Flood Risk Appraisal of the River Dour

May 2010

DOVER DISTRICT COUNCIL

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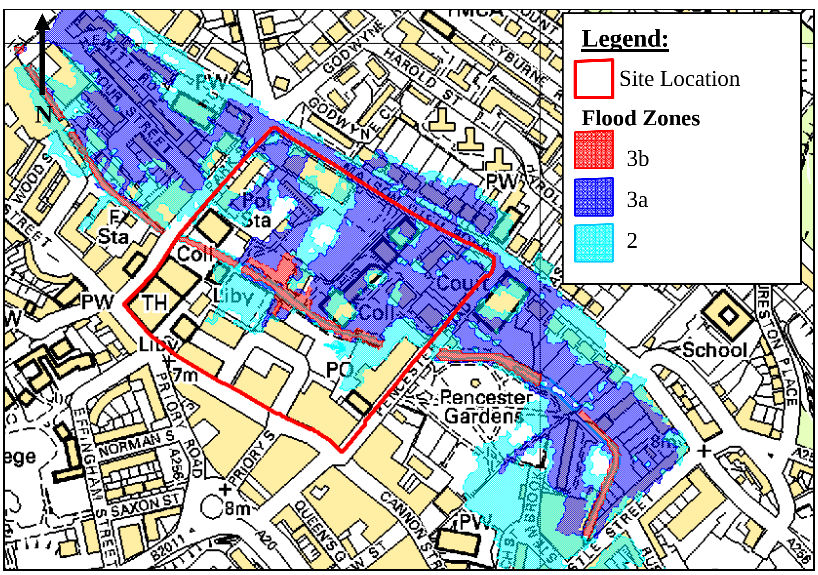
Executive Summary

Capita Symonds has been appointed by Dover District Council (DDC) to undertake a flood risk assessment of the River Dour and appraisal of flood alleviation options for the Mid Town area of Dover. This report is an appraisal of the fluvial, tidal and surface water flood risk and seeks to provide guidance to the Council on development flood risk management options within the site. The focus of this report has been on developing conceptual options to manage fluvial (river) flooding, however consideration is also given to the risk of surface water and tidal flooding.

A fully integrated two-dimensional hydraulic model of the River Dour, surface water drainage network and tidal influence has been developed to inform the assessment. The model has been reviewed by and approved by the Environment Agency for use in the assessment of Flood Zones, as well as ‘actual’ and ‘residual’ risk, and is considered the current ‘best available’ information on flooding from rivers, and surface water in Dover.

Hydraulic modelling undertaken for the River Dour indicates that the Mid Town Dover area includes a small area of Functional Floodplain ‘Flood Zone 3b’ near the river. Modelling results indicate that the existing carpark area is inundated during the 1 in 100 year return period event, including existing defences, along with other lower lying areas of the site. The removal of the existing flood defences does not change the extent or depth of flooding materially on site. The Flood Zones for the Dour (up to Minnis Lane) have also been revised in consultation with the Environment Agency. These revised maps indicate that the site is located within all Flood Zones, with the majority of the northern portion of the site being located within Flood Zone 3a. Masterplan and/or development proposals should use a sequential approach and base land use considerations on the revised Flood Zones and hazard information contained within this report.



Revised Flood Zones within the Mid Town Site

A review of the actual risk to Dover during a 1 in 100 year fluvial flood event indicates that approximately 290 properties are at risk of flooding (this will increase to 430 properties if the predicted effects of climate change are accurate). Flood management options have been investigated and are discussed within Section 6 of this study with all scenarios tested against fluvial flood risk up to events including the 1 in 100 year plus climate change event. The tested options include, upstream storage, river channel works (widening and structure modifications), and the inclusion of raised defences at strategic locations.

Based on a review of these results from the optioneering exercise, environmental impacts, benefit to the Mid Town site (and wider catchment) and costs it is concluded that an option (Option 5b) which included locating flood defences (walls or embankment ranging between 0.5 – 1m) is the most suitable flood alleviation scheme for protecting the Mid Town site. The results from the hydraulic model developed for this scheme, indicate that approximately 180 properties within the urbanised area of Dover could be removed from the risk of fluvial flooding during a 1 in 100 year plus climate event.

The detailed integrated hydraulic model indicates that the site is at a high risk of surface water flooding due to its location at the bottom of the local catchment. The surface water flood risk requires due consideration when setting finished floor levels along with any flood mitigation options so as to reduce any impacts of modifying the current surface water conveyance routes within the Mid Town site.

RECOMMENDATIONS

The revised Flood Zone Map created as part of this assessment should be adopted by the Environment Agency. These Flood Zones should also be used by Dover District Council when they update the SFRA and when the Council undertake a Sequential Test for areas identified for development within their Core Strategy document. The sequential approach should be applied to the masterplanning of the Dover Mid Town area so that the most vulnerable land uses are located in the lowest probability flood zones. A possible option would be to develop land south of the River Dour (within the site boundary) and utilise any benefits gained from this re-development to fund improvement works on the river to enable development on the northern portion of the Mid Town site.

SUDS devices should be carefully selected for the site and where possible reduce runoff rates discharging from the site to that of a undeveloped 'greenfield' scenario to reduce the impacts that development within the Mid Town site have on the local drainage infrastructure within the area during extreme rainfall events.

Further analysis is recommended to reduce uncertainty in both the 'baseline' and option assessment, including:

- Investigate alternative operating procedures or upgrade works for Wellington Docks to improve the fluvial capacity in combined fluvial/tidal event to reduce the risk of flooding within the upstream catchment.
- Incorporate additional information within the integrated hydraulic model developed for the site. This could include the combined sewer drainage network to determine any influence this system may have during surface water flood event.
- Update the Dour Hydrology assessment to incorporate the latest guidelines and provide greater detail of flows within Dover's urban catchment;
- Undertake infiltration testing of soil conditions within the site to update infiltration losses currently utilised within the integrated hydraulic model; and
- Detailed appraisal of design, cost benefit analysis and environment assessment of the options for reducing the risk of fluvial and tidal flooding within Dover.

As there is also no existing flood warning service available to Dover, it is recommended that the Environment Agency install a hydrometric gauge on the River to ensure that when flows are approaching significant levels within the watercourse a warning can be given to existing residents and property owners to take appropriate and timely action.

The steering group should continue their integrated approach to addressing flooding within Dover, in particular surface water flooding. The surface water flood risk should be informed by the DEFRA funded SWMP, currently commissioned by Kent County Council, and utilise information provided within the SWMP where appropriate as this appraisal has indicated that surface water flooding is a particularly significant issue in the Dover Mid Town area.

Contents

1. Introduction

1.1 Scope of Assessment

1.1.1 Capita Symonds has been appointed by Dover District Council (DDC) to undertake a flood risk assessment of the River Dour and appraisal of flood alleviation options for the Dover Mid Town Area.

1.1.2 Environment Agency Flood Zone mapping indicates that the site is located predominately within Flood Zone 3a. It should be noted that the existing Flood Zones for the River Dour were determined using broad scale modelling techniques, as well as historic flooding data, to determine possible areas at risk of fluvial or tidal flooding. This report forms part of a more detailed assessment of the River Dour and has been undertaken to define the actual risk of flooding from the river.

1.1.3 The primary objectives of this study have been to:

- Provide more accurate flood zone maps for Dover; the overall objective of this study is to supply Dover District Council with detailed hydraulic model which satisfies the Environment Agency's requirements for remapping the Flood Zones within Dover;
- Identify the actual flood risk and the hazard of flooding to the Mid Town site; the hydraulic model that has been created for this assessment is a fully integrated fluvial, tidal and surface water model which will provide flood risk information which can be used by the Environment Agency and Dover District Council to inform future development proposals throughout Dover in relation to fluvial and tidal flood depth and hazard;
- Investigate flood alleviation options for the Dover Mid Town site as part of a wider strategic solution. If possible, these options should provide a benefit to the wider River Dour urban floodplain and not just the Mid Town area; and
- Investigate the risk of surface water flooding within the Mid Town site through hydraulic modelling. This information should be utilised and enhanced as required for use within the current Surface Water Management Plan being prepare by Kent County Council for the wider Dover area.

1.1.4 The preparation of this study has comprised of two key stages;

- Stage 1: Prepare a Flood Risk Appraisal (FRA) of the Mid Town site to inform the appropriate land use locations based on the sequential approach. This will scope out all flooding related issues and will help to inform the second phase of the study.
- Stage 2: Identify a range of flood alleviation options that can reduce the risk of flooding (fluvial, tidal and surface water) to the Mid Town site. The degree of flood risk reduction will need to be assessed against two key criteria:
    - In order to demonstrate development is 'compatible' on the Mid Town site, in accordance with PPS25 it will be necessary to demonstrate that the site can be removed from the functional floodplain (FZ3b);
    - However, in order to facilitate development of the nature proposed, it will be necessary to meet the indicative standard of protection which is taken in this situation as being the 1 in 100 year return period for fluvial flooding and 1 in 200 years for tidal flooding.

1.1.5 It should be noted that the flood alleviation options identified within Section 6 are conceptual and their selection and feasibility would be subject to detailed appraisal of design, cost benefit analysis and environment assessment. These options should also be appropriately tested using sensitivity analysis. Detailed design will need to verify that selected options reduce the risk of flooding to the site and do not increase flood risk up or downstream.

1.2 STEERING COMMITTEE

1.2.1 A Steering Group led by Dover District Council was formed in 2009 to determine the actual risk of flooding to the site and assist development in the city through greater confidence in the accuracy of flood risk information. The commission of this report illustrates the commitment of the following steering group members to sustainably manage the flood risk within Dover:

- Dover District Council;
- Environment Agency;
- Southern Water; and
- Kent Highway Services.

1.3 RESPONSIBILITY

1.3.1 This report does not constitute a detailed flood risk assessment that could support a planning application, as required by Planning Policy Statement 25 (PPS 25). This Flood Risk Appraisal seeks to demonstrate flood risk constraints on site can be overcome, and measures to manage and where possible reduce flood risk within the site which can be reasonably incorporated into the Dover Mid Town Study area (part c of the Exception Test).

1.3.2 Dover District Council is responsible for promoting the site for redevelopment. Capita Symonds is responsible for assessing flood risk on the Mid Town site and providing conceptual flood risk management options, informed by detailed hydraulic modelling of the River Dour (and local 'surface water' drainage system).

2. Site Background

2.1 EXISTING DEVELOPMENT AND LOCATION

2.1.1 The Mid Town study area (approximately 5.9ha) is the most northerly block of Dover town centre located between the High Street, Maison Dieu Road, Park Street and Pencester Road. The River Dour bisects the site and flows in a north-westerly to south-easterly direction (refer to Figure 2.1). Information taken from the Dover District Council Core Strategy identifies Mid Town as a Strategic Allocation (Policy CP9).

2.1.2 The Mid Town area includes a number of uses including South Kent College, retailers that front onto Biggin Street and Pencester Road, the Town Hall, Dover Town Council Offices, Visitor Centre, two Health Centres, BT Telephone Exchange, EDF Depot, Bowling Green, car parks and residential properties.

Figure 2.1 Proposed Mid Town Development Area (Source Dover Masterplan Final Report, 2006)

2.2 TOPOGRAPHY

2.2.1 A review of the processed LiDAR (a process that filters out of buildings and vegetation to give a bare earth surface) and the topographical survey undertaken within the car park area of the site concludes that ground levels within the study area vary between 7 m AOD and 4.95 m AOD. Ground levels within the carpark vary between 5.14 – 6.2 m AOD. Figure 2.2 below provides a graphical representation of the ground levels as recorded within the processed LiDAR information provided by the Environment Agency (refer to Appendix A, Figure A2 for a larger map).

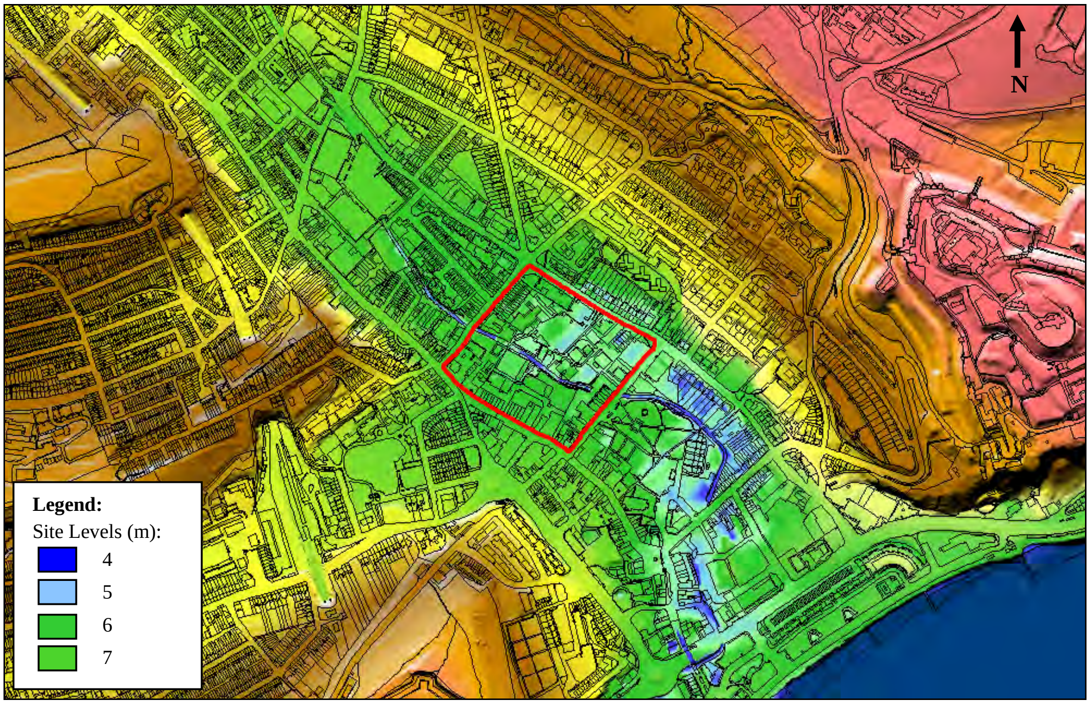


Figure 2.2. Topographical Information for Dover (Source Environment Agency; Processed LiDAR)

2.2.2 From this graphical representation, it can clearly be seen that ground levels within Dover vary from sea level up to elevations above 100mAOD. A closer inspection of the catchment and study area indicates that the site is located at the bottom on a basin.

2.3 PROPOSED DEVELOPMENT

2.3.1 The Dover Masterplan report completed in May 2006, emphasised that the river should be embraced as an important asset rather than ignored. This report states that: “The River is not only an important ecological habitat, but it also provides visual interest to the otherwise built up urban environment and provides an attractive alternative pedestrian link to the town centre. There is a fundamental need to improve and create new opportunities in Dover town centre. The priority is for better employment, residential, retail and leisure choices for people who live in Dover and to help generate a new level of interest in the future of the town centre”.

2.3.2 The Core Strategy was adopted by the District Council in February 2010. The Core Strategy states:

The site is suitable for a mixed development of public sector uses, retail and residential. While the area should be planned for redevelopment as a whole, multiple land ownership and differing programmes and priorities make it likely that development will occur in stages over the plan period. The key factor is to ensure that no individual stage would prejudice further stages of the redevelopment. In this respect the completion of a comprehensive masterplan, prepared in conjunction with landowners and others and agreed by the Council, will be particularly important. Each development should then demonstrate how it will contribute to the completion of the masterplan. It is likely that the public sector will need to lead on the production of the masterplan.

2.3.3 Figure 2.3 illustrates the principal issues with the proposed redevelopment of the area to be used in informing the masterplanning process.

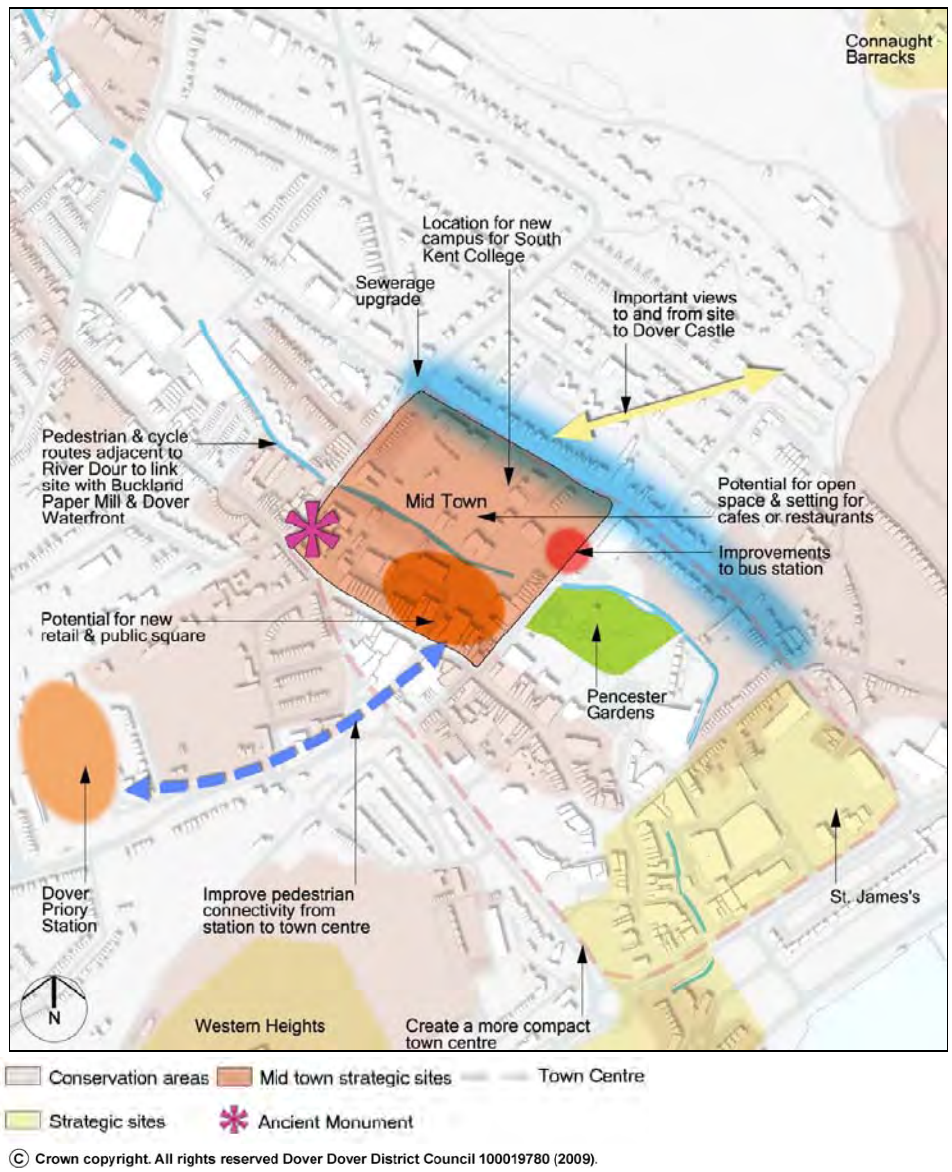


Figure 2.3 Mid Town Constraints and Opportunities

2.4 River Dour

2.4.1 The Stour CFMP identifies that the River Dour is approximately 7.5km in length with the head of the River rising upstream of Kearsney Abbey and joining the English Channel at Wellington Dock. The river receives inflows from the Kearsney Tributary and the Alkham Bourne.

2.4.2 The Dour Hydrology report (PBA, 2007) provides the following useful overview of the River Dour catchment:

The Dour catchment is relatively small, approximately 67km2. The upper catchment is rural, and mainly groundwater fed from springs which contribute to the high baseflow component of flow. The lower catchment through Dover is highly modified and urbanised and responds quickly to any rainfall events. The channel through Dover serves as the primary route for storm drainage for the town.

The geology of the catchment is predominantly upper and middle Chalk and baseflows are highly dependent on the local groundwater levels. The upper catchment has two tributaries. The main river source drains the Lydden Valley and rises in Watersend Pond, Temple Ewell. The Alkham Bourne drains the Alkham Valley and has perennial springs at Bushy Ruff and Kearnsey Abbey Lake. Both tributaries meet at Kearnsey Abbey Lake before flowing in a southeast direction and draining into the English Channel at the Western Docks, Dover.

The geology of the catchment ensures a high baseflow component to the river with flashy peaks superimposed on the hydrograph due to storm runoff form the urban area.

2.4.3 The River Dour bisects the Dover Mid Town site and flows in a north-westerly to south-easterly direction. The River Dour has recently been classified as a 'Main River'. This classification provides the Environment Agency with permissive powers to undertake maintenance works on the watercourse. The river is largely undefended as it flows through the town and is heavily constrained (extensive urbanisation) and has been extensively modified by concrete channels, culverts and weirs.

2.4.4 A review of cross sectional survey information of the River Dour indicates that the river is approximately 8m wide within the Mid Town area (near the pedestrian footbridge) and narrows as it approaches the culvert adjacent to the college. Downstream, the River Dour passes through Pencester Gardens and then through several culvert sections before discharging into Wellington Docks.

2.5 Existing Flood Risk Management Infrastructure

2.5.1 The heavily engineered River Dour effects flood mechanisms throughout the catchment. There are no recognised formal flood defences in the catchment that provide a designated standard of protection. However, there are a number of small raised walls which influence flood mechanisms during the modelled return period events. Figure 2.6 provides the indicative location of these walls. These walls have been removed within the modelling scenarios required for delineating the revised Flood Zone Maps for Dover, However, in determining the 'actual risk' to the site the walls have been verified by topographical survey and incorporated within the hydraulic model as appropriate. Within the site there are clearly visible walls that assist in providing a small benefit in protecting the site from fluvial (river) flooding (refer to Figure 2.4, overleaf).

Figure 2.4. Upstream View of De Facto Defences located within the Mid Town Site.

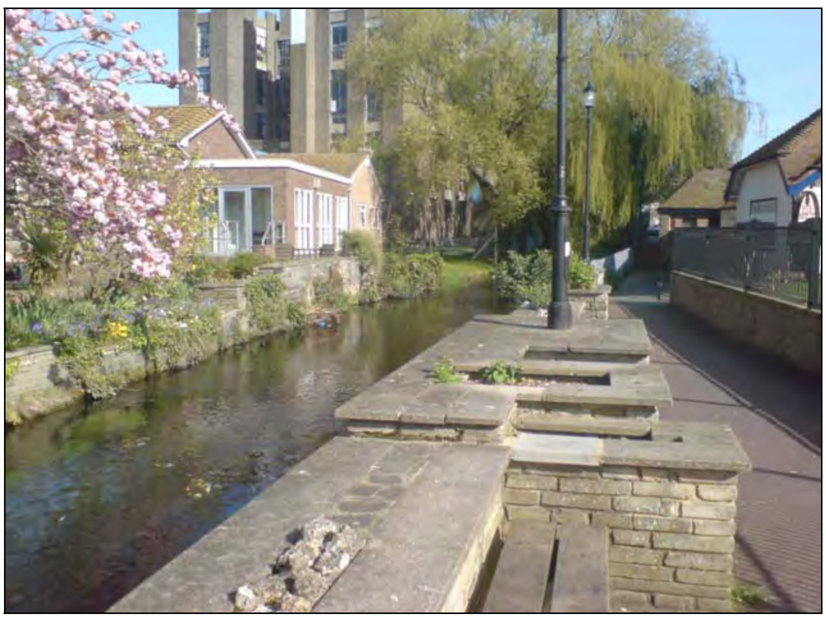


Figure 2.5. Downstream View of De Facto Defences located within the Mid Town Site.

2.5.2 Hydraulic modelling has been undertaken of the River Dour to determine the actual risk of flooding to the site by both fluvial (river), and tidal (sea) and sources of flooding. Section 3 identifies the current risk of flooding from the river as defined by the Environment Agency Flood Zone Maps. Appendix C provides a summary of the methodology utilised to assess the actual risk of flooding to the site from a combined one and two dimensional (1D/2D) model of the River Dour.

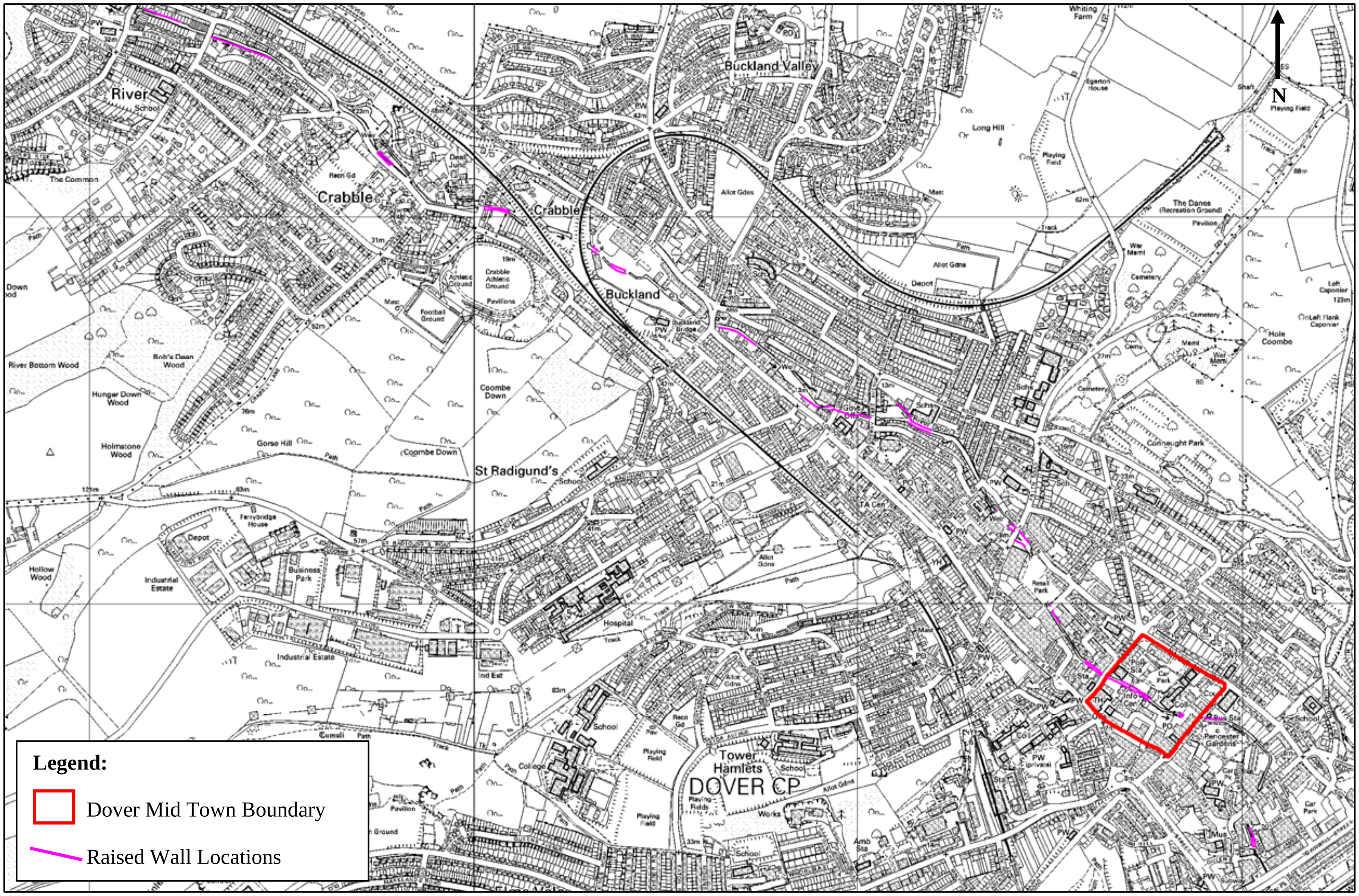


Figure 2.6 Location of existing raised walls and embankments on the Rive Dour

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2.6 SOIL AND GEOLOGY CLASSIFICATION

2.6.1 The British Geological Society Soil Survey Map Sheet 6 indicates that the site is "Unsurveyed, mainly urban and industrial areas". An extract from this plan can be found in Figure 2.7 below.

The soil map:
Soils of England and Wales
Sheet 6 South East England

1:250,000 scale
Copyright: 1983

Site Legend:

U

Unsurveyed, mainly urban and industrial areas

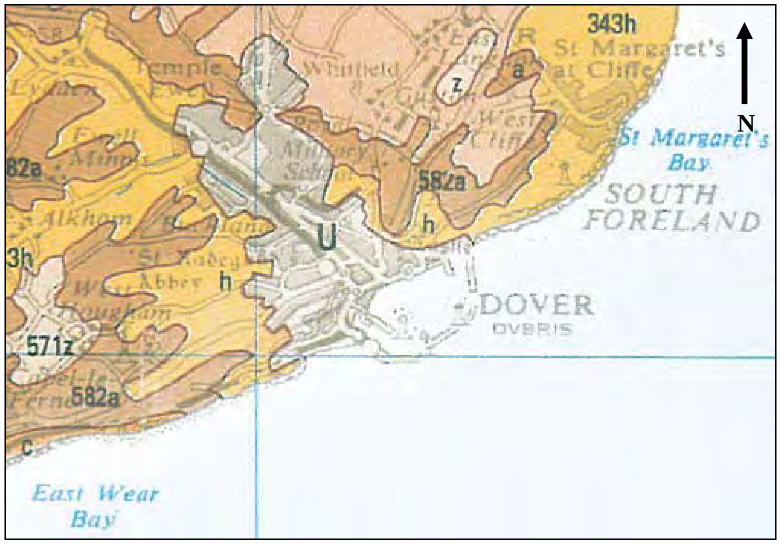


Figure 2.7 Extract of British Geological Society Soil Map Sheet 6

2.6.2 The British Geological Society Solid and Drift Geology Map 290 (Figure 2.8), indicates that the site is on alluvium underlain by middle Chalk. Both the CFMP and SFRA indicate that the Mid Town site is mainly chalk covered by a thin layer of alluvium. The Stour CFMP indicates that river is closely 'coupled' with the underlying chalk aquifer and so is affected by groundwater levels. The geology of the catchment ensures a high baseflow component to the river with flashy peaks caused by storm runoff from the urban area.

The geology map:
Solid and Drift
1:50,000 scale
Sheet 290 Dover
Copyright:1977

Site Legend:

Alluvium

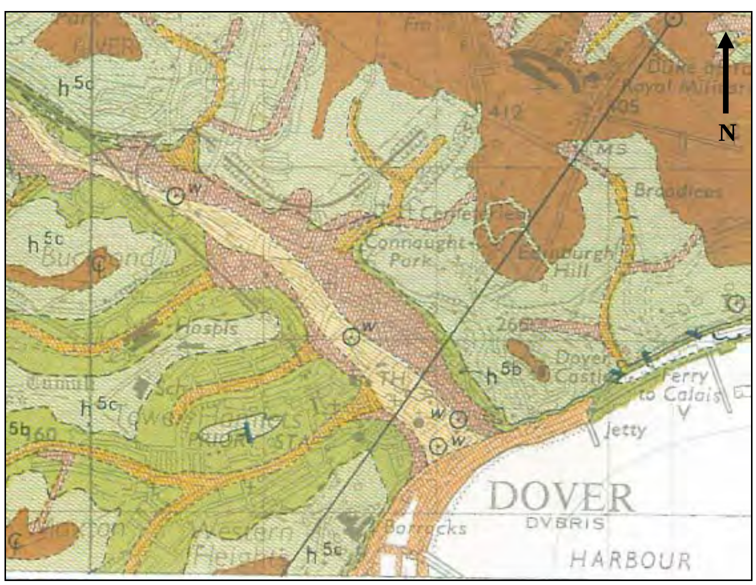


Figure 2.8 Extract of British Geological Society Geology Map Sheet 290.

CAPITA SYMONDS

3. Policy, Guidance and Relevant Studies

3.1 National Policy

Planning Policy Statement 25: Development and Flood Risk (PPS25), DCLG (December 2006)

3.1.1 In determining an approach for the assessment of flood risk for the study area, there is a need to review the policy context. Government guidance requires that consideration be given to flood risk in the planning process. PPS25 outlines the national policy on development and flood risk assessment. It was issued in December 2006 as the replacement to Planning Policy Guidance 25: Development and Flood Risk (PPG25) - developed in response to significant flood events in the UK in Easter 1998 and Autumn 2000. PPG25 adopted a precautionary, risk-based, sequential approach to flood risk and requires that future effects of climate change are evaluated. PPS25 maintains this approach; however it provides additional guidance on land use and strategic considerations. The assessment and management of flood risk within the context of the Study area has followed this approach in the layout and design by incorporating sustainable drainage techniques throughout.

3.1.2 The policy states that flood risk should be considered at all stages throughout the planning and development process to ensure that new development is not exposed to unnecessary flood risk and where possible floodplains are maintained as natural flood storage areas. The essence of PPS25 is that:

- The susceptibility of land to flooding is a material planning consideration;
- The Environment Agency has the lead role in providing advice on flood issues, at a strategic level and in relation to planning applications;
- Policies in development plans should outline the consideration which will be given to flood issues, recognising the uncertainties that are inherent in the prediction of flooding and that flood risk is expected to increase as a result of climate change;
- Planning authorities should apply the precautionary principle to the issue of flood risk, using a risk-based search sequence to avoid such risk where possible and managing it elsewhere. With respect to the masterplan, the limited area of Flood Zone 3 within the Study area has been deliberately included to allow for flood management as well as environmental and public access benefits;
- The vulnerability of a proposed land use should be considered when assessing flood risk;
- Planning authorities should recognise the importance of functional floodplains, where water flows or is held at times of flood, and avoid inappropriate development on undeveloped and undefended floodplains;
- Developers should fund the provision and maintenance of flood defences that are required because of the development;
- Planning policies and decisions should recognise that the consideration of flood risk and its management needs to be applied on a whole catchment basis and not restricted to floodplains; and
- A strategic approach should be adopted in keeping with Government’s aims to ensure that new development is sustainable, including the need to apply Strategic Flood Risk Assessment to decisions taken at all levels of planning, i.e. the need for assessment at the Regional Spatial Strategy.

3.2 LOCAL POLICY

LOCAL DEVELOPMENT DOCUMENTS

3.2.1 The Dover District Local Plan was adopted in 2002. This plan was not developed in accordance with PPS25 or PPG25 but it does recognise that areas at risk from flooding need to be minimised.

3.2.2 The Council's Core Strategy was adopted on the 24th February 2010 and is the central document in the Council's Local Development Framework (LDF), providing the statutory spatial planning framework for the district to 2026 and beyond. The Strategy also sets out the policies for the four strategic sites in Dover (including Mid Town) and the Development Management Policies for the District.

3.2.3 This is the first document to be adopted in the Council's LDF. The next Development Plan Document to be progressed will be the Site Allocations Document.

3.2.4 The District is one of the drier parts of the region and because of this the Council will seek to conserve water in new developments through the use of the Code for Sustainable Homes (Core Strategy Policy CP5, Sustainable Construction Standards). The use of SuDS, for example, would be supported to reduce surface runoff and localised flooding.

3.2.5 For developments in flood risk areas the Council would use the guidance in Planning Policy Statement 25, Flood Risk, to ascertain whether the proposed scheme would be acceptable, working in close conjunction with the Environment Agency.

3.2.6 The Adopted Core Strategy includes a policy which relates directly to development located near the River Dour. This policy is DM 18 and specifies that:

Development proposals that affect the setting of the River Dour should, wherever possible, ensure that they create a connected active river frontage, improve public access and enhance wildlife interest

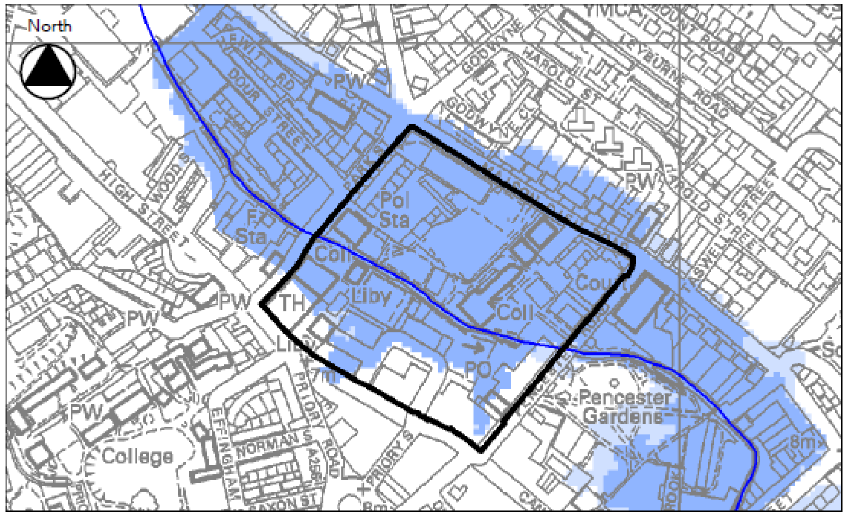
Dover District Council Level 1 Strategic Flood Risk Assessment (SFRA) (September 2007)

3.2.7 The Strategic Flood Risk Assessment (SFRA) informed the preparation of the Core Strategy and any subsequent Local Development Documents, ensure the Council are meets its obligations with regard to the relevant planning guidance, assist developers in fulfilling their obligations provide an overview of the catchments within the Dover.

3.2.8 The SFRA identifies that Dover District Council, covers a total area of 31,930ha. The majority of the urban development is located along the coast, with dispersed village's further inland.

3.2.9 A summary of the risk of flooding to the site as determined within the SFRA can be located within Table 3.1, overleaf.

Table 3.1 Mid Town Dover SFRA Flood Risk Summary

SFRA Flood Zone Coverage Main River Development Site Flood Zone 3a Flood Zone 3b Flood Zone 2	FZ3a 80%, FZ2 2%, FZ1 18% 
Tidal/Fluvial	Fluvial
Other Sources of Flooding	Potential groundwater flooding due to underlying chalk. Surface water runoff could be a flood risk due to the surrounding urban development.
Historical Flooding	During Flooding in June 2007, fluvial flooding from the Dour occurred and the surcharged drains at TR31754180 (within the site boundary) onto Maison Dieu Road and College area
Soil and Geology	Geology – Chalk Soil – Shallow silty over chalk
Indicative Suitability for SUDS	Low
Current Site Conditions	Brownfield
Source Protection Zone	No
Additional Information	Flood Warning Area: None
Exception Testing	The Exception test is applicable to this site
Liklihood of passing	Low
Range of Modelled Flood Depths and velocities	Not applicable as no defences are present and therefore no further analysis was undertaken.
Recommendations	Desktop assessment highlighted historical flooding and is at 'high' risk due to regularly occurring flood events. Recommended that a detailed hydraulic model is developed. The EA suggested that a small portion of the site lies within Flood Zone 3b and should be confirmed within FRA. Land raising and flood compensation may not be viable for this development but should be discussed with the Environment Agency.

3.2.10 The SFRA also provides guidance on mitigation techniques available to sites that are identified as being within an area of flood risk. Table 5-44 of the SFRA identifies screening criteria for site mitigation measures.

3.2.11 The SFRA states that:

It is recognised that in some locations urban regeneration and redevelopment will be essential to maintain the long term viability and vitality of communities and the balance of the raft of planning considerations may support redevelopment. These social considerations may justify a relaxation of the screening criteria set out below (Table 5-44) and the retention of housing and employment allocations in certain areas. In these instances the commercial viability of the development and risks to public safety will need to be given careful considerations during the planning of the development. A range of flood management and flood proofing measures are available that can reduce the financial impacts of flooding.

3.2.12 It also indicates that in some instances the findings of individual FRAs may determine that the risk of flooding to a proposed development is too great and mitigation measures are not feasible. The Environment Agency may object to the development in these instances if the risk to the site is too high.

STOUR CATCHMENT FLOOD MANAGEMENT PLAN

3.2.13 The Environment Agency has formally agreed The Stour Catchment Flood Management Plan (CFMP). The plan was signed off by the Southern Regional Director in September 2008 and was agreed by the Southern Regional Flood Defence Committee on 1 October 2008. The CFMP was prepared in partnership with regional and local planning authorities, community and environmental groups and other stakeholders.

3.2.14 The Stour CFMP gives an overview of the flood risk in the wider Stour catchment and sets out our preferred plan for sustainable flood risk management over the next 50 to 100 years.

3.2.15 The CFMP outlines several policy requirements which relate to the Dour. Policy 4 was selected for the Dour. The purpose of this policy is to: *Take further action to sustain the current scale of flood risk into the future (responding to the potential increases in flood risk from urban development, land use change and climate change).* Table 6.2-Dour within the Stour CFMP provides a justification for this policy selection over others.

3.2.16 Table 3.2, overleaf, provides a summary of the recommendations for the Dour Catchment in order to satisfy Policy 4.

3.2.17 The information provided within the hydraulic model developed as part of this study delivers Dover District Councils requirements for undertake a Dour fluvial Study (Action 3) and also provides the initial stage of undertaking an Integrated Urban Drainage Strategy via the development of the integrated hydraulic model which incorporates fluvial, tidal and pluvial elements. It is envisaged that this model can be further enhanced to assist the steering group in developing coordinated solutions to manage surface water flooding In Dover (Action 2).

Table 3.2 Stour CFMP Policy Recommendations for the Dour Catchment.

Action	Delivery Plan Type	Success Criteria	Lead Partners	Timescale	Priority	Objectives	Indicator(s)
1. Develop a **System Asset Management Plan** (SAMP) to ensure existing defences in Dover are in good condition and able to accommodate increased flooding due to climate change.	SAMP	SAMP completed	Environment Agency	0 – 5 years	High	Provide sustainable flood risk management options to manage the risk of fluvial flooding to the built environment, taking account of future climate, sea level and land-use changes. Avoid increasing the current fluvial flood risk to all transport links and reduce flood risk to key road and rail routes.	• Properties at risk of flooding • Social flood vulnerability index • Average Annual Damages • Roads and other transport infrastructure at risk of flooding.
2. **Integrated Urban Drainage Strategy** for Dover	SWMP	Integrated Urban Drainage Strategy completed	Dover District Council, Environment Agency	5-20 years	Med	Provide sustainable flood risk management options to manage the risk of fluvial flooding to the built environment, taking account of future climate, sea level and land-use changes. Avoid increasing the current fluvial flood risk to all transport links and reduce flood risk to key road and rail routes.	• Properties at risk of flooding • Social flood vulnerability index • Average Annual Damages • Roads and other transport infrastructure at risk of flooding.
3 Carry out **Dour Fluvial Study,** focusing on understanding future flood risk from the Dour in Dover	Further study	Study completed	Environment Agency	5-20 years	Low	Provide sustainable flood risk management options to manage the risk of fluvial flooding to the built environment, taking account of future climate, sea level and land-use changes. Avoid increasing the current fluvial flood risk to all transport links and reduce flood risk to key road and rail routes.	• Properties at risk of flooding • Social flood vulnerability index • Average Annual Damages • Roads and other transport infrastructure at risk of flooding.

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Dover District Council Water Cycle Study

3.2.18 The purpose of the Water Cycle Study (WCS) was to identify if there were any water related issues that present significant obstacles to the success of development in the Dover District area. The study examined how much growth could be accommodated within the existing infrastructure. It examines:

- Whether sufficient water resources are available to supply forecast demand;
- How much growth the existing drainage and wastewater treatment works (WwTW) can accommodate; and
- Whether or not the streams, rivers, and coastal waters in the area have sufficient capacity to meet any additional discharges, or varied discharge concentrations without water quality deteriorating.

3.2.19 In report found that the water quality of the Dour in the Dover district was consistently high based on chemistry and biology (from 2000 – 2007). The River Dour at both Wellington Dock (downstream of Buckland Paper Mill) and at the Paper Mill at Chilton has on both accounts good water quality with higher standards than these observed on the Little Stour and Wingham.

3.2.20 The report states that although less extensive than the tidal flood risk, there is a risk of fluvial flooding in the District from the River Dour through Dover, the River Stour through Sandwich and its tributary the River Wingham through Wingham and toward West Stourmouth. The WCS states that the River Dour is a relatively small river and as a result the associated flood risk zones are closely contained to the river channel. Nevertheless, the river has been culverted as it flows through the centre of Dover.

3.2.21 Due to the site specific nature of drainage requirements/opportunities this study has made high level recommendations that Sustainable Drainage Systems (SuDS) should be incorporated into development plans. The report indicates that there is potential for using infiltration SuDS in the study catchments due to the permeable geology of the District. It also indicates that the potential for surface water flooding is low, however the WCS does identify that within Dover where there is urban development over the Dour valley, combined with sewer capacity issues, there is a higher risk of surface water flooding.

Recommendations

3.2.22 The WCS recommends that new developments should aim to manage surface water runoff in a sustainable manner by considering SuDS as early as possible in the planning process. Each new development greater than 1 ha surface area must prepare an appropriate scale Flood Risk Assessment that demonstrates that SuDS can control runoff rates and volumes from the site to existing runoff rates. These requirements stem from PPS25.

3.2.23 The WCS also recommends that a site specific assessment of ground conditions is needed to determine the most appropriate SuDS for use at a new development. Reference to the SFRA where appropriate will aid the assessment for SuDS suitability. SuDS must be designed so that no flooding occurs at properties at a 1 in 100 year storm event (1% annual probability). A 30% increase in rainfall must be added to the runoff calculations when designing SuDS at both outline and detailed planning application to account for the possible increases as a result of climate change. Priority should be given to SuDS over more traditional drainage systems, and if SuDS are not considered appropriate then justification should be given.

3.2.24 In order to further assist in meeting the development targets and improving the sustainable use and treatment of water in the District the report recommends that a Phase 2 study is undertaken for the District.

3.3 GUIDANCE DOCUMENTS

DEVELOPMENT AND FLOOD RISK: A PRACTICE GUIDE TO PPS25, CLG (JUNE 2008)

3.3.1 The Practice Guide provides advice on the practical implementation of PPS25, and provides additional guidance on what is required at regional and local level.

UK CLIMATE IMPACT PROGRAMME 2009 (UKCIP09)

3.3.2 In June 2009 the UK Climate Impact Programme released new guidance with respect to climate change predictions. The predictions have moved from a deterministic approach (i.e. one range of outcomes) to a probabilistic approach (i.e. a range of possible outcomes based on a range of scenarios).

3.3.3 The results indicate that based on a central estimate of likely outcomes (i.e. 50 percentile), increases in rainfall are expected to remain similar to those predicted by UKCP02 (i.e. those used in this FRA). A high estimate of likely outcomes (i.e. 95 percentile) could result in significantly more intense rainfall than at present.

3.3.4 At present DEFRA and the Department for Communities and Local Government (CLG) have advised to continue using the existing climate change guidance (PPS25).

4. Existing Flood Risk

4.1 Background

4.1.1 A review of the CFMP and SFRA indicates that there is no confirmed data that indicates Dover has experienced widespread flooding solely from the River Dour. However localised areas along the watercourse have been flooded. The CFMP determined that the highest risk of flooding is caused by a long period of rainfall that results in high groundwater and high baseflow within the river. If this is then followed by a high intensity storm over Dover, there is likely to be a very fast runoff into the channel causing localised flooding.

4.1.2 This section of the report provides a summary of the flood risk to the Mid Town site. Details on the hydraulic model outputs used to inform this section are located within Appendix C of this report.

4.2 Historic Flooding

4.2.1 A number of sources including local newspapers, residents, internet, Southern Water and the Environment Agency, have advised flooding has occurred in or near the study area. The most recently events occurred in June 2007 and July 2009. It is unclear if this flood event occurred specifically due to the flooding from the River Dour, rainfall exceeding the drainage capacity the existing drainage network, failure of a pump station within the existing drainage network, a blockage of downstream drainage infrastructure (including infrastructure within the Dour) or a combination of the above.

4.2.2 An analysis of the rainfall recorded at the Dover rain gauge (approximately 350m away from the site), indicates that the rainfall events for 2007 and 2009 were estimate as being, 1 in 17 year and a 1 in 11 year return period pluvial rainfall event, respectively.

4.2.3 The Stour Catchment Flood Management Plan indicates that:

- A flood event in February 2001 is believed to have been caused by fluvial flooding within Dover on top of a high water table, following a wet winter; and
- On the 27th September 2003 excess runoff caused flooding in the London Road area of Dover (northwest of the study area) following an intense storm event.

4.3 Previous Studies

4.3.1 Several studies have been commissioned by both the Environment Agency and Dover District Council which relate either directly or indirectly to the Mid Town site. These reports and their findings are summarised below.

Dour Hydrology Report, prepared by Peter Brett Associates – date 2007

4.3.2 The Kent Area of the Environment Agency Southern Region commissioned Peter Brett Associates (PBA) to undertake a hydrological study of the River Dour in Kent.

4.3.3 This main purpose of the report was to:

- Re-rate the Crabble Mill Gauging Station;
- Estimate hydrological inflows for the potential for inclusion in a hydraulic model (at a later date); and
- Prepare guidelines in agreement with the Environment Agency for flood risk assessment on the River Dour, to include recommendations to developers on the most appropriate method for determining site specific flood levels.

4.3.4 The report provided guidance on how to use the broad scale model generated for the Dour catchment along with recommendations for future assessments. The hydrological information prepared as part of this report was utilised within the revised River Dour model produced for the Mid Town site.

Mid Town, Dover Flood Risk Assessment, Prepared by JBA – October 2008

4.3.5 Dover District Council undertook an initial Flood Risk Assessment for the Mid Town area of Dover in October 2008.

4.3.6 This report concluded that the main flood risk is fluvial flooding from the River Dour and from surface water.

4.3.7 A key conclusion from the hydraulic model developed to inform the FRA is that the majority of the site was likely to flood in both a 1 in 20-year (Figure 4.1 below) and 1 in 100-year fluvial flood event. The report also concluded that the River Dour was tidally affected in its lower reaches. However the hydraulic model also indicated that the 1000-year tidal level would not affect the site. This identification of the functional floodplain within the site would restrict the redeveloped site. It should be noted that these results were not signed off by the Environment Agency and as such did not constitute the basis for updating the Flood Zones within the site.

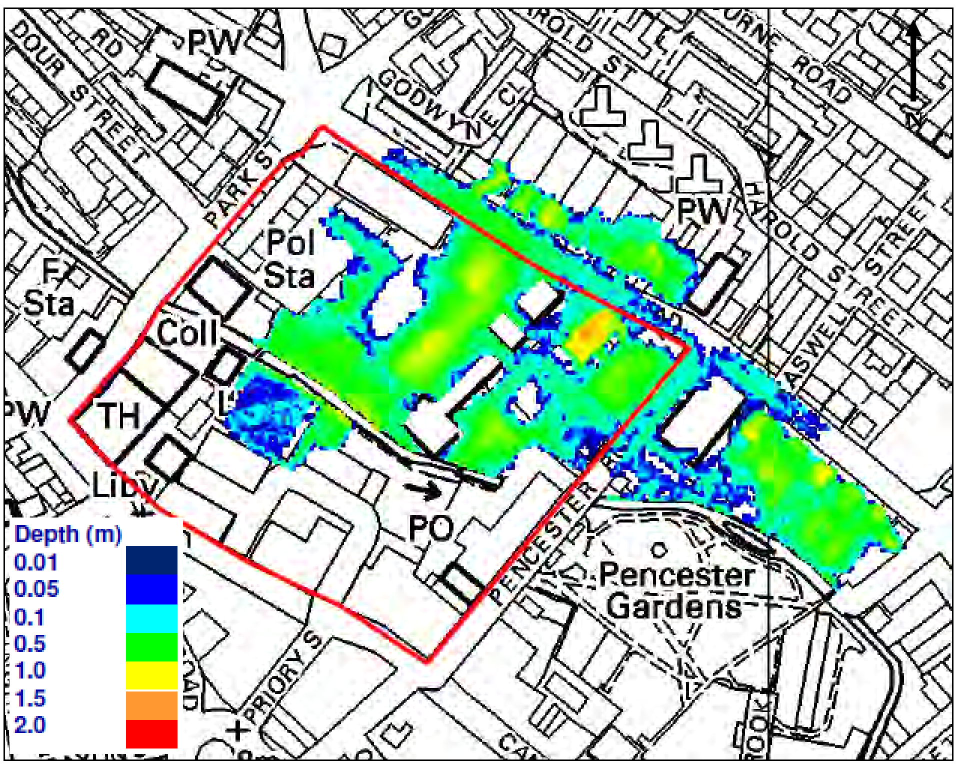

Figure 4.1 1 in 20 Year Fluvial Flood Extent as Estimated within the JBA Flood Risk Assessment, November 2008

4.3.8 The surface water model risk map (based on a 1000-year storm and hydraulic modelling of overland flows) created by JBA indicated that the site was at a high risk of surface water flooding in this event.

4.3.9 The report recommended that surface water drainage should be improved on the site along with future redevelopment. This may include new surface water sewers and a possible surface water pumping station to discharge surface water into the River Dour. The site layout should be designed to cater for the safe flood routing of surface water flows in excess of the design standard of the sewers.

Mid town, Dover Flood Mitigation report, Prepared by JBA – January 2009

4.3.10 Dover District Council commissioned a flood mitigation report for the Mid Town site. This report followed on from the findings of the previous Flood Risk Assessment prepared by JBA in October 2008.

4.3.11 This report determined that the preferred mitigation option for the site would be to: "construct a flood wall that was 155m long and 1m high on the left bank of the River Dour adjacent to the Mid Town area of Dover. In conjunction with this, the River Dour should be widened by 5m at high level over a distance of 155m from the footbridge across the river into Maison Dieu Gardens to the upstream face of the Pencester Road culvert. Also some low spots on the left bank of the river opposite Pencester Gardens should be raised approximately 300mm to protect properties in Maison Dieu Road and Castle Street".

4.4 FLOOD ZONES

4.4.1 As identified in Section 1.1, a key objective of this study was to re-map the Flood Zones in Dover as well as define the actual and residual flood risk to the site, based on detailed hydraulic modelling of the River Dour. This section provides a summary and details the revised flood zones within the Mid Town site.

Hydraulic Modelling of the River Dour and Local Surface Water Drainage Network

4.4.2 To understand the risk of flooding on site, as well as develop measures for reducing existing flood risk, a combined one-dimension ESTRY and two-dimensional TUFLOW computational model has been developed for River Dour. This Environment Agency approved computer software simulates a flood event to determine water levels, directions of flow, and the extent of any flooding, along the River Dour using topographic channel survey, surface terrain data and flows from the contributing catchment.

4.4.3 The modelling has been undertaken in consultation, and approved by, the Environment Agency. The purpose of the hydraulic model has been to define fluvial, tidal and surface water flood risk to the Mid Town site and investigate options for reducing the existing flood risk. However, prior to determining flood alleviation options it is necessary to understand the baseline flood risk conditions and existing flooding mechanisms on site. Several mitigation options tested to reduce the flood risk to the site have also been developed and are discussed in Section 6.

4.4.4 The hydraulic model of the River Dour developed to inform this assessment extends from upstream Minnis Lane, through Dover and discharging into the English Channel at Wellington Dock. The model has been constructed so it can be updated if improved data becomes available.

4.4.5 An outline of the model construction is provided below. Further details can be found in the Hydraulic Assessment, Appendix C:

- The model extends from Minnis Lane (upstream boundary) to Wellington Dock downstream boundary);
- Hydrology from the Peter Brett Associates River Dour Hydrology were used within the assessment based on consultation with the Environment Agency;
- Topographic survey, including channel and structure survey was used to define the channel and floodplain boundaries within the River Dour;
- Topographic site survey was obtained for the river bank throughout the Mid Town site;
- Topographical survey of the carpark and areas most likely to flood during an extreme event within the Mid Town site were incorporated into the model;
- Digital Terrain Mapping based on LiDAR was used to replicate the ground surface of the

modelled catchment. This model also removed all buildings and vegetation to provide a 'bare earth' representation of the catchment;

- Surface water drainage network information was provided by Southern Water for inclusion with the report;
- Downstream tidal information was provided by the Environment Agency;
- Information relating to the Wellington Dock and its outfall were provided by the Dover Harbour Board.

4.4.6 The extents of the hydraulic model can be found in Figure 4.2 below. This diagram also identifies the locations of the hydrological inflows into model.

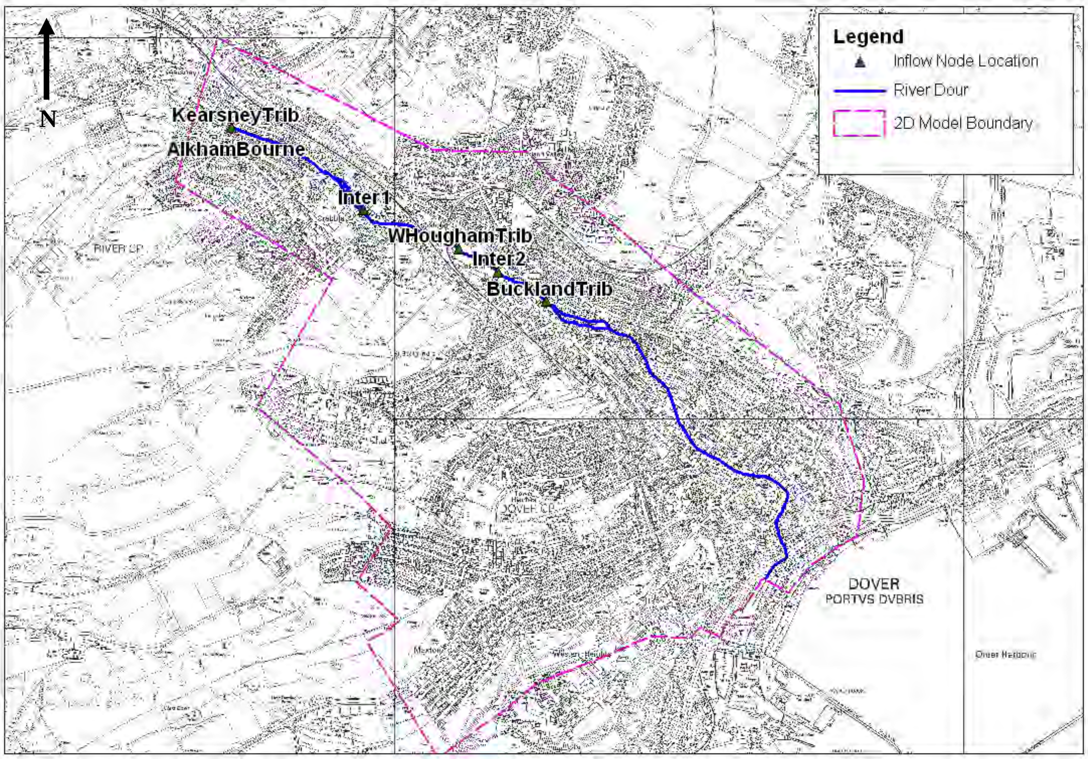

Figure 4.2 Revised River Dour Hydraulic Model Extents

4.4.7 The up and down stream invert level of all of the culverts within the river were confirmed via survey provided by the Environment Agency and additional structure surveys were commissioned by Dover District Council for this study. The model has utilised bank level information from LiDAR to provide a more accurate representation of the banks within the Dour where cross sections are greater than 50m and where bends occurred in the watercourse. Sensitivity testing of flows and roughness coefficients has also been undertaken and is discussed within Appendix C.

Flood Zone Definitions

4.4.8 The Flood Zones describe the extent of flooding during a specified probability or return period and identify the extent of flooding that is expected to occur on the basis that no flood defences are present. Table D.1 of PPS25 defines these flood zones as:

- Zone 1 – land assessed as having a less than 1 in 1000 year annual probability of river or sea flooding in any year (<0.1%);
- Zone 2 – land assessed as having between a 1 in 100 year and 1 in 1000 year annual probability of river or sea flooding (1%-0.1%) or between a 1 in 200 and 1 in 1000 annual probability of sea flooding (0.5%-0.1%) in any year;
- Zone 3a – land assessed as having a 1 in 100 or greater annual probability of river flooding (>1%) or a 1 in 200 or greater annual probability of flooding from the sea (>0.5%) in any year; and
- Zone 3b – This zone comprises land where water has to flow or be stored in times of flood. SFRAs should identify this Flood Zone (land which would flood with an annual probability of 1 in 20 (5%) or greater in any year or is designed to flood in an extreme (0.1%) flood, or at another probability to be agreed between the LPA and the Environment Agency, including water conveyance routes).

4.4.9 It is important to understand the definition of the Flood Zones, as the October 2008 JBA FRA indicates the open carpark area within the site is located within the 1 in 20 year return period extent, which the Environment Agency have advised in correspondence (May 2009) is considered the functional floodplain (Flood Zone 3b). This can affect the compatibility of land uses within the site in accordance with policy in PPS 25.

Existing and Revised Flood Zones

4.4.10 A review Flood Zone Mapping undertaken by the Environment Agency has identified that the majority of the site is located within Flood Zone 3a – high probability of flooding (approximately 80% as determined within the Dover Strategic Flood Risk Assessment).

4.4.11 The Stour CFMP concludes that the broad scale model used to create these flood zones is not accurate and is assumed to over predict the impacts of flooding from the Dour within Dover. A review of the revised Flood Zones produced as part of this assessment indicates that the extents of both Flood Zone 3a and Flood Zone 2 have reduced on site and that only a limited area of land located behind the Age Care building could be considered part of the function floodplain for the River Dour (Flood Zone 3b).

4.4.12 The methodology for the predicting of the revised Flood Zones has been agreed with the Environment Agency and was signed off in January 2010.

4.4.13 Figure 4.3 and Figure 4.4 (both overleaf) identify the existing and revised Flood Zones of the River Dour, as it effects the Mid Town development area (a revised broader Flood Zone Map can be located within Appendix A). The methodology for the calculation of the revised Flood Zones, along with maximum flood depths and hazard can be located within the Appendix D: Hydraulic Modelling Assessment.

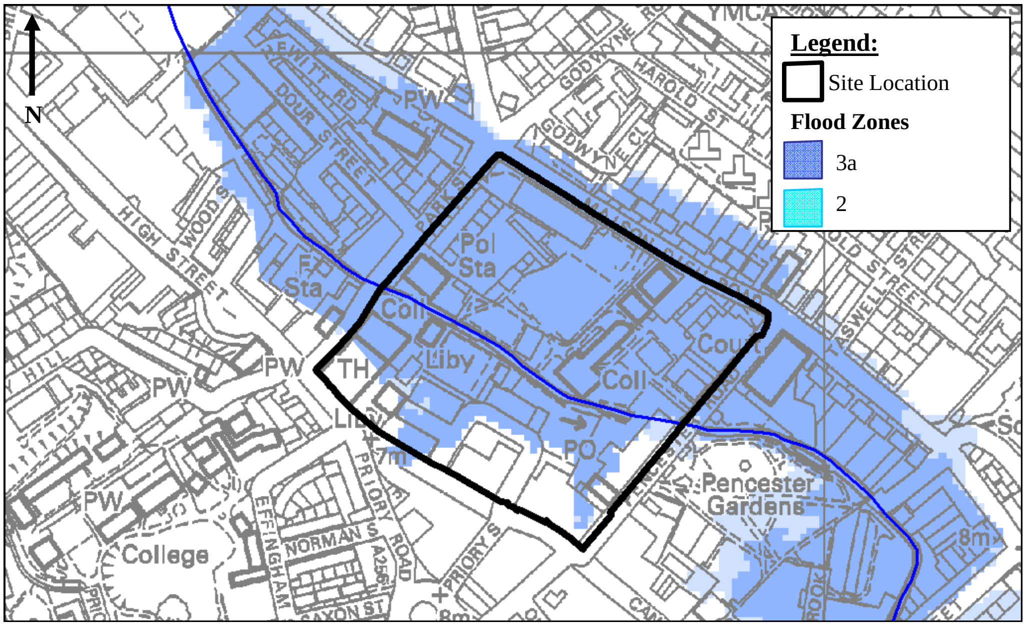

Figure 4.3 Existing River Dour Flood Zones (Source: Dover District SFRA)

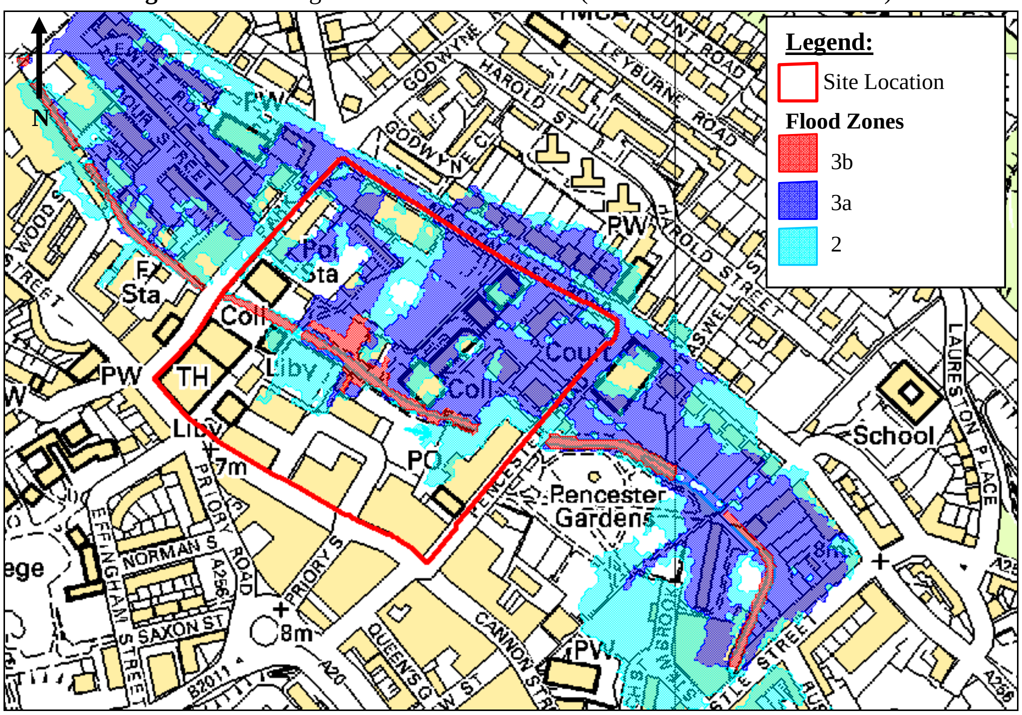

Figure 4.4 Revised River Dour Flood Zones

A review of the revised Flood Zone Maps, Figure 4.4, above, indicates that the Mid Town site is now located within:

- Flood Zone 1 (Low Probability) – 46% or 27,300m^2
- Flood Zone 2 (Medium Probability) – 19% or 11,210m^2
- Flood Zone 3a (High Probability) – 31% or 18,530m^2
- Flood Zone 3b (Functional Floodplain)- 2% or 1270m^2
- River Corridor - 2% or 1310m^2

4.4.14 This demonstrates the benefit of the detailed River Dour modelling, which predicts decreased areas at risk of flooding within the site (in particular Flood Zone 3a and 3b) and identifies a significant portion of the site is located within Flood Zone 1.

4.5 SOURCES OF FLOODING

4.5.1 PPS25 Annex C describes potential sources of flooding. The site is most likely to be at risk of flooding from rivers, extreme tides, land and sewers, and potentially flooding from groundwater. This section provides a review of flooding from all sources. As discussed within the previous section, a detailed hydraulic model of the River Dour and surface water drainage network was developed to inform this study. The following section provides a brief summary of the modelling results (where appropriate) and information obtained from other sources (Environment Agency, CFMP, SFRA etc).

4.6 FLUVIAL FLOODING

4.6.1 To assess the level of flood risk presented by the River Dour to the Mid Town site a series of modelling scenarios were undertaken in consultation and agreement with the Environment Agency, these scenarios can be found in Table 4.1 overleaf:

Table 4.1 Modelled Fluvial Flood Scenarios

Risk Evaluation	Scenario	Impacts on Mid Town Site
Actual Risk[1]	Fluvial - 1 in 20 year	Small functional flood plain located near Aged Care facility.
	Fluvial - 1 in 100 year	Out of bank flooding within the site along with additional flows entering the site from Dour Street and Maison Dieu Road due to out of bank flooding upstream of the Mid Town site.
	Fluvial - 1 in 100 year plus climate change	As above with additional flood depths recorded within the site and additional flood effects downstream of the site due to additional flow path down Maison Dieu Road into Pencester Gardens
Residual Risk[2]	Fluvial - 1 in 1000 year	Flood mechanisms similar to 1 in 100 year event with additional flood depths experienced within the site and additional flow paths forming and conveying flood waters downstream via Maison Deiu Road.
	Fluvial - 1 in 100 year plus climate change, culvert blockage	Backing up behind culvert modelled, flooding low ground near but having minimal effects on overall flood extents

4.6.2 Figures 4.6 through to 4.9 provide a graphical illustration of the flood extents and depths predicted to occur within the Mid Town site for the 'Actual Risk' modelled scenarios.

Flood extents and mechanisms

4.6.3 A review of the flood extents within Dover provide the following conclusions about flooding in the site:

Fluvial:

- There are a number of constraints to conveyance of flow on the River Dour, including weirs and culverts that result in back up of flow. There are only isolated areas of existing infrastructure that contain this flooding, and it is not clear whether these are maintained flood defences. The constrained channel capacity is the most significant factor in flooding in Dover generally, including the Mid Town area.
- Flood waters exceed the lowest point of the River Dour bank (located south of the Age Concern building) during a 1 in 20 year fluvial flood event. The topographical survey of this area indicates that the lowest bank level in this area (red line shown in Figure 3.4 below) is 5.15mAOD. During the 1 in 20 year event this area reaches a maximum flood depth of approximately 30cm.
- During higher return period events it is identified that overtopping of the river banks upstream of the Mid Town area (at Charlton Green due to the constriction in flow generated from the existing culvert), resulting in overland flow onto the site with flood waters flowing down both Dour Street and Maison Dieu Road.
- Downstream of the site there is little out of bank flooding as a result of fluvial flooding. The channel is generally larger, less constrained and with higher surrounding ground levels. Review of water levels indicates there is capacity within the channel downstream of the Dover Mid Town area during a fluvial flood event.

[1] Hydraulic modelling incorporates the existing 'de facto' defences located throughout the River Dour

[2] Hydraulic modelling removes all of the existing defences located throughout the River Dour (similar to Flood Zone Mapping)

- The outfall from River Dour into the Wellington Docks is through a completely submerged culvert which does not include any structures/gates to exclude tidal waters entering the river. This submerged downstream boundary therefore influences the ability of the River Dour to freely discharge flood waters as the downstream tidal levels will influence river levels upstream of this culvert (specifically during peak tidal levels).

Figure 4.5 Location of lowest bank elevation (red line) within the Mid Town Site

4.6.4 Figures 4.6 through to 4.9 identify the predicted flood extents and depths for the followings fluvial flood events; 1 in 20, 1 in 100, 1 in 100 plus climate change and 1 in 1000 year return period.

4.6.5 A review of the 'actual' flood risk during a 1 in 100 year fluvial flood event indicates that approximately 290 properties are at risk of fluvial flooding .

