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QUALITY MODELLING - Applying UPM

J R Allen - STW Ltd, R W Crabtree - WRc plc

1.0 Current Practice

Traditionally, the standard approach adopted for the management of storm flows in urban waste water systems has been by the application of Formula A or, for sewage treatment, 6PG. Where downstream capacities were restricted or where discharges were to particularly sensitive locations, storage based on population equivalent, for example the SDD method, has been employed.

Overflows, correctly designed to these criteria were generally successful in maintaining and improving the aesthetic profile of the receiving water by the retention of gross solids. However, these methods take no account of either operational efficiency or environmental protection. Similarly, storm tanks and overflows at sewage treatment works were designed to operate and store flows based solely on empirical design methods.

The reason for the continued use of these fundamentally flawed practices has largely been due to the inability to do anything better.

2.0 Introduction to UPM

The underlying reason for continuing with these traditional approaches to design has been due to the lack of effective and usable investigative tools to allow more flexible and site- specific analysis to be carried out. The *Urbcn Pollution Management (UPM) programme* has sought to identify and address the deficiencies of these empirical design methods and respond also to recent EC Directives and domestic legislation, through the development of dynamic modelling tools and planning methodologies.

The UPM approach requires that sewage discharges from overflows, and sewage treatment works, must be limited to the assimilative capacity of the receiving water to ensure that environmental standards and river quality objectives are achieved. To apply this approach, the following questions need to be addressed:

* What polluting load is discharged from the system?

* What is the impact on the receiving water?

* What is an acceptable impact?

Answers to these questions are not provided by using the traditional design methods and planning procedures. Therefore, the identified efficiencies in the current modelling and planning procedures were translated into requirements for products to be developed as part of UPM programme. The list of products identified as being required for controlling urban waste water discharges to inland waters included:

* An improved rainfall model to provide inputs to models.

* A sewer flow quality simulation model to complement existing sewerage network hydraulic analysis models.

* A model to predict sewage treatment works performance under storm conditions.

* A river impact model.

* Water quality criteria for intermittent wet weather pollution.

* Appropriate planning methodologies to apply the above models to design solutions at a hierarchy of levels.

* Improved engineering designs to ensure that design requirements could be met.

Under the UPM programme technology has progressed sufficiently to address the above questions effectively and enable designs to suit site-specific circumstances. This provides the industry with a realistic opportunity to understand and manage pollution from urban waste water disposal systems more effectively.

The UPM research programme has been the Industry's principal driver in the development of the complex investigative tools and planning methodologies required to implement the approach. The publication of the NRA's guidelines for consenting intermittent sewage discharges in early 1993, represented a watershed for the industry by establishing a framework for the management of wet weather urban discharges.

The UPM programme has been influential in shaping this regulatory framework and through the complex computer tools and methodologies developed under the programme, provides the means of complying with it.

3.0 UPM Products

Much of the effort invested by the industry in the UPM programme has been directed towards the development of comprehensive, investigative tools to predict sewage and sewage treatment works effluent quality, rainfall events and river impact. The current capability and status of each of the UPM products is reviewed below:

a) **A rainfall data generator and processing package - STORMPAC**
A key aspect of using the UPM tools to address problems in a meaningful way is the definition of the rainfall inputs used to drive the models.

When the UPM programme started, the accepted form of rainfall input for sewer modelling purposes was the synthetic "design" storm. Whilst possessing many virtues, this form of rainfall clearly has deficiencies for pollution studies and the concept of rainfall time series was soon identified as being more appropriate. Annual Time Series Rainfall was developed and has become widely used for all forms of pollution investigation throughout most sectors of the Industry. WRc has made the series available to users, on request, since 1986.

Work has continued to develop more flexible, reliable and robust tools based on the time series concept. The Stochastic Rainfall Generator (SRG) model has been developed and has been incorporated by WRc into a software package called STORMPAC.

b) **A deterministic sewer flow quality modelling component of the WALLRUS analysis package - MOSQITO**

It was recognised that a comprehensive approach to describing sewage discharges was required to protect ecological health and define optimum engineering solutions. Hence, a major programme of research was put in hand to define the exact needs; to develop the fundamental understanding of component processes; and to produce the requisite software for a detailed deterministic sewer flow quality simulation model. The product of this work is MOSQITO. Many organisations contributed to the data collection and fundamental research activities underpinning this model. The software has been made commercially available through Wallingford Software since July 1993.

