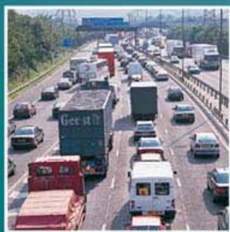
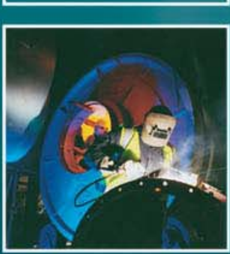
London Borough of Bexley

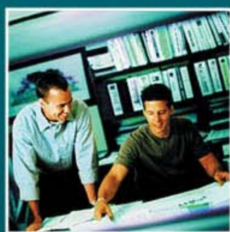
Bexley Strategic Flood Risk Assessment Level-1

Bexley SFRA Level-1 Report

August 2010







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August 2010

Entec UK Limited

Report for

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Appendix B	Breach Modelling Report
Appendix C	SuDS Supporting Information
Appendix D	Tables D.1, D.2 & D.3 – Reproduced from Annex D PPS25

Glossary

Abbreviation	Definition
ABDs	Areas Benefiting from Defences
ABI	Association of British Insurers
AP event	Annual Probability event
Bexley	The London Borough of Bexley
CIRIA	Construction Industry Research and Information Association
COWs	Critical Ordinary Watercourses
Defra	Department of the Environment and Rural Affairs
Flood Zones	Indicative zones of flood risk developed, maintained and issued by the Environment Agency
FRA	Flood Risk Assessment
Freeboard	An increase in finished floor levels (to be agreed with the Environment Agency) above the predicted flood water levels. To account for uncertainties in the modelling process
GIS	Geographical Information Systems
GLA	Greater London Authority
ISIS	1-dimensional hydraulic modelling software
LDF	Local Development Framework
LiDAR	'Light Detecting and Ranging' – High resolution digital terrain data
Main River	High Status rivers. Under the Water Resources Act 1991 the Environment Agency has powers to maintain and improve Main Rivers in order to ensure the efficient passage of flood flow and to manage water levels.
mAOD	m Above Ordnance Datum
NFCDD	National Flood and Coastal Defence Database
PACEC	Public and Corporate Economic Consultants
PPS1	Planning Policy Statement 1 – Delivering Sustainable Development
PPS25	Planning Policy Statement 25 – Development and Flood Risk
SAR	Synthetic Aperture Radar – Digital terrain data
SFRA	Strategic Flood Risk Assessment
SPZ	Source Protection Zones. Zones surrounding groundwater abstractions to safeguard against pollution of groundwater.
SuDS	Sustainable Drainage Systems
TE2100	Thames Estuary 2100 (TE2100) is an Environment Agency project to develop a tidal flood risk management plan for the Thames estuary through to the end of the century.
TuFLOW	A 2-dimensional hydraulic modelling software package

Abbreviation	Definition
UDP	Unitary Development Plan
1 in 20 year event	The 5% Annual Probability Flood
1 in 100 year event	The 1% Annual Probability Flood
1 in 200 year event	The 0.5% Annual Probability Flood
1 in 1000 year event	The 0.1% Annual Probability Flood
Plus climate change	The modelled climate change allowance in this SFRA represents the predicted tide levels in the year 2107. The pluvial modelling accounts for climate change by simulating a 30% increase in rainfall intensity and the fluvial model of the River Cray accounts for climate change by simulating a 20% increase in peak river flows.

Acknowledgements

The London Borough of Bexley and Entec UK Ltd would like to extend their thanks to the London Borough of Greenwich for making the breach modelling analysis undertaken as part of the Greenwich SFRA, available to the Bexley SFRA. We would like to thank the following for their cooperation and assistance in supplying data and guidance to the SFRA:

- Bob Smith Drainage Engineer at the London Borough of Bexley;
- Ian Blackburn and Sarah Smith (Environment Agency) for assistance on determining the scope and requirements of the SFRA;
- William Mackay (Environment Agency) for reviewing the breach modelling analysis; and
- Lizzie Daniels and Tanya Gorgie (Environment Agency) for supplying the data to the SFRA.

1. Introduction

1.1 Overview

Entec have been appointed to undertake a Strategic Flood Risk Assessment (SFRA) of the London Borough of Bexley, (herein Bexley). Entec have worked with Bexley on a number of flood risk projects including the Crayford Town Centre SFRA, the Howbury Site Flood Risk Assessment (FRA) and the Erith Western Gateway FRA. To date, these location specific projects have been favoured by Bexley over Borough wide assessments and have typically been undertaken in areas of known flood risk, either within the Thames or River Cray floodplains. In 2008, Bexley procured a Borough wide assessment, seeing this as an opportunity to build on the Council's existing level of flood risk knowledge and extend it to incorporate the whole Borough, including those currently outside the Environment Agency's Flood Zones 2 and 3.

National planning legislation and policy guidance has been considered throughout the preparation of this SFRA. The planning process is driven by legislation and guidance developed at a national, regional and local level, of which flood risk is just one of many factors needing to be considered when making decisions relating to landuse and development. The challenge for a SFRA is to develop pragmatic principles for steering future development towards areas of lower flood risk within the context of other planning policies and local drivers.

This SFRA has been undertaken in two distinct parts to reflect the two levels of SFRA presented by Planning Policy Statement 25 – Development and Flood Risk Practice Guide[1]. This approach has been adopted by Bexley as it is aligned with their current position in the formulation of their Local Development Framework (LDF). A summary of differences between Level-1 and Level-2 assessments in Bexley is presented below.

Level 1 SFRA

The purpose of the Level-1 assessment is to provide an evidence base to support spatial planning decisions at the Borough wide scale. The Level-1 SFRA is considered to be the most suitable tool to assist Bexley in the re-allocation of employment sites. This process is being driven by the Greater London Authority (GLA) and requires Bexley to determine which of their currently allocated employment sites should be released for other land-uses, including residential. The SFRA assesses flood risk at the Borough wide scale. This includes the delineation of the PPS25 flood risk zones, an assessment of the implications of climate change, and the review of flood risks from all possible sources. The output of the detailed ISIS-TuFLOW modelling undertaken as part of the Crayford Town Centre SFRA will be incorporated. The Environment Agency Flood Zones will be supplemented with TuFLOW modelling of defence failure scenarios. This level of detail is typically associated with Level 2 assessments.

[1] Communities and Local Government, Development and Flood Risk – A Practice Guide Companion to PPS25 "Living Draft. (2006)

Level 2 SFRA

The Level 1 assessment is designed to facilitate the application of the Sequential Test at the Borough wide scale. In addition to this, Bexley's Level 1 SFRA provides very detailed analysis of the residual tidal flood risks and presents guidance on safe development and appropriate design criteria to pass the Exception Test.

The Level 2 assessment will enable the sequential approach to be applied within the specific 'Opportunity Areas for Regeneration' and it will facilitate the application of sequential approach to landuse planning at the site specific level. Thus, the Level 2 assessment will in particular inform the Erith Area Action Plan and Site Specific Allocations development plan documents within the Local Development Framework, to ensure the delivery of homes and jobs, as set out in the Core Strategy.

The principal purpose of a Level 2 SFRA is to facilitate application of the Exception Test, as defined in PPS25, in all parts of the Borough where it will need to be applied. The level 2 assessment will consider in detail the nature of the flood hazard. This will allow a sequential approach to site allocation to be adopted within a Flood Zone (refer to paragraphs 17 and D4 of PPS25). It will establish practices required to ensure that development in such areas satisfies the requirements of the Exception Test. The Level-2 SFRA will focus in Bexley's 'Opportunity Areas for Regeneration,' which cover a large area stretching across Bexley's northernmost wards adjacent the River Thames, from Thamesmead/Erith Marshes to North End, extending south down to the Borough's north-eastern boundary to Crayford. The Opportunity Areas are set within the Thames Gateway 'Growth Area' and as such, have been earmarked both by the Government and Mayor of London as a priority for regeneration. The Level 2 SFRA provides the scope to refine the guidance to location specific flood risks.

1.2 Geographical Overview

Bexley covers an area of 64 square kilometres (25 square miles) in South East London. It consists of several different communities whose physical boundaries mostly disappeared during the 1930's with their rapid growth and consequent merging. There are striking differences between areas in the Borough, from the rural surroundings and activities of Bexley's Green Belt, to the large areas of industry and business in Belvedere and Erith.

Bexley is predominantly a residential area. Over half the homes were built between the First and Second World Wars, mainly for people working in industry along the Thames, and in central London. Over many years, Bexley has become closely linked socially and economically with adjoining Boroughs and Districts. 40% of Bexley's employable residents find work within the Borough, and account for two-thirds of Bexley's internal employment.

Despite being part of the London East sub-region, the third largest-economy in the country, many of the Borough's residents are in low-paid jobs and average earnings are lower than surrounding Boroughs.

Figure 1 in Appendix A provides an overview of the geography of the Borough and the underlying base geology is presented in Figure 2 and the Superficial Geology is presented in Figure 3. The Environment Agency Flood Zones provide a useful initial indication of potential fluvial and tidal flood risk zones (see Figure 6). The digital topography of the Borough is illustrated in Figure 9, and is derived from SAR data (Synthetic Aparture Radar). SAR data is captured by scanning satellites which is processed into a gridded surface model with a cell resolution of 5m. This data was supplied to the SFRA by the London Borough of Bexley under a licence agreement held between Local Government and Intermap (the suppliers of the data).

1.3 Relevant Planning Policy

1.3.1 Planning Policy Statement 25: Development and Flood Risk

PPS25 specifies that Local Planning Authorities (LPAs) should adopt a risk-based approach to planned development through the application of a Sequential Test, which seeks to steers new development towards areas of lowest flood risk. PPS25 also sets out the need to consider other sources of flood risk (such as groundwater and surface water) in addition to the main fluvial and tidal sources. The implications of climate change on flood risk also need to be assessed.

PPS25 introduces the Exception Test which allows some scope for departures from the sequential approach. This is for circumstances where development is necessary to meet the wider development needs and urban regeneration. Providing the evidence to support the departure from the sequential approach is only one part of the Exception Test. Development will only be permitted where it is demonstrated that flood risks are appropriately managed, the development is safe and flood risks elsewhere are not increased.

The Town and Country Planning (Flooding) (England) Direction 2006 has made the Environment Agency a Statutory Consultee on all applications for development in flood risk areas, including areas with critical drainage problems and for developments exceeding 1 hectare outside of flood risk areas. After discussion with the Agency LPAs are required to notify the Secretary of State if they remain minded to approve a planning application contrary to a sustained objection from the Environment Agency.

This SFRA has been undertaken in accordance with PPS25[2] and its accompanying Practice Guide (*Development and Flood Risk – A Practice Guide Companion to PPS25 "Living Draft*). Box 1 (overleaf) presents a Summary of the guidance presented in PPS25.

This SFRA describes (using Table 5.1 on page 32 and Figure 7 in Appendix A) the land-uses that are considered appropriate for each identified development site within the town centre, adopting the sequential approach in doing so. This assessment is based upon the vulnerability classifications presented in Annex D of PPS25 and the level of flood risk posed to each site.

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[2] Communities and Local Government, Planning Policy Statement 25: Development and Flood Risk. (2006)

Box 1	Summary of Guidance in PPS25

PPS25 Objectives

Through PPS25, the Government has sought to provide clarity on what is required at a regional and local level to ensure that appropriate and timely decisions are made to deliver sustainable planning for development. The key planning objectives as stated in PPS25 are that:

"Regional Planning Bodies (RPBs) and LPAs should prepare and implement planning strategies that help to deliver sustainable development by:

- APPRAISING RISK

Identifying land at risk and the degree of risk of flooding from river, sea and other sources in their areas;

Preparing Regional Flood Risk Assessments (RFRAs) or Strategic Flood Risk Assessments (SFRAs) as appropriate, as freestanding assessments that contribute to the Sustainability Appraisal of their plans;

- MANAGING RISK

Framing policies for the location of development which avoid flood risk to people and property where possible, and manage any residual risk, taking account of the impacts of climate change;

Only permitting development in areas of flood risk when there are no reasonably available sites in areas of lower flood risk and benefits of the development outweigh the risks from flooding

- REDUCING RISK

Safeguarding land from development that is required for current and future flood management e.g. conveyance and storage of flood water, and flood defences;

Reducing flood risk to and from new development through location, layout and design, incorporating sustainable drainage systems (SuDS);

Using opportunities offered by new development to reduce the causes and impacts of flooding e.g. surface water management plans; making the most of the benefits of green infrastructure for flood storage, conveyance and SuDS; re-creating functional floodplain; and setting back defences;

- A PARTNERSHIP APPROACH

Working effectively with the Environment Agency and other operating authorities and other stakeholders to ensure that best use is made of their expertise and information so that plans are effective and decisions on planning applications can be delivered expeditiously; and Ensuring spatial planning supports flood risk management and emergency planning.

1.3.2 Planning Policy Statement 1: Delivering Sustainable Development

Published in February 2005, this document sets out the overarching planning policies for the delivery of sustainable development across the planning system. PPS1 explicitly states that development plan policies should take account of existing and future flood risk and proposes that new development in areas at risk of flooding should be avoided. Planning authorities are also advised to ensure that developments are sustainable, durable and adaptable, and this should be achieved through taking into account natural hazards, such as flooding. PPS1 places an emphasis on *spatial planning* in contrast to the more rigid *land-use planning* approach which it supersedes. It is important for the Bexley LDF to recognise the contribution that non-structural measures can make to effective flood management, i.e. a risk based avoiding an approach advocated by PPS2S.

1.3.3 Local Development Framework

At present, the Unitary Development Plan (UDP) is the document that guides decisions on planning applications in Bexley. However, the Government requires the UDP to be replaced by a series of documents collectively called

the Local Development Framework (LDF). The SFRA is required as a statutory evidence base to support the policies in the LDF.

1.4 The purpose of this Report

The SFRA is intended to:

- Identify and quantify flood risks;
- Delineate residual flood risk zones;
- Provide guidance on the application of the Sequential Test; and
- Provides guidance on flood risk management through the design process.

This SFRA covers a relatively large geographic area, encompassing areas of known flood risk and areas where flood risk is currently not perceived to be a restriction to planning. Nonetheless, Bexley is a Borough in which significant regeneration and development are proposed. This SFRA has been prepared to provide guidance to inform the application of the Sequential Test for Bexley, and sufficient data is provided in the mapping (Appendix B) to allow the Council to make informed decisions when processing windfall site applications.

The production of the SFRA involved consultation with the Environment Agency[3] throughout the assessment process.

1.5 Using the SFRA

The SFRA is a tool to inform the spatial planning process and guide safe development. The information has been presented in such a way to facilitate this objective. Appendix B is a key component of the Report, it includes detailed mapping sufficient to inform the application of Sequential Test.

For the purposes of informing the Sequential Test the key pieces of information are:

- Figures 7, 22 and 23 in Appendix A in conjunction with Table 5.1;
- Section 5 – Information to support the Sequential Test; and
- Section 6, 7 and 8 – guidance on appropriate flood risk management.

[3] Environment Agency Staff – Will MacKay (Flood Risk Mapping and Data Management) and Sarah Smith and Ian Blackburn (Development Control).

The SFRA has involved the modelling of nine breaches, and one overtopping scenario, in the tidal flood defences of the River Thames. The modelling incorporated the most up to date data at the time of issue of production. It must be noted that the SFRA does not negate the need to contact the Environment Agency to discuss development proposals or the need to prepare site specific FRAs. Over the lifespan of the LDF, the predicted tide levels in the Thames are likely to be amended and the Environment Agency must always be consulted to ensure that the most recent data is being used to inform detailed design.

1.6 Report Structure

The structure of this report is aligned with delivering the key aim of providing information to perform the Sequential Test. As such, the report is comprised of the following sections:

- Section 1 – provides on overview of the SFRA and sets it within national planning policy. The introduction is also designed to provide guidance on how to extract the most information from the SFRA;
- Section 2 – provides an overview of all the sources of flood risk that have been identified within Bexley;
- Section 3 – outlines the results of the assessment of the residual tidal flood risk;
- Section 4 – outlines the principals of flood risk management in Bexley;
- Section 5 – describes flood risk management in Bexley through the planning process;
- Section 6 – details how flood risk can be managed through the design process.
- Section 7 – outlines the principals of sustainable surface water management in Bexley
- Section 8 – Addresses flood risk management in the residual tidal flood risk zones of Thamesmead/Erith Marshes and Crayford Marsh
- Section 9 – Describes the need for Flood Risk Assessments (FRAs) and processing windfall site applications
- Section 10 – Presents recommendations for inclusion in the LDF

2. Overview of Flood Risks

2.1 Introduction

This section of the report outlines the context of the Bexley SFRA and the flood-based assessments that have been undertaken as part of the current study. The Level-1 assessments are not location or site-specific, rather they involve an assessment of each identified source of risk across the whole Borough.

2.2 Flood Zones

Figure 6 (in Appendix A) illustrates the extents of the Environment Agency's Indicative Flood Zones 2 and 3 (issued September 2008). This SFRA uses the Environment Agency's Flood Zone 2 and 3 outlines to represent PPS25 Flood Zone 2 and 3b respectively. The PPS25 definitions of the Flood Zones are presented below.

- **Flood Zone 1** – This zone comprises land assessed as having a less than 1 in 1000 annual probability of river or sea flooding in any year (<0.1%). PPS25 considers all uses of land to be appropriate in this Zone; and

- **Flood Zone 2** – This zone comprises land assessed as having a 1 in 100 and 1 in 1000 annual probability of river 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.

PPS25 subdivides Flood Zone 3 into Zone 3a and 3b, the PPS25 definitions are presented below:

- **Flood Zone 3a** – This zone comprises 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

- **Flood Zone 3b** – This zone comprises land where water has to flow or be stored in times of flood, SRFAs should identify this Flood Zone (land which would flood with an annual probability 1 in 20 (5%).

Flood Zones are determined without consideration to the presence of flood defences. Areas identified by the Environment Agency as 'benefiting from the defences' (ABDs) are presented in Figure 5 (in Appendix A). An ABD is an area which is protected from the 1% Annual Exceedence Probability (AEP) flood event. The Flood Zones are intended to provide an appreciation of the potential flood risks that exist, and indicate the areas which should be considered in the planning process.

These flood zone extents are subject to change as part of the Environment Agency's ongoing programme of Flood Map improvements. The current Flood Zone extents are sufficient to inform spatial planning; however it is advised that for site specific applications, the Environment Agency always be consulted to ascertain the exact Flood Zone delineation at a given location.

2.3 Additional Hydraulic Modelling

2.3.1 Crayford Town Centre SFRA

The River Cray in Crayford town centre was modelled in detail in 2007/2008 as part of the Crayford Town Centre SFRA, prepared by Entec on behalf of the London Borough of Bexley. A 1D/2D approach was adopted, using an ISIS-TuFLOW model, which modelled the channel in 1-dimension whilst allowing the flood flow routes, depths and velocities over the floodplain to be determined in the 2-dimensional domain. The 1 in 100 year, 1 in 100 year plus climate change and 1 in 20 year design flood events were simulated. This work included the flood defence infrastructure, and therefore the results are not replacements of the Environment Agency Flood Zones, however the results represent a more detailed appreciation of the actual flood risks posed to the town centre and the outputs have been incorporated into this Borough-wide SFRA. Further details on the modelling approach and outcomes can be obtained from the Crayford Town Centre SFRA (2008).

Figures 24 and 25 (in Appendix A) provides the modelled flood extents in Crayford.

2.3.2 Bexley Breach Modelling

Detailed modelling of defence failure scenarios in the Thames defences has been undertaken as part of this SFRA using the 2-dimensional modelling software TuFLOW. The Bexley SFRA modelling builds upon previous modelling undertaken for the Howbury Site Flood Risk Opportunities and Constraints Study (2008)[4], the Erith Western Gateway Appraisal of Masterplans (2008)[5] and the London Borough of Greenwich SFRA (2008)[6]. The results of the breach modelling are discussed in detail in Section 3 and the Modelling Report can be found in Appendix B.

2.3.3 Surface Water Modelling

In preparing this Level-1 SFRA, the effect of an extreme rainfall event in Bexley was simulated to identify potential overland flow routes and ponding areas

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[4] London Borough of Bexley, Erith Western Gateway Regeneration Scheme – Flood Risk Appraisal of Masterplans (May 2008), Entec

[5] London Borough of Bexley, Howbury Site Flood Risk Constraints and Opportunities Assessment, (April 2008) Entec

[6] London Borough of Greenwich, Strategic Flood Risk Assessment (2008), JBA and Entec

The surface water modelling approach adopted is summarised below.

- The Borough was subdivided into six hydrodynamically[7] distinct regions, which enabled a greater definition of the topography to be incorporated in the simulation. Figure 2.1 illustrates the six distinct areas;

- For each of the six areas (shown in Figure 2.1), the statistical 1 in 100 year plus climate change rainfall depth was calculated, using the FEH software. The FEH percentage runoff losses model was then used to convert the total rainfall into effective rainfall, which was an approximate way of accounting for how much rainfall may become runoff. The model used catchment descriptors to estimate effective rainfall, considering the influences of catchment slope, catchment length, standard percentage runoff (for soils), catchment wetness index, and urban cover. Urban cover was assumed to be uniform in the four main urban areas. Effective rainfall was then increased to account for the influence of climate change.   The formalised piped drainage network was not considered in the estimations of rainfall, or in the subsequent surface runoff modelling as its capacity is unknown; and

- The rainfall storms were then applied to the DTM surface within the hydraulic model TuFLOW. The modelling software routed the water over the digital terrain surface and highlighted potential flow routes and ponding areas for surface water.

