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Sustainable Urban Water Planning Across Boundaries

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Flood Alleviation at Devonshire Park and Mayfield Road, Bradford, West Yorkshire, England

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INTRODUCTION

Several flooding incidents in recent years have caused considerable concern over flooding in the vicinity of Devonshire Park. Apart from the physical damage, local citizens suffer from the mental stress each time it rains, especially when thunderstorms are forecast in summer, even though a storm forecast does not necessarily mean that flooding will occur. There is a long standing history of flooding in the area; however, the perception amongst residents is that both the frequency and intensity is increasing.

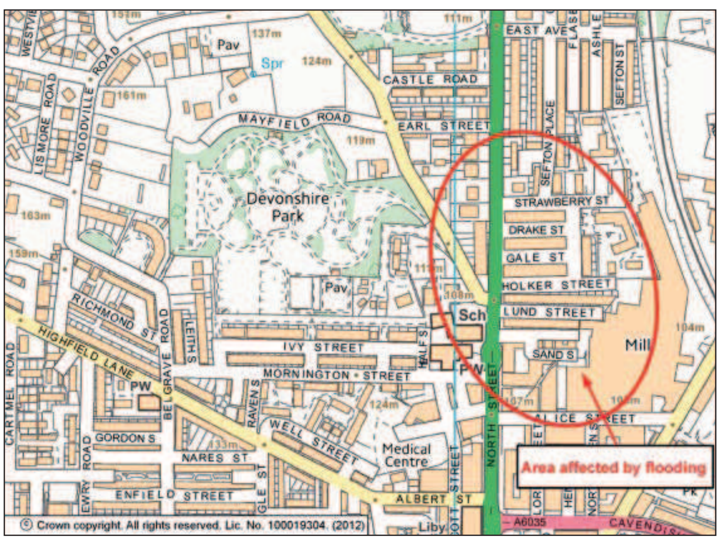

FIGURE 1. LOCATION PLAN

Devonshire Park is located immediately to the north-west of Keighley town centre. The ground slopes from west to east. The area is served predominantly by a combined drainage system, but there is also a complex, though poorly defined natural drainage system, much of which has been culverted and some of which has been destroyed. During extreme rainfall, water from the park and adjacent housing flows down the hill and into the area around Spring Gardens Lane and North Street. This causes flooding to properties along Spring Gardens Lane and North Street, and also to properties in lower-lying areas to the east of North Street. There is also flooding in the urban area to the south of Devonshire Park, but this problem is not described here. The area around Devonshire Park is identified in Figure 1.

Water flows from the hillside to the west of North Street. This is shown in Figure 2, in which the principal flow paths are shown in blue, public sewers in red and known locations of property flooding with red stars. In recent years, prolonged wet weather and/or extreme rainfall has caused water to flow from Devonshire Park and Mayfield Road (Locations 1 and 2 in Figure 2) and areas to the north and west of these. The main flooding problems occur at the junction of Spring Gardens Lane and North Street (Location 3 in Figure 2), where property owners have constructed upstands at the entrance to their properties to minimise ingress of water, and to the east of North Street culminating in the flooding of Tonson Court, which is a sheltered housing scheme operated by a housing association (Location 4 in Figure 2).

