Blackpool Borough Council

Blackpool SWMP

Assessment of Flood Alleviation Options (Strategic and Local)

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Executive summary

This report is produced as part of Arup’s assistance with Blackpool Borough Council (BBC) to allow them to produce their own Surface Water Management Plan (SWMP). It builds on the Blackpool SWMP Risk Assessment Report, which identified High Risk Areas (HRAs) within Blackpool potentially subject to severe flooding from large storm events.

In the context of these HRAs, this report then considers the potential borough level Strategic Options that BBC could implement that would reduce the flow of surface water to the HRAs. It highlights those which have the potential to produce the highest benefit for the most people at the lowest cost for BBC based on a qualitative approach. This report also identifies and compares the potential combined solutions that could be used to protect the community at the HRAs against flooding following a 1in100 year storm event, by using local solutions. The comparison is undertaken based on broad brush benefits and costs for each area.

It should be noted that, as with the Environment Agency flood maps, the level of detail within this work is not intended to be used to identify solutions at a detailed design level. However the results do give an indication of which parts of the catchment are at a higher risk of potential flooding and as such can be used to ‘focus in’ on areas that could benefit from further investigation to fully understand all the potential flood mechanisms that could contribute to flood risk within these High Risk Areas (HRAs). The review of options both at strategic and local level is based on the analysis of the flood model along with broad brush assessment of the likely costs or effects of implementation of the option. Therefore although the comparisons are suitable to allow ranking of options they are not suitable for the generation of economic business cases to promote defence schemes.

Assessment of Strategic Options

A long list of potential options has been produced and a qualitative assessment of capital cost, operational cost and benefit has been undertaken on each option to produce a short list of options that should be considered at the next stage of this study.

The short listed options are

Option	Comments
Retrofit Suds into existing green areas	Easier to construct than within the urban spaces
Planning conditions to less than green field run off (2014) for all new developments	Not only beneficial to the new development but this will reduce the flow either in the drainage system or over land to the surrounding area.

	Low cost to the council. Actual level of reduction would need to be considered.
Grants to retrofit surface water run off reducing measures at property level	Low cost to the council, both capital and operational.
Grants / applications for wider property level defences	Low cost to the council, both capital and operational. Also low liability but would need a surface water flood warning system
Strategic road closures / traffic management to reduce flows and direct flows away from properties	Could be implemented as part of a wider traffic calming initiative.
Research and further studies	Needs to be continuous to ensure proposals are in line with current best practice

In addition to the Short Listed options the following additional options merit consideration

Option	Comments
Include storage at high risk area only	Not a strategic option but needs to be considered within the economic assessment to ensure best value solutions are implemented
Retrofit Suds into urban area	More expensive than retrofitting into green areas, but as more locations this would have a greater effect. Also undertaking this works in the urban areas will improved the local environment potentially leading towards other wider benefits to the community
Retrofit resilience measures to HRA	Not a strategic option but needs to be considered within the economic assessment to ensure best value solutions are implemented
Planning conditions to green field run off for all new developments	Would not gain as many benefits as reducing below green field run off but may be more acceptable for developers and therefore considered.

An assessment on the effect on implementing the top five strategic options has been undertaken at high level. This has consider the change in flood outline that would be produced by the 1in100 and 1in30 year storm event after the strategic options has been implemented. Future stages of assessment and design would be needed to confirm the assumptions made during this assessment.

Option	Equivalent flood outline for 1in30 storm following implementation	Equivalent flood outline for 1in100 storm following implementation
Retrofit Suds into green area	1in10	1in50
Planning conditions to less than green field run off for all new developments	1in15	1in56
Grants to retrofit surface water run off reducing measures at property level	1in26	1in97
Grants / applications for wider property level defences	1in24	1in54
Strategic road closures / traffic management to reduce flows and direct flows away from properties	Unable to estimate without consultation with the highway department and detailed modelling	

Although this indicates that the best solution in term of benefits would be inclusion of SUDs, this would be a very high cost for the council and therefore the change in planning conditions for new developments would probably give a better economic case for the council for a strategic improvement to surface water flooding within the communities of Blackpool.

Options for alleviation works within the High Risk Areas

Three board brush solutions have been considered for potential works to alleviate flood risk within the HRAs.

1. On-site storage
2. Removal of water via pump stations and rising main to an outfall to the sea
3. Property level defences

The costs and benefits of the options at each site have been assessed at a high level to indicate the broad viability of the potential solution.

Location	Potential Cost (k)	Potential Benefit (k)	Benefit cost ratio (BCR)	Ranking on BCR	Option
HRA1	£681	£ 70	0.10	15	Storage Option
HRA2	£2,887	£ 1,351	0.47	4	Removal by Pumping
HRA3	£3,592	£ 415	0.12	13	Storage Option
HRA4	£2,338	£ 980	0.42	6	Removal by Pumping
HRA5	£3,104	£ 91	0.03	16	Storage Option
HRA6	£4,070	£ 1,342	0.33	8	Removal by Pumping
HRA7	£1,290	£ 513	0.40	7	Storage Option
HRA8	£4,571	£ 2,102	0.46	5	Removal by Pumping
HRA9	£7,851	£ 2,441	0.31	9	Removal by Pumping
HRA10	£4,132	£ 4,125	1.00	2	Removal by Pumping
HRA11	£4,143	£ 1,069	0.26	10	Removal by Pumping
HRA12	£3,604	£ 3,559	0.99	3	Removal by Pumping
HRA13	£1,985	£ 364	0.18	11	Storage Option
HRA14	£2,721	£ 297	0.11	14	Storage Option
HRA15	£4,959	£ 639	0.13	12	Storage Option
HRA16	£4,904	£ 6,480	1.32	1	Removal by Pumping

At this high level there is only one potential scheme which has a benefit cost ratio greater than 1. For comparison the required ratio for an EA scheme is 8.

However the process undertaken at this stage is very high level and has been undertaken based on a consistent approach for the areas highlighted from the modelling stage to only allow a ranking of areas.

The next step would be to consider the top ranked options further to establish if a more viable scheme could be identified.

1 Introduction

1.1 Context

This report is produced as part of Arup's assistance with Blackpool Borough Council (BBC) to allow them to produce their own Surface Water Management Plan (SWMP).

It builds on the Blackpool SWMP Risk Assessment Report, which used surface water modelling techniques to identify high risk areas within Blackpool potentially subject to severe flooding from large storm events.

These locations are termed the "High Risk Areas" (HRAs)

1.2 Review of Strategic Options

In the context of these HRAs this report then considers the potential borough level Strategic Options that BBC could implement that would reduce the flow of surface water to the HRAs.

This report looks at these potential options, highlighting those which have the potential to produce the highest benefit for the most people at the lowest cost for BBC based on a qualitative approach.

This is not intended to inform BBC on which of those options that should be implemented but simply those options which could result in improvements to surface water flooding and therefore should be considered in more detail at later stages in their works to reduce flood risk for the residents of Blackpool.

1.3 Economic Appraisal of Site Options to reduce flood risk

In addition to the review of the strategic options, this report identifies and compares the potential combined solutions that could be used to protect the community at the HRAs against flooding following a 1in100 year storm event.

The 1 in 100 level of defence was proposed by Blackpool borough council as the base line for this assessment.

The purpose of this is not to build an economic case for any particular solution. It is to allow the council to understand which locations it would be best to focus the next stage of the design process.

The potential solutions at each HRA have been ranked in terms of overall costs and also benefit cost ratio. All assessment of cost and benefit are based on a 1 in 100 storm event over a 100 year appraisal period.

1.4 Limitations to this Project

It should be noted that, as with the Environment Agency flood maps, the level of detail within this work is not intended to be used to identify solutions at a detailed design level.

However the results do give an indication of which parts of the catchment are at a higher risk of potential flooding and as such can be used to 'focus in' on areas that could benefit from further investigation to fully understand all the potential flood mechanisms that could contribute to flood risk within these High Risk Areas (HRAs).

1.5 The Brief

1.5.1 Strategic Options

The following extract summarises the brief for this work

"Strategic options will be considered for the whole of Blackpool Borough. The difference between Strategic solutions and solutions for HRA, will be defined as strategic will reduce the volume of water flowing towards the HRA, whereas local solutions will "treat" the water ponding at the HRA.

The strategic solutions will be presented at an appropriate level for this stage of work. A maximum of five options will be highlighted that could be used to reduce the volume of run off that would be produced following a rainfall event.

The ability of each of these strategic options to reduce flood risk on a Borough wide basis, will be assessed based on our understanding of the existing situation, and expressed in terms of the reduction in flood risk that they have the capacity to achieve.

So for example an option may be described as being capable of reduction the impact of a particular rainfall event from a 1 in 10 year flood event to a volume of surface water equivalent to that from a 1 in 5 year storm event.

This will allow an assessment of the benefit of implementing these strategic solutions by comparison of the calculated damages between the relative storm events (already produced). Therefore we will be able to rank the strategic options, and make recommendations on which options would be best to investigate further."

1.5.2 Local Options

The following extract summarises the brief for this work

"An agreed standard of protection (SOP) for all HRA will be agreed with yourselves across Blackpool, this will match an existing modelled storm event. The total volume of water that would require to be "treated" will be calculated by the water ponding at the HRA due to the storm event.
An internal design workshop will be undertaken to agree the discrete element make-up of the solution for each individual HRA. The list of suitable elements will be produced based on site constraint. The information used for this workshop will be the existing feasibility study, and information from Google maps / street view. The complete solution will be based upon a percentage of volume of water that will need to be "treated" by each suitable individual element.
A review of similar projects will be undertaken to generate a unit cost of each individual solution element per 1m3 of "treated" water for both construction and on-going maintenance. These unit rates will be used to generate a total cost for the construction and also on-going maintenance of the solution at each HRA.
The output of this will be an annex to the feasibility report giving a list of the build-up of each individual element contained within the complete solution for each HRA including a construction and maintenance cost. This will allow a whole life cost to be calculated.

The cost analysis detailed above will allow a construction cost for mitigating the food risk at each HRA to be produced.
The existing total damages across Blackpool for each storm event has already been produced. This will be split into the discrete HRA. From the agreed standard of protection (SOP) for all HRA which matches an existing modelled storm event, the benefit from providing defences will match the damages that would have occurred, and have previously been calculated. Therefore an economic assessment of the benefits can be produced based on this information over the agreed time period. An inclusion of maintenance costs for the below ground hard storage will be made in this economic assessment
The HRA will then be rated based on their cost-benefits.
Analyse strategic options and provide recommendations
A summary addendum will be produced making recommendations of the next steps that Blackpool Borough Council could consider."

2 Background

Flood risk is now being recognized as being a significant issue across the UK and following the widespread flooding that occurred in 2007 and the subsequent Pitt Review the UK Government introduced new legislation.

The Flood and Water Management Act (FWMA) 2010 requires Lead Local Flood Authorities (LLFAs) to become Sustainable drainage (SuDS) Approving Bodies (SABs). The implementation date of the remaining part of this Act (Schedule 3) has yet to be announced but the last indication that was given by DEFRA was October 2014.

The Surface Water Management Plan (SWMP) is a valuable starting point in this process but cannot answer all the questions that will arise across the catchment. The SWMP is effectively a filter to highlight areas that will need further investigation and the ‘broad brush’ flood mapping that is produced will serve in allowing the many areas at risk to be prioritized based on the potential severity of the flooding identified. The SWMP gives a ‘macro’ approach to flood risk in showing which areas are at a higher or lower risk than other areas.

It should not be assumed that this level of analysis is accurate enough to produce detailed design solutions as it will not have looked at all the potential flood mechanisms that may contribute to the ‘real’ flooding. Normally a SWMP will have the same limitations as the EA flood maps in that it may give a reasonable indication of the potential ‘effects’ of flooding, but it is unlikely that it will adequately identify the actual ‘cause’ of flooding as it does not include all the potential flood mechanisms, such as underground flow paths or detailed flood thresholds (boundary walls, dropped kerbs etc.)

The SWMP also needs to be updated to take account of any significant changes in the catchment as changes in flow paths can have a significant impact on the flow balance in an area that may have ‘knock on’ effects in several other areas. It should be therefore a live document.

This legislation (FWMA 2010) represents a fundamental change in the way surface water will be managed in future and has significant implications on Blackpool as the LLFA. All future developments will be required to use Sustainable Drainage systems unless there is evidence based reasoning that proves they are not possible or viable.

BBC as the LLFA is now responsible for Surface Water Management in Blackpool and will need to use a variety of methods to manage the surface water and also ‘influence’ other parties that affect the flow of surface water throughout the catchment.

The legislation puts in place a new statutory approval and adoption regime for surface water drainage, and makes the existing right to connect surface water drainage to the public sewer conditional on SAB approval. This is subject to some exclusions and a phased introduction.

3 Strategic Options

3.1 Introduction

3.1.1 Approach

This section considers the strategic options to reduce flood risk for the HRAs in Blackpool.

The approach taken has been to consider a Long List of options that could be adopted   The costs and benefits of these options are then considered, and from this high level assessment a short list of Strategic Options has been prepared.

These shortlisted options can then be considered further by BBC as they develop their SWMP.

3.1.2 Impact of Change

In a similar way to the actual SWMP being a live document the options discussed below and summarised in the table are based on the current snap shot of Blackpool at the current time. New developments may be proposed which would lead to some of the options dismissed as unsuitable now to become much more viable. For example by opening up the opportunity of a new open water course that existing drainage could be tied into at a much lower cost than would be required at present.

3.1.3 Prevention of Flooding

The prevention of flooding is a difficult objective as it is not possible to guarantee that any area will not flood at some future date. A more realistic objective is to mitigate the effect of flooding by the management of surface water. Even doing this will require 'sacrificial' areas within the catchment that will be allowed to act as temporary storage of flood water. Areas shown on the SWMP maps that are not occupied by residential development and that will not impact on any critical infrastructure can be targeted as potential 'sacrificial' areas. But these areas should not be allocated as such until detailed analysis has confirmed all the relevant flood mechanisms in those areas.

3.1.4 Level of Detail

The work done in this study identifies areas that may have a high risk of flooding at a generic level. It should be noted that as with the Environment Agency flood maps the level of detail within this work is not intended to be used to identify solutions at a detailed design level or at the individual property level. However the results do give an indication of which parts of the catchment are at a higher risk of potential flooding and as such can be used to 'focus in' on areas that could benefit from further investigation to fully understand all the potential flood mechanisms that could contribute to flood risk within these High Risk Areas (HRAs).

At the next stage the high level model should be used to perform a number of sensitivity runs looking at changes in flooding areas based upon some of the more suitable strategic options high-lighted within this report. This will allow a more quantitative assessment made on which options would provide the greatest benefit to the overall community of Blackpool.

3.2 Key Principles behind the Options

3.2.1 Retrofitted SUDS in Green field locations and existing Urban locations

Sustainable Drainage systems (SUDS) are systems that are designed to minimise the adverse impacts that have resulted in many of the 'traditional' design methods. They attempt to promote a 'green infrastructure' approach that can have multiple benefits. The principles of SUDs is to minimise the surface run off, which therefore reduces the potential of flooding locally or for the wider area.

SUDS are relatively straightforward for new developments but can be a bit more challenging as retrofit solutions. However both new and retrofit SUDS are starting to be used across the UK and there use will become more widespread once schedule 3 of the FWMA has been implemented. Green field locations will be much easier to install SUDS systems rather than in urban environments.


Existing Photo - Wide Street

Figure 1 Example of proposed retrofit SUDS, Before (top) and After (bottom)

3.2.2 Water Conveyance improvements

Improvements to water conveyance is looking towards the principle of allowing the water to be removed away from areas of flooding. This would either be via drainage networks, outfalls and natural water bodies. This would be achieved by either improvements to the existing systems or the introduction of new infrastructure.

Historically many of the sewers that were built were combined sewers, but this approach stemmed from a time when all the sewers discharged directly to the rivers or the sea. Over time most of these systems have been diverted to wastewater treatment works (WWTW) to improve the quality of the water discharged into the environment. WWTW were designed to treat a range of flows to cater for the diurnal variation of flow generated. The WWTW cannot cater for the excessive flow that can occur in the combined systems during storm events and in the past much of this ‘storm water’ would either be stored in storm tanks at the works (till later) or discharged to the environment via combined sewer overflows (CSOs). Although this sewage is very diluted with a high proportion of storm water it is still sewage so the water companies have spent significant sums of money ensuring that these ‘spills’ are minimized.

If the surface water was not allowed to enter the combined system there would be no need to treat it at the WWTW or allow it to spill at the CSOs. So undertaking surface water separation schemes to remove as much surface water from the combined systems can in some cases have multiple benefits for both the water companies and the environment.

New outfalls for the surface water drainage system would need to be located, and potentially some form of treatment (e.g. oil interceptors) would be required to ensure that pollution incidents did not occur. There would also be a need for downstream hydraulic modelling to be undertaken to consider the impact of the surface water discharging from the outfalls. This could lead to improvement in the natural water bodies’ capacity or looking to introduce new systems that could transmit water to locations more suitable for dealing with the increased flows.

United Utilities (UU) will continue to manage the existing combined Surface Water and Foul Sewer network and may be prepared to adopt new Surface Water Sewers that satisfy the Sewers for Adoption standards and the company’s requirements. However it is possible that they may expect the LLFA to take on all new surface water systems. The only potential issue with this approach is that the LLFA has no powers to assist developers cross third party land to reach a suitable outfall. Under the current proposals, only the Water Company has the power to requisition a ‘sewer’ across third party land. In some parts of the country the Water Companies have indicated that they are prepared to consider using their powers on behalf of the LLFA, but to Arup’s knowledge UU have not to date confirmed that they are prepared to do likewise.

There is potential for undertaking ‘joint funded’ retrofit schemes with UU that will benefit UU by including surface water separation mentioned above, which will ‘ease’ the existing burdens on some of their assets. Welsh Water has already provided funded for a couple of schemes in Wales.

Existing flood defences for both fluvial and tidal events would also need to be considered to ensure that these were not creating areas of surface water flooding by restricting flows to the natural water bodies.

3.2.3 Resilient and resistant development

In areas that are prone to flooding, new development should not be permitted unless there is an evidenced based economic regeneration need and even then any permitted development should include robust resilient and resistant design measures.

Where flooding is occurring to areas already developed similar solutions can be implemented but similar to SUDs these will be more expensive to implement. There are grants available to allow homeowners to consider retrofitting their own flood defence products to their buildings. BBC could assist with the gaining of such grants by local residents and also consider adding local money to these. This could be a cost effective method of reducing property flooding.

The usual risk associated with active flood defence system is that if they are not actively managed then a large number of residents are at risk. This would not be the situation for this option as each individual property would be a stand-alone system. Therefore if one properties active system was not deployed then only that property would be at risk. It would be advantageous for the home owners if the systems were more passive e.g. flood doors that seal when closed rather than a stop log system.

Any active system would also need to be linked to a warning system, with the residents informed when they would need to install their defences.

3.2.4 Planning policy

Local Planning Authorities (LPAs) all have some form of sustainable development policies and under the National Planning Policy Framework (NPPF) development must be assumed to be sustainable.

However the proposed SABs are not directly linked to the LPAs and unless the SAB and the LPA work together there is a chance that requirements of the SAB may frustrate LPA aims. If the LPA and the SAB do work in tandem, this can have benefits for both parties.

Therefore to reduce the effect of surface water flooding these 2 bodies need to work together to a consistent goal and agree the approval procedures for applications to either organisation.

3.3 Description of Strategic Options (Long List)

Strategic Options	Description
Do Nothing	Assumes that nothing is done to maintain the existing arrangements for surface water management, which will eventually deteriorate and fail.
Do Minimum (continue as current)	Assumes all that is done, is to maintain the existing arrangements. These first two options are used to provide a comparison to the impact of the other Strategic Options
Modify sea defences to allow surface water more readily to the sea	The existing sea defences, which providing protection against coastal flooding, can in some circumstances prevent surface water from the land side from discharging to the sea. This option considers works that could amend that, such as the provision of further pump stations (Section 4.2.2)
Modify fluvial defences to allow surface water more readily entre the natural water courses	Similarly the existing flood defences on the watercourses in the Borough can in some positions, prevent surface water from the land side discharging into the watercourse. This option considers works that could amend that, such as the provision of further pump stations. (Section 4.2.2)
Include storage at high risk area only	This option considers a strategic programme to introduce additional surface water storage at or near the HRAs
Retrofit Suds into green area	This option considers a strategic programme to retrofit SuDS (Section 4.2.1) into Green Areas.
Retrofit Suds into urban area	This option considers a strategic programme to retrofit SuDS (Section 4.2.1) into urban areas.
Retrofit resilience measures to HRA	This option considers a strategic programme to improve the resilience of properties in the HRAs from flooding. (Section 4.2.3)
Construct segregated drainage system	This option considers the modification of Blackpool's drainage network to separate foul flows from surface water. (Section 4.2.2)
Construct new water course	This option considers constructing new watercourses that would allow surface water to flow away from and not towards the HRAs (Section 4.2.2)
Improve existing water courses to increase capacity	This option considers improvements to relevant existing watercourses, such as section widening or removal of throttle sections to increase their capacity. (Section 4.2.2)
Construct new interceptor drainage	This option considers a strategic programme to construct new interceptor drainage that would divert surface water flooding away from the HRAs. (Section 4.2.2)

Construct key pumping stations to relieve key bottle necks	This option considers strategic programme to construct new pump stations that would pump surface water flooding away from the HRAs and into appropriate watercourses. (Section 4.2.2)
Planning conditions to green field run off for all new developments	This options considers BBC applying a policy of only consenting developments that reduced the runoff from their sites to the equivalent flow, had the site been a green field, rather than with development on it. This would require the developers of new sites to provide additional SuDS or other flow control techniques as part of their developments. (Section 4.2.4)
Planning conditions to less than green field run off for all new developments	This option is similar to that above, but it would require the run off from new developments to be appreciably less than had the site been a green field. (Section 4.2.4)
Grants to retrofit surface water run off reducing measures at property level	This option would establish a process of grants from BBC to residents in the borough to reduce surface water runoff from their properties, for example to encourage residents to introduce SuDS within their own property. (Section 4.2.3)
Increase number of highway drainage gullies	This option is specifically targeted at local flooding caused by insufficient pathways for rainfall to get into the drainage network. It would provide additional highway drainage gullies to capture excess runoff and divert it onto the drainage network, preventing it passing via overland flow towards the HRAs. (Section 4.2.2)
Grants / applications for wider property level defences	This option would establish a process of grants from BBC to residents in the borough to improve the flood resilience of their properties. (Section 4.2.3)
Strategic road closures / traffic management to reduce flows and direct flows away from properties	This option would look to target overland flow routes for surface water runoff, by amending the road network either on a temporary or permanent basis to divert overland flow routes away from the HRAs. (Section 4.2.2)
Research and further studies	This general heading considers options where more research or further studies are undertaken into the existing risk of surface flooding and its mitigation.
Make room for water by altering town plan and introducing green corridors	This option considers more radical changes to the drainage patterns within the Borough by amending parts of the town to introduce green corridors to reduce runoff and allow surface water to flow away from areas of development. (Section 4.2.1 and 4.2.2)

3.4 Assessment of Strategic Options Long List

The table below contains a high level qualitative assessment of the cost and benefits of the various strategic options that could be implemented in order to quick arrive at a viable shortlist.

