Yorkshire UPM Studies - Getting it right and learning from mistakes

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Abstract

Yorkshire Water has carried out a large programme of UPM studies to address unsatisfactory intermittent discharges. The programme was carried out by several consultants working independently but collaborating with regular technical meetings to discuss problems and potential solutions to them.

The work followed a well-defined procedure with clear milestones and this allowed rapid progress with the studies. The procedure included a strong involvement of the EA in each study to agree the issues, the scope and the outputs.

The studies then continued with the models and conceptual solutions being handed over to capital delivery teams for construction. This is an excellent test of how good a study has been if a separate team can take the modelling and solution forward and make it work.

The paper describes the many lessons that were learnt about how to do UPM studies. These included both the approach to organising the studies and the technical problems and issues that arose.

1 Scale of the problem

Yorkshire Water had a large legacy of unsatisfactory overflows on the combined sewerage system that were contributing to both aesthetic and water quality impacts on the receiving watercourses. As part of AMP3 a programme was established to resolve most of these. In many cases this involved starting from scratch to model the sewerage system before using the model to assess the discharges, designing solutions and building them.

In total Yorkshire Water assessed 1100 intermittent discharges in AMP3. Of them 751 were deemed unsatisfactory and 15% of these required water quality solutions

This paper concentrates on the assessment of those discharges that were believed to be contributing to a water quality impact on the receiving water and the water quality modelling that was carried out to confirm this and to develop solutions.

This work was carried out after the construction, verification and audit of a conventional hydraulic model of the sewerage system using HydroWorks. For water quality catchments this model was then upgraded to a water quality model. This was linked to a river impact model and the entire system assessed for events from a 10 year rainfall timeseries.

The water quality modelling was sandwiched between the production of the hydraulic model and the need for the capital delivery teams to start pouring concrete. The hydraulic models were sometimes delayed by flow surveys, foot and mouth, poor data etc, but the capital programme could not be delayed so the timescale for the water quality modelling was constrained.

The initial target was for a water quality study to take only 9 weeks from start-up meeting to definition of notional storage schemes. In practice the outturn was for 12 weeks. The delays were due to a number of factors including:

- Overloading of EA resources to check and approve studies
- Technical problems with innovative methods
- Some models took almost a month to run the timeseries.

There was, needless to say, a limited budget for both the whole programme so there was pressure for accurate answers to keep down solution and study costs but also to ensure the solutions were compliant with the required water quality standard.

2 Programme management

Yorkshire Water realised at the outset that three key factors were needed to achieve these targets.

- A standard methodology; so that all studies used the same approach and so that lessons could be shared more quickly
- Standard software tools that met the needs of these particular studies.
- A collaborative approach; with everyone working together to share information, share advice and agree study milestones.

2.1 Standardised methodology

The basic methodology is shown in the flow chart below. (Read from bottom to top).

The early tasks were split into separate streams covering rainfall, hydraulic model, HydroWorks water quality model and river. These could be carried out in parallel. Once agreement was reached on all of these early tasks then the streams could be integrated to produce the full assessment.

An important part of the process was getting the EA to agree with data and interim tasks at the earliest possible time in the study so as to avoid delays and re-work later on.

The flow chart was supported by a detailed specification for each task that identified the data required, how to carry out the task and the reporting requirements. This included standard report templates that made heavy use of standard text and, "delete where not applicable", instructions. An example is shown below.

