Newark Sewer Flooding Strategy – the balancing act of protecting the community and protecting the environment

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Introduction

The Newark Sewer Flooding Strategy

Newark-on-Trent is a market town in Nottinghamshire, with an estimated population of 31,500 in 2015 and a potential increase in population to 37,677 by 2026. Sewer flooding has been an issue in Newark for several years, and approximately 400 properties are known to be at risk of internal or external flooding due to hydraulic deficiencies in the existing sewerage system. Urban creep and proposed infill developments will lead to additional pressures on the existing sewerage system, increasing flood risk within the catchment.

Severn Trent Water (STW) has proposed a £60 million scheme to increase hydraulic capacity within the existing sewerage system, and reduce the risk of flooding to their customers. The Newark Sewer Flooding Strategy involves the construction of a 2.8m diameter collector tunnel, a 1.5m diameter feeder tunnel, upsizing 7.1km of the existing sewer system and replacing 20km of ageing pipes. It will also rationalise the Combined Sewer Overflows (CSOs) that discharge to the River Trent at Newark.

To achieve the right balance between protecting the community from the risk of sewer flooding, and continuing to care for the environment, RPS were asked to undertake a water quality assessment was undertaken on the River Trent.

Water quality: Water Framework Directive and 'good status'

The Water Framework Directive is a European Union directive which aims to achieve a 'good status' for all ground and surface waters by 2027. The 'good status' is measured against a set of ecological and chemical standards. In 2015, the River Trent at Newark was classified by the Environment Agency to be a 'heavily modified' watercourse of 'moderate ecological status'.

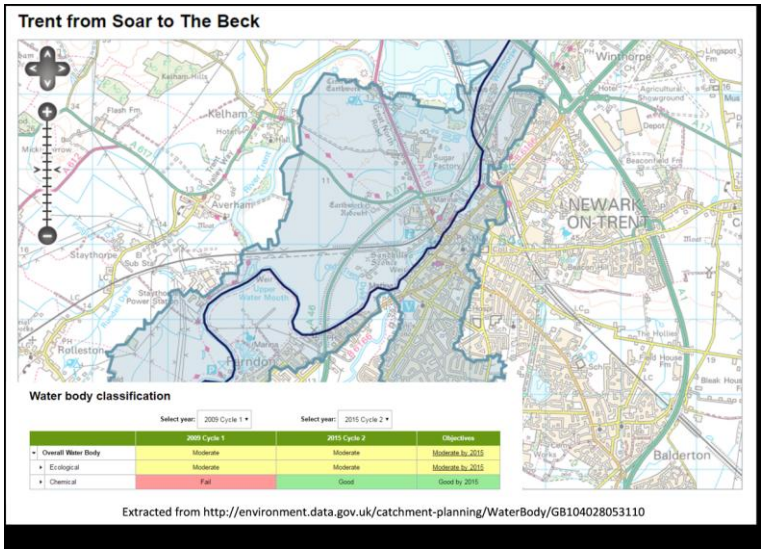

Figure 1: The water body classification of the River Trent at Newark, extracted from the EA's Catchment Data Explorer

Intermittent discharges from CSOs are measured against a number of physico-chemical quality elements: Biochemical Oxygen Demand (BOD), dissolved oxygen (DO) and ammonia (NH3). There are two main 'types' of standards that intermittent discharges are measured against:

1. Fundamental Intermittent Standards
2. Percentile Standards

Fundamental Intermittent Standards (FIS) measures those environmental qualities that are directly linked to conditions that cause stress in freshwater systems. As such, they provide measures for DO and un-ionised ammonia, and are expressed in terms of concentration and duration over a range of return periods. These standards take

into account that events with longer return periods are likely to have a more severe impact upon the watercourse and the biological ecosystem within it.

