

# Retrofitting Sustainable Urban Drainage Systems

Case Study - Dunfermline

June 2004

Report No: NE02351/D1





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## Executive Summary

Dunfermline and the surrounding area is divided into two catchments. Dunfermline catchment includes most of the main city itself and outlying areas to the east and south. The northwest of the city and villages to the north and west form the Ironmill Bay catchment. There is an extensive combined sewer network and a number of separate areas with interactions between the systems.

The objective of this desktop study is to explore the feasibility and benefits of removing surface water runoff from the combined sewer network by the retrofitting of Sustainable Urban Drainage Systems (SUDS) into an existing urban catchment and to compare that with the costs and practicalities of conventional sewerage measures.

This study has been undertaken in partnership with the Scottish Environment Protection Agency (SEPA), Scottish Water (SW), Scottish Executive (SE) and Hyder Consulting (UK) Ltd (HCL).

Dunfermline was selected for the case study because a significant amount of data was readily available and the town represented a fairly typical conurbation.

A comprehensive area analysis has been undertaken for Dunfermline. For the Dunfermline and Ironmill Bay catchments as a whole, over 75% of the total contributing area and nearly 75% of the impermeable area drains initially to the foul and combined system. Only 19% of roof area is contributing to the surface water network.

Whilst road and roof areas contributed the highest percentage of runoff to the system, it is accepted that SUDS retrofit is more practicable at institutional sites (education, sports centres etc) than highways or residential areas.

A detailed analysis of the Ironmill Bay catchment identified a number of retrofit sites and suitable SUDS techniques. If the SUDS retrofit potential was realised at these sites, there would be less than 10% reduction in impermeable area and a predicted CSO spill reduction of just over 20%. Given that, in reality, it may only be feasible to implement schemes in a proportion of these sites, it is clear that SUDS retrofitting (using these sites) would only have a minor part to play in the resolution of problems on the foul and combined system.

A higher degree of benefit could be achieved by source control measures at individual properties. Removing additional runoff from residential areas in proximity to watercourses reduced the impermeable area to 24% and CSO spills to nearly 30%.

There are a number of constraints to SUDS retrofitting, or indeed new build SUDS, such as engineering feasibility, cost, ownership, liability, maintenance and community acceptance. Potential difficulties associated with SUDS retrofitting in Dunfermline include clay soils limiting the potential for infiltration, and a predominance of relatively high-density housing where changes to drainage would be disruptive. Further detailed investigation would need to be carried out to determine if, in reality, each site would be suitable for SUDS retrofit.

Climate change and the associated predicted increase in rainfall and storm events should be considered when implementing drainage schemes in any location. Predictions for the Dunfermline area, based on rainfall uplift values,

suggest that 70% more rainfall could occur during short storm events, and that major storm events could occur up to 5 times more frequently.

Case studies carried out on a number of sites have demonstrated that SUDS are cheaper to install and maintain than a traditional drainage system. A SUDS retrofit, however, is an attempt to implement sustainable techniques to a built environment that already has a drainage infrastructure in place. Additional costs associated with SUDS retrofitting, when compared to new build SUDS, are the separation of the combined sewer network to foul and surface water and excavation of existing infrastructure. Also additional land acquisition may be required to accommodate potential SUDS systems.

At the time of this report a possible incentive for removing a property's surface water contribution from the combined sewer network is a reduction in the Scottish Water Surface Water Drainage (SWD) charges. The SWD charge reduction for residential customers is based on the property's council tax band and is approximately 50% of the residential SWD charge. The reduction for business and commercial properties is approximately 43%.



# 1 Introduction

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## 1.1 Project Background

An increase in urbanisation, with the expansion of towns and cities, has usually been accompanied by an increase in impermeable areas. In these areas, rainfall can no longer infiltrate into the soil. The resulting increase in surface water runoff can lead to flooding and pollution events caused by insufficient capacity in combined drainage systems and watercourses. Conventional methods to overcome these problems have been to upgrade sewers and increase the capacity in drainage systems by constructing large storage chambers and storm overflows.

Combined Sewer Overflow (CSO) discharges combined with the culverting of watercourses have long been recognised as having a major contribution to the poor quality of urban rivers. Scottish Water (SW) is currently undertaking a programme of work (Q & SII) to improve existing CSOs that have been identified as unsatisfactory and do not comply with the requirements of the Urban Waste Water Treatment Directive.

Innovative technologies will increasingly be required to address current and future legislative requirements such as the EU Water Framework Directive, which will be the principle driver for water quality improvements in Scotland over the next decade and beyond.

Alternative methods of dealing with the capacity problems, known as Sustainable Urban Drainage Systems (SUDS), are based on controlling the surface water runoff before it enters the sewer networks. The reduction or removal of surface water from the system, allowing the system to convey foul flows only, alleviates the risk of flooding and reduces the pollution impact by ensuring foul flows are held in the system before being conveyed for treatment.

SW, SEPA, local authorities and other organisations in Scotland are represented on the Sustainable Urban Drainage Scotland Working Party and are committed to the SUDS concept. It is SEPA policy to promote sustainable urban drainage systems as the preferred solution for the drainage of surface water runoff, including roof water, for all proposed developments. SEPA Policy 15 (Regulation of Urban Drainage) acknowledges that SUDS can be designed to provide considerable attenuation capacity, which provides the benefits of:

- flood/flow control, and/or,
- reducing the load in the sewerage network, where discharges are made to the sewer.

Although the application of SUDS retrofits is directly outwith SEPA's regulatory remit, SEPA supports the use of SUDS to gain these benefits as they provide protection for the wider environment.

Use of SUDS in Scotland has, until recently, been concentrated mainly in new developments, such as the Dunfermline Eastern Expansion (DEX) site east of the town, which became the first major UK demonstration site for the emerging SUDS concept.

Very few SUDS have been retrofitted to help control runoff from existing urban areas. The retrofit process involves the construction of new SUDS facilities in



existing areas that do not have any dedicated storm water systems. Funding is available for the construction of pilot SUDS schemes, aimed at demonstrating the cost and effectiveness of the technology in comparison with more conventional engineering solutions. The current Ayrshire SUDS Retrofit Project for Bathing Waters Improvements, a research pilot funded by the Scottish Executive and run in partnership with SEPA and SW, will provide the experience to develop methodologies within SW's capital expenditure programme for reducing the impact of its assets on bathing water quality. It will also aim to develop a decision-making framework to assist in determining if, when and where SUDS retrofits are the most appropriate solution.

This study has been undertaken in partnership with the Scottish Environment Protection Agency (SEPA), Scottish Water (SW), Scottish Executive (SE) and Hyder Consulting UK Ltd (HCL). SEPA, SW and SE have contributed data in addition to the funding for this study. HCL are currently undertaking Dunfermline and Ironmill Bay drainage area plans (DAP) for Scottish Water and therefore have extensive knowledge of the Dunfermline and Ironmill Bay catchment area. Dunfermline was selected for the pilot desktop case study because a significant amount of data was readily available and the town represented a fairly typical conurbation. Retrofitting of SUDS may be more readily accepted in the Dunfermline catchment as a number of SUDS schemes are already in operation in the DEX site.

## 1.2 Project Objectives

The objective of this desktop study is to explore the feasibility and benefits of removing surface water runoff from the combined sewer network by the retrofitting of Sustainable Urban Drainage Systems (SUDS) into an existing urban catchment and to compare that with the costs and practicalities of conventional sewerage measures.

This report:-

- establishes existing surface water runoff volumes contributing to the sewer network in the catchments targeted for investigation;
- identifies the different land use types in the Dunfermline area, in particular the Ironmill Bay catchment, and ranks areas contributing to surface water flow in the combined sewer system by order of retrofit feasibility;
- identifies areas within specific subcatchments where SUDS could be retrofitted;
- presents quantified data on spill and volume reductions at selected storm tanks as a result of theoretical SUDS retrofitting;
- attempts to compare the costs associated with conventional sewerage systems such as CSOs and storm tanks with those of SUDS.
- considers the feasibility of and constraints on different SUDS technologies with regard to issues ranging from physical local conditions, through community and the local environment, through to future climate change predictions.

## 1.3 Catchment Description

Dunfermline town and surrounding area is the cultural and economic centre of West Fife. Once the capital of Scotland during the 11<sup>th</sup> century reign of Malcolm III, it has since developed and expanded as a result of prosperous weaving and coal mining industries. The population of the town decreased during the 1970's and 1980's due to the closure of the linen mills and coal mines, as well as the Rosyth Naval Base. However, regeneration in recent years has resulted in a steady increase in population to a current level of around 70,000, which is projected to increase.

Dunfermline lies to the west of the M90 motorway from Edinburgh to Aberdeen and to the east of the A985. These excellent transport links are the basis for the large projection in growth. There are a number of developments proposed, however the Dunfermline Eastern Expansion (DEX) alone comprises 4,000 new houses and 131 hectares of commercial properties that are presently greenfield sites to the east of the town. The re-development of Rosyth Dockyard is expected to bring major investment into the area. These large-scale housing and industrial developments are expected to have a significant impact on water consumption and use.

