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Burry Inlet Investigations

Welsh Water uses retro-fit SuDS to reduce CSO spills - a case study

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Executive Summary

Surface water inflow and infiltration into the combined sewerage networks in the Llanelli and Gowerton catchments in South Wales has led to excessive spills from combined sewer overflows into the Burry Inlet, a protected shellfish water. This resulted in the threat of European Commission Infraction Proceedings in 2009. To alleviate this threat Dŵr Cymru Welsh Water, in collaboration with Morgan Sindall and Arup, undertook a comprehensive catchment-wide hydraulic modelling assessment and detailed solution design. The result is a range of targeted, sustainable solutions designed to deliver reduced CSO spills.

The projected cost for delivering the sustainable targeted strategy was estimated at £145m; this compares to an estimated £600m to deliver a “traditional” solution comprising 432,280m³ of storage.

1 Introduction

Dŵr Cymru Welsh Water (DCWW) have set themselves apart in developing a forward thinking strategy to solve a common problem in the UK – how to sustainably reduce the frequency of intermittent discharges from Combined Sewer Overflows (CSO).

This paper discusses a two year study starting with the threat of potential infraction proceedings from Europe in 2009 through to current day – a time when DCWW are confident that they can deliver an innovative, concerted, sustainable and affordable CSO spill reduction strategy.

The success of the strategy lies predominantly within three elements; a close working relationship between key stakeholders, in-depth catchment knowledge and a robust hydraulic model. These three elements were the key to developing a two spill reduction strategy options - a traditional storage solution versus a suite of individual intervention schemes ranging from flow optimisation techniques through to retro-fit Water Sensitive Urban Design elements (WSUD – see section 7 for more detail).

2 Drivers

The primary catchment driver for this project is for all combined sewer overflows (CSOs) to be in compliance with the Shellfish Waters Directive. In simple terms Environment Agency Wales (EAW) has set a standard of 10 spills per annum for each CSO, averaged over 10 years. There were two further drivers; to alleviate flooding caused by hydraulic overload of the sewer network and to lift planning restrictions on development due to lack of sewer capacity.

2.1 Participants and Programme

Role	Company
Client	Dŵr Cymru DCWW
Design Engineer and Hydraulic Modeller	Arup
Coastal Modeller	Intertek-METOC
Contractor	Morgan Sindall

Project Phase	Dates
Model Build and Verification	May 2010 – April 2011
Solution Development	April 2011 – Sept 2011
Design and Build Phase “top ten solutions”	Sept 2011 – March 2015
Design and Build Phase Schemes 11 – 74 *(tbc)*	April 2015 – March 2020

3 Defining the Problem

From the outset it was clear that there were a number of significant problems and challenges would have to be overcome. These include poor asset data, an inadequate existing model, an initial lack of catchment understanding, widely varying catchment characteristics, the physical scale of the catchment, high CSO spill frequency, large flood volumes and finally timescale and political pressures.

3.1 Catchment Understanding and Asset data

At the start of the study it was clear that a far better catchment understanding was required. It was understood that there were major flooding and CSO issues in the catchment; what was not understood was the root cause. The existing asset data available was limited and of varying quality, the existing models a poor reflection of reality.

3.2 Modelling Challenges

The existing model was of a low quality due to historic catchment drivers; as such it was a patchwork of linked subcatchment models which did not come near to representing true observed data i.e. high spill counts and widespread flooding.

The existing sewer network exhibits long drain down times after prolonged wet periods. This is due to the nature of the catchment and the storage volume available within the network, both inherent and in some cases purpose built. Coupled with the sheer scale of the catchment it was clear from the outset that extended model run times was going to be a major factor during the study.

The new model had to be of a high enough quality to not only reflect flooding and spills (a challenge in itself), but to be capable of representing and refining a wide range of potential future solutions.

Based on the aspirations of DCWW and the project team, the removal of stormwater from combined sewers and WSUD was at the heart of the study. Accordingly the hydraulic model would need to be detailed and robust enough to replicate such solutions.

3.3 External Pressure From Third Parties

At the height of the threat of infraction proceedings in 2009, the perception of DCWW from third parties was relatively poor – third parties being DCWW's customers, local government and local media. Most of this negative feeling was based on the opinions of a vocal few; opinions which newspapers were happy to put to print; *"Floods scheme 'not the solution'"*, *"'£6m flooding fix fund disappears down drain'"*, *"DCWW firm to be sentenced for estuary sewage pollution"*, *"Council voices fears on sewage work in town"* (All quotes courtesy of thisissouthwales.co.uk). Promoting a change towards this negative feeling presents a great challenge.