Percentile standards define the concentrations that must be complied with for either 90% or 99% of the year. The percentile standards are defined for BOD, total ammonia and un-ionised ammonia. The specific standard to measure against is defined using the typology of the watercourse, which is determined from its altitude and alkalinity. The River Trent at Newark is classified as a lowland river with high alkalinity, which needs to meet a minimum of "good" standards for 99%ile and 90%ile criteria, and be compliant with the FIS Sustainable Cyprinid standards.

The Infoworks UPM Tool

The Infoworks UPM tool was utilised to investigate the impact of the Newark Sewer Flooding Strategy upon the water quality of the River Trent. The Infoworks UPM tool is an in-built piece of software within the Infoworks CS/ICM package. It uses a Monte Carlo method to randomly sample different environmental states of the watercourse, before mixing these randomly sampled water quality and upstream river parameters with the modelled discharges from the sewer network (including storm and CSO spills). This generates a probability distribution of the potential impact of the sewer network upon the water quality of the watercourse.

The Infoworks UPM tool requires three things:

1. The upstream and downstream watercourse boundary conditions
2. The modelled spill discharges (storm and CSO)
3. The physical characteristics of the watercourse

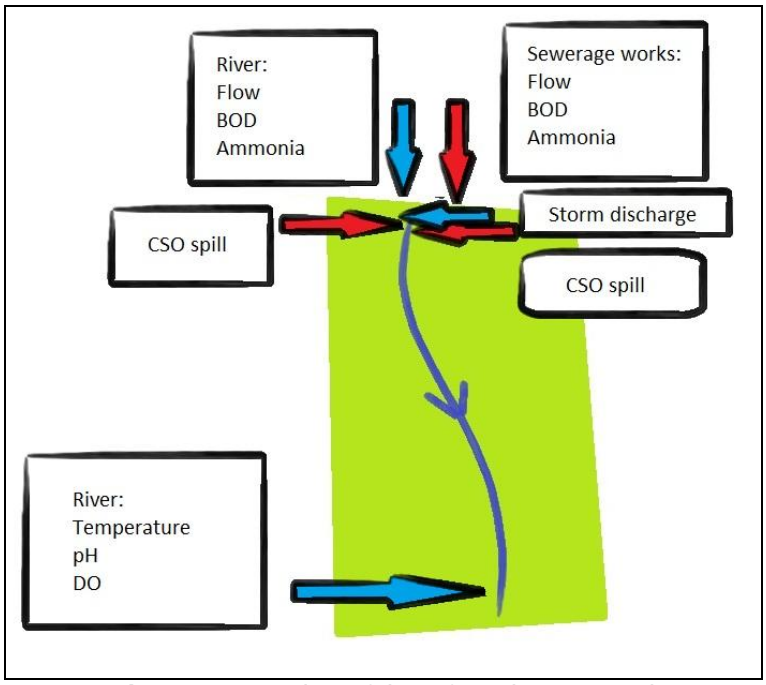

Figure 2: Overview of the Infoworks UPM tool

The upstream and downstream watercourse boundary conditions

The Infoworks UPM tool requires mean and standard deviation values of ammonia, BOD and river flow in order to define the upstream boundary conditions (assuming a log normal distribution). It then requires the mean and standard deviation values of pH, temperature and DO to define the downstream boundary condition using a log normal distribution.

The LowFlows software was used to estimate the annual and seasonal flow statistics for the River Trent at Newark-on-Trent. The LowFlows software estimates the natural flows for a given catchment and does not take into account any artificial diversions or influences. At Newark-on-Trent, there is a weir which diverts a significant proportion of the River Trent towards Kelham. As there were no monitoring stations near this area, and the LowFlows software is unable to take into account artificial diversions, the cross-sectional data of the divergent branches were used to estimate that 40% of the mean annual flow travels down the Newark branch of the River Trent.
The nearest EA water quality monitoring location upstream of the River Trent at Newark is approximately 15km away at Gunthorpe. To determine the suitability of the water quality data at Gunthorpe for this assessment, the EA carried out a LAPWING modelling assessment to determine whether the BOD, DO and ammonia concentrations vary significantly with distance down the River Trent. Whilst there were some limitations to this methodology, the EA determined that these water quality parameters were suitable for the use of the River Trent at Newark water quality assessment.