Dunfermline and the surrounding area is divided into two catchments (Appendix D). Dunfermline catchment includes most of the main city itself and outlying areas to the east and south. The northwest of the city and villages to the north and west form the Ironmill Bay catchment. There is an extensive combined sewer network and a number of separate areas with interactions between the systems. It is estimated that the sewer system in the Ironmill Bay catchment is approximately 55% combined and 45% separate. Within the Dunfermline catchment it is approximately 60% combined and 40% separate.

The topography falls from the northern edges around Hill of Beath and Kingseat towards Crossgates and Halbeath and Belyeoman, down towards Rosyth and Inverkeithing to the east and Ironmill Bay to the west. In general the land undulates across the catchment. The soils in the area are generally clayey, with impermeable layers at shallow depth. Although in the past the area has undergone extensive mining operations, the catchments do not appear to suffer from significant mining subsidence.

There is no information available to suggest any specific history of problems with groundwater within the catchments however, mining during the 17<sup>th</sup> and 18<sup>th</sup> centuries has had an adverse impact on the watercourses. Horizontal adits or entrance shafts were driven into the side of the valley floors to the coal seams within the hillside. The adit system totalled some 43km over the whole coalfield, the longest in the Dunfermline area being 8.7km. Their construction was sufficiently robust that many still act as drainage channels even though they have been out of use for over a century. Stream flows have been reduced due to the water capture of these adits. The impact has been so great that many streams dry up completely while the adits themselves are perennial.

Within the Dunfermline catchment boundary are a number of watercourses (Appendix E), the main ones being Mowbray Burn, the Lyne Burn and the Keithing Burn. The Lyne Burn is also the main watercourse within the Ironmill Bay catchment as well as the Torry Burn, which discharges into the Firth of Forth, the Tower Burn, the Broomhead Burn, the Baldrige Burn and the Crossford Burn. A number of unnamed tributaries throughout both catchments flow into these main watercourses.

The area has had a history of water pollution problems that include CSO spills resulting in faecal indicator organisms polluting watercourses, and foul sewer blockages leading to dry weather foul discharges via surface water sewers, facilitated by the presence of dual manholes. All these sources of pollution have caused certain watercourses in Dunfermline to be downgraded in the past (O'Keefe *et al*, 2003).

## 2 Development of Dunfermline Sewerage Network

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### 2.1 Sewerage Infrastructure

The WwTW for the Dunfermline catchment is located on the north side of the Forth estuary near the Forth Bridges. Areas within the catchment are connected by an interceptor sewer, which conveys domestic effluent, surface water runoff from impermeable areas, trade effluent and base infiltration.

The Ironmill Bay WwTW is located further west along the estuary, at Waulkmill. Three main interceptor sewers, the Broomhead Trunk Sewer, Tower Burn Sewer and Ironmill Bay Trunk Sewer drain this catchment to the WwTW.

Where separate systems exist, storm flows in both catchments drain to watercourses. Many housing developments utilise the principles of the separate system where both foul and surface water flows are routed in the one manhole. These dual manholes caused major pollution problems from storm sewage discharges or dry weather discharges via surface water sewers as a result of foul sewer blockages.

The principal consequence of the dual manhole policy was that the surface water sewer regularly carried foul discharges. The precise source of these discharges was very difficult to locate. A large number of low-side weir overflows were installed creating a parallel pipe system with multiple cross connections. This system, known as the Lyne Burn Sewer ends at a major overflow at Bothwell Street. The remainder of the system on the Tower Burn Sewer had no cross connections but was chronically overloaded as far downstream as a similar low-side weir overflow at Lady's Mill.

Improvements were required and since the surface water drain conveyed discharges from such a variety of locations, the solution adopted was to intercept both foul and surface water flows on the Lyne Burn Sewer. The flows collected would be directed through a combined sewer overflow with an off-line tank at the same site. A similar structure was needed on the Tower Burn branch. The sites for the tanks were at TA Yard for the Tower Burn and Rex Park for the Lyne Burn branch. Another tank was sited at Broomhead to alleviate problems associated with the Bothwell Street overflow. A map of Dunfermline and Ironmill Bay watercourses and tank locations can be found in Appendix E. Details of the storm tanks and their design can be found in Appendix A.

### 2.2 Maintenance and Operational Issues

A number of operational and maintenance issues were reported during the course of the studies, as follows:

- broken baffle board at Broomhead Tank; subsequently addressed;
- return pumps were non operational at both the TA Yard Storm Tank and Rex Park Storm Tank before the flow survey was due to commence. Between July and August 2002 both tanks were cleaned out and the return pumps subsequently reported fully operational.
- broken screen at Rex Park Tank; subsequently addressed

TA Yard Tank and Rex Park Tank struggled to drain down fully after a severe storm. Figure B.5.1 in Appendix A shows the layout of both TA Yard and Rex Park Storm Tanks. Flow enters the tanks via the CSO and then travels along a channel towards the blind compartment.

The flow fills the blind compartment first and then backs up the channel and spills into the first of the storage compartments, followed by the second and so on until all three compartments are full. All compartments, except the blind compartment, allow flow to spill into the surface water relief sewer.

Once the storm passes, the tanks drain down by passing flow through the drain down valves located on the bottom of each tank. The flow then finds its way to the return pumps, which pass the flow back into the combined system at a point downstream of the CSO.

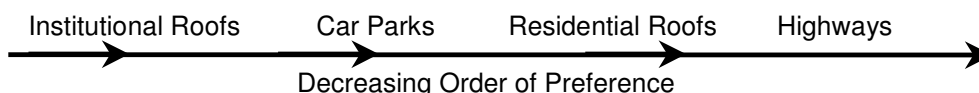
It is considered that the 200mm diameter drain down valves are too small and become blocked by settled solids when the tanks are full. In addition, the return pumps are consequently unable to cope with the flow that reaches them due to the high solid content.

The cost implications of such maintenance is discussed in Chapter 7.

## 3 Identification of SUDS Retrofit Sites

### 3.1 Introduction

Sheffield University has developed a SUDS retrofit decision-making framework, which uses a hierarchical approach to selection of retrofit sites. Swan and Stovin (2002) developed flowcharts to direct engineers to consider the range of options in a logical and efficient manner. The research describes the order of preference for introducing SUDS into different land use areas (see diagram below).



The framework recommends the use of retrofit SUDS devices to deal with drainage from institutional roofs in preference to car parks, then residential roofs, and finally highways. The rationale, which supports this hierarchy, is as follows:

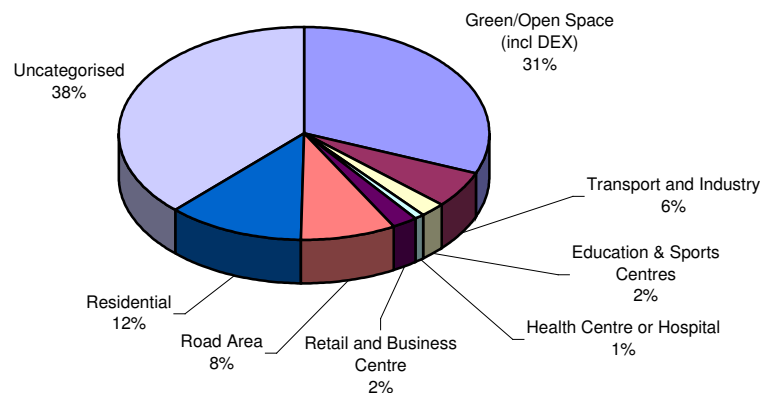
- Roof runoff is cleaner than that from car parks and highways.
- Drainage alterations at institutional buildings such as schools, colleges, hospitals, prisons etc – and particularly those in public ownership – are likely to be more straightforward to implement than those at numerous residential properties. Monitoring and maintenance are also likely to be easier.
- Car parks are relatively large paved areas that can generate significant volumes of runoff. Some existing car parks may be oversized, and space for SUDS could be found within the site itself. Altering a hard paved surface to, for example, permeable paving, with storage capacity underneath is likely to be less disruptive in a car park than in a highway. Water quality from car park drainage is arguably less variable than that from highways.
- Residential roofs, although having cleaner runoff than that from car parks, will typically have greater SUDS retrofit difficulties than car parks. A long row of terraced houses could, however, have a single drain that could be intercepted. Areas of council housing should be easier to alter than private homes. Even in private houses, a simple measure like the use of water butts provides a degree of attenuation. Disconnection to soakaways is not likely to be possible in areas characterised by clay soils such as Dunfermline.

### 3.2 Identification of Sites

To identify suitable sites for SUDS retrofit, the distribution of land use in Dunfermline was first determined, and is shown in Figure 3.1.

38% of the total land use in Dunfermline and Ironmill Bay is 'uncategorised', which includes cemeteries, residential gardens, driveways and grass verges. Green/open space is the second biggest land use type at 31%. Green/open space will not contribute significant runoff to the overall sewer network because of the presence of vegetation and the permeability of the surface. However, 'uncategorised' areas are considered to contribute runoff to the sewer network through infiltration.

