Concept Flood Risk and Drainage Strategy Bailrigg Garden Village, Lancaster

2017s6815

Final Report

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Lancaster City Council

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This report describes work commissioned by Julian Inman, on behalf of Lancaster City Council. Lancaster City Council's representative for the contract was Julian Inman. Howard Keeble and Inmaculada Lastres Espejo of JBA Consulting carried out this work.

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Purpose

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Executive Summary

This Executive Summary has been prepared following submission of a Draft Report to Lancaster City Council.

The focus of this assessment was to provide a review of flood risks and develop a concept drainage strategy for the proposed Bailrigg Garden Village.

Following recent flooding to Galgate, consideration has also been given to wider flood risk and flood management opportunities to existing communities at risk of flooding.

Catchments

The proposed Bailrigg area covers two catchments comprising the Conder Catchment to the east and the Burrow Beck Catchment to the west.

The Conder Catchment flows through Galgate and includes Ou Beck and Whitley Beck. Opportunities to reduce risk to existing communities within these areas should be considered as part of the Bailrigg scheme.

The Burrow Beck Catchment flows west to outfall into the River Lune. Catchment runoff from this area does not, therefore, contribute to existing flood risk at Galgate.

River Conder catchment

Whilst there are three primary causes of flooding to Galgate the River Conder represents the greatest risk. The source of the River Conder is a spring at Conder Head on Black Fell near Littledale. From there the river flows off the hillside and down towards the M6.

Upstream of the M6, flood mapping indicates an extensive floodplain. The river continues through Galgate passing through several road culverts including beneath the A6 before reaching the confluence with Ou Beck.

Whitley Beck appears to flood when water levels in the Conder are high. Opportunities for flood risk management will, therefore, need to look at these areas if flood risk is to be effectively managed.

Any development proposals that could potentially increase risk to Galgate would need to be considered in detail. Indeed, the starting point of any new development should be defined by a need to reduce and manage risks to existing communities.

In order to evaluate the scale and type of flood risk mitigation required further appraisal will be necessary. This falls outside the scope of this spatial flood risk strategy and further consultation with key stakeholders including the Environment Agency and Lead Local Flood Authority is recommended to ensure a coordinated response to flooding.

Whitley Beck Sub-catchment

Flooding on Whitley Beck resulted from interactions with the River Conder. Raised water levels on the river caused flood levels to increase along the beck. Runoff from the M6 motorway is likely to have been significant and caused increased flows in the beck.

Whitley Beck is located upstream of Galgate and opportunities to reduce flood risk associated with the catchment and M6 motorway may be considered as part of any wider Bailrigg development strategy.

Burrow Beck Catchment

The Burrow Beck catchment flows west to outfall into the River Lune. Catchment runoff from this area does not, therefore, contribute to flood risk at Galgate. Opportunities for development of a Garden Village within this area would not, therefore, impact on known areas of flooding.

It is recognised that small communities are located along Burrow Beck. Any proposed Garden Village development will need to consider risk through a Flood Risk Assessment. The premise for any new development will need to be based on flood mitigation and no offsite impacts.

Ou Beck Sub-catchment

Ou Beck flows to the west of Galgate and, based on Environment Agency flood maps, areas of Galgate are at direct risk of flooding from Ou Beck rather than the River Conder. The sub-catchment is relatively small and is located on the periphery of the Burrow Beck catchment area. Whilst current mapping indicates flood risk to Galgate, there are considerable areas of low-lying land upstream of Ou Beck that may prove beneficial in terms of future flood risk management. . Land upstream could be retained for potential flood risk management and this may form part of a blue green corridor for the Garden Village.

November 2017 Flooding

It is understood that approximately 120 properties and businesses were flooded in Galgate. The Environment Agency is currently undertaking post flood investigations and surveys. This information will then be used to update and calibrate their available river models.

Flood Zones

After passing beneath the M6 the River Conder flows through Galgate flowing beneath the A6 and railway line. Downstream of Galgate, Ou Beck flows into the River Conder. In accordance with the Environment Agency's flood mapping, areas of Galgate are identified as being at significant risk of flooding from both the River Conder and Ou Beck.

It is noted that the Environment Agency is currently in the process of updating the River Conder and Ou Beck models for this area. Updated flood mapping has not been released yet and it is likely that the new flood extents will result in changes to the published flood maps. The new modelling will be updated to include recent hydrology, modelling enhancements, climate change and the impacts of recent flooding.

In addition, the Environment Agency is undertaking post flood evaluation and wrack mark surveys to define the extent and mechanism of recent flooding.

Preliminary Options for flood risk management

Options may include:

- **Avoidance**: No development within the Conder catchment. Whilst this would eliminate the risk of new development increasing flooding at Galgate. appropriately located development may be a means of funding wider compensatory storage or defence measures. For instance, the proposed M6 slip roads could be formed to contain flood water upstream to the east of the motorway.
- **Flood storage**: Provision of additional flood storage through excavation. This would need to be tested using modelling and may be required in conjunction with other flood risk management techniques, including raised defences, culvert replacements, floodplain restoration and natural flood risk management techniques.
- **Burrow Beck**: Reliance on the Burrow Beck catchment would result in a significant reduction in land available for a Garden Village. However, development within this catchment could not, in terms of flood risk, impact on Galgate. Opportunities to reduce flood risk associated with Ou Beck may be achievable if combined with areas of public open space or habitat creation. Opportunities to divert runoff in a controlled manner may be achievable to the north of the catchment again helping to alleviate flooding in the Galgate catchment.
- **Retrofitting**: Areas of existing urban development may benefit from retrofitting of SuDS.
- **Surface Water Attenuation**: Flood risk will now be a significant concern to stakeholders including residents. New development must be based on the premise that any development at Bailrigg will result in no increase in surface water runoff. Additional flood storage may be provided as part of any development proposals so that surface water runoff is effectively reduced.

Proposed sites and requirements of surface water attenuation

Potential development areas

No development layout is currently available for the Bailrigg Garden Village. Instead, the focus of this assessment is to define the likely suitability of various areas of land for development in terms of flood risk and flooding constraints. The Bailrigg area has been defined as six discrete areas (Figure 5.1).

In order to understand the likely implication for development, as well as outlining opportunities for flood risk management, a summary of opportunities is provided on Table 5.1.

Outline Drainage Strategy.

It should be noted that no site investigation or contaminated land results are available at this preliminary stage. This drainage strategy does not, therefore, include consideration of contamination issues, or detailed design of drainage and SuDS measures.

Drainage strategies are based on using water as an integral feature for development. This may involve the formation of new blue green corridors for public access or as the basis of habitat creation. Exiting drainage ditches and watercourses running through a development site may be enhanced to include wetland and attenuation basins.

In this instance, it is proposed that surface water runoff will be managed through the use of SuDS features in the form of cascading storage basins.

Surface water drainage and attenuation requirements have been determined based on the 1 in 30 plus climate change event. Exceedance volumes up to the 1 in 100 plus climate change have also been considered with discharge restricted to greenfield rates.

Whilst the development layout has not been confirmed, shallow SuDS features are likely to require substantive areas of land and this will need to be quantified and taken into consideration during Master Planning. The following is provided as an indication only at this stage.

Recommendation

Although the proposed cascading storage basins are likely to provide sufficient storage for the 1 in 100 climate change scenario it is recommended that additional storage should be provided within the developed areas to accommodate exceedance volumes. This could be achieved by landscaping and making best use of available green space to contain exceedance flows.

Opportunities to reduce the current and future levels of flood risk through the integration of an integrated SuDS scheme across the Bailrigg area will help provide opportunities to both manage surface water flooding and improve water quality by mitigating the impacts of diffuse pollution. Appropriate SuDS techniques also provides opportunities to enhance local amenity and wider biodiversity benefits.

Development of a Garden Village provides opportunity to incorporate effective SuDS approaches within future development that considers of increased runoff from the new development as well as existing limitations and flood risk downstream. There is also opportunity to encourage the retrofitting and incorporation of SuDS within existing development.

All new development proposals will need to consider the Bailrigg SuDS requirements and future development should incorporate appropriate SuDS measures to:

- Reduce the flood risk to the development site associated with surface water runoff.
- Reduce the offsite surface water flood and pollution impacts from the proposed development.

Development within certain areas of the Bailrigg Garden Village may be prioritised in terms of development suitability and flood risk Development within other areas should be restricted.

Development of the Bailrigg Garden Village may provide opportunity to reduce existing flood risk.

Options for wider flood risk management will need to be discussed with the Environment Agency and Lead Local Flood Authority.

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Abbreviations

ABD .... Areas Benefitting from Defences
ACD................................ Area of Critical Drainage
AEP .... Annual Exceedance Probability
AIMS .... Asset Information Management System
AStGWF.......................... Areas Susceptible to Groundwater Flooding
CC .... Climate change
CCA................................ Civil Contingencies Act
CDA................................ Critical Drainage Area
CFMP .... Catchment Flood Management Plan
CIL.................................. Community Infrastructure Levy
CSO .... Combined Sewer Overflow
DCLG .... Department for Communities and Local Government
DPD................................ Development Plan Documents
DTM .... Digital Terrain Model
EA .... Environment Agency
FAA .... Flood Alert Area
FCA .... Flood Consequence Assessment
FCDPAG .... Flood and Coastal Defence Project Appraisal Guidance
FCERM .... Flood and Coastal Erosion Risk Management Network
FDGiA .... Flood Defence Grant in Aid
FEH .... Flood Estimation Handbook
FRA .... Flood Risk Assessment
FRCC-PPG .... Flood Risk and Coastal Change Planning Practice Guidance
FRM .... Flood Risk Management
FRMP .... Flood Risk Management Plan
FRMS .... Flood Risk Management Strategy
FRR .... Flood Risk Regulations
FSA .... Flood Storage Area
FWA .... Flood Warning Area
FWMA .... Flood and Water Management Act
GI .... Green Infrastructure
GIS .... Geographical Information Systems
HFM .... Historic Flood Map
IDB .... Internal Drainage Board
LA................................... Local Authority
LDF .... Local Development Framework

LFRMS .... Local Flood Risk Management Strategy
LLFA............................... Lead Local Flood Authority
LPA .... Local Planning Authority
LRF .... Lancashire Resilience Forum
MAFP .... Multi-Agency Flooding Plan
NGO .... Non-Governmental Organisation
NPPF.............................. National Planning Policy Framework
PFRA.............................. Preliminary Flood Risk Assessment
PPG17............................ Planning Policy Guidance Note 17
RBD................................ River Basin District
RBMP............................. River Basin Management Plan
RMA .... Risk Management Authority
RoFRS .... Risk of Flooding from Rivers and the Sea Map
RoFSW........................... Risk of Flooding from Surface Water
RSS................................ Regional Spatial Strategy
SA .... Sustainability Appraisal
SEA .... Strategic Environmental Assessment
SFRA.............................. Strategic Flood Risk Assessment
SHLAA .... Strategic Housing Land Availability Assessment
SMP .... Shoreline Management Plan
SoP .... Standard of Protection
SPD................................ Supplementary Planning Documents
SuDS.............................. Sustainable Drainage Systems
SWMP............................ Surface Water Management Plan
UDP................................ Unitary Development Plan
uFMfSW .... updated Flood Map for Surface Water
WFD .... Water Framework Directive

1 Introduction

1.1 Overview

This report has been prepared on behalf of Lancaster City Council. The focus of this assessment is to provide a review of flood risks and develop a concept drainage strategy for the proposed Bailrigg Garden Village.

Following recent flooding to Galgate, consideration has also been given to wider flood risk and flood management opportunities to existing communities at risk of flooding. This includes opportunities to create potential flood mitigation and management measures including compensatory storage, flood defences and natural flood management measures.

The Bailrigg Catchment is split into two key areas comprising the Conder catchment to the east and the Burrow Beck Catchment to the west. The Conder Catchment flows through Galgate and includes Ou Beck. Burrow Beck discharges to the River Lune.

1.2 Scope of this appraisal

This report outlines a concept drainage strategy for the potential Garden Village at Bailrigg, Lancaster. This strategy is subject to detailed design, but it is intended to outline surface water management opportunities and constraints for the area. The aims and objectives of this outline surface water attenuation and drainage strategy are:

- GIS mapping to confirm the extent of the developable areas against all sources of flood risk. (Appendix B)
- Prepare a concept drainage and surface water strategy. (Section 5)
- Review catchment and hydrological interactions. (Section 5)
- Determine areas within the initial development plan that will need adjusting to avoid existing flood risk areas. (Sections 4 & 5)
- Quantify attenuation volumes including exceedance/storage requirements for concept development based on achieving existing green field runoff rates. (Section 5 & Appendix D)
- Develop mapping of key drainage areas. (Section 5)
- Identify options for interconnecting development areas to form blue green corridors to outfall into receiving watercourses. (Sections 5 and 7)
- Identify controlling structures, including the need for cascading basins, headwalls and hydrobrakes and culverts as this will impact on likely sequencing of development as well as flood risk management. (Section 5)
- Identify options for managing flows and develop initial/indicative schematics. (Section 5)
- Develop a concise summary report demonstrating how a surface water strategy may be taken forward that effectively controls surface water flood risk without increasing risk elsewhere.
- Develop a list of recommendations and investigations. Review the scope of any further investigations and analysis required. (Section 9)
- Identify and map flood extents including surface water, groundwater and fluvial risks. (Sections 4 & 8 and Appendix B)
- Identify and map areas of key infrastructure including pylons and M6, and canal including interactions and potential highway crossings. (Section 5)
- Identify and map areas of existing risk to current urban areas where flood risk management may be used to reduce risk. (Section 7)
- Summarise the benefits of SuDS to both existing and proposed development to aid the Council in consultations. (Section 6)
- Wider opportunities for flood risk management (especially Natural Flood Management (NFM)) have been identified (especially to the East of the M6). Working with Natural Processes (WWNP) can reduce flood risk. This involves acting to manage fluvial and coastal flood risk by protecting, restoring and emulating the natural regulating function of catchments, rivers, floodplains and coasts. If properly assessed, NFM can reduce the risk

of flooding and increase the resilience of both existing and hard flood defences to projected climate change effects. (Section 7)

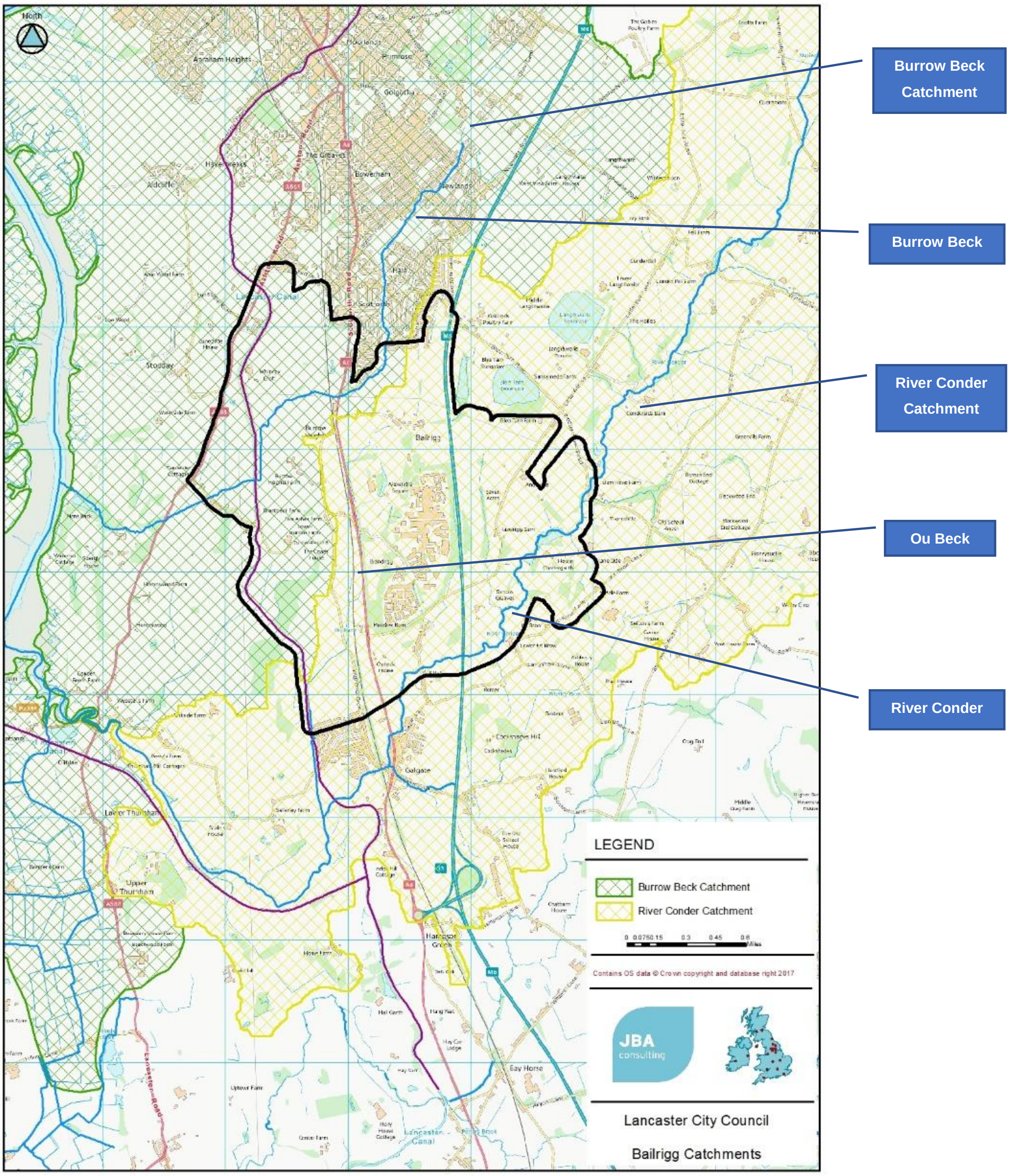
- Based on previous culvert inspection work, typical runoff rates for potential key river and ditch crossings will be quantified in order to identify any constrictions on the system. (Appendix E)

2 Location of the proposed Bailrigg Garden Village

The Bailrigg area is located to the south of Lancaster and north of Galgate (Figure 2-1). It comprises areas of existing development, including the University of Lancaster, as well as extensive rural land. The area is spilt by the M6, A6, railway, and the Lancaster Canal.

The Bailrigg catchment is split into two key areas comprising the Conder catchment to the east and the Burrow Beck catchment to the west. Two watercourses within the Conder catchment form the primary flood risk to Galgate. These are the River Conder, which flows southwest through Galgate and Ou Beck which flows to the west of Galgate. Burrow Beck discharges to the River Lune.

Figure 2-1: Location map



Based on British Geological information, the bedrock of the area is predominantly siltstone, sandstone and mudstone. This is overlain by superficial deposits of glacial till and alluvium, with areas of peat, clay, silt, sand and gravel. Overall the area slopes downwards in a south westerly direction from approximately 75 mAOD at Blea Tarn Road down to approximately 20 mAOD at the Lancaster Canal.

The most significant Main River is the River Conder which drains into the Irish Sea at Morecambe Bay.

3 The Planning Framework and Flood Risk Policy

3.1 Introduction

The main purpose of this section is to provide an overview of the key planning and flood risk policy documents that have shaped the current planning framework. This section also provides an overview and context of Lancaster City Council's responsibilities and duty in respect to managing local flood risk including but not exclusive to the delivery of the requirements of the Flood Risk Regulations (FRR) 2009 and the Flood and Water Management Act (FWMA) 2010.

3.1.1 Flood & Water Management Act

The FWMA was passed in April 2010. It aims to improve both flood risk management and the way we manage our water resources.

The FWMA has created clearer roles and responsibilities and helped to define a more risk-based approach to dealing with flooding. This included the creation of a lead role for LAs, as LLFAs, designed to manage local flood risk (from surface water, ground water and ordinary watercourses) and to provide a strategic overview role of all flood risk for the EA.

The content and implications of the FWMA provide considerable opportunities for improved and integrated land use planning and flood risk management by LAs and other key partners. The integration and synergy of strategies and plans at national, regional and local scales, is increasingly important to protect vulnerable communities and deliver sustainable regeneration and growth.

3.1.2 Water Framework Directive & Water Environment Regulations

The purpose of the Water Framework Directive (WFD), which was transposed into English Law by the Water Environment Regulations (2003), is to deliver improvements across Europe in the management of water quality and water resources through a series of plans called River Basin Management Plans (RBMP). The Lancaster City Council's area is covered by the North West River Basin Management Plan, managed by the EA and published in 2015. Water quality and flood risk can go hand in hand in that flood risk management activities can help to deliver habitat restoration techniques. The North West RBMP, 2015, includes examples such as the Living Waterways project, whereby failing urban waterbodies have been targeted to reduce flood risk whilst also improving water quality, restoring habitats and reducing diffuse pollution.

The EA is responsible for monitoring and reporting on the objectives of the WFD on behalf of Government. They work with Government, Ofwat, local government, non-governmental organisations (NGOs) and a wide range of other stakeholders including local businesses, water companies, industry and farmers to manage water[1].

The second management cycle of the WFD[2] has already begun and the second river basin management plans were completed in 2015, building upon the first set of RBMPs completed in 2009.

The main responsibility for Lancaster County Council is to work with the EA to develop links between river basin management planning and the development of Local Authority plans, policies and assessments. In particular, the programme of actions (measures) within the RBMP highlights the need for:

- Water Cycle Studies to promote water efficiency in new development through regional strategies and local development frameworks,
- Surface Water Management Plan implementation,
- Considering the WFD objectives (achieving good status or potential as appropriate) in the spatial planning process, including LDDs and Sustainable Community Strategies, and
- Promoting the wide scale use of SuDS in new development.

1 https://www.gov.uk/government/policies/improving-water-quality/supporting-pages/planning-for-better-water
2 http://ec.europa.eu/environment/water/water-framework/info/timetable_en.htm

3.2 Planning Policy

3.2.1 National Planning Policy Framework

The NPPF was published in March 2012 and is based on core principles of sustainability. It forms the national policy framework in England and is accompanied by a number of Planning Practice Guidance notes. It must be considered in the preparation of Local Plans and is a material consideration in planning decisions. Section 10 Paragraph 100 of the NPPF states that Local Plans…

"...should be supported by a Strategic Flood Risk Assessment and develop policies to manage flood risk from all sources, taking account of advice from the Environment Agency and other relevant flood risk management bodies, such as Lead Local Flood Authorities and Internal Drainage Boards. Local Plans should apply a sequential, risk-based approach to the location of development to avoid, where possible, flood risk to people and property and manage any residual risk, taking account of the impacts of climate change, by applying the Sequential Test, if necessary applying the Exception Test, safeguarding land from development that is required for current and future flood management, using opportunities offered by new development to reduce the causes and impacts of flooding and where climate change is expected to increase flood risk so that some existing development may not be sustainable in the long term, seeking opportunities to facilitate the relocation of development including housing to more sustainable locations".

The Flood Risk and Coastal Change Planning Practice Guidance (FRCC-PPG) sits alongside the NPPF and sets out detailed guidance on how this policy should be implemented.

3.2.2 Flood Risk and Coastal Change Planning Practice Guidance (FRCC-PPG)

On 6 March 2014 the Department for Communities and Local Government (DCLG) launched their planning practice guidance, including guidance for flood risk and coastal change, which replaces the previous Technical Guidance. This new guidance is available as a web-based resource[3], which is accessible to all and is regularly updated. Whilst the NPPF concentrates on high level national policy, the FRCC-PPG is more detailed. The practice guidance advises on how planning can take account of the risks associated with flooding and coastal change in plan making and the development management process. This is in respect of Local Plans, SFRAs, the sequential and exception tests, permitted development, site-specific flood risk, Neighbourhood Planning, flood resilience and resistance techniques and the vulnerability of development to make development safe from flooding.

3.2.2.1 Sustainability Appraisal

The Sustainability Appraisal (SA) is a key component of the Local Plan evidence base, ensuring that sustainability issues are addressed during the preparation of local plans. The SA is a technical document that, among other things, is to meet the requirements of the Strategic Environmental Assessment Directive 2001/42/EC which assesses and reports on a plan's potential impact on the environment, economy, and society. The SA carries out an assessment of the draft policies at various stages throughout the preparation of the Local Plan, and does this by testing the potential impacts, and consideration of alternatives are tested against the plan's objectives and policies. This ensures that the potential impacts from the plan on the aim of achieving sustainable development are considered, in terms of the impacts, and that adequate mitigation and monitoring mechanisms are implemented.

Ongoing Sustainability Appraisals have been undertaken on the draft Land Allocations DPD and the Development Management DPD since 2012. The latest SAs on the Land Allocations and Development Management DPDs, published in January 2017, state the following objectives in relation to flood risk under SA objective EN1:

'To reduce or manage flooding'

'To encourage the inclusion of flood mitigation measures such as SuDS'

It also recognises that areas at risk of flooding should be protected from development that would increase that risk and that new developments should be encouraged to use SuDS to manage runoff and further reduce flood risk.

For further information refer to the 2017 SFRA.

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3 http://planningguidance.planningportal.gov.uk/blog/guidance/flood-risk-and-coastal-change/

4 Understanding Flood Risk

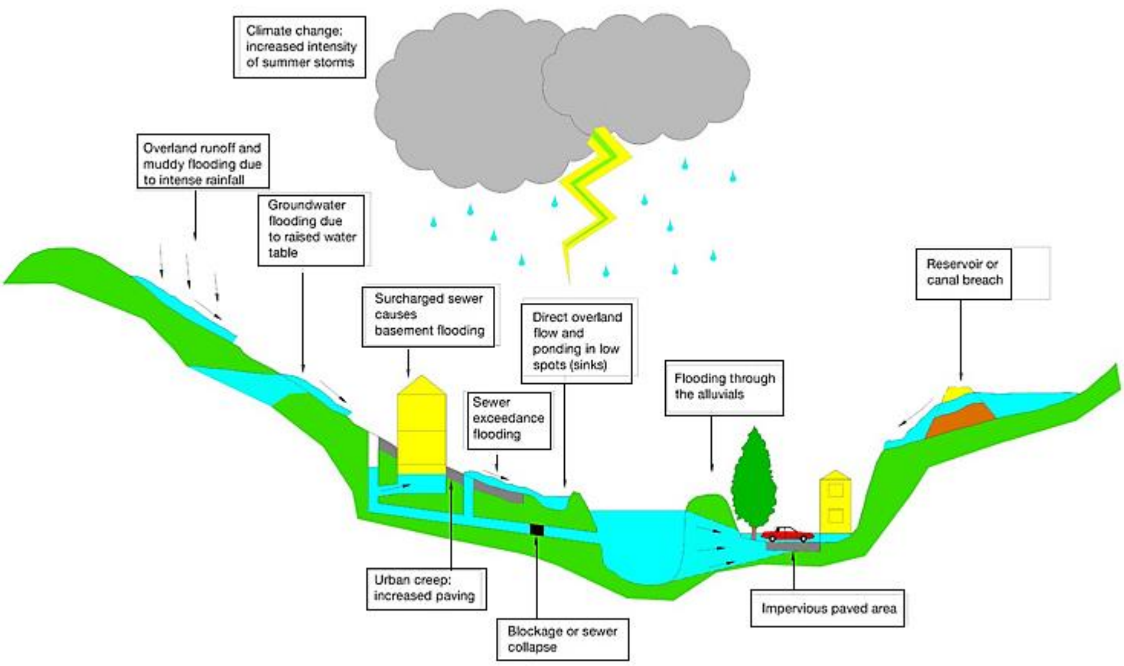
4.1 Sources of Flooding

Flooding is a natural process and can happen at any time in a wide variety of locations. It constitutes a temporary covering of land not normally covered by water and presents a risk when people and human or environmental assets are present in the area that floods. Assets at risk from flooding can include housing, transport and public service infrastructure, commercial and industrial enterprises, agricultural land and environmental and cultural heritage. Flooding can occur from many different and combined sources and in many different ways. Major sources of flooding (also see Figure 4-1) include:

- **Fluvial** (rivers) - inundation of floodplains from rivers and watercourses; inundation of areas outside the floodplain due to influence of bridges, embankments and other features that artificially raise water levels; overtopping or breaching of defences; blockages of culverts; blockages of flood channels/corridors.
- **Surface water** - surface water flooding covers two main sources including direct run-off from adjacent land (pluvial) and surcharging of piped drainage systems (public sewers, highway drains, etc.)
- **Groundwater** - water table rising after prolonged rainfall to emerge above ground level remote from a watercourse; most likely to occur in low-lying areas underlain by permeable rock (aquifers); groundwater recovery after pumping for mining or industry has ceased.
- **Infrastructure failure** - reservoirs; canals; industrial processes; burst water mains; blocked sewers or failed pumping stations.

Different types and forms of flooding present a range of different risks and the flood hazards of speed of inundation, depth and duration of flooding can vary greatly. With climate change, the frequency, pattern and severity of flooding are expected to change and become more damaging.

