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Hydrolink

This is a summary of the presentation given in the first meeting of the Cardiff IAHR Young Professionals Network held in November

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USING **RETRO-FIT GREEN INFRASTRUCTURE** TO **REDUCE POLLUTION** AND **FLOODING** IN LLANELLI AND GOWERTON, SOUTH WALES

BY LOUISE ELLIS & CHRIS ELLIS

Surface water inflow into the combined sewerage networks in Llanelli and Gowerton (UK) led to excessive spills from Combined Sewer Overflows (CSOs) into the Loughor Estuary, a protected shellfish water. This resulted in the threat of European Commission Infraction Proceedings for a breach of the Urban Wastewater Treatment Directive (UWWTD). Dŵr Cymru Welsh Water (DCWW), the 'not-for-profit' water and sewerage company in Wales, adopted a pioneering approach with their partners, Morgan Sindall and Arup. Extensive hydraulic modeling was undertaken to establish the root cause of the CSO spills and led to a strategy of widespread, innovative green infrastructure solutions, which provided a capital cost reduction along with social and environmental benefits when compared with the traditional solution of storage.

Introduction

Llanelli, a large town in South Wales, has a highly impermeable response to rainfall due its extensively urbanised nature and aging, predominantly combined sewerage network. Gowerton, located to the east of Llanelli, is a rural catchment and suffers from groundwater infiltration into its combined sewerage network, which is largerly laid through areas of marshlands. The two catchments are separated by the Loughor Estuary, a tidal water body protected by several environmental designations, including the Shellfish Waters Directive. Ninety-two CSOs from the Llanelli and Gowerton catchments discharge into the Loughor Estuary, with the 'worst performer' discharging over 2.36 million m^3 of combined sewage annually, exposing the shellfish waters to sewage pollution. Since 2002, a mass decline in cockle numbers within the Loughor Estuary came to the attention of the European Commission, who responded with the threat of infraction proceedings against the UK for a breach of the UWWTD. Arup, in partnership with Morgan Sindall, were commissioned by DCWW in 2010 to develop and implement a catchment strategy. The primary aim of the strategy was to reduce the number of spills to 10 spills per CSO per annum to comply with the UWWTD. In addition, there were two further drivers, addressing flooding of 115 properties and lifting restrictions on development due to sewer capacity.

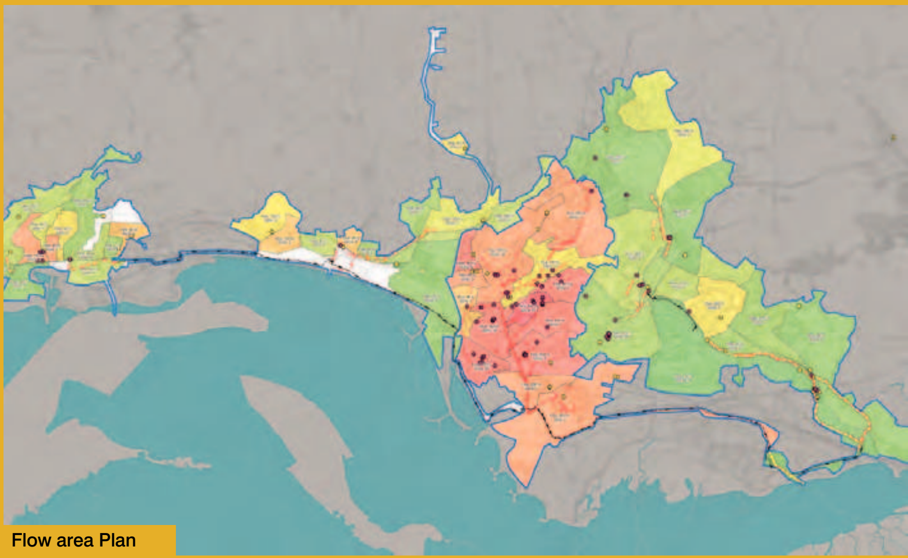
The overall strategy for improving the Llanelli and Gowerton catchments was divided into three distinct stages:

	Stage	Dates
1	Data Collection and Hydraulic Modelling	May 2010 – April 2011
2	Solution Development	April 2011 – Sept 2011
3	Solution Implementation	Sept 2011 – March 2020

Location Plan

Data Collection and Hydraulic Modeling

The existing catchment model was a patchwork of linked subcatchment models, which did not represent the observed behaviour of the catchment and as a result DCWW did not fully understand the performance and interaction of their assets.



