Oxford City Level 2 SFRA
Final Report

February 2012

ATKINS

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1. Introduction

1.1. Overview

The City of Oxford lies wholly within the catchment of the River Thames. The city has generally developed eastwards from the Thames (or Isis), which flows southwards through the western/south western side of the city. The main tributary in the area, the River Cherwell, also flows through the city, as do a number of minor watercourses, both natural and artificial.

The 2001 census reported that the City of Oxford had a population of approximately 135,000 at the time of the census. Of these, the inhabitants of approximately 5,000 properties are at risk of flooding with the most recent events of December 2000, January 2003 and July 2007 resulting in significant flooding across the city.

Planning Policy Statement 25: Development and Flood Risk (PPS25)[1] states that a Strategic Flood Risk Assessment (SFRA) *"should be carried out by the local planning authority to inform the preparation of its Local Development Documents, having regard to catchment-wide flooding issues which affect the area".* A Level 1 SFRA covering the Oxford City Council area was completed in June 2008 and an update was completed in February 2011. The 2011 SFRA incorporates the most up-to-date information on the flood zone maps and flooding from non-fluvial sources.

The updated Level 1 SFRA has been used to carry out a Sequential Test for sites being considered for allocation in the Sites and Housing Policies Development Plan Document (DPD). The Sequential Test has suggested pressure to allocate sites in Flood Zone 3a for more vulnerable uses such as housing. In order to have enough information to show that the Exceptions Test could be passed for all relevant sites, a Level 2 SFRA is required.

1.2. Objectives

The aim of the Level 2 SFRA is to carry out a more detailed assessment of the sites identified within the Level 1 SFRA update, to provide sufficient information to show whether the part c) of the Exception Test can be passed. A technical appraisal will be undertaken to provide greater detail on the flood risk for the site that will require an Exception Test including an assessment of whether the development can be feasibly designed to be safe from flooding in a manner that does not increase flood risk elsewhere. The aim of the Level 2 SFRA is to provide enough information that a site specific flood risk assessment developed at a later stage of the planning process will not result in a change in flood risk which would make the site less developable. The Level 2 SFRA will also inform a surface water management strategy and the use of SUDS.

1.3. Scope of this Document

The Oxford Level 2 SFRA report has been prepared in accordance with PPS25 to assess the findings of the data collection, flood hazard assessment and the undertaking of the Exception Test in respect of potential development areas/sites identified throughout Oxford as part of the Core Strategy.

The report firstly provides an overview of the planning context in relation to the Exception Test for development within Oxford (Section 2). The assessment of flood hazard is provided in Section 3. The delineation of Critical Drainage Areas and a Surface Water Management Strategy is provided in Section 4 and 5. Whether sites that require an Exception Test can pass the part c) of the test is outlined in Section 6.

The Environment Agency regularly review and update, if necessary, their Flood Map as more detailed hydraulic modelling of rivers and mapping of flood risk is undertaken along with more recent historical events. This work will improve the quality of data available and the understanding of flood risk within the City. It may also result in changes to the predictions for flood levels and flood extents that may have to be taken into account in future decisions at development control level. All SFRAs should be considered to be living documents, subject to regular review in response to changing policy requirements and improved understanding of flood risk in the areas to which they apply.

[1] Planning Policy Guidance Note 25: Development and Flood Risk. DETR, 2001.

2. PPS 25 and the Exception Test

2.1. Background

The Government expects Local Planning Authorities (LPAs) to apply a risk-based approach to the preparation of development plans and their decisions on development control. The introduction of Planning and Policy Statement: Development and Flood Risk (PPS 25) in 2006 has encouraged LPAs to steer development away from areas affected by flood risk and recommends the application of a 'Sequential Test' that splits a local planning district into zones of high, medium or low risk. PPS 25 is the key guidance for planners managing flood risk as it clearly defines the appropriateness of the development type for each of the defined flood risk zones.

2.2. Sequential Test

Historically settlements have evolved along river corridors where the river has provided a source of water, food, transport and energy. The result of this is that Oxford, like many of the urban centres of England are at risk of flooding due to their close proximity to rivers.

Planning needs to be at the forefront of managing flood risk in a sustainable manner by steering development away from areas that are susceptible to flooding. PPS25 advocates a sequential approach that will guide the planning decision making process (i.e. the allocation of sites). The aim of the Sequential Test is to:

"steer new development to areas at the lowest probability of flooding (Flood Zone 1). Where there are no reasonably available sites in Flood Zone 1, decision-makers identifying broad locations for development and infrastructure, allocating land in spatial plans or determining applications for development at any particular location should take into account the flood risk vulnerability of land uses and consider reasonably available sites in Flood Zone 2, applying the Exception Test if required. Only where there are no reasonably available sites in Flood Zone 1 or 2 should decision-makers consider the suitability of sites in Flood Zone 3, taking into account the flood risk vulnerability of land uses and applying the Exception Test if required".

"Within each flood zone, new development should be directed first to sites at the lowest probability of flooding and the flood vulnerability of the intended use matched to the flood risk of the site, e.g. higher vulnerability uses located on parts of the site at lowest probability of flooding".

The Sequential Test has been applied throughout the entire planning authority district to ensure that development sites are considered on a sequential basis in reference to flood risk. The Sequential Test should not be limited to fluvial flood risk; all sources of flood risk should be considered when applying the Sequential Test and the other sources of flood risk are detailed within the Level 1 SFRA (February 2011).

2.3. ExceptionTest

The aim of the application of the Sequential Test is to ensure that more vulnerable property types, such as residential housing are not allocated in areas at high risk of flooding. In exceptional circumstances, there may be valid reasons for a development type which is not compatible with the level of flood risk at a particular site to be considered. In these circumstances the LPA or developer must demonstrate that the development passes all elements of the Exception Test.

In accordance with PPS25, for the Exception Test to be passed:

a) *It must be demonstrated that the development provides wider sustainability benefits to the community that outweigh flood risk, informed by a SFRA where on has been prepared…….the benefits of the development should contribute to the Core Strategy's Sustainability Appraisal.*
b) *The development should be on developable previously developed land or, if it not on previously developed land, that there are no reasonable alternative sites on developable previously-developed land; and*
c) *A FRA must demonstrate that the development will be safe, without increasing flood risk elsewhere, and, where possible, will reduce flood risk overall.*

The Exception Test should be applied to Local Development Documents site allocations for development and used to draft criteria based policies against which to consider planning applications. Where application of the Sequential Test indicates it needs to be applied, PPS 25 recommends that this should be done as early in the planning process as possible thus minimising the need to apply it to individual planning applications. The objective of this Level 2 SFRA is to assess whether part c) of the Exception Test can be passed for the sites identified within the Level 1 SFRA Report as requiring the application of the Exception Test.