The modelling process used to map surface water risk in Bexley represents a significant simplification of reality and assumptions had to be made. These should be taken into consideration when interrogating the modelled results.

Figures 18 and 19 (in Appendix A) present the results of the surface water run-off modelling. The rainfall model involves the wetting of every DTM cell in the Borough and as such, a map showing every cell wet is not useful to indicate the main potential flow paths and accumulation areas. As such, it was decided that a minimum water depth needed to be applied to the data in order to clean/tidy the dataset and importantly to highlight the key areas of potential risk. The minimum depth selected was 0.2m. This reflects the purpose of the modelling which was to identify potential areas of surface water flooding. Figures 18 and 19 are intended for use in the Application of the Sequential Test only and to inform site specific FRAs of a potential surface water run-on flood risk.

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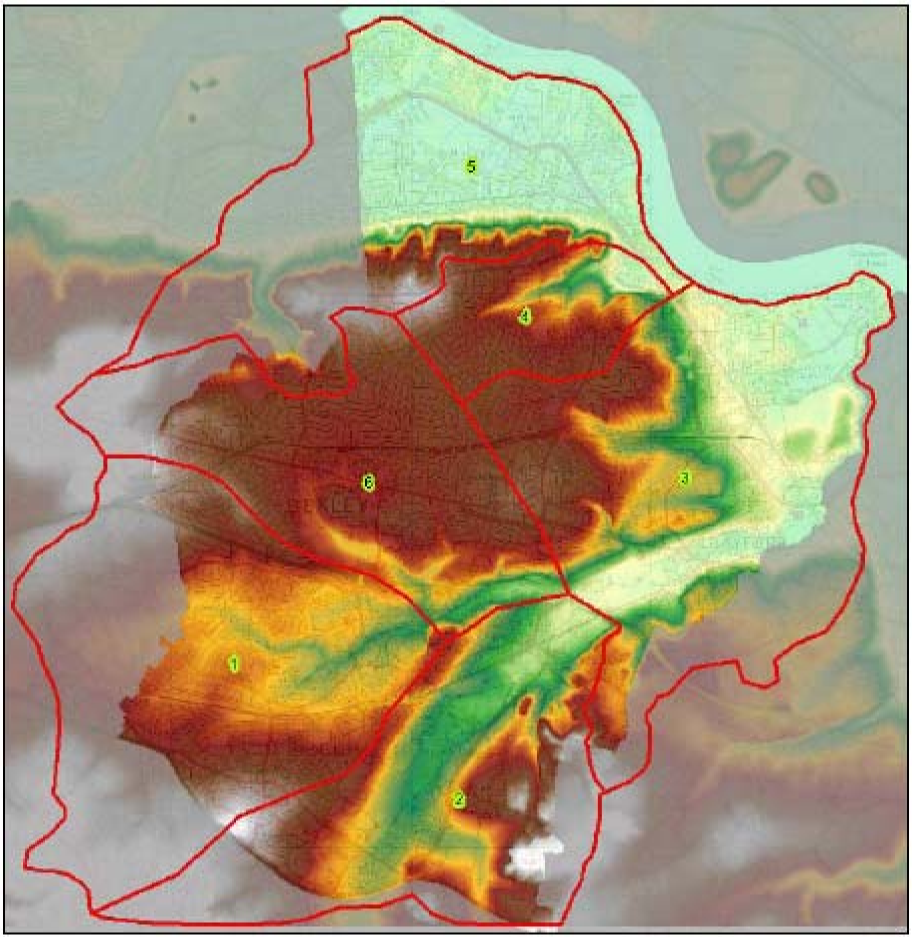
[7] Hydrodynamically distinct = there is no route for water to flow between two areas. i.e. a watershed exists between two catchments

Figure 2.1 Illustration of the Six Surface Water Modelling Catchments in Bexley



2.4 Historic Flood Events

In Bexley, the only recorded flood incident from the Thames which is held by the Environment Agency is that associated with the 1953 tidal event. This was an event which affected much of eastern and south eastern England. The extent of this flood even can be seen in Figure 4 in Appendix A, which provides a clear indication of the potential flood risk along the Thames Estuary. Historic flood events have also been recorded on the rivers Cray and Shuttle in 1968 and again on the upper River Cray in 1977.

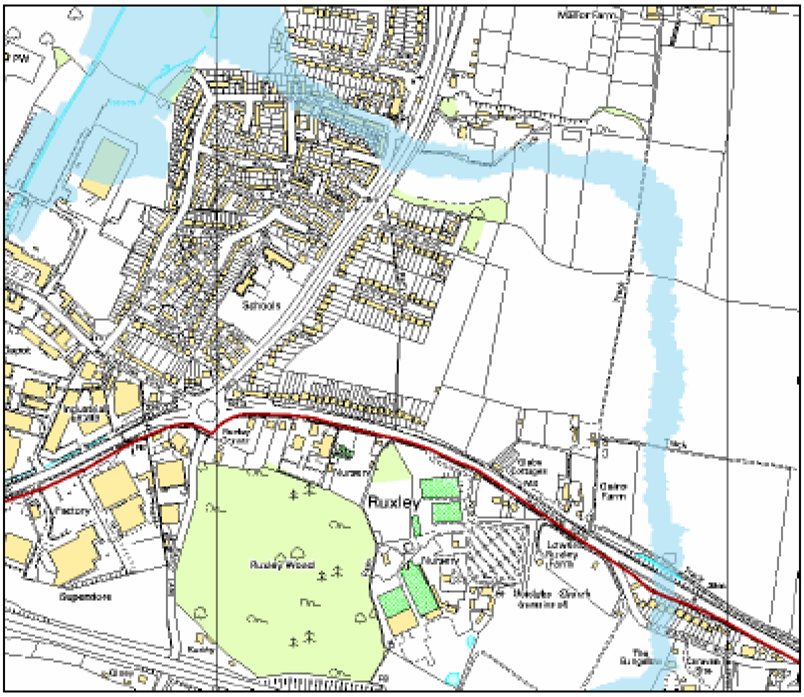
2.5 Source of Flood Risk

Flooding may occur from a range of other potential sources and their impact on the natural and built environment are material planning considerations. The following sections discuss the sources of flooding and their potential flood risk to Bexley.

2.5.1 Fluvial Flooding

Environment Agency fluvial Flood Zones exist for the rivers Cray and Shuttle in Bexley. The Flood Zones on the River Shuttle extend upstream to the end of Hollyoak Wood Park at Days Lane Bridge. On the Wincham Stream (tributary of the River Shuttle) the Flood Zones extend as far upstream as where the B2214 (Halfway Street) crosses the watercourse. The Flood Zones on the River Cray extend all the way to the Borough's boundary at the Sidcup Bypass (A20T). There is a Flood Zone extent which occupies a *dry valley*[8] the head of which is near Upper Ruxley, the valley descends northward for approximately 800m before turning westwards and descending through the northern part of Foots Cray and along the axis of Ellenborough Road (See Figure 2.2).

Figure 2.2 Flood Zone in a Dry Valley in Foots Cray.



Environment Agency Flood Zone 3 (September 2008) illustrated.

Figure 6 (in Appendix A) illustrates the extent of the Environment Agency Flood Zones and shows the combined extent of the fluvial and tidal zones.

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[8] Dry Valley = A valley shaped feature in the topography which has no identifiable water course running in the bottom of it. In this instance there is no watercourse marked on the OS 10k map. These features are typical to chalk and limestone geologies and are the product of periglacial climatic conditions which have intermittently prevailed over the last *c*.2 million years.

The Environment Agency Fluvial Flood Zones 2 and 3 were produced using JFLOW modelling. The Environment Agency is currently re-modelling the rivers Cray and Shuttle and the revised Flood Zone outlines are due for completion in March 2010.

Functional Floodplain

A Functional Floodplain has been defined in Crayford town centre. The designation extends from the tidal boundary upstream to the A2. The functional floodplain was defined as part of the Crayford Town Centre SFRA (2007)[9] by routing the 1 in 20 year fluvial flow through an ISIS-TuFLOW hydraulic model. The functional floodplain is not extensive in Crayford town centre. The main area is within a purpose built flood storage reservoir. This is located in the recreational grounds near Hall Place nurseries upstream of the town centre. Figure 7 (in Appendix A) illustrates the extent of the modelled functional floodplain. The reader is directed towards the Crayford Town Centre SFRA for further details of the detailed modelling.

Main River Designations

Figure 4 illustrates the locations of the watercourses designated as Main River by the Environment Agency. Development proposals within 8m of the bank-top require consultation with the Environment Agency. The majority of these are covered by the Environment Agency Flood Zones (2 and 3) and as such development proposals in these areas require FRAs to accompany planning submissions. As such most sites within the 8m buffer will be captured for assessment by the processes enforced by PPS25. Nonetheless, the proximity of a site to an Environment Agency Main River should be reviewed in all cases as development controls apply for assessment by the processes enforced by PPS25.

Erith Marshes

The surface water drainage network in the northern part of the Borough is a complex system comprising piped networks, open ditches and pumps.

A piped surface water drain system collects water from the Abbywood and Belvedere and discharges into open ditches in Erith Marshes. The water levels in the Marshes are maintained by pumping stations and a weir at Great Breach pumping station. Two pumping stations are in place in Erith Marshes, these are located on Great Breach Dyke (adjacent to the eastern boundary of the Crossness Sewage works) and at Green Level (shown in Figure 2.4). This complex interaction is compounded by the multiple owners of the system components (Thames Water, London Borough of Bexley, Environment Agency and the land owner).

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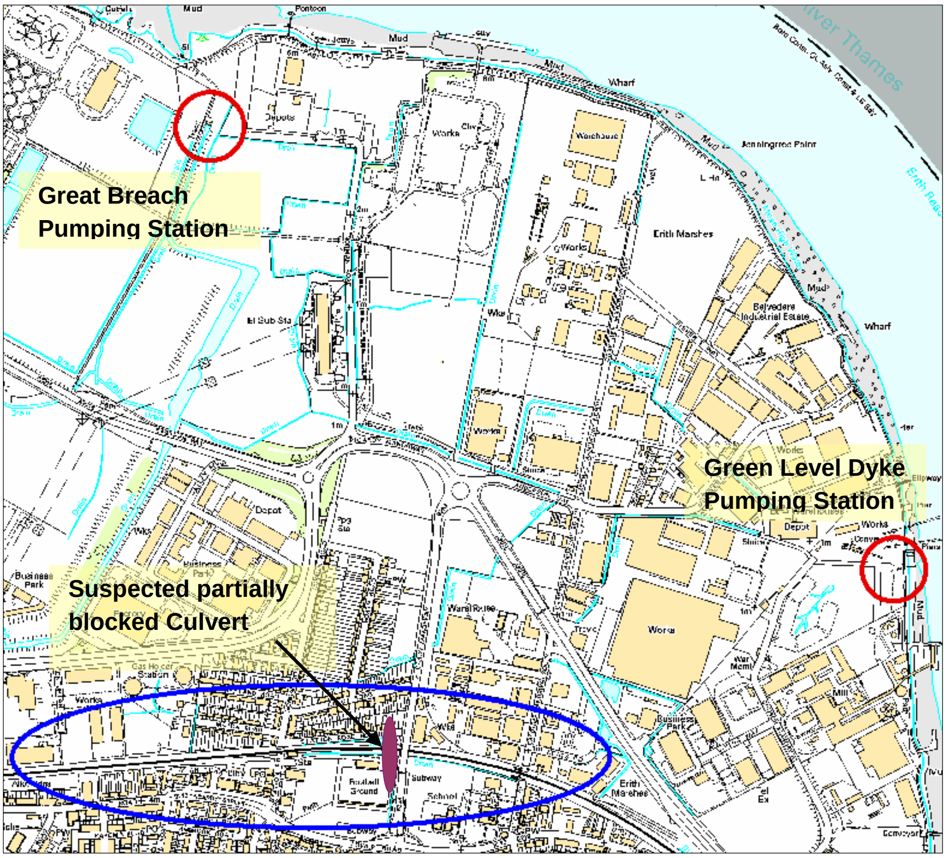
[9] London Borough of Bexley, *Crayford Town Centre SFRA*, (2007), Entec

Figure 2.3 Marsh Dyke Catchment



The southern edge of the Marshes (see Figure 2.3) was highlighted by Bexley as being at particular risk of surface water flooding. This location is where the piped drainage network discharges into ditches and dykes. Flooding issues in this area are associated with a culvert which runs under the railway line. Bexley's Drainage Engineers believe this culvert restricts the conveyance of the surface water drainage ditch, and subsequently during periods of high discharge rates, the water levels in the ditch increase and cause surface water drains to surcharge in the area around Abbeywood Station (Station Road and Lower Road). There are also perceived to be under capacity issues associated with the Thames surface water drainage network in this area. The level 2 SFRA details the findings of the Erith Marshes Ditches and Dykes Study (Entec, 2009), which included the construction of a detailed hydraulic pipe and ditch model of the Marsh Dyke catchment.

2.5.2 Tidal Flooding and Residual Tidal Flood Risk

Tidal flooding and the resultant tidal flood zones in Bexley are associated with the River Thames. By virtue of this, the only portion of the Borough along the low lying land adjacent to the Thames is affected.

This part of London benefits from the protection offered by the Thames flood defences, which currently[10] offer protection against the 1 in 1000 year flood. The potential for defence failure means that despite this level of protection, these areas are not free from the risk of flooding. There remains a residual risk - being the risk that which exists despite the presence of measures reducing the actual risk, i.e. the flood defences.

Residual risk of flooding behind defences is either associated with the structural failure or the over topping of flood defences. This SFRA focuses on the consequence of a structural failure in flood defences, as PPS25 does not require events with magnitude greater than the 1 in 1000 year (which would be needed to overtop the defences) to be considered in the sequential approach to spatial planning. However, structural failure in flood defences can occur irrespective of the magnitude of an event and as such the associated risk is assessed. It is understood that the likelihood of a structural failure in maintained flood defences is low. The probability increases as the magnitude of the tidal event increase. The SFRA does not focus on the probability of failure, but rather the consequence of failure during the 1 in 200 year (plus climate change – year 2107) event.

There is no undefended tidal flood risk in Bexley[11]; the residual tidal flood risks are discussed in more detail in Section 3.

2.5.3 Groundwater Flooding

Historically, groundwater flooding has not always been considered in sufficient detail in the SFRA process, principally as a result of a lack of data to support strategic level decision making. However, the potential flood risk associated with groundwater flooding is increasingly being recognised.

The Environment Agency has provided a series of groundwater level contours to support the preparation of the Bexley SFRA. These represent the groundwater head contours in 10m intervals. Groundwater head is the level recorded in a borehole should it be sunk into the aquifer. The contours were derived from maximum levels recorded and compiled in the late 1990s, and consequently do not include the exceptionally high levels experienced in early 2001. The contours were generated for the purposes of considering groundwater pollution issues.

By definition, the groundwater head does not necessarily define the level below ground at which the water table sits. The water table is controlled by the nature of the surface deposits. In locations where there are thick layers of impermeable London Clay, the water table is suppressed below the groundwater head. This is because the clay prevents the water in the aquifer from rising towards the surface. Only where conduits exist which connect the underlying aquifer with the surface (natural or manmade), will groundwater emerge at the surface.

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[10] Currently = Valid at the present. The standard of protection will decrease in the future as predicted sea level rise occurs.

[11] This description excludes the small areas of land that exist between the high water mark and the flood defence crest along the edge of the Crayford Marsh Embayment.

The groundwater head contours were interpolated into a smooth surface within ArcGIS and then subtracted from the surface elevation. The interpolation was undertaken as part of the SFRA process. These calculations produced a grid of Depth to Groundwater Head (see Figure 8 in Appendix A). The smaller values indicate where there is the potential for groundwater to be nearest the surface and thus the areas where there is the greatest potential for basement flooding. The areas where the groundwater head is predicted to be nearest the surface are characterised by Chalk bedrock overlain by Quaternary deposits of alluvium, sands and gravels. These deposits, unlike the London Clay which cap the higher parts of Bexley, are not typically described as impermeable. The 1:50,000 geology mapping suggests that there is a potential route for groundwater to reach the surface. Groundwater flooding is therefore a potential risk in these areas.

All the low lying areas where the groundwater head is nearest, the surface are capped with impermeable clays, so it is not predicted that there will be any significant issues arising from *clear water* flooding[12].

The other potential source of groundwater related flooding is where superficial sand and/or gravel deposits are perched on the clay strata. In these instances the local sand/gravel aquifer can become saturated during prolonged intense rainfall and result in flooding at the surface. Any site specific FRAs should consider this potential risk through a review of local superficial and solid geology.

2.5.4 Surface Water Flooding

Bexley's Drainage Engineer (Robert Smith) was consulted for information on surface water and drainage flooding within the Borough. Bexley has prepared a database detailing the locations of recorded flooding incidents. This database is designed to contribute to the National Flood Database that the Environment Agency is currently compiling. The recorded flooding incidents are classified by the source and the receptor of flooding. Figures 14 and 15 (in Appendix A) illustrate the locations of recorded flooding events and distinguishes the reports on the receptor of the flooding, whilst Figures 16 and 17, provide an indication of the reported source of the flooding. The points have been plotted using the six figure national grid references supplied by Bexley. These records have been compiled from reports obtained from members of the public and as such the potential inaccuracy of the data must be recognised.

A review[13] of the data indicated that the majority of reported incidents are related to surface water and affect highways or highways/domestic. Figures 14 to 17 are presented with the digital terrain model in the background and the 50k OS map, this illustrates that there is a reasonably strong correlation between roads and reported flood events. It must be noted that this apparent correlation may be skewed by the fact that it is along roads where most residents live and therefore where flood incidents are more likely to be recorded. Importantly there is little

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[12] Clear Water Flooding being the action of groundwater rising to the surface and causing flooding.

[13] review = a visual analysis of the data was undertaken to identify broad trends, statistical analysis was not performed.

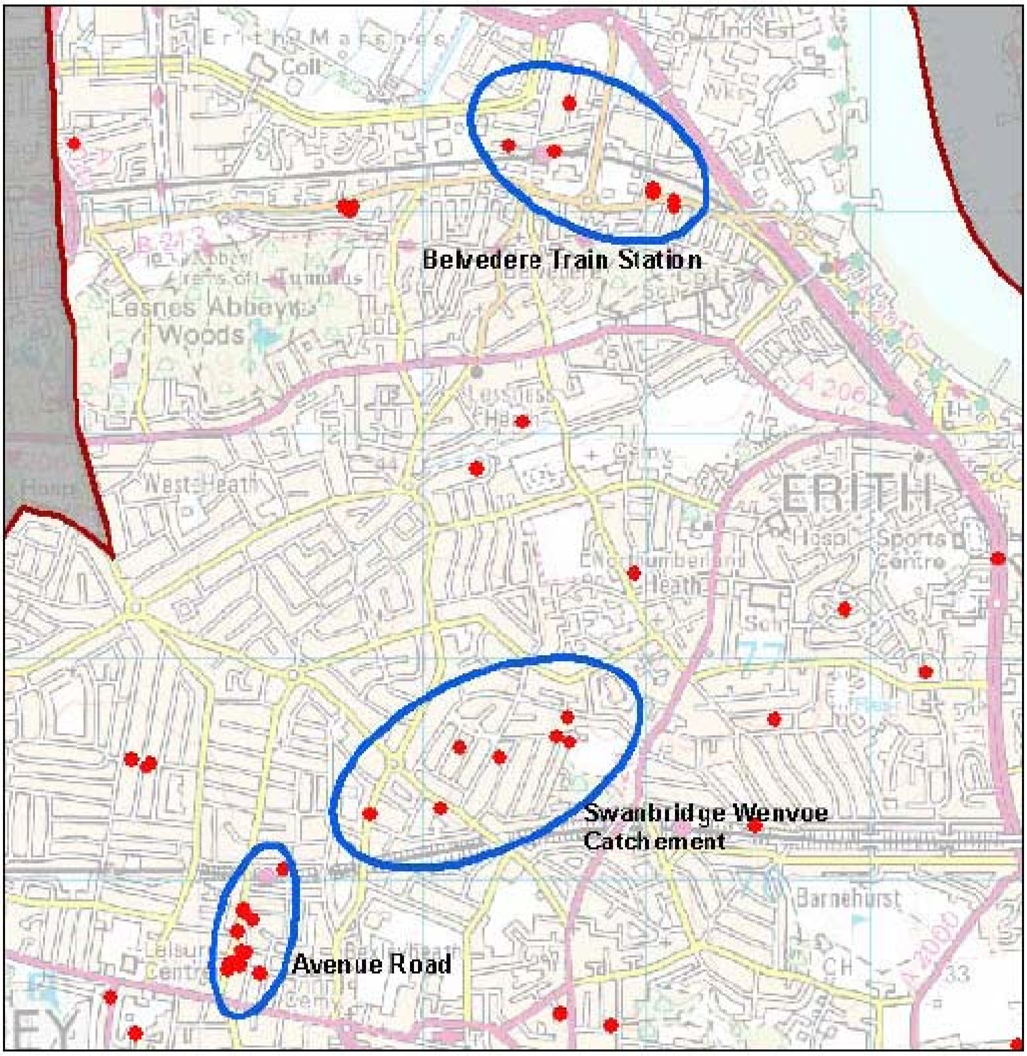
correlation between the reported incidents and topographic low points, which may suggest that these are surface water flow route areas. The nature of the underlying piped drainage network will be a significant factor and importantly, the slope of the topography is not necessarily reflected in the fall of the piped drainage network.

