DEVELOPMENT OF AN INTEGRATED DRAINAGE PLAN FOR TYNESIDE

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ABSTRACT

The requirements placed upon drainage systems are continuously changing. The need to accommodate future growth, climate change and urban creep without exacerbating existing flooding issues is a significant challenge. It is not practical or cost effective to continue to build bigger systems and therefore we need to find better ways of working if we are to continue to provide the expected levels of service to our customers and the environment.

Northumbrian Water Limited (NWL) initiated a pilot project, working with other drainage partners to complete a sustainable sewerage study on Tyneside, an area broadly aligned to the catchment of the lower River Tyne in northeast England. The purpose of the project was to establish a proactive cross party process and procedure in order to:

- Create a template of how the drainage partners can work together in their communities to understand current and future sewerage issues;
- Establish and implement data share and communication protocols;
- Produce and apply a methodology that can be used to rank risk locations for more detailed studies;
- Promote integrated sustainable drainage opportunities;
- Promote 'best possible' service to the customer balanced against environmental needs and costs; and
- Provide risk based evidence to inform future business planning requirements for all partners.

In support of these goals MWH have collaborated with the partners in leading the development of an integrated approach. Central to this was the development of an integrated catchment model (ICM) using InfoWorks ICM software. The ICM included all of the foul and combined sewers from existing models, all of the surface water systems, all major watercourses, and a digital terrain model (DTM).

The paper outlines the entire process, including the evolution and application of methodologies necessary to support the purpose of the project. It describes the construction and validation of the ICM and its use to identify Sustainable Drainage System (SuDS) opportunities, concluding with an insight into some of the potential benefits and the key learning that has evolved from the study.

THE APPROACH

NWL worked with their drainage partners to complete a pilot study exploring sustainable drainage opportunities for the management of current and future flood risk on Tyneside. The drainage partners for this study are:

Gateshead Council
Newcastle Upon Tyne City Council
Northumberland County Council
North Tyneside Council
South Tyneside Council
The Environment Agency
Consumer Council for Water
Northumbrian Water Limited