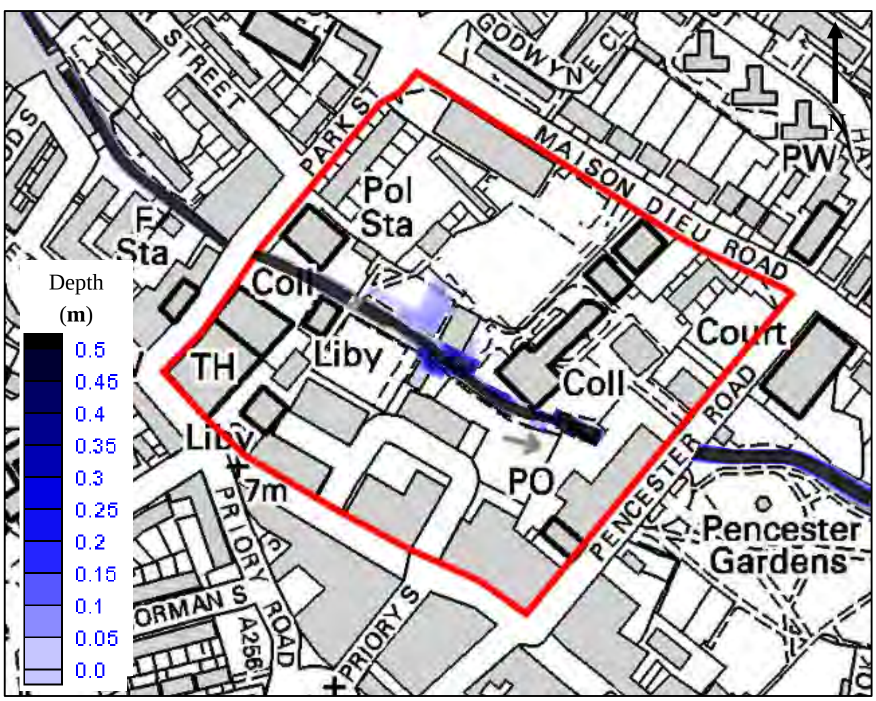

Figure 4.6 1 in 20 Year Fluvial Flood Event

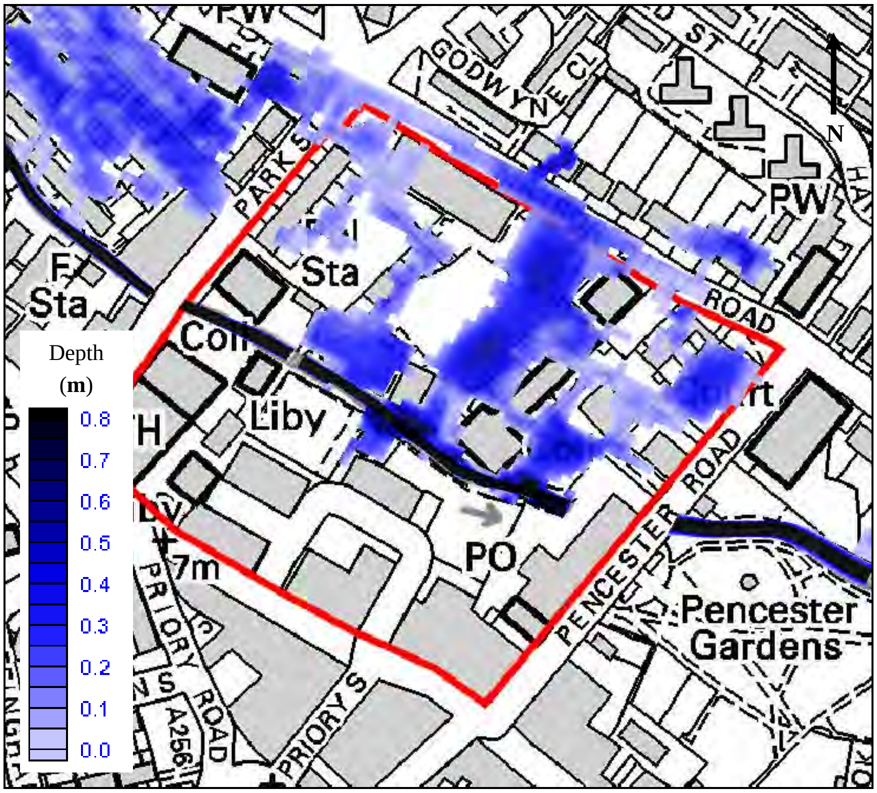

Figure 4.7 1 in 100 Year Fluvial Flood Event

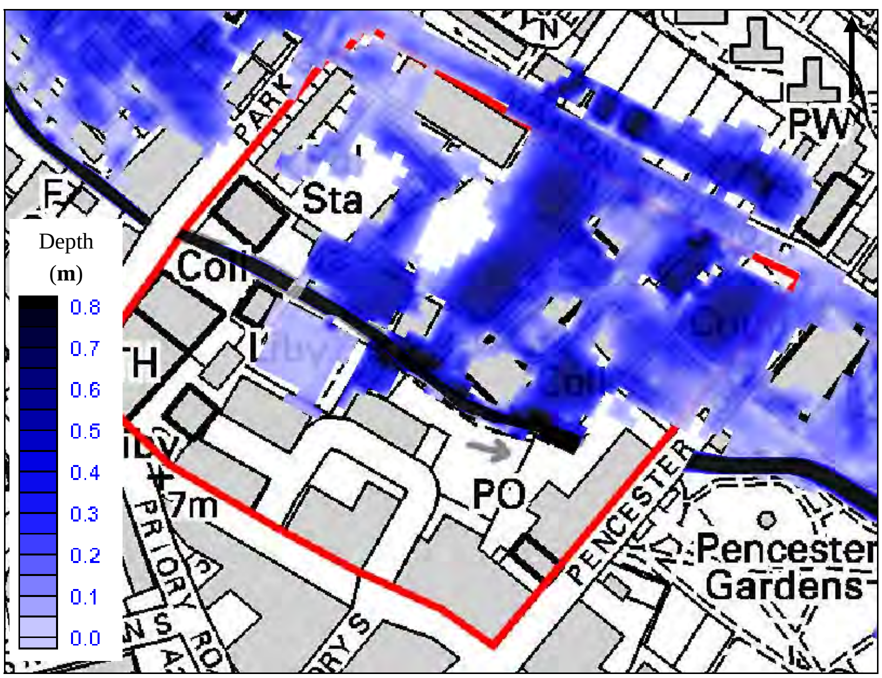

Figure 4.8 1 in 100 Year (Including an Allowance for Climate Change) Fluvial Flood Event

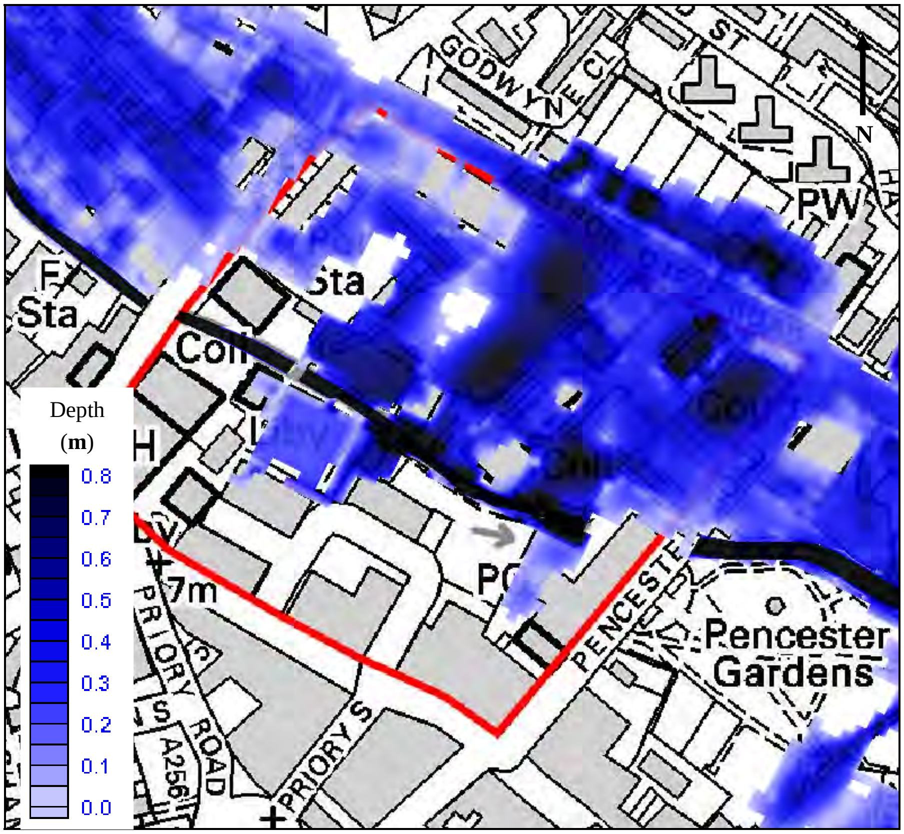

Figure 4.9 1 in 1000 Year Fluvial Flood Event

4.7 FLOODING FROM THE SEA (TIDAL SOURCES)

4.7.1 No information relating to tidal flooding is currently available from the Environment Agency. Based on consultation with the Environment Agency, and agreement from the Dover District Council, it was requested that this source of flooding was included within the revised River Dour hydraulic flood model. Table 4.2 identifies the scenarios tested within the hydraulic model and their associated impacts on the Mid Town site.

4.7.2 Discussions with Dover Harbour Board indicates that there are; no tidal exclusion structures located within the interface between the River Dour and Wellington Docks; and that the operating regime of the other docks gates within Dover Harbour would not prevent extreme sea levels influencing river levels.

4.7.3 Although outside of the remit of this study it is recommended that the management of water levels and tidal controls in Wellington Docks are considered to reduce this risk of flooding in Dover in the future as a result of climate change on sea level rise.

Table 4.2 Modelled Tidal Flood Scenarios

Risk Evaluation	Scenario	Impacts on Mid Town Site
Tidal Flood Zone Mapping	1 in 200 year	Flood waters effect the site as a result of the tidal levels exceeding the river bank (due to the removal of existing walls) and activating an out of bank flooding mechanism near Charlton Green (due to the removal of walls within this area). The out of bank flooding conveys flood waters down Dour and Maison Dieu Roads which then flow into the site due to the topographical location of the site.
	1 in 1000 year	Flood mechanisms similar to 1 in 200 year undefended scenario event with additional flood depths experienced within the site and flooding additional areas downstream of the site.
Actual Risk[3]	1 in 200 year	Indicates a low risk to the Mid Town site. Some effects of this source of flooding are evident downstream of the site.
Residual Risk	1 in 1000 year	The site tidal levels exceeding the level of the existing river banks within the site and also causing a backwater effect of the fluvial flows which would normally discharge into the Wellington Dock.

4.7.4 Based on a review of the hydraulic model, it is concluded that flooding from tidal sources will occur during a 1 in 1000 year tidal event. The undefended tidal scenarios indicate the site is located within Flood Zone 3a as it is effected by the 1 in 200 year tidal event (undefended scenario) resulting in a similar flood extent to the fluvial Flood Zone 3a.

4.7.5 Figures 4.10 through to 4.13 identify the predicted flood extents and depths for the followings defended and undefended 1 in 200 year, and 1 in 1000 year return period tidal flood events.

[3] Hydraulic modelling incorporates the existing 'de facto' defences located throughout the River Dour

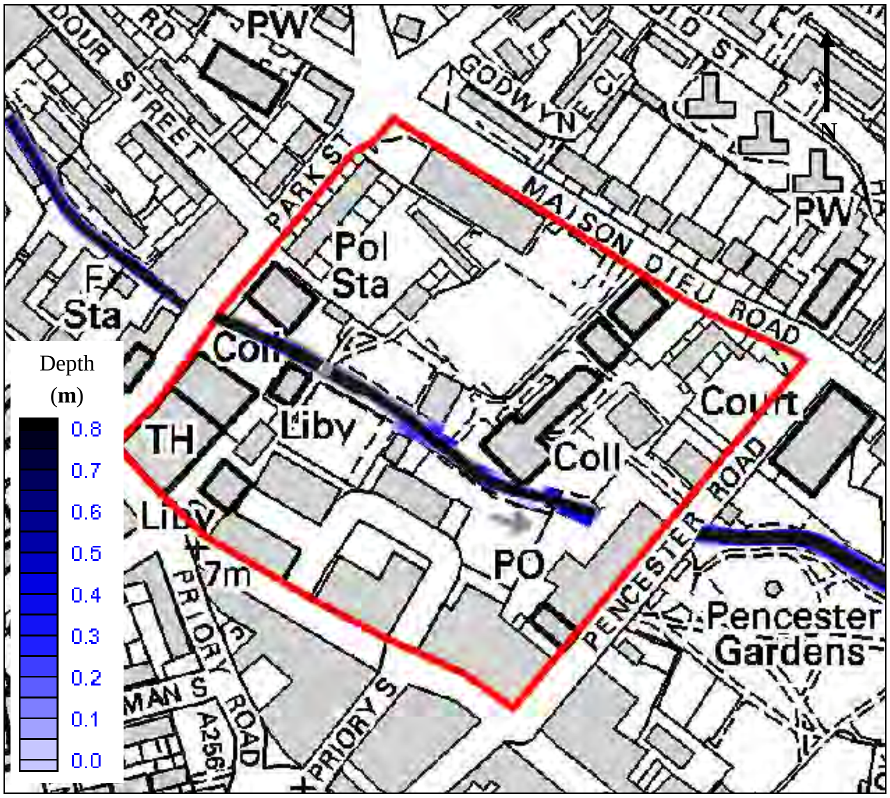

Figure 4.10 1 in 200 Year Tidal Flood Event (Defended) – Actual Risk

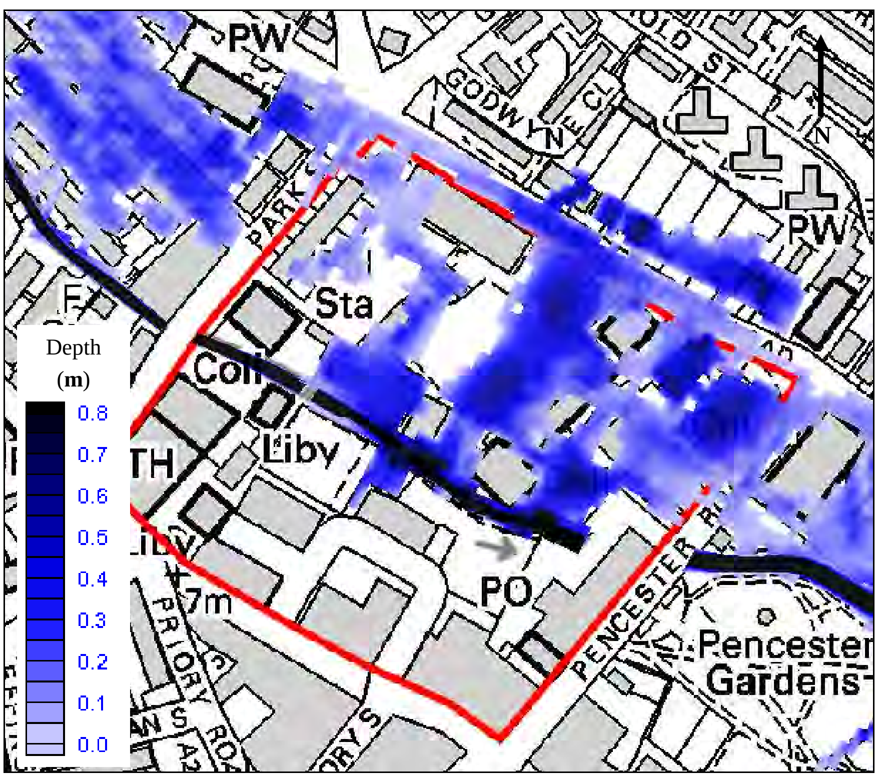

Figure 4.11 1 in 200 Year Tidal Flood Event (Undefended)

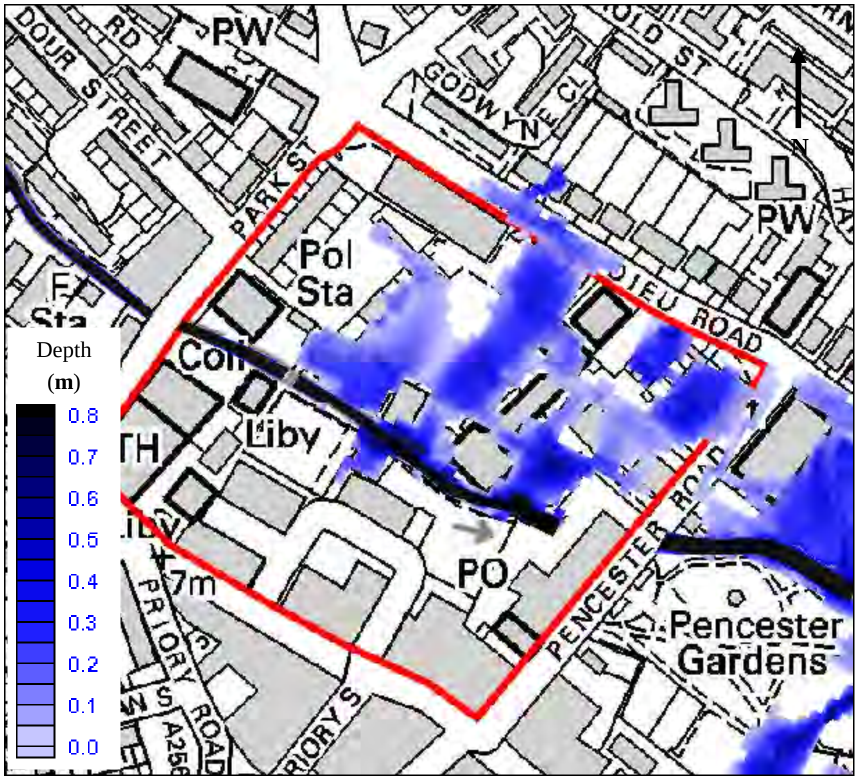

Figure 4.12 1 in 1000 Year Tidal Flood Event (Defended) – Actual Risk

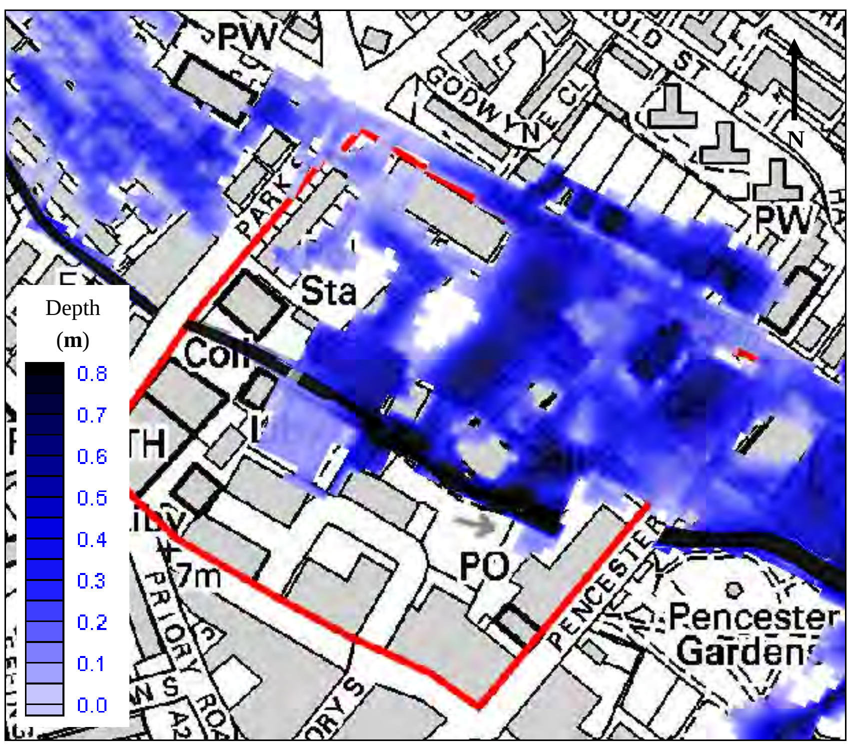

Figure 4.13 1 in 1000 Year Tidal Flood Event (Undefended)

4.8 FLOODING FROM LAND (SURFACE WATER RUNOFF)

4.8.1 This form of flooding can be caused by rainfall being unable to infiltrate into the natural ground or entering drainage systems due to blockage, or flows exceeding the networks design capacity. This can then result in (temporary) localised ponding and flooding. The natural topography and location of buildings/structures can influence the direction and depth of water flowing off impermeable and permeable surfaces.

4.8.2 The Environment Agency commissioned a study to determine the Areas Susceptible to Surface Water Flooding in 2009. These series of maps were produced as a preliminary national output to provide Local Resilience Forums with an initial indication of areas that could be at risk of surface water flooding. These maps were created using a 1 in 200 year rainfall event with duration of 6.5 hours. These broad scale maps indicate that the Mid Town site is classified as 'more' susceptible to surface water flooding. The broad-scale modelling and mapping does not consider drainage infrastructure.

4.8.3 A fully integrated fluvial, tidal and drainage hydraulic model was developed for this study to assess the risk of surface water flooding, and approved by the Environment Agency in January 2010. This model includes Southern Water's 'surface water' network as well as the local topography to model the effects of surcharging sewers and overland flow paths. The combined sewer network was not included within the remit of this study. Kent Highways were not able to provide any specific drainage information relating to their network.

4.8.4 A review of the topographic survey undertaken for the Council carpark in the Mid Town site, indicates that no drainage infrastructure is located at the lowest portion of the site which would drain any local ponding during a storm event.

Scenarios

4.8.5 Several scenarios were modelled to provide a broad understanding of the flood mechanisms within Dover during a surface water flood event. Additional testing of hydraulic modelling was undertaken to understand the sensitivity of surface water flooding to both the capacity of the drainage network and influence of the River Dour, these included testing the 1 in 30 year rainfall event, reducing rainfall volumes by 20%, 30% and 50%, and reducing the duration of the storm event to 1.5hrs. Results from these tests provide confidence in the model results presented below, as the mechanisms for flooding from the sensitivity tests were very similar to the selected scenarios identified within Table 4.3, below.

Table 4.3 Modelled Surface Water Scenarios

Scenario	Fluvial Input	Tidal Boundary	Rainfall Input	Rainfall Duration	Surface Water Network Modelled
1	Baseflow	MHWS	Q100 – Q30	17 hours[4]	Excluded
2	Baseflow	MHWS	2 year event	17 hours	Included
3	1 in 10 year + CC	MHWS	1 in 100 year + CC	17 hours	Included
4	Baseflow	MHWS	Actual rainfall from June 2007 event	3.5hrs	Included

MHWS = Mean High Water Spring tide CC = Climate Change

4.8.6 A brief explanation of the modelled scenarios is provided below along with the maximum predicted depths occurring at any time during the modelled event. Note that all flood depths have filtered out the first 10cm of flooding to provide greater clarity of the areas at risk of surface water flooding:

[4] Based on catchment duration outlined within the Dour Hydrology report, prepared by PBA, 2007

Scenario 1

- Scenario 1 is a theoretical model, rather than a test of the 'actual' risk of flooding. In accordance with Sewers for Adoption, surface water sewers should be designed so there is 'no flooding' during a 1 in 30 year return period event. Therefore by modelling a rainfall event that 'removes' a 1 in 30 year rainfall event from the 1 in 100 year rainfall event it is possible to understand what the reasonable current 'best case' flooding baseline may b, and compare this to the current modelling scenarios that include the surface water drainage network.

- A review of the flood mechanisms indicates that rainfall within the local catchment, on the northern side of the Dour, tends to drain towards the site as it is located in the lowest part of the catchment and the portion of Maison Dieu Road north of the site conveys runoff into the site.

- Figure 4.14, below, identifies the maximum depth recorded during the model simulation.

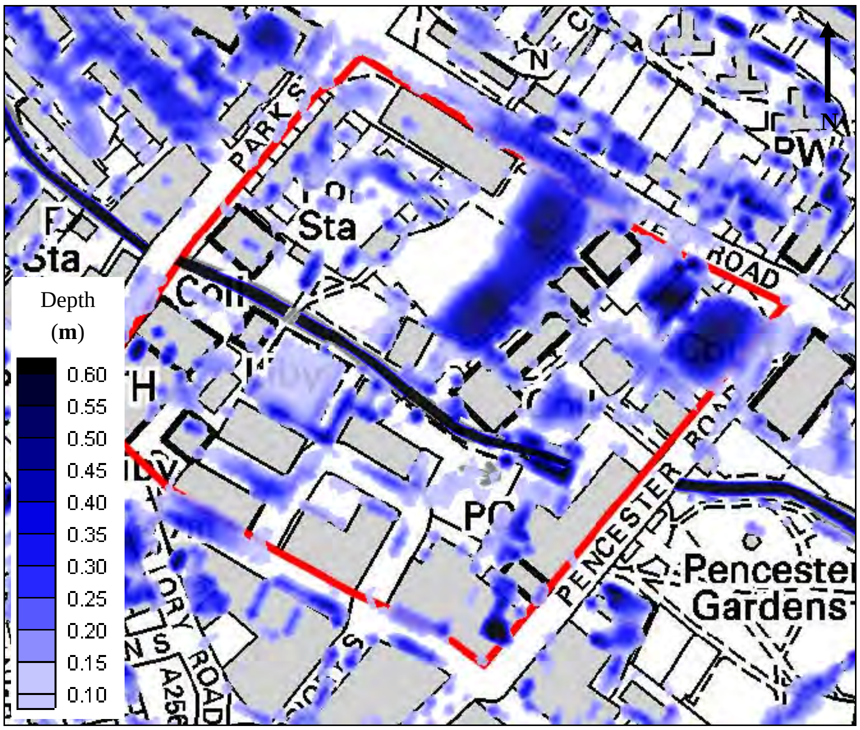

Figure 4.14 Maximum Flood Depths Predicted for Scenario 1

- Flood depths of up to 50cm are identified within the existing carpark on site as the topographical survey indicates that there is no drainage infrastructure to remove water from this area and as such it tends to pond instead of flowing into the Dour, or draining via the surface water network as other surface water runoff in the area does.

- It should also be noted that Maison Dieu Road and properties directly opposite the northern boundary of the site appear to be affected by surface water flooding due to the natural topography of the area. Flood depths on Maison Dieu Road are predicted to reach a maximum depth of 30cm (at its lowest point) but average around 10-20cm during the flood peak.

CAPITA SYMONDS

Scenario 2:

- This scenario was selected to identify the possible surface water flood mechanisms within Dover during a low return period event. This model incorporated the surface water drainage network but did not include the combined sewer network and as such is assumed to over predict the depth of flooding within the site.
- Flood mechanisms in this scenario are similar to Scenario 1, as it appears that the surface water that cannot drain into the surface water network is conveyed into the site down the roads within the local catchment and also drain into the site via the natural topography of Dover. Maximum flood depths predicted during the model simulation are shown on Figure 4.15, below.

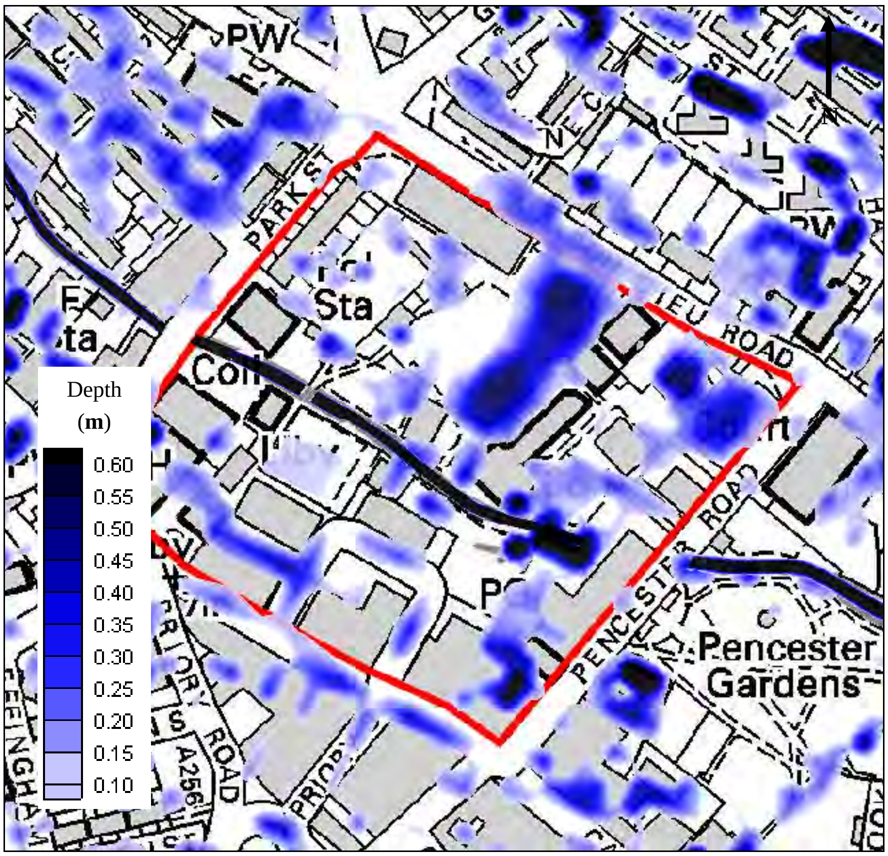

Figure 4.15 Maximum Flood Depths Predicted for Scenario 2

- Flood depths of approximately 20-30cm are predicted to occur within the site due to the carpark area not being able to drain to either the river or the nearby drainage network due to this part of the site lacking any formal drainage infrastructure.

Scenario 3

- This scenario was selected to identify the possible surface water flood mechanisms within Dover during an extreme rainfall event (1 in 100 year plus climate change rainfall event) within Dover. This model incorporated the surface water drainage network but did not include the combined sewer network and as such it may over predict the depth of flooding within the site. This scenario is therefore considered to current 'worst case' flooding baseline, and adopting the 'precautionary approach' in PPS25, should be considered until improved data becomes available.
- Flood mechanisms in this scenario are similar to Scenarios 2 and 3 as it appears that the surface water that cannot drain into the surface water network is conveyed into the site down the roads within the local catchment and also drain into the site via the natural topography of Dover.
- An additional flood mechanism occurs within this scenario due to out of bank flooding caused by the additional volume of flood waters entering the river (which flows at nearly bank full capacity). This additional flood mechanism can be clearly seen in Figure 4.16 below.

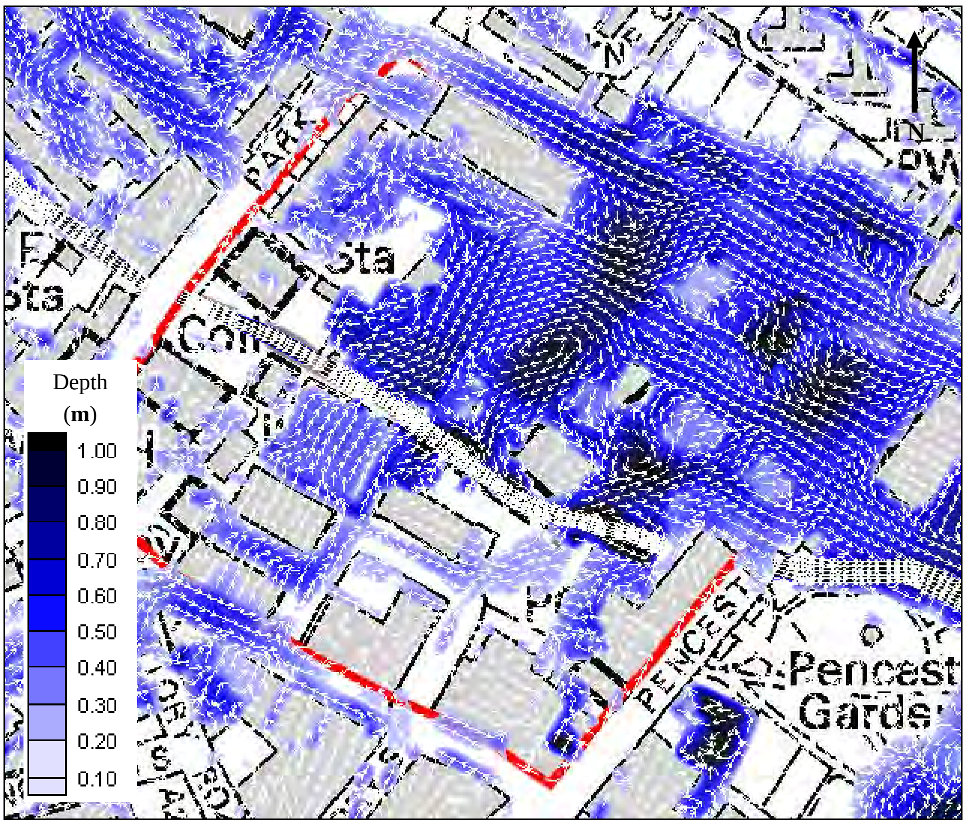

Figure 4.16 Flow Direction of Runoff Within Scenario 2

- The extent of flooding has increased in this scenario as a result of the volume of water draining to the site during the 1 in 100 year plus climate change event. Results from the integrated fluvial-surface water model indicate that flood depths of up to 90cm are predicted to occur within the lowest parts of the site (within the carpark area) and an extensive area of the site may be subject to flood depths ranging from 10 -50cm. Maximum flood depths predicted during the model simulation can be located within Figure 4.17 below.

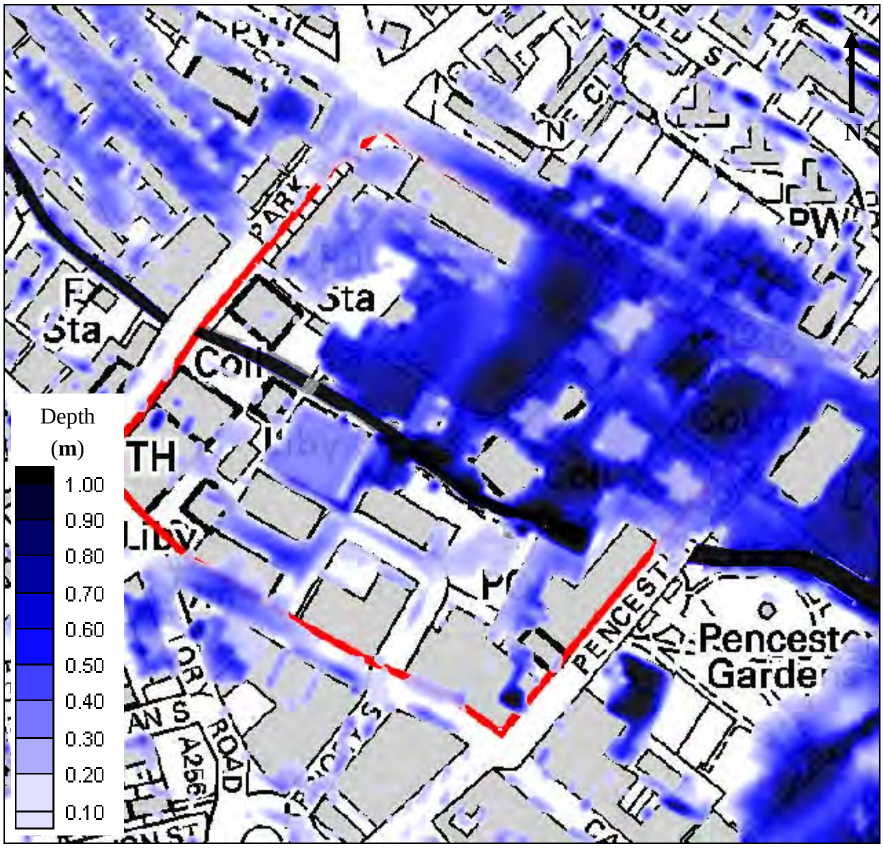

Figure 4.17 Maximum Flood Depths Predicted for Scenario 3

- The majority of the southern section of the site is not at a significant risk of flooding from this event with a small portion of Biggins Road receiving depths greater than 30cm for approximate 2.5hrs. Flood waters on Maison Dieu Road are predicted at being over 30cm (at the lowest part of the road) for approximately 5hrs of the model simulation and reach a maximum flood depth of 70cm.

Scenario 4:

- Scenario 4 was selected to broadly calibrate the hydraulic model results by testing a recent high intensity rainfall event. This model incorporated the surface water drainage network but did not include the combined sewer network and therefore may over predict the depth of flooding within the site.
- This scenario utilised actual rainfall obtained from the Environment Agency for the rainfall event recoded on the 19 June 2007. Records indicate that the storm lasted for approximately 3.5 hrs (staring at 5:45pm and ending at 9:15pm) and was equivalent to approximately a 1 in 17 year return period. Figure 4.18 shows the actual rainfall recorded at the Dover WW rainfall gauge during the event.

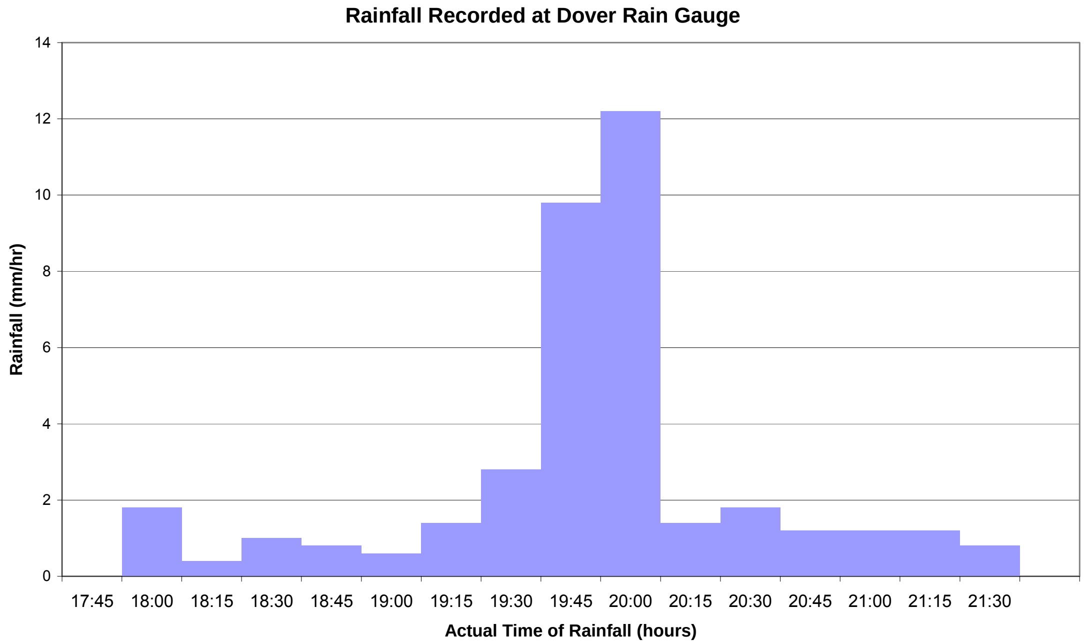

Figure 4.18 Actual Recorded Rainfall During 19 June 2007

- Modelled flood depths which occurred during this event can be found in Figure 4.19 below:

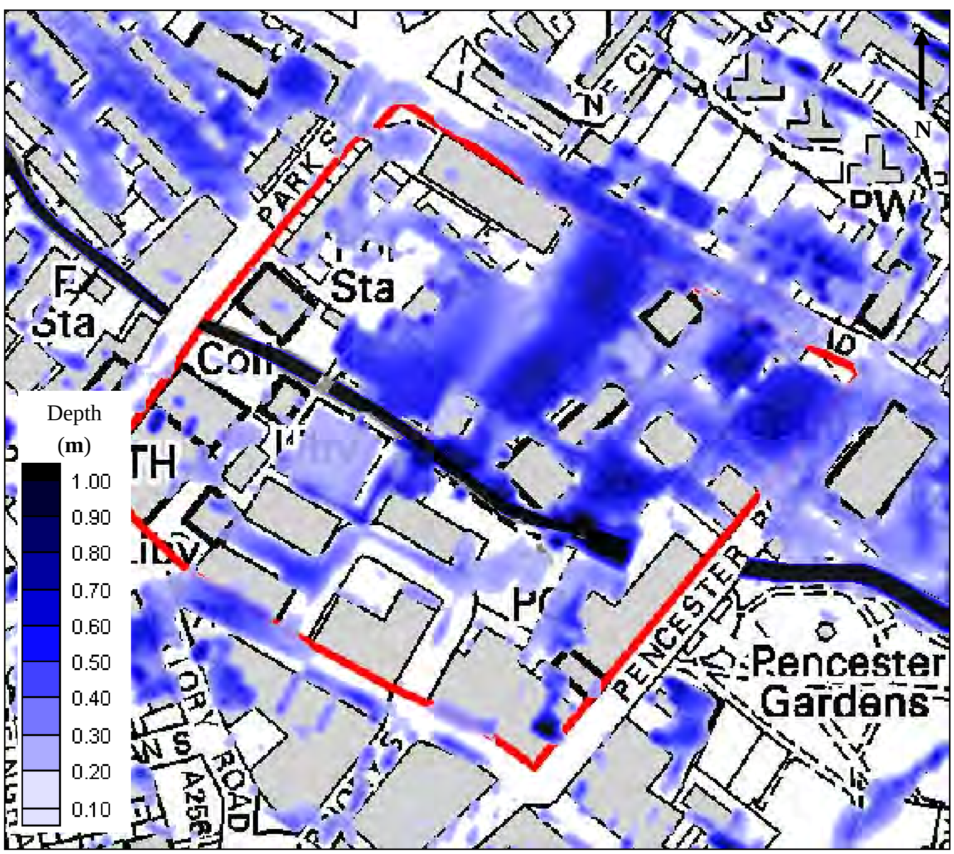

Figure 4.19 Maximum Flood Depths Predicted for Scenario 4

- A review of online information, evidence provided by Southern Water and anecdotal information provided by Dover District Council, clearly indicates that parts of the site were subject to flooding during this event with Figure 4.20 below showing some of the affects of the flood taken after the June 2007 storm event (exact date and time of photos are unknown).

Figure 4.20 Photos of River Dour within the Mid Town Site Taken After the June 2007 event. (Source: JBA consulting)

- The lowest portion of Maison Dieu Road (running parallel with the carpark) is below 30cm of flood water for approximately 1.75hrs of the model simulation. Anecdotal evidence provided in a letter to Southern Water (dated 24 July 2007 from Mrs Diane Finch) indicates that '*the drains in the road were not coping – as the evening progressed*, and that *the road outside our guesthouse began to flood*'. A review of the model simulation identifies a similar flood mechanism, due to the topography of the area.
- This letter also identifies that flood waters entered the property through the front and back basement doors and that cars driving along Maison Dieu Road sent 'waves' of water up the forecourt and into the property. A review of LiDAR levels in this location indicates that the forecourt appears to be approximately 15-20cm above Maison Dieu Road. This indicates that the depth of flooding was significant enough to exceed the existing property drains and enter the basement of the property, and was also deep enough on the road to send water above the driveway when cars travelled down the road.

Figure 4.21 Frontage of Property affected in June 2007 (Source: http://www.maisondieu.com/)

- Figure 4.21, left, is an image of the front of the property in which it is clearly visible that the forecourt is in an elevated position (blue line), when compared to the road (red line).

- The model results indicate a maximum water level on the road in this location of approximately 15cm which when 'pushed' into the property by moving vehicles would cause flood waters to enter the basement. This further confirms that the results identified within the integrated model are a reasonable representation of the flood event which occurred in June 2007.
- The letter indicates that once a call was made to emergency services (time unknown) the drains began to clear within 20-30 minutes. A review of the model simulation indicates that once the maximum depth of flooding occurs near the site after 1 hour water on the road receded to an approximate flood depth of 5cm. Dependent upon the time of the call this could indicate that the surface water drainage network is not draining/removing runoff within the model as quickly as that which might occur if the combined sewer was included within the assessment. This could indicate that the model may slightly over predict depths and durations of flooded areas.
- A review of the surface water pipe capacity and Southern Waters Sewerage Incident Report Form (SIRF) database indicates that the surface water volumes generated during this event exceeded the capacity of the existing drainage network within Dover. This indicates that the drainage capacity of the surface water network is below current standards and cannot manage surface water runoff from events with an estimated 1 in 17 year return period. This could be a combination of undersized pipe and inlets, or sheets flow from runoff being unable to enter the surface water drainage network due to the overland flow routes avoiding the location of existing drainage inlets.
- This scenario indicates that the predicted flood depths within the site vary based on the elevation of the existing ground. A review of the results indicates that the area most at risk is the Council carpark. As discussed earlier, there is no formal drainage network in this location and as a result flood water can only pond during the rainfall event and not drain into River Dour (either via sheet flow or discharging into the surface water drainage network) or discharging offsite via the combined sewer network.
- Predicted flood depths within the land north of the river range from 20 – 40cm with the floodwater reaching approximately 70cm in the carpark during the peak of the flood. Levels within the carpark are determined be above 40cm for approximately 3hrs of the model simulation.
- Model results indicate that the flood depths during the 2007 event may have been a result of overloaded drainage networks and out of bank flooding within the River Dour

Summary Surface Water Flooding

4.8.7 The site is perceived as being at a high risk of flooding from land due to natural topography of the site drain waters through the site towards the River Dour. It is recommended that overland flow paths and existing drainage capacities are considered within any future detailed drainage design for the site in order to reduce the risk of this type of flooding within the proposed Mid Town site and that all future development within the Dour catchment investigate incorporating SUDS features and attention devices to reduce peak flows (to Greenfield rates if possible) and pollutants discharging into the River Dour.

4.8.8 The current hydraulic model provides the most up to date information relating to surface water flood risk within Dover, however it may over predict the depth and possible duration of surface water flooding within Dover due to the current exclusion of the combined sewer network and drainage infrastructure maintained by Kent highways.

4.8.9 It is unlikely that the risk of flooding from surface water will be completely removed due to sites topographic location, but additional information could be incorporated into the model to improve its accuracy (e.g. more representative infiltration rates, combined sewer network, etc).

4.8.10 It is recommended that as the information from the Surface Water Management Plan (SWMP), currently being undertaken by Kent County Council (KCC), is made available the impacts of this risk are reassessed to determine how this can influence the re-development of the site.

4.9 FLOODING FROM SEWERS

4.9.1 Sewers are typically utilised in an urban environment for draining rainwater runoff. Sewers which drain rainwater only, are know as 'surface water runoff' whilst those which drain both surface and wastewater are referred to as 'combined sewers'. Flooding can result when sewers, typically combined foul and surface water, are overwhelmed (or blocked) and surcharge water into the nearby environment.

4.9.2 Due to the local topography (and the site being a local basin for the catchment), if pipe surcharging or blockage occurred, there is the potential for flooding from drainage systems to affect the Mid Town site.

4.9.3 Information provided by Southern Water confirms that several properties within, and adjacent to, the Mid Town site have experience this type of flooding. Figure 4.22, overleaf, identifies the properties that have reported an incident of sewer flooding. A review of these records indicated that the properties on the south of the River Dour (blue stars) were affected by an event in October 1993 whilst the properties on the north side of the River Dour (red stars) were affected by the surcharging as a result of the June 2007 summer storm event (which led to the Pitt review).

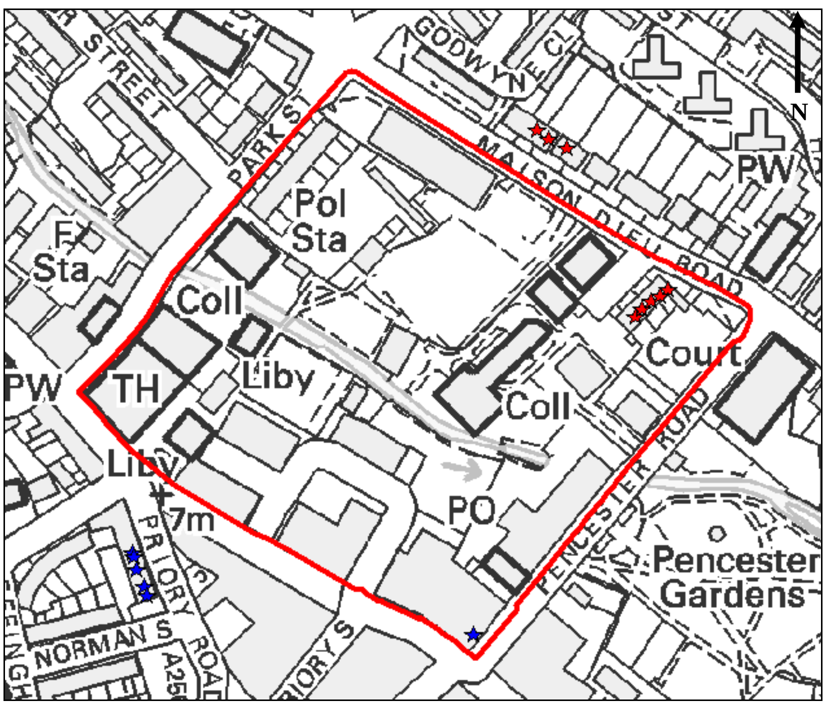

Figure 4.22 Records of Sewer Flooding as provided by Southern Water (Source: Southern Water).

4.9.4 Southern Water are currently completing investigations for determining the appropriate management options and techniques for reducing this risk to the area near the Mid Town site. It should be noted that the final management techniques for the area (if adopted should be informed by the DEFRA funded SWMP for Dover currently commissioned by Kent County Council.

4.9.5 It is recommended that any proposed development on the site carefully assess the management of surface water runoff and attempt to reduce the amount of runoff discharging into the sewers by incorporating appropriate SUDS devices for events up to and including the 1 in 100 year return period event plus climate change.

4.10 FLOODING FROM GROUNDWATER

4.10.1 Groundwater flooding occurs when the water level within the groundwater aquifer rises to the surface. In very wet winters these rising water levels may lead to flooding of areas that are normally dry. This can also lead to streams that only flow for part of the year being reactivated. These intermittent streams are typically known as bournes.

4.10.2 Water levels below the ground can rise during winter (dependant on rainfall) and are known to fall during drier summer months as water discharges from the saturated ground into nearby watercourses, such as the Dour.

4.10.3 The Stour CFMP indicates that the chalk stream areas of the Nailbourne, Petham Bourne and the Dour experience groundwater flooding. The Stour CFMP indicates that under a climate change scenario the large baseflow component fed by groundwater, such as that on the Dour and Little Stour, is relatively unresponsive to climate change compared with the more responsive tributaries. Longer winter rainfall may mean that groundwater levels remain high throughout the winter, changing the current hydrological pattern to flashier peak flows and a longer flood event. On the other hand, drier summers may mean that groundwater levels become depleted and, therefore, take longer to rise, reducing the risk of flooding.

4.10.4 Information within the Dover District Council SFRA (and from the underlying geology based on the BGS mapping) indicates that there is moderate potential for groundwater flooding to occur at the site. Further ground investigation (boreholes and trial pits) and soakage tests should be undertaken to confirm the underlying geology and to provide site specific information on the groundwater, infiltration rates and soakaway potential (if determined to be appropriate) at the site when proposed development schemes are identified for the site.

FLOODING FROM ARTIFICIAL SOURCES

4.10.5 Artificial sources of flooding include reservoirs, canals, lakes and mining abstraction. Based on OS Mapping and a site survey, no artificial sources of flooding have been identified near the site. Therefore flooding from this source is not considered a significant risk at the site and has not been explored further.

4.11 SUMMARY OF FLOOD RISK

Table 4.4 overleaf details the maximum flood depths as recorded within the detailed River Dour Model at the locations identified within Figure 4.23

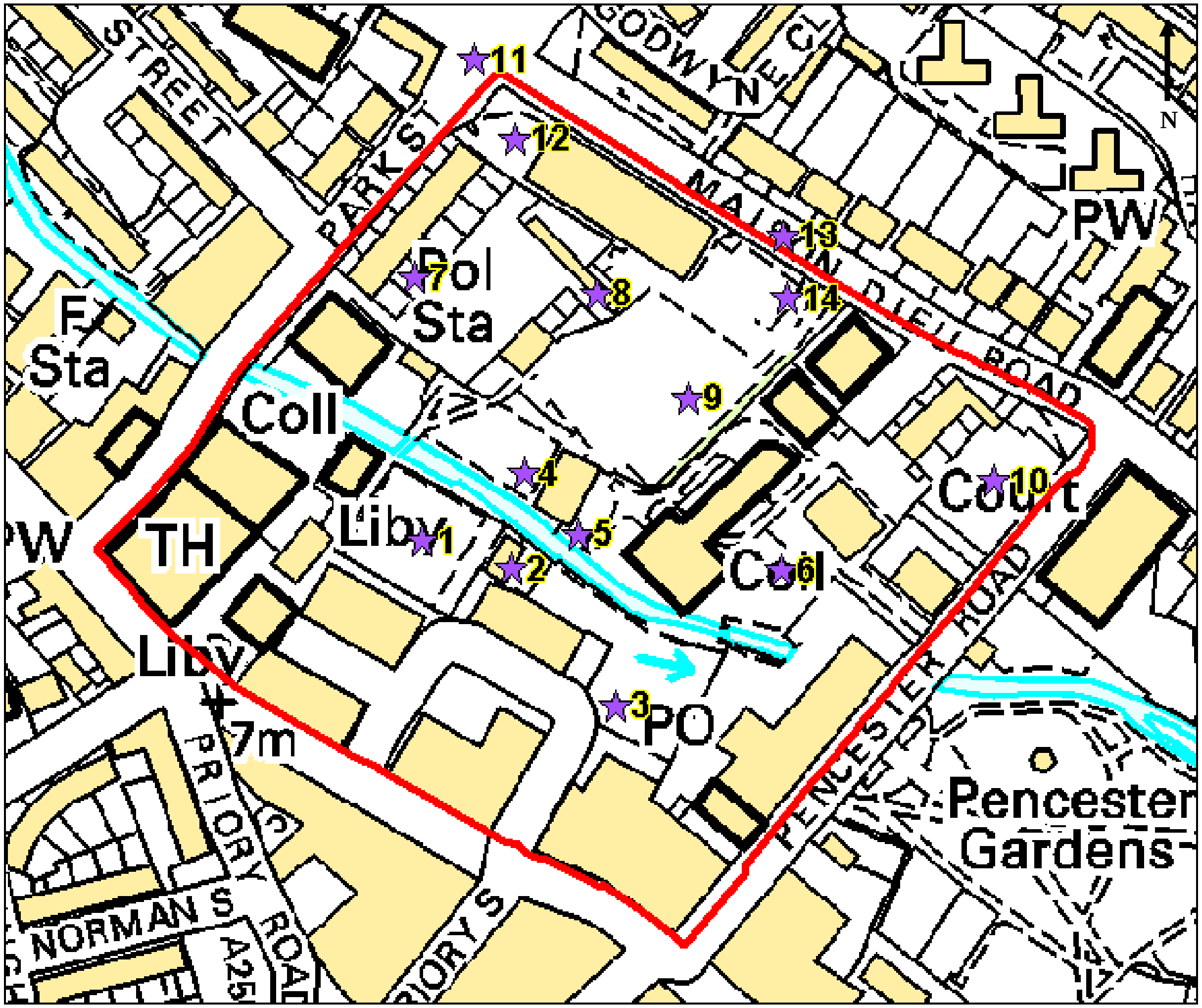

Figure 4.23 Location of Data Points Used For Extracting Peak Flood Levels

Table 4.4 Maximum Flood Levels Recorded During Each Model Simulation

		Fluvial				Tidal		Surface Water			
Point ID	LIDAR Levels	1 in 20yr	1 in 100yr	1 in 100yr+CC	1 in 1000yr	1 in 200yr	1 in 1000yr	Scenario 1	Scenario 2	Scenario 3	Scenario 4
1	5.84	-	- 5	.84	6.01	-	-	5.91 5.	91	6.09 5.	95
2	5.57 5	.42	5.65	5.80	5.98	-	5.64	5.61 5.	60	6.09 5.	83
3	6.15	-	-	-	-	-	-	6.25 6.	26	6.31 6.	30
4	5.37 5	.40	5.68	5.84	6.01	-	5.65	5.43 5.	53	6.12 5.	85
5	5.27 5	.40	5.70	5.80	5.97	-	5.69	5.29 5.	49	6.09 5.	82
6	5.07	- 5	.55	5.73	5.92	-	5.62	5.40 5.	42	6.08 5.	79
7	5.84	- 5	.83	5.86	6.02	-	-	5.85 5.	85	6.11 5.	90
8	5.78	- 5	.69	5.84	6.01	-	5.64	5.81 5.	77	6.10 5.	87
9	5.35	- 5	.63	5.77	5.95	-	5.56	5.67 5.	66	6.09 5.	84
10	5.08	- 5	.46	5.72	5.88	-	5.53	5.64 5.	64	6.07 5.	79
11	6.15	- 6	.19	6.23	6.30	-	-	6.19 6.	19	6.30 6.	25
12	5.99	- 6	.17	6.19	6.25	-	-	6.17 6.	16	6.30 6.	23
13	5.37	- 5	.63	5.77	5.95	-	5.56	5.67 5.	66	6.10 5.	84
14	5.22	- 5	.63	5.77	5.95	-	5.56	5.67 5.	66	6.10 5.	84

5. Development Considerations

5.1 FLOOD ZONES AND THEIR IMPACTS ON DEVELOPMENT

5.1.1 As indicated within Section 3, PPS25 advises that a strategic approach should be adopted in keeping with the Government's aims to ensure that new development is sustainable. Notably it introduces:

- The concept of the formal classification of the vulnerability of development;
- The Sequential Test which aims to steer development away from areas with a high probability of flooding;
- It identifies the need to apply the Strategic Flood Risk Assessment to decisions taken at all levels of planning, i.e. the need for assessment at the Regional Spatial Strategy level, Local Development Framework and at site level; and
- The concept of flood risk reduction, particularly where development has been sanctioned on the basis of the "Exception Test".

5.1.2 It can be concluded that; based on the detailed River Dour hydraulic model, the Mid Town site is located in all Flood Zones. It has been identified that land south of the Dour is predominantly Flood Zone 1 and the area north of the Dour is predominantly within Flood Zone 3a and Flood Zone 2 (refer to Figure 4.4 and 5.1).

5.2 FLOOD ZONE POLICY AIMS

5.2.1 Section 4.4 sets out the definition of the Flood Zones in accordance with Table D.1 of PPS25.

5.2.2 The following policy information is provided for development sites in each Flood Zone:

- **Flood Zone 2**, policy aims are that "In this zone, developers and local authorities should seek opportunities to reduce the overall level of flood risk in the area and beyond through the layout and form of the development, and the appropriate application of sustainable drainage techniques"[5].
- In **Flood Zone 3a** , developers and local authorities should seek opportunities to:
  - Reduce the overall level of flood risk in the area through the layout and form of the development and the appropriate application of sustainable drainage techniques;
  - Relocate existing development to land in zones with a lower probability of flooding; and
  - Create space for flooding to occur by restoring functional floodplain and flood flow pathways and by identifying, allocating and safeguarding open space for flood storage.
- In **Flood Zone 3b**, developers and local authorities should seek opportunities to:
  - reduce the overall level of flood risk in the area through the layout and form of the development and the appropriate application of sustainable drainage techniques; and
  - Relocate existing development to land with a lower probability of flooding.

[5] Annex D, Planning Policy Statement 25: Development and Flood Risk (PPS 25). Department for Communities and Local Government, December 2006

5.2.3 Section 4, of this report, provided information relating to the risk of flooding to the site based on the detailed River Dour hydraulic model.

5.2.4 Prior to locating proposed development via a 'sequential' approach it is necessary to understand the impacts that the revised Flood Zones will have on the types of development and their vulnerabilities within Dover Mid Town and the wider area. Table D3 of PPS25 (reproduced as Table 5.1 below) identifies the compatible land use vulnerabilities associated with each Flood Zone, whilst Table D2 found within PPS25 (reproduce as Table 5.2 overleaf) identifies the vulnerability classification for differing types of development.

Table 5.1. Table D3 Extracted from PPS 25 Annex D

Flood Risk Vulnerability classification (see Table 5.2)	Essential Infrastructure	Water Compatible	Highly Vulnerable	More Vulnerable	Less Vulnerable
Zone 1	✓	✓	✓	✓	✓
Zone 2	✓	✓	Exception Test Required	✓	✓
Zone 3a	Exception Test Required	✓	✗	Exception Test Required	✓
Zone 3b 'Functional Floodplain'	Exception Test Required	✓	✗	✗	✗

Key:
✓ Development is appropriate
✗ Development should not be permitted

Table 5.2. Table D2 Extracted from PPS 25 Annex D

Essential Infrastructure	Highly Vulnerable	More Vulnerable	Less Vulnerable	Water-Compatible
• Essential transport infrastructure (including mass evacuation routes) which has to cross the area at risk. • Essential utility infrastructure which has to be located in a flood risk area for operational reasons, including electricity generating power stations and grid and primary substations; and water-treatment works that need to remain operational in times of flood. • Wind turbines.	•Police stations, Ambulance stations and Fire stations and Command Centres and telecommunications installations required to be operational during flooding. •Emergency dispersal points. • Basement dwellings. •Caravans, mobile homes and park homes intended for permanent residential use. •Installations requiring hazardous substances consent. (Where there is a demonstrable need to locate such installations for bulk storage of materials with port or other similar facilities, or such installations with energy infrastructure or carbon capture and storage installations, that require coastal or water-side locations, or need to be located in other high flood risk areas, in these instances the facilities should be classified as 'Essential Infrastructure').	• Hospitals. •Residential institutions such as residential care homes, children's homes, social services homes, prisons and hostels. • Buildings used for: dwelling houses; student halls of residence; drinking establishments; nightclubs;and hotels. •Non–residential uses for health services, nurseries and educational establishments. •Landfill and sites used for waste management facilities for hazardous waste. •Sites used for holiday or short-let caravans and camping, subject to a **specific warning and evacuation plan**.	• Police, ambulance and fire stations which are not required to be operational during flooding. •Buildings used for: shops; financial, professional and other services; restaurants and cafes; hot food takeaways; offices; general industry; storage and distribution; non–residential institutions not included in 'more vulnerable'; and assembly and leisure. •Land and buildings used for agriculture and forestry. •Waste treatment (except landfill and hazardous waste facilities). •Minerals working and processing (except for sand and gravel working). •Water treatment works which do not need to remain operational during times of flood. • Sewage treatment works (if adequate measures to control pollution and manage sewage during flooding events are in place).	•Flood control infrastructure. • Water transmission infrastructure and pumping stations. •Sewage transmission infrastructure and pumping stations. • Sand and gravel workings. • Docks, marinas and wharves. • Navigation facilities. •MOD defence installations. •Ship building, repairing and dismantling, dockside fish processing and refrigeration and compatible activities requiring a waterside location. •Water-based recreation (excluding sleeping accommodation). •Lifeguard and coastguard stations. •Amenity open space, nature conservation and biodiversity, outdoor sports and recreation and essential facilities such as changing rooms. •Essential ancillary sleeping or residential accommodation for staffrequired by uses in this category, subject to a **specific warning and evacuation plan**.

5.2.5 Figure 5.1, below, details the revised Flood Zones within the site. These should be used when determining the 'compatibility' of proposed landuses within the site and when addressing the Sequential and Exception Tests detailed within PPS25. These tests are briefly discussed below

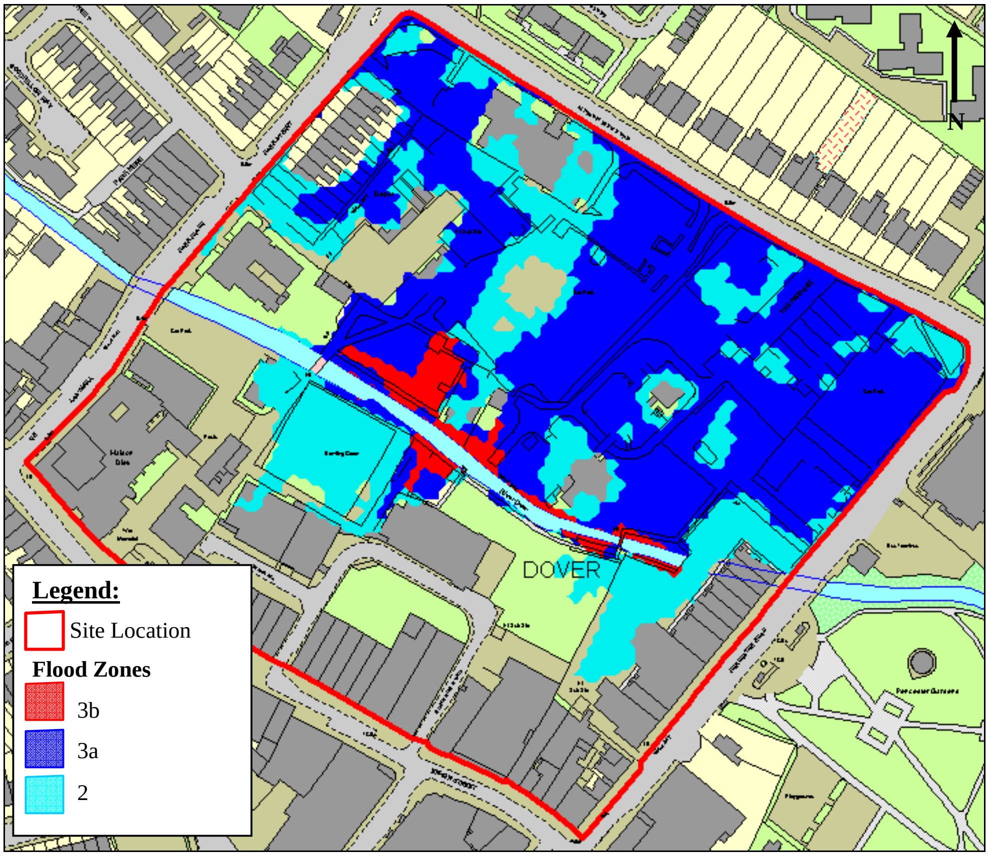

Figure 5.1 Revised Flood Zones within the Mid Town Site

5.3 THE SEQUENTIAL APPROACH

5.3.1 In accordance with PPS25, Local Planning Authorities allocating land in Local Development Documents should apply the Sequential Test to demonstrate that there are no reasonably alternative sites in areas with a lower probability of flooding. This is usually done using information contained in a Strategic Flood Risk Assessment (SFRA), however, the information contained within this report provides greater detail in relation to flood extents and hazard and has been used in assessing the Mid Town site in its current layout configuration. It is recommended that the revised Flood Zone maps and hazard calculations for the site are utilised when applying the sequential approach to development in the Mid Town area.

5.3.2 The Sequential Approach is to locate landuses with higher vulnerabilities in locations at a lower probability of flooding (e.g. promote locating highly vulnerable landuses located within Flood Zone 1). The clear distinction in Flood Zones within the Mid Town site offers the opportunity to apply the Sequential Approach to development proposals.

5.4 THE EXCEPTION TEST

5.4.1 A large proportion of the Mid Town site is located within Flood Zones 2 and 3a. With reference to Table 3.1, a 'more vulnerable' land use (e.g. a hospital development) is not required to pass the Exception Test for development located within Flood Zone 1 or 2, however preference should be given to 'more vulnerable' land uses being located within Flood Zone 1.

5.4.2 If the development includes uses with a higher vulnerability classification (e.g. emergency services, basement dwellings or installations requiring hazardous substances consent) in Flood Zone 2, or it will be necessary to pass the Exception Test after the Sequential Test has been passed.

5.4.3 To meet Part (c) of the Exception Test it must be demonstrated that the development will be safe, without increasing flood risk elsewhere, and, where possible, will reduce flood risk overall.'

5.4.4 It is the responsibility of the developer to ensure the site is safe for the lifetime of the development, covering:

- Design of any flood defence infrastructure;
- Access and egress;
- Operation and maintenance;
- Design of development to manage and reduce flood risk wherever possible;
- Resident awareness;
- Flood warning; and
- Evacuation procedures and funding arrangements.

5.4.5 The PPS 25 Practice Guide provide guidance on how to make development safe (refer to Table 5.3 below):

Table 5.3 PPS 25 Practice Guide, Making Development Safe

PPS 25 Practice Guide – Making Development Safe	Applicability to Developing the Site
Avoid flood risk by not developing in areas at risk from floods	Avoid locating 'more vulnerable' and 'highly vulnerable' landuses within Flood Zones 2 and 3a. The Sequential Test will need to justify why it is not possible to locate the these land uses in a lower flood risk zone.
Substituting higher vulnerability land uses for lower vulnerability uses in higher flood risk locations (and vice versa)	Apply the 'Sequential Approach' within the site. Where necessary demonstrating that these land uses cannot be located elsewhere at a lower flood risk.
Providing adequate flood risk management infrastructure which will be maintained for the lifetime of the development	Potential option for managing flood risk. Proposed measures will need to be designed in consultation with the Environment Agency and will need to demonstrate that they do not increase flood risk to others.
Mitigating the potential impact of flooding through design and resilient construction	Design and resilient construction will need to be considered where appropriate, however not to justify development in flood risk areas.

5.4.6 The failure of flood risk management infrastructure must also be considered during the proposed site design to determine the residual risk of flooding that the development may have both on site and to others.

5.5 Site Safe Access and Egress

5.5.1 PPS 25 requires that safe access and egress is provided for new development. The PPS 25 Practice Guide advises that:

Access routes should allow occupants to safely access and exit their dwellings in design flood conditions. Vehicular access to allow emergency services to safely reach the development during design flood conditions will also normally be required. Wherever possible, safe access routes should be provided that are located above design flood levels. Where this is not possible, limited depths of flooding may be appropriate, provided that the proposed access is designed with appropriate signage, etc. to make it safe. The acceptable flood depth for safe access will vary depending on flood velocities and the risk of debris within the flood water

5.5.2 Adults are unlikely to be able to stand in still floodwater with a depth of about 1.5m or greater. The depth of flowing floodwater where people are unable to stand is much less. For example, some people will be at risk when the water depth is only 0.5m if the velocity is 1m/s. If the velocity increases to 2m/s, some people will be unable to stand in a depth of water of only 0.3m. Most people will be unable to stand when the velocity is 2m/s and the depth is 0.6m.

5.5.3 Guidance on the depths and velocities of floodwater that cause risks to people is shown on Figure 5.2.

d * (v+0.5) + DF

Velocity \ Depth	0.25	0.50	0.75	1.00	1.25	1.50	1.75	2.00	2.25	2.50
0.00	0.13	0.25	0.38	0.50	0.63	0.75	0.88	1.00	1.13	1.25
0.50	0.25	0.50	0.75	1.00	1.25	1.50	1.75	2.00	2.25	2.50
1.00	0.38	0.75	1.13	1.50	1.88	2.25	2.63	3.00	3.38	3.75
1.50	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00
2.00	0.63	1.25	1.88	2.50	3.13	3.75	4.38	5.00	5.63	6.25
2.50	0.75	1.50	2.25	3.00	3.75	4.50	5.25	6.00	6.75	7.50
3.00	0.88	1.75	2.63	3.50	4.38	5.25	6.13	7.00	7.88	8.75
3.50	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00
4.00	1.13	2.25	3.38	4.50	5.63	6.75	7.88	9.00	10.13	11.25
4.50	1.25	2.50	3.75	5.00	6.25	7.50	8.75	10.00	11.25	12.50
5.00	1.38	2.75	4.13	5.50	6.88	8.25	9.63	11.00	12.38	13.75

Categories of flood hazard:

	From	To	
Class 1	0.75	1.50	Danger for some
Class 2	1.50	2.50	Danger for most
Class 3	2.50	20.00	Danger for all

Note: The table gives values of flood hazard (= d.(v+0.5) +DF)

Figure 5.2 Combinations of flood depth and velocity that cause danger to people
(Source: DEFRA/Environment Agency research on Flood Risks to People - FD2321/TR2)

5.5.4 Many deaths in floods occur because people attempt to drive through or away from floodwater and get swept away or trapped in their cars. Their cars either then get swept away as a result of positive buoyancy or stuck in the floodwater.

5.5.5 FD2321/TR2 indicates that most cars and vans are unstable in 0.5m of still water and that this depth reduces as the velocity of the water increases. The report also indicates that large vehicles such as fire engines become unstable in 0.9m of still water, and this value also reduces as the velocity of the water increases.

5.5.6 Figures 5.3 – 5.8 provide an overview of the 'actual' flood hazard for the:

- Fluvial scenarios: 1 in 100, 1 in 100 plus climate change and 1 in 1000 year events;

- Tidal scenarios: 1 in 1000 year event; and
- The four surface water events.

