JBA consulting

Dartford Surface Water Management Plan

Stage 2

Final Report

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Kent County Council
County Hall
MAIDSTONE
Kent
ME14 1XQ

Kent County Council kent.gov.uk

JBA Project Manager

Jack Southon
35 Perrymount Road
Haywards Heath
RH16 3BW

Revision History

Revision Ref / Date Issued	Amendments	Issued to
V 1 June 2014	n/a	Max Tant, KCC
V 2 August 2014	Address comments from MT	Project steering group
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V 4 November 2015	Address comments from MT	Max Tant, KCC
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Contract

This report describes work commissioned by Max Tant, on behalf of Kent County Council, by an email dated 11th November 2013. Jennifer Hill of JBA Consulting carried out this work.

Prepared by ....Jennifer Hill BSc MSc

Analyst

Reviewed by ....Paul Eccleston BA CertWEM CEnv MCIWEM C.WEM

Technical Director

Purpose

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Acknowledgements

We would like to acknowledge and thank Kent County Council, Dartford Borough Council, Thames Water Utilities Limited and the Environment Agency for their assistance during this project.

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Executive Summary

A Stage 1 Surface Water Management Plan (SWMP) for Kent Thameside was commissioned after the Preliminary Flood Risk Assessment (PFRA) for Kent found the settlements of Gravesend and Dartford ranked second and third most at risk in the county. The Stage 1 SWMP for Thameside found that the predicted flood risk in Dartford is supported by a history of flooding. A common source of the flooding was found to be highway flooding from exceeded drains.

This Stage 2 SWMP, focussing specifically on Dartford, was commissioned in 2013 as a detailed assessment of local flood risk, following Defra (2010) guidance. The aim of this study was to provide a detailed understanding of the causes and consequences of surface water flooding and to test the benefits and costs of mitigation measures.

Understanding the causes of surface water flooding was achieved by;

- updating the flood history to include recent incidents and understanding the source and pathway of the flooding; and
- creating an integrated model of flood risk and analysing the results to understand the flood mechanisms.

Understanding the consequence of the flooding was achieved by;

- understanding the receptor of recorded flood incidents;
- counting the dwellings and critical infrastructure predicted to flood; and
- calculating the economic damages of predicted flooding to dwellings and critical infrastructure.

Hotspots were defined as areas with repeated flood history or predicted risk from the Integrated Urban Drainage Model and the updated Flood Map for Surface Water. The hotspot areas in Dartford were: Stone, Hawley Road, Riverside Industrial Park, Windsor Drive, Greenhithe and Bow Arrow. Riverside Industrial Estate was considered the highest priority of the hotspots

Flooding hotspots have defined relative to Dartford, as opposed to considering flood prone areas in Kent as a whole. The flood risk in the Dartford hotspots can generally be characterised as localised surface water flooding. Often the reported flood receptor is a highway, and there are few incidents of internal flooding that have been recorded. Highways are considered to be a lower value receptor, as the damages are less than flooding to a property. Therefore, the relative priority of these hotspots on a county wide scale is likely to be low.

Suitable mitigation measures were discussed by the Dartford steering group and opportunities to apply them were assessed using model results at a site visit. The site visit also identified potential restrictions to the mitigation measures. In particular, the application of street level measures such as rain gardens and swales were limited by; parked cars, existing utilities and narrow roads or paths. However, areas where property level and area level options had been suggested were less limited.

The relative effectiveness was then calculated using the model. The flood mitigation measure was modelled and the results from the scenario and the baseline were then contrasted. The indicative construction and maintenance costs were estimated using the SUDS Manual and the benefits of the mitigation measure were estimated from the scenario results.

The options appraised during the SWMP were reported back to the Steering Group at this meeting, and the options were prioritised according to where the evidence base shows recorded flooding and the model results show a risk of flooding. The actions resulting from the Stage 2 SWMP have been classified as short term or long term, indicating what are quickly achievable and should be taken immediately and what will be ongoing following this project.

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Abbreviations

CfSH ..... Code for Sustainable Homes
DA ..... Drainage Area
DBC ..... Dartford Borough Council
DTM ..... Digital Terrain Model
EA ..... Environment Agency
GAP ..... Generic Action Plan
GPZ ..... Groundwater Protection Zone
IDB ..... Internal Drainage Board
KCC ..... Kent County Council
LLFA ..... Lead Local Flood Authority
LSAP ..... Location Specific Action Plan
NPPF ..... National Planning Policy Framework
NRD ..... National Receptors Database
PRoW ..... Public Right of Way
RMA ..... Risk Management Authority
SFRA ..... Strategic Flood Risk Assessment
SHLAA ..... Strategic Housing Land Availability Assessment
SPZ ..... Source Protection Zones
SuDS ..... Sustainable Drainage Systems
SWMP ..... Surface Water Management Plan
TW ..... Thames Water Utilities Ltd.

1 Introduction

1.1 What is a Surface Water Management Plan

A Surface Water Management Plan (SWMP) is a study to understand the flood risks that arises from local flooding, which is defined by the Flood and Water Management Act 2010 as flooding from risk from surface runoff, groundwater, and ordinary watercourses.

SWMPs are led by a partnership of flood risk management authorities who have responsibilities for aspects of local flooding, including the County Council, Local Authority, Sewerage Undertaker and other relevant authorities.

The purpose of a SWMP is to identify what the local flood risk issues are, what options there may be to prevent them or the damage they cause and who should take these options forward. This is presented in an Action Plan that the partners agree.

Kent County Council (KCC) often takes a two stage approach to SWMPs. Initially, a Stage 1 SWMP is undertaken which collects all the available flood risk and flood history data in the catchment. Where this process identifies a flood prone area a Stage 2 SWMP can be required to make a more detailed assessment of flood risk and focus the resulting action plan of flood mitigation measures.

1.2 Stage 1 SWMP: key findings

In 2011, Kent County Council undertook a Preliminary Flood Risk Assessment[1] for the whole county of Kent. This included a ranking of settlements by the number of dwellings at risk from deep surface water flooding at a 1 in 200-year event. This analysis showed Gravesend and Dartford in the Thameside region ranked second and third most at risk settlements in the county. As a result, Kent County Council in partnership with the Environment Agency, Dartford Borough Council, Gravesham Borough Council, Sevenoaks Borough Council, Southern Water and Thames Water Utilities Limited have prepared a Stage 1 SWMP to investigate the local flood risks[2] to Thameside.

The Thameside SWMP study area was subdivided into Drainage Areas to allow more in depth analysis. A list of all the drainage areas in the Thameside SWMP is available in Table 1-1.

Table 1-1 Thameside Stage 1 SWMP Drainage Areas

Drainage Area	Location
DA01	Dartford Town
DA02	Gravesend
DA03	Gravesham Rural
DA04	Swanley and Hextable Towns
DA05	Sevenoaks Rural North
DA06	Dartford Rural

The area of the Dartford Stage 2 Surface Water management plan falls within DA01, Dartford Town. As a result of the findings of the Stage 1 SWMP certain areas have been highlighted as being high risk. A recommended action was a further, detailed SWMPs to be completed in Dartford, Swanscombe and Gravesend.

1.3 Stage 2 SWMP: drivers

The preparation of a Stage 2 SWMP was driven in response to the following primary considerations:

- The need to manage local flood risk as a consequence of assessments performed under the Flood Risk Regulations, 2009 or the Flood and Water Management Act 2010;
- The need to inform spatial planning and development control, develop a strategy for flood risk management, and provide evidence that future new development can be implemented and local flood risk safely managed; and

[1] KCC (2011) Preliminary Flood Risk Assessment. [online] Available at: http://cdn.environment-agency.gov.uk/flho1211bvsi-e-e.pdf [Accessed: 25 Mar 2014].

[2] KCC (2012) Thameside Surface Water Management Plan. [online] Available at: http://www.kent.gov.uk/environment_and_planning/flood_risk_management/how_we_manage_flood_risk/surface_water_management/thameside_swmp.aspx [Accessed: 25 Mar 2014].

- The need to build on the understanding of high risk areas highlighted within the Stage 1 SWMP and to develop feasible options for improving local flood risk within known hot spot areas. We note that options development and associated costing of preferred options should look to identify investment opportunities. Consideration will be given to mobilising capital, and routes that could be explored include redevelopment areas, and / or appropriate links to other capital investment programmes proposed by Kent County Council, Dartford Borough Council, Thames Water Utilities Ltd., the Environment Agency and others.

The Flood Risk Management drivers must not be forgotten. In preparing the SWMP it will be important to present evidence that also demonstrates that the SWMP is consistent with the Local Flood Risk Management Strategy[3] that has been prepared by the KCC, as the Lead Local Flood Authority.

1.4 Study objectives

The objectives of the Dartford Stage 2 SWMP as set out in the scope of work are:

1. The establishment of a local partnership as a steering group;
2. The collation and mapping of a comprehensive flood history for all relevant local flood risk sources which may include collecting data from residents of Dartford;
3. The preparation of source pathway receptor models for all the risks and sources that are identified;
4. The preparation of a hydrodynamic flood model in an appropriate modelling package, which should include:
    a. All appropriate local water infrastructure, e.g. surface water sewers, combined sewers, ordinary watercourses, the sea and any other controls
    b. Collation of the modelling with any monitoring data and recorded events
    c. Sensitivity analysis of the model's performance
5. The predicted flooding, including depth, velocity and hazard, to the town from the 1 in 2, 5, 20, 30, 75, 100, 100 +CC and 200 events for the three storm durations to be determined;
6. Determine the areas at risk of flooding, as identified by the model and historic flooding data, including allocated sites;
7. Identification of the causes of flooding and/or constraints to drainage;
8. Using the model outputs to estimate the economic impact of flooding to the town and to assess mitigation options for the flood risk identified;
9. A clear plan for further work that may be necessary to manage or better understand the risks identified, including the owner of the action, the timeframe for undertaking them and indicative costs; and
10. Public engagement on finding of the SWMP and proposed action plan.

All actions and further work proposed by the SWMP should be agreed by the project steering group and the proposed owner of the action prior to the end of the project.

1.5 Study area

The Stage 2 SWMP focuses on the town of Dartford within the Dartford Borough. This area (shown in Figure 1-1) spans north of the A2 to the River Thames and east of the county boundary to the B255.

[3] KCC (2013) Local flood risk management strategy. [online] Available at: http://www.kent.gov.uk/environment_and_planning/flood_risk_management/how_we_manage_flood_risk/local_strategy.aspx [Accessed: 25 Mar 2014].

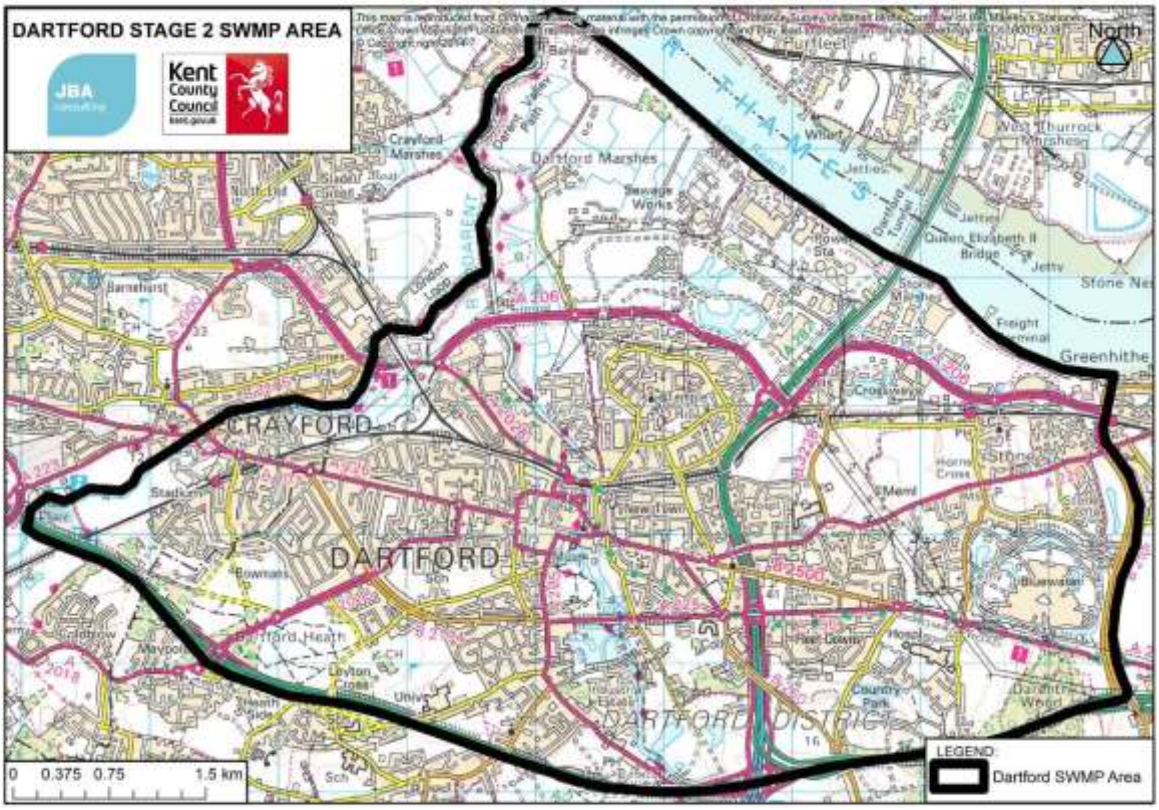

Figure 1-1 Dartford Stage 2 SWMP study area

1.6 Using this report

Use Table 1-2 to find the information that you need.

Table 1-2 Report layout

Section	Description of contents
1. Introduction	This section defines objectives of the Stage 2 SWMP and describes the background of the study area.
2. Partnership and Communications	This section provides a summary of the key partners and the consultation and engagement that accompanied the development of the SWMP.
3. Risk Assessment	Briefly describes the process followed to assess flood risk, and identifies the risk at hotspots within the study area.
4. Options	Describes the assessment of options to manage and reduce flood risk, including cost-benefit analysis.
5. SWMP Action Plan	Provides details of the generic and location specific Action Plan and potential funding opportunities.

2 Partnership and Communications

2.1 Partnership approach

Surface water cannot be managed by a single authority, organisation or partner; all the key organisations and decision-makers must work together to plan and act to manage surface water across Dartford. Many organisations have rights and responsibilities for management of surface water. Although Kent County Council commissioned this project, the key partners have been consulted at appropriate stages in the study. Working in partnership encourages co-operation between different agencies and enables all parties to make informed decisions and agree the most cost effective way of managing surface water flood risk across Dartford in the long term. The partnership process is also designed to encourage the development of innovative solutions and practices and improve understanding of surface water flooding.

2.1.1 Key partners

Partners are defined as organisations with responsibility for the decision or actions that need to be taken to manage surface water flooding. The key partners involved in this project are listed in

Table 2-1 Partners involved in the Dartford SWMP

Partner Organisation	Representative(s)
Kent County Council (Flood Risk Management)	Max Tant Joe Williamson
Kent County Council (Highways)	Kathryn Lewis Jamie Finch
Dartford Borough Council (Planning Policy)	Melissa Cooper Tania Smith
Dartford Borough Council (Emergency Planning)	Andy Nicholls
Thames Water Utilities Ltd	David Harding Dagmara Janicka
Environment Agency	Mike Wilkinson

During the period between the Thameside Stage 1 SWMP and the Dartford Stage 2 SWMP, some of the key contacts within the partner organisations had left. However, new contacts were formed based on the legacy of the partnerships formed during Stage 1.

2.2 The Communications and Engagement Plan

A Communications and Engagement Plan (CEP) was developed and maintained to;

- Illustrate internally and externally the importance of communicating honestly and transparently with our delivery partners, stakeholders and communities;
- Support the project team in spending time and resources wisely, informing and involving the right people about the right things, at the right time; and
- Act as an overarching umbrella plan which ensures co-ordination between stakeholder engagement activities, media communications, internal/external communications, external funding and stakeholder support, other consultations.

The full Communications and Engagement Plan is provided in Appendix B.

2.3 Communications

A letter was sent to residents of the hotspot areas. This letter was designed to inform the residents that the SWMP was ongoing and that their involvement was encouraged. The letter invited them to contribute to an online questionnaire to confirm if flooding had been experienced in the area. This confirmation or denial of flooding could then be used by Kent County Council to prioritise action based on areas of greatest impact.

Table 2-2: Public responses to the questionnaire

Street	Hotspot	Period of residency	Experienced flooding?
Evans Close	Greenhithe	13 years	No
Priory Road	Riverside	2 years	Yes
Priory Road	Riverside	14 years	Yes
Lingfield Avenue (same IP address)	Bow Arrow	28 years 7 months	Yes
Lingfield Avenue (same IP address)	Bow Arrow	28 years 7 months	No
Evans Close	Greenhithe	2 years	No
Windsor Drive	Windsor Drive	32 years	Yes
Windsor Drive	Windsor Drive	36 years	No

Although the responses to the questionnaire are not extensive, the answers do tally up with the data collected by Kent County Council Highways.

The two respondents from Priory Road both report flooding. One of the residents has only been in the property two years, and has witnessed flooding in that time. The other resident reports that water damage has led to damage of their garage which is at the end of their garden.

Of the two respondents of Windsor Drive, only one has experienced flooding during their residency. They report that their property is located at a low point on the road. They have experienced surface water flooding during heavy rainfall on three incidents in 32 years. The flood water has affected both the back and front garden but they have not experienced internal flooding.

The response from Lingfield Avenue is confused as the same resident has submitted two conflicting answers. It has been assumed that the first response was in error and the second response was the intended answer. This is supported by Kent County Council Highways data, which has not recorded flooding at Lingfield Avenue.

The only respondent from the Greenhithe Hotspot was a resident of Evans Close. They reported that they have not experienced flooding in the last 13 years.

Where flooding had been observed, the reporter was directed to Kent County Council's online flood report tool. This form requested more information on the source, location and duration of the flood event, the response of which is sent directly to Kent County Council. However, KCC report that none of the residents who witnessed flooding chose to complete this form.

2.4 Partnership meetings and engagement events

The meetings that have taken place as part of Stage 2 Dartford SWMP are listed in Table 2-3.

Table 2-3: Partnership meetings

Meeting	Date	Purpose	Attendees
Start-up meeting	22/11/2013	Confirm project steering group. Review and agree the scope for Stage 2 and agree data provision	KCC and JBA
Stakeholder meeting	18/03/2014	Introduce project partners to the SWMP process, discuss flooding hotspots and suggest suitable options	KCC, DBC, TW, EA and JBA
Site visit	18/03/2014	Ground truth suggested options and identify potential constraints	JBA
Options workshop	09/06/2014	Prioritise actions and assign actions owners.	JBA, DBC, TW, EA KCC

3 Risk Assessment

3.1 Levels of assessment

The Thameside Stage 1 SWMP highlighted the drainage area covering Dartford as having a significant history of flooding, particularly on the highways. Therefore, in line with the Defra guidance[4], a **detailed assessment** has been undertaken for this Stage 2 SWMP. This level of assessment aims to provide a detailed understanding of the causes and consequences of surface water flooding, and to test the benefits and costs of mitigation measures. This will be achieved through the modelling of surface and sub-surface drainage systems. The results of the detailed analyses have then been used to prepare an action plan.

The risk assessment carried out used the Source > Pathway > Receptor approach:

- Source - the origin of flood water
- Pathway - a route or means by which a receptor can be affected by flooding
- Receptor - something that can be adversely affected by flooding

Having applied the Source-Pathway-Receptor model it is possible mitigate the flood risk by addressing the source (often very difficult), block or alter the pathway and even remove the receptor e.g. steer development away.

3.2 Catchment characteristics

Both the natural and built environment impacts the risk of flooding from local sources. This section characterises the catchment including the fluvial network, geology and drainage network from urban areas.

3.2.1 Physical features

Dartford is bound by the River Thames to the north, the River Cray to the west and the River Darent flows through the centre of the town. Each of these watercourses has been classified as Main River and falls under the jurisdiction of the Environment Agency. In addition, the area surrounding the confluence of the River Darent and River Thames is Dartford Marshes. Some of these marsh drains are classified as Ordinary Watercourses and are the responsibility of Kent County Council as Lead Local Flood Authority. The watercourses within Dartford have been highlighted in Figure 3-1**Error! Reference source not found.**. Main Rivers are shown in dark blue whereas the Ordinary Watercourses are in green.

