Prioritising Flooding Investment in the Northumbrian Water Region

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1. INTRODUCTION

Reported flooding from the public sewerage system is a relatively rare occurrence. In the Northumbrian Water region flooding affects on average approximately 0.02% of households per annum. About half of this flooding is the result of hydraulic incapacity of the sewerage network. The remainder are the result of serviceability problems such as blockages, collapses or failures of M&E equipment such as pumps or screen cleaning systems.

In contrast to the historical statistics, during the period between April to October 2005, 6 major rainfall events resulted in over 600 properties in the Northumbrian Water region suffering sewer flooding for the first time. This is 5 times the current average and 14 times the average for the 5 years preceding 2005. Northumbrian Water Limited (NWL), like all water companies, has a legal obligation to keep records of properties that have experienced flooding and maintain a register of those considered to be at risk of flooding more often than once in 20 years.

Through the annual reporting process to OFWAT, NWL is required to report both existing and first time flooded properties against DG5 indicators. Where hydraulic overload is the confirmed flooding mechanism, the properties are to be added to the DG5 'At Risk' Register under an appropriate category, 2 in 10, 1 in 10 or 1 in 20 years, indicating the potential frequency of flooding.

Those properties deemed to be at risk of flooding more than once in 10 years will normally require a solution to be identified. Due to the relative rarity of flooding events, the development of flooding solutions presents particular challenges in terms of how we gain confidence in understanding the causes of the problem, and the most cost-effective way to solve it. NWL originally developed a system of Cause Reports to overcome this challenge and MWH has assisted in refining the process.

2. BACKGROUND

Cause Report investigations have been used by NWL as a flooding investment tool for almost 10 years, with the majority of Cause Reports carried out internally. In 2006, in response to the number of flooding incidents generated in 2005, NWL decided to utilise its framework consultant partners to compile these reports.

The key to inviting the framework consultant partners was to develop and streamline the Cause Report process and to ensure that despite the unusually high number of flooding investigations, a standardised and robust approach was adopted.

MWH, as a framework consultant partner was engaged to support NWL in the delivery of the programme and has completed more than 55 Cause Reports to date. These investigations follow a rapid assessment method focusing on identifying the cause and mechanism of service failure. They include collating all existing information and gathering additional data to facilitate an abridged hydraulic analysis. The reports' output must provide the necessary level of understanding to allow for inclusion in the annual report submitted to OFWAT and to allow NWL to focus investment to provide best value to customers.

As a pre-requisite of the framework consultant partner appointments, key learning points were to be shared and team working was expected. This process is considered to have worked very well, and has exceeded NWL's initial expectation. Further benefits are also being realised when investment projects are launched after prioritisation, where background information is already compiled and the cause of the problem has been identified.