Figure 4-1: Flooding from all sources



4.2 Likelihood and Consequence

4.2.1 Likelihood

Likelihood of flooding is expressed as the percentage probability based on the average frequency measured or extrapolated from records over a large number of years. A 1% probability indicates the flood level that is expected to be reached on average once in a hundred years, i.e. it has a 1% chance of occurring in any one year, not that it will occur once every hundred years.

Note that the Flood Zones shown on the Flood Map for Planning (Rivers and Sea) do not take account of the possible impacts of climate change and consequent changes in the future probability of flooding.

4.3 Risk

Flood risk cannot be described simply as a fixed water level that will occur if a river overtops its banks or from a high spring tide that coincides with a storm surge. It is therefore important to consider the continuum of risk carefully. Risk varies depending on the severity of the event, the source of the water, the pathways of flooding (such as the condition of flood defences) and the vulnerability of receptors as mentioned above.

4.3.1 Actual Risk

This is the risk 'as is' taking into account any flood defences that are in place for extreme flood events (typically these provide a minimum Standard of Protection (SoP)). Hence, if a settlement lies behind a fluvial flood defence that provides a 1 in 100-year SoP then the actual risk of flooding from the river in a 1 in 100-year event is generally low. However, the residual risk may be high in that the impact of flood defence failure would likely have a major impact.

Actual risk describes the primary, or prime, risk from a known and understood source managed to a known SoP. However, it is important to recognise that risk comes from many different sources and that the SoP provided will vary within a river catchment. Hence, the actual risk of flooding from the river may be low to a settlement behind the defence but moderate from surface water, which may pond behind the defence in low spots and is unable to discharge into the river during high water levels.

4.3.2 Residual Risk

Defended sites, located behind EA flood defences remain at residual risk as there is a risk of overtopping or defence breach during significant flood events. Whilst the potential risk of failure may be reduced, consideration of inundation and the impact on development needs to be considered.

Paragraph 041 of the FRCC-PPG defines residual risk as:

"…those remaining after applying the sequential approach to the location of development and taking mitigating actions. Examples of residual flood risk include:

The failure of flood management infrastructure such as a breach of a raised flood defense, blockage of a surface water conveyance system, overtopping of an upstream storage area, or failure of a pumped drainage system".

Even when flood defences are in place, there is always a likelihood that these could be overtopped in an extreme event or that they could fail or breach. Where there is a consequence to that occurrence, this risk is known as residual risk. Defence failure can lead to rapid inundation of fast flowing and deep floodwaters, with significant consequences to people, property and the local environment behind the defence. Because of this, it is never appropriate to use the term "flood free".

Developers must be able to demonstrate that development will be safe to satisfy the second part of the Exception Test. To that end, Paragraph 042 of the FRCC-PPG states:

"Where residual risk is relatively uniform, such as within a large area protected by embanked flood defenses, the Strategic Flood Risk Assessment should indicate the nature and severity of the risk remaining and provide guidance for residual risk issues to be covered in site-specific flood risk assessments. Where necessary, local planning authorities should use information on identified residual risk to state in Local Plan policies their preferred mitigation strategy in relation to urban

form, risk management and where flood mitigation measures are likely to have wider sustainable design implications".

4.4 Flood Risk Datasets

This section of the report provides an overview of flood risk from all sources within the Bailrigg area. The information contained is the best available at the time of publication and is intended to provide Lancaster City Council with an overview of risk. Where further detail is available, then the source of information is provided. Table 4-1 provides a summary of the key datasets used in this report according to the source of flooding.

Table 4-1: Flood source and key datasets

Flood Source	Datasets / Studies
Fluvial	EA Flood Map for Planning (Rivers and Sea) (February 2017 version)
	EA Risk of Flooding from Rivers and Sea map
	Latest available EA Flood Risk Mapping Studies
	EA Historic Flood Map
	LLFA historic flood incident register
	River Lune & River Wyre Catchment Flood Management Plans
NOTE	The EA is currently updating the River Conder and Ou Beck models. This will include current hydrology, climate change and model adaptations
Pluvial (surface water runoff)	EA Risk of Flooding from Surface Water (RoFSW)
	Critical Drainage Areas
	Lancashire Preliminary SFRA
Groundwater	EA Areas Susceptible to Groundwater Flooding (AStGWF)
Canal	Canal and River Trust breaches and overtopping incidents data
Reservoir	EA Reservoir Flood Maps (available online)
All sources	Lancaster Level 1 SFRA 2016

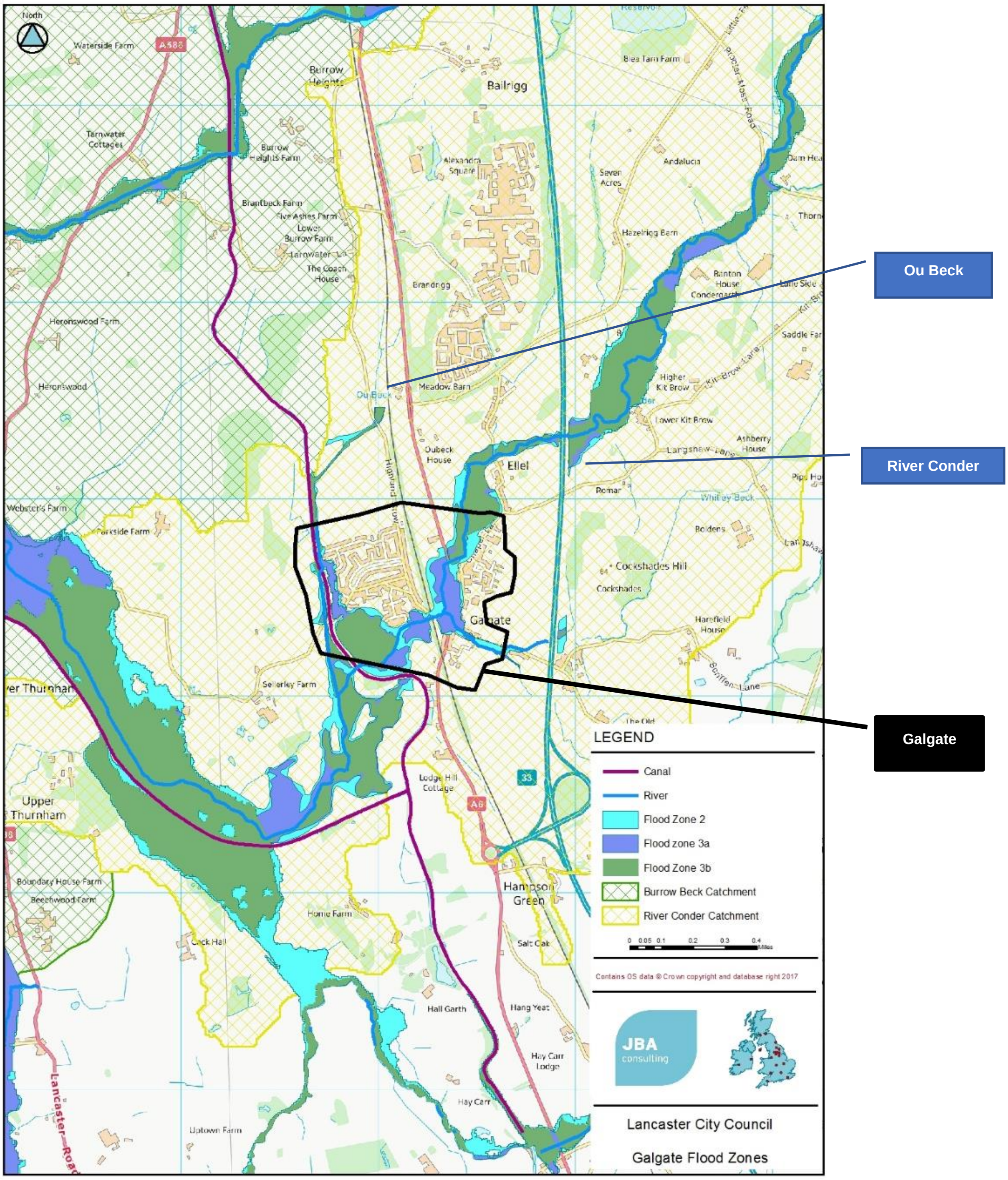
4.5 Fluvial Flooding

Fluvial flooding is associated with the exceedance of channel capacity during higher flows. The process of flooding from watercourses depends on a number of characteristics associated with the catchment including geographical location and variation in rainfall; steepness of the channel and surrounding floodplain; and infiltration and rate of runoff associated with urban and rural catchments.

Based on the EA's Flood Map for Planning, the majority of fluvial flood risk to existing communities comes from the River Conder and Ou Beck at Galgate (Figure 4.2).

The premise for new development, including infrastructure, is that Flood Zone 1 (low risk) areas will be prioritised for future development. Where essential infrastructure is required, such a new bridge crossing, then structures need to be designed so as not to increase flood risk. Requirements will need to be confirmed as part of a site-specific Flood Risk Assessment. This may need to include for single span crossings, flood relief culverts and the impacts of climate change during design flood events.

Figure 4-2: Environment Agency defined Flood Zones



4.6 Flood Zone Definitions

4.6.1 EA Flood Map for Planning

The EA's Flood Map for Planning is the main dataset used by planners for predicting the location and extent of fluvial flooding. This is supported by the CFMPs and FRMPs along with a number of detailed hydraulic river modelling reports which provide further detail on flooding mechanisms.

The EA Flood Map for Planning is precautionary in that it does not take account of flood defence infrastructure (which can be breached, overtopped or may not be in existence for the lifetime of the development) and, therefore, represents a worst-case scenario of flooding. The flood zones do not consider sources of flooding other than fluvial and tidal, and do not take account of climate change.

The Flood Map for Planning is updated at quarterly intervals by the EA, as and when new modelling data becomes available. The reader should therefore refer to the online version of the Flood Map for Planning to check whether the flood zones may have been updated:

http://apps.environment-agency.gov.uk/wiyby/37837.aspx

4.6.2 Functional Floodplain (Flood Zone 3b)

The functional floodplain forms a very important planning tool in making space for flood waters when flooding occurs. Development should be directed away from these areas.

Table 1, Paragraph 065 of the FRCC-PPG defines Flood Zone 3b as:

"…land where water has to flow or be stored in times of flood. Local planning authorities should identify in their Strategic Flood Risk Assessments areas of functional floodplain and its boundaries accordingly, in agreement with the Environment Agency."

Paragraph 015 of the FRCC-PPG explains that t*he identification of functional floodplain should take account of local circumstances and not be defined solely on rigid probability parameters. However, land which would naturally flood with an annual probability of 1 in 20 (5%) or greater in any year or is designed to flood (such as a flood attenuation scheme) in an extreme (0.1% annual probability) flood, should provide a starting point to help identify the functional floodplain.*

The area identified as functional floodplain should consider the presence and effect of all flood risk management infrastructure including defences. Areas which would naturally flood, but which are prevented from doing so by existing defences and infrastructure or solid buildings, will not normally be identified as functional floodplain. If an area is intended to flood, e.g. an upstream flood storage area designed to protect communities further downstream, then this should be safeguarded from development and identified as functional floodplain, even though it might not flood very often.

Any site-specific FRA should further assess the areas of functional floodplain through detailed investigation and assessment of the actual risk and extent of the functional floodplain. Flood extents for Bailrigg will need to be updated based on the Environment Agency's latest modelling update.

4.6.3 EA Risk of Flooding from Rivers Map

This map shows the likelihood of flooding from rivers and the sea based on the presence and effect of all flood defences, predicted flood levels and ground levels. The map splits the likelihood of flooding into four risk categories:

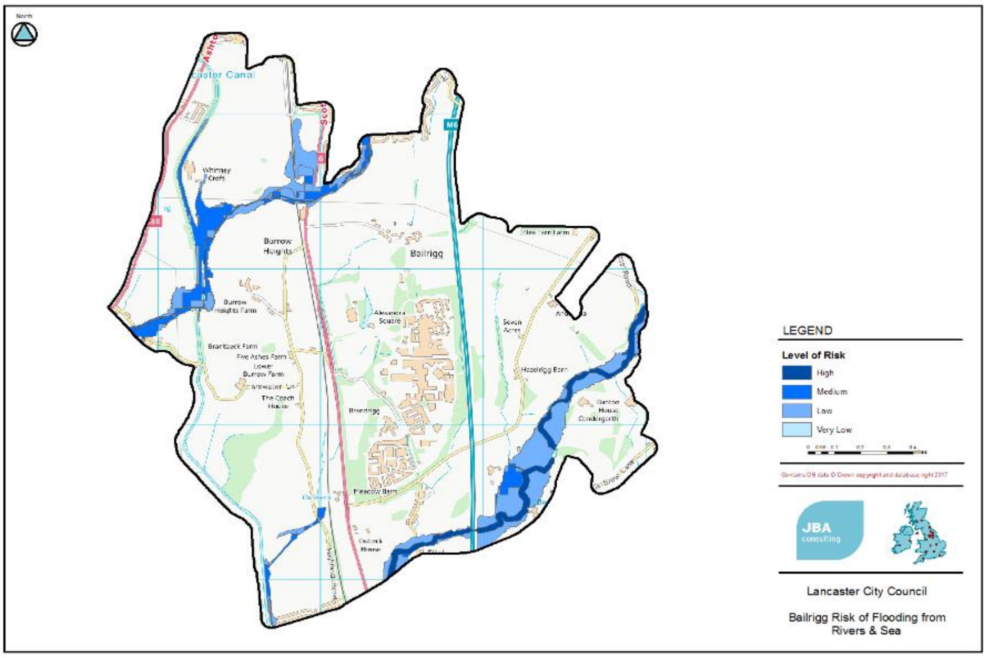
- High – greater than or equal to 1 in 30 (3.3%) chance in any given year
- Medium – less than 1 in 30 (3.3%) but greater than or equal to 1 in 100 (1%) chance in any given year
- Low – less than 1 in 100 (1%) but greater than or equal to 1 in 1,000 (0.1%) chance in any given year
- Very Low – less than 1 in 1,000 (0.1%) chance in any given year

The Risk of Flooding from Rivers and Sea map (RoFRS) is included as Figure 4-3.

High level of risk has been identified around River Conder as well as low risk and medium and low level of risk have been identified around the Burrow Beck.

Some areas with medium and low risk have also been identified around the Ou Beck to the southwest of the site.

Figure 4-3: Flooding from Rivers



4.7 Surface Water Flooding

There are certain locations, generally within urban areas, where the probability and consequence of pluvial flooding are more prominent due to the complex hydraulic interactions that exist in the urban environment. Urban watercourse connectivity and the location and condition of highway gullies all have a major role to play in surface water flood risk.

It should be acknowledged that once an area is flooded during a large rainfall event, it is often difficult to identify the route, cause and ultimately the source of flooding without undertaking further site-specific and detailed investigations.

4.7.1 EA Risk of Flooding from Surface Water

The EA updated the second generation FMfSW in 2013 to produce a third-generation national surface water flood map, the updated Flood Map for Surface Water (uFMfSW), now referred to the Risk of Flooding from Surface Water map. The RoFSW is much more refined than the second-generation map in that:

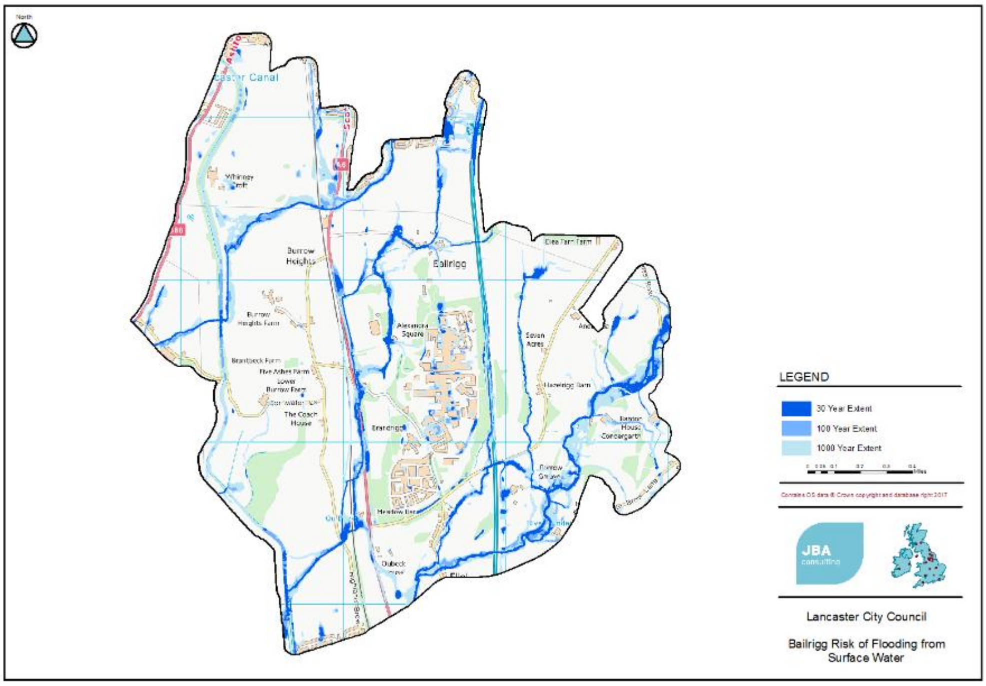
- More detailed hydrological modelling has been carried out using several design rainfall events rather than one for the second generation,
- A higher resolution Digital Terrain Model (DTM) has been used – 2m, compared to 5m for the second generation,
- Manual edits of DTM to improve flow routes at over 91,000 locations compared to 40,000 for the second generation,
- DTM edited to better represent road network as a possible flow pathway, this was not done for the second generation,
- Manning's n roughness (used to represent the resistance of a surface to flood flows in channels and floodplains) values varied using Master Map Topography layer compared to blanket values for urban and rural land use applied in the second-generation surface water flood map.

The National Modelling and Mapping Method Statement, May 2013 details the methodology applied. The RoFSW is included as Figure 4-4. Whilst Figure 4-4 indicates surface water flow routes following the alignment of ditches and river in the Bailrigg area it also identifies additional areas and asset that are vulnerable to surface water flooding such as the A6 and areas of low lying topography.

Surface water flood risk is prevalent across the area, particularly in the Conder River and Burrow Beck valleys as well as along the surrounding area to the Lancaster Canal. There are also some areas in the Ou Beck valley and within the university campus, where the terrain begins to flatten off and surface water can accumulate.

When planning for development in Bailrigg, isolated areas of flooding are generally considered manageable. Patterns of flowing water are likely to be of greater concern and any new development will need to maintain or manage conveyance routes without increasing flood risk elsewhere.

Figure 4-4: Flooding from Surface Water



4.8 Groundwater flooding

Groundwater flooding is caused by the emergence of water from beneath the ground, either at point or diffuse locations. The occurrence of groundwater flooding is usually local and unlike flooding from rivers and the sea, does not generally pose a significant risk to life due to the slow rate at which the water level rises. However, groundwater flooding can cause significant damage to property, especially in urban areas, and can pose further risks to the environment and ground stability.

There are several mechanisms that increase the risk of groundwater flooding including prolonged rainfall, high in-bank river levels, artificial structures, groundwater rebound, and mine water rebound. Properties with basements or cellars or properties that are located within areas deemed to be susceptible to groundwater flooding are at particular risk. Development within areas that are susceptible to groundwater flooding will generally not be suited to SuDS; however, this is dependent on detailed site investigation and risk assessment at the FRA stage.

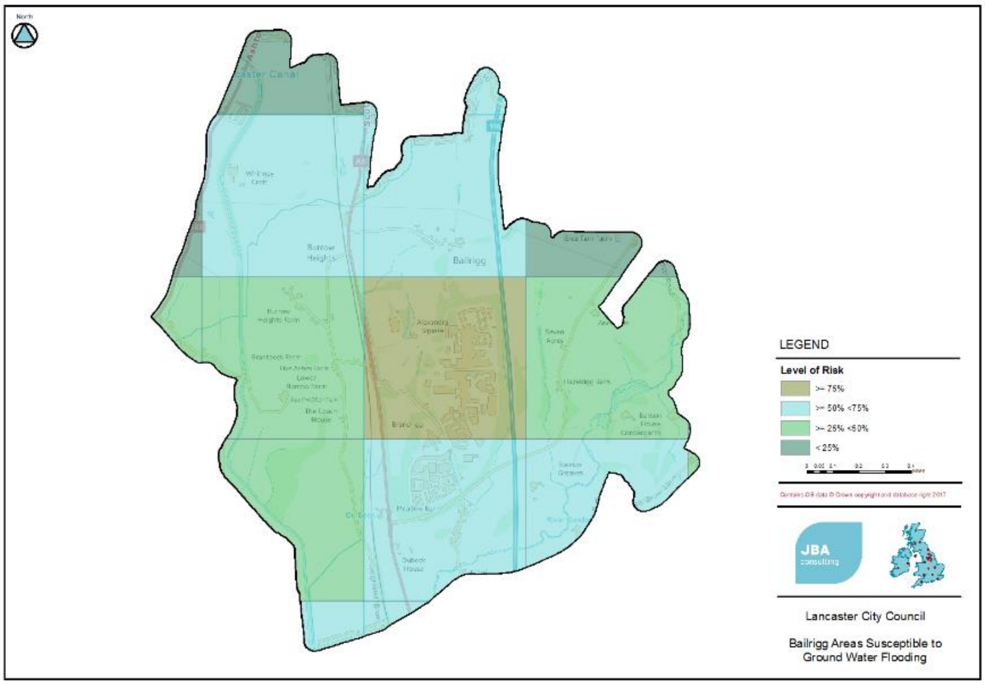
Taken from the Level 1 SFRA, there have been no reported instances of groundwater flooding in the catchment area. The groundwater flood map is showing a moderate risk for the river terrace gravels and glacial fluvial sands and gravels which line the Conder and Burrow Beck. The geology maps show several areas of lacustrine deposits and these former lake areas could be the core of wetland systems.

4.8.1 Areas Susceptible to Groundwater Flooding (AStGWF)

The EA's national dataset, Areas Susceptible to Groundwater Flooding (AStGWF), is a low-resolution map which uses four susceptibility categories to show the proportion of a network of 1 km grid squares where geological and hydrogeological conditions show that groundwater might emerge. It does not show the likelihood of groundwater flooding occurring and is not suitable for planning considerations at a site-specific level. It should only be used as a trigger for further investigation as to the possibility of groundwater flooding.

The AStGWF is included as Figure 4-5. It is noticed that some areas with high level of risk are located to the centre of the site and some medium risk areas are located to the northwest and southeast of the site. However, as mentioned before, further investigations will be required for a more detailed design, including ground investigations to determine ground water levels and the permeability of soils.

Figure 4-5: Areas Susceptible to Ground Water Flooding



4.9 Canal and Reservoir Flood Risk

4.9.1 Canals

The Lancaster Canal runs north to south down the western edge of the Lune catchment. The River Conder feeds the canal through a side weir and the Glasson Branch of the canal extends westwards from Galgate to Glasson Dock. There is the potential flood risk posed by a breach in the canal substructure, particularly at raised locations.

Data received from the Canal and River Trust (CRT) for the 2017 SFRA indicates incidents of canal breach or overtopping in the Lancaster District. These incidents are shown in Table 4-2.

Table 4-2: CRT Canal overtopping incidents

Date	Type	Location	Comments
06/09/11	Overtopping	River Conder Feeder	Heavy rainfall caused overtopping of River Conder into feeder channel
26/10/08	Overtopping	River Conder Feeder	High water levels in River Conder coincided with high tide, causing river to overtop into the feeder channel and flood field between river and Conder Feeder
26/10/08	Overtopping	Between Conder Feeder and Glasson Basin	High water levels due to heavy rainfall combined with inflow from feeder channel caused overtopping at several locations
17/06/11	Overtopping	Glasson Branch at Cliffdale	Overtopping onto towpath caused by water levels being drawn down on main line for maintenance work

4.9.2 Reservoirs

A reservoir can be described as an artificial lake where water is stored for use. Some reservoirs supply water for household and industrial use, others serve other purposes, for example, as fishing lakes or leisure facilities. Like canals, the risk of flooding associated with reservoirs is residual and is associated with failure of reservoir outfalls or breaching. This risk is reduced through regular maintenance by the operating authority. Reservoirs in the UK have an extremely good safety record with no incidents resulting in the loss of life since 1925.

The EA is the enforcement authority for the Reservoirs Act 1975 in England and Wales. All large reservoirs must be regularly inspected and supervised by reservoir panel engineers. LAs are responsible for coordinating emergency plans for reservoir flooding and ensuring communities are well prepared.

According to the EA Register of Reservoirs, there are no 'large raised reservoirs' directly located within the boundaries of Lancaster or surrounding local authorities. Whilst large reservoirs provide the obvious source of residual risk (breaching/overtopping) from artificial sources, there could potentially be a number of smaller water bodies within the area. Smaller water bodies have potential ownership issues resulting in a lack of regularly inspected and poor embankment conditions. This will increase the residual risk of breaching or overtopping associated with them.

The EA has produced reservoir flood maps (RFM) for all large reservoirs that they regulated under the Reservoirs Act 1975 (reservoirs that hold over 25,000 cubic meters of water).

The maps show the largest area that might be flooded if a reservoir were to fail and release the water it holds, including information about the depth and speed of the flood waters.

The RFM can be viewed nationally at: https://flood-warning-information.service.gov.uk/long-term-flood-risk/map?map=SurfaceWater#Reservoirs_3-ROFR

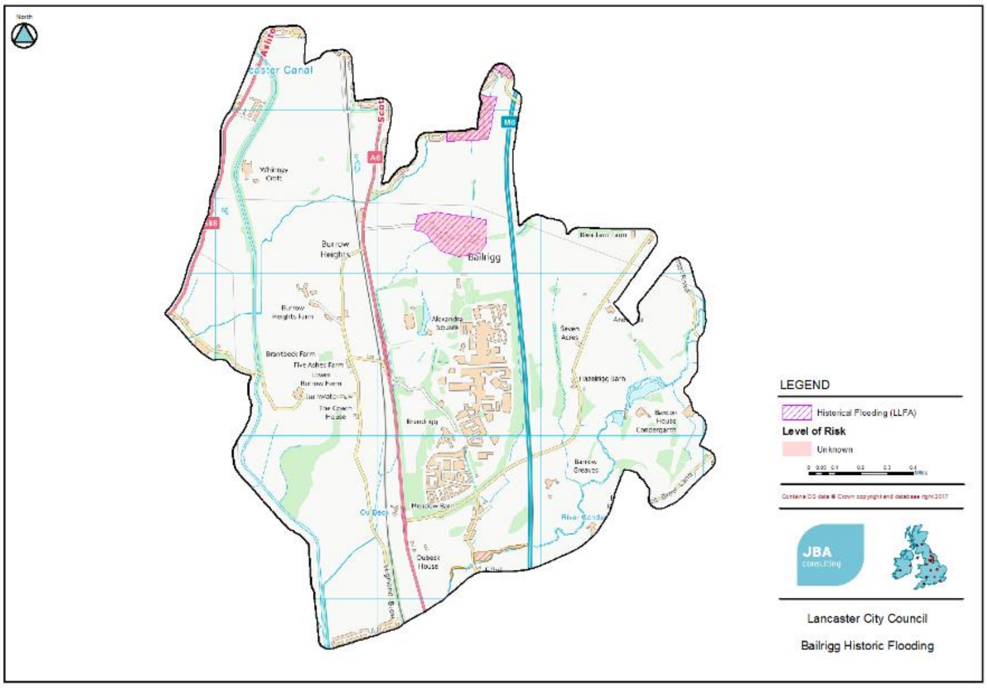
Within the Bailrigg area there are two reservoirs that may potential increase risk to the Conder catchment. These are Blea Tarn Reservoir and Langthwaite Reservoir.

4.10 Historical Flooding

As part of the 2017 SFRA, Lancaster City Council provided its historic flood incident register, required under the FWMA, which includes flood incidents of multiple sources having occurred across the City. This includes flooding of property, gardens to property, highways and footpaths. A historical flooding area has been identified to the west of the M6 near the Bailrigg Chase area (Figure 4-6).

On the 27th November 2017 Galgate was affected by significant flooding. The implications of this on the Bailrigg Garden Village are reviewed further in Section 7.

Figure 4-6: Historic Flooding incidents



5 Proposed sites and requirements of surface water attenuation

5.1.1 Potential development areas

The City Council's starting point for planning and designing the Bailrigg Garden Village is to ascertain the land and requirements for the proper management of water and mitigation of flood risk. Land required for such will be reserved from built development for environmental and flood risk mitigation and enhancement. The focus of this assessment is to define the likely suitability of various areas of land for development in terms of flood risk and flooding constraints. It is understood that the proposed development will comprise approximately 3500 houses with associated roads, parking and service areas, green infrastructure and transport links.

