comprehensive integrated management capability for urban wastewater systems. The principal vehicle by which these developments are taking place is a European Union funded collaborative project led by WRc and DHI together with numerous other partners. The project comprises both technological developments in terms of procedural issues, hardware and software and extensive practical testing via a series of pilot studies.

KEYWORDS

Integrated modelling; MIKE™; MOUSE™; real time control; STOAT™; urban wastewater.

INTRODUCTION

Most urban wastewater systems can be considered to comprise of three components: the collection network (sewer system), the treatment plant and the receiving water. Few who are involved in the management of these systems would not agree that it is logical and beneficial to plan, design and operate these components in an integrated manner. However, because of the limitations of the available technology, historical reality has been far removed from this situation and independent pragmatic criteria for each component have been the norm. For example, sewers are typically designed to contain storm events of a specified return frequency without surcharging rather than to protect against flooding; combined sewer overflows (CSOs) are engineered to pass forward flow rates dictated by downstream sewer or treatment plant capacity rather than the ability of the receiving water to accept the spilled flows; treatment plants themselves are designed to cope with an arbitrary multiple of dry weather flow.

The logic of integrated management is not, of course, new and many workers have developed tools over the last few decades which provide capabilities in this direction. The advent of computer simulation modelling has been perhaps the biggest single factor in supporting this trend by allowing the development and application of many software packages for modelling sewer systems (MOUSE, HydroWorks, SWMM, etc.), sewage treatment works (STOAT, GPS-X, etc.) and receiving waters (MIKE et al.). The UK's Urban Pollution Management procedure (FWR 1994 and 1998) provides a planning framework which allows the interaction between components to be considered within the limitations of the available implementation tools. Hence, progress has been made towards practical integrated wastewater management, but the available tools are imperfect and there is plenty of scope for improvement.

It is from this stance that WRc and DHI have developed a "vision" for comprehensive integrated wastewater management based on a modular software package which described all of the components of the urban wastewater system (see Fig 1). All of the modules in this package would operate within a common environment and have a common look-and-feel so that a user familiar with one module would be comfortable with any of the others. The modules would all communicate with one another in an entirely compatible and consistent manner allowing the seamless transfer of data forwards and backwards during simulations such that feed-forward and feed-back control loops could be implemented (Real Time Control of urban wastewater systems is an integral part of the vision for the future). Users could choose which components they wished to include in their simulations, including non-engineering elements such as costs, and also the level of detail/complexity appropriate to the issues being addressed.