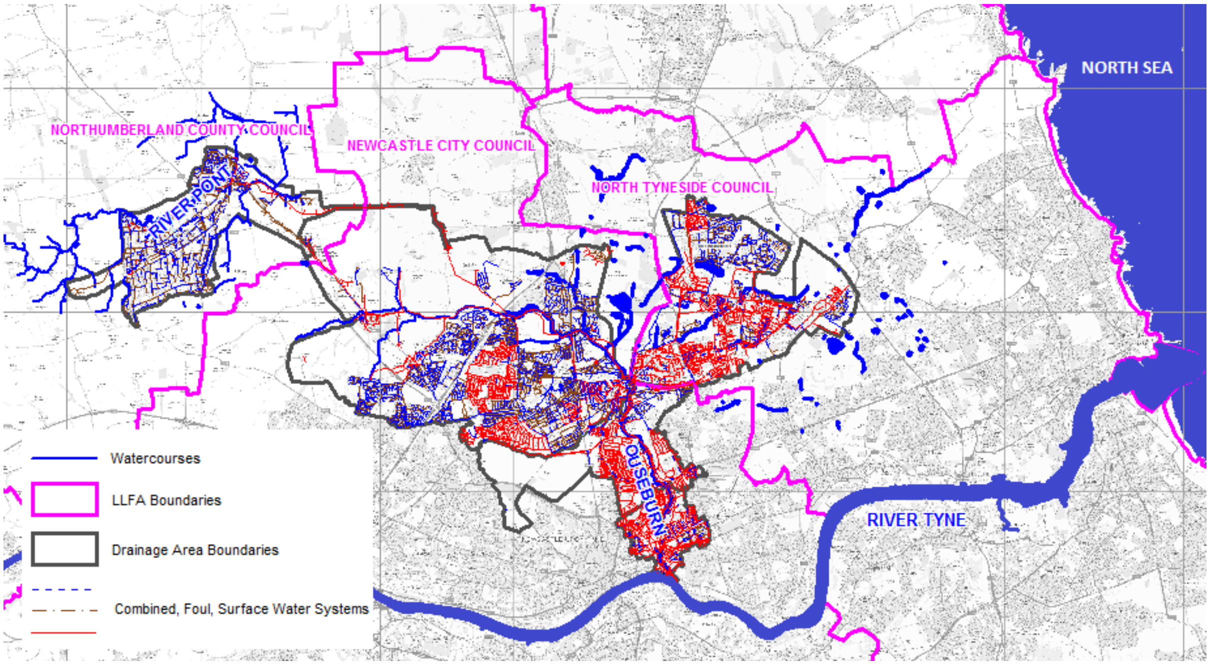

Figure 1 Drainage Areas shown with LLFA Boundaries and the lower River Tyne

Individuals representing each of the drainage partners formed a project steering group to provide high level guidance and direction throughout the project. The group facilitated:

- Definition and control of project scope;
- Agreement and application of an approach for the timely sharing of data and information;
- Sharing of knowledge and experience;
- Agreement and application of a methodology for the identification of high risk drainage areas;
- Delivery of studies at high risk locations; and
- Improved understanding and communication of flood risk between partners.

The study adopted a three stage approach, aligning with and supporting the principles of Surface Water Management Planning (Defra, 2010).

- Stage 1 (Complete) — Focus on the collection, collation and analysis of detailed information to identify locations of potential dependency and interaction between drainage systems
- Stage 2 (Complete) — Using the outputs from Stage 1 focus on the application of a risk based approach to identify and assess sustainable drainage options
- Stage 3 Commenced — Investment planning

All of the 58 drainage areas within the Tyneside catchment were considered and 11 prioritised as high risk locations. These locations were then grouped into six study areas based on their drainage interdependencies.

THE INTEGRATED CATCHMENT MODEL (ICM)

MWH led the initial development of the study, and over time all of NWL's Framework Technical Services Consultants were involved in the delivery of the project. One of the successes noted during the study was the ability to resolve modelling queries, identify and reuse methodologies and apply consistency and ICM standards. These were achieved through a collaborative approach adopted by all consultants involving the sharing of ideas, processes and the collective development of these ideas.

Modelling was completed using InfoWorks ICM software, the basis for the ICM were NWL sewer models previously built in InfoWorks CS and converted to ICM. The baseline level of data was successfully transferred and offered a starting point from which to work. In some cases further enhancement was necessary.

The ICM modelling for the purposes of this project required the incorporation of watercourses, rivers and other water features including a lake. There were a number of issues addressed including the physical detail mapping and the hydrological conversation. The conversion from HEC-RAS and ISIS was challenging as the variability of the previous approaches to creating watercourse models meant that there were very few opportunities to fully automate the process. The bathymetry of irregular channels was not a simple conversion and whilst InfoWorks ICM is able to fully support the data, the data fields, units and levels of co-ordination varied between models and therefore manual intervention was required.

The complexity of the ICMs was greater than previous approaches to catchment wide modelling and in order to achieve an acceptable balance between complexity and programme (WaPUG, 2009) MWH adopted an iterative approach to upgrading the models. This approach was shared with the other framework consultants to ensure consistency across the entire project. The approach centred on establishing an initial level of confidence across the drainage areas for those locations identified during the stage 1 problem identification phase. Combined, foul, and surface water system data was added and subcatchments delineated to reflect individual land uses. The identified areas became the focus for the enhancements to improve confidence in the model predictions where the needs were greatest. The addition of the missing system data was applied using a combination of Geographical Information System (GIS) and Light Detection and Ranging (LiDAR) data, but in some cases these areas were further enhanced with survey information; this was particularly prevalent where sewer systems interacted with watercourses.

Two Dimensional Modelling

The basis for the two dimensional model (2D) was the DTM created from LiDAR. When utilising the DTM there was the need to analyse the data to identify and address anomalies to ensure that the ICM was fully integrated. Checks were completed during the compiling of the ICMs to ensure that manhole, outfall and watercourse bank levels were compatible. Where data discrepancies occurred, careful adjustment of the ICMs was required based on the need for confidence in the model.