The category Green/Open Space also includes areas of the Dunfermline East Expansion (DEX) which have yet to be fully developed. In the Dunfermline Local Plan it is envisaged that a further 255ha will be developed with approximately 2,000 houses. Nevertheless, the DEX development proposals incorporate SUDS so it can be assumed that runoff from roofs, residential paved areas and roads will drain to the SUD systems as green/open space.



**Figure 3.1 Land Use in Dunfermline and Ironmill Bay Catchments**

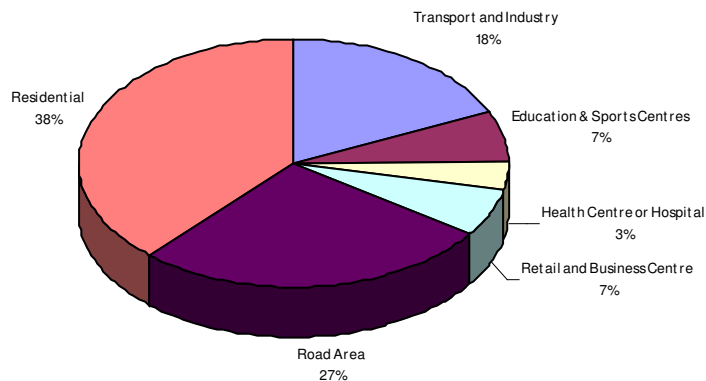
Under guidance from SEPA, the impermeable land use types were categorised in a similar manner to the hierarchy described in Section 3.1. The categories are listed below and presented in Figure 3.2:

- Retail and business.
- Health centres and hospitals.
- Education and sports centres.
- Transport and industry.
- Residential
- Roads

It must be emphasised that the selection was based solely on inspection of mapping – no further assessment of feasibility has been undertaken at this stage.

Based on the distribution of land use described, a GIS database of the six categories was created using MapInfo and digital OS background maps. Focussing on sites with significant roof and paved area, reference to drainage asset data allowed classification by drainage type (combined/separate). A drawing showing all land use across the Dunfermline area is shown in Appendix F (Dunfermline and Ironmill Bay area categorization).





**Figure 3.2 Categorised Areas Contributing to Combined & Separate Systems**

### 3.3 Area Analysis

A basic area assessment of both catchments as a whole is useful to provide a context for considering changes such as SUDS retrofitting. Hyder Consulting constructed hydraulic models for both the Ironmill Bay and Dunfermline catchments in 2003. The total area contributing flows is made up of impermeable (roof and paved areas) plus permeable areas. These areas contribute flows to either the combined sewer network or separate foul and surface water sewers. The drawing in Appendix G shows the contributing areas for the Dunfermline and Ironmill Bay catchments.

For the purpose of this analysis only areas contributing to combined sewers were analysed. For areas where there are separate foul and surface water sewers an assumed percentage impermeability of road/paved area was applied to the foul subcatchments to account for illegal surface water connections and deterioration in the foul systems that may have occurred over time. A percentage impermeability of surface water catchments was reduced accordingly to account for contributions to the foul subcatchments. Table 3.1 presents the results of this analysis.

Contributing Area	Roof Area (ha) A	Paved Area (ha) B	Impermeable Area (ha) C = A + B	Permeable Area (ha) D	Total Contributing Area (ha) E = C + D
Ironmill Bay Network	32.93	40.01	72.94	55.45	128.39
Dunfermline Network	128.53	150.65	279.18	234.36	513.54
Total	161.46	190.66	352.12 (55%)	289.81 (45%)	641.93

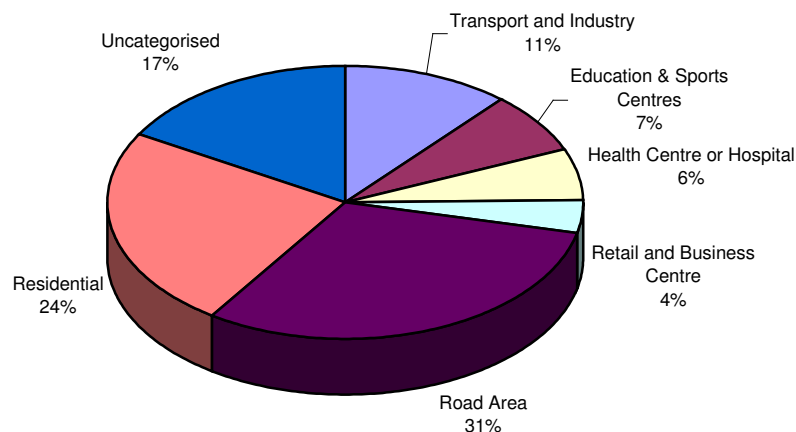
**Table 3.1 Catchment Areas Contributing to Combined Sewer**

GIS software was used to determine the percentage of categorised area that contributes surface runoff to the combined system, which is illustrated in Figure 3.3. The two biggest contributors of runoff to the combined sewer are residential areas (24%) and roads (31%).

Using the retrofit rationale (see section 3.1), the preferred sites to reduce the amount of surface water runoff entering the sewerage system, would be transport and industry, education & sports, health centres & hospitals and retail & business sites. These sites together comprise 29% of the catchment total.

With regard to road runoff, SEPA wanted to investigate the use of permeable paving in Dunfermline High Street. Further investigation determined that the steep slope initially prevented this being a viable an option, as runoff would end up ponding at the bottom of the slope. Manufacturers of permeable paving have since developed a method of construction that allows permeable paving to be used on sloping sites.

It is also of note that 17% of the contributing area is from uncategorised landuses. This 17% includes Dunfermline Abbey, a cemetery and residential gardens and driveways.



**Figure 3.3 Impermeable Areas Contributing to Combined System**

## 4 Assessment of Impacts

A more in depth analysis focussing on the Ironmill Bay catchment was undertaken and two significant reasons support this approach. Firstly, the Ironmill Bay catchment is smaller than the Dunfermline catchment and secondly, the critical positioning of the detention tanks within the catchment of Ironmill Bay. TA Yard detention tank is at the most downstream point of the Ironmill Bay sewerage network (within the limits of the city of Dunfermline) and therefore receives the majority of flows in the catchment. The area upstream of Broomhead detention tank is considered an ideal size for discreet assessment of the impact of SUDS retrofitting.

Runoff volumes and the potential impermeable area reduction from retrofitting SUDS were calculated for these sites. Within the Ironmill Bay catchment, a thorough analysis was carried out on both the TA Yard detention tank and the Broomhead detention tank (chapter 5). The upstream subcatchment of the Broomhead detention tank has a mixed land use and a large area of open space, which offer considerable SUDS potential which is discussed in detail in Chapter 5.

Analysis indicated that if the entire SUDS retrofit potential in Ironmill Bay is fully realised, there would be a 7% reduction in impermeable area (Table 4.1).

	Paved Area (ha)	Roof Area (ha)	Impermeable Area (ha)	Permeable Area (ha)	Total Contributing Area (ha)
Impermeable Area in Ironmill Bay	23	29	52	37	89
Potential SUDS	1 (4%)	2.5 (9%)	3.5 (7%)	2 (5%)	5.5 (6%)

**Table 4.1 Total Identified SUDS Retrofit Potential in Ironmill Bay**

### 4.1 TA Yard Detention Tank

Using the critical duration of a 5-year return period with a 60-minute duration, the reduction shown in table 4.1 would reduce the inflow volume to T.A. Yard detention tank by 50m<sup>3</sup> (0.5%) and spill volume to the tank by 50m<sup>3</sup> (1.5%).

The critical duration of the catchment was identified from the analysis of results from the summer and winter design storms with a return period of five years. The storms were generated using the UK Rainfall Generator tool that is present within InfoWorks. This produces design storms in accordance with the recommendations detailed in the Wallingford Procedure. Storms of 60, 120, 180, 240, 300 and 600 minutes were analysed and a critical storm duration of 60 minutes was identified as having the maximum impact on the system.

## 5 Broomhead Detention Tank Subcatchment

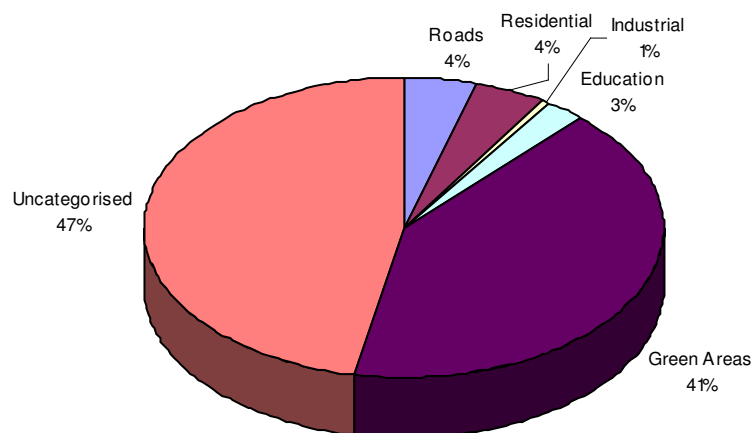
Broomhead detention tank is situated in the playing fields off Headwell Road in the Townhill area of Dunfermline. A description of the Broomhead detention tank is given in Appendix A. The area upstream of Broomhead detention tank was chosen as the study area because of the mixture of land use and also the amount of green space that could be utilised for SUDS ponds or wetlands. A drawing of the area categorization upstream of the Broomhead tank can be found in Appendix H.