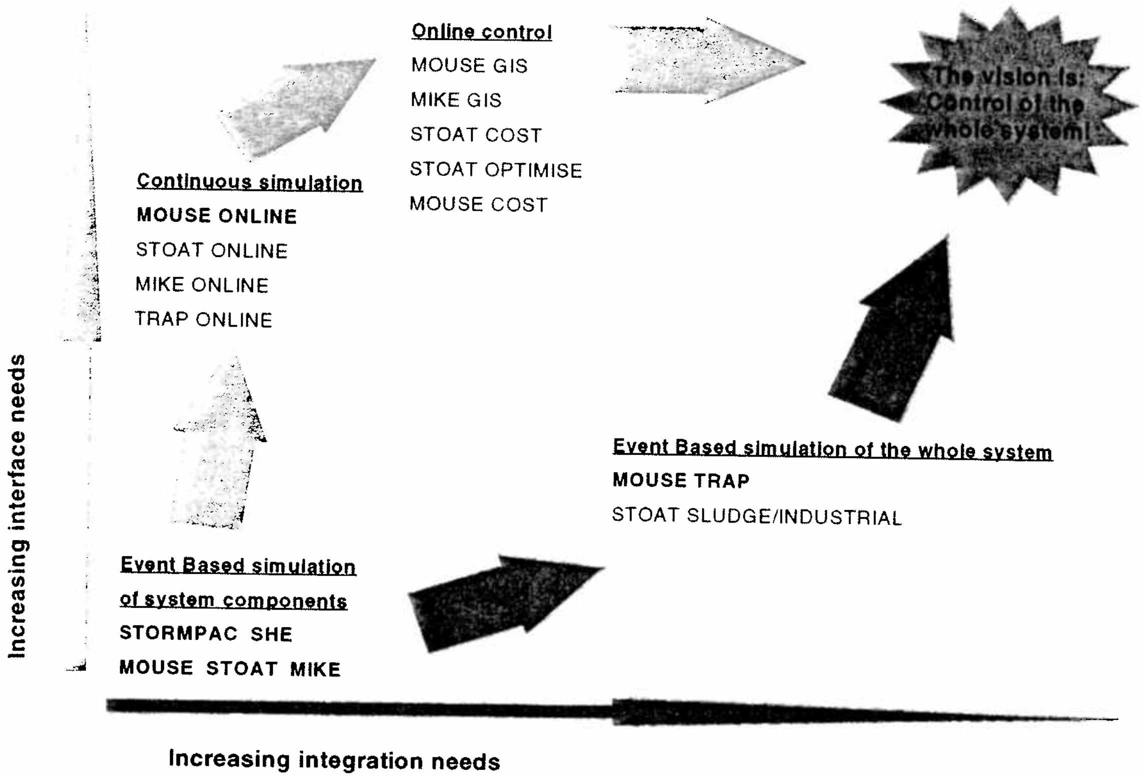

Fig. 1. Integrated modelling tools – Present and future

It is one thing to have such a vision. It is quite another to develop it to reality. WRc and DHI and a group of other organisations who share similar views are undertaking a major development project which is the vehicle by which significant progress is being made towards realisation of this vision. It is this project which is the subject of the paper.

"INTEGRATED WASTEWATER" PROJECT

The Technology Validation Project (TVP) on Integrated Wastewater is being undertaken under the auspices of the European Union's 4th Framework "Innovation" programme. Fourteen partners from six countries (see Acknowledgments) have joined together to implement the project which has the stated aim of demonstrating that "an integrated, model based approach to the planning and management of urban wastewater facilities is both feasible and cost effective". To achieve this aim the project includes elements of technology development and practical implementation, as well as dissemination. Further information regarding the project is available on the dedicated Website "www.tvp-wastewater.com".

The project commenced in late 1996 and is due to finish at the end of 1999. Initial emphasis was on the technology development aspects, which, as reported below, are now largely completed. For the remaining duration of the project, emphasis moves to the pilot studies which will prove the practical value of the technology.

TECHNOLOGY DEVELOPMENT/ADAPTATION ASPECTS

Regulation

The concept of integrated wastewater planning involves important aspects relevant to environmental regulation. These relate to suitable environmental standards against which the performance of wastewater systems may be designed and subsequently assessed, and to a methodology for assessing compliance of the system with the required performance targets.

Typical legislation and implementation practice reflects the variety of local environmental circumstances, water uses and socio-economic conditions in different countries. However, such approaches often do not provide an appropriate foundation for the systematic application of integrated wastewater planning.

The "Integrated Wastewater" project has identified a generic, widely applicable legislative framework, fully compatible with the concept of integrated wastewater planning (WRc 1997 and 1998). The proposed standards are environmental criteria for the protection of aquatic life from short-term exposure to ammonia and to low dissolved oxygen based on those already established in some countries (UK and Denmark). Standards relating to aesthetic, bacteriological and other pollutants have also been considered.

Water Quality Sensor Development

Real Time Control is a key aspect of successful integrated management of large scale urban wastewater systems. RTC systems require appropriate flow and water quality information from within the sewers, wastewater treatment plants and receiving waters to be available to the operators or automatic controllers within the time scales compatible with the decision making process. While the technology already exists to allow this for many of the important measurands, such as rainfall, flow, levels and some quality determinands, it is not currently feasible to obtain on-line data for many of the key quality parameters. The "Integrated Wastewater" project has met this shortfall through a focused action to identify the instrument on the market which most closely meets the application requirements and its' adaptation/upgrade to fully meet these needs.