Modelling Watercourses

A key consideration when modelling the watercourses was the hydrology. In the case of Tyneside the watercourse models were provided by the Environment Agency (EA) and Lead Local Flood Authorities (LLFAs) and had been created without a focus on urban drainage. The hydrology had been derived using different parameters from those used in the sewer models. In some cases it was necessary to use the runoff models within ICM to replicate the peak flow and volumetric predictions, comparing the outputs against the original model predictions. This was particularly applicable when the ground model and the river bank interactions were a key driver requiring the representation of longitudinal flooding from the watercourse. Alternatively applying inflow / level hydrographs and omitting watercourse bathymetry and topography was adopted in those locations where the need for confidence was lower.

Validating the ICM

In validating the ICMs, the important choice to make was ensuring the model gave an acceptable representation of the reported issues and that the model was able to replicate performance. The existing model of the study area was augmented with verified data that had been completed for various flooding schemes. These provided localised verification, but not a full area wide verification. No further verification of the models was completed as part of this study. Reported flooding from the various stakeholders was compared with predicted flooding. In majority of instances there were acceptable matches.

Scenario modelling and opportunity assessment

Following the construction and validation of the ICMs, three baseline scenarios and one scenario with the opportunities implemented were modelled. These opportunities included the agreement by all partners for the evaluation of the impacts of SuDS and the assessment of potential benefits. The scenarios and the information included in the each scenario were:

Current Scenario	**2020 Scenario**	**2050 Scenario**	**2050 Opportunities Scenario**
• Committed Growth	• Climate Change • Urban Creep • Proposed Growth	• Climate Change • Urban Creep • Strategic Housing Land Availability Assessment	• Climate Change • Urban Creep • Strategic Housing Land Availability Assessment • Opportunities Implemented

Creep was applied to the models in accordance with the *Impact of urban creep on sewerage systems* (Allitt R. et al, 2009) and climate change uplifts were applied based on the *2009 UK Climate Change projections*, (UKCP09, 2009).

The results from the two future scenarios were used to identify predicted hydraulic overload flooding, CSO performance, forecast energy consumption and estimated future treatment costs. Based on the findings of the models in conjunction with partner's needs, land use and availability of space, the source – pathway – receptor approach (Digman et al, 2012) was used to identify the key locations where surface water management measures could be incorporated into the catchments offering the most effective surface water management opportunities.

An initial range of integrated opportunities was drafted based purely on effectiveness to manage peak flows and volumes, fitting in with current land use and availability of space, (Woods-Ballard et al, 2007). These opportunities were shared with the partners, allowing local direction to be added and ensuring that the proposals fitted into their wider programmes, initiatives and directives. It was at this point that further local biodiversity and amenity needs were considered; changes to the proposals were made to meet specific needs of each location. In some cases this led to the inclusion of local features including ponds and the encouragement of specific techniques to improve habitats. Figure 2 shows how suitable SuDS were incorporated to provide cross partner benefits.