[4] Defra (2010) Surface Water Management Plan Technical Guidance. Defra: London

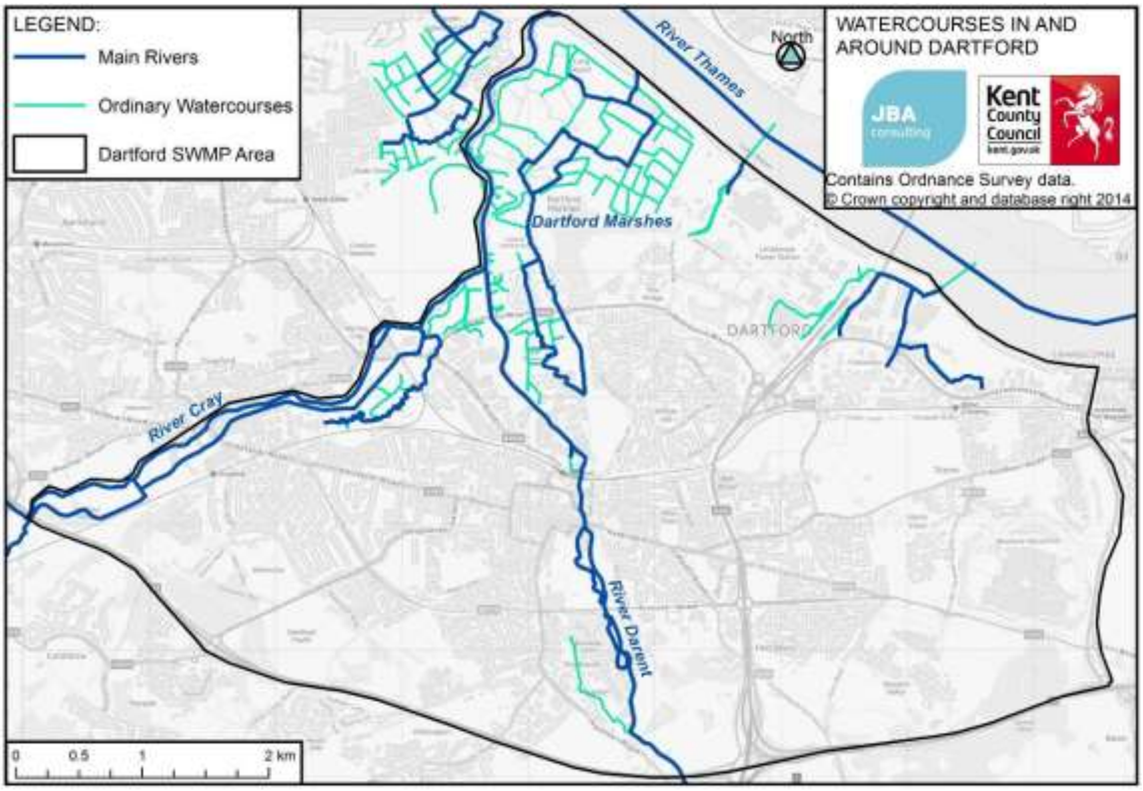

Figure 3-1 Dartford watercourses

Dartford is a predominately underlain by chalk and sand. Periodic flood events throughout geological time have facilitated the deposition of alluvial superficial deposits, which overlay most of the catchment. The distribution of bed rock and superficial deposits is shown in Figure 3-2.

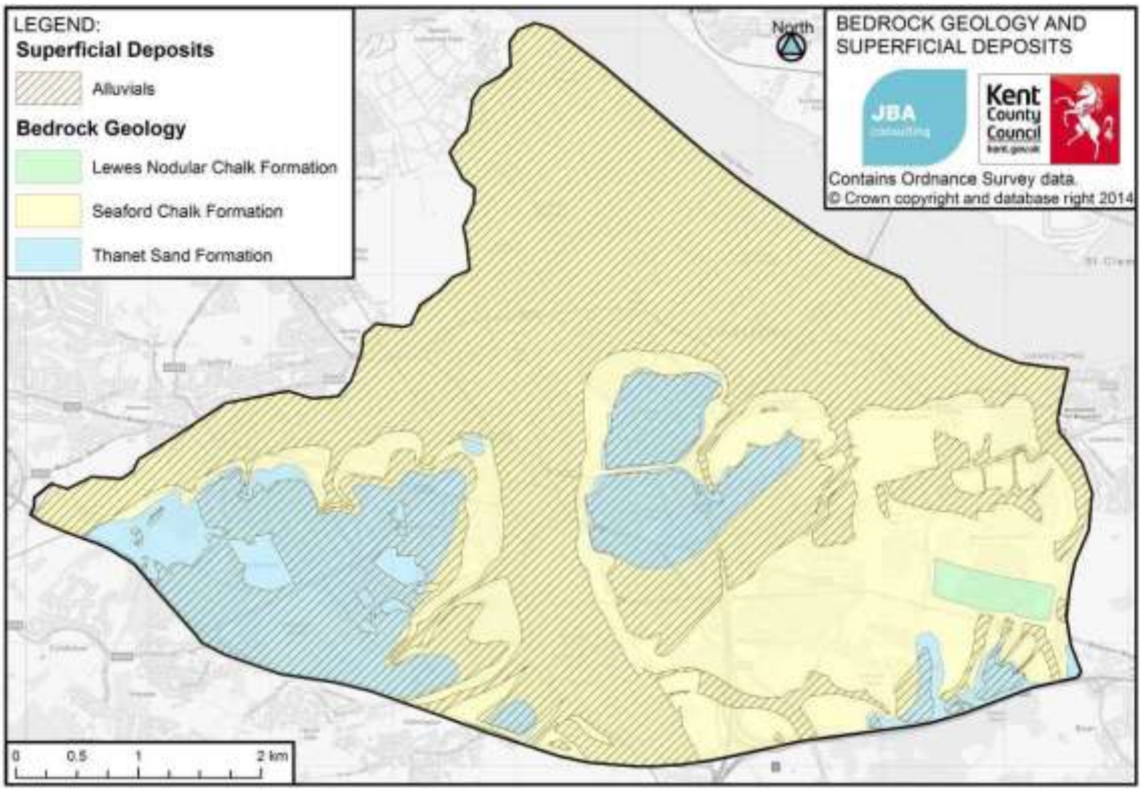

Figure 3-2 Dartford geology

Chalk is a porous geology, meaning water can be conveyed through the pores and fissures in the rock. Therefore, the rate of infiltration from chalk can be rapid. In unpaved areas of chalk, runoff rate is low as surface water infiltrates to the sub-surface.

The ground elevation varies dramatically across the SWMP area. The River Darent has carved a valley through Dartford and meets the River Thames at 1 mAOD. Chalk hills in the south east and south west of the study area rise to 75 m AOD. In addition, a history of chalk mining has left a legacy of steep escarpments. These steep slopes encourage runoff as water moves on the surface under gravity quicker than the rate of infiltration.

3.2.2 Land use

Dartford town is an urban area and plans for the area involve growth and regeneration. The land use is predominately residential but with significant areas of commercial and industrial land use. Within the town there are also areas of green space as parks and school playing fields.

3.2.3 Urban drainage

Dartford operates a largely separate sewerage system, with a sewer network solely for draining surface water.

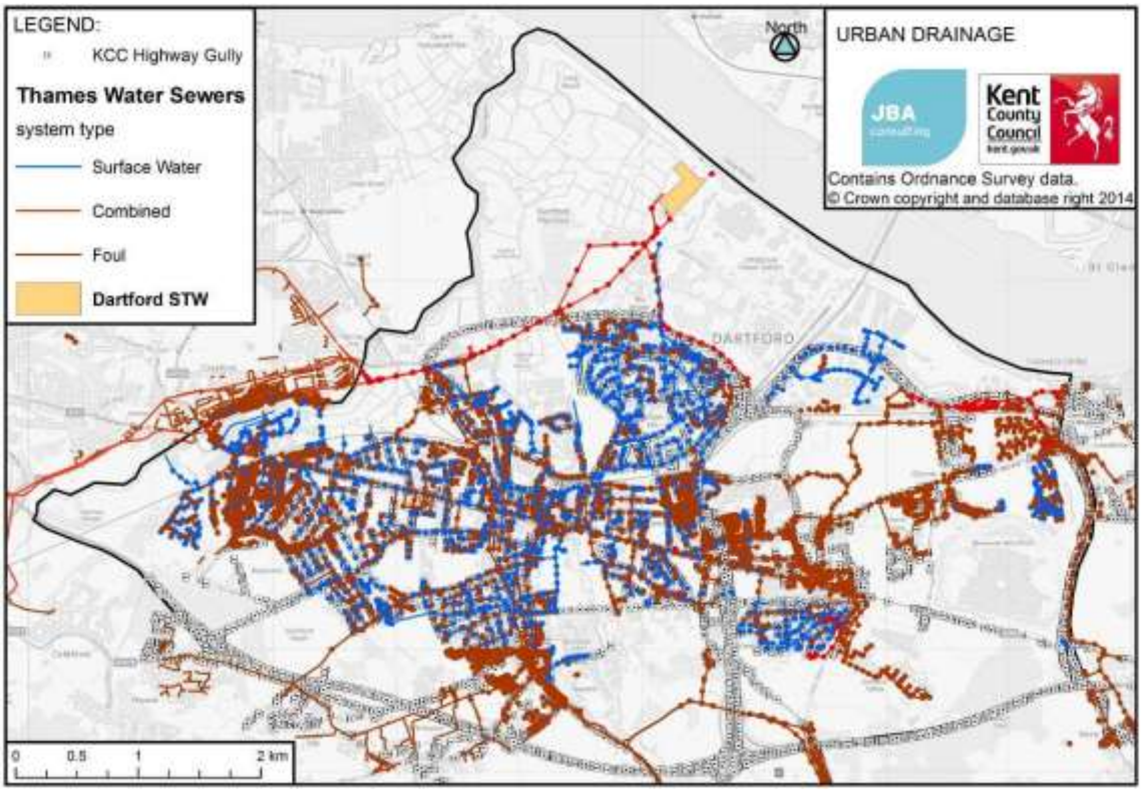

Figure 3-3 Dartford urban drainage network

In Figure 3-3 the urban drainage network has been divided into foul (brown), combined (red) and surface water (blue) sewers and highway drainage (illustrated in Figure 3-3). Dartford is predominately served by separate foul and surface water systems. However, there is also a combined trunk sewer cutting through the north of the study area to Dartford Sewage Treatment Works (STW). There are areas of Dartford, particularly in the east of the study area where Thames Water do not operate a surface water drainage network. Here, the urban areas are drained to soakaways.

Highway drainage exists across Dartford, operated by Kent County Council. For the purposes of this study it has been assumed that the highway gullies drain to a Thames Water surface water sewer when one is available. Otherwise the highways drain to soakaway. This assumption was, where possible, tested and verified when on site.

3.3 Flood history

The recorded flood history in Dartford indicate that the flood mechanisms operating within the town are; groundwater emergence, following periods of prolonged rain, over land flow during intense rainfall and sewer exceedance during intense and prolonged rainfall.

The Stage 1 SWMP for Thameside collated data on incidents of historical flooding from each Risk Management Authority. The records begin in 1953 and extend to the date of collection in 2011. During this study, these flood incident records have been updated to 2013. A summary of flood incident source and location is shown in Figure 3-4. For a more complete discussion of flood history in Dartford, please see Thameside SWMP.

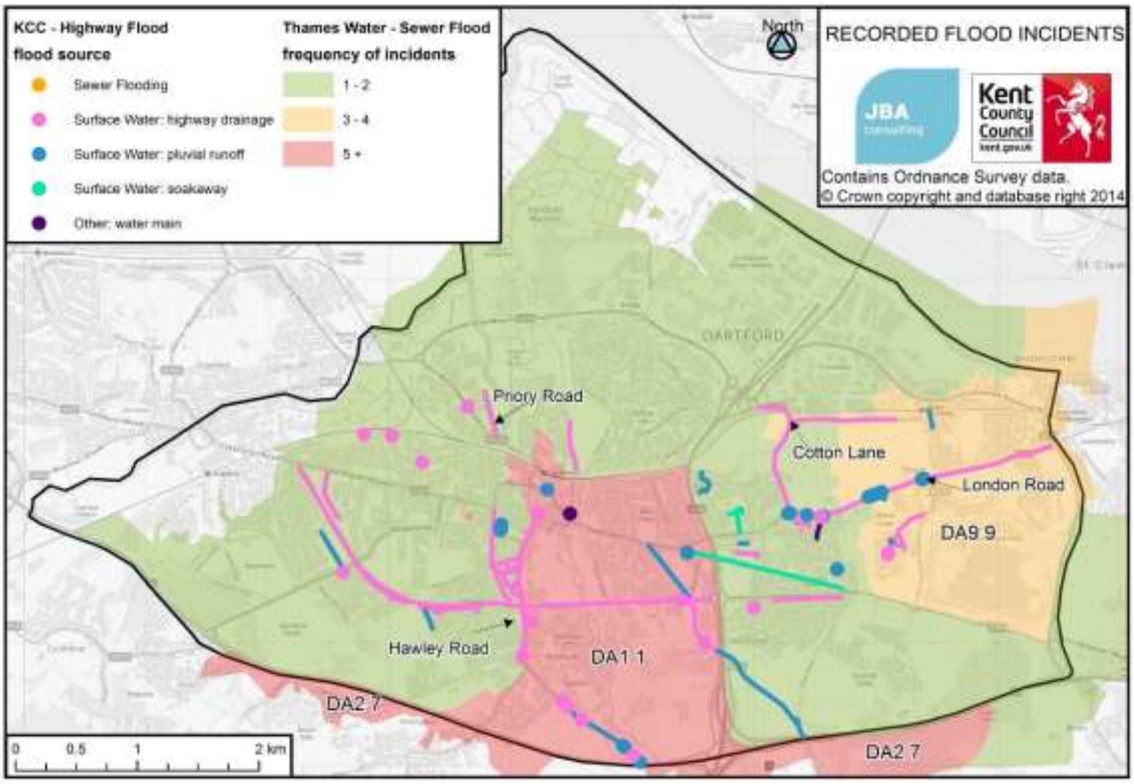

Figure 3-4 Flood history from local sources in Dartford

The most relevant flood incidents to this study were recorded by Kent County Council highways. Their records show periodical flooding of the highway network especially on London Road, Hawley Road, Cotton Lane and Priory Road. The location of Kent Highways flood reports is shown in Figure 3-4.

46 incidents of highway flooding have been reported on London Road, which are attributed to both pluvial runoff and incapacity of this highway drainage network. On Hawley Road, 42 incidents of flooding have been reported which are attributed to both pluvial runoff and incapacity of the highway drainage network. A site investigation confirmed that highway drainage on these roads goes to highway owned soakaway, rather than surface water sewer. Flooding has been reported on Cotton Lane 10 times and it is thought that these instances all occurred outside the new Ward Homes estate. On Priory Road, flooding has been reported on eight occasions. It is understood that these are caused by exceedance of the highway drainage network.

Thames Water provided their flood history record for use in this project. To protect their customer's confidentiality, this information was only available to the fifth digit of the postcode. The records show that in a 1 in 2-year event no properties in Dartford have flooded internally from sewers, although four properties had reported external flooding. From a 1 in 10-year event, only one property in Dartford had reported flooding internally, but 10 reported external flooding. At a 1 in 20-year return period, eight properties had recorded internal flooding and 15 had recorded external flooding. The postcodes with the highest frequency of recorded flooding are DA1 1 (eight instances) and DA2 7 (six instances). Figure 3-4 shows the frequency of sewer flooding within a five-digit postcode polygon. The frequency of flooding has been colour coded, high frequency events (greater than 5) are red, medium frequency (3-4) events are amber and low frequency (1-2) events are coloured green.

3.4 Predicted flood risk

This section discusses surface water flood risk mapping from both the national dataset and the local modelling undertaken as part of this study.

3.4.1 Updated Flood Map for Surface Water (uFMfSW)

National surface water flood risk mapping, known as the uFMfSW exists for England and Wales and has been published by the Environment Agency. The uFMfSW for a 1 in 30, 1 in 100 and 1 in 1000-year rainfall events in the Dartford area is a show in Figure 3-5.

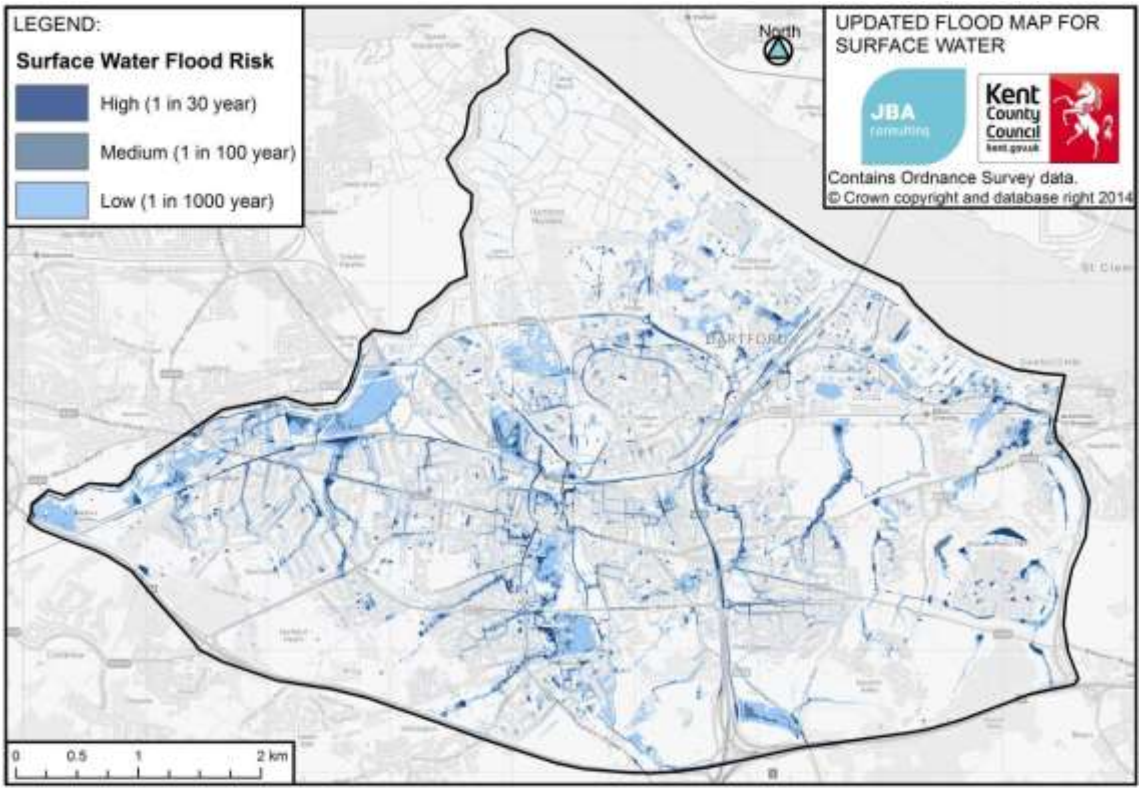

Figure 3-5 High, medium and low surface water flood risk in Dartford according to the uFMfSW

The uFMfSW shows that surface water is conveyed and pools on the highway network, for example Bob Dunn Way, Windsor Drive, Priory Road, the A282 and the A2026. In addition to the road conveyance, a significant overland flow path is simulated across scrub land between London Road and Cotton Lane and over Blackdale Farm.

3.4.2 Integrated Urban Drainage Model (IUDM)

An integrated modelling approach was selected, which includes all drainage systems and overland flows. The drainage systems modelled include Thames Water's surface water sewers and Kent County Councils Highway drainage, which drain to the sewer network. However, some areas in Dartford are drained to soakaway. This private drainage has not been modelled as the information is not available. Associated with this, the highway drainage to soakaways has not been modelled as this information is not available.

This detailed approach is justified by the requirement to use the model to test a variety of flood risk management measures to reduce flood risk in Dartford, and sought to address the key limitations of the national updated Flood Map for Surface Water (uFMfSW) and give a better understanding on integrated flood mechanisms operating in the catchment.

In brief, a surface water flood risk model was built and run using the hydraulic modelling software InfoWorks ICM. Full technical details are provided in Appendix D. The following points briefly describe the modelling:

- InfoWorks ICM was selected principally for its ability to model sewer networks and surface water flow routes in one software package.

The model utilised data provided by Environment Agency, Thames Water and Kent County Council. A full list of supplied data is provided in Appendix D.

- The surface water sewer network has been built from Thames Water's sewer records
- The locations where the surface water sewer systems discharge into watercourses have been modelled

- The model of the catchment surface includes representation of features which play an important role in directing, diverting and storing surface water, including buildings, road kerbs, railway embankments and small ditches

The contribution of runoff from the rural area south of Dartford was tested but it was found that the A2 embankment blocked flow routes (further discussion is reported in Appendix C).

- The model has been run using 1 in 2, 5, 20, 30, 75, 100, 100 +CC and 200 year events.
- The model was tested with a range of rainfall durations to calculate which produced the worst-case flooding. Although a short 60-minute storm produced the greatest depth of flooding in most places, the 120 and 600-minute storm also produced worst case flood depths in other areas of the catchment. Therefore, all three storm durations where used for baseline risk assessment.