In order to pass the Exception Test, Part c: Safe Development, the PPS 25 Practice Guide[2] states that:

It is the responsibility of the developer to prepare a comprehensive flood risk management strategy for the site to ensure the site is safe, covering:

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

PPS25 requires that wherever development is permitted in flood risk areas it must be safe, for the lifetime of the development, taking into account climate change and safe access and escape routes are required along with the safe management of any residual risk. New developments should be designed and constructed such that the health, safety and welfare of people are appropriately managed. New development can be made safe by:

- avoiding flood risk by not developing in areas at risk from floods;
- substituting higher vulnerability land uses for lower vulnerability uses in higher flood risk locations and locating higher vulnerability uses in areas of lower risk on a strategic scale, or on a site basis;
- providing adequate flood risk management infrastructure which will be maintained for the lifetime of the development; and
- mitigating the potential impacts of flooding through design and resilient construction.

When considering safety, specific local circumstances need to be taken into account, including:

- the characteristics of a possible flood event, e.g. the type and source of flooding and frequency, depth, velocity and speed of onset;
- the safety of people connected with the development, i.e. people within the building if it floods and also the safety of people around the building and in adjacent areas;
- the structural safety of the building; and
- the impact of a flood on the service provided to the development, e.g. water, electricity and fuel supplies.

Access routes should allow occupants to safely access and exit their dwellings in design flood conditions. Vehicular access to allow the emergency services to safely reach the development during design flood conditions will also normally be required.

2.4. Findings of the Sequential Test

The Sequential Test undertaken as part of the Level 1 SFRA has identified sites where development in areas of high flood risk can be avoided easily and sites that will need a more detailed assessment. Where sites have been identified as being partially located within Flood Zone 3b or Flood Zone 3a for the purposes of the Sequential Test they were treated as being in the next lowest flood zone providing that the highest flood risk zone covers no more than 20% of the site and is a clearly developable area remains. However, these sites will still require the Exceptions Test.

[2] Planning Policy Statement 25: Development and Flood Risk - Practice Guide. Communities and Local Government. December 2009

Those sites that the Level 1 SFRA has suggested have only a small area of higher flood risk on the edge of the site are listed in Table 2-1.

Table 2-1: Sites where development can be avoided easily in areas of high flood risk

Site Name	Address	Site Size (Ha)	Proportion of site in Flood Zone 2, 3a or 3b	Potential Allocation
Littlemore Park	Armstrong Road	5.44	3b:2.3%	Housing / extra care housing
Northfield School	Kestral Crescent	3.32	2: 1% 3a: 0.3% 3b: 2.4%	Housing
Kassam Stadium and surrounding area	Grenoble Road	8.94	2: 3.3% 3a: 0.2% 3b: 2.8%	Mixed including estimated 100 residential units
Wolvercote Paper Mill	Mill Road	4.65	2: 66.7% 3a: 0.02% 3b: 0.001%	200 residential units
Court Place Gardens	Rivermead Road	3.89	2: 26.5% 3a: 14% 3b: 2%	Housing / student accommodation
Faculty of Music	St. Aldate's	0.32	2: 98% 3a: 2%	Student accommodation

Those sites that the Level 1 SFRA has suggested have a large area of higher flood risk within the site and therefore require a more detailed assessment to identify whether part c) of the Exception Test can be passed are listed in Table 2-2.

Table 2-2: Sites that require a more detailed assessment

Site Name	Address	Site Size (Ha)	Proportion of site in Flood Zone 2, 3a or 3b	Potential Allocation
St. Cross College Annex	Holywell Mill Lane	1.39	2: 19% 3a: 29% 3b: 3%	Housing / student accommodation
Canalside Land	Dawson Street, Jericho	0.49	3a: 97% 3b: 3%	Housing and community uses
Riverside Hotel and 3-15 Botley Road	Botley Road	0.22	2: 74.5% 3a: 25.5%	Hotel and housing
Avis Site	1, 3, 5 & 7 Abbey Road and 4, 6 & 8 Botley Road	0.32	2: 66.7% 3a: 0.02% 3b: 0.001%	Housing
Fox and Hound Pub and Petrol Station	Abingdon Road	0.35	3a: 100%	Housing

3. Flood Hazard Assessment

When considering the safety of the development in terms of part c) of the Exception Test, specific local circumstances need to be taken into account including the characteristics of a possible flood event in terms of the frequency, speed of onset of flooding, depths and velocity of the flood water.

Flood hazard describes the physical risk that floodwater presents to people (and to vehicles and property). It is a function of water depth (D), velocity (v) and a debris factor (DF). The flood hazard classification is summarised in Table 3-1 and is based on Defra guidance FD2320[3].

Table 3-1 - Flood Hazard Classification (risks to people)

Flood Hazard Rating (D x (v + 0.5) + DF	Degree of Flood Hazard	Description
<0.75	Low	Caution – flood zone with shallow flowing water or deep standing water
0.75-1.25	Moderate	Dangerous for Some (i.e. children, elderly and infirm) – Danger: flood zone with deep or fast flowing water
1.25-2	Significant	Dangerous for most people (i.e. general public) – Danger: flood zone with deep fast flowing water
>2	Extreme	Dangerous for all (i.e. emergency services) – Extreme danger: flood zone with very deep fast flowing water

3.1. Methodology

For the sites identified in Table 2-2 an assessment of flood hazard for the development site has been undertaken and the methodology is provided below for each of the development sites.

3.1.1. St. Cross College Annex

The proposed St. Cross College Annex development site is within the River Cherwell floodplain. The floodplain has been modelled as part of the 2006 Environment Agency Lower Cherwell 1D model which used the SAR DTM (National data to +/-0.5m accuracy. The SAR DTM does not provide sufficient accuracy and Lidar data is now available which will provide a much greater accuracy of representation of the floodplain.

The proposed approach for deriving hazard maps for the St. Cross College Annex development was:

- Develop an ISIS-TUFLOW linked model of the reach of the River Cherwell extending from Marston Ferry Road to the north, and the High Street (A420) to the south
- Undertake a hydrological assessment using standard FEH methodology
- Derive 2D area based on the Lidar data covering the Flood Zone 2 extent from the existing ID model
- Assign roughness values to 2D area using OS Map data
- Produce depth, velocity and hazard maps from the TUFLOW model outputs

The methodology is provided in greater detail in Appendix A (Hydrological Assessment) and Appendix B (Hydraulics Assessment).