For the purpose of this strategy, the Bailrigg area has been defined as six discrete areas (Figure 5-1):

- Areas 1 and 2 located to the east of the M6 (Conder catchment).
- Area 3 located to the north of Bailrigg (Conder and Burrow Beck catchments).
- Area 4 located to the east of the A6 (Burrow Beck catchment (including Ou Beck – Conder catchment)).
- Area 5 located to the north of Galgate (Conder catchment).
- Area 6 located on the existing Bailrigg site (Conder catchment).

Recent flooding in Galgate highlights the need for safe development and the need to manage flood risks to existing communities.

In order to understand the likely implications for development, as well as outlining opportunities for flood risk management, a summary of opportunities is provided on Table 5-1.

Figure 5-1: Potential Development Areas

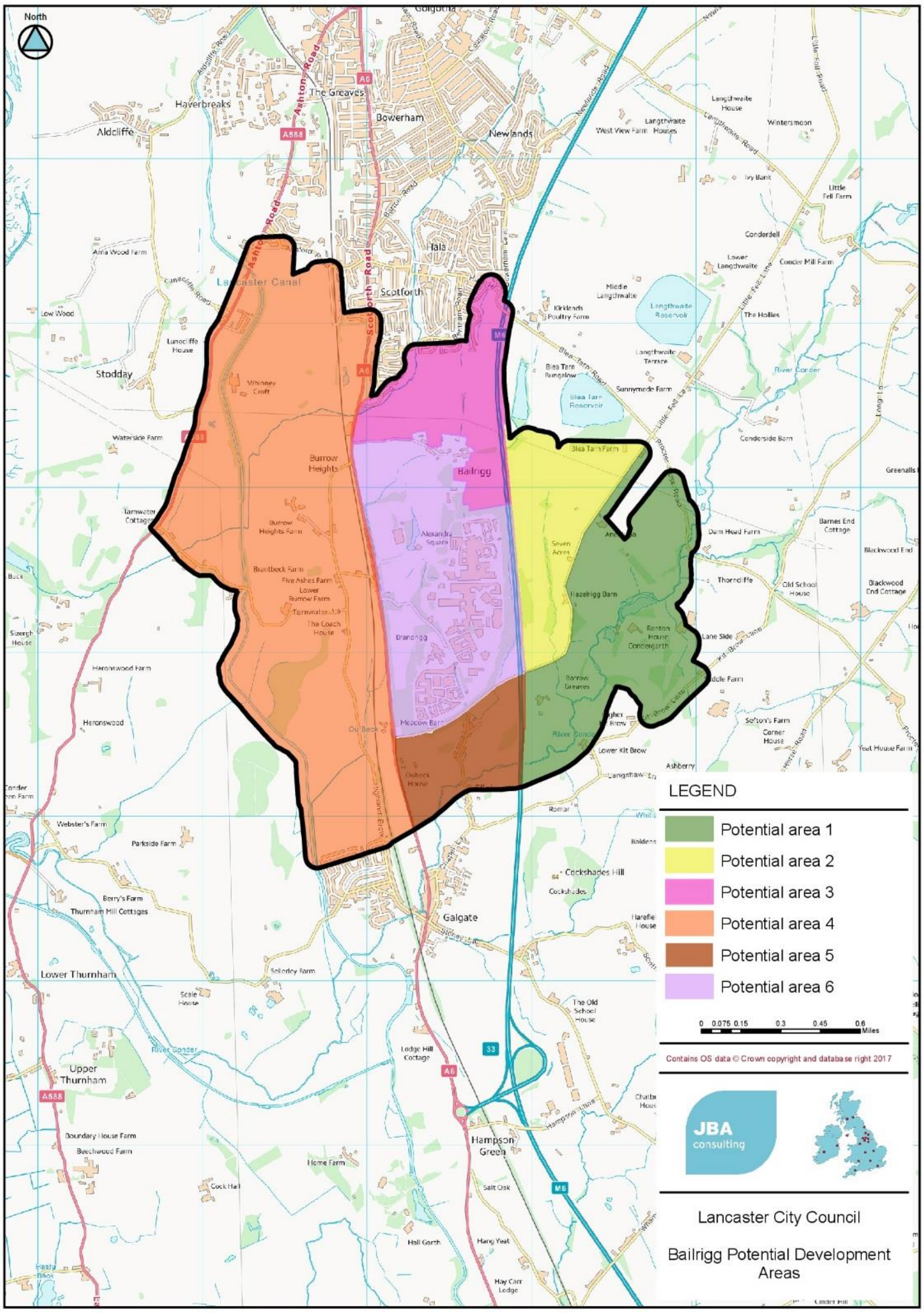


Table 5-1: Summary of potential development area suitability

Area	Catchment	Suitability for development #	Issues and Constraints	Potential to reduce flood risk at Galgate
1	River Conder	Lower (upstream of Galgate with extensive flood zones)	River Condor Catchment upstream of the M6 Extensive floodplain Bridge crossing required to link land south of the river. (potential flood interactions and cost) New access required from M6 Culvert capacity issues at Galgate may increase risk locally.	Yes (if combined with other measures) Public perception of risk, development here is upstream of Galgate. Consider retaining land for flood risk management New M6 slip road could be designed to increase upstream flood storage* Potential for natural flood risk management measures (long-term strategy) *
2	River Conder	Lower (upstream of Galgate with steeper ground profiles)	River Condor Catchment upstream of the M6 Lower risk of direct flooding (residual risk from upstream reservoirs) New access required from M6 Culvert capacity issues may increase risk locally.	Yes (if combined with other measures) Public perception of risk, development here is upstream of Galgate. Consider retaining land for flood risk management. (Variation in ground levels may preclude flood attenuation techniques) New M6 slip road could be designed to increase upstream flood storage* Potential for natural flood risk management measures (long-term strategy) *
3	River Conder and Burrow Beck catchments	Higher (proximity to existing urban areas and Burrow Beck)	Land north of Bailrigg with potential connection to the Burrow Beck catchment	Yes (if combined with other measures) Consider SuDS and the provision of additional flood storage to reduce runoff to the Conder catchment. Consider retaining land for flood risk management as part of any development proposal. Consider diversion and alternative discharge opportunities to Burrow Beck (reducing runoff to the River Conder).

Area	Catchment	Suitability for development #	Constraints	Potential to reduce flood risk at Galgate
4	Burrow Beck Catchment (with Ou Beck draining to Condor Catchment)	Higher (most of the catchment drains to the River Lune via Burrow Beck) (land availability upstream of Ou Beck could be used for flood risk management)	Burrow Beck catchment (including Ou Beck sub catchment to the River Conder) Land to the east of A6	Yes (if combined with other measures) Consider SuDS and the provision of additional flood storage to reduce runoff to Ou Beck. Consider retaining land for flood risk management for Ou Beck. Discharge opportunities to Burrow Beck (reducing runoff to the River Conder).
5	River Conder Catchment	Lower (upstream of Galgate	River Condor Catchment downstream of the M6 Extensive floodplain	Yes (if combined with other measures) Public perception of risk, development here is upstream of Galgate. Consider retaining land for flood risk management. Potential for natural flood risk management measures (long-term strategy) *
6	River Conder Catchment	Lower (existing urbanised)	River Condor Catchment predominantly urbanised	Limited owing to existing urbanisation Consider SuDS and opportunities for retrofitting Consider retaining land for flood risk management.

Notes:

It is assumed that the premise for any new development will be no net increase in runoff (i.e. flood risk will be managed on site with no downstream impacts.

* Subject to detailed modelling and further appraisal.

Groundwater information is pending.

5.2 Concept Drainage Strategy.

It should be noted that no site investigation or contaminated land results are available at this preliminary stage. This drainage strategy does not, therefore, include consideration of contamination issues, or detailed design of drainage and SuDS measures. Outline drainage and potential SuDS proposals have been made and the layout and arrangement are subject to Master Planning.

For the purposes of this assessment, the development proposals include all proposed properties, associated garden areas and other green spaces, likely to include SuDS features, and any internal roads.

Drainage strategies are based on using water as an integral feature of development. This may involve the formation of new blue green corridors for public access or be used as the basis of habitat creation. Exiting drainage ditches and watercourses running through a development site may be enhanced to include wetland and attenuation basins.

In this instance, it is proposed that surface water runoff will be managed through the use of SuDS features in the form of a series of cascading storage basins. Other options may also be considered. (If established SuDS measures such as attenuation basins and soakaways are found to be of limited capacity or even unsuitable, then a tanked sewer system is envisaged for development.)

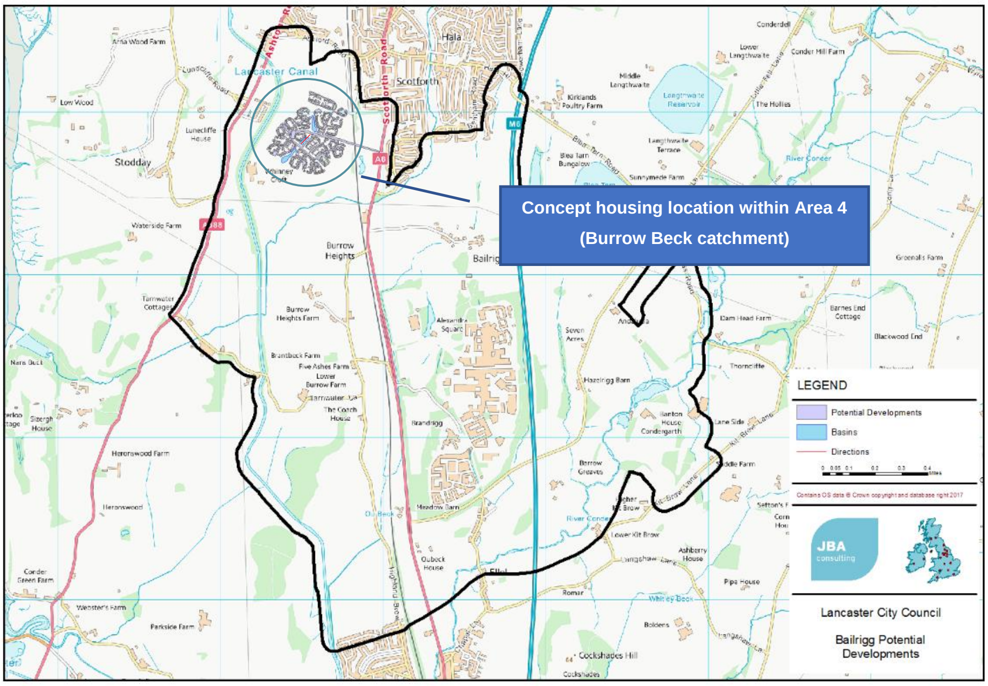
Surface water drainage and attenuation requirements have been determined based on the 1 in 30 year plus climate change event. Exceedance volumes up to the 1 in 100 year plus climate change have also been considered with discharge restricted to greenfield rates.

Whilst the development layout has not been confirmed shallow SuDS features are likely to require substantive areas of land and this will need to be quantified and taken into consideration during Master Planning. The following is provided as an indication only at this stage.

5.2.1 Concept development sites

For the purposes of developing the drainage strategy, a representative area coinciding with the development of 300 houses and associated typical infrastructure is represented in Figure 5-2. It should be noted that the housing development is representative, and its location is shown for demonstrative purposes only. The number and location of development areas will need to be scaled accordingly to reach the 3500 houses envisaged for the Garden Village.

Figure 5-2: Concept Development Site (Note the development location is illustrative only)

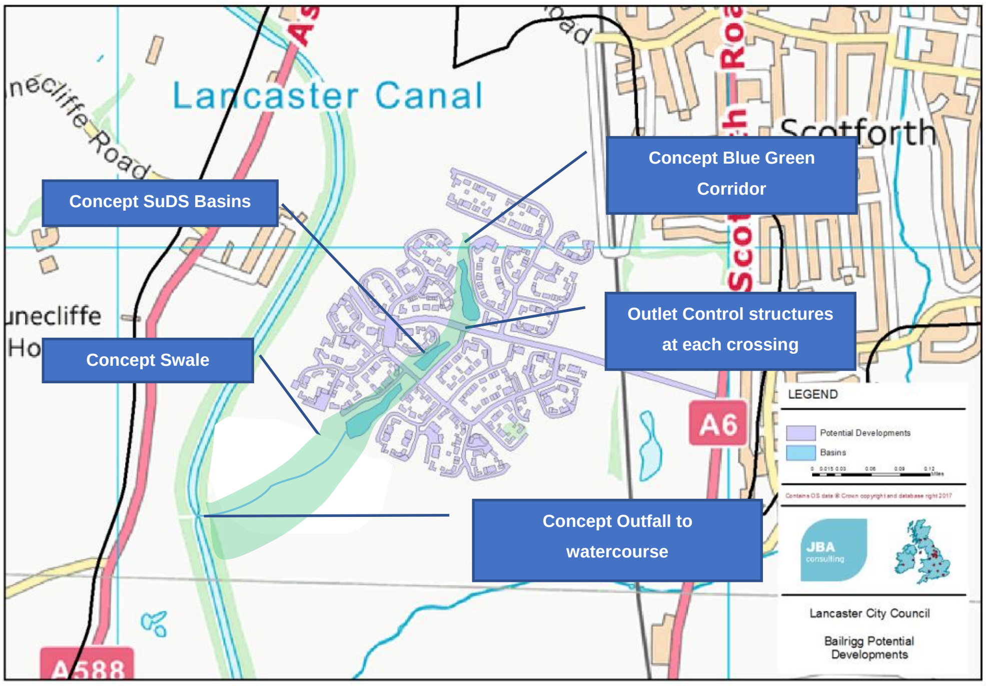


5.2.2 SuDS features

The primary solution proposed to attenuate surface runoff flows from the development site is to intercept the flows in a series of cascading storage basins. Basins may be linked by swales to form either linear or meandering water features located with the housing estates. Discharge from each basin will need to be controlled so that basins downstream are not inundated. This will also ensure that discharge to the receiving watercourse is not increased following development.

Attenuation requirements are based on providing storage for the 1% AEP event including climate change. Figure 5-3 presents a concept SuDS layout showing the location of the proposed cascading basins to be formed within the indicative housing layout.

Figure 5-3: Concept SuDS layout (Note the development location is concept only)



Basins are likely to be formed making best use of existing topography. Consideration of safe design is required and banks within the basins should be sloping at 1 in 3 to allow safe access and egress for residents and for future maintenance purposes. In-channel control structures such as weirs or vortex controls will limit discharge to subsequent basins and cause each basin to fill. In addition, proposals for the basins assumes a freeboard allowance will be required below crest levels for each basin. Basins will need to be formed through excavation. Land raising to form elevated flood bunds to basins should be avoided where practical.

Rainfall depths were used to calculate runoff flows from impermeable surfaces for the 1 in 30 year plus climate change event and the 1 in 100 year plus climate change event. A storm duration of 17 hours was assessed as the critical storm duration for the catchment. The rational method was used to calculate runoff flows which assumes a constant rainfall rate over the duration of the storm event.

5.2.3 Surface Water Runoff

Rainfall depths for the area were abstracted from FEH. The rainfall depths have been used to estimate runoff volumes and were increased by an allowance of 30% to account for the effects of climate change (Table 5-3).

Table 5-3: Design rainfall depths (mm)

Duration (hours)	1 in 30 year rainfall (mm)	1 in 30 year rainfall plus 30% (mm)	1 in 100 year rainfall (mm)	1 in 100 year rainfall plus 30% (mm)
0.25	21.39	27.80	31.99	41.58
0.5	26.22	34.10	38.37	49.88
0.75	29.54	38.40	42.67	55.47
1	32.15	41.80	46.02	59.82
1.5	36.22	47.10	51.18	66.54
2	39.42	51.20	55.20	71.76
3	44.41	57.70	61.39	79.81
4	48.32	62.80	66.21	86.07
6	54.44	70.80	73.64	95.73
8	59.25	77.00	79.41	103.24
10	63.27	82.20	84.20	109.46
12	66.75	86.80	88.33	114.83
18	73.13	95.10	95.53	124.20
24	78.02	101.40	101.00	131.30
36	85.47	111.10	109.24	142.01
48	91.18	118.5	115.49	150.14

5.2.4 Greenfield runoff estimation

Greenfield runoff rates have been estimated for the concept development in accordance with EA guidance rainfall runoff management for developments using the drainage tools provided on the UK SUDS Tools Website[4]. Greenfield runoff peak flow rates for design events have been estimated (

Table 5-4: Estimated Greenfield runoff rates

Event	Greenfield runoff (l/s)
QBAR* (l/s)	39.7
1 in 1 year(l/s)	34.54
1 in 30 years(l/s)	67.49
1 in 100 years(l/s)	82.58

*QBAR - Mean Annual Flood flow rate.

5.2.5 Potential storage volumes

The potential volumes for each attenuation basin has been estimated based on:

- The discharge rate from the first pond is based on the greenfield runoff rate of that contributing area.
- For the second basin, the discharge rate will be the sum of the greenfield runoff rates for the first and second areas.
- For the third basin, the discharge rate to the watercourse will be the greenfield runoff rate for the whole development area ensuring runoff to the watercourse is not increased following development.

The estimated volumes for each basin are included as

4 http://geoservergisweb2.hrwallingford.co.uk/uksd/

Table 5-5. The associated area required for each basin will be dependent on existing topography and the actual depth of excavation.

Table 5-5: Storage basin dimensions

Basin	Potential attenuation volume (m^3)	Estimated Bed level LiDAR (m AOD)	Estimated Depth (m)	Typical area required (m^2)
1	2400	29.5	1	2400
2	1400	32.0	0.75	1900
3	1000	34.7	0.75	1300

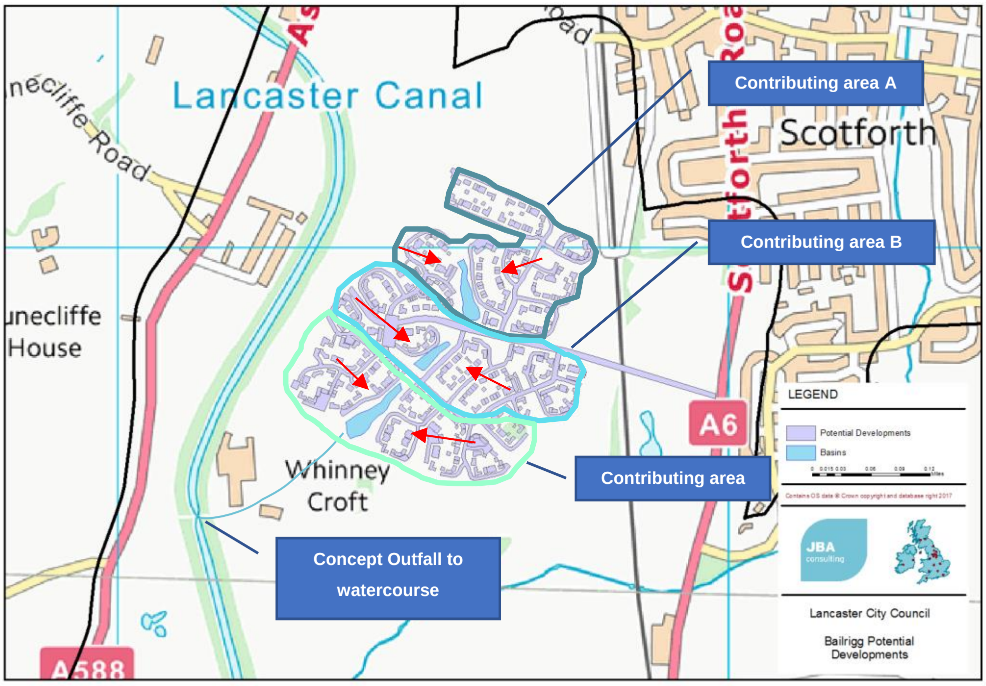
It is noted that all exceedance flows are assumed to be routed to storage basins. Alternative approaches may also be considered including, for example, using estate roads and parking areas to temporarily contain exceedance flows. These measures may reduce the size of any attenuation basins and an optimised approach is envisaged.

Each basin has been sized based on an assumed development layout (Figure 5-4) and impermeable area (Table 5-6).

Table 5-6: Assumed impermeable area to each basin.

Basin	Impermeable area (ha)
Area A to basin 1	2.5
Area B to basin 2	1.5
Area C to basin 3	1

Figure 5-4: Concept SuDS Layout Catchment Areas



5.2.6 Conceptual drainage model

A conceptual drainage model detailing how development may be focussed on green blue infrastructure and cascading attenuation basins is included as Figure 5-5. Each basin needs to be designed to attenuate surface water runoff from development whilst allowing controlled discharge. The discharge rate is dependent on existing greenfield runoff rates and includes allowances for:

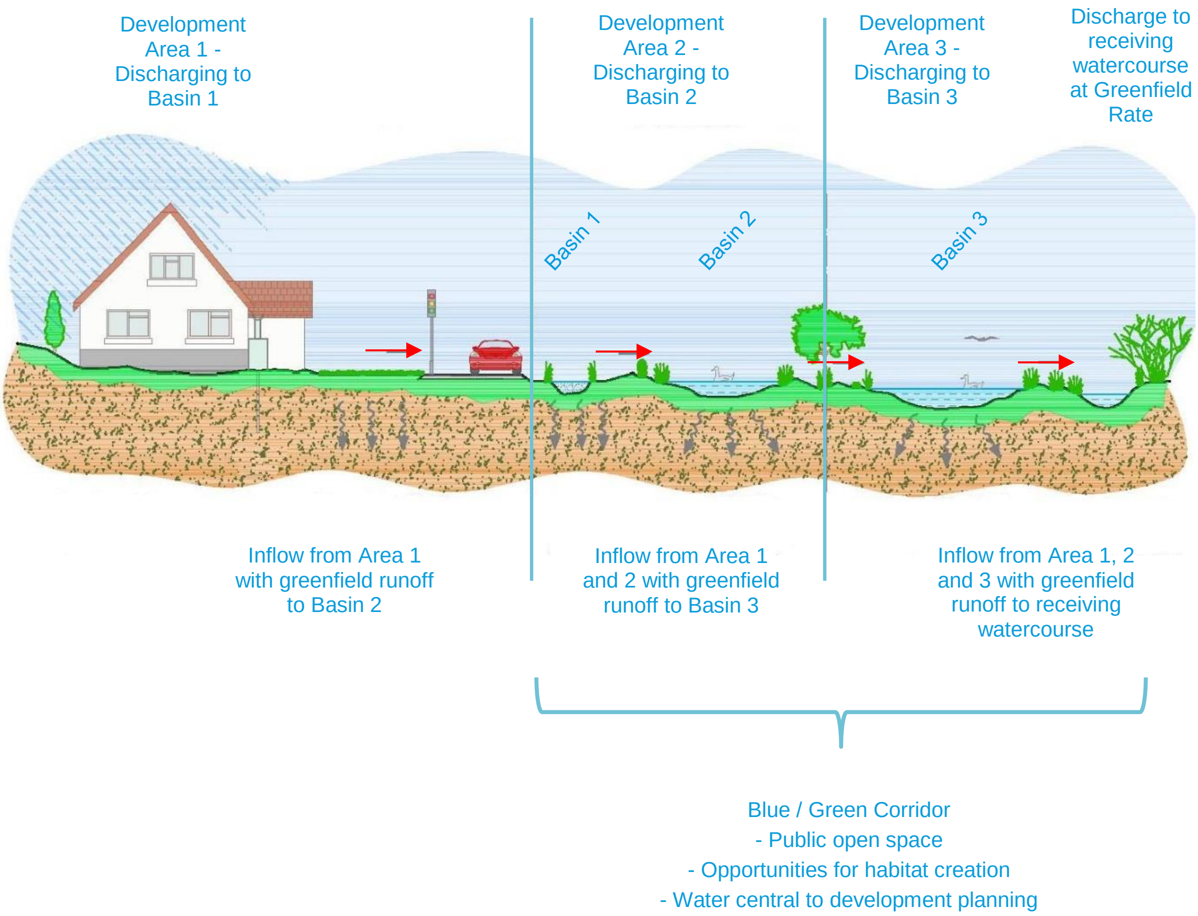
- Climate change;

- Runoff for a variety of design events;
- Freeboard to prevent overtop;
- Control structures to limit discharge from each basin;
- Pollution control measures.

Basins can either be connected via swales or as a series of controlling structures beneath site access roads. A description of the various SuDS techniques is included in Section 6 and depending on ground conditions infiltration systems may be considered as a suitable alternative control measure.

Basins may be designed to be dry (unless flooded) or as a permanent wetland habitat. They are generally formed with shallow slopes for egress and a hard bed for ease of access and maintenance. Above all, the basins are designed to replicate current greenfield discharge rates so that runoff from newly formed impermeable areas may be stored within the development without increasing risk elsewhere.

Figure 5-5: Surface water conceptual model



5.2.7 Recommendation

Although the proposed cascading storage basins are likely to provide sufficient storage for the 1 in 100 year climate change scenario it is recommended that additional storage should be provided within the developed areas to accommodate exceedance volumes. This could be achieved by landscaping and making best use of available green space to contain exceedance flows in swales.

Use of raised kerbs could also provide additional storage within internal road areas. These approaches can be used to allow certain areas of the site to flood to shallow depths when the capacity of the onsite drainage network is exceeded. Flood water will then be able to pond before gradually discharging back into a watercourse

It should be noted that this is a preliminary screening assessment of basin capacities, which is simple in its approach and is based upon several assumptions. Modelling of the basins is required during detailed design stage to provide a better understanding of the storage volumes used in each basin and to develop an optimum configuration of basin outflow rates. It is possible that detailed analysis of the basins could conclude that further attenuation measures may be required to restrict runoff from the development site to a suitable greenfield runoff rate.

5.2.8 SUDS considerations

Opportunities to reduce the current and future levels of flood risk through the integration of a coherent and integrated SuDS approach across the Bailrigg area will help provide an opportunity to both manage surface water flooding and improve water quality through mitigating the impacts of diffuse pollution. Appropriate SuDS techniques also provides opportunities to enhance local amenity and wider biodiversity benefits.

Development of a Garden Village provides opportunity to incorporate effective SuDS approaches within future development that considers of increased runoff from the new development as well as existing limitations and flood risk downstream. There is also an opportunity to encourage the retrofitting and incorporation of SuDS within existing development (both public and private areas) particularly through the improved utilisation of areas of open green space and highways and relatively low scale modifications to current water management and land management practices in order to reduce the existing flood risk.

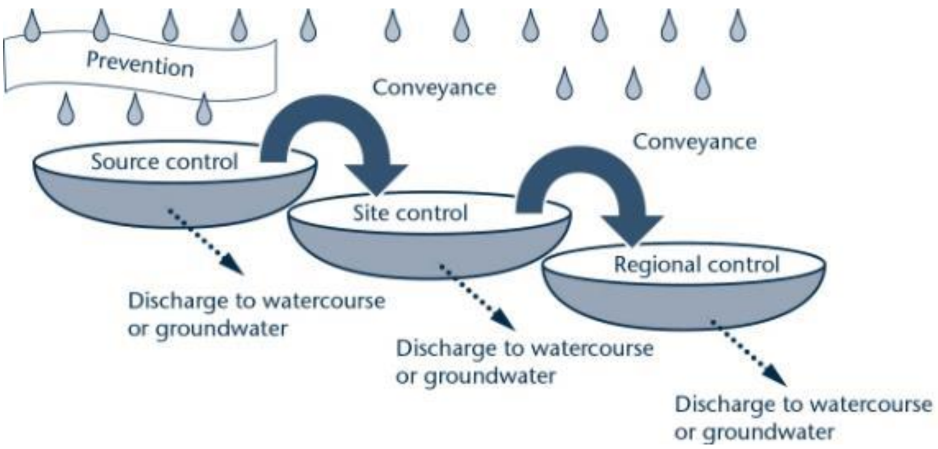
All new development proposals will need to consider requirements for SuDS. Future development should incorporate appropriate SuDS measures to:

- Reduce the flood risk to the development site associated with surface water runoff.
- Reduce the offsite surface water flood and pollution impacts from the proposed development.

Lancaster City Council will encourage future development proposals that contribute to reducing the existing risk from surface water flooding and pollution in the locality of the development. This can be achieved through the incorporation of additional attenuation allowances to accommodate existing unattenuated impermeable development and climate change impacts.

There are a variety of SuDS components which are considered suitable which may be used independently or in combination as part of the SuDS management train (Figure 5-6).

Figure 5-6: SuDS Management Train Principles



6 SuDS selection

The following section summarises the most common SuDS techniques (based on the 2015 CIRIA SuDS Manual[5]) and indicates the general suitability for Bailrigg area. Further information to aid the selection of appropriate SuDS techniques can be found in the SuDS Selection Summary, included as Appendix C.

6.1.1 Rainwater Harvesting

Rainwater harvesting is the localised interception of rainwater runoff, normally for use at source. Runoff collected from roofs and impermeable surfaces can be stored and following appropriate treatment utilised for use within domestic or commercial properties. This approach can reduce surface water flood risk by reducing the volume of runoff from a site and can reduce the volume of attenuation storage required. This approach provides sustainability and climate resilience benefits and can be used to meet some or all of the properties water demands. Harvesting systems usually require the provision of a storage tank, pump, power controls and pipework.