Results

Flood risk mapping has been prepared for the 1 in 2, 5, 20, 30, 75, 100, 100 +CC and 200-year rainfall events, see Appendix A. The maps show depth of flooding, the hazard to people rating, which uses a combination of depth and velocity of flow to assess health and safety hazards to people.

3.5 Flood risk metrics

Taking the modelled results, in the form of a map showing predicted depth, velocity and hazard to people, the next step was to estimate the receptors which are at risk of flooding at different return periods. This involved both a simple count of properties at risk, but also an assessment of the damage costs, based on the depth of flooding and the plan area of the property. A full description of the damage calculation is in Appendix E.

Receptors are people, buildings, infrastructure or areas of land which can be impacted adversely by flooding. The principal source of information on receptors used for this study was the National Receptor Database (NRD) maintained and supplied by the Environment Agency. This is a geographically referenced database of all homes, public buildings and services, commercial premises, above-ground utility services and environmentally designated areas. Housing units are classified by their lowest level (basement, ground floor, first floor etc.) to assist the quantification of risk to people and property.

Damages to receptors have been assessed using the methodology in the 2010 Multi-Coloured Manual[5]. It is acknowledged that the Multi-coloured Manual was updated in 2013. The method for assessing damages to residential dwellings did not change between the 2010 edition and the 2013 edition; however, an adjustment factor to consider inflation was included. The method to assess flood losses to critical infrastructure has been refined in some cases. There is not a clear trend in terms of if the changes to damage curves on non-residential properties calculate higher or lower damages. It is accepted that not using the latest damage curves is a limitation to this approach. However, to give the broad scale indication of damages required here, this approach is suitable.

3.6 Flooding hotspots

Hotspots have been identified as areas with a significant flood history and or predicted risk. Within Dartford there are six flooding hotspots, herein referred to as Riverside, Hawley Road, Windsor Drive, Bow Arrow, Stone and Greenhithe, as shown in Figure 3-6.

[5] Penning-Rowsell E, Viavattene C, Pardoe J, Chatterton J, Parker D and Morris J (2010) The Benefits of Flood and Coastal Risk Management: A Manual of Assessment Techniques (Multi-Coloured Manual). Flood Hazard Research Centre, London

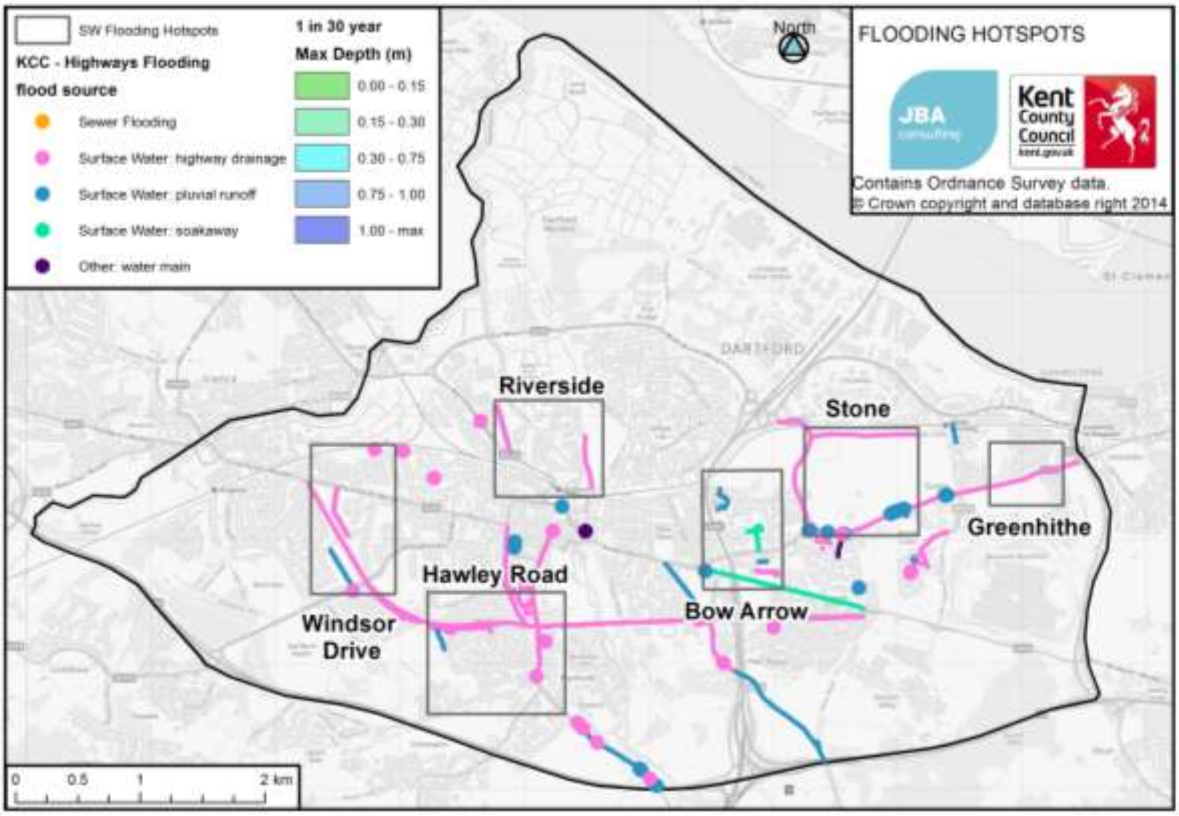

Figure 3-6 Flooding hotspots

Information packs on each hotspot area, including the flood risk source, flood pathways and potential receptors have been included in Appendix B. These information packs also include an estimation of potential damages and measures to alleviate flood risk.

The analysis of flood risk and flood history has enabled the hotspots to be ranked according to priority:

- the Riverside hotspot was the highest priority as regular flooding has caused damage to residential properties in this area;
- the Stone hotspot is ranked second. Here highly trafficked roads, particularly London Road, are regularly flooding which has caused road closures;
- the Hawley Road hotspot is ranked third. Here flooding causes disruption to the Hawley Road, a highly trafficked road;
- the Windsor Road hotspot is ranked fourth. Flooding has been recorded affecting residential curtilage, but not internal flooding and the highway is used for access only;
- the Bow Arrow hotspot is ranked fifth. Here highway flooding of low trafficked roads has been reported, but this is not known to have affected any properties; and
- the Greenhithe hotspot is the lowest priority. The model predicts flooding at this location but this is not supported by reported highway or property flooding.

3.7 Validation of the risk assessment

A variety of approaches have been taken to validate this risk assessment, as outlined in the following sections.

3.7.1 Model verification against hydrometric data

To verify sewer flow models Water Companies, undertake in pipe flow and level surveys accompanied by a network of rain gauges. These are often temporary and remain in the ground long enough to record three storms of sufficient depth and intensity with which to verify the model against. This detailed verification process compensates for not being aware of the condition of the piped network or the exact contributing areas. The parameters can be tweaked to produce results representative of what occurred in the catchment. However, temporary flow surveys are expensive and therefore are prioritised towards key assets; which for a water company are rarely surface water sewerage networks. As a result, there is no in pipe flow data to verify this model against.

Therefore, the verification has focussed on surface water flow paths and pooling areas.

3.7.2 Model review meeting

The baseline model results were presented to the project steering group for their approval based on local knowledge of flood mechanisms. Dartford Borough Council did not identify any particular surface water flood issues that they were aware of in the area. KCC Highways were unable to attend the meeting where baseline model results were presented. However, KCC were able to extract the latest flood records from the system and these historic events where used to validate the model.

3.7.3 Historic events

Thames Water records flood events from sewers. The data they have provided for this project is a count of flooding incidents within a 5-digit postcode. The data has been supplied in this format to respect their customer's confidentially. Therefore, its uses for model validation are limited, as we do not know if the flooding was from a foul or surface water sewer and where the incident occurred exactly.

Kent County Council highways keep a log of flooding incidents in Dartford. This highlights stretches of road that have had flooding and occasionally, points data of where the flooding has occurred. This more precise data is more useful for model validation. As a result, this data set has been the primary source of information for model validation. Further discussion of historic flooding datasets can be found in section 3.2.

Table 3-1: Summary of model performance against historic flooding

Hotspot	Road Name	Recorded Flooding Incidents	Predicted Flooding Receptors	Conclusion
Greenhithe	Evans Close	0	Semi-Detached Dwellings	This flow path was predicted by the IUDM and the uFMfSW but no flooding has been reported. Site investigations found evidence that overland flow from the park towards the residential area. The accuracy of the model at this location is limited due to a lack of data regarding private and highway soakaways.
	Low Close	0	Highway	
	Steele Avenue	0	Semi-Detached Dwellings	
	Perkins Close	0	Detached/ Semi-Detached Dwellings	
	Whitby Close	0	None	
Stone	Cotton Lane	10	Highway	The location of where flow paths intercept and pool on London Road is confirmed with flood history point data. Flood reports also support the modelled flow path. Flooding recorded on Cotton Lane is not on the east-west stretch of road.
	London Road	46	Highway	
	Bevis Close	1	Apartment Dwellings	
	Edwin Petty Place	2	Terraced Dwelling	
Bow Arrow	Osbourne Road	1	Apartment Dwellings	Recorded flooding along this flow path suggests that the model is performing accurately. However, key receptors such as the School and properties on Lingfield Avenue have not reported flooding. Onsite investigations found that these receptors were low lying and likely to receive an overland flow path.
	Dewlands Avenue	2	Detached Dwellings	
	Lingfield Avenue	0	Semi-Detached Dwellings	
	Rosedale Close	1	Semi-Detached Dwellings	
	Milestone Road	2	Highway	
	Colin Close	2	None	
Hawley Road	Hawley Road	42	Highway/ Commercial Properties	Flooding has been recorded across this hotspot, supporting the model

Hotspot	Road Name	Recorded Flooding Incidents	Predicted Flooding Receptors	Conclusion
	Lowfield Street	30	Highway	results. Point locations confirm that the flow path across Hawley Road near Trafalgar Road. Flooding has affected Highfield Road, but only when drainage gullies are blocked. This flow path continues onto Phoenix Place which also has recorded flooding. Conversations with the warden at Phoenix Place suggested that although water has been known to pond, it has not affected properties. Records also confirm the flow path to Linden Avenue and that flooding has occurred on Laburnum Avenue, but again, this is attributed to blocked assets.
	Trafalgar Road	1	Terraced Dwellings	
	Phoenix Place	2	Terraced Dwellings	
	Highfield Road South	1	Highway/ Terraced Dwellings	
	Linden Avenue	1	Semi-Detached Dwellings	
	Rowan Crescent	0	None	
	Princes Road	4	None	
	Laburnum Avenue	2	Highway, Semi-Detached Dwellings	
Windsor Drive	Windsor Drive	1	Semi-Detached/ Apartment Dwellings	One incident of flooding has been reported to KCC, but the model predicts highway flooding frequently; 20% AEP. The modelled components include sewers and highway drainage, which should improve model accuracy at this location.
	Knole Road	1	Semi-Detached Dwellings	
	Princes Road	4	Semi Detached Dwellings/ Highway	
Riverside	Priory Road	8	Terraced/ Apartment Dwellings	Repeated incidents of flooding have been recorded on Priory Road supporting the model results. This has been attributed to the slow discharge of highways assets to the surface water sewer network.
	Humber Road	0	None	
	Central Road	1	Highway	

In conclusion, the model performs well and recreates known issues in Dartford. However, there are areas of predicted flooding which are not supported by recording flooding; particularly in the Greenhithe hotspot. This coincides with areas of less modelling confidence as there are several assumptions regarding highway and private soakaways. In the case of Greenhithe, the dominant flow path onto Perkins Close is generated on rural land. We have more confidence in this flow route because there were signs of an overland flow path seen on the site visit. Therefore, it is assumed that this flow path does exist, but has not caused flooding to properties in this area.

3.7.4 Stakeholder input to the risk assessment

To find out more information on the recorded flood incidents and if flooding had occurred but had not been reported, communities living within the hotspots were contacted. The means of communication included a letter to householders and posters put on community notice boards and in communal areas. The letters and posters were designed to publicise the study and invite contribution (see Appendix B). The residents were asked if flooding had occurred in their area to report this using the Kent online tool. This database is continually evolving, and will be used to provide the evidence base for future investment in the catchment.

4 Options

A full list of potential options to mitigate flood risk in Dartford can be found in Appendix C. This includes indicate costs and benefits of each measure, as well as examples where these measures are being successfully used in Dartford.

4.1 Objectives

The objective of the options assessment process was to identify, shortlist and assess a suite of measures (individual actions or procedures to manage current and future surface water flood risk, or to meet other SWMP objectives) for mitigating surface water flooding and agree preferred options (a single measure or combinations of measures) across the study area. The preferred options are then included in the Action Plan.

4.2 Options workshop

The initial project steering group meeting discussed potential options to alleviate flood risk in Dartford. During this meeting, it was agreed that managing surface water on the surface was a preferred option and the use of SuDS within Dartford is encouraged. In addition, Dartford Borough Council highlighted that ongoing maintenance of drainage assets such of gullies was important to managing surface water flood risk. Dartford Borough Council planners suggested that there might be opportunities as part of new development and the Green Grid Plan to make the most of available green space.

During the options workshop it was agreed that the site-specific options should be focused on the flood hotspots, as defined by areas of high predicted flood risk and areas of recorded flood history.

4.3 Opportunities

Where work is planned or ongoing, there is an opportunity to combine programmes, which can lead to efficiencies. Particularly, if works are in the planning stage, there is a chance to provide multi-benefits or even 'no regret' measures.

4.3.1 Development

The borough of Dartford will experience significant growth up to 2026 and beyond[6]. It is estimated that between 2006 and 2026 Dartford's population will increase by 43%. Development of this scale need to be strategically planned and has been reviewed in the Core Strategy for Dartford. The areas where developments are planned are shown in Figure 4-1.

[6] Dartford BC (2010) Dartford Open Spaces Technical Paper

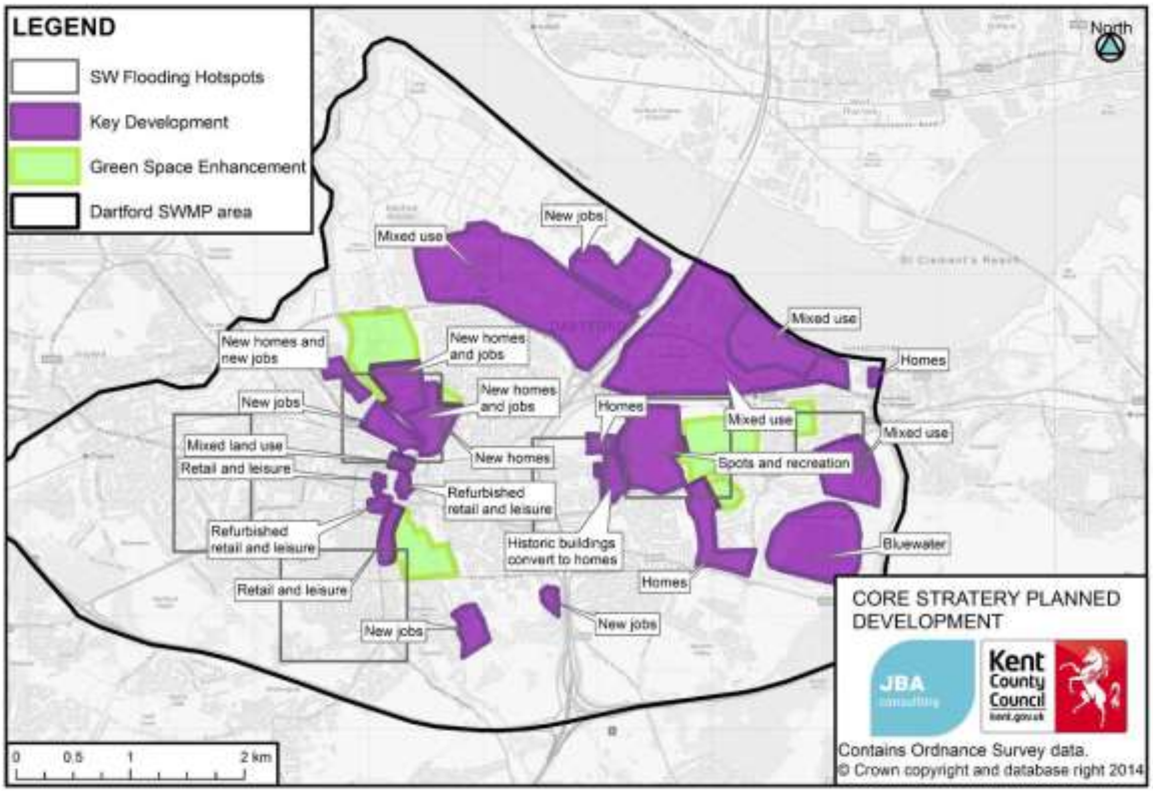

Figure 4-1 Planned development and green space enhancement in Dartford

Further development could exacerbate the existing surface water problems in Dartford as the surface water and highway drainage networks receive more flows from areas of hard standing. However, the Water Cycle Study 2009[7] comments that a large proportion of sites are on brownfield land and through attenuation such as Sustainable Urban Drainage systems (SuDS and open space provision "it is evident that development will in effect be providing 'betterment' by reducing surface water runoff.

On the 10th April 2015 Kent County Council (KCC) became a statutory consultee on planning applications. The consultation responses from KCC are based on guidance from existing planning policies, National Planning Practice Guidance, and the recently published national 'non-statutory technical standards for the design, maintenance, and operation of SuDS. As a result, a new major development should demonstrate that an appropriate SuDS system will be incorporated, unless demonstrated that this would be inappropriate. This is also supported by Dartford Core Strategy 24[8].

Considering Sustainable Drainage Systems (SuDS) at the master planning stage of a new development allows an optimum design to be conceived, without the constraints of existing land use. In addition, the cost of implementing a SuDS scheme at a new development will generally fall to the developer. These costs are typically similar to the equivalent conventional drainage systems[9]. Guidance and best practice relating to SuDS design and implementation is ever developing. For example, a new CIRIA SuDS Manual is expected in autumn 2015. Therefore, it is recommended that the latest best practice guidance is adhered to.

4.3.2 Water stress

Water stress, as classified by the Environment Agency and Natural Resources Wales are areas where:

- The current household demand for water is a high proportion of the current effective rainfall available to meet that demand; or

[7] Dartford Borough Council (2009) Kent Thameside Water Cycle Study Phase 1. Dartford
[8] Dartford Borough Council (2011) Core Strategy – Proposed Adoption Document. Dartford
[9] Woods-Ballard B, Kellagher R, Martin P, Jefferies C, Bray R and Shaffer P (2007) The SUDS manual. CIRIA: London

- The future household demand for water is likely to be a high proportion of the effective rainfall available to meet that demand[10]

Following this approach, Thames Water's supply area is currently under 'serious stress' and will remain under serious stress in future scenarios.

In Thames Water's Water Resources Management plan[11], their supply area is divided into Water Resource Zones (WRZ). Dartford sits in the London WRZ. The supply and demand balance in the London WRZ (Table 4-1) shows that from 2015, water demand will outstrip supply.

Table 4-1: The supply demand balance in the London Water Resource Zone

WRZ	2011	2015	2020	2025	2030	2035	2040
London	**18.8**	**-59.4**	**-132.7**	**-213.1**	**-291.7**	**-359.1**	**-413.9**

Figures taken from Thames Water WRMP (2014)

Sustainable Drainage Systems (SuDS) can help to recharge groundwater supplies by infiltrating surface water to the sub-surface. However, this could have an implication of water quality where urban runoff pick up contaminants. Under Dartford's Core Strategy Policy 24 infiltration SuDS in Water Source Protection Zones (WSPZ) have to demonstrate that surface water runoff infiltration to the ground will not lead to deterioration in ground water quality. The SPZ in Dartford are shown in Figure 4-2.