### 5.1 Area Analysis

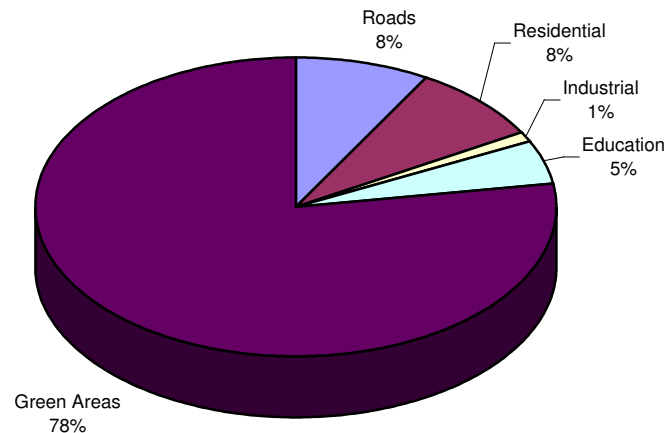
Figures 5.1 - 5.3 show the landuse analysis of the Broomhead subcatchment. The largest contributors to the combined network are roads and residential areas (Figure 5.3). Only two other categorised areas actually contribute to the combined network, these being education & sport centres and transport & industry. Initially only these areas were identified as potential retrofit sites as both have large impermeable paved and roof areas which could be retrofitted with SUDS. If these areas were to be fully realised it would account for 9% of the impermeable area upstream (Table 5.1).

	Paved Area (ha)	Roof Area (ha)	Impermeable Area (ha)	Permeable Area (ha)	Total Contributing Area (ha)
Impermeable Area upstream Broomhead CSO	6.46	6.65	13.11	11.45	24.56
Potential SUDS	0.58 (9%)	0.53 (8%)	1.12 (9%)	1.12 (10%)	2.24 (9%)

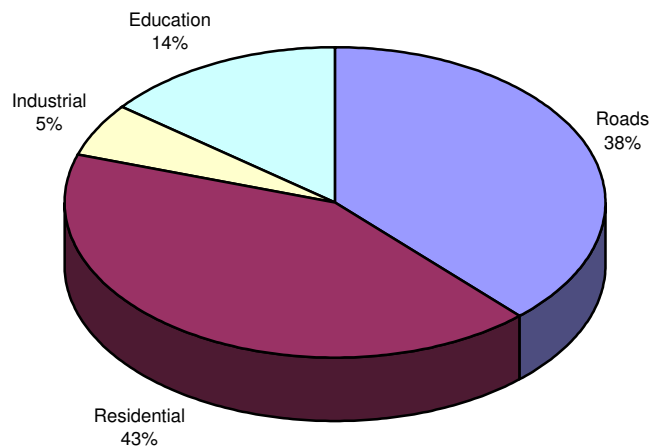
**Table 5.1 Total Identified SUDS Retrofit Potential**



**Figure 5.1 Landuse Upstream of Broomhead CSO**



**Figure 5.2 Categorised Area Upstream of Broomhead CSO**

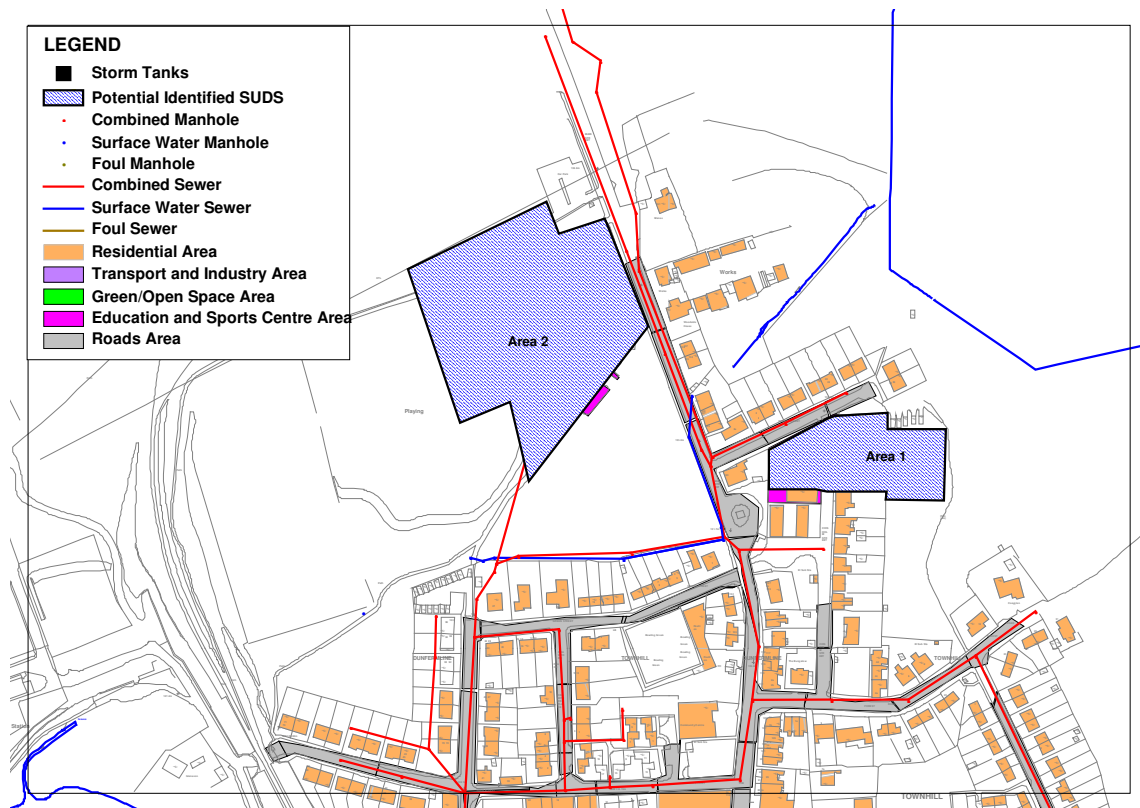


**Figure 5.3 Categorised Areas Contributing to Combined Network Upstream of Broomhead CSO**

## 5.2 Retrofit Sites and SUDS Techniques

Seven areas were identified as suitable for SUDS retrofit upstream of the Broomhead storm tank. These areas are a mixture of residential, industrial and leisure facilities.

The suitability of different SUDS techniques was considered. Dunfermline has predominately low-permeability clay soils therefore infiltration techniques will be limited. The concept described in the CIRIA Design manual for Scotland and Northern Ireland was used to identify the most suitable SUDS for each site. Consents from SEPA may be required where SUDS are discharging to surface waters.



**Figure 5.3 Area 1 & Area 2**

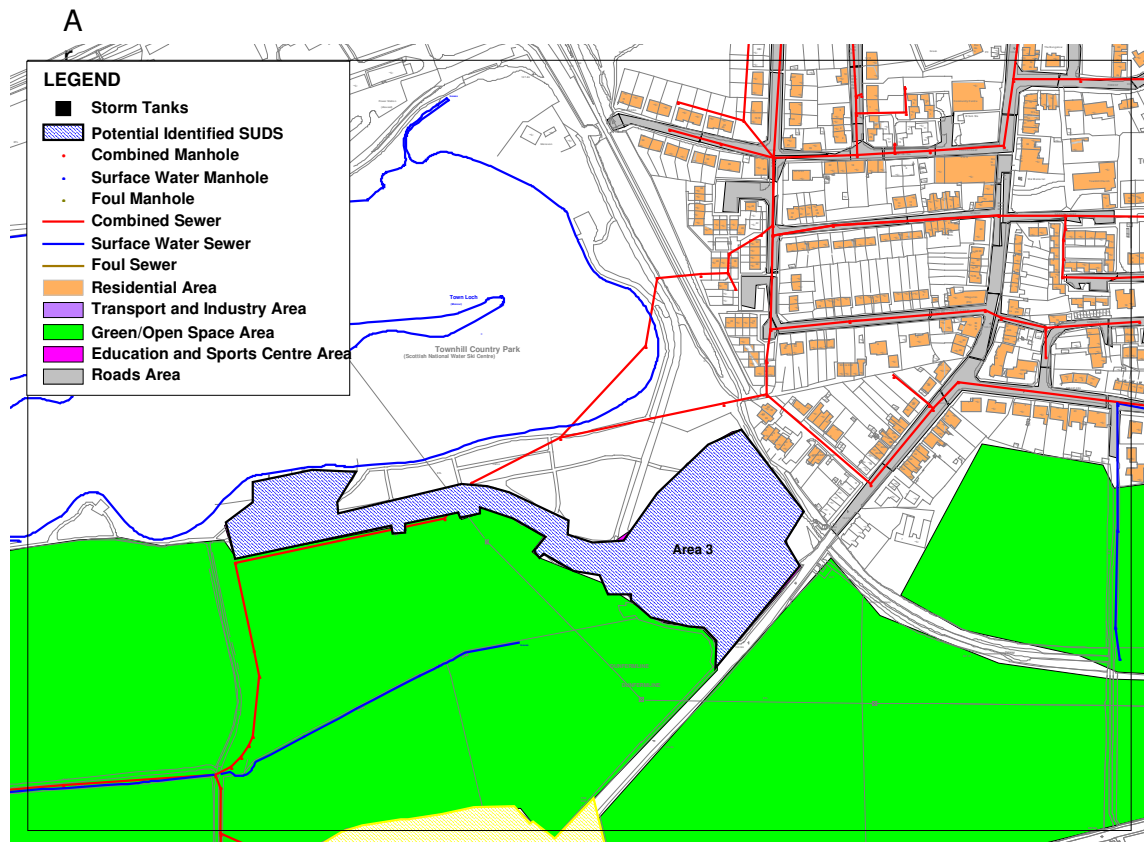
### **Area 1**

Area 1 is Townhill Primary School located off Wilson Street. Permeable Paving could be used to replace any existing impermeable paved surfaces and would also control the roof drainage. The permeable paving would provide attenuation and treatment of the surface runoff. An infiltration trench could then be used to convey the surface runoff from the permeable paved car park to the burn at the rear of the school.