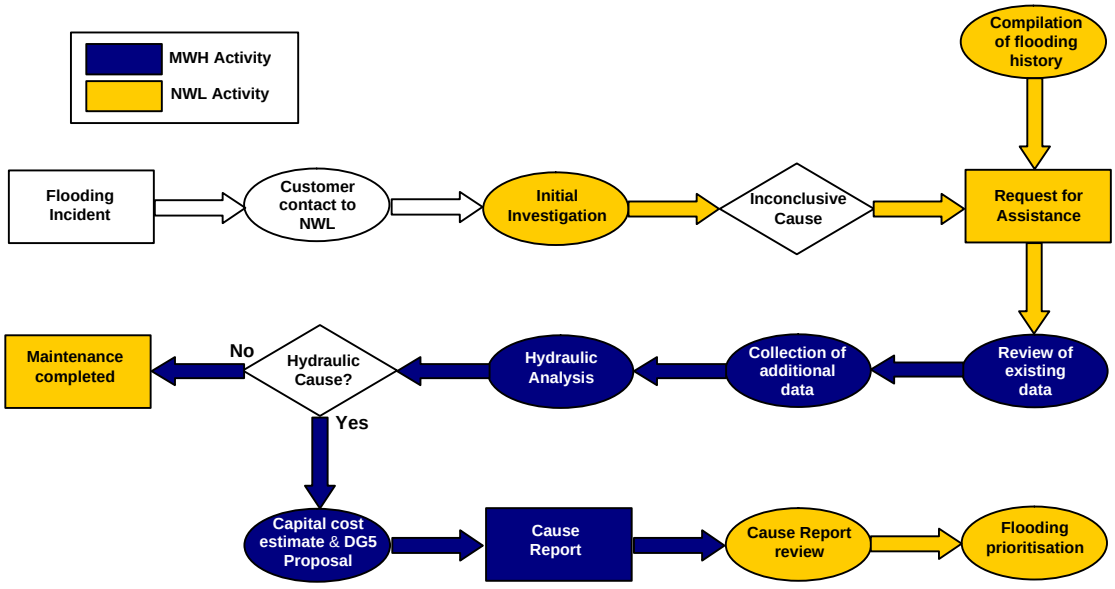
3. THE CAUSE REPORT APPROACH

The primary objective of the Cause Report programme was to develop a robust but rapid and affordable procedure to aid the prioritisation of flooding investment. The application of a common approach and ultimately the identification of a 'level playing field' against which prioritisation of a number of flooding locations could be assessed were necessary. Cause Reports are designed to meet these needs and are now a recognised approach to flooding investment prioritisation in the Northumbrian Water region. The constituent parts of a Cause Report can be summarised as follows.

- Collation and review of existing asset data
- Collation of Customer and NWL Operations knowledge
- Collection of addition survey and customer contact data
- Hydraulic modelling, simulation and analysis
- Flood frequency assessment
- Identification of cause and mechanism of flooding
- Identification of possible mitigation measures
- Identification possible site specific construction constraints
- Identification of other potential risk areas
- Indicative cost estimates

Cause Reports and flooding prioritisation are aimed at the identification and quantification of hydraulic flooding only. During the completion of a Cause Report investigation, should the flooding mechanism be identified as a cause other than hydraulic overload, no further investigation is completed and the recommendations of the report relates solely to the implementation and / or review of maintenance practices. The key stages of a Cause Report are summarised below in Figure 1.

Figure 1 – Cause Report Key Stages Flow Chart



3.1 Initial Investigations

An initial investigation is completed by NWL Technical Support Team after a customer reported flooding incident. These response investigations typically include CCTV surveys and can act as a filtering exercise. Identifying serviceability problems attributable as the cause of flooding renders a Cause Report unnecessary. However, where these investigations are restricted and / or inconclusive, a Cause Report is recommended,

3.2 Existing Data Review

The initial scoping procedure for a Cause Report is to review the existing data. The data reviewed at this stage of the Cause Report is summarised below, and whilst these headings represent the typical range of available information, since each Cause Report looks at a specific problem, this is not an exhaustive list:

- Reported Problem - This is the 'Request for Assistance' received by MWH from NWL's sewer flooding team and summarises the customer contact and the perceived problem. Also included are details of any previous investigations and the outcome of those investigations

- Existing hydraulic models - The review covers whether the model is 'fit for purpose' for investigating flooding at a specific location. The review considers the model extents, the level of detail, the software used to build the model, whether verification has been completed, and if so, for what purpose, what ancillary data is included and whether the latest capital schemes are included. Where no existing model is available this step is omitted

- Existing surveys – the review includes identifying the extent of previous surveys and whether it is of sufficient quality to be used as part of a Cause Report

- Flooding history - Customer contact information relating to the property under investigation is available from the Customer contact database. This data is available back to 1997. A synopsis of all reported sewer related incidents within a 500m radius of the affected property is also made available at this stage of the investigation.

3.3 Understanding the Flooding Mechanism

Understanding the flooding mechanism is key to defining where best to direct the investigation. Information provided by customers who have witnessed flooding incidents is of great value in gaining this understanding. Knowing whether the flooding emanates from the foul or surface water system where the sewers are separate, whether flooding is predicted from private drains to the front or rear and whether flooding has travelled overland are used to direct the data collection for the hydraulic modelling investigation.

Experience has shown that whilst the customer has more often than not been able to provide information on the exact source of flooding, it has been necessary to discuss the problems with NWL Technical Support and Production Operatives. Technical staff are able add further background information particularly the history of previous investigations, why they were commissioned and the outcomes.

