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Verification - Raising the Standards

1. INTRODUCTION

This paper has stemmed from the results of a large number of model and flow survey audits which I have carried out over the past 12 - 15 months. There has been a wide variation in the quality of flow survey planning and implementation. Additionally it was found that some 'verified' models, were on closer examination verified by only applying part of the current (complex) criteria (eg only peak flow). As an industry we need to bring the verification criteria up to date to match current technology and to have a clearer mechanism for viewing whether a model is adequately verified and "Fit for Purpose".

A recent project involved High Court action and required model simulations based on a 1996 rainfall event for which there was only weather radar information available. This proved that such data can be used and therefore a greater emphasis can now be placed on verification against historical flooding and CSO spills recorded by permanent loggers which are becoming more widely used. Data suitable for direct use in Hydroworks or Infoworks, for historical rainfall can now be obtained for most areas from the Met Office.

2. Current Verification Criteria

The current verification criteria set out in the WaPUG Code of Practice stems from the first edition which was compiled in 1991 and was at that time aimed at setting a uniform standard which the whole of the industry would accept. In practice the criteria was largely based upon the available technology in late 1989 and 1990.

The available simulation software at that time was WALLRUS which was introduced in 1989. The first versions of WALLRUS did not simulate backwater effects in all pipes and special flags needed to be inserted. Spatially varying rainfall was starting to become introduced and 9 different rainfall profiles could be used. The program would not handle looped systems, there was only one PR Runoff Equation available and there was no wastewater generator though one could apply a dwf file. Many papers were written about the various "dodges" and "fixes" which could be used to overcome software limitations.

Flow measurement in 1989/90 used 1st or 2nd generation flow monitors but as this was still quite expensive the less sophisticated maximum level recording methods like cups on sticks, water sensitive tape etc were still widely used. Corks placed on weirs at CSO's were still used to ascertain whether the CSO had spilled since the previous visit.

In comparison to current technology it is easy to see why the verification criteria were set at a comparatively low level. The criteria in the WaPUG Code of Practice are:-

"8.3 VERIFICATION WITH HISTORIC DATA

……. All reported flooding should be generally reproduced by the model both in terms of location, severity and……frequency…..

8.4 VERIFICATION WITH FLOW SURVEY DATA

a) …. routine stability test requirements…

b) DWF verification should be carried out for two dry weather days. the predicted flows/depths compared to the observed flows/depths should meet the following criteria:

(i) peak flow rate + 10% to - 10%.

(ii) volume of flow +10% to -10% over the period for which the observed flows are expected to be accurate

c) For the events from the flow survey, the predicted flows/depths compared to the observed flows/depths should meet the following criteria:

(i) peak flow rate + 25% to - 15%.

(ii) volume of flow +20% to -10% over the period for which the observed flows are expected to be accurate

(iii) surcharge should be +0.5m to - 0.1m.

(iv) The general shape of the two hydrographs should be similar and should continue until substantial recession has occurred.

d) For the events from the flow survey flooding locations predicted to have volumes of flooding in excess of 25m³ should be substantiated by some evidence of real flooding or a clear explanation for there being none. All sites where flooding was known to occur during the storms should be reproduced by the model.

Where the above criteria are met for two out of the three storms the model may be considered verified. Where this is not achieved for two out of three storms, it may still be possible to consider the model sufficiently verified provided that:

a) The reasons for the non-compliance have been determined but cannot be modelled and have been assessed as not being important to the subsequent use of the model. For example, a transient feature such as the operation of a penstock is known to be a cause of the discrepancy.

b) The cause of the discrepancy cannot be isolated but an assessment of the effect of likely causes on the accuracy of the model have shown that this will not be detrimental to the purpose of the model.

c) That infiltration is the cause of the discrepancy and this will be taken into account in other ways in subsequent use of the model."

It can be seen that the full criteria as set out above is quite lengthy, can be difficult to interpret and has several 'get out clauses'.

