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Oxford Flood Risk Management Strategy

Technical Report

ea/br/e/std/v1

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Contents

1. Introduction

1.1 What is a Flood Risk Management Strategy?

1.1.1 The Environment Agency has permissive powers to manage the flood risk from designated main rivers in England and Wales under Section 165 of the Water Resources Act 1991. To investigate whether the flood risk can be reduced in the city of Oxford, the Environment Agency commissioned Black & Veatch to develop a long-term strategy for the city and surrounding areas. This project is known as the 'Oxford Flood Risk Management Strategy' (OFRMS).

1.1.2 The Department for Environment Food and Rural Affairs (Defra) is responsible for national flood risk management policy. It requires operating bodies such as the Environment Agency to consider flood management in an integrated and sustainable way over a 100 year time period. A long-term plan known as a Flood Risk Management Strategy is developed and sets out the policy and objectives for flood risk management taking into account a broad range of local interests and issues, within the context of national guidance and funding priorities. Such an approach allows the Environment Agency to make more effective flood risk management decisions and seeks to avoid uncoordinated actions that may adversely affect other areas.

1.1.3 The OFRMS aim is to achieve long-term, sustainable and cost-effective solutions that reduce the impact of flooding in the Oxford area, whilst taking into consideration the natural and built environment. The strategy includes technical, economic and environmental assessments of the OFRMS strategic options in accordance with the Flood and Coastal Defence Project Appraisal Guidance (FCDPAG) (MAFF, 2001).

1.2 Why are we developing a Flood Risk Management Strategy?

1.2.1 The city of Oxford is situated in the floodplain at the confluence of the River Thames and the River Cherwell. The likelihood of flooding in low-lying areas of Oxford has been recognised for many years. However, flooding of several areas of the city in 2000, 2003 and most recently in July 2007 has raised concerns and highlights the need for measures to reduce the risk of flooding in Oxford.

1.2.2 Therefore, the OFRMS has been commissioned to undertake a strategic assessment of future flood risk management options to establish the most effective way of managing flood risk in Oxford and surrounding areas over the next 100 years.

1.3 Development of the Strategy Approval Report (StAR)

1.3.1 The Strategy Approval Report (StAR) describes the Environment Agency's Flood Risk Management Strategy for the 100 year period to 2108 for the city of Oxford and its surrounding villages. The key objectives of the Oxford Strategy are to: identify sustainable solutions to reduce flood risk to people and property; reduce the disruption and financial loss associated with road and railway flooding; improve the natural environment for the enjoyment of people and benefit of wildlife; and to be adaptable to future climate change.

1.3.2 This StAR implements the Thames Catchment Flood Management Plan's (CFMP) Upper Thames unit policies UT1 and UT6, which promote increasing conveyance in urban locations and improved use of floodplains in rural locations, respectively. This Strategy will also contribute to the Water Framework Directive (WFD) targets for maintaining and improving good ecological status or achieving good ecological potential in watercourses and the key aims of the Defra-led programme 'Making Space for Water', as well as contribute to the Environment Agency's corporate strategy 'Creating a Better Place'.

1.4 The purpose of this Technical Report

1.4.1 This report describes the technical studies of the OFRMS, how the project was developed, what decisions have been made and where theses decisions are recorded. It brings together all the investigations that have been undertaken as part of the OFRMS.

1.4.2 The investigations include hydrology, hydraulic modeling, hydrogeology, archaeology and contaminated land. This report is supported by a series of technical appendices which include detailed reports and briefing notes that explain the key elements within the OFRMS.

1.4.3 The contents of this report and its appendices will aid the development of project level appraisals and inform future project teams as to the level of technical detail completed at the Strategy stage.

1.4.4 This report supports the StAR which will be submitted to the National Review Group (NRG) in June 2009. The StAR sets out the business case for the preferred strategic option, and for reasons of clarity cannot include the vast amount of detail that is contained within this Technical Report and its Appendices.

1.5 Report Structure

1.5.1 This Technical Report is one of three reports that support the StAR. The other two reports are the Strategic Environmental Assessment (the SEA) and the Economic Appraisal.

1.5.2 This Technical Report is divided into a series of sections which describe and explain the key technical aspects of the work completed to identify the preferred strategic option to reduce flood risk in Oxford.

1.5.3 In order to make the report clear, summaries of detailed technical studies are included in the main text. The detailed technical studies are included for reference in Appendices to this report.

1.5.4 Sections 1 and 2 cover the background to the Strategy and the problems of flooding in Oxford. Section 3 covers the previous investigations that were carried out in the early stages of the OFRMS. It also describes the over 100 possible measures that were considered to reduce flood risk and the reasons for discounted them or taking them further.

1.5.5 Section 4 describes the work recently completed for the OFRMS. It addresses the technical constraints and issues identified within the Strategy, and it considers both structural and non-structural mitigation measures to alleviate flooding in Oxford.

