Scottish WaPUG Meeting, 19 June 2003, Dunblane

Paper No 4 - The Strategic Response to Glasgow East End Flooding

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1. Introduction

Following a severe storm event in the afternoon of Tuesday 30 July 2002 major flooding occurred in many parts of the west of Scotland. Main railway-lines, motorways and many main roads were brought to a standstill. Over 500 residential properties experienced internal flooding and this resulted in many families having to be temporarily decanted to alternative accommodation. Worst affected areas were in the east end of Glasgow, East Dunbartonshire, and parts of South and North Lanarkshire.

The drainage infrastructure for Glasgow East End is seriously over-loaded. The capacities of most urban watercourses and sewers are well below the capacities of an ideal system, such that rainfall induced pluvial flooding is both widespread and regular. This was evident during the exceptional rainfall of July 2002, which indicated safe flood routes are limited. There is a backlog of investment in drainage infrastructure, which is now hampering efforts to regenerate the area, and the situation is attracting considerable public and political attention.

The lessons learned from this major flood event have highlighted the need for a strategic approach to drainage masterplanning in order that conflicting objectives can be addressed and an integrated and optimised investment plan promoted by the public agencies involved.

This paper describes how the Glasgow Strategic Drainage Plan has evolved and will be developed and considers some of the problems encountered in some detail.

2. The Flood Event of 30 July 2002

The storms at the end of July 2002 affected much of the UK and produced extreme amount of rainfall at several locations in localised intense heavy downpours. West and central Scotland were particularly badly affected.

The full storm began at approximately 10:30 on 30 July 2002 and continued for a total of approximately 10 hours. The full storm measured 75mm depth and had a maximum intensity of 94.5mm/hr. This equates to a maximum return period of 100 years. The maximum period within the full storm with no rain is 70 minutes, hence as this value is low, the full storm can be considered as one event. This full storm is therefore not typical of a short duration summer storm, but is more like a winter storm with high intensity summer storms interspersed within it. For comparison purposes, a 100 year return period 10 hour duration design storm generated using the Wallingford Procedure gives a total depth of 61mm and 62mm for summer and winter respectively, both of which are less than the 75mm recorded.

In the Glasgow area widespread surface water flooding ensued where heavy showers and thunderstorms occurred, small urban watercourse, drainage systems and sewers particularly badly affected. None of the main rivers (the River Clyde, River Kelvin, Whitecart Water and Blackcart Water) were affected.

3. Why did it Flood?

There is always a risk of flooding. This arises from the unpredictability of rainfall and the occurrence of blockages together with the limited capacity of urban drainage systems.

On 30 July 2002 the storm event that affected the East End was extreme with an estimated maximum return period of 100 years. There is no doubt from observers' accounts and videos that it was the intensity and volume of rainfall that caused flooding. Road gullies, drains, sewers and culverts are simply not designed to convey a 100 year storm event.

However, evidence from GCC, Scottish Water and the local community suggests that the risk of flooding is unacceptably high in parts of the East End. The key question is therefore not why did it flood on 30 July 2002 but why is flood risk unacceptable in parts of the East End?

The existence of flooding hot spots suggests that there are critical capacity limitations that increase the risk of flooding at some locations. It is not generally possible to unravel the complexities and inter-dependencies without detailed site surveys (the location and capacity of all drains and the location and performance of connections may be uncertain). For example, the immediate source of flooding may have been identified as say a sewer. However, the cause of flooding may well relate to the capacity of the sewer, the design of the CSO, the capacity of the recipient watercourse and the maintenance regime of any gullies and culvert screens.

As investigations into the flood event progressed it became evident that there had been considerable inter-action between the sewers and watercourses at certain flood locations. It is important therefore to understand the inter-dependency of these systems for the effectual drainage of an area and for the identification of possible solutions.