Flow area Plan

QMW Bioswale

Louise Ellis **is a civil engineer working in the water group at Arup. She has been working on the solution development and implementation of green infrastructure schemes for Llanelli and Gowerton since 2011. She is currently based in Arup's New York Office, where she is working on the retro-fit of green infrastructure in NYC and flood resilience of the NYC subway following Hurricane Sandy. Louise has a Master's degree in Engineering Science from the University of Oxford (UK).**

Chris Ellis **is a graduate engineer working in the water group at Arup's Cardiff office. He has worked on a wide range of projects, including the implementation of green infrastructure schemes within Llanelli and Gowerton since 2012. Chris has an undergraduate degree in Civil Engineering from the University of Exeter (UK) and a postgraduate degree from Cardiff University (UK), where he developed a keen interest in hydraulics.**

In order to pinpoint the causes of CSO spills and target interventions effectively, a new 7000 node Infoworks Collection Systems (CS) model was built covering Llanelli and Gowerton, approximately 2,493 ha, with a population of 120,721. This was used to assess CSO spill frequencies, durations and volumes at all assets. Existing sewer network data was supplemented with surveys of 390 manholes and all of the CSOs and sewage pumping stations; 66 in total.

The model was verified for dry weather and storm events using DCWW's historical flooding records, spill data over the period 2000 to 2010, a short-term flow survey (308 flow monitors for 8 weeks) and a long-term flow survey (50 flow monitors for 6 months) to assess seasonal variation in infiltration and baseflow. River level gauges were placed in local watercourses to assess sewer-river interactions.

The outputs of spill frequencies, durations and volumes from the hydraulic model were transferred to a coastal dispersion model to assess the relative significance of the impact of spills from each CSO on the Loughor Estuary.

Model run times during verification and solution development presented a challenge. The model had to be run for consecutive storms rather than individual storms to assess the impact on the filling and emptying of the storage and ensure that the number of spills was not under predicted. However, for a 1 year dataset, the model run time for an individual catchment scenario was approximately 4 hours using a high specification computer. Our approach was to divide the catchment into manageable subcatchments and during solution development each scenario was tested against a representative wet month based on ten years of observed data. Once the solutions within each subcatchment were optimised, the subcatchments were stitched together and tested using the ten year dataset for final optimisation.

Solution Development

The traditional solution in the UK for reducing CSO spills within a catchment is to attenuate flows with storage tanks. Although this solution has the benefit of familiarity within the industry with design guidance and standards, there are key risks: storage tanks can prove ineffective during prolonged wet periods; the costs can be significant especially in pumped catchments like Llanelli; and treatment issues can arise due the inconsistency of the stored effluent.

We developed an alternative intervention strategy with retro-fit green infrastructure (GI) at its heart. Key elements include:

- Using GI as a stormwater management tool to mimic natural processes to manage rainwater with additional social and environmental benefits, including improved amenity opportunities and improved air quality;
- Best use of existing assets through Real Time Control (RTC) at key network locations, including pinch points, storage tanks and pumping stations, to control and divert flows to better utilize existing storage tanks and CSOs;
- Removing of land drainage connections from the public sewers as well as lining and replacing degraded sewers in areas of high groundwater infiltration; and
- Working with homeowners to encourage water re-use through the supply of rainwater harvesting units on a single household scale.

To target the solutions effectively to address the CSO spills, a number of indicators were brought together using Geographic Information Systems (GIS):

- Properties which have experienced internal (DG5s) or external flooding (SEFs) and known highway flooding;
- Assets identified by the operations team as having operational problems or limitations;
- Areas identified on the flow/area thematic map as contributing significant flow per unit of contributing area, giving an indication of where interventions to remove surface water would bring greatest benefit;
- Impact of each CSO on the water quality of the Loughor Estuary, assessed using the coastal dispersion model; and
- Proximity of a watercourse/storm network.

The model was used to test a variety of traditional and non-traditional solutions to assess the impact on peak flow reduction, CSO spills and flooding. Whilst modeling the traditional solution of storage is commonplace and much guidance is available, modeling GI elements within wastewater network analysis software such as Infoworks CS is a new concept. The intricate GI networks were simplified for modeling by using critical point storage nodes, flow controls and estimated flow removed from the collection system through infiltration and evapotranspiration.