Suitability for Bailrigg area:

Given that development within Bailrigg area generally encompasses large impermeable areas including extensive roof areas, rainwater harvesting offers significant opportunities both for incorporation in new development and also retrofitting within existing development. In addition to the potential savings from non-potable domestic water for use such as flushing toilets, individual sites may benefit from commercial or industrial use of the collected water.

6.1.2 Green Roofs

Green roofs involve the localised interception of rainwater through the installation of vegetated areas on building roofs. The intercepted rainfall is absorbed by the vegetation and substrate which reduces runoff most significantly from normal summer rainfall events due to the evapotranspiration process and temporary storage provided. Whilst it is recognised that green roofs are generally more expensive to install and maintain they can provide additional benefits such as improving the visual appearance of an area, providing ecological value and enhancing the buildings thermal performance (reducing energy use). They can also extend the design life of roof waterproofing by protecting it from mechanical damage, ultraviolet radiation and temperature extremes.

Suitability for Bailrigg area:

As development within Bailrigg area encompasses residential units with large extensive roof areas. Green roofs therefore offer opportunities to improve surface water management, are particularly suitable for incorporation in new development. Retrofitting, whilst less straightforward can often be undertaken providing the existing roofs have sufficient structural capacity (or are strengthened accordingly). Whilst it is recognised that lightweight industrial buildings may not normally have sufficient structural capacity to support a green roof, the cost of the green roof and extra structural provision can be offset against the long-term benefits in reduces attenuation costs and improved building efficiency. Incorporation of green roofs in both new development and through retrofitting opportunities will therefore be actively encouraged by Lancaster City Council.

5 The SuDS Manual CIRIA Report C753. CIRIA. 2015

6.1.3 Infiltration Systems

There is a range of SuDS systems which collect and store runoff, allowing it to infiltrate into the ground. This contributes to reduce runoff rates and surface water flooding whilst supporting baseflow and groundwater recharge. The inclusion of overlying vegetation can reduce the risk of pollution to underlying soils through filtration. Types of infiltration systems include soakaways, infiltration trenches, infiltration blankets and infiltration basins. Bioretention systems and pervious pavements can also be designed to allow infiltration. Infiltration systems are reliant on groundwater levels being at least 1m below the base of the feature and soils having a suitable permeability. Infiltration to the ground at or near the source reduces reliance on downstream drainage systems.

Suitability for Bailrigg area:

Dependent on the groundwater levels and the permeability of the soil these systems are useful for small urban catchments as is characterised by the drainage within Bailrigg area. They can therefore potentially be used to intercept and infiltrate local surface flows. Infiltration systems can be compact and therefore are potentially suited for retrofitting in existing green space areas or other available areas within an area, however their suitability will require a consideration of the location of impermeable areas and flow routes. As the system facilitates discharge ultimately to groundwater it is critical to ensure runoff is suitably clean so that groundwater is not put at risk of contamination. They are subsequently best suited to deal with runoff from roofs. Retrofitting infiltration systems to existing sites and redirecting roof drainage from the existing drainage system to these areas components may provide the opportunity to reduce surface water flood risk and would be encouraged. New development will be expected to have considered infiltration as a means of managing both existing and post development surface water flood risk.

6.1.4 Trees

Trees can be incorporated within a range of SuDS components to improve their performance and contribute to effective surface water strategies. Including trees in new development can provide a number of surface water benefits by increasing transpiration, interception, increased infiltration and phytoremediation (where through drawing up water from the soil through transpiration harmful contaminants are taken into the tree and may be transformed into less harmful substances. In addition, trees within impermeable areas can effectively incorporate root storage systems as part of an effective bioremediation approach. Trees therefore contribute both to managing surface water quantities and contamination. Trees also have many other benefits to the surrounding environment including aesthetics, filtering harmful chemicals from the air, masking and reducing noise, creating wildlife habitats and absorbing and storing carbon dioxide.

Suitability for Bailrigg area:

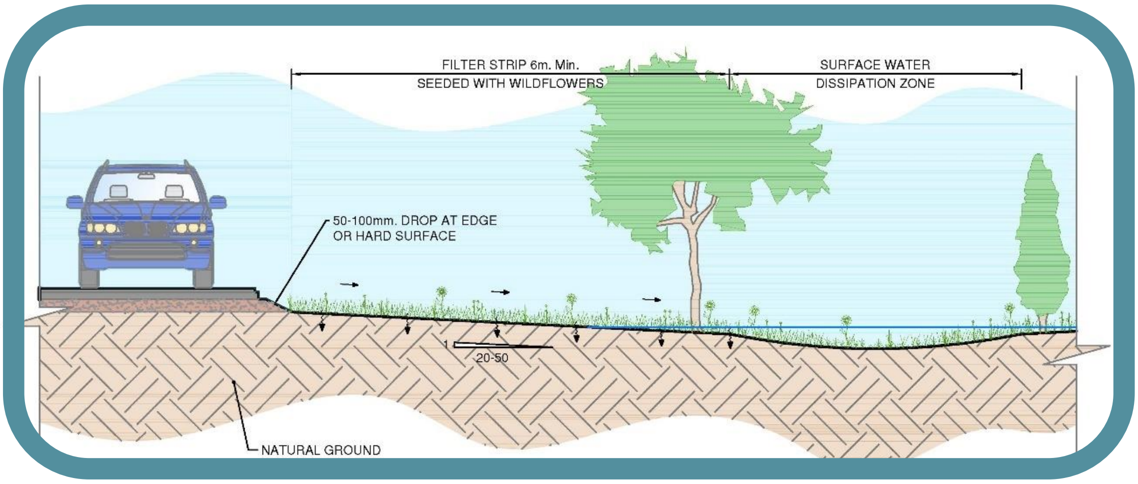
Whilst incorporating trees alone are unlikely to be sufficient to manage surface water issues, the local and site wide benefits they can deliver as part of a coherent SuDS strategy is recognised. Their incorporation would therefore be encouraged both in new development as part of a retrofitting approach. Landscape management practices will be reviewed so that they contribute to effective surface water management.

6.1.5 Filter Strips

Filter Strips are uniformly graded gently sloping grassed or densely planted areas which are located between impermeable area and the receiving drainage systems or watercourse. Filter strips are designed to intercept sheet flows and provide vegetative filtration to contaminants and sediments as the water flows across them. They can also encourage some infiltration. They generally provide a pre-treatment component, capturing silt before flow enters bioretention systems or swales. Alternatively, if there is sufficient flow path surface they can provide a more significant contamination treatment component. Where space allows, filter strips are useful for managing runoff from linear features such as roads and also from carparks and other impermeable areas. Filter strips should generally be lined to prevent infiltration where there is a high risk of leaching on brownfield sites or a high risk of groundwater pollution from significantly contaminated runoff. Designed primarily for water quality treatment, filter strips tend not to reduce peak flows or significantly reduce runoff volume, although they can help to retain runoff from smaller rainfall events on site. Filter strips do require maintenance to ensure their continued operation, although the maintenance requirements are generally limited to mowing (ideally grass length of 75-150mm across the treatment surface) and occasional silt removal. Therefore, the additional costs are relatively low. They are also useful on industrial sites where the surface feature enables visible pollution and sources to be identified.

Suitability for Bailrigg area:

Filter strips should always be considered within new development areas as they provide an effective means to reduce runoff contamination through either a pre-treatment or full treatment approach. They are particularly suitable for use with small contributing areas. Filter strips should be used in combination with attenuation SuDS approaches to manage surface water runoff quantity and reduce existing and future flood risk. Retrofitting filtration strips within existing green landscaped areas (many of which are adjacent to roads and impermeable areas) may be possible, however, space and other constraints may limit their suitability. The land-take is usually moderate, requiring a minimum 6m width with a slope not exceeding 1 in 20.

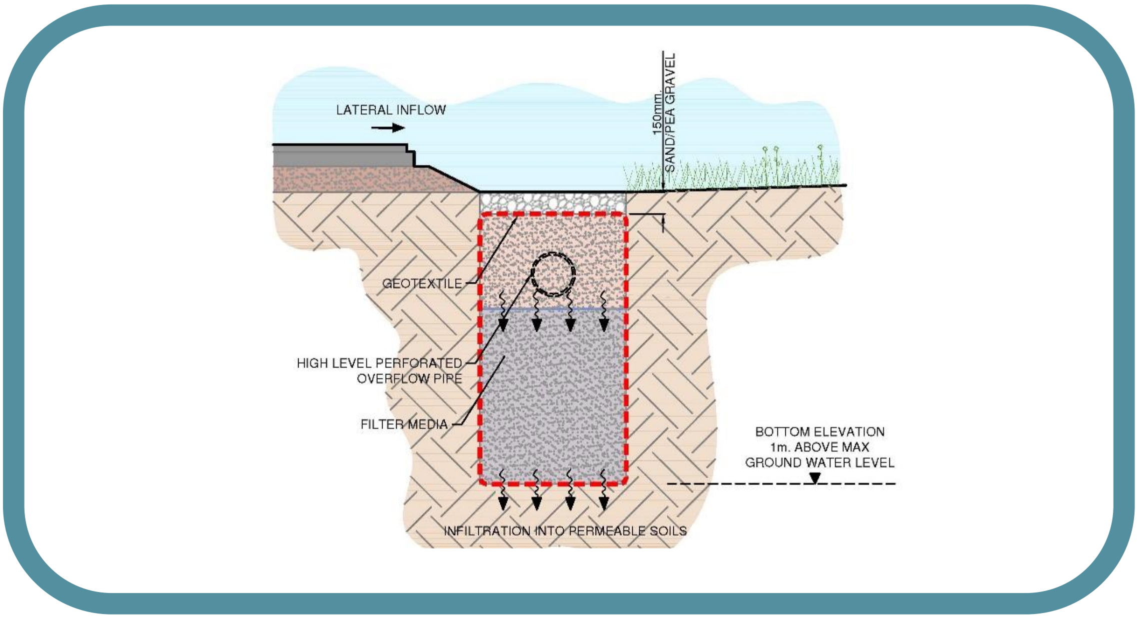


6.1.6 Filter Drains

Filter drains are gravel filled trench that creates subsurface storage for infiltration or downstream discharge. They also provide some filtration of surface water runoff. They are not normally intended as sediment traps and ideally should receive inflow from adjacent impermeable areas that is pre-treated using a vegetated filter strip or equivalent. Trenches can be used to filter, attenuate, convey and dissipate storm water into the ground through the base and sides of the trench and/or provide a level of treatment prior to reaching a secondary SuDS feature. There is a requirement to separate filter media from surrounding ground with a geotextile where infiltration is desirable, or include a membrane where infiltration is not permitted. Where there is no upstream filtration they should incorporate a geotextile or sacrificial stone at a shallow depth which can be regularly removed and cleaned of silt. The filter drain should incorporate a perforated pipe near the base to collect and convey water to downstream drainage. The voids in the filter drainage material and pipe can provide attenuation storage and they can in certain circumstances replace conventional conveyance drainage systems. Filter drains require regular maintenance to ensure continued maintenance and should incorporate inspection points and rodding points.

Suitability for Bailrigg area:

Filter strips should always be considered within new development areas as they provide an effective means to both reduce runoff rate and volume. They also provide a water quality treatment function. They are particularly suitable for use with small contributing impermeable areas and in areas without significant slopes. The land take for filter drains is usually low, typically 0.5-1.0m width meaning that they are potentially suited for retrofitting within existing green landscaped areas. However, they do need to be used in conjunction with additional treatment where runoff is likely to be contaminated. In addition, with a depth of 1-2m they need to consider constraints such as existing utilities and groundwater levels. The location of the filter trenches should be carefully considered so there is no interaction with people and vehicles. They therefore may not be suitable for all areas although it is noted that they can also be located beneath impermeable areas. As a conveyance and storage system, there will need to be a requirement to consider connectivity to the runoff source, connectivity between green areas and also to the downstream discharge points such as the existing conventional surface water drainage system, downstream SuDS components or direct to watercourse.

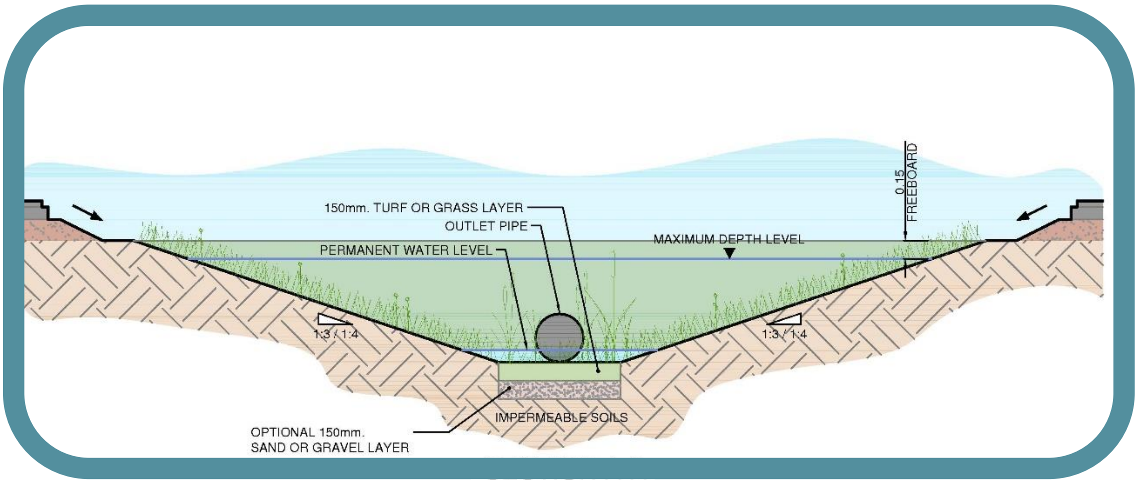


6.1.7 Swales

Swales are shallow flat-bottomed channels or depressions designed to treat, filter, store and convey runoff as part of the SuDS management train. Usually vegetated with grass, swales can be either 'dry' (where water is stored beneath the ground in a gravel filter drain layer except after rainfall events) or 'wet' where runoff is stored above the surface in the channel so may be permanently wet. Swales can be lined or unlined (to accommodate infiltration). Where runoff may be contaminated, appropriate geotextile filtration linings can be incorporated. To limit the rate and volume of runoff, swales can incorporate check dams across the flow path to provide attenuation storage. Where incorporated into site design, swales can enhance the natural environment and provide aesthetic and biodiversity benefits. They can also be designed to incorporate bioretention systems or constructed deeper to provide additional attenuation storage volume. Whilst requiring maintenance, this is relatively straightforward which should not be dissimilar to that which would be required for standard public open spaces.

Suitability for Bailrigg area:

Swales are an effective method of collecting and conveying runoff from impermeable areas and provide an alternative to conventional piped drainage which can provide additional surface attenuation storage. Their use should therefore be considered as part of the surface water management train in all new development as they will provide an effective means of providing attenuation to manage surface water flood risk, provide additional surface water treatment benefits and a conveyance route. As long surface level features with shallow side slopes, they are likely to be potentially suitable for retrofitting within some of the existing developed areas, however this will be dependent upon constraints such as existing services and land area. Providing connectivity between green areas will require consideration of existing site accesses. Swales are well suited for managing runoff from roads, carparks and other impermeable areas and as a surface feature they are well suited for industrial sites as any pollution is visible. The swales will however be likely to require enhancement or deepening to provide sufficient storage to reduce current levels of flood risk.

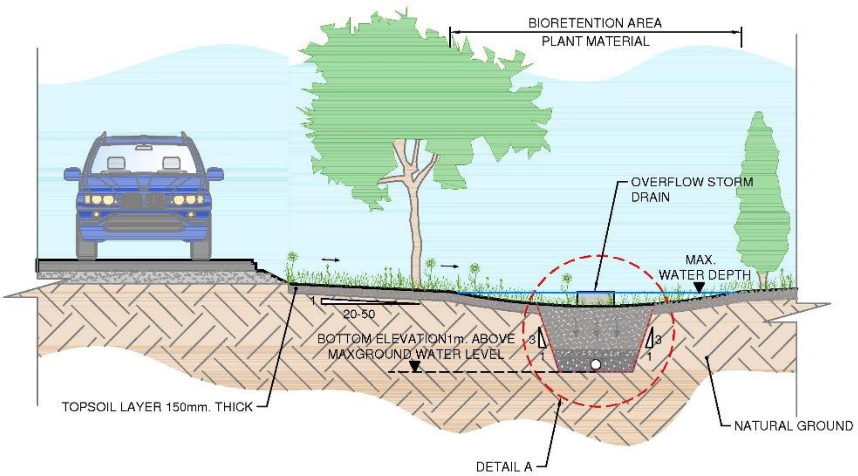


6.1.8 Bioretention Systems

Bioretention systems are vegetated areas such as shallow depressions rain gardens or raised planters which can reduce run off rates and volumes and provide a pollution treatment process. These areas are planted with specially selected plant species to allow runoff to pond temporarily on the surface and filter through vegetation and soils where it is either infiltrated or conveyed further along the surface water management train. They can be integrated into a wide variety of development landscapes. Trees can also be classed as bioretention systems, where they are incorporated into impermeable areas with an appropriate tree pit and geocellular root cell. Bioretention systems are most commonly used for managing and treating runoff from more frequent less extreme rainfall events. In addition to the vegetation, bioretention systems usually incorporate an appropriate underlying filter medium (to filter out pollutants and control rate of infiltration) and an underlying drainage layer which is designed to collect water and transfer it to the perforated pipes for further conveyance downstream.

Suitability for Bailrigg area:

Bioretention systems take several different forms and combined with other SuDS measures are likely to provide a suitable solution to managing surface water. The measures may range from rain gardens and raised planters which can be used to collect roof runoff and contribute to the management of runoff from individual sites through to site wide bioretention tree pits, swales or trenches both within new development and existing public green spaces. The nature of bioretention systems means that they are particularly well suited for local site retrofitting and can provide amenity and biodiversity enhancements.



6.1.9 Pervious Pavements

Pervious pavements are structural paving in roadways, carparks, hard standings and pedestrian areas which are designed to allow runoff to soak through them. They can consist of block pacing (with gaps between the blocks) or porous blocks where water drains through the blocks themselves. Pervious pavements are designed with a sub base which allows water to be stored and discharge to the ground via infiltration and they provide an efficient means of managing surface water close to the source. They can contribute to reduce both the peak flow and volume of run off. The structure and underlying subsurface layer can also provide a water quality treatment function. Examples forms of permeable pavements include modular surfacing and block paving, porous asphalt, grass reinforcement or resin bound gravel. Pervious pavements can be designed to allow total infiltration to the sub soil, partial infiltration to the subsoil (where there is an overflow drainage connection used when the underlying soil can no longer infiltrate) or no infiltration (where infiltration is not technically feasible, and water is conveyed to an outfall point via perforated subsurface pipes). Pervious pavements systems can incorporate subsurface tanks to attenuate or collect flow before reuse within rainwater harvesting systems or discharge to downstream SuDS. In terms of maintenance, pervious pavements need to be cleaned of silt and other sediments to preserve their infiltration capacity.

Suitability for Bailrigg area:

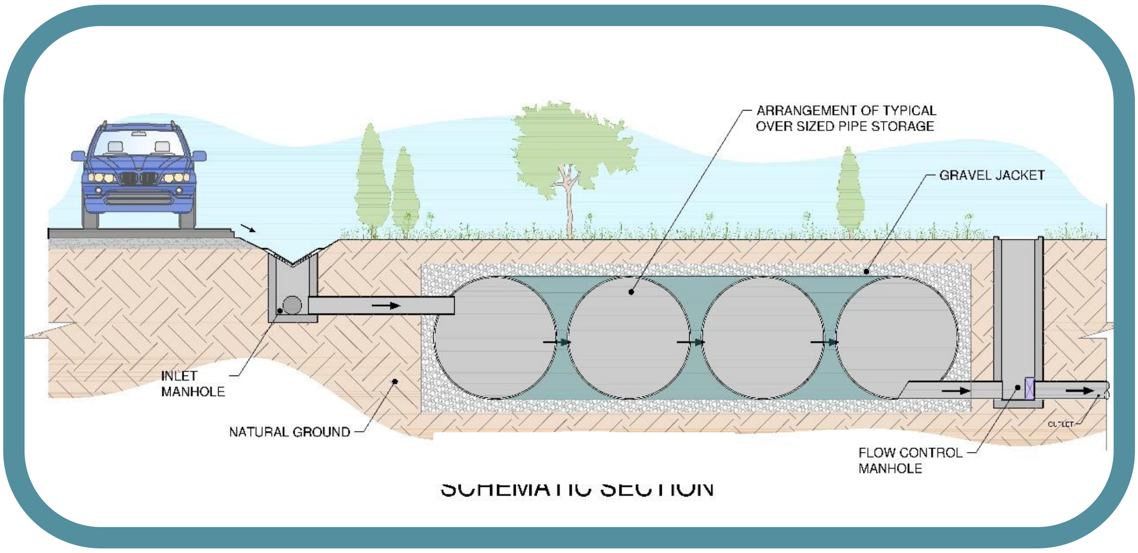
Pervious pavements can be used on most sites and will be particularly suitable where new and existing development includes extensive areas of carparking and hardstanding. Pervious pavements are an effective alternative to impermeable surfaces and therefore require no extra development space for their construction. As they only require a small head difference between the runoff level and the outfall, they are suitable for use on flat terrain. Whilst they generally tend to be used in areas with low traffic volumes and light traffic loading (such as car parks) they are capable of supporting heavy goods vehicles. Pervious pavements can be used in most ground conditions and by incorporating suitable lining systems they can be used in brownfield areas. Runoff contamination, groundwater levels and existing services will require consideration and the design will need to consider proximity to existing building foundations as is the case with infiltration systems. Given their suitability and benefits, the use of permeable pavements should therefore be integral to the design of new surfaces. They can be combined with other SuDS solutions to effectively manage surface water. Retrofitting of pervious pavements to existing impermeable areas would also be encouraged.

6.1.10 Attenuation Storage Tanks

Attenuation tanks are designed to temporarily store runoff before infiltration, controlled release or use. They usually consist of subsurface tanked systems such as geocellular storage systems, glass reinforced plastic or concrete tanks or oversized pipes. The key benefits of attenuation tanks are that they can provide high storage volumes (compared to aggregate filled structures such as filter drains and bioretention systems) and they can be installed below roads, carparks (with appropriate structural loading design) and open space areas thus reducing land take. As an attenuation/storage system, tanks are generally used in combination with other SuDS approaches including treatment components. Regular maintenance of attenuation tanks is an important consideration as any failures or blockages are less visible.

Suitability for Bailrigg area:

The requirement to make best use of available space on the already developed areas means that providing subsurface attenuation and storage tanks is likely to be a suitable approach to managing surface water within new development. The tanks can be integrated beneath areas of carparking, hardstanding and open space without significantly impacting available development area. As storage systems, their use will need to consider connectivity to downstream discharge points and will therefore need to be employed alongside other SuDS techniques to provide an effective surface water management approach. However as large storage volumes can be provided by subsurface storage tank systems, given the extent and volumes of surface water runoff and flooding, their use is therefore likely to particularly suitable. However, given the maintenance requirements, other forms of attenuation are likely to be preferableAttenuation storage tanks will also be required to be used in conjunction with effective upstream surface level vegetated pre-treatment.

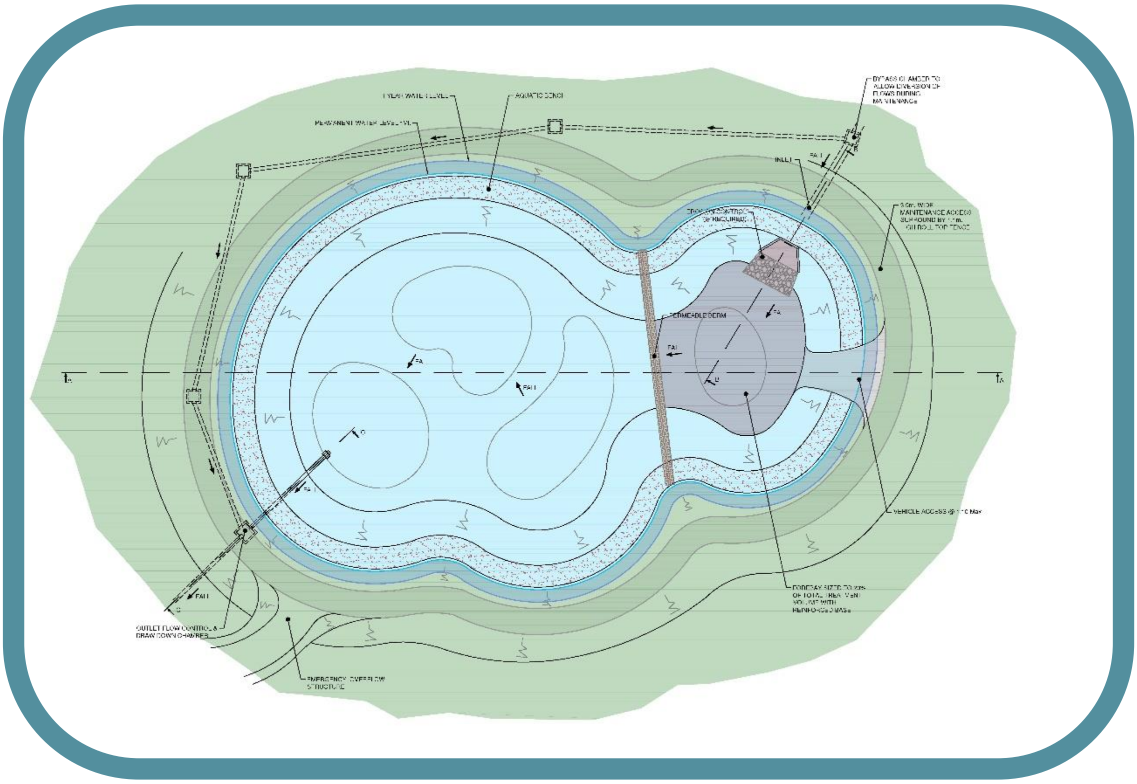


6.1.11 Retention Ponds & Wetlands

Landscaped depressions containing permanent pools of water, retention ponds are similar in many respects to detention basins, in that they can collect and temporarily store / attenuate surface water runoff and release it more slowly to the discharge point. The attenuation storage volume is provided above the permanent water level and thus they provide a smaller storage volume than the equivalent sized detention pond. However, they can provide an enhanced level of water quality treatment and also provide biodiversity and amenity benefits by supporting emergent and submerged vegetation along the waterline and within shallow marshy areas. Retention ponds need to be designed with suitable upstream pre-treatment systems to prevent open water areas becoming blocked with silt, odorous due to pollution or stagnant. Well managed ponds and wetlands can add significant economic value to a development.

Suitability for Bailrigg area:

Similar to detention basins retention ponds are generally suitable to most types of development and can be used for retrofitting where existing drainage networks and land availability allows. They will however provide less storage than detention basins and therefore their siting and use will require consideration of existing and future flood volumes. They do however provide an effective means to manage surface water flood risk and can provide valuable multifunctional benefits aesthetic, amenity and biodiversity benefits. The volumes of surface water flooding indicate that a number of smaller retention basins (constrained by areas of available green space) appropriately connected may provide an effective means of managing surface water flooding.



6.1.12 Detention Basins

Detention basins are a dry landscaped depression which are designed to collect runoff and fill up temporarily during and for a short while after rainfall events. By integrating a suitable flow control at the outlet, they provide an effective means to attenuate flow by providing flood storage and releasing it to the downstream system more slowly and in line with flow control limits. As well as reducing flood risk locally by collecting surface water runoff they reduce the risk of downstream flooding by reducing the rate of discharge. Through the incorporation of suitable vegetation, basins can also form a useful water quality treatment function by enabling settlement of particulates. Detention basins work well in areas with low permeability soils but can also reduce the volume of runoff by allowing infiltration where this is technically viable. Basins can also be designed to function as recreational areas or habitat areas when planted, for example wet woodlands and are generally relatively easy to construct and maintain. Detention basins can also be hard landscaped areas which are normally designed to manage runoff during more extreme events.

Suitability for Bailrigg area:

Detention basins are generally suitable to most types of development and can be used for retrofitting where existing drainage networks and land availability allows. They will provide an effective means to manage surface water flood risk and can provide valuable multifunctional benefits aesthetic, amenity and biodiversity benefits. The size of the detention basins will be constrained by the available areas of open space, both in new development and in retrofitting to areas of public open space. The volumes of surface water flooding indicate that a number of smaller detention basins (constrained by areas of available green space) appropriately connected may provide an effective means of managing surface water flooding. All available open space should be reviewed for their suitability of incorporating a detention basin.

6.1.13 Proprietary Treatment Systems

These manufactured SuDS systems are designed to provide treatment of surface water through the removal of contaminants. They are generally most suitable where site constraints such as available space limitations preclude the use of other more natural treatment measures.