3. Advances in Simulation Programs

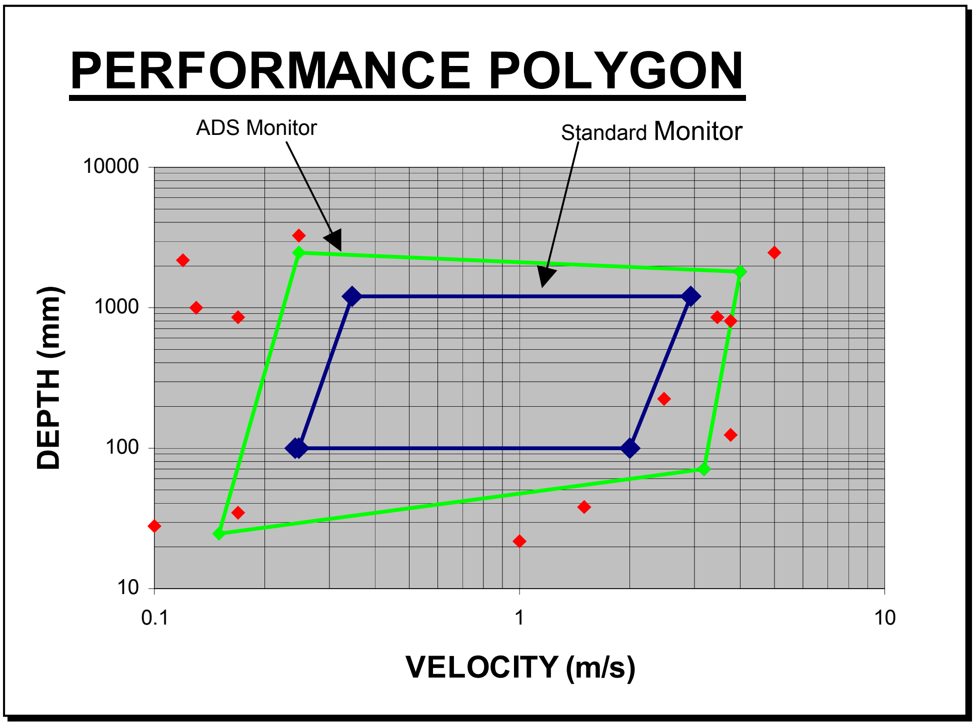
Current simulation software has progressed so far since 1989/90 that it is difficult for current day modellers to appreciate the difficulties which modellers had in the early 1990's. The standard programs now are Hydroworks and Infoworks but since they have the same simulation engine they are considered as being identical.

These programs can handle looped systems, steep pipes, flat pipes with backwater effects, numerous complex shapes and can model almost every variation of ancillary structure which can be dreamt up. Current day software can also handle Real Time Control rules, spatially varying rainfall with up to 999 profiles, different land uses, different runoff conditions, time varying trade effluents flows, infiltration at specific points and so many other features that they are too numerous to mention. Probably the greatest advance, which is possibly not appreciated by current day modellers, is the stability of the programs. The days have gone where spurious spikes would suddenly appear for no apparent reason and volumes balances needed to be checked laboriously.

It is clear that the simulation software has progressed so far since the early days of WALLRUS that the current verification criteria are well within the capabilities of the software. There is no longer a need for the criteria to be eased to take account of software limitations.

4. Advances in Flow Measurement

The days have now passed where reliance had to be made on cups fixed on sticks or water sensitive tape to record maximum water levels. Flow measurement technology has advanced so much since the late 1980's thanks largely to advances made in America and Australia where accurate flow measurement is needed far more for billing purposes and for locating inflows and infiltration. Current day ADS Flow Monitors are now 5th generation technology.



The "Performance Polygon" on the left shows envelopes for both Standard Monitors and ADS Monitors.

The depth ranges for a Standard Monitor are 100mm up to 1200mm and the velocity range is from 0.25m/s to 3.0m/s. It is easy to find potential monitoring sites which are outside of this envelope with fast shallow flows in steeper sewers being a frequent condition.

The ADS Monitors have a far wider envelope and can handle depths from 25mm to 2500mm without difficulty with velocities from 0.16m/s to 4.0m/s. There have actually been several successful locations outside of this range.

Extensive testing has been carried out in USA, Germany, France and Australia with this 5th generation equipment (ADS Monitors) and it has been found that flows can be measured to within 5% in all cases with many within 2%. The use of ultrasonic depth measurement together with advances in doppler velocity sensors and the used of mean velocities based on peak velocity rather than attempts at measuring average velocities have all contributed to these advances.

It is clear from this that flow measurement technology has advanced considerably since the WaPUG Code of Practice was first written and that there is no longer any need for the verification criteria to be lowered specifically to allow for inaccuracies in flow measurement.