5.5.7 Table 5.4 identifies the key utilised in Figures 5.3-5.8 to define the degree of hazard to the Mid Town site.

Table 5.4 Flood Hazard to People Legend

Degree of Flood Hazard	Hazard Rating (HR)		Description
Low	<0.75 Cau	tion	Flood zone with shallow flowing water or deep standing water
Moderate	0.75b – 1.25	Dangerous for some (i.e. children)	Danger: Flood zone with deep or fast flowing water
Significant	1.25 -2.5	Dangerous for most people	Danger: Flood zone with deep fast flowing water
Extreme	>2.5	Dangerous for all	Extreme danger: Flood zone with deep fast flowing water

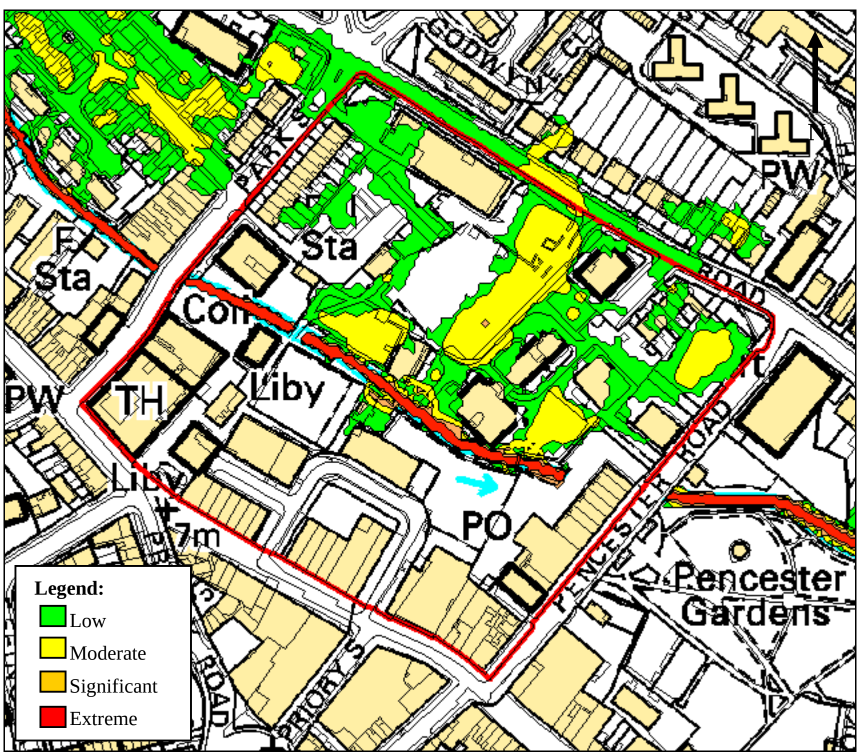

Figure 5.3 Hazard Levels for Fluvial Flooding – 1 in 100 Year Return Period Event

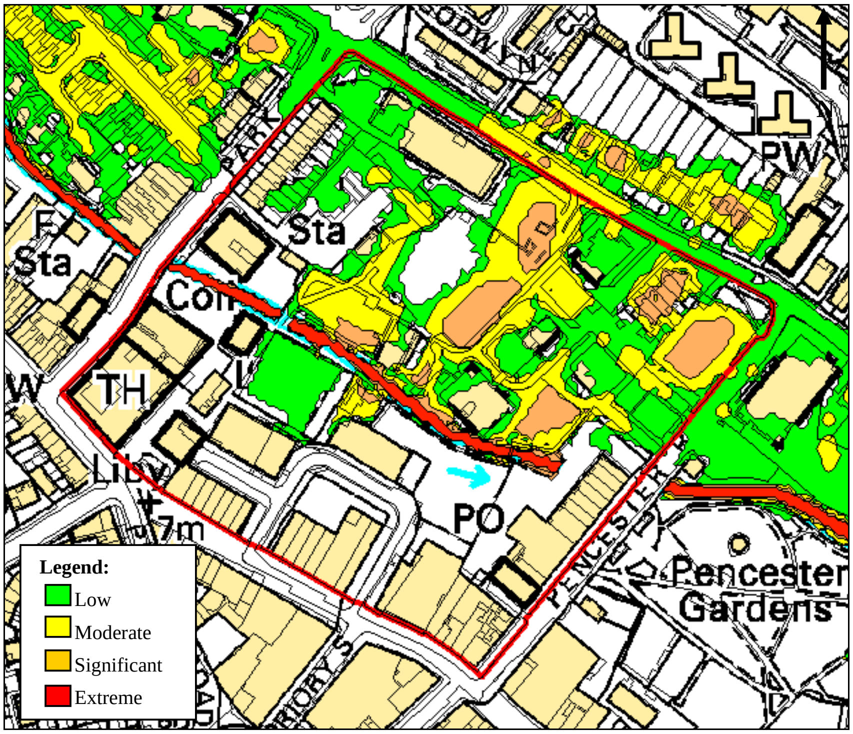

Figure 5.4 Hazard Levels for Fluvial Flooding – 1 in 100 Year Plus an Allowance for Climate Change Return Period Event

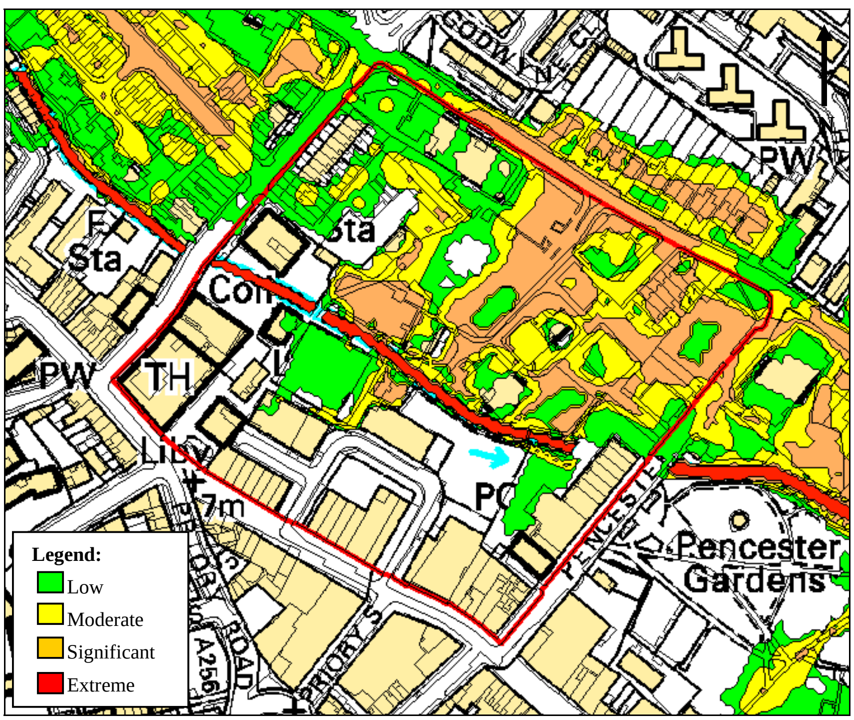

Figure 5.5 Hazard Levels for Fluvial Flooding – 1 in 1000 year Return Period Event

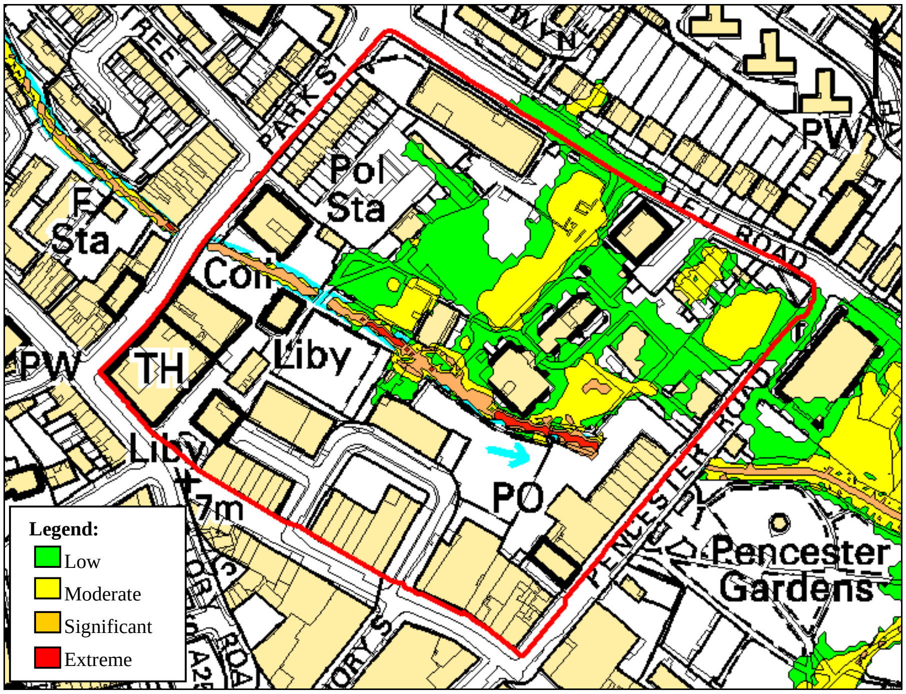

Figure 5.6 Hazard Levels for Tidal Flooding – 1 in 1000 year Return Period Event

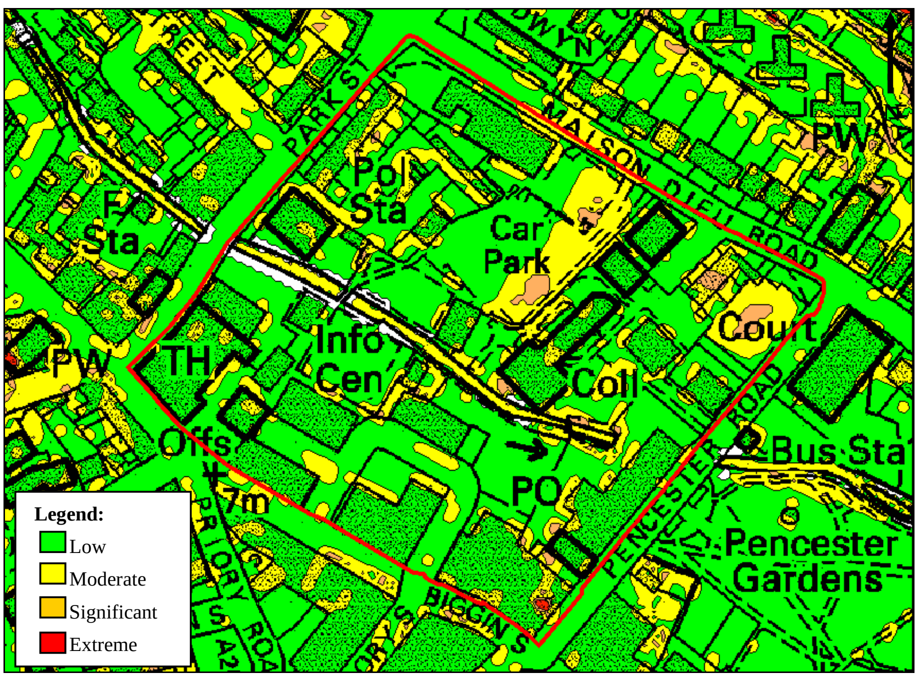

Figure 5.7 Hazard Levels for Surface Water Flooding: 1 in 100 Year – 1 in 30 Year Return Period Rainfall Event (Scenario 1)

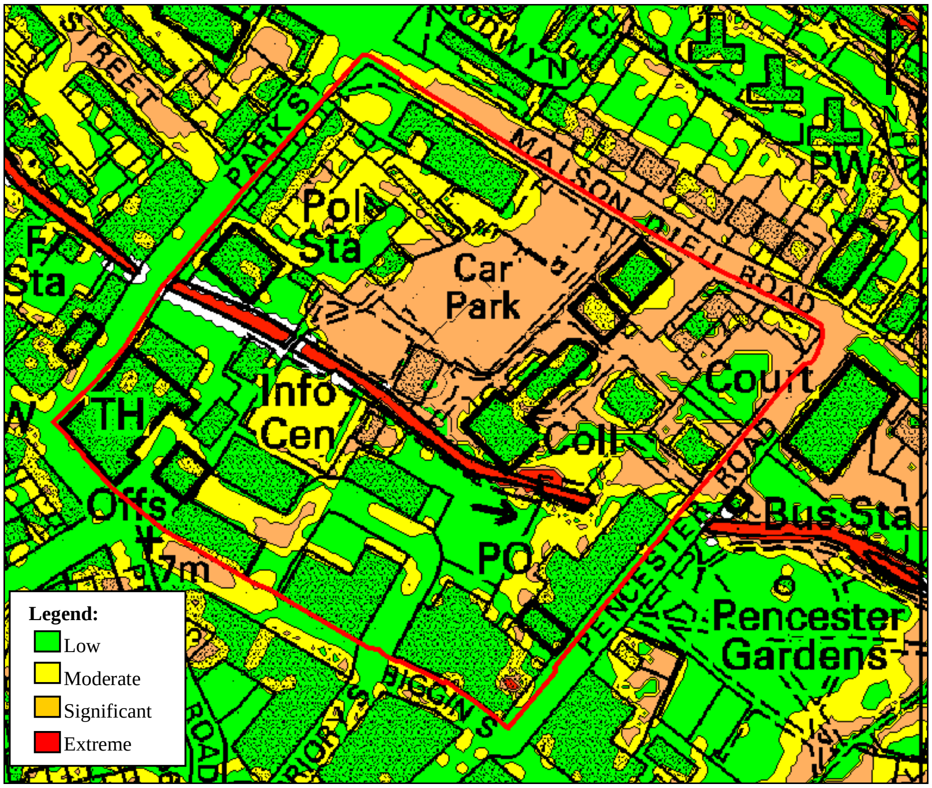

Figure 5.8 Hazard Levels for Surface Water Flooding: 1 in 100 Plus Climate Change Year Return Period Rainfall Event (Scenario 3)

5.5.8 Dry access is not currently available to the central area of the site (existing carpark). Surface water flooding results for the 1 in 100 year plus an allowance for climate change rainfall period event show greater flood depths on site (in particular the existing Council carpark) than a corresponding fluvial or 1 in 1000 year return period (defended scenario) tidal flood event on the River Dour. However, the hazard rating during the rainfall scenario is lower than the fluvial event due to the predicted velocities being much lower during surface water flooding.

5.5.9 Surface water modelling also indicates that Maison Dieu Road is flooded up to 70cm deep during a 1 in 100 year return period event, plus climate change, rainfall event (in the lowest portion of the road), and averages about 20 – 40cm elsewhere on the road (along the sites northern boundary). Areas within the existing carpark are predicted to flood to a maximum depth of 90cm deep and averages around 50cm on the remaining areas of the carpark. The highest hazard for this event is recorded west of the Age Concern building with a rating of 'significant' whilst the carpark and Maison Dieu Road is determined to be at a 'moderate' hazard. Although the predicted velocities from this event are low, this depth of water does have the potential to move vehicles.

5.5.10 Modelling indicates Park Street to the north west of the site has a 'low' hazard rating during the modelled surface water, tidal and fluvial flood events. If a dry pedestrian access route could be provided from the centre of the site to Park Street, adjacent to the Police Station, it may be possible to satisfy the requirements of PPS 25. Conceptual solutions such as a suitably sized and raised walkway that did not constrain the flow of water might be suitable, however the feasibility of this type of solution would need to be reviewed by site designers. It would also require access through third party land. Vehicular access to the northern portion of the site via Maison Dieu Road would still remain constrained.

5.5.11 The availability of safe access for parts of the northern portion of the site will be difficult to provide based on this current risk of surface water flooding. Safe Access for development fronting onto Biggin Street can be obtained for all modelled surface water, tidal and fluvial scenarios.

5.5.12 The implementation of flood alleviation measures on the River Dour, as discussed in Section 6, could provide dry access for the lifetime of the development during design fluvial flooding conditions.

5.5.13 Reducing the extent and depth of surface water flooding on Maison Dieu Road and the centre of the site would assist in providing safe access. This requires the input and guidance of Southern Water on any amendments to proposed local measures and should utilise information that will be produced within the Surface Water Management Plan currently being prepared by Kent County Council.

5.5.14 Safe access has been determined using the information obtained from the design 1 in 100 year plus climate change fluvial and surface water flood events Figure 5.4 and 5.8.

5.5.15 A review of the 1 n 1000 return period year fluvial and tidal flood event and the 1 in 100 year plus climate change surface water flood scenarios indicate that Emergency access could be obtained for the entire site as the maximum recorded flood depths on the lowest section of road are around 70-78cm. This depth does not exceed the 90cm fire truck threshold identified within DEFRA guidance Flood Risks to People (FD2321/TR2).

6. Flood Risk Management Options

6.1.1 An assessment of the flood mechanisms on the River Dour has been made in determining appropriate conceptual options to manage fluvial flood risk. The following section provides a summary of the scenarios tested and determines the most appropriate option for the site which will require a detailed appraisal.

6.1.2 Flood risk management in Dover should be considered strategically. Although the assessment and management of flood risk in this study has focused on the Mid Town site, it has also considered the wider flood risk management in the catchment and how this could benefit the Mid Town site.

6.2 SITE SPECIFIC FLOOD RISK MANAGEMENT

FLOOD AVOIDANCE

6.2.1 As discussed in Table 5.1, the Sequential Test needs to demonstrated for all land uses in Flood Zone 2 and 3. Dover District Council will need to identify that there are no ‘reasonably available’ sites at lower flood risk where this land use could be located and that there is sufficient justification to allow the use (subject to the hazard to the site), as indicated within Section 5.7 of the Dover District Council SFRA. Assuming this can be demonstrated, flood avoidance cannot be taken further as a risk management option.

6.2.2 As an example, using the northern portion of the Mid Town site for public open space (water compatible use), and locating development in Pencester Gardens – predominantly Flood Zone 1, could significantly reduce the need for flood mitigation to enable regeneration.

SITE LAYOUT/SEQUENTIAL APPROACH

6.2.3 The variance in probability of flooding across the Dover Mid Town area means that a sequential approach can be applied to the wider masterplanning. The layout of the Dover Mid Town masterplan should consider a sequential approach based on Flood Zones, with the higher vulnerability land uses located in the lower probability flood zones.

6.2.4 Where the ‘Sequential Approach’ has been applied and development remains necessary in areas identified at ‘actual’ or ‘residual’ risk of flooding, measure to ‘control’ or ‘mitigate’ flooding can be considered. The extent of flooding on site means it is expected that development in ‘actual’ flood risk areas is likely to be necessary to enable regeneration.

RAISING FLOOR LEVELS

6.2.5 Raising floor levels within areas of ‘moderate’ and ‘high’ probability flood events would potentially offer the opportunity to keep site occupiers ‘safe during periods of flooding.

6.2.6 Significantly raising floor levels often causes physical access difficulties, however may be possible to overcome through appropriate building design and layout. Raising floor levels is a site specific solution and would not assist in the overall reduction of flood risk or address safe access requirements through the site but may keep certain land use vulnerabilities safe during times of flooding.

6.2.7 Raising floor levels may be appropriate in managing residual risk from an extreme flood event (e.g. fluvial 1 in 1000 year return event period).

Modification of Ground Levels

6.2.8 Raising of ground levels within area prone to flooding does have the potential to make development safe. However safe access within the northern portion of the site (in particular the existing carpark) for the lifetime of the development remains difficult to overcome, unless raising of local roads can also be undertaken.

6.2.9 As described in Section 4, flood mechanisms on the River Dour include overtopping of culverts and weirs upstream resulting in overland flow that floods the Dover Mid Town area. Ground raising in isolation would divert this flow, increasing flood risk to others and compensatory flood storage will be difficult to provide.

6.2.10 Ground raising in combination with additional flood risk measures may offer a solution to manage ‘actual’ as well as ‘residual’ risk without increasing flood risk to others.

6.3 Strategic Flood Risk Management

6.3.1 As identified within Section 4, a review of the flood mechanisms indicates that improving conveyance on the River Dour is likely to provide the most appropriate strategic benefit to flood risk, however for completeness a range of options has been reviewed.

Development behind Floodwalls and Embankments

6.3.2 The PPS 25 Practice Guide advises:

Wherever possible construction of new defences to enable development to take place should be avoided, so that residual risks are not created. Developers proposing this solution will need to show that other options, such as upstream storage and attenuation of flows, have been considered, justify why they are not feasible and that the proposal is compatible with the long-term plans for the general flood risk management in the area, such as CFMPs.

6.3.3 Flood defence scenarios that protect the site have been considered and tested using the hydraulic model (Option 4 and 5).

Upstream Flood Storage

6.3.4 A reduction in the peak flow passing down the River Dour has the potential to reduce the extent and depth of flooding across a wider area than just the Mid Town site. There are a series of lakes in the upper catchment of the River Dour which are likely to provide some attenuation at present. The location of flow nodes in the PBA River Dour Hydrology study (2007) enables the testing of the implications of increased storage in this area and the benefit it may have on the downstream catchment. Review of the catchment hydrology indicates the flows entering the lakes in the upper catchment of the River Dour are relatively limited in comparison to the flow entering the river from the urbanised area downstream. Intuitively this indicates that storage in the upper catchment is unlikely to result in a significant benefit downstream (Option 1).

6.3.5 Downstream of the lakes the River Dour is heavily engineered, with existing development in close proximity to the watercourse. This indicates that the opportunity to provide additional flood storage is heavily constrained. One area of potential flood storage has been identified is at Buckland Mill and the creation of addition flood storage in this area has been tested using the hydraulic model (Option 2).

Downstream Tidal Interface

6.3.6 As discussed within Section 4.7 consultation with the Dover Harbour Board indicated that there were; no tidal exclusion structures located within the interface between the River Dour and Wellington Docks.

6.3.7 It was also identified that the operating procedure of the other Wellington Dock gates required that they were left open during high tide and closed during low tide, in order to maintain a minimum water level within the dock.

6.3.8 Although outside of the remit of this study, it is recommended that the management of water levels (operating procedures) and tidal controls in Wellington Docks are investigate in a detailed feasibility study to determine if there is a viable option reduce this risk of flooding in Dover in the future as a result of climate change on sea level rise. It is also recommended that any future studies investigate opportunities to increase the River Dour's ability to discharge floodwaters more efficiently during times of high tide and high rainfall (alternative dock operational rules or additional outlets into the English Channel).

6.4 Conceptual Flood Management Options

6.4.1 The proposed mitigation options for reducing and managing the flood risk within the study area will need to not only address the current fluvial and tidal flood risks but will also need to address the risks that climate change may have on the site. It is imperative that these options do not create an adverse affect to any area of Dover (either upstream or downstream of the study area). Many of the options identified include undertaking works on land owned by third parties (i.e. riparian owners). The assessment of these conceptual options has assumed that permissive powers to undertake the works will be available, following consultation.

6.4.2 Options have been tested for the 1 in 20 year, 1 in 100 year, 1 in 100 year plus climate change, and 1 in 1000 year return period events. The 'baseline' results demonstrate there is limited constraint from the 1 in 20 year return period event. Hydraulic modelling has focussed on option testing that demonstrates the Mid Town site would be safe during the 1 in 100 year return period event, for the lifetime of the development.

6.4.3 Options have been run for the 1 in 1000 year return period event to determine the remaining (residual) risk.

6.4.4 The conceptual options that have been assessed to date include the following:

1. Reduction of upstream flows;
2. Flood storage at Buckland Mill;
3. Removal of weirs and Regrading of the existing channel;
4. Removal of Weir and Raised defences (walls and embankments);
5. Retention of Weir and Raised Defences (walls and embankments);
6. Removal of the Combined Sewer pipe located under Pencester Road; and
7. Widening of the river corridor through Mid Town.

CAPITA SYMONDS

6.5 Discussion of Options

The following section provides a brief summary of the conceptual option assessment and an environmental sieve analysis undertaken to understand the potential environmental implications for the investigated flood management options. The full Environmental Sieve Analysis can be found within Append D.

Option 1 – Reducing Upstream Flows

The upstream boundary of the model is located downstream of two lakes which are fed by the upper catchments. The possibility of using these lakes to provide additional storage has been tested as Option 1. This was done by changing the hydrological inflows from the Kearsney Tributary and Alkham Bourne into the lakes so that they provide river 'baseflow' only, with removal of the flow 'peak'. This is likely to be a 'best case' storage scenario and has been used to test whether this provides any benefit.

6.5.1 The results from modelling this option indicate there would be a reduction in flood extent at various locations along the River Dour; notably along Lower Road and Common Lane, adjacent to Crabble Road, Crabble Hill and reduced flooding of the properties on Brookfield Place, Buckland Avenue and Alfred Road. There is also a minor reduction in flooding in the Mid Town area, along Maison Dieu Avenue and the properties adjacent to Pencester Gardens. Figure 6.1 provides a comparison between the baseline event and Option 1 for the 1 in 100 year plus climate change fluvial event (as it affects the site). In order to attenuate flows to the 'baseflow' rate it is predicted that a volume in excess of 200,00m^3 will be required within the upper catchment.

6.5.2 Refer to Figure 6.1 for a comparison of the food extents within the study area (for a 1 in 100 year plus climate change fluvial flood event).

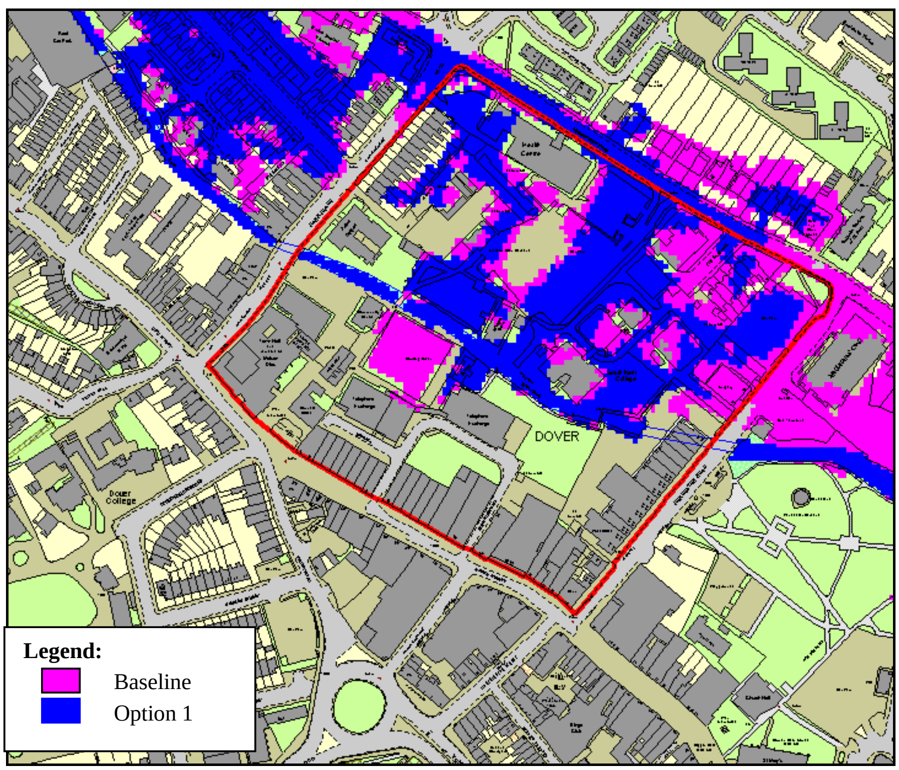

Figure 6.1 Baseline 1 in 100 Year Plus Climate Change Return Period Flood Extent Comparison: Baseline Vs Option 1

6.5.3 Key environmental aspects potentially likely to be affected in the development of Option 1 are the landscape and heritage value of the Upper Lakes area in relation to the potential increase in storage capacity of these lakes. Whilst this may not be a significant constraint, the development of this Option is likely to require extensive consultation with both Dover District Council and English Heritage which should be factored into programme and cost implications for any proposed project which investigated this Option. Furthermore, buried archaeological and palaeoenvironmental remains may be present in the floodplain area which can be potentially adversely impacted upon through changes in water levels as a result of repeated flood events or changes in water flow. Nevertheless, the continuation of existing groundwater levels may help to preserve existing organic remains.

6.5.4 There are also potential opportunities and constraints on this site in relation to flora and fauna. Whilst changes in the storage capacity of the site may result in disturbance to species and habitats already existing in the Upper Lakes area (including in river species), the Option also offers the opportunity to create wetland habitat such as coastal and floodplain grazing marsh and reedbeds which are both priority BAP habitats for Kent. Changes in water quality may also potentially occur as a result of changes in storage capacity, for example through alteration of increased nutrient loading, changes to turbidity and siltation etc. This may have potentially detrimental effects for species and habitats on site and downstream. Potential impacts of this Option on groundwater and downstream geomorphology would also need to be considered.

6.5.5 Finally, residents and tourists to the area may also be affected by this Option if currently publicly accessible open space in the Upper Lakes area is lost through changes in storage capacity on the Site. However, this is likely to be infrequent and temporary.

Option 2 – Flood Storage at Buckland Mill

6.5.6 Storage lower down the catchment has been tested to determine whether peak flows entering further downstream can be managed to reduce flooding on the River Dour. Land adjacent to Buckland Mill was identified as the most logical, currently undeveloped area which is located next to the river. This site is also located immediately downstream of the largest inflow in the catchment.

6.5.7 This option was conceptually tested by lowering an area of the bank below peak water levels to create a spillway, as well as lowering areas of ground by 300-500mm (to 16mAOD). An embankment/wall around the storage area was incorporated into the layout to maximise the storage of floodwater in his area (refer to Figure 6.2).

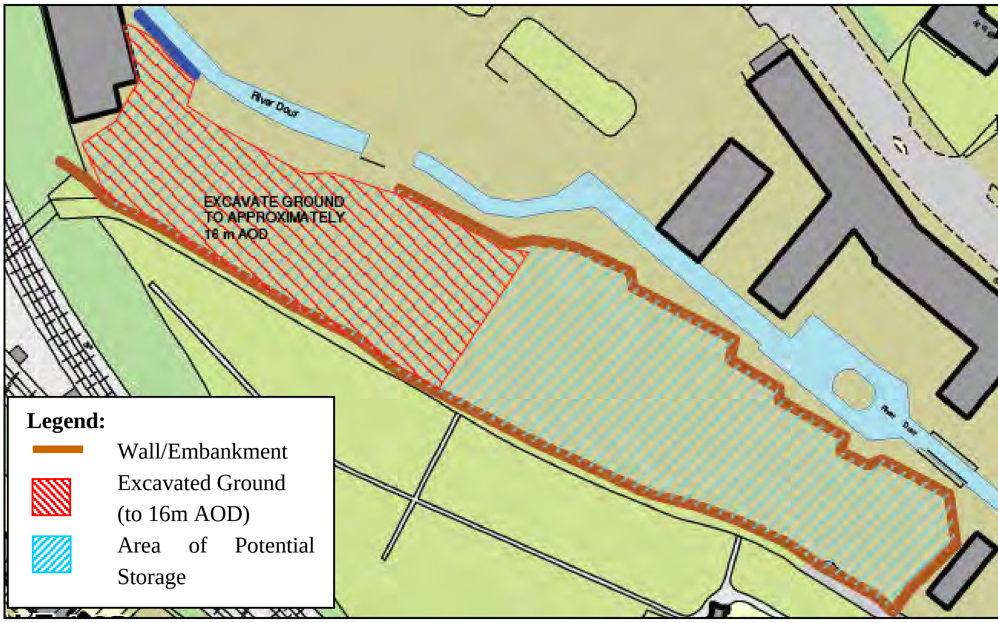

Figure 6.2 Location of Conceptual Buckland Mill Flood Storage Area

6.5.8 Modelling results of Option 2 show minimal change in flood extent in comparison to the baseline results, with the only noticeable difference being the bowling green in the Mid Town area now remaining dry (refer to Figure 6.3)

6.5.9 Under this Option, similar opportunities and constraints may arise at Buckland Mill as seen under Option 1 in the Upper Lakes area. However, landscape is likely to be less of a constraint under this Option as the Buckland Mill area is not designated for its landscape importance, although existing residential properties may have views over this area. Creation of a wetland area may have landscape and ecological benefit.

6.5.10 Additionally, given the historic land use of the area adjacent to the proposed flood storage area, potential for contamination exists. This could potentially be mobilised during construction of the spillway or through the presence of standing water. This risk would require the relevant site investigations studies to be undertaken to determine the feasibility of this option prior to any detailed designs being undertaken.

6.5.11 The land is currently under the ownership of South East England Development Agency (SEEDA) and has also been granted planning permission from DDC. Therefore, any proposed option to utilise this site for flood storage would require that SEEDA (with any relevant development partners) are compensated for the loss of developable land. Figure 6.3, below, provides a comparison of the baseline 1 in 100 year plus climate change event flood extent against the benefit provided from Option 2.

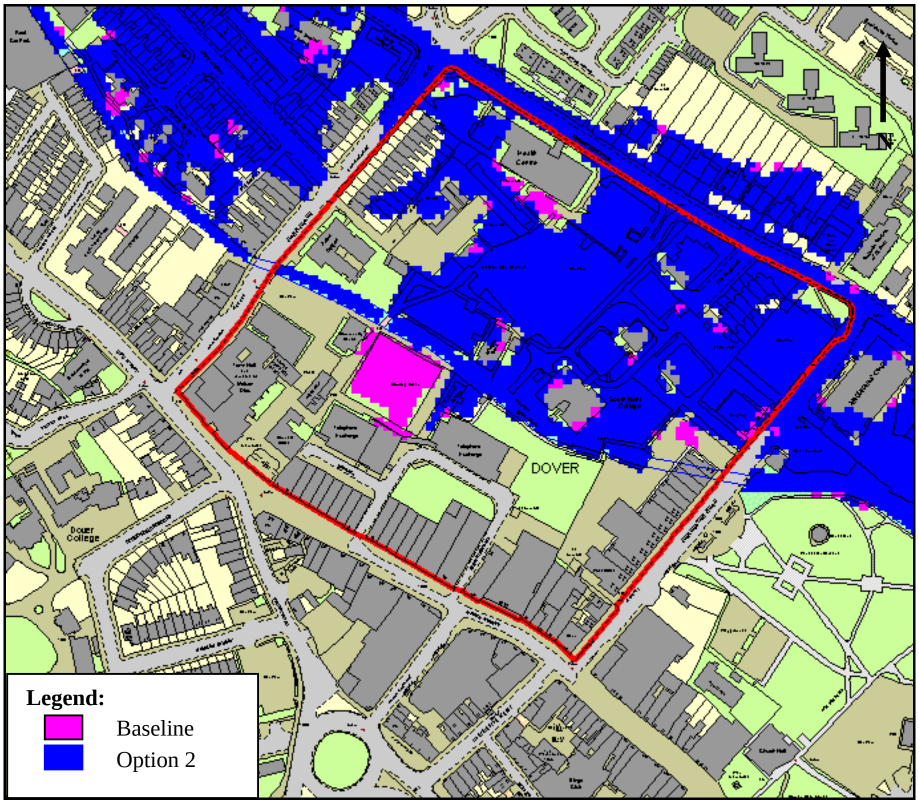

Figure 6.3 Baseline 1 in 100 Year Plus Climate Change Return Period Flood Extent Comparison: Baseline Vs Option 2

6.5.12 Results from Option 1 and 2 indicate upstream flood storage in isolation is unlikely to provide a feasible option to manage flood risk in Dover.

OPTION 3 – REMOVAL OF WEIRS

6.5.13 The weir located near Halfords results in water backing up in the channel due to the 'flat' gradient of the river bed. The low left bank means water is able to spill out and over the existing infrastructure (short wall) bordering the river. This option investigated the lowering of the weir and regrading the channel in this section to improve the channel capacity and reduces the local water level. Figure 6.4, overleaf, provides conceptual diagram of this option with Figure B3 (located in Appendix B) identifying the location of the weir in relation to the study area.

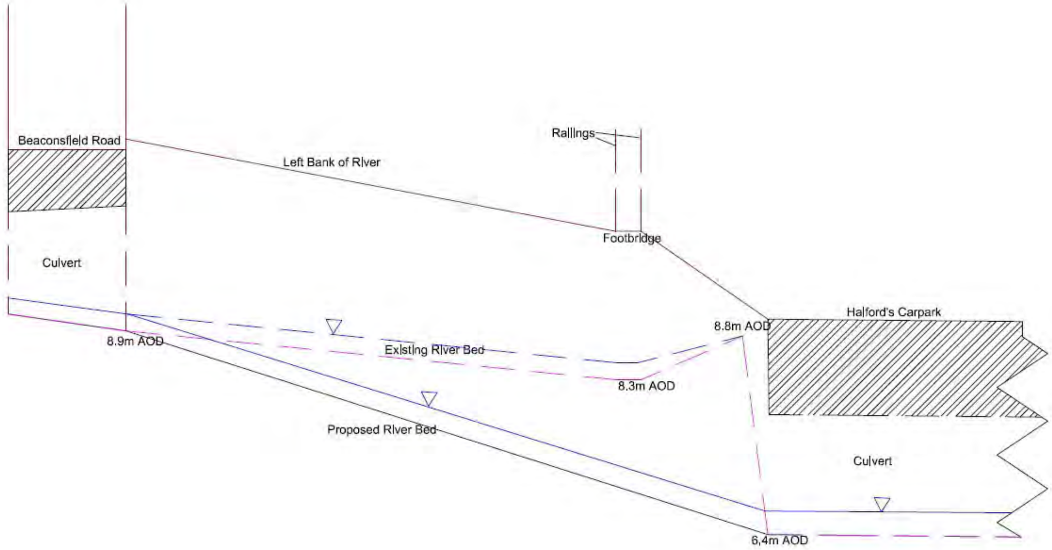

Figure 6.4 Conceptual Regrading Option for the Weir near Halfords

6.5.14 Re-grading the channel section assists in reducing local flood levels, with the banks no longer overtopped upstream of Halfords during a 1 in 100 plus climate change event. Although this removes the flow route down Granville Street, water overtops the left bank downstream of Bridge Street, creating a significant overland flow path down Charlton Green and into Maison Dieu Road; this flood water in turn enters the Mid Town study area from the north west (refer to Figure 6.5). Therefore this option reduces overland flow but does not prevent the study area from significant flooding during a 1 in 100 year plus climate change event.

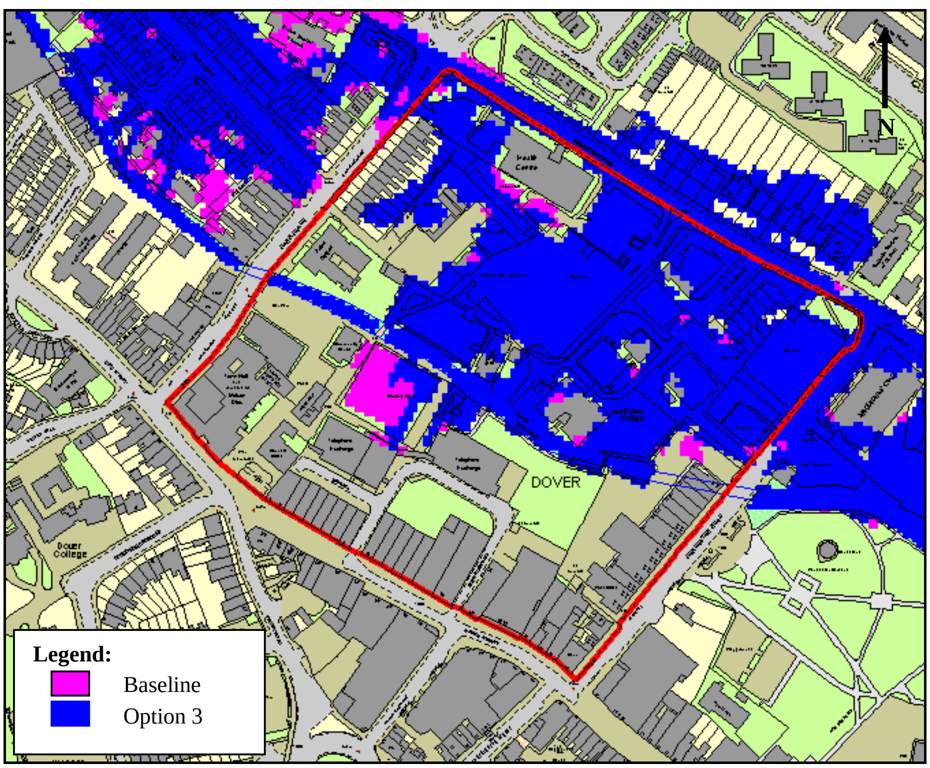

Figure 6.5 Baseline 1 in 100 Year Plus Climate Change Return Period Flood Extent Comparison: Baseline Vs Option 3

6.5.15 A review of local drainage and gas infrastructure indicates there are no services crossing below the weir. Telecommunication and electricity plans are not currently available, however are more easily relocated if they are found to be in this area.

6.5.16 Limited potential environmental constraints have been identified for this Option. The demolition and construction works involved in removal of the weir and re-grading of the channel have the potential to result in air quality impacts (through dust arisings), noise and vibrations to nearby buildings (through plant works) and landscape and townscape impacts (through construction within an existing area of public realm). These potential impacts are likely to be of short duration and temporary, though they may lead to an adverse temporary impact for the local population. In addition, ecological impacts could potentially result from loss of existing vegetation, and change in depth and velocity of flow (both adjacent to the weir and downstream). Potential impacts of this Option on geomorphology would also need to be considered.

Option 4 – Weir Removal and Raised Defences

Option 4a – Raised defences (Mid Town)

6.5.17 Providing raised walls at key locations prevents water overtopping the channel and flooding the Mid Town Dover area, as well as the wider community, during the 1 in 100 year return period event, including climate change. Development at the Dover Mid Town area would therefore be 'safe' for actual risk event, but there would remain a residual risk of flooding from overtopping during extreme events, or in the unlikely event of a breach/defence failure.

6.5.18 In isolation constructing these walls does result in an increase in flood risk to properties immediately downstream of Pencester Gardens.

6.5.19 The results for Option 3 were investigated when developing this option and defences were raised within the model, where water overtopped the banks and created overland flowpaths. Walls were added in at heights 300mm (freeboard) above the 1 in 100 year event water level. The walls are located at the following locations:

- Weir at Morrisons store – up to 0.4m high (8mAOD), 80m long;
- Left bank downstream of Crafford Street – up to 0.3m high (6.5mAOD), 60m long;
- Left bank through Dover Mid Town site – up to 1m high (6.3mAOD), 150m long; and
- Right bank through Dover Mid Town – up to 1m high (6.3mAOD), 140m long.

6.5.20 Note: a wall has been added on the right bank of the rover downstream of Crafford Street up to 0.3m high to 'fill' in a area of lowered LiDAR which would not exist due to the existing carpark wall – this has been done for all scenarios utilising raised defences. Due to a lack of survey this feature is not defined in the hydraulic model and it is recommended that any future studies in this area should verify the condition of this wall, determine if strengthening works are required to reduce the risk of floodwaters entering the carpark.

6.5.21 Providing raised walls at these key locations prevents water overtopping the channel and flooding the Mid Town Dover area (refer to Figure 6.6), as well as the wider community, during the 1 in 100 year return period event, including climate change. Development at the Dover Mid Town area would therefore be 'safe' for actual risk event, but there would remain a residual risk of flooding from overtopping during extreme events, or in the unlikely event of a breach/defence failure.

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6.5.22 This option results in the River Dour remaining in bank downstream of Limes Road until Pencester Gardens, with the exception of the left bank overtopping upstream of Park Place, resulting in flooding to properties on Goodfellow Way, Dour Street and Hewitt Road (refer to Figure 6.6). The flooding adjacent to Pencester Gardens is also slightly reduced in comparison to the baseline results.

6.5.23 This option has been tested including the channel regrading at the Halford's weir. If the weir was not regraded a wall in this area would need to be constructed approximately 0.5m high to retain the floodwater within the banks of the river.

6.5.24 This option has been tested including the channel regrading at the Halford's weir. If the weir was not regraded a wall in this area would need to be constructed approximately 0.5m high.

6.5.25 All wall designs will need to incorporate one-way non-return piped outlets in the wall (at appropriate locations) to allow any surface water ponding behind the structure to drain into the Dour once flood water recede below the outlets invert level.

6.5.26 Figure 6.6, overleaf, provides a comparison of the baseline 1 in 100 year plus climate change event flood extent against the benefit provided from Option 4a.

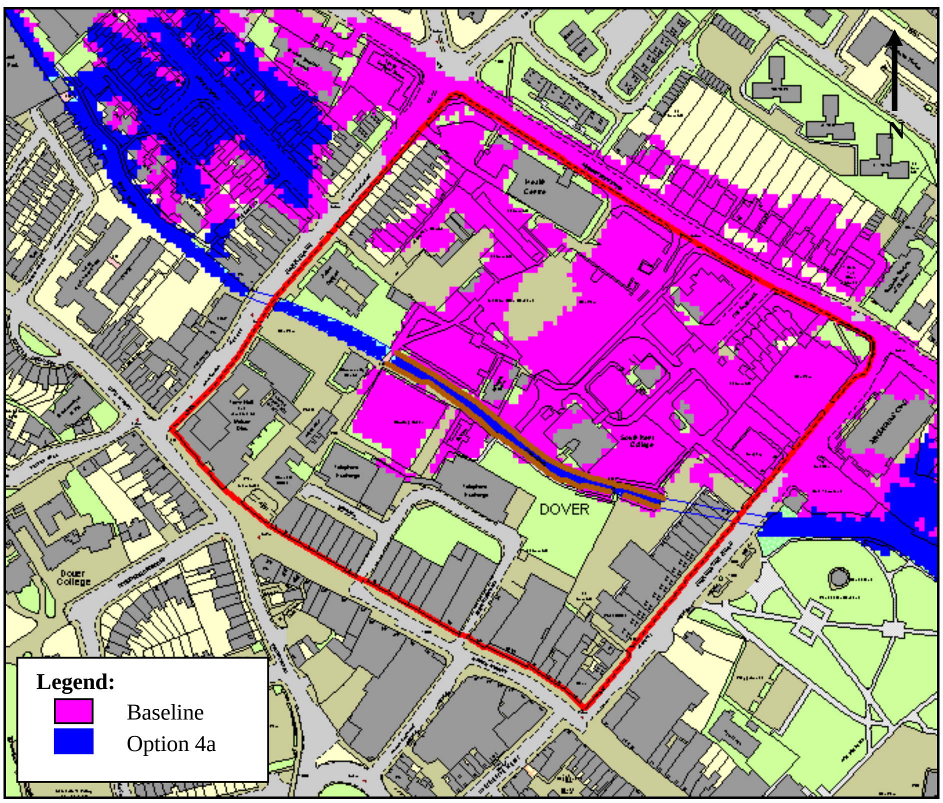

Figure 6.6 Baseline 1 in 100 Year Plus Climate Change Return Period Flood Extent Comparison: Baseline Vs Option 4a

6.5.27 As with Option 3, the construction of raised defences under Options 4a, 4b and 4c has the potential to lead to short duration temporary air quality, noise and vibration, landscape and townscape and ecology impacts. In addition, the presence of large trees along the riverbanks could potentially constrain the development both as a result of potential Tree Protection Orders on some of the trees and the likely size of root protection areas. This could lead to landscape impacts. Loss of any large trees could also lead to ecological impacts as the river corridor may potentially provide suitable habitat for bats and other species including breeding birds. Depending on the final height of any flood defence walls and development layout behind the defences, these could also have potential visual impacts through loss of view to the river bank from the footpaths, and further impacts if access to the river is restricted (particularly in terms of fishing, etc.). This, along with the potential need for temporary diversion of riverside footpaths whilst work is taking place and in conjunction with noise and vibration and air quality impacts, could lead to potential population impacts.

6.5.28 Finally, the presence of conservation areas and potentially listed buildings adjacent to the River where flood defence walls are required may constrain the project in terms of programme and cost, since they may trigger the need for Conservation Area Consent (if demolition of existing walls are required) or planning permission (refer to Figure A3 for relevant listed build locations).

OPTION 4B – ADDITIONAL RAISED DEFENCES

6.5.29 Option 4b does not worsen the flooding in Dover, however the River Dour still overtops its banks in two location downstream of Lime Street – adjacent to Goodfellow Way and in Pencester Gardens.

6.5.30 This option includes the raised defences in Option 4a, plus additional raised defences adjacent Goodfellow Way on the left bank of the river, upstream of Park Street, and on the left and right bank of the river through stretches of Pencester Gardens. Refer to Figure B4-B (in Appendix b) for the overall scheme layout. All the raised defences included in this option are listed below:

- Weir at Morrisons store – up to 0.4m high (8mAOD), 80m long;
- Left bank downstream of Crafford Street – up to 0.3m high (6.5mAOD), 60m long;
- Left bank upstream of Park Street – up to 0.5m high (6.5mAOD),135m long;
- Left bank through Dover Mid Town site – up to 1m high (6.3mAOD), 150m long;
- Right bank through Dover Mid Town – up to 1m high (6.3mAOD), 140m long;
- Left bank in Pencester Gardens – up to 0.6m high (ranging between 5.4 and 5.8mAOD), 190m total length; and
- Right bank in Pencester Gardens – up to 0.5m high (ranging between 5.4 and 5.6mAOD), 80m total length.

6.5.31 Figure 6.7 provides a comparison of the baseline 1 in 100 year plus climate change event flood extent against the benefit provided from Option 4b. The figure represents the River Dour remaining in bank downstream of Lime Street to Wellington Dock, therefore dramatically improving the fluvial and tidal flooding situation for this area of Dover.

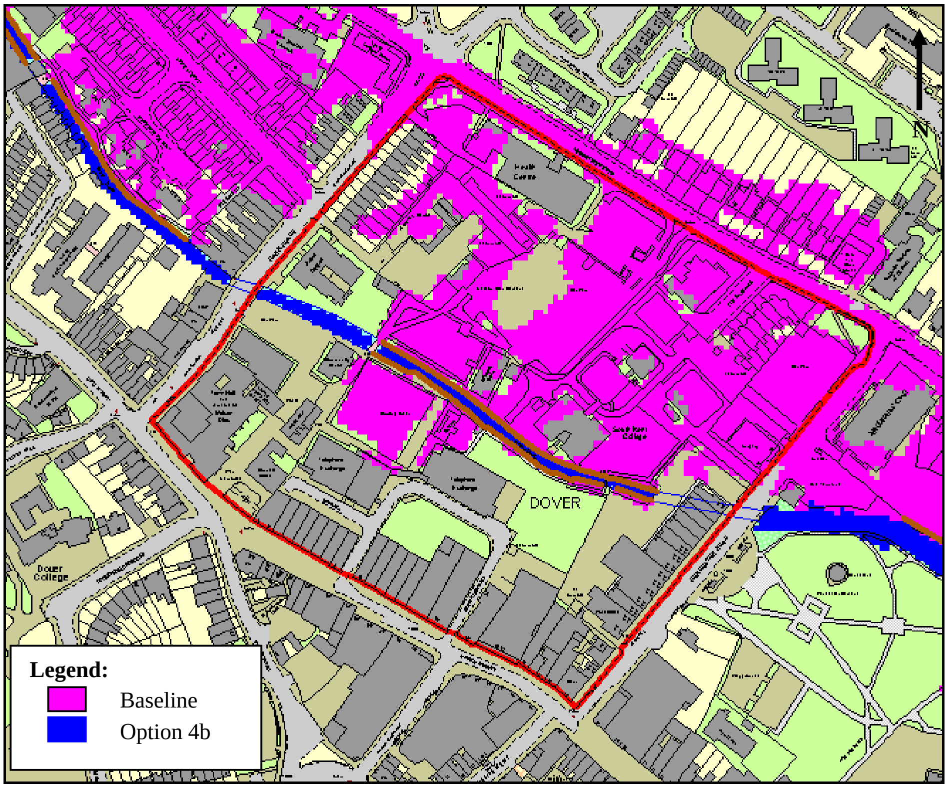

Figure 6.7 Baseline 1 in 100 Year Plus Climate Change Return Period Flood Extent Comparison: Baseline Vs Option 4b

6.5.32 All wall designs will need to incorporate one-way non-return piped outlets in the wall (at appropriate locations) to allow any surface water ponding behind the structure to drain into the Dour once flood water recede below the outlets invert level.

6.5.33 The environmental impacts that could occur as a result of this Option are broadly the same as those identified within option 4a, however there environmental impacts are perceived as being greater due to the necessary works located along the banks of Pencester Gardens.

OPTION 4C– RAISED DEFENCES AND FLOOD STORAGE WITHIN PENCESTER GARDENS

6.5.34 Option 4c incorporates the proposed walls and weir removal identified within Option 4a but also includes of a lowered area of land in Pencester Gardens to assist with compensatory flood storage and an additional flood defence upstream of Park Street, on the left bank (as in Option 4b) to prevent Dour Street from flooding. The raised defences included in this option are as follows:

- Weir at Morrisons store – up to 0.4m high (8mAOD), 80m long;
- Left bank downstream of Crafford Street – up to 0.3m high (6.5mAOD), 60m long;
- Left bank upstream of Park Street – up to 0.5m high (6.5mAOD),135m long;
- Left bank through Dover Mid Town site – up to 1m high (6.3mAOD), 150m long; and
- Right bank through Dover Mid Town – up to 1m high (6.3mAOD), 140m long.

6.5.35 Providing addition flood defences to these properties is therefore considered a more feasible option at this stage. Figure B4-C in Appendix B identifies the location utilised in this assessment. Figure 6.8, below, provides a comparison of the baseline 1 in 100 year plus climate change event flood extent against the benefit provided from Option 4c.

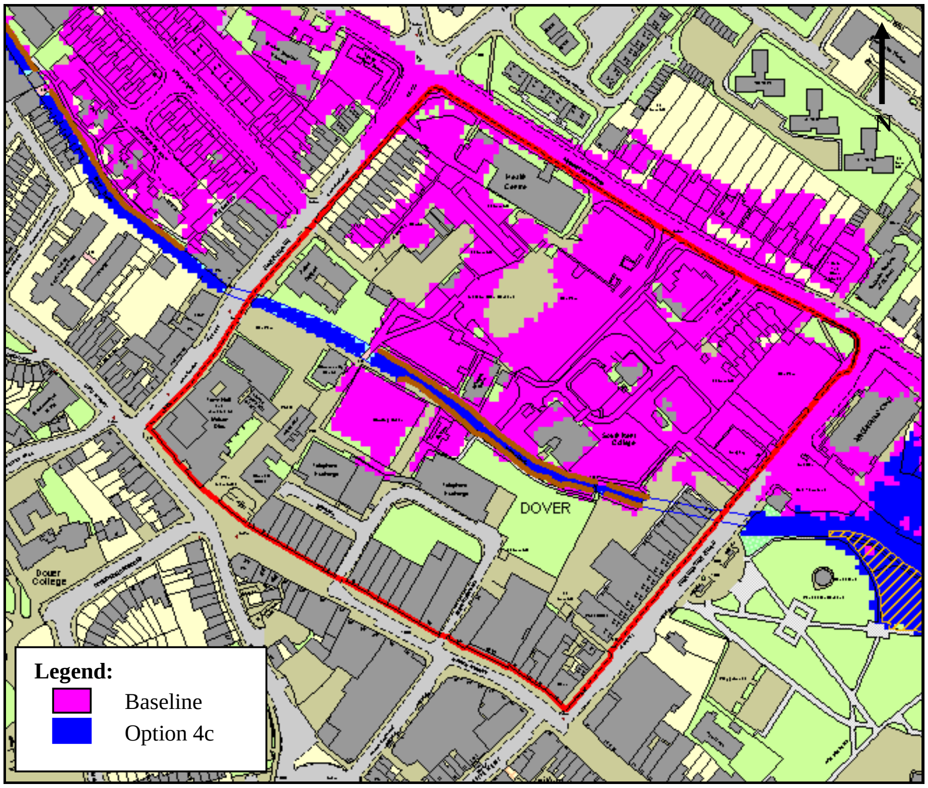

Figure 6.8 Baseline 1 in 100 Year Plus Climate Change Return Period Flood Extent Comparison: Baseline Vs Option 4c

6.5.36 Key environmental aspects likely to be affected in the development of Option 4c relate to the landscape and population value of the Pencester Gardens, and the possible loss or reduction of this value through the lowering of Pencester Gardens to facilitate appropriate compensatory flood storage in the Gardens. Whilst this may not be a significant constraint, the development of this Option is likely to require extensive consultation with Dover District Council, the local population and local interest groups which could have programme and cost implications for the project.

6.5.37 There are also potential constraints on this site in relation to flora and fauna, water quality, contaminated land, and archaeology and built heritage. Lowering Pencester Gardens may result in loss of trees, which could potentially lead to wider ecological impacts through loss of habitats. Changes in water quality may also occur as a result of changes in storage capacity, for example through alteration of increased nutrient loading, changes to turbidity and siltation etc. This may have potentially detrimental effects for species and habitats on site and downstream Nevertheless, this potential is limited given the downstream location of Pencester Gardens. Depending on historic land uses of Pencester Gardens, there is also potential for mobilisation of contaminants as a result of flood water storage on the Gardens. Temporary impacts could also arise in relation to air quality and noise and vibration as a result of construction works. Potential impacts of this Option on groundwater and downstream geomorphology would also need to be considered.

6.5.38 In relation to archaeology and built heritage, Pencester Gardens are located adjacent to the Town Centre Conservation Area. The proposals for Option 4c have the potential to affect the setting of this Conservation Area.

OPTION 5 – RETENTION OF WEIR AND RAISED DEFENCES

OPTION 5A – RAISED DEFENCES(MID TOWN)

6.5.39 Option 5a is very similar to Option 4a with the exception that in this option Halford's weir is retained and no channel works are proposed. To prevent water from overtopping the river banks upstream of the Halford's weir it is proposed to construct a wall of up to 1m high (10mAOD) and approximately 50m long. This wall should be located along both banks of the river (directly upstream of the culvert) and also on top of the existing headwall of the culvert – refer to Figure B5-A in Appendix B. The raised defences included in this option are as follows:

- Weir upstream of Halfords – up to 1m high (10mAOD), 50m long
- Weir at Morrisons store – up to 0.4m high (8mAOD), 80m long;
- Left bank downstream of Crafford Street – up to 0.3m high (6.5mAOD), 60m long;
- Left bank through Dover Mid Town site – up to 1m high (6.3mAOD), 150m long; and
- Right bank through Dover Mid Town – up to 1m high (6.3mAOD), 140m long.

6.5.40 The results from modelling this options as similar to Option 4a, as the proposed wall at Halford's weir retains the water within the River Dour, similar to the removal or the weir, preventing the flowpath down Charlton Green at this location. The flood water also overtops the left bank upstream of Park Street, similar to Option 4a results, however in this option the volume of water is greater, resulting in the flooding of Goodfellow Way, Dour Street and Hewitt Road, as well as an additional flowpath entering Maison Dieu Road and causing flooding on the Mid Town study area, as illustrated in Figure 6.9, overleaf.

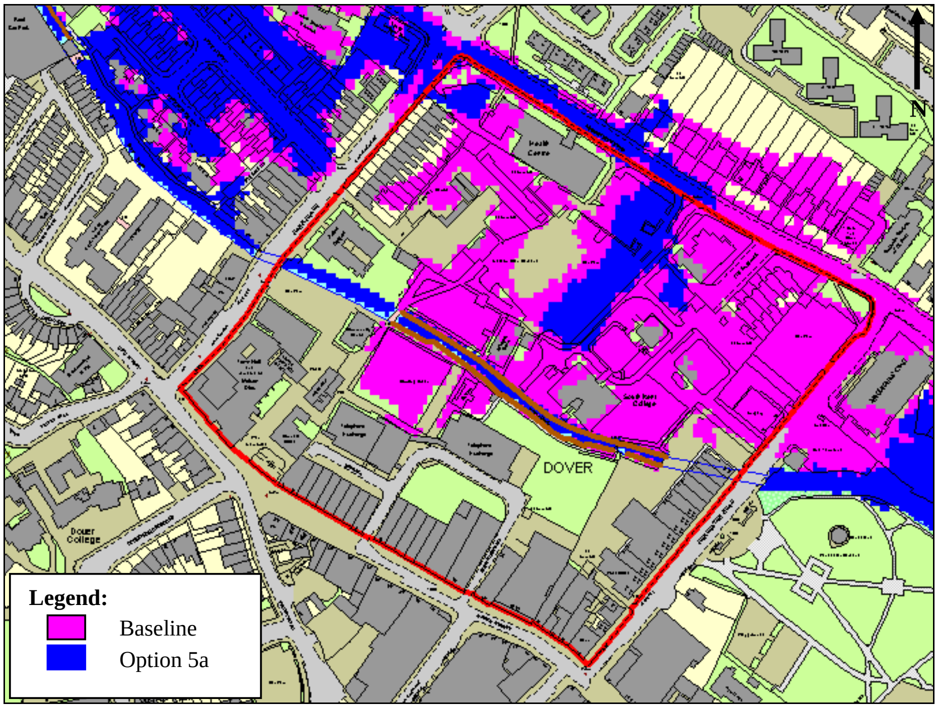

Figure 6.9 Baseline 1 in 100 Year Plus Climate Change Return Period Flood Extent Comparison: Baseline Vs Option 5a

6.5.41 The construction of raised defences under Options 5a and 5b has the potential to lead to short duration temporary air quality, noise and vibration, landscape and townscape and ecology impacts. In addition, the presence of large trees along the riverbanks could potentially constrain the development both as a result of potential Tree Protection Orders on some of the trees and the likely size of root protection areas. This could lead to landscape impacts. Loss of any large trees could also lead to ecological impacts as the river corridor may potentially provide suitable habitat for bats and other species including breeding birds. Depending on the final height of any flood defence walls and development layout behind the defences, these could also have potential visual impacts through loss of view to the river bank from the footpaths, and further impacts if access to the river is restricted (particularly in terms of fishing, etc.). This, along with the potential need for temporary diversion of riverside footpaths whilst work is taking place and in conjunction with noise and vibration and air quality impacts, could lead to potential population impacts.

6.5.42 Finally, the presence of conservation areas and potentially listed buildings adjacent to the River where flood defence walls are required may constrain the project in terms of programme and cost, since they may trigger the need for Conservation Area Consent (if demolition of existing walls are required) or planning permission (refer to Figure A3 for relevant listed build locations).

OPTION 5B– RAISED DEFENCES (STRATEGIC LOCATIONS)

6.5.43 This option is based on Option 5a, which includes a number of raised defences, but retains the weir at Halfords. This option also includes an additional wall upstream of Park Street, and adjacent to Goodfellow Way, to prevent the housing on Goodfellow Way, Dour Street and Hewitt Street from flooding. The raised defences included in Option 5b are as follows:

- Weir upstream of Halfords (Wall 1) – up to 1m high (10mAOD), 50m long
- Weir at Morrisons store (Wall 2) – up to 0.4m high (8mAOD), 80m long;
- Left bank downstream of Crafford Street (Wall 3) – up to 0.3m high (6.5mAOD), 60m long;
- Left bank upstream of Park Street (Wall 4) – up to 0.5m high (6.5mAOD),135m long;
- Left bank through Dover Mid Town site (Wall 5) – up to 1m high (6.3mAOD), 150m long; and
- Right bank through Dover Mid Town (Wall 6) – up to 1m high (6.3mAOD), 140m long.

6.5.44 The results from this option identify a very similar flood extent to Option 4c, with the River Dour remaining in bank downstream of Limes Street, with the exception of areas within Pencester Gardens (refer to Figure 6.10). The flooding occurring adjacent to, and within, Pencester Gardens decreases through the incorporation of this option.

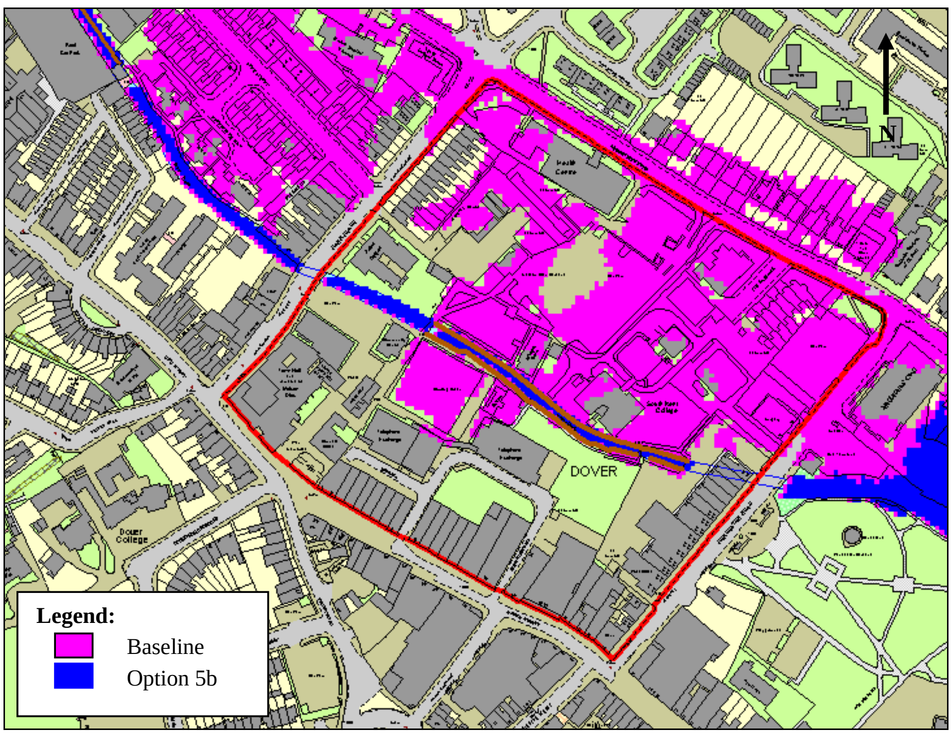

Figure 6.10 Baseline 1 in 100 Year Plus Climate Change Return Period Flood Extent Comparison: Baseline Vs Option 5b

6.5.45 Refer to the environmental considerations identified within option 5a (paragraph 6.5.42).

Option 6 – Removal of the combined sewer pipe beneath Pencester Road

6.5.46 The pipe does cause a constriction to flow locally, however removal of the pipe by itself results in limited flood risk benefit to the Mid Town area.

6.5.47 The removal or realignment of this combined sewer (refer to Figure 6.11 below for the pipe location) would need to be agreed with and undertaken in consultation with Southern Water to provide a programme of works that would not disrupt services for residents and businesses within the affected area of Dover.

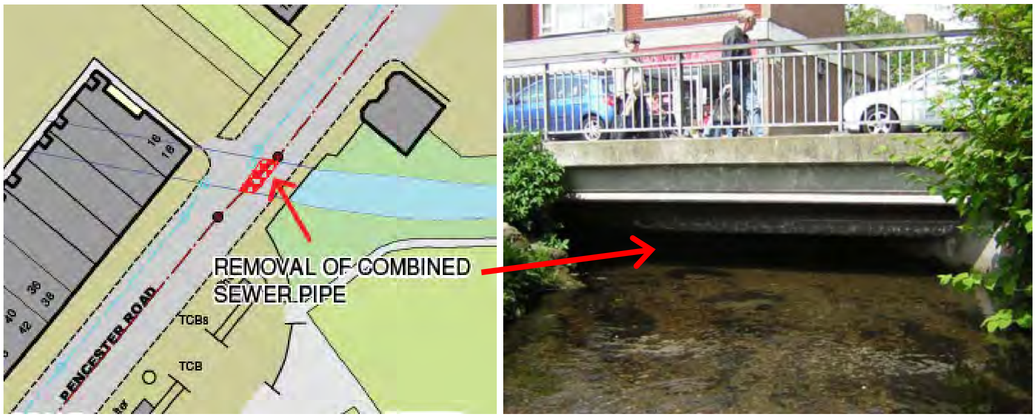

Figure 6.11 Location and Image of Combined Sewer Location under Pencester Road

6.5.48 Option 6 reduces flooding within the Mid Town study area slightly, and also within the area surrounding Pencester Gardens. However the study area still experiences significant flooding during 1 in 100 year fluvial flood (both including and excluding an allowance for climate change) event (refer to Figure 6.12, overleaf); this flooding is partly caused by overland flow from upstream of the site and is therefore a problem that Option 6 cannot resolve.

6.5.49 Works above the river channel to remove the combined sewer pipe could potentially lead to changes in river water quality, through increased sedimentation for example, or as a result of contaminants entering the watercourse during the works.

6.5.50 In addition, air quality, noise and vibration which could potentially be affected through the demolition and construction work required under Option 6. This could also lead to population impacts. Population could also be adversely impacted as a result of potential temporary traffic disruption during the works.

6.5.51 Figure 6.12, overleaf, provides a comparison of the baseline 1 in 100 year plus climate change event flood extent against the benefit provided from Option 6.

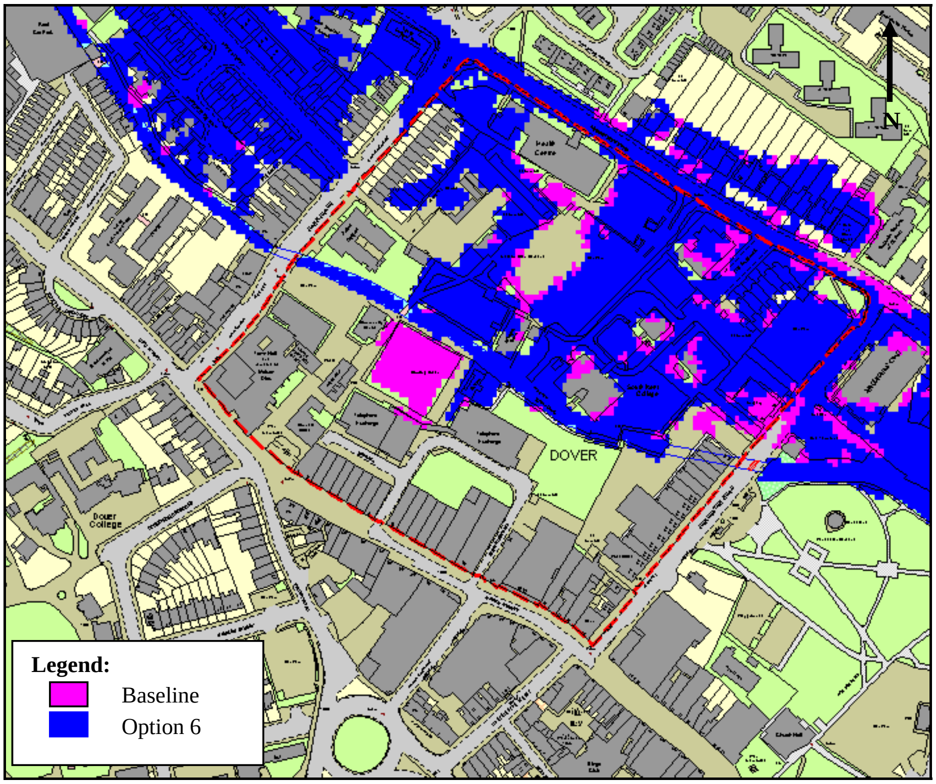

Figure 6.12 Baseline 1 in 100 Year Plus Climate Change Return Period Flood Extent Comparison: Baseline Vs Option 6

OPTION 7 – CHANNEL WIDENING

6.5.52 The flood mechanisms affecting the Dover Mid Town site mean that widening of the River Dour through the site does not reduce flooding to acceptable levels by itself (with the only notable reduction being within the Bowling Green), refer to Figure 6.13 overleaf. This measure could be considered in combination with flood defences to provide additional habitat and locally reduce flow velocities In accordance with DEFRA guidance 'Making Space for Water'.

6.5.53 Figure 6.13, overleaf, provides a comparison of the baseline 1 in 100 year plus climate change event flood extent against the benefit provided from Option 7.

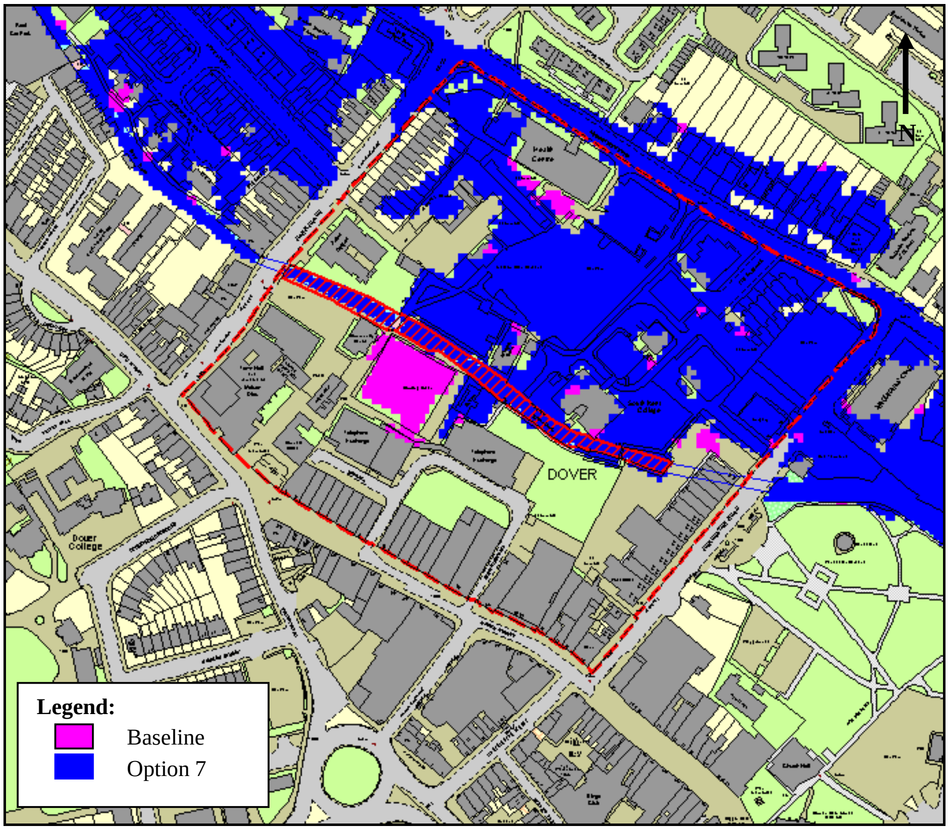

Figure 6.13 Baseline 1 in 100 Year Plus Climate Change Return Period Flood Extent Comparison: Baseline Vs Option 7

6.5.54 As with Options 3, 4 and 5, the widening of the river channel under Option 7 has the potential to lead to short duration temporary air quality, landscape and townscape and ecology impacts. In addition, the presence of large trees along the riverbanks could potentially constrain channel widening both as a result of potential TPOs on some of the trees and the likely size of root protection areas. Loss of any large trees could also lead to landscape and visual impacts, as well as ecological impacts as the river corridor may potentially provide suitable habitat for bats and other species including breeding birds. The construction activities required for channel widening along with the potential need for temporary diversion of riverside footpaths whilst work is taking place, could lead to potential population and landscape/townscape impacts. Temporary impacts could also arise in relation to air quality and noise and vibration as a result of construction works, with associated population impacts. Potential impacts of this Option on downstream geomorphology would also need to be considered.

6.5.55 Finally, the presence of conservation areas adjacent to the River where channel widening is required may constrain the project in terms of whether this type of option would be acceptable, the programme and cost, since it would need Conservation Area Consent (if demolition of existing walls is required).

6.6 SUMMARY OF OPTIONS

6.6.1 Table 6.1 provides a summary of the issues relating to each option and their benefit to the wider Dover area.

Table 6.1. Summary of Issues and Benefits of Each Option

Scenario/ Option	Issues	Feasible/Not Feasible	Approximate No. of Properties benefiting from
Baseline	NA	NA	Approx 430 properties flood
1	•Greatest impact upon environment and reduction in open space. •may require a potential storage area in excess of 200,000m^3 to be created within the upstream catchment.	Unlikely to be Feasible	200
2	•Land ownership constraint. •Site already has planning consent – compensation may be required to landowners and developers. •Minimal benefit to Dover.	Feasible	30
3	•Constrained site access for weir works and some wall locations. •Impacts on existing river wall stability. •Potential environmental impacts from altered flow regime.	Feasible	40
4a	•Constrained site access and impacts on existing river wall stability •Removal of weir and regarding of channel increase construction costs. •Potential environmental impacts from altered flow regime (greatest with option 4b and 4c). •Reduced public access to pedestrian linkages during time of construction. •Option 4a provides greatest benefit to Mid Town.	Feasible	120
4b		Feasible	210
4c		Feasible	180
5a	•Constrained site access to some wall locations. •Minor environmental impacts arising from construction works. •Demolitions of existing walls may be necessary •Reduced public access to pedestrian linkages during time of construction. •Option 5b provides the greatest benefit to Dover.	Feasible	100
5b		Feasible	185
6	•Minimal benefit to Mid Town (and Dover). •Relocation of combined sewer network under Pencester Road.	Unlikely to be Feasible	1
7	•Extensive channel works required within the river. •Minimal benefit to Mid Town and the wider Dover area. •Potential environmental impacts to existing riverbank vegetation.	Unlikely to be Feasible	1

6.6.2 Table 6.2 (overleaf) provides a velocity comparison within the River Dour at various locations upstream, through and downstream of the study area in Mid Town against the tested flood alleviation options. Figure 6.12 identifies the locations of these nodes. The results also indicate that several nodes actually experience a reduction in velocity as a result of incorporating raised defences within Dover.

6.6.3 Table 6.3 (overleaf) provides a comparison of the water levels at the node locations identified in Figure 6.12. The results indicate that Options 4 and 5 increase water levels within the channel where raised flood defences are proposed. This is a direct result of confining the floodwaters to the river channel and not allowing it to overtop the banks and enter the urban floodplain. Although several of the alternative options identify a minor reduction in flood levels through the Mid Town site, none of these options remove the risk of flooding to the site and the wider Dover area.

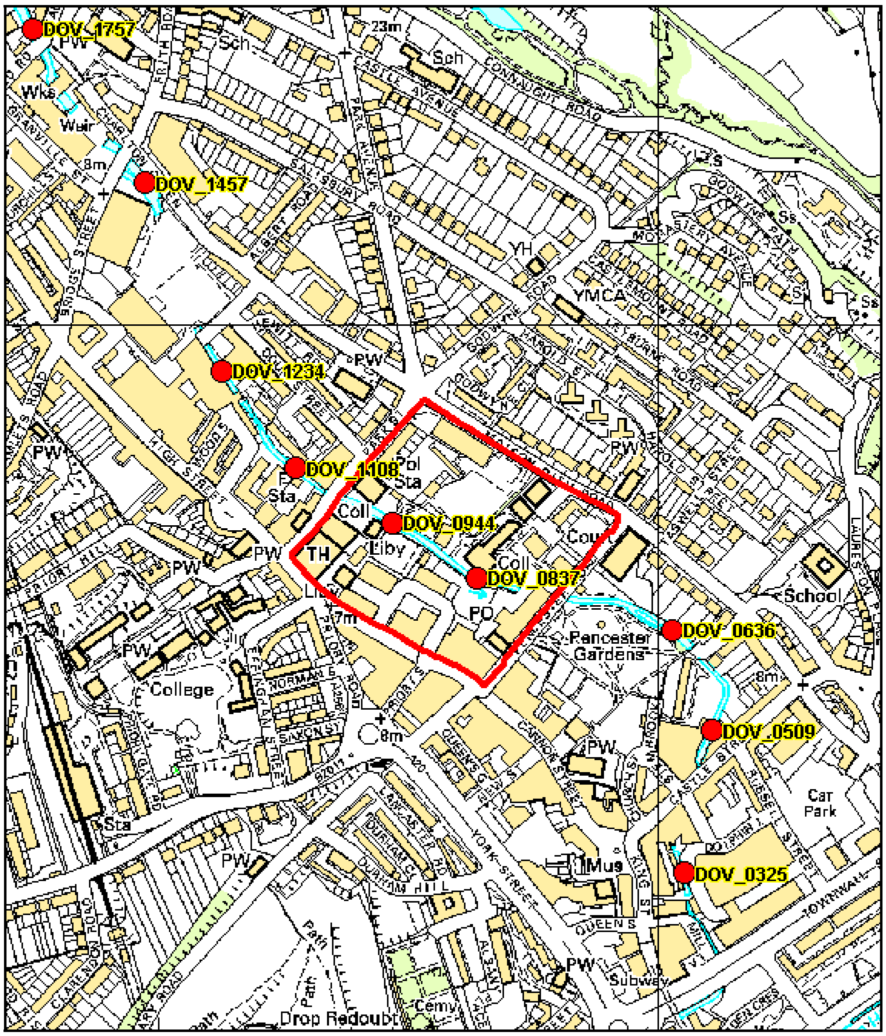

Figure 6.12: Location of Nodes

Table 6.2: Comparison of Velocity Results

	Baseline	Option 1	Option 2	Option 3	Option 4a	Option 4b	Option 4c	Option 5a	Option 5b	Option 6	Option 7
DOV_1757	1.12	1.05	1.09	1.20	1.20	1.20	1.20	1.11	1.11	1.12	1.10
DOV_1457	0.62	0.59	0.62	0.66	0.64	0.65	0.64	0.65	0.65	0.62	0.62
DOV_1234	1.49	1.43	1.49	1.45	1.42	1.45	1.42	1.45	1.45	1.49	1.51
DOV_1108	1.34	1.28	1.35	1.36	1.27	1.27	1.27	1.27	1.27	1.37	1.40
DOV_0944	1.21	1.04	1.16	1.23	1.26	1.28	1.28	1.28	1.30	1.19	1.21
DOV_0837	1.12	1.13	1.12	1.12	1.03	1.03	1.03	1.07	1.07	1.20	0.82
DOV_0636	0.98	0.97	0.98	0.96	0.98	0.98	0.98	0.98	0.98	0.98	0.99
DOV_0509	1.25	1.21	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25
DOV_0325	1.67	1.57	1.66	1.67	1.67	1.67	1.67	1.67	1.67	1.67	1.67

Table 6.3: Comparison of Water Level Results

	Bed Level	Baseline	Option 1	Option 2	Option 3	Option 4a	Option 4b	Option 4c	Option 5a	Option 5b	Option 6	Option 7
DOV_1757	8.92	9.94	9.85	9.92	9.86	9.86	9.86	9.86	9.96	9.96	9.93	9.93
DOV_1457	5.61	7.28	7.22	7.27	7.31	7.34	7.34	7.34	7.35	7.35	7.27	7.27
DOV_1234	5.22	6.42	6.34	6.39	6.46	6.54	6.52	6.55	6.53	6.54	6.40	6.39
DOV_1108	4.73	6.13	5.98	6.09	6.12	6.25	6.27	6.26	6.27	6.29	6.07	6.07
DOV_0944	4.16	5.87	5.70	5.82	5.83	6.03	6.05	6.04	6.05	6.07	5.78	5.81
DOV_0837	4.26	5.77	5.60	5.73	5.74	5.92	5.95	5.93	5.94	5.97	5.67	5.74
DOV_0636	3.91	5.33	5.15	5.28	5.31	5.30	5.32	5.30	5.32	5.34	5.31	5.31
DOV_0509	3.67	5.12	4.91	5.06	5.09	5.09	5.10	5.10	5.12	5.14	5.10	5.10
DOV_0325	3.33	4.81	4.62	4.76	4.79	4.78	4.79	4.79	4.81	4.82	4.79	4.79

Legend:

= Increase in water levels/velocity

= Decrease in water levels/velocity

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6.7 PREFERRED OPTION

6.7.1 Based on a review of the results from the optioneering exercise, environmental impacts, reduction in flood risk to the Mid Town site (and wider catchment), it is concluded that Option 5b is the most suitable flood alleviation scheme for protecting the Mid Town site. The results from the hydraulic model developed for this scheme, indicate that approximately 180 additional properties within the urbanised area of Dover could be removed from the risk of fluvial flooding during a 1 in 100 year plus climate event.