1.5.6 Section 5 examines the possible measures and describes in detail those measures that can appropriately be used to reduce the impact of flooding in Oxford.

1.5.7 Section 6 compares these options, describes the selection methodology, and identifies the preferred option.

1.5.8 Section 7 proposes the timescale and implementation process for the preferred option.

2. Study Area and Flooding in Oxford

2.1 The City and Surrounding Area

2.1.1 Oxford is the main urban settlement within Oxfordshire and holds significant historic, cultural and socio-economic importance in the region. Parts of the city of Oxford are within the floodplains of the River Thames and the River Cherwell and are subject to flooding.

2.1.2 The study area has higher ground to the east and west, and a promontory of relatively high ground between the floodplains of the River Thames and River Cherwell on which the older part of the city of Oxford is located.

2.1.3 The newer parts of Oxford are generally to the east of the River Thames and River Cherwell whilst the village of Botley occupies higher ground approximately 3 kms to the west of the city centre. The land in the study area generally lies between 50 and 70 metres above Ordnance Datum.

2.1.4 The land use within the study area is mainly rural except for the city of Oxford and its surrounding suburbs. Over time Oxford city has expanded and now urban areas encroach into the River Thames floodplain. As a consequence, these urban areas are prone to flooding. These areas include the villages of; Wolvercote, Wytham, New Botley, Osney, Kennington, South Hinksey, North Hinksey, New Hinksey and the city centre areas of Jericho and Grandpont.

2.1.5 The majority of the study area is covered by alluvial silty clay with underlying River Terrace Deposits of sands and gravel. The silty clay is on average 1m thick and the thickness of the underlying sands and gravel varies from 1m to more than 4m.

2.1.6 The sands and gravel are water bearing and the groundwater level in this strata is generally 1m below ground level. The beds of the existing main river channels are often below the top of the sands and gravel deposits and therefore groundwater is likely to be in hydraulic continuity with those surface water features. Groundwater levels respond immediately to recharge events and surface water level variations.

2.2 The River System

2.2.1 The main rivers within the study area are the River Thames and the River Cherwell. The River Thames catchment draining to Sandford Lock is 3,086km^2, with its source in the Cotswold Hills to the north west. The lengths of the River Thames and River Cherwell in the study area are approximately 15km and 6km respectively.

2.2.2 There is a complex network of braided secondary watercourses (which are mostly located in the floodplain to the west) that contribute towards flow conveyance through and around Oxford. The most significant of these watercourses are listed below and shown on Figure 2.1:

- The Seacourt Stream is reputedly the original course of the River Thames. However, it now receives its flow by means of an overspill weir upstream of Kings Weir Lock.
- The Wolvercote Mill Stream diverges from the River Thames just above Kings Weir Lock and is navigable at least as far as the Dukes Cut, which provides a connection with the Oxford Canal. The Wolvercote Mill Stream continues as an overlarge impounded watercourse as far as Wolvercote Mill, below which it becomes a smaller more natural channel. It rejoins the River Thames at Godstow Lock.
- The Castle Mill Stream diverges from the River Thames at Fiddlers Island and