A market survey identified that the SIEMENS "AquaScan" instrument delivered the best results for the key parameters of BOD, suspended solids and ammonia. The instrument also measures COD, TOC, pH, colour, conductivity and temperature. Measurements of these parameters are continuous and an updated average is recorded every 60 seconds. Prototypes have been installed at each of the pilot sites and are currently being tested for robustness and accuracy.

Planning/Applications Framework

The scale and complexity of integrated management of urban wastewater systems calls for a generalised framework within which the planning and applications process can be implemented in an objective manner.

The "Integrated Wastewater" project has addressed this issue through the development of a guideline document titled "Integrated Planning Framework for Urban Wastewater Systems" (WRc, 1999). This document has its origins in UK Urban Pollution Management (UPM) procedure (FWR 1998) which provides a methodology for the planning of integrated urban wastewater systems in generalised, yet instructive terms. However, whilst the UPM Manual focuses on the wet weather performance of passive systems, the "Integrated Wastewater" document introduces the concepts of RTC and continuous urban hydrology (i.e. long-term simulations). The integration concept has also been extended to include consideration of both wet and dry weather system performance.

Integrated Catchment Simulator

Integrated modelling of the whole urban wastewater cycle is at the heart of both the WRc/DHI "vision" and the "Integrated Wastewater" project. The development of a software package named the Integrated Catchment Simulator (ICS) is a key part of the whole project.

The ICS has the following functional requirements:

- a strong graphical capacity of the user interface to provide a user-friendly working environment, including the visualisation of the modelled catchment, individual models and the model interaction points;
- the model integration to be done intuitively through the user's response to simple dialogues and graphics, i.e. without the need for an in-depth understanding of the underlying data processing techniques and transfer of flow and pollution components between different models;
- the system to be capable of sequential and simultaneous simulations, in order to cover the full range of applications, including hydraulic and RTC feed-back in the upstream direction;
- the system to allow integrated modelling at various scales (i.e. levels of detail), in order to match actual study requirements; and
- the system to be as open as possible, in order to enable the integration of various models within the same generic framework.

Development of the ICS has been based on well-established baseline modelling tools: MOUSE TRAP for urban drainage and sewer systems, STOAT for wastewater treatment plants and MIKE11 for receiving water bodies. These three deterministic, fully dynamic modelling systems are complemented by SIMPOL™ - a simple, mass balance based system for fast screening simulations in the early planning phase. Provision has been made in the design that other models built under similar modelling systems could eventually be included in the integrated system. ARC View™ has been selected as a suitable GIS development platform for the integration framework.

Behind the user interface, there is a data processing engine which bridges the gaps between the component models arising from different approaches to software design, file formats and pollution modelling philosophies. It enables fully automated data transfer between the models and, in the simultaneous simulation mode, controls the "parallel" running of the component models, with data exchange at the time step level.

The need for both sequential and simultaneous simulation capability of the software system can be explained if the information flow within the simulated system is analysed. In most cases, the flow of information coincides with the flow direction, i.e. from upstream to downstream (Fig. 2). In this case, information transfer can be achieved simply by using the time series outputs from the "upstream" models as the inputs for the "downstream" models. This can be done without any loss of accuracy at the file level, i.e. with the models running one after the other in a pre-defined sequence.

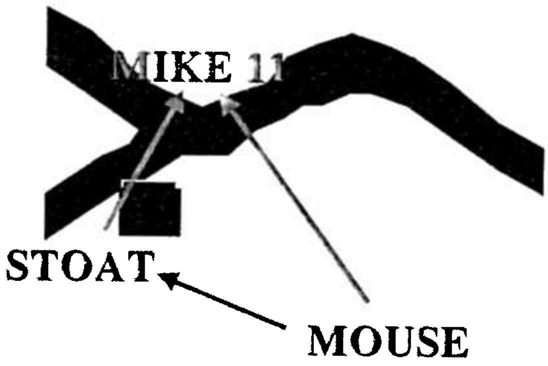

Fig. 2 Information flow between the sub-systems (i.e. models) in a sequential simulation set-up

The schematic representation of the software implementation of the ICS for sequential simulations is given in Fig.3.