6.7.2 Discussions with the Environment Agency indicate that they would prefer if raised defences within Dover were avoided until they are confident that the structures will not exacerbate the risk of surface water flooding within Dover. However, the Stour CFMP identifies that for Dover the CFMP policy requirement is to: '*take further action to sustain the current scale of flood risk into the future (responding to the potential increases in flood risk from urban development, land use change and climate change)*'. Therefore, to maintain the current flood risk within Dover, a flood alleviation scheme is required as it has been estimated that approximately 140 additional houses could be at risk of fluvial flooding when the predicted effects of climate change area applied to the fluvial model scenario (actual risk) and that upstream storage may not be a feasible option for the catchment due to the necessary attenuation volume.

6.7.3 Reverting the heavily engineered river channel back to its 'natural state' will also not be possible within the urbanised areas of Dover. This is a direct result of the urban encroachment into the floodplain and the fact that there are now no areas in which this re-naturalisation could occur without displacing residents/business, affecting current pedestrian linkages and relocation existing infrastructure (sewers, electricity etc). From this assessment, the construction of river walls/embankments in strategic locations will provide the greatest benefit with the least environmental and social impact.

6.7.4 Initial estimates indicate that this scheme may cost between in excess of £1.8M (based on present day capital costs) – refer to Appendix F for preliminary cost estimates undertaken by Team Van Oord.

6.8 ACCOUNTING FOR CLIMATE CHANGE

6.8.1 The final design of a flood alleviation scheme should be designed to be adaptable to account for the effects of climate change, in particular given the current uncertainty. For example, a 300mm freeboard has been allowed above 1 in 100 year return period flood levels. Modelling demonstrates this provides protection based on current climate change guidance for the next 100 years. Design would then need to allow for further raising of the defences if necessary (managed adaptive approach). The predicted flood extents for the 1 in 100 year plus an allowance for climate change fluvial flood event, for all of the proposed options, can be located within Appendix B.

6.9 MANAGEMENT OF SURFACE WATER FLOODING

6.9.1 The management of surface water runoff is a significant issue in parts of the Dover Mid Town area. The existing council carpark is located directly in the area predicted to have the deepest surface water flooding yet topographical survey of this area identifies that there is no drainage infrastructure in this location.

6.9.2 Strategic flood risk management measures will not reduce surface water flood risk. Reducing surface water flood risk requires further input and should be investigated within the DEFRA funded Surface Water Management Plan currently commissioned by Kent County Council.

6.9.3 It is recommended that Dover District Council (in consultation with Southern Water) investigate locating surface water drainage infrastructure within the lowest part of the Council carpark to reduce the risk of water ponding in this area of Mid Town. Due to the current network capacity issues, it may be necessary for this infrastructure to include a pump station to connect the new surface water network to drainage infrastructure located several hundred meters downstream of the site.

6.9.4 Measures to manage the risk of surface water flooding to the site could include raising finished floor levels, as described in Section 6.2; however this does not address the source of the problem. Safe access and egress will remain problematic (refer Section 4.8 and 5.5).

6.10 MANAGING RESIDUAL RISK

6.10.1 Reviewing the extent of the 'baseline' 1 in 1000 year return period flood event indicates all of Dover Mid Town, and much of the city centre becomes inundated. Providing a 1 in 1000 year standard of protection is unlikely to be economical however should be reviewed as part of a detailed cost benefit analysis.

6.10.2 Hydraulic modelling indicates the conceptual options are unlikely to provide much benefit during a 1 in 1000 year return period event as the river banks (and current defence levels) are overtopped throughout the catchment. Based on an assessment of Option 5b, flood depths within the site will decrease by up to 10cm (at the deepest point), but will increase flood levels by a similar amount in other areas of the catchment (e.g. directly behind raised defences 3 and 4 – refer to paragraph 6.5.44 for their locations). Flood depths are still predicted to be up to 70cm within the site. Similarly, on Maison Dieu Road flood depths are predicted to still be approximately 50cm (at the roads lowest point located at the entrance into the carpark) during the peak of the flood event – a reduction of approximately 8cm from the baseline 'actual risk' scenario .

6.10.3 Residual risk across the Dover Mid Town site is most appropriately managed through appropriate resilient design and emergency planning (e.g. flood plans, including flood warning). These management techniques should be investigated during the initial layout design process to ensure that this risk has been designed into all developments at risk of this source of flooding, and in consultation with Dover District Council Emergency Planners.

6.11 ISSUES FOR CONSIDERATION IN DETAILED FEASIBILITY ASSESSMENT

6.11.1 A number of issues will need to be considered in a detailed feasibility study prior to confirming a flood alleviation scheme can be delivered:

MITIGATION WORKS AND EXISTING INFRASTRUCTURE

6.11.2 Flood risk mitigation is likely to be necessary to enable regeneration in the northern part of the Mid Town site. It is expected this will require providing additional flood defences to third parties. It is assumed for the purposes of the conceptual options assessment that Dover District Council, with the assistance of the Environment Agency, will be able to undertake any necessary works using permissive powers.

6.11.3 Ecological mitigation is also likely to be required as well as removal of some trees in close proximity to the river (e.g. adjacent to the college building). A baseline ecological study and tree survey should assess the existing conditions to inform any mitigation necessary.

6.11.4 Existing services do not appear to be a significant constraint based on currently available data, however confirmation from utility providers should be sought.

6.11.5 The property which is located between Walls 3 and 4 (spanning the River Dour) may require additional flood proofing measures to minimise any water ingress into the structure as a result of floodwaters being confined to the river channel (both up and downstream of the property). It is recommended that this is incorporated into the final design along with ensuring that all flood defences tie into existing building/structures along the River Dour.

6.11.6 The footbridge located upstream of the Pencester Road Culvert may need to be raised by 300mm (or to 6.3mAOD) to remove the risk of flood waters utilising this feature to gain access to the urban catchment north of the river.

6.11.7 The final design must also consider all drainage outlets (both private and public) discharging directly into the River Dour and ensure that the ability for this infrastructure to operate in its current condition is not compromised due to the construction of these flood alleviation works.

LAND OWNERSHIP AND ACCESS

6.11.8 It will be necessary to determine land ownership and any possible issues with land acquisition prior to the design of the preferred flood mitigation option. This will identify access and maintenance issues and also identify any compensation requirements for the proposed measure.

TIMING

6.11.9 Implementing a staged approach to both the site and flood risk management reduces the need to undertake immediate engineering works, however it will be necessary to demonstrate the feasibility of a strategic scheme, as well as the funding, and responsibility for management and maintenance, prior to granting of planning permission. Any proposed alleviation design appraisal for the site (and wider Dover area) should factor these requirements into its programme.

MANAGEMENT AND MAINTENANCE

6.11.10 Securing the management and maintenance of a flood alleviation scheme for the development lifetime will be an important consideration. The Water Resources Act 1991 sets the responsibility for management and maintenance of the river bank, including any defences, with the riparian owner.

6.11.11 Although the Environment Agency have permissive powers to maintain flood defences. Funding for continued maintenance means the Environment Agency may be unable to guarantee they can undertake maintenance.

6.11.12 Under the terms of the Water Resource Act 1991, all works within 8 metres of the top of the bank of the river will require land drainage consent from the Environment Agency, in addition to planning permission. The Environment Agency will need to be consulted on any works proposed in this area, however they cannot unreasonably withhold consent. Some works can take place in this ‘buffer zone’, however the Environment Agency will have particular consideration for flood risk, biodiversity and watercourse access issues in granting consent and it will be necessary to demonstrate that any works within this area do not have a detrimental effect (and preferably a benefit) to the local environment.

PLANNING POLICY

6.11.13 As stated earlier within paragraph 6.7.2, the Stour CFMP requires that there is a need to:

'*take further action to sustain the current scale of flood risk into the future (responding to the potential increases in flood risk from urban development, land use change and climate change)*'

6.11.14 Based on this requirement it is necessary for something to be done within Dover to maintain the flood risk at its current level. If any works are to be undertaken within the catchment, it is recommended that these works not only maintain the risk of flooding but reduce it where possible.

6.11.15 It is recommended that prior to any further design consultation the Council and the Environment Agency determine if the proposed option can satisfy all of their (DDC and EA) policy requirements and is still be achievable.

6.12 PPS 25 COMPLIANCE

6.12.1 Table 6.4, overleaf, provides a summary of the Mid Town area and its compliance with PPS25.

Table 6.4 PPS25 Compliance for the Mid Town Site.

PPS 25 Requirement	Mid Town Site
Compatibility with Flood Zones	This will depend upon the type of land use proposed within the site. 'Less vulnerable' land uses are compatible within the site and 'More vulnerable' development is compatible within Flood Zone 3a but will be subject to passing the Exception Test. Mid Town Dover does include a small area located within the 1 in 20 year return period flood extent, and development in this area should be limited to 'water compatible' uses such as public open space.
Relocate existing development to land in zones with a lower probability of flooding	The Sequential approach will need to demonstrate that wherever possible higher vulnerability land uses have been located in the lowest probability flood risk area of the site. Careful land use planning is required within any masterplan layout for the site.
Demonstrate site remains safe for 'lifetime of development'	A conceptual option of increasing bank height on and off site will provide protection to the site during the 1 in 100 year return period event including safe access, and has been designed account for future climate change.
Proposals do not increase flood risk to others	In its current condition the site is a risk of fluvial, tidal and surface water flooding. Any proposed development within the site (or in the wider masterplanning context) will need to demonstrate that the design does not impact on the floodplain of the River Dour. This may require compensatory storage located within the site and tested using the detailed River Dour hydraulic model developed as part of this assessment. The conceptual option testing demonstrates that to provide a meaningful reduction in flood risk to the Mid Town Dover area works will be required off site, including some mitigation works that additional reduce flood risk overall.
Reduce the overall level of flood risk in the area through the layout and form of the development and the appropriate application of sustainable drainage techniques	The conceptual option reduces flood risk to a significant area in the centre of Dover. Further testing of options upstream will determine whether further works could be implemented to reduce flood risk, whilst not adversely impacting upon the environment. SUDS techniques to be investigated within future studies.
Create space for flooding to occur by restoring functional floodplain and flood flow pathways and by identifying, allocating and safeguarding open space for flood storage.	The masterplanning of the Mid Town Dover area offers the opportunity to locally increase the functional floodplain as well as provide biodiversity and additional river access. However, providing storage areas within the site independently of any other defence will not reduce the overall risk of flooding to the Mid Town area.

7. Conclusion and Recommendations

CONCLUSION

7.1.1 Capita Symonds has been appointed by Dover District Council (DDC) to undertake a flood risk assessment of the River Dour and appraisal of flood alleviation options for the Mid Town area of Dover. This report appraised the flood risk from fluvial, tidal and surface water sources to the site and provides guidance to the Council on flood risk management options within the site. This report does not constitute a detailed flood risk assessment that could support a planning application, as required by Planning Policy Statement 25 (PPS 25).

7.1.2 A completely integrated fluvial, tidal and drainage (surface water network) model was created for this study. Revised Flood Zone Maps were generated for Dover based on this assessment, with the model obtaining Environment Agency approval in January 2010 (refer to Appendix E).

7.1.3 The hydraulic model has identified that the Mid Town site is at risk of flooding from fluvial and tidal sources and located with all of the Flood Zones. This study has identified that the extent of flooding within the site is lower than that identified within the SFRA. Figure 7.1 identities the revised Flood Zones within Mid Town.

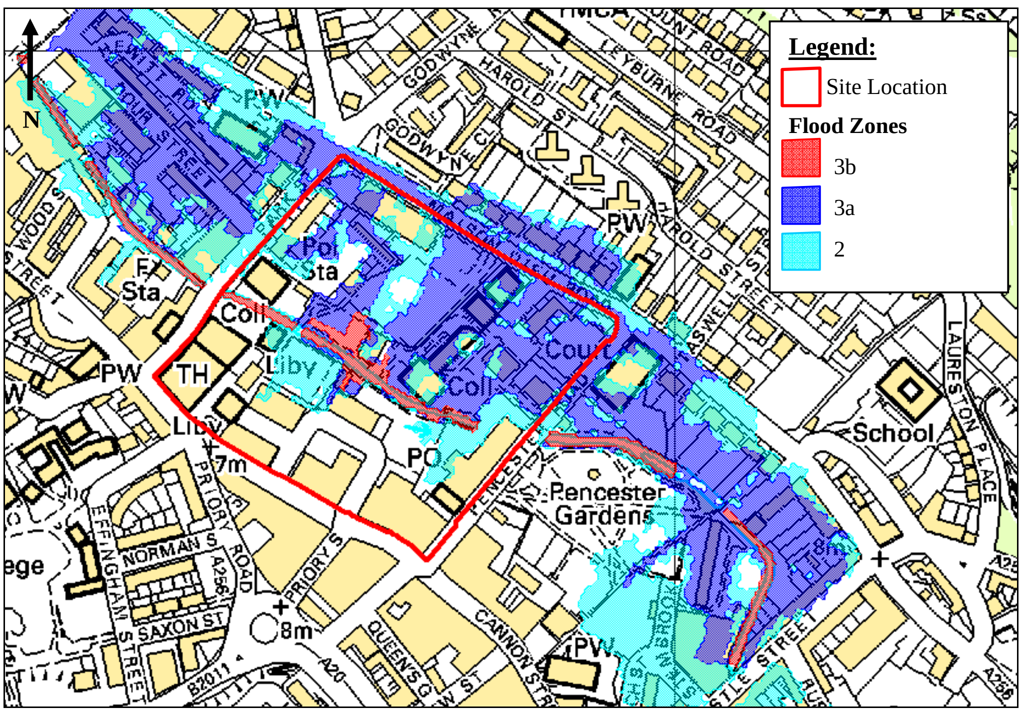

Figure 7.1 Revised River Dour Flood Zones

7.1.4 Integrated hydraulic modelling, incorporating Southern Waters surface water drainage network, also indicates that due to local topography and drainage constraints, it is at risk of surface water flooding. These results identify that in a 1 in 100 year plus climate change return period rainfall event parts of Maison Dieu Road indicate that although there are flood waters on site they hazard to people is classed as ‘moderate’ to ‘significant’. Results from Scenario 1, a reasonable ‘best case’ prediction of an extreme rainfall event, indicates that in a 1 in 100 year event the existing Council carpark may be subject to flood waters of 50-60cm with maximum water levels on Maison Dieu Road reaching approximately 30cm before draining either via sheet flow into the site (or down Maison Dieu Road) or draining into the existing drainage network. Using the estimate ‘worst case’ scenario this flooding is predicted to be approximately 90cm within the Mid Town carpark and 70cm at the lowest section of Maison Dieu Road (flood waters are predicted to be over 30cm for 5 hours of the model simulation)

7.1.5 A review of the surface water flood risk scenarios identifies a consistent trend with consistent ponding of the eastern portion of the Council carpark (within the site). It is recommended that Dover District Council and any future development partners (in consultation with Southern Water) investigate incorporating additional drainage infrastructure (and their associated cost) in this portion of the site to allow these predicted flood waters to drain between events.

7.1.6 The majority of the northern half of the Dover Mid Town area (north of the river) is located in Flood Zone 2 or 3a. The majority of the southern half of the Dover Mid Town area (south of the river) is located in Flood Zone 1.

7.1.7 Flood management options have been investigated and are discussed within Section 6 of this study. A series of conceptual strategic flood risk management options have been tested to manage the risk of flooding from the River Dour. Option included upstream storage, river widening and raised defences. The locations of the hydrological inflows entering catchment indicate that providing storage in the upper catchment will offer little benefit to the Dover Mid Town area. Development in close proximity to the river means it is unlikely to be feasible to uniformly widen the channel and remove existing constrictions throughout the watercourse. Provision of raised walls at key locations where water spills ‘out of bank’ during the 1 in 100 year and 1 in 100 year plus climate change return period events has been conceptually tested.

7.1.8 This study has determined that the Mid Town site can be removed from fluvial flood risk up to events including the 1 in 100 year plus climate change event via the construction of walls within strategic areas of Dover (option 5b). The feasibility of this option would be subject to a detailed cost benefit analysis, detailed design, review against National and Local policy requirements and a detailed environmental impact assessment. The hydraulic modelling results for this scheme, indicate that this option could reduce the risk of fluvial flooding for over 80 properties (and not just the Mid Town development) and tidal flooding (up to 1 in 200 year tidal event). The flood mechanisms on the River Dour require that this option relies on improvement works being undertaken outside of the Dover Mid Town area and would require funding and approval from the Environment Agency.

7.1.9 Dry access will not be available for the site during extreme me fluvial, tidal or surface water flood events, however safe access is available for development fronting Biggins Street and parts of Pencester Road (southern section), North Street, Ladywell, and Park Street. Emergency access should be available to the Mid Town Site via Maison Dieu Road, however this area has a significant hazard that under the DEFRA classification is a ‘danger for most’.

RECOMMENDATIONS

7.1.10 The revised Flood Zone Map created as part of this assessment should be adopted by the Environment Agency. These Flood Zones should also be used by Dover District Council in any subsequent update of the SFRA and assist the Council into undertaking the Sequential Test for areas identified for development within their Core Strategy document.

7.1.11 The sequential approach should be applied to the masterplanning of the Dover Mid Town area so that the most vulnerable land uses are located in the lowest probability flood zones. A possible option would be to develop land south of the River Dour (within the site boundary) and utilise any benefits gained from this re-development to fund improvement works on the river to enable development on the northern portion of the Mid Town site.

7.1.12 SUDS devices should be carefully selected for the site and where possible reduce runoff rates discharging from the site to that of a undeveloped 'greenfield' scenario to reduce the impacts that development within the Mid Town site have on the local drainage infrastructure within the area during extreme rainfall events.

7.1.13 Further analysis is recommended to reduce uncertainty in both the 'baseline' and option assessment, including:

- Investigate alternative operating procedures or upgrade works for Wellington Docks to improve the fluvial capacity in combined fluvial/tidal event to reduce the risk of flooding within the upstream catchment.
- Incorporate additional information within the integrated hydraulic model developed for the site. This could include the combined sewer drainage network to determine any influence this system may have during surface water flood event.
- Update the Dour Hydrology assessment to incorporate the latest guidelines and provide greater detail of flows within Dover's urban catchment;
- Undertake infiltration testing of soil conditions within the site to update infiltration losses currently utilised within the integrated hydraulic model; and
- Detailed appraisal of design, cost benefit analysis and environment assessment of the options for reducing the risk of fluvial and tidal flooding within Dover.

7.1.14 As there is also no existing flood warning service available to Dover, it is recommended that the feasibility of installing a hydrometric gauge on the River is investigated, to ensure that when flows are approaching significant levels within the watercourse, a warning can be given to existing residents and property owners to take appropriate and timely action.

7.1.15 The steering group should continue their integrated approach to addressing flooding within Dover, in particular surface water flooding. The surface water flood risk should be informed by the DEFRA funded SWMP, currently commissioned by Kent County Council, and utilise information provided within this assessment where appropriate.

Appendix A – Revised Flood Zones and Site information

Appendix B – Conceptual Flood Management Options

Appendix C – Hydraulic Modelling Assessment

Appendix D – Environmental Sieve Analysis

Appendix E – Data Collection and Correspondence

Appendix F – Indicative Construction Costs

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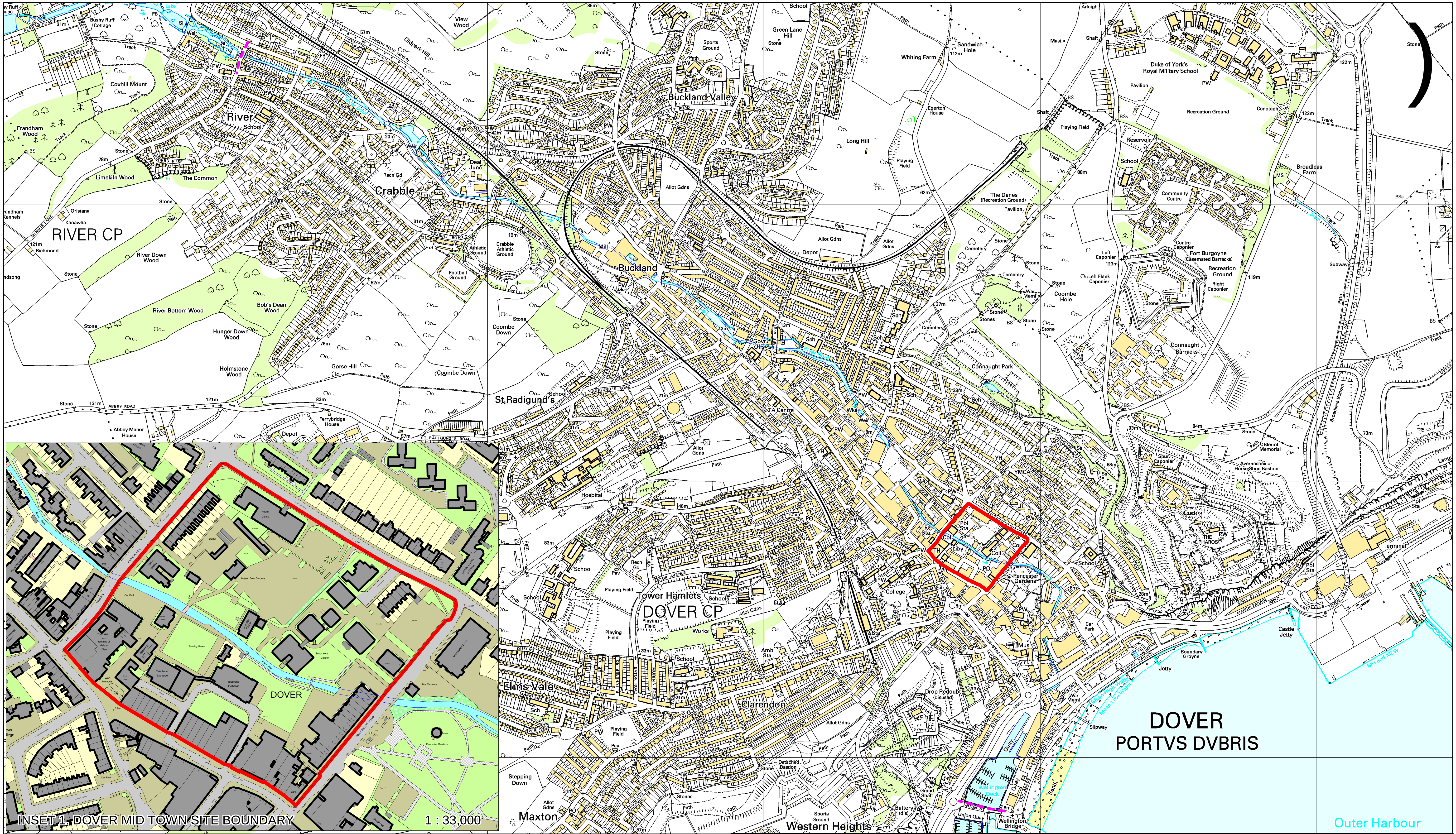

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LEGEND:

SITE BOUNDARY OF DOVER MID TOWN AS DEFINED BY THE ADOPTED CORE STRATEGY

HYDRAULIC MODEL EXTENTS

FLOOD RISK APPRAISAL OF THE RIVER DOUR

FIGURE A1:
RIVER DOUR MODEL EXTENTS AND
DOVER MID TOWN SITE LOCATION PLAN

DOVER DISTRICT COUNCIL

CAPITA SYMONDS

DRAWN BY	CHECKED BY	PASSED BY	DATE	SCALES @ A3	ISSUING OFFICE	DRAWING NUMBER	REV
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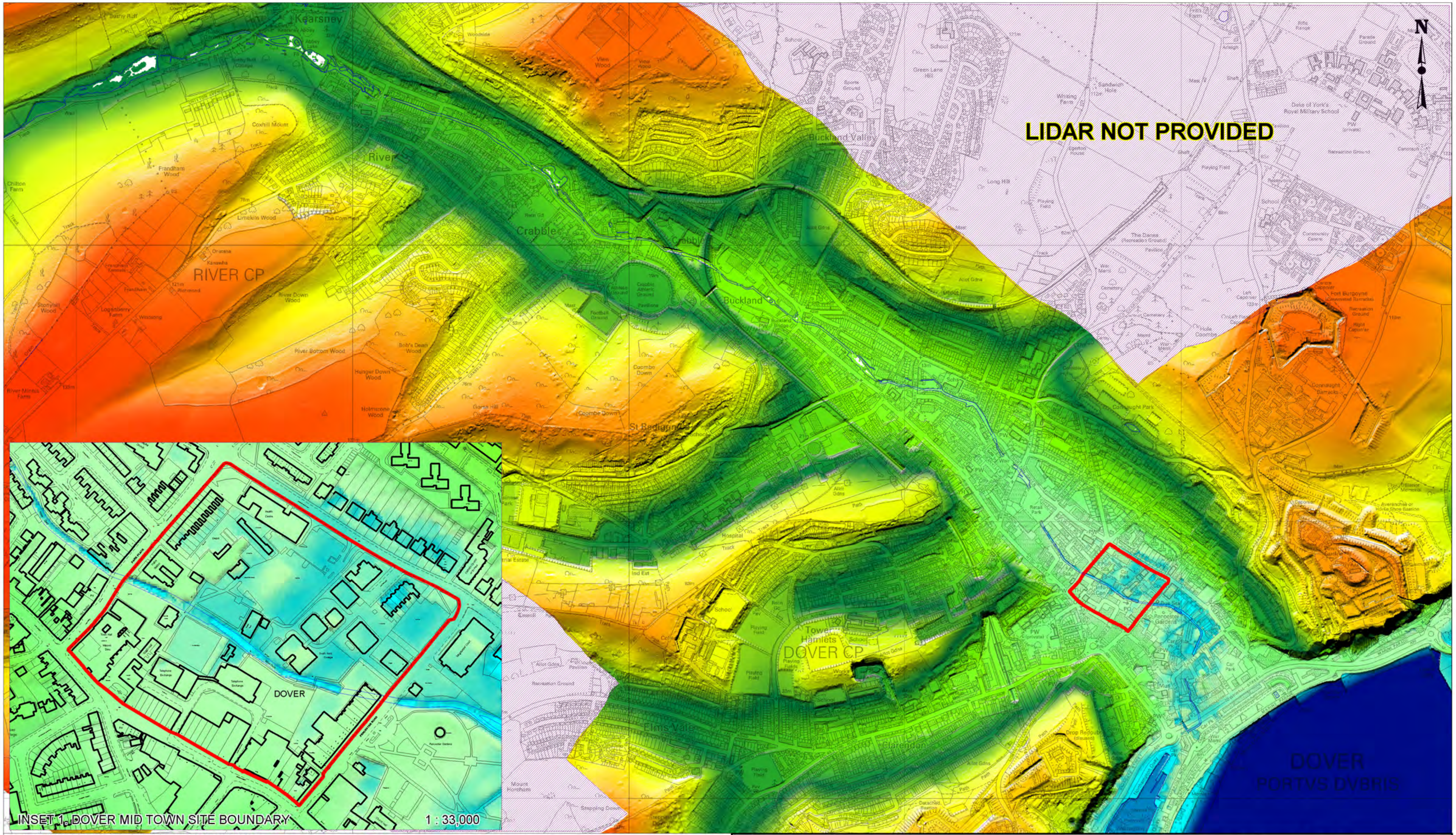

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LEGEND:

DOVER MID TOWN

ELEVATION (mAOD):

-2.5 to 0.0	40 to 50
0.0 to 2.5	50 to 60
2.5 to 5.0	60 to 70
5.0 to 7.5	70 to 80
7.5 to 10.0	80 to 90
10.0 to 12.5	90 to 100
12.5 to 15.0	100 to 110
15.0 to 17.5	110 to 120
17.5 to 20.0	120 to 130
30 to 40	130 to 140+

FLOOD RISK APPRAISAL OF THE RIVER DOUR

FIGURE A2:
GROUND LEVELS WITHIN DOVER
(PROCESSED LIDAR)

DOVER DISTRICT COUNCIL

CAPITA SYMONDS

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LEGEND:

- DESIGNATED OPEN SPACE
- DOVER MID TOWN
- CONSERVATION AREA
- LISTED BUILDINGS

FLOOD RISK APPRAISAL OF THE RIVER DOUR

FIGURE A3:
CONSERVATION AND OPEN SPACE AREAS

DOVER DISTRICT COUNCIL

CAPITA SYMONDS

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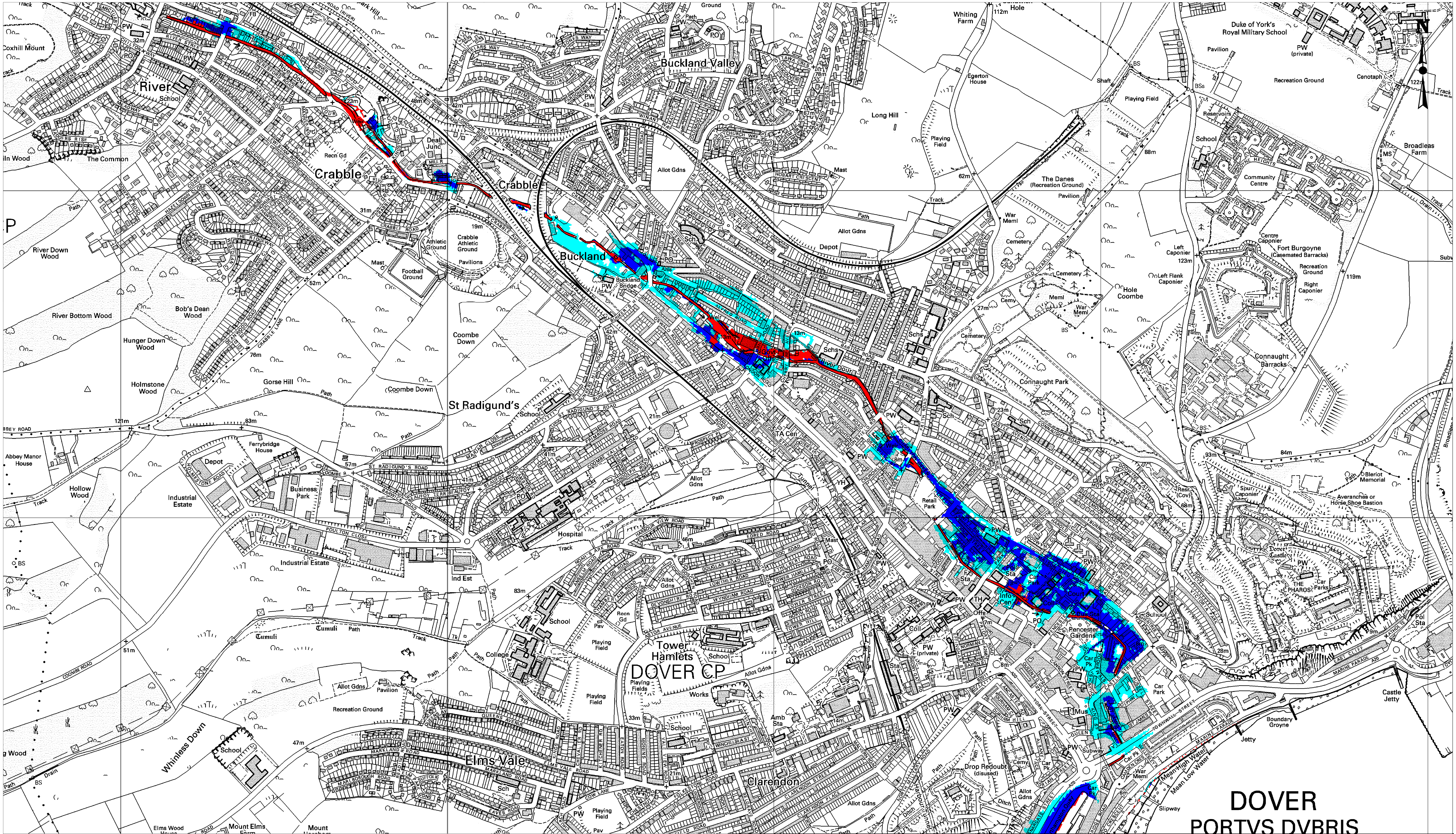

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LEGEND:

- FLOOD ZONE 3b
- FLOOD ZONE 3a
- FLOOD ZONE 2

FLOOD RISK APPRAISAL OF THE RIVER DOUR

FIGURE A4:
REVISED FLOOD ZONES FOR DOVER

DOVER DISTRICT COUNCIL

CAPITA SYMONDS

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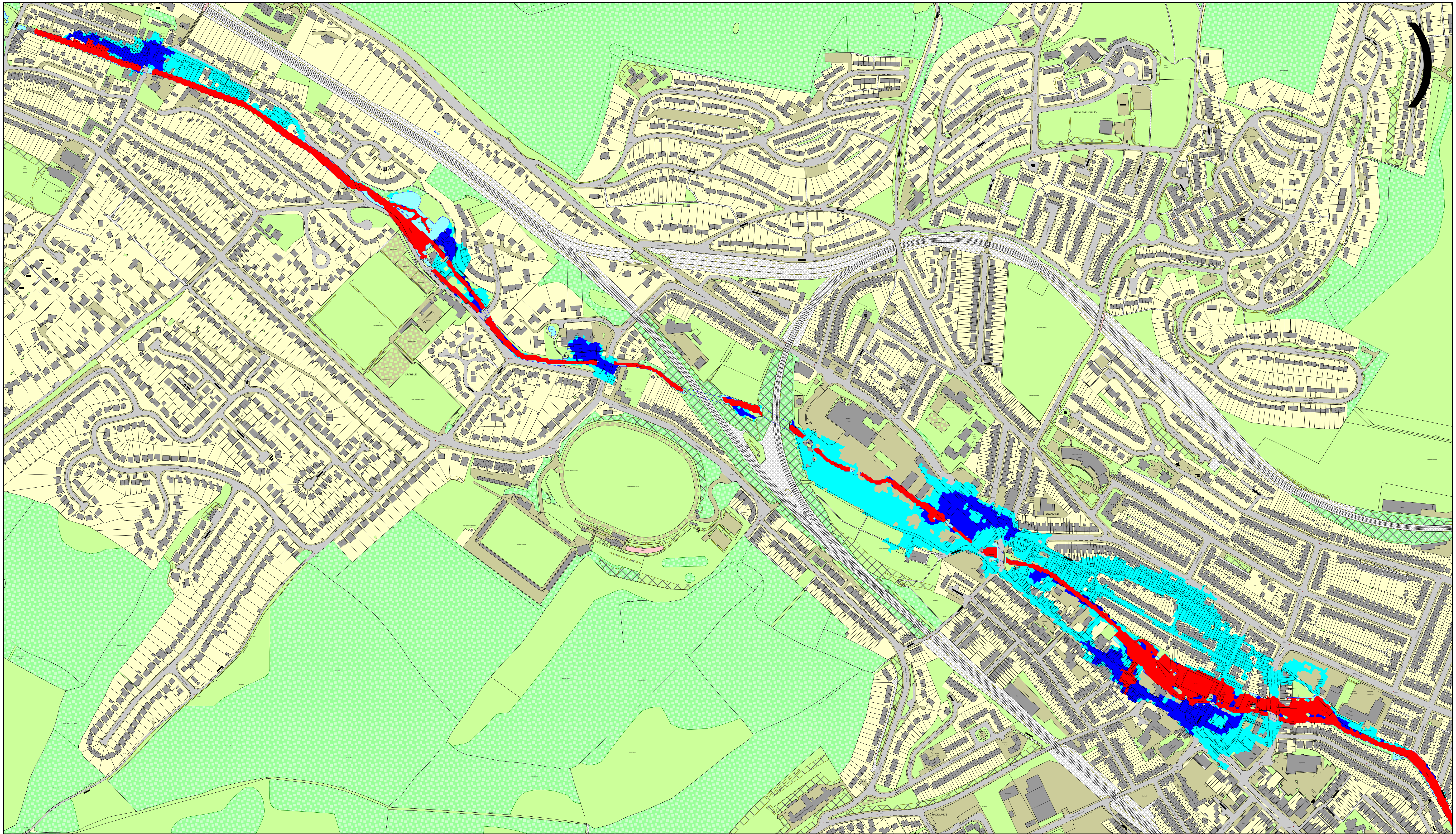

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LEGEND:

- FLOOD ZONE 3b
- FLOOD ZONE 3a
- FLOOD ZONE 2

FLOOD RISK APPRAISAL OF THE RIVER DOUR

FIGURE A5:
REVISED FLOOD ZONE FOR NORTHERN DOVER

DOVER DISTRICT COUNCIL

CAPITA SYMONDS

DRAWN BY	CHECKED BY	PASSED BY	DATE	SCALES @ A3	ISSUING OFFICE	DRAWING NUMBER	REV
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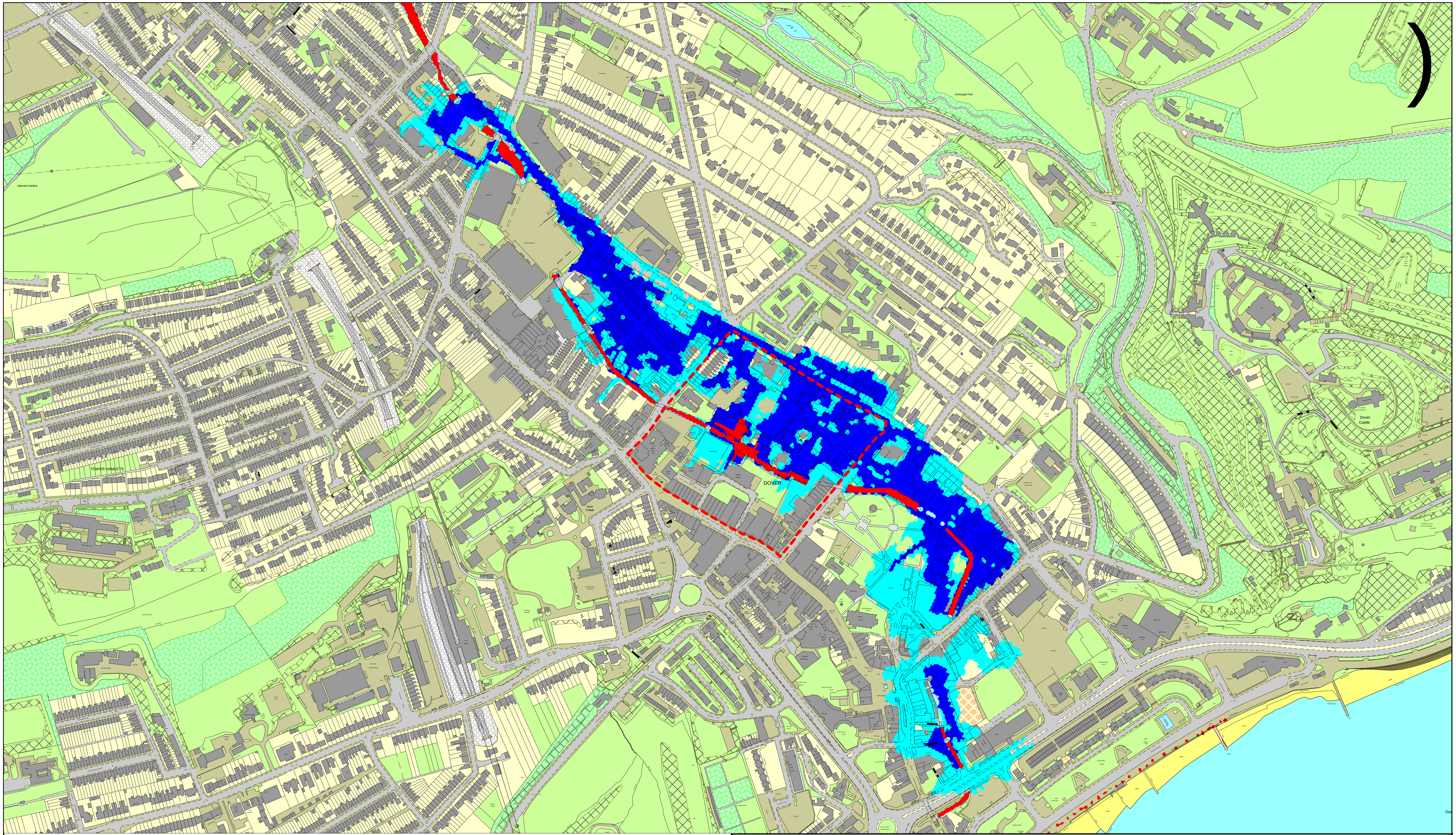

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LEGEND:

- FLOOD ZONE 3b
- FLOOD ZONE 3a
- FLOOD ZONE 2
- DOVER MID TOWN

FLOOD RISK APPRAISAL OF THE RIVER DOUR

FIGURE A6:
REVISED FLOOD ZONE FOR SOUTHERN DOVER

DOVER DISTRICT COUNCIL

CAPITA SYMONDS

DRAWN BY	CHECKED BY	PASSED BY	DATE	SCALES @ A3	ISSUING OFFICE	DRAWING NUMBER	REV
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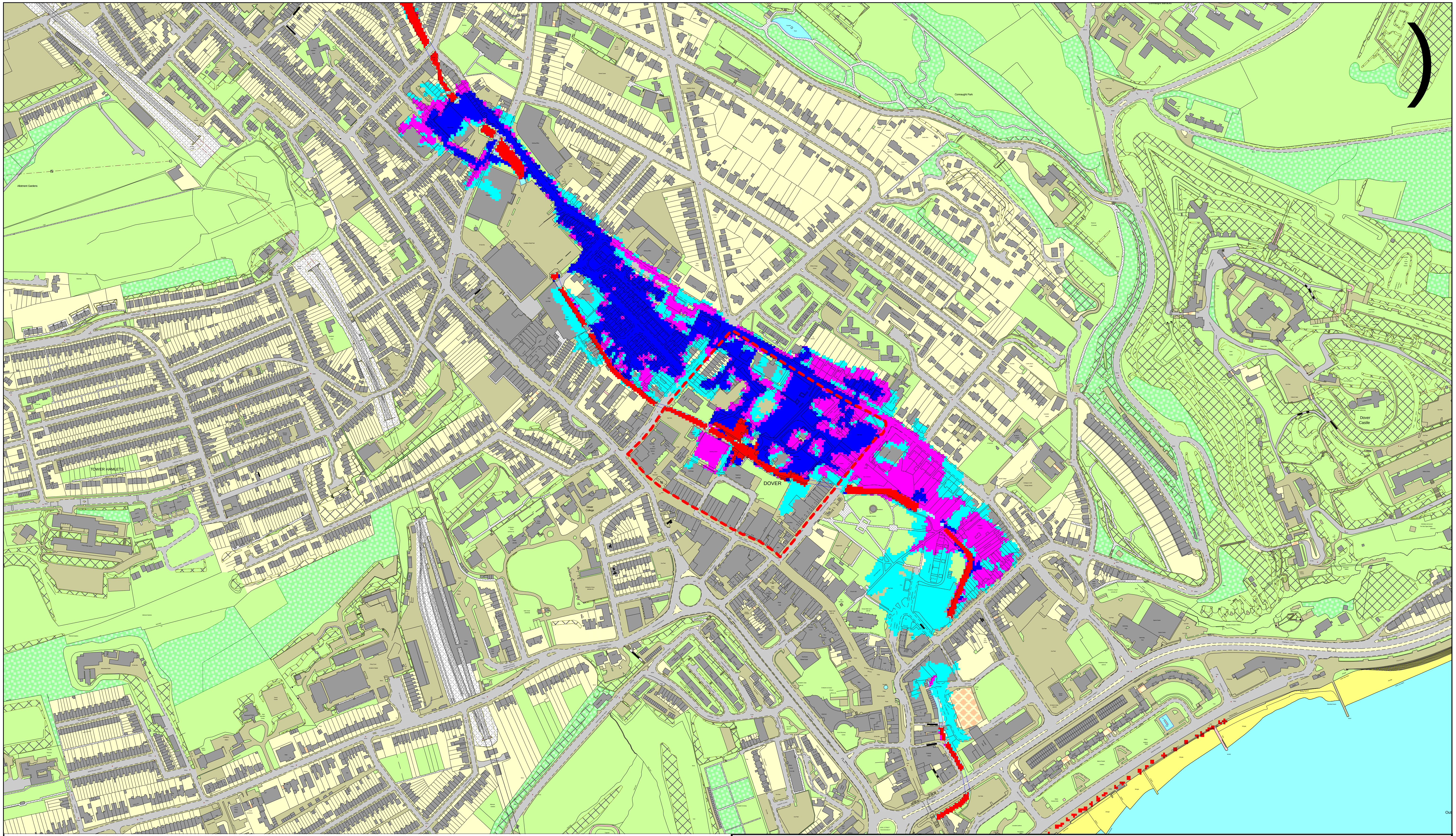

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LEGEND:

- 1 IN 20 YEAR RETURN PERIOD EVENT
- 1 IN 100 YEAR RETURN PERIOD EVENT
- 1 IN 100+CC YEAR RETURN PERIOD EVENT
- 1 IN 1000 YEAR RETURN PERIOD EVENT
- DOVER MID TOWN

FLOOD RISK APPRAISAL OF THE RIVER DOUR

FIGURE A7:
FLUVIAL FLOOD EXTENTS AROUND DOVER MID TOWN (ACTUAL RISK)

DOVER DISTRICT COUNCIL

CAPITA SYMONDS

DRAWN BY	CHECKED BY	PASSED BY	DATE	SCALES @ A3	ISSUING OFFICE	DRAWING NUMBER	REV
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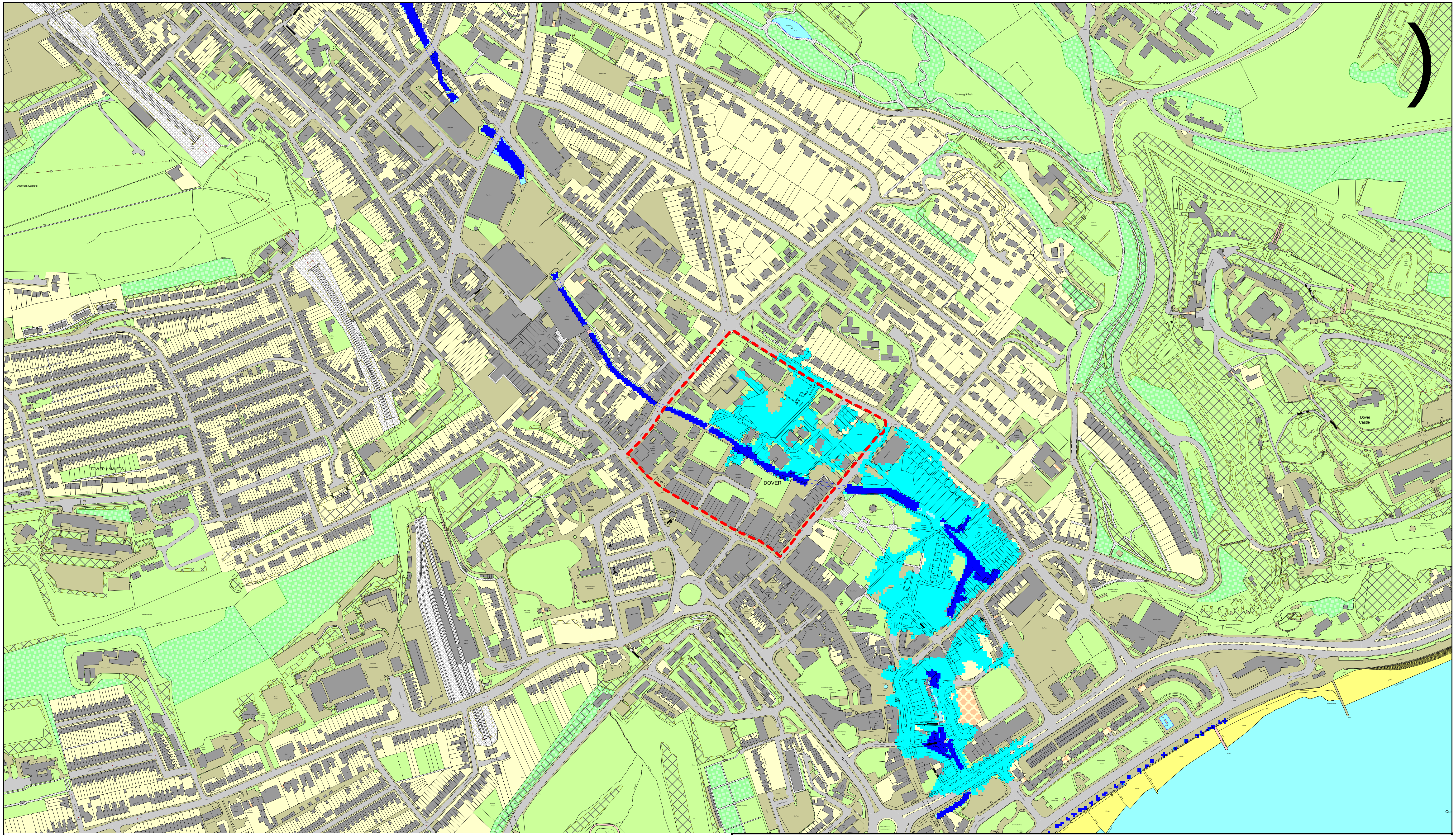

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LEGEND:

- 1 IN 200 YEAR RETURN PERIOD EVENT
- 1 IN 1000 YEAR RETURN PERIOD EVENT
- DOVER MID TOWN

FLOOD RISK APPRAISAL OF THE RIVER DOUR

FIGURE A8:
TIDAL FLOOD EXTENTS AROUND DOVER MID TOWN (ACTUAL RISK)

DOVER DISTRICT COUNCIL

CAPITA SYMONDS

DRAWN BY	CHECKED BY	PASSED BY	DATE	SCALES @ A3	ISSUING OFFICE	DRAWING NUMBER	REV
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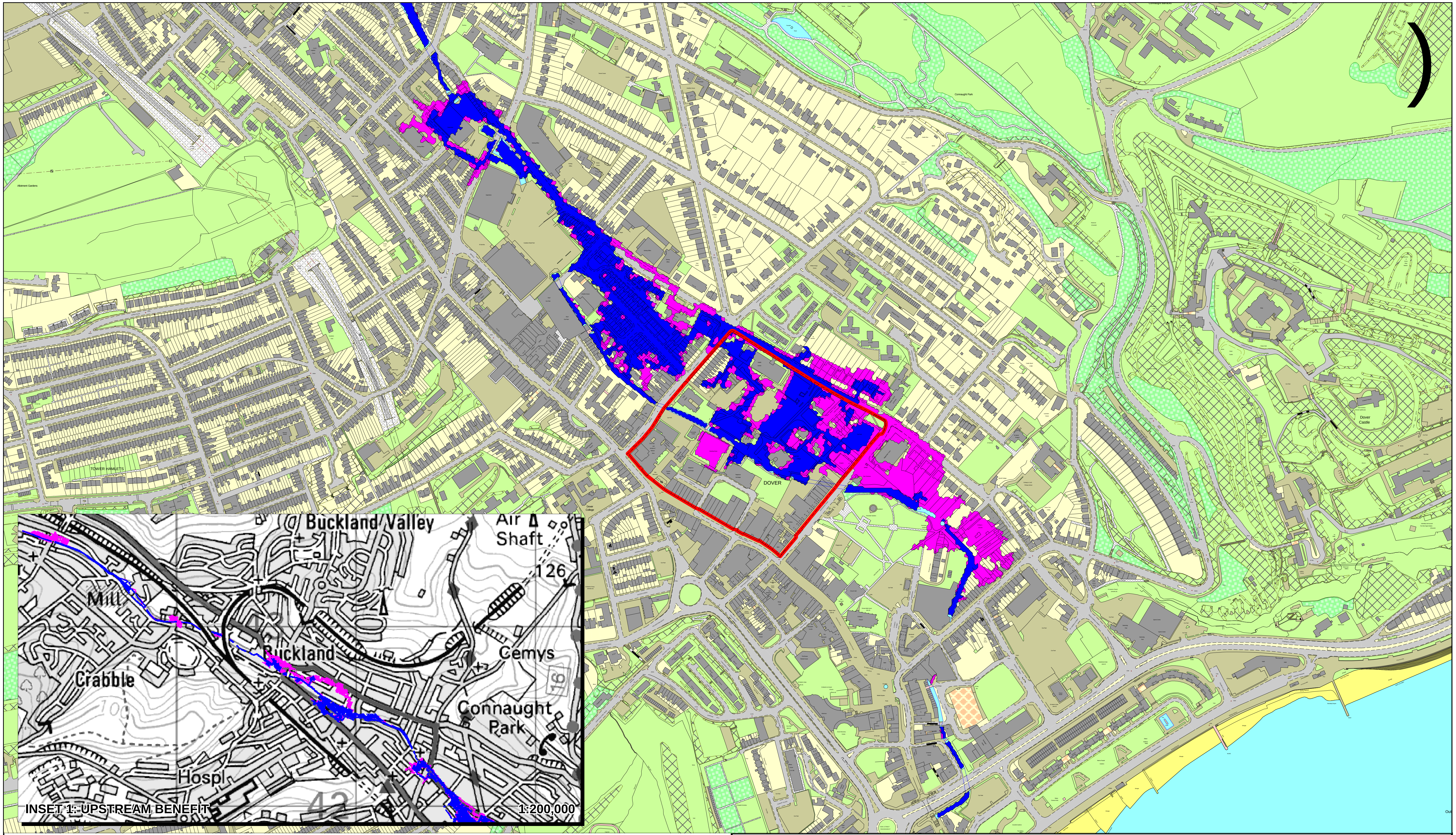

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LEGEND:

- 1 IN 100+CC YEAR RETURN PERIOD EVENT (BASELINE)
- 1 IN 100+CC YEAR RETURN PERIOD EVENT (OPTION 1)
- DOVER MID TOWN

FLOOD RISK APPRAISAL OF THE RIVER DOUR

FIGURE B1:
COMPARISON OF FLOOD EXTENTS FOR OPTION 1
UPSTREAM FLOOD STORAGE

DOVER DISTRICT COUNCIL

CAPITA SYMONDS

DRAWN BY	CHECKED BY	PASSED BY	DATE	SCALES @ A3	ISSUING OFFICE	DRAWING NUMBER	REV
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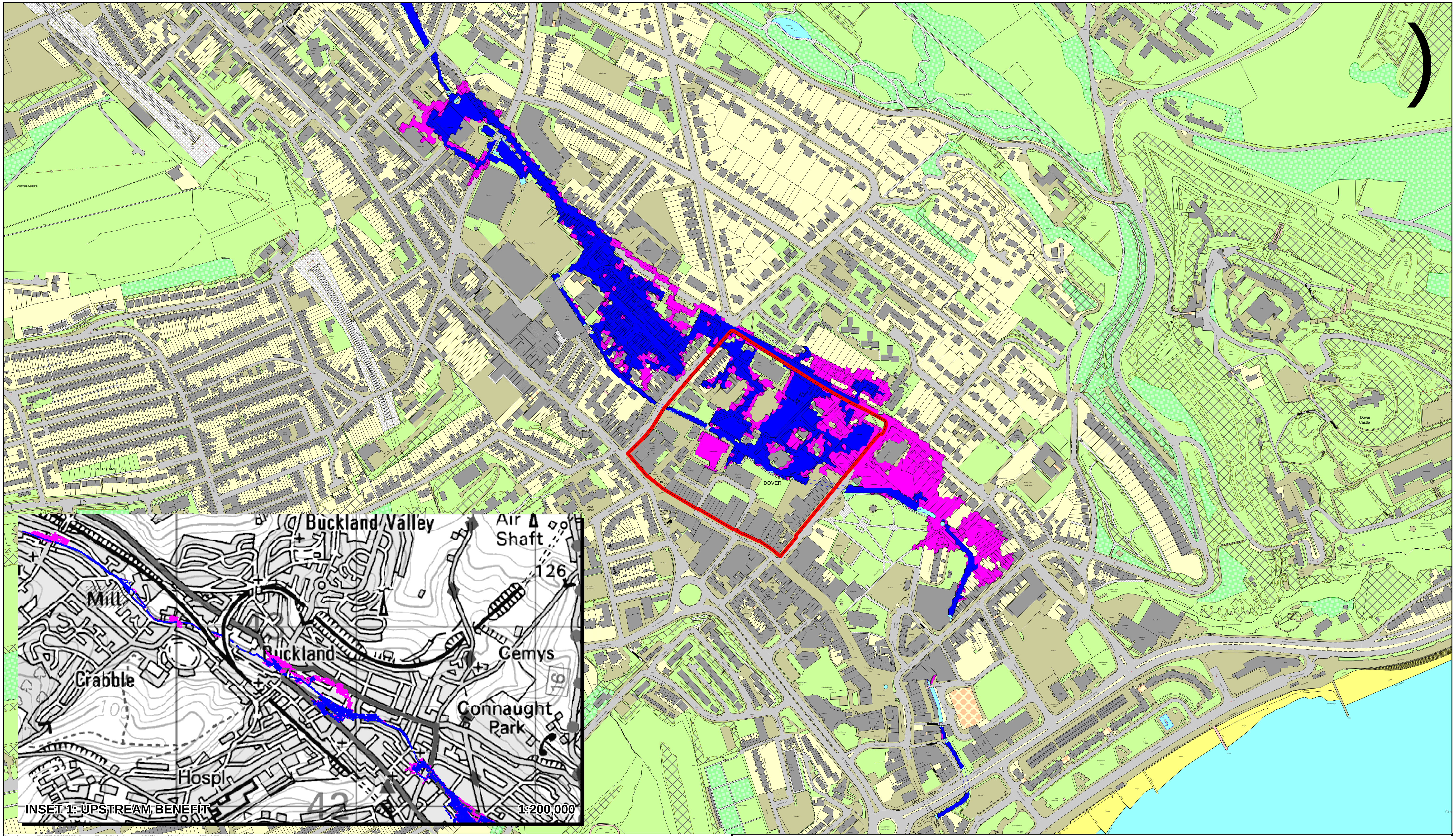

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LEGEND:

- 1 IN 100+CC YEAR RETURN PERIOD EVENT (BASELINE)
- 1 IN 100+CC YEAR RETURN PERIOD EVENT (OPTION 1)
- DOVER MID TOWN

FLOOD RISK APPRAISAL OF THE RIVER DOUR

FIGURE B1:
COMPARISON OF FLOOD EXTENTS FOR OPTION 1
UPSTREAM FLOOD STORAGE

DOVER DISTRICT COUNCIL

CAPITA SYMONDS

DRAWN BY	CHECKED BY	PASSED BY	DATE	SCALES @ A3	ISSUING OFFICE	DRAWING NUMBER	REV
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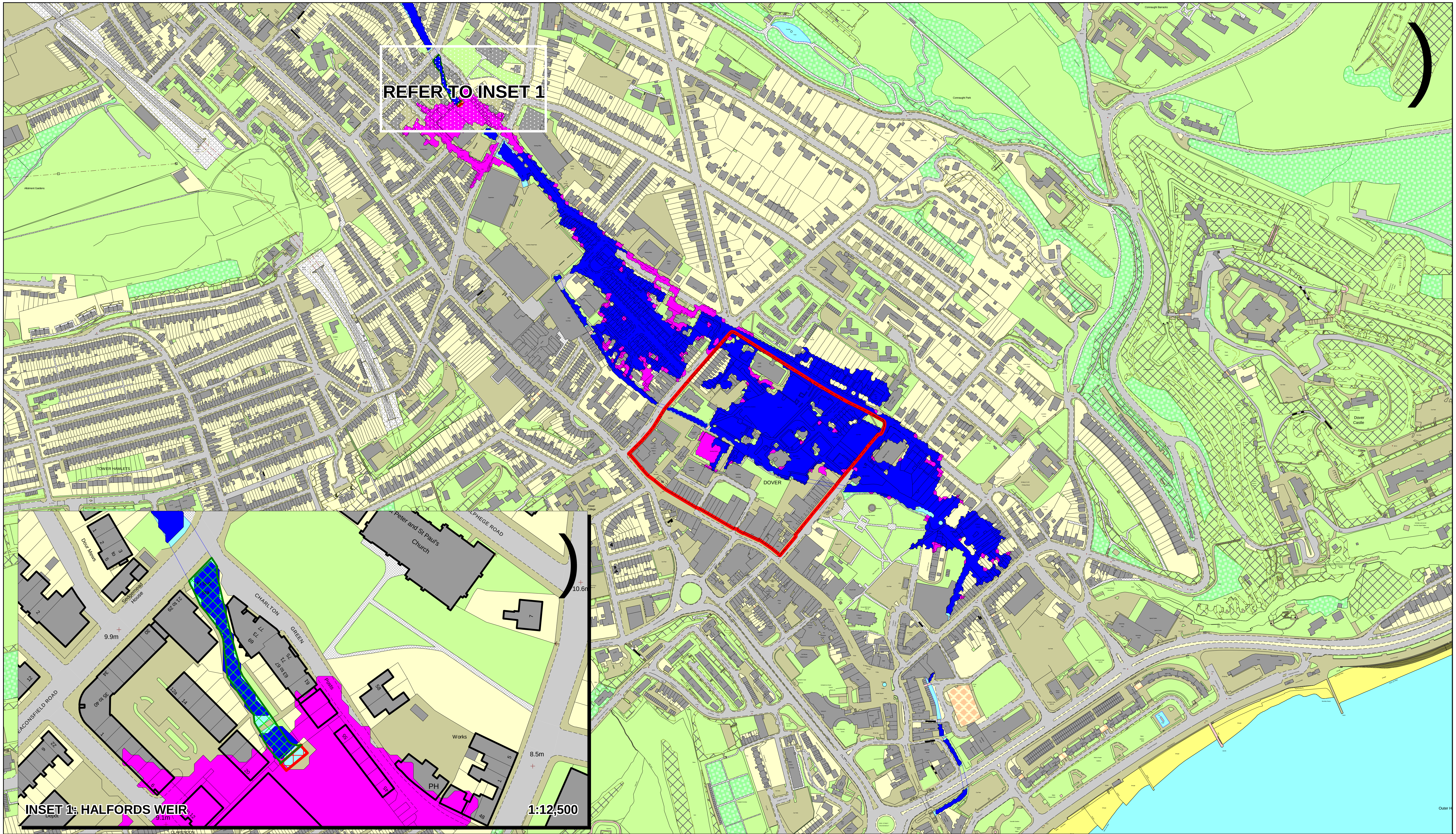

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LEGEND:

- 1 IN 100+CC YEAR RETURN PERIOD EVENT (BASELINE)
- 1 IN 100+CC YEAR RETURN PERIOD EVENT (OPTION 3)
- DOVER MID TOWN
- CHANNEL REGRADING
- REMOVAL OF WEIR

FLOOD RISK APPRAISAL OF THE RIVER DOUR

FIGURE B3:
COMPARISON OF FLOOD EXTENTS FOR OPTION 3
REMOVAL OF WEIR

DOVER DISTRICT COUNCIL

CAPITA SYMONDS

DRAWN BY	CHECKED BY	PASSED BY	DATE	SCALES @ A3	ISSUING OFFICE	DRAWING NUMBER	REV
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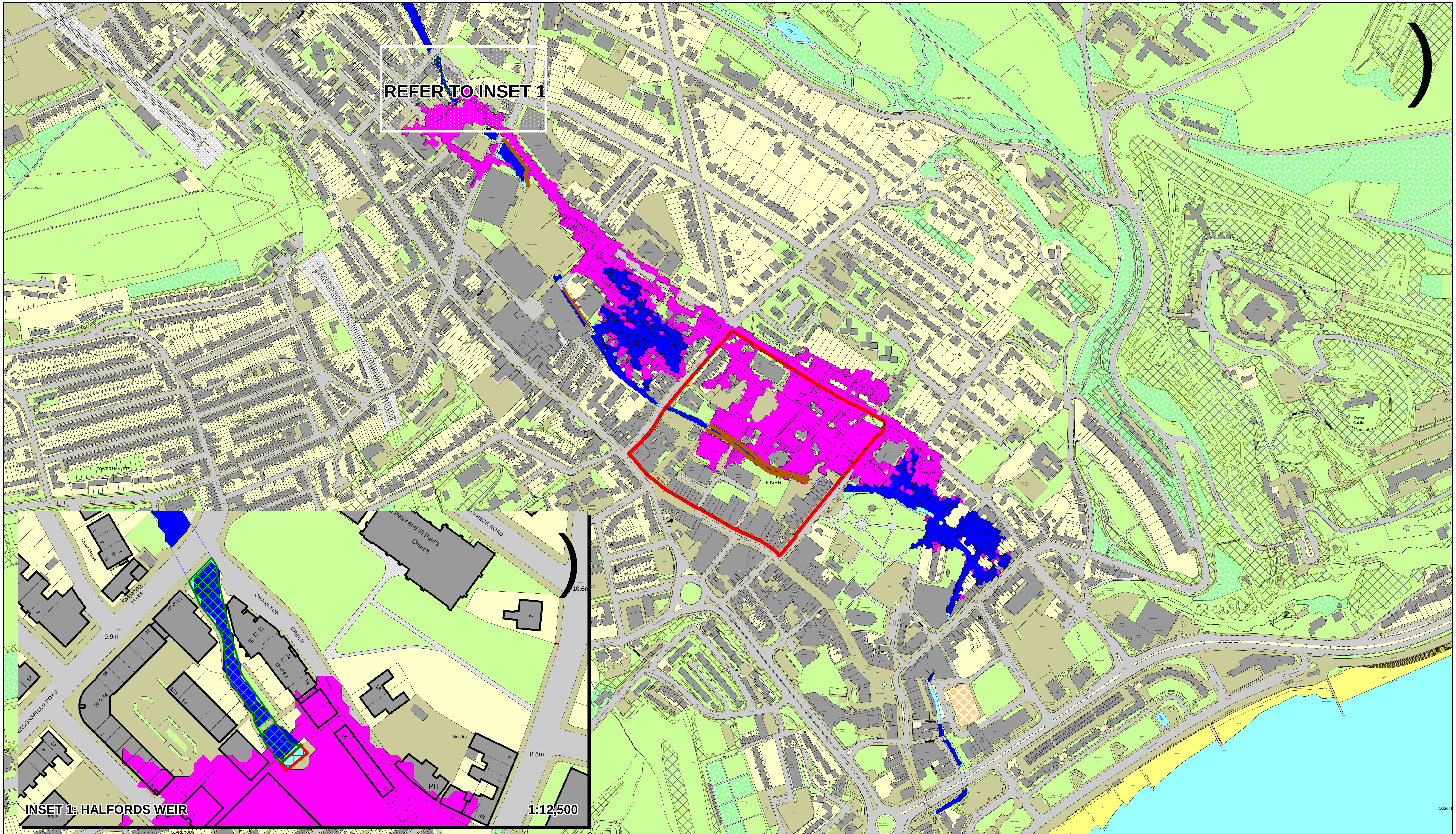

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LEGEND:

- 1 IN 100+CC YEAR RETURN PERIOD EVENT (BASELINE)
- 1 IN 100+CC YEAR RETURN PERIOD EVENT (OPTION 4a)
- DOVER MID TOWN
- CHANNEL REGRADING
- REMOVAL OF WEIR
- WALL OR EMBANKMENT

FLOOD RISK APPRAISAL OF THE RIVER DOUR

FIGURE B4a:
COMPARISON OF FLOOD EXTENTS FOR OPTION 4a
REMOVAL OF WEIR WITH WALLS

DOVER DISTRICT COUNCIL

CAPITA SYMONDS

DRAWN BY	CHECKED BY	PASSED BY	DATE	SCALES @ A3	ISSUING OFFICE	DRAWING NUMBER	REV
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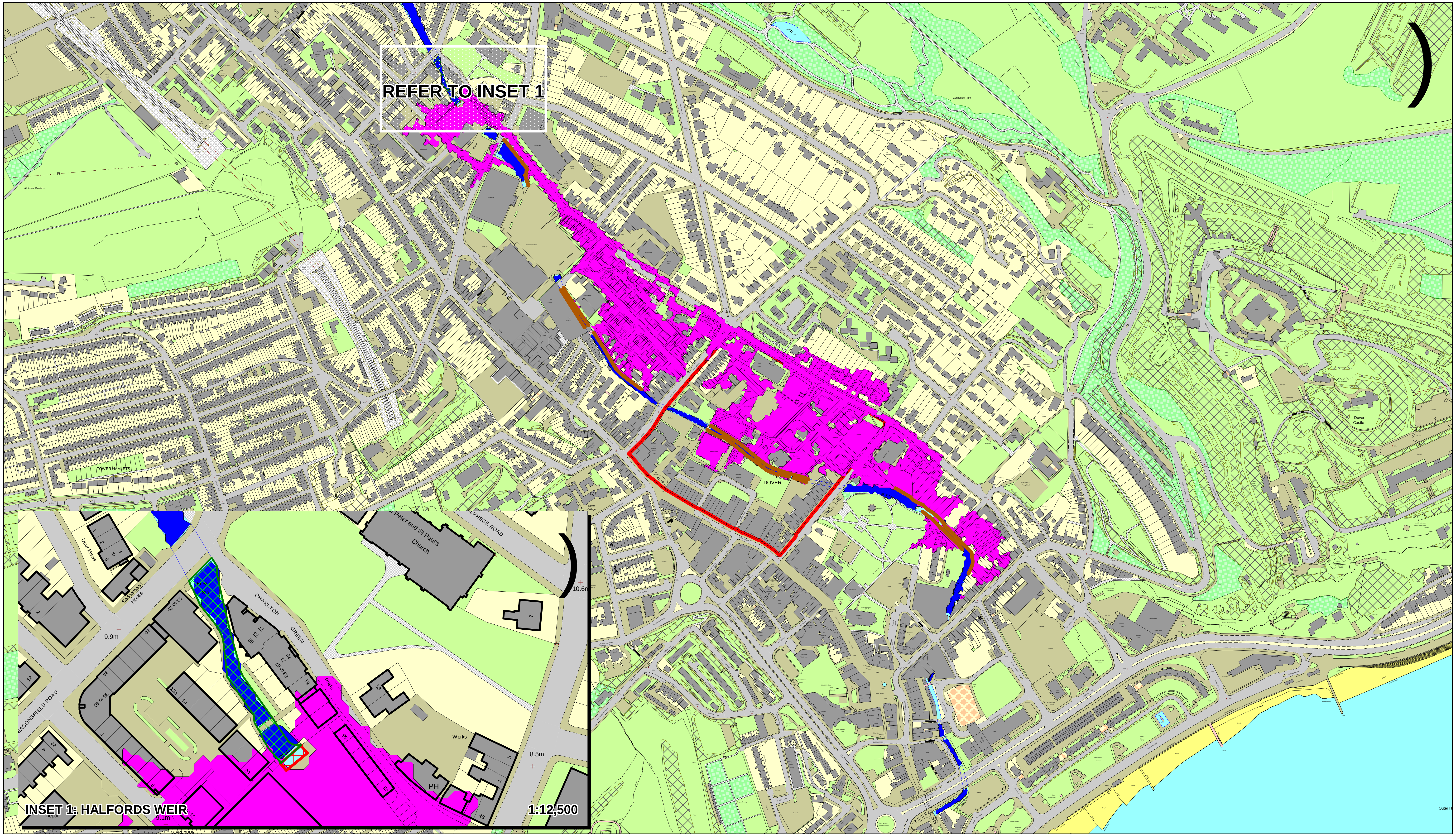

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LEGEND:

- 1 IN 100+CC YEAR RETURN PERIOD EVENT (BASELINE)
- 1 IN 100+CC YEAR RETURN PERIOD EVENT (OPTION 4b)
- DOVER MID TOWN
- CHANNEL REGRADING
- REMOVAL OF WEIR
- WALL OR EMBANKMENT