3.4 Data Collection Needs

Having reviewed available data, the next step is to identify what additional or new data is required. The list of requirements is specific to each location. The list below summarises the most commonly identified needs.

- Customer visits to confirm source of flooding and mechanism

- Site visits to visually inspect the local topography and land use and to check connectivity to the public sewer. Also checked is whether urban creep is a contributory factor and what adjustment to the percentage impermeable would be needed, whether there any obvious restrictions to construction and where flood mitigation techniques would be applicable

- Manhole / CSO / SPS and topographic surveys around the flooding location(s). Where available, LiDAR data can be used in lieu of the topographic surveys or in majority of cases is used in conjunction with localised topographic survey data

- Sewer network performance data, whether regular maintenance is in operation in a particular area of the network and whether there have been any network alterations, maintenance works or capital schemes

- In the event of widespread flooding being reported, NWL published an internal report collating region wide raingauge data, attributing indicative return periods. However, the widespread nature of the locations and the high level of spatial variability of the recorded rainfall make it difficult to reach a firm conclusion as to whether the return period attributed to rainfall at a particular gauge is directly applicable to a flooding incident. For this reason the rainfall data provides a reality check for the model predictions rather than historical calibration data.

3.5 Hydraulic Analysis

The hydraulic analysis for all Cause Reports was completed using InfoWorks CS software. The models used in the Cause Reports generally fall into 2 categories:

- Existing models that require upgrading to meet the needs of the investigation

- Models built specifically for investigating flooding at a particular location(s).

The success of the hydraulic modelling element of a Cause Report centres on defining and applying a series of standard procedures. Where a model has been available for a particular Cause Report, it is typically a Type II model constructed during AMP III to address uCSOs. The focus of the details and verification therefore centres on the CSOs and it is purely by chance if a monitor was located adjacent to a Cause Report flooded property. Therefore confidence in predictions has to come from adopting a standardised ‘good practice’ approach. The same standardised modelling approach is also adopted when constructing new models, specifically for the purpose of addressing these flooding problems.

In addition to the good practice detailed in the WaPUG Code of Practice and MWH’s Model Build and Verification Guide, the headings below summarise some of key areas of the modelling process specifically detailed in each Cause Report to ensure future model usage is not hindered by unclear assumptions and decisions.

3.5.1 Impermeability

The following rules are applied:

- Existing models
    - Redefine subcatchments recalculate percentage impermeabilities + urban creep allowance local to the flooding site

- New model builds
    - Combined systems are applied using GIS + urban creep allowance
    - Foul systems apply a nominal 5% as Area 1
    - Surface Water systems as combined with 5% allowance for foul sewer excluded

3.5.2 Runoff models

- Existing models
  - The same runoff model is used as in the original version. Including the application of the New UK runoff model and ground infiltration module. (Calibrated parameters are not altered).

- New model builds
  - Combined or surface water runoff is applied using the Wallingford runoff model (Fixed PR)
  - Foul runoff uses the fixed runoff model with 100% fixed runoff
  - Partially separate (roof area only) use the fixed runoff model with 85% fixed runoff

3.5.3 Boundary conditions

Downstream boundary conditions are defined as the first point on the network where there is no hydraulic influence at the flooding location. Any point on the sewer network can be suitable if the catchment is sufficiently steep sloping, although typically SPSs and CSOs where a top water level can be assumed, or outfalls to watercourses on surface water systems are used.

3.5.4 DWF Inputs

- Population is applied using Census data and distributed using the GIS seed counts. Consumption figures are set at 157l/s/head set by applying the 2000 consumption figure of 146l/s/head + 1% annual compound increase up to 2006/7.
- Trade and commercial flows are added as per the consent where applicable or as included in the original model
- Infiltration flows are applied at 50% domestic flow in the absence of other information. In the cases where a model is verified, the existing infiltration conditions are maintained
- Serviceability conditions added in accordance with the findings from CCTV surveys. For hydraulic only conditions a ks=3mm is applied to all sewers

3.5.5 Impact on adjacent system

Interaction with downstream systems are identified and recorded wherever applicable, although the full potential impact any upstream network changes are not investigated. Typical interactions included ongoing AMP IV schemes.