c) **A dynamic sewage treatment works model - STOAT**

The major thrust of work in this area has been the development of a detailed dynamic sewage treatment works (STW) model to complement the sewer modelling capability of MOSQITO. Most of the development work has been carried out at WRc with the collaboration of Imperial College. The software product, available from WRc, is known as STOAT. This allows models of most configurations of treatment works to be produced, which can then be used to investigate wet weather responses and the effects of changes in configuration.

d) **A dynamic river impact model - MIKE 11**

The complementary river impact modelling tool to MOSQITO and STOAT is MIKE 11. This established software was selected in 1990 as the best basis for development to meet the full requirements of the UPM approach. Since that time, the software has been enhanced and now matches the capabilities of the other UPM models. MIKE 11 was developed by the Danish Hydraulic Institute (DHI) and is available commercially in England and Wales from W S Atkins and from Babtie in Scotland. This model has been successfully tested against the UPM requirement specification. The NRA have supported the production of a MIKE 11 Application Guide to complement existing documentation for users.

e) **Environmental Standards - short duration river quality standards for dissolved oxygen and un-ionised ammonia**

The results from the models must be evaluated against some form of performance criteria to design solutions to achieve regulatory standards. A programme of fieldwork and laboratory studies was carried out by WRc between 1988 and 1991 to derive relationships for intensity, duration and frequency of exposure to low levels of dissolved oxygen and high levels of un-ionised ammonia, compatible with the protection of aquatic life. These have been used as the basis for the wet weather water quality criteria recently promulgated by the NRA.

f) **Planning Methodologies - interim tools and the UPM Manual Procedure**

Many different interim tools and methodologies related to the objective and cost-effective integrated management of urban waste water disposal have been evaluated or developed under the auspices of the UPM programme; for example, QUALSOC and CARP. Many of these are incorporated in current planning guidelines; along with the detailed UPM modelling procedure. A comprehensive planning approach, based on a consistent set of application methodologies which supersede these interim approaches, is documented in the UPM Manual.

g) **Improved Engineering Solutions**

Effort in this area has concentrated on characterising all aspects of the performance of existing designs of CSO structures. This has included the development of improved CSO designs and the design of detention facilities to minimise both the spill of pollutants and maintenance demands. In addition, the potential benefits of the real time control of sewer systems has been investigated.

4.0 The UPM Manual

A comprehensive range of planning procedures, including the integrated use of the suite of detailed simulation models, is currently being documented in the UPM Manual. This will offer guidance on the choice of appropriate planning methodologies and modelling tools to suit individual circumstances in a consistent manner, to achieve cost-effective solutions. The Manual will describe a single comprehensive planning framework referred to as the UPM Procedure. The following key criteria underpin the UPM procedure:

a) **Variability of Discharge Loads**

Loads discharged from urban drainage systems during wet weather vary because of vagaries in the weather, changes in foul discharges to sewers and the complex physical, biological and chemical processes in sewers and sewage treatment works.

b) Variability of Impacts

Impacts resulting from these discharges are further complicated by environmental processes in the receiving waters and by the variability in background conditions, such as river flow and quality.

c) Holistic Approach

Because of these interactions, it is essential that the urban drainage system - that is, the sewers, treatment works and receiving waters - is treated as one integrated system and not as three disparate parts.

d) Cost-effectiveness

Furthermore, as financial resources are scarce, investment decisions need to recognise the individual nature of pollution problems by tailoring solutions to local prevailing conditions.

e) Improved Understanding

Such tailor-made solutions are only possible if the processes which contribute to the pollution problems are understood in each individual case and the effects are quantified in a cost-effective way.

f) Consistent Hierarchial Methodology

A hierarchy of planning tools is available to understand and represent these processes at different levels of detail, up to full dynamic simulation. Therefore, it is possible to select a level of planning which is commensurate with the complexity of the problem and likely cost of the solution.

The latter point is achieved by using the intermittent discharge standards as the design criteria for all levels of planning. Using detailed simulation modelling it is, in theory, possible to simulate the full rainfall/spill/river impact sequence to produce a continuous record of river DO and ammonia which can be checked against the standards. Unfortunately, this approach is impracticable at present because of the time and computing constraints associated with running detailed models.

Means of overcoming this difficulty have, in the past, tended to concentrate on sampling of the rainfall inputs to reduce the number of model runs required. The form of the environmental standards has encouraged the use of simplified models of the various components of the system (calibrated against detailed models) which can be rapidly run for prolonged rainfall time series, without the need for sampling.