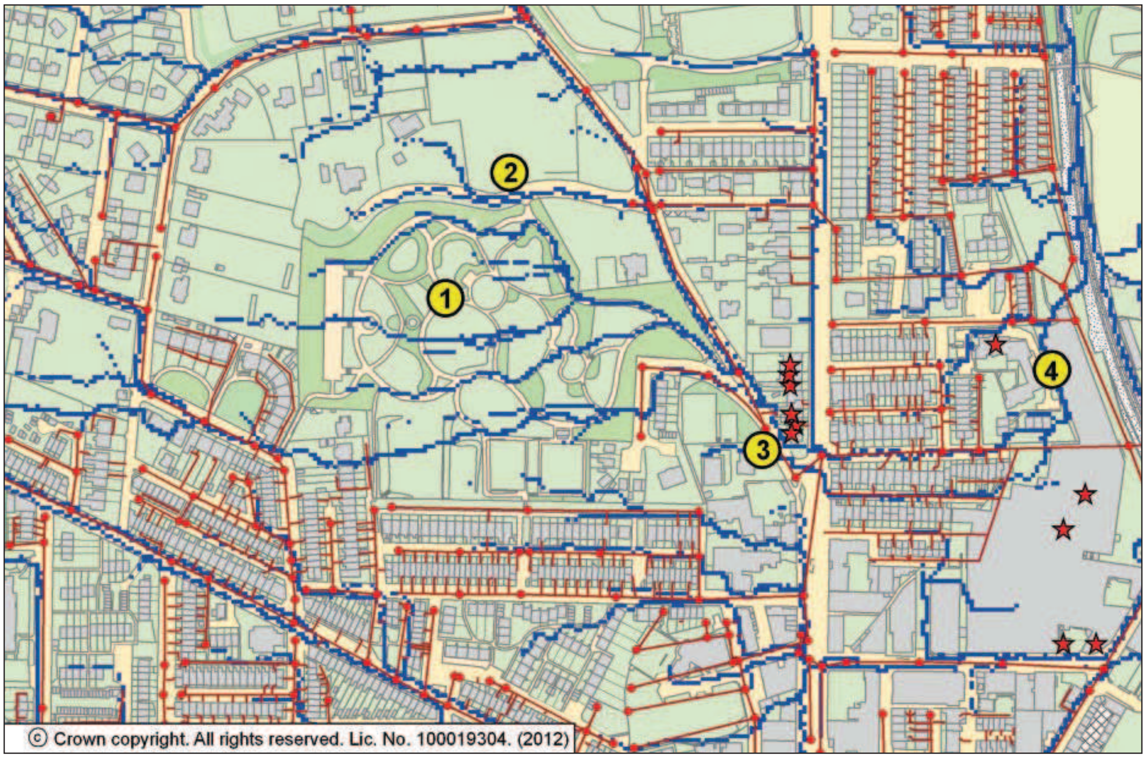

FIGURE 2. SOURCES, PATHWAYS AND RECEPTORS

MAIN STAKEHOLDERS AND THEIR INVOLVEMENT

It was immediately recognised that CBMDC had a major role to play in the flood risk management within the area. Notwithstanding the many other priorities relating to statutory responsibilities, and the lack of funding, there was a clear need for leadership and for the council to set an example as a key stakeholder. The role was to work with other key stakeholders to define the problems, facilitate the apportionment of responsibilities and identify appropriate adaptive responses to which it could contribute. It was evident that there was a need for more than a cursory investigation, and so steps were taken to reveal the location, size and condition of key watercourses and surface water drainage systems and to carry out GPS surveys in key locations to supplement the Lidar data which had been acquired in 2004.

Analysis of the rainfall data showed that the situation throughout the area was tolerable for rainfall return periods of up to 10 years. Above this there was a real risk of flooding somewhere in the area. It was also recognised that without an expensive and disruptive renewal programme, there was little benefit in increasing the capacity of the sewerage system. Even if that was done, it would still be necessary to manage the runoff from permeable areas and to compensate for the loss of capacity in the major drainage system. Finally, it was evident that infiltration was not the solution as the permeable surfaces were saturated when flooding occurred.

Community engagement has taken place throughout the duration of the investigation process. This has involved visits during and after the flood events, for the compilation of the questionnaires and whilst further investigations were being undertaken. Once an appreciation of the problems had been gained, a meeting was held with the local community to confirm that this appreciation was correct and to test the initial ideas for solutions. At this meeting further flood locations were identified and additional information on flood pathways and the drainage system was obtained.

Engagement with individual householders and landowners has continued where appropriate and, given that a stream of funding may emerge, it is now time to go back to the community to present the more detailed proposals worked up since the first meeting for assistance with prioritisation and to identify the focus of further investigations within the area.

The main stakeholders and their roles are summarised in Table 1.

Stakeholder	Role				Interest										
					Regulators and interest groups						Planning bodies				Others
	Decision-maker	Advisor	Developers	Long term ownership	Wild life	Heritage	Environment	Water quality	Water quantity	Local communities	Strategy planners	Development control	Building control	Road/Transport	
City of Bradford Metropolitan District Council	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
University of Sheffield		x													
Householders and landowners	x		x	x						x					

TABLE 1. MAIN STAKEHOLDERS AND THEIR ROLES

THE INVESTIGATION PROCESS

DOCUMENT INCIDENTS

In addition to the archive of photographs of the flooding, the incidents were documented in the CBMDC drainage incident database and many householders responded to the flood incident questionnaires that were sent out. The response was further improved following public meetings held to consult about the problems.