3.5.6 Model verified

A description of the model type and coverage is reported. Also detailed are the extents of any previous verification and whether verification was completed in the vicinity of the flooding location.

3.5.7 Confidence rating

A confidence rating is detailed in every Cause Report. The ratings are based on a comparison between reported flooding mechanism and the predicted results from the model. Levels of verification, size of the upstream catchment, quality of the asset data all contribute to the final confidence rating. In most cases applying the standard modelling approach gives a higher confidence rating to the predicted mechanism than to the predicted flood volumes. The rapid assessment approach is considered robust in the prediction of peak flows and depths but confidence is often lower in the predicted flood volumes since some of the more subtle inputs such as infiltration and local internal conditions are not as accurately replicated.

The constructed / upgraded models are simulated with 1 in 5, 10 and 20 year design rainfall events to predict the frequency and extent of flooding. Where the reported flooding history is

available for a property or group of properties, the predicted frequency can be assessed against the recorded flooding, a good correlation strengthens the level of confidence in the model predictions and is duly noted in the Cause Report.

This approach is deemed acceptable, since Cause Reports are designed to identify flooding mechanisms and risk of failure for investment prioritisation purposes, not to identify solutions.

3.6 Cause of Flooding

The results of the hydraulic analysis provide insight into the cause and severity of the reported problem. If the problem cause is considered to be hydraulic overload, the completed Cause Report makes a recommendation to the NWL Sewer Flooding Group as to which DG5 register the property should be placed on, and a construction cost estimate is developed.

If the cause is considered to be non-hydraulic, the Cause Report is terminated and a recommendation is forwarded to NWL Operations to consider a reactive solution such repair or cleansing.

3.7 Solutions Investigation

The development of a solution is not an integral part of the Cause Report process. Cause Reports are a rapid assessment tool designed to categorise problems rather than to investigate solutions. The level of engineering detail collected within the bounds of a Cause Report is insufficient to develop robust solutions.

3.8 Cost Estimates

To guide the Flooding Prioritisation Committee when applying a ranking to the Cause Report recommendations, a simple methodology has been developed by MWH that facilitates the application of a 'level playing field' across all Cause Report recommendations. The approach involves applying the following unit costs:

- £1,000 per m^3 of surface flooding predicted during the critical duration 1 in 20 year return period storm event and directly applicable to the flooding location
- £250 per m length of sewer identified as hydraulically inadequate and contributing to the flooding location

Since each Cause Report looks at a specific problem, weighting factors were introduced to allow site specific factors to be accounted for at each location. Whilst not wanting to distort costs relative to one another, the weighting relates to information gathered during the site visit which is perceived to be a possible constraint to construction. Each factor has been attributed a fixed percentage. This factor when applied to the unit costs will increase the estimated construction cost to give a more realistic estimate relative to other Cause Report locations. Table 1 below summarises the identified constraints and their associated weighting factors.

Table 1 – Construction Constraints and Weighting Factors

Problem	Estimated Cost Adjustment Factor
Access	+10%
Work in Highway	+10%
Major Utility Diversions	+25%
Bus Route	+10%
Poor Ground	+25%
Protected Species / Habitats	+10%
Mature Trees	+5%

Problem	Estimated Cost Adjustment Factor
Third Party Issues	+2%
SSSI	+2%
Rail Crossing	+30%
Water Crossing	+30%

Cost estimating at this 'high level' may introduce certain inaccuracies to the calculated cost estimates. However, since the completed Cause Reports are currently being used as the initial scope for the Project Definition stage of investment projects, a review will be undertaken to understand the accuracy of the Cause Report estimates. Until there is sufficient data to complete the review, any inaccuracy in the current approach will be applied universally and therefore the estimated costs should suitable for comparative purposes.

3.9 Mitigation Measures

Within the bounds of a Cause Report and in addition to the capital cost estimates, consideration is given to possible short term, low cost mitigation measures. Table 2 below summarises the more common available techniques. Each possible measure is considered and depending on the suitability and / or constraint, recommendations are included accordingly.