It was found that the volume of storage required to achieve a target of ten spills per annum from the Llanelli and Gowerton catchments is 432,280 m^3, which when implementing traditional hard engineering solutions would cost around £600m with significant additional operation and maintenance costs. However, using GI it was found that the project targets could be met with only £150m of investment. Multi-criteria analysis was carried out on a number of proposed GI solutions, scoring them against the weighted criteria of peak flow reduction, flooding prevention, surface water reduction, spill reduction, ease of construction, amenity value, environmental impact, carbon footprint and whole life cycle cost. The outcome of this exercise was 180 individual schemes which together form a long term strategy for the catchment, and will be implemented over a 10 year period. The top ten schemes will be implemented by 2015, reducing peak flow for a 1 in 5 Annual Exceedance Probability by 25%.

Stakeholder Engagement

There were two key aims to the stakeholder engagement: acceptance of the strategy by key regulatory stakeholders and to gain support for the proposed interventions from the local community. Monthly technical meetings were held between DCWW and the Regulator, Natural


Glevering St Roadside Planter


Stebonheath School Education Garden

Resources Wales, to agree the modeling method, and subsequently with the Local Authority to agree the design and the arrangements for the maintenance of the individual GI schemes.
Throughout the project, drop-in sessions have been organized for local residents and businesses and DCWW involved local schools with engaging lessons on the topic of GI. As a result of the community engagement, the local community will play an active role in maintaining the vegetation associated with the GI, an added benefit for DCWW.

Solution Implementation

To date, three GI schemes have been successfully implemented; Queen Mary's Walk, Stebonheath School, and Glevering Street. Each scheme was a typical representation of the urban environment in Llanelli with roofs, car parks, roads and playgrounds, producing an urban response to storms, where rainfall arrives very quickly in the sewer system. These three sites were found to contribute in excess of 680 l/s (1 in 5 Annual Exceedance Probability) into the combined sewer network. Model predictions showed that, through implementation of GI interventions, a reduction of over 65% in peak flow could be achieved to relieve pressure on the downstream network.
The schemes are located at the top of the catchment and involve intercepting surface water to re-direct it away from the combined sewer network through overland flow channels into a selection of basins, planters and swales. These green elements remove a significant proportion of flow from the system via vegetation and trees that thrive within a moist, graded, nutrient rich soil and attenuate the remainder allowing it to return to the combined sewer at a controlled rate. The result is flood alleviation and a reduction in CSO spills downstream. In addition, the GI elements provide community and environmental benefits, resulting from improved recreational and educational spaces, and enhanced biodiversity.

Solution Performance

The hydraulic benefit of each of the schemes is being quantified with flow and depth monitors. These have shown that the responses of the individual systems to rainfall events are surpassing expectations. For instance during a typical annual storm event at Queen Mary's Walk (1 in 1 Annual Exceedance Probability), a 77% reduction in peak flow in the combined sewer was achieved, 20% greater than predicted during the design stage. This additional hydraulic benefit can be attributed to the green elements; the process of interception, evapotranspiration and soil void storage capacity.

Scheme Name	Scheme Ethos	Programme	Cost (Design & Construction)	Model Prediction for Peak Surface Water Reduction (1 in 5)
Queen Mary's Walk	Conveying surface water from roofs and roads into a 125m bioswale located in adjacent recreational grounds	Sept 2012 – Aug 2013	£813.3k	125 l/s
Stebonheath School	Several bespoke attenuation units providing additional educational benefits within a primary school site	July 2013 – Sept 2013	£447.5k	53 l/s
Glevering Street	Channelling surface water from a large, densely populated subcatchment into strategically placed roadside planters and basins	Sept 2013 – Sept 2014	£2195.5k (Projected)	326 l/s

Conclusions

The strategy of catchment-wide hydraulic modeling and detailed solution design has resulted in innovative GI solutions which provide a clear pathway to reducing CSO spills to less than 10 per annum, resulting in the EC Infraction Proceedings against Welsh Water being suspended.
The solutions not only provide a cost saving of approximately £450million when compared with traditional solutions of storage but also provide environmental benefits, such as improved air quality and greater biodiversity, and social benefits, such improved access to green space and aesthetic quality of the area. The implementation of GI in Llanelli is proving to be a catalyst for the regeneration of a historically deprived area.
This wide-scale strategy is the first of its kind in the UK and, naturally, generating client and third party confidence was difficult. However, this was overcome through attention to detail during the technical analysis and design, together with positive stakeholder engagement throughout the project. The resulting strategy is an example of best practice in the implementation of GI and will act as a blueprint for similar future projects in the UK.

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