The options have not been tested by modelling or economical assessment. It is recommended that those which are showing as potential options are tested at the next stage of the process.

For the costing 1 is very low or zero cost whereas 5 is very high cost, for the benefits 1 is no benefit whereas 5 is benefit for the whole of the area of BBC. Therefore high values of the benefit cost ratio indicates a good solution whereas low values are poor solutions.

The colouring of the table has been added on the following basis.

Outcome	Discounted	Impractical	Lowers flood risk locally / mitigation	Intervention as part of adaptive approach	
Description	Fails to meet objective of reducing flood risk to study area	Meets objective but likely economic / environmental / technical show stoppers	Localised reduction in flood risk	Intervention meets objective and a potential component of an adaptive approach to flood risk. Low return	Intervention meets objective and a potential component of an adaptive approach to flood risk. Reasonable return

Description	Cost capital	Cost Opex	Benefits	Benefit / cost ratio
Do Nothing	1	1	1	0.5
Do Minimum	1	1	1	0.5
Modify sea defences to allow surface water more readily to the sea	3	2	2	0.4
Modify fluvial defences to allow surface water more readily entre the natural water courses	3	2	2	0.4
Include storage at high risk area only	4	3	3	0.42
Retrofit Suds into green area	3	2	4	0.57
Retrofit Suds into urban area	5	3	4	0.5
Retrofit resilience measures to HRA	3	1	2	0.5
Construct segregated drainage system	5	3	3	0.38
Construct new water course	5	3	3	0.38
Improve existing water courses to increase capacity	3	3	1	0.17
Construct new interceptor drainage	5	4	3	0.33
Construct key pumping stations to relieve key bottle necks	4	4	3	0.38
Planning conditions to green field run off for all new developments	1	1	2	0.5
Planning conditions to less than green field run off for all new developments	1	1	3	1.5
Grants to retrofit surface water run off reducing measures at property level	2	1	3	1
Increase number of highway drainage gullies	3	3	1	0.17
Grants / applications for wider property level defences	2	1	2	0.67
Strategic road closures / traffic management to reduce flows and direct flows away from properties	3	2	3	0.6
Research and further studies	2	1	3	1
Make room for water by altering town plan and introducing green corridors	4	2	2	0.33

Notes:

Capital and Opex cost 1 to 5 (1 very low, 5 very high)
Benefits 1 to 5 (1 no benefit, 5 borough wide benefit)

Benefit cost ratio – high is good, low is bad (potential range 2.5 to 0.1)

4 Short List of Strategic Options

Based on this high level analysis, the short listed options are as follows. These are further discussed in the following sections.

Option	Comments
Retrofit Suds into existing green areas	Easier to construct than within the urban spaces
Planning conditions to less than green field run off (2014) for all new developments	Not only beneficial to the new development but this will reduce the flow either in the drainage system or over land to the surrounding area. Low cost to the council. Actual level of reduction would need to be considered.
Grants to retrofit surface water run off reducing measures at property level	Low cost to the council, both capital and operational.
Grants / applications for wider property level defences	Low cost to the council, both capital and operational. Also low liability would need a flood warning system
Strategic road closures / traffic management to reduce flows and direct flows away from properties	Could be implemented as part of a wider traffic calming initiative.
Research and further studies	Needs to be continuous to ensure proposals are in line with current best practice

In addition to the Short Listed options the following additional options merit consideration.

Option	Comments
Include storage at high risk area only	Not a strategic option but needs to be considered within the economic assessment to ensure best value solutions are implemented
Retrofit Suds into urban area	More expensive than retrofitting into green areas, but as more locations this would have a greater effect. Also undertaking this works in the urban areas will improved the local environment potentially leading towards other wider benefits to the community
Retrofit resilience measures to HRA	Not a strategic option but needs to be considered within the economic assessment to ensure best value solutions are implemented
Planning conditions to green field run off for all new developments	Would not gain as many benefits as reducing below green field run off but may be more acceptable for developers and therefore considered.

5 Assessment of potential change in flood risk for the Short Listed Strategic Options

The top five shortlisted options are further appraised in the section below in order to determine the potential they have to appreciably reduce flood risk in the HRAs.

This has been done at this high level stage by comparing the likely flood outline for a 1 in 30 and 1 in 100 year rainfall event following the implementation of the strategic option. This resultant flood outline is compared against the flood outlines of lesser rainfall event (without the Strategic Option) to assess the potential impact the Strategic Option on the flooding experience of residents in the HRAs.

5.1 Retrofit Suds into green area

5.1.1 Assumptions made

The reduction in flood risk will be dependent on the area of green space within the borough that contributes to the flood volumes.

The benefit would be to capture the first rain fall entering the drainage system from the green spaces and this would allow the surface water from the streets and roofs to enter the drainage system and be moved away before the water from the green spaces enters the system.

Assume green area drainage accounts for 10% of the surface area.

Assume the system reduces peak flow from the property by 75%

Therefore this system could intercept 7.5% of the peak flow.

The flood mapping and modelling currently undertaken does not consider peak flow but does look at total volumes of water entering the high risk areas. Peak flow will be proportional to total volume. Therefore, for a broad brush, assessment of reduction in flood risk, a 7.5% reduction in total volume has been assessed to show the reduction in flood risk.

For example for HRA 1 – Cranbrook Av

Return Period	2	20	30	75	100	1000
2113 flood volume	1,332	1,894	2,305	4,368	4,715	8,092
Volume following implementation	1,188	1,464	1,586	2,461	3,254	6,377

Therefore equivalent return periods are produced by comparison of volumes

5.1.2 Assessment of Equivalent Flood Event

This would potential mean that the current 1in10 year flood outline would be the actual outline following a 1in30 year storm event once the system was implemented. Similarly the current 1in50 year flood outline would be the actual outline following a 1in100 year storm event once the system was implemented.

Conversely the current flood maps would be approximately equivalent to the flood maps for the following events after the inclusion of this strategic option

Current map	**1in2**	**1in20**	**1in30**	**1in75**	**1in100**
Following implementation	1in20	1in50	1in75	1in400	1in500

5.2 Planning conditions to less than green field run off for all new developments

5.2.1 Assumptions Made

The value of this would be dependent on the number of new developments undertaken within the overall borough.

Assuming that the proposed developments which were assumed in the future modelling situation are constructed and the level of reduction below the green field run off was to counter any increase due to climate change.

The reduction of flood risk would be calculated by assuming that the current day flood volume modelled would occur in the future. Therefore the comparison between the current day flood volume and the future flood volume will indicate the reduction in flood risk. This is probably an overestimate of the benefit as this also assumes that the new developments reduction reduces the overall effect of climate change over the whole borough. Further modelling would be required to confirm the effect and this should be undertaken in the next phase of work.

For example for HRA 1 – Cranbrook Av

Return Period	2	20	30	75	100	1000
2113 flood volume	1,332	1,894	2,305	4,368	4,715	8,092
Volume following implementation	1,285	1,583	1,714	2,660	3,518	6,894

Therefore equivalent return periods are produced by comparison of volumes

5.2.2 Assessment of Equivalent Flood Event

This would potential mean that the current 1in15 year flood outline would be the actual outline following a 1in30 year storm event once the system was implemented. Similarly the current 1in56 year flood outline would be the actual outline following a 1in100 year storm event once the system was implemented.

Conversely the current flood maps would be approximately equivalent to the flood maps for the following events after the inclusion of this strategic option

Current map	1in2	1in20	1in30	1in75	1in100
Following implementation	1in5	1in30	1in75	1in300	1in400

5.3 Grants to retrofit surface water run off reducing measures at property level

5.3.1 Assumptions Made

The value of this will be dependent on the take up of this opportunity. The benefit would be to capture the first rain fall entering the drainage system from the roofs of the properties and this would allow the surface water from the streets to enter the drainage system and be moved away before the water from the roofs enters the system.

Assume 25% take up of the system.

Assume roof drainage accounts for 25% of the surface area.

Assume the system reduces peak flow from the property by 50%

Therefore this system could intercept 3.1% of the peak flow.

The flood mapping and modelling currently undertaken does not consider peak flow but does look at total volumes of water entering the high risk areas. Peak flow will be proportional to total volume. Therefore, for a broad brush, assessment of reduction in flood risk, a 3.1% reduction in total volume has been assessed to show the reduction in flood risk.

For example for HRA 1 – Cranbrook Av

Return Period	2	20	30	75	100	1000
Present day vol	1,285	1,583	1,714	2,660	3,518	6,894
Volume following implementation	1,245	1,534	1,661	2,578	3,409	6,681

5.3.2 Assessment of Equivalent Flood Event

Therefore equivalent return periods are produced by comparison of volumes

This would potential mean that the current 1in26 year flood outline would be the actual outline following a 1in30 year storm event once the system was implemented. Similarly the current 1in97 year flood outline would be the actual outline following a 1in100 year storm event once the system was implemented.

Conversely the current flood maps would be approximately equivalent to the flood maps for the following events after the inclusion of this strategic option

Current map	**1in2**	**1in20**	**1in30**	**1in75**	**1in100**
Following implementation	1in2	1in20	1in30	1in75	1in100

5.4 Grants / applications for wider property level defences

5.4.1 Assumptions Made

Although this could be considered not as a strategic solution as this does not prevent flows into the high risk area. It does have a strategic element as this is linked to the application of funds to the borough.

This cannot be measured in terms of reduction of flood risk but can be measure in terms of benefits.

Assume a 25% take up of this system, and a 95% installation at time of flood warning.

Therefore the residential damages for a standard of protection would be reduced by 23.8%.

Standard of Protection (return period)	10	20	30	75	100	1000
Residential benefits (k)	£0	£15	£25	£40	£43	£59
Benefit following implementation (k)	£0	£12	£19	£30	£33	£45

5.4.2 Assessment of Equivalent Flood Event

Therefore equivalent return periods are produced by comparison of benefit

This would potential mean that the current 1in24 year flood outline would be the actual outline following a 1in30 year storm event once the system was implemented. Similarly the current 1in54 year flood outline would be the actual outline following a 1in100 year storm event once the system was implemented.

Conversely the current flood maps would be approximately equivalent to the flood maps for the following events after the inclusion of this strategic option

Current map	**1in2**	**1in20**	**1in30**	**1in75**	**1in100**
Following implementation	1in2	1in25	1in55	1in600	1in1000

5.5 Strategic road closures / traffic management to reduce flows and direct flows away from properties

The outcome from this strategy solution is difficult to estimate at this stage.

Without consultation with the Borough Council highway team, the potential closures of roads and inclusion of raised junctions to divert direction of surface water flow cannot be readily assumed. The generation of the reduction in flood risk for this option would require a detailed model. This is because the level of works done on the roads would be small – increase in localised road levels would be in the order of 150mm. The wider effect of these changes would also need to be understood as this solution is simply preventing water from entering the identified HRA, and could result in simply moving the risk elsewhere.

5.6 Summary of potential impact of Shortlisted Strategic Options

Option	Equivalent current flood outline for 1in30 storm following implementation	Equivalent current flood outline for 1in100 storm following implementation
Retrofit Suds into green area	1in10	1in50
Planning conditions to less than green field run off for all new developments	1in15	1in56
Grants to retrofit surface water run off reducing measures at property level	1in26	1in97
Grants / applications for wider property level defences	1in24	1in54
Strategic road closures / traffic management to reduce flows and direct flows away from properties	Unable to estimate without consultation with the highway department and detailed modelling	

5.7 Preferred Options

However from this analysis the best strategic option to benefit the wider community would be the inclusion of SUDSs within the existing green spaces of Blackpool. However, this is based on high level assumptions and would these would need to be confirmed at future design stages. It is also noted that the high benefit is related to a very high cost for Blackpool Borough Council, which would be a significant barrier to implementation.

The second best solution, in terms of benefits, would be the consideration of reducing the allowable discharge from all new developments to current day (2014) green field run off. Although this would not provide the same level of protection as the SUDs option this would be a very low cost for the council and therefore would potentially be, on economically terms for the council, a better solution. It would however potentially have an impact on the development activity in the town.

6 Review of Options for alleviation works within the High Risk Areas

6.1 Methodology For Option development

This note follows on from the works undertaken in developing potential options which was summarised in "Feasibility study to investigate options to reduce flood risk" dated 8th April 2014.

Blackpool Borough Council have asked for these options detailed in the feasibility report to be considered, to produce a combined solution which could be constructed at each location.

The combined solution should be applicable to the location and able to deal with the water ponding in the area following a 1in100 storm event. An estimate of the combined solution cost should be produced to allow comparisons between the different areas.

The locations highlighted in the previous reports have been reviewed using previous site visit information, the feasibility study, photographs and also google street view. As agreed with the council no specific site visits were undertaken for this part of the study.

6.2 Options considered

Three board brush solutions have been considered;

1. On-site storage
2. Removal of water via pump stations and rising main to an outfall to the sea
3. Property level defences

The volume of water to be dealt with, on each site, was generated from the original modelling and considered the total water volume ponding at each of the HRAs following the 1in100 storm event. It does not consider the time taken for water to reach the site. The effect of the existing drainage in the area is considered within the overall model and therefore is not considered within the study of potential solutions.

6.2.1 On Site Storage

This is methods of storage of storm water either above ground or below ground so that it prevents flooding of the surrounding buildings.

Options considered were

- Storage below ground in soft area
- Storage off public highway below ground
- Storage off public highway above ground (basin)
- storage below footway (inc tree pits)
- Storage below Highway
- Storage in permeable paving

The selection of which of these options would be applicable for each locations was developed based on the initial information from the feasibility report and reviewing the locations on google street view. This allowed the percentage of each solution potential to be estimated to treat the water. A hierarchy of the potential solutions was used with those with lower cost preferred over those with higher costs, e.g. storage above ground off the public highway was selected in preference to storage below the highway if both solutions were potentially viable.

These storage options would discharge to the existing drainage system following the storm event. It should be noted that if there were two events in close proximity the storage might not be empty and therefore there is a risk that the storage might not be fully available. Therefore is would not protect the community against the complete extent of flooding. A risk assessment / joint probability assessment should be undertaken to assist the sizing of the required storage at the next design stage.

Consultation would also be required with UU as the discharge from these storage areas would be thought the existing drainage network.

6.2.2 Removal of water via pump stations

This is a method of removing the flooding water via a new drainage system. The construction of local surface water pump station has been assumed to be required. This would also require a long rising mains to the sea. This options would require the inclusion of a new outfall below the promenade and across the beach, to allow discharge of storm water.

For sizing of the pump stations it has been assumed that the station would need to remove the total water volume in 60mins. This is not to say that the water would be ponded on site for 60mins, but just that the total volume could be pumped in this time period. As the time required for water to arrive on the site has not been considered it has been assume that water would enter the pumping system and be removed as the event occurs.

Consideration at later date would be required to the actual localised drainage network to link into the pump station. This would need to consider the time of entry of water into the system and also the time for the water to arrive via overland flow from the surrounding area.

Route of the rising pumped main was undertaken at very high level using the existing road network. There will be construction issues with the routing of this pipe due to large amounts of existing services, utilities and structures within the ground. As well as generally working within the public highway network. However, an increased cost has been assumed for the installation cost for this pipe, to deal with these issues.

6.2.3 Property level defences

Property level defences would be applicable for pluvial events. However, we have assessed that these options would be not be applicable for average threshold depths greater than 300mm. This is due to additional strengthen that would be required to the individual buildings where the depth of water would be greater than 300mm, which would be costly and highly disruptive to the residents. There is also a greater risk to circulation around the locations when average threshold depths are greater than 300mm.

There has been an average assessment of threshold depths based on the hydraulic model output.

6.3 Cost Estimation

Whole life costing for the options have been undertaken.

6.3.1 Cost of Storage

This is based on a capital cost per 1m3 of water to be treated for storage options. The maintenance costs have been taken as a percentage of the capital costs based on a net present value over a 100 year appraisal period. The capital and maintenance cost, have been based upon estimates from previous schemes.

Option	Capital cost per 1m3 storage	Maintenance cost of capital net present value
Storage below ground in soft area	£100	5%
Storage off public highway below ground	£500	5%
Storage off public highway above ground (basin)	£50	3%
storage below footway (inc tree pits)	£500	7%
Storage below Highway	£750	10%
Storage in permeable paving	£250	10%

6.3.2 Cost of Pumping

Pump station costs have been based on cost per cumec pumping rate that is required to remove the water within the 60mins as described above. The pipe has been sized to limit the velocity of the water within this pipe to 1.5m/s. As noted above the pump main costs have been inflated to take into consideration working within the existing road network, including avoiding existing services and structures. The pipe cost has been estimated based on previous scheme estimates including an option for changing drainage systems in areas of Blackpool.

A new individual outfall has been assumed for each pump station. Due to the need to cross the promenade and also the beach there is the need to investigate the potential of joining up pumped main to a single combined outfall at the next design stage.

A cost has been included for replacement of the mechanical equipment of 1/3 of the total capital costs at the midpoint of the appraisal period. This is an additional cost on top of the annual maintenance costs.

Element	Capital cost	Maintenance cost of capital net present value
Cost of PS per m^3/sec rate	£550,000	25%
Cost for pipe per m dia per m length	£1,000	7%
Outfall at the beach	£1,250,000	7%

6.3.3 Costs of Property Protection

The costs for property level protection has been based on current estimates from similar schemes.

A cost has been included for replacement of the equipment 1/3 of the total capital costs every 20 year of the appraisal period. This is an additional cost on top of the annual maintenance costs.

Element	Capital cost	Maintenance cost of capital net present value
cost for protection per property	£5,000	40%

6.4 Options Selection for each HRA

The option for each HRA were selected based on relative costs. The spreadsheet showing options considered and the cost of each HRA solution reviewed is included in Appendix A.

The spreadsheet includes the information on the percentages of each storage opportunities at each location, the length of the pumping main, the volumes of water and the depth of water for property level defences.

6.4.1 Summary of Costs

Location	Cost (k)	Ranking on cost	Option
HRA1	£681	1	Storage Option
HRA2	£2,887	6	Removal by Pumping
HRA3	£3,592	8	Storage Option
HRA4	£2,338	4	Removal by Pumping
HRA5	£3,104	7	Storage Option
HRA6	£4,070	10	Removal by Pumping
HRA7	£1,290	2	Storage Option
HRA8	£4,571	13	Removal by Pumping
HRA9	£7,851	16	Removal by Pumping
HRA10	£4,131	11	Removal by Pumping
HRA11	£4,143	12	Removal by Pumping
HRA12	£3,604	9	Removal by Pumping
HRA13	£1,985	3	Storage Option
HRA14	£2,721	5	Storage Option
HRA15	£4,959	15	Storage Option
HRA16	£4,904	14	Removal by Pumping

6.5 Assessment of Benefits

6.5.1 Basis of Assessment

The benefits have been calculated as a damages avoided, by the inclusion of a defence solution. The protection that has been considered is for a 1 in 100 year storm event.

The benefits are built up from direct influences of the flood water on properties and the content of these properties. This is built up based on industry standard approaches for the calculation of flood damages. There are also some indirect benefits by the inclusion of defences these include reduction of emergency response and effect on the utilities serving the area. Again industry standard approaches have been used. These effects have been summed and also considered in net present value over the appraisal period.

There are some additional benefits that could be included such as damage to parked cars, however, as cars could be moved, by the residents, these have not been included at this stage. At the next design stage when economical case would need to be developed then this could be looked at in more detail. However, at this stage where only direct comparison between schemes is being undertaken it was felt that a simple like for like comparison of benefits was the best approach.

This allows the Benefits to be considered directly against the costs of the defences which allows for a cost benefit ratio to be calculated.

The Output of the Benefits associated with each option are summarised below for the 1 in 100 year storm event. Benefits associated with the solutions are calculated as damages avoided by the construction of the solution. The complete damage assessment for all HRA and all storm events modelled is included within Appendix B.

6.5.2 Benefit Cost Ratio

Summary

Location	Cost (k)	Benefit (k)	Benefit cost ratio	Ranking on cost benefit ratio	Option
HRA1	£681	£ 70	0.10	15	Storage Option
HRA2	£2,887	£ 1,351	0.47	4	Removal by Pumping
HRA3	£3,592	£ 415	0.12	13	Storage Option
HRA4	£2,338	£ 980	0.42	6	Removal by Pumping
HRA5	£3,104	£ 91	0.03	16	Storage Option
HRA6	£4,070	£ 1,342	0.33	8	Removal by Pumping
HRA7	£1,290	£ 513	0.40	7	Storage Option
HRA8	£4,571	£ 2,102	0.46	5	Removal by Pumping
HRA9	£7,851	£ 2,441	0.31	9	Removal by Pumping
HRA10	£4,131	£ 4,125	1.00	2	Removal by Pumping
HRA11	£4,143	£ 1,069	0.26	10	Removal by Pumping
HRA12	£3,604	£ 3,559	0.99	3	Removal by Pumping
HRA13	£1,985	£ 364	0.18	11	Storage Option
HRA14	£2,721	£ 297	0.11	14	Storage Option
HRA15	£4,959	£ 639	0.13	12	Storage Option
HRA16	£4,904	£ 6,480	1.32	1	Removal by Pumping

6.6 Discussion

There are potential schemes for each of the HRAs based upon a mixture of solutions. At this high level there is only 1 potential scheme which has a benefit cost ratio greater than 1. The benefit cost ratio is very low and if the values are compared to the required benefit cost ratio for a fluvial scheme with the Environment Agency which is currently 8, this options would not be able to be developed to detailed design and construction. However, this study was not to show an economical case for a solution but only to rank the HRA in terms of their potential benefit cost ratio. This was to allow the council to consider where it would be best to consider solutions to surface water issues. The process undertaken at this stage is very high level and has been undertaken based on a consistent approach for the areas highlighted from the modelling stage to only allow a ranking of areas.