Locations with higher concentrations of reported flooding incidents include:

- Avenue Road (See Figure 2.3) all these events are classified as surface water flooding;
- Within the historic catchment of Swanbridge Wenvoe (See Figure 2.4) all these events are classified as surface water flooding; and
- At the eastern Edge of the Erith Marshes between Erith train station and Belvedere station (See Figure 2.3).

The Environment Agency have noted that the there are flow conveyance issues associated with the Yarton Way Culvert which is permanently underwater and the Picardy Manorway Culvert which has severely reduced conveyance leading to flooding issues in the Belvedere railway station area.

Figure 2.4 Areas of Concentrated Recorded Flood Incidents

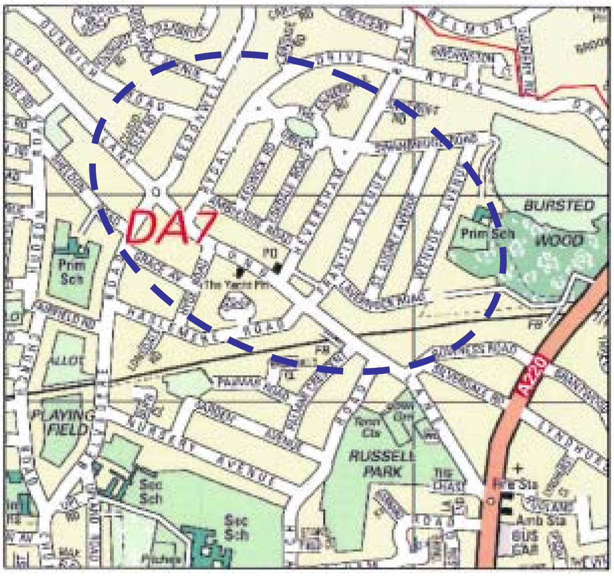


Bexley's Drainage Engineers highlighted the following areas as being either considered susceptible to surface water or drainage related flooding:

Swanbridge Wenvoe Catchment

Prior to the 1950's, a water course flowed through this area of Bexley, however this river valley was infilled and the stream culverted during the 1950's. The surcharging of this drainage network has been identified as a problem by Bexley's Drainage Engineers. The Engineers noted that problems have been exacerbated by the recently constructed residential development and associated car park at the head of the drainage run. Figure 2.5 presents an indicative extent of the study area modelled by Bexley in 2007.

Figure 2.5 Location of the Swanbridge Wenvoe Catchment



Source "Swanbridge Road/Wenvoe Avenue Bexleyheath, *Existing Surface Water Sewer System Analysis*, (2007), Waterman Civils Consulting Engineers.

= Indicative area of the study.

The modelling assessment (2006) identified that surcharging and surface flooding occur during a 1 in 1 year storm. The flooding issues were noted to be exacerbated by the local topography, as the sewer catchment area forms a bowl, with no overland escape route for flood water. The lowest levels in the catchment are identified by the modelling report (2007) to be in Swanbridge Road adjacent to No 88 Wenvoe Avenue. Any surface water flooding from the system will flow downstream along the roads towards the lowest point in the catchment unless it can re-enter the system at a non-flooded gully. The report produced in 2007 made the three conclusions listed below:

- The modelling work undertaken in the study suggests that the sewer system is significantly undersized in comparison to current design guidelines for sewer capacity;
- Surcharging and flooding occur during a 1 in 1 year return period storm, which was noted to suggest that the system would flood on a more regular basis than is normally acceptable; and
- Any surface water flooding resulting from over capacity issues is predicted to be retained in the lowest point in the catchment area as there is no overland escape flow route.

Surface Water Run-on

Site specific FRA's should consider the risk associated with surface water run-on. Surface Water run-on is flooding associated with surface water which is generated off site, which can impact a site because of local flow routes. Surface water run-on is distinct from surface water run-off, in that run-off is associated with the generation of surface water from a developed site whereas run-on describes the flow of water on to a site. This type of flooding typically occurs following intense rainfall events. Sources of surface water flooding can include:

- Surface water generation is more likely in heavily urbanised catchments and in areas with low infiltration potential. Following intense rainfall events, water can flow over the surface from surrounding areas and cause localised flooding;
- During intense rainfall events, drainage networks can become surcharged and result in water being discharged to the surface, this can lead to localised flooding issues; and
- Burst water mains can result in significant volumes of water being discharges to the surface, which may result in localised flooding issues.

The potential for the above sources to be a risk should be considered when preparing site specific FRAs. Figures 18 and 19 (in Appendix A) should be used to inform site specific FRAs of a potential surface water run-on flood risk.

2.6 Reservoirs and Dams

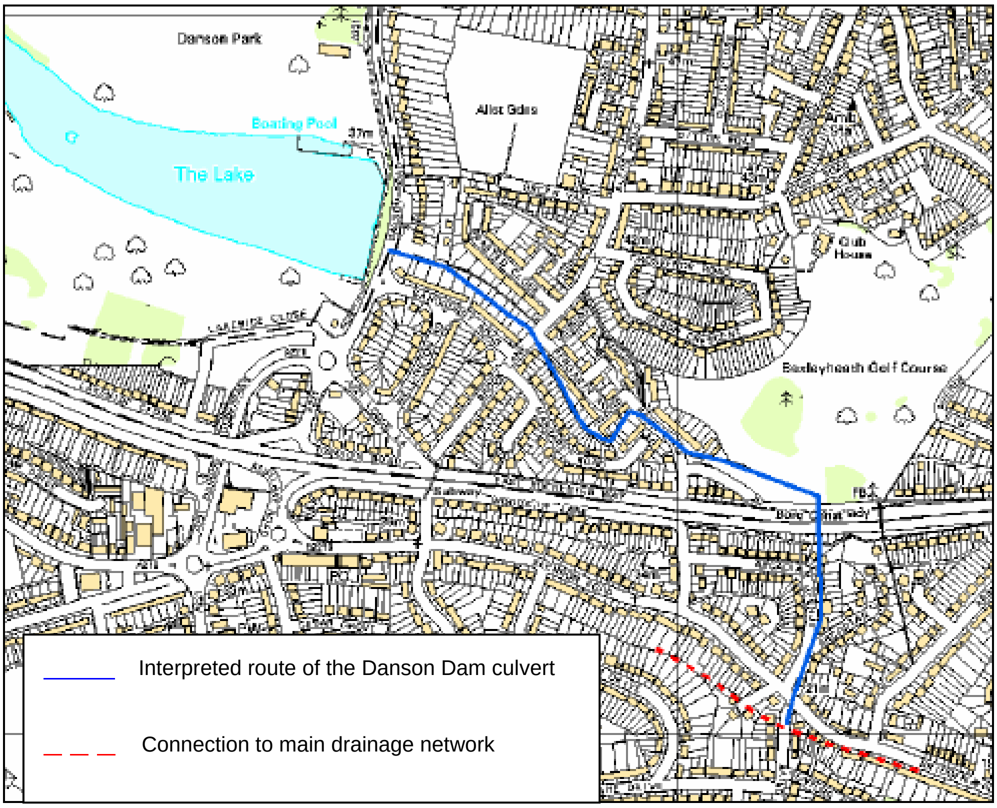
Danson Park Dam

The largest body of open water within Bexley is Danson Park reservoir, which is located on a tributary of the River Shuttle, in the centre of the Borough. The reservoir receives discharge from the local surface water drainage network. It has been reported that foul water can also surcharge from sewer system during periods of intense rainfall and route is to the reservoir (a known issue, raising water pollution concerns). The capacity of the reservoir was reduced in the years following the Second World War as building rubble was deposited in the lake, however it remains sufficient to facilitate recreational water sport activities and water levels are maintained at a consistently high level to enable this.

The crest of Danson Dam runs parallel with Danson Road and stands in the order of 7 to 8m higher than the road. The reservoir is drained through a chamber built into the dam wall which collects water and routes it into a culvert which routes flow into the River Shuttle. This path follows the natural low point in the topography and as such reflects the potential flow route of flood waters should the integrity of the dam be compromised. Figure 2.6 illustrates a simplified representation of the route of the Danson Dam culvert. An overflow spillway is built into the dam structure and is designed to be effective when the water levels in the dam reach a critical level so as to avoid structural damage to the dam wall. The spill way is understood to discharge onto Danson Road. The precise flow routes of any over spill water are not currently mapped. Bexley understand that the Environment Agency will be releasing Reservoir inundation maps which will further the understanding of flood risks associated with the failure of this structure.

Potential flood risks posed by Danson Dam are monitored by the Council. The dam is subject to regular inspections to assess its structural integrity. The Council have an Emergency Procedure Strategy for the dam if the water levels begin to rise. This procedure is in place to limit the risk of flooding to residents downstream of the dam. The dam is subject to the controls enforced by the Reservoirs Act, which limits the data that can be published in this publicly available document.

Figure 2.6 Danson Park Dam Downstream Drainage Routes



2.7 Other Sources of Flooding – Southern Outfall Sewer

It has historically been considered that the Southern Outfall Sewer is a raised structure, located within the linear embankment locally known as 'The Ridgeway'. A review of Thames Water Sewer data, as part of the Erith Marshes Study (Entec 2009), revealed that the Southern outfall sewer is in fact buried 2-3m underground. The effluent is raised to the surface at Crossness Sewerage Works by pumps. The Ridgeway is in fact a relict of the times when the pumps were steam powered and required a coal supply, as this embankment is actually a disused railway line. As such there it is not assessed that the Southern Outfall Sewer presents a risk to the Borough of Bexley.

2.8 Flood Management Infrastructure

Figure 5 (in Appendix A), details the location of the raised flood defences in the Borough. The defences presented in Figure 5 are regularly inspected by the Environment Agency to ensure they remain fit for purpose. All Thames tidal defences currently offer a 1 in 1000 year standard of protection. The Environment Agency's National Flood and Coastal Defence Database (NFCDD) does not provide a comprehensive record of crest heights, as such the Environment Agency should be consulted for defence information when preparing site specific FRAs. The areas benefiting from the Environment Agency defences (ABDs) are illustrated in Figure 5 and were provided for the SFRA in September 2008. Please note that not all flood defences in Figure 5 have associated ABDs, this reflects the current availability of mapping data and does not imply that other defences do not benefit areas. An ABD designation does not imply that flood risk has been completely removed, as there remains a residual risk associated with defence failure of the defences. Residual tidal flood risk is discussed in Section 3.

2.9 Summary of Flood Risks

Section 2 of the SFRA which identifies flood risks present the greatest flood risk to Bexley. A quantitative assessment of flood risk requires knowledge of the probability of occurrence and the consequence of the event. In the absence of numeric modelling of all sources of flooding is has not been possible to provide a flood risk value in accordance with the guidance presented in Flood Risk to People Report[14].

Nonetheless it is considered appropriate in the Level 1 SFRA to qualitatively rank the identified Borough wide sources in order of the risk they pose to the Borough. The purpose of which is to identify which sources of flooding potentially represent the greatest risk to the Borough. The resultant classifications are generalisations based on the entire Borough. As such there may be specific areas where a particular source poses a well appreciated risk (e.g. the surface water flooding in the vicinity of Belvedere station) but is classified as posing a low risk to the Borough as a whole. This reflects the Borough wide nature of the probability and consequence classifications.

The methodology adopted to rank the Borough wide sources, uses qualitative classifications of probability of occurrence and consequence. Table 2.1 illustrates the qualitative probability categories and Table 2.2 illustrates the qualitative consequence categories.

[14] Defra/Environment Agency (2006). *Flood Risk to People*, FD2321/TR1 – The Flood Risks to People Methodology

Table 2.1 Definitions of Qualitative Flooding Probability Categories

Qualitative Probability Category	Definition
Likely	Events of common occurrence that an individual may experience a few times in their lifetime.
Infrequent	Events that an individual may experience once in a lifetime.
Possible	Events that may be seen once in every few lifetimes.
Remote	Events that are of a low order of likelihood but combined with a failure of flood defences designed to protect against such an event.
Very Remote	Extreme flood events with an annual probability of less than 0.1%.

Table 2.2 Definitions of Qualitative Flooding Consequence Categories

Qualitative Consequence Category	Definition
High	Serious damage to property and high risk of injury and loss of life. High depths of floodwater and high flood flow velocities
Medium	Moderate damage to property, moderate flood depths and flow velocities. Some risk of injury.
Low	Minor damage to property, low depths of floodwater and low flow velocities. Minor risk of injury
Negligible	No damage to property or risk of injury

The Probability and Consequence categories are combined in a risk matrix to determine the level of risk (risk = probability x consequence). The risk matrix used for this study is presented in Table 2.3

Table 2.3 Risk Matrix

		Likelihood (probability)				
		Likely	**Infrequent**	**Possible**	**Remote**	**Very Remote**
Consequence	**High**	Very High	Very High	High	High	High
	Medium	High	High	Medium	Medium	Medium
	Low	Medium	Medium	Low	Low	Negligible
	Negligible	Low	Negligible	Negligible	Negligible	Negligible

Table 2.4 summarises the flood risks identified in Bexley and based on the likelihood and consequence assessments, provides a risk classification

Table 2.4 Qualitative Ranking of Borough Wide Flood Risks in Bexley

Source of Flooding	Area at Risk	Risk
Tidal	All low lying areas adjacent to the River Thames	High
Fluvial	Low lying areas adjacent to the rivers Cray and Shuttle	High
Surface water	All areas, especially local topographic depressions	Medium
Groundwater	Low lying areas, including the floodplains of the Rivers Thames, shuttle and Cray.	Low

3. Residual Flood Risk in Bexley

The flood defences along the banks of the Thames protect the Borough from direct tidal flooding. However, a residual flood risk exists as these tidal defences could be breached. As part of the SFRA, the residual risk of defence failure has been investigated and modelling has been undertaken to quantify this risk. Due to the inherent nature of numerical modelling and the number of assumptions made, the results should be considered as estimations of peak flooding potential in the Borough. Appendix B presents a detailed modelling methodology.

The tidal River Thames floodplain is divided into discrete flood cells. This SFRA refers to the flood cells as embayments. The embayments are topographic features which comprise of low-lying areas separated by ridges of higher ground. Bexley has two such embayments, Thamesmead/Erith Marshes and Crayford Marsh. It is the purpose of this section to define the residual risk, including likely depths and levels, and predicted flood hazard.

3.1 Overview

Figures 20, 21, 22 and 23 (in Appendix A), illustrate the results of the modelling and define the predicted residual tidal flood risk. These figures present combined maximum values from all the breach simulations undertaken, and the area likely to be flooded if a breach were to occur during the 1 in 200 year tidal event, including an allowance for climate change up to the year 2107. Affected areas in Bexley include Abbeywood, Erith Marshes, Thamesmead, Belvedere, Erith and Howbury.

Predicted flood depths are high in the two embayments, with most flooded areas exceeding 2m (Figure 20 in Appendix A). Depth of flooding is highly dependant of variations in localised topography. Thamesmead embayment, east of Erith, has a predicted flood water level of just above 6m AOD. While Crayford Marsh embayment, west of Erith, has a predicted flood level of just above 4m AOD. Flood Hazard across both embayments is high, with most areas having a hazard classification of ‘hazard to all’ as defined by *Flood Risk to People*[15] as illustrated in Figure 22 (in Appendix A).

The remainder of this section details the results of the residual risk modelling, whilst Section 8 addresses the flood risk management approaches, for these two embayments, which are unique from other areas in the Borough.

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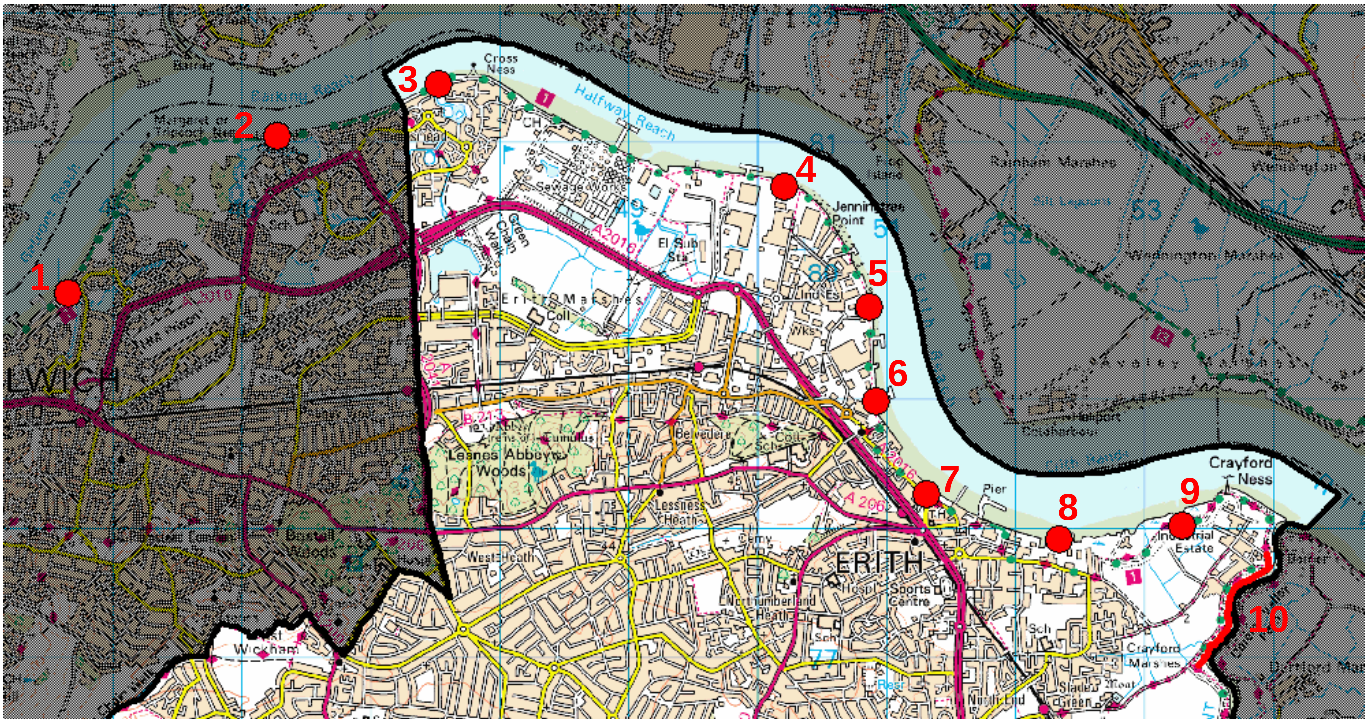
[15] Defra/Environment Agency (2006). *Flood Risk to People*, FD2321/TR2, Guidance Document.

3.2 Quantification of Residual Flood Risk

3.2.1 Breach Locations

The nine breach locations and one overtopping location (see Figure 3.1) were identified through consultation with the Environment Agency[16]. The modelled breach locations have been spaced along the tidal defences. The locations have been selected according to their potential to cause the most significant consequences, rather than locations with the highest probability of failure. The overtop location (10) is located along the western bank of the River Darent. This scenario was modelled because there is a risk is posed in the event that the tidal defence gate is not closed during an extreme tidal event.

Figure 3.1 Breach and Overtop Locations used in the Bexley SFRA.



The shaded out areas represents the areas outside the London Borough of Bexley.

The results of the breach modelling at locations 1, 2, 3 and 5 have been taken from the Greenwich SFRA, with the permission of the London Borough of Greenwich. Further details are presented (in Appendix B).

[16] Anthony Hammond – Flood Risk Mapping at the Environment Agency (Thames Barrier Office)

3.2.2 Nature of Tidal Flood Risk in Bexley

Design Stage Hydrographs[17] were received from the Environment Agency for the current day 1 in 200 year tidal event, at various points along the River Thames. These hydrographs include a storm surge component and have been extracted from the Environment Agency's tidal Thames ISIS model. The potential increase associated with climate change has been accounted for by scaling the current 1 in 200 year event hydrographs up to the peak of the predicted 2107 level using the evidence in table B.1 in PPS25. See Appendix B for further details on the levels used.

3.2.3 Model Output

The modelling produced results for each of the nine breaches and the one overtopping location. The mapped model output is presented as a maximum encountered at any point in the simulation, which may not necessarily coincide with the time of maximums for all other cells. To represent residual risks in Bexley the maximum risk from all modelled simulations has been combined into composite from all the individual breaches simulations. This ensures that the greatest risk to any part of Bexley is considered when interrogating the model outputs and is considered to be a conservative and risk-averse approach.

Peak Depths

Figure 20 (in Appendix A) illustrates the composite maximum flood depth predicted by the TuFLOW breach modelling across the two embayments. Depths of flooding are predicted to be in the order of 3.5m in Abbeywood, Erith Marshes, Thamesmead, Belvedere and Crayford Marsh. In Erith, predicted flood depths alongside the Thames are limited to 1.5m, this is because of the elevated topography in this area.