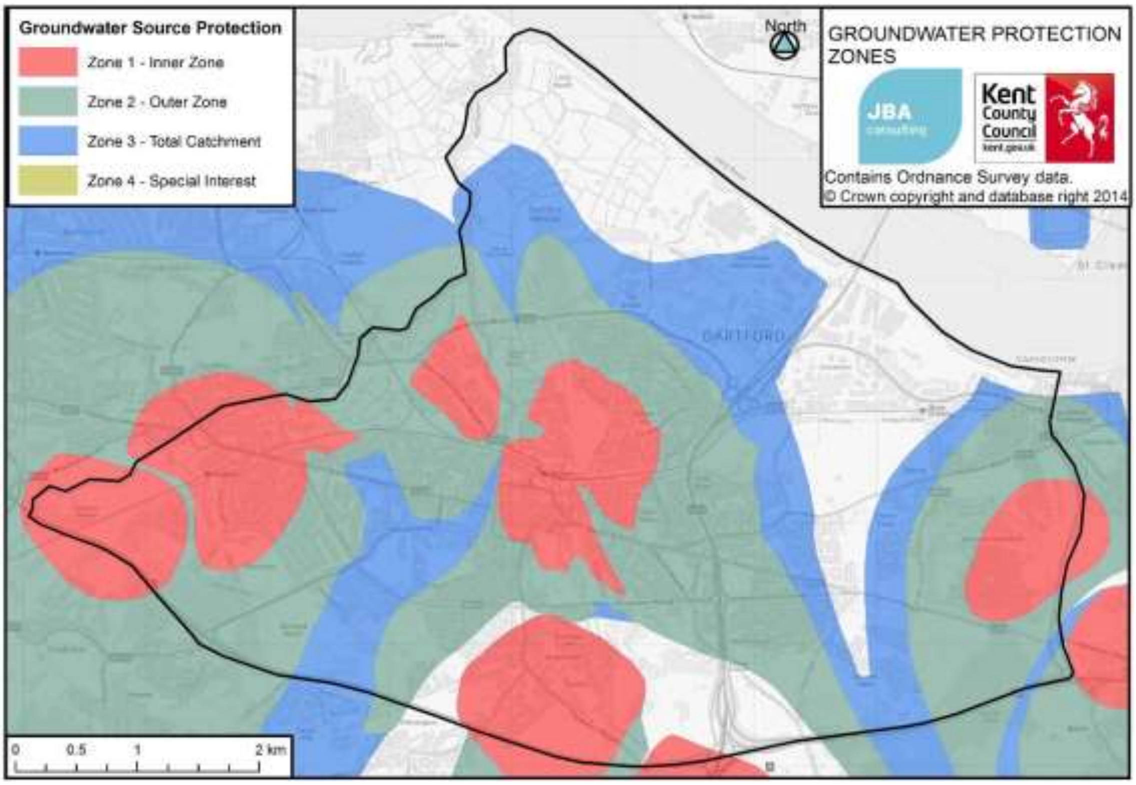

Figure 4-2: Groundwater Source Protection Zones in Dartford

The Environment Agency's position statements on groundwater protection are listed in Groundwater protection: principles and practice[12]. This states that the discharge of clean runoff from roofs to soakaway is acceptable in all Source Protection Zones. Discharge of runoff from roads, railways or airports to soakaway should be outside SPZ 1 and ideally outside SPZ2 but this would be considered on a case-by-case basis with a suitable risk assessment. Discharge of surface water from sites affected by contamination (e.g. garage forecourts and lorry parks) to soakaway would be subject to a risk assessment to demonstrate that pollution to groundwater will not occur in all SPZ.

[10] EA NRW (2013) Water stressed areas - final classification. Horizon House: Bristol

[11] Thames Water (2014) Revised Draft Water Resources Management Plan 2015 - 2040.

[12] Environment Agency (2013) Groundwater protection: Principles and practice (GP3) Horizon House: Bristol

There is an opportunity to revise the SFRA guidance regarding SuDS draining to soakaway, particularly in light of the water stress in the region and the revised groundwater protection guidance set out in the Environment Agency's position statement.

4.3.3 Green grid

In recognition of the threat of urban encroachment into green spaces as a result of continued growth development across Thameside, Kent County Council produced a Green Grid Design Strategy and Guidance[13] document in 2004. This promotes high quality, well-designed multi-functional and integrated environmental infrastructure for new and existing communities. The guidance recognises the value of green spaces, not only for flood-risk management but also for sports, leisure, education, biodiversity, tourism and the economy. Dartford Borough Council then implemented this guidance as part of the Local Framework Directive.

Investigations into the proportion of green spaces in Dartford undertaken by the Borough Council were presented in Dartford's Open Spaces Technical Paper. The results found a significant and varying amount of open space is needed across the borough in order to meet the demand arising from the new population and to compensate for the loss of non-publicly accessible and Public Right of Way (PRoW) natural green space sites.

The technical paper concluded that a policy should be implemented in the Core Strategy to guarantee the preservation of open spaces in the Borough in future.

Dartford Borough Council has responded to the threat of loss of open space and to enable sufficient open space to be available to future residents by creating a policy within their core strategy regarding green space allowances. Core strategy 14[14] states that:

- Creation of 300 hectares of new or improved green spaces as part of developments by 2026
- New developments are required to contribute to the Green Grid network
    - Sites of 20 ha and over: at least 30 % of the site area
    - Sites between 2 and 20 ha: at least 20 % of the site area
    - Sites of less than 2 ha will be considered on a site-by-site basis.

The green grid policy is supported by Dartford's SFRA which states that green infrastructure should be utilised for flood storage, conveyance routes and SuDS.

4.4 Mitigation in hotspots

A full discussion of the potential flood mitigation measures and preferred option has been included in in the hotspot information packs, in Appendix B. These information packs include a consideration of the potential cost of the flood measure and calculation of any benefits provided.

[13] Kent County Council (2004) Kent Thameside Green Grid Design Strategy and Guidelines

[14] Dartford BC (2011) Core Strategy - Proposed adoption document. Dartford

5 SWMP Action Plan

5.1 Introduction

The Stage 2 SWMP identified a range of recommended actions for the reduction of flood risk across the Dartford area. The Action Plan collates all information undertaken and collated as part of this SWMP study and:

- Outlines the actions required and where and how they should be undertaken;
- Sets out which partner or stakeholder is responsible for implementing the actions and who will support them;
- Provides indicative costs; and
- Identifies priorities.

Please note, this considers this action plan considers the relative priority of actions across Kent as a whole. As Dartford has relatively few flood incidents reported, it is a lower priority area then other areas of the county.

5.2 Generic Action Plan

Table 5-1 Dartford Generic Action Plan

Ref	Action	Implementation Plan	Action Owner	Supporter	Priority*	Indicative Cost (£)**
Short Term Generic Actions						
GAP01	*The Environment Agency have updated their policies regarding ground water protection*	1. Review Environment Agency guidance in relation to current policy	DBC	EA, KCC	Short Term	Low
	Revise planning guidance in respect to discharging surface water to the ground.	2. Consider the need to update planning policy				
GAP02	*On the 10th April 2015 Kent Sussex County Council became a statutory consultee on planning applications, required to provide technical advice on surface water drainage strategies.*	1. Monitor developments in SuDS guidance and best practice documents.	KCC	DBC, EA	Short Term	Low
	Requirements for Surface Water Drainage Strategies should be aligned to the latest planning/ drainage guidance.	2. Align assessment criteria with latest best practice				

Long Term Generic Actions						
GAP03	*Significant growth is planned in Dartford. Further development could exacerbate the existing surface water problems as the drainage networks receive more flows from areas of hard standing.*	1. Ensure new developments incorporate SuDS in accordance with national and local planning policy	KCC	EA, TW	Long Term	Low
	Consider the impact of development on flood risk at planning stage.	2. Continue to work with developers to implement the most appropriate drainage strategy.	KCC, DBC			
GAP04	*Large areas of the Dartford have been identified as draining to soakaway. There is very little asset data available on these soakaways.*	1. Identify and map soakaway locations	KCC highways		Long Term	High
		2. Identify connectivity to surface gullies				
	Improve understanding of the highway drainage to soakaways	3. Identify geometry of soakaway chamber				
		4. Assess soakaway drainage potential				
GAP05	*The accuracy of the modelling is limited due to the lack of information of highway soakaways.*	1. Undertake asset surveys to understand the size, condition and infiltration rate of these assets in priority areas.	KCC	KCC Highways	Long Term	Low
	Revise modelling to include highway soakaway data where evidence suggests it is needed.	2. Revise the modelling to include a more accurate representation of this highway drainage				
GAP06	*The SFRA covering Dartford town centre was published in 2008 and updated in 2009.*	1. Review current SFRA in due course	DBC	EA	Long Term	Low
		2. Assess the need to revise the document				
	Revise the SFRA considering policy of surface water discharge to groundwater and special consideration of surface water hotspots. If evidence under GAPO5 indicates update required.	3. Revise and publish an updated SFRA.				

**Priority: Quick win = within 12 months. Short Term = up to 2 years. Medium Term = up to 5 years. Long Term = open ended/indefinite.*
*** Indicative Cost: Up to 50k, 50-150k, 150-250k or 250+k*

DBC: Dartford Borough Council	*KCC: Kent County Council*	*EA: Environment Agency*	*TW: Thames Water*	*KCC Highways: Kent County Council Highways*

5.3 Location specific Action Plan

Table 5-2 describes the action plan for specific locations. The site-specific action plan has been divided by those actions which can be undertaken in the short term and those that are recommended for future plans of work, and can be undertaken in the longer term.

Table 5-2 Site specific, short term Action Plan Dartford

Ref	Area of benefit	Location of action	Action	Benefits	Next Steps	Action Owner	Supporter	Priority *	Indicative Cost (£)**
Short Term Site Specific Actions									
LSAP01	Stone Hotspot	Bevis Close	*Flooding of the London Road has been a repeated issue in Dartford. Flow from the South is impounded on the highway by a concrete wall.* 1. Review transport study to understand the impact of closure on the London Road 2. Ascertain the purpose and owner of concrete wall running along the North of London Road 3. Make an exceedance route through the concrete wall	Reduce flood risk to key highway receptor	Make contact will the DBC transport and wall owner	1. DBC 2. DBC 3. KCC	1. KCC 2. KCC 3. DBC	Low	High
LSAP02	Stone Hotspot	Cotton Lane	*Stone Lodge, greenfield land, is identified for future development. This would make this section of Cotton Lane a more valuable receptor and the pathway could potentially affect proposed dwellings. However, development would provide the opportunity for soakaways, SuDS and other surface water mitigations* 1. Planners to be aware of the surface water flow path as a potential hazard to development	Provide better information to potential developer.	Track planning applications at Stone Lodge,	DBC	KCC	Low	Low

Ref	Area of benefit	Location of action	Action	Benefits	Next Steps	Action Owner	Supporter	Priority *	Indicative Cost (£)**
Short Term Site Specific Actions									
LSAP03	Hawley Road	Hawley Road	*Surface water flooding has repeatedly been an issue at the junction of Hawley Road and Oakfield Lane. Investigation in upsizing highway drainage has found that other utilities prevent increasing capacity.* 1. Maximise conveyance by the cleansing of a highway gulley on Hawley Road at the junction with Trafalgar Road.	Optimise existing drainage network and reduce an existing surface water flooding problem	Commission a cleansing crew to clean out the gully pot.	KCC Highways		Medium	Low
LSAP04	Riverside	Priory Wharf Pumping Station	*The surface water sewer has been identified to drain to a terminal pumping station to discharge to the River Darent* *Thames Water asset data for the pumping station only relates to design standards for these pumps.* 1. Ascertain current pumping arrangements using operation data 2. If ops data is insufficient then commission a pumping station survey	Understand the current costs of running this asset.	Review DAP Stage 2 for Long Reach catchment and speak to Operations dept.	TW		Medium - high	Low

**Priority: Quick win = within 12 months. Short Term = up to 2 years. Medium Term = up to 5 years. Long Term = open ended/indefinite.*
*** Indicative Cost: Up to 50k, 50-150k, 150-250k or 250+k*

DBC: Dartford Borough Council	*KCC: Kent County Council*	*EA: Environment Agency*	*TW: Thames Water*	*KCC Highways: Kent County Council Highways*

Table 5-3 Stage 2 Site specific, long term Action Plan for Dartford

Ref	Area of benefit	Location of action	Action	Benefits	Next Steps	Action Owner	Supporter	Priority *	Indicative Cost (£)**
Long Term Site Specific Actions									
LSAP05	Stone Hotspot	Stone Recreation Ground	*Flooding of the London Road has been a repeated issue in Dartford. Flow comes across the recreation ground to the south and down the highway from the west and the east.* 1. Monitor the performance of the reinstated soakaway 2. Detailed design of an infiltration basin on Stone Recreation Ground.	Reduce flood risk to key highway receptor		1. DBC 2. DBC 3. KCC	1. KCC 2. KCC 3. DBC	Low	High
LSAP06	Stone Hotspot	Cotton Lane	*A large-scale development has been allocated on Greenfield land called Stone Lodge, although no planning application has been made. Road layout plans could make this section of Cotton Lane a more valuable receptor and the pathway could potentially affect proposed dwellings* 1. If a planning application is made, understand the impact of development on traffic on Cotton Lane 2. Drainage and surface water flood risk must be considered at master planning stage. 3. Detailed design of an infiltration basin	Potentially solve an existing problem and provide a more sustainable future	Track applications at Stone Lodge	1. DBC 2. Developer 3. Developer	DBC, KCC	Low	Medium

Ref	Area of benefit	Location of action	Action	Benefits	Next Steps	Action Owner	Supporter	Priority*	Indicative Cost (£)**
Long Term Site Specific Actions									
LSAP07	Hawley Road	Hawley Road/ Oakfield Park	*Surface water flooding has repeatedly been an issue at the junction of Hawley Road and Oakfield Lane. Investigation in upsizing highway drainage has found that other utilities prevent increasing capacity.* 1. Monitor future flood instances at this location 2. If flooding continues; detailed design and build of a bund and basin at Oakfield Park. 3. If flooding continues; detailed design and build of temporary storage at Oakfield Park Primary School car park.	Staged implication of measures which in isolation will reduce the SW flooding problem and in combination resolve the SW flooding problem	Recording of flood incidents inc. source of flooding (groundwater is also an issue here)	1. KCC/ KCC highway 2. KCC	DBC	Low	1. Low 2. Low - medium 3. Low - medium
LSAP08	Hawley Road	Phoenix Place/ Highfield Road	*A surface water flow path is simulated from East to West, across Highfield Road, pooling on Highfield Road* 1. Monitor future flood instances 2. If flooding continues, detailed design and build of temporary flood storage at a roadside car park on Highfield Road.	Reduce flood risk to key highway receptor		KCC	KCC Highways	Low	1. Low 2. High
LSAP09	Riverside	Priory Wharf Pumping Station	*The surface water sewer has been identified to drain to a terminal pumping station to discharge to the River Darent. Surface water drainage and flooding has been identified as an issue.* 1. Investigate the potential to optimise pumping at this station. 2. Investigate the cost and energy savings from removing the surface water contribution upstream of this pumping station. 3. Implement surface water reduction measures in the Priory Wharf PS catchment	Potentially reduce the energy consumption for this asset and resolve SW flooding at Priory Road	Understand current pumping arrangement	TW	KCC	Medium	1. Low 2. Low - medium

Ref	Area of benefit	Location of action	Action	Benefits	Next Steps	Action Owner	Supporter	Priority *	Indicative Cost (£)**
Long Term Site Specific Actions									
LSAP10	Bow Arrow	Rosedale Close	*A flow path originates on Rosedale Close which then continues onto Laburnum Av, Mile Stone Road and eventually Osbourne Road. Dealing with the problem at the source could benefit many.* 1. Monitor future flood incidents along this flow path 2. If flood incidents continue, undertake the detailed design and build of rain gardens	Reduce SW at the source of a flow path and encourage Sustainable Drainage Systems	Monitor future flood incidents	1. KCC 2. KCC Highways		Low	1. Low 2. Medium
LSAP11	Bow Arrow	Gateway Primary School	*A flow path is bound by a brick wall. When this ends, the flow path is directed towards the Gateway Primary School* 1. Replace existing fencing with a brick wall 2. Plan exceedance route from school car park to playing field for infiltration - including a soakaway	Direct flow away from high value receptor	Monitor future flood incidents	KCC	Gateway Primary School	Low	Low
LSAP12	Windsor Drive	Windsor Drive	*Sewer exceedance and an overland flow path converge on a low area of Windsor Drive* 1. Monitor future instances of flooding at this location.	Build the evidence base for investigating future options.	Monitor future flood incidents	KCC, TW	DBC	Low	Low
LSAP13	Greenhithe	Perkins Close	*A flow path is simulated down a chalk escarpment to the back of properties on Perkins Close. This has not been supported by anecdotal evidence.* 1. Monitor future instance of flooding at this location 2.Undertake detailed design of flood wall and storage area on Worcester Park	Build the evidence base for investigating future options.	Monitor future flood incidents	KCC	DBC	Low	Low

**Priority: Quick win = within 12 months. Short Term = up to 2 years. Medium Term = up to 5 years. Long Term = open ended/indefinite.*
*** Indicative Cost: Up to 50k, 50-150k, 150-250k or 250+k*

DBC	Dartford Borough Council
EA	Environment Agency
TW	Thames Water
KCC	Kent County Council, Flood Risk Management Dept.
KCC Highways	Kent County Council, Highways Dept.

5.4 Review timeframe and responsibilities

High priority actions identified in the 'Action Plan' are likely to be those addressed first. However, this report can only consider relative priorities within Dartford. Some partner organisations, including the Environment Agency, Thames Water and Kent County Council have flood risk management responsibilities beyond the geographic scope of this study, and therefore the priority of actions within Dartford will have to be assessed against actions in other areas. Kent County Council is currently undertaking SWMPs in several other settlements across the county and delivering existing Action Plans.

Dartford was ranked third in the summary of settlement flood risks from 1 in 200 years greater than 0.3 m surface water event (ranked by dwellings at risk) detailed within the PFRA[15].

It is recommended that, an annual review of the High and Medium Priority actions is undertaken. This will allow for forward financial planning in line with external partners and internal budget allocations. Low priority actions should be reviewed on a three-year cycle.

5.5 Sources of funding

Funding for local flood risk management may come from a wide range of sources. In Folkestone and Hythe these may include:

- Defra (Flood Defence Grant in Aid)
- Kent County Council (highways)
- Thames Water
- Industrial estate owners and businesses
- New developments (directly through the developer or through CIL)
- Local communities
- Dartford District Council

It is likely that schemes in Dartford will not have sufficiently strong cost-benefit ratios to attract 100% funding from Defra Flood Defence Grant in Aid (FDGiA), and would therefore require a portfolio of funding to be developed from various sources, including funding sources available for delivering other objectives such as improvements to highways, public open spaces and bio-diversity.

5.6 Ongoing monitoring

The partnership arrangements established as part of the SWMP process should continue beyond the completion of the SWMP in order to discuss the implementation of the proposed actions, review opportunities for operational efficiency and to review any legislative changes.

The SWMP Action Plan should be reviewed and updated once every six years as a minimum, but there may be circumstances which might trigger a review and/or an update of the Action Plan in the interim, for example:

- Occurrence of a surface water flood event;
- Additional data or modelling becoming available, which may alter the understanding of risk within the study area;
- Outcome of investment decisions by partners is different to the preferred option, which may require a revision to the Action Plan, and;
- Additional (major) development or other changes in the catchment which may affect the surface water flood risk.

The Action Plan should act as a live document that is updated and amended on a regular basis, and as a minimum this should be as agreed in the Local Flood Risk Management Strategy for Kent, although individual partners may wish to review their actions more regularly.

15 Kent County Council (2011) Preliminary Flood Risk Assessment available at http://www.kent.gov.uk/__data/assets/pdf_file/0013/12091/Preliminary-flood-risk-assessment.pdf - Table 5

Appendices

A Maps

B Flooding Hotspots Information Packs

Flooding hotspots

B.1 Greenhithe

The Greenhithe hotspot covers a residential development. It is estimated that these properties are around 20 years old and are located in a disused quarry. The dwellings are a mixture of detached and semi-detached homes. To the west of the development, there is an area of publicly accessible parkland. To the south and south west of the development is a chalk escarpment and this development lies approximately 25 metres lower than land to the south.

There are no Thames Water surface water sewers in this area and it is assumed that roofs and area of hard standing drain to private soakaways. The highway drainage was confirmed to drain to soakaways during the site visit.

Figure B-1: Flooding hotspot - Greenhithe

There is no recorded flooding within this hotspot. While on site, signs of an overland flow path down a footpath in the park, west of the end of Steele Avenue were seen. It was dry at the time, but sediment and detritus had been deposited around a double gully pot (as shown in Figure B-1) suggesting that rapid over land flows can occur.

Figure B-2: Sediment likely to have been deposited by a previous overland flow path at Greenhithe Park

The model results show two flow paths from the higher land in the south west towards this residential area. The dominate flow path flows down into the back gardens of Perkins Close. The simulated flooding at a 100-year return period affects several detached and semidetached houses on Perkins Close.

B.1.1 Greenhithe flood risk metrics

A count of buildings at risk of surface water flooding based on model results and a calculation of damage costs, based on the depth of flooding and the plan area of the building.