A spreadsheet simplified pollution modelling tool called SIMPOL has been designed to combine most of the key processes involved in wet weather pollution modelling, so that many events can be processed rapidly. Hence, the main uses of SIMPOL in the UPM Procedure are to screen rainfall events for use with detail models and, to test the performance of potential solutions against standards quickly.

In the latter case, SIMPOL can be used after calibration against the results of the detailed models. Alternatively, for simple systems, which do not require the use of detailed modelling, SIMPOL may be used in a default mode to identify acceptable solutions. Used in this way, it provides soundly based alternatives to existing simple procedures.

5.0 Benefits of UPM

New obligations have emerged from the broad requirements of the Urban Waste Water Treatment Directive (UWWTD) and the National Rivers Authority's interpretation of these requirements have been detailed in the 'NRA AMP2 Guidelines'. This document represents the position of the regulators for implementing the Directive in the UK. The AMP2 Guidelines recognise a number of planning procedures for consenting intermittent discharges to inland waters. One of these is the approach based on intermittent standards. The UPM Manual uses this approach exclusively and shows that it has widespread application for all situations involving wet weather discharges to inland waters.

The NRA Guidelines identifies the UPM procedures as mandatory for considering impact assessment for consent settings in relation to discharges to inland waters. Specifically, the UPM procedure is to be adopted where discharges are considered to be of 'High Significance' and in these instances, the full suite of UPM tools may have to be used to demonstrate compliance.

The tools and methodologies developed under UPM have been influential in shaping the NRA's policy for the management of storm water sewage discharges. It is likely that without the collaborative approach to research provided by UPM and the development of complex tools in which all parties could have confidence, a much more restrictive regulatory framework would have been implemented.

The NRA Guidelines provide the minimum acceptable standards to be achieved. Discharges which are considered as 'Medium or Low significance' in the draft AMP2 guidelines, accept simple control methods (Formula A) and minimal impact assessment methods (SDD, Carp, etc). These simplistic control methods will be superseded by the UPM procedures. However, consistent with the hierarchial approach, the level of detailed application will vary from the simple (SIMPOL) to the complex (MOSQITO, STOAT, MIKE 11 and SIMPOL).

The UPM programme in shaping the regulatory framework and in developing the range of computer tools and identified planning methodologies, provides the Industry with the means of complying with it and at the same time deriving additional benefits, these are:

* more cost effective solutions,

* more reliable solutions,

* more consistent plans,

* more rapid agreement on CSO consents,

The main advantages of quality modelling will be fully realised in complex problematic river catchments. Where a co-ordinated integrated approach between sewerage, sewage treatment and environmental planners will improve the understanding of overall system performance and as a consequence potentially more reliable and capital efficient solutions may be identified.

As confidence and the necessary experience in the use of the UPM tools and procedures is developed, there may be additional benefits from adopting the UPM approach in other circumstances, which would broaden the scope of quality modelling. For example, the combined use of MOSQITO, STOAT a SIMPOL could, through simulation, demonstrate the inaccuracies in traditional design methods and identify investment savings through a greater understanding of direct organic loading at the treatment works.

However, at this early stage of the UPM implementation, the need still remains to demonstrate the advantages of the approach relative to other techniques.

6.0 UPM Demonstration Project

To close the UPM Research Programme, a Demonstration Project is now underway in Derby City to show that real financial and environmental benefits can be derived from the application of the UPM tools and planning methodologies. There are high levels of investment planned for both sewerage and sewage treatment for the Derby City catchment and the quality of the River Derwent is affected directly from CSO discharges.

The objective of the project is to demonstrate to the Industry the environmental and financial benefits to be realised from the effective application of the full UPM procedure. This will be achieved by carrying out a comprehensive application of the UPM modelling tools (MOSQITO, STOAT, MIKE 11, STORMPAC and SIMPOL) to a real catchment.

The selection of large city catchment for the Demonstration project will provide an opportunity to demonstrate the value of the UPM approach in situations where the level of investment and, hence, potential cost savings will be large. Also, Derby will test the sensitivity, reliability and applications of the models and procedures at a scale not attempted before.

The Demonstration Project is being funded by the Industry and the NRA, through the FWR and is scheduled for completion in late 1994 to support the release of the UPM manual. Support to the project at a local level is being provided by Severn Trent Water Limited and the Severn Trent Region of the National Rivers Authority.