To the east of Erith, high flood depths are mostly associated with the Crayford Marshes, including the Darent Industrial Park. Some residential fringe areas in Slade Green, along Hollywood Way and Duriun Way are potentially susceptible to deeper flooding. Some localised deeper flooding is also possible in the low area north of the intersection between Bilton Road and Manor Road and in the low area west of Walnut Tree Road in Erith. West of Erith, potentially significant depths occurred through large residential areas of Abbeywood, Thamesmead and Belvedere.

Peak Water Levels

Unlike flood depth, which is variable due to underlying topography, flood levels are far more uniform with distinct areas across the embayments. Figure 21 (in Appendix A) presents the composite map of the predicted maximum flood water levels in the two embayments during the 1 in 200 year event in 2107.

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[17] A 'Stage Hydrograph' is a data series representing water level over time

In Crayford Marsh embayment, the volume of water predicted to flow through the breaches is sufficient to fill the embayment up to the crest level of the Darent defences (*c*.6.2m AOD). Once the crest level is exceeded, water spills into the Darent and then into the Dartford portion of the Crayford Marsh embayment. The majority of Erith is on higher topography, which creates a topographic divide between Thamesmead/Erith Marshes and Crayford Marsh embayments. This prevents significant volumes of water from flowing from one embayment to another and prevents much of Erith town centre from flooding.

In Abbeywood, Thamesmead and Belvedere and the Borough of Greenwich, maximum water levels reach approximately 4.4m AOD. This consistency is despite the topographic divide presented by the Southern Outfall Sewer. The similarity in maximum levels is explained by the presence of the culvert passing beneath the Outfall Sewer into South Mere, and the underpass at Plumstead Station which allow water to pass to the other side of the Outfall Sewer. The Plumstead Station Underpass becomes a flow route once water levels in the embayment reach 3.1m AOD.

The significance of the flood water levels to safe flood management is described in Sections 6, 7 and 8.

3.2.4 Flood Hazard

Figure 22 (in Appendix A) illustrates how most of the embayment is defined as having a high '*hazard to all*' classification. Hazard is defined as a function of the depth and velocity of flood water plus a debris factor. TuFLOW uses the following hazard equation which is defined in the FD2321/TR1[18] Report.

$$D*(V+0.5)+DF$$

Where: D = Depth, V = Velocity, 0.5 = a constant to provide a conservative estimate, DF = Debris Factor which is variable according to depth.

In the Bexley embayments depth is the most influential factor on the categorisation. The exceptions to this are in the immediate vicinities of the breach location, or where moving water becomes bottlenecked. In these cases velocities have the greatest impact on hazard categorisation. Flow bottlenecks are noted along Erith's West Street, beneath New Bridge and along Church Manorway.

3.2.5 Areas of Potential Rapid Inundation (Unmodelled)

The resultant water levels in the embayments do not reach that of the 1 in 200 year tide level (plus climate change). This is because the water levels in the embayments is a function of the volume of water that can pass through the breach in any given tidal cycle. The sheer volume of these embayments prevents the same level to be reached at

[18] Defra/Environment Agency (2006). *Flood Risk to People*, FD2321/TR2, Guidance Document.

both sides of the defence line, before the tide level starts to recede. Despite the large number of breaches modelled in this SFRA (10 including the data supplied by the London Borough of Greenwich SFRA), there are areas immediately behind the defences that were not shown to flood. These areas were not covered by the modelled breach extent as the resultant extent is controlled by flood water level. Which as outlined above, is lower than the 1 in 200 year (plus climate change) tide level. As such there are parcels of land immediately behind the defence line, which have a ground elevations below the 1 in 200 year tide level (plus climate change), yet are not included within the flood envelope. These areas are considered to be at risk if there were a failure in the defences in the vicinity of these areas. Figure 7 (in Appendix A) identifies these locations as *'Areas of Potential Rapid Inundation (Unmodelled)'*, the SFRA recommends that development proposals in these areas should be accompanied by breach modelling analysis.

3.2.6 Speed of Onset

A map depicting the speed of onset of flooding was created in order to provide an indicator at the rate at which parts of the embayment become affected by propagating flood waters. Figure 23 (in Appendix A) presents the output of this assessment. As Appendix B describes, the limitations of the TuFLOW modelling software inhibit a '*dam failure*' scenario being modelled and as such the rate of onset is considered to be indicative only. Figure 23 provides a representation of flood propagation. The implications of this on development are presented in Section 8.

4. Flood Risk Management in Bexley

Approaches to flood risk management can broadly be described as either planning, design or response based. The advocated approach places reference on firstly avoiding the risk, and where this is not entirely possible, to mitigate the risk through design.

The Association of British Insurers (ABI) put forward recommendations as part of the *Managing Flood Risk in Government Growth Areas* report in 2005[19]. The examined the potential economic costs of flooding arising from the additional development in the growth areas, and considers the most effective approaches to manage the risk. This report is written from an economic perspective and, unlike PPS25, it is not focused on safety to people. Nonetheless, both documents advocate similar approaches to either reduce economic losses or to reduce the risk to people.

The London Thames Gateway is one of the four main growth areas identified to address the housing shortage in the South East. It stated that an extreme flood would lead to damages in excess of £12–16 billion in Thames Gateway, with £4–5 billion coming from new development.

Damage costs from flooding could be substantially reduced in the growth areas through careful management of the risks. The ABI state that a Sequential Approach in the Thames Gateway is needed, due to the high proportion of sites located entirely on the floodplain. The ABI identify two potential ways in which the flood losses could be reduced: avoidance and property resilience. Allocating properties first to lower flood risk sites within existing development boundaries is said to reduce losses by 40 – 52% depending on the housing density. Effective land-use planning can reduce flood damages by minimising exposure to flooding. The economic losses caused by flooding could be further reduced by making properties in the floodplain more resilient to flooding. The promotion of ground-level avoidance (i.e. building apartments and/or raising ground-floor levels) is particularly important for the future development sites proposed in significant flood probability areas, where potential losses will be greatest. Where properties have to be located in flood risk locations due to lack of alternative sites, flood losses could be mitigated through the use of measures that reduce the amount of water entering a property (dry-proofing/resistance) or reduce the damage and cleanup costs once water does enter the property (wet-proofing/resilience).

PPS25 adds a further approach through managing the communities responses to flooding, which encompasses such things as evacuation planning and flood warning procedures. Sections 5 and 6 address flood risk management in Bexley based on these defined approaches. Section 8 then applies this approach specifically to the two embayments within Bexley (Thamesmead/Erith Marsh and Crayford Marsh)., as these have been identified as unique areas.

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[19] Association of British Insurers, Managing Flood Risk in Government Growth Areas, (2006)

5. Flood Risk Management through the Planning Process

5.1 Sequential Approach

Through the planning process, PPS25 aims to reduce the flood risks faced by future developments, and advocates a risk avoidance approach to spatial planning. Avoidance has always been an option for risk management, but it was rarely deployed. There has recently been a paradigm shift which now prioritises the importance of avoidance. Annex D of PPS25 has been reproduced (in Appendix D) of this SFRA for reference purposes. A sequential risk-based approach to determining the suitability of land for development in flood risk areas is central to the Policy Statement and should be applied at all levels of the planning process.

Application of the sequential approach to spatial planning reinforces the most effective risk management measure – that of avoidance. PPS25 states that application the Sequential Test at the Local Development Document level, will help ensure that development including regional housing targets, can be safely and sustainably delivered.

5.1.1 Sequential Approach in Bexley

The sequential approach offers a simple decision making tool that is designed to ensure that areas of little or no risk of flooding are developed in preference to areas at higher risk. PPS25 notes that LPAs should make the most appropriate use of land to minimise flood risk, by planning the most vulnerable development is located in the lowest known risk areas. However, it is recognised that there are cases when development within higher risk zones is unavoidable. This is particularly true for the London Borough of Bexley, where most of the Thames Gateway Growth Area and London Plan Opportunity Areas located within areas of higher flood risk.

Bexley have maintained the view that avoidance of risk is the most effective means of managing the identified flood risks. Indeed flood risk was a one of a suite of criteria used by Bexley during the SHLAA (Strategic Housing Land Availability Assessment). In this way, the principal of avoidance has been applied where possible in the Borough's formulation of the 'Opportunity Areas for Regeneration'. Nevertheless, other socio and economic factors have resulted in some of the Opportunity Areas for Regeneration being partially located within areas of identified flood risk. For the Level 1 SFRA assessment to provide the greatest benefit to Bexley, it has been acknowledged that this development is likely to occur in areas of flood risk and as such hydraulic modelling and information to support the Exception Test has been included. The level of detail provided in this Level 1 SFRA is therefore more typical of a Level 2 assessment.

Bexley have constructed the wider socio-economic justifications evidence bases for the size and location of the Opportunity Areas for Regeneration (sometimes referred to as Growth Areas). Bexley will however, not support windfall development in areas outside these designated locations.

5.2 Sequential Test – Vulnerability and Flood Risk

The Sequential Test is a key component of the hierarchical approach to avoiding and managing flood risk. The SFRA has mapped the flood risk zones (Figure 7 in Appendix A) and has identified the landuses which are considered appropriate[20] for each site based on the guidance specified in PPS25 (see Table 5.1 and Figure 7 in Appendix A). Table D.1 (in Appendix D) defines the risks associated with each Flood Zone and Table D.2 indicates the types of landuse considered appropriate for each Flood Zone. There are several key points that the Council should consider when applying the Sequential Test, these are outlined below.

- Increasing the vulnerability of a site by proposing an alternative use of a higher vulnerability (even if consistent with the risk) is considered an increase in flood risk and is not inline with the principals of PPS25;
- The most vulnerable landuses should be allocated first, in the areas of least risk;
- Placing less vulnerable uses in low risk areas and thus reducing the amount of available space for more vulnerable uses in the lower risk zones is not appropriate. Such a situation can only be considered if it can be demonstrated that the only suitable site for the low vulnerability land-use, is in the area of low risk; and
- If land in Flood Zone 3a has to be utilised, development should be steered towards the areas of lowest hazard within that zone. The information presented in Section 3 can be used to inform this process.

5.2.1 Data to Support the Application of the Sequential Test

The flood risk classifications defined for the Borough are presented in Figures 7 (in Appendix A). The Borough is coloured from red (highest flood risk) to green (lowest flood risk). Table 5.1 presents guidance on appropriate landuse guidance for each of the flood risk zones. Figure 7 and Table 5.1 can be used to guide the decision making process when the Council are presented with windfall sites.

5.2.2 Other Sources of Flooding

When considering the Sequential Test, the potential extent of surface water flow routes and ponding areas (Figures 18 and 19 (in Appendix A) should be reviewed. If there are two otherwise equally suitable sites for development in Flood Zone 1, with one site is identified as being potentially at risk of surface water flooding and the other site is outside the potential zone of surface water flood risk, then the site outside the potential surface water flooding risk zone should be preferentially selected for development.

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[20] appropriate = as defined by Table D.2 in PPS25

Figures 18 and 19 (in Appendix A) can also be used to inform site specific FRAs as to where there may be a risk posed by surface water run-on.

Table 5.1 Attribution of Flood Risk to Development Sites

Flood Zone	Probability	PPS25 Landuse Guidance
Flood Zone 3b	Functional Flood Plain	Only the water compatible uses and the essential infrastructure listed in Table D.2 (Appendix D) should be permitted in this zone. Development should be designed and constructed in such a way to: • remain operational and safe for users in times of flood; • result in no net loss of floodplain storage; • not impede water flows; and • not increase flood risk elsewhere • Essential Infrastructure in this zone should pass the Exception Test This zone is present in Crayford town centre, and was produced as part of the Crayford Town Centre SFRA.
Tidal Residual Risk Zones	No PPS25 classification	This zone depicts the zone of residual tidal flood risk, i.e. the zone which could potentially flood during a failure in the flood defences during the 1 in 200 year tidal event (plus climate change allowance). More vulnerable landuses are not considered appropriate below the predicted flood water level. Section 9 provides further guidance. This zone is based on the TuFLOW breach modelling undertaken as part of the SFRA (Section 3)
Flood Zone 3a	High	This Zone in the SFRA comprises of the Environment Agency's Flood Zone 3 extent, supplied September 2008. The water compatible and less vulnerable uses of land in Table D.2 are appropriate in this zone. The highly vulnerable uses should not be permitted in this zone. The more vulnerable and essential infrastructure uses in Table D.2 should only be permitted in this zone if the Exception Test is passed. All developments in this zone should be accompanied by a FRA.
Flood Zone 2	Medium	This Zone in the SFRA comprises of the Environment Agency's Flood Zone 2 extent, supplied September 2008.The water compatible, less vulnerable and more vulnerable uses of land and essential infrastructure in Table D.2 are appropriate in this zone. Subject to the Sequential Test being applied, the highly vulnerable uses in table D.2 are only appropriate in this zone if the Exception Test is passed. All development proposals in this zone should be accompanied by a FRA
Flood Zone 1	Low	All uses of land are appropriate in this zone. Other sources of flooding should be reviewed.

Guidance for zones 3b, 3a, 2 and 1 based on Table D.1 in PPS25

The colours in Table 5.1 reflect the colours illustrated on Figure 7 (in Appendix A)

5.3 The Exception Test

The PPS25 Exception Test recognises that there will be some exceptional circumstances when development within higher risk zones is unavoidable. To meet the Borough's regeneration aspirations, development is likely to occur In areas of identified flood risk. The Council's development targets, driven by Planning Policy Statement 3 –

Housing (PPS3) and the London Plan, result in some of this future development being residential. The allocation of this necessary development must still follow the sequential approach and where exceptions are proposed, the Exception Test must be satisfied.

The instances where a FRA is required to support the planning application is discussed in Section 9. Flood mitigation measures should be considered as early as possible in the design development process to reduce and manage the flood risks associated with development. Section 6 describes how flood risk can be managed through development design, these principals are applicable Borough wide. In addition, Section 8 discusses flood management guidance specific to the areas of Thamesmead/Erith Marshes and Crayford Marsh embayments.

5.3.1 Passing the Exception Test

To pass the Exception Test three key criteria must be met. These criteria and the sources of supporting information are presented in Table 5.2,

Table 5.2 Exception Test Guidance

Part	Criteria	Guidance
a	It must be demonstrated that the development provides wider sustainability benefits to the community that outweigh flood risk, informed by a SFRA where one has been prepared. If the DPD has reached the 'submission stage' – the benefits of the development should contribute to the Core Strategy.	Review site against aims and objectives of SA and LDD
b	The development should be on previously-developed land or, if it is not on previously developed land, that there are no reasonable alternative sites on developable previously developed land	PPS3
c	A FRA must demonstrate that the development will be safe, without increasing flood risk else where, and where possible reduce the overall flood risk.	Refer to Sections 7, 8 and 9 of this report.

Criteria based on paragraph D9 of PPS25

PPS25 states that the Exception Test should be undertaken by only after the Sequential Test has been applied and passed. For the Sequential Test to have been passed, it must be demonstrated that there are no other reasonably alternative sites available in zones of lower flood risk. This is an essential evidence base and should be considered a prerequisite for any development proposed in a zone of flood risk. Once the Sequential Test has been applied and passed, PPS25 requires the Exception Test to then demonstrate that the development provides wider sustainability benefits to the community that outweigh the flood risks. Where development is essential in a flood risk zone, PPS25 requires it to be on previously developed land, if this is not possible it must be demonstrated that there are no reasonable alternative sites on developable previously developed land. The final requirement of the Exception Test states that the development must be safe, without increasing the flood risk elsewhere and where possible reduce overall flood risk. Sections 6 and 8 of this SFRA provide design principals to inform safe development.

5.3.2 Part c of the Exception Test

Part c of the Exception Test requires an FRA, demonstrating that the proposed development will be safe, without increasing the flood risk elsewhere. To achieve this, PPS25 identifies a number of factors which need to be considered.

- Safe 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.

These key aspects are expanded in the following sections 6 and 8, where flood risk management is discussed in terms of design and emergency responses.

5.4 Site Specific Flood Risk Assessments

Section 9 provides guidance on the need for and scope of site specific Flood Risk Assessments in Bexley. The Environment Agency is a statutory consultee in the planning process.

The Environment Agency's consent is required for development on the riverward side of any flood defence and where development is proposed within 16m of the landward toe of a tidal flood defence and 8m of a non-tidal flood defence or top of river bank. In all cases the FRA process should result in safe development (from a flood risk perspective) and where possible achieve a reduction in overall flood risk.

6. Flood Risk Management through Design in Bexley

6.1 Approach

The guidance presented in Section 5 and 6, is intended for application across the whole Borough. However, owing to the complexities of the risks that have been identified in the Thamesmead/Erith Marshes and Crayford Marsh embayments, an additional section (Section 8) has been provided to inform flood risk management in these areas of tidal flood risk.

Flood risk management by design should only be considered after the sequential approach has been applied to development proposals. The sequential approach is applicable both in terms of site allocation and site layout. Only when it has been established that there are no suitable alternative options in lower risk areas, should building design solutions be considered to exceptionally allow development to proceed in flood risk areas.

The sequential approach to landuse planning on site can mitigate some of the floodrisks. However, there will be instances where a level of risk remains. In these circumstances, flood risk management through design is required. This would need to be addressed as part of site-specific FRA. The following sections provide some over-arching guidance to Bexley when considering planning applications.

6.2 Site Layout

Following the full application of the Sequential Test, a site may be proposed for development within a Flood Risk Zone[21]. The sequential approach to the spatial distribution of landuses on site should be deployed ahead of building design solutions (See Sections 6.6 to 6.14 in the PPS25 Practice Guide).

6.3 Evacuation Routes

Safe escape to outside the flood risk zone should be incorporated into site designs to facilitate safe evacuation. Additional detailed modelling of watercourses may be required to provide the necessary flood levels and speeds of onset and flood hazard classifications needed to inform safe evacuation routes. Safe routes should be identified both inside and beyond the site boundary of the new development. Even where a new development is above the floodplain and is considered to be acceptable with regard to its impact on flood flows and flood storage, it should

[21] This section 6 refers to the fluvial floodplains of the rivers Cray and Shuttle

be demonstrated that the routes to and from the development are also safe to use. All sources of flooding should be considered during the design of flood evacuation routes.

6.4 Development Controls

Development in Fluvial Flood Risk Areas

Please note that these development controls differ from those applied to the areas of residual tidal flood risk which are outlined in Section 8.3.

The Flood Zones described in Section 2 are concentrated in the eastern and northern parts of the Borough. It is possible that there is a flood risk associated with other water courses in the Borough, which are not currently mapped by the Environment Agency. Figure 4 (in Appendix A), illustrates the extent of the Environment Agency's Main rivers and New Main Rivers (formerly Critical Ordinary Watercourses - COWs). To ensure that flood risk management can be efficiently and effectively carried out the Environment Agency seeks to have development set back 16 from a tidal flood defence structure and 8m from a fluvial flood defence structure or top of river bank. Development proposal s within this zone will require Environment Agency consent. See section 5.4

Development Controls may include:

- The FD230/TR1 Report Section 7.5.3 states that - New developments are required to provide safe access and exit during a flood. The measures by which this will be achieved should be clear in the site-specific FRA. Safe access and exit is required to enable the evacuation of people from the development, provide the emergency services with access to the development during a flood and enable flood defence authorities to carry out necessary duties during the period of flood. A safe access or exit route is a route that is safe for use by occupiers without the intervention of the emergency services. The FD230/TR1 emphasises that a route can only be completely safe in flood risk terms if it is dry at all times. However it is recognised that this is not always practicable, necessitating more detailed analysis;

- Finished floor levels of more vulnerable uses should be above the predicted 1 in 100 year water levels (plus climate change and inclusive of a freeboard allowance of 300mm). Ideally less vulnerable landuses should also have floor levels that do not flood and where possible this arrangement should be sought where ever possible. Predicted fluvial flood water levels are being revised by the Environment Agency for the rivers Cray and Shuttle and the results of this modelling will be available in March 2010. Prior to the Environment Agency re-modelling exercise, the water surface levels in Crayford should be inferred from the depth data presented in Figure 24 (in Appendix A). Water level data for areas in the floodplain of the Shuttle and the Cray (upstream of Crayford) should be obtained upon request from the Environment Agency; and

- The existing footprint of buildings on a site must not be increased post re-development. This is because additional construction can reduce floodplain storage and increase the risk of flooding elsewhere. PPS25 does not permit this. Options to offset the increased footprint of a proposed structure could be possible. Such schemes should be discussed in detail with the Environment Agency.

- Development is not permitted to reduce floodplain storage. To achieve this compensatory storage may be required, the Environment Agency requires that lost floodplain storage volumes are compensated for on a level for level basis for flood events up to the 1 in 100 plus climate change. The need for compensatory storage and the requirements of compensatory storage should be discussed with the Environment Agency as part of the FRA process.

Development in Areas Designated as Functional Floodplain (Zone 3b)

Development in the functional floodplain should be avoided in line with the Sequential Approach presented in PPS25. Only water compatible uses will be permitted providing there is no reduction on flood conveyance or flood storage. Less vulnerable, more vulnerable and highly vulnerable uses are not permitted in Zone 3b. Essential Infrastructure may be permitted providing the Exception Test is satisfied.

