Applying the UPM methodology to a large CSO study programme

Richard Norreys[1], Steve Kenney[1], Graham Squibbs[2] and Luke Pearson[2]

[1] MWH and [2] United Utilities

Abstract

The larger number of outputs and tight deadlines required by the United Utilities AMP 3 Unsatisfactory Intermittent Discharge (UID) Programme have been both a technical and managerial challenge.

Now, with the completion of the majority of the studies, this paper describes the general approach, methodologies and the tools used to identify problems, develop solutions and maintain product quality for different types of water quality studies. A number of case studies will be presented illustrating how these methods and tools have been applied, providing cost-effective solutions for delivering maximum environmental benefit.

Introduction

The United Utilities (UU) AMP3 UID programme is the largest programme of work in the UK to identify and address pollution of surface waters by urban wastewater discharges in wet weather. The 914 UIDs were initially identified for assessment, grouped into 77 study areas. UU undertook water quality based Urban Pollution Management (UPM) studies in 38 of the study areas in the programme. The number of catchments which required assessment probably made this the largest hydroinformatics programme ever carried out in the UK. This paper discusses the water quality based UPM studies. These studies demanded integrated modelling of all elements of the wastewater networks and the watercourses that the networks discharge to. The studies required the building and verification of sewer models for flow and quality; the constructing and calibration of river quality models; the development of design rainfall series; and the production of wastewater treatment works (WwTW) models. To feed this modelling effort vast amounts of data had to be collected. Table 1 illustrates the scale of the modelling and data collection exercise.

Table 1 - The scale of the data collection and modelling required for the UU UPM Studies

Flow monitors installed (all studies)	1750
Quality samplers installed	255
CSOs / Manholes surveyed	1750/8500
Study catchments (inc. Bathing Waters and Spill Frequency)	77
Water Quality Studies	38
Total population of all catchments	4 million
Number of river models constructed/Length of rivers modelled	8/126 km
Number of WwTWs Final Effluent models produced	27
Number of design rainfall series	34

A single UPM study offers a big technical challenge but 38 of them was a daunting prospect. The prospect became even more daunting when the constraints of time, equipment availability and staff resources were also factored in.

The only way to achieve the completion of the studies was to develop and apply sound technical approaches, exercise tight management, practise good quality control and exploit software and IT system capabilities as much as possible.

Data Collection

Data collection was the most expensive element of the work. The collection of wet weather data was the most critical element of the data collection programme. To reduce the risk of missing events or sampling non-events, wet weather data collection was controlled by a team-member monitoring the weather. This individual was responsible for mobilising the data collection contractors, notifying the laboratories of the arrival times of samples and actually triggering the events or demobilising the data collection teams. Despite this the weather did not play into our hands. On average a planned survey for 8 weeks extended into 16 weeks and a planned 16 week water quality survey extended into 36 weeks.

Time series flow and quality data were collected in sewers, rivers and WwTW. An important lesson from this is that the quality of the data has to be closely checked as soon as it is collected as environmental changes can affect sites, data can be mixed up in the labs, and devices can measure the wrong parameter. On a big programme of work it is all too easy to collect and archive the data until it is needed for modelling by which time it is too late to correct some mistakes as the survey will have been removed.

Modelling Tool Approaches

The studies were classified into 5 types each subject to a different modelling approach based on the size of the catchments, their characteristics, and the significance of the study. The simpler the approach the more conservative the modelling, so there was a trade-off between the cost of undertaking the study and the conservativeness of the impact assessment. Table 2 details the different levels of study.

Table 2 Original Classification of UPM Studies

Type	Description	Studies	UIDs
Full	Detailed Network, Detailed River*	15	333
Type A	Detailed Network, Simple River*	4	35
Type B	Default Network, Simple River*	9	64
Type C	Default Network, Mass Balance river	7	26
Type D	Default Network, Mass Balance river	3	23

*Number of studies requiring river models was significantly with reduced with the reduction of the number of FIS studies

Developing Detailed Assessment Methodologies

The 2nd edition of the UPM manual provides a planning framework for these studies however a lot of details about methodologies and reporting had to be agreed between the study participants UU, the Environment Agency (EA) and MWH. The strict time constraints dictated that once an acceptable approach had been agreed between the stakeholders it was adhered to for all subsequent studies.