The council next steps should be to study each individual HRA in more detail, in order, based on the benefit cost ranking noted above. This ranking indicates where their finances would potentially return the highest benefit for the communities of Blackpool. The future studies would need to produce outline design solutions to allow more accurate costings to be produced. This would involve interrogating the modelling further to understand the timings of flooding, the direct influence of the local and wider drainage network as well as consideration of the localised ground levels. It would be our recommendation that a more detailed optioneering exercise was undertaken at the start of the study. Once the outline design of a solution is generated the benefits will also need to be re-investigated in detail. The whole wide ranging benefits will need to be reviewed to assist with generating the economical case for the solution. The next stage study should also include investigations into other potential funding sources, this will include approaching business which will directly benefit from the proposed solutions to surface water flooding.

Appendix A

HRA Options Considered and Costing of these Options

High Risk Area Number	1	Cranbrook Avenue		
Volume of water at the location	3518	m3	From Modelling for 1in100 year rainfall event (present day)	
Distance from potential receiving water course	2000	m	Measured from point central in area	
Acceptable time to remove water	60	mins		
velocity of flow assumed	1.5	m/s		
Ground permeability	low		Assumed from geological maps (high, medium low) (high 50% ; Med 75% ; Low 100% of storage required	
Flow diversion upstream to green areas outside HRA	25%		% based on maps and flow areas	
Volume of water at HRA to be managed	2638.5			
	assumed percentage			
Storage below ground in soft area	30%		£105	/m3
Storage off public highway below ground	30%		£525	/m3
Storage off public highway above ground (basin)	30%		£52	/m3
storage below footway (inc tree pits)	10%		£535	/m3
Storage below Highway	0%		£825	/m3
Storage in permeable paving	0%		£275	/m3
	100%	total		
cost	£258	m3		
Assumed Flood depth at Thresholds	0.5	m	Assumed from feasibility site visit and Google street view	
Number of properties	21	no	From Flood modelling (1in100 event)	

storage costs	
infratration rates	0%
Volume to be "lost" to infratration	0
Volume to be stored	2638.5
Assumed costs due to site constraints	£258
total cost of storage options	£680,601

Removal costs		
volume to be removed	2638.5	
velocity of flow assumed	1.5	m/s
flow rate required	0.732916667	m3/sec
pipe area required	0.49	
pipe dia required	0.79	
Cost of PS per m3/sec rate	£687,500	
cost assumed for PS	£503,880	
Cost for pipe per m dia per m length	£1,070	
Cost per m for pipe	£844	
cost for pipe	£1,687,915	
Outfall	£1,337,500	
total cost for removal	£3,529,295	

property protection	
protection acceptable	not acceptable
cost for protection per property	£7,000
total cost for protection	£147,000

Summary		
Preferred option is	**Storage Option**	
Cost of preferred option	**£680,601**	
Storage below ground in soft area	**792**	**m3**
Storage off public highway below ground	**792**	**m3**
Storage off public highway above ground (basin)	**792**	**m3**
storage below footway (inc tree pits)	**264**	**m3**
Storage below Highway	**0**	**m3**
Storage in permeable paving	**0**	**m3**

Benefits from economics 1in100 scheme			
Present day	£	70	K
Inc Climate Change	£	295	K

Benefit cost ratio	
Present day	0.102802
Inc Climate Change	0.43309

High Risk Area Number	2 Sandhurst Avenue		
Volume of water at the location	5056	m3	From Modelling for 1in100 year rainfall event (present day)
Distance from potential receiving water course	500	m	Measured from point central in area
Acceptable time to remove water	60	mins	
velocity of flow assumed	1.5	m/s	
Ground permeability	low		Assumed from geological maps (high, medium low) (high 50% ; Med 75% ; Low 100% of storage required
Flow diversion upstream to green areas outside HRA	0%		% based on maps and flow areas
Volume of water at HRA to be managed	5056		

	assumed percentage		
Storage below ground in soft area	0%	£105	/m3
Storage off public highway below ground	0%	£525	/m3
Storage off public highway above ground (basin)	0%	£52	/m3
storage below footway (inc tree pits)	20%	£535	/m3
Storage below Highway	70%	£825	/m3
Storage in permeable paving	10%	£275	/m3
cost	£712 m3		

Assumed Flood depth at Thresholds	0.7	m	Assumed from feasibility site visit and Google street view
Number of properties	28	no	From Flood modelling (1in100 event)

storage costs	
infratration rates	0%
Volume to be "lost" to infratration	0
Volume to be stored	5056
Assumed costs due to site constraints	£712
total cost of storage options	£3,599,872

Removal costs		
volume to be removed	5056	
velocity of flow assumed	1.5	m/s
flow rate required	1.404444444	m3/sec
pipe area required	0.94	
pipe dia required	1.09	
Cost of PS per m3/sec rate	£687,500	
cost assumed for PS	£965,556	
Cost for pipe per m dia per m length	£1,070	
Cost per m for pipe	£1,168	
cost for pipe	£584,138	
Outfall	£1,337,500	
total cost for removal	£2,887,194	

property protection	
protection acceptable	not acceptable
cost for protection per property	£7,000
total cost for protection	£196,000

Summary	
Preferred option is	**Removal by Pumping**
Cost of preferred option	**£2,887,194**

Benefits from economics 1in100 scheme		
Present day	£ 1,351	K
Inc Climate Change	£ 1,791	K

Benefit cost ratio	
Present day	0.468026
Inc Climate Change	0.620241

1 number pump station with flow of	**1.4044444**	**m3/sec**
with an outfall pipe of	**500**	**m long**
	1.09	**m dia (min)**

High Risk Area Number	3	Lentworth Avenue	
Volume of water at the location	5766	m3	From Modelling for 1in100 year rainfall event (present day)
Distance from potential receiving water course	10000	m	Measured from point central in area
Acceptable time to remove water	60	mins	
velocity of flow assumed	1.5	m/s	
Ground permeability	low		Assumed from geological maps (high, medium low) (high 50% ; Med 75% ; Low 100% of storage required
Flow diversion upstream to green areas outside HRA	30%		% based on maps and flow areas
Volume of water at HRA to be managed	4036.2		

	assumed percentage		
Storage below ground in soft area	20%	£105	/m3
Storage off public highway below ground	0%	£525	/m3
Storage off public highway above ground (basin)	0%	£52	/m3
storage below footway (inc tree pits)	20%	£535	/m3
Storage below Highway	60%	£825	/m3
Storage in permeable paving	0%	£275	/m3
cost	£623	m3	

Assumed Flood depth at Thresholds	0.7	m	Assumed from feasibility site visit and Google street view
Number of properties	22	no	From Flood modelling (1in100 event)
			From Flood modelling (1in100 event)

storage costs	
infratration rates	0%
Volume to be "lost" to infratration	0
Volume to be stored	5766
Assumed costs due to site constraints	£623
total cost of storage options	£3,592,218

Removal costs

volume to be removed	4036.2	
velocity of flow assumed	1.5	m/s
flow rate required	1.121166667	m3/sec
pipe area required	0.75	
pipe dia required	0.98	
Cost of PS per m3/sec rate	£687,500	
cost assumed for PS	£770,802	
Cost for pipe per m dia per m length	£1,070	
Cost per m for pipe	£1,044	
cost for pipe	£10,438,264	
Outfall	£1,337,500	
total cost for removal	£12,546,567	

property protection

protection acceptable	not acceptable
cost for protection per property	£7,000
total cost for protection	£154,000

Summary		
Preferred option is	**Storage Option**	
Cost of preferred option	**£3,592,218**	
Storage below ground in soft area	**1153**	**m3**
Storage off public highway below ground	**0**	**m3**
Storage off public highway above ground (basin)	**0**	**m3**
storage below footway (inc tree pits)	**1153**	**m3**
Storage below Highway	**3460**	**m3**
Storage in permeable paving	**0**	**m3**

Benefits from economics 1in100 scheme

Present day	£	415	K
Inc Climate Change	£	1,433	K

Benefit cost ratio

Present day	0.115526
Inc Climate Change	0.399018

High Risk Area Number	4	Cranleigh Avenue	
Volume of water at the location	4899	m3	From Modelling for 1in100 year rainfall event (present day)
Distance from potential receiving water course	300	m	Measured from point central in area
Acceptable time to remove water	60	mins	
velocity of flow assumed	1.5	m/s	
Ground permeability	low		Assumed from geological maps (high, medium low) (high 50% ; Med 75% ; Low 100% of storage required
Flow diversion upstream to green areas outside HRA	25%		% based on maps and flow areas
Volume of water at HRA to be managed	3674.25		
	assumed percentage		
Storage below ground in soft area	0%		£105 /m3
Storage off public highway below ground	100%		£525 /m3
Storage off public highway above ground (basin)	0%		£52 /m3
storage below footway (inc tree pits)	0%		£535 /m3
Storage below Highway	0%		£825 /m3
Storage in permeable paving	0%		£275 /m3
cost	£525	m3	
Assumed Flood depth at Thresholds	0.7	m	Assumed from feasibility site visit and Google street view
Number of properties	22	no	From Flood modelling (1in100 event)
			From Flood modelling (1in100 event)
storage costs			
infratration rates	0%		
Volume to be "lost" to infratration	0		
Volume to be stored	4899		
Assumed costs due to site constraints	£525		
total cost of storage options	£2,571,975		

Removal costs		
volume to be removed	3674.25	
velocity of flow assumed	1.5	m/s
flow rate required	1.020625	m3/sec
pipe area required	0.68	
pipe dia required	0.93	
Cost of PS per m3/sec rate	£687,500	
cost assumed for PS	£701,680	
Cost for pipe per m dia per m length	£1,070	
Cost per m for pipe	£996	
cost for pipe	£298,777	
Outfall	£1,337,500	
total cost for removal	£2,337,957	

property protection	
protection acceptable	not acceptable
cost for protection per property	£7,000
total cost for protection	£154,000

Summary

Preferred option is	**Removal by Pumping**
Cost of preferred option	**£2,337,957**

Benefits from economics 1in100 scheme		
Present day	£ 980	K
Inc Climate Change	£ 1,311	K

Benefit cost ratio	
Present day	0.419106
Inc Climate Change	0.560644

1 number pump station with flow of	**1.020625**	**m3/sec**
with an outfall pipe of	**300**	**m long**
	0.93	**m dia (min)**

High Risk Area Number

Volume of water at the location	3899	m3	From Modelling for 1in100 year rainfall event (present day)
Distance from potential receiving water course	1500	m	Measured from point central in area
Acceptable time to remove water	60	mins	
velocity of flow assumed	1.5	m/s	
Ground permeability	low		Assumed from geological maps (high, medium low) (high 50% ; Med 75% ; Low 100% of storage required
Flow diversion upstream to green areas outside HRA	0%		% based on maps and flow areas
Volume of water at HRA to be managed	3899		

	assumed percentage		
Storage below ground in soft area	0%	£105	/m3
Storage off public highway below ground	0%	£525	/m3
Storage off public highway above ground (basin)	0%	£52	/m3
storage below footway (inc tree pits)	10%	£535	/m3
Storage below Highway	90%	£825	/m3
Storage in permeable paving	0%	£275	/m3
cost	£796 m3		

Assumed Flood depth at Thresholds	0.7	m	Assumed from feasibility site visit and Google street view
Number of properties	15	no	From Flood modelling (1in100 event)
			From Flood modelling (1in100 event)

storage costs	
infratration rates	0%
Volume to be "lost" to infratration	0
Volume to be stored	3899
Assumed costs due to site constraints	£796
total cost of storage options	£3,103,604

Removal costs		
volume to be removed	3899	
velocity of flow assumed	1.5	m/s
flow rate required	1.083055556	m3/sec
pipe area required	0.72	
pipe dia required	0.96	
Cost of PS per m3/sec rate	£687,500	
cost assumed for PS	£744,601	
Cost for pipe per m dia per m length	£1,070	
Cost per m for pipe	£1,026	
cost for pipe	£1,538,898	
Outfall	£1,337,500	
total cost for removal	£3,620,999	

property protection	
protection acceptable	not acceptable
cost for protection per property	£7,000
total cost for protection	£105,000

Summary		
Preferred option is	**Storage Option**	
Cost of preferred option	**£3,103,604**	
Storage below ground in soft area	**0**	**m3**
Storage off public highway below ground	**0**	**m3**
Storage off public highway above ground (basin)	**0**	**m3**
storage below footway (inc tree pits)	**390**	**m3**
Storage below Highway	**3509**	**m3**
Storage in permeable paving	**0**	**m3**

Benefits from economics 1in100 scheme			
Present day	£	91	K
Inc Climate Change	£	603	K

Benefit cost ratio	
Present day	0.029198
Inc Climate Change	0.194215

High Risk Area Number	6	Enfield Road	
Volume of water at the location	7074	m3	From Modelling for 1in100 year rainfall event (present day)
Distance from potential receiving water course	1000	m	Measured from point central in area
Acceptable time to remove water	60	mins	
velocity of flow assumed	1.5	m/s	
Ground permeability	low		Assumed from geological maps (high, medium low) (high 50% ; Med 75% ; Low 100% of storage required
Flow diversion upstream to green areas outside HRA	0%		% based on maps and flow areas
Volume of water at HRA to be managed	7074		

	assumed percentage		
Storage below ground in soft area	0%	£105	/m3
Storage off public highway below ground	0%	£525	/m3
Storage off public highway above ground (basin)	0%	£52	/m3
storage below footway (inc tree pits)	10%	£535	/m3
Storage below Highway	90%	£825	/m3
Storage in permeable paving	0%	£275	/m3
cost	£796	m3	

Assumed Flood depth at Thresholds	0.7	m	Assumed from feasibility site visit and Google street view
Number of properties	36	no	From Flood modelling (1in100 event)
			From Flood modelling (1in100 event)

storage costs	
infratration rates	0%
Volume to be "lost" to infratration	0
Volume to be stored	7074
Assumed costs due to site constraints	£796
total cost of storage options	£5,630,904

Removal costs

volume to be removed	7074	
velocity of flow assumed	1.5	m/s
flow rate required	1.965	m3/sec
pipe area required	1.31	
pipe dia required	1.29	
Cost of PS per m3/sec rate	£687,500	
cost assumed for PS	£1,350,938	
Cost for pipe per m dia per m length	£1,070	
Cost per m for pipe	£1,382	
cost for pipe	£1,381,893	
Outfall	£1,337,500	
total cost for removal	£4,070,331	

property protection

protection acceptable	not acceptable
cost for protection per property	£7,000
total cost for protection	£252,000

Summary

Preferred option is	**Removal by Pumping**
Cost of preferred option	**£4,070,331**

Benefits from economics 1in100 scheme

Present day	£	1,342	K
Inc Climate Change	£	2,273	K

Benefit cost ratio

Present day	0.329735
Inc Climate Change	0.558381

1 number pump station with flow of	**1.965**	**m3/sec**
with an outfall pipe of	**1000**	**m long**
	1.29	**m dia (min)**

High Risk Area Number	7	Wall Street	
Volume of water at the location	1620	m3	From Modelling for 1in100 year rainfall event (present day)
Distance from potential receiving water course	600	m	Measured from point central in area
Acceptable time to remove water	60	mins	
velocity of flow assumed	1.5	m/s	
Ground permeability	low		Assumed from geological maps (high, medium low)
			(high 50% ; Med 75% ; Low 100% of storage required
Flow diversion upstream to green areas outside HRA	0%		% based on maps and flow areas
Volume of water at HRA to be managed	1620		
	assumed percentage		
Storage below ground in soft area	0%		£105 /m3
Storage off public highway below ground	0%		£525 /m3
Storage off public highway above ground (basin)	0%		£52 /m3
storage below footway (inc tree pits)	10%		£535 /m3
Storage below Highway	90%		£825 /m3
Storage in permeable paving	0%		£275 /m3
cost	£796	m3	
Assumed Flood depth at Thresholds	0.4	m	Assumed from feasibility site visit and Google street view
Number of properties	19	no	From Flood modelling (1in100 event)
			From Flood modelling (1in100 event)
storage costs			
infratration rates	0%		
Volume to be "lost" to infratration	0		
Volume to be stored	1620		
Assumed costs due to site constraints	£796		
total cost of storage options	£1,289,520		

Removal costs		
volume to be removed	1620	
velocity of flow assumed	1.5	m/s
flow rate required	0.45	m3/sec
pipe area required	0.30	
pipe dia required	0.62	
Cost of PS per m3/sec rate	£687,500	
cost assumed for PS	£309,375	
Cost for pipe per m dia per m length	£1,070	
Cost per m for pipe	£661	
cost for pipe	£396,781	
Outfall	£1,337,500	
total cost for removal	£2,043,656	

property protection	
protection acceptable	not acceptable
cost for protection per property	£7,000
total cost for protection	£133,000

Summary		
Preferred option is	**Storage Option**	
Cost of preferred option	**£1,289,520**	
Storage below ground in soft area	**0**	**m3**
Storage off public highway below ground	**0**	**m3**
Storage off public highway above ground (basin)	**0**	**m3**
storage below footway (inc tree pits)	**162**	**m3**
Storage below Highway	**1458**	**m3**
Storage in permeable paving	**0**	**m3**

Benefits from economics 1in100 scheme			
Present day	£	513	K
Inc Climate Change	£	782	K

Benefit cost ratio	
Present day	0.397888
Inc Climate Change	0.606734

High Risk Area Number	8 Collingwood Avenue		
Volume of water at the location	6118	m3	From Modelling for 1in100 year rainfall event (present day)
Distance from potential receiving water course	2000	m	Measured from point central in area
Acceptable time to remove water	60	mins	
velocity of flow assumed	1.5	m/s	
Ground permeability	low		Assumed from geological maps (high, medium low) (high 50% ; Med 75% ; Low 100% of storage required
Flow diversion upstream to green areas outside HRA	20%		% based on maps and flow areas
Volume of water at HRA to be managed	4894.4		

	assumed percentage		
Storage below ground in soft area	0%	£105	/m3
Storage off public highway below ground	0%	£525	/m3
Storage off public highway above ground (basin)	0%	£52	/m3
storage below footway (inc tree pits)	10%	£535	/m3
Storage below Highway	90%	£825	/m3
Storage in permeable paving	0%	£275	/m3
cost	£796 m3		

Assumed Flood depth at Thresholds	0.3	m	Assumed from feasibility site visit and Google street view
Number of properties	40	no	From Flood modelling (1in100 event)
			From Flood modelling (1in100 event)

storage costs	
infratration rates	0%
Volume to be "lost" to infratration	0
Volume to be stored	6118
Assumed costs due to site constraints	£796
total cost of storage options	£4,869,928

Removal costs		
volume to be removed	4894.4	
velocity of flow assumed	1.5	m/s
flow rate required	1.359555556	m3/sec
pipe area required	0.91	
pipe dia required	1.07	
Cost of PS per m3/sec rate	£687,500	
cost assumed for PS	£934,694	
Cost for pipe per m dia per m length	£1,070	
Cost per m for pipe	£1,149	
cost for pipe	£2,298,908	
Outfall	£1,337,500	
total cost for removal	£4,571,103	

property protection	
protection acceptable	not acceptable
cost for protection per property	£7,000
total cost for protection	£280,000

Summary
Preferred option is **Removal by Pumping**
Cost of preferred option **£4,571,103**

Benefits from economics 1in100 scheme	
Present day	£ 2,102 K
Inc Climate Change	£ 2,677 K

Benefit cost ratio	
Present day	0.45986
Inc Climate Change	0.58566

1 number pump station with flow of **1.3595556 m3/sec**
with an outfall pipe of **2000 m long**
1.07 m dia (min)

High Risk Area Number	9	Mere Road	
Volume of water at the location	18278	m3	From Modelling for 1in100 year rainfall event (present day)
Distance from potential receiving water course	1600	m	Measured from point central in area
Acceptable time to remove water	60	mins	
velocity of flow assumed	1.5	m/s	
Ground permeability	low		Assumed from geological maps (high, medium low)
			(high 50% ; Med 75% ; Low 100% of storage required
Flow diversion upstream to green areas outside HRA	10%		% based on maps and flow areas
Volume of water at HRA to be managed	16450.2		

	assumed percentage		
Storage below ground in soft area	0%	£105	/m3
Storage off public highway below ground	10%	£525	/m3
Storage off public highway above ground (basin)	0%	£52	/m3
storage below footway (inc tree pits)	20%	£535	/m3
Storage below Highway	70%	£825	/m3
Storage in permeable paving	0%	£275	/m3
cost	£737	m3	

Assumed Flood depth at Thresholds	0.6	m	Assumed from feasibility site visit and Google street view
Number of properties	90	no	From Flood modelling (1in100 event)
			From Flood modelling (1in100 event)

storage costs	
infratration rates	0%
Volume to be "lost" to infratration	0
Volume to be stored	18278
Assumed costs due to site constraints	£737
total cost of storage options	£13,470,886

Removal costs

volume to be removed	16450.2	
velocity of flow assumed	1.5	m/s
flow rate required	4.5695	m3/sec
pipe area required	3.05	
pipe dia required	1.97	
Cost of PS per m3/sec rate	£687,500	
cost assumed for PS	£3,141,531	
Cost for pipe per m dia per m length	£1,070	
Cost per m for pipe	£2,107	
cost for pipe	£3,371,689	
Outfall	£1,337,500	
total cost for removal	£7,850,720	

property protection

protection acceptable	not acceptable
cost for protection per property	£7,000
total cost for protection	£630,000

Summary

Preferred option is	**Removal by Pumping**
Cost of preferred option	**£7,850,720**

Benefits from economics 1in100 scheme

Present day	£	2,441	K
Inc Climate Change	£	3,940	K

Benefit cost ratio

Present day	0.310882
Inc Climate Change	0.501849

1 number pump station with flow of	**4.5695**	**m3/sec**
with an outfall pipe of	**1600**	**m long**
	1.97	**m dia (min)**

High Risk Area Number	10	Albert Road		
Volume of water at the location	9577	m3	From Modelling for 1in100 year rainfall event (present day)	
Distance from potential receiving water course	600	m	Measured from point central in area	
Acceptable time to remove water	60	mins		
velocity of flow assumed	1.5	m/s		
Ground permeability	low		Assumed from geological maps (high, medium low) (high 50% ; Med 75% ; Low 100% of storage required	
Flow diversion upstream to green areas outside HRA	0%		% based on maps and flow areas	
Volume of water at HRA to be managed	9577			
	assumed percentage			
Storage below ground in soft area	0%		£105	/m3
Storage off public highway below ground	0%		£525	/m3
Storage off public highway above ground (basin)	0%		£52	/m3
storage below footway (inc tree pits)	5%		£535	/m3
Storage below Highway	95%		£825	/m3
Storage in permeable paving	0%		£275	/m3
cost	£811	m3		
Assumed Flood depth at Thresholds	1	m	Assumed from feasibility site visit and Google street view	
Number of properties	88	no	From Flood modelling (1in100 event)	
			From Flood modelling (1in100 event)	
storage costs				
infratration rates	0%			
Volume to be "lost" to infratration	0			
Volume to be stored	9577			
Assumed costs due to site constraints	£811			
total cost of storage options	£7,762,159			