Trade discharges

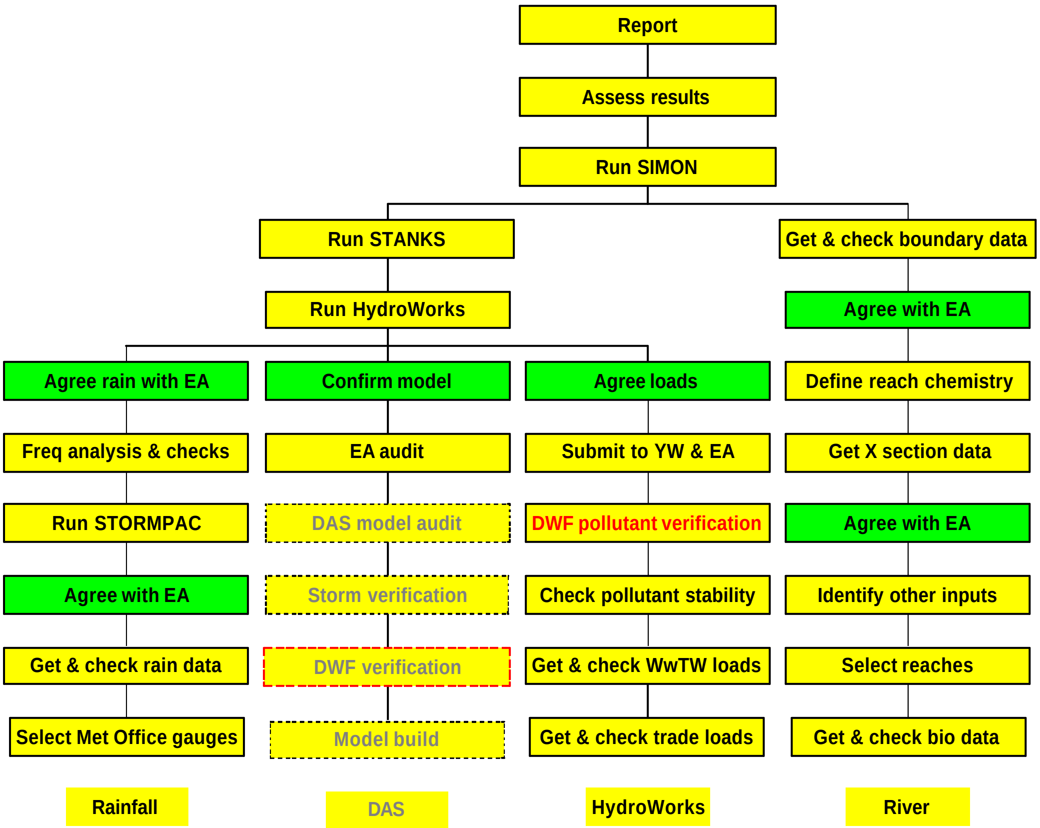
If appropriate [Significant trade effluent discharges have been included in the sewer quality model. Where trade effluent loads were available only as COD these have been converted to BOD using the following ratios. *Describe how the ratios were derived and why they are appropriate.*

Where adjustment was required the trade flows were adjusted first by considering the use of measured rather than consented values.

Trader	Flow l/s	Status	BOD mg/l	Status	Ammonia mg/l	BOD:COD	Status

Further detail on trade effluent discharges is given in appendix D.]

Figure 1 Methodology



2.1.1 Verification

An important part of the methodology was the approach to verification. Rather than seek to carry out detailed verification of the water quality models by sampling sewage in dry weather and storm events the methodology used available data on pollutants in the sewage and verification by measuring the impact on the receiving water. By analogy with verification of a hydraulic model the approach was akin to historic verification rather than flow survey verification.

The pollutants in the sewer model in dry weather flow conditions were compared with available sampling data at the treatment works. Almost all treatment works carry out routine sampling for BOD and ammonia so that they can demonstrate compliance with consents. The model predictions were compared with the mean and variation of these routine samples and the model parameters adjusted if necessary. This technique was particularly useful for identifying unusual contributions from major trade dischargers.

The impact of individual CSOs or groups of CSOs on the receiving watercourses was assessed by sampling to determine the health of the ecology. This was carried out four times to cover the four seasons. This approach was described in a paper at the Autumn 2001 conference. (*The Use of FR0466 and Macro-Invertebrate Surveys to Identify UIDs, Surradge, Tinsdeall & Rees*). The results of this assessment were compared with the predictions of the model to confirm that the model results were reasonable. Although there was no firm procedure to identify the **reasons** for disagreement between the model and the survey, this was still a useful approach. It avoided the costs and delays of in-sewer and in-river pollutant sampling. It also had the additional benefit of not getting bogged down in the tedium of detailed verification and so kept the focus on the real problem of the impact on the rivers.

2.2 Software tools

The work used the standard tools of Stormpac to generate timeseries rainfall where historic data was inadequate and used HydroWorks to model the sewerage systems. However rather than using SIMPOL to assess the impact on the receiving water a programme specific suite of tools was developed by MWH. These were BOUNDER – for generating boundary conditions, STANKS – for treated effluent and stormwater inputs and SIMON – for river impact mass balance and comparison with standards.

2.3 Collaboration

The third key component in the successful conduct of the studies was the adoption of a collaborative approach for both the programme as a whole and each individual study within it.