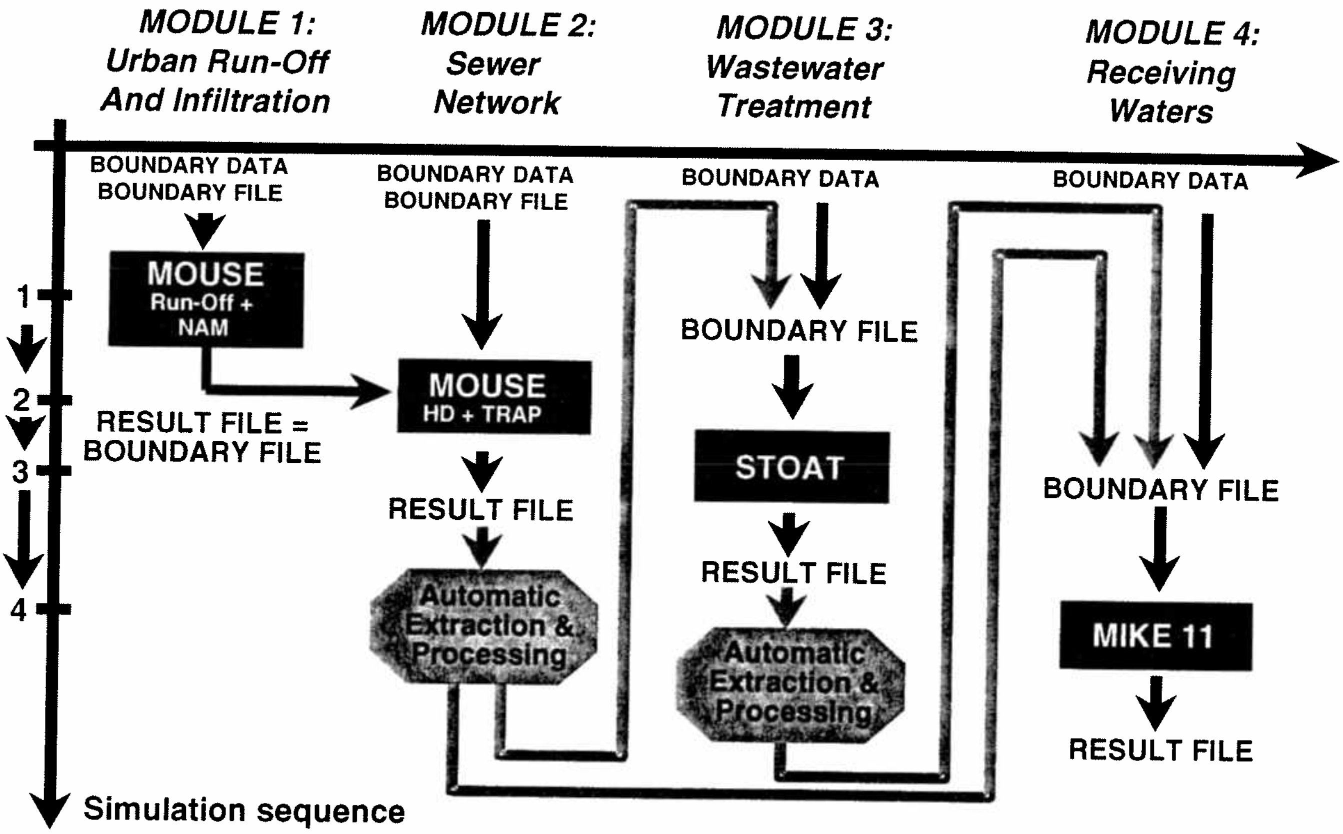

Fig. 3 Schematic of the integrated system for sequential simulations

However, if an important backwater effect is present, propagating for example from the receiving water system into the upstream sewer system, or if the system is furnished with an RTC scheme extending over two or more sub-models, simultaneous simulations of all models with two-way information exchange is needed (Fig.4)