DATA COLLECTION

The data immediately available for the investigation was as follows:

- OS master map
- Sewer data
- Combined sewers
- Surface water sewers
- Terrain data (1 m horizontal and ± 150 mm vertical resolution).
- LIDAR elevation model
- LIDAR terrain model
- LIDAR terrain model with buildings
- Rainfall data
- 15 minute data from EA gauge sites within 10 km of Keighley
- 2 minute data from CBMDC rain gauge network commissioned August 2005
- 2 minute data from Yorkshire Water short term sewer flow survey rain gauge network installed May–July 2002
- Flood archives
- CBMDC drainage incident database
- CBMDC flood questionnaires
- Yorkshire Water incident database and Keighley High Level model build report

INITIAL REVIEW – CURRENT PRESSURES

The City of Bradford MDC took on the responsibility to lead the investigations. Not only does it have responsibilities of Civil Contingencies, it is also the highway authority and has responsibilities for drainage and as a major landowner in the area.

RAINFALL

Reports of flooding have been received on several occasions, but the major event affecting all of the area occurred on 11 August 2003. This was caused by extreme short duration rainfall superimposed upon relatively low return period longer duration rainfall. Nevertheless, the 2-day rainfall was significant enough to saturate the ground and with up to 40 mm of rainfall falling within 3 hours, a return period of 25 years, the resultant runoff caused widespread flooding in the area.

DRAINAGE SYSTEM

This area of Keighley is predominantly drained by a combined sewer system operated by Yorkshire Water. The natural drainage system is poorly defined, but investigations have revealed a piped surface water drainage system flowing from Devonshire Park, down Spring Gardens Lane, through the area affected by flooding and then eastwards to join the River Aire (Figure 3). When Tonson Court was constructed, the piped system was severed and the upstream section was diverted into the public sewer in Holker Street. Downstream, the culvert became blocked. Investigations have been carried out and the route of the watercourse has now been traced for some distance downstream, and work will continue until the entire route down to the river Aire is proven. As a result of the investigation, riparian owners are being contacted and work is now ongoing to clean the culvert and to check its structural condition.

The current challenge is to maximise the effective capacity of the minor drainage system and to compensate for the loss of the major drainage system, allowing members of the local community to take appropriate measures to minimise the residual risk to their own properties without causing problems to others. Given that there are significant flooding problems within the entire area, and that thoughtless actions in one location can cause problems further down the hillside, it was evident that the solutions developed should avoid the rapid conveyance of flows through the affected areas.

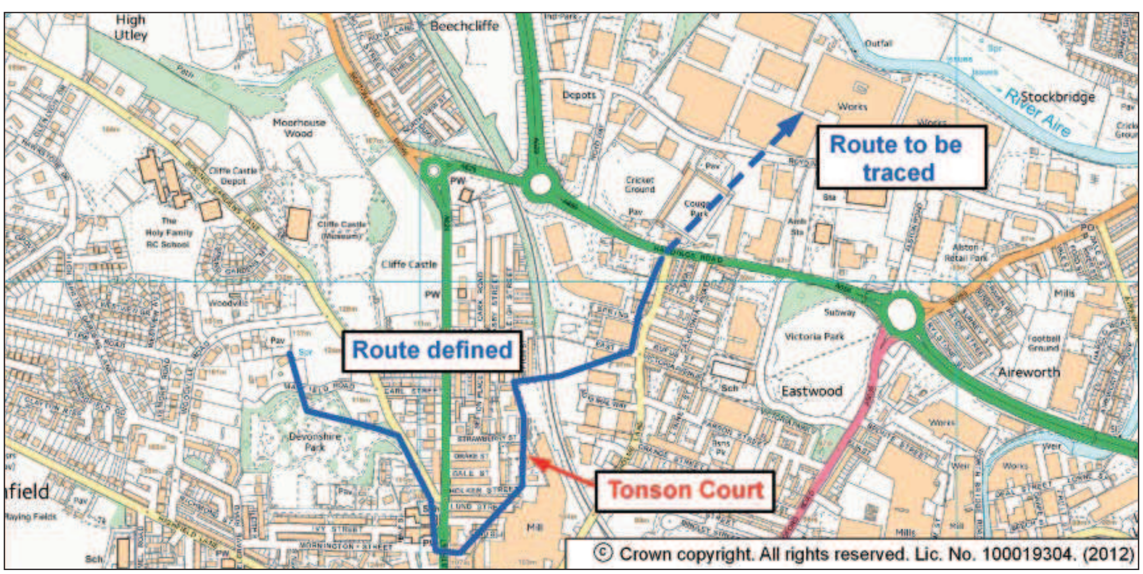

FIGURE 3. ROUTE OF THE DRAINAGE SYSTEM

TONSON COURT

Tonson Court was constructed on a former school playing field and provides sheltered accommodation for more vulnerable members of the community.