### **Area 2**

Area 2 is Townhill Recreational Park located off Main Street. Permeable paving could again be used as source control also receiving runoff from roofs. An infiltration trench could be used to handle the discharges from the permeable paved areas to a nearby burn.

Another possible option would be to set up a regional control for both areas 1 and 2. A retention pond could be used to provide additional attenuation of flows and provide treatment. This pond would have to be located on the Townhill Recreational Park side of Main Street away from the residential area beside Townhill Primary School. Treated and attenuated flows could then be discharged to the nearby burn.



**Figure 5.4 Area 3**

### **Area 3**

Area 3 is the car park that serves Townhill Country Park. The existing impermeable car park could be replaced with permeable paving, which would provide source control. The resulting flows could then be directed to the existing combined sewer. In this case permeable paving will provide attenuation during storm conditions. A further option would consist of using filter strips to redirect flows to the nearby burn.

### **Areas 4, 5 and 6**

Areas 4, 5 and 6 are all residential areas. Area 4 incorporates the area known as the Fairways, which is located beside Canmore Golf Course. Area 5 includes the residential areas along Chamberfield Road, Kent Street, Lothian View and Townhill Road. Area 6 includes the residential area along Burt Street.

A number of options could be used to remove surface runoff from this area. One of these consists of totally separating the foul and surface runoff flows from the existing combined sewer. This would involve laying a new pipe to intercept foul only flows, convey them to a point downstream and reconnect them into the combined system. The combined sewer where the foul flows have been removed can then be used to convey the surface runoff to a nearby burn via a retention pond.

The second option that can be used would be to attenuate the flows draining from roofs and redirect flows from any impermeable residential area to road drainage. Modular block arrangements could then be used to attenuate road drainage. Hence flows from roof, road and any residential impermeable areas will be attenuated during storm conditions. The modular block arrangements can



be used in conjunction with a vortex flow control, which enables controlled discharge from the modular block arrangements to the combined sewer.