Full network detail was included in the sewer models and models were run to produce results at a five-minute resolution. This enabled the methods for testing compliance to be refined.

- All events from a ten year rainfall series (typically 1100 to 1500 events) were run to assess compliance.
- Sewer Models were run with a 5 or 7 day antecedent dry period to build up sediment loads in the network.
- Large Surface Water Systems were included in the modelling and assumed to have a discharge quality of 10 mg/l BOD and 1 mg/l ammonia.
- High Percentile Standards were assessed based on an hour by hour breakdown of CSO spills from the 10 year runs.
- High Percentile standards were adjusted to account for dry weather failures.
- Fundamental Intermittent Standards (FIS) were assessed based on the worst hour/six hour of spill from an event.

- Default network modelling used CIRIA recommended default water quality profiles and was verified against observed crude sewage quality at the receiving works.
- A look-up table of default river quality parameters was produced to aid the development of Simple River Models.
- Once storage solutions were developed, these were built into the sewer models, 10 years of rainfall data run through the model and the compliance tested once more.

Modelling Tools

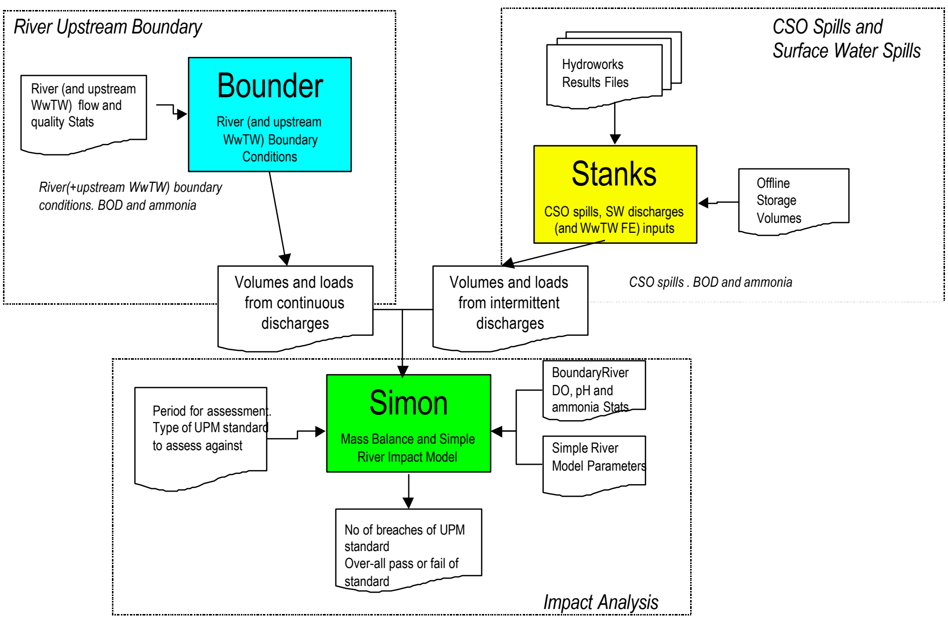
For most of the studies ten year design rainfall series were produced in **Stormpac 2** and verified with observed data, although observed hourly data was used for two rainfall zones. The North West was divided up into 34 zones of similar rainfall and series developed for these zones. Software developed by MWH was used to add API30 values and tidy up the series.

Sewer network flow and quality modelling was carried out using dynamic network models in either HydroWorks or InfoWorks. Simplified models were not used.

Wastewater treatment works hydraulics, and stormtank spill quality were included in the sewer network model. The sewer model provided final effluent flow predictions and final effluent quality was simulated using a probability distribution.

River quality impact models (RQIMs) were constructed and calibrated in Mike 11 and then used to calibrate simplified river models (SRM) which incorporated the algorithms in **SimpolV2**. The SRIM was built in an in-house MWH tool **SIMON**.

Figure 1-Impact Analysis Tools



The MWH program **Stanks** was used to process CSO spill flow and load time-series predictions from the HydroWorks/InfoWorks models. This program produces table of data summarising the spills from CSOs and formats the data for input to **Simon**. **Stanks** further role was to simulate the effect of off-line storage or altered pass-forward flows as part of solution development. **Stanks** also allows the user to impose BOD or ammonia qualities on a set of hydraulic predictions, allowing surface water system or WwTW Final Effluent quality to be simulated.