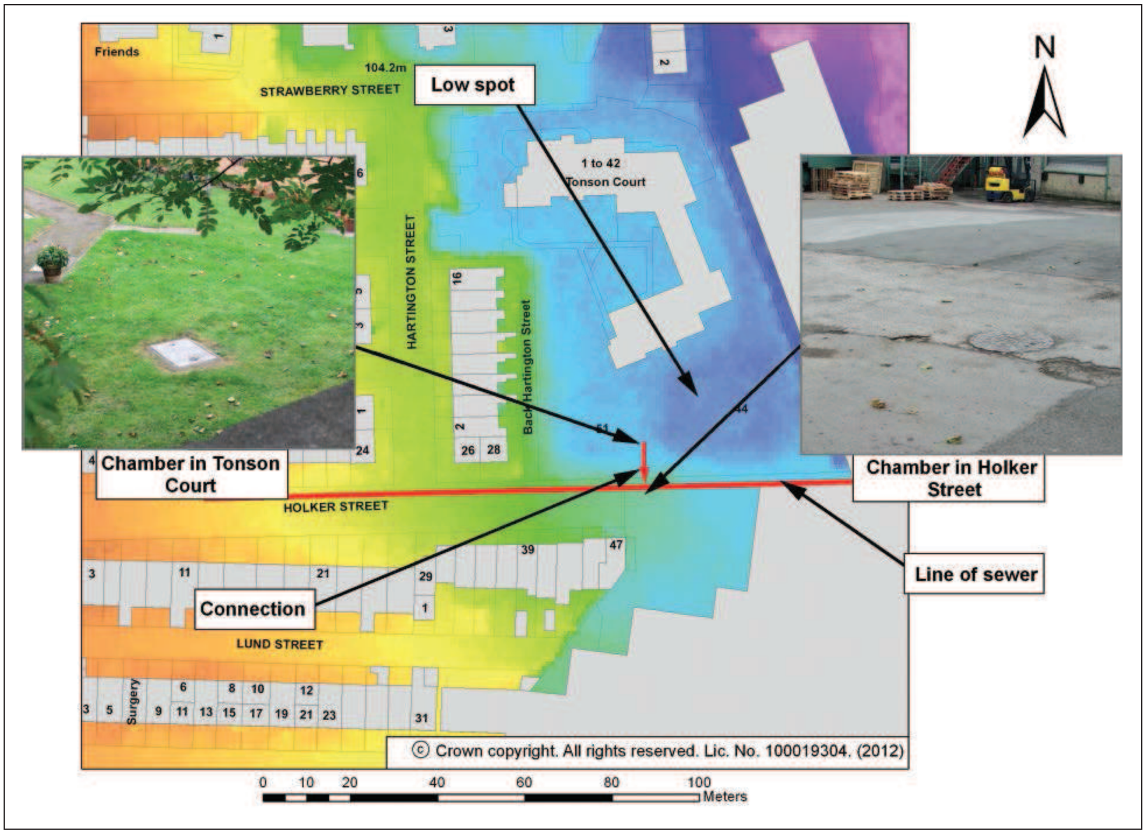

FIGURE 4. FLOODING AT TONSON COURT

The development has been constructed in a hollow and flooding frequently occurs. When the development was constructed, the surface water drain was severed and was connected to the combined sewer in Holker Street together with the drainage from the site. The ground level in Holker Street is significantly higher than that in Tonson Court, and so, as the sewer surcharges in normal operation, Tonson Court floods prematurely. The problem is exacerbated by the overland flow from the area to the west of North Street which migrates to the low point. There is evidence of flooding to a depth of approximately 300mm (Figure 4). The flooding has normally occurred in the summer months as a result of intense rainfall, and the physical damage is compounded by the distress caused to occupants.