Within the majority of urban areas there are two drainage systems. One is naturally occurring, viz. streams and rivers while the other is designed, viz. the sewerage system. Surface water run-off from rainfall events will invariably migrate to one of these drainage systems or alternatively permeate through the ground and join the naturally occurring ground water table. Development within the urban area has affected the hydrological cycle via the paving of surfaces that were previously permeable and the creation of additional flow paths along which surface water runoff will pass much more rapidly than in the natural state. Surface water run-off that cannot be intercepted and conveyed by either the watercourses or sewerage system will cause flooding.

The primary purpose of the sewerage system is to convey household and trade effluent wastewater to a treatment facility. Traditionally, storm water runoff from house roofs, parking areas, streets and other hard surfaces has also been allowed to enter the same sewerage system. This type of system is commonly referred to as a combined sewerage system. A traditional combined sewerage system will also include a number of combined sewer overflows (CSO's). These devices act as 'relief valves' to prevent sewage from backing up within the sewerage system and entering people's homes during storm events. A traditional combined sewerage system such as Glasgow's was designed to cope with a peak rainfall intensity of 6 mm/hr, i.e. there should be no stormwater discharge at any CSO unless the rainfall intensity is in excess of 6 mm/hr. From the 1950's onwards, a twin pipe system started to be introduced nationally for new development where infrastructure allowed, to reduce the stormwater burden placed on combined sewerage systems with foul sewage only being taken to treatment with surface water sewers conveying storm water from paved and roofed surfaces to local watercourses.

A severe storm event will invariably expose inadequacies in the ability of the urban drainage system to assimilate and dispose of stormwater run-off. These inadequacies (e.g. lack of capacity, blocked or obstructed culverts and blocked gullies) will manifest as urban flooding in one or more of the following ways:

- Sewer flooding
- Roads flooding
- Watercourse flooding
- Surface water run-off flooding from non-paved areas leading to overland flooding.

The East End is drained by a number of tributaries to the Clyde including the Camlachie Burn and the Tollcross Burn. These watercourses drain urban catchments and therefore receive runoff from paved areas, roads, roofs and sewers. As the catchments of these watercourses have become developed the watercourses have been increasingly contained within culverts to the extent that today over 95% of the Moledinar Burn, Carntyne Burn, Light Burn, over 85% of the Camlachie Burn and over 30% of the Tollcross Burn flow within culverts. In the past there has been no planning control of culverts and hence landowners have constructed them with little or no consideration for any impacts beyond their boundaries.

Connections between sewers, drains and watercourses are many and complex. It has only been through studies and surveys by Scottish Water and Glasgow City Council (and their predecessors) that the number and location of these connections have become evident. What is evident is that the watercourses are now an integral part of the urban drainage system.

Arguably, responsibilities for providing 'effectual storm drainage' rest primarily with Scottish Water but because of the lack of capacity in the urban watercourses serving Glasgow East End, new storm drainage would have to outfall directly to the River Clyde and would therefore be inordinately expensive. Impermeable areas drained by most sewerage systems account for approximately 45 to 55% of drainage catchments with rainfall falling on the remaining areas either passing through the soil to join the groundwater table or migrating to local watercourses. Safe flood routing becomes a greater problem in Glasgow East End where over 90% of the watercourses are culverted leading to increased overland flow risks and potential flooding of low lying areas. It is important to note that urban flooding attributed to surface water overland flow is not the responsibility of any public agency in the same way that SuDS policies and procedures would be applied by several agencies for new development. There is currently no agency responsible for the provision of strategic surface water infrastructure and Scottish Water is not required to act as the urban 'land drainage' authority.

4. Making the Case for a Strategic Response

In the immediate aftermath of 30 July 2002, a group involving representatives of Scottish Water, SEPA and Glasgow City Council was established to examine the issues arising from this rainfall event. The group reported back in November 2002 with the following main conclusions:

- A multi-agency approach to the mitigation of flooding should be adopted
- Regular reviews should take place of monitoring and forecasting systems.
- Protocols for communications should be reviewed, i.e. triggers for major incidents.
- Public awareness should be raised.