The MWH programs **Simon** and **Bounder** were initially used to undertake the impact analysis. However as the project developed the **Stanks**, **Simon** and **Bounder** were combined into a single piece of software **RIOT** (River Impact Optimisation Tool).

RIOT was developed to enable multiple off-line storage scenarios to be assessed and an optimiser routine was included to identify optimal storage configurations based on least cost or overall storage volume. The approach of using full network models resulted in very complicated analyses. In one study RIOT co-ordinated inputs from about 180 CSOs, drawn from a total of 3 Gb of results files (1172 events * 5 results files per event = 5860 files per network) from ten separate network models. Once this complicated scenario was set-up new results could be inserted and the same basic set-up used for needs assessment, solutions development and final impact assessment using the final solutions models. RIOT turned out to be an essential tool in the programme; the automated procedures allowed many simulations to be carried out with minimal modeller input.

Other Software Tools

At the beginning of the studies a library of MapInfo GIS data was compiled at a central server location. This contained all the information pertaining to the studies from UU asset databases, SIRS, DG5 and outfall locations and additional background mapping, rivers and contours. A front end termed **SAMS** with a number of control buttons and routines was written to call up individual tables and produce plans. This permitted the information to be easily accessed by all members of the team.

The underlying philosophy of the studies was to efficiently undertake the impact analysis and pass data and models seamlessly from the Needs to the Solution and detailed Solution phases of the studies. The MWH **DM** (Data Manager) software was used to build the network models and hold and process modelling information. **DM** holds the asset data, standardises model build or alteration and undertakes quality checks on the data. These permit changes to models to be tracked over time, providing an audit trail from the development of the models of the existing systems through to the modelling of solutions. **DM** had the advantage that it was available to all staff concerned with the modelling without the need for precious HydroWorks/InfoWorks dongles being tied-up in model builds when they were needed for simulations.

MWH **GraphViewer** software was used to present the results from the sewer network calibrations. The program presents observed and modelled data for all calibration sites. **GraphViewer** produces comparative plots of rainfall, flow and quality, and will produce summary statistics and scattergraphs. Once configured it will repeat the production of plots for different model runs allowing the modeller to focus on the verification rather than data processing. Once satisfactory verification is obtained then the observed and modelled data can be written to CD along with a copy of graph viewer for model sign-off or audit.

Having software developers on-hand was particularly beneficial, since as the programme progressed new problems arose which needed fixes or developments of the existing tools.

Technical Management

With such a complicated project strong technical management is required to roll out software and methodologies and ensure they were adhered to. At certain stages in the job, work was going on in seven different MWH offices (on three continents). This offered a considerable challenge to provide a uniform product. Although there is no substitute for good old-fashioned nagging, technology was available to help produce a consistent project. Centralised Lotus Notes databases were provided to hold all of the project communications very useful for keeping track of changes to each particular project. In addition the MWH company Intranet, KNET which held all of the methodologies and processing tools, giving easy access to all staff.

Fundamental Intermittent vs. High Percentile Standards

At the start of the studies it was undecided what standard should be applied to each watercourse. Two different standards are described in the UPM manual, but there was no policy as to which standard should be applied. The studies progressed with the aim of meeting both standards, however as time progressed it became increasingly clear that attempting to fully model compliance both would significantly impact on the programme. The standards had their pros and cons but the high percentile standards had the advantages that they were easier to apply and more definitive. Having reviewed at lot of the data collected, and in the light of initial modelling results, UU and the EA decided to apply high percentile standards only for the majority of studies.

A few watercourses with a high pH were also assessed against an additional FIS un-ionised ammonia standard, whilst others with marginal DO levels were assessed against additional FIS DO and un-ionised ammonia standards. UU and the EA then decide the standard that should be attained in the watercourse, setting the target for solutions development.

This adoption of a simpler methodology and a significant reduction in the workload had a big impact on reducing the work programme.

Example of the benefits of Integrated Modelling

One UPM study determined that there was a requirement for nearly 50,000 cu.m storage at a WwTW to reduce the spills from the Stormtanks and the inlet CSO. This presented a problem. The WwTW has taken more flow over the years as other smaller works in the area had been decommissioned and their effluents pumped to it. Consequently there is little excess capacity to treat the returned flows from the required increased storage on the site. Furthermore there isn t sufficient space at WwTW to construct the required storage volume.