Removal costs		
volume to be removed	9577	
velocity of flow assumed	1.5	m/s
flow rate required	2.660277778	m3/sec
pipe area required	1.77	
pipe dia required	1.50	
Cost of PS per m3/sec rate	£687,500	
cost assumed for PS	£1,828,941	
Cost for pipe per m dia per m length	£1,070	
Cost per m for pipe	£1,608	
cost for pipe	£964,735	
Outfall	£1,337,500	
total cost for removal	£4,131,176	

property protection	
protection acceptable	not acceptable
cost for protection per property	£7,000
total cost for protection	£616,000

Summary	
Preferred option is	**Removal by Pumping**
Cost of preferred option	**£4,131,176**

Benefits from economics 1in100 scheme		
Present day	£ 4,125	K
Inc Climate Change	£ 5,573	K
Benefit cost ratio		
Present day	0.998543	
Inc Climate Change	1.349124	

1 number pump station with flow of	**2.6602778**	**m3/sec**
with an outfall pipe of	**600**	**m long**
	1.50	**m dia (min)**

High Risk Area Number	11	Chapel Street	
Volume of water at the location	11469	m3	From Modelling for 1in100 year rainfall event (present day)
Distance from potential receiving water course	500	m	Measured from point central in area
Acceptable time to remove water	60	mins	
velocity of flow assumed	1.5	m/s	
Ground permeability	low		Assumed from geological maps (high, medium low) (high 50% ; Med 75% ; Low 100% of storage required
Flow diversion upstream to green areas outside HRA	10%		% based on maps and flow areas
Volume of water at HRA to be managed	10322.1		
	assumed percentage		
Storage below ground in soft area	0%		£105 /m3
Storage off public highway below ground	80%		£525 /m3
Storage off public highway above ground (basin)	10%		£52 /m3
storage below footway (inc tree pits)	0%		£535 /m3
Storage below Highway	10%		£825 /m3
Storage in permeable paving	0%		£275 /m3
cost	£508	m3	
Assumed Flood depth at Thresholds	0.5	m	Assumed from feasibility site visit and Google street view
Number of properties	30	no	From Flood modelling (1in100 event)
			From Flood modelling (1in100 event)
storage costs			
infratration rates	0%		
Volume to be "lost" to infratration	0		
Volume to be stored	11469		
Assumed costs due to site constraints	£508		
total cost of storage options	£5,822,238		

Removal costs

volume to be removed	10322.1	
velocity of flow assumed	1.5	m/s
flow rate required	2.86725	m3/sec
pipe area required	1.91	
pipe dia required	1.56	
Cost of PS per m3/sec rate	£687,500	
cost assumed for PS	£1,971,234	
Cost for pipe per m dia per m length	£1,070	
Cost per m for pipe	£1,669	
cost for pipe	£834,634	
Outfall	£1,337,500	
total cost for removal	£4,143,368	

property protection

protection acceptable	not acceptable
cost for protection per property	£7,000
total cost for protection	£210,000

Summary

Preferred option is	**Removal by Pumping**
Cost of preferred option	**£4,143,368**

Benefits from economics 1in100 scheme

Present day	£ 1,069 K
Inc Climate Change	£ 1,456 K

Benefit cost ratio

Present day	0.257927
Inc Climate Change	0.351451

1 number pump station with flow of	**2.86725**	**m3/sec**
with an outfall pipe of	**500**	**m long**
	1.56	**m dia (min)**

High Risk Area Number	12	Rigby Road	
Volume of water at the location	8666	m3	From Modelling for 1in100 year rainfall event (present day)
Distance from potential receiving water course	400	m	Measured from point central in area
Acceptable time to remove water	60	mins	
velocity of flow assumed	1.5	m/s	
Ground permeability	low		Assumed from geological maps (high, medium low) (high 50% ; Med 75% ; Low 100% of storage required
Flow diversion upstream to green areas outside HRA	0%		% based on maps and flow areas
Volume of water at HRA to be managed	8666		
	assumed percentage		
Storage below ground in soft area	0%		£105 /m3
Storage off public highway below ground	0%		£525 /m3
Storage off public highway above ground (basin)	0%		£52 /m3
storage below footway (inc tree pits)	10%		£535 /m3
Storage below Highway	90%		£825 /m3
Storage in permeable paving	0%		£275 /m3
cost	£796	m3	
Assumed Flood depth at Thresholds	0.6	m	Assumed from feasibility site visit and Google street view
Number of properties	87	no	From Flood modelling (1in100 event)
			From Flood modelling (1in100 event)
storage costs			
infratration rates	0%		
Volume to be "lost" to infratration	0		
Volume to be stored	8666		
Assumed costs due to site constraints	£796		
total cost of storage options	£6,898,136		

Removal costs		
volume to be removed	8666	
velocity of flow assumed	1.5	m/s
flow rate required	2.407222222	m3/sec
pipe area required	1.60	
pipe dia required	1.43	
Cost of PS per m3/sec rate	£687,500	
cost assumed for PS	£1,654,965	
Cost for pipe per m dia per m length	£1,070	
Cost per m for pipe	£1,530	
cost for pipe	£611,803	
Outfall	£1,337,500	
total cost for removal	£3,604,268	

property protection	
protection acceptable	not acceptable
cost for protection per property	£7,000
total cost for protection	£609,000

Summary	
Preferred option is	**Removal by Pumping**
Cost of preferred option	**£3,604,268**

Benefits from economics 1in100 scheme		
Present day	£ 3,559	K
Inc Climate Change	£ 4,641	K

Benefit cost ratio	
Present day	0.987373
Inc Climate Change	1.287575

1 number pump station with flow of	**2.4072222**	**m3/sec**
with an outfall pipe of	**400**	**m long**
	1.43	**m dia (min)**

High Risk Area Number	13	Queen Victoria Road		
Volume of water at the location	7055	m3	From Modelling for 1in100 year rainfall event (present day)	
Distance from potential receiving water course	1200	m	Measured from point central in area	
Acceptable time to remove water	60	mins		
velocity of flow assumed	1.5	m/s		
Ground permeability	low		Assumed from geological maps (high, medium low) (high 50% ; Med 75% ; Low 100% of storage required	
Flow diversion upstream to green areas outside HRA	0%		% based on maps and flow areas	
Volume of water at HRA to be managed	7055			
	assumed percentage			
Storage below ground in soft area	50%		£105	/m3
Storage off public highway below ground	0%		£525	/m3
Storage off public highway above ground (basin)	20%		£52	/m3
storage below footway (inc tree pits)	10%		£535	/m3
Storage below Highway	20%		£825	/m3
Storage in permeable paving	0%		£275	/m3
cost	£281	m3		
Assumed Flood depth at Thresholds	30	m	Assumed from feasibility site visit and Google street view	
Number of properties	27	no	From Flood modelling (1in100 event)	
			From Flood modelling (1in100 event)	
storage costs				
infratration rates	0%			
Volume to be "lost" to infratration	0			
Volume to be stored	7055			
Assumed costs due to site constraints	£281			
total cost of storage options	£1,984,572			

Removal costs		
volume to be removed	7055	
velocity of flow assumed	1.5	m/s
flow rate required	1.959722222	m3/sec
pipe area required	1.31	
pipe dia required	1.29	
Cost of PS per m3/sec rate	£687,500	
cost assumed for PS	£1,347,309	
Cost for pipe per m dia per m length	£1,070	
Cost per m for pipe	£1,380	
cost for pipe	£1,656,043	
Outfall	£1,337,500	
total cost for removal	£4,340,852	

property protection	
protection acceptable	not acceptable
cost for protection per property	£7,000
total cost for protection	£189,000

Summary		
Preferred option is	**Storage Option**	
Cost of preferred option	**£1,984,572**	
Storage below ground in soft area	**3528**	**m3**
Storage off public highway below ground	**0**	**m3**
Storage off public highway above ground (basin)	**1411**	**m3**
storage below footway (inc tree pits)	**706**	**m3**
Storage below Highway	**1411**	**m3**
Storage in permeable paving	**0**	**m3**

Benefits from economics 1in100 scheme			
Present day	£	364	K
Inc Climate Change	£	760	K
Benefit cost ratio			
Present day	0.183473		
Inc Climate Change	0.383032		

High Risk Area Number	14	Nuttal road	
Volume of water at the location	4285	m3	From Modelling for 1in100 year rainfall event (present day)
Distance from potential receiving water course	1500	m	Measured from point central in area
Acceptable time to remove water	60	mins	
velocity of flow assumed	1.5	m/s	
Ground permeability	low		Assumed from geological maps (high, medium low) (high 50% ; Med 75% ; Low 100% of storage required
Flow diversion upstream to green areas outside HRA	0%		% based on maps and flow areas
Volume of water at HRA to be managed	4285		

	assumed percentage		
Storage below ground in soft area	10%	£105	/m3
Storage off public highway below ground	20%	£525	/m3
Storage off public highway above ground (basin)	0%	£52	/m3
storage below footway (inc tree pits)	20%	£535	/m3
Storage below Highway	50%	£825	/m3
Storage in permeable paving	0%	£275	/m3
cost	£635 m3		

Assumed Flood depth at Thresholds	0.4	m	Assumed from feasibility site visit and Google street view
Number of properties	26	no	From Flood modelling (1in100 event)
			From Flood modelling (1in100 event)

storage costs	
infratration rates	0%
Volume to be "lost" to infratration	0
Volume to be stored	4285
Assumed costs due to site constraints	£635
total cost of storage options	£2,720,975

Removal costs		
volume to be removed	4285	
velocity of flow assumed	1.5	m/s
flow rate required	1.190277778	m3/sec
pipe area required	0.79	
pipe dia required	1.01	
Cost of PS per m3/sec rate	£687,500	
cost assumed for PS	£818,316	
Cost for pipe per m dia per m length	£1,070	
Cost per m for pipe	£1,076	
cost for pipe	£1,613,276	
Outfall	£1,337,500	
total cost for removal	£3,769,092	

property protection	
protection acceptable	not acceptable
cost for protection per property	£7,000
total cost for protection	£182,000

Summary	
Preferred option is	**Storage Option**
Cost of preferred option	**£2,720,975**
Storage below ground in soft area	**429 m3**
Storage off public highway below ground	**857 m3**
Storage off public highway above ground (basin)	**0 m3**
storage below footway (inc tree pits)	**857 m3**
Storage below Highway	**2143 m3**
Storage in permeable paving	**0 m3**

Benefits from economics 1in100 scheme		
Present day	£ 297	K
Inc Climate Change	£ 1,309	K

Benefit cost ratio	
Present day	0.109186
Inc Climate Change	0.481226

High Risk Area Number	15	Falkland Avenue	
Volume of water at the location	7540	m3	From Modelling for 1in100 year rainfall event (present day)
Distance from potential receiving water course	2500	m	Measured from point central in area
Acceptable time to remove water	60	mins	
velocity of flow assumed	1.5	m/s	
Ground permeability	low		Assumed from geological maps (high, medium low) (high 50% ; Med 75% ; Low 100% of storage required
Flow diversion upstream to green areas outside HRA	0%		% based on maps and flow areas
Volume of water at HRA to be managed	7540		
	assumed percentage		
Storage below ground in soft area	0%		£105 /m3
Storage off public highway below ground	30%		£525 /m3
Storage off public highway above ground (basin)	10%		£52 /m3
storage below footway (inc tree pits)	0%		£535 /m3
Storage below Highway	60%		£825 /m3
Storage in permeable paving	0%		£275 /m3
cost	£658	m3	
Assumed Flood depth at Thresholds	0.7	m	Assumed from feasibility site visit and Google street view
Number of properties	29	no	From Flood modelling (1in100 event)
			From Flood modelling (1in100 event)
storage costs			
infratration rates	0%		
Volume to be "lost" to infratration	0		
Volume to be stored	7540		
Assumed costs due to site constraints	£658		
total cost of storage options	£4,958,681		

Removal costs		
volume to be removed	7540	
velocity of flow assumed	1.5	m/s
flow rate required	2.094444444	m3/sec
pipe area required	1.40	
pipe dia required	1.33	
Cost of PS per m3/sec rate	£687,500	
cost assumed for PS	£1,439,931	
Cost for pipe per m dia per m length	£1,070	
Cost per m for pipe	£1,427	
cost for pipe	£3,566,709	
Outfall	£1,337,500	
total cost for removal	£6,344,139	

property protection	
protection acceptable	not acceptable
cost for protection per property	£7,000
total cost for protection	£203,000

Summary		
Preferred option is	**Storage Option**	
Cost of preferred option	**£4,958,681**	
Storage below ground in soft area	**0**	**m3**
Storage off public highway below ground	**2262**	**m3**
Storage off public highway above ground (basin)	**754**	**m3**
storage below footway (inc tree pits)	**0**	**m3**
Storage below Highway	**4524**	**m3**
Storage in permeable paving	**0**	**m3**

Benefits from economics 1in100 scheme		
Present day	£ 639	K
Inc Climate Change	£ 1,145	K

Benefit cost ratio	
Present day	0.128959
Inc Climate Change	0.230944

High Risk Area Number	16	Pleasure Beach	
Volume of water at the location	16469	m3	From Modelling for 1in100 year rainfall event (present day)
Distance from potential receiving water course	200	m	Measured from point central in area
Acceptable time to remove water	60	mins	
velocity of flow assumed	1.5	m/s	
Ground permeability	low		Assumed from geological maps (high, medium low) (high 50% ; Med 75% ; Low 100% of storage required
Flow diversion upstream to green areas outside HRA	0%		% based on maps and flow areas
Volume of water at HRA to be managed	16469		
	assumed percentage		
Storage below ground in soft area	0%		£105 /m3
Storage off public highway below ground	50%		£525 /m3
Storage off public highway above ground (basin)	0%		£52 /m3
storage below footway (inc tree pits)	50%		£535 /m3
Storage below Highway	0%		£825 /m3
Storage in permeable paving	0%		£275 /m3
cost	£530	m3	
Assumed Flood depth at Thresholds	0.3	m	Assumed from feasibility site visit and Google street view
Number of properties	37	no	From Flood modelling (1in100 event)
			From Flood modelling (1in100 event)
storage costs			
infratration rates	0%		
Volume to be "lost" to infratration	0		
Volume to be stored	16469		
Assumed costs due to site constraints	£530		
total cost of storage options	£8,728,570		

Removal costs		
volume to be removed	16469	
velocity of flow assumed	1.5	m/s
flow rate required	4.574722222	m3/sec
pipe area required	3.05	
pipe dia required	1.97	
Cost of PS per m3/sec rate	£687,500	
cost assumed for PS	£3,145,122	
Cost for pipe per m dia per m length	£1,070	
Cost per m for pipe	£2,109	
cost for pipe	£421,702	
Outfall	£1,337,500	
total cost for removal	£4,904,323	

property protection	
protection acceptable	not acceptable
cost for protection per property	£7,000
total cost for protection	£259,000

Summary	
Preferred option is	**Removal by Pumping**
Cost of preferred option	**£4,904,323**

Benefits from economics 1in100 scheme		
Present day	£ 6,480	K
Inc Climate Change	£ 19,820	K

Benefit cost ratio	
Present day	1.321253
Inc Climate Change	4.041433

1 number pump station with flow of	**4.5747222**	**m3/sec**
with an outfall pipe of	**200**	**m long**
	1.97	**m dia (min)**

Appendix B

HRA Benefits / Damages Avoided

PRESENT DAY

Total damages

Return period (Years)	10	20	30	75	100	1000
Residential	£13,056,688	£16,838,243	£18,857,827	£26,365,975	£29,791,741	£101,468,737
Non-Residential	£35,520,553	£53,198,052	£55,286,537	£62,589,473	£65,721,832	£110,719,371
Total	£48,577,241	£70,036,295	£74,144,364	£88,955,448	£95,513,573	£212,188,108
HRA-1	£0	£0	£0	£195,986	£500,509	£1,340,866
HRA-2	£431,048	£518,876	£552,149	£670,132	£707,281	£1,280,822
HRA-3	£0	£22,367	£133,477	£914,997	£1,098,354	£2,602,851
HRA-4	£306,920	£453,001	£489,101	£624,345	£662,170	£1,273,640
HRA-5	£0	£0	£8,395	£258,553	£435,305	£3,077,921
HRA-6	£54,910	£420,271	£741,962	£1,346,573	£1,523,119	£7,515,124
HRA-7	£84,883	£189,265	£226,121	£403,571	£512,248	£2,256,063
HRA-8	£828,827	£870,782	£884,659	£937,735	£955,062	£1,159,451
HRA-9	£0	£885,865	£1,307,737	£2,509,024	£2,930,375	£6,495,316
HRA-10	£796,651	£1,543,107	£1,784,584	£2,572,701	£2,888,388	£6,120,450
HRA-11	£372,790	£427,590	£448,330	£567,527	£642,085	£2,163,463
HRA-12	£1,141,133	£1,377,371	£1,477,286	£1,844,206	£1,967,621	£3,949,498
HRA-13	£0	£96,038	£194,780	£415,203	£527,413	£2,760,753
HRA-14	£0	£11,092	£35,416	£767,556	£1,363,162	£5,563,252
HRA-15	£34,402	£193,146	£314,786	£613,097	£684,913	£3,050,719
HRA-16	£3,791,403	£3,988,329	£4,068,732	£4,593,961	£4,829,435	£6,511,973
Non-HRA	£ 40,734,273	£ 59,039,196	£ 61,476,848	£ 69,720,282	£ 73,286,133	£ 155,065,948

Annual average damages

Standard of Protection (return period)	Do Nothing	10	20	30	75	100	1000
Residential	£ 2,089,550	£ 2,089,550	£ 1,377,292	£ 1,083,283	£ 653,628	£ 561,092	£ 105,318
Non-Residential	£ 5,201,390	£ 5,201,390	£ 3,157,801	£ 2,254,725	£ 1,088,240	£ 874,587	£ 113,222
All Blackpool	£ 7,290,940	£ 7,290,940	£ 4,535,092	£ 3,338,008	£ 1,741,868	£ 1,435,680	£ 218,540
HRA-1	£ 10,737	£ 10,737	£ 10,737	£ 10,737	£ 9,757	£ 8,710	£ 1,387
HRA-2	£ 55,200	£ 55,200	£ 32,463	£ 23,564	£ 11,603	£ 9,315	£ 1,312
HRA-3	£ 29,621	£ 29,621	£ 29,342	£ 28,398	£ 20,934	£ 17,597	£ 2,685
HRA-4	£ 47,866	£ 47,866	£ 29,853	£ 22,031	£ 11,181	£ 9,043	£ 1,307
HRA-5	£ 16,519	£ 16,519	£ 16,519	£ 16,484	£ 14,993	£ 13,894	£ 3,222
HRA-6	£ 77,703	£ 77,703	£ 70,360	£ 61,039	£ 41,257	£ 36,541	£ 7,840
HRA-7	£ 28,291	£ 28,291	£ 22,332	£ 18,870	£ 13,002	£ 11,525	£ 2,350
HRA-8	£ 88,683	£ 88,683	£ 46,351	£ 31,755	£ 13,690	£ 10,535	£ 1,171
HRA-9	£ 116,150	£ 116,150	£ 105,077	£ 87,366	£ 52,481	£ 43,528	£ 6,689
HRA-10	£ 179,193	£ 179,193	£ 125,719	£ 98,050	£ 54,947	£ 45,855	£ 6,300
HRA-11	£ 51,221	£ 51,221	£ 31,461	£ 24,186	£ 14,382	£ 12,389	£ 2,246
HRA-12	£ 154,245	£ 154,245	£ 91,683	£ 67,941	£ 35,140	£ 28,792	£ 4,059
HRA-13	£ 24,628	£ 24,628	£ 23,427	£ 21,272	£ 15,606	£ 14,078	£ 2,883
HRA-14	£ 42,162	£ 42,162	£ 42,024	£ 41,679	£ 37,054	£ 33,554	£ 5,794
HRA-15	£ 33,957	£ 33,957	£ 30,147	£ 26,157	£ 17,579	£ 15,429	£ 3,178
HRA-16	£ 419,402	£ 419,402	£ 225,154	£ 158,012	£ 72,735	£ 57,029	£ 6,606
Non-HRA	£ 5,915,359	£ 5,915,359	£ 3,602,444	£ 2,600,468	£ 1,305,526	£ 1,067,864	£ 159,515

FUTURE CLIMATE

Total damages

Return period (Years)	10	20	30	75	100	1000
Residential	£13,348,359	£21,427,740	£24,906,809	£38,478,541	£45,665,764	£152,779,260
Non-Residential	£36,987,382	£57,680,620	£61,208,253	£72,338,673	£76,142,006	£134,752,572
Total	£49,781,574	£78,198,672	£85,088,225	£109,263,715	£119,981,263	£282,240,766
HRA-1	£0	£0	£39,702	£864,777	£973,494	£1,471,889
HRA-2	£432,755	£606,820	£668,074	£851,994	£932,673	£1,500,672
HRA-3	£0	£438,598	£814,273	£1,420,463	£1,566,218	£3,046,479
HRA-4	£324,437	£521,304	£603,753	£764,850	£809,212	£1,419,472
HRA-5	£0	£139,404	£231,286	£937,482	£1,363,943	£3,852,183
HRA-6	£55,322	£1,010,164	£1,244,522	£2,104,452	£2,971,544	£8,582,101
HRA-7	£88,059	£257,096	£351,466	£761,517	£926,806	£2,648,577
HRA-8	£834,740	£910,246	£925,504	£986,605	£1,002,372	£1,269,794
HRA-9	£0	£1,690,259	£2,243,579	£3,513,555	£3,946,589	£7,828,452
HRA-10	£854,564	£1,942,561	£2,306,628	£3,343,912	£3,710,999	£7,217,042
HRA-11	£375,257	£463,326	£519,489	£743,036	£893,270	£2,896,695
HRA-12	£1,173,461	£1,556,314	£1,736,115	£2,128,336	£2,253,297	£4,835,347
HRA-13	£0	£279,877	£372,436	£758,621	£1,015,019	£3,278,828
HRA-14	£0	£59,224	£388,970	£2,482,924	£3,029,693	£6,584,020
HRA-15	£36,190	£439,247	£584,489	£913,794	£1,137,099	£4,826,681
HRA-16	£3,814,687	£4,152,638	£4,333,022	£5,129,062	£5,315,983	£7,152,351
Non-HRA	£ 41,792,102	£ 63,731,593	£ 67,724,918	£ 81,558,335	£ 88,133,051	£ 213,830,183