The key players in the studies were:

- Yorkshire Water – responsible for setting the policy for the approach, negotiating with the EA and approving studies and outputs.
- The Environment Agency – responsible for defining the standards to be achieved in each watercourse and approving studies and outputs.
- DAS study consultants – responsible for collecting data, constructing the models, running the assessments to produce notional storage solutions.
- Capital programme delivery partnerships – responsible for developing the notional solutions into final designs for construction.

Earth Tech has been lucky to be involved as both study consultants and capital programme delivery and so has seen both aspects of schemes. Interestingly this has not necessarily involved carrying out both roles on the same schemes. Some of our studies have been handed over to other capital programme teams and studies carried out by others have been taken through to construction by us.

Collaboration happened at both the programme and scheme level through a variety of mechanisms. At the programme level:

- Training seminars to explain the methodology and software tools initially to the study consultants and later to the design consultants.
- Monthly technical meetings of all study consultants to exchange experiences, problems, lessons learned etc. These meetings achieved a no-blame atmosphere by avoiding any discussion of contractual issues such as progress and cost of individual studies and focussed on technical issues and suggestions for improving performance. All parties at one meeting or another presented something that they had got wrong and learned from.
- A software help desk to answer questions on the use of the software tools and to respond to limitations identified with them.

At the study level collaboration was achieved by having the EA attend each of the progress meetings for a study and hear the full details of the conduct of the study and agree the criteria and methodology at each stage rather than being presented with the finished study and then have to question the basis for the work. This was obviously a significant drain on the EA resources and did lead to delays on some studies.

The capital programme teams were not greatly involved during the study phases. This had the advantage of not involving them in meetings for studies that might show that no capital solutions were required. However this affected the handover of the study for development of the design in some of the early WQ studies. To prevent this the process was modified to include a representative from the capital team in the study phase. This greatly smoothed out the model handover and prevented the previously encountered delays.

3 Technical lessons

3.1 Factors affecting river impacts

The UPM methodology is based on comparing the water quality in the rivers resulting from discharges with permitted values set to project the river. There are two ways in which these standards can be defined. The fundamental intermittent standards (FIS) are defined as thresholds for ammonia and dissolved oxygen for durations from 1 hour to 24 hour and return periods from 1 month to 1 year. These will generally be assessed for the summer months when river flows are low and dilution less.

The alternative percentile standards define concentrations of BOD and ammonia that cannot be exceeded for more than 1% of the hours in a year. These are assessed over the whole year for both summer and winter.

The implementation of UPM2 standards in Yorkshire was agreed in August 2000 after tri-partite negotiations between YWS, the EA and Ofwat. Each zone was characterised using the criteria described in the EA UPM policy statement along with other key descriptors such as sewer:river dilution, population, fisheries status and river quality. In summary, this resulted in FIS standards where rivers were complying with their River Quality Objective and 99%ile where rivers were non-compliant, the majority of which were in the west of the region.

One of the key lessons of these projects was confirmation that one of the key factors is the amount of headroom that there is between the background river water quality and the standards. If the river is already close to breaching the standard then discharges must be restricted. If the background pollution is already breaching the standard then it is assumed that improvements to discharges upstream will remedy this, but as each section of river is looked at in isolation it is difficult to justify how much headroom should be allowed in these situations.

Experience also showed that the data selected for generating boundary conditions was fundamental to the river impact process. It was agreed that where river quality was already in breach of the appropriate standard that artificially generated ‘compliant’ boundaries (provided by the EA) would be used. However the ‘compliant’ boundary would restrict headroom on the assumption that upstream river quality would never be perfect. This led to extensive challenges by YWS when boundaries were deemed to have failed and the failure was due to wet weather discharges from upstream CSOs. In essence the ‘compliant’ boundary was causing ‘double counting’ of intermittent discharge impacts. It is proposed to audit and agree raw data in future studies to prevent delays.

Our experience is that the percentile standards seem to be more restrictive than the FIS standards with more discharges identified as unsatisfactory. This is mainly due to the use of 99%iles in the Pennine catchments where small watercourses are receiving significant spills from densely populated urban areas. For percentile standards the most critical standard is BOD and for FIS standards it is for dissolved oxygen. Ammonia does not seem to be significant in causing failures.