Typical treatment systems include proprietary bioretention systems, treatment channels, hydrodynamic or vortex separators, filtration systems and oil and multi process system. These types of treatment systems are generally used alongside SuDS techniques which are designed to manage water quantity.

Suitability for Bailrigg area:

Whilst suitable for incorporation as part of the SuDS surface water management train in Bailrigg area, Lancaster City Council would discourage proprietary systems that require regular maintenance in favour of alternative more sustainable approaches such as green roofs, bioretention and filter strips. Whilst it is recognised that these systems would be likely to be incorporated within individual sites (both new and retrofit) with individual operators, they rely on regular maintenance and therefore their ongoing reliability cannot be easily monitored by LPAs. However, it is recognised that space constraints and runoff contamination levels mean that in some circumstances proprietary systems provide the most suitable approach to treat surface water prior to discharge.

All SuDS and drainage proposals outlined in this strategy are to assist the planning process only and are subject to detailed design.

7 Existing risks and opportunity mapping

7.1 Introduction

It is recognised that existing areas of Galgate are currently at risk of flooding as defined by the Environment Agency's flood zone mapping. Whilst opportunities to mitigate risk to existing urban areas have been highlighted as a priority for the Bailrigg strategy new development planning may also provide a catalyst for flood mitigation and flood risk management to existing risk areas.

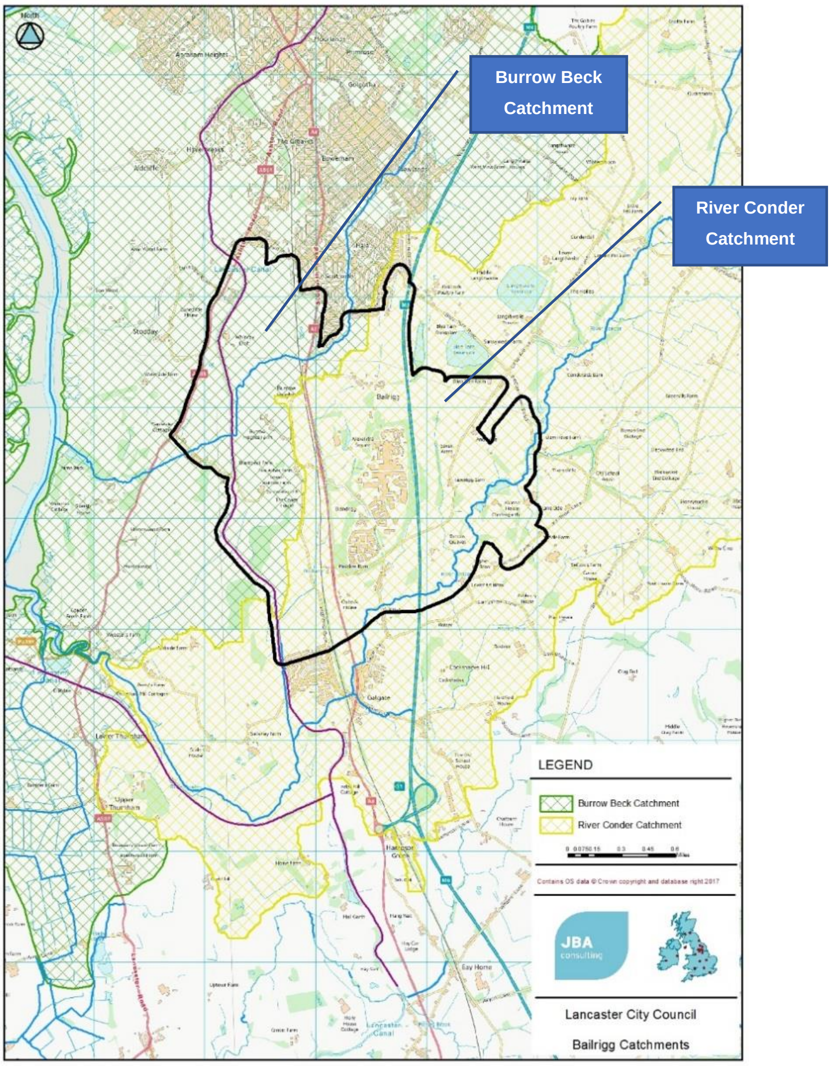
Development of a Garden Village may provide opportunity to create flood mitigation and management measures including compensatory storage, flood defences and natural flood management measures to existing communities at risk.

The Hazelrigg weather monitoring station at Lancaster University recorded 73.6 mm of rain in 24 hours up to 9am on Thursday, 24th November 2017. This was the highest rainfall for more than 50 years and exceeded rainfall intensity for the 2015 Storm Desmond event.

7.2 Bailrigg Catchments

The Bailrigg Catchment is split into two key areas comprising the Conder catchment to the east and the Burrow Beck catchment to the west (Figure 7-1). Catchment areas have been defined based on FEH.

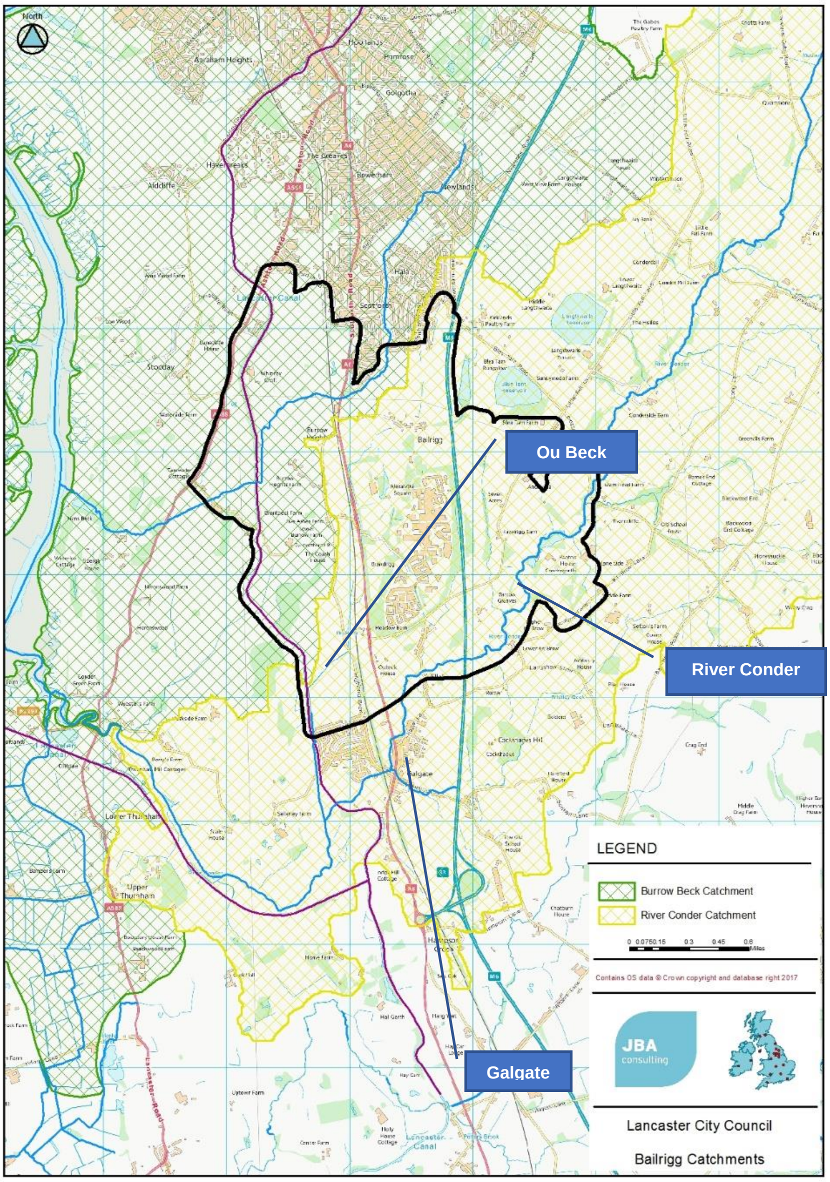
Figure 7-1: Catchment areas



7.3 Watercourses

Two watercourses form the primary flood risk to Galgate. These are the River Conder, which flows southwest through Galgate and Ou Beck which flows to the west of Galgate (Figure 7-2).

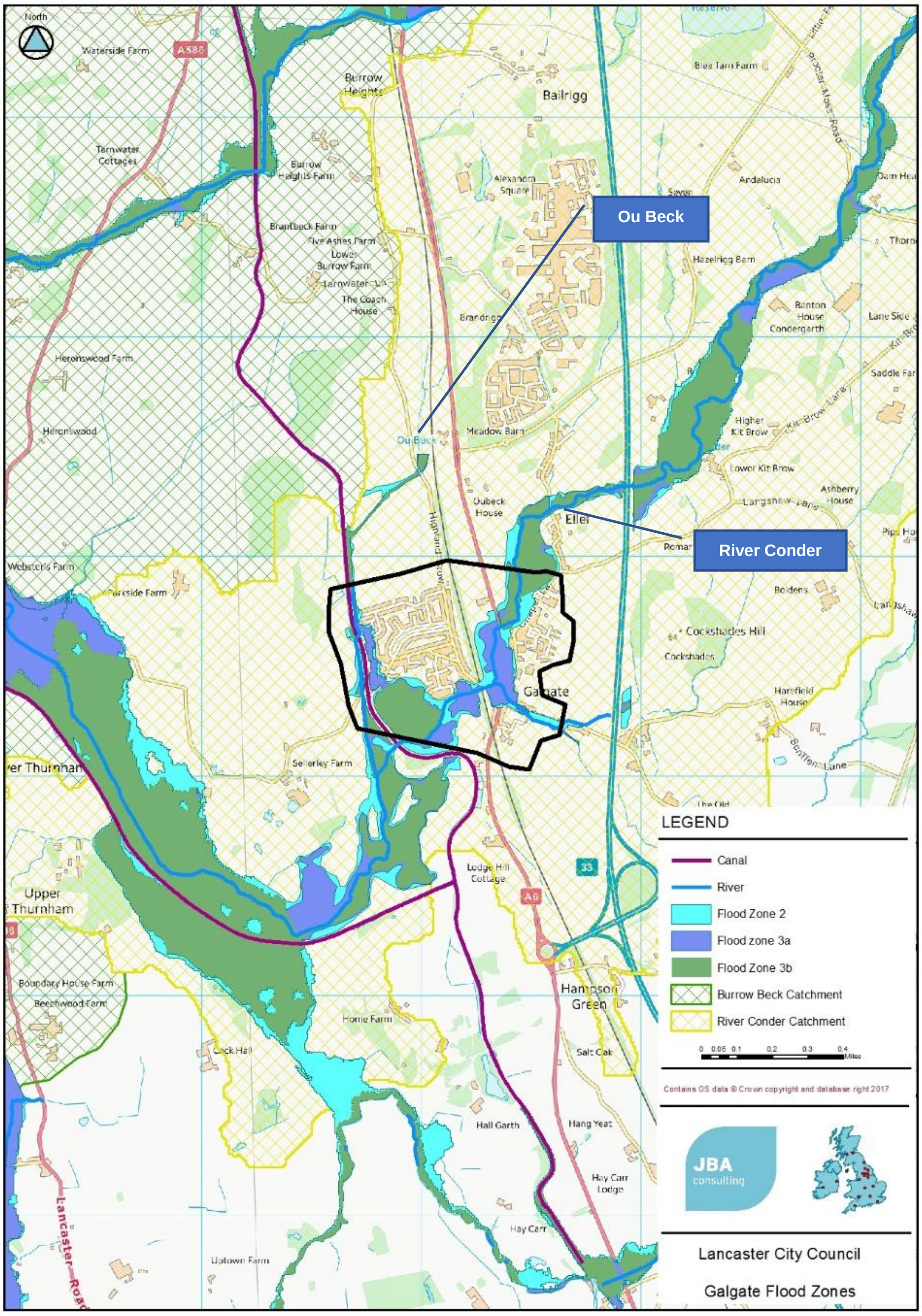
Figure 7-2: Watercourses



7.4 Flood Zones

After passing beneath the M6 the River Conder flows through Galgate passing beneath the A6 and railway line. Downstream of Galgate, Ou Beck flows into the River Conder. In accordance with the Environment Agency's flood mapping, areas of Galgate are identified as being at significant risk of flooding from both the River Conder and Ou Beck (Figure 7-3).

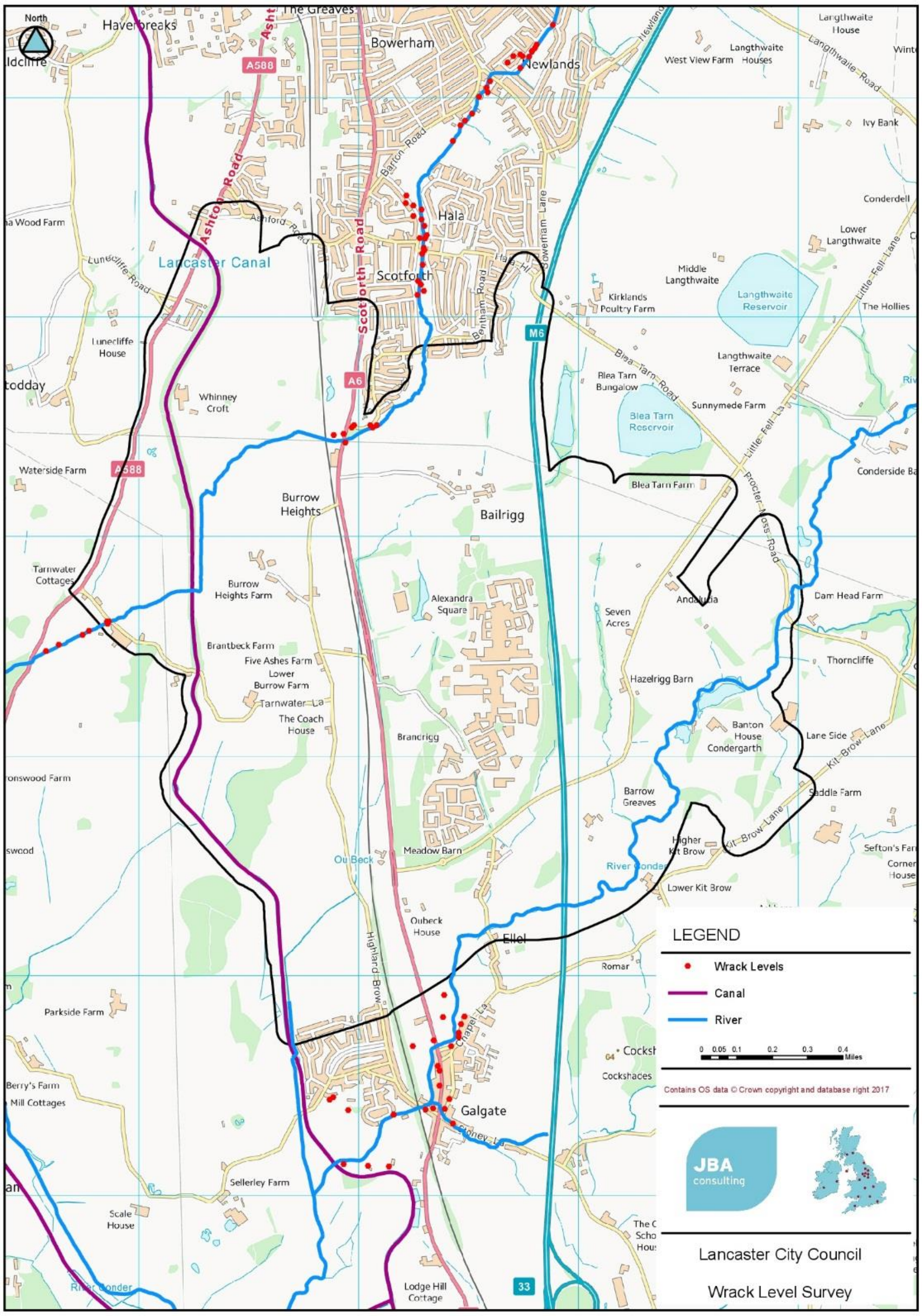
Figure 7-3: Environment Agency defined Flood Zones



It is noted that the Environment Agency is currently in the process of updating the River Conder and Ou Beck models for this area. Updated flood mapping has not been released yet and it is likely that the new flood extents will result in changes to the published flood maps. The new modelling will be updated to include recent hydrology, modelling enhancements, climate change and the impacts of recent flooding. EA Flood Maps, as published on their website, are updated on a quarterly basis. Ongoing work includes:

- The Environment Agency is undertaking post flood evaluation to define the extent and mechanism of flooding.
- The Environment Agency has undertaken wrack mark surveys, shown on Figure 7-4. Wrack marks indicate the extent of flooding recorded during the 24th November 2017 event.

Figure 7.4: Wrack Mark Surveys



- JBA, working with the Environment Agency, is currently updating the River Condor and Ou Beck models. The outcomes to this modelling update are not yet released for use by the Environment Agency. The Environment Agency will need to be consulted to confirm current programme for publication of revised flood mapping.

7.5 Flood Zone Definitions

Flood Zones refer to the probability of river and sea flooding, ignoring the presence of defences. They are shown on the Environment Agency's Flood Map for Planning (Rivers and Sea), available on the Environment Agency's web site. Requirements for development within flood zones, in accordance with the NPPF, are summarised in the following Tables.

Table 7-1: Flood Zone 1 Definition

Flood Zone 1: Low Probability	
Definition	This zone comprises land assessed as having a less than 1 in 1000 annual probability of river and sea flooding in any year (<0.1%).
Appropriate uses	All uses of land are appropriate for development in this zone.
FRA requirements	For development proposals on sites comprising one hectare or above the vulnerability to flooding from other sources as well as from river and sea flooding, and the potential to increase flood risk elsewhere through the addition of hard surfaces and the effect of the new development on surface water run-off, should be incorporated in an FRA [Flood Risk Assessment]. This need only be brief unless the factors above or other local considerations require particular attention.
Policy aims	In this zone, developers and local authorities should seek opportunities to reduce the overall level of flood risk in the area and beyond through the layout and form of the development and the appropriate application of sustainable drainage techniques.

Table 7-2: Flood Zone 2 Definition

Flood Zone 2: Medium Probability	
Definition	This zone comprises land assessed as having between a 1 in 100 and 1 in 1000 annual probability of river flooding (1% – 0.1%) and between a 1 in 200 and 1 in 1000 annual probability of sea flooding (0.5% – 0.1%) in any year.
Appropriate uses	The water-compatible, less vulnerable and more vulnerable uses of land and essential infrastructure listed in… [The Flood Risk Vulnerability Classification] are appropriate in this zone. Subject to the Sequential Test being applied, the highly vulnerable uses are only appropriate in this zone if the Exception Test is passed.
FRA requirements	All development proposals in this zone should be accompanied by a FRA.
Policy aims	In this zone, developers and local authorities should seek opportunities to reduce the overall level of flood risk in the area through the layout and form of the development and the appropriate application of sustainable drainage techniques.

Table 7-3: Flood Zone 3A Definition

Flood Zone 3A: High Probability	
Definition	This zone comprises land assessed as having a 1 in 100 or greater annual probability of river flooding (>1%) and a 1 in 200 or greater annual probability of flooding from the sea (>0.5%) in any year.
Appropriate uses	The water-compatible and less vulnerable uses of land are appropriate in this zone. The highly vulnerable uses should not be permitted in this zone. The more vulnerable and essential infrastructure should only be permitted in this zone if the Exception Test is passed. Essential Infrastructure permitted in this zone should be designed and constructed to remain operational and safe for user in times of flood.
FRA requirements	All development proposals in this zone should be accompanied by a FRA,
Policy aims	In this zone, developers and local authorities should seek opportunities to: reduce the overall level of flood risk in the area through the layout and form of the development and the appropriate application of sustainable drainage techniques; relocate existing development to land in lower Flood Zones; and Create space for flooding to occur by restoring functional floodplain and flood flow pathways and by identifying, allocation and safeguarding open space for flood storage.

Table 7-4: Flood Zone 3B Definition

Flood Zone 3B: Functional Floodplain	
Definition	This zone comprises land where water has to flow or be stored in times of flood. SFRAs should identify this Flood Zone (land which would flood with an annual probability of 1 in 20 (5%) or greater in any year or is designed to flood in an extreme (0.1%) flood, or at another probability to be agreed between the LPA and the Environment Agency, including water conveyance routes).
Appropriate uses	Only the water-compatible uses and the essential infrastructure that has to be there should be permitted in this zone. It should be designate and constructed to: Remain operational and safe for users in times of flood; Result in no net loss of floodplain storage; Not impede water flows; and Not increase flood risk elsewhere. Essential infrastructure in this zone should pass the Exception test.
FRA requirements	All development proposed in this zone should be accompanied by a FRA.
Policy aims	In this zone, developers and local authorities should seek opportunities to: Reduce the overall level of flood risk in the area through the layout and form of the development and the appropriate application of sustainable drainage techniques; and Relocate existing development to land with a lower probability of flooding.

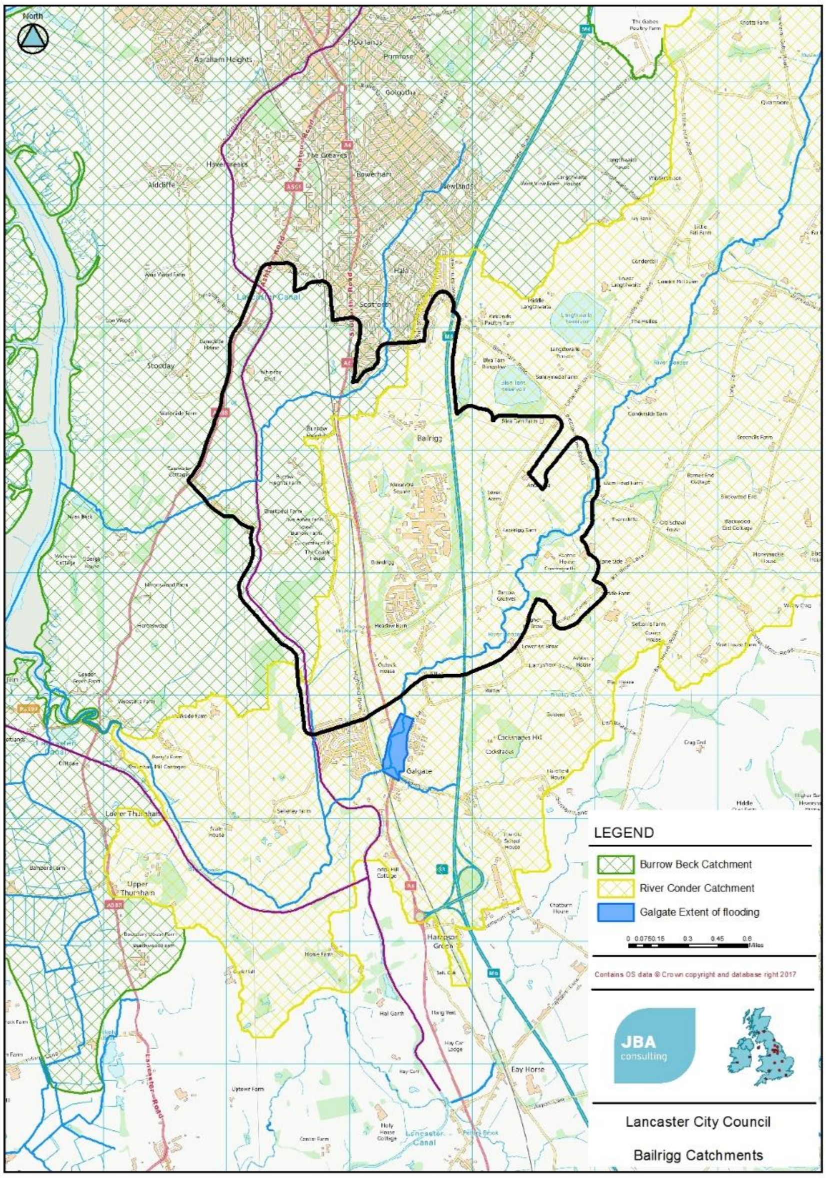
7.6 November 2017 Flooding

Galgate was the worst-affected area in the recent storms that took place on the 23rd November 2017. 70 people were rescued by firefighters and 27 people evacuated from their cars as rivers burst their banks and drains overflowed.

It is understood that approximately 120 properties and businesses were flooded in Galgate and the potential impacts of a Garden Village on existing risk will need to be addressed as part of the viability appraisal.

It is noted that the extent of flooding may change following further evaluation with the Council and Environment Agency. Further it is noted that this provisional plan (Figure 7-4) may not reflect the full extent of flooding. It is understood that the Environment Agency is currently undertaking post flood investigations and surveys and that this information will be used to confirmed model extents and predicted flooding associated with the current modelling update.

Figure 7-4: Indicative flood extents 27th November 2018



7.6.1 Images of Galgate

Selected images of flooding in Galgate have been included in this Section of the report.

Figure 7-5: Galgate on 23rd November 2017.

Source: www.bbc.co.uk

"Water reached up to 2ft high in many properties, destroying furniture as well as damaging cars. The City Council opened crisis centres for flood stricken residents."

"Two lanes on the M6 motorway southbound remained closed, between junctions 35 and 36 and the A6 at Galgate was also shut in both directions. Figure 1-7 shows the approximate extent of flooding in Galgate."

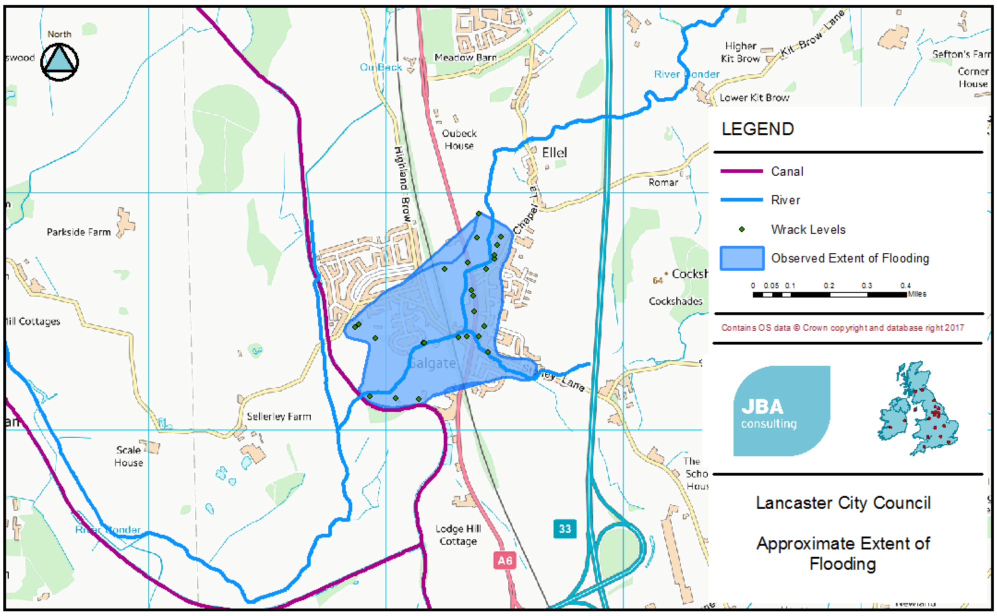
Figure 7-6: Flooded roads, Galgate.

Source: www.expressandstar.com

Figure 7-7: Flooded roads, Galgate.

Source: Lancaster City Council

Figure 7-8: Approximate extent of flooding.



7.7 Opportunities mapping

7.7.1 River Condor catchment

Whilst there are three primary causes of flooding to Galgate, the River Conder, the Ou Beck and the Whitley Beck. However, the River Conder represents the greatest risk. The source of the River

Conder is a spring at Conder Head on Black Fell near Littledale. From there the river flows off the hillside and down towards the M6 (Figure 7-8).