Another major issue was the difficulties faced by the planning authorities. It is a difficult situation to approve developments when the existing sewer network is causing so many problems for existing residents. Developers were becoming increasingly vocal and frustrated by the situation.

4 Solutions

4.1 Catchment Understanding and Data Collection

Catchment understanding has formed the spine of the study. The first target was to pool all existing knowledge and data from all the key stakeholders. This was achieved through monthly workshops between all interested parties; DCWW, Carmarthenshire County Council (CCC), Environment Agency Wales (EAW) and Welsh Government (WG). A direct result of these workshops was detailed catchment schematics, an example of which is shown in Figure 1 below.

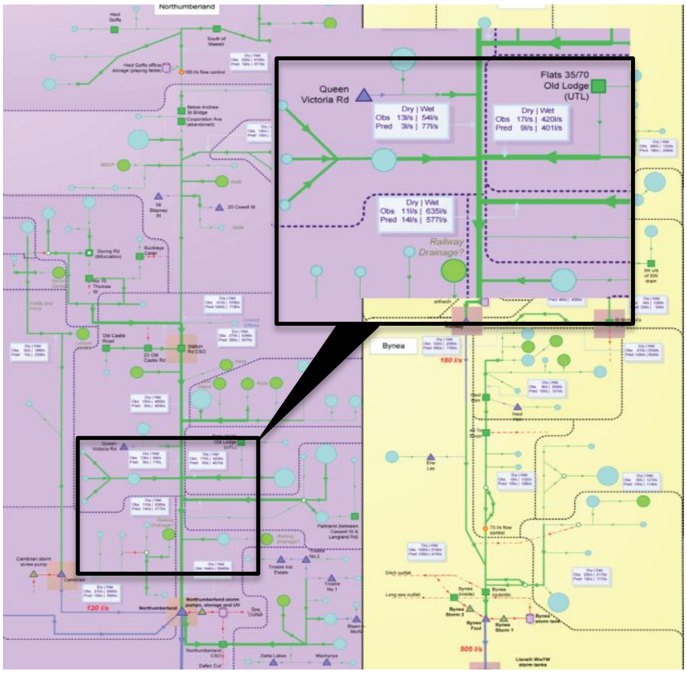

Figure 1: Example of catchment schematic

As the study progressed the team were updated on developments, issues, major inflows, etc. During this process more and more information became apparent from key stakeholders. The detailed schematic became a live document underpinning the study and is still used by Operator’s today.

Site walkovers played a pivotal role during the study; the design team walked almost every street in the catchment to develop in depth catchment knowledge. This would prove invaluable during the latter stages of the project. All the survey specifications were peer reviewed by all parties to ensure no omission of key issues or elements. This collaborative approach was the first towards instilling a feeling of ownership and confidence in the study from all parties.

As with most water companies, shrewd spending has been a key driver for DCWW during Asset Management Period 5 (AMP5, April 2010-2015); as such a key driver for us was to ensure the survey specification was both targeted and affordable for a 2500ha, 120,000 population site.

The data collection exercise cost in excess of £1m and included a survey of every key asset (66 CSOs and pumping stations) in the catchment as well as 308 flow monitors, 390 manhole surveys, 16km CCTV surveys and over 200 hundred connectivity surveys (or impermeable area surveys).

4.2 Modelling

A new hydraulic model was built from scratch using Infoworks Collection Systems (CS) software. Geographic Information System (GIS) asset data and ground model data was used to generate a “rough model”; this was then refined with survey information and as built data. This was calibrated in two stages; a short term flow survey (8 weeks) and a long term survey at key network points (some 50 of the 308 flow monitors) to confirm any seasonal variation in infiltration and baseflow. Water level gauges were also placed in local watercourses at key sewer/river network locations to confirm any interactions.