INITIAL REVIEW – FUTURE PRESSURES

URBANISATION

There has been a significant amount of development within the catchment since the 1960s. This is illustrated in Figure 5.

FIGURE 5. STUDY AREA AROUND 1960 AND IN 2000

Figure 5 shows that in the 1960s the area to the north and west of Devonshire Park was largely farmland with some areas of predominantly low-density housing. During the intervening period, much of the farmland has been developed, mainly with medium-density housing, and a school has also been constructed

In addition to planned development, there has been a considerable amount of development within the curtilages of properties, and it is anticipated that this will increase into the future. This is known as urban creep or intensification. A study was commissioned in order to quantify the amount of creep over the past 20 years and to estimate the potential for creep into the future. Typical increases in impermeability are presented in Table 2, which shows the proportion of permeable area, paved area, pitched roofs and total impermeable area as a percentage of the total area within the curtilages of properties. The study only considered properties that were constructed prior to 1971.

	Low Density				Medium Density			
Year	Permeable Area	Paved Areas	Pitched Roofs	Impermeable Area	Permeable Area	Paved Areas	Pitched Roofs	Impermeable Areas
1971	72.9	11.8	15.3	27.1	65.5	15	19.5	34.5
1989	60.8	22.8	16.4	39.2	46.1	26.4	27.5	53.9
2002	55.5	27	17.5	44.5	44.2	27.3	28.5	55.8

TABLE 2. GROWTH OF IMPERMEABILITY 1971–2001

The main inferences that can be drawn from this information are that there was a significant increase in paved areas in both low and medium density dwellings during the period from 1971 to 1989 and that significant increases in the roof area of medium density properties also took place during the same period. The increase in both paved and roof areas slowed during the period 1989–2002, but did not stop. It is anticipated that a steady but slow increase in overall roof and paved areas within curtilages will continue as additional parking spaces are provided and those houses currently without extensions are further developed, and that low density development will tend to a peak of 55% impermeability, while medium density development will peak at 70%.

CLIMATE CHANGE

The impact of climate change is difficult to predict. As the amount of CO_2 emissions is dependent on global socio-economic responses, they are not within the control of local communities. The effect on precipitation is likely to be seasonal. During winter, the intensity and volume of rainfall is predicted to increase, whereas in summer, intensity is predicted to increase but overall volume to decrease. Because the change in precipitation are dependent on the CO_2 emissions this is difficult to predict, but a pragmatic approach of hoping for the best but preparing for the worst is being adopted and provision is being made for increasing the volume of storage should this prove necessary. In the meantime, a 10% increase in rainfall intensity and volume is being factored into the design. This equals the guideline allowance in PPS 25 up to 2055.

DRAINAGE ASSETS

Drainage assets have a long life, and it is not possible to “tinker” with them as small changes occur. From the perspective of the asset, major changes should only occur as the serviceable life of the asset ends.

WATER MANAGEMENT SOLUTIONS

SELECTED SOLUTIONS

RATIONALE BEHIND SOLUTION

Future urbanisation and climate change will continue to increase the annual probability of flooding, unless something is done to increase the capacity of the drainage assets. A strategic flood risk assessment of the Keighley area has shown that disconnection and source control are the most cost-effective way of reducing the impact, which means that solutions are required at source rather than at end of pipe. In addition, all available assets should be utilised. The blocked and severed culverts should be restored, and where capacity is exceeded, storage should be distributed throughout the upstream catchment.

The rationale behind the design for Devonshire Park and Mayfield Road is to utilise the full capacity of the surface water drainage system which runs through the area and to store excess flows from Devonshire Park and Mayfield Road when the capacity is exceeded. The reality of this is that the greater the flow that can be passed down the culvert, the less the storage requirement. However, the culvert serves an area larger than Devonshire Park and Mayfield Road and in the long term, its capacity should be apportioned across the whole area that it serves.

ELEMENTS OF SOLUTION

The elements of the solution are shown in Table 3.

Element	Action
Trace route of downstream culvert to river Aire, clean and reinstate to provide drainage outlet at Tonson Court.	Investigation by Bradford MDC. Cleaning and rein-statement by culvert owners.
Reconstruct severed culvert at Tonson Court.	Design by Bradford MDC. Reconstruction by Housing Association.
Connect Tonson Court surface water drainage and upstream culvert to new section.	Design by Bradford MDC. Connections by Housing Association.
Provide high level pumped connection to sewer for Tonson Court foul drainage.	Specification by Yorkshire Water. Connection by Housing Association.
Storage pilot project to reduce runoff from council owned land.	Specification and design by Bradford MDC.