[3] Flood Risk Assessment Guidance for New Development: Phase 2 R&D Technical Report FD2320/TR2; Defra, October 2005

3.1.2. Canalside Land; Riverside Hotel and 3-15 Botley Road; Avis Site; and Fox and Hound Pub

The four proposed development sites of Canalside Land; Riverside Hotel and 3-15 Botley Road; Avis Site; and Fox and Hound Pub and Petrol Station are situated within the Flood Zone 3 floodplain. The floodplain has been modelled as part of the 2006 Environment Agency Wolvercote 1D model which used LIDAR for the DTM (+/- 0.15m accuracy).

The proposed approach for deriving hazard maps for the four proposed development sites is:

- Extract water level for the 1% annual exceedance probability (AEP) event from the hydraulic model
- Derive depths within the development site using the LiDAR DTM using ARC GIS
- Produce depth maps
- Derive Flood Hazard Rating for a range of assumed velocities and debris factors. Velocity outputs from the 1D model is an average velocity and thus the velocity across the floodplain has to be assumed, hence our approach is to look at a range
- Produce flood hazard maps

3.2. Results

The flood hazard outputs are summarised in Table 3-2 and maps are provided in Appendix G

Table 3-2 - Flood Hazard Assessment for sites requiring the Exception Test

Site	Maximum Flood Depth (m)	Maximum Flood Velocity (m/s)	Flood Hazard	Comments
St. Cross College Annex	0.3	0.1	Moderate	The flood hazard modelling shows that the majority of the site (>99%) is not considered to be at risk from flooding and, there is, therefore no associated flood hazard.
Canalside Land	0.4	1.0 (assumed as sensitivity analysis has shown lower and higher velocities do not alter the flood hazard rating)	Significant	Flood Depth analysis has shown that approximately 50% of the site is not considered to be at risk from flooding so could be developed as there is no associated flood hazard.
Riverside Hotel and 3-15 Botley Road	0.4	1.0 (assumed as sensitivity analysis has shown lower and higher velocities do not alter the flood hazard rating)	Significant	Flood Depth analysis has shown that approximately 75% of the site is not considered to be at risk from flooding so could be developed as there is no associated flood hazard.
Avis Site	0.4	1.0 (assumed as sensitivity analysis has shown lower and higher velocities do not alter the flood hazard rating)	Significant	Flood Depth analysis has shown that the majority of the site is considered to be at risk from flooding with approximately 30% of the site having a significant flood hazard.

Fox and Hound Pub and Petrol Station	0.4	1.0 (assumed as sensitivity analysis has shown lower and higher velocities do not alter the flood hazard rating)	Significant	Flood Depth analysis has shown that the majority of the site is considered to be at risk from flooding. Approximately 30% of the site is not considered to be at risk from flooding so could be developed as there is no associated flood hazard.

4. Critical Drainage Areas

4.1.1. Overview

The Town and Country Planning Order 2006[4] defines Critical Drainage Areas as "*an area within Flood Zone 1 which has critical drainage problems and which has been notified… [to]…the local planning authority by the Environment Agency*." However, the Environment Agency Standing Advice[5] also recognises the part that SFRAs play in identifying areas with drainage problems and in doing so highlighting areas that need a Flood Risk Assessment (FRA) to consider drainage in detail.

PPS25 highlights that the Environment Agency should be consulted on 'areas with critical drainage problems'. However there is as yet no national guidance on the definition of Critical Drainage Areas.

Certain locations are particularly sensitive to an increase in the rate of surface water runoff and/or volume from new development and there are generally known local flooding problems associated with these areas. We have identified areas where evidence indicates that there will be a genuine benefit from controlling run-off rates and we have defined these areas as Critical Drainage Areas. We have derived Critical Drainage Areas on the basis of the following:-

- high risk of localised flooding from ordinary watercourses, including culverts surcharging and overland surface water flows;
- potential for flooding from the sewer network due to failure / blockage or exceedance events when the storm return period is greater than the sewer was designed for;
- existing flooding based on Local Authority incident records;
- Thames Water sewer records and drainage areas;
- Areas Susceptible to Surface Water Flooding map;
- Flood Map for Surface Water;
- constraints on existing drainage systems;
- potential for development which may change drainage patterns.

4.1.2. Sewers

The sewerage infrastructure of Oxford is largely based on Victorian sewers and there is a risk of localised flooding associated with the existing drainage and sewer system.

Flooding from sewers can occur when the artificial drainage system is overwhelmed hydraulically, becomes blocked or suffers structural failure or pump failure. Blockage and structural failure incidents tend to be isolated and unpredictable. Thames Water is responsible for the management of the urban drainage system throughout Oxford including surface water and foul sewerage. Thames Water has procedures in place to respond to and rectify such incidents, which are also recorded on databases to inform maintenance and improvement plans.

A review of areas where the sewer system has been overwhelmed can potentially identify under capacity of the drainage system or where the system does not provide an adequate level of service. Thames Water maintains an extensive database of incidents of hydraulic overload of sewers. This is a strategic level problem and is addressed by Thames Water through their ongoing asset management procedures, supported by a programme of detailed network modelling. Thames Water has the following target levels of protection against sewer flooding of properties:

- Foul and combined systems: 1 in 10 to 1 in 50 years (depending on property type).
- Surface water system: 1 in 10 to 1 in 30 years (depending on property type).

Wherever possible, Thames Water seeks to promote the highest specified standard. However, this is dependent on the cost-benefit analysis of the improvement scheme. It is therefore not appropriate for the SFRA to recommend strategic options for managing sewer flooding where levels of protection to properties are inadequate as this is a fundamental part of Thames Water's existing asset management procedures.

[4] The Town and Country Planning (General Development Procedure) (Amendment) (No. 2) (England) Order 2006. OPSI, 2006
[5] Environment Agency. Flood Risk Standing Advice for England - PPS25 National Version 2.0. Can be accessed online at http://www.environment-agency.gov.uk/research/planning/82584.aspx

Thames Water holds records of flooding issues relating to surface and foul water sewers and they were consulted to provide their up to date information. The records provided show flood incidents on a postcode area basis during the last 10 year period. This data does not provide the specific location of each incident and is therefore of limited use for providing location specific information. This data is tabulated in Table 4-1 below and presented graphically in Appendix C.