Model run times during calibration and solution development/optimisation was a major challenge. The model, once calibrated and verified, was used to test a variety of large and small scale intervention schemes all having a varying and inter-related impact on the catchment. The model run time for an individual complete catchment solution scenario was approximately 4 hours for a 1 year dataset using a high specification optimised computer. Now consider the challenge of testing hundreds of solution scenarios against 10 years’ worth of rainfall data - to overcome this, a series of iterative steps were developed;

- Divide the catchment up into manageable subcatchments
- Select and optimise a typical “wet month” based on ten years of observed rainfall data to initially test each scenario. This ensures a better reflection of the impact of existing and proposed storage units than a stand alone synthetic storm i.e. the tanks are potentially already full when the rainfall begins
- Develop and model a set of bespoke solutions within each subcatchment
- Stitch the subcatchments and solutions together. Test the full model using the “wet month” followed by the ten year dataset when appropriate
- Assess the results and change/optimise the solution. Assess the “wet month” storm to ensure it provides a fair reflection on the ten year dataset.

These steps form the crux of the spill reduction strategy. It is a time consuming process which relies heavily on catchment knowledge and understanding.

A key requirement of the model was to replicate the impact of retro-fit Sustainable Urban Drainage Systems (SuDS) and the removal of surface water from the combined sewer. The model therefore needed to accurately reflect impermeable areas and infiltration throughout the catchment. To achieve this, targeted impermeable area surveys were undertaken based on land use data and observed flows. This was supplemented by “chasing” inflow and infiltration within the sewer network by constantly adapting the flow survey. GIS was also used to highlight potential surface water connections, areas of potential mass infiltration (large sewers through fields, adjacent to rivers, etc.) and large steep sewers capable of conveying excessive flows within the sewer network.

To accurately model SuDS elements a large amount of detailed site information is required; more detail than that afforded by catchment wide strategies e.g. local ground permeability data. Without this information, educated assumptions were made and the modelling process was simplified; a percentage of the impermeable area was assumed to be attenuated with a portion “lost” to soakaway and exceedance flows returned to the combined sewer with an appropriate delay.

The result of the process was a calibrated model which accurately reflected observed CSO spill counts as well as flooding. The collaborative approach ensured all key stakeholders felt trust and ownership towards the model.

4.3 Working With Third Parties

There were two key elements to this; firstly to improve the local public perception of DCWW and secondly to gain support and buy-in for the strategy from the local community.

A number of workshops and presentations were organised for local residents to come and learn about the study and what it actually meant for them as individuals. Simplified interactive maps and Google Earth tools were developed to explain the process and give the community a hands-on experience. Those who attended the workshops almost invariably left feeling positive about the strategy. However, it has been those who refuse to attend who tend to promote negative feelings towards the strategy. To provide the opportunity to speak with and influence these people, a full time display area will be set up in Llanelli town to allow residents to drop in, learn, and ask questions.

Working with local government and the press has been a difficult task and, despite the teams best efforts, press releases to date regarding the strategy have generally been negative – the headlines at least. This is predominantly due to the opinion of the vocal minority. Again, these vocal few have not made the effort to attend organised workshops and speak with the engineers, landscape architects and planners. To promote the strategy, DCWW have employed a full time communications professional to work with local government, the media and local residents to promote a positive and more educated view towards to strategy.

5 The Strategy

As part of the study two catchment strategies for comparison were developed. The two strategy options will be referred to as “traditional” - a storage solution, and “non traditional” - a suite of targeted sustainable solutions.

5.1 Traditional Strategy - Storage

A traditional strategy for delivering CSO spill reduction is to provide storage units to contain storm overflows during rainfall events and slowly return flow to the sewer network post rainfall, rather than discharging to a receiving watercourse.

It is easy to see why such a strategy is appealing; it is a known technology to water companies, their operators and environmental bodies. In addition, in the UK there is a back catalogue of successful design and construction experience. The overall result is a potentially lower risk solution.

However there are still risks associated with a traditional storage strategy. For example it is a risk that large tanks will fill and never empty, or future development and urban creep may significantly reduce the effect of the storage. Storage can also lead to increased operational costs, especially in pumped catchments such as Llanelli and Gowerton, and cause treatment issues due to an increased dilution of sewer flows.

The traditional approach sites storage at key CSO locations for obvious reasons and therefore does not necessarily address other key issues in the sewer network e.g. local pinch points. As such this approach does not alleviate all sewer flooding nor does it create enough headroom for future development in Llanelli and Gowerton.