FLOOD RISK APPRAISAL OF THE RIVER DOUR

FIGURE B4b:
COMPARISON OF FLOOD EXTENTS FOR OPTION 4b
REMOVAL OF WEIR WITH ADDITIONAL WALLS

DOVER DISTRICT COUNCIL

CAPITA SYMONDS

DRAWN BY	CHECKED BY	PASSED BY	DATE	SCALES @ A3	ISSUING OFFICE	DRAWING NUMBER	REV
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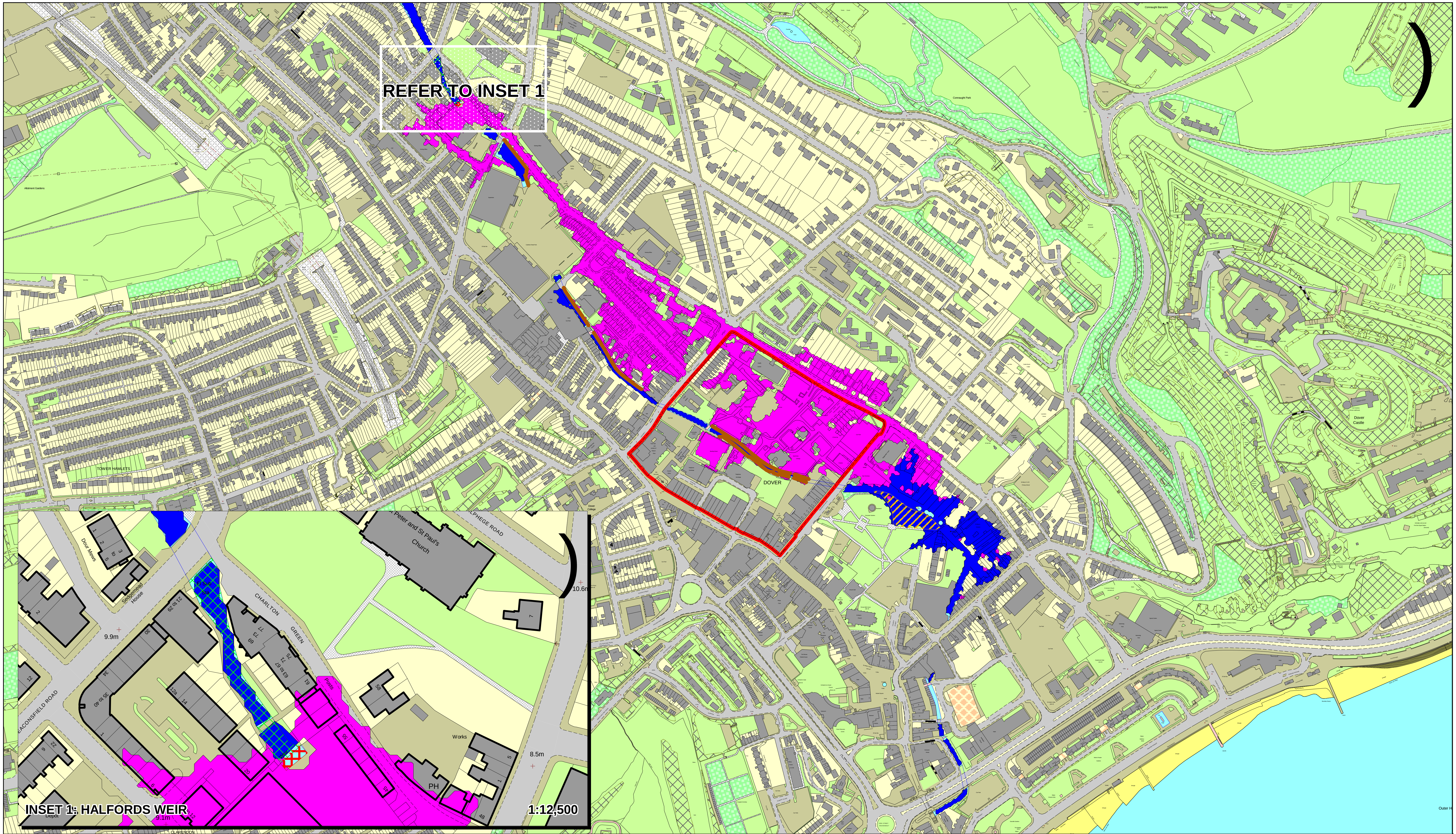

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LEGEND:

- CHANNEL REGRADING
- REMOVAL OF WEIR
- 1 IN 100+CC YEAR RETURN PERIOD EVENT (BASELINE)
- 1 IN 100+CC YEAR RETURN PERIOD EVENT (OPTION 4c)
- DOVER MID TOWN
- EXCAVATION ZONE
- WALL OR EMBANKMENT

FLOOD RISK APPRAISAL OF THE RIVER DOUR

FIGURE B4c:
COMPARISON OF FLOOD EXTENTS FOR OPTION 4c
PENCESTER GARDENS FLOOD STORAGE

DOVER DISTRICT COUNCIL

CAPITA SYMONDS

DRAWN BY	CHECKED BY	PASSED BY	DATE	SCALES @ A3	ISSUING OFFICE	DRAWING NUMBER	REV
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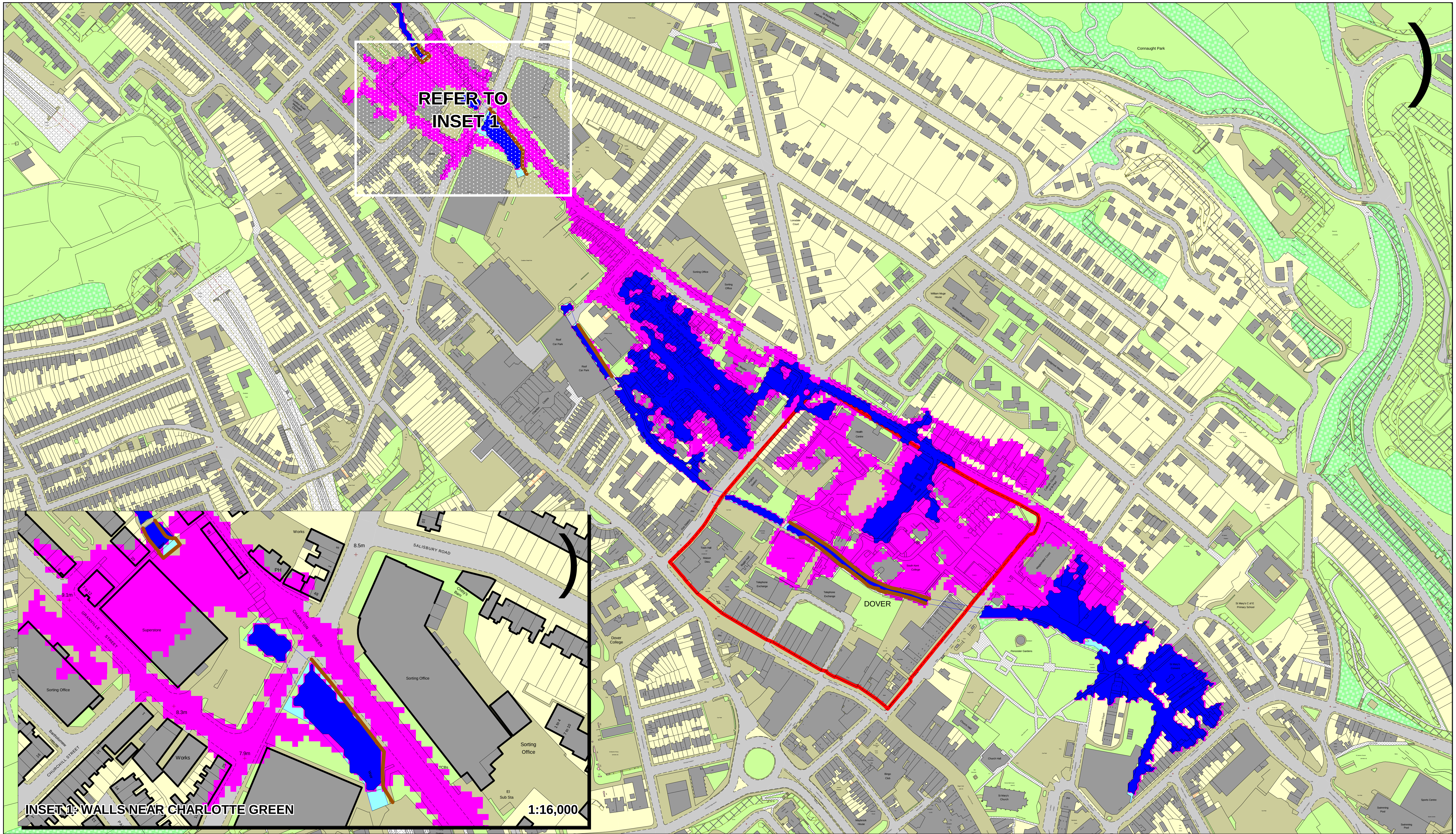

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LEGEND:

- 1 IN 100+CC YEAR RETURN PERIOD EVENT (BASELINE)
- 1 IN 100+CC YEAR RETURN PERIOD EVENT (OPTION 5a)
- DOVER MID TOWN
- WALL OR EMBANKMENT

FLOOD RISK APPRAISAL OF THE RIVER DOUR

FIGURE B5a:
COMPARISON OF FLOOD EXTENTS FOR OPTION 5a
RAISED DEFENCES

DOVER DISTRICT COUNCIL

CAPITA SYMONDS

DRAWN BY	CHECKED BY	PASSED BY	DATE	SCALES @ A3	ISSUING OFFICE	DRAWING NUMBER	REV
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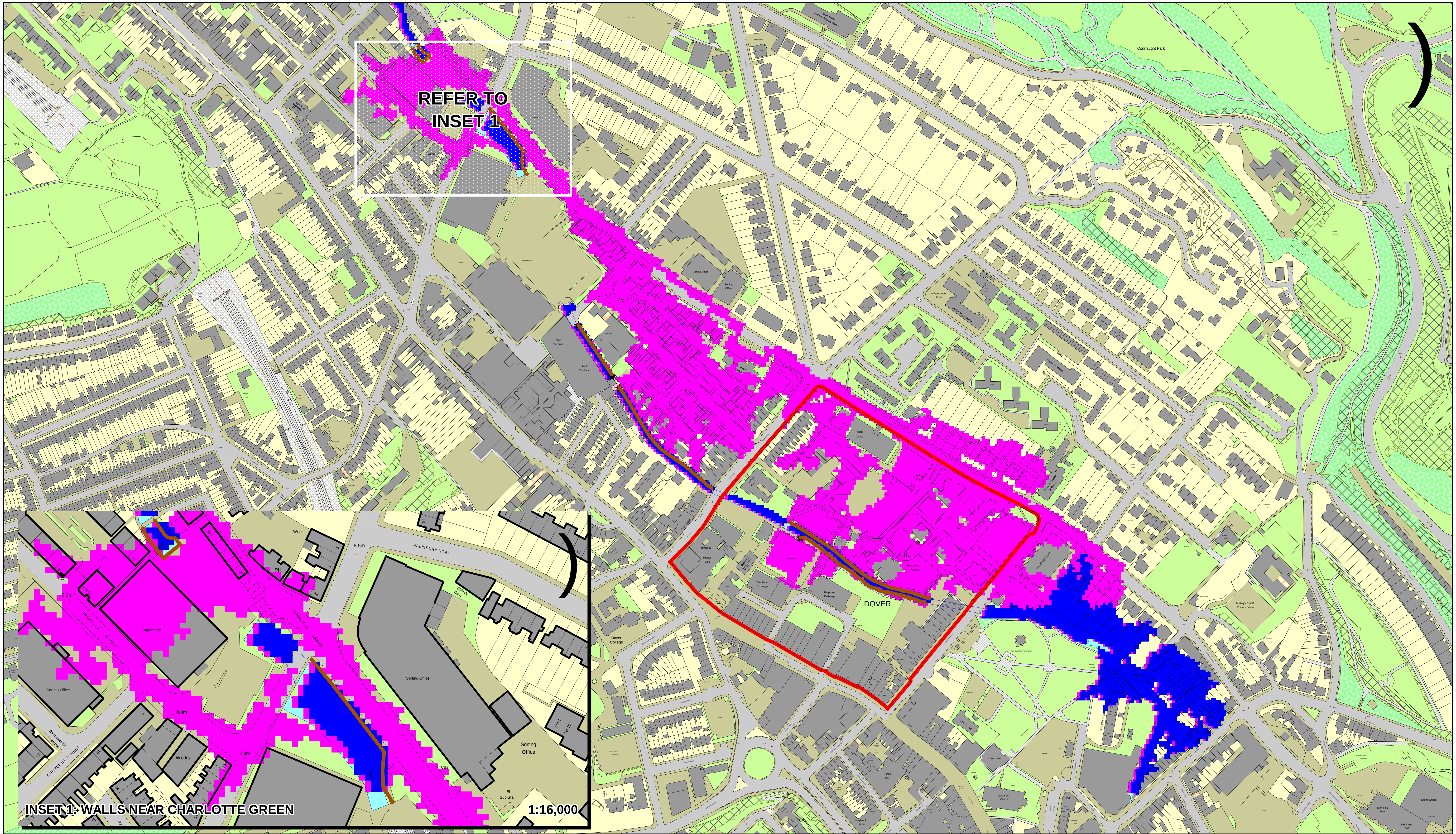

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LEGEND:

- 1 IN 100+CC YEAR RETURN PERIOD EVENT (BASELINE)
- 1 IN 100+CC YEAR RETURN PERIOD EVENT (OPTION 5b)
- SITE BOUNDARY
- WALL OR EMBANKMENT

FLOOD RISK APPRAISAL OF THE RIVER DOUR

FIGURE B5b:
COMPARISON OF FLOOD EXTENTS FOR OPTION 5b RAISED DEFENCES

DOVER DISTRICT COUNCIL

CAPITA SYMONDS

DRAWN BY	CHECKED BY	PASSED BY	DATE	SCALES @ A3	ISSUING OFFICE	DRAWING NUMBER	REV
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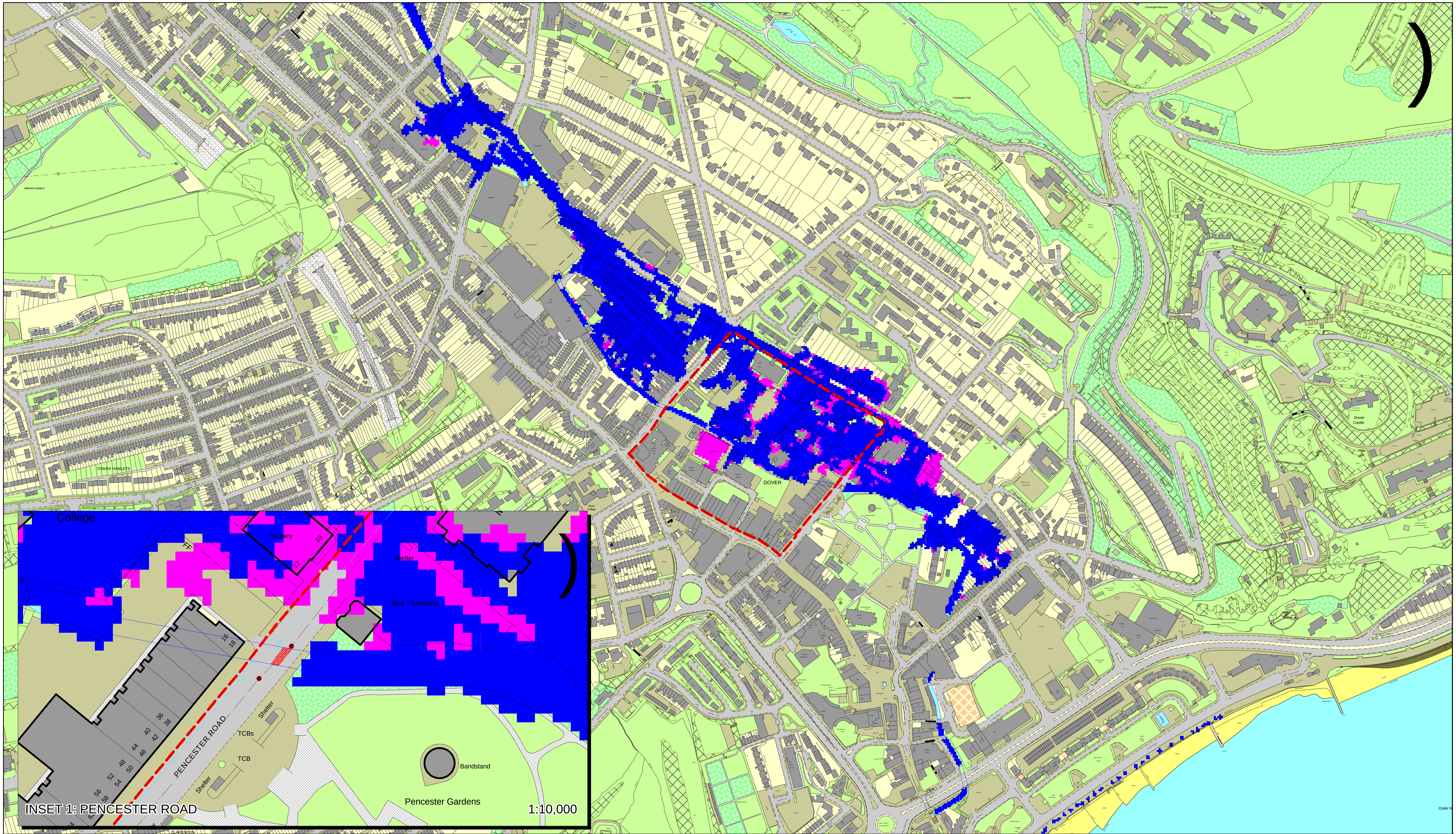

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LEGEND:

- 1 IN 100+CC YEAR RETURN PERIOD EVENT (BASELINE)
- 1 IN 100+CC YEAR RETURN PERIOD EVENT (OPTION 6)
- DOVER MID TOWN
- AREA OF PIPE REMOVAL
- COMBINED SEWER NETWORK
- SURFACE WATER NETWORK

FLOOD RISK APPRAISAL OF THE RIVER DOUR

FIGURE B6:
COMPARISON OF FLOOD EXTENTS FOR OPTION 6
REMOVAL OF COMBINED SEWER PIPE

DOVER DISTRICT COUNCIL

CAPITA SYMONDS

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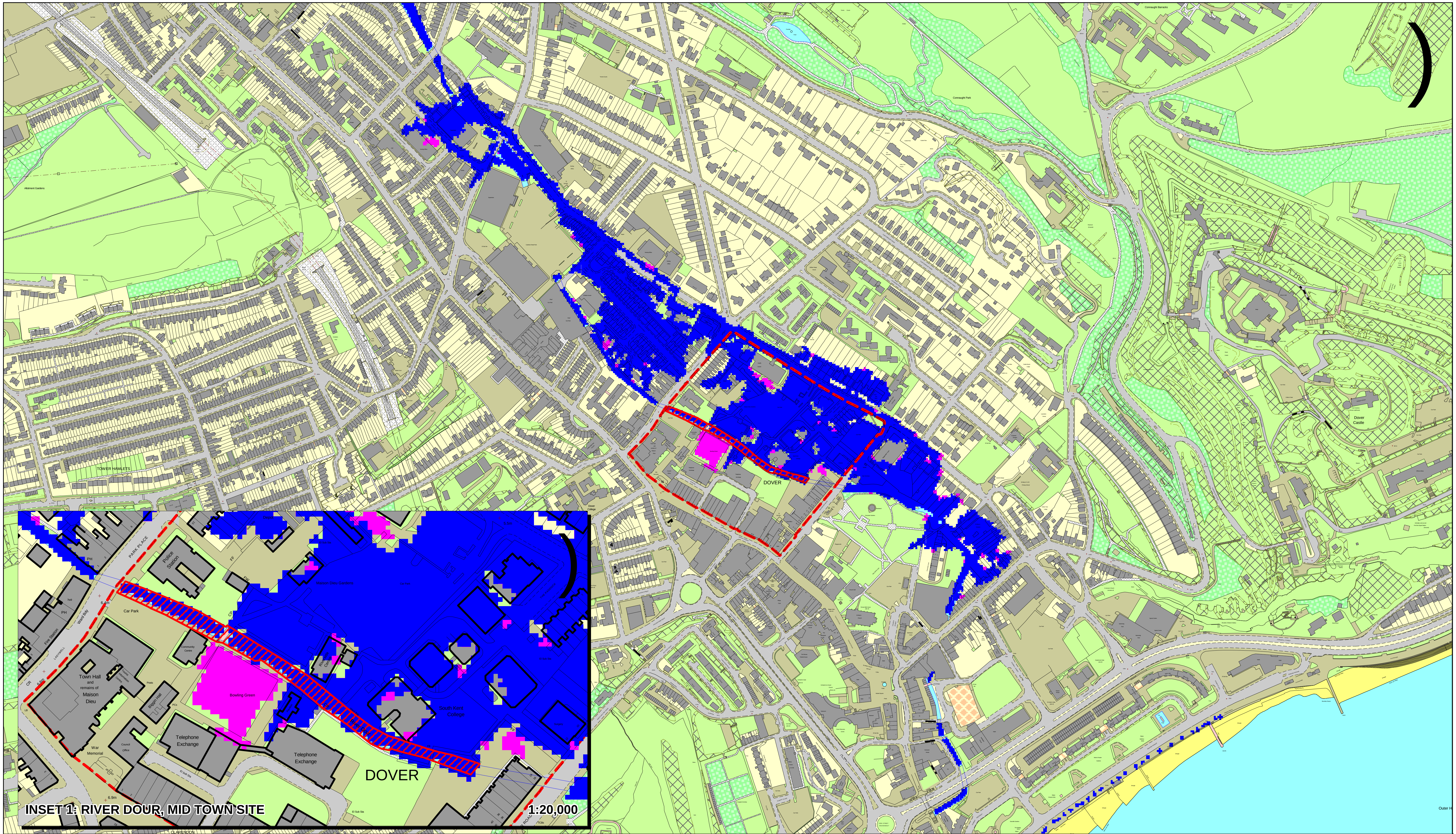

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LEGEND:

- 1 IN 100+CC YEAR RETURN PERIOD EVENT (BASELINE)
- 1 IN 100+CC YEAR RETURN PERIOD EVENT (OPTION 7)
- DOVER MID TOWN
- AREA CHANNEL WIDENING

FLOOD RISK APPRAISAL OF THE RIVER DOUR

FIGURE B7:
COMPARISON OF FLOOD EXTENTS FOR OPTION 7
WIDENING OF THE RIVER DOUR

DOVER DISTRICT COUNCIL

CAPITA SYMONDS

DRAWN BY	CHECKED BY	PASSED BY	DATE	SCALES @ A3	ISSUING OFFICE	DRAWING NUMBER	REV
PH	JR	JR	19/05/10	1:50,000	LONDON	CS37272_OPT7_B7	B

Dover
Flood Risk Appraisal of the River Dour

TUFLOW model

Appendix C: Hydraulic Modelling Assessment

April 2010

CAPITA SYMONDS

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CONTENTS

CAPITA SYMONDS

Appendix A: iSIS and ESTRY Model Comparison
Appendix B: Sensitivity Analysis Results
Appendix C: Response to Initial EA Model Review

CAPITA SYMONDS

1 INTRODUCTION

Capita Symonds has been appointed by Dover District Council (DDC) to undertake a flood risk assessment and appraisal of flood alleviation options for the Mid Town Dover Area. The proposed redevelopment of the Mid Town study area in Dover is located at NGR 631800, 141800. The study seeks to provide guidance to the Council on potential options for managing flood risk in compliance with PPS 25, The Practice Guide, and guidance from the Environment Agency for the site.

The study is focused on developing conceptual options to manage fluvial flooding, however consideration is also given to the risk of surface water flooding.

The objectives of the study are to:

- Set out the existing 'baseline' flood risk conditions, considering Flood Zones as defined by the Environment Agency, as well as the 'actual' and 'residual' risk of flooding; and
- Outline possible measures to reduce flood risk to the site from the River Dour on site to an acceptable level.

The hydraulic model was reviewed by the Environment Agency in September 2009 and approved in January 2010.

2 EXTERNAL DATA SOURCES

The following external data has been obtained for this study:

- 3D topography and channel sections (topography);
- Inflows (hydrology);
- Materials definition;
- Structure data; and
- Downstream boundary conditions.

Details of the origin and applicability of this external data are given below.

2.1 Topography

DTM data

The LiDAR data, as detailed in Table 2-1, covers approximately 39km^2, extending from Lydden in the North, Hougham in the West and Guston in the East. The LiDAR data was received from the Environment Agency in May/June 2009 in ASCii format and incorporates data which was flown in 2004, 2006 and 2008. The resolutions of the data provided were 2m for the 2004 and 2006 data and 1m for the 2008 data. The filtered LiDAR data was processed by stamping the tiles together using Map Info/Vertical Mapper to form a DTM. LiDAR tiles with more recent flown dates take precedence over tiles with older flown dates, i.e. the 2008 data was stamped on top of the 2006 data which was stamped on top of the 2004 data.

Table 2-1: Details Of DTM Data Used Within The Hydraulic Model

Data type*	Source/ Supplier	Date Received	File Name	Projection	Notes on filtering/ completeness/ accuracy
LiDAR (ASCii Format)	Environment Agency (EA)	22/05/2009 and 10/06/2009	V0037359 to V0037372, V0065615 to V0065637 V0089689 to V0089771 V0108278 to V0108281	British national grid	The LIDAR data provided is a combination of data flown in 2004 (2m resolution), 2006 (2m resolution) and 2008 (1m resolution). Both filtered and unfiltered data were provided.

Ground survey data (including channel survey, manhole or other spot heights)

All survey information used to development the hydraulic model is detailed in Table 2-2. The modelling of the River Dour has been based on the channel survey as provided by the Environment Agency. This survey was originally commissioned for Peter Brett Associates and was carried out in 2005 by Longdin & Browning. It was observed that this survey lacked detail at certain locations, such as details of the railway structures in Crabble. Consequently, JC White Surveyors were commissioned to survey these missing details.

Table 2-2: Details Of Survey Data Used Within The Hydraulic Model

Data type*	Source/ Supplier	Date Received	File Name/ Survey Report	Projection	Notes on completeness/ accuracy
River Dour channel survey (AutoCAD)	The Environment Agency	29/04/2009	5254-LOC1.dwg - 5254-LOC3.dwg 5254-LP01.dwg - 5254-LP02.dwg 5254-XS01.dwg - 5254-XS13.dwg	British National	Survey was carried out by Longdin and Browning Surveys in 2005. The survey extents are from Temple Ewell to Wellington Dock.
River Dour Culvert Survey (PDF)	Dover Harbour Board	10/06/2009	River Dour Culvert Survey 01.04.09 - Appendix1-3.pdf	-	The provided information included: photos of the downstream end of the outfall from the River Dour to Wellington Dock along with a sketch of the culvert face (no invert levels provided)
River Dour channel survey (AutoCAD)	JC White Surveyors	12/06/2009	XSEC_JCW_03.DWG	British National	Additional channel survey at locations not previously surveyed.
Crest Level Survey (AutoCAD)	JC White Surveyors	26/06/2009	WALL_03.dwg	British National	Crest level survey of the banks on site (between Park St and Pencester Rd)
Topographic survey (AutoCAD)	JC White Surveyors	17/07/2009	HEALTH_3D.dwg HEALTH_04.DWG	British National	Topographic survey of the site only. This was stamped onto the LIDAR.
Manhole and pipe data	Southern Water	28/4/2009	DOVE_Links.TAB DOVE_Nodes.TAB DOVE_SIRF_Hydraulic.TAB	British National	Surface water, Sewerage and combine systems manhole and pipe data.

Crest level survey was also carried out by JC White Surveyors along the left and right bank walls across the Mid Town study area. A site visit of the area confirmed that the crest level of the walls varied across its length. The elevation of the walls is important as flood waters have been known to overtop at this location. No other crest level data was available. Details on manholes and the drainage network in Dover were provided by South Water.

2.2 Structures

All structures within the model have been based on the River Dour survey provided by the Environment Agency and JC White. The survey conducted by JC White contained details of a further nine structure openings, with one of the previous structures being demolished and replaced with a new bridge since the 2005 survey.

2.3 Hydrology

The following sets of hydrology were developed: one for the assessment of fluvial flooding and one for the assessment of combined fluvial and surface water flooding.

Fluvial

When assessing flooding from fluvial sources only, the hydrographs were applied to the model as shown in Figure 2-1, below. This hydrology was calculated by Peter Brett Associates (PBA) in 2007 and has been approved by the Environment Agency. ISIS models were provided by PBA for various return periods (this model was produced as part of a CFMP and as such does not include the level of detail utilised within the ESTRY-TUFLOW model).

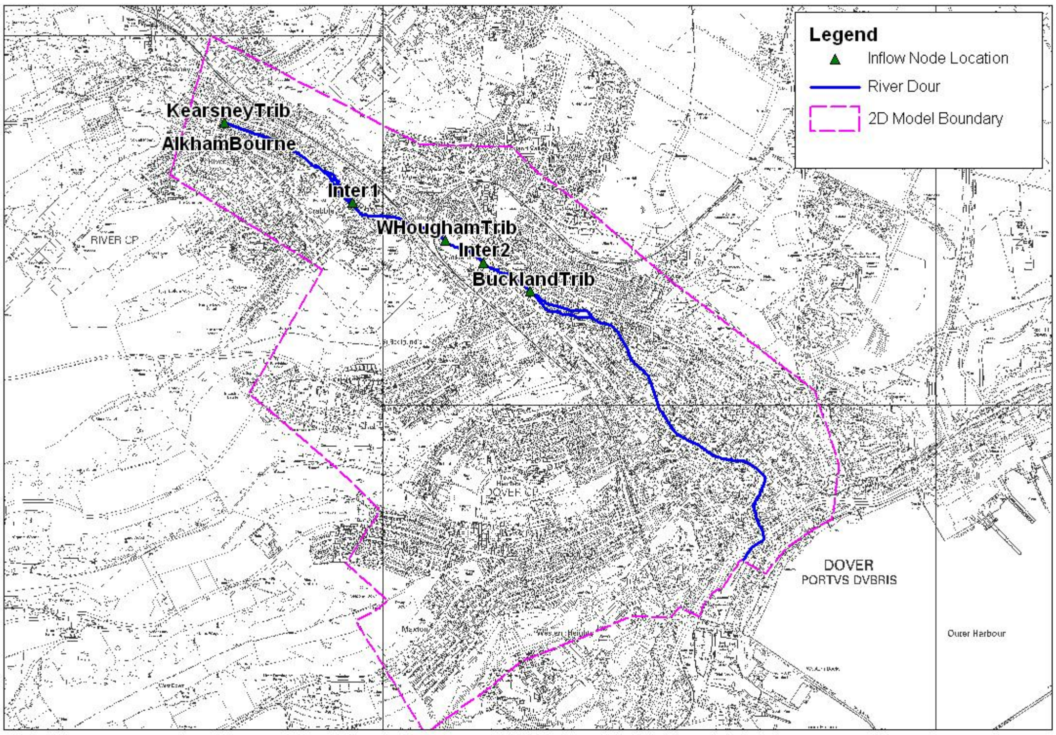


Figure 2-1: Location Of Modelled Hydrology Inflows

The iSIS models were used to extract hydrograph inflows for the detailed ESTRY-TUFLOW model of the River Dour. Two of the inflow hydrographs were calculated at locations upstream of the extent of this hydraulic model – Alkham Bourne and Kearsney Trib. Following an analysis of the hydrology and its influence on the upstream extent of the model, it was concluded that these hydrographs should be lagged by 1.75 hours and 0.75 hours respectively. This was done by examining the PBA iSIS model and calculating the time at which the peak flow is recorded at the upstream extent of the ESTRY-TUFLOW model.

Source of hydrologic inputs:

Flood Estimation Handbook

This was not used as the hydrology calculated by Peter Brett Associates was applied to the model.

Existing 1d hydraulic model

Inflows for the fluvial model were extracted from iSIS models provided by PBA.

2.4 Other Boundary Data

Tidal Boundary

The downstream extent of the River Dour outfalls into the Wellington Dock. It was therefore necessary to determine the operational rules of the Dock in order to define the downstream boundary of the model. Discussions with Dover Harbour Board determined that:

- The water level in Wellington Dock is maintained at a level of 1.16mAOD.
- The dock gate is closed when the water level falls below the maintained level and opened when the water level is higher than this level; and
- Consequently, for water levels higher than the maintained water level of 1.16mAOD, the water level in the Dock is controlled by the water level in Dover Harbour.

A figure representing the Mean High Water Level at Dover was supplied Dover Harbour Board for use within this assessment and can be seen in Figure 2-3, overleaf. All other relevant tidal information used within the model is located within Table 2-3: Sources Of Tidal Information, below.

Table 2-3: Sources Of Tidal Information

Data type*	Source	Date Rec'd
MHWS tidal peak levels	The Environment Agency	26/06/2009 (email correspondence with Peter Blackmore) and
Other tidal peak levels	JBA Extreme Sea Level report (2004)	The tidal peaks provided in this report are for the year 2000
Recorded tidal data	The Environment Agency	29/04/2009

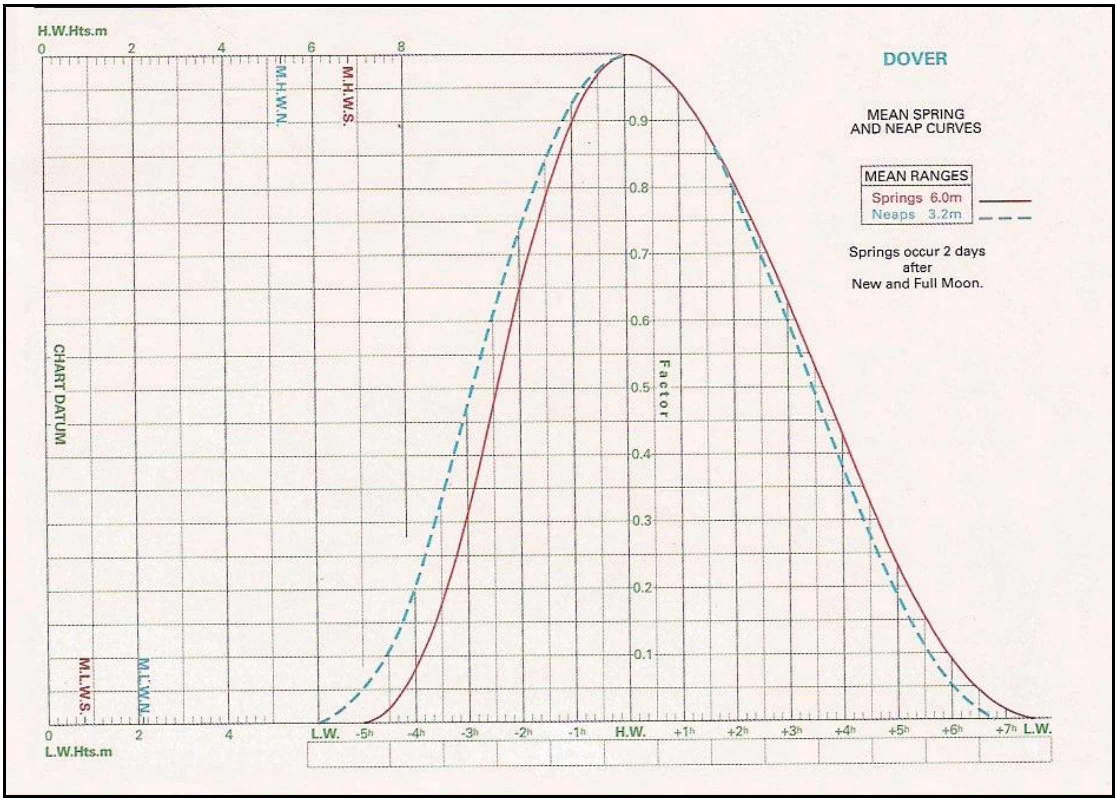


Figure 2-2: Tidal Curve For The Port Of Dover

It was agreed with the Environment Agency that, based on the operational rules provided by the Dover Harbour Board, a modified tidal curve can be utilised as the downstream boundary for the model. The tidal curve is based on recorded tidal data at Dover provided by the Environment Agency. The curve is 'levelled off' at 1.16mAOD to represent the operational rules for maintaining the 1.16mAOD water level in the dock. The tidal curve used in the model is shown in Figure 2-3: Tidal Boundary Applied To Downstream Extent Of The Hydraulic Model, over leaf.

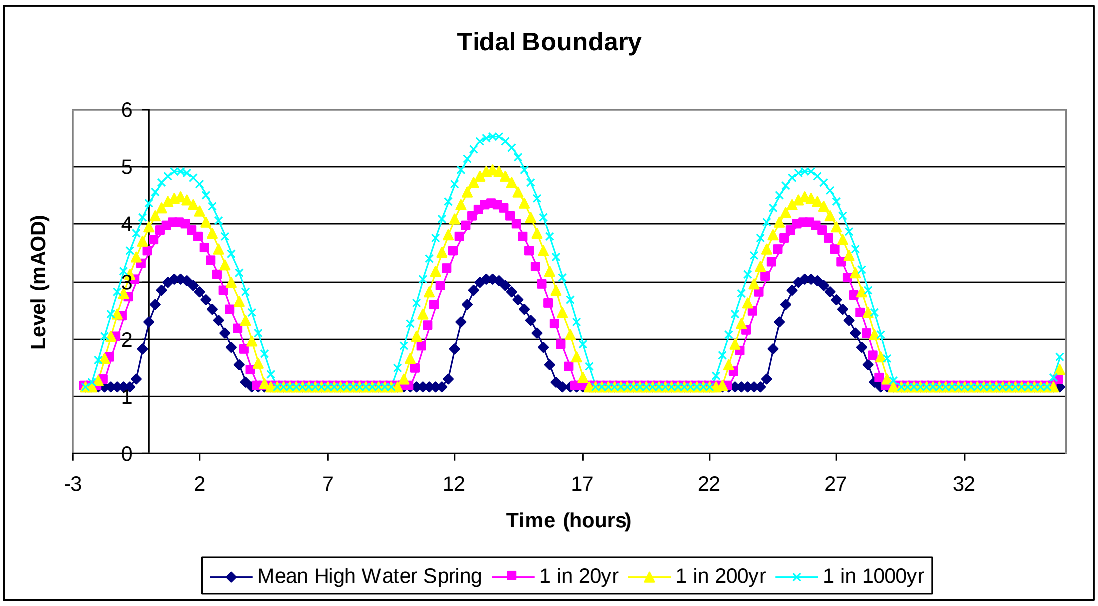


Figure 2-3: Tidal Boundary Applied To Downstream Extent Of The Hydraulic Model

Tidal Surge

A tidal surge (72 hours utilised in the calculation) was calculated for this downstream boundary. The tidal cycle has been lagged to ensure that the peak of the event coincides with the peak of the fluvial event within the River Dour, adjacent to Mid Town Dover. This surge can be identified in Figure 2-3: Tidal Boundary Applied To Downstream Extent Of The Hydraulic Model, above.

Climate Change

Sea level rise was calculated in accordance with the guidance developed by The Department for Environment, Food and Rural Affairs (DEFRA) report titled *FCDPAG3 Economic Appraisal Supplementary Note to Operating Authorities – Climate Change Impacts* and Table B.1 of PPS25. The tidal peak levels for Dover were obtained from the JBA Extreme Sea Level Analysis – Kent, Sussex and Hampshire, 2004, contained data calculated for the year 2000. Advice provided from the Environment Agency was to de-trend the tidal peaks to the year 1990 then calculate sea level rise to a horizon year of 2115 (105yrs from time of construction of 2010) in accordance with guidance provided within PPS25.

Sea level rise calculations using the DEFRA guidance yielded a net increase of 1.17m. The variation in peak tidal levels is shown in Table 2-4, below.

Table 2-4: Calculated Peak Tide Levels

Tidal Event	Peak Tidal Level: Year 2000 (mAOD)	Peak Tidal Level plus Climate Change: Year 2115 (mAOD)
MHWS	3.01	4.18
20	4.30	5.47
200	4.90	6.07
1000	5.50	6.67

2.5 Materials

The Manning's roughness values used within the model were assigned to each cell within the 2D floodplain are stated in Table 2-5: Manning's n Values Applied Within The Hydraulic Model. Each material type was assigned a roughness value based on the Feature Code attribute within Mastermap data provided by Dover District Council. The Manning's roughness value adopted for each material type has been determined with reference to a number of established reference works including Chow (1959) and Hicks & Mason (1998).

Table 2-5: Manning's n Values Applied Within The Hydraulic Model

Feature Code	Material Type	Manning's n
10021	Buildings	0.500
10053	Land	0.050
10054	Land	0.025
10056	Land	0.040
10062	Buildings	0.500
10076	Heritage And Antiquities (manmade)	0.500
10089	Water	0.030
10096	Manmade embankment around ponds	0.030
10111	Land (thick vegetation and trees)	0.080
10119	Roads Tracks And Paths	0.030
10123	Roads Tracks And Paths	0.030
10167	Rail	0.050
10172	Roads Tracks And Paths	0.025
10183	Roads Tracks And Paths	0.025
10185	Roads Tracks And Paths	0.030
10187	Structure (manmade)	0.500
10217	Land (hard standing)	0.035
10203	Foreshore	0.035

The Manning's roughness values assigned to the channel of the River Dour was 0.038 for the channel bed. This was derived from site visits, photos, and with reference to works including Chow (1959) and Hicks & Mason (1998).

The definition of buildings has been carried out differently between the fluvial (only) model and the combined fluvial and surface water model. The methodology for modelling the building pad in the surface water model is discussed within Section 5.2 of this report.

For the fluvial only assessment, buildings within the floodplain are not modelled with raised building pads, but instead as areas with high roughness values. This assumption was made on the basis that whilst buildings impede flow, they are generally permeable and water will gradually permeate through and be stored in the structure. Therefore by reducing flow rates through these areas by increasing the Manning's n roughness value, the general flood behaviour is modelled appropriately.

3 BASE MODEL SCHEMATISATION

As part of this commission, it was necessary to assess flooding from both fluvial, tidal (outside of the original scope of works but requested by the EA) and surface water sources. In order to provide an accurate assessment of the flooding mechanisms from each source of flooding (fluvial and tidal), it was determined that two baseline models were required for isolating these sources.

The hydraulic model also assessed several mitigation measures, which are discussed in more detail within Section 6 of this report.

The baseline scenarios considered are listed in Table 3-1.

Table 3-1: Baseline Scenarios Modelled

Fluvial Event	Rainfall Event	Tidal Event	Scenario
20	-	MHWS	Fluvial (defended)
100	-	MHWS	Fluvial (defended & undefended)
100CC	-	MHWS + SLR	Fluvial (defended & undefended)
1000	-	MHWS	Fluvial (defended & undefended)
5	-	20	Tidal (defended & undefended)
5	-	200	Tidal (defended & undefended)
5	-	1000	Tidal (defended & undefended)

3.1 Software

The hydraulic model has been run using the latest version of the TUFLOW software at the time of construction: TUFLOW.2008-08-AH-iDP. The "double precision" version of the software was used as the TUFLOW manual recommends the use of this version where elevations exceed 100m and when creating surface water models.

3.2 Model Extent

The upstream extent of the model is located at Minnis Lane, with the downstream extent located at the outfall of the River Dour into Wellington Dock.

3.3 Grid Cell Size

The grid cell size utilised within the 2D domain is 5 metres.

3.4 Zpts

Figure 3-1: Processed DTM illustrates the final processed DTM that is utilised within the baseline model (i.e. original LiDAR based DTM plus any changes as identified).

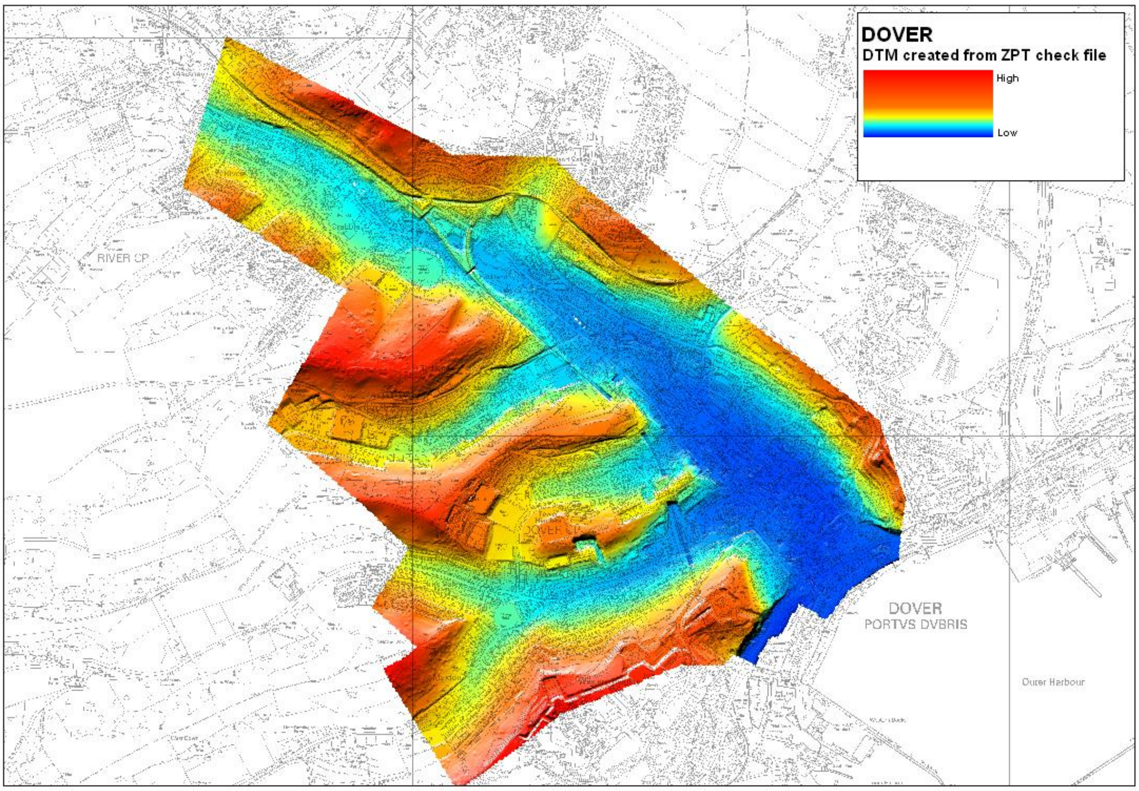


Figure 3-1: Processed DTM

3.5 Materials

Figure 3-2: Visualisation Of The Materials Definition illustrates the materials definition layer for the whole modelled area (refer to Table 2-5: Manning's n Values Applied Within The Hydraulic Modeller material types).

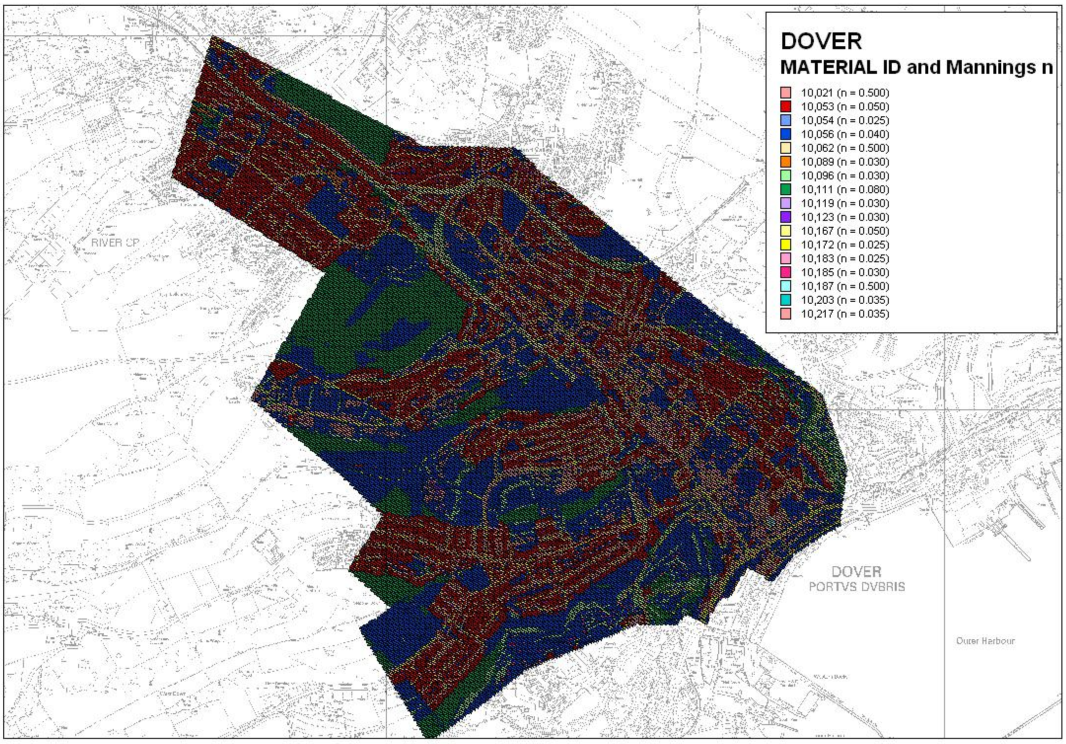


Figure 3-2: Visualisation Of The Materials Definition Layer

3.6 Open Channels

The River Dour watercourse has been modelled in 1D (ESTRY) whilst the floodplain has been modelled in 2D (TUFLOW).

Ninety-eight cross-sections along the River Dour were surveyed along the 4.2km stretch of the watercourse. Some interpolate channels have also been included within the model. These were necessary in order to provide a link between the River Dour and the modelled drainage network.

3.7 Channel Banks

The channel banks have been defined with additional z-lines to ensure that these are depicted correctly. Survey information, LiDAR and aerial photography were used to create the z-lines. The z-lines contain z-points at every channel cross-section with additional z-points located where the distance to cross sections exceed 50m, and where bends are located within the river.

<u>Structures</u>

The River Dour model includes a large urban area and consequently contains many structures. All structures included in the Environment Agency's 2005 survey have been included as well as the additional structures surveyed by JC White in June 2009. This includes 27 culverts, 9 weirs and 11 bridges.

The culverts have been defined as 'rectangular', 'circular' or 'irregular'. The rectangular and circular culverts are defined within the network layer using their known dimensions. The irregular culverts are defined with height vs. width tables that depict their irregular shape. There are a number of multiple opening culverts. These have been modelled as one opening with the opening areas totalled to represent this appropriately. Note that for sensitivity purposes, two of these structures were modelled as multiple openings to determine any differences within the two methods for culvert representation. These structures were; the triple opening structure beneath Lower road and the most upstream double opening railway bridge. This analysis showed that there were minimal impacts on either flow or water level as a result of this change, with either no change or less than 1% increase in values. Due to the minimal discrepancy between the two model results the single opening representing the multiple culverts has been used in this assessment.

The bridges have all been defined with the use of height vs. width tables with their coefficients defined within the BG table. The bridge loss coefficients have been calculated based on theory in 'Hydraulics of Bridge Waterways[1].

There are nine weirs located along this reach of the River Dour. These weirs range in height from 0.25m to 3.1m, the largest being located at Crabble Mill.

3.8 Inflows

Inflows into the model are listed in Table 3-2. For more information, refer to section 2.3:

Table 3-2: Hydrology Inflow Applied To The Hydraulic Model For Different Events

Event Name	Description
20year fluvial return period	FEH hydrographs of 17hr duration
100year fluvial return period	FEH hydrographs of 17hr duration
1000year fluvial return period	FEH hydrographs of 17hr duration

There are six inflow boundaries included in the fluvial model which are spread out along the river (refer to Figure 2-1). For the surface water model one of these inflows ('Buckland Trib') has been removed and a hyetograph has been applied to the lower area of the catchment, as identified in Figure 5-2.

3.9 Additional Boundary Conditions

A tidal boundary was applied at the downstream end of the 1D component of the model. The same boundary was applied in the 2D component of the model and is snapped to the edge of Wellington Dock. Refer to Section 2.4 for details of the boundary. The sources of tidal data used within this model are identified within Table 2-3: Sources Of Tidal Information and Table 3-3: Source Of Tidal Data of this document.

Table 3-3: Source Of Tidal Data

Location	Description*	Source	Description of modifications made
At the downstream end of the River Dour and along Wellington Dock	Tidal Boundary	JBA Extreme Sea Level Report (2004)	As explained in section 2.4 of this report.

[1] 'Hydraulics of Bridge Waterways', US Federal Highway Administration, 1978

4 BASE MODEL STABILITY AND UNCERTAINTY

4.1 Stability

The model was started at -2 hours to allow for the tidal boundary to become established and produce initial conditions for the model prior to the inflow hydrographs being applied. This has aided in the initial stability of the hydraulic model.

The model is considered to be reasonably stable with only two warnings occurring during the model simulation. These warnings are caused by negative depths occurring prior to the start of the simulation, at approximately -1 hours, just upstream of Buckland Bridge.

4.2 Uncertainty within the model

There are two structures within the hydraulic model with uncertainties associated with them: Crabble Mill and the outfall culvert into Wellington Dock.

Crabble Mill

Crabble Mill is a complex structure that consists of a large lake immediately upstream of the Mill, with a number of weirs for water from the lake to overtop. The main weir is located between the public house and a private residence. This weir is irregularly shaped but had only been surveyed perpendicularly, and therefore the length of the weir was not recorded. This length was estimated with the use of Mastermap Information.

Another uncertainty with Crabble Mill was an additional weir that is located adjacent to the private residency. This weir is connected to a culvert that flows beneath the property and rejoins the watercourse downstream of the main weir. Details of this weir and culvert were not surveyed; their dimensions were estimated with the use of site photographs.

There is also uncertainty associated with the weir adjacent to the right bank of the lake and the public house at Crabble Mill. Traditionally water flowed over this weir into a water wheel to produce power. However, this route has been closed off. During a site visit the owners of the public house indicated that water from the lake no longer overtops the weir. A decision was made to include this flowpath in the model as it may potentially become active during an extreme event. The level of this weir was unknown and has been estimated by using site photograph’s, distomat and LiDAR information of the nearby road.

Wellington Dock

There is also uncertainty associated with the culvert that discharges the River Dour into Wellington Dock (the downstream boundary of the model). No survey was conducted of the downstream face of the structure as it is permanently submerged due to the maintained water level within the Dock being above the obvert of the structure. Dover Harbour Board have provided a drawing of the culvert where it is depicted as an arch opening, but contains no details. Dimensions of the downstream face of this culvert have been assumed. As the downstream boundary is a Head vs. Time boundary, with the minimum head known to always be above the soffit of the culvert, i.e. it is always submerged, the exact dimensions of the downstream face are not thought to have an impact on results.

4.3 Comparison of Hydraulic Models

PBA produced a hydraulic model of the River Dour as part of a CFMP in 2007 for the Environment Agency. Due to the relative size of the project the iSIS model is more broadscale than the ESTRY-TUFLOW model developed by Capita Symonds Limited. The iSIS model was also observed to ‘glass wall’ within several sections of the model. This occurs when the calculated water level exceeds the highest elevation in the cross-section. The storage capacity of the channel is often under-estimated resulting in an over-estimate of water level at that location.

The results from the detailed ESTRY-TUFLOW model have been compared to results from the PBA iSIS model for the 1 in 20 year, 1 in 100 year and 1 in 100 year with an allowance climate change event. Graphs representing water stage and flow at seven locations throughout the model have been plotted and are contained in Appendix A. Location plans of these cross-sections is also contained within Appendix A.

At all cross-sections for all return periods the flow measured in the 1-dimensional channel in the ESTRY model and the PBA iSIS models were observed to be similar.

The water level results vary at the different nodes within both models. The differences in these results are attributed to the CSL model containing both 1-dimensional (ESTRY) and 2-dimensional elements which represents out of bank flooding more accurately. Another key difference between the two models is that the CSL model contains several structures along the River Dour that were not included in the PBA model, as well as additional survey that was carried out in June 2009.

The water levels at DOV_4048 and DOV_2753 are higher in ESTRY model than recorded in iSIS for all return periods. These differences are attributed to bridges located immediately downstream of these cross-section that were not included in the iSIS model. This results in a restriction in the channel that causes water to 'back-up' upstream of the bridge.

Water levels recorded at DOV_3777 were higher in the iSIS model. This is a result of out of bank flooding in the CSL model that flows into the 2-dimensional element (Tuflow) and is therefore not recorded in ESTRY.

The water levels recorded at DOV_2753 and DOV_1876 differ between the iSIS and ESTRY results. A bypass channel runs parallel to the River Dour at this location. This has been modelled in the ESTRY-TUFLOW model however has not been included within the iSIS model.

Water levels recorded at DOV_1021 and DOV_0575 are higher in the iSIS model in comparison to the ESTRY results. This is due to the large amount of water that is able to flow out of bank and into the floodplain in the ESTRY-TUFLOW model. This flowpath is not included in the iSIS model which glass-walls in this area resulting in an overestimate of peak water levels.

4.4 Verification of Hydraulic Model (June 2007 event)

Rainfall data from three 15-minute tipping bucket recorders local to Dover were provided by the EA (for the June 2007 event), along with water level and flow data recorded at a gauging station in Pencester Gardens. This data has been analysed to assist in the verification of the model and to assist in determining the flood event that occurred on the 19th June 2007.

The rain gauges that were analysed are located at Dover (TR 32170 42023), Temple Ewell (TR 28301 44416) and Lower Standen (TR 24107 40465). The depth of rainfall and the duration of the event at each station was calculated with the relevant information and then inputted into the FEH CD-ROM depth-duration-frequency (DDF) model to establish the relevant return period of the events recorded at each station. These events have been established as:

- 1 in 17 year for the Dover rain gauge, located to the northeast of the Mid Town Dover (approximately 350m away from the site);
- 1 in 14 year Temple Ewell rain gauge, located approximately 1200m northwest of the first modelled cross-section; and
- 1 in 46 year events respectively, Lower Standen is located outside of the River Dour catchment, approximately 8km west of the Mid Town Dover site.

The baseline results from the Dover hydraulic model were investigated for the 1 in 20 year and 1 in 100 year events adjacent to the site of the flow gauge in Pencester Gardens. The recorded water level for the June 2007 event was determined to be greater than the 1 in 100 year event level recorded by the hydraulic model. However, this is inconsistent with the rainfall events determined by FEH. The possible causes (or combination of events) for this variation are:

- Lack of bank survey in the area near the Pencester Garden gauging station. The recorded level at the gauging station in Pencester Gardens is approximately 0.3m greater than the river banks depicted by the model. To enable a more accurate verification of the model it is recommended that a bank survey is undertaken along this reach of the River Dour, specifically adjacent to Pencester Gardens. Currently river levels are unlikely to reach the recorded level within the hydraulic model as the river would exceed its capacity and excess flows would overtop the banks and flood Pencester Gardens and other properties in the area prior to reaching the level identified within the gauged data;
- It is also possible that a significant tidal event occurred during this rainfall event which may have influenced the capacity within the river and increased flood levels within this area. A review of the tidal scenarios run for the model indicate that this area can be influenced by tidal levels within Wellington Dock;
- Blockage of the downstream culvert may have occurred which would also create a backing up effect and increase flood levels; or
- There may be errors contained within the gauged information and/or the accuracy of the gauge deteriorates during extreme events.

4.5 Model Sensitivity

Table 4-1 (overleaf) identifies the sensitivity tests that have been undertaken for the model. Appendix B identifies the results of sensitivity analyses in a tabulated format. The table aims to highlight the change in depth and the percentage change in depth from the base case. In the case where the results show a percentage change in depth less than the percentage change in input factor, this is then deemed to have a negligible effect on the model.

Table 4-1: Sensitivity Tests Undertaken And Results

Sensitivity parameter	Percent change	Results (refer below for details)
Inflows	± 20%***	Minimal impact on water levels but changes to flood extents apparent
Roughness	± 20% in 1D and 50% 2D**	Minimal impact on water levels and minor effect on flood extents
Blockage of culvert DOV_0782	50% blockage	Minimal changes in water levels but noticeable change in flood extents
Blockage of culvert DOV_1537	50% blockage	Only impact on water levels immediately u/s and within the culvert, with no change to the flood extents

** Two runs to test the sensitivity of the model to roughness have been made. The first has an increase in roughness of 20% in the 1D component of the model and 50% in the 2D, the second has a decrease of 20% in the 1D and 50% in the 2D.

***This figure incorporates both the sensitivity of the model to possible inaccuracies in hydrograph prediction and for climate change.

+/- 20% in Flow

The input hydrographs applied along the River Dour were increased and decreased by 20%. As can be seen in the results, this has had a negligible effect on water levels in the 1D for the majority of the River's reach, with the exception of stage in the bypass culvert at Crabble Mill, located beneath the building on the south-eastern side of the lake. For the scenario of the flows decreased, the 1D stage results were affected minimally, with the only significant changes occurring through the culvert beneath Halford's carpark, at the upstream extent of the model and in the bypass channel upstream of Lorne Road.

Flood extents of these two scenarios were also produced and compared with the baseline extent. For the scenario involving an increase in inflows there was an overall increase in the general flood extent. This was particularly noticeable at the top of the model just downstream of Common Lane, where an additional flowpath is created, overtopping the left bank upstream of Buckland Bridge and flowing down Crabble Hill and now flooding the properties on Brookfield Place. There is also a significant increase in flood extent upstream of Lorne Road and in the Dover Mid Town area, especially adjacent to Pencester Gardens. For the scenario where the inflows were decreased the River generally now remains in bank, apart from small areas of flooding in the Mid Town area, the area adjacent to Lorne Road and Cherry Tree Avenue, upstream of Buckland Bridge, upstream of Crabble Road and in the properties on Lower Road at the top of the model. In all these areas of flooding the extent has reduced, with the flowpath along Charlton Green, which usually enters the Mid Town area, no longer occurring.

+/- 20% Roughness (1D) and +/- 50% in Roughness (2D)

The tabulated results in the attached spreadsheet show the change in water level as a result of an increase/decrease in Manning's value. No noticeable change is apparent when this parameter is increased or decreased.

When considering the flood extents of the two scenarios in comparison to the baseline extent there is also minimal difference. When the Manning's value has been decreased the extent remains almost the same, with a slight reduction in the extent in Mid Town Dover and the removal of a flowpath located adjacent to Alfred Road. For the scenario with the Manning values increased the extent is similar to the baseline, with the flooding along Lower Road increased, with an additional flowpath along Buckland Avenue and into Lorne Road. The flooding in the Mid Town area is also increased, with the flooding of additional properties on Maison Dieu Road, with a new flowpath forming which crosses Pencester Road and flooding properties on the left bank of the Rover Dour adjacent to Pencester Gardens.

50% Blockage of DOV_0782 Culvert

The 1D results show that the blockage of the culvert at the downstream end of the Mid Town area, beneath Pencester Gardens (DOV_0782) has a negligible effect on water.

The flood extents for this scenario, when compared to the baseline, show no change for the majority of the model, with the Mid Town area experiencing an increase in flooding. For this scenario a larger area of Mid Town floods, as well as a greater number of houses on Maison Dieu Road, and an additional flowpath created flowing over Pencester Road into the Bus Station and further down Maison Dieu Road.

50% Blockage of DOV_1537 Culvert

The 1D results show that the blockage of the culvert downstream of the weir at Halford's (DOV_1537) has a negligible effect on water levels for the majority of the river reach, and only effects levels directly upstream and within the culvert itself.

The flood extents for this scenario are the same as for the baseline model. The water levels for this scenario have increased upstream and within the blocked culvert but these are retained within the river banks.

5 SURFACE WATER MODEL

A requirement of the modelling exercise was to investigate surface water flooding in the Mid Town area of Dover, with particular focus on the study area. The baseline model has been developed to incorporate the surface water network into the model but does not include the combined Southern Water surface water drainage network.

5.1 Model Development

Piped Network

In order to understand the runoff characteristics from the surface water network, a 4.8km^2 (predominantly urban) catchment has been modelled which includes South Waters surface water sewer network being modelled with ESTRY (the manhole and pipe data was provided by Southern Water). The ESTRY representation of the surface water network includes 694 pipes (with a total length of 28.9km) and 683 manholes. All the pipes are gravitationally drained with no pumps or rising mains located within this portion of the surface water network.

With the limited information provided for the surface water network, silt has not been modelled in the surface water model as manhole surveys were not available. The pipe roughness (Mannings n) is assumed to be constant (0.015) over the surface water model. The entry and exit loss coefficient are assigned default values of 0.5 and 1 respectively. The ground levels of 50 manholes were not provided in the dataset and therefore there elevations were estimated from the LiDAR data.

Long section verification checks have been undertaken for the modelled surface water network. These checks verify that the pipe size and invert levels are consistent along the pipes upstream and downstream extent and identifies errors from the given dataset. The outfall levels and pipe sizes have been verified by site photographs and site survey (where available).

Continual and Initial Losses

Initial and continuing losses have been assigned to the design storm in the combined fluvial and surface water model. The initial loss determines the amount of water lost when the water first lands on the ground. The continual loss determines the amount of additional water lost during the rainfall event, water that infiltrates into the ground. These values can be specified by materials types and are applied, like Manning's n values, in the TUFLOW materials file. The initial and continuing loss values used in the Dover surface water modelling are based on our previous experience of direct rainfall modelling in Australia. The guidance used is called Australia Rainfall and Runoff[2]. Table 5-1 shows the initial and continual losses values that have been used for the surface types.

These values are dependent on soil types, which would be different in Australia, compared to England due to the varying climates. However we are not aware of any UK based guidance available that provided the choice of initial and continuing losses for models such as this. The initial loss value is a depth in mm, this value is deducted from the design storm before it is applied to each cell in the model. The specified depth of water is removed from the rainfall hyetograph applied to each cell at the beginning of the model run. Water continues to be deducted from the cell until the total specified is removed. Once initial losses are accounted for, the continuing loss value is applied within the model. The continuing loss represents the infiltration rate of the soil and is applied as mm/hour.

Table 5-1: Initial And Continual Loss Values Applied In The Surface Water Model

Surface Type	Initial Loss	Continual Loss (mm/hr)
Permeable Surface (eg. Grass, parkland, riparian vegetation, dense vegetation, urban areas, bare earth, low-level foliage)	10	2.5
Impermeable Surfaces (roads, railways, open concrete, buildings, harbour, dams, and water)	0	0

5.2 Building Pad Threshold Schematisation

In order to determine the influence raised building pads will have within the model, the following approach has been used for the representation of buildings in the Dover surface water model.

- A GIS layer containing the locations of all buildings has been created based on the buildings polygons in the OS Mastermap dataset;
- The LiDAR DTM has been interrogated to obtain an average 'bare earth' ground level for each building polygon. This average ground level has been applied to the building polygons to give them their base elevation in the Tuflow model;
- The building polygons have been raised a consistent 250mm above their average 'bare earth' ground level to create stubby building pads (reflecting an average building threshold level).

[2] I.E.Aust. (1987). "Australian Rainfall and Runoff". Published by the Institute of Engineers Australia, editor in chief, R.P. Canterford, 2 Vols., 1987.

This ensures that the buildings form an obstruction to flood water and that shallow flows must pass round the buildings (and not flow through them).

- A high Manning's n value (n = 0.5) has been applied to the buildings to represent the high resistance that buildings have to flow. However, for very shallow depths of flow (up to 30mm) a lower Manning's n value (n = 0.015) is applied – this is to improve the presentation of results. The Tuflow model used is a direct rainfall model which applies a rainfall hyetograph to every active cell within the 2D model extent. This includes the cells representing buildings. The Manning's n value for buildings is reduced for these very shallow depths so that the flow which is created on buildings as a consequence of the application of direct rainfall is able to flow away from the building. If the Manning's n value was not reduced for these shallow depths, the rainfall applied to the building cells would pond here in an unrealistic manner.

This methodology can be visualised within Figure 5-1: Building Pad Methodology Used Within The Surface Water Modelling Scenario.

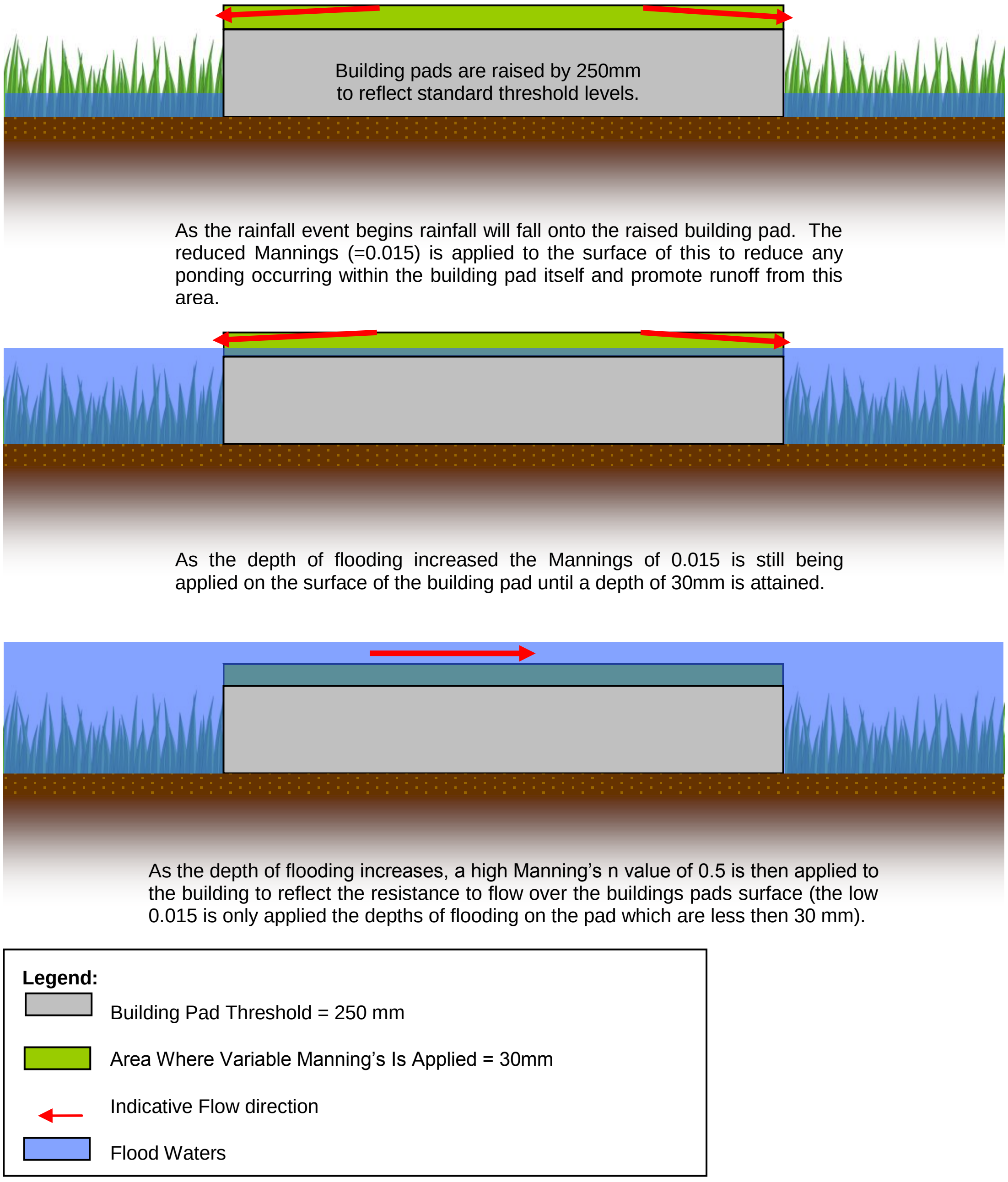


Figure 5-1: Building Pad Methodology Used Within The Surface Water Modelling Scenario

Hydrology

The hyetographs for the surface water analysis were calculated by:

- Obtaining a total rainfall depth of a certain event from the DDF modelling tool within FEH CD-ROM v2; and
- Then uniformly spreading the total rainfall depth over the 17 hour critical duration for the catchment, using the iSIS software.

The combined fluvial and surface water assessment, involved removing the hydrological inflow node furthest downstream ("Buckland Trib") and applying the calculated hyetograph to its assumed catchment (blue polygon) as shown in Figure 5-2.

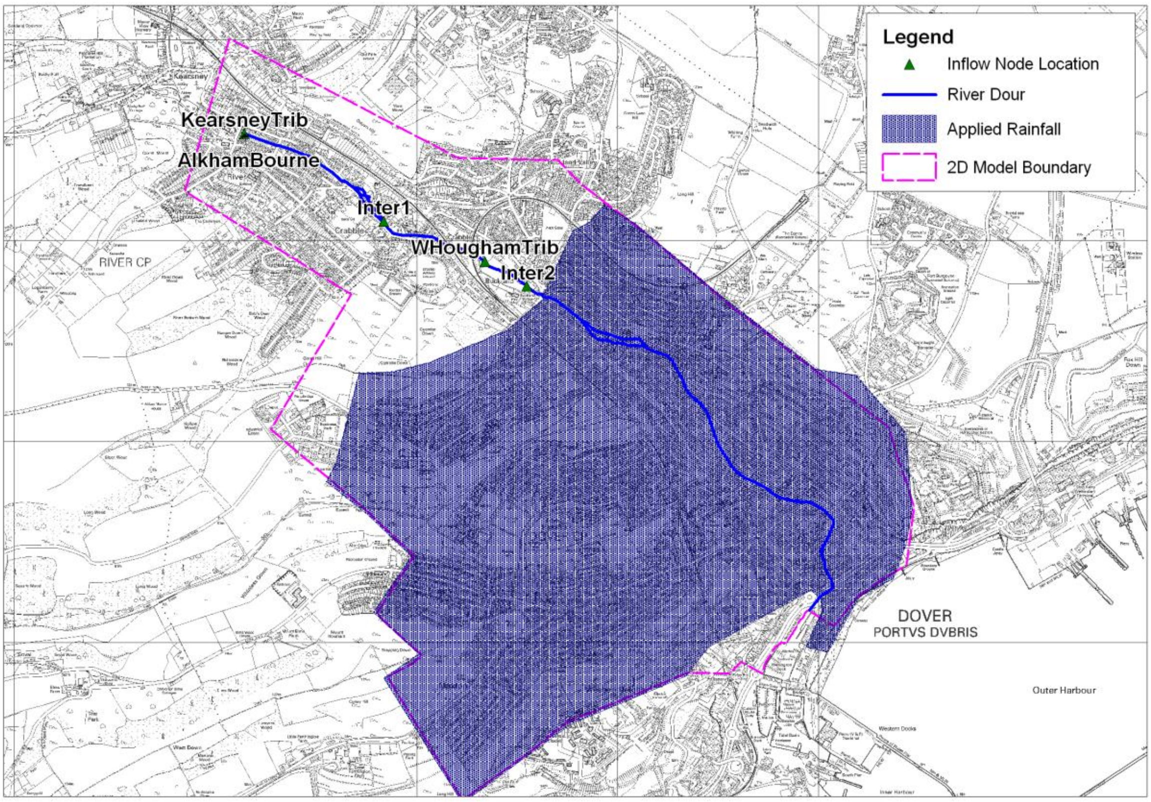


Figure 5-2: Area Of The Applied Hyetograph Used Within The Surface Water Model

5.3 Surface Water Scenario Runs

Several scenarios were modelled to provide a broad understanding of the flood mechanisms within Dover during a surface water flood event. The events are listed in Table 5.2..