Table 2 – Typical Mitigation Measures Considered

Mitigation Measure	Comments
Garden contouring	Possible mitigation includes garden landscaping and overland flood routing paths. Usage often restricted by access problems or lack of garden space
Non-return valve	Usually applicable where a property is low lying although can restrict domestic sewage flows during surcharge
Divert private drainage	Diversions are generally considered solutions, however, where more than one sewer is in the vicinity of a property, minor works may be applicable to reconnect to an alternative sewer with hydraulic capacity
Disconnect cellar	Disconnecting a cellar alone will only be applicable if there is not restriction to a property's foul water disposal. A more likely scenario would be to 'Cut and Pump' although this is likely to be a solution rather than mitigation
Air brick modification	Typically available for low lying properties affected by overland flows
Raise thresholds	As previous, although restricted access makes this measure more difficult to implement
UPVC doors	Flood doors are particularly applicable where overland flows are affecting integral garages with internal connecting doors to the property
Bolt down covers	More usually applicable in less well developed locations, fear of transferring flooding elsewhere in more urbanised area reduces the suitability of this measure
Temporary CSOs	Ideal for controlling surcharge levels and flooding, this measure involves a consent and generally requires more information about watercourses etc than is usually included in a Cause Report

Consideration is given to possible mitigation measures as an addition to any potential solution, not as an alternative. Mitigation measures are intended to be applied in the short term for flooding impact reduction in lieu of a full solution being implemented.

4. CONCLUSIONS

The current Cause Report template has been refined over the last 12 months and now involves the collation of all known asset and customer information relating to a flooding incident, identification of cause and mechanism of the service failure with an attributed predicted flood frequency and recommendation for inclusion on a specific DG5 register. The reports now incorporate an indication of possible short term mitigation measures, highlight the potential construction constraints and risks to completing a full solution and suggest an indicative construction cost estimate. Incorporating these elements is currently considered by NWL to be providing the best value approach to flooding investment prioritisation.

To date more than 150 Cause Reports have been completed and although each investigation looks at a specific problem, the costs per investigation vary from £1,500 to £10,000. The average cost per investigation is approximately £5,000 including manhole and topographic surveys and the turnaround time of a Cause Report is approximately 12 weeks. Both of these figures have reduced during 2006 through identifying, adopting and sharing of best practice throughout the teams.

The hydraulic analysis is now transparent for all users with all decisions and assumptions made within the bounds of a streamlined modelling approach. Clearly documented, all Cause Reports now include a confidence rating relating to the modelling to ensure all subsequent model users understand both the current model status and limitations.

The current Cause Report process is now sufficiently refined and well documented that it provides confidence that all investigations are completed following the same approach, enabling NWL to:

- Accurately allocate the correct cause of a flooding event
- Determine the risk associated with the flooding recurring
- Identify any mitigation measures that will reduce the impact of future flooding
- Provide accurate data with regard to customer liaison
- Prioritise investment in accordance with recognised standards of customer service and affordability
- Have effective programme management with acceptably accurate solution costs
- Provide accurate date for periodic review submissions
- Provide the initial scope for the Project Definition stage of investment projects

Cause Reports do not incorporate the development of any new modelling techniques and are not all encompassing in their approach to data collection and understanding all aspects of a particular flooding problem. Where the innovation is demonstrated is in the application of a measured approach. Undertaking targeted data collection, completing hydraulic analyses specifically with a view to DG5 recommendations and following a common methodology to ensure all outputs are comparable in terms of cost estimation are the challenges that has been met. Achieving this at an average cost of £5,000 and with a 12 week turnaround provides the best value approach to flooding prioritisation in the Northumbrian Water region.

5. REFERENCES

DoE/NWC The Wallingford Procedure, HR Wallingford, 1983

WaPUG Code of Practice for the Hydraulic Modelling of Sewer Systems, WaPUG, 2002

MWH Sewer Network Hydraulic Model Build and Verification Guide version 9, MWH

Northumbrian Water Limited, 050619_Various_T_Period_Report, NWL Internal Report, 2005

Northumbrian Water Limited, 050831_Various_T_Period_Report, NWL Internal Report, 2005