5. Decline in Flow Survey Planning

It would be nice to think that the planning of Flow Surveys and in particular the identification of suitable monitor installation sites had kept pace with the advancing technology. However, it appears somewhat to the contrary with a highly significant proportion of flow surveys undertaken over the past few years having 50% to 70% unsuitable sites with data from many of these sites being unusable.

The reasons for this are difficult to understand but there are likely to be many contributing factors. The most significant one of these is the training of newer people to the industry. The start of the AMP2 period was a very difficult time for most people in the industry and much of the knowledge and expertise was permanently lost from the industry. As the industry recovered later in the AMP2 period there were no longer the people around to train the newcomers. At best a person planning a flow survey would have been the understudy on 2 previous surveys. It is still all too common for joint pre-survey inspections to not be undertaken.

Many of the unsuitable sites are not identified as being unsuitable, very often the advice of the Flow Survey Contractor is over-ruled, and data produced from the site is used for verification purposes. It is frequently not apparent that many of the difficulties in verifying a model are due to the poor monitoring sites chosen.

6. Advances in Verification Criteria

It would also be nice to think that the normal verification criteria in use today had advanced from the beginning of the decade. Unfortunately it has not and indeed it could be considered that the standards have actually declined. It is common practice nowadays for only part of the verification criteria (eg peak flow or peak depth) to be considered and the other factors to be ignored.

7. Raising the Standard

In order to raise the standard of the verification criteria it is important that the industry has the confidence that such advances are worthwhile, affordable and can be achieved for the great majority of models without undue expenditure.

It is, however, equally important than we as modellers put over an adequate message that it can be false economy to keep the standards relatively low when there is so much more expected of models nowadays and especially with the challenges of AMP3 where water quality will become important.

The proposals for revised verification standards (to take us into the next millennium) are in 2 parts:-

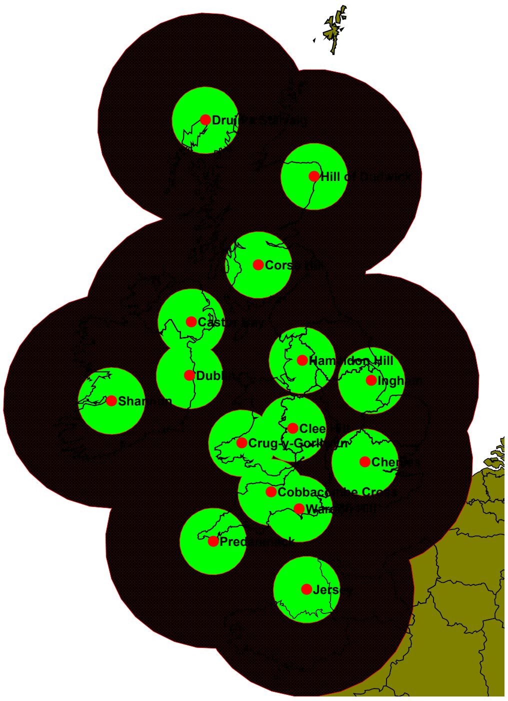
- A far greater emphasis on verification against historical flooding information or CSO spill records.

- A new concept in plotting graphs for verification against flow survey data.

8. Historical Verification

It is impossible nowadays for any sewerage upgrading scheme to gain approval unless there is clear and demonstrable improvements to the Customers (ie the public) or environmental improvements. All the Water Companies are required to report annually to OFWAT a wide range of aspects about the performance of the assets and the effects on Customers.

As a consequence of this the amount of data which is recorded has greatly increased but more importantly the data is now recorded to a uniform and reliable standard. Many aspects of concern to the Environment Agency are now routinely recorded and many CSO's now have permanent level sensing and telemetry.



The advances in weather radar over the past decade together with the amount of data which is now held by the Meteorological Office in the national archive means that a considerable amount of data is now retrievable for historical rainfall events. The plan on the left shows the current weather radar sites with 12 sites in the UK, 2 in Eire and 1 in Jersey. A considerable investment is planned over the next 5 years which will see more sites established resulting in closer resolutions.

Currently within a 75km range the resolution is 2km (comparable with the WaPUG Code of Practice criteria for raingauge spacing). In the range 75km to 240km the current resolution is 5km. Data can routinely be supplied as instantaneous rainfall intensities at 5 minute intervals but closer intervals can sometimes be provided. The rainfall intensities can be correlated by the Met Office to the widespread network of raingauges around the UK. From this the Met Office can adjust the instantaneous values if necessary. The advances in software developed by the Met Office also means that previous concerns about ice particles, size of water droplets etc are no longer a concern.