Table 5-2: Modelled Surface Water Scenarios

Scenario	Fluvial Input	Tidal Boundary	Rainfall Input	Rainfall Duration	Surface Water Network Modelled
1	Baseflow	MHWS	Q100 – Q30	17 hours[3]	Excluded
2	Baseflow	MHWS	2 year event	17 hours	Included
3	1 in 10 year + CC	MHWS	1 in 100 year + CC	17 hours	Included
4	Baseflow	MHWS	Actual rainfall from June 2007 event	3.5hrs	Included

MHWS = Mean High Water Spring tide   CC = Climate Change

A brief explanation of the modelled scenarios is provided below along with the maximum predicted depths occurring at any time during the modelled event. Note that all flood depths have filtered out the first 10cm of flooding to provide greater clarity of the areas at risk of surface water flooding:

<u>Scenario 1</u>

- Scenario 1 is a theoretical model, rather than a test of the 'actual' risk of flooding. In accordance with Sewers for Adoption, surface water sewers should be designed so there is 'no flooding' during a 1 in 30 year return period event. Therefore by modelling a rainfall event that 'removes' a 1 in 30 year rainfall event from the 1 in 100 year rainfall event it is possible to understand what the reasonable current 'best case' flooding baseline may be, and compare this to the current modelling scenarios that include the surface water drainage network. It should be noted that this scenario was run with the drainage network removed from the hydraulic model.
- A review of the flood mechanisms indicates that rainfall within the local catchment, on the northern side of the Dour, tends to drain towards the site as it is located in the lowest part of the catchment and the portion of Maison Dieu Road north of the site conveys runoff into the site.
- Figure 5-3 identifies the maximum depth recorded during the model simulation.

[3] Based on catchment duration outlined within the Dour Hydrology report, prepared by PBA, 2007

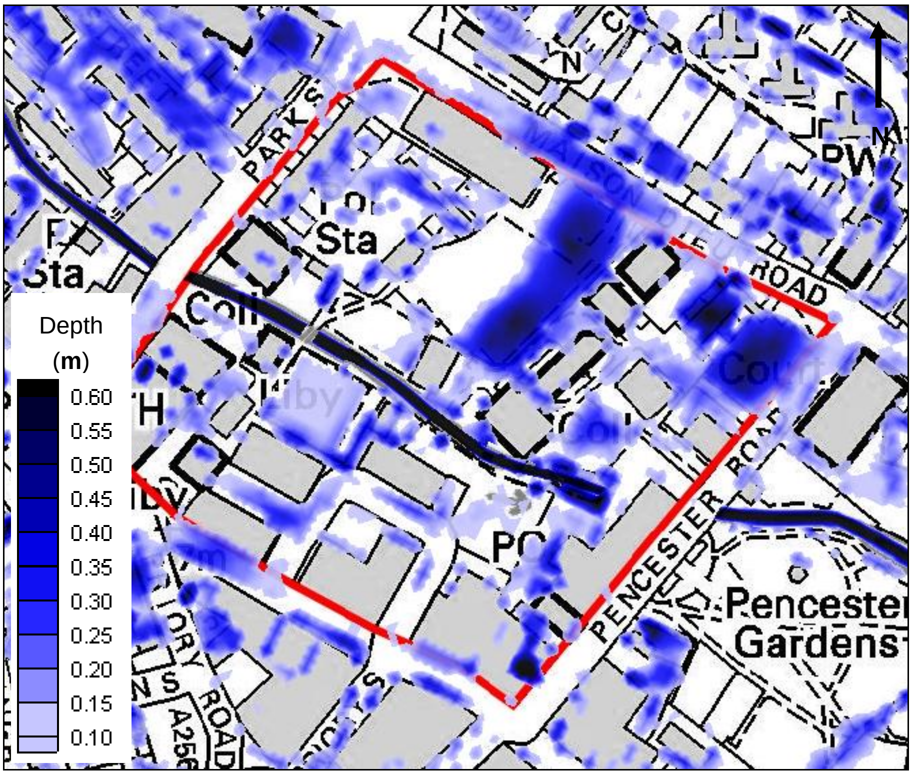


Figure 5-3: Maximum Flood Depths Predicted for Scenario 1

- Flood depths of up to 50cm are identified within the existing carpark on site as the topographical survey indicates that there is no drainage infrastructure to remove water from this area and as such it tends to pond instead of flowing into the Dour, or draining via the surface water network as other surface water runoff in the area does.
- It should also be noted that Maison Dieu Road and properties directly opposite of the northern boundary of the site, appear to be affected by surface water flooding due to the natural topography of the area. Flood depths on Maison Dieu Road are predicted to reach a maximum depth of 30cm (at its lowest point) but average around 10-20cm during the flood peak.

Scenario 2:

- This scenario was selected to identify the possible surface water flood mechanisms within Dover during a low return period event. This model incorporated the surface water drainage network but did not include the combined sewer network and as such is assumed to over predict the depth of flooding within the site.
- Flood mechanisms in this scenario are similar to Scenario 1, as it appears that the surface water that cannot drain into the surface water network are conveyed into the site down the roads (within the local catchment) and also drain into the site via the natural topography of Dover.
- Maximum flood depths predicted during the model simulation are shown on Figure 5-4.

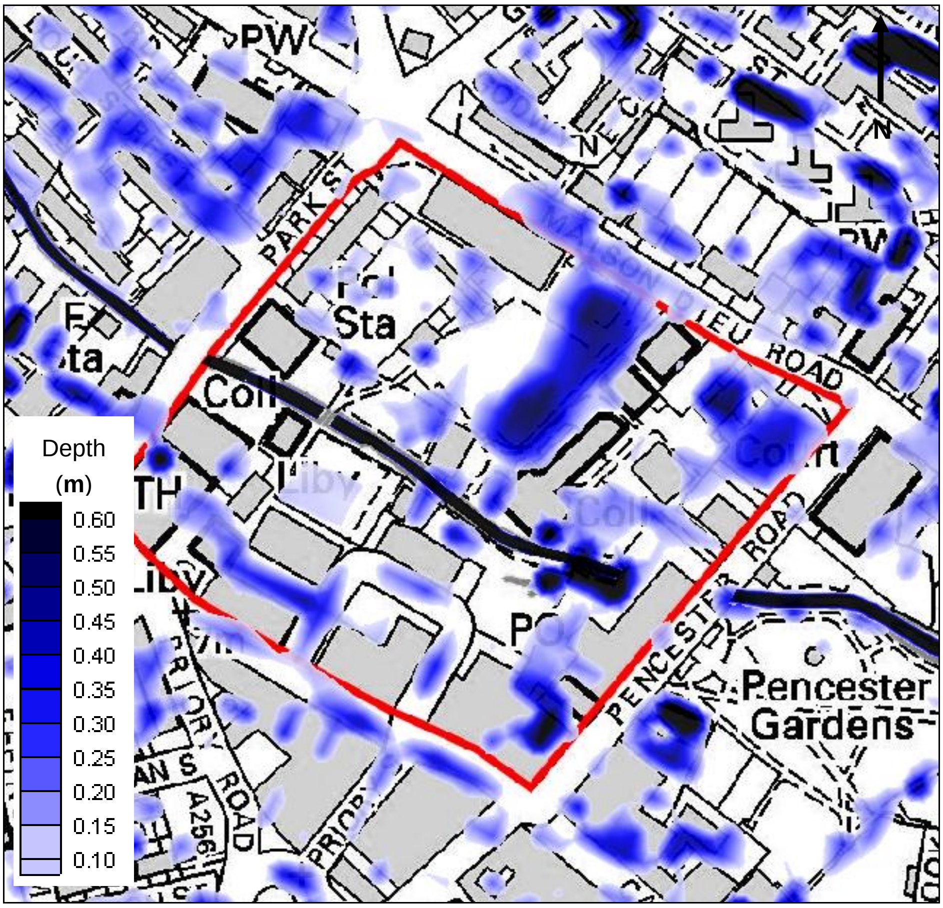


Figure 5-4: Maximum Flood Depths Predicted for Scenario 2

- Flood depths of approximately 20-30cm are predicted to occur within the site due to the carpark area not being able to drain to either the river or the nearby drainage network due to this part of the site lacking any formal drainage infrastructure.

Scenario 3

- This scenario was selected to identify the possible surface water flood mechanisms within Dover during an extreme rainfall event (1 in 100 year plus climate change rainfall event) within Dover. The surface water model incorporates the surface water drainage network but does not include the combined sewer network and as such it may over predict the depth of flooding within the site. This scenario is therefore considered the current 'worst case' flooding baseline, and adopting the 'precautionary approach' in PPS25, should be considered until improved data becomes available.
- Flood mechanisms in this scenario are similar to Scenarios 1and 2 as it appears that the surface water runoff that cannot drain into the surface water network is conveyed into the site down the roads (within the local catchment) and also drain into the site via the natural topography of Dover.

- An additional flood mechanism occurs within this scenario due to out of bank flooding caused by the additional volume of flood water entering the river (which flows at nearly bank full capacity). This additional flood mechanism can be clearly seen in Figure 5-5 below.

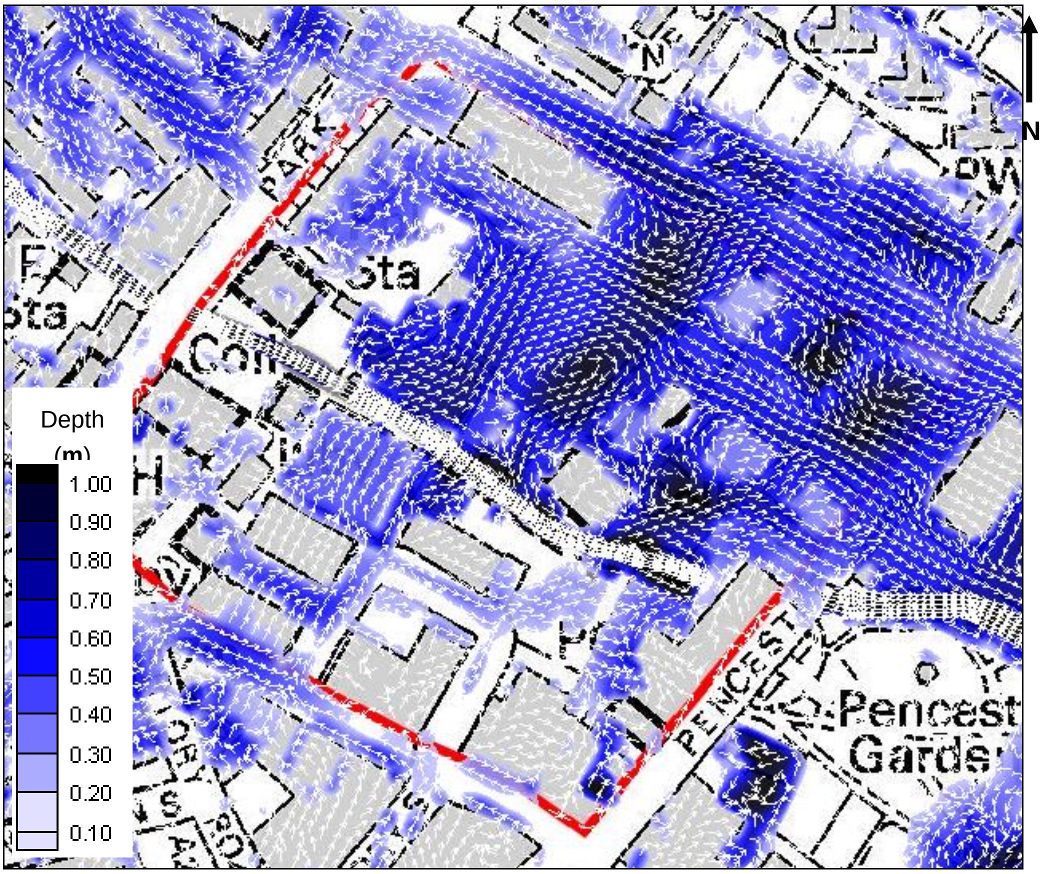


Figure 5-5: Flow Direction of Runoff Within Scenario 2

- The extent of flooding has increased in this scenario as a result of the volume of water draining to the site during the 1 in 100 year plus climate change event. Results from the integrated fluvial-surface water model indicate that flood depths of up to 90cm are predicted to occur within the lowest parts of the site (within the carpark area) and an extensive area of the site may be subject to flood depths ranging from 10 -50cm. Maximum flood depths predicted during the model simulation can be located within Figure 5-6.

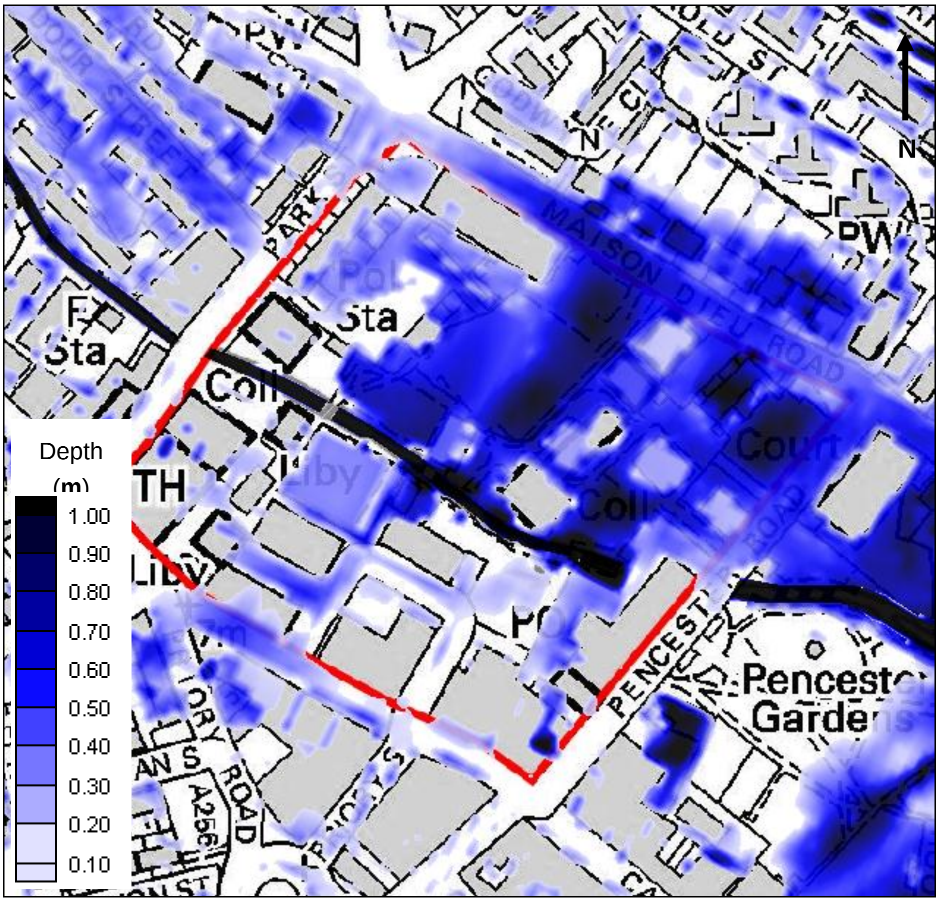


Figure 5-6: Maximum Flood Depths Predicted for Scenario 3

- The majority of the southern section of the site is not at a significant risk of flooding from this event with a small portion of Biggins Road receiving depths greater than 30cm for approximate 2.5hrs. Flood waters on Maison Dieu Road are predicted at being over 30cm (at the lowest part of the road) for approximately 5hrs of the model simulation and reach a maximum flood depth of 70cm.

Scenario 4

- Scenario 4 was selected to broadly calibrate the hydraulic model results by testing a recent high intensity rainfall event. This model incorporated the surface water drainage network but did not include the combined sewer network and therefore may over predict the depth of flooding within the site.

This scenario utilised actual rainfall obtained from the Environment Agency for the rainfall event recorded on the 19 June 2007. Records indicate that the storm lasted for approximately 3.5 hrs (staring at 5:45pm and ending at 9:15pm) and was equivalent to a 1 in 17 year return period.

- Figure 5-7 shows the actual rainfall recorded at the Dover WW rainfall gauge during the event.

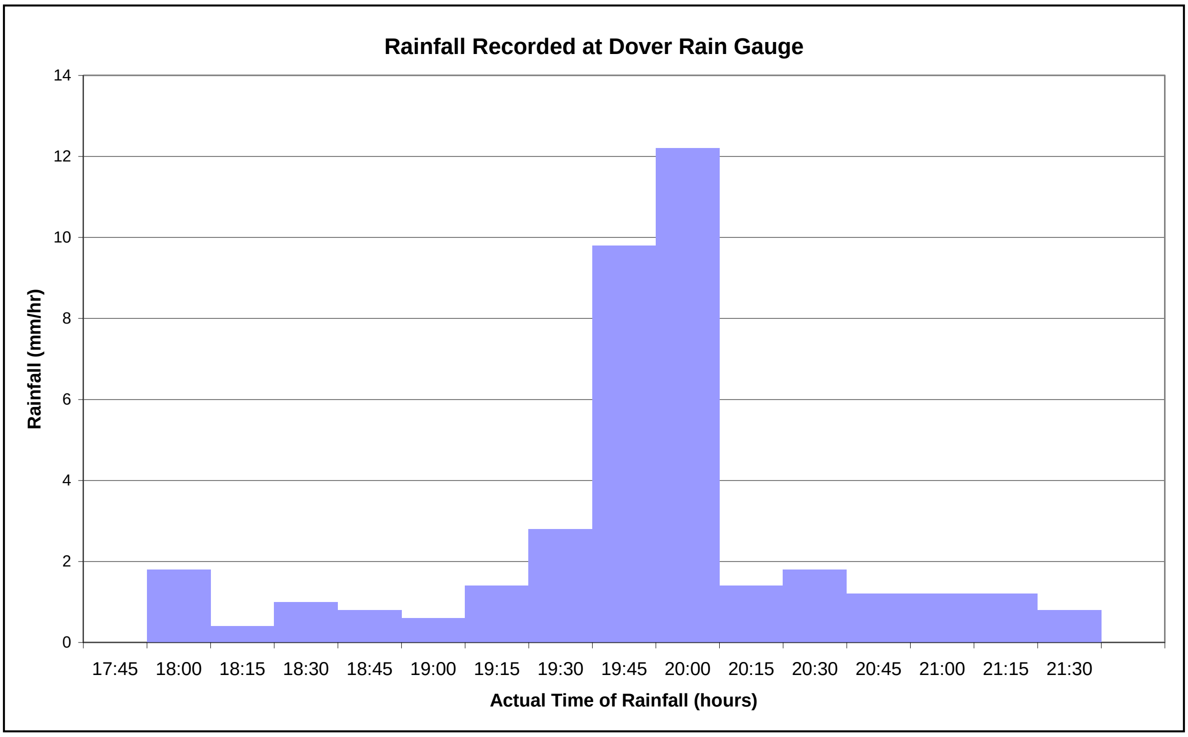


Figure 5-7: Actual Recorded Rainfall During 19 June 2007

- Modelled flood depths which occurred during this event can be found in Figure 5-8.

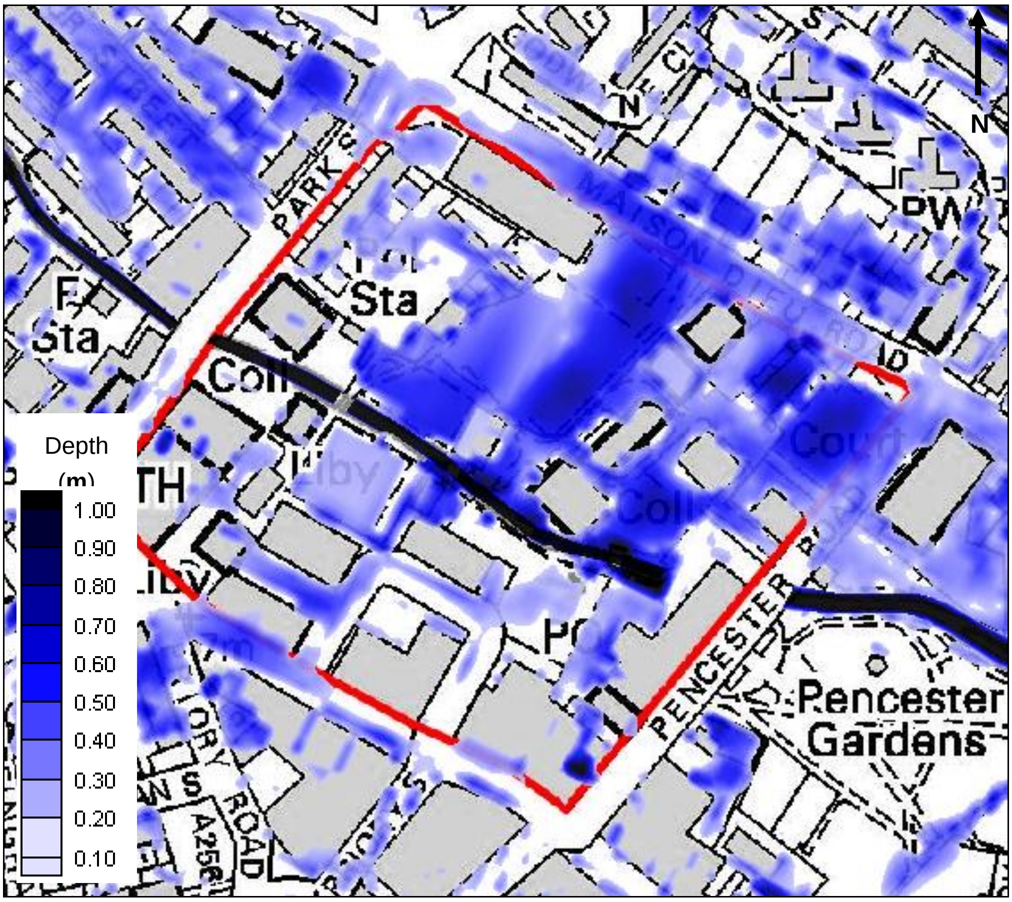


Figure 5-8: Maximum Flood Depths Predicted for Scenario 4

- A review of online information, evidence provided by Southern Water and anecdotal information provided by Dover District Council, clearly indicates that parts of the site were subject to flooding during this event with Figure 4.20 below showing some of the affects of the flood taken after the June 2007 storm event (exact date and time of photos are unknown).

Figure 5-9: Photos of River Dour within the Mid Town Site Taken After the June 2007 event. (Source: JBA consulting)

- The lowest portion of Maison Dieu Road (running parallel with the carpark) is below 30cm of flood water for approximately 1.75hrs of the model simulation. Anecdotal evidence provided in a letter to Southern Water (dated 24 July 2007 from Mrs Diane Finch) indicates that "*the drains in the road were not coping – as the evening progressed",* and that *"the road outside our guesthouse began to flood*". A review of the model simulation identifies a similar flood mechanism, due to the topography of the area.
- This letter also identifies that flood waters entered the property through the front and back basement doors and that cars driving along Maison Dieu Road sent 'waves' of water up the forecourt and into the property. A review of LiDAR levels in this location indicates that the forecourt appears to be approximately 15-20cm above Maison Dieu Road. This indicates that the depth of flooding was significant enough to exceed the existing property drains and enter the basement of the property, and was also deep enough on the road to send water above the driveway when cars travelled down the road.

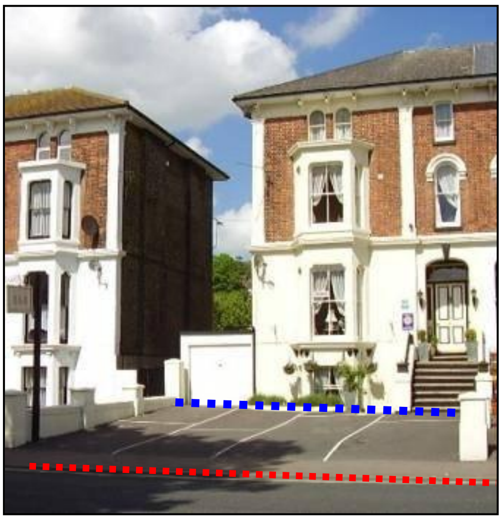


Figure 5-10: Frontage of Property affected in June 2007 (Source: http://www.maisondieu.com/)

- Figure 5.10, left, is an image of the front of the property in which it is clearly visible that the forecourt is in an elevated position (blue line), when compared to the road (red line).

- The model results indicate a maximum water level on the road in this location of approximately 15cm which when 'pushed' into the property by moving vehicles would cause flood waters to enter the basement. This further confirms that the results identified within the integrated model are a reasonable representation of the flood event which occurred in June 2007.
- The letter indicates that once a call was made to emergency services (time unknown) the drains began to clear within 20-30 minutes. A review of the model simulation indicates that once the maximum depth of flooding occurs near the site after 1 hour water on the road receded to an approximate flood depth of 5cm. Dependent upon the time of the call this could indicate that the surface water drainage network is not draining/removing runoff within the model as quickly as that which might occur if the combined sewer was included within the assessment. This could indicate that the model may slightly over predict depths and durations of flooded areas.
- Predicted flood depths within the land north of the river range from 20 – 40cm with the floodwater reaching approximately 70cm in the carpark during the peak of the flood. Levels within the carpark are determined to be above 40cm for approximately 3hrs of the model simulation.
- Model results indicate that the flood depths during the 2007 event may have been a result of overloaded drainage networks and out of bank flooding within the River Dour.

5.4 Additional Runs

Additional testing of hydraulic modelling was undertaken to understand the sensitivity of surface water flooding to both the capacity of the drainage network and influence of the River Dour, these included testing the 1 in 30 year rainfall event and reducing rainfall volumes by 20%, 30% and 50%, as detailed in Table 5-3. Results from these tests provide confidence in the model results presented below, as the mechanisms for flooding from the sensitivity tests were very similar to the selected scenarios identified within Table 5.3.

Table 5-3: Additional Surface Water Scenarios

Scenario	Fluvial Input	Tidal Boundary	Rainfall Input	Rainfall Duration	Surface Water Network Modelled
5	Baseflow	MHWS	Q30	17 hours[4]	Included
6	Q10	MHWS	80% of Q100	17 hours	Included
7	Q10	MHWS	70% of Q100	17 hours	Included
8	Q10	MHWS	50% of Q100	3.5hrs	Included

Testing 1 in 30 year Event

This scenario was undertaken to test the effect of the 1 in 30 year rainfall event on flooding in the Mid Town area, with no influence from fluvial or tidal sources, this surface water scenario was run with a Mean High Water Spring tide level at the downstream boundary, and all inflow hydrographs set to baseflow levels. The baseflow levels were extracted from the PBA iSIS model.

The results from this run show that the surface water flooding causes significant flooding to the Mid Town study area, independent of fluvial or tidal influences. This scenario shows flooding peaking at 55cm depth within the carpark in the study area, with the water remaining above 50cm for more than 10 hours (due to the lack of site drainage in this area).

Reducing Rainfall Volume

The hyetograph inputted into the model was tested by reducing rainfall amounts by 20%, 30% and 50% (this scenario includes the Southern Water surface water drainage network). These scenarios were run for sensitivity purposes, as one of the reduction amounts may reflect the benefit of the combined sewer on surface water flooding results.

[4] Based on catchment duration outlined within the Dour Hydrology report, prepared by PBA, 2007

A reduction of the rainfall volume by 20% leads to a maximum flood depth of 78cm in the carpark, with depths greater than 50cm for 8.5 hours. A 30% reduction created flood depths greater than 50cm for 7.75 hours, peaking at 76cm; with a reduction of 50% resulting in a maximum depth in the carpark of 63cm.

These results represent the potential reduction in flooding that could occur if the combined sewer was present in the model and therefore providing a closer representation of existing conditions. This indicates that surface water flooding will still be a significant issue to the Mid Town area, even if the combined sewer is accounted for.

5.5 Comparison of Results

The maximum depth results of all eight different surface water scenarios discussed in this chapter are tabulated in Table 5-4. These results have been recorded at various points across the study area, as shown in Figure 5-11.

Table 5-4 Comparison of Maximum Depth Results

Point ID	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8
1	0.11	0.11	0.32	0.11	0.20	0.11	0.11	0.10
2	0.12	0.12	0.60	0.39	0.40	0.48	0.39	0.29
3	0.11	0.11	0.11	0.11	0.10	0.11	0.11	0.10
4	0.11	0.21	0.74	0.53	0.47	0.64	0.53	0.42
5	0.14	0.34	0.91	0.69	0.80	0.77	0.70	0.58
6	0.32	0.32	0.96	0.70	0.60	0.80	0.74	0.63
7	0	0	0.28	0.11	0.20	0.11	0.11	0
8	0.10	0.08	0.37	0.14	0.31	0.19	0.16	0.14
9	0.39	0.33	0.81	0.53	0.61	0.61	0.60	0.49
10	0.53	0.53	0.96	0.64	0.60	0.74	0.74	0.63
11	0.11	0.11	0.21	0.11	0.10	0.11	0.11	0.10
12	0.21	0.19	0.32	0.22	0.19	0.22	0.22	0.21
13	0.32	0.32	0.74	0.52	0.49	0.61	0.53	0.42
14	0.39	0.39	0.85	0.55	0.65	0.64	0.60	0.53

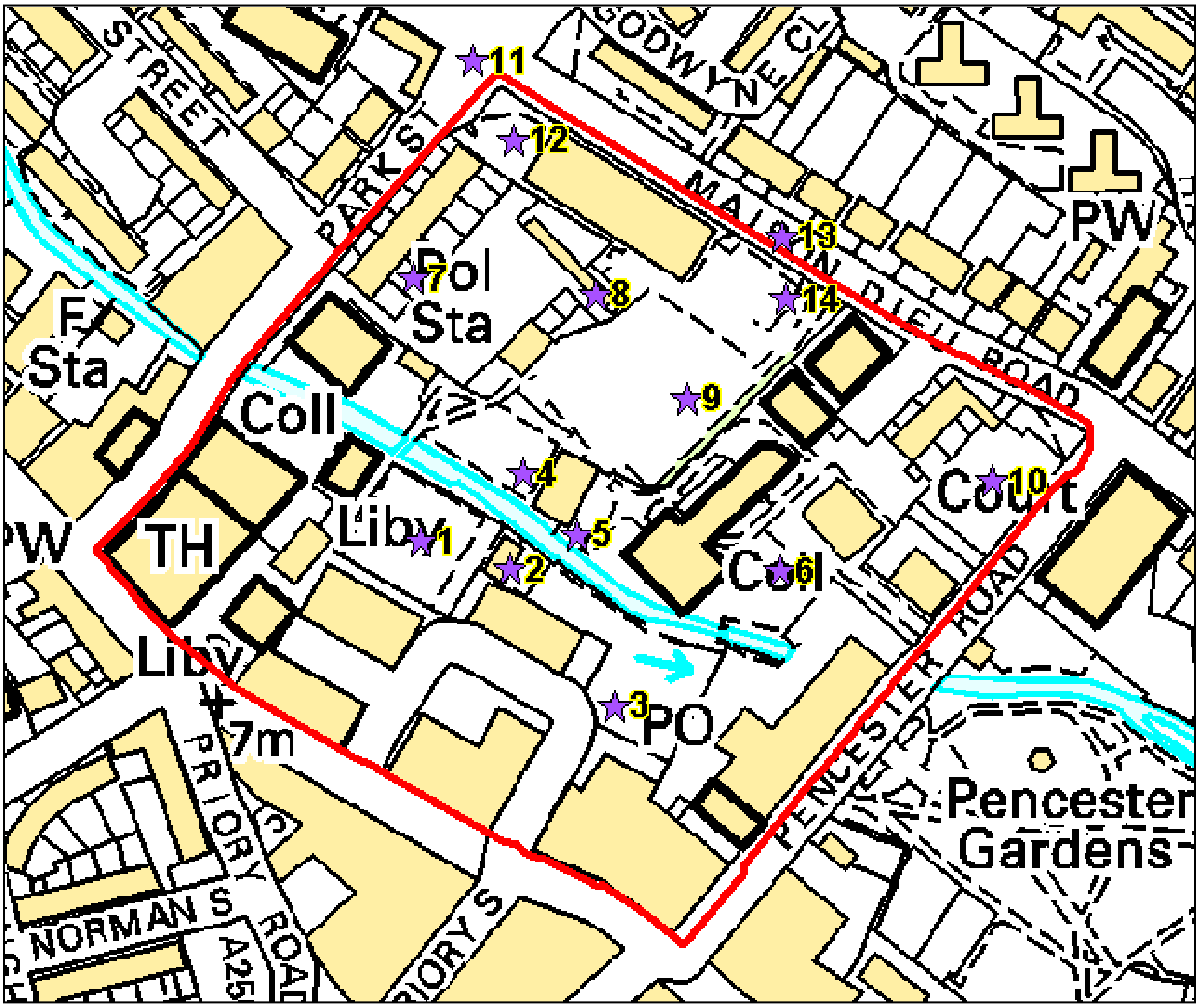


Figure 5-11: Location of Data Points Used For Extracting Peak Flood Levels

6 CONCEPTUAL FLOOD MANAGEMENT OPTIONS

Options have been tested for the 1 in 20 year, 1 in 100 year, 1 in 100 year plus climate change, and 1 in 1000 year return period events. The 'baseline' results demonstrate there is limited constraint from the 1 in 20 year return period event. Hydraulic modelling has focussed on option testing that demonstrates the Mid Town site would be safe during the 1 in 100 year return period event, for the lifetime of the development.

Options have been run for the 1 in 1000 year return period event to determine the remaining (residual) risk.

The conceptual options that have been assessed to date include the following:

1. Reduction of upstream flows;
2. Flood storage at Buckland Mill;
3. Removal of weirs and Regrading of the existing channel;
4. Raised defences (walls and embankments);
5. Flood storage within Pencester Gardens;
6. Removal of the Combined Sewer pipe located under Pencester Road; and
7. A combination of the above options.

These options only investigate the impacts on fluvial and tidal flooding and not the impacts that they may have on surface water flooding within the study boundary.

6.1 Option 1 – Reducing Upstream Flows

The upstream boundary of the model is located downstream of lakes which are fed by the upper catchments. The possibility of using these lakes to provide additional storage has been tested as Option 1.

This option was tested in the model by altering the inflow hydrographs from the Kearsney Tributary and Alkham Bourne, as it is on these two watercourses that the upper catchment lakes are located. These two inflows are input into the model at the upstream boundary and lagged as identified earlier within this report.

To represent storage being provided by the lakes these two inflows have been reduced to the river ‘baseflow’ rates, as provided in the PBA iSIS model. This is likely to be a ‘best case’ storage scenario and has been used to test whether this provides any benefit. Figure 6-1 represents the difference between the inflows for Kearsney Tributary and Alkham Bourne for the baseline model and option 1.

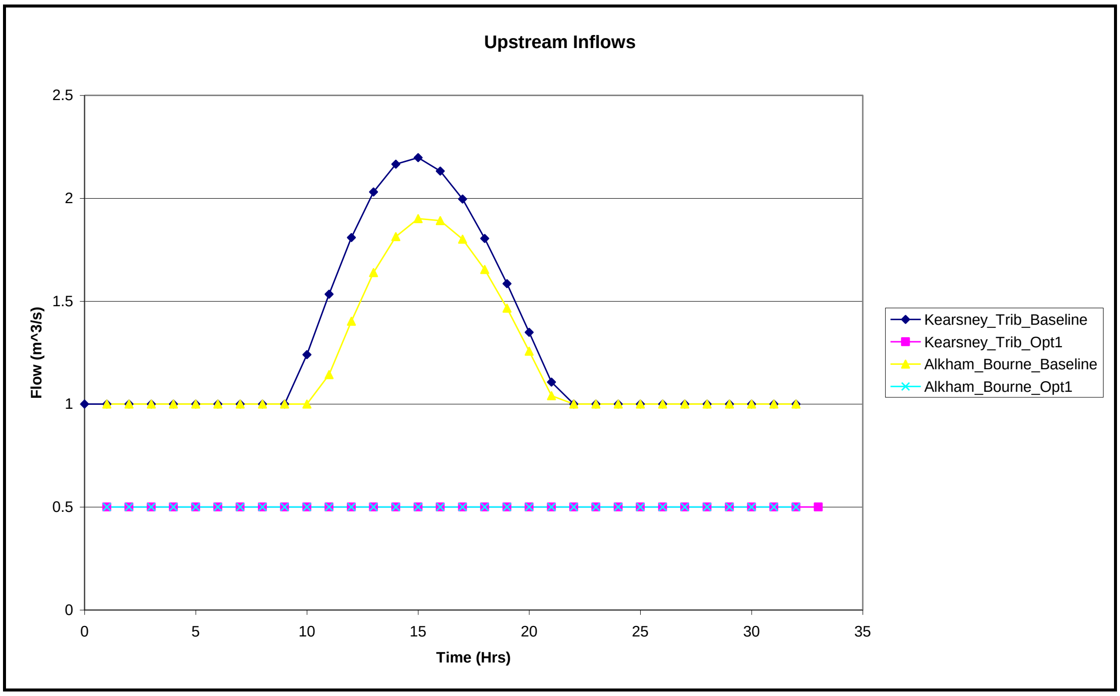


Figure 6-1: Comparison of Inflows for Baseline and Option 1

The results from modelling this option indicate there would be a reduction in flood extent at various locations along the River Dour; notably along Lower Road and Common Lane, adjacent to Crabble Road, Crabble Hill and reduced flooding of the properties on Brookfield Place, Buckland Avenue and Alfred Road. There is also a minor reduction in flooding in the Mid Town area, along Maison Dieu Avenue and the properties adjacent to Pencester Gardens.

Based on the results of the assessment it is concluded that upstream storage alone cannot remove the risk of flooding to the Mid Town site.

Refer to Figure 6.2 for a comparison of the food extents within the study are (for a 1 in 100 year plus climate change event).

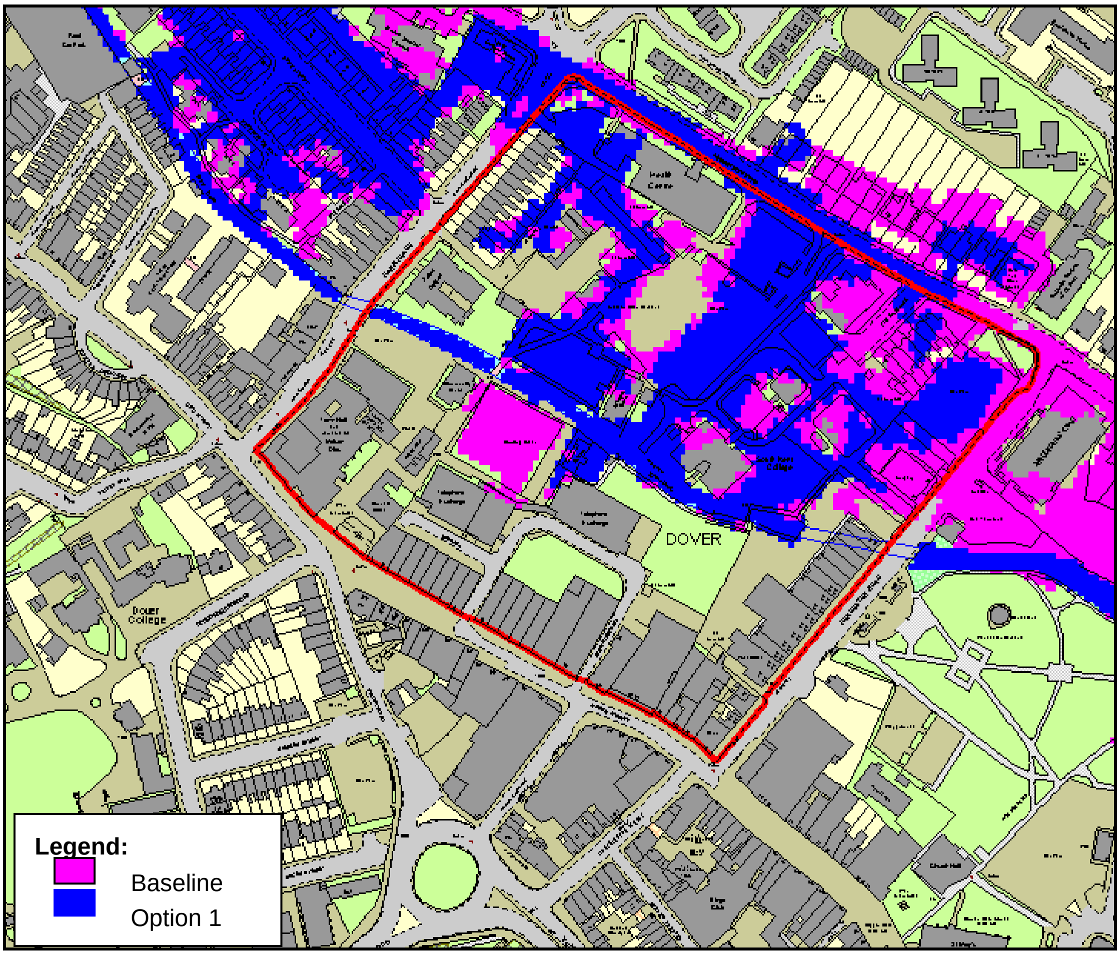


Figure 6-2: Baseline 1 in 100 Year Plus Climate Change Return Period Flood Extent Comparison: Baseline Vs Option 1

6.2 Option 2 – Flood Storage at Buckland Mill

Storage lower down the catchment has been tested to determine whether peak flows entering further downstream can be managed to reduce flooding on the River Dour. Land adjacent to Buckland Mill was identified as the most logical, currently undeveloped area which is located next to the river. This site is also located immediately downstream of the largest inflow in the catchment.

This option was conceptually tested by lowering an area of the bank below peak water levels to create a spillway, as well as lowering areas of ground by 300-500mm (to 16mAOD). An embankment/wall around the storage area was incorporated into the layout to maximise the storage of floodwater in his area.

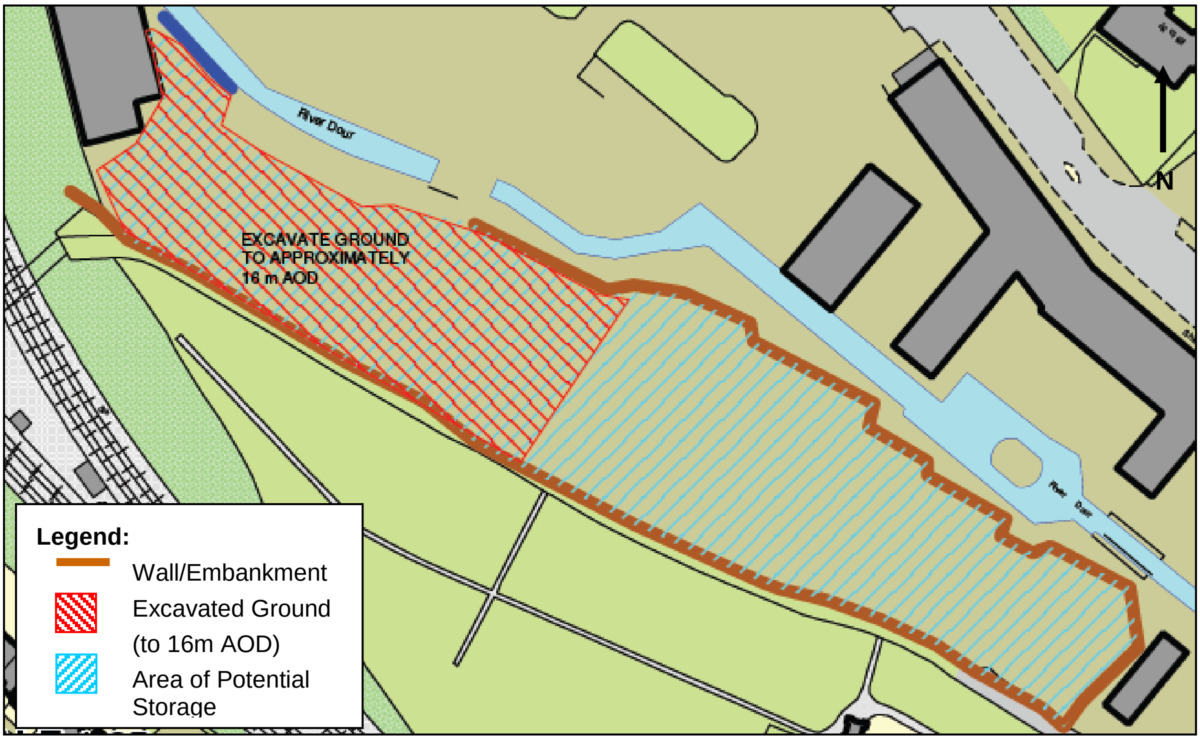


Figure 6-3: Location of Conceptual Buckland Mill Flood Storage Area

Modelling results of Option 2 show minimal change in flood extent in comparison to the baseline results, with the only noticeable difference being the bowling green in the Mid Town area now remaining dry (refer to Figure 6-4).

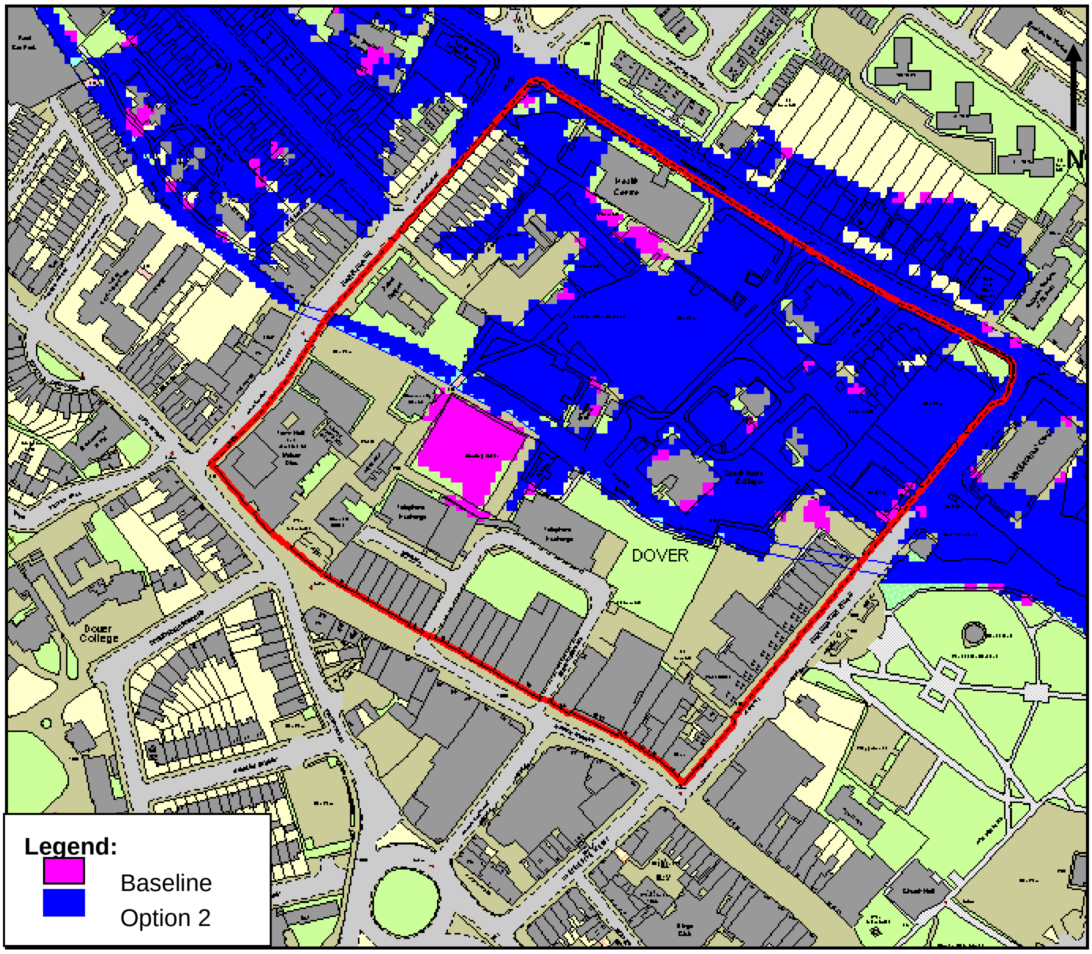


Figure 6-4: Baseline 1 in 100 Year Plus Climate Change Return Period Flood Extent Comparison: Baseline Vs Option 2

The volume of water that would need to be managed to prevent the Mid Town study area from flooding is significantly greater than that which can be reasonably accommodated in this area.

Results from Option 1 and 2 indicate upstream flood storage in isolation is unlikely to provide a feasible option to manage flood risk in Dover.

6.3 Option 3 – Weir Removal

The weir located near Halfords results in water backing up in the channel due to a flat channel gradient. The low left bank means water is able to spill out and over the existing infrastructure (short wall) bordering the river. This option investigated the lowering of the weir and regrading the channel in this section to improve the channel capacity and reduce the local water level. Figure 6.4 below overleaf provides a conceptual diagram of this option with Figure B3 (refer to main report Appendix B) identifying the location of the weir.

The option was modelled by removing the weir from the model and retaining the downstream cross-section. It is assumed that the channel will be re-graded at a constant gradient back to Beaconsfield Avenue. Tuflow interpolates between the cross-section at the downstream end of Beaconsfield Avenue and the downstream end of the weir, therefore representing a constant gradient.

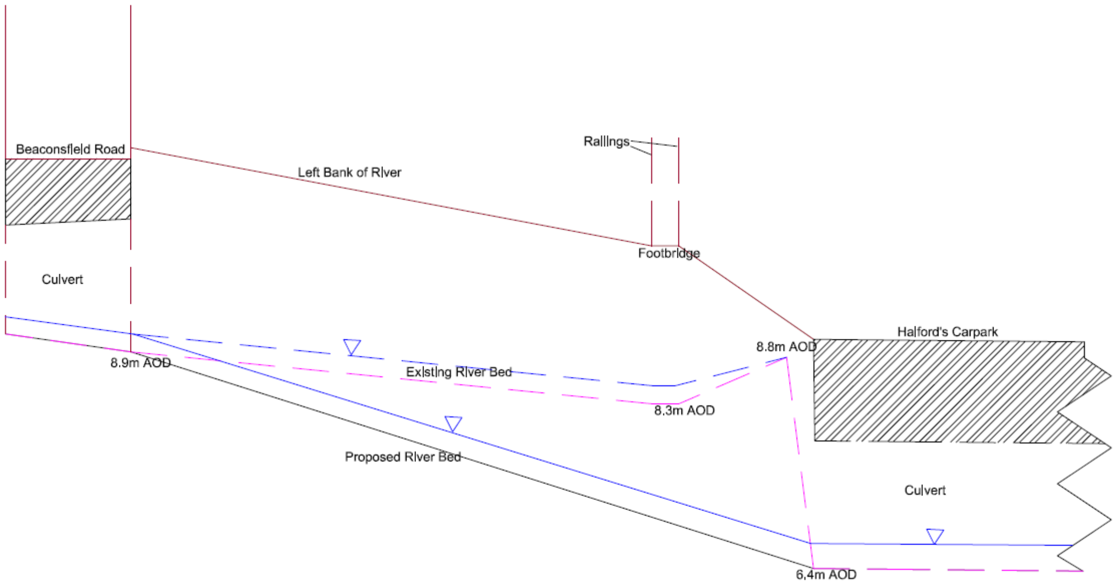


Figure 6-5: Conceptual Regrading Option for the Weir near Halfords

Re-grading the channel section assists in reducing local flood levels, with the banks no longer overtopped upstream of Halfords during a 1 in 100 plus climate change event. Although this removes the flow route down Granville Street, water overtops the left bank downstream of Bridge Street, creating a significant overland flow path down Charlton Green and into Maison Dieu Road; this flood water in turn enters the Mid Town study area from the north west (see Figure 6-6). Therefore this option reduces overland flow but does not prevent the study area from significant flooding during a 1 in 100 year plus climate change event.

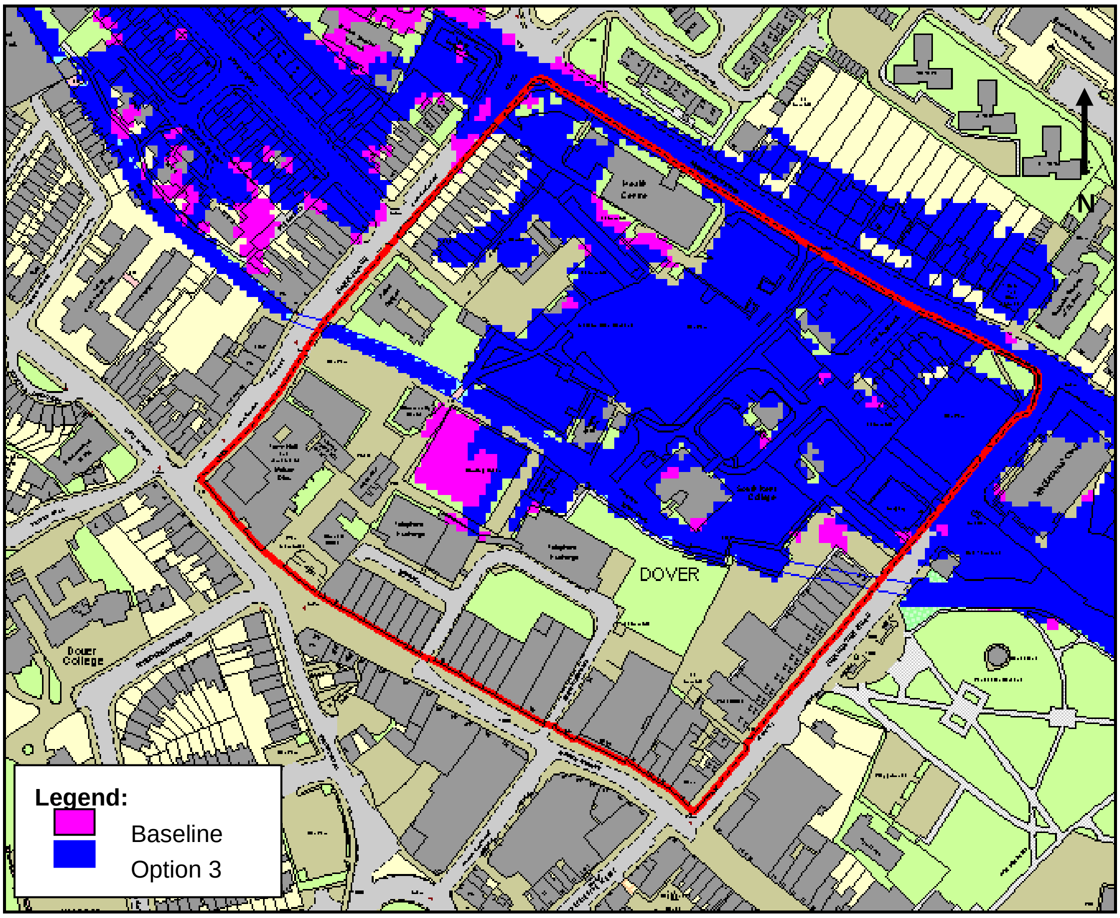


Figure 6-6: Baseline 1 in 100 Year Plus Climate Change Return Period Flood Extent Comparison: Baseline Vs Option 3

6.4 Option 4a – Raised Defences

This option utilises Option 3, and incorporates raised defences at appropriate locations to prevent overtopping of banks and therefore prevent overland flow path conveying water in to the study area.

The results for Option 3 were investigated when developing this option and defences were raised within the model, using z-lines, where water overtopped the banks and created overland flowpaths. Walls were added in at heights 300mm (freeboard) above the 1 in 100 year event water level. The walls are located at the following locations:

- Weir at Morrisons store – 0.4m high, 80m long;
- Left bank downstream of Crafford Street – approximately 0.3m high, 60m long;
- Left bank through Dover Mid Town site – approximately 1m high, 150m long; and
- Right bank through Dover Mid Town – up to 1m high, 140m long.

Note a wall has been added on the right bank of the rover downstream of Crafford Street up to 0.3m high, however it is not anticipated that this will be required as the carpark is situated here, but due to a lack of survey this feature is not defined in the hydraulic model. It is necessary to check that this wall is in full working condition without any damage that could result in water overtopping.

Providing raised walls at these key locations prevents water overtopping the channel and flooding the Mid Town Dover area (see Figure 6-7), as well as the wider community, during the 1 in 100 year return period event, including climate change. Development at the Dover Mid Town area would therefore be ‘safe’ for actual risk event, but there would remain a residual risk of flooding from overtopping during extreme events, or in the unlikely event of a breach/defence failure.

This option results in the River Dour remaining in bank downstream of Limes Road until Pencester Gardens, with the exception of the left bank overtopping upstream of Park Place, resulting in flooding to properties on Goodfellow Way, Dour Street and Hewitt Road (see Figure 6-7). The flooding adjacent to Pencester Gardens is also slightly reduced in comparison to the baseline results.

This option has been tested including the channel regrading at the Halford’s weir. If the weir was not regraded a wall in this area would need to be constructed approximately 0.5m high to ensure that the water remained in bank.

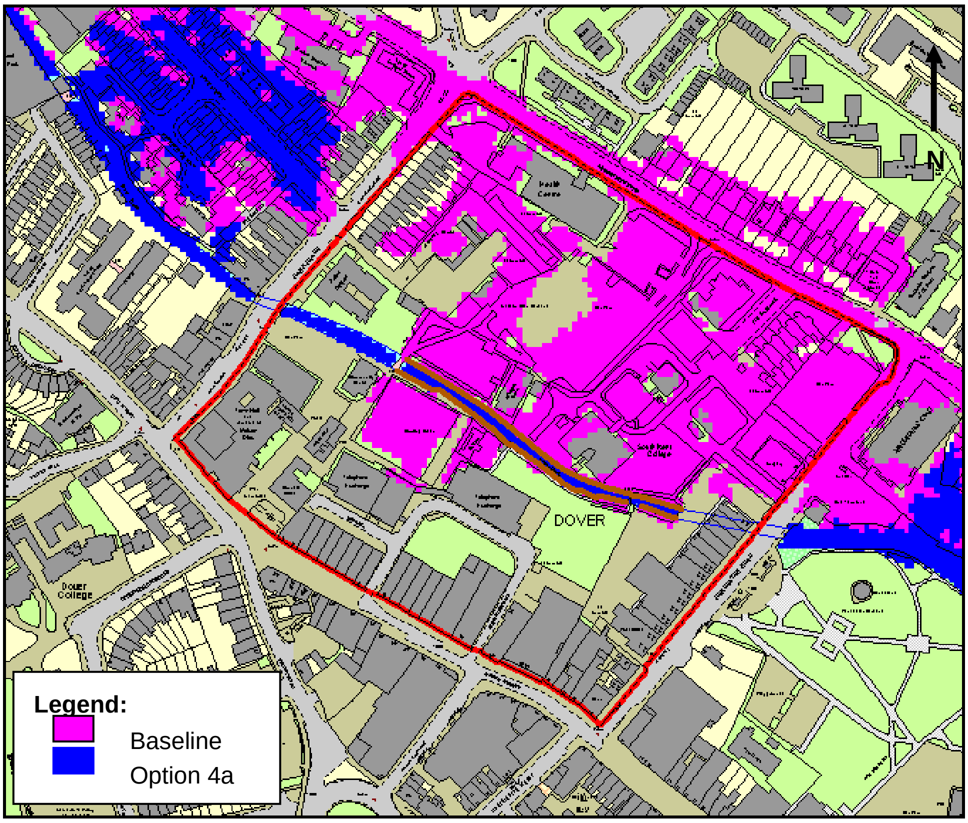


Figure 6-7: Baseline 1 in 100 Year Plus Climate Change Return Period Flood Extent Comparison: Baseline Vs Option 4a

6.5 Options 4b – Raised Defences

Option 4a does not worsen the flooding in Dover, however the River Dour still overtops its banks in two location downstream of Lime Street – adjacent to Goodfellow Way and in Pencester Gardens.

This option includes the raised defences in Option 4a, plus additional raised defences adjacent Goodfellow Way on the left bank of the river and on the left and right bank of the river through stretches of Pencester Gardens. Refer to Figure B5 for the overall scheme layout.

Figure 6-8 provides a comparison of the baseline 1 in 100 year plus climate change event flood extent against the benefit provided from Option 4b. The figure represents the River Dour remaining in bank downstream of Lime Street to Wellington Dock, therefore dramatically improving the fluvial and tidal flooding situation for this area of Dover.

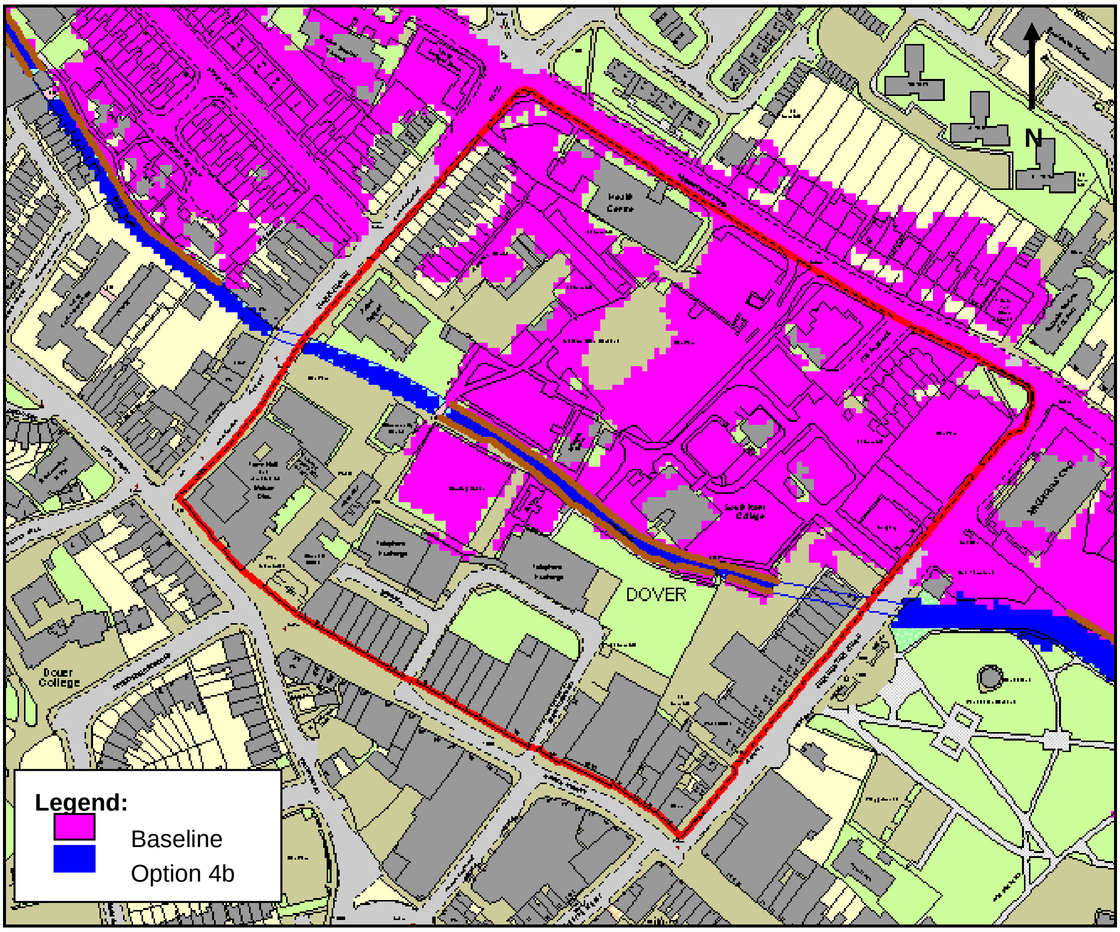


Figure 6-8: Baseline 1 in 100 Year Plus Climate Change Return Period Flood Extent Comparison: Baseline Vs Option 4b

6.6 Option 5 – Flood Storage within Pencester Gardens

Option 5 incoporates Option 4a but also includes of a lowered area of land in Pencester Gardens to assist with compensatory flood storage.

The flood storage area in Pencester Gardens has been included in the model by reducing the elevation of the right bank of the River Dour through Pencester Gardens to encourage water to overtop the right bank as oppose to the left bank. The proposed storage area within the Gardens has been lowered using a z-point patch to reduce the elevation of the area. This area has been roughly graded to tie in the remaining land in Pencester Gardens.

Option 5 results in a decrease in flooding adjacent to Pencester Gardens (see Figure 6-9). However, the impact on local water levels is minimal. To facilitate appropriate compensatory flood storage it is expected that a significant portion of Pencester Gardens would need to be lowered.

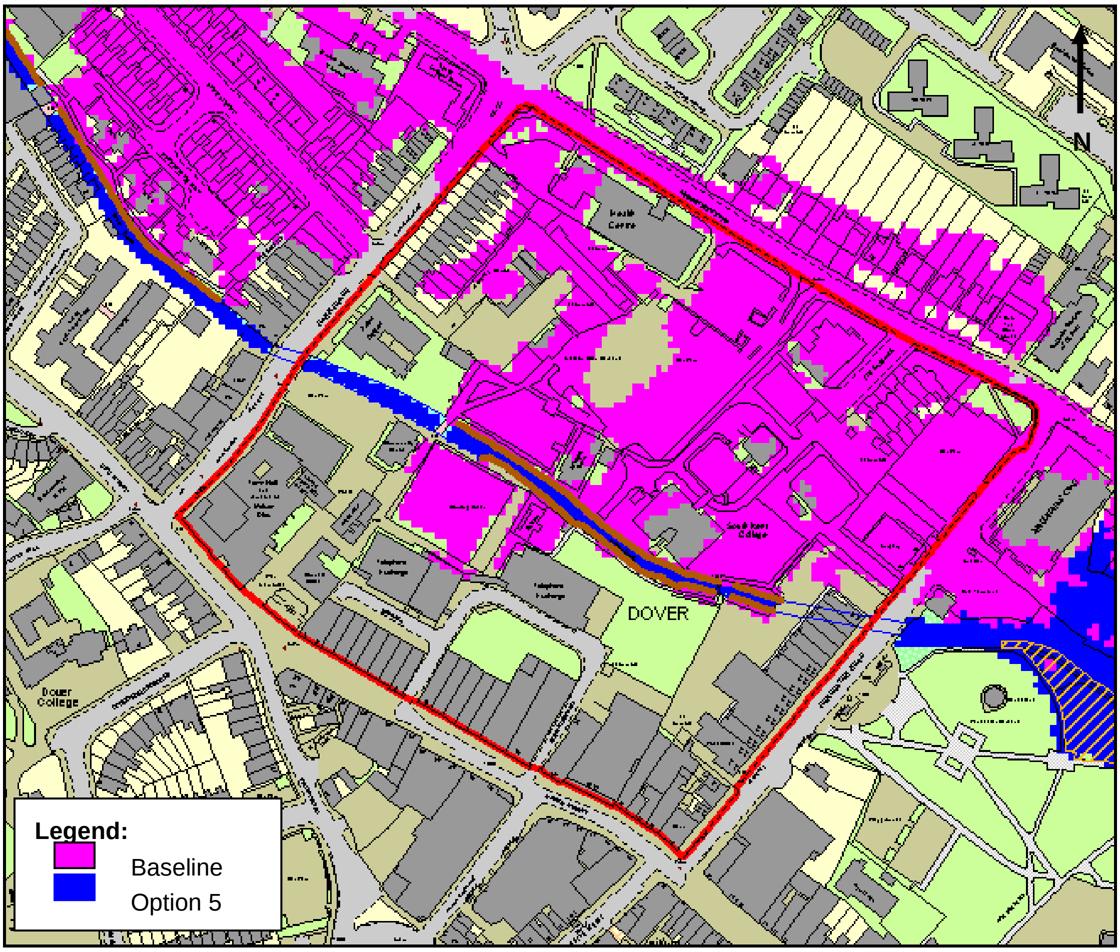


Figure 6-9: Baseline 1 in 100 Year Plus Climate Change Return Period Flood Extent Comparison: Baseline Vs Option 5

6.7 Option 6 – Removal of the Combined Sewer Pipe Beneath Pencester Road

The sewer pipe beneath Pencester Road causes a constriction to flow locally, as illustrated in Figure 6-10.

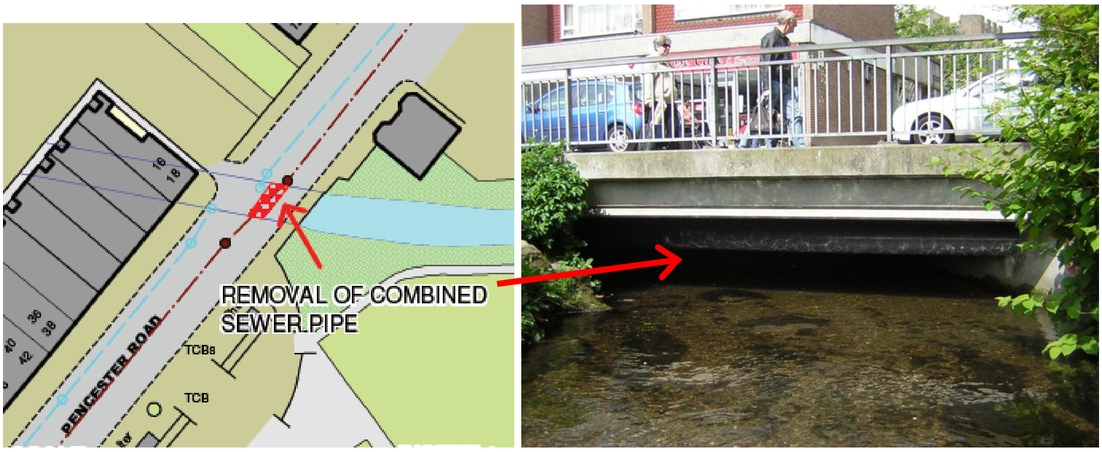


Figure 6-10: Location and Image of Combined Sewer Location under Pencester Road

This option was represented in the hydraulic model by removing the pipe from the culvert beneath Pencester Road and having the whole culvert as the flow width. This was the only change to the baseline model made for this option.

Option 6 reduces flooding within the Mid Town study area slightly, and also within the area surrounding Pencester Gardens. However the study area still experiences significant flooding during 1 in 100 year fluvial flood (both including and excluding an allowance for climate change) event (see Figure 6-11); this flooding is partly caused by overland flow from upstream of the site and therefore a problem that Option 6 can not resolve.

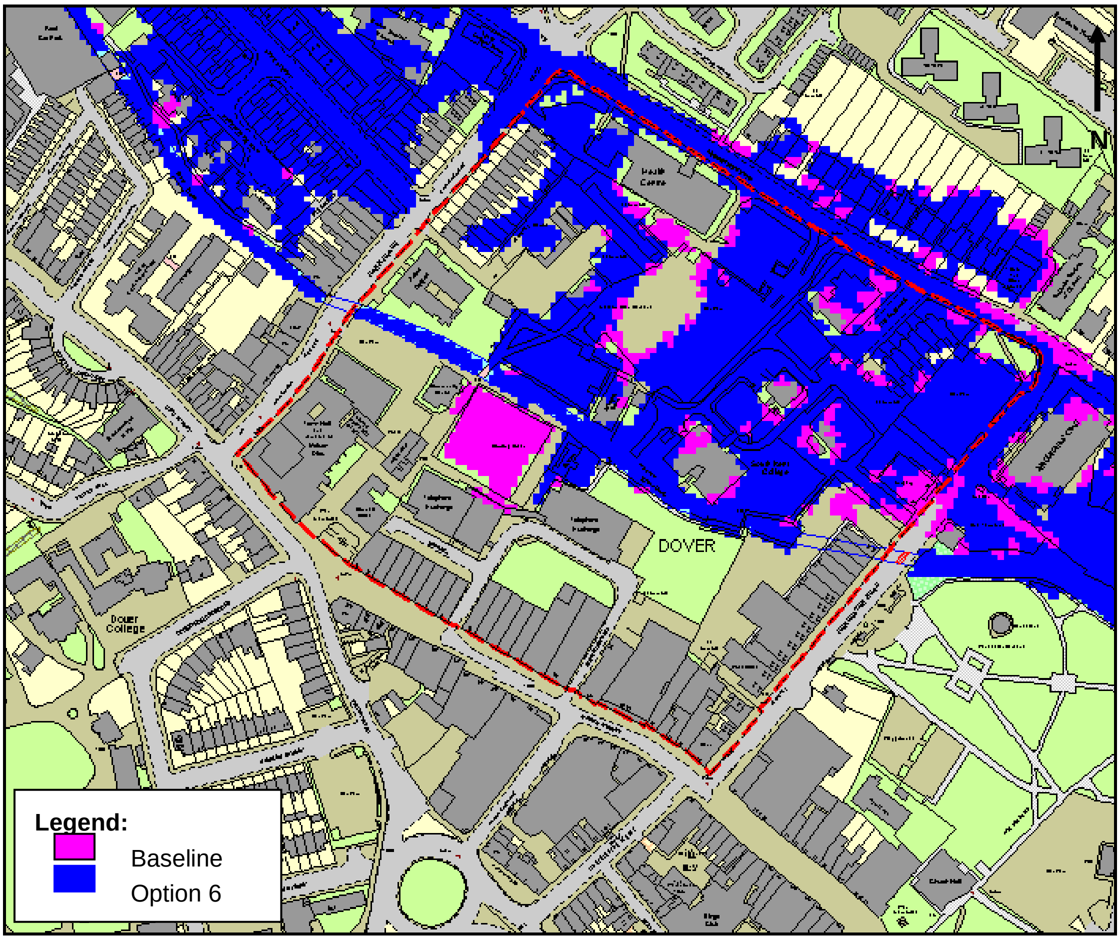


Figure 6-11: Baseline 1 in 100 Year Plus Climate Change Return Period Flood Extent Comparison: Baseline Vs Option 6

6.8 Option 7 - Channel Widening

This option involves the widening of the channel through the Mid Town study area, as represented in Figure B8.

Option 7 has been modelled by altering the cross-section .csv files that read into the model and define river channel. These cross-sections have been widened by 2m through the study area (between DOV_1005 and DOV_0782).

A review of the flood mechanisms affecting the Dover Mid Town site indicate that the widening of the River Dour through the site (as represented by this option) has a minimal effect on improving the flood risk to the site (see Figure 6-12), with the only notable reduction being the Bowling Green remaining dry.