Development in Surface Water Flood Risk Areas

- In accordance with PPS25, any new development proposed in Flood Zones 2 and 3, or on sites greater than1 hectare, must include a site-specific FRA, to be assessed by the Environment Agency. These FRA's should be inclusive of a consideration of surface water drainage and measures to mitigate against any potential increase run off. Bexley require planning applications for sited greater than 0.25 hectares to be accompanied by a drainage assessment. The Environment Agency is not required to comment on sites less than 1 hectare in area. In addition to this, Figures 18 and 19 should be reviewed to assess whether the site is within a zone of potential surface water flood risk. It is recommended that if a site falls within the zones presented in Figures 18 and 19 an assessment of the surface water flood risks should accompany the planning application;

- Site specific FRAs should consider the local drainage infrastructure in detail. When preparing site specific FRAs the impact of blocked drains and the likely consequences should be established. If necessary it might be appropriate to slightly raise ground floor levels to reduce potential damages. This is not a requirement of PPS25, it is just a means of reducing the impact of a potential risk. Such mitigation should be supported by evidence to demonstrate that surface water flow routes are not altered to the extent that the risk of flooding is made worse elsewhere; and

- The management of runoff during the construction period is an important consideration, particularly for large sites and details of measures to mitigate for this phase of development are required as part of an FRA. The Water Framework Directive (WFD) places specific requirements on the management of non-point source pollution such as that from construction site silts. Methods to reduce the volume of solids (and runoff) leaving the site include:

  - Phased removal of surface vegetation at the appropriate construction phase;

  - Provision of a grass buffer strip around the construction site and along watercourses;

  - The covering of stored materials;

- Ensuring exposed soil is re-vegetated as soon as feasibly possible;
- Protection of storm water drain inlets; and
- Silt fences, siltation ponds and wheel washes.

Development in Areas associated with Flood Risk from Reservoirs

The flood risk associated with Dansen Park Dam has not been quantified, as such specific flood risk management measures cannot be recommended in the SFRA. Bexley has not identified any potential site allocations downstream of the Dam and this area is not an area of growth. Bexley will not be supportive of development outside growth areas.

6.4.1 Consideration of Climate Change

Managing climate change and the associated heightened flood risks are key components of PPS25. As such the SFRA recommends that the design standards and potential flood extents used to inform the Sequential Test and detailed design are based on the breach modelling (which simulated the 1 in 200 year tide level in 2107) and the Crayford 1 in 100 year plus climate change flood predictions.

All subsequent FRAs should take into account climate change, for at least the next 100 years, unless it can be demonstrated that the development will have lifespan of less than 100 years in which case a shorter horizon would be considered acceptable, upon agreement with the Environment Agency.

6.4.2 Basements

It is recommended that habitable rooms in basements should not be permitted in Flood Zones 2 or 3. Adaptation of existing properties, to include a basement for habitable rooms should be discouraged in Flood Zones 2 and 3. It is however recognised that the implementation of this may be challenging, as basement development is sometimes classified as Permitted Development when within the bounds of the existing building.

Basements for less vulnerable uses or non habitable rooms must be designed with safe internal escape. Each application should be discussed with the Environment Agency. Site specific analysis should accompany any proposal, to demonstrate that a proposed basement would not impact the flow of groundwater in such a way that the risk of groundwater flooding elsewhere is increased.

6.5 Management of Flood Risk from Other Sources

Groundwater

The areas where groundwater levels are likely to be the highest are in the lowest areas of the borough which are typically within the flood zones. In these areas the basement guidance applies which says basements should be avoided. In the absence of detailed groundwater flood risk analysis, specific development control guidance cannot be provided as part of the SFRA

Burst Water Mains and Sewer Flooding

These risks have not been quantified in the Borough. The risk associated with these sources should be identified during site specific investigations and should be assessed using Thames Water asset search information and ground levels. Any identified risk should be appropriately mitigated through consideration of design aspects like floor levels and threshold levels. It should be ensured that any development proposal does not obstruct or divert any existing over land flow routes. Where possible development should seek to reduce an existing flood risk.

6.6 Building Design

The final step in the flood risk management hierarchy is to mitigate through building design. PPS25 considers this as the least preferred option and should not be used in the place of the sequential approach to landuse planning on a site.

The communities and Local Government[22] have published guidance on improving the flood performance of New Buildings. The guide identifies a hierarchy of building design which fits within step 5 of the flood risk management hierarchy of PPS25 Practice Guide. The other steps in the Practice Guide are (assess, avoid, substitute and control – see PPS25 Practice Guide June 2008) and need to have been considered first before using the hierarchy below which is taken from the PPS25 Practice Guide:

Flood Avoidance

Construction a building and its surrounds (at site level) to avoid it being flooded (e.g. by raising it above the flood level)

[22] Improving the Flood Performance of New Buildings – Flood Resilient Construction', *Communities and Local Government* (2007)

Flood Resistance

Construction a building in such a way to prevent flood water entering the building and damaging its fabric.

Flood Resilience

Constructing a building in such a way that although flood water may enter the building its impact is reduced (i.e. no permanent damage is caused, structural integrity is maintained and drying and cleaning are facilitated).

Flood Reparable

Constructing a building in such a way that although flood water enters a building, elements that are damaged by flood water can be easily repaired or replaced.

The Flood Resilient Construction Report, sets out to help the designer determine the best option or design strategy for flood management at the building site level, based on knowledge of basic flood parameters (e.g. depth, duration and frequency), these factors would normally be determined by the site specific FRA during the planning application process. Depending on these parameters (in particular depth) and after utilising options for flood avoidance at site level, designers may opt for a water exclusion strategy or a water entry strategy, as illustrated in Figure 6.1.

Figure 6.1 Flexible and Risk Averse Approaches to Managing Flood Risk and Safe Development

	Design water depth*	Approach	Mitigation measures
Resistance/Resilience**	Design water depth above 0.6m	Allow water through property to avoid risk of structural damage. Attempt to keep water out for low depths of flooding *'Water Entry Strategy'****	• Materials with low permeability up to 0.3m • Accept water passage through building at higher water depths • Design to drain water away after flooding • Access to all spaces to permit drying and cleaning
Resistance/Resilience**	Design water depth from 0.3m to 0.6m	Attempt to keep water out, in full or in part, depending on structural assessment. If structural concerns exist follow approach above***	• Materials with low permeability to at least 0.3m • Flood resilient materials and designs • Access to all spaces to permit drying and cleaning
Resistance/Resilience**	Design water depth up to 0.3m	Attempt to keep water out *'Water Exclusion Strategy'*	• Materials and constructions with low permeability
Avoidance		Remove building/development from flood hazard	• Land raising, landscaping, raised thresholds

Notes:
* Design water depth should be based on assessment of all flood types that can impact on the building
** Resistance/resilience measures can be used in conjunction with Avoidance measures to minimise overall flood risk
*** In all cases the 'water exclusion strategy' can be followed for flood water depths up to 0.3m

Figure Taken from 'Improving the Flood Performance of New Buildings – Flood Resilient Construction', *Communities and Local Government* (2007)'

In a **Water Exclusion Strategy**, emphasis is placed on minimising water entry whilst maintaining structural integrity, and using materials and construction techniques to facilitate drying and cleaning. This strategy is favoured when low flood water depths are involved (up to a possible maximum of 0.6m).

In a **Water Entry Strategy**, emphasis is placed on allowing water into the building facilitating draining and consequent drying. Standard masonry buildings are at significant risk of structural damage if there is a water lever difference between outside and inside of the building of about 0.6m or more. This strategy is therefore favoured when high flood water depths are involved

7. Sustainable Surface Water Management

PPS25 states that surface runoff is an important consideration in the assessment of flood risk and must be addressed at the SFRA and FRA level. Historically surface water drainage, in urban areas, utilised underground piped systems to remove excess water from the surface as rapidly as possible. The sole reliance on piped networks is now recognised as no longer the most sustainable means of managing surface water. The free discharge of storm water into the piped network has the potential to increase flooding in downstream areas. Additionally, pipe systems are not designed for extreme floods (greater than the 1 in 30 year) and combined with the potential for blockage, often resulting in surface water flooding issues. Furthermore, this traditional approach creates direct pathways by which pollutants from urban areas may discharge directly into watercourse or percolate into aquifers.

Recent policy changes now place a far greater emphasis on sustainable management of surface water, different approaches are therefore required. PPS25 identifies the sustainable management of surface water as an opportunity to reduce flood risk, manage water quality and provide integrated amenity and ecological benefits, through the use of Sustainable Drainage Systems (SuDS) within developments.

7.1 Surface Water Management and SuDS in Bexley

PPS25 requires surface runoff to not be increased post development. For most of the sites, which are already intensely developed, the required attenuation volumes will be small. Nonetheless the London Borough of Bexley, the GLA and the Environment Agency want to achieve additional reductions in runoff wherever possible. Creative site and building design should be able to incorporate measures to sustainable management of surface water to achieve a reduction in run-off rates, regardless of the scale of the development.

Sites greater than 1 hectare in size in Flood Zone 1, and all development within Flood Zones 2 and 3 are covered by the legislation presented in PPS25, which dictates a FRA must accompany a planning application. The FRA needs to address drainage, among other issues (see Annex E and F of PPS25) and requires consultation with the Environment Agency.

7.1.1 Drainage Assessment Requirements – Plot Threshold Size

It is recommended that the appropriate development plan document within the LDF includes a policy that requires that all new development proposals of 0.25 hectares or greater to be accompanied by a 'Drainage Strategy'. This threshold has been selected as it reflects the Greater London Authority's threshold size for housing allocations. The drainage strategy should demonstrate how surface water is to be managed on site. Unless demonstrated to be inappropriate, sustainable management practices should be included to reduce the surface water run-off rates from the site.

7.1.2 Surface Water Run-off Rates in Bexley

A minimum requirement of PPS25 is that post development rates of runoff must not exceed pre-development runoff rates. Furthermore, the Environment Agency and the Council seek to reduce runoff rates wherever possible. Given the wider sustainability aims of PPS1 and the specific requirements of PPS25, particular attention should be paid to the use of SuDS. The London Plan[23] presents further requirements by stating the following as Essential Standards:

- Use of Sustainable Drainage Systems (SuDS) measures, wherever practical; and
- As a minimum a reduction in run-off rates to 50% of a site's Greenfield rates should be achieved.

The Mayor's preferred standard is also stated, being the achievement of 100% attenuation of the undeveloped site's surface water run-off at peak times. Bexley is within the London Plan area, as such its stipulations relating to the management of surface water apply in Bexley.

7.2 Selecting Appropriate SuDS Techniques

The applicability of SuDS techniques for use on potential development sites should based on an assessment of the following key influences, put forward by CIRIA (2007)[24]:

- **Landuse characteristics** favour different SuDS techniques. For example, industrial sites where pollution could be an issue are best managed with attenuation SuDS over infiltration SuDS, with multiple treatment stages;
- **Catchment characteristics** may have a bearing of the choice of SuDS, as particular catchments may be regulated for a sensitivity to flooding or pollution and may potentially be aggravated by one SuDS technique compared to another; and
- **Quantity and quality performance** would guide the choice of a particular SuDS technique and is dependant upon the requirements.

Chapter 5 of the SuDS Manual by CIRIA (2007) provides further details regarding these key influences, and is recommended as a supporting document to this SFRA. Proposed and existing land-uses, is thought to be a significant factor, as it influences the volume of water required to be attenuated. The existing or historic landuses and have the potential to influence the choice of SuDS techniques by informing the likelihood of pollution and

[23] The London Plan (May 2006) - Supplementary Planning Guidance (Sustainable Design and Construction), Section 2.4.4 - Water Pollution and Flooding

[24] The Construction Industry Research and Information Association (CIRIA). *The SuDS Manual - CIRIA Report C697*. (2007). CIRIA London, UK.

potential contamination issues. Indications of the most suitable techniques for each site cannot be made at a strategic level due to the influence site specific characteristics. Therefore, site specific FRA's and Surface Water Drainage Assessments will provide the required recommendations. The applicability of SuDS techniques can only be assessed in the SFRA through the consideration of regional characteristics relating to the underlying geology.

The selection of the appropriate technique(s) is/are dependant on various factors. The following are presented by (CIRIA, 2007):

- ***Soils*** – soil permeability has a significant bearing on the choice of infiltration SuDS techniques;
- ***Groundwater*** – infiltration techniques require several metres of soil depth between the base of the device and the maximum expected groundwater level;
- ***Area draining to single SuDS component*** – vegetative or filtering SuDS can attenuate smaller volumes of runoff, than ponds which can handle larger volumes generated from a bigger area;
- ***Slope of drainage area*** – steeper slopes reduce the suitability of some SuDS techniques, such as infiltration, which require longer residence times; and
- ***Head*** – SuDS that require gravity to operate will require a positive head between inflow and outflow.

Table C1 (in Appendix C) CIRIA (2007) provides a summary of influential site characteristics which should be assessed at the site specific level.

7.2.1 Following the SuDS Hierarchy

As outlined in Appendix C, there are a range of possible SuDS options available, each offering different benefits. In the selection of the most appropriate SuDS scheme for a new development consideration should be given to:

- The long term sustainability of the design
- How water quality can be improved
- How biodiversity can be enhanced

Oversized pipes and underground storage cells should be considered only when all other, more beneficial solutions, have been exhausted.

7.2.2 Source Protection Zones in Bexley

Figure 10 (in Appendix A) illustrates the extent of these zones in Bexley. The Source Protection Zones (SPZs) are defined by the Environment Agency[25] as:

- SPZ1 (Inner SPZ – 50 day travel time or 50 metres): designed to protect against the effects of human activity which might have an immediate effect upon the source. SPZ1 was originally based on the need to protect against biological contaminants;

- SPZ2 (Outer SPZ – 400 day travel time or at least 25% of the recharge catchment area): designed to provide protection against slowly degrading pollutants; and

- SPZ3 (Catchment SPZ): covers the complete catchment area of the groundwater source.

Zones 1 to 3 cover approximately half of the Borough. The coverage is focussed in the south and east of the Borough around four zones of SPZ1 which exist in the Shuttle Valley. Two are to the south of Crayford, one to the north east of Sidcup and a small zone exists near Foots Cray. Surrounding and connecting the zones of SPZ 1 is a zone of SPZ 2 which extends across the Borough to the west. SPZ 3 envelopes zones 1 and 2 and extends the SPZ distinction further north and westwards from the SPZ 2 boundary.

The designated zone of SPZ in Bexley is almost divided into two distinct zones. Pollution control should be incorporated into all SuDS designs, but the SPZ designations require the Environment Agency to be consulted if SuDS techniques are proposed to discharge to groundwater in these zones.

7.2.3 Groundwater Vulnerability in Bexley

Figure 11 (in Appendix A) outlines the Groundwater Vulnerability classifications in Bexley. This dataset indicates that the areas of highest vulnerability are in the valleys of the rivers Cray, and Shuttle which are underlain *Major Aquifers*. The only exception being in a linear geological feature which runs along the southern edge of Thamesmead along the line of the Erith to Greenwich railway. The remainder of the Borough is classified as being a *Minor Aquifer* with low to intermediate vulnerability.

Major Aquifers are highly permeable formations usually with known or probable presence of significant fracturing. They may be highly productive and able to support large abstractions for public water supply and other purposes, in the East London Area, these comprise of the Chalk Group.[26] The *Major Aquifer* in the Cray valley is overlain by

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[25] Environment Agency, Groundwater Protection: Policy and Practice, Part 4: Legislation and Policies Public Consultation 2007.

[26] National Rivers Authority Policy and Practice for the Protection of Groundwater, Groundwater Vulnerability 1:100,000 Map Series, Sheet 40 Thames Estuary (1995)

soils which readily transmit liquid discharges because they are either shallow, or susceptible to rapid flow directly to rock, gravel or groundwater.

The groundwater vulnerability classifications and SPZ designations have been combined in Figure 12 (in Appendix A) to illustrate which parts of the Borough are more likely to be suitable for infiltration SuDS techniques and it identifies where there needs to be caution to avoid pollution of groundwater resources.

7.2.4 Restrictions and Controls on the use of SuDS

The groundwater vulnerability and SPZ designations however, impose significant restrictions on the use of infiltration SuDS techniques because of the contamination potential of public water supply abstractions. The Environment Agency must be consulted and a risk assessment must be undertaken if infiltration SuDS discharging to groundwater are proposed anywhere in SPZ 1, 2 or 3.

7.2.5 SuDS – Discharging to Surface Water

In locations where infiltration techniques are not appropriate, solutions that attenuate runoff and discharge to surface water (the fluvial water bodies or Thames Water drains) are likely to be the most appropriate. Such schemes will require consultation with the sewage undertaker (Thames Water) to determine discharge rates and with the Environment Agency if it is proposed to discharge into a fluvial water body.

7.3 Using the SFRA to Inform SuDS suitability

Infiltration/discharge to groundwater SuDS techniques are considered amongst the most sustainable solutions as maintenance requirements are comparatively low and the systems do not discharge to watercourses or the sewage undertakers piped drainage network. When considering the suitability of infiltration techniques the following Figures (in Appendix A) should be consulted.

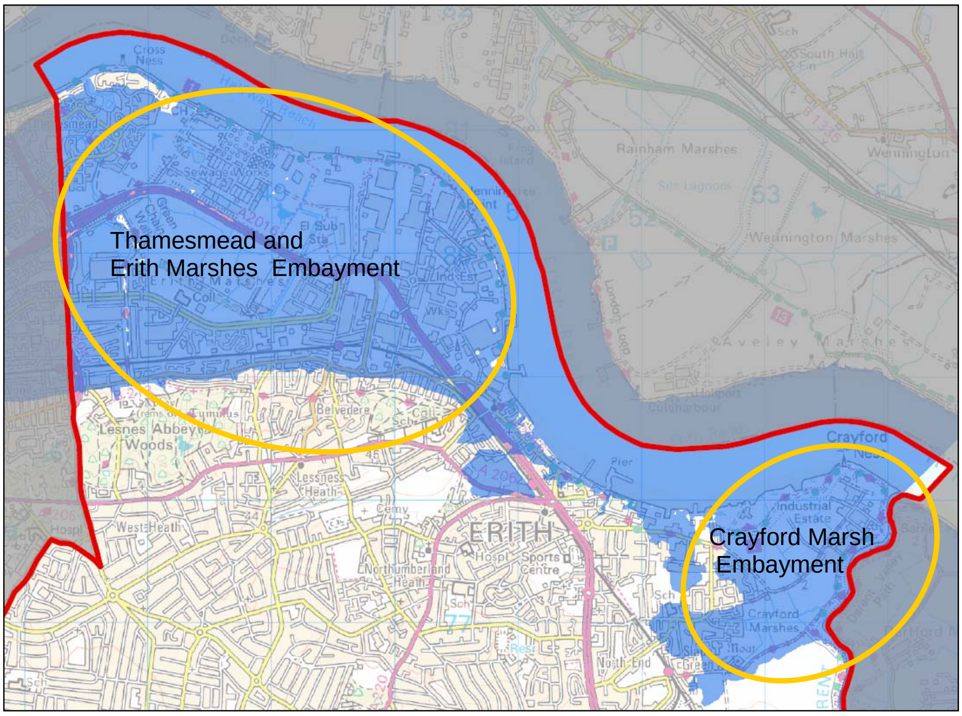
- Figure 8 – Indicates where groundwater levels are potentially nearer the surface. In areas where the water table is near the surface (<5m) the practicality of discharging to groundwater is limited, as such the feasibility of such schemes must be demonstrated;
- Figure 10 – Source Protection Zones. Less suitable in zones 1, 2 and 3 and should have Environment Agency consent. Pollution control measures will be required;
- Figure 11 – Groundwater Vulnerability. Less suitable in areas of high vulnerability, pollution control measures will be required; and
- Figure 12 – Infiltration Potential. Higher potentials are areas where the soils/geology will more likely allow greater rates of infiltration. The areas of 'no data' are characterised by London Clay, according to the 1:50,000 scale BGS Geology mapping. London Clay typifies by low infiltration rates.

The SFRA mapping does not preclude the need to undertake site specific investigations and consultation with the Environment Agency. Issues of ground contamination, ground water pollution and technical feasibility will all have to be addressed at the site specific level.

8. Flood Risk Mitigation in Thamesmead/Erith Marshes and Crayford Marsh Embayments – Zones of Residual Tidal Flood Risk

This section relates specifically to the zone of tidal flood risk in Bexley, see blue area in Figure 8.1. This area (see Section 3) is an area of residual tidal flood risk as it benefits from the protection offered by flood defences. This section is provided as the residual risk zones are significant in Bexley and is required to inform any future development. The rational for considering development (Section 8.1) is based on Opportunity and Growth areas, however the guidance in this section is not limited to these specific areas, rather it provides guidance on the entire residual risk zone. Location specific discussions are provided in the Level 2 SFRA. In all cases development proposals must demonstrate the successful application of the Sequential Test.

Figure 8.1 Location of Thamesmead/ Erith Marshes Embayment and Crayford Marsh Embayment



The blue area on Figure 8.1 is Flood Zone 2

8.1 Rational for Considering Development in the Thames Floodplain

Thamesmead, Belvedere, Erith and Slade Green (Crayford Marshes) are established employment and residential areas forming part of the Thames Gateway; an area which has been identified in the Government's Sustainable Communities Plan (2003) as the main focus for development and growth in the South East. The London Plan identifies the Thames Gateway as the priority area for new development, regeneration and investment.

The London Plan sets a housing target for Bexley for the period 2007/8 to 2016/17. Boroughs are asked to seek to exceed their housing target, and also need to look beyond 2016/17 to 2025. Both national government planning guidance and London Plan policy are pushing for higher density development on brownfield sites in locations with good public transport accessibility.