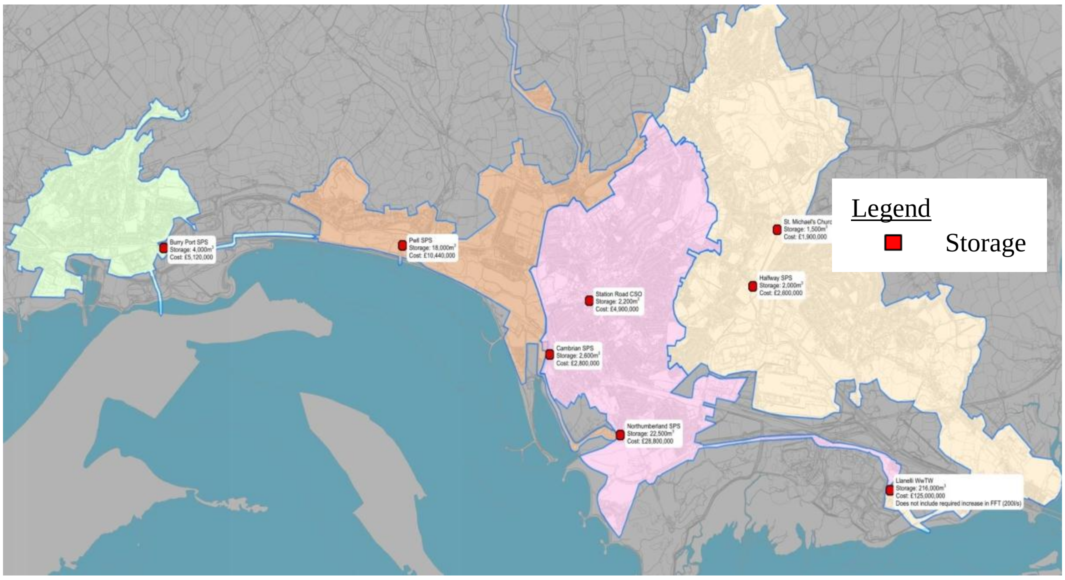

Figure 2; Storage locations in Llanelli

The storage volume required to achieve the ten spills driver in Llanelli and Gowerton is 432,280 cubic metres. The cost to provide this storage was estimated at £600m. The project team, including all key stakeholders, decided to take a different approach.

5.2 Non traditional - Sustainable Strategy

The aim of the on traditional solution is to provide a suite of targeted and sustainable intervention schemes which, when combined, deliver the three catchment drivers – spills, flooding, and development. Due to the varied nature of the catchment there is no "one size fits all" solution in Llanelli and Gowerton; this is likely to be the case across most UK catchments.

The Llanelli and Gowerton sites are extremely varied both within themselves and when compared to one another. Llanelli is generally a dense urban area served by combined sewers with fluvial and tidal issues. The Gowerton catchment is made up of small partially combined subcatchments linked by long trunk sewers which pass through fields and marshes. As such Llanelli has major sewer problems caused by large peaky storm response flows whereas Gowerton suffers from mass infiltration causing long duration spills and prolonged sewer drain down times.

Therefore each intervention scheme developed in Llanelli and Gowerton is an innovative and bespoke scheme adapted to suit particular site and flow conditions.

When confronted with a 2,500ha catchment area containing several CSO assets spilling to the receiving watercourse on an almost daily basis, it is difficult to pinpoint where to start. Effort was focussed based on a number of factors including flooding hotspots, operational issues, and areas contributing significant inflows and infiltration. A useful aid developed was a flow/area/flooding thematic map which was used to target key areas where interventions such as surface water removal could bring the greatest benefit. Figure 3 below shows the areas of greatest "flow and flooding" in red; consequently these areas received greatest attention in terms of intervention schemes.