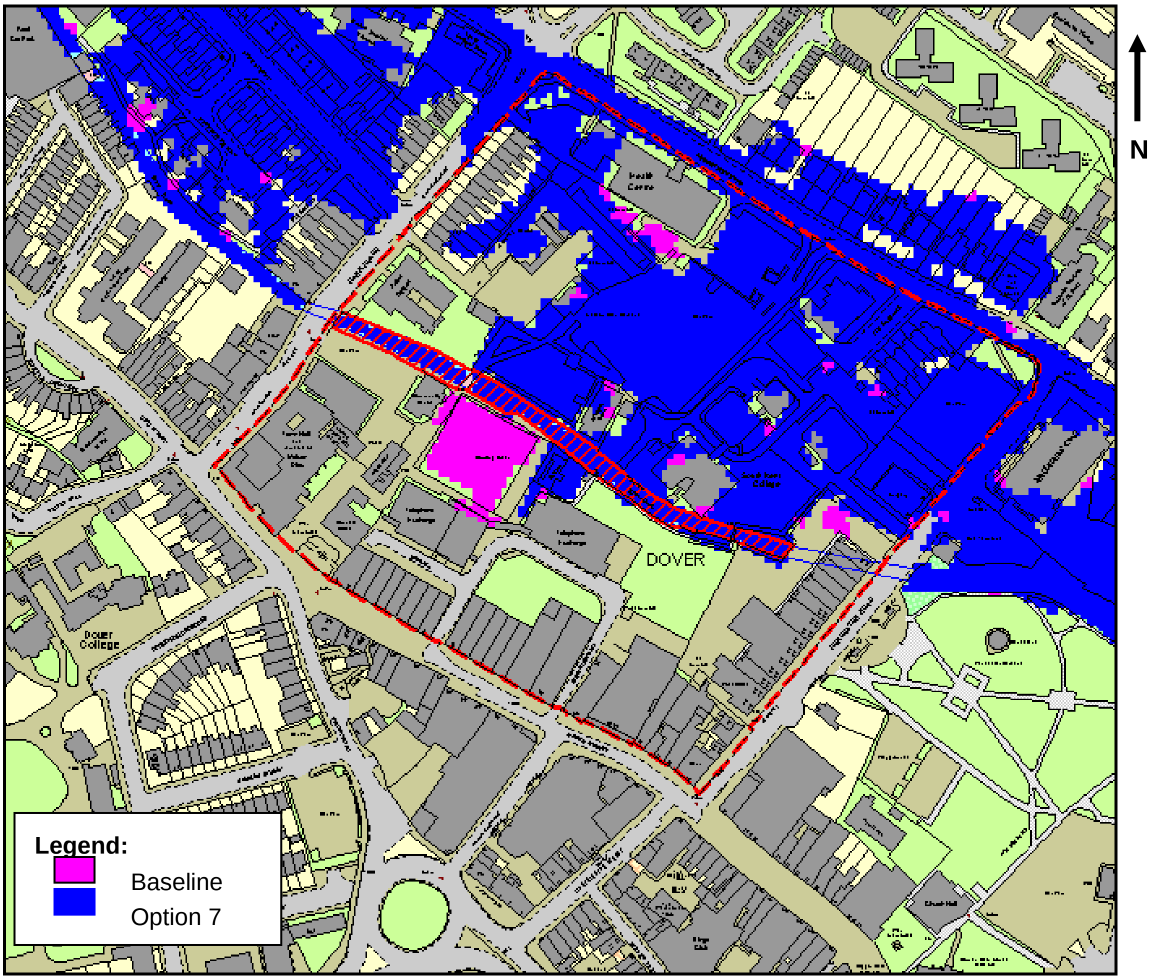


Figure 6-12: Baseline 1 in 100 Year Plus Climate Change Return Period Flood Extent Comparison: Baseline Vs Option 7

6.9 Comparison of Options

Table 6-1 provides a comparison of velocities within the River Dour at various locations upstream, through and downstream of the study area in Mid Town. Figure 6-13 shows the locations of these nodes.

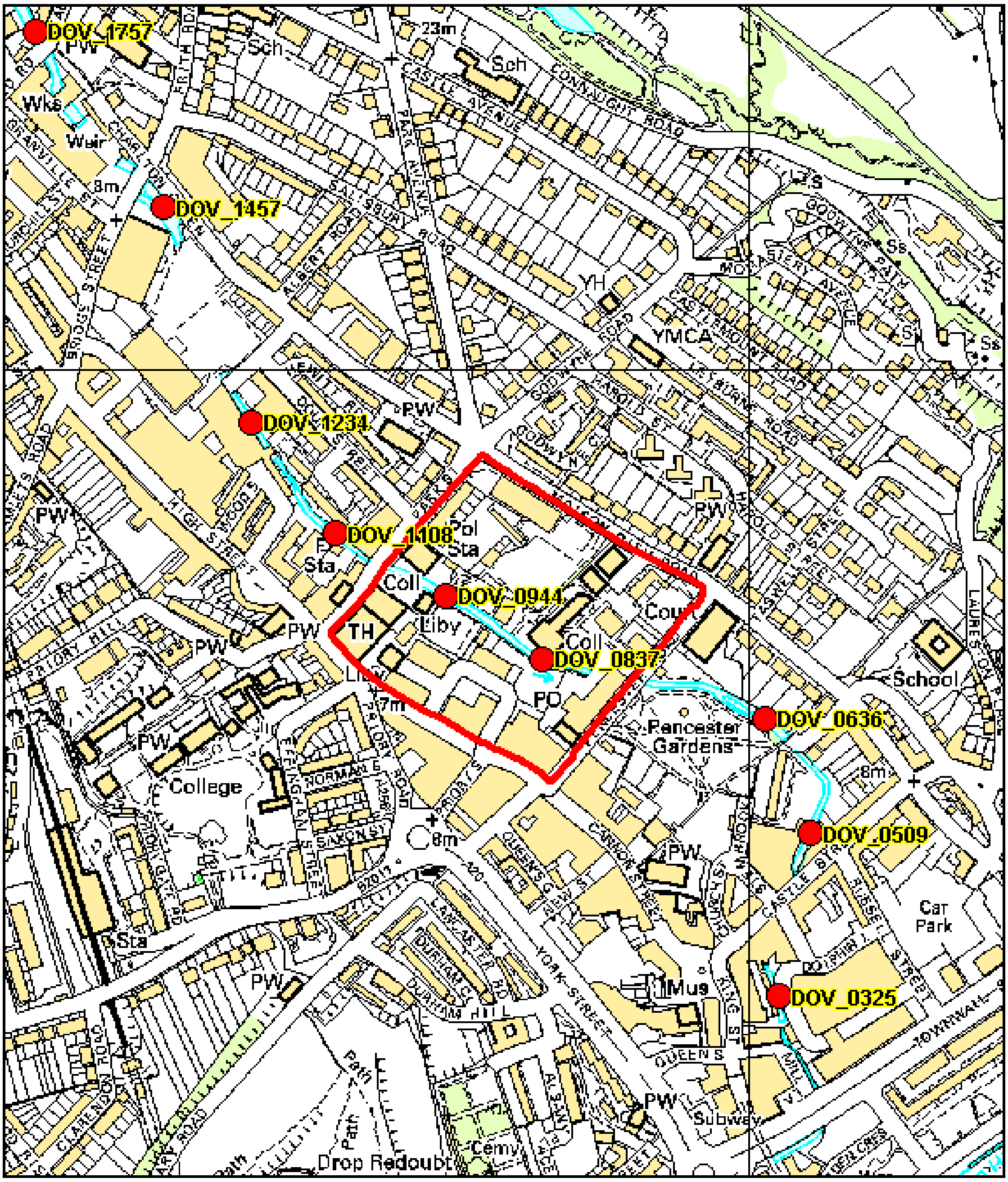


Figure 6-13: Location of Nodes

Table 6-1: Comparison of Velocity Results

Point ID	Baseline	Option 1	Option 2	Option 3	Option 4a	Option 4b	Option 5	Option 6	Option 7
DOV_1757	1.12	1.05	1.09	1.20	1.20	1.20	1.20	1.12	1.10
DOV_1457	0.62	0.59	0.62	0.66	0.64	0.65	0.64	0.62	0.62
DOV_1234	1.49	1.43	1.49	1.45	1.42	1.45	1.42	1.49	1.51
DOV_1108	1.34	1.28	1.35	1.36	1.27	1.27	1.27	1.37	1.40
DOV_0944	1.21	1.04	1.16	1.23	1.26	1.28	1.28	1.19	1.21
DOV_0837	1.12	1.13	1.12	1.12	1.03	1.03	1.03	1.20	0.82
DOV_0636	0.98	0.97	0.98	0.96	0.98	0.98	0.98	0.98	0.99
DOV_0509	1.25	1.21	1.25	1.25	1.25	1.25	1.25	1.25	1.25
DOV_0325	1.67	1.57	1.66	1.67	1.67	1.67	1.67	1.67	1.67

The results show that Option 4a, 4b and Option 5 generally increase the velocity in the River Dour the most of all the scenarios run. However these increases, in comparison to the baseline are fairly minimal, with some nodes experiencing a reduction in velocities.

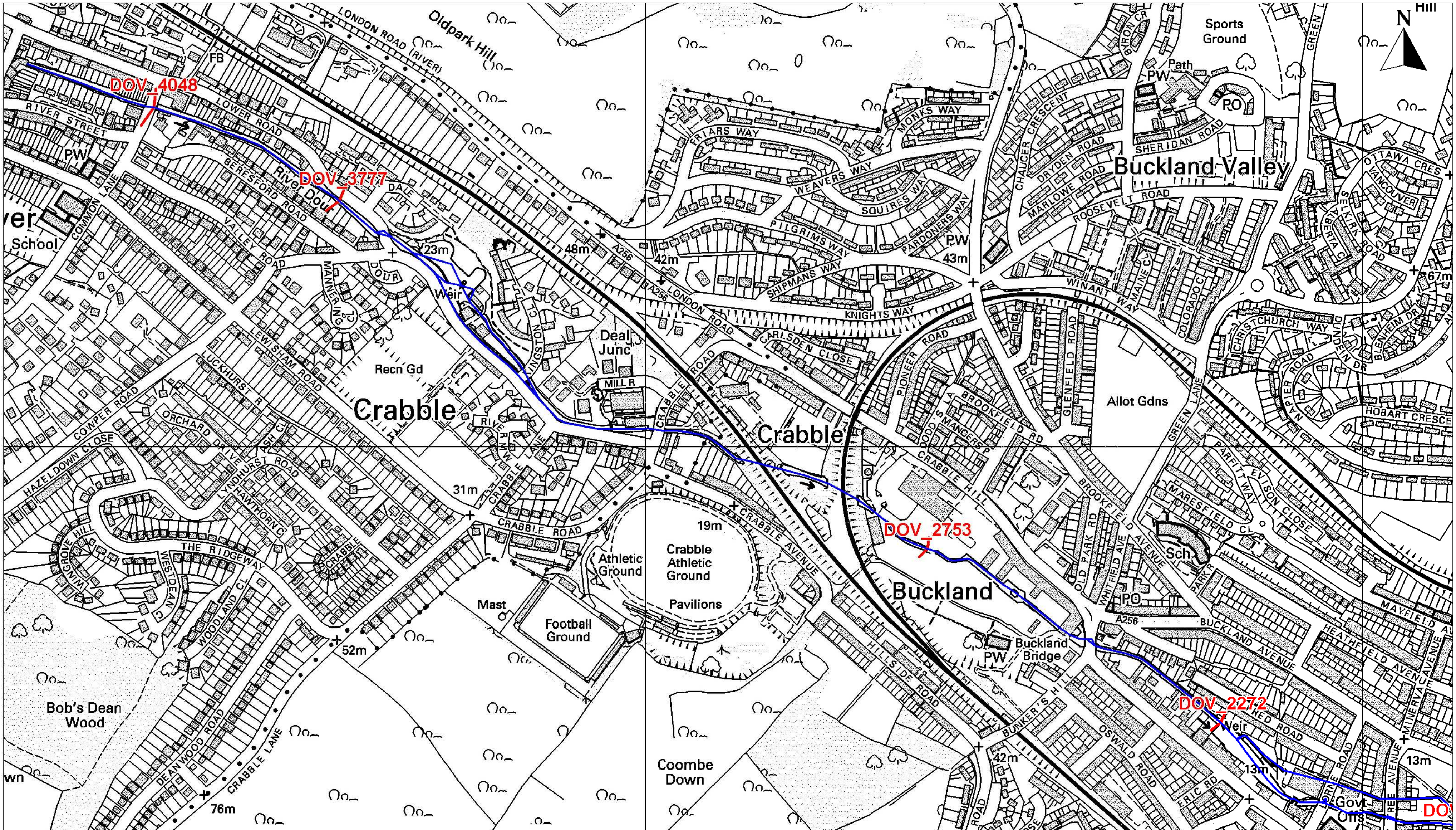
7 RECOMMENDATIONS AND FURTHER REFINEMENT

It is recommended that the following information is investigated and incorporated into the model (as it becomes available) to provide further detail and to refine the flood extents within Dover;

- If this model is proposed to be utilised within a development application that is located within Flood Zone 2 or 3, it is recommended that a topographical survey of the river banks is undertaken and incorporated into the model to confirm areas of overtopping within a site;
- If this model is proposed to be utilised within a development application located within Flood Zone 2 or 3, it is recommended that a topographical survey of the site is undertaken and incorporated into the model to confirm the depth and velocity of flooding within the site;
- It is recommended that topographical bank surveys of the River Dour are undertaken between Pencester Road and Castle Road, through Pencester Gardens (between cross-sections DOV_0728 and DOV_0728) to confirm the height of the river bank. It is recommended that these levels are incorporated into the model to confirm flood depths and velocities in this area;
- It is recommended that the enforcement of the railway embankments and any other de facto flood defence (raised roads etc) are undertaken within the 2D domain to capture any alterations to overland flow paths that may occur;
- Reassess the hydrology of the catchment to ensure all of the predicted flow estimations are in line with the latest methodologies and guidance provided by the EA; and
- The combined sewer network is incorporated into the surface water model to capture any runoff losses that occur due to the existence of this drainage network. It is envisaged that incorporating this network into the model will produce reductions in flood levels within Dover due to the removal of runoff which does not re-enter the River Dour.

Appendix A: iSIS and ESTRY Model Comparison

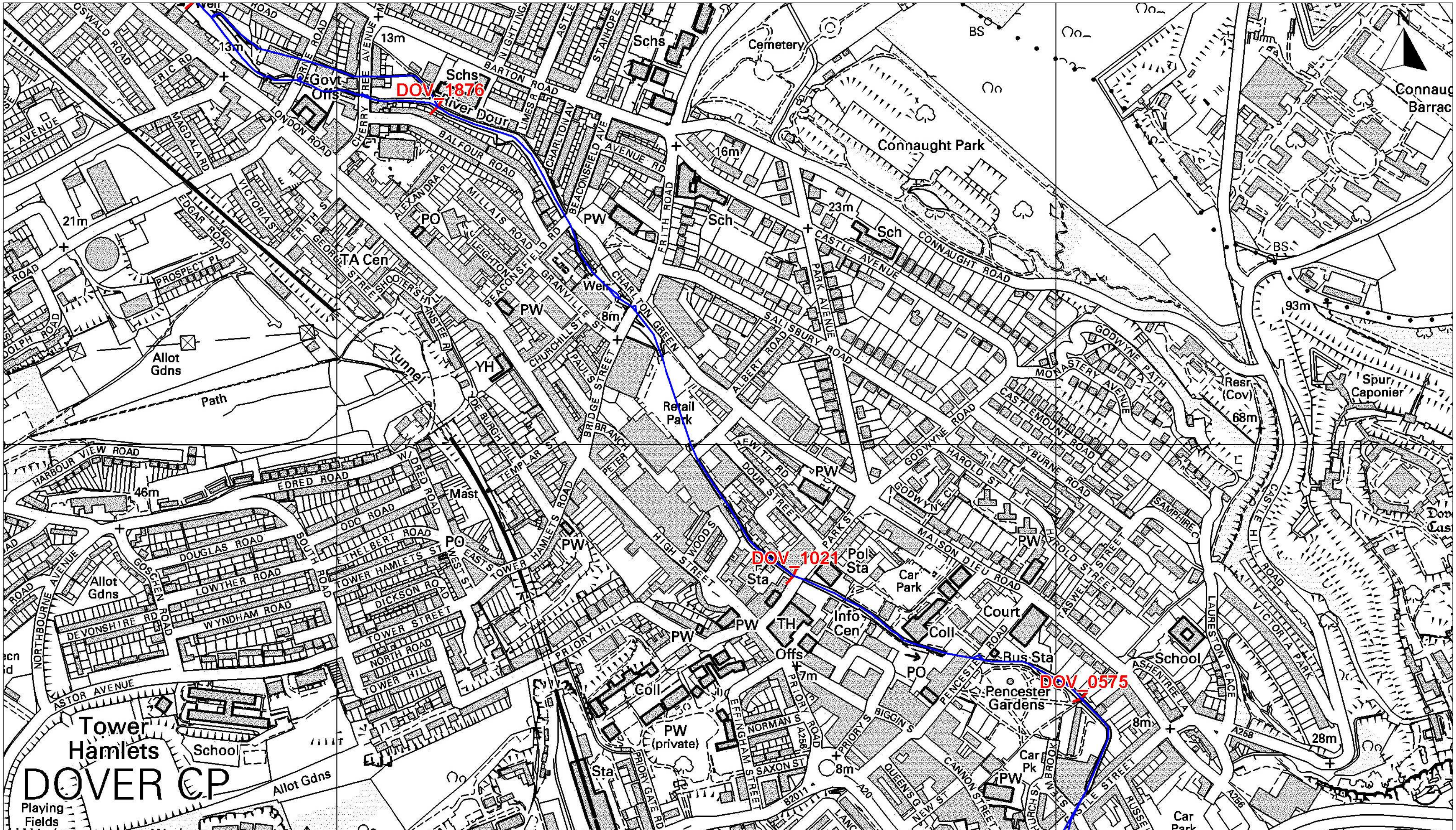
Node Location Figures



DOVER HYDRAULIC MODEL HANDOVER REPORT							
LOCATION OF NODES USED DURING CALIBRATION (1 OF 2)							
DRAWN BY	CHECKED BY	PASSED BY	DATE	SCALES @ A3	ISSUING OFFICE	DRAWING NUMBER	REV
RF	PH	JR	09/12/09	NTS	LONDON	CS37272/Model_Handover_001	A

DOVER DISTRICT COUNCIL

CAPITA SYMONDS



DOVER HYDRAULIC MODEL HANDOVER REPORT

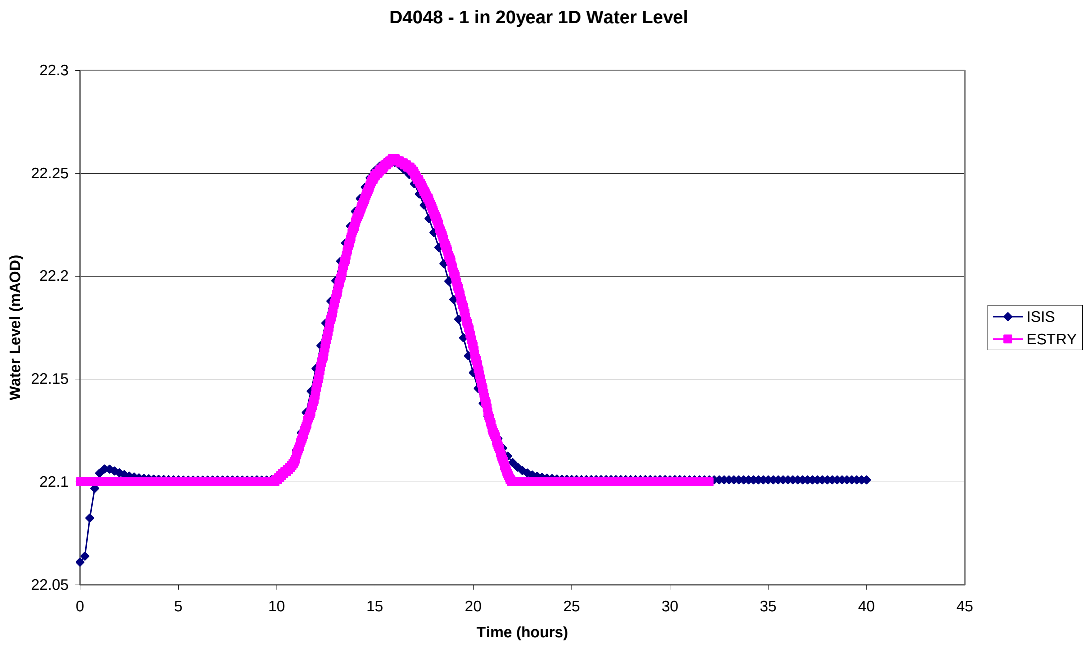
LOCATION OF NODES USED DURING CALIBRATION
(2 OF 2)

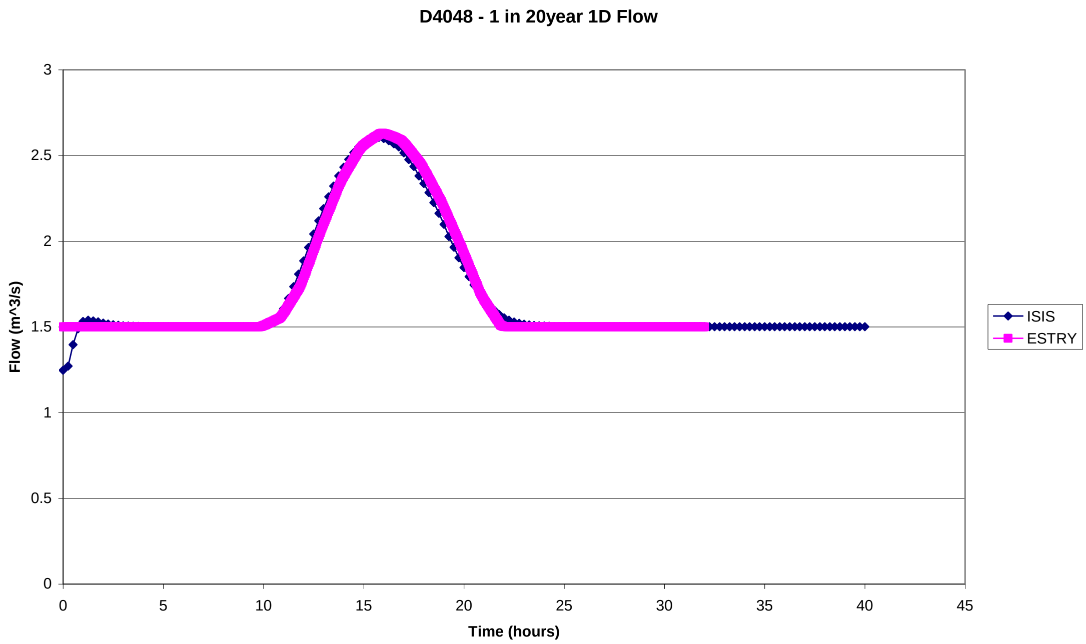
DOVER DISTRICT COUNCIL

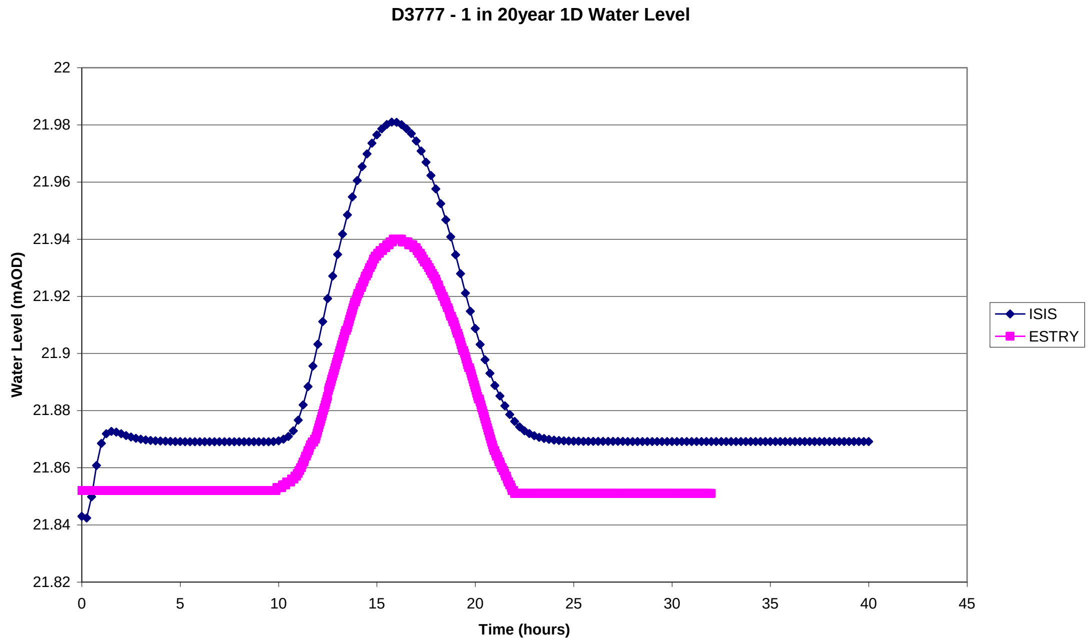
CAPITA SYMONDS

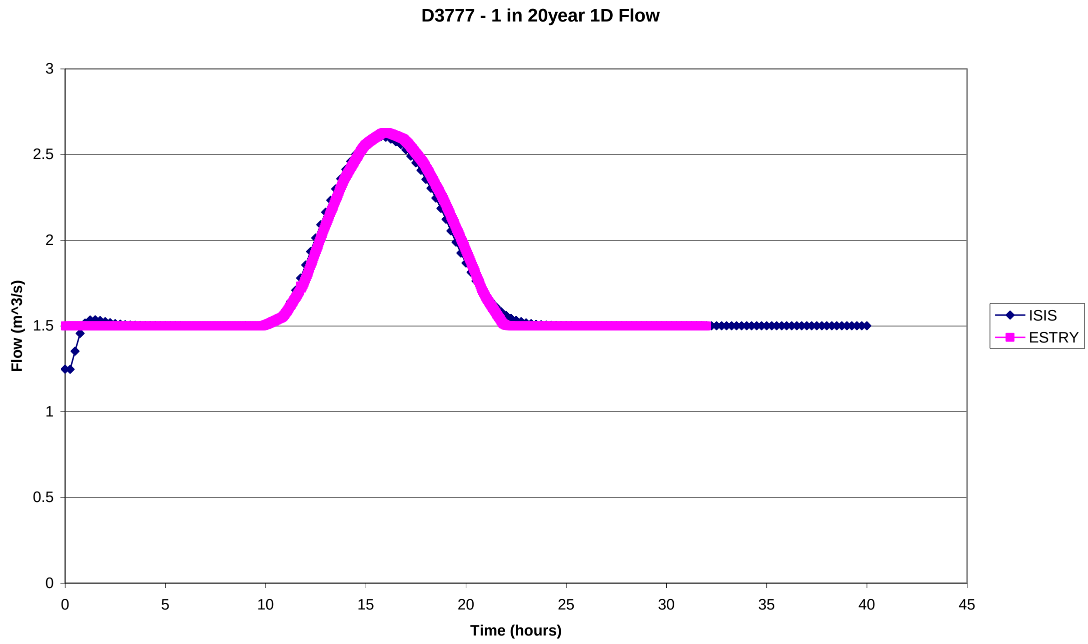
DRAWN BY	CHECKED BY	PASSED BY	DATE	SCALES @ A3	ISSUING OFFICE	DRAWING NUMBER	REV
RF	PH	JR	09/12/09	NTS	LONDON	CS37272/Model_Handover_002	A

1 in 20 year Event

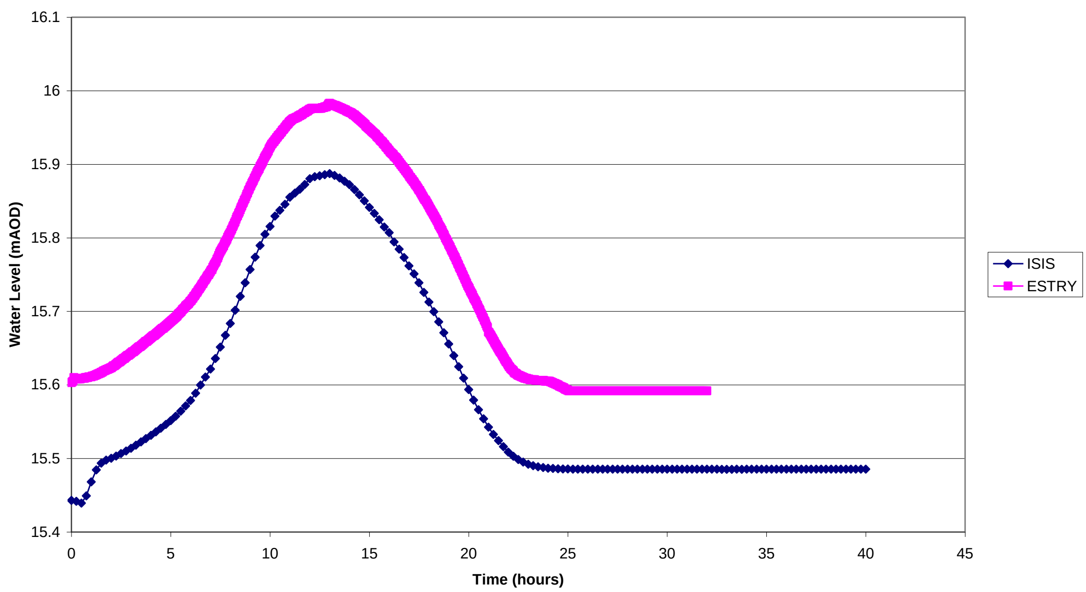

D4048 - 1 in 20year 1D Water Level
Water Level (mAOD)
22.3
22.25
22.2
22.15
22.1
22.05
0
5
10
15
20
25
30
35
40
45
Time (hours)
ISIS
ESTRY


D4048 - 1 in 20year 1D Flow
Flow (m^3/s)
3
2.5
2
1.5
1
0.5
0
0
5
10
15
20
25
30
35
40
45
Time (hours)
ISIS
ESTRY

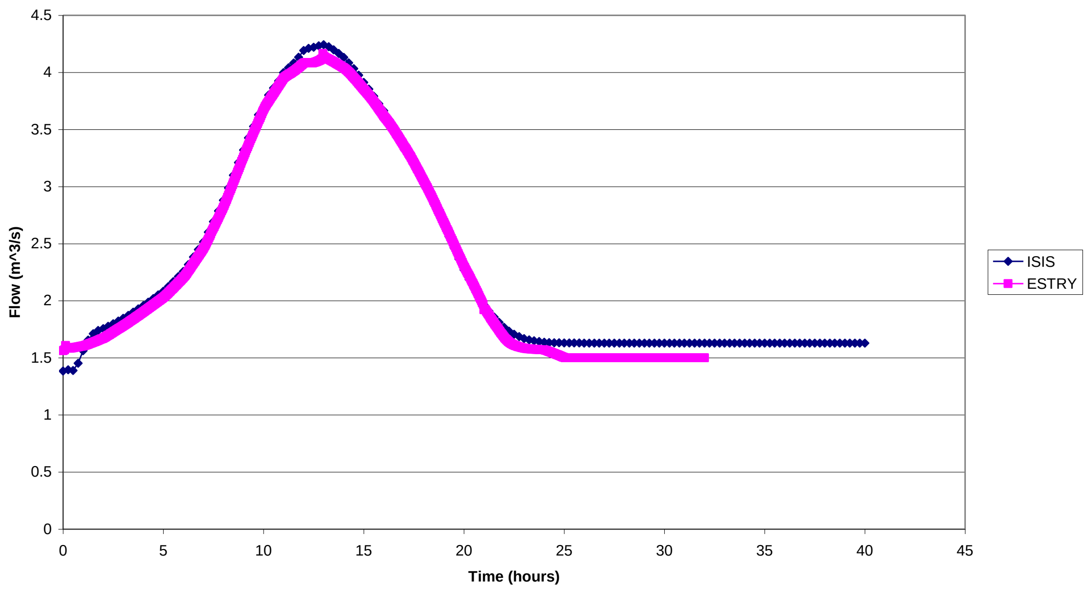

D3777 - 1 in 20year 1D Water Level
Water Level (mAOD)
22
21.98
21.96
21.94
21.92
21.9
21.88
21.86
21.84
21.82
0
5
10
15
20
25
30
35
40
45
Time (hours)
ISIS
ESTRY

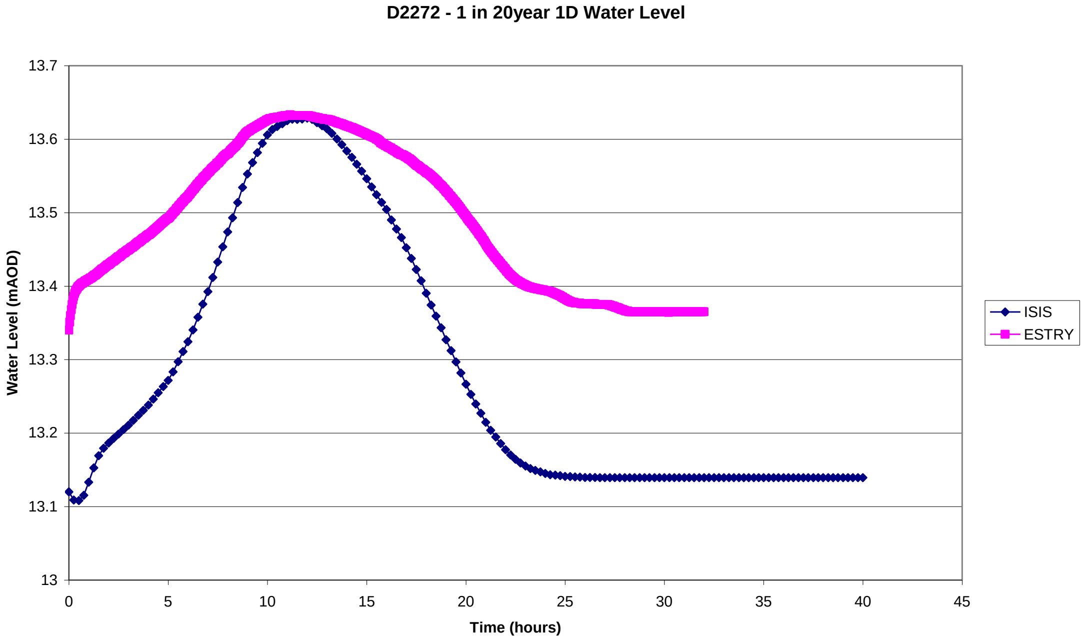

D3777 - 1 in 20year 1D Flow
Flow (m^3/s)
3
2.5
2
1.5
1
0.5
0
0
5
10
15
20
25
30
35
40
45
Time (hours)
ISIS
ESTRY

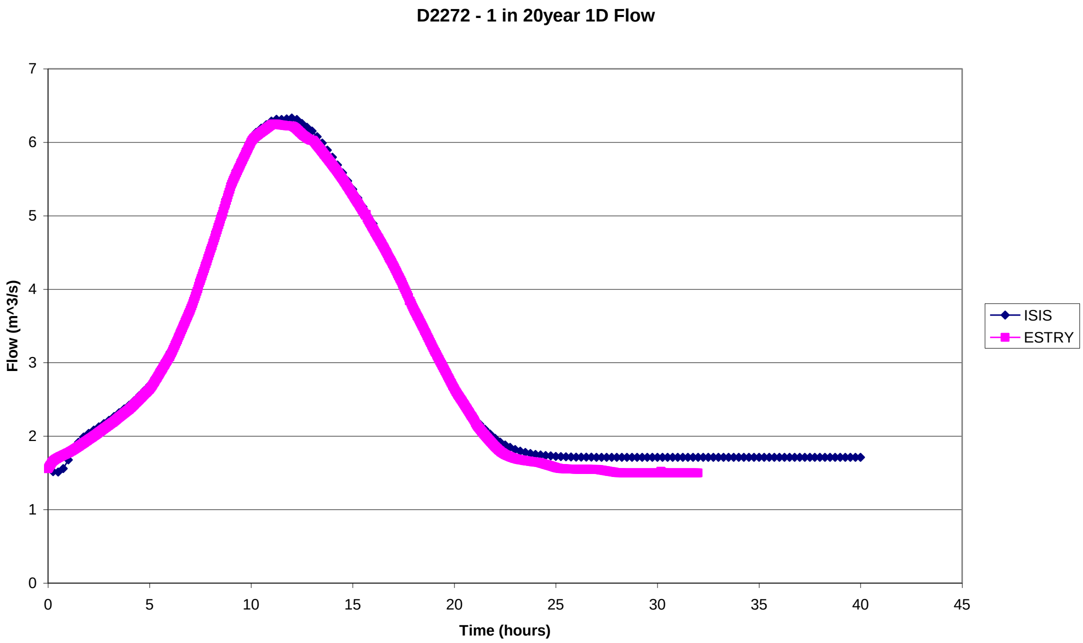
D2753 - 1 in 20year 1D Water Level

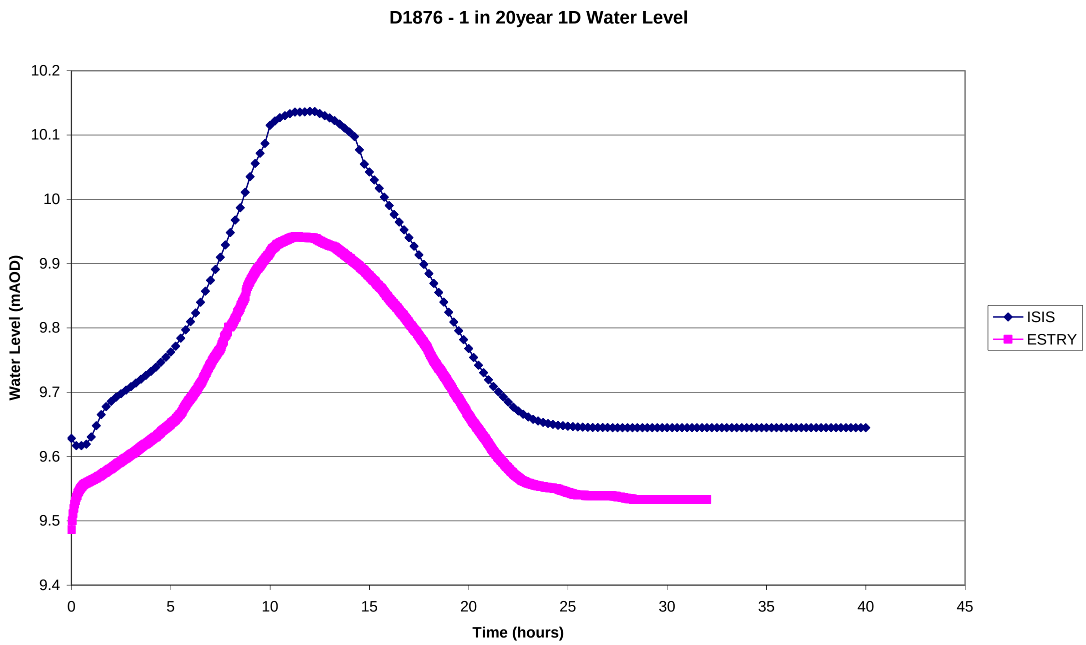


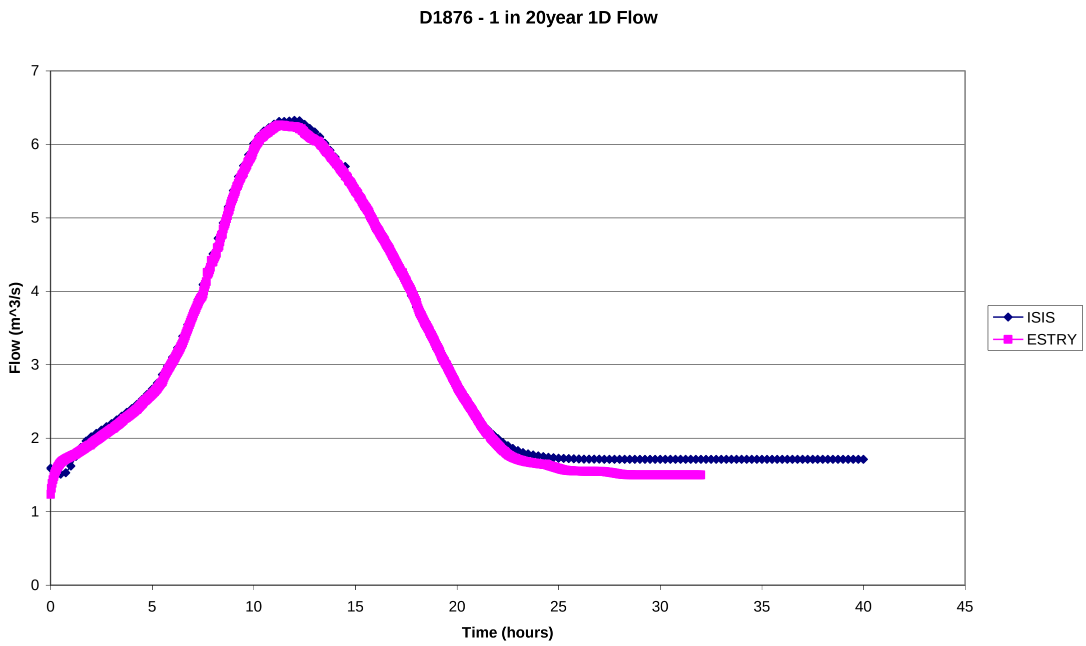
D2753 - 1 in 20year 1D Flow

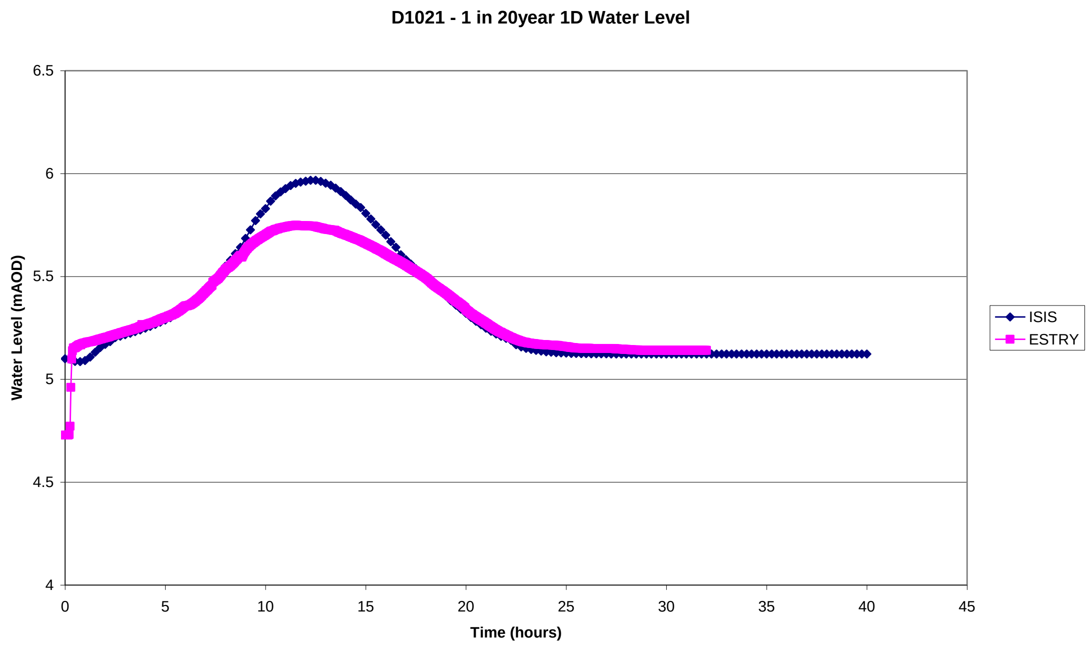


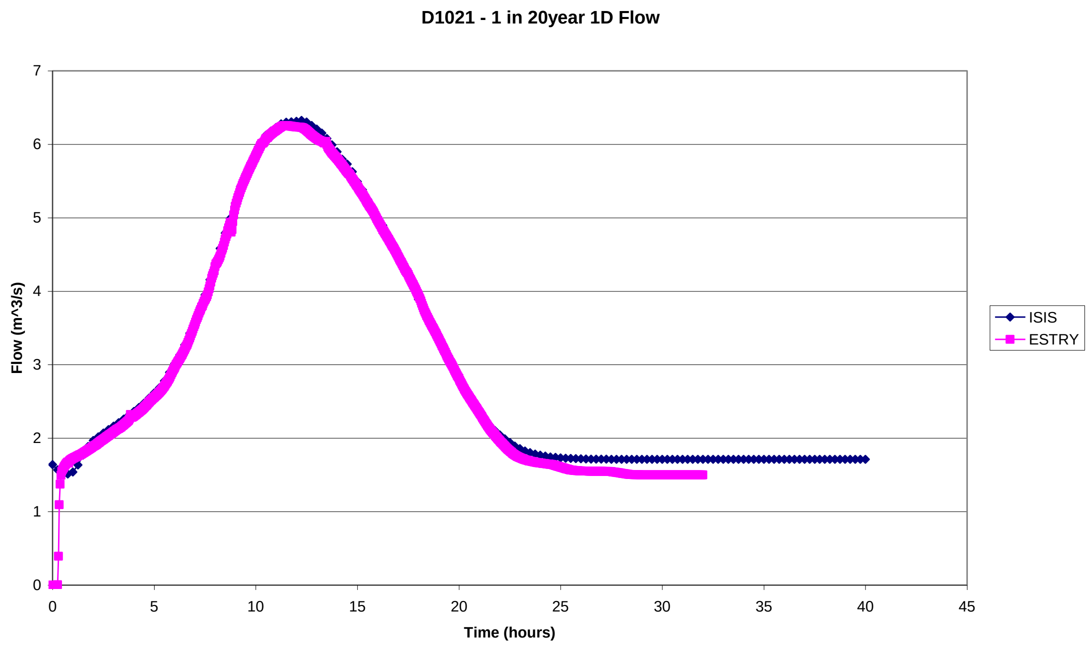

D2272 - 1 in 20year 1D Water Level
Water Level (mAOD)
13.7
13.6
13.5
13.4
13.3
13.2
13.1
13
0
5
10
15
20
25
30
35
40
45
Time (hours)
ISIS
ESTRY

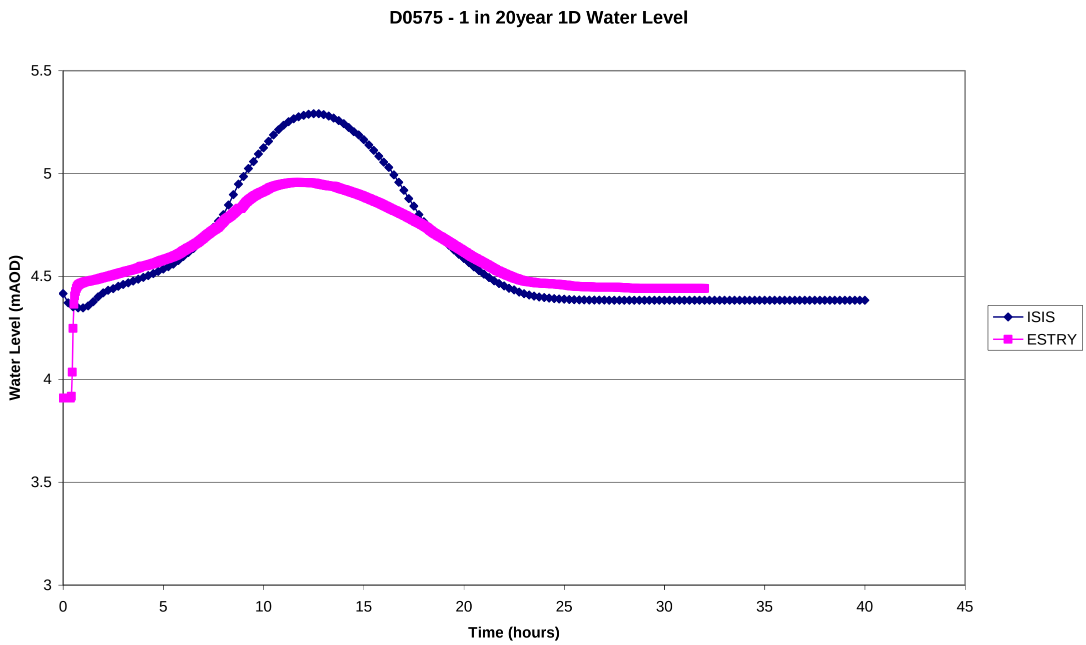

D2272 - 1 in 20year 1D Flow
Flow (m^3/s)
7
6
5
4
3
2
1
0
0
5
10
15
20
25
30
35
40
45
Time (hours)
ISIS
ESTRY

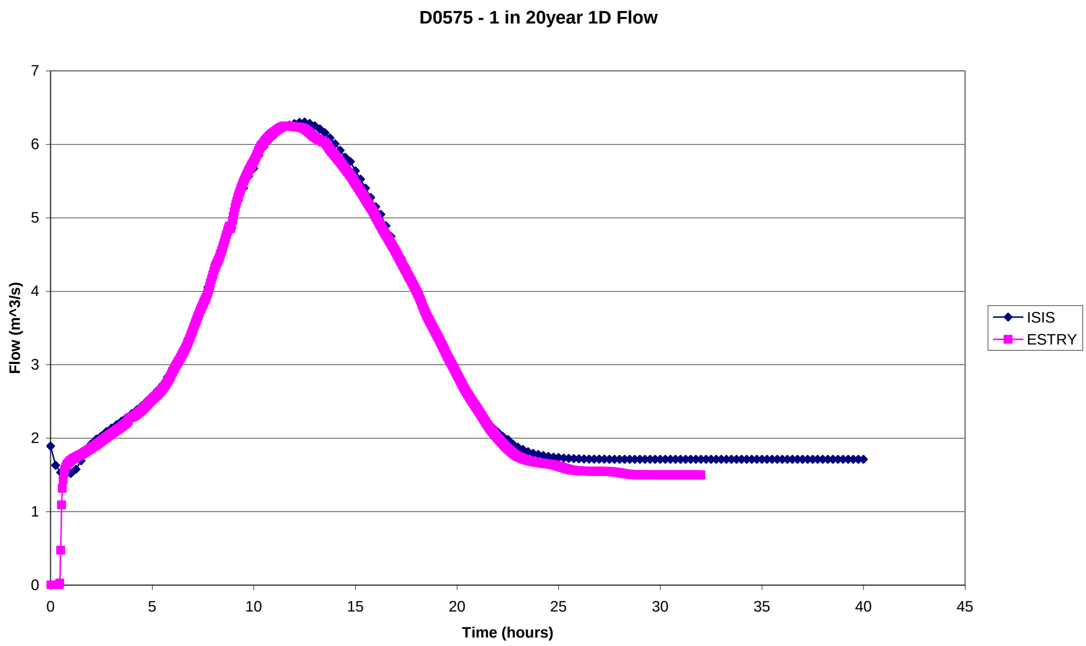

D1876 - 1 in 20year 1D Water Level
Water Level (mAOD)
10.2
10.1
10
9.9
9.8
9.7
9.6
9.5
9.4
0
5
10
15
20
25
30
35
40
45
Time (hours)
ISIS
ESTRY


D1876 - 1 in 20year 1D Flow
Flow (m^3/s)
7
6
5
4
3
2
1
0
0
5
10
15
20
25
30
35
40
45
Time (hours)
ISIS
ESTRY

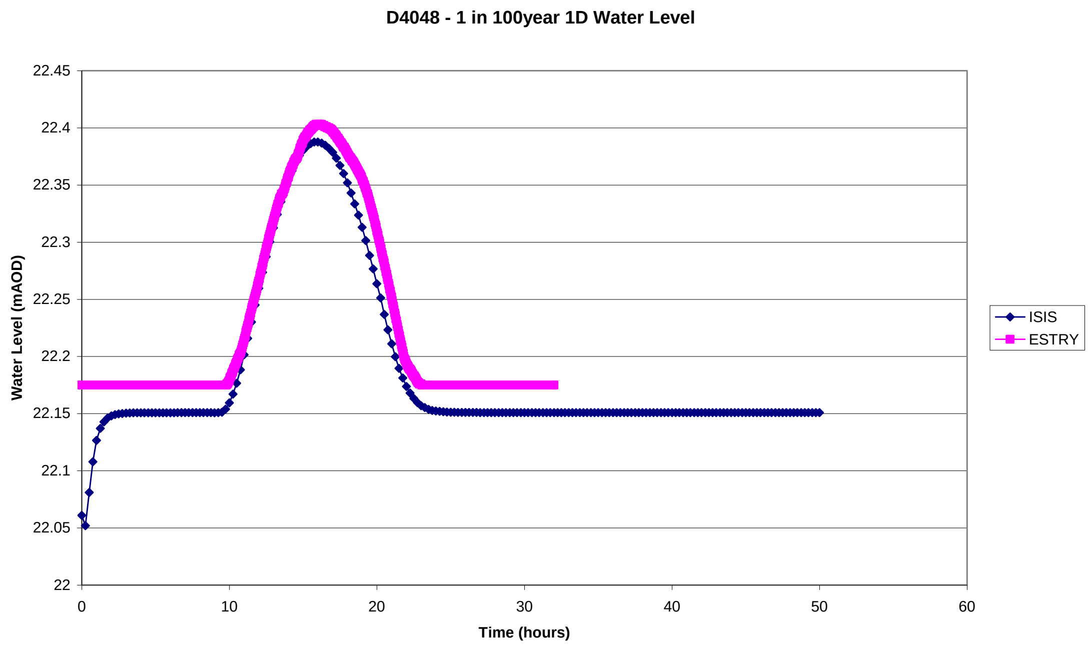

D1021 - 1 in 20year 1D Water Level
Water Level (mAOD)
6.5
6
5.5
5
4.5
4
0
5
10
15
20
25
30
35
40
45
Time (hours)
ISIS
ESTRY

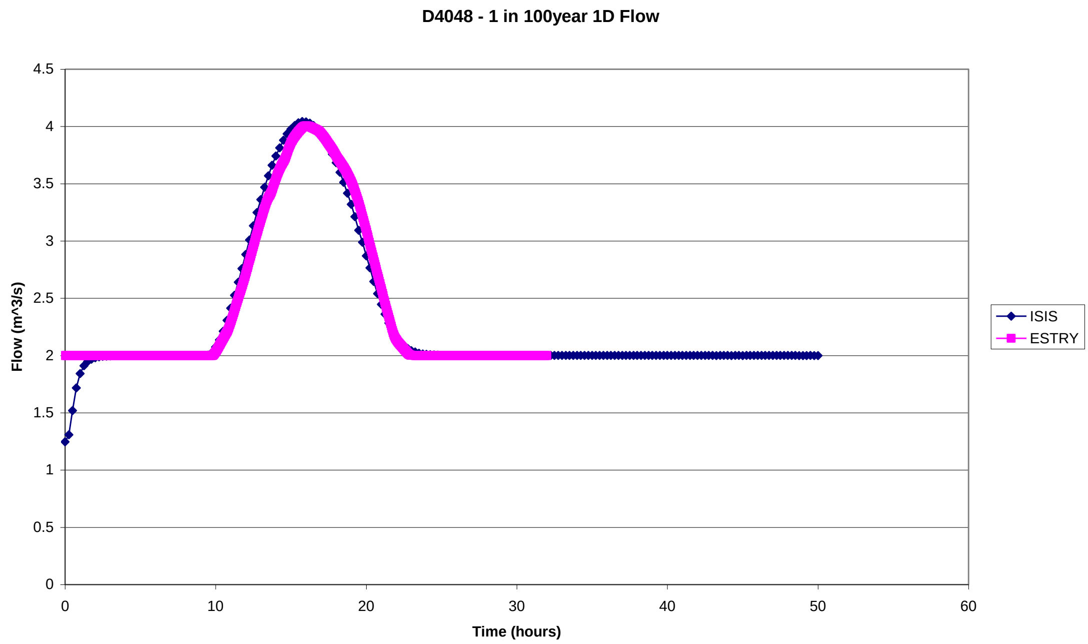

D1021 - 1 in 20year 1D Flow
Flow (m^3/s)
7
6
5
4
3
2
1
0
0
5
10
15
20
25
30
35
40
45
Time (hours)
ISIS
ESTRY

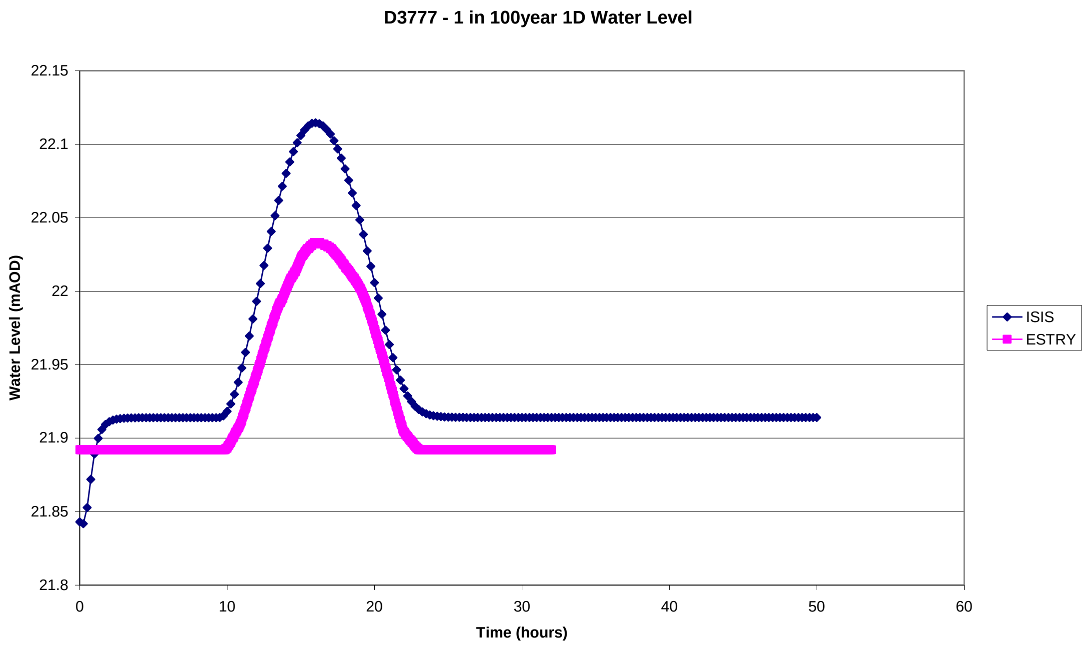

D0575 - 1 in 20year 1D Water Level
Water Level (mAOD)
Time (hours)
ISIS
ESTRY
5.5
5
4.5
4
3.5
3
0
5
10
15
20
25
30
35
40
45

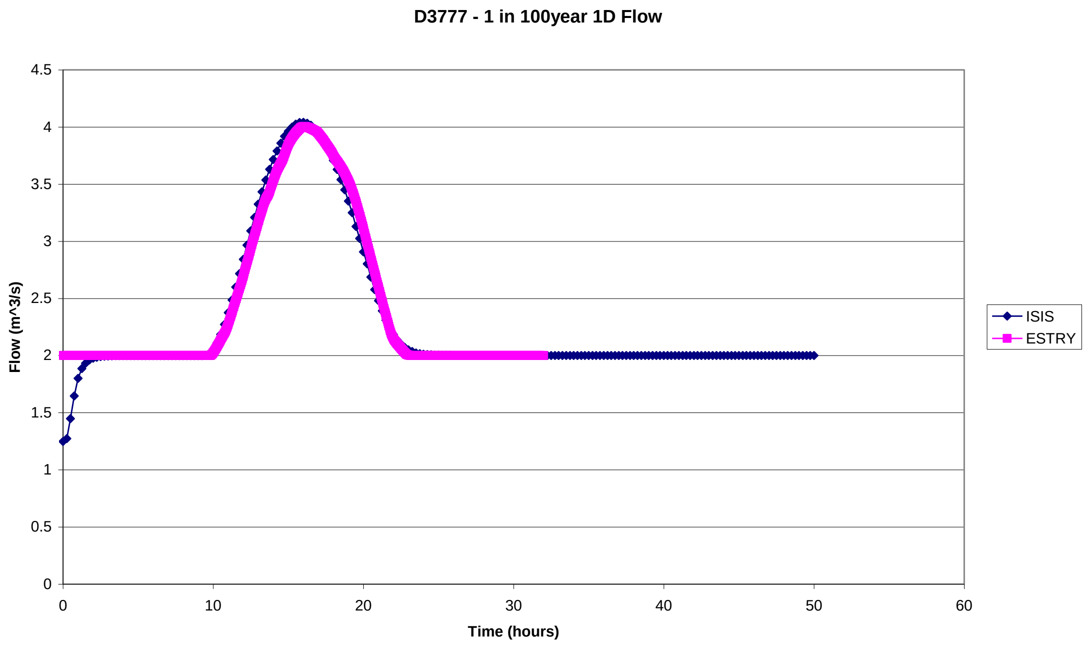

D0575 - 1 in 20year 1D Flow
Flow (m^3/s)
Time (hours)
ISIS
ESTRY
7
6
5
4
3
2
1
0
0
5
10
15
20
25
30
35
40
45

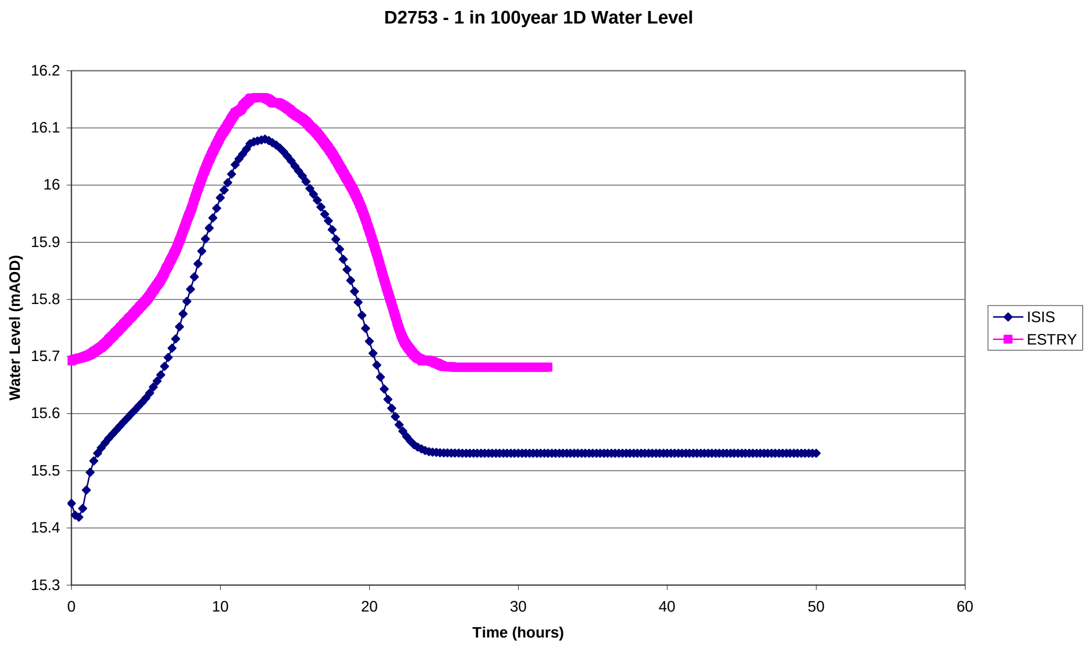
1 in 100 year Event

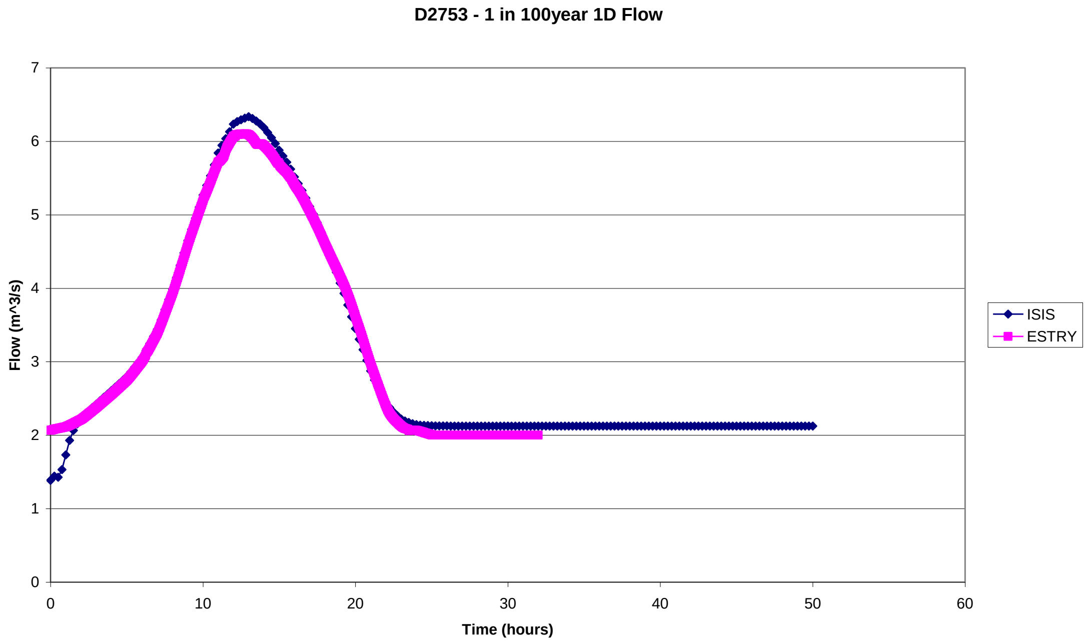

D4048 - 1 in 100year 1D Water Level
Water Level (mAOD)
22.45
22.4
22.35
22.3
22.25
22.2
22.15
22.1
22.05
22
0
10
20
30
40
50
60
Time (hours)
ISIS
ESTRY

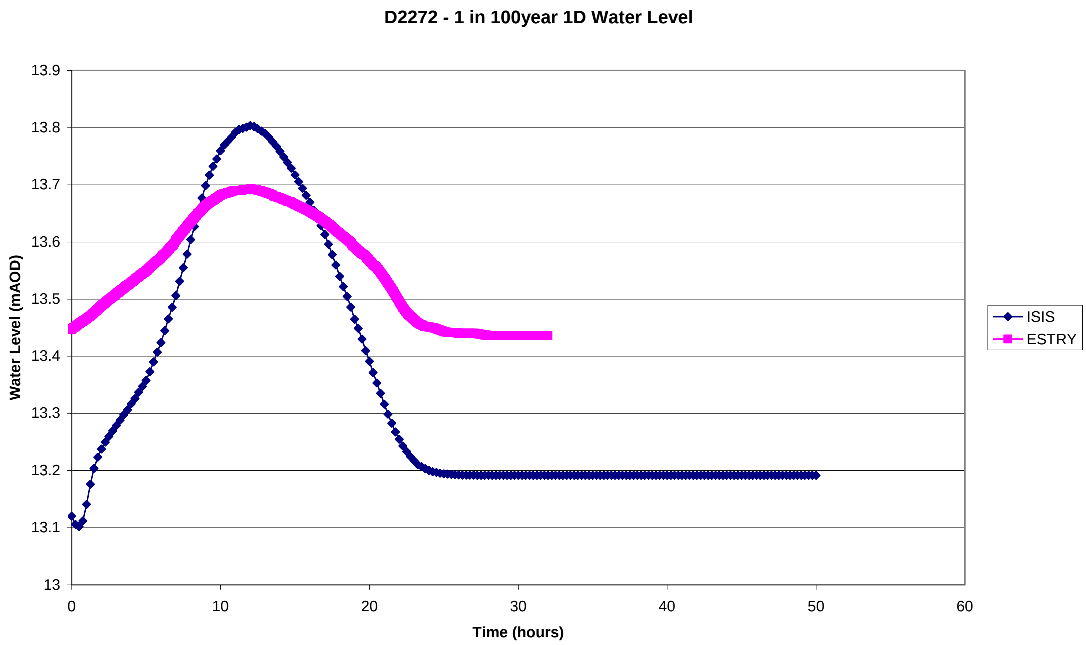

D4048 - 1 in 100year 1D Flow
Flow (m^3/s)
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0
10
20
30
40
50
60
Time (hours)
ISIS
ESTRY

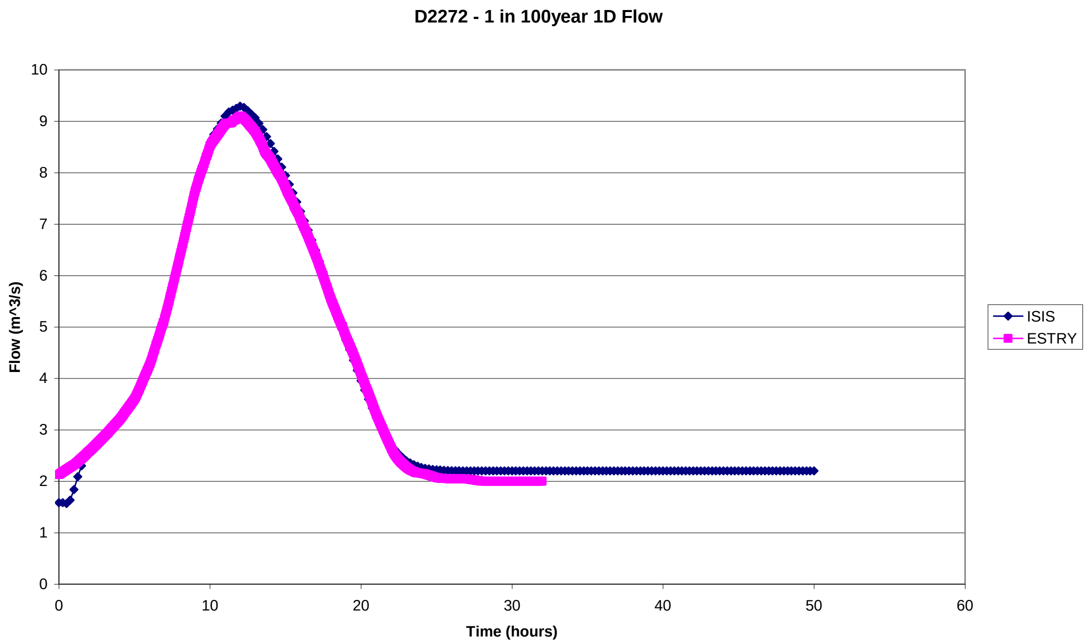

D3777 - 1 in 100year 1D Water Level
Water Level (mAOD)
Time (hours)
ISIS
ESTRY
22.15
22.1
22.05
22
21.95
21.9
21.85
21.8
0
10
20
30
40
50
60


D3777 - 1 in 100year 1D Flow
Flow (m^3/s)
Time (hours)
ISIS
ESTRY
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0
10
20
30
40
50
60

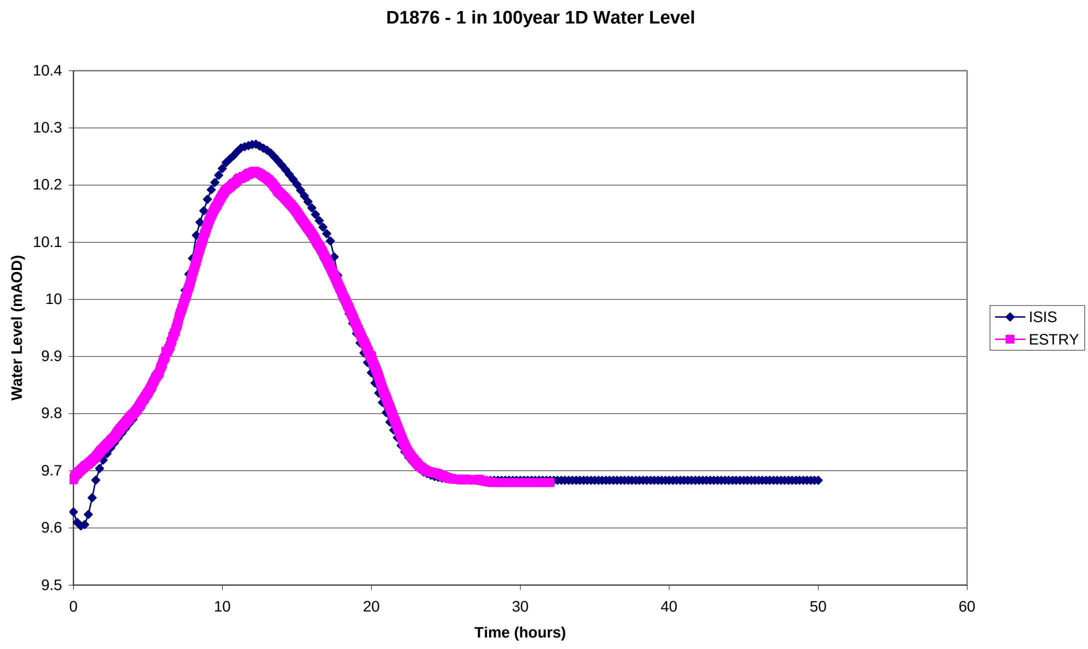

D2753 - 1 in 100year 1D Water Level
Water Level (mAOD)
16.2
16.1
16
15.9
15.8
15.7
15.6
15.5
15.4
15.3
0
10
20
30
40
50
60
Time (hours)
ISIS
ESTRY

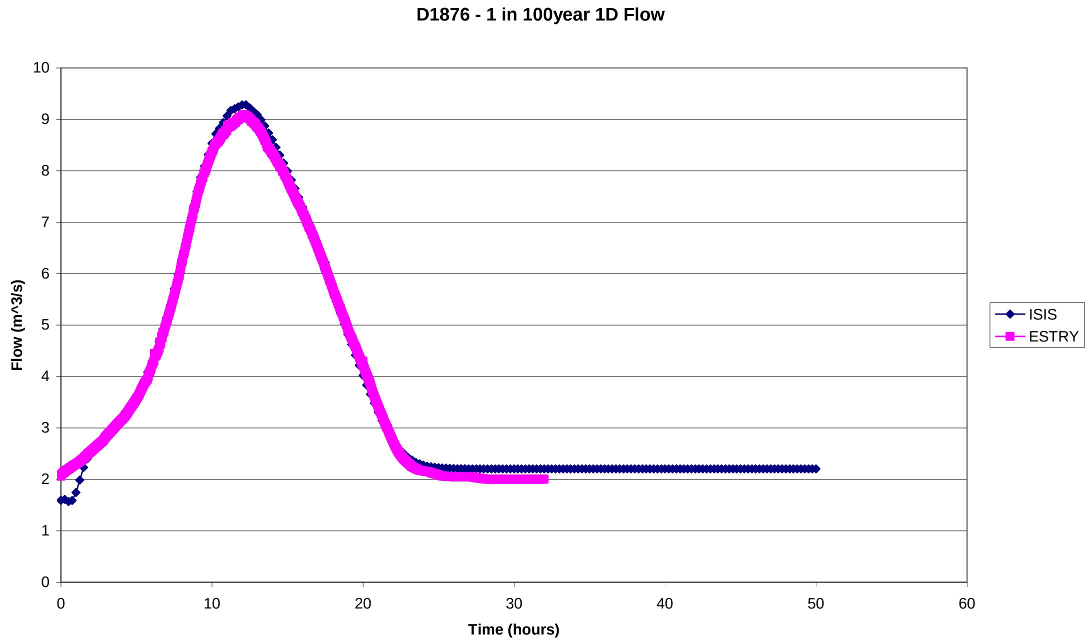

D2753 - 1 in 100year 1D Flow
Flow (m^3/s)
7
6
5
4
3
2
1
0
0
10
20
30
40
50
60
Time (hours)
ISIS
ESTRY