The rainfall profiles supplied by the Met Office can easily be compiled into a RED file and used in Hydroworks, Infoworks etc to carry out simulations.

With the far more accurate information on historical rainfall events and the far wider knowledge base (flooding etc) it has now become feasible to consider historical verification as being the primary verification criteria. Additionally this verification applies across the whole of a modelled catchment and is not just at individual parts of the catchment where flow monitors have been installed.

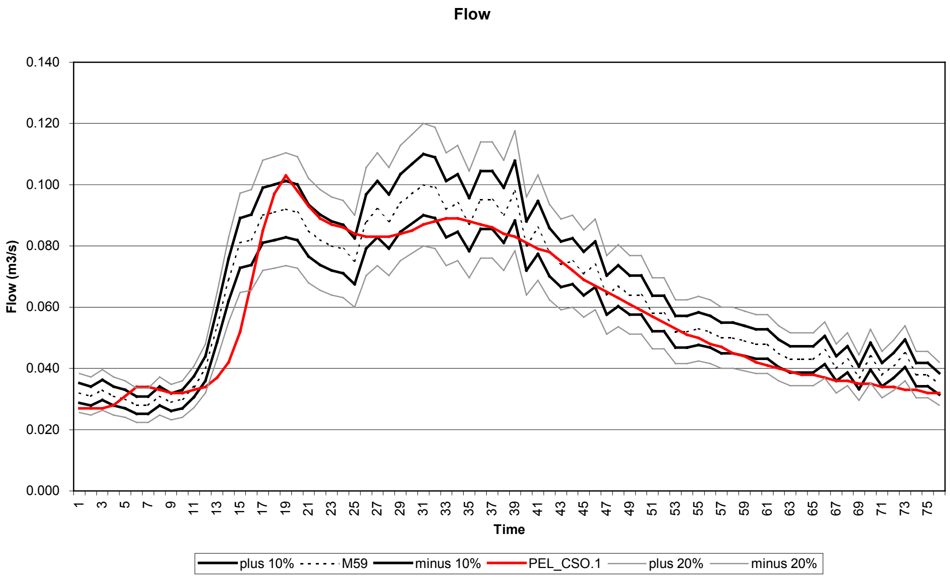
9. Verification with Flow Surveys

In order to raise the standards with respect to verification against flow survey data it is imperative that the planning of flow surveys is improved so that there are very few unsuitable sites used for flow monitoring. It is important that the philosophy of using "*fewer but better sites*" is put over. It is also important that the individuals responsible for the planning of flow surveys and for agreeing the suitability of flow monitoring sites are better trained and have access to better guidance material.

It would be useful if WaPUG could produce a practical guidance booklet on the planning of flow surveys and the points to look out for in good or bad flow monitoring sites. This should include typical photographs of good and bad sites.

Any verification against flow survey data is only particular to the individual flow monitor locations and they can only be considered as indicative of other parts of the modelled sewer network. With more flow monitors installed, the overall verification of the model is improved but it can be counter-productive to install additional flow monitors at poor sites.

A new concept is proposed in the plotting of graphs to judge whether adequate verification has been achieved. This involves plotting a "confidence envelope" either side of the recorded data. For flow measurement it is proposed that a normal confidence of ± 10% is applied. A second confidence envelope at ± 20% can also be plotted. This is shown in the graph below