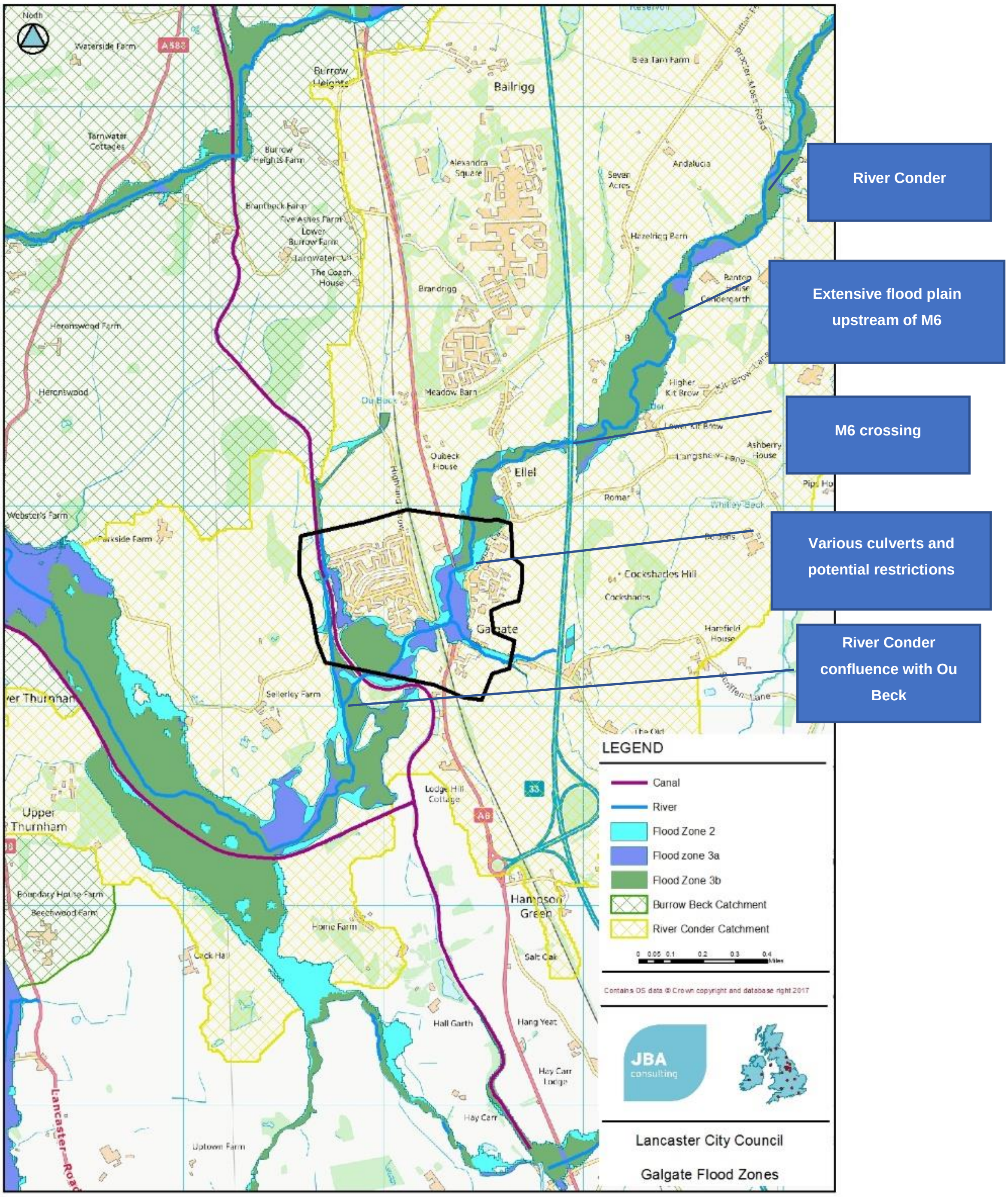
Upstream of the M6, flood mapping indicates an extensive floodplain with little variation between Flood Zones 2 and 3. The river continues through Galgate passing through several road culverts including beneath the A6 before reaching the confluence with Ou Beck.

Ou Beck flows to the west of Galgate and, based on the EA flood maps, certain areas of Galgate are at direct risk of flooding from Ou Beck rather than the River Conder. Any opportunities for flood risk management will, therefore, need to look at both areas if flood risk is to be effectively managed.

Any development proposals that could potentially increase risk to Galgate would need to be considered in detail. Indeed, the start point of any new development should be defined by a need to reduce and manage risks to existing communities.

In order to evaluate the scale and type of flood risk mitigation required further appraisal will be required. This falls outside the scope of this spatial flood risk strategy and further consultation with the Environment Agency is recommended to ensure continuity of approach following recent flooding.

Figure 7-9: River Conder

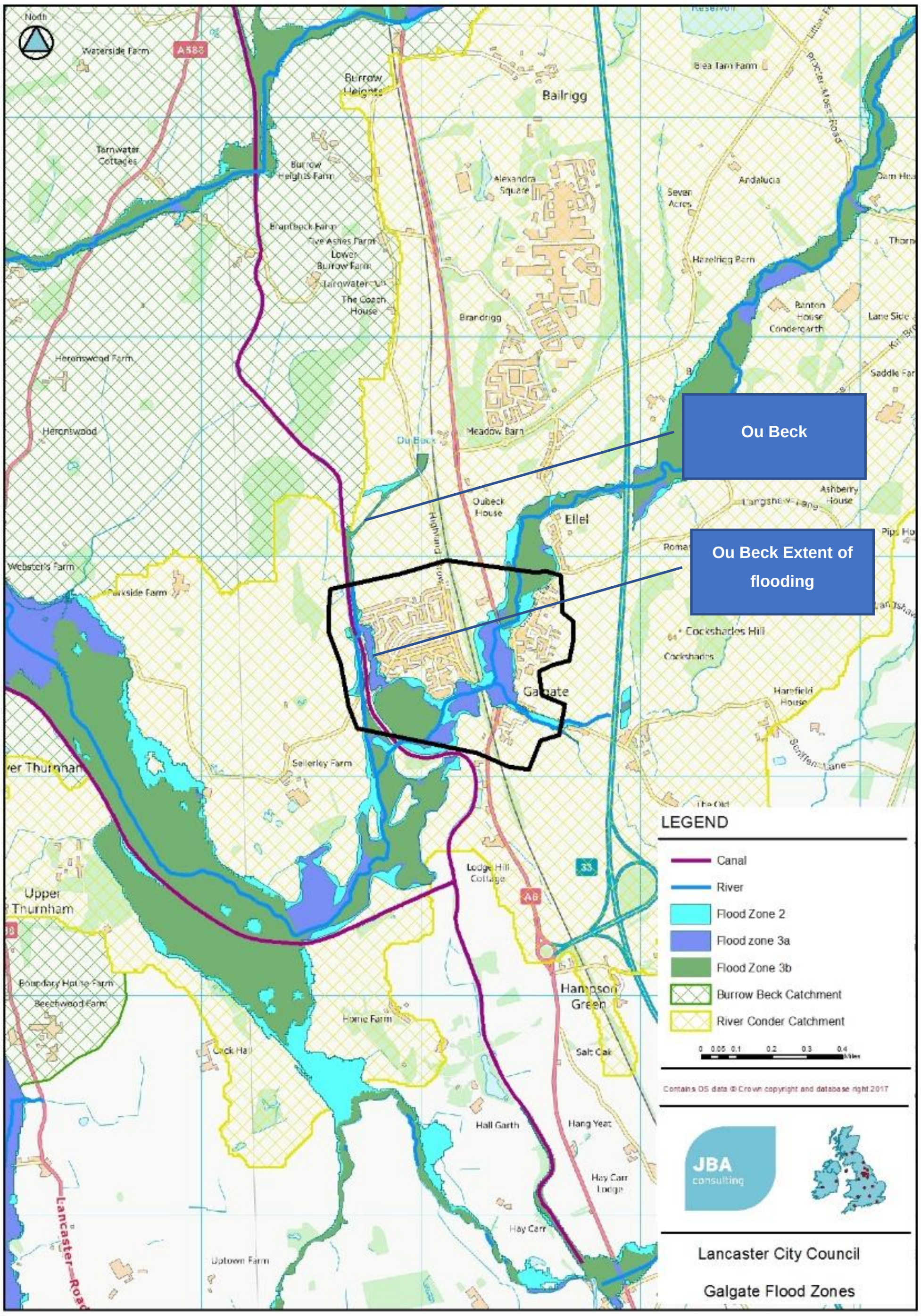


7.7.2 Ou Beck Sub-catchment

Ou Beck flows to the west of Galgate. The sub-catchment is relatively small and is located on the periphery of the Burrow Beck catchment area. Whilst current mapping indicates flood risk to Galgate, there are considerable areas of low-lying land upstream, with links to the river and floodplain, may prove beneficial in terms of future flood risk management.

Flooding from Ou Beck is not dependent on flooding from the River Conder. The risk from Ou Beck will, therefore, need to be addressed as an independent strategy. Land upstream should be retained for potential flood risk management. This could potentially form part of a blue green corridor for the Garden Village. Once again, this is subject to further modelling and assessment.

Figure 7-11: Ou Beck

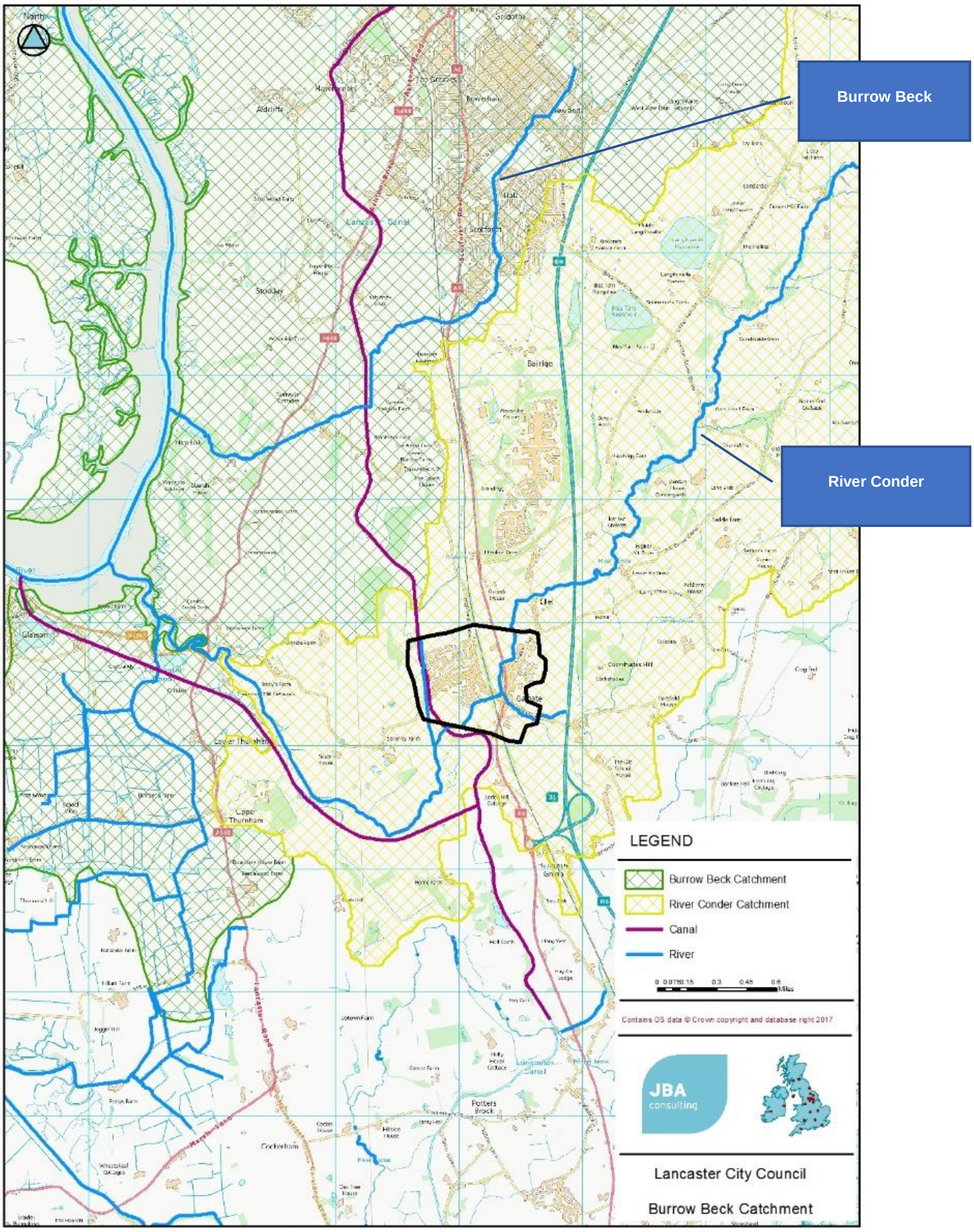


7.7.3 Burrow Beck catchment

The Burrow Beck catchment flows west to outfall into the River Lune. Catchment runoff from this area does not, therefore, contribute to flood risk at Galgate. Opportunities for development of a Garden Village within this area would not, therefore, impact on known areas of flooding.

It is recognised that small communities are located along Burrow Beck. Any proposed Garden Village development will need to consider risk through a Flood Risk Assessment. The premise for any new development will need to be based on flood mitigation and no offsite impacts.

Figure 7-10: Burrow Beck catchment



7.8 Preliminary Options for flood risk management

Options may include:

- **Avoidance**: No development within the Conder catchment. Whilst this would eliminate the risk of new development increasing flooding at Galgate. However, appropriately located development may be a means of funding wider compensatory storage or defence measures. For instance, the proposed M6 slip roads could be formed to contain flood water to the east of the motorway.
- **Flood storage**: Provision of additional flood storage through excavation. This would need to be tested using modelling and may be required in conjunction with other flood risk management techniques, including raised defences, culvert replacements, floodplain restoration and natural flood risk management techniques.
- **Burrow Beck**: Reliance on the Burrow Beck catchment would result in a significant reduction in land available for a Garden Village. However, development within this catchment would not impact on Galgate. Opportunities to reduce flood risk associated with Ou Beck may be achievable if combined with areas of public open space or habitat creation. Opportunities to divert runoff in a controlled manner may be achievable to the north of the catchment again helping to alleviate flooding in the Galgate catchment.
- **Retrofitting**: Areas of existing urban development may benefit from retrofitting of SuDS.

Surface Water Attenuation: Flood risk will now be a significant concern to stakeholders including residents. New development must be based on the premise that any development at Bailrigg area will result in no increase in surface water runoff. Additional flood storage may be provided as part of any development proposals so that surface water runoff is effectively reduced. In this instance, it is proposed that surface water runoff will be managed through the use of SuDS features in the form of a series of cascading storage basins. Other options may also be considered. (If established SuDS measures such as attenuation basins and soakaways are found to be of limited capacity or even unsuitable, then a tanked sewer system is envisaged for development.). Natural Flood Risk Management is also considered to be an option.

7.9 Natural Flood Risk Management

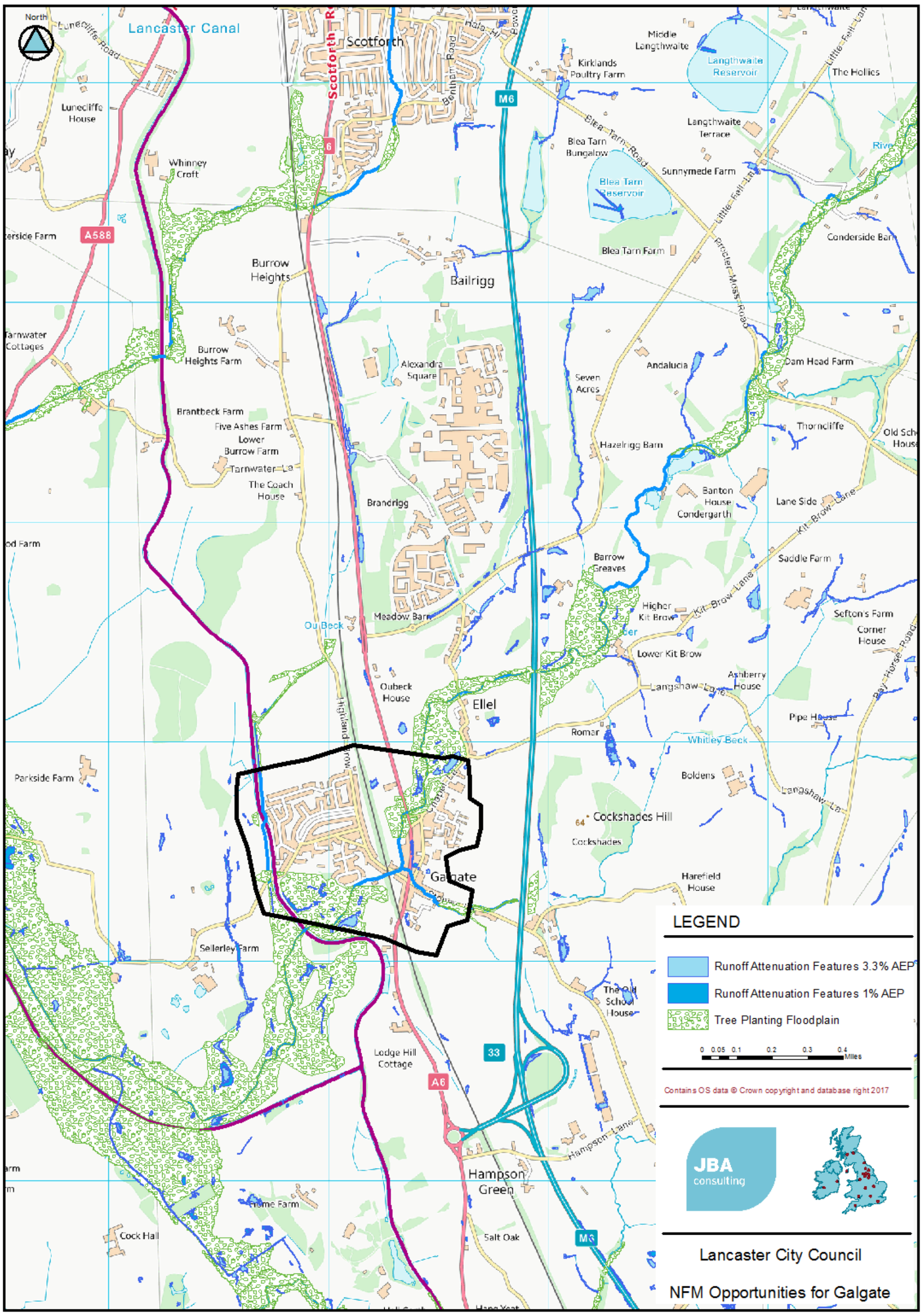
Natural Flood Management (NFM) represents a range of techniques that aim to reduce flooding by working with natural features and processes in order to store or slow down flood waters before they can damage flood risk receptors (e.g. people, property, infrastructure, etc.) (Figure 7.12).

Working with Natural Processes (WwNP) involves taking action to manage flood and coastal erosion risk by protecting, restoring and emulating the natural regulating functions of catchments, rivers, floodplains and coasts.

Both the European Commission and UK Government are actively encouraging the implementation of NFM measures within catchment and coastal areas in order to assist in the delivery of the requirements for various EC Directives relating to broader environmental protection and national policies. It is fully expected that the sustained interest in NFM implementation across the UK will continue to be considered a fundamental component of the flood risk management tool kit.

Whilst it is unlikely that NFM techniques will prevent flooding to Galgate, opportunities for combined flood risk management techniques including measures such as defences, floodplain restoration and flood attenuation may reduce flood risks along the River Conder. Further appraisal will be required to demonstrate the viability of any flood alleviation measures. Initial NFM screening has been undertaken for the Bailrigg area and further information can be found at http://naturalprocesses.jbahosting.com/#13/53.9963/-2.7603 .

Figure 7-12 Natural Flood Management (screening)



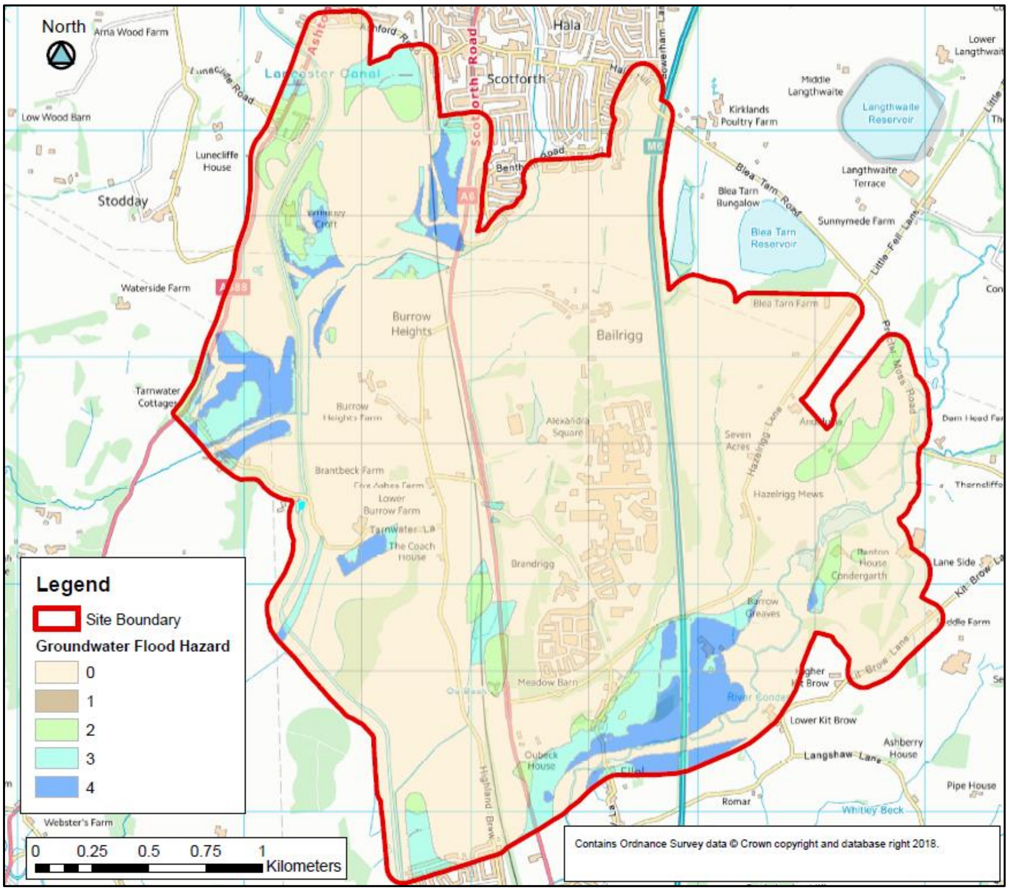
8 Geo-Environmental and Groundwater Flooding.

As part of this concept strategy, further evaluation of groundwater and ground conditions that may impact on development proposals has been completed. The main findings are outlined in the accompanying report Geo-Environmental and Groundwater Flooding Desk Study.

From the groundwater flood map, it is evident that the highest risk areas (i.e. ground water flood hazard classifications 2-4) correlate well with the presence of high permeability glaciofluvial sands and gravels and river terrace deposits. The remainder of the site, which is covered by thick, low permeability glacial till and lacustrine deposits is classified as to be at low risk of groundwater flooding. Excluded from the mapping are areas of peat, alluvium and lacustrine deposits. While these regions are likely to be regularly waterlogged, the low permeability nature of these deposits, means that the volume of water yielded from these deposits is limited.

Risk of clearwater flooding from bedrock deposits (e.g. through the activation of springs) is limited due to the thickness of superficial deposits across the site.

Figure 8.2- Groundwater flood map



9 Conclusion & recommendations

The City Council's starting point for concept planning the Bailrigg Garden Village is to confirm land and flood risk interactions. Flood risk needs to be effectively managed and development must not result in an increase in flood risk to existing land and communities.

- In terms of flood risk management, the concept development demonstrates that surface water runoff from the Bailrigg Garden Village may be effectively managed without increasing flood risk elsewhere.
- It is recognised that for existing communities, flood risk remains a significant concern. The developing Bailrigg strategy needs to consider wider opportunities to reduce flood risk to Galgate as part of any development proposals.
- This report reflects the initial assessment work undertaken to date. It is recognised that there is a considerable amount of additional investigation and appraisal work required to develop the scheme to detailed design stage.

Development will avoid areas at risk from fluvial inundation, as well as areas coinciding with significant pluvial or ground water flooding issues.

Fundamental to the Council's concept layout is the avoidance of areas susceptible to flooding and a requirement that development will not result in any increase in flood risk. Development planning needs to ensure that land is retained for flood risk management measures and that effective mitigation is put in place to prevent increased flood risk following development.

Following recent flooding at Galgate, opportunities to reduce existing risk, through flood alleviation and surface water attenuation, is integral to development planning. This will rely on making best use of current low-lying areas of land to reduce flood risk through flood storage, river restoration, natural flood risk management techniques and wetland creation.

The focus of this assessment is to define the likely suitability of various areas of land within the Bailrigg area for development in terms of flood risk. It is understood that the proposed development will comprise approximately 3500 houses with associated roads, parking and service areas, green infrastructure and transport links.

Following assessment of flood risk within the Bailrigg area, the focus for new development should ideally be directed towards the Burrow Beck catchment as this avoids potential flooding issues at Galgate.

Opportunities to enhance flood mitigation on both Ou Beck and Whitley Beck may also be considered as a means of potentially reducing flood risk to Galgate. Any flood alleviation scheme for Galgate will need to be investigated further through consultation with the Lead Local Flood Authority and the Environment Agency.

A concept drainage strategy has been defined based on a series of cascading flood basins to manage surface water runoff from new development. Runoff will need to be restricted to existing Greenfield runoff rates. It is recommended that the concept strategy is developed further when development planning defines an initial development layout.

The concept strategy may be developed further to include consideration of key transport links that avoid areas of flood risk where practical. New bridge or culvert crossings will need to be assessed to ensure flood risk is not increased and floodplains remain unimpeded.

The development of blue green corridors is key to develop areas of public open space. The aim is to make water, through the creation of basins, swales and river restoration an essential element of the Bailrigg Garden Village. This approach will enable wider opportunities for habitat creation and public amenity to be realised.

For all practical purposes a network of ground water monitoring points should be considered. Understanding seasonable variations and corresponding fluctuations in ground water levels is key to determine the suitability of sustainable drainage and flood attenuation measures.

Wider opportunities to reduce existing flood risk, such as Natural Flood Risk Management, may also be considered. These measures are likely to depend on extensive areas of tree planting outside of the defined Bailrigg area. Initial stakeholder liaison is recommended as this will help define subsequent assessment and appraisal work.

Appendices

A Flood Risk Vulnerability Classification

In order to determine the suitability of land for development in flood risk areas, the development vulnerability must first be established. The Flood Risk Vulnerability Classifications are illustrated in Table A-1.

Table A-1: Flood Risk Vulnerability Classification[6]

Classification	Explanation
Essential infrastructure	• Essential transport infrastructure (including mass evacuation routes) which has to cross the area at risk. • Essential utility infrastructure which has to be located in a flood risk area for operational reasons, including electricity generating power stations and grid and primary substations; and water treatment works that need to remain operational in times of flood. • Wind turbines.
Highly vulnerable	• Police and ambulance stations; fire stations and command centres; telecommunications installations required to be operational during flooding. • Emergency dispersal points. • Basement dwellings. • Caravans, mobile homes and park homes intended for permanent residential use. • Installations requiring hazardous substances consent. (Where there is a demonstrable need to locate such installations for bulk storage of materials with port or other similar facilities, or such installations with energy infrastructure or carbon capture and storage installations, that require coastal or water-side locations, or need to be located in other high flood risk areas, in these instances the facilities should be classified as 'Essential Infrastructure').
More vulnerable	• Hospitals • Residential institutions such as residential care homes, children's homes, social services homes, prisons and hostels. • Buildings used for dwelling houses, student halls of residence, drinking establishments, nightclubs and hotels. • Non–residential uses for health services, nurseries and educational establishments. • Landfill* and sites used for waste management facilities for hazardous waste. • Sites used for holiday or short-let caravans and camping, subject to a specific warning and evacuation plan.
Less vulnerable	• Police, ambulance and fire stations which are not required to be operational during flooding. • Buildings used for shops; financial, professional and other services; restaurants, cafes and hot food takeaways; offices; general industry, storage and distribution; non-residential institutions not included in the 'more vulnerable' class; and assembly and leisure. • Land and buildings used for agriculture and forestry. • Waste treatment (except landfill* and hazardous waste facilities).

6 https://www.gov.uk/guidance/flood-risk-and-coastal-change

	• Minerals working and processing (except for sand and gravel working). • Water treatment works which do not need to remain operational during times of flood. • Sewage treatment works, if adequate measures to control pollution and manage sewage during flooding events are in place.
Water-compatible development	• Flood control infrastructure. • Water transmission infrastructure and pumping stations. • Sewage transmission infrastructure and pumping stations. • Sand and gravel working. • Docks, marinas and wharves. • Navigation facilities. • Ministry of Defence installations. • Ship building, repairing and dismantling, dockside fish processing and refrigeration and compatible activities requiring a waterside location. • Water-based recreation (excluding sleeping accommodation). • Lifeguard and coastguard stations. • Amenity open space, nature conservation and biodiversity, outdoor sports and recreation and essential facilities such as changing rooms. • Essential ancillary sleeping or residential accommodation for staff required by uses in this category, subject to a specific warning and evacuation plan.