Table B-1: Summary of Flood Damages to Dwellings in Greenhithe

Return Period	Dwellings						
	Count	Depth			Sum of Damages		
		Min	Mean	Max	Min	Mean	Max
2	34	0.11	0.17	0.28	£439,700	£469,000	£488,400
5	57	0.13	0.19	0.44	£740,200	£788,900	£847,700
20	86	0.11	0.2	0.59	£1,177,200	£1,253,600	£1,350,300
30	111	0.11	0.2	0.62	£1,614,000	£1,712,500	£1,815,300
75	140	0.09	0.24	0.67	£2,072,000	£2,191,200	£2,319,400
100	143	0.08	0.21	0.69	£2,071,700	£2,229,000	£2,383,000
200	190	0.08	0.27	0.88	£2,880,200	£3,070,000	£3,281,000
100 + CC	211	0.07	0.29	0.98	£3,240,000	£34,642,000	£3,702,000

Damages are rounded to the nearest £100

Table B-1 shows that the count of dwellings affected by flooding increases as the Annual Exceedance Probability of the event increases. Taking mean damages as an example we can see that not only the count of properties increases, but also the average flood depth within each flooded property. The average cost of damage per dwelling increases from around £13.5 k for the two-year return period to £16.5 k for the 100 + CC return period. This can be attributed to the increase in average flood depth at each return period.

Table B-2: Summary of Flood Damages to Critical Infrastructure in Greenhithe

Return Period	Critical Infrastrucutre						
	Count	Depth			Sum of Damages		
		Min	Mean	Max	Min	Mean	Max
2	0	0.00	0.00	0.00	£0	£0	£0
5	0	0.00	0.00	0.00	£0	£0	£0
20	1	0.51	0.51	0.51	£1,500	£1,500	£1,500
30	1	0.60	0.60	0.60	£1,500	£1,500	£1,500
75	1	0.22	0.42	0.83	£1,500	£1,500	£1,500
100	1	0.66	0.66	0.66	£1,500	£1,500	£1,500
200	1	0.44	0.64	1.05	£1,500	£1,500	£1,500
100 + CC	1	0.53	0.74	1.15	£1,500	£1,500	£1,500

Damages are rounded to the nearest £100

Table B-2 shows that only one instance of building classified as critical infrastructure has been identified as at risk of flooding in this hotspot. This is an electricity substation.

B.1.2 Options

This section summarises the options tested in the Greenhithe hotspot area of Dartford. Figure B-3 shows the extent of the hotspot, the modelled features and the overland flow pathways in the baseline scenario.

Figure B-3: OS mapping showing the Greenhithe hotspot and overland flow routes during a 1 in 100-year rainfall event

5.6.1 Concept

Greenhithe is a residential area with no recorded flood incidents, although evidence of overland flow was seen during the site visit. The dominate flow path crosses parkland before flowing in the rear of properties on Perkins Close. As the flow path intercepts green space, the suggested option is to impound the water in the green space as this is a less vulnerable receptor. Infiltration to the soil will be increase by two large capacity soakaways where water pools.

This storage area can achieve multi benefits in addition to flood storage, including ground water recharge, water quality and amenity benefits.

The lead authority for flood alleviation options in this hotspot would be Kent County Council with support from Stone Parish Council.

Table B-3: Greenhithe options overview

Flood management option	Location	Benefits	Lead authority
Flood wall and temporary storage area	Perkins Close	Flood relief	KCC

The options modelled have been summarised in Table B-4 below. The impact of the option is summarised as a *negative change* which is highlighted in green and indicates a reduction in flood risk or damages, *no change* which is highlighted in orange or a *positive change*, which is highlighted in pink and indicates an increase in flood risk of damages as a result of the modelled option.

Table B-4: Greenhithe option appraisal

Perkins Close, Greenhithe Hotspot

Baseline:

Source	Pluvial runoff
Pathway	Overland flow from south west across parkland

Receptor

	5 year	30 year	100 year
Dwelling	-44	-81	-108
Crit Infra	+0	+0	+0
Highways m^2	-6402	-4377	-5695

Model confidence: low - medium
No recorded flooding. Some highway drainage modelled from assumptions. No known Thames Water assets to model.

Option 1: Storage

Build:

Results:

Modelled features
Porous wall: crest level 1.5 m above ground level
Total storage volume: 3,500 m^3

Cost

Construction: £35,000 - £52,500
Maintenance: £350 - £1,050

Benefits (receptors not flooded)

	5 year	30 year	100 year
Dwelling	-13	-27	-11
Crit Infra	+0	+0	+0
Highway m^2	-371	-494	-1,075

Benefit (financial, in £)

	5 year	30 year	100 year

	Dwelling	- 158,000	- 544,000	-280,000
	Crit Infra	+0	+0	+0

Conclusion: A flood wall along the back of properties on Perkins Close is very effective to reduce the risk to properties on this area. If accompanied with excavation to form a bio-retention area behind the wall would prevent the pathway flooding at low return periods. Any investments in this area should be justified by reported flood incidents.

B.2 Hawley Road

The Hawley Road hotspot covers an area of mixed land use, including residential and some commercial. To the north of the hotspot is a residential area consisting of semidetached houses that were built around 1950. Roads in the north of the hotspot of particular relevance are Highfield Road and Phoenix Place. To the east of the hotspot along Hawley Road itself are some commercial properties including a pub, mini-market and dog groomers. To the south of the hotspot is Oakfield Park. The surrounding residential area is predominately terraced houses built circa 1950 but includes Oakfield Community Primary School which is mixed in age.

The River Darent flows almost parallel to Hawley Road and the gradient of the hotspot flows falls from higher ground in the west to the Darent flood plain in the east.

There are no Thames Water surface water sewers in this area and it is assumed that roofs and area of hard standing drain to private soakaways. The highway drainage is also assumed to drain to soakaways.

Figure B-4: Flooding hotspot - Hawley Road

There is recorded flood history across this hotspot. In particular, Hawley Road and Lowfield Street have 47 and 30 incidents of recorded flooding incidents respectively. Highway records state that flooding regularly occurs on Hawley Road as the drainage regularly gets blocked. While on site it was found that a double gulley pot was blocked, as shown in Figure B-5.

Figure B-5: Blocked gully pots on Hawley Road

Investigations into highway drainage on Hawley Road have concluded that upsizing is not feasible due to pressures from other in road services. Solutions for flooding on Hawley Road should be strategic, addressing the upstream flow paths and reducing the sediment load to wash off, thereby addressing the blockage problem.

Flooding on Lowfield Street has primarily been at a subway and is attributed to poor power supply to pumps. This was flagged during the Stage 1 SWMP for Thameside and KCC highways have now upgraded the power supply.

The Public House on Trafalgar Road reports cellar flooding on a regular basis. The pub directly intercepts the predicted overland flow route which is likely to contribute to this flooding.

There have been two incidents of flooding recorded on Phoenix Place, which have been attributed to blocked gullies. It should be noted that accommodation to the west of Phoenix Place has a flood resilient layout, as the ground floor is garages, as shown in Figure B-6.

Figure B-6: Properties on the west side of Phoenix Place with garages on the ground floor.

Flooding has been recorded on Linden Avenue which was not attributed to blockage of assets. Instead, it was thought that a sudden downpour has overwhelmed the system. This supports the modelled flow route. There has also been recorded flooding at Highfield Road which has been linked to blockages of the highway drainage.

The model results show three flow paths, the first flows off Dartford Golf Course, through Linden Avenue and onto Laburnum Avenue. Princes Road separates this flow path with the second through Willow Road, across Highfield Road South and ponds on Phoenix Place. The third flow path comes off Oakfield Park, accumulating runoff from the residential area on route. The flow path intercepts the Oakfield School and flows down the back of Walnut Tree Avenue to Brooklands Lake.

B.2.3 Hawley Road flood risk metrics

A count of buildings at risk of surface water flooding based on model results and a calculation of damage costs, based on the depth of flooding and the plan area of the building.

Table B-5: Summary of Flood Damages to Dwellings in the Hawley Road area

Return Period	Dwellings						
	Count	Depth			Sum of Damages		
		Min	Mean	Max	Min	Mean	Max
2	237	0.09	0.18	0.55	£2,702,200	£2,806,000	£2,910,800
5	283	0.09	0.18	0.63	£2,994,700	£3,250,800	£3,597,500
20	382	0.08	0.18	0.80	£3,986,000	£4,432,400	£4,854,200
30	433	0.08	0.19	0.83	£4,724,300	£5,177,000	£5,713,900
75	539	0.07	0.19	0.89	£6,013,900	£6,629,600	£7,336,800
100	606	0.07	0.19	0.86	£6,981,500	£7,688,000	£8,607,200
200	683	0.07	0.19	0.92	£7,840,100	£8,795,200	£9,919,800
100 + CC	783	0.07	0.19	0.94	£9,096,700	£10,140,200	£11,348,200

Damages are rounded to the nearest £100

Table B-5 shows that the count of dwellings affected by flooding increases as the Annual Exceedance Probability of the event increases. Taking means as an example we can see that the count of properties increases, but the average flood depth within each flooded property remains fairly constant. As a result, the average cost of damage per dwelling does not increase considerably between return periods, from around £12,000 for the two-year return period to £13,000 for the 100 + CC return period.

Table B-6: Summary of Flood Damages to Critical Infrastructure in the Hawley Road area

Return Period	Critical Infrastrucutre						
	Count	Depth			Sum of Damages		
		Min	Mean	Max	Min	Mean	Max
2	0	0.00	0.00	0.00	£0	£0	£0
5	0	0.00	0.00	0.00	£0	£0	£0
20	0	0.00	0.00	0.00	£0	£0	£0
30	0	0.00	0.00	0.00	£0	£0	£0
75	2	0.09	0.09	0.10	£118,300	£118,300	£118,300
100	2	0.09	0.10	0.11	£128,600	£128,600	£128,600
200	3	0.09	0.11	0.14	£118,300	£131,000	£158,500
100 + CC	3	0.11	0.13	0.16	£146,000	£156,000	£182,300

Damages are rounded to the nearest £100

Table B-6 shows that no critical infrastructure is affected in the Hawley Road area until the 1 in 75-year rainfall event. At the 1 in 75-year return period the Oakfield Community Primary School and an electricity substation of Highfield Road South. The third critical infrastructure building affect at the 200 and above return period is an Ambulance Station off Prince's Road.

B.2.4 Options

This section summarises the options tested in the Hawley Road hotspot area of Dartford. Figure B-7 shows the extent of the hotspot, the modelled features and the overland flow pathways in the baseline scenario.

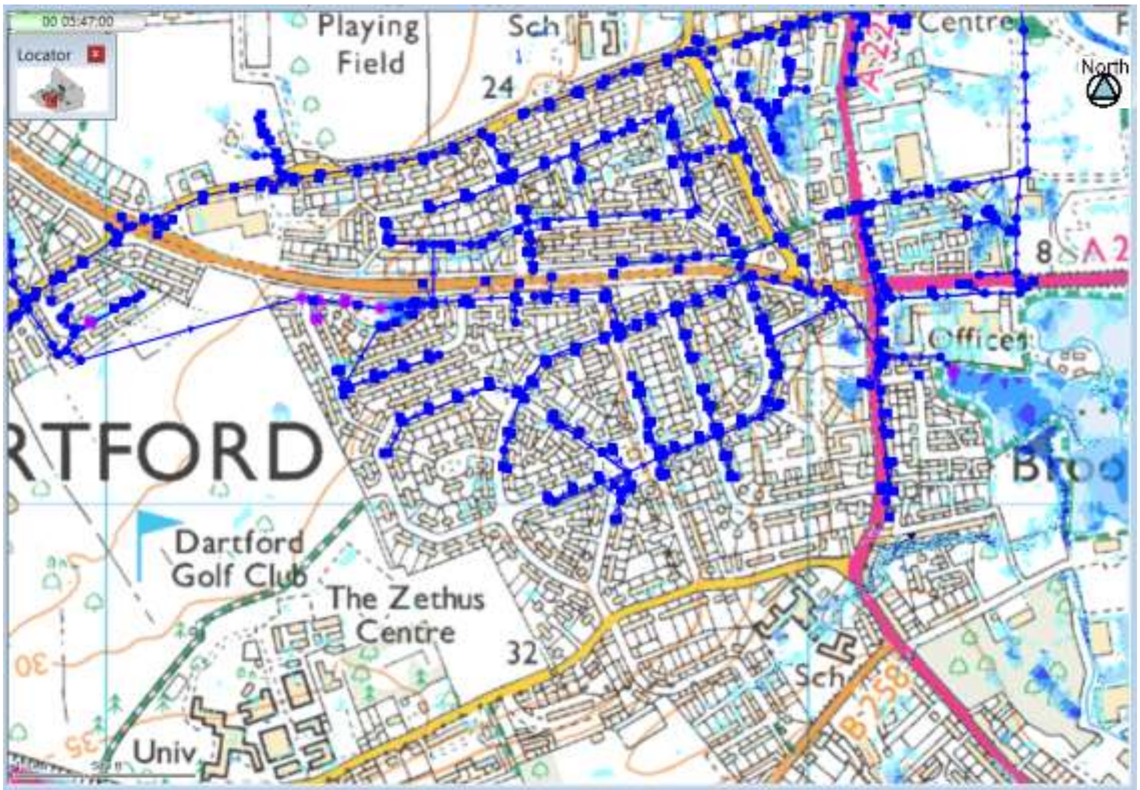

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Figure B-7: OS mapping of the Hawley Road area and overland flow routes during a 1 in 100-year rainfall event

5.6.2 Concept

The Hawley Road hotspot there is two separate flow paths. The northern flow path crosses Dartford golf course and flows onto Laburnum Avenue and Phoenix Place. The southern flow path originates at Oakfield Park and then flows through Oakfield Junior School over Hawley Road, impacting dwellings and buildings on Hawley Road and Walnut Tree Avenue.

At the source of these flow paths there are the open spaces of Oakfield Park and Dartford Golf Course. Therefore, this option will include upstream storage. In addition to this runoff is generated on the urban area. Therefore, street level measures have also been also been considered.

The lead authority for flood alleviation options in this hotspot would be Kent County Council Highways with support from Kent County Council.

Table B-7: Hawley Road options overview

Flood management option	Location	Benefits	Lead authority
Temporary storage	Oakfield Community Primary School	Flood relief, groundwater recharge	KCC
Swale	Laburnum Avenue	Flood relief, groundwater recharge	KCC
Infiltration Basin	Oakfield Park	Flood relief, groundwater recharge	KCC
Infiltration Basin	Dartford Golf Course	Flood relief, groundwater recharge	KCC
Temporary storage	Roadside car park, Highfield Road South	Flood relief	KCC

The options modelled have been summarised in Table B-8 below. The impact of the option is summarised as a *negative change* which is highlighted in green and indicates a reduction in flood risk or damages, *no change* which is highlighted in orange or a *positive change*, which is highlighted in pink and indicates an increase in flood risk of damages as a result of the modelled option.

Table B-8: Hawley Road option appraisal

Laburnum Avenue, Hawley Road Hotspot

Baseline:

Source	Pluvial runoff and surface water sewers
Pathway	Flow path originating on golf course, flowing north east and surface water sewer exceedance

Receptor

	5 year	30 year	100 year
Dwelling	2	5	12
Crit Infra	0	0	0
Highway m^2	648	920	995

Model representation: medium
Some flood history recorded. Thames Water assets modelled. Highway drainage assets modelled.

Option 1: Infiltration Basin and Swale

Retain the overland flow on Dartford Golf Course, by increasing the capacity of an existing hollow combined with a roadside swale along Laburnum Avenue.

Build:

Basin	Swale
Modelled features Mesh zone: level - 1 m Total storage volume: 3,000 m^3 Porous wall: crest level + 0 m	Modelled features Mesh zone: level - 0.2m Total storage volume: 188 m^3

Cost

Basin:	Swale:
Construction: £30,000 - 45,000 Maintenance: £300 - 900	Construction £1,900 - 2,850 Maintenance £19

Results:

Benefit (receptors not flooded)

	5 year	30 year	100 year
Dwelling	+0	-2	-6
Crit Infra	+0	+0	+0
Highway m^2	-87	-55	+84

Benefit (financial, in £)

	5 year	30 year	100 year
Dwelling	-100	-16,000	-57,000
Crit Infra	+0	+0	+0

Conclusion: The upsizing of an existing hollow effectively cuts off the flow path would otherwise affect properties on Linden Avenue. However, the impact is small, therefore this option is impractical. The swale would not collect highway water under the current camber and curbing scenario. Therefore, re-profiling would be required to make this option successful.

Oakfield Park, Hawley Road Hotspot

Baseline:

Source	Pluvial runoff from park and residential areas
Pathway	Over land flow through properties on Oakfield Park Road and via Oakfield School.

Receptor

	5 year	30 year	100 year
Dwelling	2	5	12
Crit Infra	0	0	0
Highway m^2	561	864	1,079

Model representation: medium to low
Repeated flood incidents on Hawley Road, but none reported by the school. There are no known Thames Water assets modelled. Highway drainage has not been modelled

Option 2: Infiltration Basin

Flow path cut behind the houses of Carsington Gardens by a bund and hollowed area to temporarily store water.

Build

Modelled features
Mesh zone: level - 1m
Porous wall: +1.5 m
Total storage volume: 1,000 m^2

Cost

Construction £10,000 - 15,000
Maintenance £100 - 300

Benefit (receptors not flooded)

	5 year	30 year	100 year
Dwelling	+0	-2	-6
Crit Infra	+0	+0	+0
Highway m^2	-87	-55	+84

Results

Benefit (financial)

	5 year	30 year	100 year
Dwelling	-100	-16,000	-57,000
Crit Infra	+0	+0	+0

Conclusion: This option was effective when the porous wall representing the bund was extended around the rear of properties. It is only a partial solution as more runoff is generated further down the flow path.

Highfield Road, Hawley Road Hotspot

Baseline:

Source			
Pathway	Overland flow from west to east through properties on Chester Road, over Highfield Road South and onto Phoenix Place.		

Receptor

	5 year	30 year	100 year
Dwelling	106	133	169
Crit Infra	0	0	1
Highways m^2	616	991	1,628

Model representation: medium - high
Recorded flooding on Phoenix Place but nothing on the flow path (Highfield Road or Chester Road)
Thames Water and highway drainage assets modelled.

Option 4: Plan for Exceedance - Temporary Storage

Build

Modelled features
Mesh zone: level 10.25 mAOD
Porous wall: 210 m crest level + 0.1 m
Total storage volume: 850 m^3
Soakaway capacity: 19.6 m^3

Cost

Lower Car Park: Construction = £12,750 - £21,250 Maintenance	Soakaway: Construction = £2,000 Maintenance = £2	Wall: Construction = £ 25,200 Maintenance = £ 0

Benefit (receptors not flooded)

	5 year	30 year	100 year
Dwelling	-6	-15	-5
Crit Infra	+0	+0	+0
Highway m^2	-6	+72	-18

Benefit (financial)

	5 year	30 year	100 year
Dwelling	-57,000	-194,000	-184,000
Crit Infra	+0	+0	+0

Results

Conclusion: This storage area is very effective at receiving flows as it is directly on the flow path. However, its capacity is limited, as excavation is likely limited as the car park should remain accessible. Impounding water with a wall to the east of the car park causes detriment to properties on the west of Highfield Road.

B.3 Windsor Drive

The Windsor Drive hotpot is a residential area. The buildings are predominately semi-detached houses, some of which have been converted into flats, it is estimated that these homes were built in the 1930s.

The pavements are wide, which could offer opportunities for roadside greening or rain gardens. However, constraints exist such as roadside parking and existing utilities, as show in Figure B-8.

Figure B-8: Wide pavements on Windsor Drive are used for parking and utility cables.

There are Thames Water surface water sewers running down the centre of Windsor Drive. There are two branches of network which drain the main sewer line at this location, one of which drains a catchment of over 8 hectares. Records show that following this junction, the pipe is upsized from 375 mm to 600 mm. It has been assumed that the highway drainage drains to the sewers in this location.

Figure B-9: Flooding hotspot - Windsor Drive

There is recorded flood history in this hotspot. Windsor Drive has one incident of recorded flooding, there has also been four flooding incidents recorded on Princes Road, although the exact location along this long road is unknown.

The Windsor Drive flood incident occurred in 2009 and was attributed to blocked gullies.

The model results show two flow paths converging on Windsor Drive. The first flows down the highways (Prices Road - Heathlands Rise - Windsor Drive) and the second flows through the back gardens of Windsor Drive before meeting at a low point of the Windsor Drive. Here, the capacity of the surface water sewer is exceeded and water also spills from the surcharged sewer network.

B.3.5 Windsor Drive flood risk metrics

A count of buildings at risk of surface water flooding based on model results and a calculation of damage costs, based on the depth of flooding and the plan area of the building.