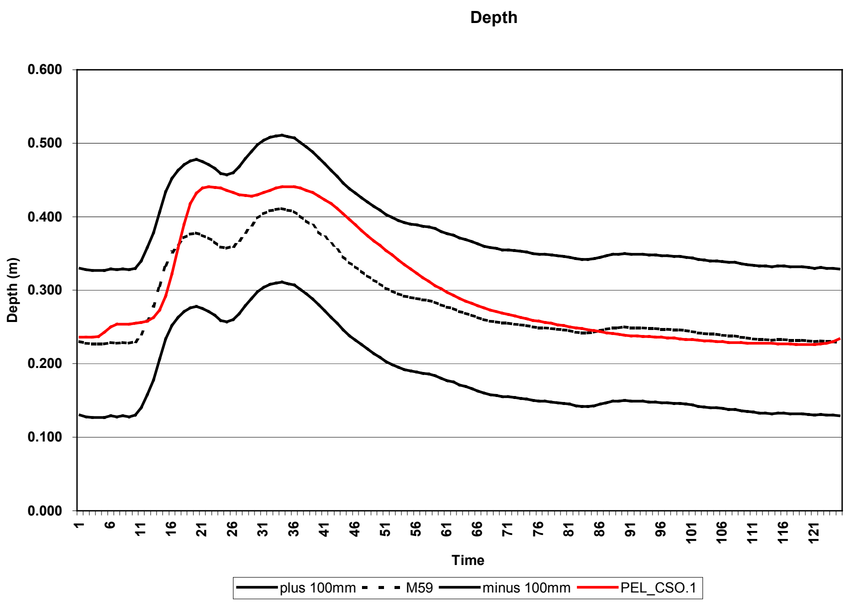
The envelope boundaries can easily be calculated by using a spreadsheet program. The graphs can easily be produced using the spreadsheet program or by exporting back to Hydroworks for plotting. It is also possible to fill in a sensible envelope boundary for odd times when the flow monitor is ragged or looses velocity data for a short period.

It is also feasible that the confidence envelope is not defined by the modeller or by a Client organisation but could be plotted by the Flow Survey Contractor based upon his expert judgement of the reliability of the individual sites and the likely accuracy of the results achieved.

With the predicted flow hydrograph also plotted it can easily be seen whether the hydrograph remains within the envelope. This takes care of all the previous criteria in one go as peak flows, volumes, timing and hydrograph shape are all taken care of. The above graph shows quite a spiky measured flow hydrograph (the envelope for which could be smoothed out if necessary) and shows that the predicted hydrograph generally lies within the ± 10% envelope except in terms of the rising part of the hydrograph where the predicted flows are about 3 minutes too slow which could be indicative of inappropriate roughness values being used.

Where flow monitoring sites are close to pumping station discharge locations there can be very spiky graphs and these can be almost impossible to interpret when adding the envelope lines. However, any site which is close to a pumping station discharge point is unreliable and should be avoided. Where this cannot be avoided then the envelope lines can be smoothed to take out the worst of the spikes.

In terms of flooding, CSO spills etc it is more important to consider water levels rather than flows and therefore a similar concept is proposed for depth but instead of working on percentages it is considered more appropriate to work in terms of a distance. It is proposed that ± 100mm is adopted as the normal criteria. This is illustrated in the graph below.



The observed data is plotted with the ± 100mm limits either side and the simulated hydrograph is then plotted against these. If the simulated results stay within the envelope then the depth verification can be considered satisfactory.

This very simple method for flows and depths is very clear for everyone to see and this single criteria for each takes away the need to calculate percentages and to tabulate then to check if all the criteria have been met.

It is hoped that this concept will gain wide acceptance and that ± 10% for flows and ± 100mm for depths will become the established normal verification criteria for use in the early part of the next millennium.

10. Summary and Recommendations

It is clear that there have been considerable advances in hydraulic simulation software and in flow measurement technology over the past decade. The criteria by which adequate verification is judged has not kept pace with the advancing technology and now is out of step with a comparatively loose range of criteria which no longer need to account for limitations in software or technology. It is appropriate that the verification criteria is updated for the start of the new millennium.

In the past decade, especially since privatisation of the water industry, a far greater amount of information is routinely gathered on a uniform basis. Important amongst this is more reliable recording of flooding incidents due to hydraulic inadequacies and more recording of CSO spills. Measurement and recording of rainfall has also advanced considerably over the past decade with a good UK coverage of weather radar installations, with more planned over the next 4 years, and great advances in the archiving of rainfall data. The Meteorological Office can now produced accurate rainfall profiles for almost all storms in the UK in a format which will allow RED files to be directly compiled. With these advances the verification of models with historical rainfall and compared to historical flood records must be considered as the primary verification criteria.

Recommendations made are:-

- Historical verification techniques are more widely used;
- A practical guidance booklet is produced to assist in the planning of flow surveys and identification of good flow monitoring sites;
- Installation of flow monitors at poor sites is discontinued as they are a false economy, always produce unsatisfactory results and make model verification more difficult;
- Criteria for verification with flow survey data is updated and reformatted with verification to within ± 10% on flows and ± 100mm on depths being taken as the norm. The models verified to this standard could then be termed a 10%/100mm or a 10/100 model.