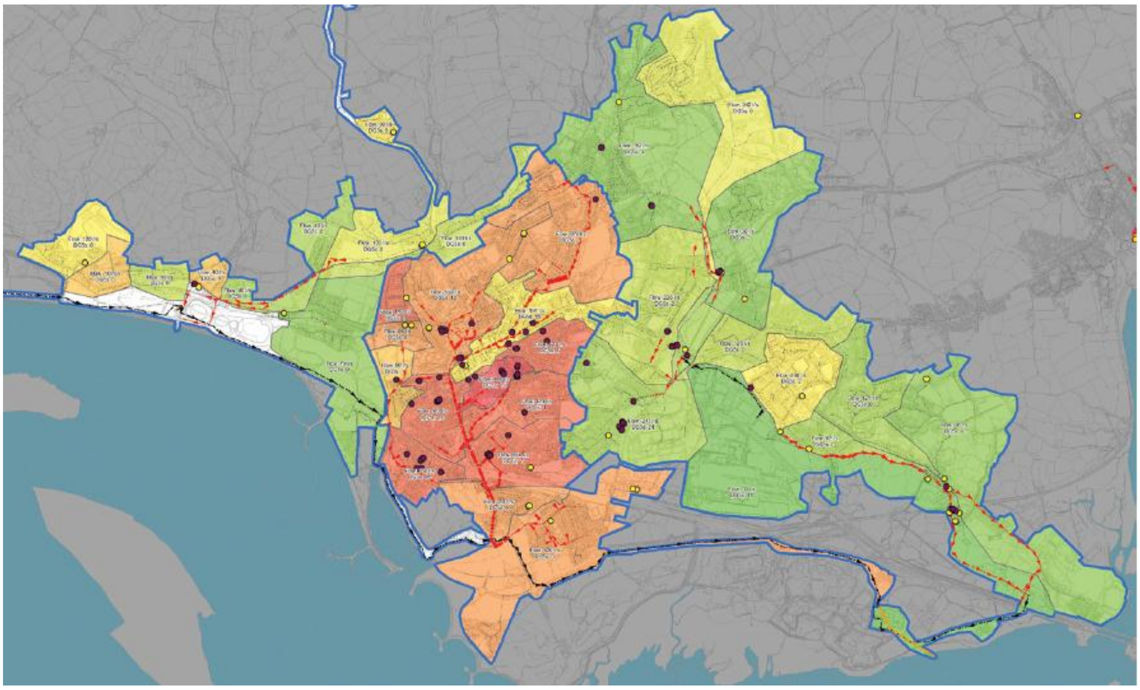

Figure 3: Flow/area/flooding thematic map

Some of the typical examples of intervention schemes developed in Llanelli and Gowerton are as follows;

Retro-fit WSUD

This report previously referenced retro-fit SuDS as a key element of the strategy. The integrated approach developed to manage and value stormwater run-off in Llanelli and Gowerton is better described as WSUD, which is explained further in section 7. This is surface water management at its most simple and effective; utilising existing topography and open space to convey and control surface water runoff through a series of swales, basins and soakaways which in turn can create amenity and ecological zones within a dense urban environment.

Making best use of existing assets

Unlike most of the sewers in the catchment which run at capacity during significant rainfall events, there are some assets which are not being nearly as stressed. The strategy includes schemes to divert peak flows between adjacent catchments, control flows to better utilise existing storage tanks and CSOs, and implementing smart controls to manage sewer flows during high river levels to alleviate flooding.

Managing land drainage

As part of the strategy a series of capital maintenance schemes to line and replace degraded sewers in areas of high groundwater was developed. In addition removal of land drainage connections from the public sewer was specified with provision of replacement filter drains, outfalls, etc.

Working with homeowners – small scale on a large scale

The partially combined nature of Gowerton creates a challenging situation for DCWW. The runoff generated by a single rear roof and garden is seemingly insignificant. However that insignificant flow accumulated from over 25,000 properties becomes a major problem downstream. The strategy proposes several Gowerton catchments to be retro-fitted with private rainwater harvesting units on a single household scale. The unit itself includes a slow drain mechanism, providing a small scale local solution to address a large scale problem. This simple technology can provide benefits to individual homeowners; the challenge remains for the team to work with the community to promote wide scale adoption of the technology.

Summary

The adopted strategy itself consists of 181 individual intervention schemes which, when fully implemented, will deliver the three key drivers. The strategy will also deliver a number of other less tangible social and environmental benefits. The predicted cost to implement the strategy is £145m.