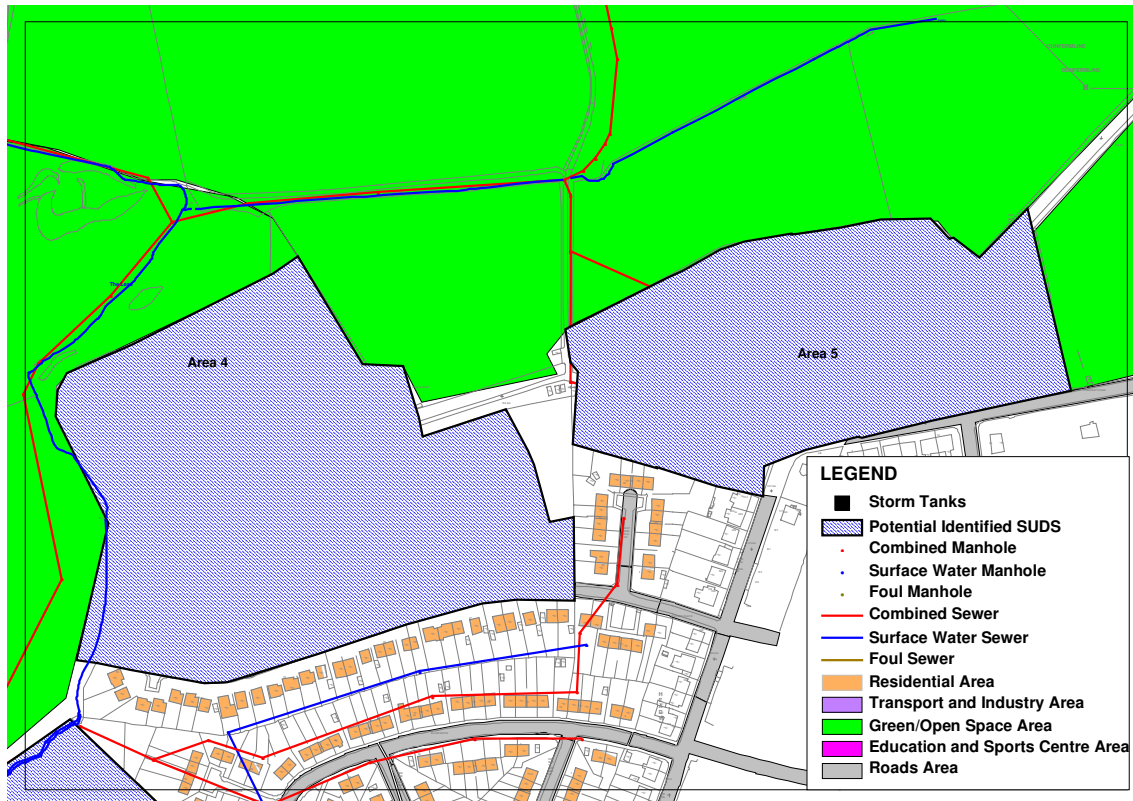


Figure 5.5 Area 4 & Area 5

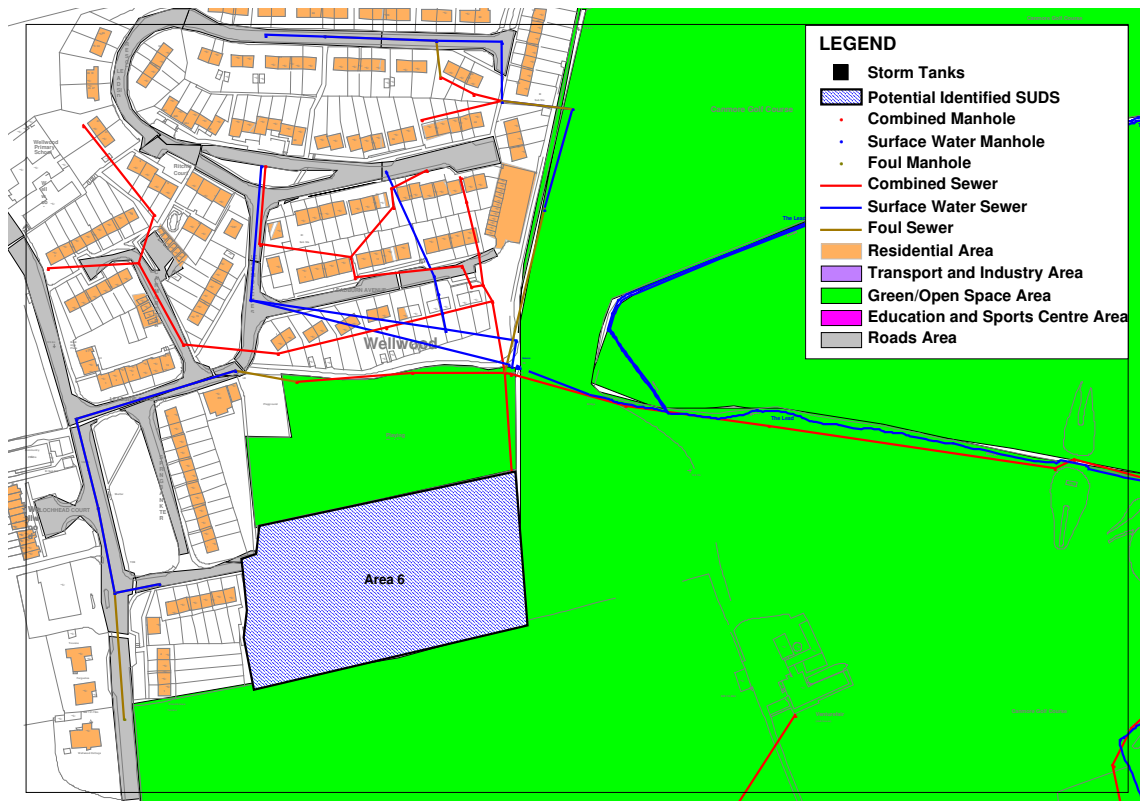


Figure 5.6 Area 6

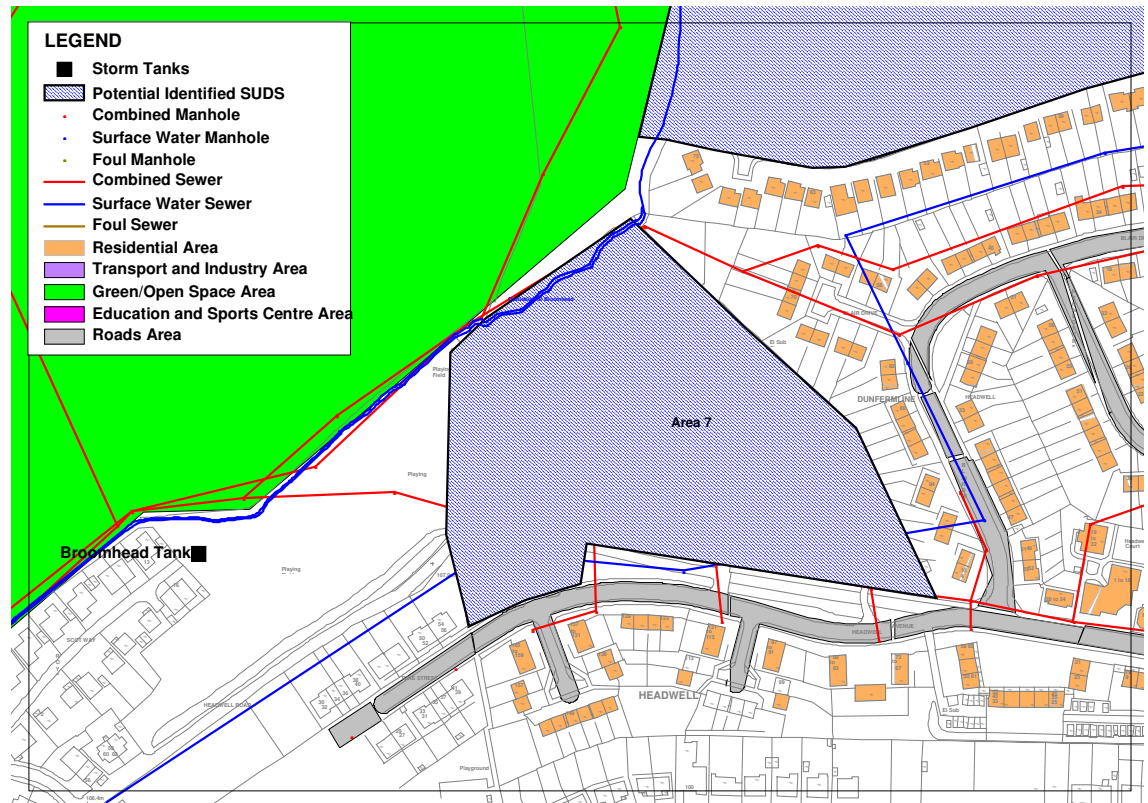


Figure 5.7 Area 7

### Area 7

Area 7 is located along Headwell Road and Canmore Grove and has a mixture of residential, industrial and educational properties. Permeable paving could be used to replace the impermeable areas around the schools, and industrial properties. Where this is possible the roof drainage could be redirected to the permeable paved areas. The discharge from these permeable paved areas could then be directed to the nearby Broomhead Burn. An oil interceptor may be required, however, some manufactures of permeable paving claim that the discharge from the permeable paving can be as “clean” as the water discharged from a modern sewage works.

Attenuation as described for areas 4, 5 and 6, can be used for the residential properties along Canmore Grove. The road drainage could be attenuated with the roof and residential impermeable areas redirected to the road drainage. Another option would be to use permeable paving along Canmore Grove with roof and residential impermeable areas redirected to the permeable paving.

## 5.3 Detailed Modelling

Following identification of the areas suitable for SUDS retrofit, detailed modelling was carried out on the subcatchment upstream of the Broomhead Storm Tank.

The first simulation run was based on existing conditions using a typical year rainfall set (obtained from SW). From this, the volume entering the CSO, the spill frequency into the storm tank and the spill frequency from Broomhead Storm Tank into the Broomhead Burn were obtained for a typical year. It also provided a benchmark for any reductions to be measured against.

Firstly a conventional solution was considered. This involved construction of new foul pipes intercepting all foul connections and conveying them forward to the WwTW. This would eliminate the need for a CSO structure at Broomhead, as the area upstream would effectively be on a separate sewer system. The existing sewers would then be used to convey all surface runoff, which could be discharged to nearby watercourses with or without treatment.

The surface water flows from areas where potential SUDS retrofits could be undertaken were then removed from the model. A plan showing the areas omitted can be found in Appendix I (Ironmill Bay Potential SUDS retrofit sites). These areas are essentially transport and industry and education & sports centres and contribute about 9% of the total impermeable area upstream of Broomhead CSO. The reduction in volume to the tank is 16.8%, the reduction in spill frequency per year to the tank is 6% and the reduction in spills per year from the tank to the watercourse is 21.9%.

The scope was widened to remove runoff from some residential areas including Burt Street in Wellwood, Fairways, Chamberfield Road, Kent Street, Lothian View and Townhill Road. These areas were selected as they were in close proximity to local watercourses. The results from the detailed modelling analysis are presented in Table 5.3. The inclusion of these areas reduced the impermeable area by a further 15% (a total reduction of 24%). With runoff from these areas omitted from the model, the typical year was simulated again. The reduction in volume to the tank is 33.4%, the reduction in spill frequency per year to the tank is 10.2% and the reduction in spills per year from the tank to the watercourse is 28.1%.

Scenario	Impermeable Area (ha)	Inflow to Tank (m <sup>3</sup> )	Spills to Tank		Spills to Watercourse	
			m <sup>3</sup>	No	m <sup>3</sup>	No
Existing	13.11	260,500	46,490	49	32,790	32
Foul Pipe	0	96,483	None	None	None	None
Potential SUDS Areas	11.99	254,380	38,698	46	26,201	25
Potential SUDS + Further Residential Reduction	10	241,998	30,983	44	19,950	23

**Table 5.3 Volumes and Spill Frequency per Year at Broomhead CSO**

## 6 SUDS Feasibility & Constraints

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Whilst a number of sites have been identified during this study on the basis of land use, not all of these may be suitable for retrofitting. There are a number of further issues relating to SUDS retrofitting or indeed new build SUDS, which require consideration, such as engineering feasibility, cost, ownership, liability, maintenance, community acceptance and, not least, climate change. Further detailed investigation would need to be carried out to determine if a particular site would be suitable for SUDS retrofit. Issues that will be common to the majority of sites are described below.

### 6.1 Physical Factors

SUDS consist of a flexible series of options, which allow the designer to select the systems most suited to a site. Physical factors affecting the suitability as a site for SUDS retrofitting include:

**Land availability:** some areas may be too densely populated and/or no land may be available to accommodate SUDS. Even so, there may still be options available to provide attenuation e.g. tank sewer along with the use of vortex flow controls, or water butts fitted to individual houses.

**Slope:** many types of SUDS require relatively flat ground levels in order to work effectively. Certain systems can operate in steep slopes if designed correctly e.g. swales can be used if check dams are introduced along their lengths, to slow the velocity of flow.

**Soil:** soils in Dunfermline are classified as Soil Class 4<sup>1</sup> and defined as clayey or loamy over clayey soils with impermeable layers at shallow depth. This provides little opportunity for infiltration, limiting the use of such techniques unless the devices are under-drained.

**Groundwater:** the base of the SUDS should be a minimum of 1.5 m from any groundwater sources.

**Contaminated Land:** SUDS can be situated on contaminated land as long as remedial measures are carried out prior to the construction of the facility.

**Impervious Cover:** a certain water depth needs to be maintained to ensure some types of structure operate effectively for example ponds and wetlands need a constant supply of water to prevent them becoming stagnant.

**Gravity Operation:** the SUDS facility needs to be situated downstream of the area that it is draining, to eliminate the need for pumping.

**Access:** the site needs to have adequate construction and maintenance access opportunities.

**Traffic Use:** certain types of system such as permeable paving may not be suitable for areas that are heavily trafficked or used for heavy goods vehicles.

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<sup>1</sup> This soil class is derived from The Wallingford Procedure which classifies five soil types by Winter Rain Acceptance Potential (WRAP Class 1-5). This soil classification is used with The Wallingford Procedure (Runoff Model), a similar model to that used for the Ironmill Bay drainage area study.

## 6.2 Ownership

Many of the properties/sites which have been identified for retrofitting may be privately owned. The owner may be unwilling to release this land for the construction of SUDS (e.g. developers may be reluctant to use ponds in favour of a higher housing density). The most feasible options are most likely to be at sites under local council ownership.

## 6.3 Community and the Environment

As well as attenuating flows and providing water quality improvements, the introduction of SUDS also offers the additional advantage of creating new wildlife habitats. Dunfermline has significant areas of green space, which could be utilised and enhanced.

Consideration should be given to the scope for implementing ecological principles into the design and management of SUDS and other soft engineering structures. It is widely accepted that these schemes are part of a wider environment and as such should be integrated with existing semi-natural habitats, as well as with the needs of development. Above ground water bodies can be designed to maximise their wildlife value incorporating design features such as:

- irregular profiles and shapes;
- shallow pools;
- islands;
- encouraging shaded areas;
- avoiding planting of exotic species.