Table 4-1: Thames Water Sewer Flooding Incidents

Postcode	Properties flooded by surface water sewers in last ten years	Properties flooded by foul water sewers in the last ten years	Properties flooded by combined sewers in the last ten years	Total
OX1 2	1	0	0	1
OX2 0	1	6	0	7
OX2 6	0	2	1	3
OX2 8	0	1	0	1
OX4 3	0	1	0	1
OX4 4	0	1	0	1
OX4 6	0	1	0	1
OX4 7	0	1	0	1
Total	2	13	1	16

Of the 16 flood incidents recorded within the Thames Water data, 13 of these incidents were attributed to foul water flooding and therefore it is assumed that the surface water flood risk from the surface water sewer network, as reported by Thames Water, within the city is low.

It is essential to ensure that future development does not exacerbate known existing problems and conditions should be placed upon future development to ensure that these capacity issues are rectified before development is permitted to proceed. It is important, however, to consider that all hydraulic improvements to the systems, required due to new development, are subject to approval in line with the strategies and policies of Thames Water.

4.1.3. Surface Water

Surface water flooding occurs when excess water runs off across the surface of the land. Surface water flooding has the potential to contribute significant flood risk in urban areas due to the rapid run off rates associated with urban land use.

Surface water flooding, either on its own or as a contributing factor in other types of flooding is considered to be relatively frequent. The scale of the disruption or damage caused is less certain, and there are few records of significant losses resulting from surface water flooding.

Making Space for Water[6] defines surface water flooding as an *"event that results from rainfall generated overland flow before the runoff enters any watercourse or sewer. Usually associated with high intensity rainfall (typically >30mm/hr) resulting in overland flow and ponding in depressions in the topography, but can also occur with lower intensity rainfall or melting snow where the ground is saturated, frozen, developed or otherwise has low permeability. Urban underground sewerage/drainage systems and surface watercourses may be completely overwhelmed, preventing drainage. Surface water flooding does not include sewer surcharge in isolation.'*

The Areas Susceptible to Surface Water Flooding (AStSWF) maps show areas where surface water would be expected to flow or pond. The map was procured as a preliminary national output to provide Local Resilience Forums with an initial indication of areas that may be susceptible to surface water flooding. It was also provided to Regional Resilience Teams for use in their functions which relate to emergencies as defined and as required by the Civil Contingencies Act 2004 and to LPAs for land use planning purposes.

The AStSWF maps are based on the modelling of a single rainfall event with a 1 in 200 chance of occurring in any year. The maps display the chance of this rainfall and not of the resulting flood

[6] Making Space for Water – Flooding from other sources (HA4a), 2006, Defra.

extent occurring. Consequently, the map provides only a general indication of areas which may be more likely to suffer from surface water flooding for this rainfall probability. The map provides three bandings, indicating 'less' to 'more' susceptible to surface water flooding. The AStSWF map is shown in Appendix D.

The AStSWF map shows there are substantial areas of Oxford City susceptible to surface water flooding including New Botley, Osney, City Centre, Walton Manor, Littlemore, Blackbird Leys and New Headington. There are also areas outside of the urban area of Oxford City which are susceptible to surface water flooding.

The Flood Map for Surface Water (FMfSW) was developed from a number of improvements to the original model in areas where it was known to be weaker; for example considering:

- more storm events;
- the influence of buildings;
- the influence of the sewer system.

Two rainfall events, one with a 1 in 30 and the other with a 1 in 200 chance of occurring in any year, are modelled and mapped. The map shows Surface Water flooding greater than 0.1m deep, Deeper Surface Water Flooding greater than 0.3m deep and flooding between 0.1 and 0.3m deep. The 0.3m threshold was chosen as it represents a typical value for the onset of significant property damages when property flooding may start (above doorstep level) and because it is at around this depth that moving through floodwater (driving or walking) may become more difficult; both of which may lead users to consider the need to close roads or evacuate areas.

The FMfSW map is shown in Appendix E. The map shows that there are isolated areas in Wolvercote, Cutteslowe, New Botley, Osney, City Centre, Walton Manor, Littlemore, Blackbird Leys and New Headington which are at risk from depths of surface water flooding of greater than 0.3m.

4.1.4. Delineation of Critical Drainage Areas

The sewer network can have a significant impact on the location of surface water and sewer flooding for more frequent events. It can also affect the distribution of water throughout urban catchments during flood events, passing excess flows from the combined network into watercourses through combined sewer overflows. Without detailed Thames Water flood risk data, natural catchments have been combined with the postcode areas with historical sewer flooding and surface water flooding greater than 0.3 m (as defined by the 1 in 200 chance of occurring in a year FMfSW map) to define Critical Drainage Area boundaries.

The Critical Drainage Areas are shown in Appendix F and it can be seen that without risk based information for the sewer network the Critical Drainage Areas cover an extensive area. The Critical Drainage Areas provided in the SFRA should be refined over time as more detailed information on flood risk and local flood management assets, including sewered catchments, becomes available. The Critical Drainage Areas identified here should therefore only be taken as a starting point in the identification of areas for which a Surface Water Management Plan would be beneficial.

Table 4-2 shows the Critical Drainage Areas delineated throughout Oxford based on the criteria defined in Section 4.1.1.

The Critical Drainage Areas are areas with complex surface water flooding problems that would benefit from a drainage strategy, which is most effectively done in a Surface Water Management Plan.

Specific drainage requirements are required in these areas to help reduce local flood risk and these are detailed in Section 5 of this report.

Table 4-2: Critical Drainage Areas

Critical Drainage Area	Reason
Park Town	Development is planned for this catchment, which has the potential to increase flood risk downstream in the Cherwell catchment if surface water discharges are not carefully managed. The FMfSW shows that there is a high risk of surface water flooding to properties. Within a postcode area where properties affected by internal flooding on the DG5 register.
Walton Manor and Jericho	A large amount of development is planned for this catchment, which has the potential to increase flood risk downstream in the Thames catchment if surface water discharges are not carefully managed. The FMfSW shows that there is a high risk of surface water flooding to properties. Within a postcode area where properties affected by internal flooding on the DG5 register.
New Botley and Osney	Development is planned for this catchment, which has the potential to increase flood risk downstream in the Thames catchment if surface water discharges are not carefully managed. The FMfSW shows that there is a high risk of surface water flooding to properties. Within a postcode area where properties affected by internal flooding on the DG5 register.
Cowley	Development is planned for this catchment, which has the potential to increase flood risk downstream in the Thames catchment if surface water discharges are not carefully managed. The FMfSW shows that there is a high risk of surface water flooding to properties. Within a postcode area where properties affected by internal flooding on the DG5 register.
Littlemore and Blackbird Leys	A large amount of development is planned for this catchment, which has the potential to increase flood risk downstream in the Thames catchment if surface water discharges are not carefully managed. There is a high risk of flooding from watercourses within the area, e.g. Northfield Brook and Littlemore Brook through Blackbird Leys. The FMfSW shows that there is a high risk of surface water flooding to properties. Within a postcode area where properties affected by internal flooding on the DG5 register.
New Marston	A large amount of development is planned for this catchment, which has the potential to increase flood risk downstream in the Peasmoor Brook and the River Cherwell to the west and Bayswater Brook to the north if surface water discharges are not carefully managed. There has been frequent surface water flooding reported in Headington and New Marston, which may be attributed to the local drainage system and surface water runoff. There is a high risk of flooding from ordinary watercourses within the area, e.g. the tributaries of Peasmoor Brook have been associated with localised flooding within Headington and New Marston. The FMfSW shows that there is a high risk of surface water flooding to properties.
New Headington	A large amount of development is planned for this catchment, which has the potential to increase flood risk downstream in the River Cherwell if surface water discharges are not carefully managed. The FMfSW shows that there is a high risk of surface water flooding to properties.