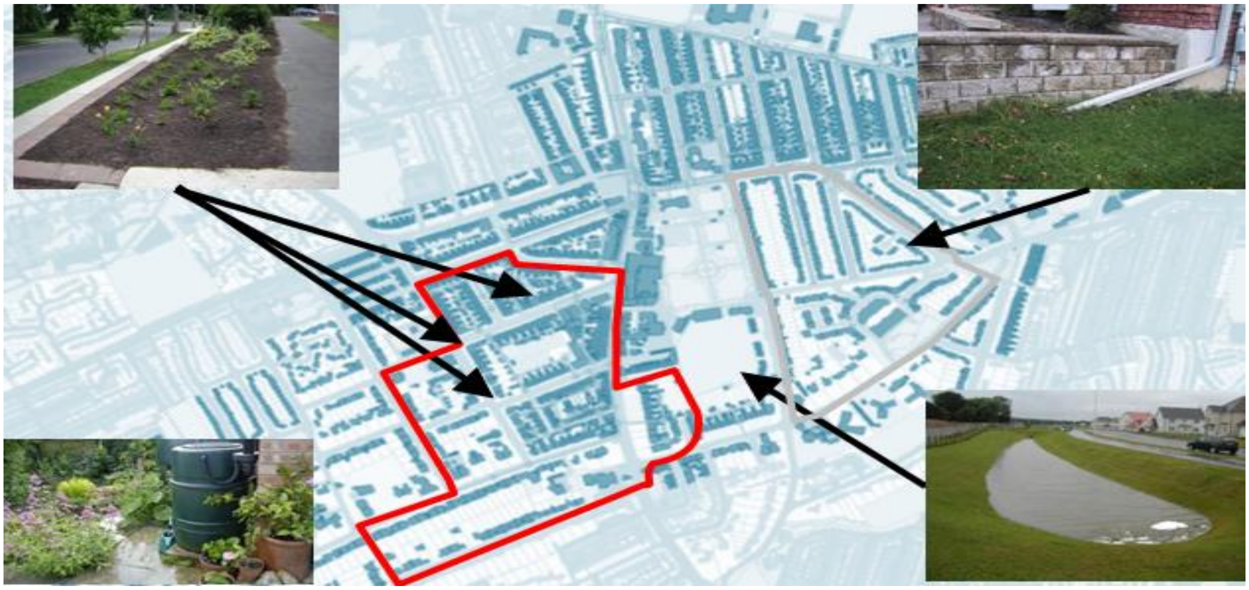

Figure 2 Application of SuDS to the modelled catchment

In all cases a representation of the final agreed SuDS opportunities were incorporated into the models. The effect of the SuDS on the modelled runoff was able to be analysed both in terms of the identification of potential partner benefits but also in the individual influence of the SuDS. Figure 3 shows the rainfall hyetograph and the effects of the routing of runoff through a series of rain gardens. Features to note are the reduction in peak runoff flows and the introduction of a lag time demonstrating that whilst the rain gardens slow the effects of runoff, in this instance they are also able to prevent a finite volume from entering the sewer system.

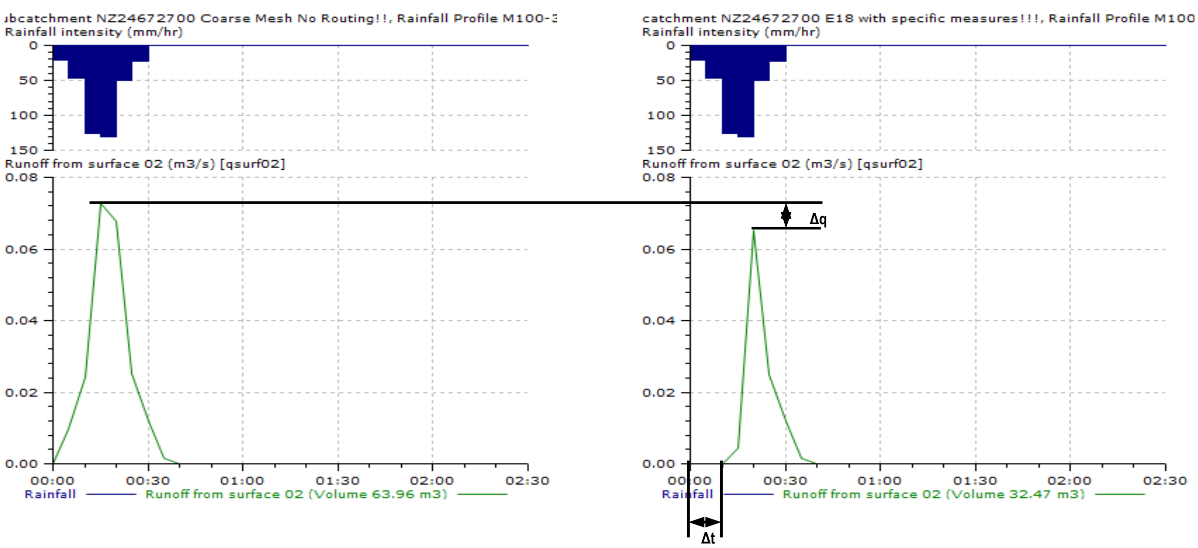

Figure 3 Demonstration of the effects of the SuDS on the runoff hydrographs

Identifying partner benefits

Identifying partner benefits were key deliverables of the Tyneside Sustainable Sewerage Study. The ICMs were central to meeting the goals and the collaboration between MWH and the partners, including the mapping of which benefits were important to them and what opportunities existed within the modelled catchments. Table 1 summarises the identified benefits and available opportunities.