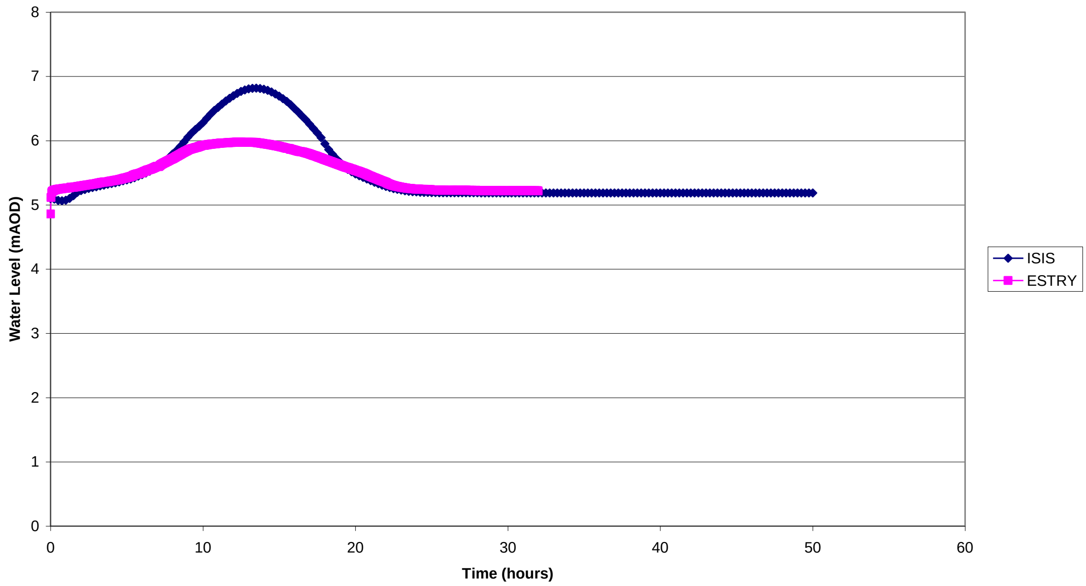


CAPITA SYMONDS

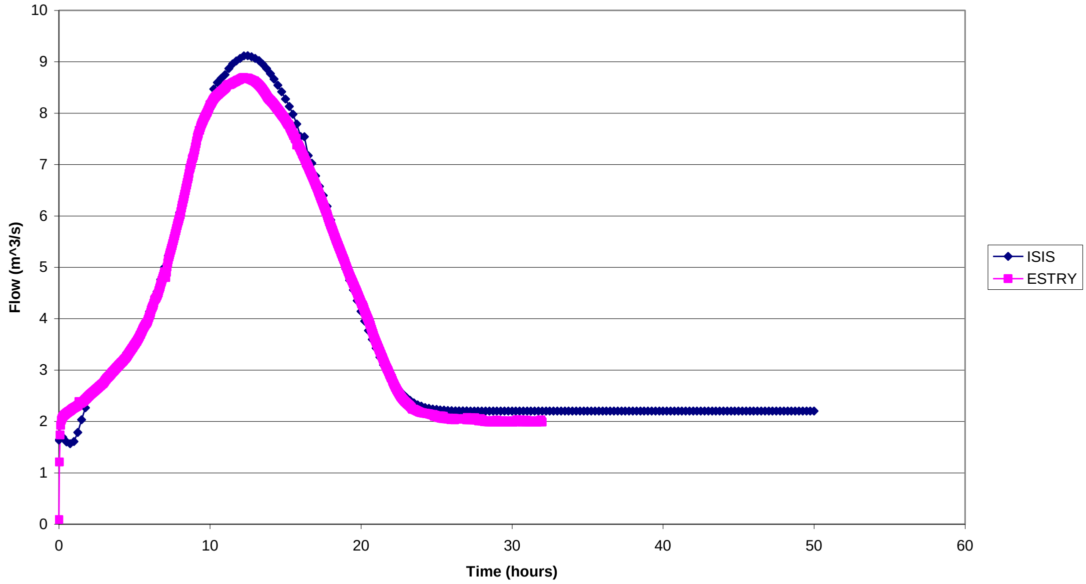

D1876 - 1 in 100year 1D Water Level
Water Level (mAOD)
10.4
10.3
10.2
10.1
10
9.9
9.8
9.7
9.6
9.5
0
10
20
30
40
50
60
Time (hours)
ISIS
ESTRY

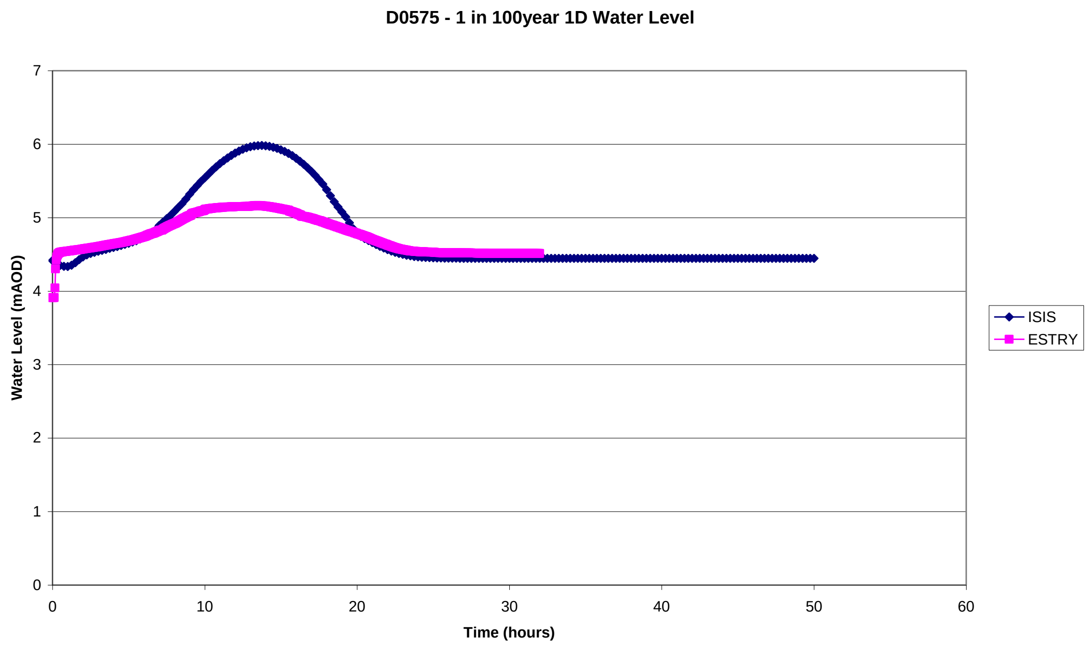

D1876 - 1 in 100year 1D Flow
Flow (m^3/s)
10
9
8
7
6
5
4
3
2
1
0
0
10
20
30
40
50
60
Time (hours)
ISIS
ESTRY

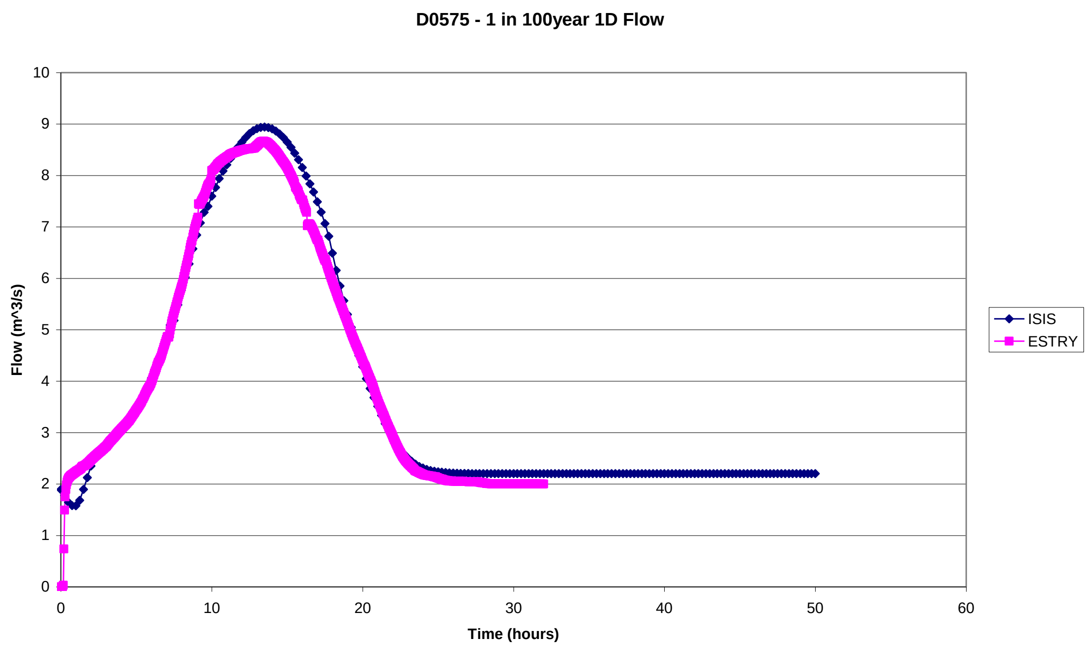
D1021 - 1 in 100year 1D Water Level



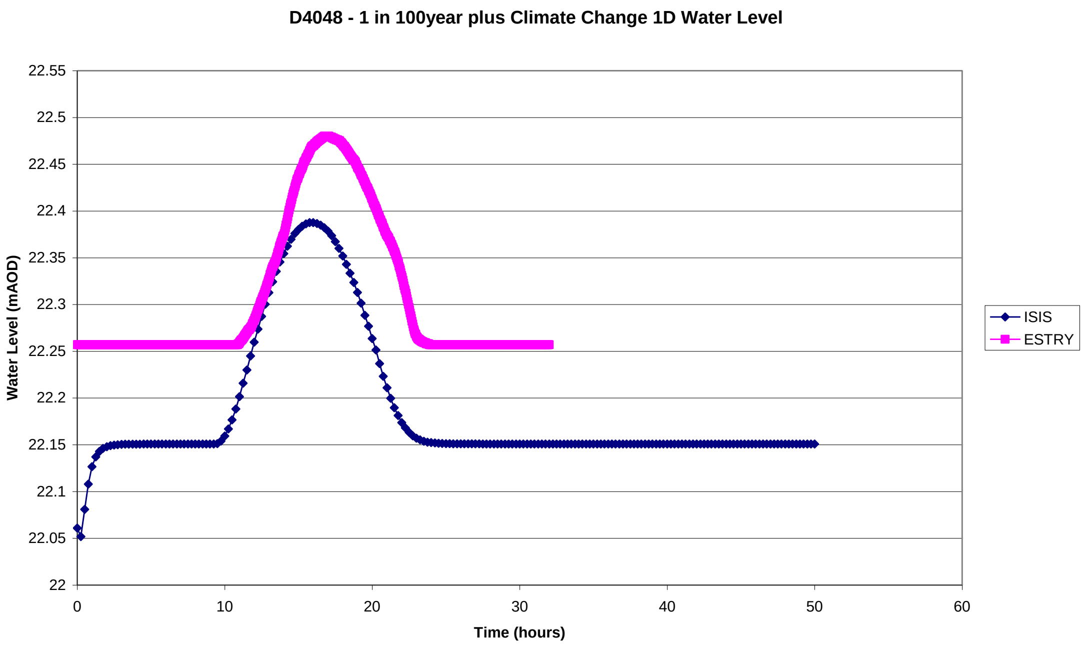
D1021 - 1 in 100year 1D Flow

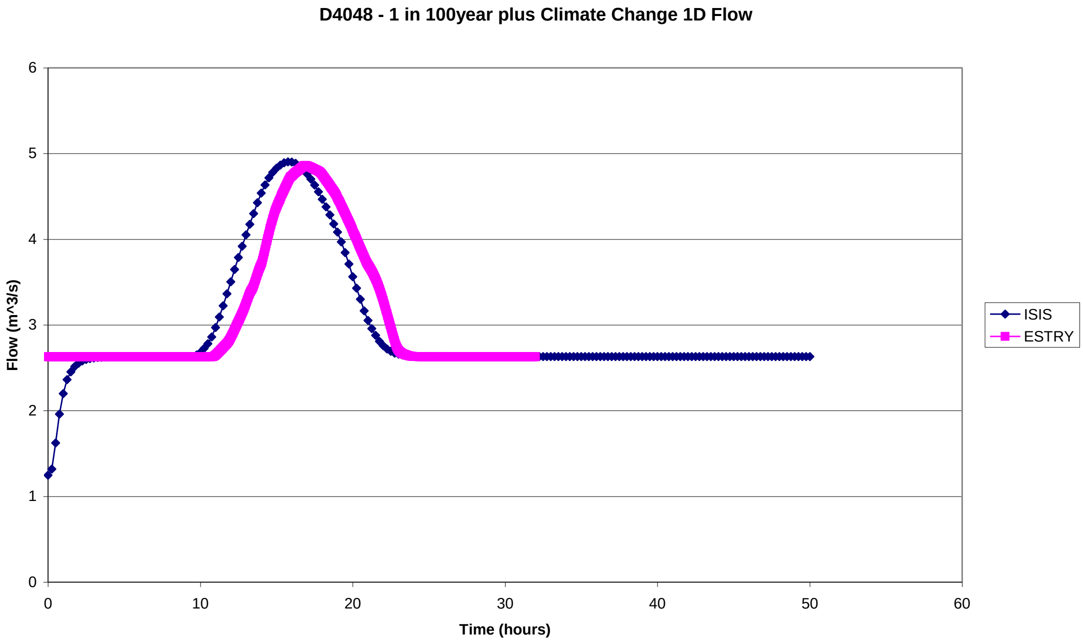


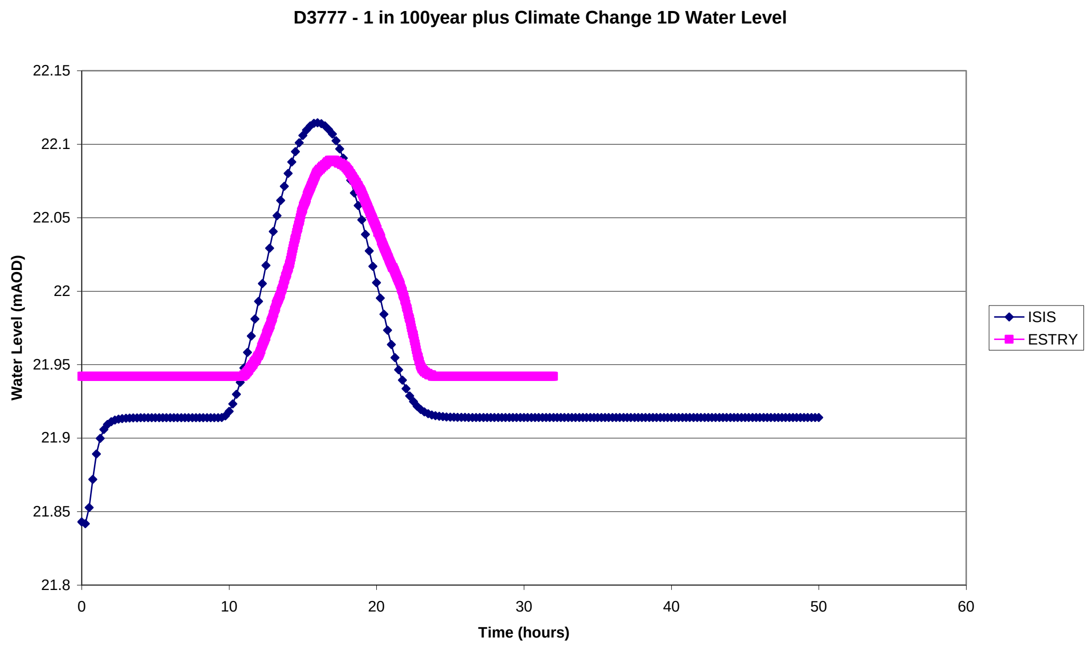

D0575 - 1 in 100year 1D Water Level
Water Level (mAOD)
7
6
5
4
3
2
1
0
0
10
20
30
40
50
60
Time (hours)
ISIS
ESTRY

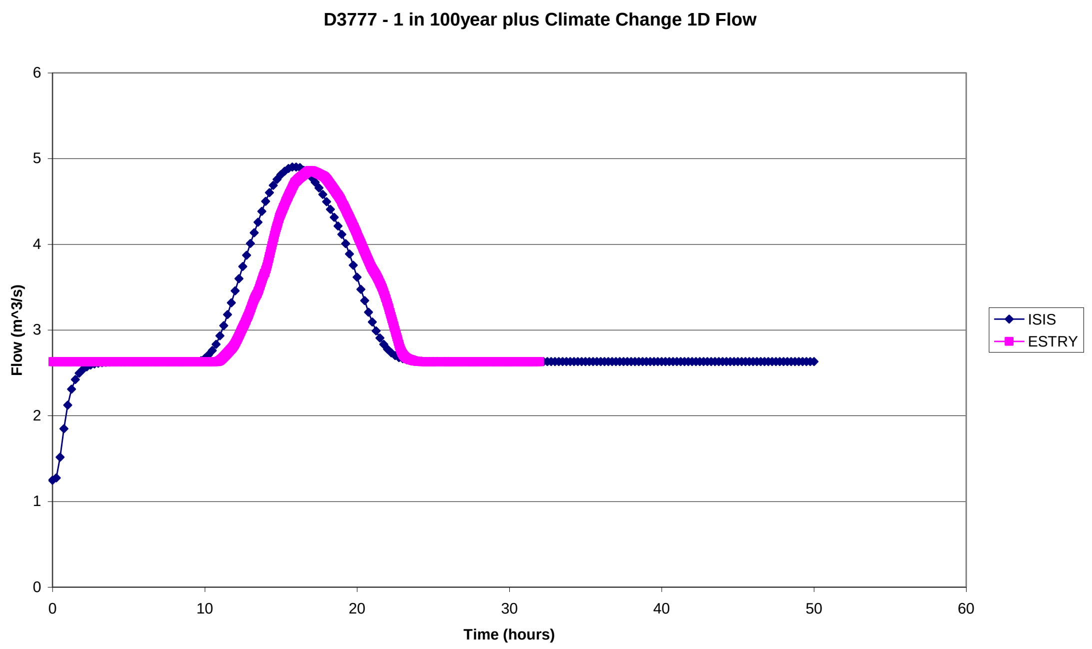

D0575 - 1 in 100year 1D Flow
Flow (m^3/s)
10
9
8
7
6
5
4
3
2
1
0
0
10
20
30
40
50
60
Time (hours)
ISIS
ESTRY

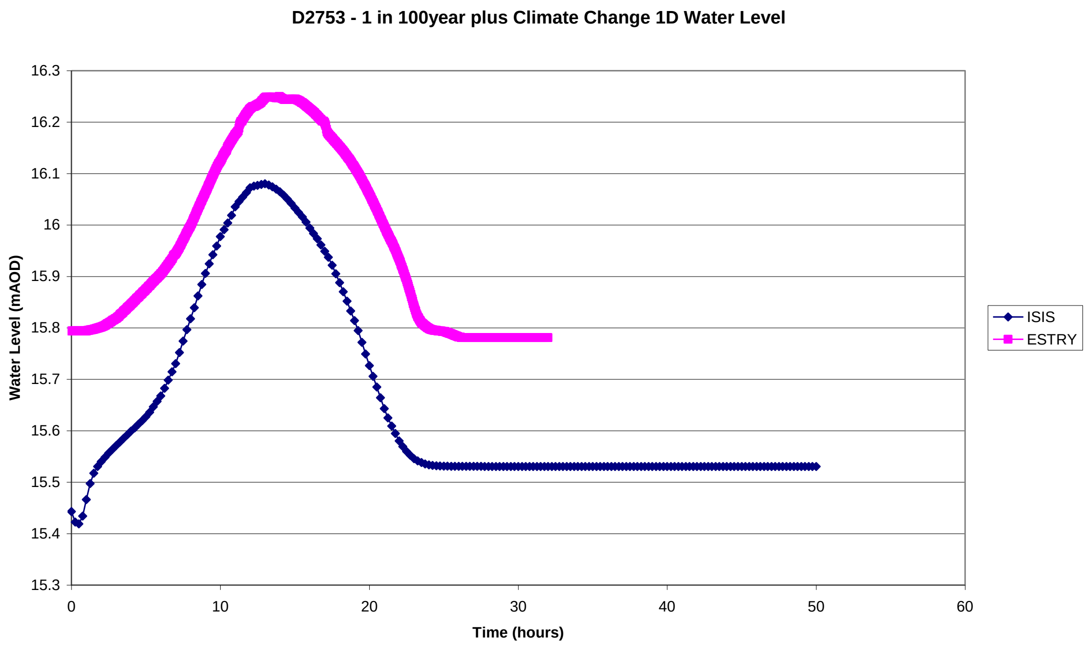
1 in 100 year plus Climate Change Event

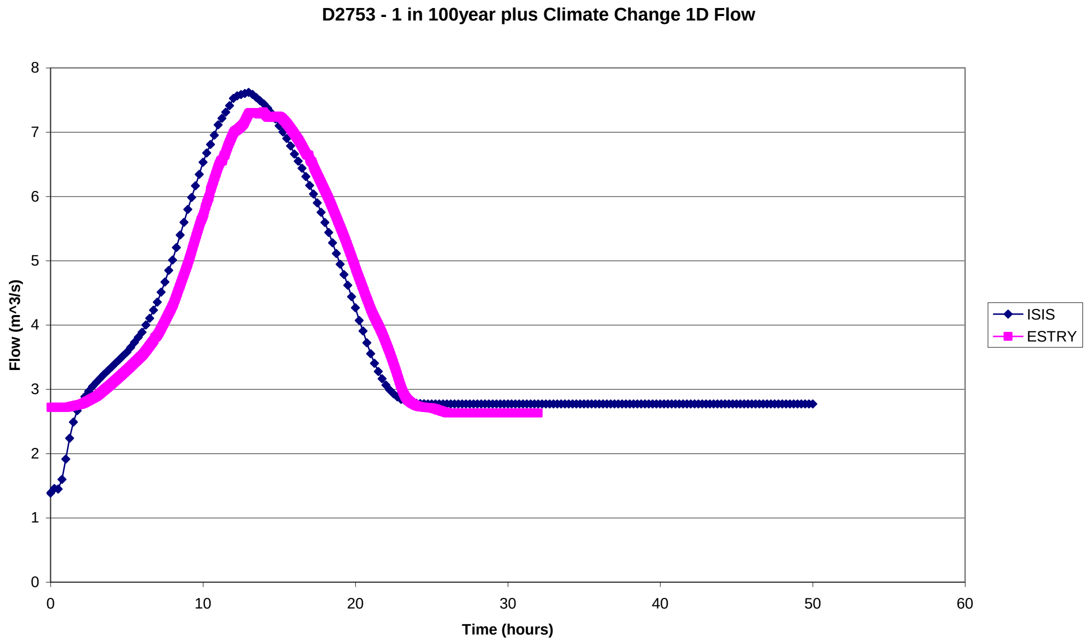

D4048 - 1 in 100year plus Climate Change 1D Water Level
Water Level (mAOD)
22.55
22.5
22.45
22.4
22.35
22.3
22.25
22.2
22.15
22.1
22.05
22
0
10
20
30
40
50
60
Time (hours)
ISIS
ESTRY

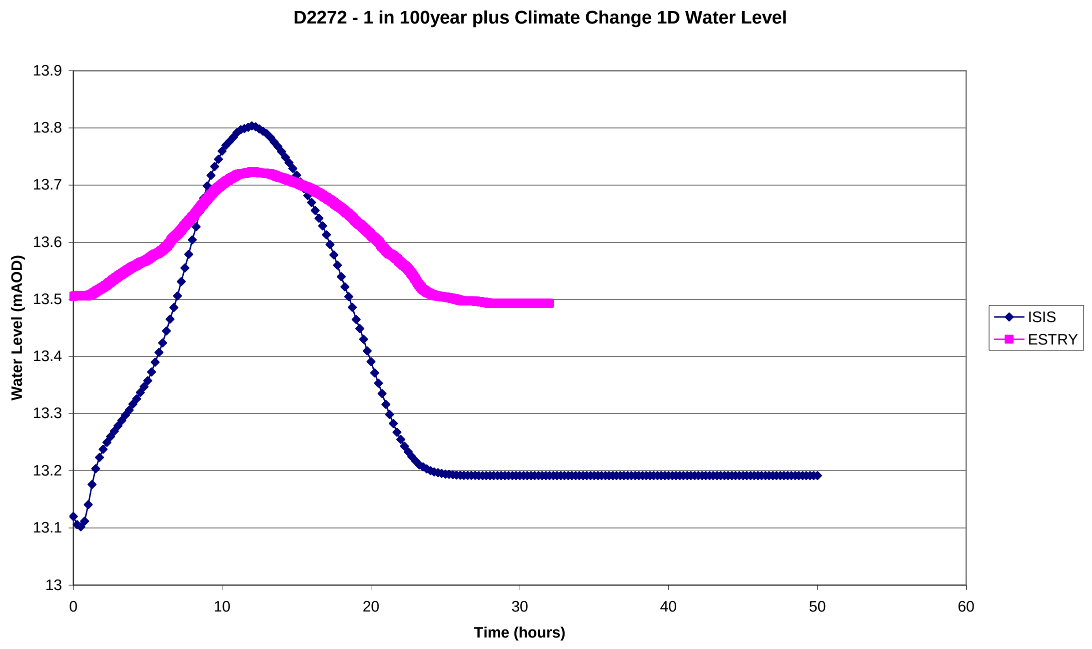

D4048 - 1 in 100year plus Climate Change 1D Flow
Flow (m^3/s)
6
5
4
3
2
1
0
0
10
20
30
40
50
60
Time (hours)
ISIS
ESTRY

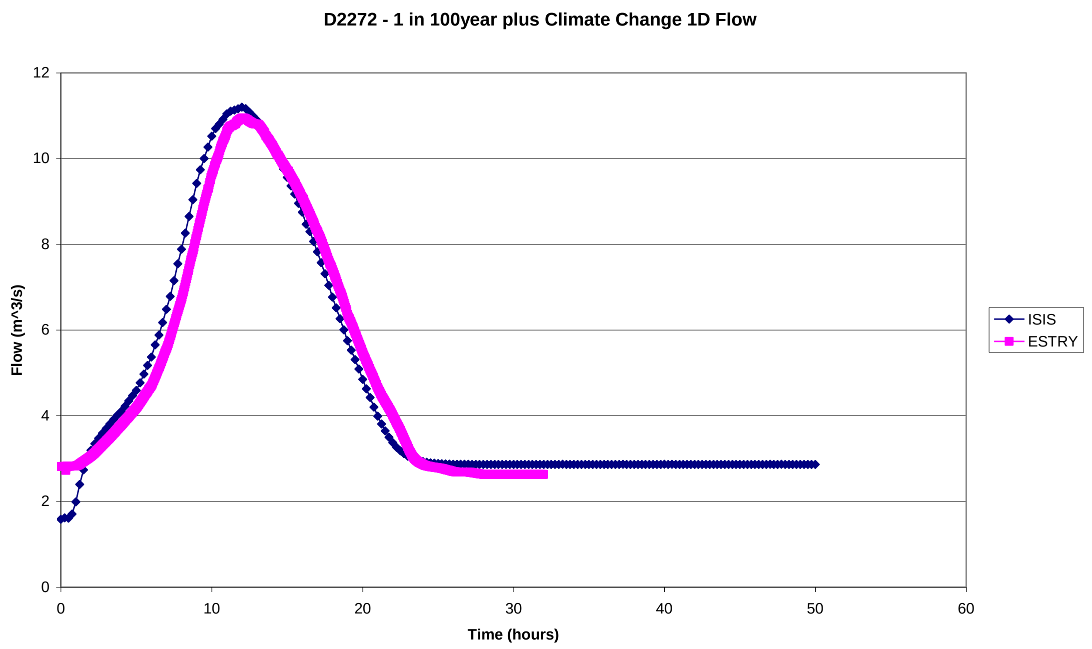

D3777 - 1 in 100year plus Climate Change 1D Water Level
Water Level (mAOD)
22.15
22.1
22.05
22
21.95
21.9
21.85
21.8
0
10
20
30
40
50
60
Time (hours)
ISIS
ESTRY

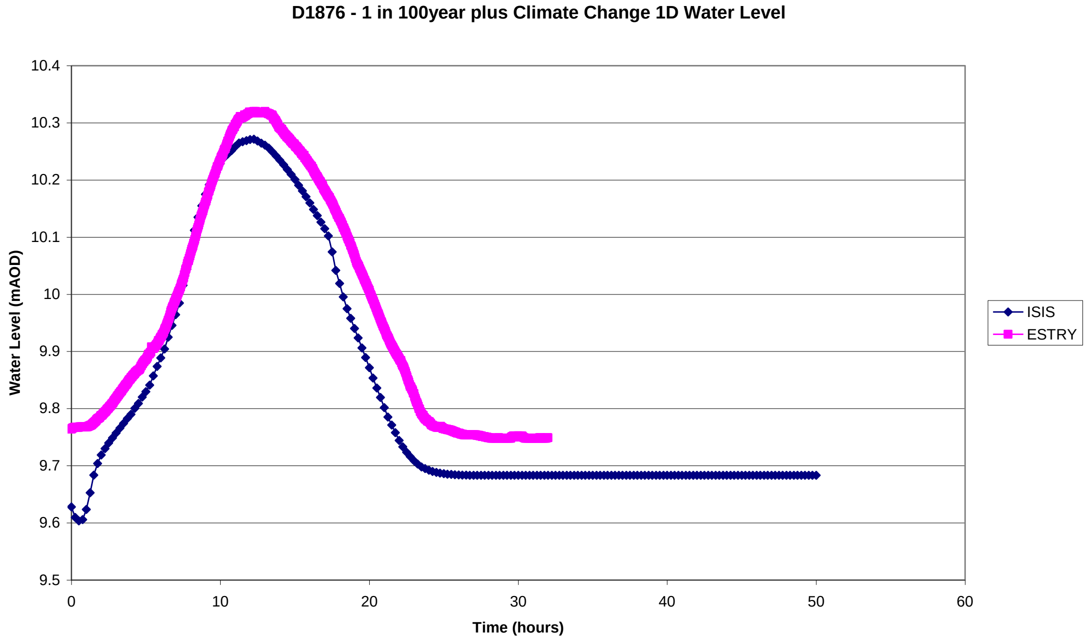

D3777 - 1 in 100year plus Climate Change 1D Flow
Flow (m^3/s)
6
5
4
3
2
1
0
0
10
20
30
40
50
60
Time (hours)
ISIS
ESTRY

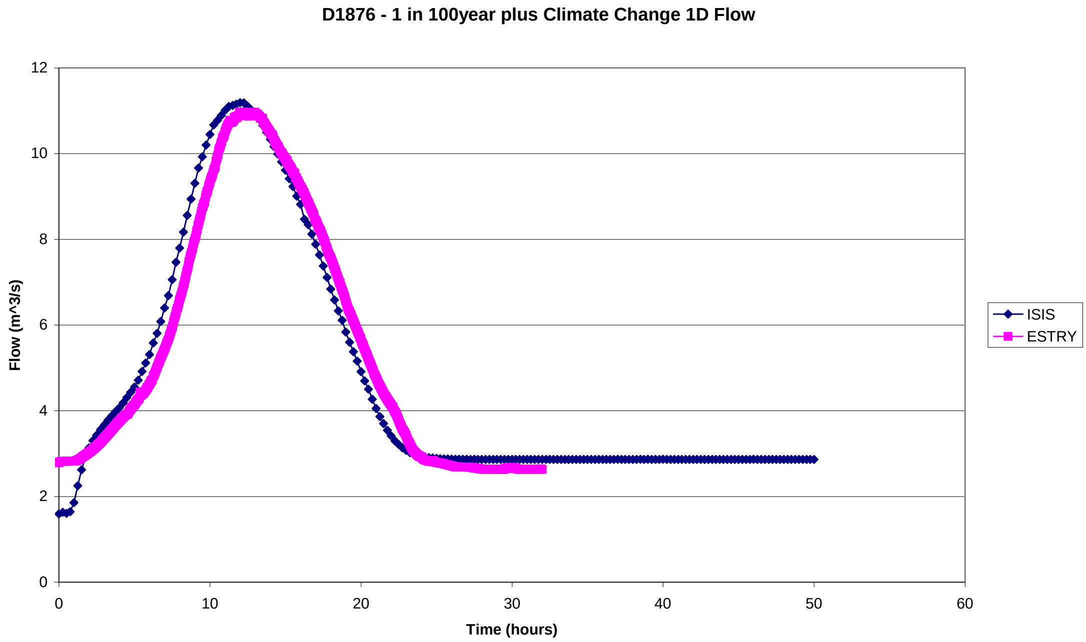

D2753 - 1 in 100year plus Climate Change 1D Water Level
Water Level (mAOD)
16.3
16.2
16.1
16
15.9
15.8
15.7
15.6
15.5
15.4
15.3
0
10
20
30
40
50
60
Time (hours)
ISIS
ESTRY

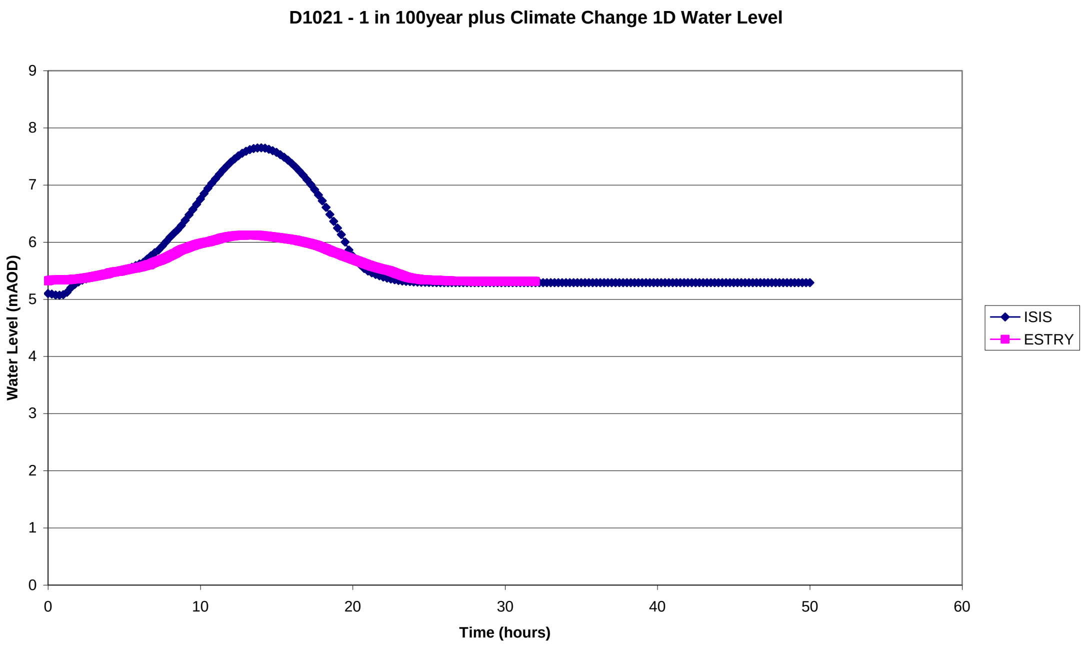

D2753 - 1 in 100year plus Climate Change 1D Flow
Flow (m^3/s)
8
7
6
5
4
3
2
1
0
0
10
20
30
40
50
60
Time (hours)
ISIS
ESTRY

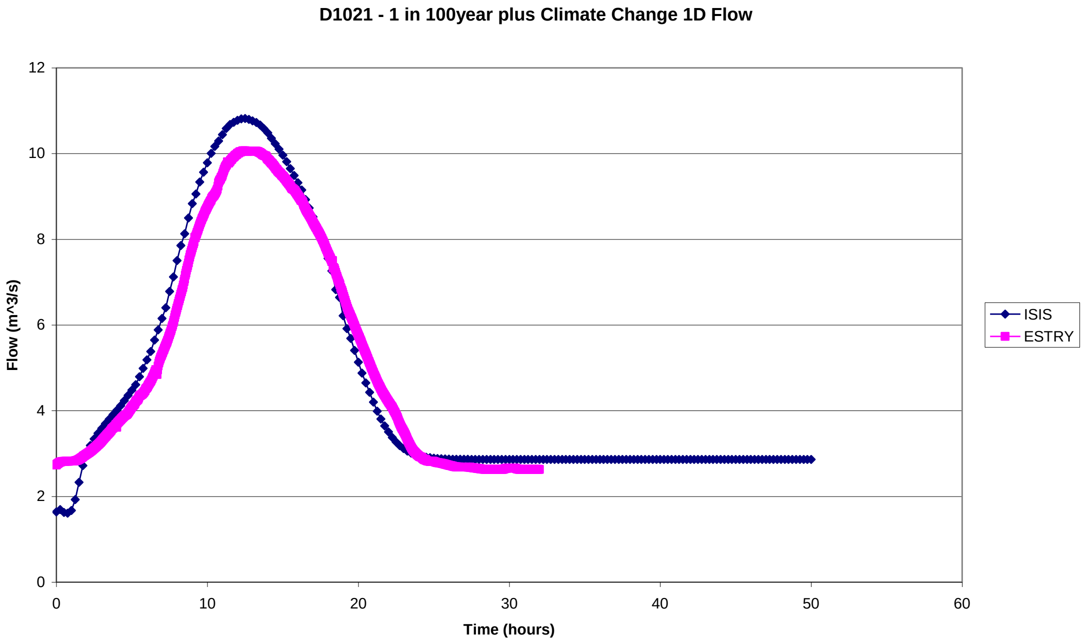

D2272 - 1 in 100year plus Climate Change 1D Water Level
Water Level (mAOD)
13.9
13.8
13.7
13.6
13.5
13.4
13.3
13.2
13.1
13
0
10
20
30
40
50
60
Time (hours)
ISIS
ESTRY

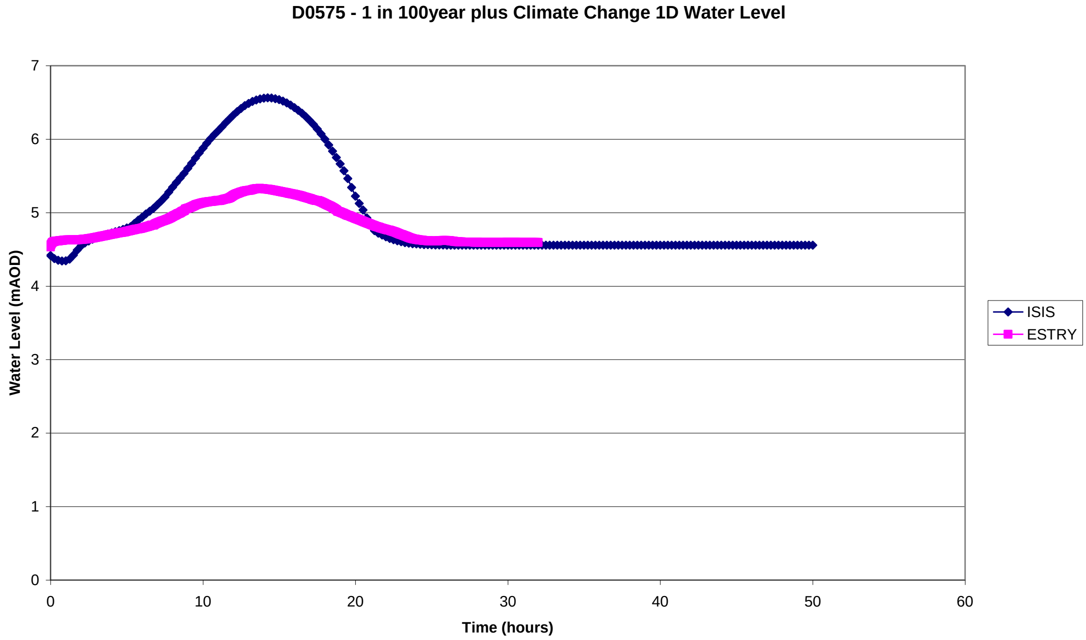

D2272 - 1 in 100year plus Climate Change 1D Flow
Flow (m^3/s)
12
10
8
6
4
2
0
0
10
20
30
40
50
60
Time (hours)
ISIS
ESTRY

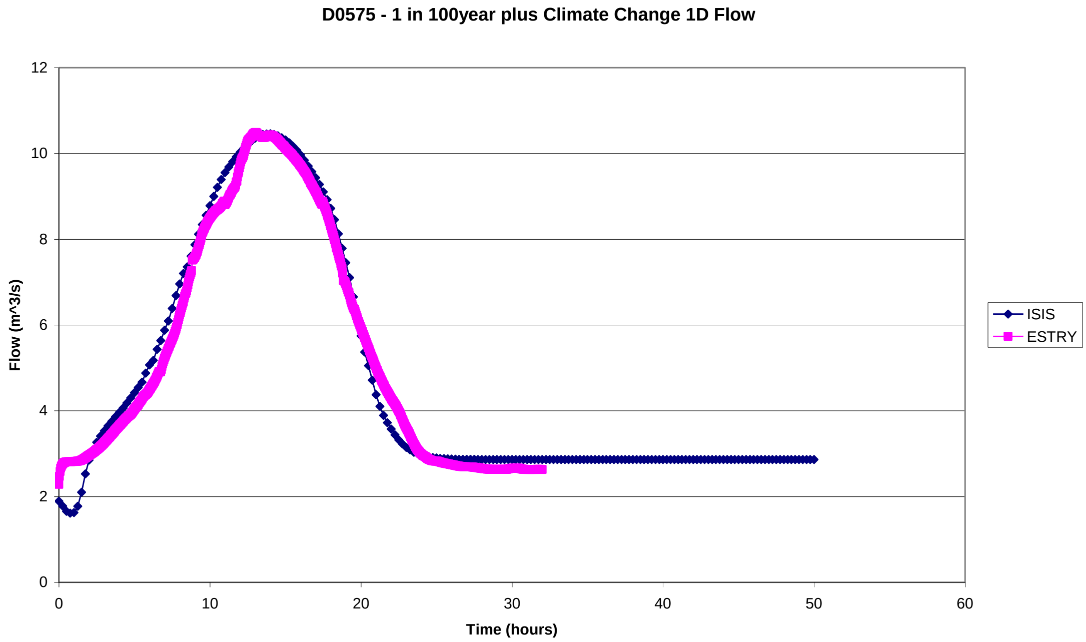

D1876 - 1 in 100year plus Climate Change 1D Water Level
Water Level (mAOD)
10.4
10.3
10.2
10.1
10
9.9
9.8
9.7
9.6
9.5
0
10
20
30
40
50
60
Time (hours)
ISIS
ESTRY


D1876 - 1 in 100year plus Climate Change 1D Flow
Flow (m^3/s)
12
10
8
6
4
2
0
0
10
20
30
40
50
60
Time (hours)
ISIS
ESTRY


D1021 - 1 in 100year plus Climate Change 1D Water Level
Water Level (mAOD)
Time (hours)
0
1
2
3
4
5
6
7
8
9
0
10
20
30
40
50
60
ISIS
ESTRY


D1021 - 1 in 100year plus Climate Change 1D Flow
Flow (m^3/s)
Time (hours)
0
2
4
6
8
10
12
0
10
20
30
40
50
60
ISIS
ESTRY


D0575 - 1 in 100year plus Climate Change 1D Water Level
Water Level (mAOD)
Time (hours)
ISIS
ESTRY
0
1
2
3
4
5
6
7
0
10
20
30
40
50
60


D0575 - 1 in 100year plus Climate Change 1D Flow
Flow (m^3/s)
Time (hours)
ISIS
ESTRY
0
2
4
6
8
10
12
0
10
20
30
40
50
60

Appendix B: Sensitivity Analysis Results

Sensitivity Analysis Results Table

Existing Floodplain
Baseline sensitivity analysis

DOVER MIDTOWN MODEL SENSITIVITY ANALYSIS

Water level (mAOD) for a 1 in 100 Year Flood Event

Node label	Channel Bed Elevation (mAOD)	Baseline 100 Year Level (mAOD)	Flow +20% (Level in m AOD)	Difference (m)	Difference (%)	Flow - 20% (Level in m AOD)	Difference (m)	Difference (%)	Mannings n + 20% (Level in m AOD)	Difference (m)	Difference (%)	Mannings n - 20% (Level in m AOD)	Difference (m)	Difference (%)	50% Blockage of culvert DOV_0782	Difference (m)	Difference (%)	50% Blockage of culvert DOV_1537	Difference (m)	Difference (%)
3592a.1	20.87	21.97	22.00	0.04	3.46	21.93	-0.04	-3.49	21.97	0.00	0.02	21.97	0.00	-0.05	21.97	0.00	0.00	21.97	0.00	0.00
3592a.2	20.69	21.96	22.00	0.04	2.91	21.93	-0.04	-2.94	21.96	0.00	-0.08	21.96	0.00	0.04	21.96	0.00	0.00	21.96	0.00	0.00
CrabbleLake	20.00	21.89	21.91	0.03	1.33	21.86	-0.03	-1.34	21.89	0.00	-0.02	21.89	0.00	0.01	21.89	0.00	0.00	21.89	0.00	0.00
DOV_0108R.1	1.57	3.10	3.12	0.02	1.49	3.08	-0.02	-1.01	3.11	0.01	0.36	3.09	-0.01	-0.35	3.10	0.00	0.05	3.10	0.00	0.01
DOV_0108R.2	0.50	3.05	3.05	0.00	0.00	3.05	0.00	0.00	3.05	0.00	0.00	3.05	0.00	0.00	3.05	0.00	0.00	3.05	0.00	0.00
DOV_0167.1	1.73	3.18	3.23	0.05	3.47	3.14	-0.04	-2.58	3.21	0.03	2.28	3.15	-0.03	-2.19	3.18	0.00	0.11	3.18	0.00	0.00
DOV_0200I..1	2.22	3.45	3.61	0.16	12.66	3.34	-0.11	-9.24	3.45	0.00	-0.02	3.46	0.00	0.18	3.46	0.01	0.52	3.45	0.00	0.00
DOV_0248B.1	2.79	3.82	3.97	0.15	14.56	3.73	-0.09	-8.87	3.91	0.09	9.06	3.70	-0.12	-11.88	3.82	0.01	0.53	3.82	0.00	0.00
DOV_0248B.2	2.79	3.81	3.95	0.14	13.73	3.72	-0.09	-8.78	3.90	0.09	8.84	3.69	-0.13	-12.28	3.82	0.01	0.54	3.81	0.00	0.01
DOV_0270.1	3.13	4.10	4.22	0.12	12.31	4.02	-0.08	-8.49	4.20	0.10	9.88	3.99	-0.12	-11.90	4.11	0.00	0.49	4.10	0.00	0.01
DOV_0276B.1	3.18	4.14	4.29	0.15	15.26	4.04	-0.10	-9.99	4.24	0.10	10.17	4.01	-0.13	-13.12	4.15	0.01	0.54	4.14	0.00	0.01
DOV_0325.1	3.30	4.60	4.75	0.15	11.81	4.49	-0.11	-8.57	4.65	0.05	4.18	4.55	-0.05	-4.06	4.60	0.01	0.49	4.60	0.00	0.01
DOV_0328B.1	3.33	4.62	4.83	0.21	16.32	4.50	-0.12	-9.16	4.68	0.06	4.64	4.56	-0.06	-4.57	4.63	0.01	0.60	4.62	0.00	0.01
DOV_0328us.1	3.35	4.65	4.86	0.21	15.76	4.53	-0.12	-9.53	4.72	0.07	5.11	4.59	-0.07	-5.08	4.66	0.01	0.58	4.65	0.00	0.00
DOV_0429I..1	3.55	4.76	4.92	0.16	12.96	4.63	-0.13	-10.99	4.78	0.02	2.07	4.65	-0.11	-8.85	4.77	0.01	0.65	4.76	0.00	-0.02
DOV_0429I..2	3.50	4.68	4.89	0.20	17.24	4.55	-0.13	-10.88	4.75	0.07	5.69	4.60	-0.08	-6.82	4.69	0.01	0.66	4.68	0.00	0.03
DOV_0509.1	3.67	4.92	5.07	0.15	11.85	4.81	-0.12	-9.54	4.99	0.07	5.21	4.80	-0.12	-9.55	4.93	0.01	0.57	4.92	0.00	-0.01
DOV_0575B.1	3.84	5.08	5.23	0.15	12.23	4.95	-0.12	-10.00	5.16	0.09	7.06	4.94	-0.14	-11.01	5.08	0.01	0.59	5.08	0.00	-0.01
DOV_0575B.2	3.84	5.06	5.19	0.13	10.84	4.95	-0.11	-9.16	5.14	0.08	6.69	4.94	-0.13	-10.23	5.07	0.01	0.53	5.06	0.00	0.00
DOV_0575us.1	3.91	5.16	5.30	0.14	10.86	5.05	-0.11	-9.05	5.25	0.09	7.08	5.03	-0.13	-10.49	5.17	0.01	0.52	5.16	0.00	-0.01
DOV_0728.1	4.06	5.31	5.42	0.11	8.58	5.21	-0.10	-8.01	5.40	0.08	6.71	5.19	-0.12	-9.90	5.31	-0.01	-0.42	5.31	0.00	-0.02
DOV_0782I.1	4.21	5.49	5.66	0.17	13.12	5.35	-0.14	-11.04	5.61	0.12	9.24	5.40	-0.10	-7.73	5.62	0.13	9.78	5.49	0.00	-0.03
DOV_0782I.2	4.07	5.48	5.62	0.14	9.72	5.34	-0.14	-9.80	5.57	0.09	6.13	5.38	-0.10	-7.02	5.59	0.11	7.51	5.48	0.00	0.13
DOV_0807B.1	4.10	5.56	5.75	0.19	13.35	5.41	-0.14	-9.82	5.67	0.11	7.46	5.45	-0.10	-7.10	5.66	0.10	6.86	5.56	0.00	-0.03
DOV_0807B.2	4.11	5.54	5.69	0.16	10.88	5.40	-0.14	-9.72	5.65	0.11	7.97	5.43	-0.10	-7.29	5.65	0.11	7.75	5.53	0.00	-0.03
DOV_0808us.1	4.17	5.60	5.75	0.15	10.45	5.44	-0.16	-11.35	5.71	0.10	7.32	5.49	-0.12	-8.12	5.70	0.09	6.47	5.60	0.00	-0.03
DOV_0837.1	4.26	5.61	5.76	0.15	11.16	5.46	-0.15	-10.92	5.72	0.10	7.65	5.50	-0.11	-8.11	5.70	0.09	6.54	5.61	0.00	-0.03
DOV_0918.1	4.12	5.68	5.82	0.14	8.99	5.56	-0.12	-7.59	5.78	0.10	6.64	5.58	-0.10	-6.29	5.76	0.08	5.12	5.68	0.00	-0.03
DOV_0918.2	4.16	5.66	5.80	0.15	9.71	5.53	-0.13	-8.40	5.76	0.10	7.00	5.56	-0.10	-6.59	5.74	0.09	5.74	5.66	0.00	-0.02
DOV_0944B.1	4.16	5.70	5.85	0.14	9.26	5.58	-0.12	-7.92	5.81	0.11	6.90	5.60	-0.10	-6.71	5.78	0.08	5.11	5.70	0.00	-0.02
DOV_0944B.2	4.15	5.69	5.83	0.14	8.97	5.58	-0.12	-7.58	5.80	0.10	6.72	5.60	-0.10	-6.40	5.77	0.08	4.98	5.69	0.00	-0.02
DOV_1000.1	4.39	5.77	5.91	0.14	10.32	5.65	-0.12	-8.95	5.88	0.11	8.28	5.66	-0.11	-8.09	5.84	0.07	5.11	5.77	0.00	-0.01
DOV_1021I.1	4.41	5.79	5.94	0.15	10.78	5.66	-0.13	-9.19	5.91	0.12	8.84	5.67	-0.12	-8.34	5.86	0.07	5.13	5.79	0.00	-0.01
DOV_1110.1	4.73	5.98	6.11	0.13	10.43	5.85	-0.13	-10.42	6.11	0.13	10.08	5.85	-0.13	-10.57	6.03	0.05	3.67	5.98	0.00	0.05
DOV_1134.1	4.83	6.09	6.21	0.12	9.77	5.96	-0.12	-9.84	6.22	0.13	10.27	5.95	-0.14	-10.85	6.12	0.03	2.74	6.09	0.00	0.20
DOV_1171I.1	4.90	6.14	6.22	0.08	6.37	6.01	-0.13	-10.76	6.26	0.12	9.54	6.03	-0.11	-8.71	6.17	0.03	2.05	6.14	0.00	0.04
DOV_1234.1	5.22	6.34	6.41	0.07	6.52	6.20	-0.14	-12.83	6.46	0.12	10.53	6.22	-0.12	-10.84	6.35	0.01	1.18	6.33	0.00	-0.41
DOV_1247I.1	5.28	6.44	6.55	0.11	9.11	6.30	-0.14	-11.73	6.60	0.16	14.14	6.32	-0.12	-10.36	6.45	0.01	1.26	6.44	0.00	-0.42
DOV_1256.1	5.28	6.46	6.56	0.10	8.75	6.33	-0.13	-11.37	6.62	0.16	13.67	6.34	-0.12	-10.29	6.47	0.01	1.15	6.46	0.00	-0.40
DOV_1388R.1	5.84	6.69	6.76	0.06	7.09	6.60	-0.09	-11.07	6.69	0.00	-0.27	6.69	0.00	-0.22	6.69	0.00	0.00	6.69	0.00	-0.05
DOV_1396W.1	6.09	7.18	7.24	0.06	5.17	7.10	-0.09	-8.05	7.18	0.00	-0.18	7.18	0.00	-0.15	7.18	0.00	0.00	7.18	0.00	-0.03
DOV_1457.1	5.61	7.22	7.27	0.06	3.61	7.13	-0.09	-5.59	7.23	0.01	0.70	7.20	-0.01	-0.81	7.22	0.00	0.00	7.22	0.00	-0.02
DOV_1468B.1	5.68	7.37	7.47	0.10	5.91	7.23	-0.14	-8.33	7.38	0.01	0.77	7.35	-0.02	-0.91	7.37	0.00	0.00	7.37	0.00	-0.04
DOV_1488.1	6.00	7.38	7.48	0.10	7.20	7.24	-0.14	-10.12	7.40	0.02	1.27	7.36	-0.02	-1.39	7.38	0.00	0.00	7.38	0.00	-0.04
DOV_1488I.1	6.22	7.92	8.16	0.24	13.88	7.60	-0.32	-18.99	7.92	0.00	-0.11	7.86	-0.06	-3.59	7.92	0.00	0.00	9.36	1.44	84.51
DOV_1537I.1	6.44	7.93	8.17	0.24	15.90	7.61	-0.32	-21.71	7.93	0.00	-0.10	7.87	-0.06	-4.29	7.93	0.00	0.00	9.37	1.44	96.52
DOV_1540.1.1	8.79	9.57	9.61	0.05	6.07	9.49	-0.08	-9.70	9.56	0.00	-0.24	9.56	0.00	-0.21	9.57	0.00	0.00	9.57	0.00	0.13
DOV_1555.1	8.27	9.59	9.64	0.05	3.87	9.51	-0.08	-5.98	9.60	0.01	0.54	9.58	-0.01	-0.74	9.59	0.00	0.00	9.59	0.00	0.11
DOV_1555br.1	8.27	9.59	9.65	0.05	3.92	9.52	-0.08	-6.00	9.60	0.01	0.54	9.59	-0.01	-0.73	9.59	0.00	0.00	9.60	0.00	0.05
DOV_1627.1	8.85	9.72	9.79	0.07	8.28	9.63	-0.09	-10.76	9.77	0.05	5.39	9.67	-0.05	-5.17	9.72	0.00	0.00	9.72	0.00	0.03
DOV_1628I.1	8.87	9.79	9.87	0.08	9.14	9.69	-0.10	-11.28	9.79	0.00	-0.08	9.76	-0.03	-3.63	9.79	0.00	0.00	9.79	0.00	0.02
DOV_1757.1	9.11	10.01	10.10	0.08	9.30	9.91	-0.10	-11.44	10.07	0.05	5.96	9.94	-0.08	-8.37	10.01	0.00	0.00	10.01	0.00	0.00
DOV_1757.1.2	8.92	9.85	9.93	0.08	9.02	9.74	-0.11	-11.41	9.87	0.02	2.09	9.80	-0.05	-5.32	9.85	0.00	0.00	9.85	0.00	0.00
DOV_1757.2	8.98	9.91	9.99	0.08	9.12	9.80	-0.11	-11.40	9.94	0.04	3.79	9.85	-0.06	-6.58	9.91	0.00	0.00	9.91	0.00	0.00

Appendix C: Response to Initial EA Model Review

Priority	Environment Agency Comments	Capita Symonds Response
A	No evidence that the surge element has been considered in the downstream tidal boundary conditions (E.14, Appendix A).	A 72hr storm surge has been applied to the relevant tidal data. Refer to Section 5.4 for details.
	River bank levels in between cross sections away from the Hospital site have not been enforced using LiDAR and/or other supplementary information (J.8, Appendix A).	River bank levels have been enforced throughout the model where the distance between cross sections exceeds 50m and at bends within the river. A review of aerial photography (Multimap birds eye view) for the River Dour was used to confirm areas where bank levels from the LIDAR were lower than the cross section interpolations. This was undertaken to confirm which level appeared to best represent the bank level.
	The relationship of Manning's 'n' with increasing depth is inconsistent with scientific principles and research for the surface water baseline model (F.7, Appendix A).	Refer to Sections 5.6 and 5.7 for details on the approach utilised within the surface water model. No amendments to this scenario have been undertaken.
B	Wellington Dock gate is modelled as open for the defended model runs in extreme tidal events (1 in 200yr and 1in 1000yr) which may not be a valid assumption (F.12, Appendix A).	Discussions with Vicki Case of the Dover Harbour Board has determined that there are currently no specific operational rules for Wellington Dock gates during extreme tidal events (refer to email 11th June 2009 points 6 and 9). We have modelled the gates based on current operational rules provided to us by the Dover Harbour Board. No amendments to the model have been made.
	No calibration of the 1D-2D baseline models has been carried out using gauge data from Crabble Mill and Dover Ultrasound particularly relating to the 2007 flood event (E.12, Appendix A).	Refer to Section 7.4 for a discussion on the comparison between the gauged data provided by the Environment Agency for the gauged near Pencester Gardens. A review of the rainfall on the July event indicates that the rainfall that landed within the catchment was approximately a 1 in 20year event however the flood stage information indicates that levels exceeded the 1 in 100 year flood depths. It has been concluded that this could be caused by a combination of influences which include: insufficient bank level detail based on LIDAR; the possible influence of a large downstream tidal event affecting the capacity of the channel, a possible blockage of the downstream culvert causing flood waters to back up within the channel, or errors with the gauge and gauged data.
	No update of the hydrology using gauging data from the last five years has been carried out (E.8, Appendix A).	It was agreed with the Environment Agency that use of the hydrology from PBA would be sufficient for this commission. It is recommended that revised hydrological estimations are undertaken and incorporated into future iterations of the hydraulic model. No amendments have been undertaken to the model.
	Some culverts are not modelled appropriately including number of culverts and inappropriate parameters are used for some culverts (F.9, Appendix A).	Two of the structures with multiple culverts were modelled as multiple openings to determine any differences within the two methods for culvert representation. These structures were; the triple opening structure beneath Lower road and the most upstream double opening railway bridge. This analysis showed that there was minimal impact on either flow or water level as a result of this change, with either no change or less than 1% increase in values. Due to the minimal discrepancy between the two model results the single opening representing the multiple culverts has been retained within the hydraulic model.
	A 6 mm/yr rate has been used for detrending extreme sea levels back to 1990 which is inconsistent with PPS25 and FCDPAG3 (E.14, Appendix A).	De-trending the sea at a rate of 6mm/year was carried out based on advice provided to CSL by the Environment Agency (30th June 2009). However, we have amended these inputs to conform to guidance identified within PPS25 and FCDPAG3 (refer to Section 5.4).
	Crest levels of key floodplain features such as raised infrastructure have not been enforced, particularly for baseline surface water model (J.4, Appendix A).	Based on discussions with the EA this has not been incorporated within this model. It is recommended that within future iterations of the model that these de facto defences are incorporated into the model.
C	No 1D-2D model log detailing the model structure, development and assumptions in the final model handover has been provided (F.19, Appendix A).	The Dover Flood Risk Appraisal Peer Review Proforma (December 2009) is provided to in lieu of this information. This revised document should provide any modellers with sufficient information for understanding the model. No model log has been supplied to the EA.

Hlinovsky, Paul (Capita Symonds)

From: Hook, Emma [emma.hook@environment-agency.gov.uk]
Sent: 17 May 2010 10:14
To: Hlinovsky, Paul (Capita Symonds)
Subject: Dover Midtown Modelling

Dear Paul,

Following the review completed by Mott Macdonald (and the subsequent updates completed), I am pleased to confirm that we consider the model to be fit for purpose, in establishing the flood risk for Dover Midtown.

Kind Regards

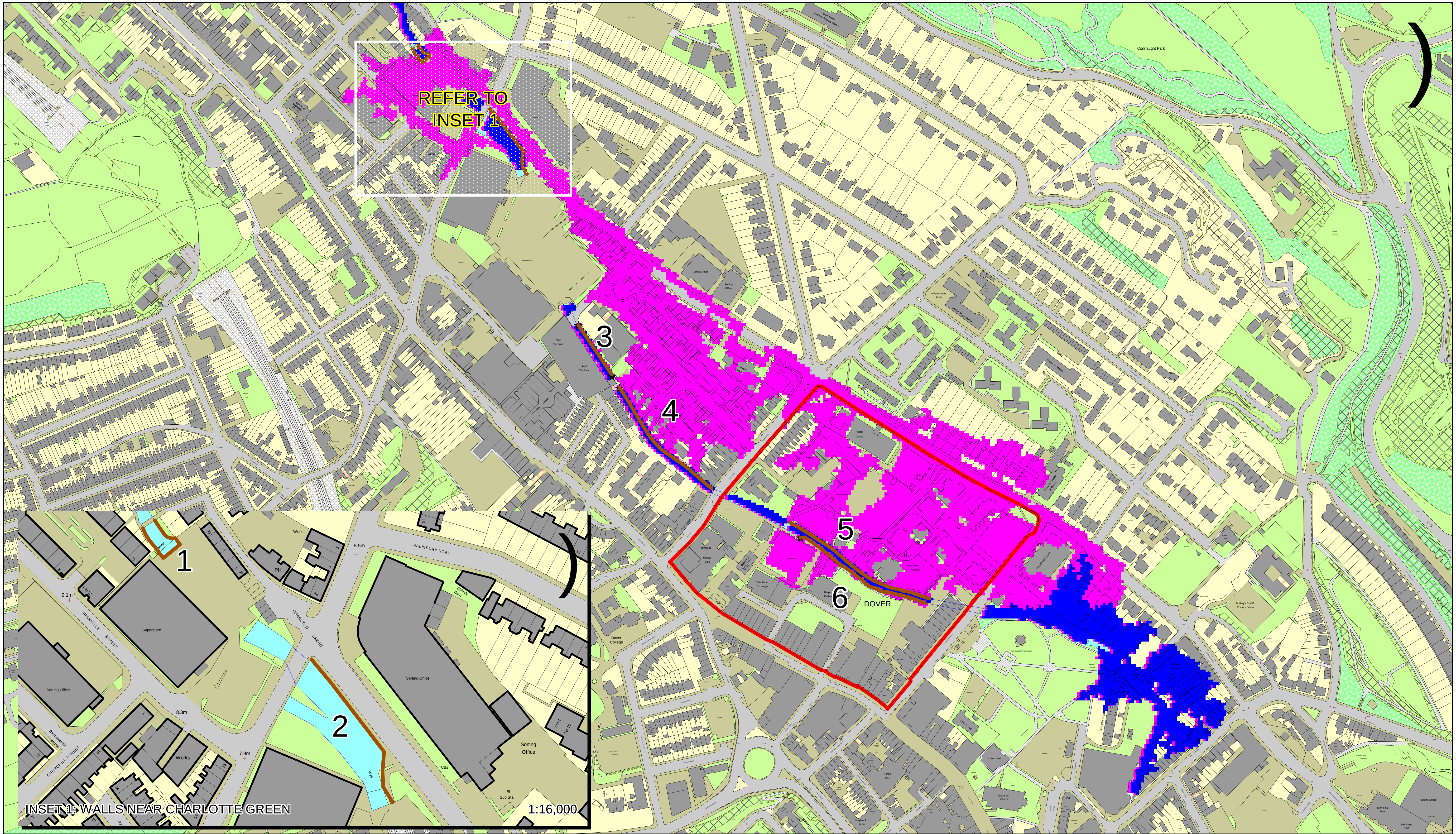
Emma

Emma Hook
Flood Risk Mapping & Data Management Team Member 1
Southern Region, Kent and East Sussex Area

☎ 723 3149 ☏ 01732 223149 🖶 01732 875057
emma.hook@environment-agency.gov.uk

With the help of all our staff, last year the Environment Agency drove 14 million miles fewer than it did three years ago, a reduction of 24%.

Item	Information	To be supplied by	Comment	Date received	Status
1	Existing JBA hydraulic model files and associated documentation (model logs, original survey data in 3D etc);	DDC	Email sent to JBA requesting model and survey files 5/5/2009	13/05/2009	Provided
2	Any topographic and asset survey information available within the borough which has been undertaken within previous reports or other Council works;	DDC	Simon recommends that we contact DDC (8/4/2009)	-	None available
3	Environment Agency information relating to the topographic data of the Dour including all its structures;	EA	Survey undertaken in 2005. Additionao cross sections and verifications required.	29/04/2009	Provided
4	River Dour Hydrology Report prepared by Peter Brett and Associates;	EA	Photos missing from survey. Review of the Isis model: The coordinates of hydrology inflow of the iSIS model are not consistant with the coordinates of the attached cross-sections. The surveyed cross-section is believed to be more relialbe. Survey photos not included. Have instructed JC White to obtain photos of all surveyed cross sections.	29/04/2009	Provided
5	Tidal level information held by the EA for the Wellington Docks;	EA	Tidal curve information obtained by the EA	29/04/2009	Provided
6	Extreme Sea Levels in Kent, Sussex, Hampshire and the Isle of White report prepared by JBA consulting;	SH	Adjust levels based on advice from EA during the inception meeting. Still require a tidal curve from the EA.	09/04/2009	Provided
7	LiDAR of the Borough;	EA via Twerton	Lidar provided 22/05/2009 but does not exted to upstream boundary. Have requested additional Lidar information.	10/06/2009	Provided
8	OS mapping and Mastermap information in a digital format;	DDC	-	30/04/2009	Provided
9	A plan from the Council indicating all council owned properties (including parkland etc) within Dover;	DDC	-	30/04/2009	Provided
10	A plan of the proposed (and approved) developments within the Borough and areas earmarked for development;	DDC	Midtown Dover is located within CP9 and as such the relevant vision for this area should be incoorporated into the proposed scheme.		Framework documentaion provided to CS for review
11	Drainage asset information (in a digital format compatible with GIS or CAD systems) from Dover District Council	DDC	Only identifies possible manhole and gulley locations	30/04/2009	Provided
12	Drainage asset information (in a digital format compatible with GIS or CAD systems) from Southern Water	Southern Water	Full GIS layout is relevant height and size information. Some areas are missing and have been interpolated from upstream and downstream information	28/04/2009	Provided
13	Drainage asset information (in a digital format compatible with GIS or CAD systems) from Highways Authority	Kent Highways	ESRI Format with Caveat: *The data was originally stored in a non spatial database against the streets and positioned with chaninge and cross sectional position, this position along with the start street X and Y was used to plot the data onto GIS.* *At present we are undertaking a data verification exercise for the whole of Kent which will involve drainage engineers visiting every gully location to correct the position. We have just started this exercise and as yet we haven't visited the Dover area. This data will therefore be at best a good guide to the number of assets along a street and the exact position cannot be guaranteed.*	09/04/2009	Information does not identify pipe network information and will require survey to determine exact asset location, cover lever, pipe size, outlet information.
14	Drainage asset information (in a digital format compatible with GIS or CAD systems) from KCC	KCC	Kent Highways information includes KCC information	09/04/2009	No further action required (refer above)
15	Information relating to the Southern Water drainage improvement works;	Southern Water	Only relevant to combined sewer network	Not Available to CS	No further information can be obtained
16	Historical Flooding Information and records	EA,DDC,Southern Water, DDC, Kent Highways	Photos of 2007 event provided by JBA. SFRA indicates othjer historical information	13/05/2009	Only one set of photos os a histrical event obtained.
17	Ground Survey of Midtown study area	Others	Site topographical survey to be completed by JC White week ending 17 July	17/07/2009	Incorporated topographical survey into LIDAR
18	CCTV information of culverts within Dover	EA	Emailed the EA but have not received any information to date.	-	Not received
19	Dover Rainfall Data	EA		19/05/2009	Provided
20	Dover Harbour information regarding wellington docks operations and levels	Dover Harbour	information confirms that there is no structure on the downstream of the culvert that excluded tidal waters from entering the River Dour		Awaiting more accurate details of operating levels
21	Combined surface water modelling outputs	Southern Water	Provided by Atkins on 11/05/2009. Volume outputs only and with no flow rate information .	26/06/2009	No further action required (refer above)
22	Jacobs Report regarding Kent Highways flooding report	Kent Highways	Email sent to Kent Highways for assistance 5/5/2009	-	Not Provided
23	Dover Council Strategic Flood Risk Assessment	CS	Site is identified as an area at risk of fluvial and surface water flooding.	-	Provided
24	Hydrometric gauge data	EA	For model calibration	24/11/2009	Provided
25	Rainfall records from 2007 and 2009 events	EA	Provided hyetograph for inclusion within pluvial assessment	27/01/2010	Provided
26	Stour CFMP	EA	Dour is located within an area in which the flood risk to be managed at current levels	17/02/2010	Provided



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Notes:
Wall Requirements (h x l):
1. to 10.0mAOD (approx. 1m) x 50m
2. to 8.0mAOD (approx. 0.5m) x 80m
3. to 6.5mAOD (approx. 0.5m) x 60m
4. to 6.5mAOD (approx. 0.5m) x 135m
5. to 6.3mAOD (approx. 1m) x 150m
6. to 6.3mAOD (approx 1m) x 140m

LEGEND:

- 1 IN 100+CC YEAR RETURN PERIOD EVENT (BASELINE)
- 1 IN 100+CC YEAR RETURN PERIOD EVENT (OPTION 5b)
- SITE BOUNDARY
- WALL OR EMBANKMENT

FLOOD RISK APPRAISAL OF THE RIVER DOUR

FIGURE F1:
PREFERRED FLOOD ALLEVIATION OPTION
CONCEPTUAL LAYOUT

DOVER DISTRICT COUNCIL

CAPITA SYMONDS

DRAWN BY	CHECKED BY	PASSED BY	DATE	SCALES @ A3	ISSUING OFFICE	DRAWING NUMBER	REV
PH	JR	JR	19/05/2010	1:35,000	LONDON	CS37272_PREF_F1	A

MID TOWN DOVER FLOOD RISK APPRAISAL

BUDGET PRICE From Team Van Oord EA Framework Contractor

	Qty	Unit	Rate	Amount	Duration	
Wall 1						
New wall on top of existing Capping	20	M	£ 955.00	£ 19,100.00	10 days	Brickwork with concrete infill and dowel bars & brick coping
New wall with foundation along the river bank	30	M	£ 1,900.00	£ 57,000.00	32 days	RC wall with brick cladding & coping
Reinstatement of gardens	4	Nr	£ 2,000.00	£ 8,000.00	12 days	
Surface water outlets	4	nr	£ 300.00	£ 1,200.00	2 days	
Total				**£ 85,300.00**	56 days	
Wall 2						
Remove and replace handrail	80	M	£ 175.00	£ 14,000.00	5 days	
New wall on top of existing wall	80	M	£ 955.00	£ 76,400.00	30 days	New wall on top of existing wall
Footpath reinstatement	320	M2	£ 30.00	£ 9,600.00	3 days	80 x 4m = 320m2
SW outfall	1	Nr	£ 750.00	£ 750.00	2 days	
Total				**£ 100,750.00**	40 days	
Wall 3						
New wall on top of existing wall	30	M	£ 955.00	£ 28,650.00	12 days	Brickwork with concrete infill and dowel bars & brick coping
New embedded wall with foundation	30	M	£ 1,900.00	£ 57,000.00	30 days	RC wall with brick cladding & coping
Footpath reinstatement	240	M2	£ 30.00	£ 7,200.00	2 days	60 x 4 = 240m2
Surface water outlets	4	Nr	£ 300.00	£ 1,200.00	2 days	
Total				**£ 94,050.00**	46 days	
Wall 4						
New wall on top of existing wall	75	M	£ 955.00	£ 71,625.00	28 days	Brickwork with concrete infill and dowel bars & brick coping
New embedded wall with foundation	60	M	£ 1,900.00	£ 114,000.00	50 days	RC wall with brick cladding & coping
Tie into existing buildings	2	nr	£ 1,000.00	£ 2,000.00	4 days	
Footpath reinstatement	540	M2	£ 30.00	£ 16,200.00	4 days	135 x 4 = 540m2
Surface water outlets	6	Nr	£ 300.00	£ 1,800.00	3 days	
Total				**£ 205,625.00**	89 days	
Wall 5						
Sheet piles 6m long	90	M	£ 1,200.00	£ 108,000.00	20 days	Left bank. Include timber cladding
New wall on top of existing wall	50	M	£ 955.00	£ 47,750.00	15 days	
Demoilition of existing	50	M	£ 50.00	£ 2,500.00	5 days	
Reinstatement	750	M2	£ 30.00	£ 22,500.00	5 days	150 x 5 = 750m2
SW outfall	2	Nr	£ 750.00	£ 1,500.00	4 days	
Surface water outlets	6	Nr	£ 300.00	£ 1,800.00	3 days	
Total				**£ 184,050.00**	52 days	
Wall 6						
New embedded wall with foundation	150	M	£ 1,900.00	£ 285,000.00	120 days	
Demoilition of existing	150	M	£ 50.00	£ 7,500.00	15 days	
SW outfall	2	Nr	£ 750.00	£ 1,500.00	4 days	
Surface water outlets	6	Nr	£ 300.00	£ 1,800.00	3 days	
Raise footbridges	2	Nr	£ 10,000.00	£ 20,000.00	10 days	
Ramps to footbridges	4	Nr	£ 10,000.00	£ 40,000.00	40 days	12m long ramps with handrails
Final Reinstatement	750	M2	£ 30.00	£ 22,500.00	5 days	
Total				**£ 378,300.00**	197 days	
Sub Total				**£ 1,048,075.00**		
Prelims	32	Wks	£ 10,000.00	£ 320,000.00		
Insurance/Profit/Overhead	12	%		£ 164,169.00		
Risk	20	%		£ 306,448.80		
Total				**£ 1,838,692.80**		