5. Surface Water Management

5.1. Overview

The planning system can act as an effective means of ensuring that all new developments manage surface water in a sustainable manner. Conventional surface water drainage systems have traditionally used underground pipe networks to efficiently convey water away from sites. In the past this has led to problems of downstream flooding, reductions in groundwater recharge and waste pollution incidents associated with surface water overwhelming combined sewers. Both 'Making Space for Water' and the 'Water Framework Directive' have highlighted the need for an improved understanding and better management of how our urban environments are drained.

PPS25 requires that a site-specific flood risk assessment is undertaken for all sites including those in Flood Zone 1 with an area greater than one hectare to ensure that downstream flooding problems are not made worse by surface water runoff from the development.

Surface water drainage systems for a development should ensure that there is little or no residual risk of flooding for events in excess of the return period for which the sewer system on the site is designed.

The Environment Agency Standing Advice provides advice based on the level of flood risk assessment that is appropriate for a development with regard to the PPS25 Flood Zones and whether it is greater than a hectare in area.

The Standing Advice Flood Risk Assessment Guidance notes that *"In areas where the Local Planning Authority has identified drainage problems through a Strategic Flood Risk Assessment or Surface Water Management Plan and they have indicated that a formal flood risk assessment is required.* FRA Guidance Note 1[7] requires FRAs to provide *"Proposals for surface water management that aims to not increase, and where practicable reduce the rate of runoff from the site as a result of the development (in accordance with sustainable drainage principles, and the Local Planning Authority's published SFRA).*

SUDS aim to mimic the natural drainage processes whilst also removing pollutants from urban runoff at the source before entering a watercourse. There are a wide range of SUDS techniques, including green roofs, permeable paving, swales, detention basins, ponds and wetlands.

As the River Cherwell and the River Thames flow through Oxford City the Council has responsibility to ensure development does not increase flows downstream in neighbouring authorities.

5.2. Applicability of the use of SUDS

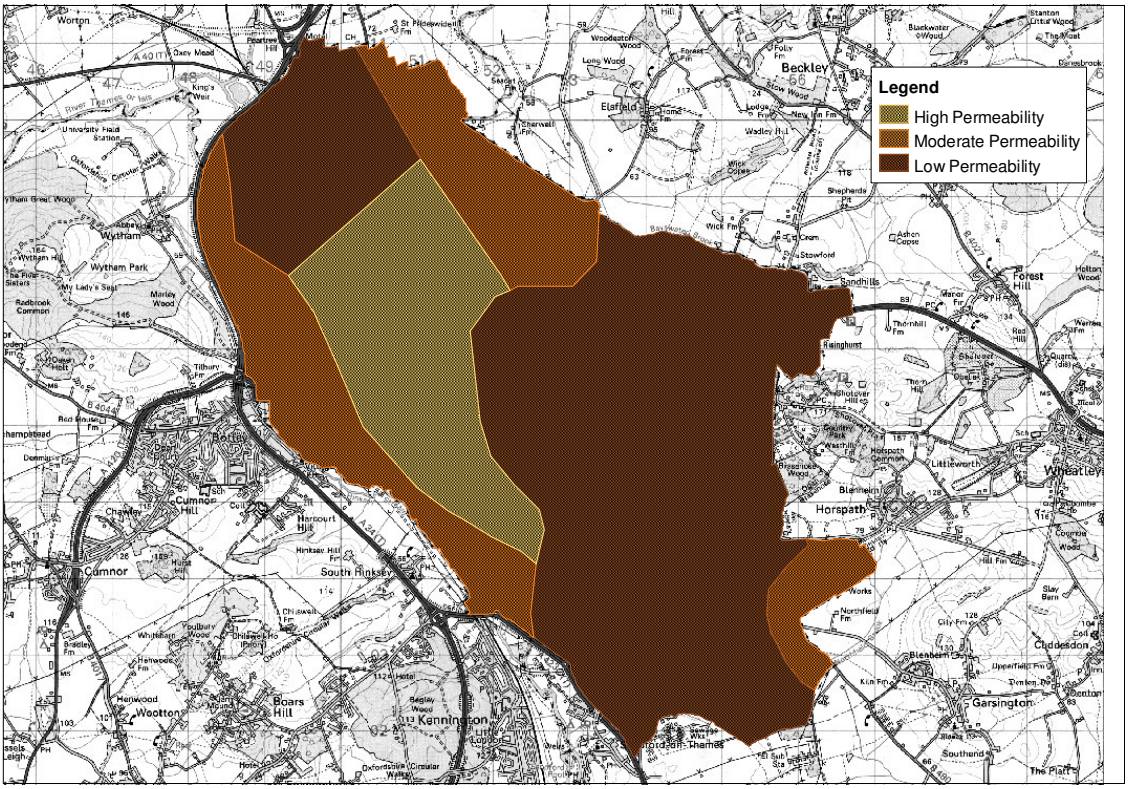
PPS25 states that Local Authorities should prepare and implement planning strategies that help to deliver sustainable development, by using opportunities offered by new development to reduce the causes and impacts of surface water flooding. By implementing policies to encourage developers to incorporate SUDS wherever possible, Local Authorities can help to mitigate the impacts that development has on surface water runoff rates and volumes.

Oxfofd City Council: LA100019348 2010.Figure 5.1 provides information relating to the spatial variation of permeability across Oxford based on soils and underlying geology. This information can be used as a first estimate of the suitability of different types of SUDS within Oxford as shown in

Table 5-1.