Annual average damages

Standard of Protection (return period)	Do Nothing	10	20	30	75	100	1000
Residential	£ 3,420,640	£ 2,753,212	£ 1,969,790	£ 1,589,532	£ 999,278	£ 861,441	£ 158,538
Non-Residential	£ 7,632,573	£ 5,783,176	£ 3,615,965	£ 2,627,698	£ 1,304,165	£ 1,056,839	£ 138,013
All Blackpool	£ 11,053,213	£ 8,536,388	£ 5,585,754	£ 4,217,230	£ 2,303,443	£ 1,918,280	£ 296,550
HRA-1	£ 20,753	£ 20,753	£ 20,753	£ 20,588	£ 15,272	£ 12,213	£ 1,499
HRA-2	£ 85,595	£ 63,957	£ 40,029	£ 29,507	£ 14,814	£ 11,866	£ 1,532
HRA-3	£ 63,670	£ 63,670	£ 58,187	£ 48,373	£ 27,109	£ 22,139	£ 3,127
HRA-4	£ 71,467	£ 55,245	£ 35,809	£ 26,632	£ 13,289	£ 10,665	£ 1,453
HRA-5	£ 41,227	£ 41,227	£ 39,485	£ 36,534	£ 27,456	£ 23,763	£ 3,988
HRA-6	£ 127,818	£ 125,052	£ 110,313	£ 91,816	£ 61,340	£ 53,251	£ 8,889
HRA-7	£ 45,046	£ 40,643	£ 33,550	£ 28,638	£ 18,776	£ 15,968	£ 2,742
HRA-8	£ 133,690	£ 91,953	£ 48,853	£ 33,555	£ 14,522	£ 11,207	£ 1,284
HRA-9	£ 175,187	£ 175,187	£ 154,059	£ 122,105	£ 67,719	£ 55,396	£ 8,039
HRA-10	£ 263,949	£ 221,220	£ 158,052	£ 122,702	£ 67,199	£ 55,444	£ 7,411
HRA-11	£ 79,088	£ 60,325	£ 39,908	£ 31,847	£ 19,734	£ 17,060	£ 3,005
HRA-12	£ 233,152	£ 174,478	£ 107,360	£ 80,082	£ 41,657	£ 34,356	£ 4,978
HRA-13	£ 42,497	£ 42,497	£ 38,999	£ 33,615	£ 23,369	£ 20,472	£ 3,403
HRA-14	£ 85,769	£ 85,769	£ 85,029	£ 82,588	£ 56,964	£ 47,831	£ 6,779
HRA-15	£ 59,906	£ 58,097	£ 51,111	£ 42,776	£ 28,564	£ 25,242	£ 5,026
HRA-16	£ 633,425	£ 442,688	£ 244,653	£ 173,990	£ 79,857	£ 62,453	£ 7,255
Non-HRA	£ 8,890,973	£ 6,773,628	£ 4,319,605	£ 3,211,883	£ 1,725,802	£ 1,438,955	£ 226,140

Net present value - Allowed direct damages

Standard of Protection (return period)	Do Nothing	10	20	30	75	100	1000
Residential	£ 52,641,073	£ 52,641,073	£ 40,796,246	£ 32,342,484	£ 19,514,701	£ 16,751,959	£ 3,144,373
Non-Residential	£ 114,467,027	£ 114,467,027	£ 86,313,508	£ 66,035,388	£ 32,490,474	£ 26,111,665	£ 3,380,346
All Blackpool	£ 167,108,100	£ 167,108,100	£ 127,109,754	£ 98,377,872	£ 52,005,174	£ 42,863,624	£ 6,524,718
HRA-1	£ 320,562	£ 320,562	£ 320,562	£ 320,562	£ 291,305	£ 260,036	£ 41,406
HRA-2	£ 1,415,691	£ 1,415,691	£ 969,206	£ 703,540	£ 346,434	£ 278,119	£ 39,168
HRA-3	£ 884,367	£ 884,367	£ 876,020	£ 847,842	£ 625,006	£ 525,374	£ 80,150
HRA-4	£ 1,069,029	£ 1,069,029	£ 852,767	£ 657,754	£ 333,830	£ 269,998	£ 39,020
HRA-5	£ 493,201	£ 493,201	£ 493,201	£ 492,156	£ 447,631	£ 414,812	£ 96,183
HRA-6	£ 2,241,400	£ 2,241,400	£ 2,100,653	£ 1,822,372	£ 1,231,772	£ 1,090,979	£ 234,082
HRA-7	£ 779,078	£ 779,078	£ 666,734	£ 563,386	£ 388,202	£ 344,084	£ 70,172
HRA-8	£ 2,052,619	£ 2,052,619	£ 1,383,865	£ 948,069	£ 408,715	£ 314,530	£ 34,950
HRA-9	£ 3,401,998	£ 3,401,998	£ 3,137,169	£ 2,608,390	£ 1,566,861	£ 1,299,585	£ 199,693
HRA-10	£ 4,873,173	£ 4,873,173	£ 3,724,145	£ 2,927,365	£ 1,640,511	£ 1,369,044	£ 188,079
HRA-11	£ 1,257,720	£ 1,257,720	£ 938,612	£ 722,096	£ 429,380	£ 369,895	£ 67,045
HRA-12	£ 3,834,081	£ 3,834,081	£ 2,706,054	£ 2,028,448	£ 1,049,129	£ 859,624	£ 121,171
HRA-13	£ 735,290	£ 735,290	£ 699,449	£ 635,108	£ 465,927	£ 420,312	£ 86,069
HRA-14	£ 1,258,795	£ 1,258,795	£ 1,254,656	£ 1,244,366	£ 1,106,278	£ 1,001,796	£ 172,980
HRA-15	£ 1,013,807	£ 1,013,807	£ 900,072	£ 780,931	£ 524,851	£ 460,636	£ 94,868
HRA-16	£ 6,494,754	£ 6,494,754	£ 5,300,105	£ 4,451,651	£ 2,171,572	£ 1,702,664	£ 197,217
Non-HRA	£ 134,982,535	£ 134,982,535	£ 100,786,484	£ 76,623,835	£ 38,977,771	£ 31,882,135	£ 4,762,465

5.6% emergency services, and 10% utilities uplift

Standard of Protection (return period)	Do Nothing	10	20	30	75	100	1000
Residential	£ 9,732,147	£ 9,732,147	£ 6,414,781	£ 5,045,428	£ 3,044,293	£ 2,613,306	£ 490,522
Non-Residential	£ 24,225,645	£ 24,225,645	£ 14,707,561	£ 10,501,454	£ 5,068,514	£ 4,073,420	£ 527,334
All Blackpool	£ 33,957,792	£ 33,957,792	£ 21,122,341	£ 15,546,882	£ 8,112,807	£ 6,686,725	£ 1,017,856
HRA-1	£ 50,008	£ 50,008	£ 50,008	£ 50,008	£ 45,444	£ 40,566	£ 6,459
HRA-2	£ 257,098	£ 257,098	£ 151,196	£ 109,752	£ 54,044	£ 43,387	£ 6,110
HRA-3	£ 137,961	£ 137,961	£ 136,659	£ 132,263	£ 97,501	£ 81,958	£ 12,503
HRA-4	£ 222,940	£ 222,940	£ 139,041	£ 102,610	£ 52,077	£ 42,120	£ 6,087
HRA-5	£ 76,939	£ 76,939	£ 76,939	£ 76,776	£ 69,830	£ 64,711	£ 15,005
HRA-6	£ 361,904	£ 361,904	£ 327,702	£ 284,290	£ 192,156	£ 170,193	£ 36,517
HRA-7	£ 131,768	£ 131,768	£ 104,011	£ 87,888	£ 60,559	£ 53,677	£ 10,947
HRA-8	£ 413,044	£ 413,044	£ 215,883	£ 147,899	£ 63,760	£ 49,067	£ 5,452
HRA-9	£ 540,973	£ 540,973	£ 489,398	£ 406,909	£ 244,430	£ 202,735	£ 31,152
HRA-10	£ 834,599	£ 834,599	£ 585,541	£ 456,669	£ 255,920	£ 213,571	£ 29,340
HRA-11	£ 238,563	£ 238,563	£ 146,533	£ 112,647	£ 66,983	£ 57,704	£ 10,459
HRA-12	£ 718,403	£ 718,403	£ 427,015	£ 316,438	£ 163,664	£ 134,101	£ 18,903
HRA-13	£ 114,705	£ 114,705	£ 109,114	£ 99,077	£ 72,685	£ 65,569	£ 13,427
HRA-14	£ 196,372	£ 196,372	£ 195,726	£ 194,121	£ 172,579	£ 156,280	£ 26,985
HRA-15	£ 158,154	£ 158,154	£ 140,411	£ 121,825	£ 81,877	£ 71,859	£ 14,799
HRA-16	£ 1,953,381	£ 1,953,381	£ 1,048,662	£ 735,945	£ 338,765	£ 265,616	£ 30,766
Non-HRA	£ 27,550,981	£ 27,550,981	£ 16,778,502	£ 12,111,765	£ 6,080,532	£ 4,973,613	£ 742,944

Net present value - Allowed direct damages

Standard of Protection (return period)	Do Nothing	10	20	30	75	100	1000
Residential	£ 75,970,630	£ 71,470,272	£ 58,429,850	£ 47,457,050	£ 29,834,424	£ 25,719,154	£ 4,733,293
Non-Residential	£ 141,731,977	£ 129,551,306	£ 99,476,125	£ 77,015,731	£ 38,937,122	£ 31,552,974	£ 4,120,509
All Blackpool	£ 217,702,607	£ 201,021,578	£ 157,905,975	£ 124,472,781	£ 68,771,547	£ 57,272,127	£ 8,853,803
HRA-1	£ 619,603	£ 619,603	£ 619,603	£ 614,664	£ 455,966	£ 364,619	£ 44,760
HRA-2	£ 1,801,615	£ 1,674,035	£ 1,195,115	£ 880,954	£ 442,294	£ 354,258	£ 45,728
HRA-3	£ 1,900,922	£ 1,900,922	£ 1,737,237	£ 1,444,214	£ 809,357	£ 660,990	£ 93,362
HRA-4	£ 1,346,002	£ 1,260,009	£ 1,029,943	£ 795,135	£ 396,751	£ 318,426	£ 43,375
HRA-5	£ 1,230,882	£ 1,230,882	£ 1,178,856	£ 1,090,749	£ 819,713	£ 709,457	£ 119,065
HRA-6	£ 3,515,343	£ 3,515,343	£ 3,282,588	£ 2,741,259	£ 1,831,364	£ 1,589,848	£ 265,395
HRA-7	£ 1,123,713	£ 1,122,961	£ 1,001,672	£ 855,025	£ 560,568	£ 476,747	£ 81,873
HRA-8	£ 2,441,229	£ 2,147,885	£ 1,458,540	£ 1,001,805	£ 433,559	£ 334,588	£ 38,339
HRA-9	£ 5,035,850	£ 5,035,850	£ 4,599,584	£ 3,645,572	£ 2,021,831	£ 1,653,905	£ 240,014
HRA-10	£ 6,257,684	£ 5,854,089	£ 4,684,828	£ 3,663,402	£ 2,006,294	£ 1,655,331	£ 221,272
HRA-11	£ 1,676,653	£ 1,520,615	£ 1,190,600	£ 950,831	£ 589,192	£ 509,355	£ 89,721
HRA-12	£ 4,740,602	£ 4,345,320	£ 3,152,000	£ 2,390,914	£ 1,243,725	£ 1,025,735	£ 148,610
HRA-13	£ 1,268,790	£ 1,268,790	£ 1,164,340	£ 1,003,613	£ 697,692	£ 611,217	£ 101,599
HRA-14	£ 2,560,730	£ 2,560,730	£ 2,538,628	£ 2,465,736	£ 1,700,720	£ 1,428,029	£ 202,407
HRA-15	£ 1,737,359	£ 1,683,334	£ 1,525,963	£ 1,277,118	£ 852,815	£ 753,632	£ 150,063
HRA-16	£ 23,946	£ 23,946	£ 15,453	£ 11,662	£ 6,220	£ 5,164	£ 686
Non-HRA	£ 180,421,685	£ 165,257,263	£ 127,531,025	£ 99,640,127	£ 53,903,486	£ 44,820,826	£ 6,967,536

5.6% emergency services, and 10% utilities uplift

Standard of Protection (return period)	Do Nothing	10	20	30	75	100	1000
Residential	£ 15,931,745	£ 12,823,177	£ 9,174,360	£ 7,403,300	£ 4,654,170	£ 4,012,188	£ 738,394
Non-Residential	£ 35,548,958	£ 26,935,331	£ 16,841,474	£ 12,238,589	£ 6,074,191	£ 4,922,264	£ 642,799
All Blackpool	£ 51,480,703	£ 39,758,508	£ 26,015,834	£ 19,641,889	£ 10,728,361	£ 8,934,452	£ 1,381,193
HRA-1	£ 96,658	£ 96,658	£ 96,658	£ 95,888	£ 71,131	£ 56,881	£ 6,982
HRA-2	£ 398,663	£ 297,883	£ 186,438	£ 137,429	£ 68,998	£ 55,264	£ 7,134
HRA-3	£ 296,544	£ 296,544	£ 271,009	£ 225,297	£ 126,260	£ 103,114	£ 14,564
HRA-4	£ 332,860	£ 257,305	£ 166,782	£ 124,041	£ 61,893	£ 49,674	£ 6,767
HRA-5	£ 192,018	£ 192,018	£ 183,902	£ 170,157	£ 127,875	£ 110,675	£ 18,574
HRA-6	£ 595,318	£ 582,434	£ 513,788	£ 427,636	£ 285,693	£ 248,016	£ 41,402
HRA-7	£ 209,801	£ 189,294	£ 156,261	£ 133,384	£ 87,449	£ 74,372	£ 12,772
HRA-8	£ 622,667	£ 428,272	£ 227,532	£ 156,282	£ 67,635	£ 52,196	£ 5,981
HRA-9	£ 815,941	£ 815,941	£ 717,535	£ 568,709	£ 315,406	£ 258,009	£ 37,442
HRA-10	£ 1,229,349	£ 1,030,338	£ 736,132	£ 571,491	£ 312,982	£ 258,232	£ 34,518
HRA-11	£ 368,353	£ 280,964	£ 185,872	£ 148,330	£ 91,914	£ 79,459	£ 13,996
HRA-12	£ 1,085,912	£ 812,636	£ 500,031	£ 372,983	£ 194,021	£ 160,015	£ 23,183
HRA-13	£ 197,931	£ 197,931	£ 181,637	£ 156,564	£ 108,840	£ 95,350	£ 15,849
HRA-14	£ 399,474	£ 399,474	£ 396,026	£ 384,655	£ 265,312	£ 222,772	£ 31,575
HRA-15	£ 279,016	£ 270,588	£ 238,050	£ 199,230	£ 133,039	£ 117,567	£ 23,410
HRA-16	£ 21,967,621	£ 15,352,720	£ 8,484,742	£ 6,034,089	£ 2,769,487	£ 2,165,910	£ 251,600
Non-HRA	£ 22,392,576	£ 18,257,508	£ 12,773,439	£ 9,735,725	£ 5,640,427	£ 4,826,944	£ 835,442

Net present value - Benefits (£k)

Standard of Protection (return period)	Do Nothing	10	20	30	75	100	1000
Residential		£ 0	£ 15,162	£ 24,985	£ 39,814	£ 43,008	£ 58,738
Non-Residential		£ -	£ 37,672	£ 62,156	£ 101,134	£ 108,508	£ 134,785
All Blackpool		£ 0	£ 52,834	£ 87,141	£ 140,948	£ 151,516	£ 193,523
HRA-1		£ -	£ -	£ -	£ 34	£ 70	£ 323
HRA-2		£ 0	£ 552	£ 859	£ 1,272	£ 1,351	£ 1,628
HRA-3		£ 0	£ 10	£ 42	£ 300	£ 415	£ 930
HRA-4		£ 0	£ 300	£ 532	£ 906	£ 980	£ 1,247
HRA-5		-£ 0	-£ 0	£ 1	£ 53	£ 91	£ 459
HRA-6		-£ 0	£ 175	£ 497	£ 1,179	£ 1,342	£ 2,333
HRA-7		£ -	£ 140	£ 260	£ 462	£ 513	£ 830
HRA-8		£ 0	£ 866	£ 1,370	£ 1,993	£ 2,102	£ 2,425
HRA-9		£ 0	£ 316	£ 928	£ 2,132	£ 2,441	£ 3,712
HRA-10		-£ 0	£ 1,398	£ 2,324	£ 3,811	£ 4,125	£ 5,490
HRA-11		-£ 0	£ 411	£ 662	£ 1,000	£ 1,069	£ 1,419
HRA-12		-£ 0	£ 1,419	£ 2,208	£ 3,340	£ 3,559	£ 4,412
HRA-13		£ 0	£ 41	£ 116	£ 311	£ 364	£ 751
HRA-14		£ -	£ 5	£ 17	£ 176	£ 297	£ 1,255
HRA-15		£ 0	£ 131	£ 269	£ 565	£ 639	£ 1,062
HRA-16		-£ 0	£ 2,099	£ 3,261	£ 5,938	£ 6,480	£ 8,220
Non-HRA		£ 0	£ 44,969	£ 73,798	£ 117,475	£ 125,678	£ 157,028

Net present value - Benefits (£k)

Standard of Protection (return period)	Do Nothing	10	20	30	75	100	1000
Residential		£ 7,609	£ 24,298	£ 37,042	£ 57,414	£ 62,171	£ 86,431
Non-Residential		£ 20,794	£ 60,963	£ 88,027	£ 132,270	£ 140,806	£ 172,518
All Blackpool		£ 28,403	£ 85,262	£ 125,069	£ 189,683	£ 202,977	£ 258,948
HRA-1		-£ 0	-£ 0	£ 6	£ 189	£ 295	£ 665
HRA-2		£ 228	£ 819	£ 1,182	£ 1,689	£ 1,791	£ 2,147
HRA-3		-£ 0	£ 189	£ 528	£ 1,262	£ 1,433	£ 2,090
HRA-4		£ 162	£ 482	£ 760	£ 1,220	£ 1,311	£ 1,629
HRA-5		£ 0	£ 60	£ 162	£ 475	£ 603	£ 1,285
HRA-6		£ 13	£ 314	£ 942	£ 1,994	£ 2,273	£ 3,804
HRA-7		£ 21	£ 176	£ 345	£ 685	£ 782	£ 1,239
HRA-8		£ 488	£ 1,378	£ 1,906	£ 2,563	£ 2,677	£ 3,020
HRA-9		-£ 0	£ 535	£ 1,638	£ 3,515	£ 3,940	£ 5,574
HRA-10		£ 603	£ 2,066	£ 3,252	£ 5,168	£ 5,573	£ 7,231
HRA-11		£ 243	£ 669	£ 946	£ 1,364	£ 1,456	£ 1,941
HRA-12		£ 669	£ 2,174	£ 3,063	£ 4,389	£ 4,641	£ 5,655
HRA-13		-£ 0	£ 121	£ 307	£ 660	£ 760	£ 1,349
HRA-14		-£ 0	£ 26	£ 110	£ 994	£ 1,309	£ 2,726
HRA-15		£ 62	£ 252	£ 540	£ 1,031	£ 1,145	£ 1,843
HRA-16		£ 6,615	£ 13,491	£ 15,946	£ 19,216	£ 19,820	£ 21,739
Non-HRA		£ 19,299	£ 62,510	£ 93,438	£ 143,270	£ 153,166	£ 195,011

Appendix C

Initial Feasibility Report for the HRAs

Subject Blackpool SWMP - Options Feasibility Study

Date 8 April 2013 Job No/Ref 227357

Feasibility Study to Investigate Options to Reduce Flood Risk

1 Summary

This note is provided to follow on from the Blackpool SWMP Risk Assessment Report, which used surface modelling techniques to identify high risk areas within Blackpool potentially subject to severe flooding from large storm events. These areas were visited with a view to identifying potential measures to reduce the severity of flooding. This note provides a description of possible measures that could be used, along with a high level indication of the potential benefits that could be achieved from using these measures. The locations of the high risk areas are shown on the following figure.

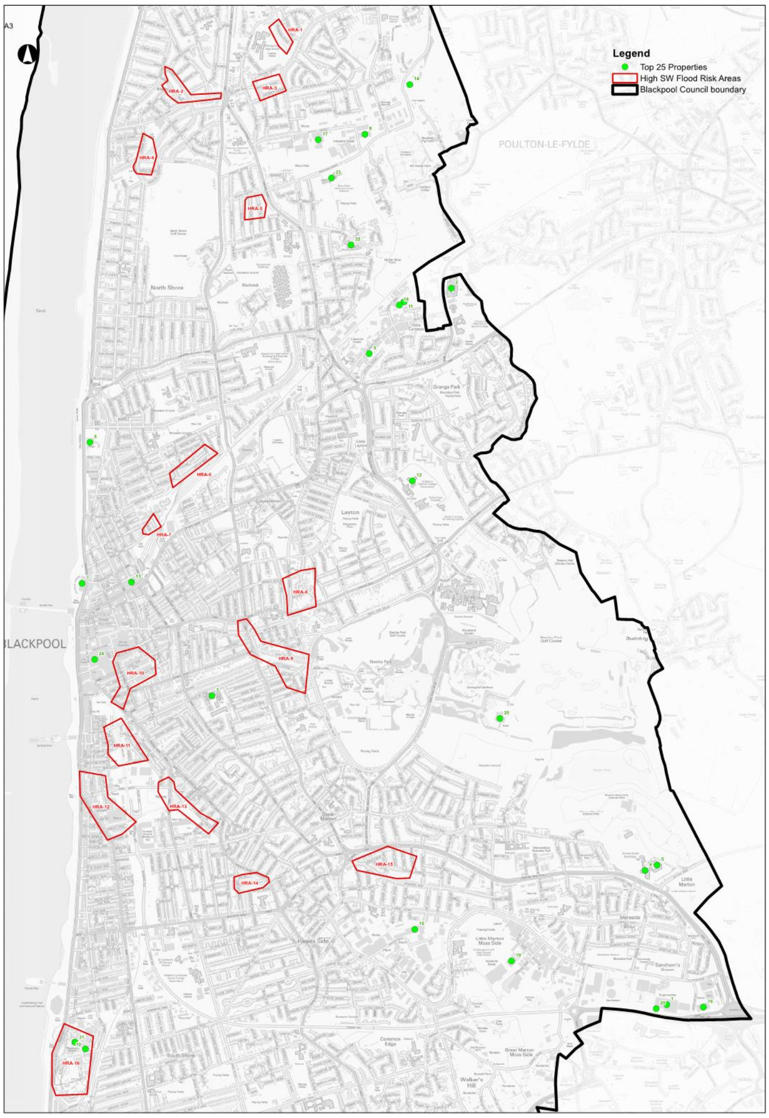


Figure 1 Locations of the High Risk Areas

2 Scope and Assumptions

This note is based on two sources of information only;

- The results of the flood analysis form the Blackpool SWMP Risk Assessment Report
- Site visits to the high risk areas to verify the above and identify possible site specific measures to reduce the severity of the flooding.