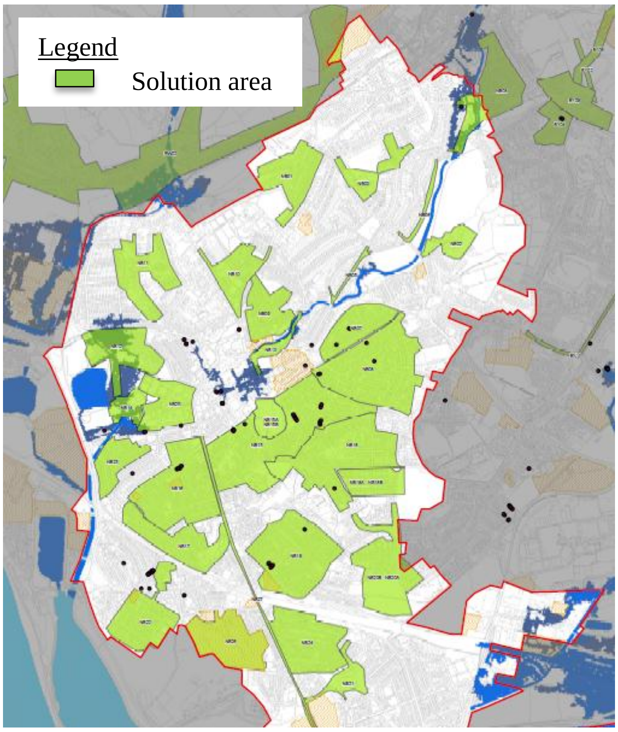

Figure 4; Map showing intervention schemes in central Llanelli

6 Prioritisation and Programme

Prioritising the 181 intervention schemes was a significant study in itself. A scoring system was developed based on different elements each with an agreed weighting. Elements included potential flow reduction (a key element of WSUD interventions) flooding impact, impact on spills, construction issues, confidence in design, carbon footprint, cost, social and environmental benefits. The outcome was 181 schemes each with a score out of 100.

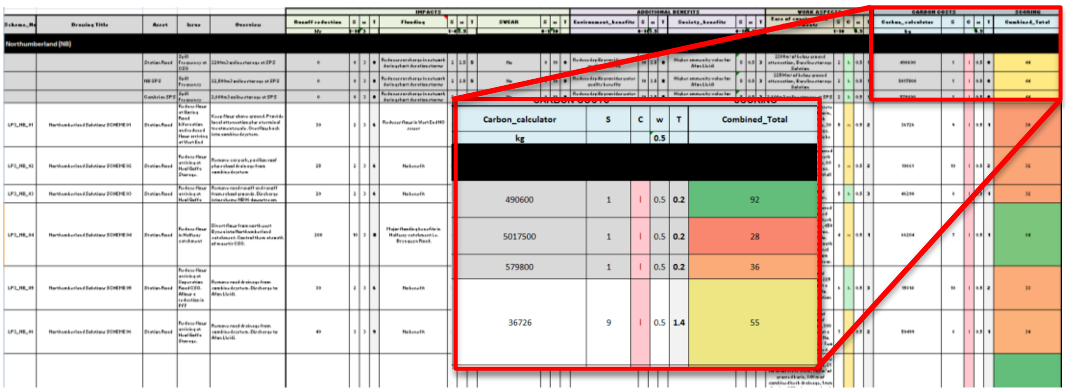

Figure 5; Prioritisation spread sheet

DCWW has the task of delivering this challenging strategy over an agreed period of time which is affordable and acceptable to the company, EAW, CCC, Ofwat and the local community.

Clearly it is not feasible to design and implement 181 schemes of varying size and complexity overnight. A short term and medium term goal has been agreed; to implement the top ten schemes by the end of AMP5 and provisionally the next highest ranking sixty four schemes by end of AMP6 (2015-2020).

7 Water Sensitive Urban Design

Due to the many tangible and intangible benefits associated with WSUD, several such schemes made it into the “top ten” during the prioritisation exercise.

WSUD is a relatively new term in the UK water industry; it refers to a sustainable and integrated approach to how we manage all forms of water in our towns and cities. It encompasses the very basic idea of treating water as the extraordinary resource it is, and not as a burden. A simple and relevant example could be this – a new development 50 years ago would require stormwater drainage; this would have been achieved using impermeable ground cover and pipe networks to get rid of the water. The next step was the idea of SuDS to return runoff rates to “greenfield” conditions; the stormwater is then controlled using storage units before entering the pipe network and the receiving water body. WSUD takes the final step to actually placing a value on that collected water; this can be in the form of re-use, creating an amenity area, promoting biodiversity, and so on.

This sort of technology is becoming commonplace within new developments; however retro-fitting WSUD features into an existing urban environment presents are far greater challenge, a challenge seldom adopted to address these kind of issues in the UK.