Table A-2: Flood Risk Vulnerability and Flood Zone 'Compatibility'

Flood Risk Vulnerability Classifications		Essential Infrastructure	Water compatible	Highly Vulnerable	More Vulnerable	Less vulnerable
Flood Zone	1	✓	✓	✓	✓	✓
	2	✓	✓	Exception Test required	✓	✓
	3A	Exception Test required	✓	×	Exception Test required	✓
	3B	Exception Test required	✓	×	Exception Test required	×

✓ Development is appropriate × Development should not be permitted

B Maps

C SuDS Selection Guide

D Calculations

Storage Calculation

Site: Bailrigg
Job Number: 2017s6815
Scenario: 2-Year Plus Climate Change (Free Discharge)

Return Period	2	Years
Impermeable Area	5	Ha
Discharge Rate Q	39.7	l/s
Discharge Coefficient C	0.5	Gravity

1	2	3	4	5	6	7	8	9	10
Storm Duration D (Hours)	Rainfall Depth (mm)	Rainfall Depth +30% (mm)	Rainfall Rate i (mm/hr)	Rainfall Rate i+30% (mm)	Inflow Rate 2.78 Ai (l/s)	Inflow Volume Rate x 3.6D (m3)	Outflow Volume C x Q x 3.6D (m3)	Storage Required (In - Out) (m3)	Time to Empty 0.277V/QC (Hours)
0.25	7.88	10.2	31.5	41.0	569.2	512	18	494	6.9
0.5	10.20	13.3	20.4	26.5	368.5	663	36	628	8.8
0.75	11.86	15.4	15.8	20.6	285.7	771	54	718	10.0
1	13.20	17.2	13.2	17.2	238.5	859	71	787	11.0
1.25	14.34	18.6	11.5	14.9	207.3	933	89	844	11.8
1.5	15.35	20.0	10.2	13.3	184.9	999	107	891	12.4
1.75	16.26	21.1	9.3	12.1	167.9	1058	125	933	13.0
2	17.09	22.2	8.5	11.1	154.4	1112	143	969	13.5
2.25	17.85	23.2	7.9	10.3	143.4	1161	161	1001	14.0
2.5	18.57	24.1	7.4	9.7	134.2	1208	179	1029	14.4
2.75	19.24	25.0	7.0	9.1	126.4	1252	197	1055	14.7
3	19.87	25.8	6.6	8.6	119.7	1293	214	1078	15.0
3.25	20.47	26.6	6.3	8.2	113.8	1332	232	1100	15.3
3.5	21.05	27.4	6.0	7.8	108.7	1369	250	1119	15.6
3.75	21.59	28.1	5.8	7.5	104.1	1405	268	1137	15.9
4	22.12	28.8	5.5	7.2	99.9	1439	286	1153	16.1
4.25	22.63	29.4	5.3	6.9	96.2	1472	304	1168	16.3
4.5	23.11	30.0	5.1	6.7	92.8	1503	322	1182	16.5
4.75	23.58	30.7	5.0	6.5	89.7	1534	339	1195	16.7
5	24.04	31.2	4.8	6.2	86.9	1564	357	1206	16.8
5.25	24.48	31.8	4.7	6.1	84.2	1592	375	1217	17.0
5.5	24.91	32.4	4.5	5.9	81.8	1620	393	1227	17.1
5.75	25.32	32.9	4.4	5.7	79.6	1647	411	1236	17.3
6	25.73	33.4	4.3	5.6	77.5	1674	429	1245	17.4
6.25	26.12	34.0	4.2	5.4	75.5	1699	447	1253	17.5
6.5	26.50	34.5	4.1	5.3	73.7	1724	464	1260	17.6
6.75	26.88	34.9	4.0	5.2	72.0	1749	482	1266	17.7

7	27.25	35.4	3.9	5.1	70.3	1772	500	1272	17.8
7.25	27.60	35.9	3.8	4.9	68.8	1796	518	1278	17.8
7.5	27.96	36.3	3.7	4.8	67.4	1819	536	1283	17.9
7.75	28.30	36.8	3.7	4.7	66.0	1841	554	1287	18.0
8	28.64	37.2	3.6	4.7	64.7	1863	572	1291	18.0
8.25	28.97	37.7	3.5	4.6	63.4	1884	590	1295	18.1
8.5	29.29	38.1	3.4	4.5	62.3	1905	607	1298	18.1
8.75	29.61	38.5	3.4	4.4	61.1	1926	625	1301	18.2
9	29.92	38.9	3.3	4.3	60.1	1946	643	1303	18.2
9.25	30.23	39.3	3.3	4.2	59.0	1966	661	1305	18.2
9.5	30.53	39.7	3.2	4.2	58.1	1986	679	1307	18.2
9.75	30.83	40.1	3.2	4.1	57.1	2005	697	1309	18.3
10	31.12	40.5	3.1	4.0	56.2	2024	715	1310	18.3
10.25	31.40	40.8	3.1	4.0	55.4	2043	732	1310	18.3
10.5	31.69	41.2	3.0	3.9	54.5	2061	750	1311	18.3
10.75	31.97	41.6	3.0	3.9	53.7	2080	768	1311	18.3
11	32.24	41.9	2.9	3.8	53.0	2097	786	1311	18.3
11.25	32.51	42.3	2.9	3.8	52.2	2115	804	1311	18.3
11.5	32.78	42.6	2.9	3.7	51.5	2132	822	1311	18.3
11.75	33.04	43.0	2.8	3.7	50.8	2150	840	1310	18.3
12	33.30	43.3	2.8	3.6	50.2	2166	858	1309	18.3
13	34.12	44.4	2.6	3.4	47.4	2220	929	1291	18.0
14	34.90	45.4	2.5	3.2	45.0	2270	1000	1270	17.7
15	35.64	46.3	2.4	3.1	42.9	2318	1072	1246	17.4
16	36.34	47.2	2.3	3.0	41.0	2364	1143	1221	17.0
17	37.02	48.1	2.2	2.8	39.3	2408	1215	1193	16.7
18	37.66	49.0	2.1	2.7	37.8	2450	1286	1164	16.2
19	38.29	49.8	2.0	2.6	36.4	2491	1358	1133	15.8
20	38.89	50.6	1.9	2.5	35.1	2530	1429	1101	15.4
21	39.47	51.3	1.9	2.4	34.0	2568	1501	1067	14.9
22	40.03	52.0	1.8	2.4	32.9	2604	1572	1032	14.4
23	40.57	52.7	1.8	2.3	31.9	2639	1644	996	13.9
24	41.10	53.4	1.7	2.2	30.9	2674	1715	959	13.4
30	43.98	57.2	1.5	1.9	26.5	2861	2144	717	10.0
36	46.48	60.4	1.3	1.7	23.3	3024	2573	451	6.3
42	48.71	63.3	1.2	1.5	21.0	3169	3001	167	2.3
48	50.72	65.9	1.1	1.4	19.1	3300	3430	-130	-1.8
54	53.18	69.1	1.0	1.3	17.8	3459	3859	-399	-5.6
60	55.48	72.1	0.9	1.2	16.7	3609	4288	-679	-9.5
66	57.64	74.9	0.9	1.1	15.8	3750	4716	-967	-13.5
72	59.69	77.6	0.8	1.1	15.0	3883	5145	-1262	-17.6
96	67.00	87.1	0.7	0.9	12.6	4358	6860	-2502	-34.9
120	73.28	95.3	0.6	0.8	11.0	4767	8575	-3808	-53.1

144	78.84	102.5	0.5	0.7	9.9	5129	10290	-5161	-72.0
168	83.87	109.0	0.5	0.6	9.0	5456	12005	-6549	-91.4

Storage Calculation

Site: Bailrigg
Job Number: 2017s6815
Scenario: 5-Year Plus Climate Change (Free Discharge)

Return Period 5 Years
Impermeable Area 5 Ha

Discharge Rate Q 39.7 l/s
Discharge Coefficient C 0.5 Gravity

1	2	3	4	5	6	7	8	9	10
Storm Duration D (Hours)	Rainfall Depth (mm)	Rainfall Depth +30% (mm)	Rainfall Rate i (mm/hr)	Rainfall Rate i+30% (mm)	Inflow Rate 2.78 Ai (l/s)	Inflow Volume Rate x 3.6D (m3)	Outflow Volume C x Q x 3.6D (m3)	Storage Required (In - Out) (m3)	Time to Empty 0.277V/QC (Hours)
0.25	11.46	14.9	45.8	59.6	828.4	746	18	728	10.2
0.5	14.54	18.9	29.1	37.8	525.4	946	36	910	12.7
0.75	16.71	21.7	22.3	29.0	402.5	1087	54	1033	14.4
1	18.44	24.0	18.4	24.0	333.2	1200	71	1128	15.7
1.25	19.91	25.9	15.9	20.7	287.8	1295	89	1206	16.8
1.5	21.19	27.5	14.1	18.4	255.3	1378	107	1271	17.7
1.75	22.34	29.0	12.8	16.6	230.7	1453	125	1328	18.5
2	23.39	30.4	11.7	15.2	211.3	1521	143	1379	19.2
2.25	24.35	31.7	10.8	14.1	195.6	1584	161	1423	19.9
2.5	25.25	32.8	10.1	13.1	182.5	1642	179	1464	20.4
2.75	26.09	33.9	9.5	12.3	171.4	1697	197	1501	20.9
3	26.88	34.9	9.0	11.6	161.9	1748	214	1534	21.4
3.25	27.63	35.9	8.5	11.1	153.6	1797	232	1565	21.8
3.5	28.34	36.8	8.1	10.5	146.3	1843	250	1593	22.2
3.75	29.02	37.7	7.7	10.1	139.8	1888	268	1620	22.6
4	29.67	38.6	7.4	9.6	134.0	1930	286	1644	22.9
4.25	30.29	39.4	7.1	9.3	128.8	1970	304	1667	23.3
4.5	30.89	40.2	6.9	8.9	124.0	2009	322	1688	23.6
4.75	31.47	40.9	6.6	8.6	119.7	2047	339	1708	23.8
5	32.03	41.6	6.4	8.3	115.7	2083	357	1726	24.1
5.25	32.57	42.3	6.2	8.1	112.1	2118	375	1743	24.3
5.5	33.09	43.0	6.0	7.8	108.7	2153	393	1760	24.6
5.75	33.60	43.7	5.8	7.6	105.6	2186	411	1775	24.8
6	34.09	44.3	5.7	7.4	102.7	2218	429	1789	25.0
6.25	34.57	44.9	5.5	7.2	100.0	2249	447	1802	25.2
6.5	35.04	45.6	5.4	7.0	97.4	2279	464	1815	25.3
6.75	35.50	46.1	5.3	6.8	95.0	2309	482	1827	25.5

7	35.94	46.7	5.1	6.7	92.8	2338	500	1838	25.6
7.25	36.38	47.3	5.0	6.5	90.7	2366	518	1848	25.8
7.5	36.80	47.8	4.9	6.4	88.7	2394	536	1858	25.9
7.75	37.22	48.4	4.8	6.2	86.8	2421	554	1867	26.1
8	37.63	48.9	4.7	6.1	85.0	2448	572	1876	26.2
8.25	38.03	49.4	4.6	6.0	83.3	2474	590	1884	26.3
8.5	38.42	49.9	4.5	5.9	81.7	2499	607	1892	26.4
8.75	38.80	50.4	4.4	5.8	80.1	2524	625	1899	26.5
9	39.18	50.9	4.4	5.7	78.7	2549	643	1906	26.6
9.25	39.55	51.4	4.3	5.6	77.3	2573	661	1912	26.7
9.5	39.91	51.9	4.2	5.5	75.9	2596	679	1917	26.8
9.75	40.27	52.4	4.1	5.4	74.6	2620	697	1923	26.8
10	40.62	52.8	4.1	5.3	73.4	2642	715	1928	26.9
10.25	40.97	53.3	4.0	5.2	72.2	2665	732	1932	27.0
10.5	41.31	53.7	3.9	5.1	71.1	2687	750	1937	27.0
10.75	41.64	54.1	3.9	5.0	70.0	2709	768	1941	27.1
11	41.97	54.6	3.8	5.0	68.9	2730	786	1944	27.1
11.25	42.30	55.0	3.8	4.9	67.9	2751	804	1947	27.2
11.5	42.62	55.4	3.7	4.8	67.0	2772	822	1950	27.2
11.75	42.93	55.8	3.7	4.7	66.0	2793	840	1953	27.3
12	43.24	56.2	3.6	4.7	65.1	2813	858	1955	27.3
13	44.20	57.5	3.4	4.4	61.4	2875	929	1946	27.2
14	45.11	58.6	3.2	4.2	58.2	2934	1000	1934	27.0
15	45.97	59.8	3.1	4.0	55.4	2990	1072	1918	26.8
16	46.79	60.8	2.9	3.8	52.8	3044	1143	1900	26.5
17	47.57	61.8	2.8	3.6	50.6	3095	1215	1880	26.2
18	48.32	62.8	2.7	3.5	48.5	3144	1286	1857	25.9
19	49.04	63.8	2.6	3.4	46.6	3190	1358	1833	25.6
20	49.74	64.7	2.5	3.2	44.9	3236	1429	1806	25.2
21	50.41	65.5	2.4	3.1	43.4	3279	1501	1778	24.8
22	51.05	66.4	2.3	3.0	41.9	3321	1572	1749	24.4
23	51.68	67.2	2.2	2.9	40.6	3362	1644	1718	24.0
24	52.29	68.0	2.2	2.8	39.4	3401	1715	1686	23.5
30	55.58	72.3	1.9	2.4	33.5	3616	2144	1472	20.5
36	58.43	76.0	1.6	2.1	29.3	3801	2573	1228	17.1
42	60.95	79.2	1.5	1.9	26.2	3965	3001	964	13.4
48	63.22	82.2	1.3	1.7	23.8	4113	3430	683	9.5
54	66.05	85.9	1.2	1.6	22.1	4297	3859	438	6.1
60	68.69	89.3	1.1	1.5	20.7	4469	4288	181	2.5
66	71.17	92.5	1.1	1.4	19.5	4630	4716	-86	-1.2
72	73.52	95.6	1.0	1.3	18.5	4782	5145	-363	-5.1
96	81.82	106.4	0.9	1.1	15.4	5322	6860	-1538	-21.5
120	88.90	115.6	0.7	1.0	13.4	5783	8575	-2792	-39.0

144	95.14	123.7	0.7	0.9	11.9	6189	10290	-4101	-57.2
168	100.7 5	131.0	0.6	0.8	10.8	6554	12005	-5451	-76.1

Storage Calculation

Site: Bailrigg
Job Number: 2017s6815
Scenario: 10-Year Plus Climate Change (Free Discharge)

Return Period	10	Years
Impermeable Area	5	Ha
Discharge Rate Q	39.7	l/s
Discharge Coefficient C	0.5	Gravity

1	2	3	4	5	6	7	8	9	10
Storm Duration D (Hours)	Rainfall Depth (mm)	Rainfall Depth +30% (mm)	Rainfall Rate i (mm/hr)	Rainfall Rate i+30% (mm)	Inflow Rate 2.78Ai (l/s)	Inflow Volume Rate x 3.6D (m3)	Outflow Volume C x Q x 3.6D (m3)	Storage Required (In - Out) (m3)	Time to Empty 0.277V/QC (Hours)
0.25	14.69	19.1	58.8	76.4	1062.0	956	18	938	13.1
0.5	18.39	23.9	36.8	47.8	664.5	1196	36	1160	16.2
0.75	20.96	27.3	28.0	36.3	505.1	1364	54	1310	18.3
1	23.01	29.9	23.0	29.9	415.8	1497	71	1425	19.9
1.25	24.73	32.1	19.8	25.7	357.5	1609	89	1519	21.2
1.5	26.23	34.1	17.5	22.7	316.0	1707	107	1599	22.3
1.75	27.57	35.8	15.8	20.5	284.7	1794	125	1669	23.3
2	28.79	37.4	14.4	18.7	260.1	1873	143	1730	24.1
2.25	29.91	38.9	13.3	17.3	240.2	1946	161	1785	24.9
2.5	30.95	40.2	12.4	16.1	223.7	2013	179	1835	25.6
2.75	31.92	41.5	11.6	15.1	209.7	2076	197	1880	26.2
3	32.83	42.7	10.9	14.2	197.7	2135	214	1921	26.8
3.25	33.69	43.8	10.4	13.5	187.3	2191	232	1959	27.3
3.5	34.51	44.9	9.9	12.8	178.1	2245	250	1995	27.8
3.75	35.28	45.9	9.4	12.2	170.0	2295	268	2027	28.3
4	36.03	46.8	9.0	11.7	162.8	2344	286	2058	28.7
4.25	36.74	47.8	8.6	11.2	156.2	2390	304	2086	29.1
4.5	37.43	48.7	8.3	10.8	150.3	2435	322	2113	29.5
4.75	38.09	49.5	8.0	10.4	144.9	2478	339	2138	29.8
5	38.73	50.3	7.7	10.1	140.0	2519	357	2162	30.2
5.25	39.34	51.1	7.5	9.7	135.4	2559	375	2184	30.5
5.5	39.94	51.9	7.3	9.4	131.2	2598	393	2205	30.8
5.75	40.52	52.7	7.0	9.2	127.3	2636	411	2225	31.0
6	41.08	53.4	6.8	8.9	123.7	2672	429	2243	31.3
6.25	41.62	54.1	6.7	8.7	120.3	2708	447	2261	31.6
6.5	42.16	54.8	6.5	8.4	117.2	2742	464	2278	31.8

6.75	42.67	55.5	6.3	8.2	114.2	2776	482	2294	32.0
7	43.18	56.1	6.2	8.0	111.5	2809	500	2309	32.2
7.25	43.67	56.8	6.0	7.8	108.8	2841	518	2323	32.4
7.5	44.15	57.4	5.9	7.7	106.4	2872	536	2336	32.6
7.75	44.62	58.0	5.8	7.5	104.0	2903	554	2349	32.8
8	45.08	58.6	5.6	7.3	101.8	2933	572	2361	32.9
8.25	45.54	59.2	5.5	7.2	99.7	2962	590	2373	33.1
8.5	45.98	59.8	5.4	7.0	97.7	2991	607	2384	33.3
8.75	46.41	60.3	5.3	6.9	95.8	3019	625	2394	33.4
9	46.84	60.9	5.2	6.8	94.0	3047	643	2404	33.5
9.25	47.25	61.4	5.1	6.6	92.3	3074	661	2413	33.7
9.5	47.66	62.0	5.0	6.5	90.7	3100	679	2422	33.8
9.75	48.06	62.5	4.9	6.4	89.1	3127	697	2430	33.9
10	48.46	63.0	4.8	6.3	87.6	3152	715	2438	34.0
10.25	48.85	63.5	4.8	6.2	86.1	3178	732	2445	34.1
10.5	49.23	64.0	4.7	6.1	84.7	3203	750	2452	34.2
10.75	49.61	64.5	4.6	6.0	83.4	3227	768	2459	34.3
11	49.98	65.0	4.5	5.9	82.1	3251	786	2465	34.4
11.25	50.34	65.4	4.5	5.8	80.9	3275	804	2471	34.5
11.5	50.70	65.9	4.4	5.7	79.7	3298	822	2476	34.6
11.75	51.05	66.4	4.3	5.6	78.5	3321	840	2482	34.6
12	51.40	66.8	4.3	5.6	77.4	3344	858	2486	34.7
13	52.46	68.2	4.0	5.2	72.9	3413	929	2484	34.7
14	53.46	69.5	3.8	5.0	69.0	3478	1000	2477	34.6
15	54.41	70.7	3.6	4.7	65.5	3539	1072	2467	34.4
16	55.31	71.9	3.5	4.5	62.5	3598	1143	2455	34.3
17	56.17	73.0	3.3	4.3	59.7	3654	1215	2439	34.0
18	56.99	74.1	3.2	4.1	57.2	3707	1286	2421	33.8
19	57.78	75.1	3.0	4.0	55.0	3759	1358	2401	33.5
20	58.54	76.1	2.9	3.8	52.9	3808	1429	2379	33.2
21	59.27	77.1	2.8	3.7	51.0	3856	1501	2355	32.9
22	59.98	78.0	2.7	3.5	49.3	3902	1572	2329	32.5
23	60.66	78.9	2.6	3.4	47.7	3946	1644	2302	32.1
24	61.32	79.7	2.6	3.3	46.2	3989	1715	2274	31.7
30	64.90	84.4	2.2	2.8	39.1	4222	2144	2078	29.0
36	67.99	88.4	1.9	2.5	34.1	4423	2573	1850	25.8
42	70.71	91.9	1.7	2.2	30.4	4600	3001	1598	22.3
48	73.15	95.1	1.5	2.0	27.5	4758	3430	1328	18.5
54	76.25	99.1	1.4	1.8	25.5	4960	3859	1101	15.4
60	79.14	102.9	1.3	1.7	23.8	5148	4288	860	12.0
66	81.84	106.4	1.2	1.6	22.4	5324	4716	607	8.5
72	84.39	109.7	1.2	1.5	21.2	5490	5145	344	4.8
96	93.39	121.4	1.0	1.3	17.6	6075	6860	-785	-11.0

120	101.04	131.3	0.8	1.1	15.2	6573	8575	-2003	-27.9
144	107.74	140.1	0.7	1.0	13.5	7009	10290	-3281	-45.8
168	113.76	147.9	0.7	0.9	12.2	7400	12005	-4605	-64.3

Storage Calculation

Site: Bailrigg
Job Number: 2017s6815
Scenario: 30-Year Plus Climate Change (Free Discharge)

Return Period 30 Years
Impermeable Area 5 Ha

Discharge Rate Q 39.7 l/s
Discharge Coefficient C 0.5 Gravity

1	2	3	4	5	6	7	8	9	10
Storm Duration D (Hours)	Rainfall Depth (mm)	Rainfall Depth +30% (mm)	Rainfall Rate i (mm/hr)	Rainfall Rate i+30% (mm)	Inflow Rate 2.78Ai (l/s)	Inflow Volume Rate x 3.6D (m3)	Outflow Volume C x Q x 3.6D (m3)	Storage Required (In - Out) (m3)	Time to Empty 0.277V/QC (Hours)
0.25	21.39	27.8	85.5	111.2	1545.9	1391	18	1373	19.2
0.5	26.22	34.1	52.4	68.2	947.6	1706	36	1670	23.3
0.75	29.54	38.4	39.4	51.2	711.7	1922	54	1868	26.1
1	32.15	41.8	32.1	41.8	580.9	2091	71	2020	28.2
1.25	34.33	44.6	27.5	35.7	496.3	2233	89	2144	29.9
1.5	36.22	47.1	24.1	31.4	436.3	2356	107	2249	31.4
1.75	37.90	49.3	21.7	28.2	391.3	2465	125	2340	32.7
2	39.42	51.2	19.7	25.6	356.1	2564	143	2421	33.8
2.25	40.80	53.0	18.1	23.6	327.7	2654	161	2494	34.8
2.5	42.09	54.7	16.8	21.9	304.2	2738	179	2559	35.7
2.75	43.28	56.3	15.7	20.5	284.4	2816	197	2619	36.6
3	44.41	57.7	14.8	19.2	267.5	2889	214	2674	37.3
3.25	45.46	59.1	14.0	18.2	252.8	2957	232	2725	38.0
3.5	46.46	60.4	13.3	17.3	239.9	3023	250	2773	38.7
3.75	47.42	61.6	12.6	16.4	228.5	3085	268	2817	39.3
4	48.32	62.8	12.1	15.7	218.3	3144	286	2858	39.9
4.25	49.19	64.0	11.6	15.0	209.2	3200	304	2896	40.4
4.5	50.03	65.0	11.1	14.5	200.9	3254	322	2933	40.9
4.75	50.83	66.1	10.7	13.9	193.4	3307	339	2967	41.4
5	51.60	67.1	10.3	13.4	186.5	3357	357	2999	41.9
5.25	52.35	68.1	10.0	13.0	180.2	3405	375	3030	42.3
5.5	53.07	69.0	9.6	12.5	174.4	3452	393	3059	42.7
5.75	53.77	69.9	9.4	12.2	169.0	3498	411	3087	43.1
6	54.44	70.8	9.1	11.8	164.0	3542	429	3113	43.4
6.25	55.10	71.6	8.8	11.5	159.3	3584	447	3138	43.8
6.5	55.74	72.5	8.6	11.1	155.0	3626	464	3161	44.1

6.75	56.36	73.3	8.3	10.9	150.9	3666	482	3184	44.4
7	56.97	74.1	8.1	10.6	147.1	3706	500	3206	44.7
7.25	57.56	74.8	7.9	10.3	143.5	3744	518	3226	45.0
7.5	58.13	75.6	7.8	10.1	140.1	3782	536	3246	45.3
7.75	58.70	76.3	7.6	9.8	136.9	3818	554	3265	45.6
8	59.25	77.0	7.4	9.6	133.8	3854	572	3283	45.8
8.25	59.79	77.7	7.2	9.4	131.0	3889	590	3300	46.0
8.5	60.31	78.4	7.1	9.2	128.2	3924	607	3316	46.3
8.75	60.83	79.1	7.0	9.0	125.6	3957	625	3332	46.5
9	61.34	79.7	6.8	8.9	123.1	3990	643	3347	46.7
9.25	61.83	80.4	6.7	8.7	120.8	4022	661	3361	46.9
9.5	62.32	81.0	6.6	8.5	118.5	4054	679	3375	47.1
9.75	62.80	81.6	6.4	8.4	116.4	4085	697	3388	47.3
10	63.27	82.2	6.3	8.2	114.3	4116	715	3401	47.5
10.25	63.73	82.8	6.2	8.1	112.3	4146	732	3413	47.6
10.5	64.18	83.4	6.1	7.9	110.5	4175	750	3425	47.8
10.75	64.63	84.0	6.0	7.8	108.6	4204	768	3436	47.9
11	65.06	84.6	5.9	7.7	106.9	4233	786	3446	48.1
11.25	65.50	85.1	5.8	7.6	105.2	4261	804	3457	48.2
11.5	65.92	85.7	5.7	7.5	103.6	4288	822	3466	48.4
11.75	66.34	86.2	5.6	7.3	102.0	4315	840	3476	48.5
12	66.75	86.8	5.6	7.2	100.5	4342	858	3485	48.6
13	67.96	88.4	5.2	6.8	94.5	4421	929	3492	48.7
14	69.11	89.8	4.9	6.4	89.2	4495	1000	3495	48.8
15	70.19	91.2	4.7	6.1	84.6	4566	1072	3494	48.8
16	71.21	92.6	4.5	5.8	80.4	4633	1143	3489	48.7
17	72.19	93.8	4.2	5.5	76.7	4696	1215	3481	48.6
18	73.13	95.1	4.1	5.3	73.4	4757	1286	3471	48.4
19	74.02	96.2	3.9	5.1	70.4	4815	1358	3457	48.2
20	74.88	97.3	3.7	4.9	67.7	4871	1429	3442	48.0
21	75.71	98.4	3.6	4.7	65.1	4925	1501	3424	47.8
22	76.50	99.5	3.5	4.5	62.8	4977	1572	3405	47.5
23	77.27	100.5	3.4	4.4	60.7	5027	1644	3383	47.2
24	78.02	101.4	3.3	4.2	58.7	5075	1715	3360	46.9
30	82.03	106.6	2.7	3.6	49.4	5336	2144	3193	44.6
36	85.47	111.1	2.4	3.1	42.9	5560	2573	2987	41.7
42	88.48	115.0	2.1	2.7	38.1	5756	3001	2755	38.4
48	91.18	118.5	1.9	2.5	34.3	5932	3430	2502	34.9
54	94.72	123.1	1.8	2.3	31.7	6162	3859	2303	32.1
60	98.00	127.4	1.6	2.1	29.5	6375	4288	2087	29.1
66	101.06	131.4	1.5	2.0	27.7	6574	4716	1858	25.9
72	103.94	135.1	1.4	1.9	26.1	6762	5145	1617	22.6

96	114.07	148.3	1.2	1.5	21.5	7420	6860	560	7.8
120	122.59	159.4	1.0	1.3	18.5	7975	8575	-600	-8.4
144	130.03	169.0	0.9	1.2	16.3	8458	10290	-1832	-25.6
168	136.66	177.7	0.8	1.1	14.7	8890	12005	-3115	-43.5

Storage Calculation

Site: Bailrigg
Job Number: 2017s6815
Scenario: 100-Year Plus Climate Change (Free Discharge)