TABLE 3. ELEMENTS OF SOLUTION

As a temporary measure, Yorkshire Water is diverting the surface water drainage system into the sewer upstream of the point where it enters Tonson Court.

DIMENSIONS OF THE SOLUTION

Extreme rainfall events

The Flood Estimation Handbook was used to obtain rainfall parameters for the Keighley area. These parameters were then used to produce synthetic summer rainfall profiles for events of different durations and probabilities.

Storage depth

Because flooding only occurs during extreme rainfall, it can be assumed that a combination of infiltration, surface ponding and the local drainage systems provide adequate capacity for low level flooding. Historical evidence suggests that the capacity is sufficient to contain flows from an event of 10% annual probability. Therefore the storage capacity required to contain an event with annual probability of 1% will be found by subtracting the volume of water generated by the 10% annual probability event from the water generated by the 1% annual probability event. This was determined for events with durations ranging between 15 minutes and 12 hours, and the peak volume occurred for an event of 2 hours duration. Making an allowance of 10% additional rainfall as a result of climate change, the storage volume was determined to be 220 cubic metres per hectare.

Storage volume

The area of Devonshire Park is 6 ha. Multiplying this by 220, the storage volume is 1,320 cubic metres and that in Mayfield Road is 220 cubic metres.
Storage in the form of SUDS was provided in Devonshire Park using a series of “trench-trough” structures (known as Mulde Rigole in Germany and wadis in the Netherlands, where they are widely used); see Figure 6. These take the form of troughs or depressions (swales), with gently sloping sides, set over trenches containing underground infiltration tanks or infiltration trenches with high void space.

FIGURE 6. TRENCH-TROUGH SYSTEM OR “WADI“ IN DEVONSHIRE PARK

FIGURE 7. COMPLETED STEPPED TRENCH SYSTEM ON MAYFIELD ROAD

The water from the troughs percolates into the infiltration tanks which are protected from sediment by a geotextile layer. The infiltration tanks provide subsurface land drainage to the troughs, thus improving their performance and reducing the general water logging of the ground that used to occur. Ground profiles were managed to direct the majority of flows into the trench troughs, and residual flows are collected in swales which are also connected to the drainage system. Controlled discharge from the infiltration tank units is directed to the drainage system in the park.

A stepped trench system was constructed on land owned by the City of Bradford MDC on the south verge of Mayfield Road with a capacity for 110 m3 storage. There is an option for another trench on the northern verge should this be required. Although benign with respect to the local environment, the trench-trough system on Mayfield Road is striking and brings attention to the drainage works that were undertaken in the area. The wadis in Devonshire Park look much like depressions in the landscape, and they neither add to nor detract from the previous aesthetics of the grassed parkland which existed previously.