The following assumptions have been made;

- The flooding events described here are extreme events only, for lesser events the local sewer, highway drainage and culvert networks would be effective in removing surface water any minimising the risk of flooding.
- For these extreme storms described, it is assumed the existing sewers, highway drainage and culvert networks are full beyond their capacity and are no longer effective in minimising the risk of flooding.
- No open watercourses have been identified within or close to the high risk areas described, it is assumed any former watercourses have been culverted and now from part of the existing underground drainage/sewer network.
- It is assumed infiltration will be small in comparison with the storm, the ground will be waterlogged and most of the water landing will contribute to overland flows.

The information provided in this note is for high level assessment only, hence many factors have not been included. These principally include the following;

- Groundwater levels have not been considered. This may compromise the use of infiltration systems.
- Contamination and other ground conditions have not been considered, this could significantly increase the cost of underground systems
- No consideration has been given to the positions of underground services, utilities and drainage. Given that all the areas considered are in the urban environment, it may not be feasible to implement some of the underground systems described in this note. Further survey work is required.
- Many of the roads described below are lined with residential or commercial properties, requiring pedestrian and vehicle access/parking. Liaison will be required with property owners prior to the implementation of any of the following systems.
- There has been no consultation with the local council, including the highways authority. Many of the systems described below are to be implemented within the public highway, therefore their input is necessary.

Before any of the systems described below are implemented, further detailed analysis will be required at each high risk area and its surrounding areas. These should determine the exact nature of the flooding problem, flow paths and the most effective type and positions of systems to reduce the flooding risks.

3 Types of Methods and Systems Proposed

Due to the urban nature of the high risk areas under consideration, many types of flood alleviation systems are not feasible or not appropriate. The systems proposed need to be compatible with the width and gradient of the highway corridor or landscape area, the requirements of adjacent property owners and the requirements of the local authorities for adoption and maintenance. The following methods and systems proposed are considered potentially compatible with these stakeholders. However further survey, analysis work and liaison will be required to confirm this.

It is important the systems do not become inundated during smaller storm events, so that there is storage capacity available for the extreme event. The positioning and collection methods should be carefully designed, and the existing highway drainage should be checked to ensure it is operational up to a reasonable storm severity.

The methods described in this note are as follows;

3.1 Underground Storage under Roadside Parking Spaces

Many of the roads are residential and most have vehicles parked along them. The proposal is to use these parking areas for underground storage. The parking areas should be defined, preferably with kerbing on heavier trafficked roads, to minimise the vehicle loading on the system. The system intersects surface water flows along the road, by the use of permeable block paving, drainage channels, beany block kerbing or similar. Storage is provided under the parking space by the use of course grade road pavement construction foundation, or geocellular storage units. Discharge form the system would preferably be by infiltration, although controlled discharge to adjacent drainage may be possible.

Figure 2 Permeable paved parking area - taken from the Aggregate Industries website 'www.aggregate.com'

3.2 Tree Pit Storage

These are very similar to the geocellular systems described above, whereby storm water runoff is intersected and stored in units underground. However these units are used as feeders for tree pits and other green landscaping areas. The advantage is that the trees and vegetation will help adsorbing the water. There are also aesthetic advantages, especially where urban regeneration project are proposed. This type of system is primarily aimed at urban areas which are predominantly paved. For this project they are considered potentially useful for providing trees along existing highway footways.

Figure 3 Example of tree pit drainage system - from 'Sustainable Drainage - Retrofitting the Built Environment' by Arup

3.3 Underground Storage under Existing Landscape Areas

In some locations there are areas of soft landscaping, which are not large enough for the use of ponds, but could be used for underground storm water storage. It is envisaged this would comprise geocellular units, with drains or flow-paths from adjacent highways.

3.4 Amendments to footway levels

The risk of flooding to some properties can be reduced by lifting or otherwise amending the adjacent highway footway levels and gradients. However careful consideration should be given as to where this water would then go, so that it is not increasing the flood risk elsewhere. This method is best combined with other systems to store storm water.

3.5 Earthworks for Flood Routing or Storage

For some areas where flood water potentially collects, it may be possible to amend adjacent soft landscaping areas to provide a flood route out of the area to another area where it can be stored with a much lower risk such as a parkland area. This will involve significant earthworks to reduce levels. The risks of water flowing between areas would need to be considered, plus the impact on the receiving area.

3.6 Detention Ponds and Swales

These generally involve the modification of the ground profile of existing landscape areas to form a depression than will help store water and therefore reduce the flood risk to adjacent properties. Due to the urban nature of the areas under consideration, there is limited scope for this type of storage, although some usage could be feasible.

Figure 4 Example of a detention basin - 'Sustainable Drainage - Retrofitting the Built Environment' by Arup

Figure 5 Example of an urban swale - CIRIA C698 'Site handbook for the construction of SUDS' by CIRIA

3.7 Permeable Car Parks

It is likely some of the high risk areas are due to existing large areas of impermeable paving, mainly car parks. Where this is the case, the reconstruction of the car park using permeable paving with foundation or underground storage should be considered. Scope may be limited by existing gradients, but it is considered this system would give significant reductions in risk to those particular areas.

Figure 6 Example of a permeable block paved car park - From Tobermore website'www.tobermore.co.uk'

4 Rating of Possible Options

The following chapters provide descriptions of options applicable to each location. Some are more appropriate or effective at reducing the flood risk in a particular location than others. The potential degree of effectiveness has been presented in table form below. Options which could be particularly appropriate and effective to the location have been given a score of 2, those which would have a smaller potential effect have a score of 1. Those measures which could be used, but it is considered there would be no significant reduction in flood risk have a rating of 0. Those options which are considered unfeasible or inappropriate to a location are rated as U.

A total rating is given for each location. This is the sum of the individual option ratings. The higher the value, then potentially the higher the feasibility that options could be used at that particular location to reduce the risk of flooding.

These ratings are based on the flood flow information provided in the risk assessment document as described in chapter 2. These need to be considered along-side other factors as described in chapter 2, which is beyond the scope of this report.

Location	Rating							Total Rating
	Storage under parking	Tree pit storage	Storage under landscaping	Footway levels	Flood routing earthworks	Detention ponds	Permeable car parks / sports pitches	
HRA-1	0	0	2	0	1	1	2	6
HRA-2	1	0	1	2	U	U	U	4
HRA-3	1	0	1	1	U	U	U	3
HRA-4	1	0	U	0	U	U	U	1
HRA-5	1	0	U	0	U	U	U	1
HRA-6	2	0	0	0	U	1	U	3
HRA-7	1	U	U	0	U	U	U	1
HRA-8	1	0	U	0	U	U	U	1
HRA-9	2	2	2	0	U	U	U	6
HRA-10	1	1	U	1	U	U	U	3
HRA-11	2	0	2	0	U	1	2	7
HRA-12	1	1	U	1	U	U	U	3
HRA-13	0	0	0	0	2	2	2	6
HRA-14	2	U	U	0	U	U	U	2
HRA-15	1	0	1	0	U	U	U	2
HRA-16	0	U	U	0	U	U	1	1

5 Options for Location HRA-1

5.1 Description

Cranbrook Avenue is a residential road containing semi-detached and modern terraced housing on both sides. The road is fairly narrow but there are grassed verges and landscaping adjacent.

Figure 7 Cranbrook Avenue looking south

It is located in a shallow valley bounded to the east by the higher ground along Fairfax Avenue and to the west by the raised school playing fields. To the north there is a drainage path through an area of flats and to parkland beyond, however it would appear then Cranbrook Avenue is lower than the area of the flats.

Figure 8 Cranbrook Avenue looking north towards the flats

5.2 Modelling Results

The modelling identified significant flow paths from the school site to the west, particularly around the north side of the school buildings. Also there were major flow paths for the east from Fairfax Avenue.

5.3 Possible Strategies

The school area to the west is possibly over 2m above road level and falls in a steep embankment close to the access to the rear of the properties. Above this embankment there are extensive sports pitches. There may be a possibility of reshaping the land profile of these pitches to contain water or divert it away from Cranbrook Avenue, possibly to the north.

It is likely the main flows from the west pass round the north of the school, over the car parks and into the area of the flats. This area comprises three story buildings surrounded by extensive grassland. Adjacent to the school the ground level of the flats is lower than the school boundary, so it is likely the flats would be severely impacted by flood water from the school. It is likely significant amounts of storm water could be captured by reconstructing the school car park using permeable paving and underground storage (geocellular), thus reducing the flood risk on surrounding properties.

Figure 9 Landscaping between the school car park and the flats

There is a possibility a flow path outfall could be formed by lowering a route through the area of the flats. This would also require lowering a section of All Saints Road so that water could pass to the sports pitches beyond. There would be issues with utilities and access to the properties. It would also be questionable whether the water could be made to flow out of the site quick enough to significantly reduce the flooding levels.

There is the possibility of increasing storage within the Cranbrook Avenue corridor . At the south end there is a wide verge area comprising grassland and some trees. Beyond this there is a small parking area. In the middle there is a smaller grass landscaped area. Both these could be potentially remodelled to provide surface storage. They could also be used to provide underground storage in the form of soakaway pits, depending on groundwater levels and infiltration rates.

Figure 10 Landscape area to south of Cranbrook Avenue

Probably the best place for surface storage would be to remodel the area to the south of Cranbrook Avenue adjacent to the blocks of flats. There are extensive grassed areas here which could be remodelled to provide surface storage and so reduce the severity of flooding. If infiltration and ground water levels are favourable, these areas could also be used for underground storage.

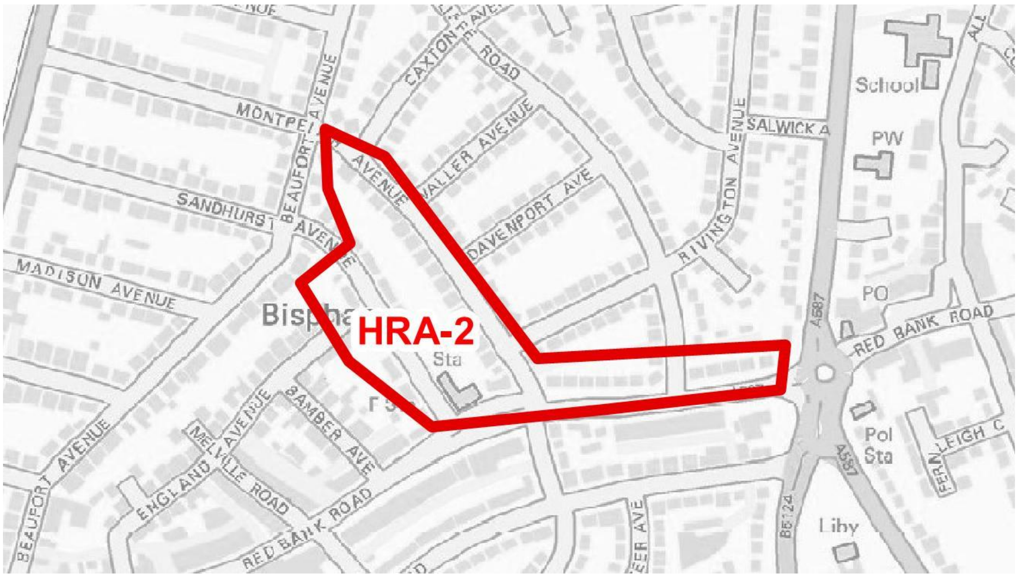
Figure 11 Blocks of flats to south of Cranbrook Avenue

5.4 Summary

- Remodel school site to provide storage, especially the use of geocellular storage under the car park to the north
- Remodel grassland around blocks of flats to provide swale/pond storage
- Modifications to ground levels between the blocks of flats to provide flow path out of Cranbrook Av area
- Use of surface pond and underground storage under landscaping within Cranbrook Av.

6 Options for Location HRA-2

6.1 Description



This is a residential area comprising predominantly semi-detached houses dating from the early part of the 20th century. Many of the houses between Sandhurst Avenue and Montpellier Avenue have thresholds below road level, and the general ground profile seems to fall to a valley which runs along the ends of the gardens between these properties. To the west, England Avenue falls towards Sandhurst Avenue and to the east there are four side roads falling towards Montpellier Avenue. To the north west there are a number of roads falling towards this area. It acts as a focus for the local catchment area.

Figure 12 Sandhurst Avenue


Figure 13 Montpellier Avenue

It is assumed storm water will flow south along Sandhurst Avenue and Montpellier Avenue towards Red Bank Road. Extreme storms will overtop the pavement on these two roads and end up in the gardens between. Flows will collect near the fire station and then flow down the verges of Red Bank Road.

6.2 Modelling Results

The modelling shows up the valley between Sandhurst Avenue and Montpellier Avenue, and the potential flows from the side roads and surrounding 'valley' sides. It also indicated the intense storm water flows along the north side of Red Bank Road as a result.

6.3 Possible Strategies

Higher up on this catchment area, space in the residential streets is very limited. The preferred strategy would be to capture as much storm water high up in the catchment as possible to reduce the amount reaching the problem area. Then measures could be provided lower down to help deal with the remaining flows.

To reduce the volumes of water reaching Sandhurst Avenue, it is proposed to provide under-road storage in England Avenue and at the Beaufort Avenue/Sandhurst Avenue junction. England Avenue ends in a turning head, from where there is a steep footway down to Sandhurst Avenue. An area of porous paving could be provided at the turning head with storage below, discharging with a controlled rate to the sewers/highway drainage or by infiltration.

Figure 14 End of England Avenue (Cul-de-Sac)

On Beaufort Avenue, just west of the Sandhurst Avenue junction, car parking spaces could be constructed along the kerbline with porous paving, with controlled discharge to sewers/highway drainage or infiltration. Similar measures could be provided at the bottom section of Sandhurst Avenue to the west of the Beaufort Av junction.

Figure 15 Beaufort Avenue west of Sandhurst Avenue junction

To reduce the volume of water reaching Montpellier Avenue, it could be possible to provide under-street storage at the bottom ends of the side roads (Claxton Avenue, Waller Avenue, Davenport Avenue and Rivington Avenue). These would be porous paving with storage provided below and controlled discharge to the sewers/highway drainage or infiltration. There is a slight low point in Montpellier Avenue at the Waller Avenue junction, so more extensive storage may be desirable here, depending on existing utilities. This may however have to remain a high risk area.

It may be possible to raise the footpath levels along the east side of Sandhurst Avenue and the west side of Montpellier Avenue to protect properties from flows of storm water on these roads.

On Red Bank Road, outside the fire station, the highway widens and there is a grasses/tarmac area in the middle. There is potential to use this for storage. The grassed areas could be 'dished' to provide surface storage. Underground storage could be provided both under the grass and tarmac areas. This would help capture a volume of storm water and reduce the intensity of flows along the north Red Bank Road kerbline. It should be noted access is required across this area for the fire station.

Figure 16 Landscape area in Red Bank Road near Fire Station

Downhill from this, Red Bank Road is very busy primary route and therefore options within the highway are limited. However there is a narrow grassed verge along each side as well as the footway. It could be possible to form some type of swale to carry a proportion of the storm water, this could potentially slow the flow down and reduce impact on areas downstream. It could also provide a degree of infiltration. The presence of existing utilities may be a constraint here. It should be noted that this highway falls to a large busy junction, this has not been highlighted as a high risk area and is therefore beyond the scope of this study.

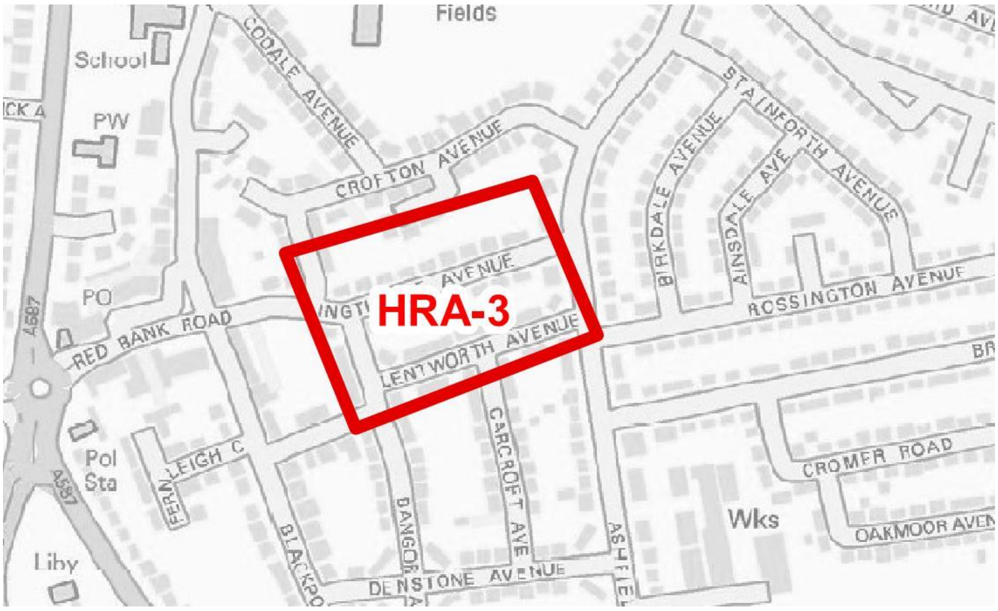
Figure 17 Red Bank Road

6.4 Summary

- Porous paving and underground storage within Beaufort Avenue, England Avenue and at the junctions of Claxton Avenue, Waller Avenue, Davenport Avenue and Rivington Avenue with Montpellier Avenue.
- Raise footpath levels along Sandhurst and Montpellier Avenues.
- Underground storage below parking places and landscaping on Red Bank Road close to fire station.

7 Options for Location HRA-3

7.1 Description



This is a residential area comprising predominantly semi-detached and terrace housing from the early to mid 20th century. Most of the roads are narrow with many property entrances and on-street parking. Red Bank Road is wider but is a much busier local route and bus route.

The whole of the area appears fairly flat, but there is a slight dip in the middle of these sections of Ingthorpe Avenue and Lentworth Avenue.

Figure 18 Ingthorpe Avenue

Figure 19 Lentworth Avenue

7.2 Modelling Results

The survey identified this area is a low point with slopes towards it from most directions. Particular storm flows were identified from Red Bank Road and Wyresdale Avenue to the west and from Bangor Avenue to the south.

It should be noted that from observations of the modelling results, a proportion of the flooding in this area could result from storm water originating in area HRA-2, described above.

7.3 Possible Strategies

A significant proportion of the storm water to this area appears to enter from Red Bank Road. Just to the west of the site, on the south side of this road, there is a wider area of grassed verge. This could potentially be used for underground storage to reduce the amount of storm water reaching the high risk areas. Controlled discharge could be to sewer/highway drainage or by infiltration if possible.

Figure 20 Landscape area on Red Bank Road

Lentworth Av is fairly narrow and the options for storage here are limited. Some parking areas could be formed on one side to provide porous paving for underground storage. The roads falling towards this area are wider and may provide a better opportunity of capturing volumes of water before they reach the problem areas. Porous paved parking areas could be provided on Wyresdale Avenue, Bangor Avenue and Carcroft Avenue.

Figure 21 Bangor Avenue

Ingthorpe Avenue is wider, there is a possibility storage could be provided on the south side in the form of porous paved parking areas, although these would have to be protected from the heaviest traffic which could mean restricting parking on the north side. It was noted the properties on the south side were fairly low relative to the road, therefore some increase on footway level may help to reduce the frequency of flooding.

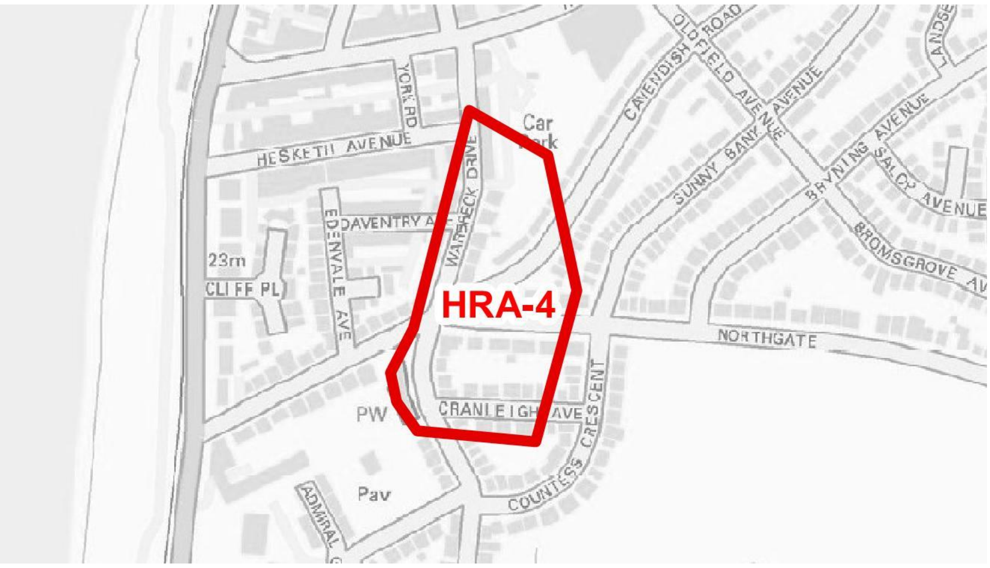
Figure 22 Ingthorpe Avenue

7.4 Summary

- Underground storage under landscape area on Red Bank Road
- Underground storage under parking areas on Wyresdale Av, Bangor Av, Carcroft Av and Ingthorpe Avenue.
- Modifications to footway levels on Ingthorpe Avenue.

8 Options for Location HRA-4

8.1 Description



This is an established residential area with terraced and semi-detached housing dating back to the first half of the 20th century. Most of it is on an east facing slope. Cranleigh Av falls from both ends to a sharp dip in the middle.