8.2 Management through Avoidance

The flood risk management outlined in this section relates the areas of residual tidal flood risk presented in Figure 22 (in Appendix A). The areas are Thamesmead/Erith Marshes and Crayford Marsh embayments. A composite maximum water depth and flood hazard map for the ten breaches has been produced to formulate the flood risk management guidance. This approach has been adopted to avoid the interpretation of multiple breach outputs and to ensure that a consistent conservative (and therefore, risk averse) approach is applied to the whole area.

The breach modelling analysis has identified significant levels of flood risk associated with a breach in the Thames flood defences during the 1 in 200 year tidal event in the year 2107. Although the probability of the flood occurring is remote, the breach analysis has highlighted that the consequences are likely to be very significant. These risks must be managed by the Council through the planning process to ensure that future development in Thamesmead/Erith Marshes and Crayford Marsh is safe.

In accordance with PPS25, a sequential approach to flood risk management should be adopted when the Council are formulating spatial planning policy. This approach seeks to avoid/reduce flood risk to development by ensuring that areas at little or no risk of flooding are developed in preference to areas at higher risk.

The application of the Sequential Test for new development in Thamesmead/Erith Marshes and Crayford Marsh is potentially difficult owing to the very small amounts of land in Flood Zone 1 and 2. Owing to the topographic shape of the two embayments (large flat areas defined by relatively steep increases in elevation along their southern boundaries), the extents of the Environment Agency's Flood Zones 2 and 3 are very similar. As such, there are very few areas of Flood Zone 2 within the Thames Floodplain. A small area of Flood Zone 1 has been identified between Crossway Lake Nature Reserve and the Thames defences. Despite this being a Flood Zone 1 designation, it is not considered a suitable location for development of highly vulnerable or vulnerable landuse types owing to the sites proximity to the defences. The breach analysis did not predict this area of land to flood. However, if a failure were to occur in the defences at this location, then this site is likely to be in a zone of rapid inundation.

A pragmatic risk based sequential approach is required to enable development in the higher risk areas. It is not thought to be possible to meet the requirements of the Bexley's Local Development Framework, the GLA's requirements (Greater London Authority) and the London Plan without development in these areas of the Borough. Where possible the most vulnerable uses should be steered towards the lowest risk areas (Zones 1 and 2). For the remainder of the embayment, the nature of the development should be guided by a sequential approach, using the hazard classifications presented in Figure 22 (in Appendix A). These hazard classifications represent the combined maximum hazard from all the breaches modelled in this SFRA and from the Greenwich SFRA (October, 2008) in the event of the 1 in 200 year tide event in the year 2107. New development should be steered towards the areas of least hazard.

8.2.1 Sequential Risk Based Approach to Planning

For the purposes of informing the sequential spatial planning process in the Thamesmead/Erith Marshes and Crayford Marsh embayments, the results of the forecasted climate change scenario (2107) should be used. This is in line with the guidance outlined in PPS25 which requires the potential impact of climate change to be factored into the planning process. The PPS25 Companion Guide (2008) states that a minimum time horizon for consideration is 100 years. A shorter period can be considered for specific developments where the lifetime of the development is known to be less than 100 years.

It is possible that much of the future development in the Thamesmead/Erith Marshes and Crayford Marsh embayments will be in the form of regeneration of residential areas and the provision of employment landuses. The exact locations of all these are not yet known. As such it is not possible to Sequentially Test these sites as they may become available at different times. The SFRA advocates a sequential approach to the selection of site and appropriate/safe development designs. This approach should utilise the hazard mapping classifications and the depth data to prescribe what development types and designs are approved by the Environment Agency as adequately mitigating the identified risks.

8.2.2 Appropriate Landuses

Table 8.1 presents the flood hazard classification illustrated in Figure 22 (in Appendix A) and the vulnerability classification of PPS25 Table D.2. Table 8.1 is the recommended tool that should be used to inform appropriate development types in the Thamesmead/Erith Marshes and Crayford Marsh embayments. Table 8.1 should be viewed in conjunction Figure 22.

Table 8.1 Suitability of Landuse Vulnerability Classifications for Below the Predicted Flood Water Level

Vulnerability	Hazard Classification (Increasing Hazard →)			
	Outside Flood Hazard†	**Danger to some (<1.5)**	**Danger to Most (1.5-2.5)**	**To All (>2.5)**
Essential Infrastructure	Suitable	Unsuitable	Unsuitable	Unsuitable
Highly Vulnerable	Unsuitable*	Unsuitable	Unsuitable	Unsuitable
More Vulnerable	Suitable	Unsuitable	Unsuitable	Unsuitable
Less Vulnerable	Unsuitable**	Possibly Suitable	Suitable	Suitable
Water Compatible	Unsuitable**	Suitable	Suitable	Suitable

Decreasing Vulnerability ↓

See Figure 22 (in Appendix A) for Hazard mapping.

† This delineates the zone outside that covered by the combined maximum extents of the breaches during the 0.5% AEP tidal event in 2107.

* Certain facilities of this category would be considered suitable if demonstrated not to be operational during flooding

** Assuming safe internal escape routes provided or safe escape to outside flood risk zone.

*** Inline with the principals of PPS25, these small areas of least hazard should be set aside for the most vulnerable landuses.

n.b.

Suitability only refers to landuses below the predicted flood level.

Suitability of development is subject to the Exception Test being passed where necessary.

The significant flood risk in the embayments means that there are many areas where "less vulnerable" and "water compatible development" would be appropriate, but few where "highly vulnerable" uses could be located[27].

It is understood that more vulnerable landuses (including residential developments), are likely to be proposed in areas with a hazard classification of 'hazard to all' and 'hazard to most'. Where possible, such landuses should be steered towards the edges of these higher risk hazard zones so that evacuation to lower hazard zones may be more easily facilitated.

[27] At ground level

In all cases the finished floor levels of residential landuses should be above the predicted 1:200 (plus climate change) water level, see Figure21.

In addition to the hazard data, the depth data presented in Figure 20 (in Appendix) A should be used to guide the site allocation process. Any proposed development of more vulnerable landuses will need to demonstrate that it remains safe in the event of a flood, through site specific FRAs.

Differentiation of Flood Hazard

The breach modelling analysis has enabled the differentiation of risk within a flood zone to be defined. These delineations should be used to undertake a sequential approach to planning development and regeneration within the flood zone. This process should involve placing the least vulnerable and water compatible landuses in the areas of greatest hazard. With appropriate mitigation (See Section 8.3) it could be possible to place more vulnerable landuses in the zones of greater hazard. Development of more vulnerable uses (as classified by Table D.2 in PPS25) in the Flood Zone 3 areas of Thamesmead/Erith Marshes and Crayford Marsh must be supported by a dossier outlining the wider community and sustainability benefits which outweigh the flood risk (Part a) of the Exception test).

Zones of Flood Inundation

The selected breach locations are representative of some of the more 'likely' breach locations which pose the greatest risk, however all of the defences within the Thamesmead/Erith Marshes and Crayford Marsh embayments have the potential to be breached. Moreover, the limitations in the modelling software do not allow for a '*dam failure*' scenario to be simulated. Rather the breach is modelled from the commencement (that is, before the tide level starts to rise). Nonetheless, the ten breaches that have been modelled in Greenwich and Bexley have provided a dense coverage of breach locations in the Thamesmead/Erith Marshes and Crayford Marsh embayments. These results have been combined together to provide mapping which indicates the likely areas of the floodplain to be inundated at the following time steps.

- 3 hours – half way up the rising limb of the first tide;
- 6 hours – at the peak of the first tidal cycle;
- 15 hours – at the peak of the second tidal cycle; and
- All other areas.

These zones are presented in Figures 23 (in Appendix B), and should be reviewed in conjunction with the hazard map (Figure 22) as it adds differentiation to the hazard zones. For example, within the areas identified as *Hazard to all* there are areas that could be classified as being at higher and lower risk based upon the time taken for the flooding to occur. When considering the suitability of sites for different landuses within the hazard zones, Figure

23 should be used to try and steer development to the 6 and 15 hour zones, which allows for more evacuation and preparation time.

It is also recommended that *highly vulnerable* land-uses (see Table D.2 in Appendix D) should be set back at least 500m[28] from the defences. Site specific FRAs should consider rapid inundation from more localised potential breach locations for developments within the 500m buffer, to inform safe development. Figure 22 (in Appendix B the hazard map of Thamesmead/Erith Marshes and Crayford Marsh) includes a zone between the defences and the extent of the TuFLOW modelling (in Figure 22 this zone is coloured blue). This zone indicates all land that is below the level of the 1 in 200 year tide level (in 2107), and which is not flooded in any one of the 10 breach simulations. Nonetheless, if the defences were to fail at these locations there is a risk that flooding could occur. As such these areas should be considered to be high risk and it is recommended that any development proposal in these blue areas zone of Potential Rapid Inundation is accompanied by a FRA and independent breach modelling analysis.

8.3 Flood Risk Management through Design

8.3.1 Site Layout and Safe Evacuation

The careful consideration of flood risk during the masterplanning process can significantly increase the safety of a development. At the simplest level, the least vulnerable uses of the development should be placed within the highest risk zones. Where there are a range of flood risks, particularly where sites are at the edge of the zone of residual risk, the development should be designed to connect higher risk areas to lower risk areas to allow for people to move to lower hazard zones through the buildings. Wherever possible, development should be designed so that they can be safely evacuated to dry land beyond the residual risk zone.

Flood-free evacuation to dry land is only possible for sites on the edge of the residual flood risk zone. Therefore, for the majority of sites in the Thamesmead/Erith Marshes and Crayford Marsh embayments, this will not be feasible. In most circumstances, where development is anticipated to be surrounded by flood waters, the only means of safe escape is internally upwards. Internal safe refugia should be provided for all occupied landuses above the design flood level inclusive of an appropriate freeboard allowance.

New developments should be designed to incorporate both internal and where possible external space where occupants can congregate and seek refuge in and/or be rescued from in the event of a breach. Where possible, new builds should be designed to allow for easy rescue by boats, from low level windows.

[28] A distance advocated by the East London SFRA (2006) Entec and JBA

8.3.2 Building Design

Please note that these development control principals apply to the areas of residual tidal flood risk only. For details of development control principals applying to the zones of fluvial flood risk please consult Section 6.4.

The finished floor levels of more vulnerable uses should be above the predicted maximum water level resulting from a breach in the defences during the 1 in 200 year plus climate change tidal event. This data should be derived from Figure 21 (in Appendix A). This figure represents a composite maximum water surface level of all the Bexley SFRA breaches and the Greenwich SFRA (October 2008) breach models.

Providing room use with a low consequence from flooding can be reasonably assured in perpetuity, then relaxations to the requirement to this requirement may be considered by Bexley. PPS25 does not distinguish between room uses within the ‘More Vulnerable’ land use classification. In the case of residual risk it is reasonable to take into account both the detailed nature of flood hazard and consequence of flooding in terms of the building design and layout. For example, the consequence of non-habitable rooms flooding (e.g. bathrooms and kitchens smaller than 13m^2, utility rooms, store rooms, garages and entrance halls) would be less than the flooding of habitable rooms (the main living areas within a residential building, including bedrooms, sitting rooms and dining rooms). The appropriateness of room uses below the predicted flood water level will need to be reviewed by Bexley on a case by case basis. In perpetuity assurance that room uses below the predicted 1 in 200 year plus climate change flood level will remain non-habitable, could be achieved through the imposition of a planning condition and a restriction on permitted development.

An appropriate freeboard allowance should be discussed with the Environment Agency and applied where necessary. Paragraphs 6.4.2 – 6.4.8 of the PPS25 Practice Guide (2009) presents guidance on appropriate free board allowances.

8.3.3 Resilience and Resistance

Building resilience in Thamesmead/Erith Marshes and Crayford Marsh embayments is a fundamental aspect to any developing proposal. Buildings must retain structural integrity in the event of a flood. Flood depths over the embayment have been estimated to be consistently in excess of 2m. It is thought that standard masonry buildings are at significant risk of structural damage if there is a water level difference between outside and inside of in excess of 0.6m. Water entry strategies are favoured in these situations which promote flood resilience rather than flood resistance.

The 'Improving the Flood Performance of New Buildings' report should be consulted for flood resilience design guidance. A summary of mitigation measures which should be considered at the detailed design stage for developments where the flood depths are expected to exceed 0.6m are:

- Accept water passage through building at higher water depths;
- Attempt to keep water out for low depths of flooding;
- Materials with a low permeability at lower levels;
- Design to drain water away after flooding; and
- Access to all spaces to permit drying and cleaning.

The impact the flood waters will have on the structural integrity of the buildings must be considered at the detailed design phase. It must be demonstrated that the buildings will remain safe in the event of a breach in the flood defences during a high tidal event.

8.3.4 Provision of New Essential Services

The installation of electric substations for developments will often be required, and the maintenance of an electricity supply is an important factor in the reduction of risk on the site. An uninterrupted power supply will mean that, in the event of a breach, residents will not be without lighting or heating, which is critical as the modelling results shows that much of the embayment will be completely cut off from dry land. The provision of electricity will reduce the risk that the most vulnerable members of the community are potentially exposed to. It is therefore recommended that new substations are designed to remain operational in the event of the site being flooded, up to and including the 2107 1 in 200 year flood level. The protection of critical infrastructure is a recommendation of the Pitt Review.

Where possible, telecommunication hubs should also be situated above the modelled flood level so that people can be contacted and make contact during a flood event. Being able to communicate could reduce people's anxieties and possibly prevent people for taking unnecessary risk in trying to leave the floodplain or trying to reach people in the floodplain in the event of a flood.

Clean water pumping stations and booster stations should also be protected so as to maintain the water supply to the area.

8.3.5 Effects of Contaminated Floodwater on Buildings

Most floodwaters carry contaminants, such as sewage, hydrocarbons, silt, salt and other biological and chemical substances, which can affect the health of the occupants and the performance of the building. Buildings may require further cleaning or extended drying times following a flood leading to increased cost and delays in reoccupation. An effective way of dealing with contamination is to use materials that minimise absorption, ensure effective drying can be achieved (by providing access to all spaces) and ensure units/fittings etc. can be easily cleaned.

8.4 Flood Risk Management through Emergency Response

The Environment Agency will issue flood warning advice if the tide levels reach a point at which the risk of flooding is considered significant. This will provide the community time to prepare and if necessary be evacuated. The risk of defence failure is reduced by a programme of defence inspection and maintenance carried out by the Environment Agency.

In the event of a breach the principal escape route in the proposed development, if not located near a safe, dry evacuation route, should be internally upwards to higher floors. This completely precludes the installation of any single storey ground floor residential units which are not situated above the predicted 2107 1 in 200 year modelled flood water level.

Fire escape routes are a fundamental component of building regulations. These well sign-posted, communal routes could be utilised in the event of a flood, but in reverse direction. Buildings will therefore require a flood evacuation procedure designed to move people upwards to safe levels. This is of particular importance for those landuses which are below the predicted flood water level (e.g. shops, offices or gyms) and these developments should be supported with a detailed evacuation plan for moving people to safety. Internal safe refugia should be provided for all occupied landuses above the design flood level inclusive of an appropriate freeboard allowance.

9. Flood Risk Assessments and Windfall Sites

9.1 Windfall sites

The Core Strategy Opportunity Areas for Regeneration are set within the Government's Thames Gateway Growth Area. The locations of these areas can be seen in Figure 9.1. Many of these areas are located within Flood Zones 2 and 3, and the Level 2 SFRA will assess identified development sites within these and the other strategic growth areas (mainly the Borough's town centres), if they are identified as flood risk areas.

Figure 9.1 One of The Government's Thames Gateway Growth Area

There will always be windfall development, and these sites will need to be assessed. The Borough's emerging Core Strategy stresses that the Opportunity Areas for Regeneration, along with the Borough's town centres, are appropriate locations for growth and redevelopment. Proposed windfall development should pass the Sequential and Exception Tests. Additionally, the sequential approach to flood risk management will be required within the development site, and this will need to be addressed within the development proposals and accompanying FRAs.

9.2 Site Specific Flood Risk Assessment (FRA) – Where are they Required in Bexley?

Table 9.1 provides a clear instruction to developers and Planning Officers as to where a Flood Risk Assessment (FRA) is required in Bexley. If any one of the criteria listed in Table 9.1 apply to the site in question then, a FRA needs to be prepared to accompany a planning application. PPS25, should then be referred to for the establishment of the scope of the FRA and the Environment Agency should also be consulted. Table 9.1 also provides an outline of the likely scope of the FRA.

Figure 7 (in Appendix A) should be reviewed in consultation with Table 9.1, as it defines the zones of flood risk that are referred to.

The following links to the Environment Agency provide additional information

http://www.environment-agency.gov.uk/research/planning/82584.aspx

Table 9.1 When is an FRA Required.

Criteria Requiring a FRA	FRA Required (Yes/No)	Scope of the FRA
In Flood Zone 3b	Yes	Follow the requirements of PPS25
In Flood Zone 3a	Yes	Follow the requirements of PPS25
In Flood Zone 2	Yes	Follow the requirements of PPS25
In the zone of Residual Tidal Flood Risk (As illustrated on Figure 7 in Appendix A)	Yes	Follow the requirements of PPS25 – use the breach modelling results in the SFRA, but in all cases check with the Environment Agency to ensure the modelling has not been superseded
In a zone of Potential Rapid inundation (As illustrated on Figure 7 in Appendix A)	Yes	Will Require additional breach modelling analysis in addition to the requirements of PPS25
Greater than 1 hectare in Flood Zone 1	Yes	Follow the requirements of PPS25.
Greater than 0.25 hectare	Drainage assessment required	For all sites over 0.25 hectare in Flood Zone 1 an assessment surface water drainage will be required with any planning application. This assessment should review the potential to incorporate sustainable drainage techniques and attenuate flows in line with the requirements of the London Plan.

In all cases, the FRA or Drainage Assessment must follow the SuDS hierarchy in the selection of an appropriate SuDS technique, in line with requirements of the London Plan. A piped solution will only be acceptable if it can be demonstrated that more sustainable SuDS techniques are not feasible.

10. Recommendations for the LDF

The most effective form of summary for an SFRA is a list of recommended inclusions that should be considered in the LDF. This is followed by a list of dates and/or events that Bexley should look out for as these could have implications on the adopted flood risk policy.

- Aim to reserve land in Flood Zone 1 for essential infrastructure and where possible highly vulnerable and more vulnerable landuses;
- Manage flood risk through avoidance of risk where possible;
- Follow the Sequential approach advocated in PPS25;
- Site design in fluvial floodplains should facilitate safe escape;
- In line with Section 8.3.2, all more vulnerable landuses to be positioned above the predicted 2107 (0.5% AP event) flood water level in the Thamesmead/Erith Marshes and Crayford Marsh embayments;
- New developments should include a detailed evacuation plan that clearly outlines how people can easily move upwards from the lower floors to safety;
- Flood resilience and resistance measures should be adopted in building codes for development within the Thames Gateway;
- An emergency evacuation procedure should be implemented for those sites which can feasibly be designed to allow for evacuation out of the flood risk zone;
- New developments should seek to meet the 50% reduction in surface water run-off rates as advocated in the London Plan;
- All new development should, where feasible, attempt to reduce surface water run-off by sustainably managing run-off on site.
- Consider requiring all new developments greater than 0.25 hectare in size to have a drainage assessment accompanying the planning application; and
- It is also recommended that development immediately behind the flood defences to be designed in such a way as to easily facilitate the raising and re-engineering of the tidal flood defences. For all development applications immediately behind flood defences, consultation with the Environment Agency should be sought.

10.1 TE2100 and Production of the LDF

Tidal flooding in London and the Thames estuary, of which Bexley is a part, is being addressed through the Environment Agency's Thames Estuary 2100 (TE2100) project. Established in 2002, a key driver for this project was to consider how tidal flood risk was likely to change in response to future changes in climate and people and property in the tidal floodplain.

The aim of the TE2100 project is to develop a strategic flood risk management plan for London and the Thames estuary through to the end of the century. In Bexley, the recommended approach is to take further action to sustain the current scale of flood risk into the future (responding to potential increases in flood risk from urban development, landuse change, and climate change).

The TE2100 Plan Consultation Document (April 2009) proposes short, medium and long-term actions, which look at the ability of flood defences, and spatial and emergency planning, to manage flood risk. A key action is for the TE2100 Plan to inform the development and revision of local authority strategic flood risk assessments (SFRAs) and flood plans.

Erith and Crayford Marshes have been identified as possibly being used for tidal flood storage and/or retreated defence. This however is not a long-term preferred option of the Plan, and the recommended short-term actions stress that the need for tidal flood storage may not be necessary. Therefore, further iterations of Bexley's SFRA will need to assess the final version of the TE2100Plan to determine whether safeguarding the marshes (or any other areas) will be needed to achieve the objectives of the TE2100 Plan.

It is recommended that it is the spatial planning process, through Local Development Framework development plan documents, that should address land-use changes such as identifying land for flood storage (from all types of flooding). It is also recommended that development immediately behind the flood defences to be designed in such a way as to easily facilitate the raising and re-engineering of the tidal flood defences. For all planning applications for development immediately behind flood defences, consultation with the Environment Agency should be sought.