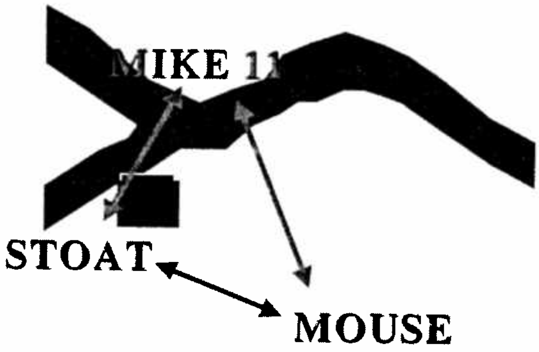

Fig. 4. Two-way, implicit information exchange requires simultaneous running of the models

This requires a completely different software design, where individual models run simultaneously and exchange information at the time step level (Fig.5).

The requirements set out at the start of this section have been achieved. Now, to move the ICS from the developers' desks towards routine use by urban water modellers, intensive testing is being undertaken though the application on a series of pilot projects, as described below.

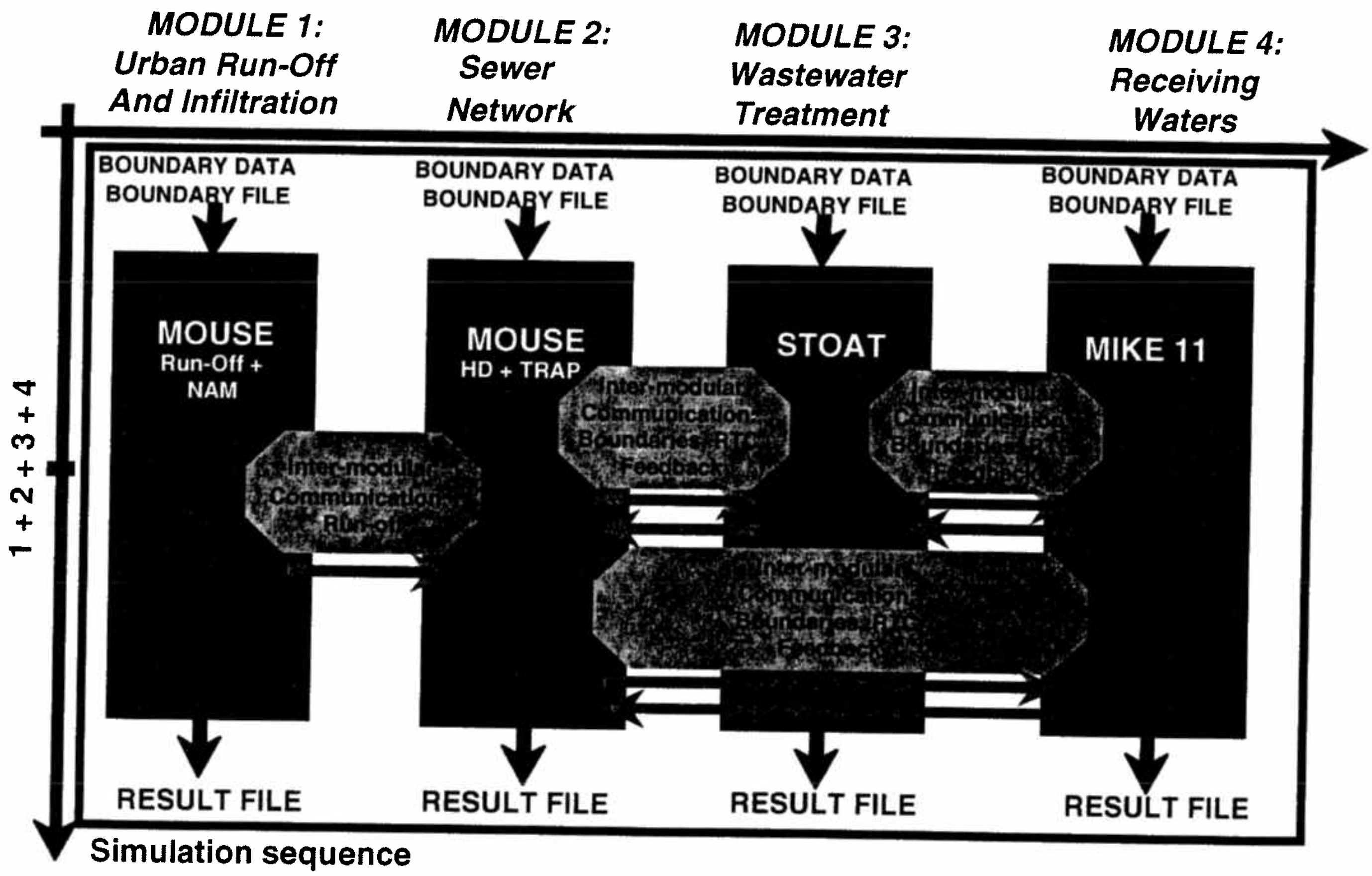

Fig. 5 Schematic of the integrated system for simultaneous model runs

PILOT PROJECTS

Six large-scale pilot projects and two smaller case studies provide a wide range of real-life situations on which to test the ICS and associated technology.

Swedish Projects: Helsingborg, Halmstad and Sundsvall

In Sweden, three pilot projects are being carried out in the cities of Helsingborg, Halmstad and Sundsvall. All three projects are focused on the analyses of the interaction between the sewer system and the wastewater treatment plant (WWTP) under variable operational conditions, created by the application of RTC in the sewer network. RTC is an effective means to improve and optimise the WWTP operation. In order to test and validate new operational strategies, appropriate MOUSE TRAP and STOAT models have been developed. Sampling and measurement campaigns have been undertaken to establish a basis for the calibration of the hydraulic, pollution transport and treatment plant models, for various operational conditions - dry weather, storm runoff and snowmelt. The validation of the MOUSE TRAP and STOAT models is important, as the total system will be evaluated with respect to the flow and the transport of dissolved substances to the WWTP and the emission from the WWTP.

In the first phase of the project, the models are integrated by ICS and used for the analyses. Based on continuous simulation of the flow and concentration at the WWTP for an average year, various control strategies will be examined in order to achieve the optimum conditions. The selected control strategies will then be evaluated with respect to changes in sedimentation pattern; i.e. the new control strategies should not increase the sediment deposits in the sewer system to an unacceptable level.

In the later phase, the integrated model for the Helsingborg system will be set into a real-time operation (on-line), provided that the earlier work demonstrates the benefits of doing this.

Oldham Pilot

Oldham is a part of the Manchester conurbation in the north west of England, which currently suffers from major pollution problems as a consequence of large-scale urban wastewater discharges into relatively small rivers. The catchment is already the subject of an integrated modelling study using the established UPM approach. The objective of the pilot study is to demonstrate the additional savings that can be achieved by use of the ICS software and RTC of the wastewater system.

Component models have been constructed for the sewer system, the wastewater treatment plant and the receiving rivers. In the pilot project, these individual models will be joined together using the ICS and a RTC solution will be identified which meets standards specified by the environmental regulator. These results will be compared and contrasted with the passive solution which has been developed from the UPM study.