8.2 Modelling Results

The modelling identified storm water flowing from the west from Cavendish Road and Daventry Avenue creating flooding at Warbreck Drive. It also identified flooding in Cranleigh Avenue as a result of storm water from Warbreck Drive to the west and Countess Crescent to the east.

8.3 Possible Strategies

This location seems to contain two flooding risk areas, the Warbeck Drive area and the Cranleigh Avenue area.

Warbreck Drive runs along the side of a slope, and has a local low-point at its junction with Daventry Avenue. The properties on the east side of Warbreck Drive are lower than the road as the ground falls steeply away. Beyond these properties there is a car park for the Sainsburys superstore. From observations of the site it is likely the problem is flooding of the properties to the east of Warbreck Drive and of the car park beyond.

Figure 23 Properties on Warbreck Avenue

Daventry Avenue and Cavendish Road fall onto it from the west and are likely sources of storm water. Warbreck Road itself is a narrow busy road and there is very little opportunity to provide drainage systems. To reduce the volume of water reaching the problem area, storage could be provided on Daventry Avenue and the upper part of Cavendish Road. The Daventry Avenue storage could be in the form of permeable paving over below-street storage with controlled outfalls to the sewer or infiltration.

Figure 24 Davenport Avenue

Cavendish Road is wider and there is a small area of verge at the junction with Warbreck Drive. More substantial permeable paving and below-street storage could be provided here.

There may be scope to raise the footway levels along the east side of Warbreck Drive to add additional protection to the properties for the smaller storms, although this would provide little protection to the larger storms. The driveways of these properties fall steeply and there may be an opportunity to influence the property owners to provide flood routes past the houses to minimise impact on the houses (removal of garden walls etc). Beyond these properties the storm water is likely to collect in Sainsburys car park. This is tarmac surfaced and there are opportunities to re-model the surface profile to allow it to hold storm water on the surface, or use a permeable paving system with underground storage.

Cranleigh Avenue is a narrow urban road with residential properties both sides. It has a well-defined low-point in the middle.

Figure 25 Cranleigh Avenue

It could be possible to provide limited below-street storage at this point using permeable. The most appropriate way to reduce the flooding on Cranleigh Avenue would be to detain volumes of storm water on the approach road. From the west the changes on Cavendish Road described above would help. To the east, runoff from Countess Crescent could be intersected by the provision of permeable paving and below-street storage at the east end of Cranleigh Avenue.

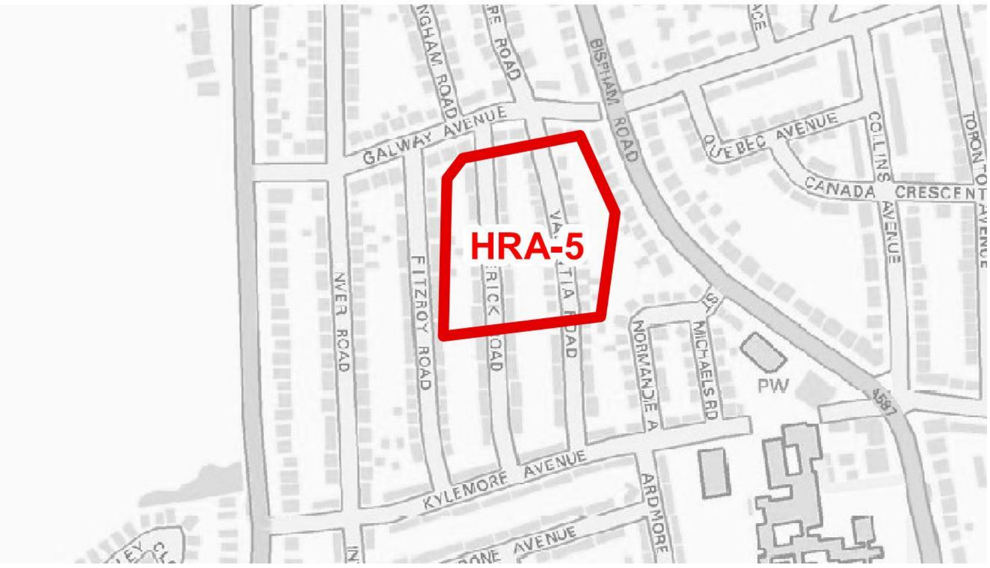

Figure 26 Cranleigh Avenue from Countess Crescent

8.4 Summary

- Underground storage under parking areas on Daventry Avenue and Cranleigh Avenue.

9 Options for Location HRA-5

9.1 Description



Both Limerick Road and Valencia Road are narrow dense urban roads. Limerick Road is predominantly post-war semi-detached and terraced properties with short front gardens.

Figure 27 Limerick Road

The southern half of Valencia Road is similar, the northern half (where the low point is) has been redeveloped with detached properties.

Figure 28 Valencia Road

Both roads have noticeable low points over the northern sections. On Limerick Road, the housing is low to the road level. The older housing on Valencia Road is similar, however the it would appear the newer housing has been constructed at a higher level, probably due to the known flooding issue in the area.

9.2 Modelling Results

General flow routes from higher ground around this area, particularly from the north west via Galway Avenue and from the south via Kylemore Avenue.

9.3 Possible Strategies

There is very little opportunities to retain storm water within Limerick and Valencia Roads, given their widths, density of housing and street parking. However it is understood a large proportion of storm flows reach the area via Galway Avenue to the north and Kylemore Avenue to the south. These are both much wider with a lower density of larger housing. There could be opportunities to locate under-road storage alongside the kerblines here to cut off flows of water before they reach the high risk areas.

Figure 29 Galway Avenue

Figure 30 Kylemore Avenue

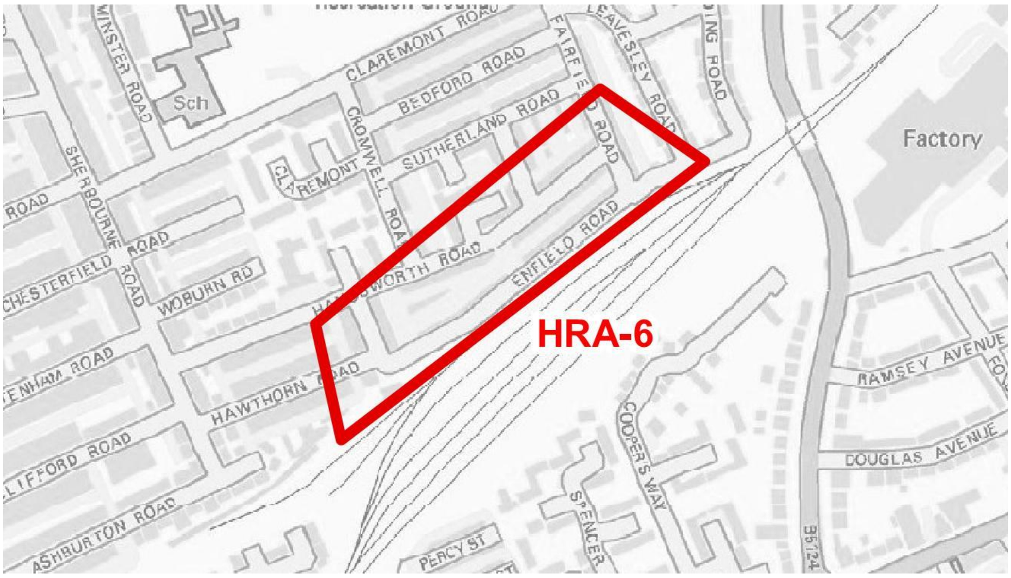
Further detailed level and flow surveys would be required to accurately locate these units to ensure they are effective.

9.4 Summary

- Provide underground storage under parking places on Galway Avenue and Kylemore Avenue.

10 Options for Location HRA-6

10.1 Description



The Enfield Road area is a dense Victorian urban area with terraced housing and narrow streets. The north side of Enfield Road is similar to this with thresholds close to road level. However the south side borders onto railway sidings along most of its length. This railway land is up to 2m above road level, there is a steep slope from the back of footway up to the railway land.

Figure 31 Enfield Road

The general profile of the area is gently falling towards Enfield road from the north west. There is a low-point in Enfield Road towards the southern end.

Figure 32 Enfield Road

10.2 Modelling Results

General flow routes from higher ground to the north via Cromwell Road and Fairfield Road, and from the west via Handsworth Road and Hawthorne Road. This water collects in Enfield Road as it is trapped by the embankment up to the railway.

10.3 Possible Strategies

Enfield Road is wide but does not appear to be particularly busy. There is potentially to significantly narrow it, particularly at the low point. This would allow the construction of some underground storage areas along the side adjacent to the railway land. A wider grassed verge will possibly a swale and filter strip could be provided to reduce the amount of impermeable surfacing and assist infiltration.

Figure 33 Enfield Road

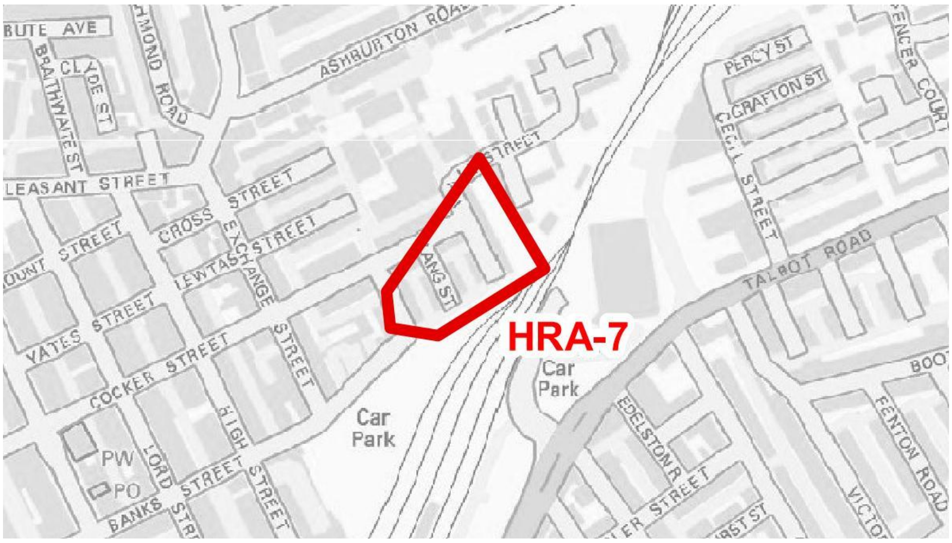
It is likely a significant proportion of the water collecting in Enfield Road originates from the railway land. This should be investigated further. If necessary, Network Rail should be asked to improve their drainage to minimise the storm water leaving their site.

10.4 Summary

- Storage under parking places on Enfield Road
- Reduce width of Enfield Road locally to provide surface storage swale/detention pond.

11 Options for Location HRA-7

11.1 Description



Wall Street, Lang Street and Howard Street are narrow Victorian terraced streets with on-street parking. They all fall in a south easterly direction. Bank Street falls from the west and turns into a wide alleyway which joins the southern ends of these three streets. To the south east of Banks Street and the alley, there is a mixture of land, some currently being redeveloped as a car park and the rest being railway land. This land is at a higher level than the streets to the north, there is a retaining wall (up to 1m in height) alongside this land.

Figure 34 Road at end of Lang Street

Figure 35 Wall Street

This alley forms the low point as all the roads to the north fall gently towards it, and the railway land lies above it to the south.

11.2 Modelling Results

Flow routes from the north via Wall Street and from the west via Cocker Street and Banks Street cause a build-up of water in this enclosed dip.

11.3 Possible Strategies

There is little space available to locate any flood storage infrastructure in the Howard Street, Lang Street and Wall Street areas. Depending on the ownership and proposed use of the current/former railway land to the south east, there is a possibility some infrastructure could be located here, although this would probably require land acquisition.

The only other option would be to try and intersect the water before it reached the problem area. Both Banks Street and Cocker Street have the potential for underground storage areas. On the railway land side of Banks Street, permeable block paving parking areas could be provided with storage underneath.

Figure 36 Bank Street

The same could be provided along the south side of Cocker Street

Figure 37 Cocker Street

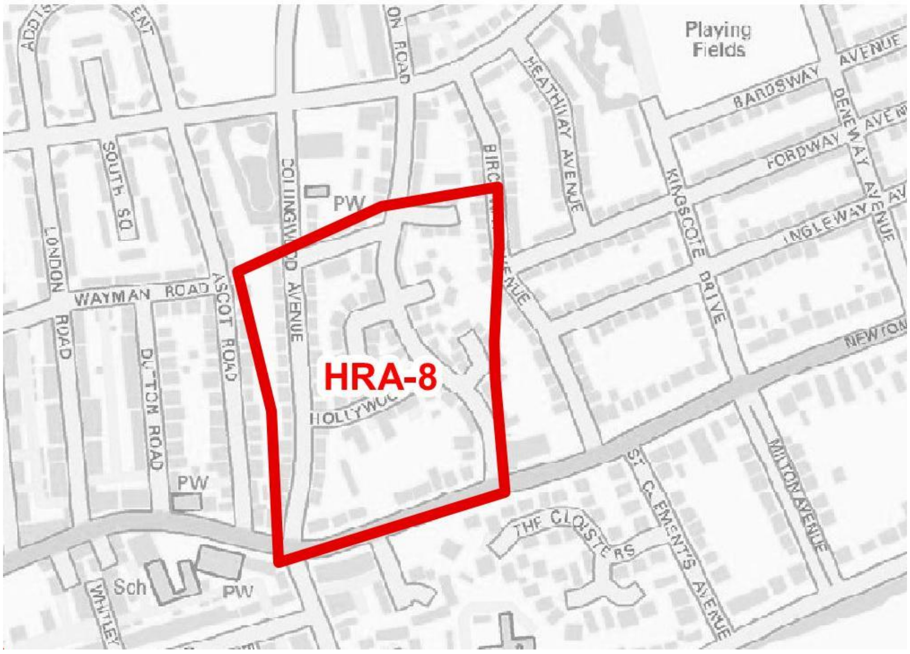
Further investigations would be required to determine the flow paths more accurately and establish the optimum locations for this storage.

11.4 Summary

- Underground storage under parking places in Bank Street and Cocker Street.

12 Options for Location HRA-8

12.1 Description



Collingwood Avenue is a late Victorian urban road with large semi-detached housing on both sides. The road is wide enough for two-way traffic plus road-side parking on both sides. It would appear to be fairly busy, being an important local traffic route. It falls gently to the northern end where there is a landscape area with trees, and a petrol station. Beyond the Caunce Street junction there is open grassland with sports pitches.

Figure 38 Collingwood Avenue, looking north

Either side of Collingwood Avenue, the land falls steeply towards it. Both sides are predominantly urban of a variety of types, but generally properties with small gardens fronting onto narrow roads.

12.2 Modelling Results

The main issue would appear to be the high velocity of storm water flowing down Collingwood Avenue. This water originates from the hillsides on both side of this road, flowing down side roads and through properties.

12.3 Possible Strategies

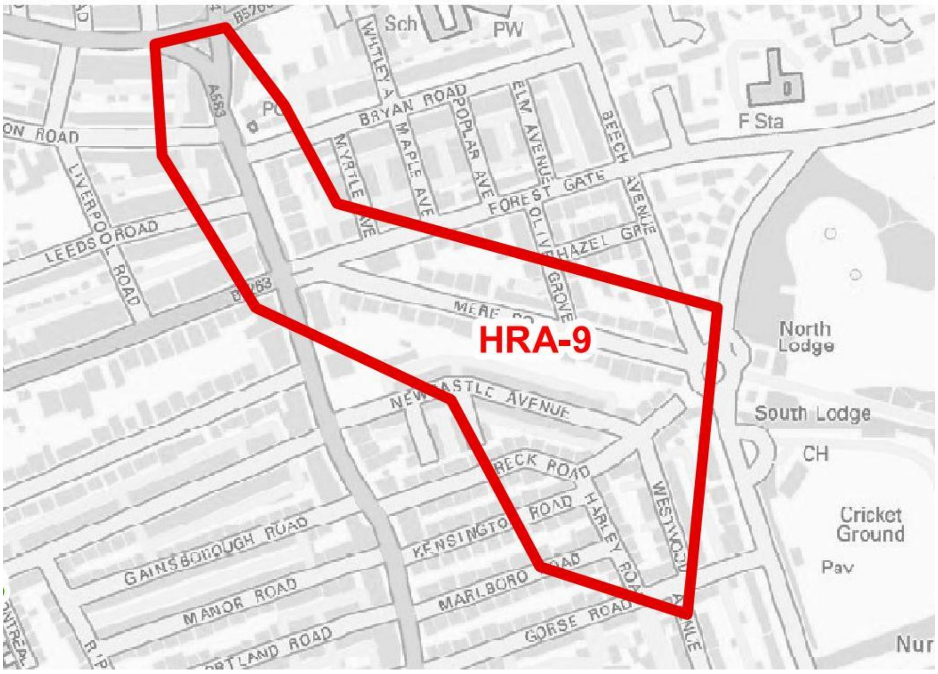
The sources of the water entering this area seem to be diverse and are from dense suburban areas with narrow roads. There seems little opportunity to intersect the water before it reached Collingwood Avenue. However there are possible modifications to Collingwood Avenue which could reduce the severity. Underground storage could be provided under the parking areas each side, with permeable paving used to capture the water. These could either be a series of small isolated units to collect and hold water, or they could be linked by pipes to form and underground means of conveyance to the relative safety of the open ground to the north.

12.4 Summary

- Underground storage under parking places on Collingwood Avenue, possibly linked by additional drainage .

13 Options for Location HRA-9

13.1 Description



This is a large area which incorporates three types of environment. To the north west, Whitegate Drive is a local commercial area, with shops and small businesses. The road is a busy local distributor road. The footways are wide with trees, lighting columns, signs and other street furniture. The road falls gently to the south.

Figure 39 Whitegate Drive at Famington Road junction

Mere Road is one of three roads which connect to Whitegate Drive at a single large junction. It is a wide straight road lined predominantly with large semi-detached houses dating from the early 20th century. It falls away from the Whitegate drive eastwards towards Stanley Park.

Figure 40 Mere Road, looking east

To the south of Mere Road there is a dense urban area comprising mainly late Victorian terraced housing and early 20th century semi-detached housing, The streets are generally narrow with on-street parking.

Figure 41 Newcastle Avenue

13.2 Modelling Results

The analysis shows significant flows of water entering Westgate Drive from Church Street, Leamington Road and Leeds Street to the west. This flows south and then east along Mere Road, causing flooding to adjacent properties. It collects in the low point in Mere Road and flows through the properties to cause flooding in Newcastle Avenue and Breck Road to the south. These roads also receive flows from the adjoining streets to the west.

13.3 Possible Strategies

There would appear to be little that can be done to contain the flows in Whitegate Drive. The busy nature of the road, the amount of street furniture and existing utilities are likely to make this location impractical.

Mere Road is a reasonably wide residential road with double yellow lines along one side. There is scope to provide storm water storage under parking areas. There are also small trees along both footways, so there is potential to install some form of tree-pit storage system. This should be distributed along the western part of Mere Road so that it would capture the storm flows before they reach the low-point, as well as at the low-point. Such provision would however need to be coordinated with property accesses and street parking requirements.

The potential flooding area extends to the residential streets to the south. Breck Road is reasonably wide and has the potential to be used for tree-pit or parking area storage.

Figure 42 Breck Road

There is a small landscape area on the corner of Breck Road and Newcastle Street, containing trees and shrubs. This could potentially be modified to provide underground storage plus limited surface storage. It is not located at the low point but could be useful in capturing flows of water before they reach the critical point on Newcastle Street.

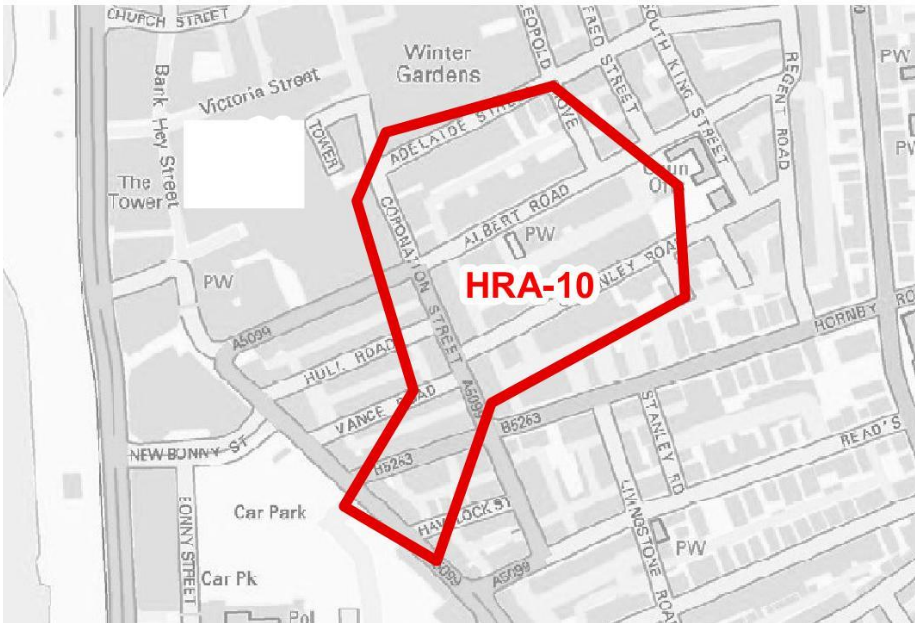

Figure 43 Landscaping on corner of Breck Road and Newcastle Avenue

13.4 Summary

- Underground storage under parking places on Mere Road and Breck Road
- Tree pit storage along Mere Road and Breck Road
- Underground storage under the landscape area on the corner of Breck Road and Newcastle Street.

14 Options for Location HRA-10

14.1 Description



This area is close to the centre of Blackpool, being just south of the Winter Gardens. Most of the buildings date from the 19th and early 20th century, being large former-residential properties. Most of these properties are now hotels and guest houses, with some commercial businesses at ground floor level.

The potential flooding occurs in small roads to the rear of the properties between Adelaide Street, Albert Road and Charnley Road. These roads generally fall in a westerly direction towards the sea-front. Parking restriction have been imposed to maintain an adequate two-way traffic flow, for Adelaide Street and Charnley Road restrictions are on both sides of the road, Albert Road is restricted on one side.

Figure 44 Adelaide Street

Figure 45 Albert Road

Figure 46 Charnley Road

The propertied affected on these roads all have basements to their front elevations. To the rear of these properties, these basements are at ground level, the roads to the rear being sunken down to provide access to these properties. Steeply sloping access-ways from the main roads provide access to these back-roads.