Table 1 Identified opportunities and partner benefits

Identified Benefits	Opportunities
Accommodate future growth	Reduction of flows in in all systems
Improved water quality & watercourse amenity	Reduced CSO spills and volume discharged to watercourses
Reduced flood risk	Reduction in peak flows in watercourses; Reduction in property flood risk
Local amenity, new habitats, biodiversity, community engagement and storage	Provision of landscaped water features
Reduced carbon production	Reduced energy consumption
Growth and sustainable use of assets	Infrastructure enhancements and improvements on life spans
Input to opportunities for future business planning	Evidence base for future investments

Flood risk assessment was one of the primary focuses and was calculated for every property within the study areas for the current, 2020, 2050 and 2050 with the opportunities applied scenarios.

To simplify the analysis, the properties were connected to the sewer network using a theoretical link at an assumed point on the closest modelled conduit. An assessment of the flood risk was made using the upstream level of the connection and the level of surcharge, combined with the overland flow pathways.

For surcharge risk, a property's threshold level (ground level+200mm) was derived from the DTM and the surcharge level was interpolated from the top water level of the upstream and downstream nodes; this interpolated level was compared with that of the property threshold. The overland flow risk was calculated by taking the maximum flood depth in the 2D triangle that intersected the building outline. The overall flood risk impact was obtained by adding the two depths together. The combined depth was divided into the three risk categories shown in Table 2.

Table 2 Flood risk categorisation

Category	Depth (above ground level)	Description	Assumptions/Comments
High	>0.2m	Foul Water in Living Accommodation	The process uses property ground level and it is assumed that typically, threshold is 200mm above this.
	0 to 0.2m	Dampness in Living Accommodation	Dampness is assumed as water ingress to under floor areas which could occur via air bricks
Medium	-0.2m to 0m	Curtilage Flooding Likely	Flows do not quite surcharge back to property, but external flooding is likely
Low	-0.5m to -0.2m	Flooding Unlikely	Boundary between low and very low categories is somewhat arbitrary
	<-0.5m	Flooding Unlikely	Boundary between low and very low categories is somewhat arbitrary

Originally the flood risk was reported across five depth classifications, this was later revised to three risk categories, high, medium and low. Included in Table 2 is how the five depths were merged into the three risk categories.

With the opportunities applied the results of the flood risk analysis showed that there is a small but positive influence on the flood risk to the properties in the study areas. As expected, the number of properties in the high risk bracket increases with time up to the 2050 model. With the integrated opportunities added to the 2050 model there is a reduction in number of properties at high risk. Figure 4 shows an example of the flood risk analysis results.