7.1 Risks

Risks associated with retro-fit WSUD includes design and construction risks associated with a new approach and technologies, adoption and maintenance risk, and securing buy-in from third parties - local residents and local government.

Design and Construction

As part of the detailed design stage each scheme is put through rigorous site investigation, modelling, design and peer review. The main constraint to date has been ground conditions – permeability rates, contamination, etc. To account for these issues, a catchment wide geotechnical desk study was undertaken which fed into the concept stage of siting potential WSUD schemes. At the strategic level a conservative approach to assessing the expected impact of each WSUD was taken – this is highly recommended for future studies.

The detailed modelling for each WSUD intervention scheme is being completed using a combination of Infoworks CS and Infoworks Integrated Catchment Modelling (ICM). Both software packages are capable of modelling detailed SuDS elements; ICM is being used for 2D flow routing with the aim to incorporate fluvial flows. The 2D element highlights the interaction of under capacity pipe networks and inadequate surface drainage elements – the proposals aim to provide an integrated solution to both. The photos shown in Figure 6 illustrate some typical WSUD elements designed in Llanelli as part of the "top ten".

Adoption

A major challenge has been how to settle agreements in terms of adoption – both the legal and practical issues. DCWW are currently geared towards maintaining buried pipes, tanks and pumping stations as opposed to swales, basins and soakaways.

A maintenance schedule has been developed based on consultation with all relevant maintenance teams including the sewer operators, highway maintenance teams, parks and ground maintenance staff, landscape architects, arborists, and engineers and planners. The output is an agreed maintenance schedule for every WSUD element with an associated annual cost factoring in short and long term maintenance activities. DCWW and CCC are currently in the process of determining a formal agreement in terms of roles and responsibilities.

Buy in From Third Parties

Retro-fit WSUD has a much greater impact on local residents than buried pipes and tanks. They will have a considerable impact, hopefully positive, on the surrounding urban environment in terms of look and feel, traffic movements, and potentially even house prices. As such the support of local residents is a major determining factor when assessing project viability. Firstly the Council will be put in a very difficult situation if they approve the works when the local community are against the proposals. Secondly, if the community have bought into the idea and design, they are much more likely to take an active role in maintaining the features.

During organised workshops the public were given the chance to speak with all the key stakeholders. The response was generally very positive and often provided constructive criticism which was in turn fed back into the design. For example some WSUD elements were moved and modified to minimise the loss of parking, especially on tightly packed terraced streets. In some cases proposed trees were moved a couple of metres to avoid a window, in some cases additional trees were provided at the request of the residents.

This positive response from residents, coupled with increased visibility through a full time communications professional and the proposed display unit in the town centre aspires to promote widespread acceptance of WSUD in Llanelli and Gowerton.

Figure 6; WSUD examples in Llanelli - before (left) and after (right) graphics

8 Conclusion

Developing and implementing a successful non traditional, sustainable and targeted approach to CSO spill reduction on this scale requires a concerted and considerable effort from many people and organisations. Not only will this lead the "better" solutions, it will also ensure a sense of trust and ownership in the chosen approach for all concerned.

Clearly it is not feasible to develop intervention schemes covering every last detail at a strategic level; however, to develop a realistic and meaningful sustainable targeted strategy requires a profound catchment understanding coupled with a modelling tool robust enough to test and refine a wide range of options.

The experience of this particular catchment has given us a direct comparison of a traditional storage strategy versus a non traditional targeted strategy for reducing CSO spills. In summary the storage approach delivered lower up front costs and requires less planning and co-operation with stakeholders, however the predicted implementation cost was higher; £600m versus £145.

A non traditional sustainable strategy can many deliver benefits beyond spill reduction; these include local and catchment wide flood alleviation, increased headroom in existing sewerage to allow for future development, and other social and environmental benefits like creating biodiversity and amenity areas. However, such a strategy does not come without risks, for example; relying on new technologies to deliver tangible results i.e. flood alleviation and spill reduction, changing and influencing the built environment, adoption issues and acceptance from third parties. The experience from Llanelli and Gowerton is that these risks are far outweighed by the potential benefits and lower outturn costs.

By this time next year there should be built examples of retro-fit WSUD elements in Llanelli in Gowerton. The key messages here have already been used to influence other schemes in Wales. Clearly it is not one size fits all, but it is hoped that the key principles developing here as we continue to implement these schemes will continue to be put to good use throughout Wales and perhaps the rest of the UK.