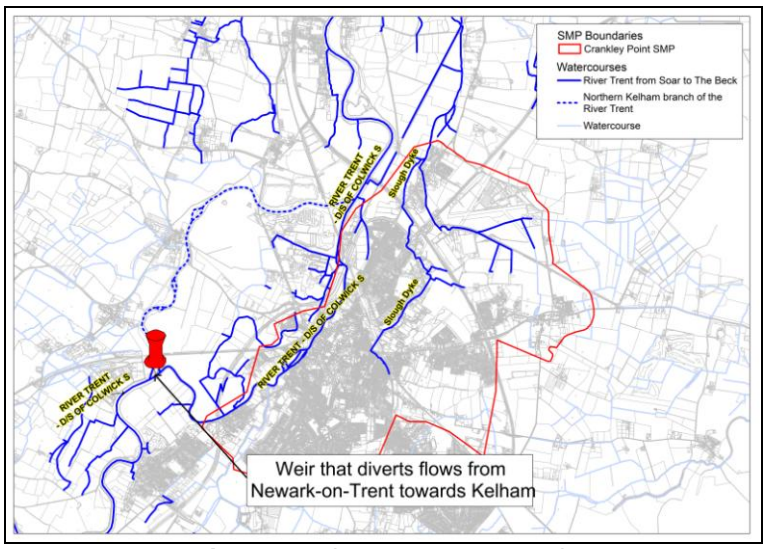

Figure 3: River Trent at Newark

Severn Trent Water's SIMCAT model was also used to determine the water quality of the River Trent at Newark. This model has been verified to observed data over a 5 year period, however, it should be noted that the weir upstream of Newark-on-Trent is not included within the SIMCAT model.

For the River Trent water quality assessment, RPS modelled the upstream water quality parameters using a combination of STW's SIMCAT model and the EA's water quality sample data at Gunthorpe. The downstream water quality parameters were modelled using the EA's water quality sample data at Gunthorpe, as there was no data derived for these parameters from the Severn Trent Water SIMCAT model. To understand the impact of these initial water quality parameters on the River Trent water quality assessment, RPS undertook sensitivity testing on the river BOD and DO parameters.

The modelled spill discharges (storm and CSO)

The Infoworks UPM tool requires a concentration loading of BOD and ammonia for storm discharges and for CSO spills. As there were no known water quality surveys at the CSO outfalls, STW's default values were used for this assessment: The CSO discharges were applied with a constant load of 125mg/l BOD and 8mg/l ammonia. The storm outfalls were applied with a constant load of 3mg/l BOD and 0mg/l ammonia. In total, there are 15 storm water links that discharge to the River Trent, and 13 overflows' outfall links (CSOs, emergency overflows and the storm tank at Crankley Point STW).

Crankley Point Sewage Treatment Works discharges final treated effluent to the River Trent. A 6 month MCERTS dataset was used to determine the mean flow from the Sewage Treatment Works, and a 10 year composite dataset for the fully treated effluent was used to estimate the mean and standard deviations of the water quality parameters (BOD and ammonia) from the site.

The physical characteristics of the watercourse

A basic representation of the channel of the watercourse is required for the Infoworks UPM tool. A physical survey of the River Trent geometry was undertaken in 1992, and the cross-sectional data from this survey was used to represent the physical shape of the watercourse.

The Infoworks UPM river units that were defined for this assessment were constructed for the section of the River Trent that takes the flows past Newark only. The most upstream UPM river unit is defined just after the weir which takes flows past Kelham, and the most downstream UPM river unit defines the length of river after the two branches of the River Trent converges. These river units were defined using natural breaks in the river, such as bridges or weirs, with the most downstream river unit being defined for a length of 5km, which was assumed to be a length suitable for the FIS analysis to be adequately considered.

STW's default parameters were then used to define the river mixing parameters, i.e. the rate at which the different chemicals decay within the water.