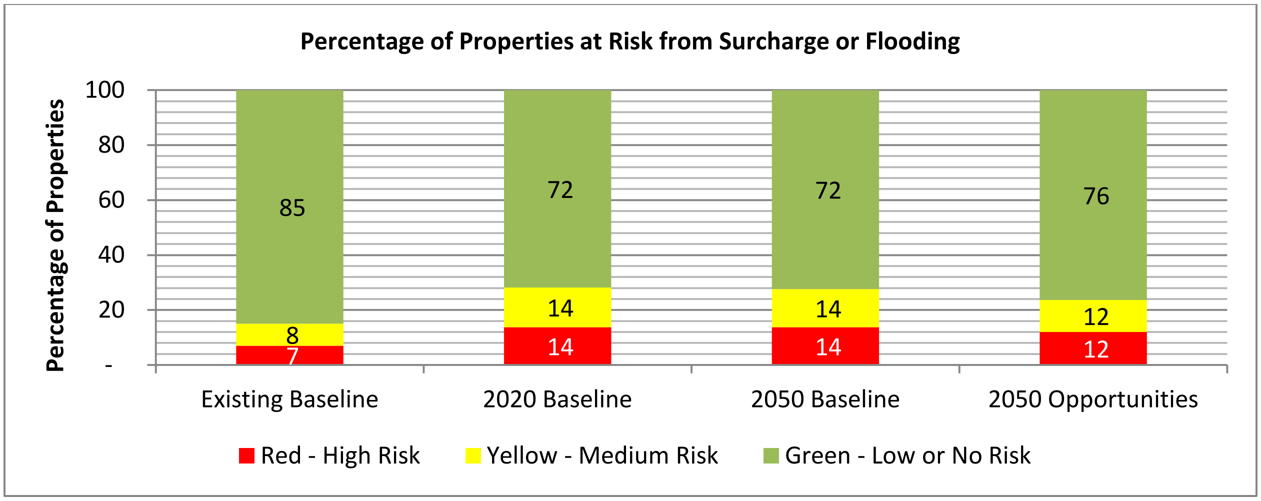

Figure 4 Flood risk results displayed in percentages

Figures 5a and 5b are an example of the effects of SuDS in the predictions for a strategic catchment CSO. These figures were typical of the influence of the SuDS opportunities on the on system performance. In this particular example the CSO forecasted performance for 2050 is similar to current day performance; although currently in a restricted growth area as a result of inadequate system capacity the upstream long term housing, industrial and commercial growth proposals are included along with the SuDS proposals. Here the ICM demonstrates that with an integrated approach the upstream growth restrictions can be overcome and longer term benefits can be realised. Economic growth, water quality improvements and reduced asset maintenance are just three longer term benefits considered applicable to this situation.

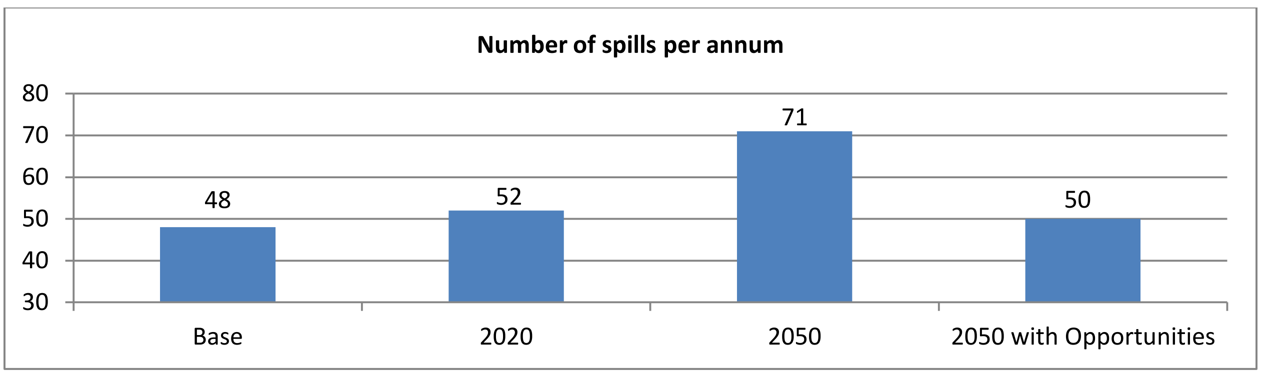

Figure 5a Spill frequency predictions for a major catchment CSO

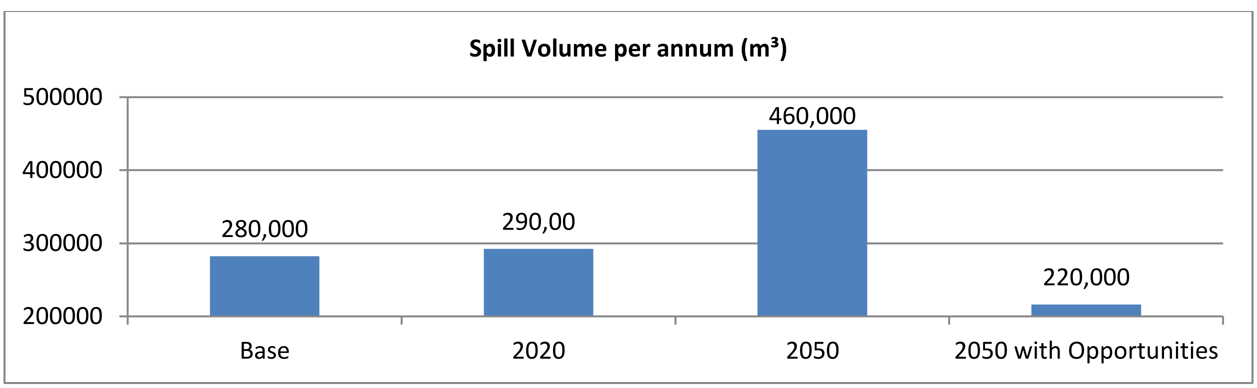

Figure 5b Spill volume predictions for a major catchment CSO

SUMMARY

Using an integrated modelling approach has allowed integrated sustainable opportunities to be identified and analysed and for a wide range of benefits to be realised for all partners. Some of the partner benefits that have been identified include:

- A reduction in pass forward flow from the combined sewer to the downstream catchment; freeing up existing sewer network capacity thereby reducing potential constraints to future growth;
- A reduction in CSO spill frequency and volume; encouraging increased amenity and biodiversity value of the receiving waters through the improvement of water quality;
- Reduced peak flows in watercourses through the provision of storage areas to slow down the response and increase capacity; the ability to facilitate growth by accepting additional surface water inflows to the watercourse;
- Reduction in number of properties classified as high or medium risk of flooding;
- Provision of landscaped water features; amenity and biodiversity benefits for the wider community;
- A reduction in energy consumption at the downstream powered assets including powered CSO screens;
- A reduction in flows arriving at the wastewater treatment works, maximising available headroom and enhancing the lifespan of the asset;
- Provision of an evidence base for future investments for all partners – the positive results of measures implemented in this study could provide the basis for other areas of investment including the ability to encourage new industrial and commercial growth; and
- Evidence that will accommodate future residential and commercial growth without increasing flood risk – freeing capacity in surface water sewers, combined sewer and watercourses to encourage betterment.

Partner feedback

Feedback received from all partners has been positive and that the findings, direction and intentions in the submitted reports are in keeping with their common goals. These goals include amongst others Surface Water Management Planning, Green Infrastructure Agenda, Sustainable Places. The common agreement is that 'All of the ideas in the reports appear well thought through and feasible and they are the sort of things that we could support and jointly fund to our mutual benefit. We would be happy to work together in the future to prioritise and implement those elements of the study that were affordable and produced the maximum benefit'.

KEY LEARNING POINTS

A summary of the key learning points from the development of an integrated drainage plan for Tyneside include:

- Using a partnership approach improves the output, whereby the results from the model are validated by a wider knowledge base and the recommendations are embraced by all involved;
- An integrated catchment model is able to consider the impact of the below ground systems, watercourses, and above ground overland flow more comprehensively than if any of these are analysed separately;
- The important choice to make in these instances is where the particular flooding mechanism needs to be accurately represented and where the setting of a boundary condition will need to be sufficient to replicate flooding;
- The representation of the interaction between systems is critical to understand in order that the flow volume distributions are proportionally represented;
- The adoption of a more measured approach that meets the needs of a study is necessary to avoid being overly data reliant, causing prolonged simulation times;

- When using a 1D and 2D modelling approach there is a need to address anomalies between surface features to ensure that the ICM is fully integrated;
- Modelling watercourses and adopting appropriate hydrologic inputs is a key step in delivering a meaningful ICM;
- Demonstration of the effects of future scenarios sends out a powerful message to those not immediately involved in the modelling process and allows inputs into more diverse range of strategies and studies; and
- The success to this project was the collaborative approach to delivering a project that met the needs of a wide range of partners and that a number of consultants were able to deliver a consistent and coherent project.

FUTURE WORK

Partners have confirmed that the current approach suits the Department for Environment Farming and Rural Affairs / EA funding mechanism(s) and with more detail of costs and benefits it would form the basis for attracting funding to address flood risk problems into the future. Discussions to undertake jointly funded feasibility studies to progress the identified opportunities with a view to realising the identified benefits are evolving.

The work described in this paper has recently (September 2012) been extended to further develop and refine specific proposals for one of the study areas. This extended study will aim to identify and address the key issues and opportunities necessary to support the implementation of SuDS / Surface Water Management (SWM) for all partners; focus will be on how opportunities can be implemented, identifying barriers to the application and to how overcome them. The study will extend to include understanding of the different challenges faced by the public and private retrofit process, future ownership and maintenance responsibilities, identification of possible funding sources and the impact of legislation and regulation.

Additional Sustainable Sewerage Studies are planned in the Teesside and Wearside areas to deliver stages 1 and 2; these new studies are expected to commence in 2013.

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