Venice Pilot

In Venice (Italy), the receiving water system – the extremely sensitive Venice lagoon - is exposed to excessive nutrient loads from very densely populated surrounding municipalities, industries and agricultural areas. Prioritisation of the investments to rehabilitate the unsatisfactory situation is currently difficult, due to the lack of detailed understanding of the relative importance of various pollution sources and their behaviour. The TVP pilot project concentrates on modelling the catchment connected to the Fusina WWTP, covering the city of Mestre and the industrial zone of Porto Marghera. The models developed and integrated during the project include the wastewater collection network (MOUSE TRAP) and the Fusina WWTP (STOAT), while the recipient modelling is being done separately, using earlier MIKE 21 models as a baseline. The project aims to provide understanding of the situation from the point of view of urban and industrial water pollution by providing reliable information for decisions about forthcoming investment in wastewater sector.

Barcelona Pilot

The city of Barcelona is one of the largest Mediterranean cities, capital of the region of Catalonia and economic centre of the West Mediterranean. With a population of 1.5 million and an additional industrial load of 2 million PE, the city covers 99 km^2 of highly impervious area. The actual drainage catchment served by the city's combined drainage system extends over 128 km^2. Along the Barcelona's sea front there are more than 4 km of beaches - most of them created recently, during the preparation for the Olympics '92. After heavy rain during the summer period, the quality of the bathing water is affected by CSO discharges.

A MOUSE TRAP model has been constructed to simulate the transport of faecal bacteria in the sewer and bacteria loads to the bathing waters. The impact in terms of bathing water quality is being investigated by means of a 2-dimensional model (MIKE 21) for the coastal zone around the beaches. Through a sequence of integrated simulations, the optimal design for the sewer system with respect to the impact on the water quality at the beaches will be identified. Integrated analyses will be undertaken to performance relative to revised and adapted local environmental standards.

Bordeaux Pilot

Large detention basins are used for urban flood control in Bordeaux (France). After rainfall, the basins are emptied into the Garonne estuary during low tide. However, during these periods the treatment plant is often not fully loaded. The pilot project is intended to establish and evaluate better control strategies, based on on-line model forecasts for the integrated operation of the detention basins, sewer collectors and the treatment plant. The expected result is a significant reduction of the total pollution loads discharged from the system. If this result is demonstrated by off-line modelling with the ICS, the improved control strategies will be implemented in practice.

Genoa Pilot

In Genoa (Italy), operation of the wastewater collection network and the wastewater treatment plant in the catchment of the ancient city centre is characterised by low efficiency of the treatment plant and large CSO loads into the inner harbour. This contributes significantly to the unsatisfactory water quality in the harbour, which is now used mainly for amenity purposes. An integrated modelling study including MOUSE TRAP and STOAT is aiming at identifying feasible and cost-effective measures for the alleviation of this situation. Integration of the models is expected to develop better operational strategies for minimisation of the total pollution loads discharged to the harbour.

CONCLUSIONS

- Comprehensive and robust integrated management of urban wastewater systems is vision for many practitioners, but one which has hitherto been unattainable because of technical and practical limitations in the available technology.
- A major European Union funded project is ongoing in which many of the technical barriers are being pushed back so as to make the vision more of a reality. In particular, a software package has been developed which makes fully integrated modelling of all components of the urban wastewater system and the development of global Real Time Control strategies a practical proposition.
- The practical feasibility and potential benefits of these new capabilities are being demonstrated on a series of large-scale pilot studies, with promising results to date.

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ACKNOWLEDGMENTS

The TVP "Integrated Wastewater" project is being undertaken with financial support from the European Commission as part of the European Union's 4th Framework Innovation Programme. The technical and financial support of both the EC and the project partners listed below is gratefully acknowledged:

Environment Agency for England & Wales (UK)
Swedish Water & Wastewater Works Association (SE)
North West Water (UK)
City of Helsingborg (SE)
Clavegueram de Barcelona S. A. (ES)
Communaute Urbaine de Bordeaux (FR)
Comune di Venezia (IT)
Azienda Mediterranea Gas e Acqua SpA (IT)
Societá Generale di Ingegneria SpA (IT)
Société Anonyme Francaise d'Etudes et de Gestion (FR)