A review of the flood defence assessment management procedure is recommended and a robust programme for maintaining and improving the defences should be prepared. This should include a regular review of the latest climate change predictions and the impact this has on the peak flood level. The strategy for flood management in the Thames Estuary will be determined by the final outcomes of the TE2100 review process. The emerging four potential flood management policies have significantly different implications on how the level of risk in Bexley will change over the next one hundred years. Upon the completion of the TE2100 project it would be pertinent to undertake a review of the SFRA to assess the implications of the adopted TE2100 policies.

At the time of this report's production the TE2100 project is appraising detailed options, the outcomes will be available in the spring of 2009. It is likely that there will be policies involving the sustained provision of the existing standard of protection and the potential for providing areas for flood water storage. The TE2100 output in 2009 should be reviewed to identify any locations identified as potential flood storage areas. It is recommended that through the spatial planning process any designated locations are safeguarded for use as flood storage areas by resisting new development.

10.2 Maintaining an up to date Flood Risk Evidence Base

The following questions are ones which the Council's are advised to ask in order to ensure that the most recent flood risk information and flood risk policies are used to inform planning decisions.

- Has the appraisal of detailed TE2100 options been released? (timetabled for 2009);
- Has the final options report of TE2100 been released? (timetabled for 2010);
- Has there been any revision to national planning policy? (check biannually);
- Has the Environment Agency issued revised/updated guidance on development in floodplains? (check biannually);
- Has revised tide level/climate change data been released or have the flood zones been modified (check biannually); and
- Has the Environment Agency finalised the revised modelling on the rivers Cray and Shuttle? Due for completion in late 2009.

11. References

Association of British Insurers, *Managing Flood Risk in Government Growth Areas*, (2006)

Communities and Local Government, *Development and Flood Risk – A Practice Guide Companion to PPS25 "Living Draft*. (2006)

Communities and Local Government, *Planning Policy Statement 25: Development and Flood Risk*. (2006)

Communities and Local Government, *Improving the Flood Performance of New Buildings – Flood Resilient Construction*, (2007)

Defra/Environment Agency (2006). *Flood Risk to People*, FD2321/TR2, Guidance Document.

Environment Agency, *Marsh Dyke Flood Risk Management Strategy: Strategic Environmental Assessment Scoping Report*, (April 2006).

Hother, J., *Applying Reliability Risk Analysis to Flood Risk Management*, 39th DEFRA Flood and Coastal Management Conference, 2004.

London Borough of Bexley, *Crayford Town Centre SFRA*, (2007), Entec

London Borough of Bexley, Erith Western Gateway Regeneration Scheme – Flood Risk Appraisal of Masterplans (May 2008), Entec

London Borough of Bexley, *Howbury Site Flood Risk Constraints and Opportunities Assessment*, (April 2008) Entec

London Borough of Greenwich, *Strategic Flood Risk Assessment* (2008), JBA and Entec

The London Plan (May 2006) - Supplementary Planning Guidance (Sustainable Design and Construction), Section 2.4.4 - Water Pollution and Flooding

The Construction Industry Research and Information Association (CIRIA). *The SuDS Manual - CIRIA Report C697*. (2007). CIRIA London, UK.

Appendix A
Mapping Appendix – Supplied in Separate Document

Entec

Bexley Strategic Flood Risk Assessment

Appendix A
2 of 2

Appendix B
Breach Modelling Report

TuFLOW Breach Modelling Report

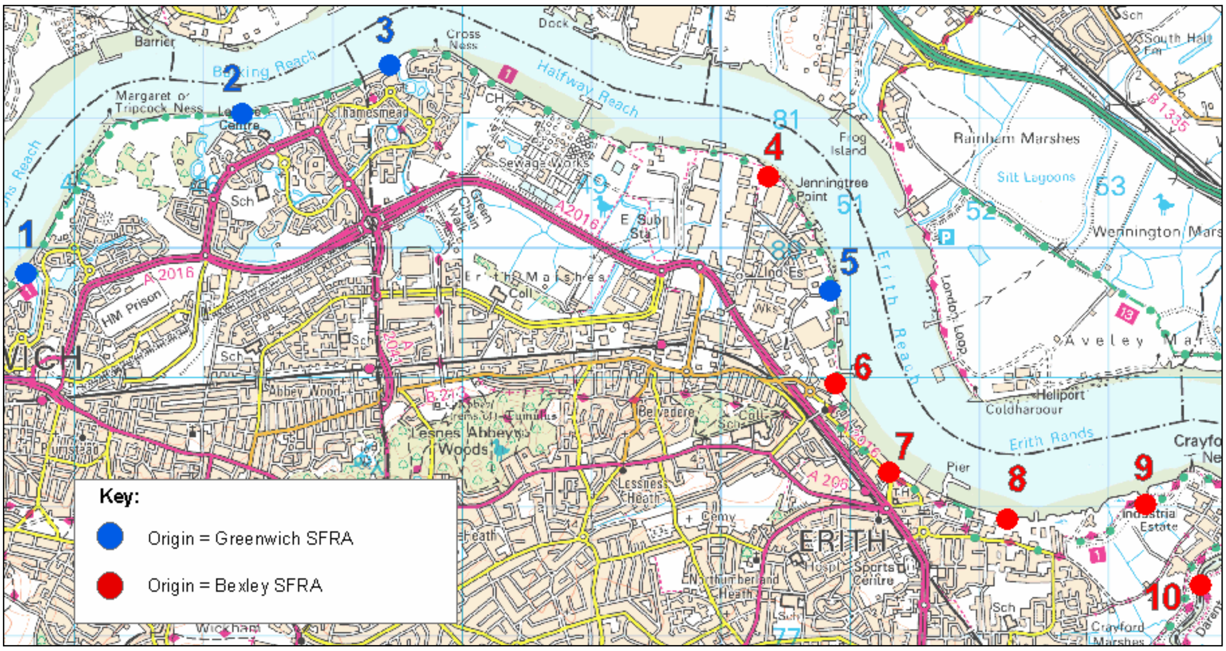
Introduction

Breach simulations were modelled at strategic points along the Thames defences, the locations of which were identified through consultation with the Environment Agency. Tidal hydrographs for the Thames and the topographic data (LiDAR) was issued by the Environment Agency.

TuFLOW is a computational engine that provides two-dimensional (2D) and one- dimensional (1D) solutions of free-surface flow to simulate flood propagation. It is recognised by the Environment Agency and Defra as being a preferred approach[29] and is commonly used for modelling the tidal Thames floodplain. TuFLOW was also used for the purposes of consistency as the recently completed Greenwich SFRA used TuFLOW to evaluate the level of residual risk in the part of the Thamesmead embayment which falls within the Borough of Greenwich. The Greenwich SFRA modelling, which was undertaken by Entec and JBA Consulting, has been incorporated into the Bexley SFRA. The Bexley SFRA includes the output of 10 individual breach models, four of which were taken from the Greenwich SFRA and the remaining six were built for the Bexley SFRA. Figure B1 illustrates the origin of 10 breaches. For completeness, the Bexley SFRA Modelling Appendix Report contains information relating to the four Greenwich SFRA models. The breach locations are numbered from west to east.

[29] Defra/Environment Agency (2006). *R&D \Output: Flood Risk to People – Phase 2.* FD231/TR2 Guidance Document.

Figure B.1 The Breach Locations Modelled in the Bexley and Greenwich SFRAs



The Greenwich SFRA breaches were numbered west to east. However locations 1, 2, 3 and 5 in this Figure were numbered 7, 8 ,9 and 10 in the Greenwich SFRA.

Model Specifics

TUFLOW was used for the breach and overtop simulations undertaken as part of this SFRA. Version TUFLOW.2008-08-AA-iSP was used and was the most recent version available at the time of modelling. The modelling of the embayment was largely two-dimensional. For breach locations 1 to 7, the model setup included 3 one-dimensional elements to represent culverts. Two of these related to the culvert passing beneath the Southern Outfall Sewer. In representing the one-dimensional elements, TUFLOW's 1-D solution scheme; ESTRY was implemented. The use of the 1-D solution of TUFLOW, enables the precise modelling of hydraulic features which are too small to accurately be captured within the model grid (which is 10m in size).

The British National Grid was the projection used for all the modelling.

Breach Configuration

Figure B.1 illustrates the location of the 10 models that were used to define the level of residual risk in Bexley. Locations 1 to 9 were breach models, breach 10 on the other hand is an overtopping model. Location 10 involved the over topping of the River Darent flood defences, under the assumption that the Darent flood barrier was not closed during the simulated 1 in 200 year tidal event.

When modelling a breach simulation, it is the Environment Agency's advice to differentiate between hard and soft defences. The reason for this is due to the impact the defence type can have on likely breach width and possible time to repair the defence. The Environment Agency's advice on modelling the two types of defence is presented below:

- ***Hard defences***, examples of these defences include concrete wall or sheet metal pilings. The modelled breach width for a hard defence is 20m. Two tidal cycles are used when simulating a breach of a hard defence (approximating 23 hrs to get the full rise and fall of two tidal cycles); and
- ***Soft defences*** are associated with earth embankments. Some soft defences may have a hard-capping; however, if the core of the structure is not strengthened, then the structure is said to be a soft defence. The breach width for a soft defence is 50m and three tidal cycles (approximately 33hrs to get the full rise and fall of all three tidal cycles).

Invert Levels

Table B.1 presents the modelled invert levels of the nine breach models and the modelled defence crest height of the River Darent defences in model 10.

Table B.1 Breach Locations and Characteristics

Breach Location	Type of Defence	Breach Width (m)	Duration of Simulation (hrs)	Invert Level (m AOD)
1	Hard	20	23	0
2	Hard	20	23	-0.3
3	Hard	20	23	-0.5
4	Hard	20	23	1.1
5	Soft	50	33	0.8
6	Hard	20	23	2.2
7	Hard	20	23	4.7
8	Hard	20	23	5.05
9	Soft	50	33	1.12
10	Overtop	Overtop (1100m)	33	5.5 (defence crest)

Model Assumptions

A number of assumptions and approximations had to be made in the modelling process, these are outlined below.

Simulating Defence Breaches in TuFLOW

A '*dam failure*' scenario, i.e. the situation where a failure in the defences occurs whilst the tide level in the Thames is at its peak, cannot accurately be modelled in TuFLOW. As such, the modelling in this SFRA simulates the *breach* to exist at the start of the simulation. In this way, flooding occurs in the embayment once the tide levels reaches and exceeds the invert level of the breach. This approach does not therefore simulate the shock wave that might be associated with a '*dam failure*' and as such there is the potential that the resultant velocities in the vicinity of the breach may be underestimated. This is not considered to be significant issue as all the areas around all of the breaches have been designated the maximum hazard classification and thus recommended for the greatest degree of caution.

Topographic Data

The topographic data used in the Bexley SFRA modelling was issued by the Environment Agency's Remote Sensing Team in Twerton. Null values in the LiDAR were removed by the Environment Agency Technical Staff. The LiDAR grid was re-sized to a 10m grid for use in the modelling process. This increase in grid resolution was required to facilitate practical model run times. A 10m grid resolution is considered to be appropriate for use at the strategic level.

Filtered LiDAR was used in the modelling process, this dataset has had buildings and vegetation removed from it. A bare earth surface model therefore provided the base of the TuFLOW simulations. Buildings and vegetation do provide some obstruction to flow, however the Environment Agency's guidance recommends that a structure is only a permanent barrier to flow if it had been designed for that purpose. The use of varying surface roughness values was used in the modelling to represent the resistance to flow offered by buildings.

Southern Outfall Sewer Culvert

The culvert passing under the Southern Outfall Sewer has a potentially significant influence on the propagation of flooding within the Thamesmead embayment. A detailed survey of the culvert dimensions was not available and so the dimensions were approximated through consultation with the Environment Agency[30]. It was agreed that all three of the culvert openings should be represented in the model as being the same size and that each was approximately a 2m by 2m box culvert. The invert levels of both ends of the culvert was set the same (-0.5m AOD) as no information was available to suggest that there is bed gradient in the culvert. Invert levels were inferred from an inspection of the LiDAR data. Culvert blockage was not accounted for, thereby allowing maximum connectivity between the divided sections of the embayment.

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[30] E-mail correspondence from Anthony Hammond – Flood Risk Mapping and Data Management 13/05/08

Baseline Model Parameters

Model Surface Roughness

The surface roughness of the model area was simplified into key landuses. These were identified as buildings, open water, channelled water and other model areas (which grouped roads, open areas and any remaining areas). The following Manning's Roughness values were used in order to quantify the energy lost by water when travelling over different surfaces. These are presented in Table B.2

Table B.2 Model Surface Roughness Values

Landuse	Manning's 'N' Value
Buildings	0.1
Open Water	0.01
Channelled Water	0.04
Other Model Areas	0.03

Topographic data

The model grid requires bridge decks and underpasses to be represented as flow routes as the LiDAR filtering process did not always open up these flow routes. The TuFLOW had to therefore incorporate "z point" correction layers to remove incorrect blockages to the propagation of flow. Table B.3 identifies the model files used to correct the topography.

Initial Water Levels

For the models at locations 8 and 9, an initial water level was set within the River Darent to mimic the tide locking of fluvial waters that may occur behind the tidal flood gate at the mouth of the Darent in the event of the gates being closed during an extreme tidal event. A conservative water level of 4m AOD was selected. For the overtopping scenario at location 10, the tidal defence gate is modelled as being open and therefore no tide locking is included.

Table B.3 Topographic data and mid/mif references used in the TUFLOW models.

	Locations 1 – 7	Locations 8, 9 and Overtop Location 10
Grid Size	10m	10m
Grid Extent	Bottom Left - TQ 431 777 Top Right - TQ 518 815	Bottom Left - TQ 513 745 Top Right - TQ 560 784
Origin of topographic Data	Greenwich SFRA – 1m filtered LiDAR	Howbury Project – 0.5m filtered LiDAR
Zpts derived from LiDAR	mi\2d_zpt_GW_10m.mid	mi\2d_zpt_HB_10m_DTM.mid
Changes to Z-pts		
Removing flow barriers and null values	mi\2d_zpts_TMEAD_LiDAR_fixv2.MIF	mi\2d_zpts_HB_LiDAR_fix.MIF
'Burning' in channels	mi\2d_zln_Fix_Watercourse.MIF	-
Redefining defences	mi\2d_zln_Defences_001.MIF	mi\2d_zln_HB_Defences.MIF
Landuse definitions	mi\2d_mat_GW_002_buildings3.mif mi\2d_mat_GW_001_water.mif	mi\2d_mat_HB_001.mif
Initial water levels	-	mi\2d_iwl_HB_003.MIF

Hydraulic Boundaries

A model boundary was created for each of the simulations and was based upon the 7.5m AOD contour. This boundary remained beyond the extent of the modelled flooding. The boundary did not in any part influence the flooding extent. In addition to each of the hydraulic boundaries, it was also necessary to create a boundary for the tidal inflow hydrograph. This required the designation of a 'pooling' area in the Thames into which the inflow boundary ("HT line") would spill.

Hydrographs for the 1 in 200 year tide in 2005 was supplied by the Environment Agency for each of the Thames ISIS model nodes within the Bexley reach. The location of these nodes is presented in Figure B.2. These were scaled to the predicted peak 1 in 200 year tide level in 2107 which was also issued by the Environment Agency. Figure B.3 presents an example of the 2005 and 2107 tide level predictions for the 1 in 200 year tidal event at node 3.8.

Figure B.2 Location and Name of the Environment Agency's ISIS model of the Thames

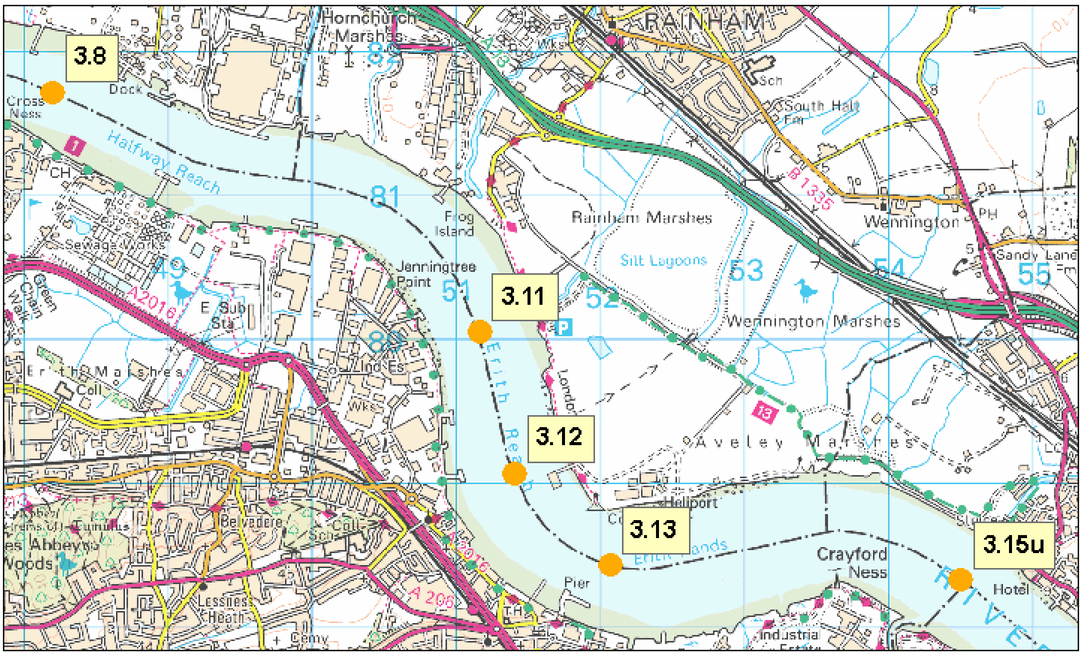
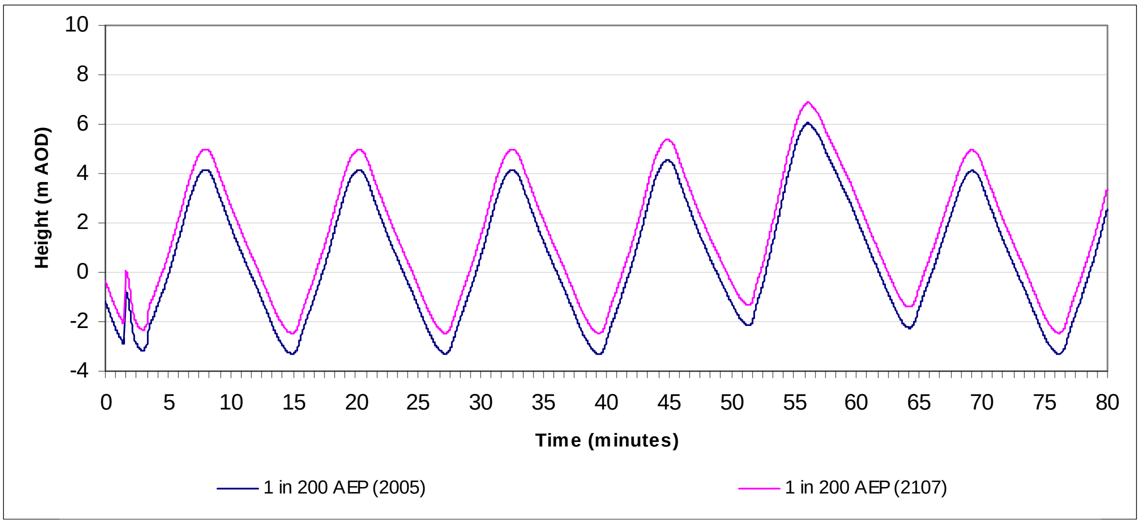


Figure B.3 The 2005 and 2107 Hydrographs for the 1 in 200 Year Event a at Node 3.8



1D Network - ESTRY

TUFLOW's 1-D ESTRY model was used for the representation of the culverts running through the Southern Outfall Sewer. A 1-D network was only included for breach locations 1 to 7. The MapInfo mid/mif file *1d_nwk_GW_001.mif* contains the 1-D network layout and is common throughout the simulations.

Simulation Specific Model Setup

The following tables present simulation specific model setup for each of the 10 model runs.