Figure 47 Access to rear of properties from Charnley Road

Figure 48 Rear of properties between Albert Road and Charnley Road

14.2 Modelling Results

The modelling indicated flows of storm water flowing down the roads form the higher ground to the east. The water is collecting in the lower back-roads to the rear of the properties between Adelaide Street, Albert Road and Charnley Road.

14.3 Possible Strategies

The back-roads form enclosed sunken areas below the general gradient of the surroundings. The roads are narrow with property accesses and parking on both sides. It is unlikely any form of storage could be feasible in these areas. The strategy most likely to reduce the impact or frequency of this flooding would be to capture surface water flows before they reach these areas.

Scope is limited on Charnley Road due to the narrow nature of the road and footways. However some planters have been placed down the footways. There is potential to improve this provision by providing tree pits with underground storage. Modifications to footway levels could be used to restrict flows entering the back-roads, but this would need to be carefully balanced by the provision of storage on the main roads to minimise the risk of passing the problem on to other areas.

Albert Road is wider with wider footways. Here there is the potential to provide underground storage on parking places and the use of tree-pit storage. This may be restricted by the requirement to maintain vehicle parking to the front of many of the properties. Again, footway levels could be modified to restrict water entering the back-roads, but this should be balanced by the provision of storage.

Some aesthetic improvement have been made to these areas, as they are busy tourist destinations further amendments could be beneficial. Storm water control systems could be installed as part of a wider strategy of area improvements.

14.4 Summary

- Tree pit storage along Charnley Street and Albert Street

- Modification to footway levels at the entrances to the back roads
- Underground storage under parking places on Albert Road

15 Options for Location HRA-11

15.1 Description

This area contains a variety of landforms.

To the north, Chapel Street passes under Seasiders Way. Adjacent to this there is an extensive area of paved car parking and access roads.

Figure 49 Chapel Street, looking towards Seasiders Way

To the south of Chapel Street, Kent Road is an established residential area comprising 19th century terraced housing.

To the west of Kent Road, there is a recently developed residential infill area up to the Seasiders Way embankment. This mainly comprises single story housing. with areas of grassed landscaping.

Figure 50 Middle Street

Chapel Street dips significantly under the Seasiders Way bridge. The surrounding area is generally flat.

15.2 Modelling Results

The modelling indicated two potential flooding areas. The first is flooding in the low point of Chapel Street under Seasiders Way. Flows into this area seem to be from the car parking to the north.

The second area of potential flooding is in the area between Kent Road and Seasiders Way. This generally seems to be the new development area around Louise Street and Middle Street. Flows into this area seem to be predominantly from the higher ground to the east.

15.3 Possible Strategies

There are two possible strategies, one for each side of the area.

Chapel Street forms an enclosed dip under the bridge. It is a busy road likely to contain many utilities. It is not thought to be practical to provide storage under the bridge structure. However it is highly likely much of the storm water flow will be from the car park areas to the north. There are extensive parking areas both sides of the Seasiders Way embankment. There is potential to provide permeable paving to these areas and use underground storage. There may also be scope to re-level the area to allow surface storage, but this may be limited due to the existing gradients adjacent to Chapel Street.

Figure 51 Chapel Street east of Seasiders Way

Figure 52 Chapel Street west of Seasiders Way

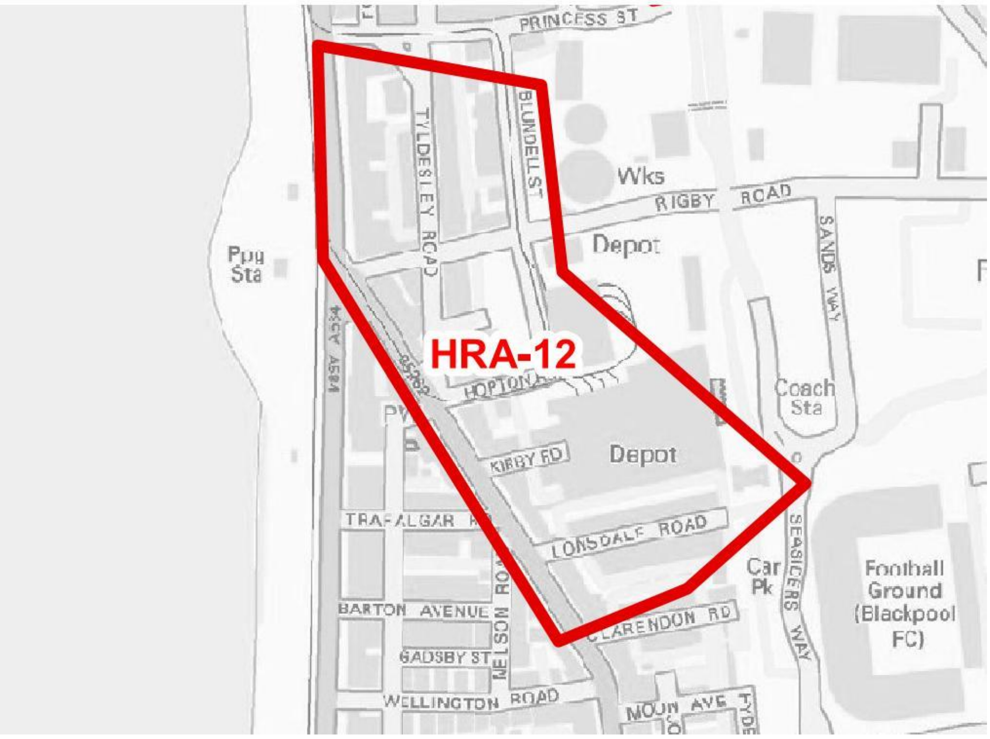
The Louise Street and Middle Street development contains large areas of grassed landscaping. These could be re-levelled to for surface storage. Areas of underground storage could also be provided. The roads serve only the development and are therefore reasonably quiet. Permeable paving and underground storage could be used under these roads.

15.4 Summary

- Large scale use of permeable paving and underground storage within the car parks at adjacent to Chapel Street.
- Modifications to landscaping areas in Louise Street and Middle Street to provide surface storage ponds/swales
- Underground storage under parking places in Louise Street and Middle Street.

16 Options for Location HRA-12

16.1 Description



This area is an established commercial and residential area of central Blackpool, set between the town centre and the Pleasure Beach. To the west there is the promenade and the sea front, to the east is Seasiders Way, the football ground and various industrial properties. The area dates originally from the 19th century with infill development from a variety of periods. The main roads are generally wide with high volumes of traffic. The side roads are much narrower.

The area is generally flat, but there is a slight general fall to the south.

16.2 Modelling Results

The analysis shows several small areas of flooding to the north of the area and larger areas to the south. Water flows are generally in a south direction along the main roads.

16.3 Possible Strategies

To the north it is difficult to define where the water is originating or where it is collecting. The dense urban environment, with high traffic use, does not lend itself to the use of storm water collection systems. Storage under parking areas could be provided, but it is difficult to identify where these should be positioned to be most effective. Further detailed analysis is required here.

For the areas to the south, it is easier to locate the potential problem. Lonsdale Road and Kirby Road have back-roads. The properties along these roads (predominantly hotels and guest houses) have basements on their front facades, the back-road giving access to the lower basement levels.

These back-roads are therefore sunken below the general ground level and potentially collect storm water.

Figure 53 Lonsdale Road

Figure 54 Access to rear of properties from Lonsdale Road


Figure 55 Rear of properties on Lonsdale Road

The back-roads are narrow and have many property accesses. It is impractical to provide storage within these areas.

The area could be better protected by amending the footway level at the entrances to reduce the surface water flowing in. However analysis is required to determine where this water would otherwise go, to minimise the risk of creating new flood problems elsewhere.

Possibly an effective strategy would be to try to trap the flood water before it gets to the potential problem area. The analysis indicates than much of the water originates from the north and flows down Lytham Road. This is a busy commercial road but it is wide with wide footways.

Figure 56 Lytham Road, looking south

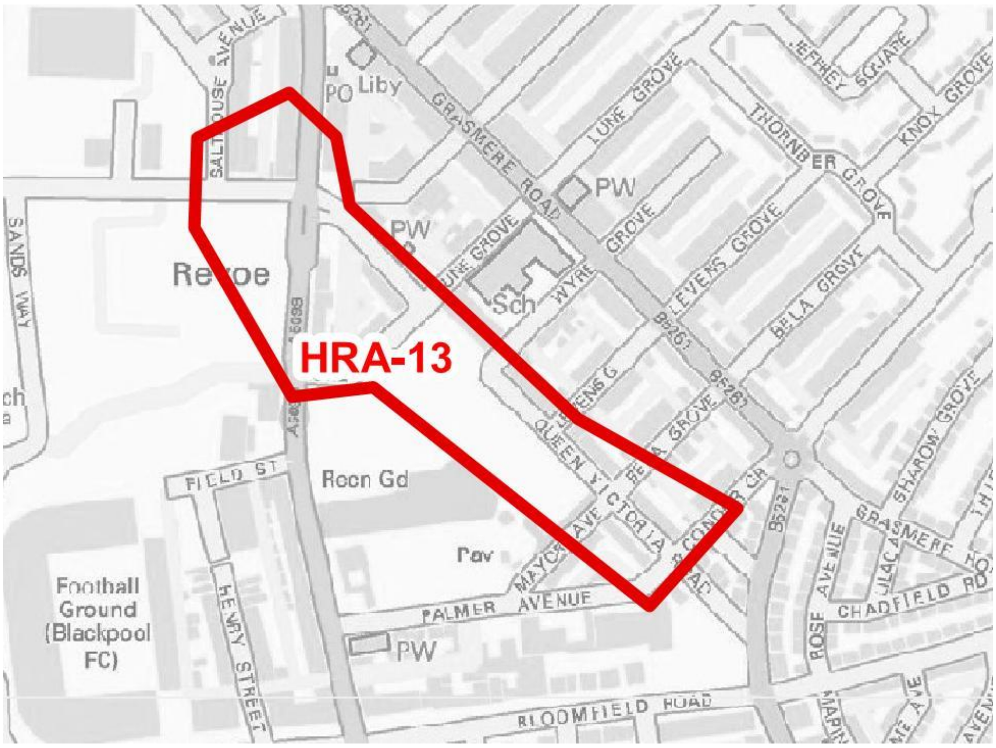
This road has the potential to contain some underground storage areas, possibly porous paving parking bays or similar. Storage within tree pits could also be used. These provisions could be included in a wider area regeneration project.

16.4 Summary

- Amend footway levels on Lonsdale Road and Kirby Road
- Provide underground storage under parking places and tree pit storage along Lytham Road

17 Options for Location HRA-13

17.1 Description



Queen Victoria Road is an established residential area, there is also a primary school. To the south west of this road there is a large recreation ground containing artificial sports pitches, a bowls green and an extensive area of grassed open space.

Figure 57 Recreation Ground from Queen Victoria Road

Figure 58 Recreation Ground from Queen Victoria Road

The area around the recreation ground is generally flat, the ground itself is slightly lower than the surroundings. To the north east the ground slopes towards the recreation ground.

17.2 Modelling Results

The analysis indicates extensive flooding in the recreation ground, extending either way along Queen Victoria Road. The water originates from a series of roads falling towards the ground from the north east.

17.3 Possible Strategies

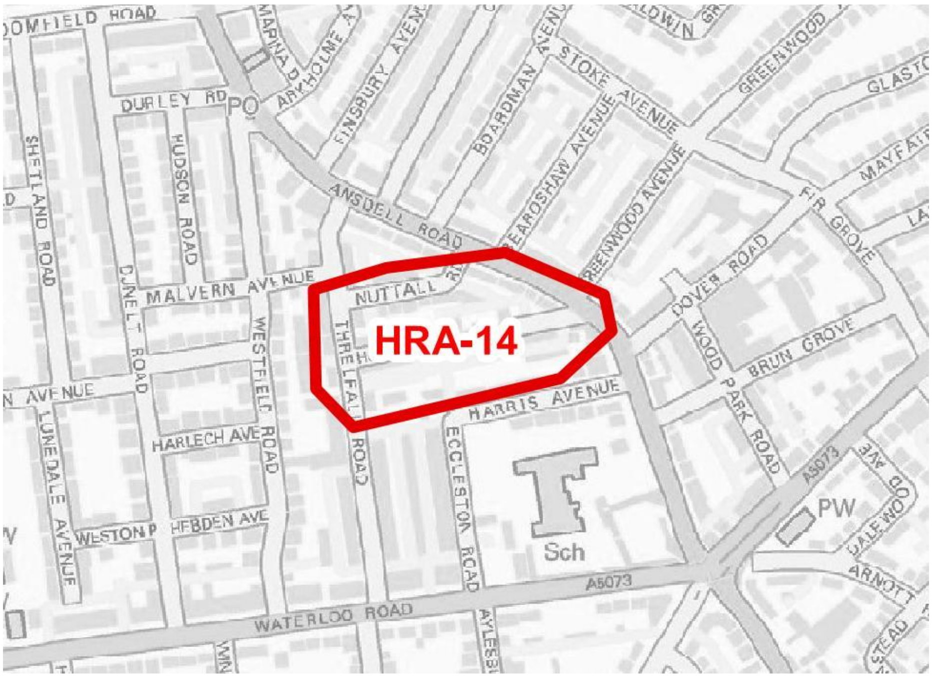
There is plenty of potential to increase storage within the recreation ground. The artificial pitches alongside Queen Victoria Road could be lowered, porous paving with underground storage could be provided beneath. Similar systems could be used on the other pitches and the play area. The park could be re-graded to provide sunken areas to store more storm water. Minor remodelling of the edges of the ground and the adjacent roads could increase flows to the ground and reduce flooding risk in the surroundings.

17.4 Summary

- Modifications to ground profile within recreation ground to increase the storm water storage
- Storage under sports pitches
- Improve flood routing from surrounding areas into recreation ground storage areas.

18 Options for Location HRA-14

18.1 Description



This area is an established residential area dating from the early 20th century. Ansdell Road is a busy main road with some commercial properties, and is generally wider than the surrounding roads. To the south the area is densely urban with narrow roads and many property entrances. Within this urban area there is a more modern infill apartment development (Dunsop Court), access to this is by Hodder Avenue for the west and Dunsop Close from the east.

Figure 59 Hodder Avenue from Threlfall Road

Figure 60 Dunsop Avenue looking towards Dunsop Court

The ground levels generally fall in a southern direction towards a low point at the Dunsop Close apartments.

18.2 Modelling Results

The analysis shows a large potential area of flooding in the area of the Dunsop Court apartments. Most of the water appears to originate from the higher ground to the north east, flowing across Ansdell Road and into Dunsop Court via the surrounding side roads.

18.3 Possible Strategies

To the west side of Dunsop Court, at the end of Hodder Avenue, there is a turning head, parking area and some landscaping. There is potential for this area to be re-levelled to provide surface storm water storage. Porous paving could be used with underground storage to contain flood water.

Figure 61 Hodder Avenue, turning head at Dunsop Court

Other than this there appears to be very little appropriate land around Dunsop Court to provide storage. An alternative solution may be to trap the storm water flowing from the north east before it reaches Dunsop Court. The surrounding side roads and narrow and densely urban. However there are wider areas of footway on Ansdell Road, and the road itself is reasonably wide. There is the potential to provide underground storage within the footways or under designated parking areas to intersect flows of storm water. These locations will have to be identified carefully for them to be affective.

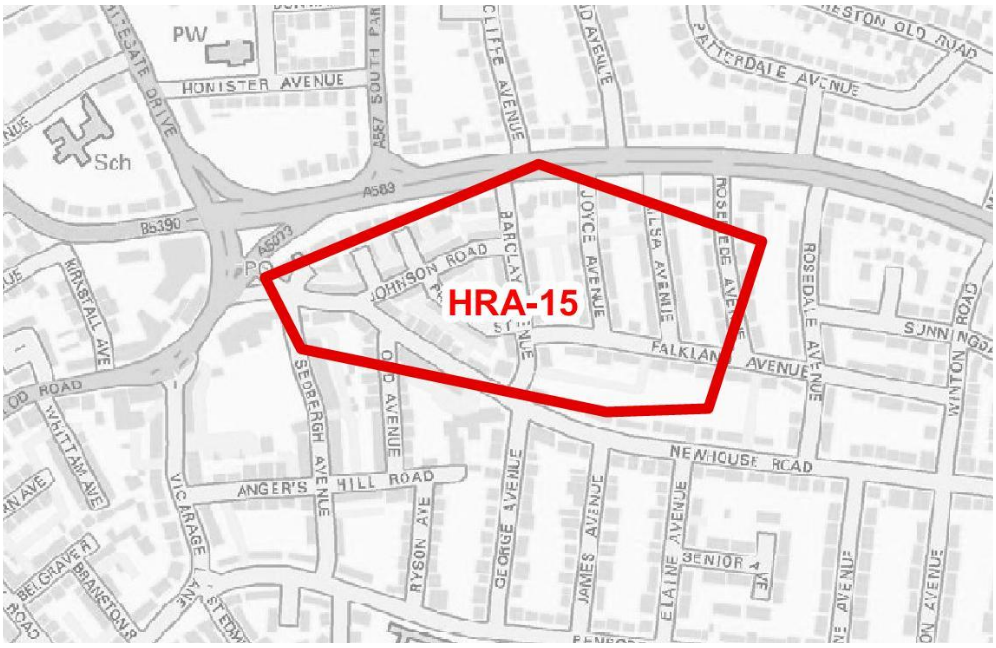
Figure 62 Ansdell Road

18.4 Summary

- Underground storage under parking places and landscaping at the end of Hodder Avenue
- Underground storage under footways and new parking areas within Ansdell Road.

19 Options for Location HRA-15

19.1 Description



This area is predominantly a residential area. In the west the housing around Johnson Road is generally late 19th century terraced.

Figure 63 Johnson Road

To the east the housing around Falkland Avenue is early 20th century semi-detached and short terraces of four properties.

Figure 64 Falkland Avenue

The area is generally flat but it is at the bottom end of a south facing hill. The roads to the north of Preston New Road (which runs parallel and to the north of both Johnson Road and Falkland Street) rise up significantly.

It should be noted there are visible signs of severe ground settlement along Falkland Avenue, both in the road profile and to the housing.

19.2 Modelling Results

The analysis indicated significant flooding along Johnson Road and Falkland Street, also on the roads between Falkland Street and Preston New Road. The main source of the water is from the higher ground to the north.

19.3 Possible Strategies

Johnson Road is narrow with many property entrances. There is little opportunity to provide storage.

Falkland Avenue and the adjoining avenues are wider, but are also densely urban with many property entrances. There is some scope to provide underground storage under parking places along this road. However the main issue with providing flood mitigation measures here is the ground settlement. This may be indicative of groundwater issues in the area. This should be investigated further before any recommendation can be made.

The land to the north falls steeply down to Preston New Road, the gradients are more gentle from this to Falkland Avenue. Flood water s are likely to cross Preston New Road on their way to Falkland Avenue. Preston New Road has wide grassed verges on both sides.

Figure 65 Preston New Road

Figure 66 Preston New Road

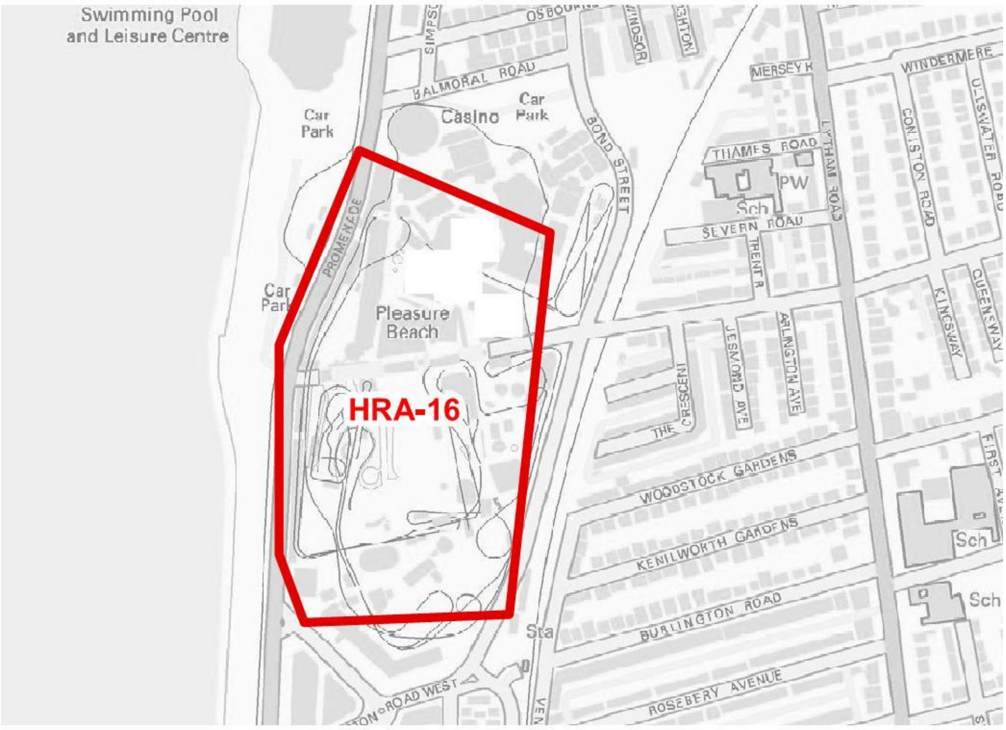
It is possible underground storage units could be provided along these verges, positioned carefully to intersect the flows of water crossing the road from the roads to the north. This may help to reduce the frequency and severity of flooding in the roads and avenues to the south.

19.4 Summary

- Underground storage under parking places in Falkland Avenue, subject to further assessment of ground conditions
- Underground storage under the verges and footways on Preston New Road.

20 Options for Location HRA-16

20.1 Description



This area is Blackpool Pleasure Beach. The surroundings are fairly flat. The Pleasure Beach site has various changes in levels. Some areas have been lowered to accommodate the infrastructure on site.

20.2 Modelling Results

The analysis shows a number of small areas within the Pleasure Beach site becoming flooded. It is not clear where this water originates from.

20.3 Possible Strategies

It is assumed the site is privately owned. It is also assumed the lower areas have been provided for the purpose of providing the on-site infrastructure. It would therefore follow that the Pleasure Beach owners should carry out their own assessment of the risks and consequences of potential flooding and provide their own strategy where necessary.

Where the flood risk is considered unacceptable, strategies could include the use of underground storage, such as geocellular units, with permeable paving.