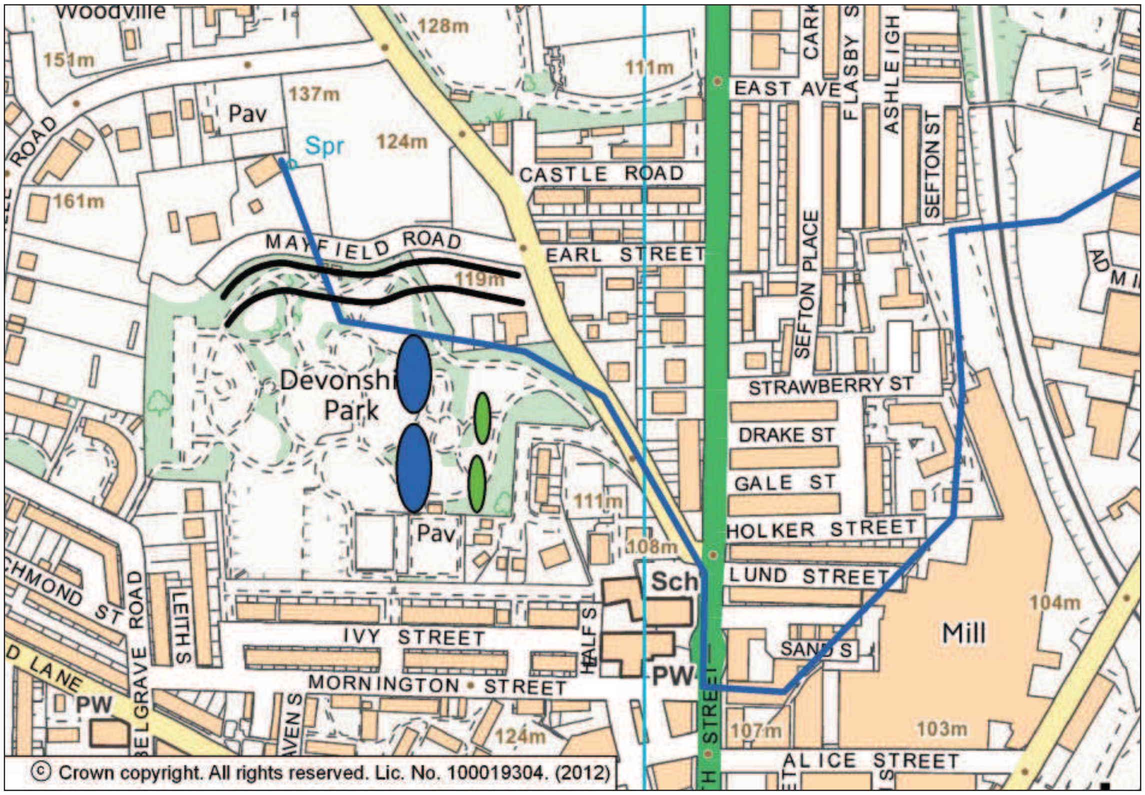

FIGURE 8. NOTATIONAL LOCATION OF TRENCH-TROUGH STRUCTURE

INTEGRATION OF WATER MANAGEMENT SOLUTIONS IN THE PLANNING PROCESS

As well as the flood abatement aspects of the storage pilots, their purpose is also to demonstrate how source control and disconnection measures can be built into the urban environment without detriment to the local community.

KEY SUCCESS FACTORS

The critical success factors enabling this scheme to go ahead were the presence of a strong driver, an overloaded drainage network causing flooding, and the presence of a local champion at the council who was able to provide the impetus behind the investigations and secure funding. A key part of the success of the project was the engagement of the community, which provided information on historical flooding and on drainage features no longer in use or filled in and helped to identify the required focus of investigations. The champion also worked in an enabling environment, with consistent political support (from Cllr Anne Hawksworth, who remained in office over a period of more than a decade) that allowed him to exercise interventions based on permissive powers, rather than through any regulatory duty.

SUSTAINABILITY ASSESSMENT

The main aim of the chosen options was to alleviate known flooding problems, reducing economic damage to local communities and improving the well-being of community members. This was achieved at no detriment to the local environment and minor improvements were made to the amenity value of Devonshire Park by reducing the water logging of the ground and hence enhancing its value to the community. Other benefits in terms of sustainability were found when comparing the impacts of the chosen option with those of the alternatives, all of which required considerable disruption within the local communities, either through work to be undertaken to provide storage or disconnect surface water drainage within properties or wide scale sewer capacity enhancements. In addition to the disruption, the alternative solutions would have required a much greater administrative and community engagement input because of the number of people and organisations that would be affected by the solutions and involved in the works. Also, the alternatives would involve significantly greater costs in terms of materials and reinstatement. Hence the chosen option was both socially and economically more sustainable.

DISCUSSION AND CONCLUSIONS

The scheme utilises the full capacity of the surface water drainage system which runs through the area and stores excess flows from Devonshire Park and Mayfield Road when the capacity is exceeded. As well as the flood abatement aspects of the storage pilots, the purpose of the design was also to demonstrate how source control and disconnection measures can be retrofitted into the urban environment with minimal disruption and without detriment to the local community. Since the works were undertaken the new drainage system appears to be working well, and there have been no reported flooding incidents despite significant rainfall in June 2007 and January 2008, when problems could have been expected to arise.

A strategic flood risk assessment of the Keighley area showed that disconnection and source control would be the most cost-effective way of reducing the impact, meaning that responses were required at source rather than at end of pipe. However, a large proportion of the surface water runs off the steep fields to the west of Keighley, and here the lack of capacity to infiltrate at source is a problem. The scheme considered the most efficient ways to use funding to provide the greatest flood mitigation benefits, and by utilising a portion of the open space available was able to achieve this.