A new approach was needed. The final effluent quality at the WwTW was due to be improved in AMP4. The combination of reduction of the intermittent discharges and the improvement of the final effluent quality offered a potential answer to the problems at the WwTW.

The UPM study had already developed tools and methods to examine upgrading scenarios. Furthermore, the RIOT software allowed this to be done efficiently combining the inputs from a number of different models, maintaining good QA, and providing optimal storage solutions for a given scenario. This was particularly useful, as an answer was required quickly.

Several scenarios were run to look at increasing the flow treated at the WwTW, and/or improving the final effluent quality, and the consequent effect on storage requirements.

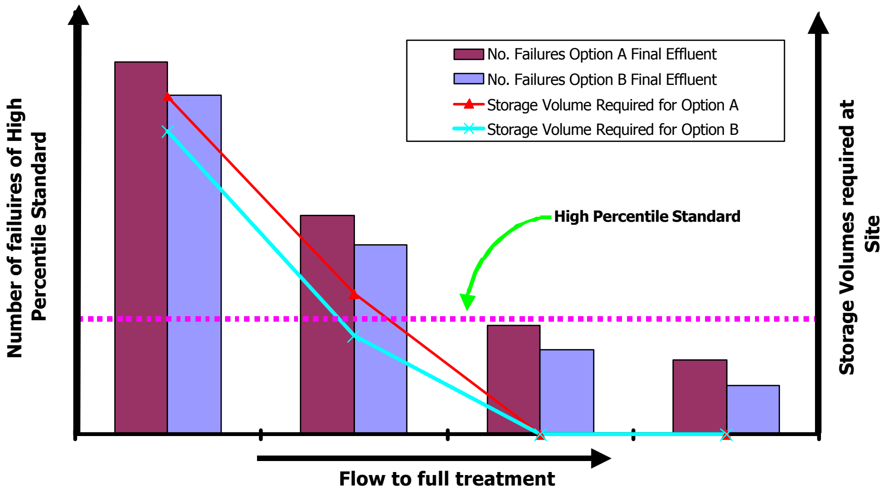
The following final effluent quality scenarios of were modelled: **Option A** and a higher effluent quality **Option B**.

The earlier work had established a model for the final effluent quality so that for a given 95%ile value a distribution mean and standard deviation could be calculated and a distribution for final effluent quality established. The quality model was applied in RIOT to the final effluent flows generated by HydroWorks.

Results

The results of the analyses are presented in the figure 3 below.

Figure 2 - Effect of WwTW FFT and Final Effluent Quality



The work showed that the existing storage at the works would be adequate to meet water quality standards if the pass forward flow was increased.

Outcomes of the Studies

All of the needs assessments were completed by the end of August 2002. The UPM procedure provided precise method to quantify the water quality impact of the intermittent discharges. The UPM methodology enabled the identification of actual problems i.e. some sites previously considered to be problematic proved not to be so, and vice versa some new sites were identified as first time issues. If this integrated approach hadn t been taken a lot of money could have been misdirected addressing CSOs that weren t causing a problem whilst missing a number that were.

Recommendations for future studies

The methods applied on the studies were technically advanced two or three years ago but in the mean time modelling software and hardware has developed further.

Ultimately this will potentially lead to the sewer quality models being run as a continuous simulation. This will reduce the arguments about antecedent dry periods and sediment build-up, and should remove the need to make conservative assessments in the modelling.

A continuous simulation approach would be beneficial for the river impact analysis; this would allow a more automated and easier assessment of the compliance of the system against 10%ile, 90%ile and 99%ile standards and potentially also FIS. However the development and use of continuous simulation and its impact on future AMP projects needs careful consideration with detailed definition to allow funding to be accurately assessed. Technical issues will also have to be resolved such as an acceptable methodology for assessing compliance against FIS in continuous simulations.

A number of watercourses were seen to fail FIS in dry weather regularly in summer as a result of the diurnal variation due to plant growth. There is no satisfactory methodology for developing solutions in such cases. The issue may be the level of nutrients in WwTW final effluent discharges, not a CSO issue. Good quality continuous observed data is essential for understanding how the system behaves and developing an acceptable solution.

A number of studies were complicated by the need to assess the impacts of distributed CSOs in a large catchment where the watercourse has a long time of travel. The approaches applied in these studies were often rather conservative and complicated. A simple river model incorporating distributed CSO inputs would be a useful development.