After further investigations and a series of workshops in February 2003, Scottish Water concluded that there was a need for partnership working with other agencies to deliver an integrated urban drainage solution if the flood risks in the East End were to be reduced to an acceptable level. Scottish Water also postulated the need for/ benefit of :

- A single agency to be responsible got the provision/ funding of strategic surface water (storm) infrastructure within the urban environment.
- Sustainable Urban Drainage Systems (SuDS) to be designed and implemented for both new and existing development
- Urban watercourses to be managed to the same level as the sewer system.
- The development of a strategic drainage masterplan for Glasgow East End that considered both sewer and watercourse investment needs.

In March 2003 the chief executives of both Scottish Water and Glasgow City Council met and agreed that joint working was the way forward to address both short-term development constraints and long-term investment requirements in Glasgow. Agreement was reached to proceed with the development of the Glasgow Strategic Drainage Plan.

5. The Glasgow Strategic Drainage Plan

The development of the Plan is now underway and a management structure has been put in place (see figure 1). The structure provides for a Steering Group to own, guide and promote the Plan and for a Technical Group to deliver the Plan. The arrangement is discussed in the following paragraphs.

The Steering Group contains representatives of asset owners (Scottish Water, Glasgow City Council and other Local Authorities), co-funders (Scottish Executive, Scottish Enterprise) and regulators (SEPA). It is intended that each of the other Local Authorities will appoint a 'Liaison Engineer' to sit on the Steering Group and act as the key point of contact for the Glasgow Strategic Drainage Plan team.

The Technical Group is chaired by the Lead Consultant but includes Scottish Water's Catchment Consultants and technical representatives of both Scottish Water and the Local Authorities.

Both groups now meet monthly, with the Lead Consultant attending meetings of the Steering Group to report on progress, communicate findings as soon as possible, and highlight any issues which need to be addressed by the action of Steering Group members or their organisations.

A Communications Plan will be implemented shortly identifying all stakeholders and setting out procedures for communicating both internally and externally.

Commissions have been awarded to Hyder Consultancy in the role of Lead Consultant and Montgomery Watson Harza and Ewan Associates as Catchment Consultants. The Plan is governed by a Project Participation Agreement that includes provisions for confidentiality. Opportunities will also be given to research associates to participate in the development of the Plan.

The Plan will be created in stages to meet the needs and priorities of the partners and subject to available finance (see figure 2). Stage 1 of the Plan covers Glasgow East End and will be complete by Dec 2003 by which time each partner will be able to make its own internal business case for securing the necessary investment (see figures 3 and 4).

The key objectives of the project are:

- **Removal of development constraints** – the backlog of investment in drainage infrastructure is now hampering regeneration efforts and much needed economic development. The benefits of other major infrastructure investment, such as the M74 extension and the East End Regeneration Route, will not be realised if development is restricted.
- **Flood risk reduction** – the risk of flooding from sewers and watercourses is unacceptable in many locations. The flood event of 30 July 2002 affected hundreds of families and businesses and caused damage estimated at £100m. Climate change could increase the frequency of such events.
- **Water quality improvement –** many of Glasgow's urban watercourses have been heavily modified over the years with culverts replacing previously open channels. Despite increasing loading due to urban development, no further deterioration in water quality can be permitted. Whilst the performance of the sewerage system is dependent on the safe operation of numerous CSOs discharging surplus stormwater to watercourses, existing water quality is unacceptable and needs to be improved to meet increasingly stringent legislative requirements.
- **Habitat improvement -** Urban regeneration should provide opportunities for improving the environment and open watercourses should be considered as assets in this regard. A further project objective is therefore to explore the possible opportunities for "de-culverting" of

watercourses. Along with other measures such as provision of attenuation ponds, this could provide valuable habitat enhancement in an area where it is much needed.