These soft engineering options allow water to be used as a feature rather than being removed as quickly as possible in below ground structures. Ponds and wetlands can be assets to the community, enhancing quality of life by providing attractive and tranquil green space in the midst of an urban environment. SUDS such as swales can also be used to provide recreational linkages (e.g. maintained paths and trails) and wildlife corridors between systems or between other water bodies.

There may be local opposition to open water bodies due to safety concerns. However, with proper design and construction (using barrier planting and shallow side slopes in ponds and wetlands), safety issues can adequately be addressed.

Environmental factors will also influence the selection of sites. Existing wetlands or ponds, particularly those that have been designated as being of environmental importance such as Sites of Special Scientific Interest, may not be suitable for surface water control, but SUDS could be used to improve surface runoff draining to such sites.

## 6.4 Climate Change

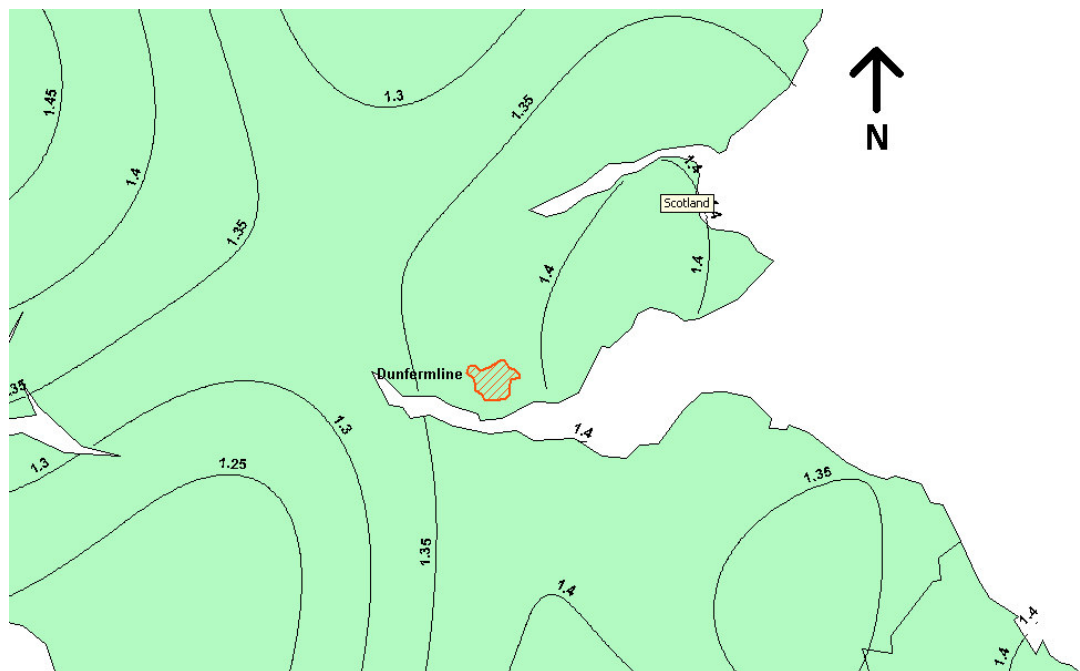
It is now almost universally accepted that environmental changes are taking place, whether it be due to man's global activities or to natural fluctuations. This has been recognised by the UK Government and the Scottish Executive, both of which have commissioned substantial climate change research. The water sector is a key area of concern because the potential effects of climate change, such as sea level rise and increased flooding, could have a significant impact.

Drainage policy needs to take into account the climatic changes that are predicted to take place during the 21<sup>st</sup> century, however difficult to quantify.

The Hadley Centre of the UK Meteorological Office is one of the world's leading climate change research centres. Their climate models are used by the UK Climate Impacts Programme (UKCIP) to predict changes in the UK. Two climate scenarios have been developed at the Hadley Centre: the UKCIP98 climate scenario and, more recently, the UKCIP02 scenario. This latest scenario has been designed to provide more detailed information about geographical variations across the UK and to provide more information about changes in extremes of weather and sea level. Further information on climate change can be found in Appendix B.

### 6.4.1 Predicted Climate - Year 2080

Met Office data for rainfall in the year 2080 has been imported into GIS together with data from the Dunfermline area to assess the changes predicted. The data is plotted as 'uplift' contours indicating predicted increases in average annual rainfall (Figure 6.1). A contour of 1.3 indicates an average annual rainfall 'uplifted' by 1.3 times that of today - a 30% increase. Figure 6.1 shows an increase of somewhere between 35% and 40% in average annual rainfall in Dunfermline by the 2080s.



**Figure 6.1 UKWIR/Met Office 'uplift' values for average annual rainfall in Dunfermline**

Table 6.1 shows uplift factors for various storm event return periods and durations. A 1 in 50 year, 15 minute storm event has an uplift factor of 1.7. This means that by the year 2080 this storm event will result in rainfall increased by 70% on present day levels.

Table 6.2 shows predicted changes in various storm event return periods in the year 2080. A 1 in 50 year storm intensity as it is known today has the potential to



occur once every 5 to 10 years by the year 2080. A 15 minute storm intensity currently expected once a year, is predicted to occur 4 or 5 times a year in 2080.

Duration	Return Period				
	1 in 1 Year	1 in 2 Year	1 in 5 Year	1 in 10 Year	1 in 50 Year
15 Minute	1.3	1.3 - 1.35	1.4	1.45 – 1.5	1.7
60 Minute	1.3	1.3 - 1.35	1.35 - 1.4	1.45	1.7
12 Hour	1.15 - 1.2	1.15 - 1.2	1.2 - 1.25	1.25 - 1.35	1.4

**Table 6.1 Rainfall ‘uplift’ factors in Dunfermline year 2080 (Met Office, 2003)**

Duration	Return Period				
	1 in 1 Year	1 in 2 Year	1 in 5 Year	1 in 10 Year	1 in 50 Year
15 Minute	0.3 - 0.4	0.6 - 0.8	2	5	5 - 10
60 Minute	0.3 - 0.4	0.6 - 0.8	2	5	5 - 10
12 Hour	0.4 - 0.5	0.8 - 1	2 - 2.5	5 - 7.5	5 - 10

**Table 6.2 Return period of FEH (Wallingford 1999) rainfall in Dunfermline year 2080 (Met Office, 2003)**

## 6.4.2 Implications

Given that the predictions for the next century indicate considerable increases in rainfall, and a greater frequency of the storm events we experience today, drainage systems must be in place to manage such rainfall. Clearly if existing systems are reviewed using future rainfall, considerable lengths of the systems that are currently acceptable could be shown to be inadequate. Any improvements to existing systems, or installation of new or retrofit systems could incur significant cost impacts associated with adoption of predicted rainfall design criteria and it is appropriate that these implications are discussed further. It is worth re-iterating that the degree of certainty with regard to hydrological change is acknowledged as being quite low, particularly for the extreme events that are critical for drainage design.

A further branch of the UKWIR study (see Appendix B) investigated the impacts of climate change on sewerage systems across the UK, focussing on flooding and CSO spills. The study found that there is a general relationship between rainfall uplift and the uplift in storage volume required to prevent sewer flooding.

The assessment of CSO spills found that the major impact of climate change is on the volume spilled rather than the frequency of spills. Spill volumes were found to increase by up to 180% across the UK with much smaller increases in spill frequency. The study concluded that as a result of the predicted increase in rainfall, associated flooding and CSO impacts the continued use of conventional solutions is unlikely to be sustainable in the future.

Drainage solutions to address deficiencies on the existing network should, at least, meet target criteria based on current rainfall. Applying the rainfall ‘uplift’ factors presented in Section 6.1 will greatly increase those costs. The decision



on whether to add the additional capacity needed to manage predicted future rainfall should be based on cost-benefit considerations.

SUDS will still be more sustainable than conventional methods but the changes in rainfall due to climate change would need to be taken into consideration when designing future SUDS solutions. A project titled “Adaptable Urban Drainage - Addressing Change in Intensity, Occurrence and Uncertainty of Stormwater (AUDACIOUS)” (Professor Richard Ashley from the University of Bradford) is a cross-disciplinary project that brings together hydrologists, building drainage and sewerage engineers, health, social and infrastructural economic specialists, to develop tools and procedures for the assessment and mitigation of the effects of climate change on urban drainage systems. The main contribution to knowledge will be in developing an improved understanding of the potential impacts of climate change on the performance of existing building drainage and local drainage systems and the downstream interfacial effects to main drainage.

## 7 Cost Estimates

### 7.1 Existing Storm Tanks

Scottish Water has estimated the cost of storm tank construction and commissioning as approximately £400 per m<sup>3</sup> of storage. Estimated capital and operational costs for the three storm tanks under consideration in Dunfermline are given in Table 7.1.