[7] Environment Agency. Flood Risk Assessment (FRA) Guidance Note 1, Development Greater Than 1 Hectare (ha) in Flood Zone 1 (and Critical Drainage areas less than 1ha) Can be accessed online at http://www.environment-agency.gov.uk/static/documents/Research/FRAGuidanceNote1.pdf

The soil type in Oxford City area varies from sandy in the vicinity of the River Thames and River Cherwell to clayey within the eastern parts of Oxford due to the presence of Oxford Clay and mudstone bedrock geology.



Reproduced from the Ordnance Survey map with the permission of the Controller of Her Majesty's Stationery Office (HMSO). © Crown Copyright. Unauthorised reproduction infringes Crown Copyright and may lead to prosecution or civil proceedings.

Oxfofd City Council: LA100019348 2010.Figure 5.1 - Permeability across Oxford

Table 5-1: Suitability of SUDS

Permeability	Indicative Suitability of SUDS Techniques
High Permeability	Infiltration and Combined Systems
Moderate Permeability	Infiltration and Combined Systems
Low Permeability	Attenuation Systems

It is important to note that the above assessment of the spatial suitability of SUDS is an indicative estimate and should be confirmed at the site specific level, using ground investigation data, including permeability tests.

5.2.1. Infiltration Systems

Infiltration systems allow surface water to discharge directly into the ground. These systems are only appropriate where ground conditions permit; 1) a suitable water acceptance potential and 2) in locations where groundwater recharge will not adversely affect drinking water aquifers as identified by the Environment Agency's source protection zones, available on their website http://www.environment-agency.gov.uk. Such systems may include:

- Permeable surfaces
  - Gravel
  - Permeable Paving

- Block Paving with voids
- Grassed areas

- Sub Surface Infiltration
  - Filter Drains
  - Geocellular Systems
  - Soakaways

5.2.2. Attenuation Systems

If ground conditions cannot support infiltration systems, surface water may need to be attenuated using measures to store surface water. Attenuation systems, if designed at ground level, have the potential to take up large areas of development sites. Early consideration of such constraints is therefore essential. Attenuation systems may include:

- Landscaped
  - Detention Basins
  - Balancing Ponds
  - Retention Ponds
  - Wetlands
  - Lagoons

- Engineered
  - Underground Tanks
  - Ornate Water Features
  - Rainwater Harvesting
  - Green Roofs
  - Oversized Pipes

5.2.3. Combined Systems

SUDS designs for most sites can include a combination of infiltration and attenuation systems and they have been categorised above according to the dominant process. Other forms of SUDS which can provide more balanced benefits of infiltration and attenuation include:

- Swales
- Filter Strips

5.3. Allowable Discharge Rates

5.3.1. Greenfield Sites

Following the Building Regulations Drainage hierarchy, surface water should drain to a soakaway or infiltration system designed in accordance with the SUDS Manual - CIRIA C697, using a minimum of a 30-year return period storm.

Where an FRA demonstrates that infiltration is not possible a sustainable drainage system shall be provided ensuring flow attenuation, no adverse impact on water quality and where possible habitat creation.

The total discharge from the site should aim to mimic greenfield rates. These shall be no more than the theoretical greenfield run-off rates from each of the corresponding 1, 10, 30 and 100 year storms (100%, 10%, 3.33% and 1% AEP)

The drainage design must take into account the appropriate allowance for increased rainfall from climate change. This should be based on the lifetime of the development, the guidance in Annex B of PPS25 and the PPS25 Practice Guide.

Underground attenuation and piped sections should be designed for a minimum of the 30-year storm (3.33% AEP). However total discharge rates from the site must still be controlled for the 100-year storm (1% AEP). Attenuation of events exceeding the piped system may be achieved

by temporary flooding of open spaces or car parks. If surface flooding of open areas is not appropriate, the formal drainage system should be designed for the 100 year storm (1% AEP) with an allowance for climate change for the lifetime of the development.

5.3.2. Brownfield Sites

Development on previously developed land should aim for the standards of a greenfield site as outlined in 5.1.3 above. Where this is not possible the FRA should demonstrate how a sustainable drainage system is being provided which meets the policy aims of PPS25 to reduce flood risk on and off site. The FRA should demonstrate how the development will reduce run-off rates as much as is reasonably practicable.

5.3.3. Critical Drainage Areas

Where Critical Drainage Areas are identified in this SFRA surface water run-off rates should be restricted to reduce flood risk. We have therefore developed a set of recommended standards that should be followed.

Development should deliver Greenfield runoff on Greenfield sites up to a 1 in 100 year (1% AEP) storm event, considering climate change.

Development should aim for a minimum reduction in surface water runoff rates of 30% for Brownfield sites, with an aim of reducing runoff to Greenfield rates up to a 1 in 100 year (1% AEP) storm event, considering climate change.

Development should be designed so that there is no flooding to the development in a 1 in 30 year (3.33% AEP) event and so that there is no property flooding in a 1 in 100 year (1% AEP) plus climate change event.

Over time, it is envisaged that local authorities will commission drainage strategies to determine in more detail and establish the evidence base for set reductions in surface water runoff from development sites.

Wherever possible, reductions in surface water should be achieved through the implementation of SUDS with source control considered firstly. There may be opportunities to deliver SUDS though integrated solutions for collections of strategic sites.

5.4. Surface Water Management Plans and Drainage Strategies

Surface Water Management Plans (SWMPs) are referred to in PPS25 as a tool to manage surface water flood risk on a local basis by improving and optimising coordination between relevant stakeholders. SWMPs will build on SFRAs to provide the vehicle for local organisations to develop a shared understanding of local flood risk, including setting out priorities for action, maintenance needs and links into local development frameworks and emergency plans.

A SWMP should establish a long-term action plan to manage surface water in an area and should influence future capital investment, drainage maintenance, public engagement and understanding, land-use planning, emergency planning and future developments.

There is the potential for groups of development sites within Oxford to share a central and integrated solution for managing surface water runoff. This should be investigated further through a SWMP or a Drainage Strategy, which may or may not be undertaken at the same time as a SWMP. A Drainage Strategy will be required to be prepared by the developer(s) where an integrated solution is necessary, due to issues of land constraints, geology, connection to public sewers and watercourses. Such solutions can provide great benefits besides water management, including providing Green Infrastructure enhancements, recreational facilities, improving biodiversity and making communities a better place to live.

Drainage Strategies can be particularly useful for considering, recommending the implementation of and long term management arrangements for SUDS and setting appropriate runoff rates from new development. Drainage Strategies should be used to set surface water runoff standards for all developments within a defined drainage catchment, including considering surface water runoff from windfall sites that may come forward.