- **Integrated investment planning** – the likely level of investment required to address development constraints, flooding and water quality needs to be understood. A business case needs to made to provide each stakeholder with the justification to secure the necessary funding support. In particular, it is considered that ERDF funding should be pursued before this becomes more difficult to obtain due to expansion of the European Union.

Benefits of an Integrated Approach to Drainage Masterplanning

There are significant benefits for Glasgow in adopting an integrated approach to drainage masterplanning. The following factors are significant :

- There can be considerable physical interaction between combined sewer systems and watercourses, e.g. via combined sewer overflows. Assessing both systems together permits a full understanding of the performance of both systems under potential loading conditions.
- Sewer systems, watercourses and treatment works, and the continuous and intermittent discharges therefrom, are subject to constantly changing loading due to urban development and regeneration. An assessment of population and land use will provide an understanding of short, medium and long term loads.
- Assessment of wastewater treatment capacities, together with an understanding of the assimilative capacity of receiving waters, will allow consideration of potential transfer/ treatment options.
- A review of drainage policy will allow appropriate design criteria to be identified and consistently applied in order to provide an acceptable level of service for both sewerage and watercourse investment.
- The recently commissioned White Cart and River Clyde Catchment Studies are looking at options to address the risk of flooding (tidal and fluvial) in the White Cart and River Clyde corridors. Appreciation of the behaviour of urban watercourses (and potential improvement solutions) will inform the design of any solutions for the White Cart and River Clyde and whether additional strategic storm water provision may be required.

The primary objective of the Plan is to develop a preliminary strategy for addressing the backlog of improvements needed to upgrade sewer systems and watercourses to a level which can then be sustained.

6. **Next Steps**

By the end of Stage 1 (December 2003), an Initial Strategic Drainage Plan is required for the East End in order to support investment planning and assist stakeholders to secure funding. This will require a number of parallel activities to be carried out on a 'macro' basis, rather than at the drainage sub-catchment level. These are described in the following paragraphs.

Sewerage Solutions – Macro Optioneering

The Dalmarnock WWTW catchment has been divided into seven sub-catchments for SW's Drainage Area Planning studies. DAPs are complete in some subcatchments but will not be complete for the whole WWTW catchment until April 2004. Engaging the existing catchment consultant to add the watercourses and hence produce an integrated catchment model is considered to be the most practical method of achieving the longer-term project objectives. This detailed modelling should commence as soon as possible during Phase 1 but is a lengthy process and will continue into Phase 2. The catchment consultant will also be responsible for producing a macro model of the East End drainage system (sewers and watercourses). This will be handed over to the lead consultant to carry out the optioneering.

This study will identify the various sources of impermeable area draining to the existing sewerage system and specifically roads runoff within watercourse corridors that could be re-routed back to individual watercourses. This study will compare the carrying capacity of trunk sewerage within each watercourse catchment and establish the collective infrastructure incapacity for the Q100 storm event.

Watercourse Solutions – Macro Optioneering

This study will examine the feasibility of watercourse solutions, both on-line and off-line. The use of on-line attenuation ponds is considered a sustainable solution with the additional benefits of amenity and habitat improvement. However, the scale of the problem may be such that transfer (off-line) options also need to be considered. The Catchment Hydrology scoping study will be the main data source for off-line watercourse optioneering.

This study will consider the practicality of shared tunnel solutions where part of the tunnel would be used to convey burn stormwater to the River Clyde while the other part would be used to convey sewage stormwater to either the River Clyde or to Dalmarnock Treatment Works. The costs and benefits of using the line of the proposed East End Regeneration Route as a surface water transfer route will also be assessed.

SuDS Macro Optioneering including Retrofitting

The scale of development and regeneration planned in the East End presents a valuable opportunity to switch over to more sustainable drainage practices. The use of SuDS simultaneously addresses quantity, quality and amenity issues. Whilst SuDS are actively promoted in Scotland, their use has been generally restricted to new developments.