Return Period 100 Years
Impermeable Area 5 Ha

Discharge Rate Q 39.7 l/s
Discharge Coefficient C 0.5 Gravity

1	2	3	4	5	6	7	8	9	10
Storm Duration D (Hours)	Rainfall Depth (mm)	Rainfall Depth +30% (mm)	Rainfall Rate i (mm/hr)	Rainfall Rate i+30% (mm)	Inflow Rate 2.78Ai (l/s)	Inflow Volume Rate x 3.6D (m3)	Outflow Volume C x Q x 3.6D (m3)	Storage Required (In - Out) (m3)	Time to Empty 0.277V/QC (Hours)
0.25	31.99	41.58	127.9	166.3	2311.9	2081	18	2063	28.8
0.5	38.37	49.88	76.7	99.8	1386.5	2496	36	2460	34.3
0.75	42.67	55.47	56.9	74.0	1028.1	2776	54	2722	38.0
1	46.02	59.82	46.0	59.8	831.6	2994	71	2922	40.8
1.25	48.79	63.43	39.0	50.7	705.4	3174	89	3085	43.0
1.5	51.18	66.54	34.1	44.4	616.6	3330	107	3222	45.0
1.75	53.30	69.29	30.5	39.6	550.3	3467	125	3342	46.6
2	55.20	71.76	27.6	35.9	498.7	3591	143	3448	48.1
2.25	56.93	74.01	25.3	32.9	457.2	3703	161	3543	49.4
2.5	58.53	76.08	23.4	30.4	423.0	3807	179	3629	50.6
2.75	60.01	78.01	21.8	28.4	394.3	3904	197	3707	51.7
3	61.39	79.81	20.5	26.6	369.8	3994	214	3779	52.7
3.25	62.70	81.51	19.3	25.1	348.6	4079	232	3846	53.7
3.5	63.93	83.11	18.3	23.7	330.1	4159	250	3909	54.5
3.75	65.10	84.63	17.4	22.6	313.7	4235	268	3967	55.4
4	66.21	86.07	16.6	21.5	299.1	4307	286	4021	56.1
4.25	67.27	87.45	15.8	20.6	286.0	4376	304	4072	56.8
4.5	68.29	88.77	15.2	19.7	274.2	4442	322	4121	57.5
4.75	69.26	90.04	14.6	19.0	263.5	4506	339	4166	58.1
5	70.20	91.26	14.0	18.3	253.7	4567	357	4209	58.7
5.25	71.10	92.44	13.5	17.6	244.7	4626	375	4250	59.3
5.5	71.98	93.57	13.1	17.0	236.5	4682	393	4289	59.9
5.75	72.82	94.67	12.7	16.5	228.9	4737	411	4326	60.4
6	73.64	95.73	12.3	16.0	221.8	4790	429	4362	60.9
6.25	74.43	96.76	11.9	15.5	215.2	4842	447	4395	61.3
6.5	75.20	97.76	11.6	15.0	209.1	4892	464	4428	61.8

6.75	75.95	98.74	11.3	14.6	203.3	4941	482	4458	62.2
7	76.68	99.68	11.0	14.2	197.9	4988	500	4488	62.6
7.25	77.39	100.61	10.7	13.9	192.9	5034	518	4516	63.0
7.5	78.08	101.51	10.4	13.5	188.1	5079	536	4543	63.4
7.75	78.76	102.38	10.2	13.2	183.6	5123	554	4569	63.8
8	79.41	103.24	9.9	12.9	179.4	5166	572	4594	64.1
8.25	80.06	104.08	9.7	12.6	175.4	5208	590	4618	64.4
8.5	80.69	104.89	9.5	12.3	171.5	5249	607	4642	64.8
8.75	81.30	105.70	9.3	12.1	167.9	5289	625	4664	65.1
9	81.91	106.48	9.1	11.8	164.5	5328	643	4685	65.4
9.25	82.50	107.25	8.9	11.6	161.2	5367	661	4706	65.7
9.5	83.08	108.00	8.7	11.4	158.0	5404	679	4725	65.9
9.75	83.65	108.74	8.6	11.2	155.0	5441	697	4745	66.2
10	84.20	109.46	8.4	10.9	152.2	5478	715	4763	66.5
10.25	84.75	110.18	8.3	10.7	149.4	5513	732	4781	66.7
10.5	85.29	110.87	8.1	10.6	146.8	5548	750	4798	67.0
10.75	85.82	111.56	8.0	10.4	144.3	5583	768	4814	67.2
11	86.34	112.24	7.8	10.2	141.8	5616	786	4830	67.4
11.25	86.85	112.90	7.7	10.0	139.5	5650	804	4846	67.6
11.5	87.35	113.55	7.6	9.9	137.3	5682	822	4860	67.8
11.75	87.84	114.20	7.5	9.7	135.1	5714	840	4875	68.0
12	88.33	114.83	7.4	9.6	133.0	5746	858	4888	68.2
13	89.71	116.62	6.9	9.0	124.7	5836	929	4907	68.5
14	91.00	118.30	6.5	8.5	117.5	5920	1000	4919	68.6
15	92.22	119.89	6.1	8.0	111.1	5999	1072	4928	68.8
16	93.38	121.40	5.8	7.6	105.5	6075	1143	4931	68.8
17	94.48	122.83	5.6	7.2	100.4	6146	1215	4932	68.8
18	95.53	124.20	5.3	6.9	95.9	6215	1286	4928	68.8
19	96.54	125.50	5.1	6.6	91.8	6280	1358	4922	68.7
20	97.50	126.75	4.9	6.3	88.1	6343	1429	4913	68.6

21	98.43	127.95	4.7	6.1	84.7	6403	1501	4902	68.4
22	99.32	129.11	4.5	5.9	81.6	6461	1572	4889	68.2
23	100.17	130.22	4.4	5.7	78.7	6516	1644	4873	68.0
24	101.00	131.30	4.2	5.5	76.0	6570	1715	4855	67.8
30	105.45	137.09	3.5	4.6	63.5	6860	2144	4716	65.8
36	109.24	142.01	3.0	3.9	54.8	7106	2573	4534	63.3
42	112.55	146.31	2.7	3.5	48.4	7321	3001	4320	60.3
48	115.49	150.14	2.4	3.1	43.5	7513	3430	4083	57.0
54	119.52	155.38	2.2	2.9	40.0	7775	3859	3916	54.7
60	123.25	160.22	2.1	2.7	37.1	8018	4288	3730	52.1
66	126.72	164.74	1.9	2.5	34.7	8243	4716	3527	49.2
72	129.97	168.97	1.8	2.3	32.6	8455	5145	3310	46.2
96	141.34	183.74	1.5	1.9	26.6	9194	6860	2334	32.6
120	150.83	196.08	1.3	1.6	22.7	9812	8575	1237	17.3
144	159.06	206.78	1.1	1.4	20.0	10347	10290	57	0.8
168	166.37	216.28	1.0	1.3	17.9	10823	12005	-1182	-16.5

Storage Calculation

Site: Bailrigg
Job Number: 2017s6815
Scenario: 100-Year Plus Climate Change (Free Discharge)_1st pond

Return Period	100	Years
Impermeable Area	1	Ha
Discharge Rate Q	7.94	l/s
Discharge Coefficient C	0.5	Gravity

1	2	3	4	5	6	7	8	9	10
Storm Duration D (Hours)	Rainfall Depth (mm)	Rainfall Depth +30% (mm)	Rainfall Rate i (mm/hr)	Rainfall Rate i+30% (mm)	Inflow Rate 2.78Ai (l/s)	Inflow Volume Rate x 3.6D (m3)	Outflow Volume C x Q x 3.6D (m3)	Storage Required (In - Out) (m3)	Time to Empty 0.277V/QC (Hours)
0.25	31.99	41.58	127.9	166.3	462.4	416	4	413	28.8
0.5	38.37	49.88	76.7	99.8	277.3	499	7	492	34.3
0.75	42.67	55.47	56.9	74.0	205.6	555	11	544	38.0
1	46.02	59.82	46.0	59.8	166.3	599	14	584	40.8
1.25	48.79	63.43	39.0	50.7	141.1	635	18	617	43.0
1.5	51.18	66.54	34.1	44.4	123.3	666	21	644	45.0
1.75	53.30	69.29	30.5	39.6	110.1	693	25	668	46.6
2	55.20	71.76	27.6	35.9	99.7	718	29	690	48.1
2.25	56.93	74.01	25.3	32.9	91.4	741	32	709	49.4
2.5	58.53	76.08	23.4	30.4	84.6	761	36	726	50.6
2.75	60.01	78.01	21.8	28.4	78.9	781	39	741	51.7
3	61.39	79.81	20.5	26.6	74.0	799	43	756	52.7
3.25	62.70	81.51	19.3	25.1	69.7	816	46	769	53.7
3.5	63.93	83.11	18.3	23.7	66.0	832	50	782	54.5
3.75	65.10	84.63	17.4	22.6	62.7	847	54	793	55.4
4	66.21	86.07	16.6	21.5	59.8	861	57	804	56.1
4.25	67.27	87.45	15.8	20.6	57.2	875	61	814	56.8
4.5	68.29	88.77	15.2	19.7	54.8	888	64	824	57.5
4.75	69.26	90.04	14.6	19.0	52.7	901	68	833	58.1
5	70.20	91.26	14.0	18.3	50.7	913	71	842	58.7
5.25	71.10	92.44	13.5	17.6	48.9	925	75	850	59.3
5.5	71.98	93.57	13.1	17.0	47.3	936	79	858	59.9
5.75	72.82	94.67	12.7	16.5	45.8	947	82	865	60.4
6	73.64	95.73	12.3	16.0	44.4	958	86	872	60.9
6.25	74.43	96.76	11.9	15.5	43.0	968	89	879	61.3
6.5	75.20	97.76	11.6	15.0	41.8	978	93	886	61.8

6.75	75.95	98.74	11.3	14.6	40.7	988	96	892	62.2
7	76.68	99.68	11.0	14.2	39.6	998	100	898	62.6
7.25	77.39	100.61	10.7	13.9	38.6	1007	104	903	63.0
7.5	78.08	101.51	10.4	13.5	37.6	1016	107	909	63.4
7.75	78.76	102.38	10.2	13.2	36.7	1025	111	914	63.8
8	79.41	103.24	9.9	12.9	35.9	1033	114	919	64.1
8.25	80.06	104.08	9.7	12.6	35.1	1042	118	924	64.4
8.5	80.69	104.89	9.5	12.3	34.3	1050	121	928	64.8
8.75	81.30	105.70	9.3	12.1	33.6	1058	125	933	65.1
9	81.91	106.48	9.1	11.8	32.9	1066	129	937	65.4
9.25	82.50	107.25	8.9	11.6	32.2	1073	132	941	65.7
9.5	83.08	108.00	8.7	11.4	31.6	1081	136	945	65.9
9.75	83.65	108.74	8.6	11.2	31.0	1088	139	949	66.2
10	84.20	109.46	8.4	10.9	30.4	1096	143	953	66.5
10.25	84.75	110.18	8.3	10.7	29.9	1103	146	956	66.7
10.5	85.29	110.87	8.1	10.6	29.4	1110	150	960	67.0
10.75	85.82	111.56	8.0	10.4	28.9	1117	154	963	67.2
11	86.34	112.24	7.8	10.2	28.4	1123	157	966	67.4
11.25	86.85	112.90	7.7	10.0	27.9	1130	161	969	67.6
11.5	87.35	113.55	7.6	9.9	27.5	1136	164	972	67.8
11.75	87.84	114.20	7.5	9.7	27.0	1143	168	975	68.0
12	88.33	114.83	7.4	9.6	26.6	1149	172	978	68.2
13	89.71	116.62	6.9	9.0	24.9	1167	186	981	68.5
14	91.00	118.30	6.5	8.5	23.5	1184	200	984	68.6
15	92.22	119.89	6.1	8.0	22.2	1200	214	986	68.8
16	93.38	121.40	5.8	7.6	21.1	1215	229	986	68.8
17	94.48	122.83	5.6	7.2	20.1	1229	243	986	68.8
18	95.53	124.20	5.3	6.9	19.2	1243	257	986	68.8
19	96.54	125.50	5.1	6.6	18.4	1256	272	984	68.7
20	97.50	126.75	4.9	6.3	17.6	1269	286	983	68.6
21	98.43	127.95	4.7	6.1	16.9	1281	300	980	68.4
22	99.32	129.11	4.5	5.9	16.3	1292	314	978	68.2
23	100.17	130.22	4.4	5.7	15.7	1303	329	975	68.0
24	101.00	131.30	4.2	5.5	15.2	1314	343	971	67.8
30	105.45	137.09	3.5	4.6	12.7	1372	429	943	65.8
36	109.24	142.01	3.0	3.9	11.0	1421	515	907	63.3
42	112.55	146.31	2.7	3.5	9.7	1464	600	864	60.3
48	115.49	150.14	2.4	3.1	8.7	1503	686	817	57.0
54	119.52	155.38	2.2	2.9	8.0	1555	772	783	54.7
60	123.25	160.22	2.1	2.7	7.4	1604	858	746	52.1
66	126.72	164.74	1.9	2.5	6.9	1649	943	705	49.2
72	129.97	168.97	1.8	2.3	6.5	1691	1029	662	46.2
96	141.34	183.74	1.5	1.9	5.3	1839	1372	467	32.6

120	150.83	196.08	1.3	1.6	4.5	1962	1715	247	17.3
144	159.06	206.78	1.1	1.4	4.0	2069	2058	11	0.8
168	166.37	216.28	1.0	1.3	3.6	2165	2401	-236	-16.5

Storage Calculation

Site: Bailrigg
Job Number: 2017s6815
Scenario: 100-Year Plus Climate Change (Free Discharge)_2nd Pond

Return Period	100	Years
Impermeable Area	1.5	Ha
Discharge Rate Q	11.91	l/s
Discharge Coefficient C	0.5	Gravity

1	2	3	4	5	6	7	8	9	10
Storm Duration D (Hours)	Rainfall Depth (mm)	Rainfall Depth +30% (mm)	Rainfall Rate i (mm/hr)	Rainfall Rate i+30% (mm)	Inflow Rate 2.78Ai (l/s)	Inflow Volume Rate x 3.6D (m3)	Outflow Volume C x Q x 3.6D (m3)	Storage Required (In - Out) (m3)	Time to Empty 0.277V/QC (Hours)
0.25	24.19	31.45	96.8	125.8	524.5	472	5	467	21.7
0.5	33.21	43.17	66.4	86.3	360.1	648	11	637	29.6
0.75	39.11	50.84	52.1	67.8	282.7	763	16	747	34.8
1	43.51	56.56	43.5	56.6	235.9	849	21	828	38.5
1.25	47.04	61.15	37.6	48.9	204.0	918	27	891	41.5
1.5	50.01	65.01	33.3	43.3	180.7	976	32	944	43.9
1.75	52.59	68.37	30.1	39.1	162.9	1026	38	989	46.0
2	54.89	71.36	27.4	35.7	148.8	1071	43	1028	47.8
2.25	57.01	74.11	25.3	32.9	137.4	1113	48	1064	49.5
2.5	58.94	76.62	23.6	30.6	127.8	1150	54	1097	51.0
2.75	60.71	78.92	22.1	28.7	119.7	1185	59	1126	52.4
3	62.33	81.03	20.8	27.0	112.6	1216	64	1152	53.6
3.25	63.83	82.98	19.6	25.5	106.5	1246	70	1176	54.7
3.5	65.23	84.80	18.6	24.2	101.0	1273	75	1198	55.7
3.75	66.52	86.48	17.7	23.1	96.2	1298	80	1218	56.6
4	67.74	88.06	16.9	22.0	91.8	1322	86	1236	57.5
4.25	68.85	89.51	16.2	21.1	87.8	1344	91	1253	58.3
4.5	69.9	90.87	15.5	20.2	84.2	1364	96	1268	59.0
4.75	70.89	92.16	14.9	19.4	80.9	1383	102	1282	59.6
5	71.82	93.37	14.4	18.7	77.9	1402	107	1294	60.2
5.25	72.7	94.51	13.8	18.0	75.1	1419	113	1306	60.8
5.5	73.53	95.59	13.4	17.4	72.5	1435	118	1317	61.3
5.75	74.32	96.62	12.9	16.8	70.1	1450	123	1327	61.7
6	75.06	97.58	12.5	16.3	67.8	1465	129	1336	62.2
6.25	75.77	98.50	12.1	15.8	65.7	1479	134	1345	62.5
6.5	76.44	99.37	11.8	15.3	63.8	1492	139	1352	62.9

6.75	77.08	100.20	11.4	14.8	61.9	1504	145	1360	63.2
7	77.7	101.01	11.1	14.4	60.2	1516	150	1366	63.6
7.25	78.28	101.76	10.8	14.0	58.5	1528	155	1372	63.8
7.5	78.85	102.51	10.5	13.7	57.0	1539	161	1378	64.1
7.75	79.39	103.21	10.2	13.3	55.5	1549	166	1383	64.3
8	79.91	103.88	10.0	13.0	54.1	1559	172	1388	64.6
8.25	80.41	104.53	9.7	12.7	52.8	1569	177	1392	64.8
8.5	80.89	105.16	9.5	12.4	51.6	1579	182	1396	65.0
8.75	81.35	105.76	9.3	12.1	50.4	1588	188	1400	65.1
9	81.8	106.34	9.1	11.8	49.3	1596	193	1403	65.3
9.25	82.24	106.91	8.9	11.6	48.2	1605	198	1407	65.4
9.5	82.66	107.46	8.7	11.3	47.2	1613	204	1409	65.6
9.75	83.06	107.98	8.5	11.1	46.2	1621	209	1412	65.7
10	83.46	108.50	8.3	10.8	45.2	1629	214	1414	65.8
10.25	83.84	108.99	8.2	10.6	44.3	1636	220	1416	65.9
10.5	84.21	109.47	8.0	10.4	43.5	1643	225	1418	66.0
10.75	84.57	109.94	7.9	10.2	42.6	1650	230	1420	66.1
11	84.92	110.40	7.7	10.0	41.9	1657	236	1421	66.1
11.25	85.26	110.84	7.6	9.9	41.1	1664	241	1423	66.2
11.5	85.59	111.27	7.4	9.7	40.3	1670	247	1424	66.2
11.75	85.91	111.68	7.3	9.5	39.6	1677	252	1425	66.3
12	86.23	112.10	7.2	9.3	39.0	1683	257	1426	66.3
13	87.39	113.61	6.7	8.7	36.4	1705	279	1427	66.4
14	88.45	114.99	6.3	8.2	34.2	1726	300	1426	66.3
15	89.43	116.26	6.0	7.8	32.3	1745	322	1424	66.2
16	90.33	117.43	5.6	7.3	30.6	1763	343	1420	66.0
17	91.17	118.52	5.4	7.0	29.1	1779	364	1415	65.8
18	91.96	119.55	5.1	6.6	27.7	1795	386	1409	65.5
19	92.69	120.50	4.9	6.3	26.4	1809	407	1402	65.2
20	93.38	121.39	4.7	6.1	25.3	1822	429	1394	64.8
21	94.05	122.27	4.5	5.8	24.3	1835	450	1385	64.4
22	94.69	123.10	4.3	5.6	23.3	1848	472	1376	64.0
23	95.31	123.90	4.1	5.4	22.5	1860	493	1367	63.6
24	95.91	124.68	4.0	5.2	21.7	1872	515	1357	63.1
30	99.36	129.17	3.3	4.3	18.0	1939	643	1296	60.3
36	102.49	133.24	2.8	3.7	15.4	2000	772	1228	57.1
42	105.39	137.01	2.5	3.3	13.6	2057	900	1156	53.8
48	108.12	140.56	2.3	2.9	12.2	2110	1029	1081	50.3
54	110.69	143.90	2.0	2.7	11.1	2160	1158	1003	46.6
60	113.16	147.11	1.9	2.5	10.2	2208	1286	922	42.9
66	115.55	150.22	1.8	2.3	9.5	2255	1415	840	39.1
72	117.89	153.26	1.6	2.1	8.9	2301	1544	757	35.2
96	126.88	164.94	1.3	1.7	7.2	2476	2058	418	19.4

120	136	176.80	1.1	1.5	6.1	2654	2573	82	3.8
144	145.1	188.63	1.0	1.3	5.5	2832	3087	-255	-11.9
168	154.27	200.55	0.9	1.2	5.0	3011	3602	-591	-27.5
180	158.89	206.56	0.9	1.1	4.8	3101	3859	-758	-35.3
192	163.54	212.60	0.9	1.1	4.6	3192	4116	-925	-43.0
204	168.2	218.66	0.8	1.1	4.5	3283	4373	-1091	-50.7
216	172.88	224.74	0.8	1.0	4.3	3374	4631	-1257	-58.5
228	177.53	230.79	0.8	1.0	4.2	3465	4888	-1423	-66.2
240	182.02	236.63	0.8	1.0	4.1	3552	5145	-1593	-74.1

Storage Calculation

Site: Bailrigg
Job Number: 2017s6815
Scenario: 100-Year Plus Climate Change (Free Discharge)_3rd pond

Return Period	100	Years
Impermeable Area	2.5	Ha
Discharge Rate Q	19.85	l/s
Discharge Coefficient C	0.5	Gravity

1	2	3	4	5	6	7	8	9	10
Storm Duration D (Hours)	Rainfall Depth (mm)	Rainfall Depth +30% (mm)	Rainfall Rate i (mm/hr)	Rainfall Rate i+30% (mm)	Inflow Rate 2.78Ai (l/s)	Inflow Volume Rate x 3.6D (m3)	Outflow Volume C x Q x 3.6D (m3)	Storage Required (In - Out) (m3)	Time to Empty 0.277V/QC (Hours)
0.25	24.19	31.45	96.8	125.8	874.2	787	9	778	21.7
0.5	33.21	43.17	66.4	86.3	600.1	1080	18	1062	29.6
0.75	39.11	50.84	52.1	67.8	471.1	1272	27	1245	34.8
1	43.51	56.56	43.5	56.6	393.1	1415	36	1379	38.5
1.25	47.04	61.15	37.6	48.9	340.0	1530	45	1485	41.5
1.5	50.01	65.01	33.3	43.3	301.2	1627	54	1573	43.9
1.75	52.59	68.37	30.1	39.1	271.5	1711	63	1648	46.0
2	54.89	71.36	27.4	35.7	248.0	1785	71	1714	47.8
2.25	57.01	74.11	25.3	32.9	228.9	1854	80	1774	49.5
2.5	58.94	76.62	23.6	30.6	213.0	1917	89	1828	51.0
2.75	60.71	78.92	22.1	28.7	199.5	1975	98	1876	52.4
3	62.33	81.03	20.8	27.0	187.7	2027	107	1920	53.6
3.25	63.83	82.98	19.6	25.5	177.4	2076	116	1960	54.7
3.5	65.23	84.80	18.6	24.2	168.4	2122	125	1997	55.7
3.75	66.52	86.48	17.7	23.1	160.3	2164	134	2030	56.6
4	67.74	88.06	16.9	22.0	153.0	2203	143	2060	57.5
4.25	68.85	89.51	16.2	21.1	146.4	2239	152	2088	58.3
4.5	69.9	90.87	15.5	20.2	140.3	2274	161	2113	59.0
4.75	70.89	92.16	14.9	19.4	134.8	2306	170	2136	59.6
5	71.82	93.37	14.4	18.7	129.8	2336	179	2157	60.2
5.25	72.7	94.51	13.8	18.0	125.1	2365	188	2177	60.8
5.5	73.53	95.59	13.4	17.4	120.8	2392	197	2195	61.3
5.75	74.32	96.62	12.9	16.8	116.8	2417	205	2212	61.7
6	75.06	97.58	12.5	16.3	113.0	2441	214	2227	62.2
6.25	75.77	98.50	12.1	15.8	109.5	2464	223	2241	62.5
6.5	76.44	99.37	11.8	15.3	106.3	2486	232	2254	62.9

6.75	77.08	100.20	11.4	14.8	103.2	2507	241	2266	63.2
7	77.7	101.01	11.1	14.4	100.3	2527	250	2277	63.6
7.25	78.28	101.76	10.8	14.0	97.6	2546	259	2287	63.8
7.5	78.85	102.51	10.5	13.7	95.0	2565	268	2297	64.1
7.75	79.39	103.21	10.2	13.3	92.6	2582	277	2305	64.3
8	79.91	103.88	10.0	13.0	90.2	2599	286	2313	64.6
8.25	80.41	104.53	9.7	12.7	88.1	2615	295	2321	64.8
8.5	80.89	105.16	9.5	12.4	86.0	2631	304	2327	65.0
8.75	81.35	105.76	9.3	12.1	84.0	2646	313	2333	65.1
9	81.8	106.34	9.1	11.8	82.1	2661	322	2339	65.3
9.25	82.24	106.91	8.9	11.6	80.3	2675	331	2344	65.4
9.5	82.66	107.46	8.7	11.3	78.6	2689	339	2349	65.6
9.75	83.06	107.98	8.5	11.1	77.0	2702	348	2353	65.7
10	83.46	108.50	8.3	10.8	75.4	2715	357	2357	65.8
10.25	83.84	108.99	8.2	10.6	73.9	2727	366	2361	65.9
10.5	84.21	109.47	8.0	10.4	72.5	2739	375	2364	66.0
10.75	84.57	109.94	7.9	10.2	71.1	2751	384	2367	66.1
11	84.92	110.40	7.7	10.0	69.8	2762	393	2369	66.1
11.25	85.26	110.84	7.6	9.9	68.5	2773	402	2371	66.2
11.5	85.59	111.27	7.4	9.7	67.2	2784	411	2373	66.2
11.75	85.91	111.68	7.3	9.5	66.1	2794	420	2374	66.3
12	86.23	112.10	7.2	9.3	64.9	2805	429	2376	66.3
13	87.39	113.61	6.7	8.7	60.7	2842	464	2378	66.4
14	88.45	114.99	6.3	8.2	57.1	2877	500	2377	66.3
15	89.43	116.26	6.0	7.8	53.9	2909	536	2373	66.2
16	90.33	117.43	5.6	7.3	51.0	2938	572	2366	66.0
17	91.17	118.52	5.4	7.0	48.5	2965	607	2358	65.8
18	91.96	119.55	5.1	6.6	46.2	2991	643	2348	65.5
19	92.69	120.50	4.9	6.3	44.1	3015	679	2336	65.2
20	93.38	121.39	4.7	6.1	42.2	3037	715	2323	64.8
21	94.05	122.27	4.5	5.8	40.5	3059	750	2309	64.4
22	94.69	123.10	4.3	5.6	38.9	3080	786	2294	64.0
23	95.31	123.90	4.1	5.4	37.4	3100	822	2278	63.6
24	95.91	124.68	4.0	5.2	36.1	3120	858	2262	63.1
30	99.36	129.17	3.3	4.3	29.9	3232	1072	2160	60.3
36	102.49	133.24	2.8	3.7	25.7	3334	1286	2047	57.1
42	105.39	137.01	2.5	3.3	22.7	3428	1501	1927	53.8
48	108.12	140.56	2.3	2.9	20.4	3517	1715	1802	50.3
54	110.69	143.90	2.0	2.7	18.5	3600	1929	1671	46.6
60	113.16	147.11	1.9	2.5	17.0	3681	2144	1537	42.9
66	115.55	150.22	1.8	2.3	15.8	3758	2358	1400	39.1
72	117.89	153.26	1.6	2.1	14.8	3834	2573	1262	35.2
96	126.88	164.94	1.3	1.7	11.9	4127	3430	697	19.4

120	136	176.80	1.1	1.5	10.2	4424	4288	136	3.8
144	145.1	188.63	1.0	1.3	9.1	4720	5145	-426	-11.9
168	154.27	200.55	0.9	1.2	8.3	5018	6003	-985	-27.5
180	158.89	206.56	0.9	1.1	8.0	5168	6431	-1263	-35.3
192	163.54	212.60	0.9	1.1	7.7	5319	6860	-1541	-43.0
204	168.2	218.66	0.8	1.1	7.4	5471	7289	-1818	-50.7
216	172.88	224.74	0.8	1.0	7.2	5623	7718	-2095	-58.5
228	177.53	230.79	0.8	1.0	7.0	5774	8146	-2372	-66.2
240	182.02	236.63	0.8	1.0	6.9	5920	8575	-2655	-74.1

HR Wallingford
Working with water

Greenfield runoff estimation for sites

www.uksuds.com | Greenfield runoff tool

Calculated by:	Inma Lastres
Site name:	Bailrigg
Site location:	Lancaster

This is an estimation of the greenfield runoff rate limits that are needed to meet normal best practice criteria in line with Environment Agency guidance "Preliminary rainfall runoff management for developments", W5-074/A/TR1/1 rev. E (2012) and the SuDS Manual, C753 (Ciria, 2015). This information on greenfield runoff rates may be the basis for setting consents for the drainage of surface water runoff from sites.

Site coordinates

Latitude:	54.00954° N
Longitude:	2.78535° W
Reference:	6164344
Date:	2017-11-13T16:06:43

Methodology	IH124

Site characteristics

Total site area (ha)	5

Methodology

Qbar estimation method	Calculate from SPR and SAAR
SPR estimation method	Calculate from SOIL type

	Default	Edited
SOIL type	4	4
HOST class	---	---
SPR/SPRHOST	0.47	0.47

Hydrological characteristics

	Default	Edited
SAAR (mm)	1071	1071
Hydrological region	10	10
Growth curve factor: 1 year	0.87	0.87
Growth curve factor: 30 year	1.7	1.7
Growth curve factor: 100 year	2.08	2.08

Notes:

(1) Is Q_{BAR} < 2.0 l/s/ha?

(2) Are flow rates < 5.0 l/s?

(3) Is SPR/SPRHOST ≤ 0.3?

Greenfield runoff rates

	Default	Edited
Qbar (l/s)	39.7	39.7
1 in 1 year (l/s)	34.54	34.54
1 in 30 years (l/s)	67.49	67.49
1 in 100 years (l/s)	82.58	82.58

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