Table B-9: Summary of Flood Damages to Dwellings in the Windsor Drive area

Return Period	Dwellings						
	Count	Depth			Sum of Damages		
		Min	Mean	Max	Min	Mean	Max
2	71	0.10	0.17	0.38	£947,600	£1,012,600	£1,068,200
5	103	0.10	0.18	0.44	£1,347,700	£1,425,900	£1,498,900
20	176	0.07	0.18	0.67	£2,419,100	£2,605,900	£2,791,500
30	204	0.08	0.20	1.00	£3,023,500	£3,288,000	£3,528,200
75	286	0.07	0.21	1.17	£4,030,100	£4,480,300	£4,824,100
100	307	0.07	0.21	1.20	£4,352,000	£4,895,300	£5,309,300
200	383	0.07	0.21	1.27	£5,206,700	£5,973,800	£6,491,000
100 + CC	422	0.07	0.21	1.33	£5,738,700	£6,657,400	£7,291,800

Damages are rounded to the nearest £100

Table B-9 shows that the count of dwellings affected by flooding increases as the Annual Exceedance Probability of the event increases. Taking means as an example we can see that the average flood depth within each flooded property remains fairly constant, with a depth of 0.21 for the 75 to 200-year return periods. As a result, the average cost of damage per dwelling does not increase considerably between return periods, from around £14K for the two-year return period to £15.7K for the 100 + CC return period.

Table B-10: Summary of Flood Damages to Critical Infrastructure in the Windsor Drive area

Return Period	Critical Infrastrucutre						
	Count	Depth			Sum of Damages		
		Min	Mean	Max	Min	Mean	Max
2	0	0.00	0.00	0.00	£0	£0	£0
5	0	0.00	0.00	0.00	£0	£0	£0
20	0	0.00	0.00	0.00	£0	£0	£0
30	0	0.00	0.00	0.00	£0	£0	£0
75	0	0.00	0.00	0.00	£0	£0	£0
100	0	0.00	0.00	0.00	£0	£0	£0
200	0	0.00	0.00	0.00	£0	£0	£0
100 + CC	0	0.00	0.00	0.00	£0	£0	£0

Damages are rounded to the nearest £100

Table B-10 shows there is no critical infrastructure predicted to flood in the Windsor Drive area.

B.3.6 Options

This section summarises the options tested in the Windsor Drive hotspot area of Dartford. Figure B-10 shows the extent of the hotspot, the modelled features and the overland flow pathways in the baseline scenario.

Figure B-10: OS Mapping of the Windsor Drive area and overland flow routes during a 1 in 100-year rainfall event

5.6.3 Concept

The Windsor Drive hotspot sees flooding from a surface water sewer and connected highway drainage. In addition, there is an overland flow path through the gardens of properties on the eastern side of Windsor Drive. Surface water from this flow path also ponds at the low spot where the surface sewer is exceeded.

In this instance, there are no large green areas to impound the flood water. Instead street level options are suggested as the pavements along Windsor Drive are relatively wide. Street level options have reduced storage in comparison to area level options and as a result can be less effective at high return periods. As sewer exceedance is also a flood mechanism at this location, sealing the low-lying manhole cover was also considered.

The lead authority for flood alleviation options in this hotspot would be Kent County Council Highways with support from Kent County Council and Thames Water.

Table B-11: Windsor Drive options overview

Flood management option	Location	Benefits	Lead authority
Seal flooding manhole	Windsor Drive	Flood relief	TW
Rain gardens	Windsor Drive	Flood relief, aesthetic value, groundwater recharge	KCC

The options modelled have been summarised in Table B-12 below. The impact of the option is summarised as a *negative change* which is highlighted in green and indicates a reduction in flood risk or damages, *no change* which is highlighted in orange or a *positive change*, which is highlighted in pink and indicates an increase in flood risk of damages as a result of the modelled option.

Table B-12: Windsor Drive option appraisal

Windsor Drive

Baseline:

Source	Pluvial Runoff and Sewer Exceedance
Pathway	Overland flow through the back gardens of Windsor drive and sewer exceedance from the surface water sewer network at a low-lying manhole.

Receptor

	5 year	30 year	100 year
Dwelling	53	98	137
Crit Infra	0	0	0
Highway	507	2,591	4,244

Option 1: Seal Manhole

Seal the flooding manhole, preventing water exceeding the surface water sewer system at this location.

Build:

Results:

Modelled features
Change manhole flood type to sealed

Cost

Construction: low
Maintenance: none

Benefit (receptors not flooded)

	5 year	30 year	100 year
Dwelling	+28	+14	+5
Crit Infra	+0	+0	+0
Highway m^2	+386	+612	+251

Benefit (financial, in £)

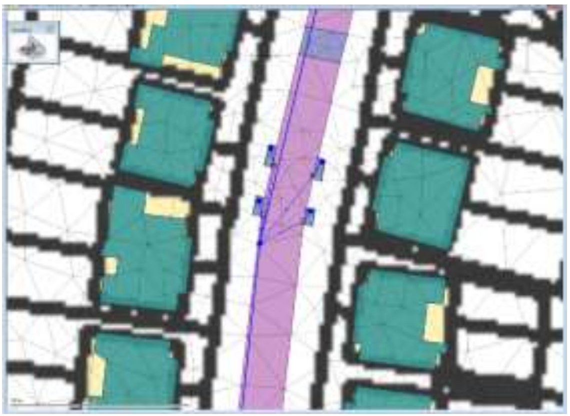
	5 year	30 year	100 year
Dwelling	+780,600	+364,800	+27,300
Crit Infra	+0	+0	+0

Conclusion: Sealing the manhole caused greater flooding from the gullies which exacerbated the flooding problem in this area. This is not suitable for taking forward.

Option 2: rain gardens

Upgrade existing highway drainage to include rain gardens, providing more storage, first flush treatment and infiltration potential for surface water. Connect these to a soakaway to add additional subterranean storage capacity and infiltrate the water.

Build:



Results:

Modelled features

Cost

Construction: low
Maintenance: medium

Benefit (receptors not flooded)

	5 year	30 year	100 year
Dwelling	-1	-1	+0
Crit Infra	+0	+0	+0
Highway	-102	-235	-184

Benefit (financial)

	5 year	30 year	100 year
Dwelling	-6,824	-25,657	+135,250
Crit Infra	+0	+0	+0

Conclusion: The rain gardens with the addition of soakaways do not have sufficient capacity to store surface water, even at the 1 in 5-year return period. A more strategic option to reduce the quantity of runoff is required.

B.4 Bow Arrow

The Bow Arrow hotspot is a residential area containing detached, semi-detached, terraced and apartment dwellings. The age of properties varies from 1940s to recent development. The area south of London Road has substantial detached and semidetached. Lingfield Avenue is a wide street with grassy verge sides, there are also trees planted in the pavement (Figure B-11). However, the pavements are narrow so widening these tree pits would be impracticable.

Figure B-11: Grassy roadsides and trees on Lingfield Avenue

Mile Stone Road (north of London Road) contains high density terraced houses, with a high percentage impermeable. At the end of Mile Stone Road is the Gateway Primary School. North of the school is Osborne Road which contains blocks of apartments.

North of London Road there are no Thames Water surface water sewers in this area and it is assumed that roofs and area of hard standing drain to private soakaways. The highway drainage is assumed to drain to soakaways in this area.

South of London Road there are Thames Water surface water sewers. The records show that this asset stops at London Road. The records do not contain information on where the water goes from the final manhole, so it has been assumed that his manhole is a soakaway.

Figure B-12: Flooding hotspot - Bow Arrow

There is recorded flood history in this hotspot. Flooding has been reported twice on Dewlands Avenue, once on Rosedale Close, twice on Mile Stone Road and once on Osbourne Road. The resident who reported the flooding on Dewlands Avenue said that the water came from the public highway, which is assumed in this case to be Lingfield Avenue.

Kent County Council highways suspected that there were illegal misconnections to highway drainage on Mile Stone Road and non-functioning soakaway. However, since a flood incident has not occurred since 2012 an investigation has not been undertaken.

The flooding reported on Osbourne Avenue was not found by the highways team when the report was acted on. It is suspected that flooding rises and falls quickly, as supported by the model results.

The model results show a flow path from south to north utilising the highway and intercepting the Gateway Primary School. The flow path continues from the school northward to Osbourne Road where it follows the low ground, intercepting some of the apartment buildings.

B.4.7 Bow arrow flood risk metrics

A count of buildings at risk of surface water flooding based on model results and a calculation of damage costs, based on the depth of flooding and the plan area of the building.

Table B-13: Summary of Flood Damages to Dwellings in the Bow Arrow area

Return Period	Dwellings						
	Count	Depth			Sum of Damages		
		Min	Mean	Max	Min	Mean	Max
2	119	0.09	0.18	0.37	£1,190,100	£1,338,500	£1,455,900
5	154	0.08	0.17	0.39	£1,485,000	£1,650,500	£1,779,600
20	226	0.1	0.18	0.41	£2,013,500	£2,325,800	£2,512,500
30	230	0.07	0.17	0.43	£2,270,000	£2,586,800	£2,944,400
75	289	0.07	0.19	0.51	£2,718,500	£3,188,600	£3,597,500
100	350	0.08	0.19	0.48	£3,084,500	£3,667,700	£4,124,600
200	379	0.07	0.21	0.54	£3,290,600	£4,051,100	£4,470,800
100 + CC	404	0.05	0.21	0.61	£3,651,200	£4,498,900	£4,959,900

Damages are rounded to the nearest £100

Table B-13 shows that the count of dwellings affected by flooding increases as the Annual Exceedance Probability of the event increases. Taking means as an example we can see that the average flood depth within each flooded property remains constant, only varying between 0.17 and 0.21 m. As a result, the average cost of damage per dwelling does not increase considerably between return periods, from around £11,000 for the two-year return period to £11,000 for the 100 + CC return period.

Table B-14: Summary of Flood Damages to Critical Infrastructure in the Windsor Drive area

Return Period	Critical Infrastrucutre						
	Count	Depth			Sum of Damages		
		Min	Mean	Max	Min	Mean	Max
2	1	0.15	0.23	0.51	£104,900	£168,500	£380,900
5	3	0.09	0.17	0.53	£112,200	£176,900	£400,700
20	3	0.07	0.19	0.56	£125,800	£191,600	£423,200
30	3	0.08	0.20	0.59	£110,000	£194,200	£238,400
75	3	0.09	0.22	0.64	£74,100	£245,100	£478,300
100	3	0.10	0.24	0.66	£79,800	£224,400	£491,400
200	3	0.10	0.26	0.65	£77,000	£243,100	£484,900
100 + CC	3	0.11	0.27	0.66	£82,000	£255,600	£495,700

Damages are rounded to the nearest £100

Table B-14 shows that not much critical infrastructure is affected by flood water. At a two-year return period, the critical infrastructure predicted to flood is the Gateway Primary School, from the fifth year onwards, in addition to the school, an electricity substation Mile Stone Road and an electricity substation on Osbourne Road is predicted to flood.

B.4.8 Options

This section summarises the options tested in the Greenhithe hotspot area of Dartford. Figure B-13 shows the extent of the hotspot, the modelled features and the overland flow pathways in the baseline scenario.

Figure B-13: OS Mapping showing the Bow Arrow area and overland flow routes during a 1 in 100-year rainfall event

5.6.4 Concept

The Bow Arrow hotspot sees a flow path from south to north flowing up the highway (Lingfield Avenue to Mile Stone Road) and affecting low lying receptors on route including residential properties and Gateway Community Primary School.

In this instance, there are no large green areas to impound the flood water. Instead street level options are suggested using grassy road verges along Lingfield Avenue. As street level options, have reduced storage in comparison to area level options, it is suggested that multiple areas are used and planning for exceedance is also undertaken. In this instance, temporary storage can be provided in the grounds of the Gateway Primary School.

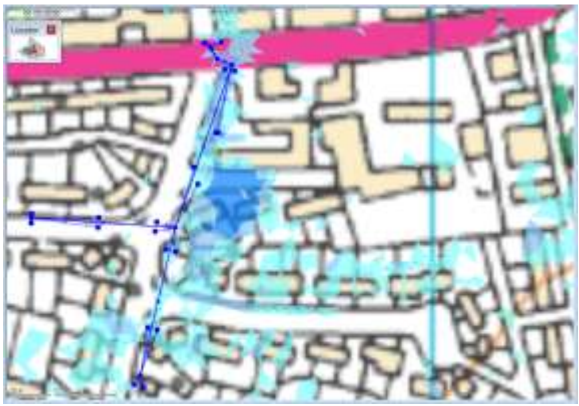
The lead authority for flood alleviation options in this hotspot would be Kent County Council Highways with support from Kent County Council.

Table B-15: Bow Arrow options overview

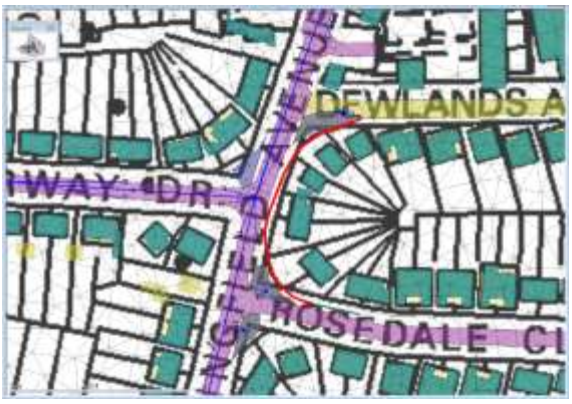
Flood management option	Location	Benefits	Lead authority
Rain gardens	Rosedale Close	Flood relief, aesthetic, ground water recharge	KCC
Flood walls	Lingfield Avenue	Flood relief, empowering residents	KCC
Flood resilience and temporary storage	The Gateway Primary School	Flood relief, groundwater recharge	KCC

The options modelled have been summarised in Table B-16 below. The impact of the option is summarised as a *negative change* which is highlighted in green and indicates a reduction in flood risk or damages, *no change* which is highlighted in orange or a *positive change*, which is highlighted in pink and indicates an increase in flood risk of damages as a result of the modelled option.

Table B-16: Bow Arrow option appraisal

<table>
<tr><th colspan="5">Rosedale Close, Bow Arrow Hotspot</th></tr>
<tr><td colspan="5">As the properties on Lingfield are lower that the road, the approach was to remove the surface water using rain gardens and protect the properties using property level protection (such as flood gates). The rain gardens utilise existing green verges.</td></tr>
<tr><td rowspan="8">Baseline:
</td><td>Source</td><td colspan="3">Pluvial runoff</td></tr>
<tr><td>Pathway</td><td colspan="3">Through properties on Lingfield avenue and onto highway proceeding northwards</td></tr>
<tr><td colspan="4">Receptor</td></tr>
<tr><td></td><td>5 year</td><td>30 year</td><td>100 year</td></tr>
<tr><td>Dwelling</td><td>18</td><td>4</td><td>47</td></tr>
<tr><td>Crit Infra</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>Highway m^2</td><td>868</td><td>1,215</td><td>1,643</td></tr>
<tr><td colspan="4">Model confidence: medium
Some recorded flooding. Thames Water assets modelled to an assumed soakaway. Most highway drainage modelled.</td></tr>
<tr><td colspan="5">Option 1: Rain Gardens and Flood Walls</td></tr>
</table>

Build:



Results:

Modelled features
Rain Gardens:
Mesh zones x 5: lowered 1m
Total storage volume: 590 m^3
Soakaways x 5: to drain the rain gardens
Property Level Protection:
Porous wall: crest level raised 0.5 m

Cost

Rain gardens:	PLP:
Construction: £29,500 - 41,300 Maintenance: £295 - 590	Construction: 7 x 3,646 = £25,522 Maintenance: £420 - 700

Total:
Construction: £55,022 - 66,822
Maintenance: £715 - 1,290

Benefit (receptors not flooded)

	5 year	30 year	100 year
Dwellings	-3	+0	-4
Crit Infra	+0	+0	+0
Highway m^2	+220	+312	+268

Benefit (financial)

	5 year	30 year	100 year
Dwellings	-41,000	+2,000	-85,000
Crit Infra	+0	+0	+0

Conclusion: The rain gardens are effective at removing surface water from the road. At high return periods, the storage offered by a rain garden is exceeded. Flood walls are effective at keeping water on the road and away from low lying properties but a secondary flow path north of Rosedale Close still affect properties on Dewlands Avenue.

Mile Stone Road, Bow Arrow Hotspot

Baseline:

Source	Pluvial runoff
Pathway	South to north along the highway of Lingfield Avenue, across London Road and up Mile Stone Road

Receptor

	5 year	30 year	100 year
Dwelling	136	228	286
Crit Infra	3	3	3
Highway m^2	1,449	2,379	2,590

Model confidence: medium - low
There are incidents of recorded flooding, but not specifically at the school. There are no known Thames Water assets to model. The highway drainage has not been modelled

Option 2: Plan for Exceedance - Temporary Storage Area

Direct the flows down the access road to the school, via the car park and round to the playing field, where the water is retained and drained by infiltration and via a soakaway.

Build:

Modelled features
Porous wall: crest level 1.5 m above ground level
High capacity soakaway to help drain the playing field.

Cost

Wall	Soakaway
Wall: Construction ≈ £41,300 Maintenance ≈ 0	Soakaway Construction: £1,500 Maintenance ≈ £1.50

Total
Construction ≈ £42,800
Maintenance ≈ £1.50

Results:

Benefit (receptors not flooded)

	5 year	30 year	100 year
Dwelling	-61	-56	-25
Crit Infra	-2	-1	-1
Highway m^2	-379	-750	-566

Benefit (financial, in £)

	5 year	30 year	100 year
Dwelling	-329,000	-391,000	-249,000
Crit Infra	-23,000	+223,000	-215,000

Conclusion: Routing the flow down the road is effective at reducing surface water flood risk to the school. Impounding the water in the school playing field alleviate flooding to properties downstream on the flow path. The benefit of this option should also be contrasted against the temporary loss of amenity and the potential risk to children.

B.5 Stone

The Stone hotspot contains London Road, which is a key conveyance route for traffic from Dartford to Bluewater and the wider Thameside. South of London Road is a residential area consisting of high density flats and terraced houses. North of London Road as open scrub land which is scheduled for development.

On the site visit, it was found that there was a concrete wall lining the north of the road (Figure B-14). This would act as a dam, preventing flows from continuing north and away from the road, which is the natural flow path.

Figure B-14: A concrete wall north of London Road would impound flows on the road

There are no Thames Water surface water sewers in this area and it is assumed that roofs and area of hard standing drain to private soakaways. The highway drainage was confirmed to drain to soakaways during the site visit.

Figure B-15: Flooding hotspot - Stone

There is recorded flooding in this hotspot. On London Road there have been 46 incidents of reported flooding, point information confirms that these flooding incidents have occurred at the locations indicated in the flood risk mapping.

The London Road has been designated as a hotspot by KCC highways. As a result, gullies are cleansed every six months. In 2011 the London Road hotspot was investigated, but no records are available from this investigation.

The incident of recorded flooding on Bevis Close was attributed to surcharge of a highway drainage manhole in heavy rainfall, which has not reoccurred since cleansing in August 2012.

On Cotton Lane ten incidents of flooding have been recorded. These incidents have predominately occurred on the section of Cotton Lane which runs north -south outside the new Ward Home estate. This area has been designated a hotspot by KCC Highways and cleansing occurs on a six-monthly basis.

The records do not explicitly mention flooding on the east west section of Cotton Lane. Currently this section of road is quiet and the impact of flooding would be low. As and when this area becomes more developed, Cotton Lane could become a more valuable receptor and flood incidents would be noticed and recorded.

The model results show two flow paths. The largest flow path flows from south to north in the west of the hotspot. Two overland flow routes of runoff from the residential area converge at London Road. A concrete wall of about one metre high, impounds this flow path, causing it to pond on the road. The flow then routes around the wall and north onto the common land. Water then impounds against a grassy bund south of Cotton Lane before exploiting a low spot and spilling onto the road.

B.5.9 Stone flood risk metrics

A count of buildings at risk of surface water flooding based on model results and a calculation of damage costs, based on the depth of flooding and the plan area of the building.

Table B-17: Summary of Flood Damages to Dwellings in the Stone area

Return Period	Dwellings						
	Count	Depth			Sum of Damages		
		Min	Mean	Max	Min	Mean	Max
2	76	0.09	0.20	0.44	£778,000	£905,000	£1,002,000
5	87	0.08	0.20	0.45	£944,000	£1,101,200	£1,230,200
20	109	0.08	0.20	0.66	£1,287,400	£1,485,000	£1,603,700
30	114	0.09	0.23	0.76	£1,410,300	£1,636,600	£1,780,500
75	146	0.08	0.24	0.99	£1,831,900	£2,116,700	£2,306,700
100	162	0.07	0.24	1.13	£1,981,700	£2,309,200	£2,533,300
200	182	0.06	0.25	1.57	£2,135,400	£2,578,100	£2,839,800
100 + CC	201	0.07	0.26	3.23	£2,420,600	£2,905,500	£3,240,200

Damages are rounded to the nearest £100

Table B-17 shows that the count of dwellings affected by flooding increases as the Annual Exceedance Probability of the event increases. Taking mean values as an example we can see that the average flood depth within each flooded property increases from 0.20 to 0.26 m. As a result, the average cost of damage per dwelling increases between return periods, from around £12K for the two-year return period to £14.5K for the 100 + CC return period.