Water Quality Impact of the Newark Sewer Flooding Strategy

The Infoworks UPM analysis was undertaken on the future baseline model, which represents the proposed future Newark catchment up to 2026, and then again with the proposed Newark Sewer Flooding Strategy in place. RPS carried out an initial spill analysis was to determine which of the CSOs were likely to spill each year. There are 13 CSOs that outfall to the River Trent from the Newark catchment, and the Newark Sewer

Flooding Strategy proposed that 8 of these CSOs are rationalised into one discharge location near Crankley Point STW.

The initial spill analysis showed that the Newark Sewer Flooding Strategy increases the number of spills from the storm tanks at Crankley Point STW by approximately 33 spills per year (i.e. a 74% increase from the future baseline model). The proposed tunnel overflow as part of the Newark Sewer Flooding Strategy would account for just over 53% of the total spill volume to the River Trent, and overall, the annual spill volume discharged to the River Trent is predicted to increase by 10%.

The UPM analysis showed that, with the Newark Sewer Flooding Strategy in place, the model predicted an increase in the frequency of FIS, 99%ile and 90%ile exceedances but did not predict a failure to comply with the relevant standards. A number of different sensitivity tests for the UPM analysis were conducted, and the results predicted that using a conservative high river BOD value with a conservative low river flow, the number of BOD exceedances were predicted to increase to the extent that, only for the 99%ile 1 hour impact duration standard, the frequency of exceedances were nearing the allowable standards.

Main limitations of the Infoworks UPM tool

There were a number of limitations of using the Infoworks UPM tool for this assessment. It was agreed with the EA that the water quality assessment would be undertaken on the 90%ile standard for DO. As the Infoworks UPM tool does not have the capability of measuring a percentile standard for DO, a separate tool was created by RPS in order to measure this specific standard. The maximum DO for each event was calculated by utilising the river temperature that the Infoworks UPM tool picked, and then calculating the percent saturation of the “worst case” downstream DO.

The file sizes of the Infoworks UPM outputs for the 1 hour impact duration assessment were also too large for the software to export the results. In order to carry out the assessment, the Infoworks UPM assessment was carried out on a yearly basis for the 1 hour impact duration assessment, and re-assessed for the full 10 years in a separate tool.

It was also found that the Infoworks UPM tool applies the standard deviation parameters in a way which leads to a significant proportion of out-of-range statistical picks (i.e. greater than 3 standard deviations from the mean). Whilst steps have been undertaken to limit the impact of these picks on the results, this was only achievable for the normal distributed water quality parameters.

Finally, the Infoworks UPM tool assesses the 6 hour and 24 hour impact durations by taking the “worst case” spill volume within each event. This can lead to an under-prediction of the number of exceedances for the 6 hour and 24 hour impact duration assessments. A manual assessment was undertaken of the spill volume of any un-assessed parts of an event, to determine if there would be a second CSO spill that would lead to an exceedance of the standards. The total number of exceedances was then recalculated to account for these double spills.

Conclusions

The Infoworks UPM tool is a simple water quality assessment which supported STW in their understanding of how their sewer systems, and proposed flood alleviation strategies, impacts upon the environment. It also helps STW to determine what measures may need to be undertaken, to ensure that they continue to protect the environment and provide an effective wastewater service to their customers.

RPS consolidated the various software outputs from LowFlows, SIMCAT, LAPWING and Infoworks to produce a joint understanding of the predicted CSO spills and impact of the Newark Sewer Flooding Strategy on the water quality of the River Trent. The River Trent water quality assessment predicted that whilst the Newark Sewer Flooding Strategy would lead to an increase in the spill volume from CSOs in the catchment, and there was a predicted increase in the frequency of FIS, 99%ile and 90%ile exceedances, it did not predict a failure to comply with the relevant standards.

To ensure that the Newark Sewer Flooding Strategy does not cause a detrimental impact on the environment, Severn Trent Water are continuing to fine tune their proposed flood alleviation solution whilst ensuring that their proposed solution is robust under future storm events.