Table B.4 Breach Location 1 – 1 in 200 year event including climate change (2107)

Simulation	Breach Location 1 – 1 in 200 AEP event including climate change (2107) Sourced from the Greenwich SFRA		
Simulations specific topographic changes	mi\2d_zln_GW_003_Breach.MIF	**Model map Output**	hVqdZUK0 (using a conservative debris factor)
Model Start Time	40.5	**Model End Time**	63.5
Timestep	2	**Approximate Run Time**	7 hours
Map Save Interval	10 minutes	**Time Series Save Interval**	1 minute

Table B.5 Breach Location 2 – 1 in 200 year event including climate change (2107)

Simulation	Breach Location 2 – 1 in 200 AEP event including climate change (2107) Sourced from the Greenwich SFRA		
Simulations specific topographic changes	mi\2d_zln_GW_004_Breach.MIF	**Model map Output**	hVqdZUK0 (using a conservative debris factor)
Model Start Time	40.5	**Model End Time**	63.5
Timestep	2	**Approximate Run Time**	10 hours
Map Save Interval	10 minutes	**Time Series Save Interval**	1 minute

Table B.6 Breach Location 3 – 1 in 200 year event including climate change (2107)

Simulation	Breach Location 3 – 1 in 200 AEP event including climate change (2107) Sourced from the Greenwich SFRA		
Simulations specific topographic changes	mi\2d_zln_GW_005_Breach.MIF	**Model map Output**	hVqdZUK0 (using a conservative debris factor)
Model Start Time	40.5	**Model End Time**	63.5
Timestep	2	**Approximate Run Time**	9.5 hours
Map Save Interval	10 minutes	**Time Series Save Interval**	1 minute

Table B.7 Breach Location 4 – 1 in 200 year event including climate change (2107)

Simulation	Breach Location 4 – 1 in 200 AEP event including climate change (2107)		
Simulations specific topographic changes	mi\2d_zln_BX_004_Breach.MIF	**Model map Output**	hVqdZUK0 (using a conservative debris factor)
Model Start Time	40.5	**Model End Time**	63.5
Timestep	2	**Approximate Run Time**	7
Map Save Interval	10 minutes	**Time Series Save Interval**	1 minute

Table B.8 Breach Location 5 – 1 in 200 year event including climate change (2107)

Simulation	Breach Location 5 – 1 in 200 AEP event including climate change (2107) Sourced from the Greenwich SFRA		
Simulations specific topographic changes	mi\2d_zln_GW_006_Breach.MIF	**Model map Output**	hVqdZUK0 (using a conservative debris factor)
Model Start Time	40.5	**Model End Time**	73.5
Timestep	2	**Approximate Run Time**	19 hours
Map Save Interval	10 minutes	**Time Series Save Interval**	1 minute

Table B.9 Breach Location 6 – 1 in 200 year event including climate change (2107)

Simulation	Breach Location 6 – 1 in 200 AEP event including climate change (2107)		
Simulations specific topographic changes	mi\2d_zln_BX_006_Breach.MIF	**Model map Output**	hVqdZUK0 (using a conservative debris factor)
Model Start Time	40.5	**Model End Time**	63.5
Timestep	2	**Approximate Run Time**	7
Map Save Interval	10 minutes	**Time Series Save Interval**	1 minute

Table B.10 Breach Location 7 – 1 in 200 year event including climate change (2107)

Simulation	Breach Location 7 – 1 in 200 AEP event including climate change (2107)		
Simulations specific topographic changes	mi\2d_zln_BX_007_Breach.MIF	**Model map Output**	hVqdZUK0 (using a conservative debris factor)
Model Start Time	40.5	**Model End Time**	63.5
Timestep	2	**Approximate Run Time**	7
Map Save Interval	10 minutes	**Time Series Save Interval**	1 minute

Table B.11 Breach Location 8 – 1 in 200 year event including climate change (2107)

Simulation	Breach Location 8 – 1 in 200 AEP event including climate change (2107)		
Simulations specific topographic changes	mi\2d_zpt_HB_Breach_002.MIF	**Model map Output**	hVqdZUK0 (using a conservative debris factor)
Model Start Time	40.5	**Model End Time**	63.5
Timestep	3	**Approximate Run Time**	1 hour
Map Save Interval	10 minutes	**Time Series Save Interval**	1 minute

Table B.12 Breach Location 9 – 1 in 200 year event including climate change (2107)

Simulation	Breach Location 9 – 1 in 200 AEP event including climate change (2107)		
Simulations specific topographic changes	mi\2d_zpt_HB_Breach_003.MIF	**Model map Output**	hVqdZUK0 (using a conservative debris factor)
Model Start Time	40.5	**Model End Time**	73.5
Timestep	1	**Approximate Run Time**	9 hours
Map Save Interval	10 minutes	**Time Series Save Interval**	1 minute

Table B.13 Breach Location 10 – 1 in 200 year event including climate change (2107)

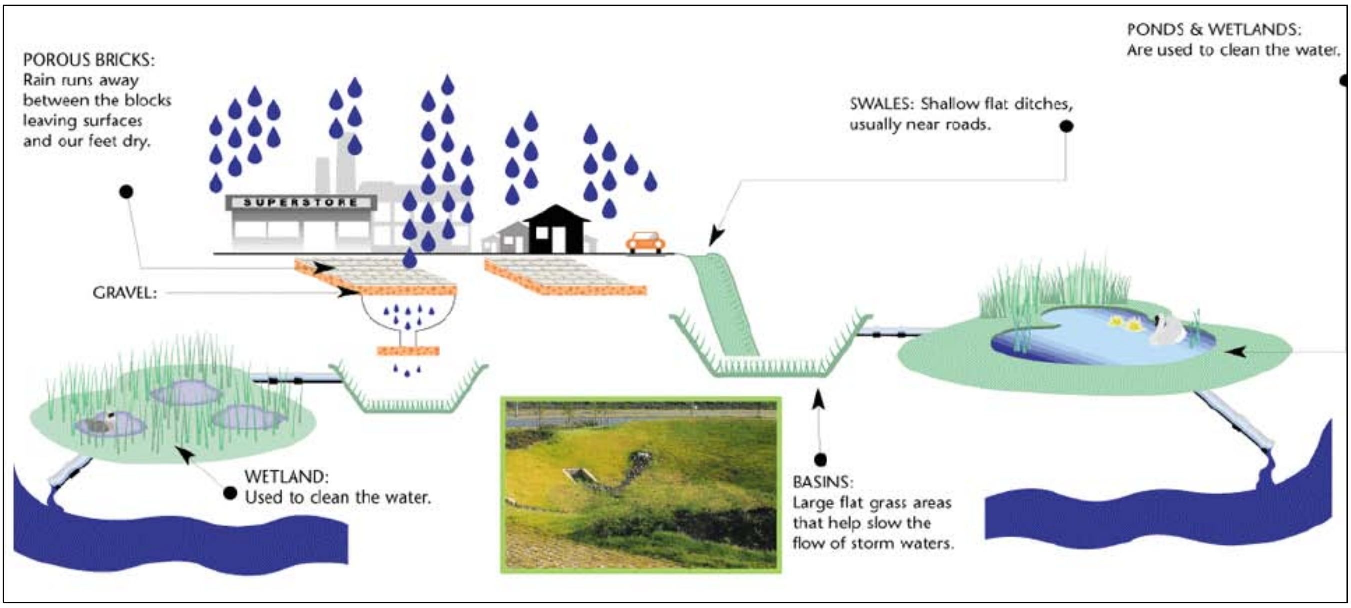
Simulation	Overtop Location 10 – 1 in 200 AEP event including climate change (2107)		
Simulations specific topographic changes	mi\2d_zpt_BX_Breach_010.MIF	**Model map Output**	hVqdZUK0 (using a conservative debris factor)
Model Start Time	40	**Model End Time**	73.5
Timestep	2	**Approximate Run Time**	7.5 hours
Map Save Interval	10 minutes	**Time Series Save Interval**	1 minute

Table B.14 – TuFLOW Model Setup File Names

Modeller	Breach	tcf	location	tgc	location	tbc	location	bc_dbase	Results
Mark Bollaert	1	GW_0011.tcf	Bexley\Greenwich \Tuflow\Runs	GW_001.tgc	Bexley\Greenwi ch\Tuflow\Model	GW_001.tbc	Bexley\Greenwich\Tufl ow\Model	Bc_dbase_GW_2107. csv	GW_0011.
Mark Bollaert	2	GW_0022.tcf	Bexley\Greenwich \Tuflow\Runs	GW_002.tgc	Bexley\Greenwi ch\Tuflow\Model	GW_002.tbc	Bexley\Greenwich\Tufl ow\Model	Bc_dbase_GW_2107. csv	GW_0022.
Mark Bollaert	3	GW_0033.tcf	Bexley\Greenwich \Tuflow\Runs	GW_003.tgc	Bexley\Greenwi ch\Tuflow\Model	GW_003.tbc	Bexley\Greenwich\Tufl ow\Model	Bc_dbase_GW_2107. csv	GW_0033
Mark Bollaert	4	BX_004_CC.tcf	Bexley\Greenwich \Tuflow\Runs	BX_004_CC.tgc	Bexley\Greenwi ch\Tuflow\Model	BX_004.tbc	Bexley\Greenwich\Tufl ow\Model	Bc_dbase_BX_2107.c sv	BX_004_CC
Mark Bollaert	5	GW_0055.tcf	Bexley\Greenwich \Tuflow\Runs	GW_005.tgc	Bexley\Greenwi ch\Tuflow\Model	GW_005.tbc	Bexley\Greenwich\Tufl ow\Model	Bc_dbase_GW_2107. csv	GW_0055
Mark Bollaert	6	BX_006_CC.tcf	Bexley\Greenwich \Tuflow\Runs	BX_006_CC.tgc	Bexley\Greenwi ch\Tuflow\Model	BX_006.tbc	Bexley\Greenwich\Tufl ow\Model	Bc_dbase_BX_2107.c sv	BX_006_CC
Mark Bollaert	7	BX_007_CC.tcf	Bexley\Greenwich \Tuflow\Runs	BX_007_CC.tcf	Bexley\Greenwi ch\Tuflow\Model	BX_007.tbc	Bexley\Greenwich\Tufl ow\Model	Bc_dbase_BX_2107.c sv	BX_007_CC
Mark Bollaert	8	BX_8_HB_003_C C.tcf	Bexley\Howbury\T uflow\Runs	BX_008.tgc	Bexley\Howbury \Tuflow\Model	BX_008.tbc	Bexley\Howbury\Tuflo w\Model	Bc_dbase_HB_2107	BX_8_HB_003_CC
Mark Bollaert	9	BX_9_HM_007_ CC_v3_Jan09.tcf	Bexley\Howbury\T uflow\Runs	HB_009_v2_Jan0 9.tgc	Bexley\Howbury \Tuflow\Model	BX_009.tbc	Bexley\Howbury\Tuflo w\Model	Bc_dbase_HB_2107	BX_9_HM_007_CC _v3_Jan09
Mark Bollaert	10	BX_10_CC.tcf	Bexley\Howbury\T uflow\Runs	BX_010.tgc	Bexley\Howbury \Tuflow\Model	BX_010.tbc	Bexley\Howbury\Tuflo w\Model	Bc_dbase_HB_2107	BX_10_CC

Appendix C
SuDS Supporting Information

Figure C1 **Likely Implementation of SuDS Management Train**



Source of this Graphic = GDSDS (2005)

Table C1 **Influential site characteristics on the applicability of SuDS (Modified after CIRIA 2007)**

SuDS Group	Technique	Soils		Area draining to a single SuDS component		Minimum depth to water table		Site slope		Available head	
		Impermeable	Permeable	0 – 2 ha	> 2 ha	0 – 1 m	> 1 m	0 – 5%	> 5 %	0-1 m	1 – 2 m
Retention	**Retention pond**	Y	Y[1]	Y	Y[5]	Y[2]	Y[2]	Y	Y	Y	Y
	Subsurface storage	Y	Y	Y	Y[5]	Y[2]	Y[2]	Y	Y	Y	Y
Wetland	**Shallow wetland**	Y[2]	Y[4]	Y[4]	Y[6]	Y[2]	Y[2]	Y	N	Y	Y
	Extended detention wetland	Y[2]	Y[4]	Y[4]	Y[6]	Y[2]	Y[2]	Y	N	Y	Y
	Pond/wetland	Y[2]	Y[4]	Y[4]	Y[6]	Y[2]	Y[2]	Y	N	Y	Y
	Pocket wetland	Y[2]	Y[4]	Y[4]	N	Y[2]	Y[2]	Y	N	Y	Y
	Submerged gravel wetland	Y[2]	Y[4]	Y[4]	Y[6]	Y[2]	Y[2]	Y	N	Y	Y
	Wetland channel	Y[2]	Y[4]	Y[4]	Y[6]	Y[2]	Y[2]	Y	N	Y	Y
Infiltration	**Infiltration trench**	N	Y	Y	N	N	Y	Y	Y	Y	N
	Infiltration basin	N	Y	Y	Y[5]	N	Y	Y	Y	Y	N
	Soakaway	N	Y	Y	N	N	Y	Y	Y	Y	N
Filtration	**Surface sand filter**	Y	Y	Y	Y[5]	N	Y	Y	N	N	Y
	Sub-surface sand filter	Y	Y	Y	N	N	Y	Y	N	N	Y
	Perimeter sand filter	Y	Y	Y	N	N	Y	Y	N	Y	Y
	Bioretention/filter strips	Y	Y	Y	N	N	Y	Y	N	Y	Y
	Filter trench	Y	Y[1]	Y	N	N	Y	Y	N	Y	Y
Detention	**Detention basin**	Y	Y[1]	Y	Y[5]	N	Y	Y	Y	N	Y
Open channels	**Conveyance swale**	Y	Y	Y	N	N	Y	Y	N[3]	Y	N
	Enhanced dry swale	Y	Y	Y	N	N	Y	Y	N[3]	Y	N
	Enhanced wet swale	Y[2]	Y[4]	Y	N	Y	Y	Y	N[3]	Y	N
Source control	**Green roof**	Y	Y	Y	N	Y	Y	Y	Y	Y	Y
	Rainwater harvesting	Y	Y	Y	N	Y	Y	Y	Y	Y	
	Permeable pavement	Y	Y	Y	Y	N	Y	Y	N	Y	Y

Y = Yes

N = No

Y1 = with liner

Y2 = with surface baseflow

Y3 = Unless follows contours

Y4 = With liner and constant surface baseflow, or high ground water table

Y5 = possible, but not recommended (appropriate management train not in place)

Y6 = Where high flows are diverted around SuDS component

Additional policy and general guidance on SuDS and drainage include the following:

- PPS25 Practice Guide, 2007;
- Water Framework Directive (200/60/EC);
- Highways Act, 1980;
- Town and Country Planning Act, 1990;
- Town and Country Planning Act, 1990 (amended) NB covers S106 Agreements;
- Town and Country Planning Act, 1991;
- Construction, Design and Management Regulations, 1994;
- Building Regulations Part C Approved Document H – Drainage and Waste Disposal of the Building Regulations 2002 Amendment;
- ODPM 2004. Planning Policy Statement 1: *Delivering Sustainable Development*;
- Communities and Local Government, 2006. Planning Policy Statement 25: *Development and Flood Risk*;
- Communities and Local Government, 2007. *Development and Flood Risk: A practice guide companion to PPS25*;
- BRE Digest 365 Soakaway Design BSE EN 752-4: 1998 Drain and Sewer Systems outside buildings, part 4;
- CIRIA. Sustainable Drainage Systems – Hydraulic, Structural and water quality advice (CIRIA 609);
- CIRIA. The SUDS Manual (CIRIA C697);
- CIRIA. *Source control using constructed previous surfaces. Hydraulic, structural and water quality performance issues* (CIRIA 582);
- CIRIA. *Infiltration Drainage – manual of good practice* (CIRIA R156);
- CIRIA. *Review of the design and management of constructed wetlands* (CIRIA R180);
- CIRIA. *Control of pollution from highway drainage discharge* (CIRIA R142);
- CIRIA. *Design of flood storage reservoirs* (CIRIA Book 14);
- CIRIA. *Designing for exceedance in urban drainage systems – good practice* (CIRIA C635);
- CIRIA. *Rainwater and grey-water use in buildings* (CIRIA C539);

- Defra, 2004. *Making Space for Water – Developing a new Government strategy for flood and coastal erosion risk management in England: A Consultation Exercise;*
- Defra, 2005. *Making Space for Water – Taking forward a new Government strategy for flood and coastal erosion risk management in England: First Government response to the Autumn 2004;*
- Defra, 2006. *Urban Flood Risk and Integrated Drainage*. Scoping report and pilot studies;
- Environment Agency, 2003. Harvesting rainwater for domestic uses: an information guide;
- HR Wallingford. Use of SUDS in high density development;
- National SUDS Working Group, 2006. Interim Code of Practice for SUDS; and
- WRc. Sewers for Adoption 6th Edition (SfA6) (published by Water UK).

Appendix D
Tables D.1, D.2 & D.3 – Reproduced from Annex D PPS25

Table D.1: Flood Zones

(Note: These Flood Zones refer to the probability of river and sea flooding, ignoring the presence of defences)

Zone 1 Low Probability

Definition

This zone comprises land assessed as having a less than 1 in 1000 annual probability of river or sea flooding in any year (<0.1%).

Appropriate uses

All uses of land are appropriate in this zone.

FRA requirements

For development proposals on sites comprising one hectare or above the vulnerability to flooding from other sources as well as from river and sea flooding, and the potential to increase flood risk elsewhere through the addition of hard surfaces and the effect of the new development on surface water run-off, should be incorporated in a FRA. This need only be brief unless the factors above or other local considerations require particular attention. See Annex E for minimum requirements.

Policy aims

In this zone, developers and local authorities should seek opportunities to reduce the overall level of flood risk in the area and beyond through the layout and form of the development, and the appropriate application of sustainable drainage techniques.

Table D.1: contd.

Zone 2 Medium Probability

Definition

This zone comprises land assessed as having between a 1 in 100 and 1 in 1000 annual probability of river flooding (1% – 0.1%) or between a 1 in 200 and 1 in 1000 annual probability of sea flooding (0.5% – 0.1%) in any year.

Appropriate uses

The water-compatible, less vulnerable and more vulnerable uses of land and essential infrastructure in Table D.2 are appropriate in this zone.

Subject to the Sequential Test being applied, the highly vulnerable uses in Table D.2 are only appropriate in this zone if the Exception Test (see para. D.9.) is passed.

FRA requirements

All development proposals in this zone should be accompanied by a FRA. See Annex E for minimum requirements.

Policy aims

In this zone, developers and local authorities should seek opportunities to reduce the overall level of flood risk in the area through the layout and form of the development, and the appropriate application of sustainable drainage techniques.

Zone 3a High Probability

Definition

This zone comprises 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.

Appropriate uses

The water-compatible and less vulnerable uses of land in Table D.2 are appropriate in this zone.

The highly vulnerable uses in Table D.2 should not be permitted in this zone.

The more vulnerable and essential infrastructure uses in Table D.2 should only be permitted in this zone if the Exception Test (see para. D.9) is passed. Essential infrastructure permitted in this zone should be designed and constructed to remain operational and safe for users in times of flood.

FRA requirements

All development proposals in this zone should be accompanied by a FRA. See Annex E for minimum requirements.

Table D.1: contd.

Zone 3a High Probability *(continued)*

Policy aims

In this zone, developers and local authorities should seek opportunities to:

i. 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;

ii. relocate existing development to land in zones with a lower probability of flooding; and

iii. 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.

Zone 3b The Functional Floodplain

Definition

This zone comprises land where water has to flow or be stored in times of flood. SFRAs should identify this Flood Zone (land which would flood with an annual probability of 1 in 20 (5%) or greater in any year or is designed to flood in an extreme (0.1%) flood, or at another probability to be agreed between the LPA and the Environment Agency, including water conveyance routes).

Appropriate uses

Only the water-compatible uses and the essential infrastructure listed in Table D.2 that has to be there should be permitted in this zone. It should be designed and constructed to:

- remain operational and safe for users in times of flood;
- result in no net loss of floodplain storage;
- not impede water flows; and
- not increase flood risk elsewhere.

Essential infrastructure in this zone should pass the Exception Test.

FRA requirements

All development proposals in this zone should be accompanied by a FRA. See Annex E for minimum requirements.

Policy aims

In this zone, developers and local authorities should seek opportunities to:

i. 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

ii. relocate existing development to land with a lower probability of flooding.

Table D.2: Flood Risk Vulnerability Classification

Essential Infrastructure	• Essential transport infrastructure (including mass evacuation routes) which has to cross the area at risk, and strategic utility infrastructure, including electricity generating power stations and grid and primary substations.
Highly Vulnerable	• 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.[19]
More Vulnerable	• Hospitals. • Residential institutions such as residential care homes, children's homes, social services homes, prisons and hostels. • Buildings used for: dwelling houses; student halls of residence; drinking establishments; nightclubs; and hotels. • Non–residential uses for health services, nurseries and educational establishments. • Landfill and sites used for waste management facilities for hazardous waste.[20] • Sites used for holiday or short-let caravans and camping, **subject to a specific warning and evacuation plan**.
Less Vulnerable	• 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 plants. • Sewage treatment plants (if adequate pollution control measures are in place).

[19] DETR Circular 04/00 – para. 18: *Planning controls for hazardous substances.* www.communities.gov.uk/index.asp?id=1144377

[20] See *Planning for Sustainable Waste Management: Companion Guide to Planning Policy Statement 10* for definition. www.communities.gov.uk/index.asp?id=1500757

Table D.2: contd.

Water-compatible Development	• 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 staff required by uses in this category, **subject to a specific warning and evacuation plan**.

Notes:

1) This classification is based partly on Defra/Environment Agency research on Flood Risks to People (FD2321/TR2)[21] and also on the need of some uses to keep functioning during flooding.

2) Buildings that combine a mixture of uses should be placed into the higher of the relevant classes of flood risk sensitivity. Developments that allow uses to be distributed over the site may fall within several classes of flood risk sensitivity.

3) The impact of a flood on the particular uses identified within this flood risk vulnerability classification will vary within each vulnerability class. Therefore, the flood risk management infrastructure and other risk mitigation measures needed to ensure the development is safe may differ between uses within a particular vulnerability classification.

Table D.3[22]: Flood Risk Vulnerability and Flood Zone 'Compatibility'

	Flood Risk Vulnerability classification (see Table D2)	Essential Infrastructure	Water compatible	Highly Vulnerable	More Vulnerable	Less Vulnerable
Flood Zone (see Table D.1)	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