Table B-18: Summary of Flood Damages to Critical Infrastructure in the Stone area

Return Period	Critical Infrastrucutre						
	Count	Depth			Sum of Damages		
		Min	Mean	Max	Min	Mean	Max
2	1	0.46	0.46	0.46	£1,500	£1,500	£1,500
5	2	0.07	0.10	0.12	£3,000	£3,000	£3,000
20	2	0.09	0.11	0.21	£3,000	£3,000	£3,000
30	2	0.11	0.14	0.23	£3,000	£3,000	£3,000
75	2	0.08	0.18	0.29	£3,000	£3,000	£3,000
100	3	0.08	0.18	0.31	£4,600	£4,600	£4,600
200	4	0.10	0.18	0.35	£7,000	£7,000	£7,000
100 + CC	4	0.11	0.20	0.38	£7,000	£7,000	£7,000

Damages are rounded to the nearest £100

In the Stone area between one and four critical infrastructure receptors are affected by flooding in the return periods tested. The receptor affected by the two-year storm is an electricity substation south of London Road, the second receptor affected by a five-year storm is an electricity substation at the Landfill Gas Plant, the third receptor affected at the 100-year storm is the electricity substation off Cotton Lane and the receptor affected by the 200-year return period is an electricity substation north of London Road.

B.5.10 Options

This section summarises the options tested in the Stone hotspot area of Dartford. Figure B-16 shows the extent of the hotspot, the modelled features and the overland flow pathways in the baseline scenario.

Figure B-16: OS mapping showing the Stone hotspot area and overland flow routes during a 1 in 100-year rainfall event

5.6.5 Concept

The Stone area shows some significant flow path across green spaces and the urban area. Where the flow path intercepts a green space, the suggested option is to impound the water in the green space as this is a less vulnerable receptor and due to the high infiltration capacity of the soils underlying the Stone area, infiltration of surface water over time is achievable. Infiltration basins can be multi beneficial, including ground water recharge, water quality and amenity benefits. These options are summarised in Table B-19.

Where flow paths cross through an urban area it is suggested to implement source control to reduce the proportion of effective rainfall and plan for exceedance, using a low-lying car park for temporary storage.

The lead authority for flood alleviation options in this hotspot would be Kent County Council with support from Kent County Council highways and Stone Parish Council.

Table B-19: Stone options overview

Flood management option	Location	Benefits	Lead authority
Infiltration basin	Stone recreation ground.	Flood alleviation on an important highway. Groundwater recharge Amenity	KCC and SPC
Infiltration basin	Cotton Lane scrub land	Flood alleviation on a highway. Groundwater recharge Amenity	KCC
Planning for exceedance	Bevis Road car park and wall north of London Road	Flooding of a low value receptor. Flood alleviation on an important highway.	KCC and KCC Highways

5.6.6 Stone: options

The options modelled have been summarised in Table B-20 below. The impact of the option is summarised as a *negative change* which is highlighted in green and indicates a reduction in flood risk or damages, *no change* which is highlighted in orange or a *positive change*, which is highlighted in pink and indicates an increase in flood risk of damages because of the modelled option.

Table B-20: Stone option appraisal

<table>
<tr><th colspan="5">London Road, Stone Recreation Ground; Stone Hotspot</th></tr>
<tr><td rowspan="8">Baseline:

</td><td>Source</td><td colspan="3">Rainfall onto Stone Recreation Ground and London Road</td></tr>
<tr><td>Pathway</td><td colspan="3">South to north over Stone Rec
east to west down London Road
west to east down London Road</td></tr>
<tr><td colspan="4">Receptor</td></tr>
<tr><td></td><td>5 year</td><td>30 year</td><td>100 year</td></tr>
<tr><td>Dwelling</td><td>0</td><td>1</td><td>5</td></tr>
<tr><td>Crit Infra</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>Highway m^2</td><td>666</td><td>1,201</td><td>4,380</td></tr>
<tr><td colspan="4">Model representation: medium to high
Repeated recorded flooding. Some highway drainage to assumed soakaways modelled. No known Thames Water assets to model</td></tr>
<tr><td colspan="5">Option 1: Infiltration Basin</td></tr>
<tr><td colspan="5">Excavate a basin south of London Road to store the overland flow from the south. Allows direct runoff from the road to the basin. Highway drainage to soakaway has a high-level overflow draining to the basin.</td></tr>
</table>

Build:

Results:

Modelled features
Mesh zone: area = 4,996 m^2; depth = 1.5m
Total storage volume: 7,494 m^3
Sewerage: overflow pipe from highway soakaway to basin (reverse flow prevented by flap valve.)

Cost

Construction ≈ £74,940 - £112,410
Maintenance (pa) ≈ £749.40 - £ 2,248.20

Benefit (difference in receptors)

	5 year	30 year	100 year
Dwelling	+0	+0	+0
Crit Infra	+0	+0	+0
Highway m^2	-384	-794	-830

Benefit (financial, in £)

	5 year	30 year	100 year
Dwelling	+0	-100	+100
Crit Infra	+0	+0	+0

Conclusion: an effective option to alleviate flooding to the London Road which has been identified as a key receptor. At a 100-year return period, the maximum flood should be passable by traffic.

Baseline:

Source	Rainfall onto a residential area of Stone south of London Road
Pathway	South - north via Almond Road and Bevis Close South - north via Kirby Road and Alamein Gardens

Receptor

	5 year	30 year	100 year
Dwelling	76	93	135
Crit Infra	1	1	1
Highway m^2	1,230	2,194	3,326

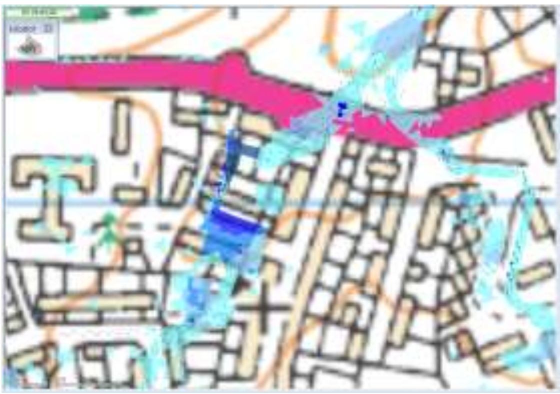
Model representation: Medium
Recorded flooding. Highway drainage not modelled. No known Thames Water assets to model

Option 2: Plan for Exceedance - temporary storage

Lower existing car parking area to allow water to stored there. Use flood walls to channel overland flow to this area. Remove concrete wall north of the London Road, allowing free flow onto scrub land and preventing pooling on the road.

Build:

Results:



Modelled features

Mesh zone: lowered 1m
Total storage volume: 300 m^3
Porous wall added: Along Bevis Close (crest height 1m above ground level)
Porous wall removed: Along London Road (crest height = 0m)

Cost

Construction: £12,900 - 15,900
Maintenance: minimal

Benefit (receptors not flooded)

	5 year	30 year	100 year
Dwelling	-8	+1	-7
Crit Infra	-1	-1	-1
Highway m^2	-581	-450	-538

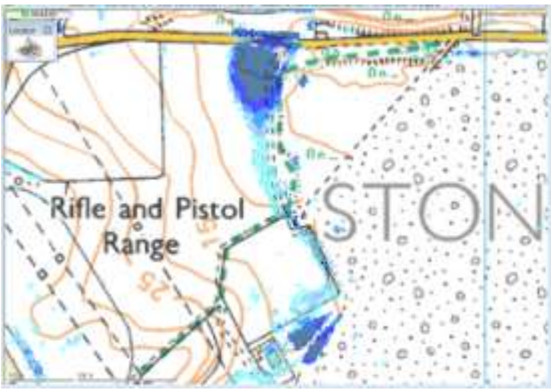
Benefit (financial, in £):

	5 year	30 year	100 year
Dwelling	-88,000	+51,000	-139,000
Crit Infra	-2,000	-2,000	-2,000

Conclusion: Removal of the wall is a quick win which will allow free drainage to the north. The area of the car park is small to offer large volumes of storage but could be useful at lower return period, flashy rainfall events. Should it not be feasible to completely remove the wall, low-lying cut-outs in the wall can be used to ensure flow pathways, with widely spaced bars where necessary to retain security.

Cotton Lane, Stone Hotspot

Baseline:



Source	Rainfall onto a residential area of Stone south of London Road
Pathway	South - north via Almond Road and Bevis Close South - north via Kirby Road and Alamein Gardens

Receptor

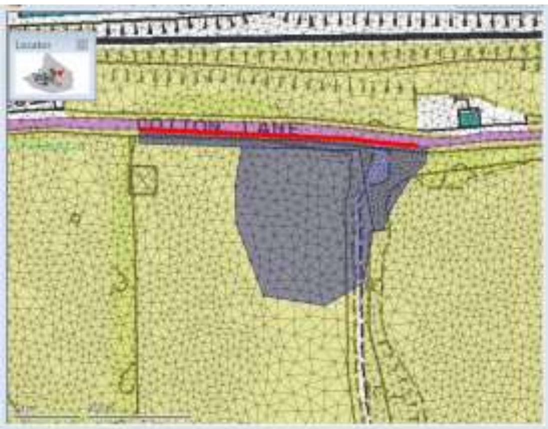
	5 year	30 year	100 year
Dwellings	0	0	0
Crit Infra	0	0	0
Highway m^2	37.6	522.4	861.4

Model confidence: Medium.
Recorded flooding. No known highway drainage assets to model. No known Thames Water assets to model.

Option 3: Reinforce existing grass bund

There is an existing grass bund south of the road. In this option, we reinforce the bund and excavate some storage south of the bund to protect the road.

Build:

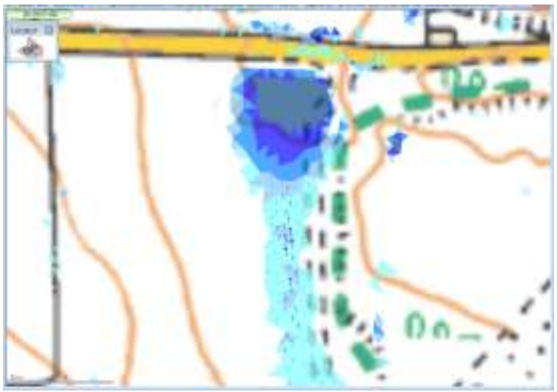


Modelled features
Mesh zone: lowered 1 m
Porous wall: 0.6 m above ground level
Total storage volume: 10, 000 m^3

Cost

Construction £100,000 - £150,000
Maintenance £1,000 - £3,000

Results:



Benefit (receptors not flooded)

	5 year	30 year	100 year
Dwelling	+0	+0	+0
Crit Infra	+0	+0	+0
Highway m^2	+13	-236	-378

Benefit (financial, in £)

	5 year	30 year	100 year
Dwelling	+0	+0	+0
Crit Infra	+0	+0	+0

Conclusion: Storage at this location is viable but as this receptor is low value, the cost: benefit ratio does not stack up. If the land south of Cotton Lane is developed, this flow path should be considered and this option revisited. There is potential to seek developer contribution.

B.6 Riverside

The Riverside has a mixture of residential and industrial land uses. To the west of the hotspot is Priory Road which has high density, terraced houses and a very high proportion of front gardens are paved over. This area drains to a Thames Water surface water sewer system which discharges to the River Darent via Priory Wharf surface water pumping station. Highway gulley inspections have shown that even when the highway drainage network is running free of blockage, the drainage is slow. It is suspected that this is due to incapacity on the surface water sewerage system as the discharge is limited by the pumping station.

On the eastern side of the hotspot is Riverside Industrial Estate. Runoff from large industrial units and paved areas collects on the highways, which could obstruct access. All the roads in Riverside Industrial Estate identified in this hotspot are served by surface water sewerage systems. South of the River Darent, the surface water sewerage drains to the Priory Road pumping station and north of this river the sewerage outfalls to an Ordinary Watercourse which drains to the Dartford Marshes. Local highway drainage is assumed to drain to the surface water sewer system.

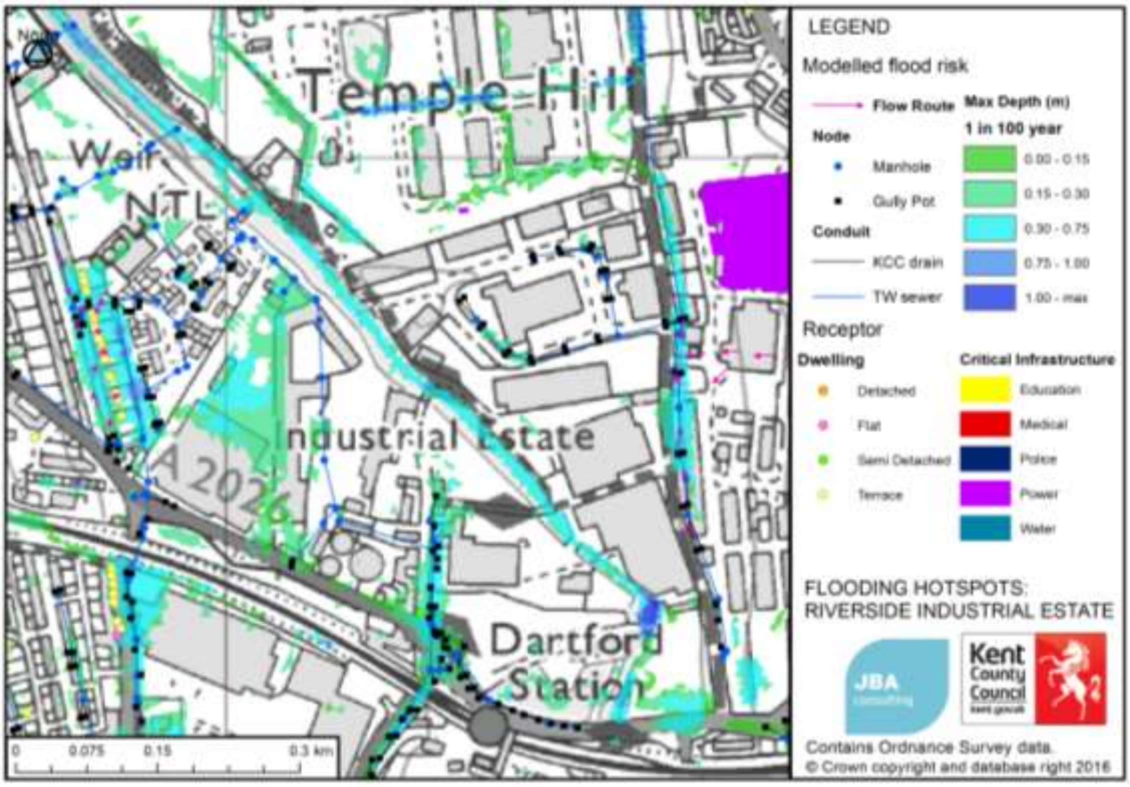


Figure B-17: Flooding hotspot - Riverside Industrial Estate

There is recorded flooding in this hotspot. On Priory Road, eight incidents of flooding have been recorded and one incident of flooding has been recorded on Central Road.

The drainage network on Priory Road was flagged during the Stage 1 SWWMP for Thameside as the water discharged slowly. We now understand that this flows to a pumping station which discharges to the River Darent. It is suspected that the capacity of the pumping station is limiting the ability of the highway drainage to accept runoff which is causing the surface water flooding problem. Any solutions to address this problem should consider the pumping station and its upstream contributing area. Standing surface water is not able to drain naturally from Priory Road as urban creep has led to the paving of driveways, as illustrated by Figure B-18.

Figure B-18: Priory Road with dense housing and a high proportion of paved driveways

The model results show that surface water cannot drain from the surface as the sewerage network is surcharged. The Priory Wharf pumping station is predicted to be constantly operational from the peak of a 60-minute storm for all return periods simulated exceeding a 1 in 2-year rainfall event.

Surface water on Central Road flows down a slope on the east and collects on the highway. The sewers are not exceeded at a 30-year return period but are running fully surcharged. As a result, there is very little additional storage for surface water from the highways, limiting the rate at which the surface water can drain.

B.6.11 Riverside Flood risk metrics

A count of buildings at risk of surface water flooding based on model results and a calculation of damage costs, based on the depth of flooding and the plan area of the building.

Table B-21: Summary of Flood Damages to Dwellings in the Riverside area

Return Period	Dwellings						
	Count	Depth			Sum of Damages		
		Min	Mean	Max	Min	Mean	Max
2	51	0.16	0.26	0.48	£786,000	£870,400	£946,600
5	69	0.12	0.25	0.52	£1,113,200	£1,216,000	£1,310,000
20	119	0.12	0.28	0.65	£1,823,300	£1,999,000	£2,160,100
30	148	0.11	0.28	0.70	£2,168,100	£2,377,500	£2,568,600
75	185	0.1	0.30	0.81	£2,872,400	£3,150,200	£3,377,200
100	138	0.11	0.24	0.61	£2,075,100	£2,277,000	£2,434,600
200	261	0.07	0.35	1.01	£4,086,500	£4,476,000	£4,813,400
100 + CC	279	0.08	0.39	1.10	£4,774,900	£5,212,700	£5,544,000

Damages are rounded to the nearest £100

Table B-21 shows that the count of dwellings affected by flooding increases as the Annual Exceedance Probability of the event increases. Taking mean values as an example we can see that the average flood depth within each flooded property increases from 0.24 to 0.39 m. As a result, the average cost of damage per dwelling increases between return periods, from around £16.5K for the two-year return period to £18.6K for the 100 + CC return period.

Table B-22: Summary of Flood Damages to Critical Infrastructure in the Riverside area

Return Period	Count	Critical Infrastrucutre					
		Depth			Sum of Damages		
		Min	Mean	Max	Min	Mean	Max
2	4	0.13	0.22	0.50	£3,600	£3,600	£3,600
5	4	0.15	0.30	0.64	£3,600	£3,600	£3,600
20	7	0.14	0.32	0.74	£5,900	£5,900	£5,900
30	7	0.15	0.32	0.76	£6,900	£6,900	£6,900
75	7	0.14	0.36	0.80	£6,900	£6,900	£6,900
100	6	0.14	0.37	0.81	£6,000	£6,000	£6,900
200	7	0.12	0.41	0.86	£6,900	£6,900	£6,900
100 + CC	7	0.11	0.45	0.90	£6,900	£6,900	£6,900

Damages are rounded to the nearest £100

Table B-22 shows that in the Riverside area a relatively high number of critical infrastructure receptors area affected by flooding. Five of these are electricity sub stations. In addition, two are industrial chimneys.

B.6.12 Options

This section summarises the options tested in the Windsor Drive hotspot area of Dartford. Figure B-19 shows the extent of the hotspot, the modelled features and the overland flow pathways in the baseline scenario.

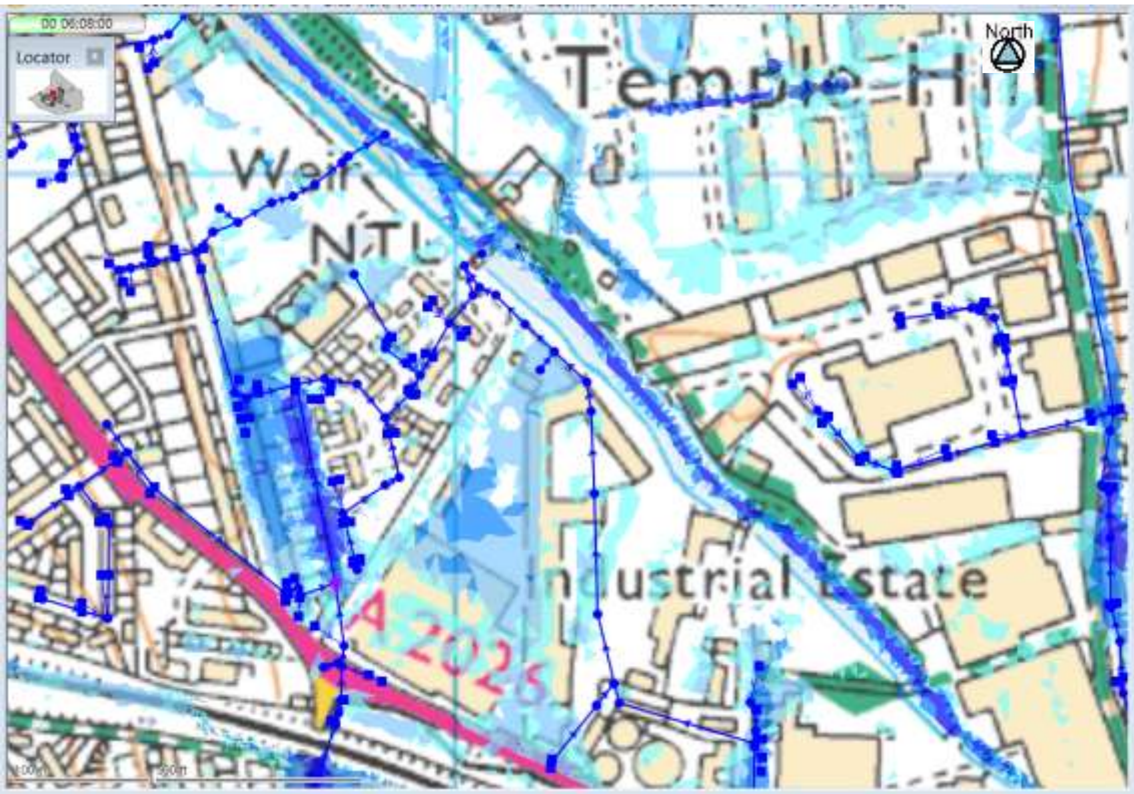


Figure B-19: Mapping of the Riverside Industrial Estate hotspot and flow routes during a 1 in 100-year rainfall event

5.6.7 Concept

In the Riverside Industrial Estate, Priory Road and Avonmouth Road are affected by surface water flooding and surface water sewer exceedance. This area is dense terraced housing with around 90% paved front gardens. The highway is busy, there are parked cars along the length of the roadway and pavements are narrow. As a result, area and street level options are significantly restricted in this hotspot. The underlying problem in this area is that surface water sewer discharge is limited by Priory Road surface water pumping station. Therefore, there is limited head room to accept surface water runoff via the highway drainage network.