3.2 Choice of rainfall data

It took longer than we anticipated to get agreement on appropriate timeseries rainfall. The key factor was judged to be a close agreement between the average annual rainfall in the timeseries and the annual average rainfall for the catchment. Rainfall timeseries were generally generated using Stormpac and events were identified and selected using the facilities in Stormpac.

A key lesson that had already been learned was to use a long inter-event dry period similar to the drain down time of the system. In this way events that occur close together and that will interact are run together. This drain down time is likely to increase when storage is included in the system and this should be taken into account when selecting the events.

To reduce the number of events that need to be simulated, Stormpac can exclude small events that are below thresholds for:

- Depth
- Peak intensity
- Average intensity

We discovered that when using a long inter-event dry period the average intensity of many events becomes very small as they include significant dry periods. This threshold should therefore not be used to exclude events.

3.3 Idiosyncrasies of HydroWorks

HydroWorks continues to make life interesting by behaving in unexpected ways and giving unexpected results. This is particularly so with the parts – like pollution modelling – that have not been widely used. Experience with the pollution model in InfoWorks indicates that it will also have surprises in store for us.

We were surprised to find that different versions of HydroWorks gave different results, sometimes significantly so. This could affect the hydraulic results although it was more marked for the water quality results. In the absence of firm information as to which version was definitively correct we took the pragmatic decision to continue to use the version that had been used for the hydraulic verification of the model.

We also found that water quality results varied significantly with the QSIM timestep multiplier used for the simulation. The use of longer timesteps seemed to give significantly greater pollutant discharge. We therefore suggest that the timestep multiplier should always be set to 1.

3.4 Impact of modelling inaccuracies

The pollutant transport in HydroWorks is much more sensitive to the detail of the modelling than is the hydraulics. This is particularly the case for sediment and pollutants attached to sediment. Model errors such as incorrect invert levels that may have negligible impact on the hydraulics can lead to large deposition of pollutants during dry weather and then washout in storms where it can be discharged over CSOs.

It is therefore important to check the model details during model build and to check the model results.

As an example some results are attached from a model handed to our design consultancy team. We reviewed the results of the model for some test events and noticed high concentrations of sediment and pollutants attached to sediment at the very beginning of the event.

We therefore produced sediment deposition reports for the system at the end of the dry weather period before the event and at the end of the event. Five pipes showed washout of more than 10 kg of sediment. Of these, four showed errors in sewer levels, including large steps in levels and backfalls. Worryingly, the only distinguishing factor of the fifth pipe was that it had a steep gradient and small flow in dry weather. We are investigating this further.

Additional checks should therefore be made on models to be used for water quality simulations.

Long sections throughout the model should be checked thoroughly and any anomalies investigated.

Test simulations should be checked to identify any high concentrations of pollutants at the start of the event.

Sediment deposition reports should be checked to identify those pipes with significant deposition of sediment and those with significant changes in deposition during an event.

4 Lessons still to learn

We still have some lessons to learn about the best way to model water quality to give reliable results with minimum effort. Many of these are issues that we have discussed for some time but have not yet resolved to everyone's satisfaction.

4.1 Boundary conditions

Production of the appropriate upstream river flow and quality conditions is still something of a black art requiring a lot of judgement to produce a fair set of conditions that represents the real world but that gives some scope for permitting CSO discharges. A definitive guide on this would be welcome.

4.2 Sewerage modelling

There is still a lot to understand about the modelling of sediment movement in sewerage models and in particular the significance of the linkage between sediment and hydraulics and the affect that this has on both hydraulics and sediment.

Even with increasing speed of computers we are still constrained by the simulation times for long timeseries. We need to get better at the tricks involved in getting models to run more quickly without affecting the results.

4.3 Procedures

Although all consultants have their own procedures for checking and auditing water quality models there is no industry standard guidance on this topic.

We have learned how to document hydraulic models so that they can be handed over to another organisation and used successfully but we still have lessons to learn on including all of the necessary information for water quality models and on preparing the handover during the study to avoid delays.

5 Conclusions

The Yorkshire Water programme has shown that it is possible to carry out UPM studies quickly and relatively cheaply. At the start we thought that the deadlines might be unrealistic – but we found that we could meet them despite still being on a learning curve.

We have also confirmed yet again that computers do not replace people; they just help them to make mistakes faster. It is still essential to have someone ask, “Does that answer look right?”

The experience of working collaboratively between competing consultants teams was very valuable and improved the performance and the rate of learning of all involved. It provides a model for future innovative work.