This study will examine opportunities for using SuDS techniques in Glasgow East End. A proposal by the Pennine Water Group (Sheffield and Bradford Universities), in conjunction with Abertay-Dundee and Heriot-Watt Universties, relating to research into retrofitting of SuDS is currently being considered by the Steering Group. Glasgow East End would provide an ideal opportunity for a research case study in this field and it is proposed that this chance will be pursued further.

Initial Strategic Drainage Plan – Stage 1 (Draft)

The key output from Stage 1 will be the Initial Strategic Drainage Plan for the East End. This will cover the Dalmarnock WWTW catchment and the catchment areas of the Molendinar Burn, Camlachie Burn, Tollcross Burn, Battle Burn and their tributaries. The Plan will be developed from the combined outputs of the study streams identified above and will provide an outline integrated catchment strategy to address development constraints, flood risk and water quality. Estimation of costs for implementing the Plan will be needed for investment planning and the pursuit of external funding, e.g. Scottish Executive or ERDF.

It is acknowledged that the Plan will be in draft form at this stage and will need to be refined following completion of the detailed integrated modelling.

The following activities will apply to the full Plan Area:

Catchment Hydrology – Macro Assessment

Flood Estimation Handbook (FEH) techniques will be used to carry out an initial hydrological assessment of the watercourses which pass through urban Glasgow and drain to the River Clyde. This was undertaken by HCL for the East End watercourses prior to the February workshop and gave a useful feel for the approximate flow volumes generated in the catchment for various return periods.

For all non-main river watercourses within the study area, the FEH methodology will be applied to determine the Q1,Q2,Q5,Q10,Q30,Q50 and Q100 flows. Cumulative runoff at 1m3/sec increments for each watercourse will be shown on a plan of the drainage catchment. Based on existing record data, this study will also estimate the average carrying capacity of all open channel and closed conduit structures for each 250 metre length of watercourse. This carrying capacity will be shown on bar charts and compared with the Q2, Q5, and Q100 catchment flows.

(NB: It should be recognised that FEH procedures are not recommended for highly urbanised catchments (Urban Extents > 0.5) and this will be highlighted where applicable.)

Land Use and Development study/database

Production of GIS database for identification of short, medium and long term land use. The database will collate information on all known development sites and include details such as: gross site area; housing units; commercial floor space; industrial area; green space area; planning permission status (full/outline); sewerage catchment; watercourse catchment; current drainage proposals; identified drainage constraints etc.

This study will review the drainage strategies for each proposed development and estimate the area and cost of land take for on-site SuDS solutions where appropriate.

It is understood that stakeholders may operate existing databases. Whilst the best use will be made of any such existing information and outputs of other land use studies, there are clear benefits in having a specific database tailored to the requirements of drainage planning.

Flow and Rainfall Monitoring – Permanent Sites

The SEPA/GCC/SW report on Flooding in the East End of Glasgow on 30th July 2002 recommended that the effectiveness of monitoring and forecasting systems should be reviewed. It was suggested that this be carried out within a multi-agency framework.

This review will be undertaken as a Stage 1 activity so that required improvements can be put in place as soon as possible. The review will cover:

- the effectiveness of current weather warnings and how uncertainties can be reduced,
- assessment of current rainfall monitoring network and requirements for additional rain gauges,
- assessment of the potential for weather radar for providing rainfall warnings,
- identification of appropriate sites for permanent flow monitoring,
- consideration of the potential benefits of applications making use of flow and rainfall data, e.g. Real Time Control (RTC).

Policy Review and Recommendations

Stakeholders at the Glasgow East End workshop in February 2003 agreed that drainage policy should be reviewed and that clear direction was required on design criteria and levels of service. It is proposed that a Policy Review be undertaken by the Lead Consultant and that this should commence in parallel with the Initial Planning.