	Broomhead	TA Yard	Rex Park
Volume	190m <sup>3</sup>	2,500m <sup>3</sup>	3,000m <sup>3</sup>
Capital Cost*	£76,000	£1,000,000	£1,200,000
Operating costs	£750/year	£1,500/year	£1,500/year
Additional operating costs 2002-2003	£3,500	£17,197	£28,699
	Repairing faults that occurred during this period.	Replacing pumps, clearing chokes and emptying a build up of sludge.	Replacing pumps, clearing chokes and emptying a build up of sludge.
Electricity costs June 2002–June 2003		£401	£315

**Table 7.1 Approximate Capital Costs for Storm Tanks**

Notes: \*The costs do not include the laying of new sewers in the vicinity of these tanks.

Based on experience of previous projects HCL estimates that, in some situations over a forty-year period, power costs can contribute in the order of 40% of the whole life cost of the project. The elimination of any power requirements will realise operational expenditure (OPEX) savings and regarding wider considerations, will contribute to global warming and sustainability objectives.

### 7.2 SUDS

Case studies carried out on a number of new build sites have demonstrated that SUDS are cheaper to install and maintain than a traditional drainage system (Construction Industry Research and Information Association's Best Practice Manual for SUDS). Table 7.2 shows the cost of some SUDS systems that have already been implemented.

SUDS retrofitting is however an attempt to implement sustainable techniques to a built environment that already has a drainage infrastructure in place. There are additional costs associated with SUDS retrofitting when compared to new build SUDS. In a combined system, separation of the foul and surface water would have to take place. Existing roads and pathways may need to be excavated causing disruption to the public and would incur additional excavation costs and reinstatement costs. Additional land acquisition may need to be undertaken to accommodate potential SUDS systems.

Nevertheless, the installation of SUDS techniques is cheaper than conventional systems so any additional costs a SUDS retrofit would incur may still be cheaper than conventional drainage techniques.

Type of SUDS Technique	Size of Development	Cost
Extended Detention Basin, Swales, Filter Drains. Wetlands, Retention Ponds	370 hectares	£2,000,000
Extended Detention	15 hectares	£30,000
Swale, Pond	350 units	£30,000
Swale, Detention Basin	12 hectares	£45,000
Swales	250 houses	£26,000
Swale	220 houses	£26,000
Swales	50 units	£10,000
Swale, Detention Basin, Retention Pond	1,200 units	£500,000
Swales, Infiltration Trenches	54 units	£20,000
Infiltration Trenches	20 units	£15,000
Infiltration Trench	100 houses	£45,000
Infiltration Trenches	330 space car park	£100,000
Infiltration Trenches, Attenuation	50 units	£15,000
Infiltration Trench	40,000ft <sup>2</sup>	£50,000
Infiltration Trench	35,000ft <sup>2</sup>	£20,000
Infiltration Trenches & soakaways	25,000ft	£20,000
Filter Trench	9 units	£1,500
Filter Trench	18 units	£3,000
Filter Trench	55 units	£6,000
Filter Trench	2.5 hectares	£25,000
Infiltration Area	70 houses	£22,000
Infiltration Drains, Infiltration Area	80 houses	£32,000
Infiltration Drain	150 houses	£10,000
Pond	4 hectares	£65,000
Ponds	>300 houses	£75,000
Pond	4 hectares	£36,600
Wetlands, Pond	250,000ft	£200,000
Wetland	75km <sup>2</sup> catchment	£48,000
Attenuation Tank, Porous Pavement	3 hectares	£12,500
Porous Paving	32,000ft <sup>2</sup>	£75,000
Attenuation Ponds, Swales, Filter Drains	61 hectares	£300,000

**Table 7.2 Costs associated with SUDS**

Maintenance costs for SUDS have been generally reported to be less than conventional schemes as SUDS can be managed as part of normal landscape maintenance. Such maintenance is generally less costly than the specialist contractors required for conventional drainage systems. SUDS also eliminate the need for costly cleaning of gullies and interceptors.

## 7.3 Incentives

The major incentive for any individual to remove their surface water from the public sewer would be the reduction in SW surface water drainage charges (SWD) (Table 7.2). In order to avail of the reduction in SWD charges the property has to be metered. The SWD charge made for a property not draining rainwater to the public sewer covers the cost of drainage from public areas.

	Band A		Band B		Band C		Band D	
	East & West	North	East & West	North	East & West	North	East & West	North
Full SWD	£45.65	£49.68	£53.26	£57.96	£60.86	£66.24	£68.47	£74.52
Reduced SWD	£22.82	£24.84	£26.63	£28.98	£30.43	£33.12	£34.24	£37.26
	Band E		Band F		Band G		Band H	
	East & West	North	East & West	North	East & West	North	East & West	North
Full SWD	£83.69	£91.08	£98.90	£107.63	£114.12	£124.19	£136.94	£149.03
Reduced SWD	£41.84	£45.54	£49.45	£53.82	£57.06	£62.10	£68.47	£74.52

**Table 7.3 Scottish Water Surface Water Drainage Charges for Residential Properties 2003/2004**

Surface water drainage charges for business and commercial properties are dependent on the rateable value (RV) of the property. Fife Council defines this as the net annual value a property would generate in rent for one year. If the surface water from a business/commercial property drains to the public sewer then the SWD charge is 3.5p/£RV. If the surface water from a business/commercial property does not drain to the public sewer then the SWD charge is 2.0p/£RV.

For example, based on 2003/04 figures provided by SW, Townhill Primary School located in Townhill has a rateable value of £34,500. The school currently drains its surface water to the public sewer. The SWD charge would therefore be  $0.035 \times 34,500 = £1,208$ . If the school were to remove its surface water from the public sewer the SWD charge would be  $0.02 \times 34,500 = £690$  achieving a saving of £518 per year.

## 8 Conclusions

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55% of the landuse in the Dunfermline area is impermeable, and the majority of surface water runoff from this area (75%) drains into the foul or combined sewer network. The assessment identified road and roof areas as the two largest contributors of surface runoff to the sewerage system. Using a ranking system which highlights institutional roofs as most feasible for SUDS, and highways as least feasible, 29% of the total catchment areas is suitable for SUDS retrofit.

If the SUDS retrofit potential of these areas within the Ironmill Bay catchment are realised the impermeable area of the catchment is reduced by less than 10%. The inclusion of residential areas near watercourses, where surface water could potentially be discharged, would reduce the 'impermeable' areas by a further 15%, giving a total reduction of 24%. These areas are, however, the least feasible for SUDS retrofit due to the number of individual households. Nevertheless, a financial incentive exists in the reduced surface water drainage charges for removing a property's surface water from the public sewer network.

Given that it may only be feasible to implement schemes in a proportion of these identified sites, these figures suggest retrofitting SUDS would only play a minor part in resolving problems on the foul and combined system. Clearly targeting roads and residential roofs by source control measures would reduce the impermeable areas contributing to surface water runoff.

Detailed studies of the spill volumes and frequencies from storm tanks and CSOs suggests that the identified retrofit potential would result in a reduction in CSO spills from the Broomhead Tank to the watercourse of 22%. Removing further runoff from residential areas located near watercourses would reduce the CSO spills to watercourse by 28%. This reduction in spills could represent a significant environmental improvement in the receiving watercourses.

In terms of cost, numerous case studies have demonstrated that SUDS are cheaper to implement than more conventional options. SUDS retrofitting is however, likely to incur additional costs compared to new build SUDS in terms of additional land purchase and modifications to the existing network. In the long term, maintenance costs for SUDS are far lower than conventional techniques as they comprise mainly landscaping maintenance in contrast to technical engineering maintenance.

Selecting the Dunfermline area for SUDS retrofit has the following advantages:

- significant amount of green space available that could be utilised for SUDS techniques such as detention/attenuation ponds;
- SUDS already have public acceptance as a result of the Dunfermline Eastern Expansion project which incorporates SUDS to manage surface runoff.

Potential disadvantages associated with SUDS retrofitting in Dunfermline include:

- clay soils limiting the potential for infiltration;
- predominance of relatively high-density housing where changes to drainage would be disruptive.

In addition to local constraints, the philosophy of SUDS must take into account the predicted global changes in rainfall frequency and intensity. In the Dunfermline area such changes may bring about a 70% increase in rainfall during short storms, a five-fold increase in major storm occurrences.

## 9 Recommendations

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The following recommendations are made:

- Climate change predictions should not be considered lightly, and, whilst the feasibility of retrofit may appear to be limited by property owner involvement or public disturbance, it does merit further review in particular circumstances.
- A number of SUDS options and recommendations for specific areas are made in chapter 5.2. Further detailed investigation of these proposed retrofit sites would need to be carried out to determine if, in reality, each site would be suitable for SUDS retrofit.
- The potential for surface water runoff removal from council housing, roads and terraced housing should be investigated and encouraged.
- Control of runoff from residential roofs should be encouraged and facilitated, with particular emphasis on those near watercourses where SUDS may more easily be implemented.
- Emphasis should be given to financial incentives for residential properties from reduced water charges;
- Residential runoff control could be facilitated by an awareness scheme including provision of water butts for example, in a similar manner to council provision of compost bins in many areas.
- Consideration should be given to the potential for SUDS retrofit to become feasible in any particular area in conjunction with an adjacent new-build scheme, where the costs and disruption are therefore minimised.

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