Oxford City Council, Oxford County Council and the Environment Agency should work closely with Thames Water, using the outputs from the SFRA as a starting point, to identify the potential

locations of and priorities for SWMPs. Oxford County Council, as the lead for local flood risk management, should co-ordinate any future surface water management work. The recent Defra Surface Water Management Plan Guidance (2010)[8] supports the use of SFRAs in providing the evidence base for where SWMPs are required.

Surface water management needs to take a holistic approach, taking into account all the sources of local flood risk, including from sewers, overland flow, culverted and open watercourses and groundwater. SWMPs should provide the opportunity to undertake detailed sewer modelling and pool together the knowledge and understanding from different organisations to help assess options to reduce surface water flood risk to new and existing development.

[8] Surface Water Management Plan Technical Guidance. Defra. March 2010

6. Assessment of proposed development sites requiring the Exception Test

This section provides a discussion of whether the sites identified within the Level 1 SFRA that require the Exception Test to be considered are able to pass part c) of the test.

Littlemore Park, Northfield School, Kassam Stadium and surrounding area, Wolvercote Paper Mill, Court Place Gardens, Faculty of Music are sites with a small proportion within Flood Zone 3. Through careful masterplanning these sites can easily pass the Exception Test part c) by ensuring vulnerable developed is located within the lower flood risk areas of the site.

The five sites, St. Cross College Annex, Canalside Land, Riverside Hotel and 3-15 Botley Road, Avis Site and Fox and Hound Pub and Petrol Station are sites located within Flood Zone 3 which have required a more detailed assessment to identify the likelihood of passing the Exception Test part c).

Factsheets for each of these five sites are provided in Appendix G and the outcome of the assessment of whether the Exception Test can be passed is summarised in Table 6-1.

Table 6-1 - Exception Test part c) Assessment

Site Name	Is the site partially in FZ 2?	Is the site partially in FZ 3a?	Is the site partially in FZ 3b?	Is the flood depth >0.3m?	Is the flood hazard significant or extreme?	Is the site protected by flood defences?	Is there dry access and egress?	Is there safe access and egress for emergency vehicles?	Is the site within a Flood Warning Area?	Is the site within a CDA?	Can surface runoff be managed?	Is part c) likely to be passed?
St. Cross College Annex	√	√	√	*x*	*x*	*x*	√	√	√	*x*	√	√
Canalside Land	*x*	√	*x*	√	√	*x*	√	√	√	√	√	*x*
Riverside Hotel and 3-15 Botley Road	√	√	*x*	√	√	*x*	*x*	√	√	√	√	√
Avis Site	√	√	*x*	√	√	*x*	*x*	√	√	√	√	*x*
Fox and Hound Pub and Petrol Station	*x*	√	*x*	√	√	*x*	*x*	√	*x*	*x*	√	*x*

6.1. St. Cross College Annex

6.1.1. Assessment

- Is it safe? – **YES**. The flood hazard modelling shows that the majority of the site (>99%) is not considered to be at high risk from flooding and, there is, therefore no associated flood hazard. Up to 25% of the site is at risk of surface water flooding but only 6% of the site is at risk of >0.3 m deep flooding. The majority of the site has between 50% and 75% susceptibility to groundwater flooding. There is dry access and egress to the site from St. Cross Road and the site is served by flood warnings.
- Does it increase flood risk elsewhere? - **NO**. Surface water runoff can be managed on site through the use of SUDS
- Does it reduce flood risk overall? – **NO**. There is unlikely to be an opportunity to reduce surface water runoff as the site is greenfield.

6.1.2. Result

The Exception Test part c) is likely to be passed as part of a site specific flood risk assessment.

6.1.3. Recommendation

Surface water runoff should be managed on the site through the use of SUDS, attenuating runoff to Greenfield runoff rates.

6.2. Canalside Land

6.2.1. Assessment

- Is it safe? – **NO**. Flood Depth analysis has shown that approximately 50% of the site is not considered to be at risk from flooding so could be developed as there is no associated flood hazard. Up to 30% of the site is at risk of surface water flooding but the site is not at risk of >0.3 m deep flooding. The site has greater than 75% susceptibility to groundwater flooding. There is no dry access and egress to the site and the site is not served by flood warnings.
- Does it increase flood risk elsewhere? - **NO**. Surface water runoff can be managed on site through the use of SUDS
- Does it reduce flood risk overall? – **YES**. There may be an opportunity to reduce surface water runoff as the site is brownfield and as it is within a Critical Drainage Area there is an onus on betterment of the existing runoff rates.

6.2.2. Result

The Exception Test part c) is unlikely to be passed as part of a site specific flood risk assessment due to safety.

6.2.3. Recommendation

A site specific flood risk assessment should undertake detailed 2d modelling using topographic survey data of the site to better understand the depths and velocities. The Environment Agency are currently developing the Oxford Strategy Model which is a 1D-2D linked hydraulic model and the outputs of this model may be used to undertake a more detailed assessment of the site in the future.

Surface water runoff should be managed on the site through the use of SUDS, attenuating runoff to Greenfield runoff rates if possible but at least 30% less than existing runoff in accordance with recommendations for Critical Drainage Areas.

6.3. Riverside Hotel and 3-15 Botley Road

6.3.1. Assessment

- Is it safe? – **YES**. Flood Depth analysis has shown that approximately 75% of the site is not considered to be at risk from flooding so could be developed as there is no associated flood hazard. Up to 15% of the site is at risk of surface water flooding but the site is not at risk of >0.3 m deep flooding. The site has greater than 75% susceptibility to groundwater flooding There is no dry access and egress to the site; however there is likely to be access and egress for emergency service vehicles from Botley Road as depths are <0.3m and the site is served by flood warnings.
- Does it increase flood risk elsewhere? - **NO**. Surface water runoff can be managed on site through the use of SUDS
- Does it reduce flood risk overall? – **YES**. There may be an opportunity to reduce surface water runoff as the site is brownfield and as it is within a Critical Drainage Area there is an onus on betterment of the existing runoff rates.

6.3.2. Result

The Exception Test part c) is likely to be passed as part of a site specific flood risk assessment.

6.3.3. Recommendation

Careful master-planning of the site should be undertaken to steer vulnerable development away from the high risk areas of Flood Zone 3 and develop within the Flood Zone 2 area.

A site specific flood risk assessment should be undertaken detailing appropriate design floor levels based on hydraulic model outputs. The Environment Agency are currently developing the Oxford Strategy Model which is a 1D-2D linked hydraulic model and the outputs of this model may be used to undertake a more detailed assessment of the site in the future.

Surface water runoff should be managed on the site through the use of SUDS, attenuating runoff to Greenfield runoff rates if possible but at least 30% less than existing runoff in accordance with recommendations for Critical Drainage Areas.