The Policy Review will include the following tasks:

Practice

- Review current drainage practice – sewers and rivers,
- Review current planning practice – interaction between planning regime and drainage planning

Legislation

- Review current drainage legislation
- Assess implications of the Water Framework Directive and other recent / imminent legislation

Design Criteria

- Identify all criteria in current use for Sewerage Rehabilitation, Flood Prevention Schemes, New Developments, SUDS, Insurance
- Assess inconsistencies
- Assess the implications of climate change
- Recommend alternative criteria where appropriate.

It is suggested that an Initial Policy Review document is produced and circulated for comment. Following this, a workshop may provide the best means of addressing comments and obtaining consensus on policy before recommendations are finalised.

WWTWs Assessment

This will include analysis of existing treatment capacities, review of current flows and loads to each of the principal Glasgow WWTWs, and estimation of future flows and loads. The assessment will also cover the assimilative capacity of the receiving waters and will permit consideration of potential transfer/treatment options.

In broad terms, the proposed strategy described above is required to bring stakeholders together and to step-elevate the infrastructure to a steady-state standard which can then be sustained. The concept of 'The Glasgow Strategic Drainage Plan' is proposed as the best means of achieving this aim.

It is recognised that there is considerable work already underway, such as Scottish Water's DAP programme and Glasgow City Council (GCC)'s flood studies of the River Clyde, the White Cart Water and others.

7. Glasgow Flooding Case Studies

CASE STUDY No 1: ROEBANK STREET

Roebank Street is located in the Dennistoun area of Glasgow, approximately 2miles north-east of the city centre. The area consists of a mixture of pre and post-war tenement housing, bordered by the M8 to the north, the Springburn railway line to the east, industrial land to the west and the A8 – Alexandra Parade to the south.

The location of the flooding is shown on Figure 5. Flooding at this location had been previously reported and 10 properties (indicated as blue stars) were on Scottish Water's flooding database when MWH were commissioned to carry out a DAP of this area.

The Garngad trunk sewer (shown as a thick red line) and the Molendinar Burn (shown as a thick blue line) both run north-south across the western end of Roebank Street. These sections are comparatively steep, but immediately downstream the sewer and watercourse turn to run across the slope of the hill.

Two CSOs were constructed on branches to the trunk sewer in the 1970s. However, the spill levels of these CSOs are too high to protect Roebank Street from flooding.

Further downstream, the trunk sewer passes through a significant CSO at Wishart St. This CSO consists of a low side weir spilling from the trunk sewer into the immediately adjacent Molendinar Burn. This CSO is close to spilling in dry weather. The low weir is believed to be set to provide flooding protection to the Tennents brewery site downstream.

A further 3 CSOs spill from branch sewers to the Molendinar Burn in the Duke Street area. Five of the six CSOs in the catchment are classed as unsatisfactory. The water quality of the Molendinar Burn at the monitoring point downstream of Duke Street is D, implying that the CSOs may contribute to this low classification.

A large development is proposed in Robroyston, draining to the head of the Garngad trunk sewer. This development - if unrestricted - is predicted to have a significant effect on the volumes of flooding at Roebank St and at other flooding sites in the catchment, and also on the volume of discharge to the Molendinar Burn, principally from the Wishart St CSO.

The location of these CSOs and of the proposed development is shown in relation to the flooding site on Figure 6.

A considerable area of flooding occurred from the 30th July event, indicated by the blue shaded area on Figure 5. This led to a re-examination of solutions developed during the DAP. Analysis of the flooding mechanisms suggested that the influence of the watercourse may not have been fully understood.

The extent of flooding in a further event on 4th September 2002 greatly exceeded that predicted by the hydraulic model for the given rainfall, even assuming the culverted watercourse was surcharged to ground level, preventing the CSOs relieving the system. This led to the conclusion that the majority of flooding on this event originated from the watercourse.