The strategy for managing surface water flooding in this location would be to isolate the surface water sewer catchment draining to Priory Road pumping station and reduce the contribution of surface water from roofs and hard standing using source control measures such as rainwater harvesting, green roofs (where redevelopment occurs) and permeable paving.

The lead authority for flood alleviation options in this hotspot would be Thames Water with support from Kent County Council.

Table B-23: Priory Road options overview

Flood management option	Location	Benefits	Lead authority
Enhance Priory Wharf pumping station	Priory Wharf	Reduce flood risk	Thames Water
Reduce surface water contribution	US surface water sewer catchment from Priory Wharf SPS	Reduce carbon and running cost of the SPS. Reduce flood risk.	Thames Water

The options modelled have been summarised in Table B-24 below. The impact of the option is summarised as a *negative change* which is highlighted in green and indicates a reduction in flood risk or damages, *no change* which is highlighted in orange or a *positive change*, which is highlighted in pink and indicates an increase in flood risk of damages as a result of the modelled option.

Table B-24: Riverside Hotspot option appraisal

Priory Road, Riverside Industrial Estate

Baseline:

Source	Pluvial and surface water sewer
Pathway	Overland flow pooling on highway as the drainage network is surcharged. Exceedance flows from the SWS along the rear of Priory Road

Receptor

	5 year	30 year	100 year
Dwelling	55	102	70
Crit Infra	0	0	0
Highways m^2	2,300	4,500	3,400

Model representation: high
Thames Water assets modelled from records.
Flood history verifies model outputs.

Option 1: Enhance Priory Wharf PS

Double the pump rate at Priory Wharf surface water pumping station to 144 l/s utilising all three existing pumps.

Build:

Modelled features
Pump rate increased to 0.144 m^3/s

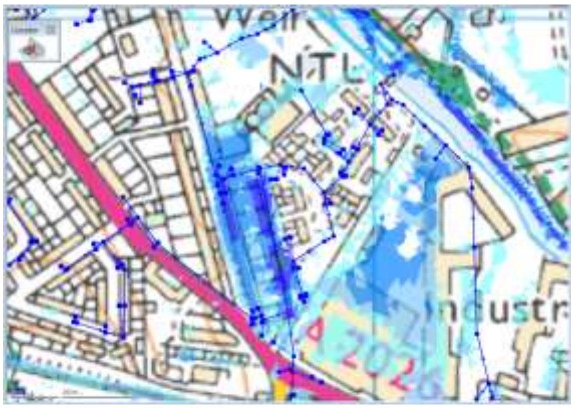
Cost

Construction: Potentially none (if spare capacity exists)
Running ≈ £0.138/kWh

Benefits (receptors not flooded)

	5 year	30 year	100 year
Dwelling	-8	-3	+62
Crit Infra	+0	+0	-1

Results:



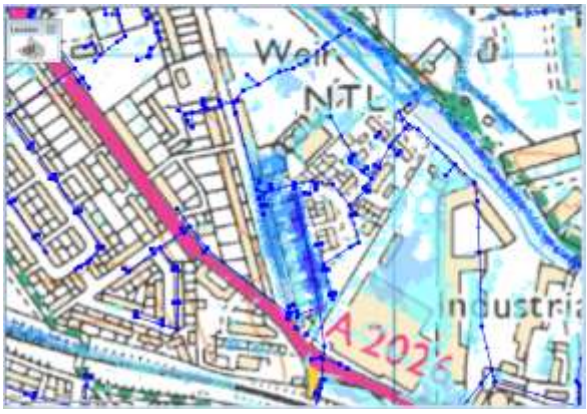
Highway m^2	+217	+262	-3,623
Benefit (financial, in £)			
	5 year	**30 year**	**100 year**
Dwelling	-147,000	-143,000	1,122,000
Crit Infra	+0	+0	-1

Conclusion: Increased pumping reduces risk to properties at low return periods, and is particularly affective at a 1 in 5-year return period. However, at the 1 in 100-year return period the risk of flooding to properties is increased.

Option 2: Reduce Surface Water Contribution

Reduce the contribution of surface water from roofs by disconnecting drainpipes or using water butts which could increase available capacity in the network.

Results:



Modelled features

Remove all contribution from roofs to the surface water sewer system. (Inflows from gullies remain).

Cost

Construction: 1, 450 x water butts = 58,000 - 145,000
Maintenance: none

Benefit (receptors not flooded)

	5 year	30 year	100 year
Dwelling	-4	-16	+59
Crit Infra	+0	+0	+0
Highway	-211	-537	+3,000

Benefit (financial)

	5 year	30 year	100 year
Dwelling	-78,000	-291,000	+887,000
Crit Infra	+0	+0	+0
Highway	-211	-537	+3,000

Conclusion: Eliminating the surface water contribution from roofs reduces the impact of flooding at low return periods, up to and including a 30-year storm. However, at a 1 in 100-year storm the source control measures do not reduce impact of flooding and damages to properties increase.

C Potential flood alleviation options

Potential flood alleviation options

The potential options for application in Dartford were broken into Area, Street and Property level based on the scale of the scheme. A list of the options discussed and their relative merits and disadvantages are summarised in Table C-1, Table C-2 and Table C-3.

C.1 Area level

Area level options have the benefits large scale attenuation, but can have a high land and construction cost associated with them.

Table C-1: Area level surface water mitigation measures

Retention Pond	Infiltration Basin
	
A permanent water feature can offer multiple benefits, including storage for surface water flood flows. Benefits: educational, biodiversity, popular with developers as waterfront properties can fetch high prices. Disadvantages: significant land take, perceived HSE issues Examples in Dartford: Crossways development	An area of temporary storm water storage before natural percolation into the substrate. Advantages: can offer a large storage area, water filtration leads to improved water quality, water table recharge Disadvantages: large land take, dependent on infiltration rate of soil, not suitable for draining pollution hotspots Examples in Dartford: none identified
Construction Cost: £15 - 25 / m^3 volume Maintenance Cost (per annum): £0.5 - 1.5 / m^3 volume[16]	Construction Cost: £10 - 15 / m^3 volume Maintenance Cost (per annum): £0.1 -0.3 / m^3 volume[5]
Conveyance	**Underground Storage**
	
Planning for exceedance to manage flow routes in the urban environment. If overland flows can be channelled away from property to a temporary storage area the impact of flooding will be reduced. Benefits: Low land take Disadvantages: Requires road profiling, increased curb heights can disrupt access (cars, wheelchairs etc.) Examples in Dartford: none identified	Large scale subterranean storage in tanks or geocellular storm crates. Advantages: no surface land take, can provide infiltration, can be high capacity Disadvantages: large scale construction, no water quality treatment Examples in Dartford: none identified
Construction Cost: Depends on measure. Flood walls can be around £120 / m Maintenance Cost: minimal	Construction Cost: High but variable (around £100 - 200 / m^3 volume) Maintenance Cost:

[16] HR Wallingford (2004) SUDS - Economic incentives, social impacts and ecological benefits. Wallingford

C.2 Street level

Street level flood mitigation options have a smaller capacity for receiving storm water but as a result require less land and often can be used as alternative to traditional drainage methods when planning new development, or retrofitted. Street level SuDS can encourage community spirit in terms of a sense of ownership.

Table C-2: Street level surface water mitigation measures

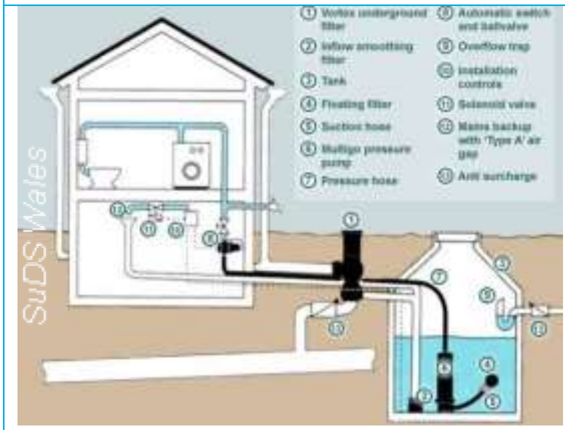
Rain gardens (or bioretention)	Permeable paving
	
Shallow, landscaped depressions which allow for infiltration but are typically also positively drained to an urban drainage network. Advantages: can be planned in landscaping easily, effective at removing urban pollutants Disadvantages: require ongoing maintenance as they are susceptible to clogging, good retrofit capability Examples in Dartford: none identified	A surface suitable for pedestrians and/or vehicles while allowing rainwater to infiltrate through the surface. Advantages: removal of urban runoff pollutants, suitable for installation in high density development, no additional land take Disadvantages: cannot be used where large sediment loads may be washed onto the surface, only suitable for low traffic volumes. Examples in Dartford: Dewlands Avenue
Construction Cost: £50 - 70/ m^2 area[17] Maintenance Cost (per annum): £ 0.5 -1.0/ m^3 volume	Construction Cost: £30 - 40 / m^2 area Maintenance Cost (per annum): £0.5 - 1.0 / m^2 area[5]
Swale	**Soakaways**
	
Linear, vegetated drainage features in which surface water can be stored or conveyed Advantages: easy to incorporate into landscaping, good removal of urban pollutants, low capital cost Disadvantages: not suitable in steep areas or areas with roadside parking Examples in Dartford: Dartford marshes	Excavations providing storm water attenuation and filtration. Advantages: minimal land take, provides groundwater recharge, can be retrofitted Disadvantages: not suitable for poor draining soils or high water tables, property owner responsible for maintenance Examples in Dartford: Highway drainage across south and west Dartford
Construction Cost: £10 -15 / m^2 area Maintenance Cost (per annum): £0.1 / m^2 area[5]	Construction Cost: >£100 m^3 volume Maintenance Cost (per annum): £0.1 / m^3 volume[5]

[17] Department of Environmental Resources (2007) Bioretention Manual. Maryland

C.3 Property level

Property level mitigation measures can be effective where there is not space in a dense urban area for a larger scheme. Individually, these measures may not be effective for reducing surface water, but combined they can offer flood mitigation and ancillary benefits including empowering home owners to manage their own flood risk.

Table C-3: Property level surface water mitigation measures

<table>
<tr><th>Rainwater harvesting</th><th>Disconnected drainpipes</th></tr>
<tr><td>
</td><td>
</td></tr>
<tr><td>A means to store and use rain water for non-potable use
Advantages: reduces demands on mains water
Disadvantages: systems can be complex and costly

Examples in Dartford: Dartford Football Club, Princes Park.</td><td>A means of harvesting rainwater for garden use
Advantages: easy to install and operate, inexpensive
Disadvantages: property owner is responsible for operation and maintenance

Examples in Dartford: Residential properties in south and west Dartford.</td></tr>
<tr><td>Construction Cost: £2,000 - 5,000 (per dwelling)[18]
Maintenance Cost: £260 - 520 (per dwelling)</td><td>Construction Cost: £40 - 100 per water butt
Maintenance Cost: £0 per water butt</td></tr>
<tr><th>Green roofs</th><th>Flood resilience</th></tr>
<tr><td>
</td><td></td></tr>
<tr><td>Vegetation cover over a drainage layer designed to intercept and retain precipitation.
Advantages: can be applied in high density developments, ecological, insulation and air pollution benefits.
Disadvantages: cost (compared to conventional roofs), retrofitting opportunities limited.

Examples in Dartford: The Base for Business, Victoria Road.</td><td>Reducing vulnerability of properties to flood water. Examples include, covers for air bricks and flood gates for doors.
Advantages: can be a cost effective alternative to a large flood defence scheme
Disadvantages: often dependant on owner operation

Examples in Dartford: no known examples</td></tr>
<tr><td>Construction Cost: 60 - 100 / m^2 area[19]
Maintenance Cost: Depends on roof type, minimum, 2 inspections a year.</td><td>Construction Cost: £3,646 (per dwelling) (this is an average, the actual cost is dependent on measures required)
Maintenance Cost: £60 - 100 (per dwelling)[20]</td></tr>
</table>

[18] Rainwater Harvesting Association (2014) http://www.ukrha.org/wp-content/uploads/2012/02/FAQs1.pdf

[19] Groundwork (Sheffield) (2014) Green Roof Guidelines

[20] Defra (2012) Establishing the Cost Effectiveness of Property Flood Protection: FD2657.

D Communication and Engagement Plan

E Hydrological Assessment

F Model Operation Manual

G Damage Calculation

G.1 Damages calculation methodology

G.1.1 Summary

Property counts and damage estimates have been calculated using Frism, JBA's in-house flood metrics software.

G.1.2 Flooding Data

The Frism calculation was run for the following return periods;

Threshold - hazard > 0.575

G.1.3 Receptor Data

The receptor datasets used for the calculations were the NRD property point layer together with Master Map building polygons. The NRD data was filtered to remove properties which did not have a building footprint in Master Map. This removes features such as ponds and post boxes and ensures they are not included in the property count. The NRD data was then further subdivided into residential properties and critical services to define the metrics used for the Frism calculation (Table G-1). Table G-2 shows the attribute queries used to create the subdivisions of NRD.

Table G-1: Metric Definition

Metric Name	Definition
NRD All Count	All NRD property points, filtered to remove points without a corresponding Master Map footprint
NRD Res Count	NRD residential properties
Number of people	Res properties * 2.34
NRD Critical Count	Critical services comprise: schools, hospitals, care homes / nursing homes, police, fire and ambulance stations, prisons, electricity installations and water and sewage installations.

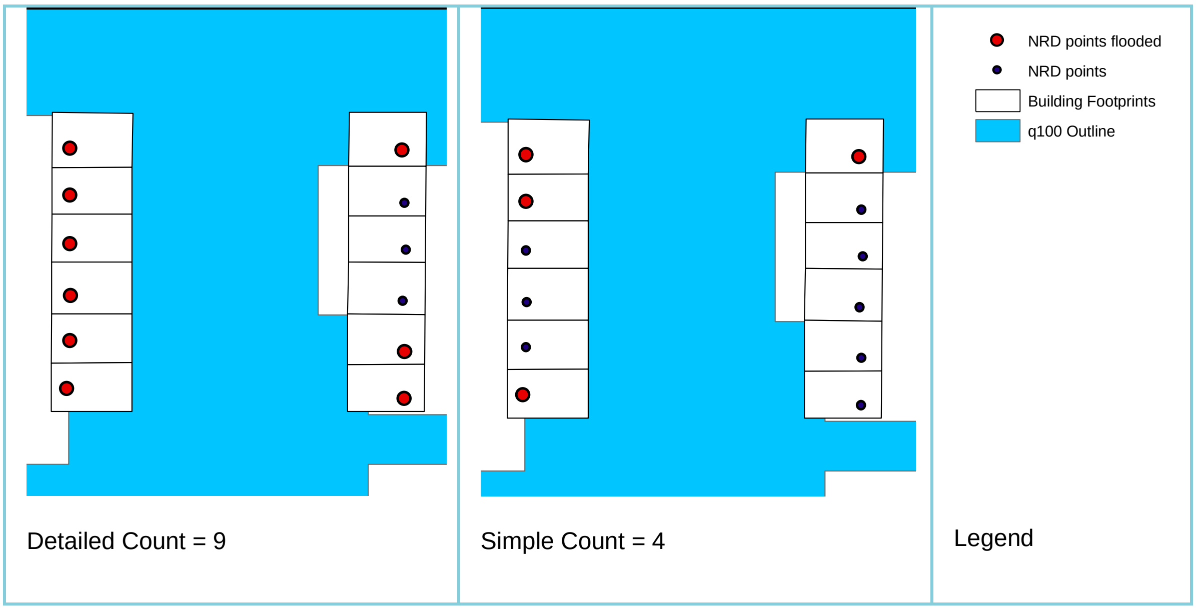
Table G-2: Relationship between individual receptors and the NRD

Receptor	Selection by Attributes WHERE Clause
Res Properties	"mcmcode" = 1
Nursing homes/Care homes/Prisons	"mcmcode" =625
Hospitals	"mcmcode" =660
Police Stations	"mcmcode" = 651
Fire & Ambulance Stations	"mcmcode" = 650
Sewage & Water Works	"mcmcode" = 840
Electricity Installations	"mcmcode" = 960
Schools	Os_class = 'ADULT EDCUATION' OR "Os_class" = 'EDUCATION' OR "Os_class" = 'FIRST SCHOOL' OR "Os_class" = 'FURTHER EDUCATION' OR "Os_class" = 'FURTHER EDUCATION COLLEGE' OR "Os_class" = 'HIGH SCHOOL' OR "Os_class" = 'HIGHER EDUCATION' OR "Os_class" = 'INFANT SCHOOL' OR "Os_class" = 'JUNIOR SCHOOL' OR "Os_class" = 'MIDDLE SCHOOL' OR "Os_class" = 'NURSERY' OR "Os_class" = 'PRIMARY SCHOOL' OR "Os_class" = 'PRIVATE PRIMARY SCHOOL' OR "Os_class" = 'SCHOOL' OR "Os_class" = 'SCHOOL FOR THE DEAF' OR "Os_class" = 'SECONDARY SCHOOL' OR "Os_class" = 'SPECIAL SCHOOL' OR "Os_class" = 'TECHNICAL COLLEGE' OR "Os_class" = 'UNIVERSITY' OR "Os_class" = 'PRE SCHOOL EDUCATION'

G.1.4 Property counts

Property counts were undertaken using the detailed counting method. This method utilises the Master Map building footprints in conjunction with the NRD property points. A property point is counted as flooded if its corresponding building footprint is within the flood outline, even if the property point itself may not fall within the flood outline, this is illustrated in Figure G-1.

Figure G-1: Counting method



G.1.5 Damages

Each flooded property point is attributed with a min, max and mean damage value these values correspond to the damage value for the minimum, maximum and mean depth within the property footprint.

The damage value is in pounds and is worked out by obtaining a unit damage value (£/m2) using the depth damage curves from the Multi Coloured Manual 2010 (Flood Hazards Research Centre 2010). The unit damage value depends on the depth at the property and the property type. This damage value is then multiplied by the value in the floor area field of the NRD to obtain an absolute damage value.

Damages have not been calculated for properties whose floor level is 'pU'. These are potential uppers which are generally upper floors in flats, however properties with a floor level of 'pU' have been included within the property counts. This is because the damage occurred by an upper floor flat is likely to be nil however the residents of the property will still be affected by the flooding.

The values of damages to each property have been capped so that they cannot exceed the value of the property. This is in accordance with best practice as set out in the MCM. The property values were calculated as follows:

- Residential properties: Set at the average property value for each housing type, sold in Kent in June 2013, sourced from the Land Registry web-site[21].
- The damages were not capped

[21] http://www.landreg.gov.uk/house-prices

Table G-3: Average value by housing type

NRD Housing type	Average value (Kent, June 2011)	Notes
Detached	£317,000	
Semi-detached	£185,000	
Terraced	£143,000	
Maisonette / flat	£108,000	
Unknown	£181,000	Based on average for all properties in Kent.

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North Yorkshire
BD23 3AE

t:+44(0)1756 799919
e:info@jbaconsulting.com

Jeremy Benn Associates Ltd
Registered in England
3246693

Visit our website
www.jbaconsulting.com