6.4. Avis Site

6.4.1. Assessment

- Is it safe? – **NO**. Flood Depth analysis has shown that the majority of the site is considered to be at risk from flooding with approximately 30% of the site having a significant flood hazard. Up to 13% of the site is at risk of surface water flooding but only 6& of the site is at risk of >0.3 m deep flooding. The site has greater than 75% susceptibility to groundwater flooding. There is no dry access and egress to the site; however there is likely to be access and egress for emergency service vehicles from Botley Road as depths are <0.3m and the site is served by flood warnings.
- Does it increase flood risk elsewhere? - **NO**. Surface water runoff can be managed on site through the use of SUDS
- Does it reduce flood risk overall? – **YES**. There may be an opportunity to reduce surface water runoff as the site is brownfield and as it is within a Critical Drainage Area there is an onus on betterment of the existing runoff rates.

6.4.2. Result

The Exception Test part c) is unlikely to be passed as part of a site specific flood risk assessment due to safety.

6.4.3. Recommendation

A site specific flood risk assessment should undertake detailed 2d modelling using topographic survey data of the site to better understand the depths and velocities. The Environment Agency are currently developing the Oxford Strategy Model which is a 1D-2D linked hydraulic model and the outputs of this model may be used to undertake a more detailed assessment of the site in the future.

Surface water runoff should be managed on the site through the use of SUDS, attenuating runoff to Greenfield runoff rates if possible but at least 30% less than existing runoff in accordance with recommendations for Critical Drainage Areas.

6.5. Fox and Hound Pub and Petrol Station

6.5.1. Assessment

- Is it safe? – **NO**. Flood Depth analysis has shown that the majority of the site is considered to be at risk from flooding with approximately 30% of the site having a significant flood hazard. Up to 11% of the site is at risk of surface water flooding but only 6& of the site is at risk of >0.3 m deep flooding. The site has greater than 75% susceptibility to groundwater flooding. There is no dry access and egress to the site; however there is likely to be access and egress for emergency service vehicles from Abingdon Road as depths are <0.3m and the site is served by flood warnings.
- Does it increase flood risk elsewhere? - **NO**. Surface water runoff can be managed on site through the use of SUDS
- Does it reduce flood risk overall? – **YES**. There may be an opportunity to reduce surface water runoff as the site is brownfield and there is an opportunity to reduce the existing runoff rates to greenfield runoff rates.

6.5.2. Result

The Exception Test part c) is unlikely to be passed as part of a site specific flood risk assessment due to safety.

6.5.3. Recommendation

A site specific flood risk assessment should undertake detailed 2d modelling using topographic survey data of the site to better understand the depths and velocities. The Environment Agency are currently developing the Oxford Strategy Model which is a 1D-2D linked hydraulic model and the outputs of this model may be used to undertake a more detailed assessment of the site in the future.

Surface water runoff should be managed on the site through the use of SUDS, attenuating runoff to Greenfield runoff rates.

7. Conclusions

Littlemore Park, Northfield School, Kassam Stadium and surrounding area, Wolvercote Paper Mill, Court Place Gardens, Faculty of Music are sites with a small proportion within Flood Zone 3. Through careful masterplanning these sites can easily pass the Exception Test part c) by ensuring vulnerable developed is located within the lower flood risk areas of the site.

St. Cross College Annex, Canalside Land, Riverside Hotel and 3-15 Botley Road, Avis Site and Fox and Hound Pub and Petrol Station are sites located within Flood Zone 3 which have required a more detailed assessment to identify the likelihood of passing the Exception Test part c).

A flood hazard assessment has been undertaken for each of the 5 sites requiring a more detailed assessment. St. Cross College Annex was assessed as having a moderate flood hazard; however flood hazard modelling shows that the majority of the site (>99%) is not considered to be at high risk from flooding and, there is, therefore no associated flood hazard. The other 4 sites have areas which are classified as significant flood hazard.

Critical Drainage Areas have been delineated using a combination of natural catchments, areas with historical sewer flooding and areas susceptible to surface water flooding greater than 0.3 m (as defined by the 1 in 200 chance of occurring in a year FMfSW map). The Critical Drainage Areas delineated are Park Town, Walton Manor and Jericho, New Botley and Osney, Cowley, Littlemore and Blackbird Leys, New Marston and New Headington.

The Critical Drainage Areas are areas with complex surface water flooding problems that would benefit from a drainage strategy, which is most effectively done in a Surface Water Management Plan. Specific drainage requirements are recommended in these areas to help reduce local flood risk.

Drainage Strategies can be particularly useful for considering, recommending the implementation of and long term management arrangements for SUDS and setting appropriate runoff rates from new development. Drainage Strategies should be used to set surface water runoff standards for all developments within a defined drainage catchment, including considering surface water runoff from windfall sites that may come forward.

Oxford City Council, Oxford County Council and the Environment Agency should work closely with Thames Water, using the outputs from the SFRA as a starting point, to identify the potential locations of and priorities for SWMPs. Oxford County Council, as the lead for local flood risk management, should co-ordinate any future surface water management work.

An assessment has been undertaken of the 5 sites identified as requiring a more detailed analysis to assess the likelihood of passing part c) of the Exception Test. The Exception Test part c) is likely to be passed as part of a site specific flood risk assessment for the St. Cross College Annex and Riverside Hotel and 3-15 Botley Road sites. However, the Exception Test part c) is unlikely to be passed as part of a site specific flood risk assessment for the Canalside Land, Avis Site and Fox and Hound Pub and Petrol Station sites.

For the sites, where the Exception Test part c) is unlikely to be passed a site specific flood risk assessment should undertake detailed 2d modelling using topographic survey data of the sites to better understand the depths and velocities. The Environment Agency are currently developing the Oxford Strategy Model which is a 1D-2D linked hydraulic model and the outputs of this model may be used to undertake a more detailed assessment of the sites in the future.

A. Hydrological Assessment of St. Cross College Annex Site

A.1. Cherwell Hydrological Technical Note

A.2. Cherwell Flood Estimation Handbook Calculation Record

B. Hydraulic Assessment of St. Cross College Annex Site

C. Thames Water Sewer Flooding Incidents by Postcode Area

D. Areas Susceptible to Surface Water Flooding

E. Flood Map for Surface Water

F. Critical Drainage Areas

G. Factsheets for site requiring the Exception Test

Esther Ainsworth
Chadwick House
Birchwood Science Park
Risley
Warrington
WA3 6AT
Email: esther.ainsworth@atkinsglobal.com
Telephone: 01925 238000
Direct telephone: 01925 238342
Fax: 01925 238500