To summarise, this flooding site is associated with a number of other problems. A solution would clearly have to take account of all these factors to satisfy all stakeholders. To resolve this and similar problems, a working group has been set up including Scottish Water, Glasgow City Council and SEPA. Further modelling of the culverted watercourse system in the East End may be required to fully understand the flooding mechanism at this location.

Construction expected to commence on site – January 2004.

CASE STUDY No 2: HOGARTH GARDENS

Hogarth Gardens lies approximately 2 miles east of the city centre. A recent residential development ruins downhill to the south of Edinburgh Road, the A8. A high bund shelters the houses from the Hogarth Park to the south.

The location of the flooding is shown on Figure 7. Flooding at this location had been previously reported and 12 properties (indicated as blue stars) were on Scottish Water's flooding database prior to the 30th July event.

The light blue shaded area shows the extent of flooding in the July 2002 event. The bund effectively held the floodwater to a depth of over 2m. Pumps were brought on site by Scottish Water and, to provide security to the residents, these are still on site.

The Hogganfield trunk sewer runs at a depth of around 9m north-south across the development. Local sewers at shallower depths drain into a 600mm by 400mm sewer running broadly parallel to the trunk sewer before turning to run alongside the culverted Camlachie Burn.

A flow survey to study this flooding was in place during the July 2002 event, and construction of a hydraulic model had commenced. Residents accounts showed that the Hogganfield sewer had surcharged to ground level and flooding had also occurred from the local sewers.

Following the flooding, construction of this model was accelerated. This enabled options for resolving the flooding to be developed rapidly by Scottish Water, MWH as modellers and Johnston MacKenzie as strategic partners.

In this case the solution appeared comparatively simple. The provision of storage downstream of the bund allowed predicted surcharge levels to be lowered sufficiently to prevent flooding. However, consideration of the option on site led to a number of problems being discovered.

Firstly, the option required flows to be bifurcated from the 600mm by 400mm sewer immediately at the connection from the development. As this node was located at the summit of the bund, the depth of excavation would be considerable. Secondly, investigations indicated the presence of contaminated land within the open space. This led to a reconsideration of the option. However, subsequent site investigations confirmed that the risk of encountering contaminated land was assesed as low.

Construction work is now due to start on site in July 2003 with the provision of an off-line storage structure located in Hogarth Park.

CASE STUDY No 3: WOODFIELD AVENUE

Woodfield Avenue is located in Bishopbriggs, approximately 4miles north of the city centre. The road runs from Callieburn Road eastwards into a dip before rising again, however houses to the south of the road remain at a low level.

The location of the flooding is shown on Figure 8. Flooding at this location had been previously reported and 1 property (indicated as a blue star on Figure 8) was on Scottish Water's flooding database when MWH were commissioned to carry out a DAP of this area.

Flooding on the July 2002 event. was concentrated around the low point of the road, including internal flooding at numbers 18 and 20 (indicated as yellow rectangles). Residents accounts show that this flooding was contributed to by overland flow running down Callieburn Road to the west and Firpark Road to the south. Red coloration in the surface water runoff shows that it originated in the grounds of the Auchinairn Primary School, some 400m uphill to the south.

A main sewer runs from the south-west across open space and then through the gardens of properties on the south of Woodfield Avenue into the road itself. Firpark Road runs at the back of the affected properties, at around 5m above the ground level at the front.

The preferred solution identified for this flooding in the DAP involved the provision of storage in Woodfield Avenue itself. However, this solution addressed only the flooding predicted to arise from the local sewers. In order to address the surface water runoff issue, additional works were required on Firpark Road to the south.

Consideration was given to the laying of separate drains to take surface water runoff into the culverted watercourse to the east. However, there were concerns regarding the capacity of the watercourse system to accommodate these extra flows. A solution was then developed involving additional storage on the combined sewers in Firpark Road.

Construction work has commenced in Firpark Road and will start in Woodfield Avenue in July.