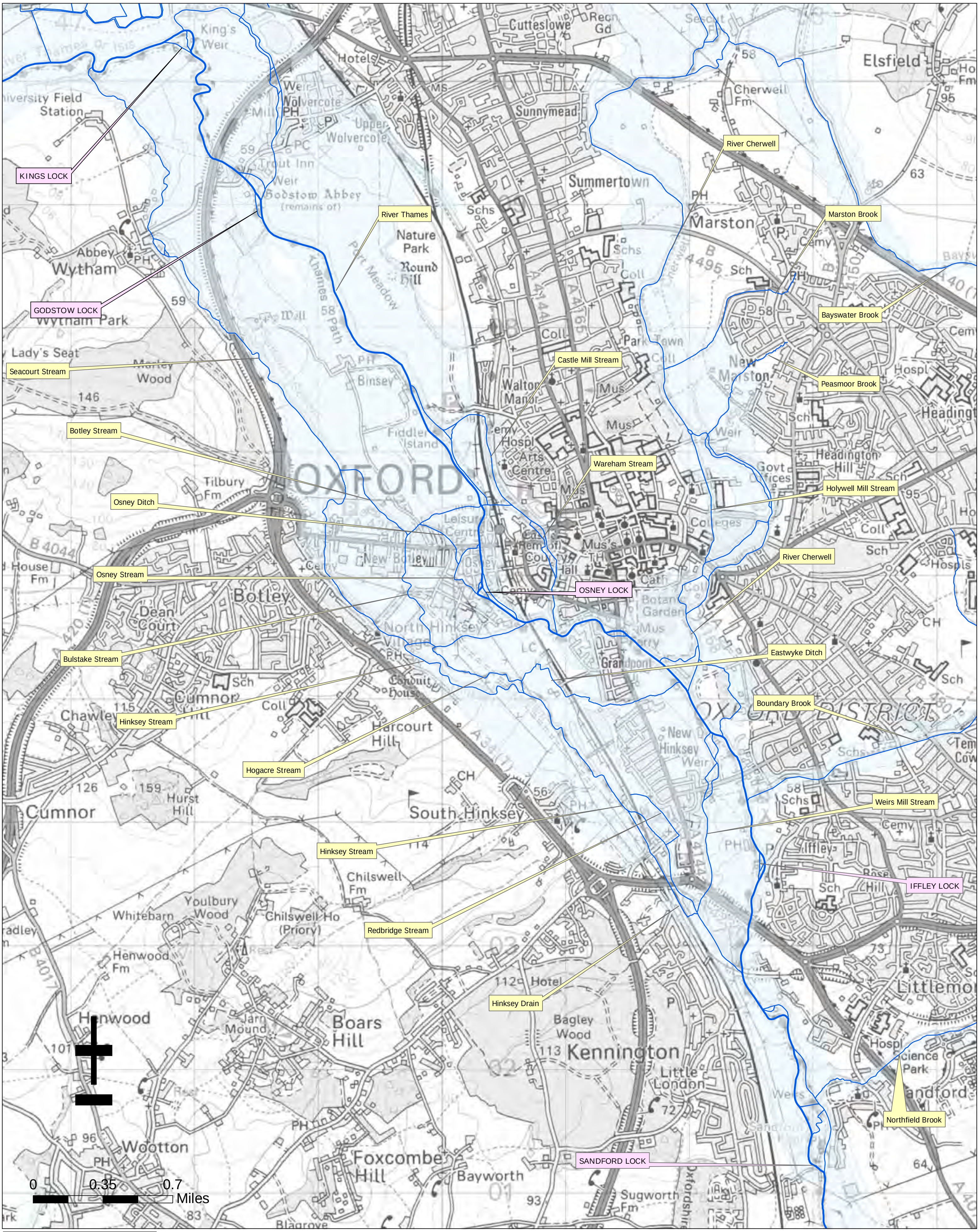
joins the Oxford Canal near the city centre. The canal joins the River Thames nominally 1 km south of the city centre.

- The Bulstake Stream diverges from the west bank of the River Thames north of Osney and rejoins the River Thames at the eastern end of Osney Mead Industrial Estate. Along its short course, the Bulstake Stream links with the Osney Ditch, the Botley Stream and the Seacourt Stream. The Botley Stream is just under 1 km in length diverging from the Seacourt Stream north of the Botley Road and joining the Bulstake Stream near the Botley Road.
- The Osney Ditch links the Bulstake Stream to the Osney Stream.
- The Hinksey Stream is effectively a continuation of the Seacourt Stream diverging at North Hinksey where the Seacourt Stream turns eastward to join the Bulstake Stream. It joins the Weirs Mill Stream near Kennington roundabout.
- The Eastwyke Ditch is a minor link approximately 1km long between the River Thames and the Hogacre Stream (which is a parallel branch of Hinksey Stream) just north of New Hinksey.
- The Redbridge Stream is a small drain that joins the Hinksey Stream just south of New Hinksey.
- The Hinksey Drain splits from the Hinksey Stream at South Hinksey and runs parallel with the Hinksey Stream until it re-joins it about 1 km downstream.
- The large Weirs Mill Stream splits from the River Thames at New Hinksey and passes through a weir system before joining the Hinksey Stream just south of the A4144/A4074 Kennington roundabout. About 500m after this confluence the Weirs Mill Stream joins with the River Thames at a control weir.

2.2.3 The width of the floodplain within the study area varies noticeably, with it being less than 500m wide upstream of Sandford Lock and over 2km wide to the west and north of Oxford city (refer to Figure 2.1on the following page).

Oxford Flood Risk Management Strategy - Stage II

Environment Agency



Key:

- River Thames
- Main River Watercourse
- Flood Zone 3 - 1 in 100

June 2007

2.3 The Mechanism of Flooding in Oxford

2.3.1 Flooding from the River Thames has been a constant threat to more than 3,600 homes and businesses that encroach into the floodplain of the rivers and watercourses in and around Oxford. Approximately 3,117 residential properties and 456 commercial properties are at risk from flooding (where the onset of economic damage occurs) in the 1 in 100 year (1% annual probability) flood event.

2.3.2 The cause of flooding is heavy rainfall on the upstream catchments with the result that rising groundwater in the underlying gravels cause surface flooding, whilst the rivers and other smaller watercourses over-top their banks. This mechanism has been discussed in the British Geological Survey (BGS) Defra conference paper on Groundwater Flooding in Oxford (refer to Appendix B).

2.3.3 The Oxford geomorphology is complex due to the natural environment and to the long history of human development. The old parts of the city tend to be sited on high ground with a number of Roman and Medieval roads cutting across the natural floodplain to reach the city. These roads have been developed over time and now act as significant barriers across the floodplain and to overland flood water.

2.3.4 Oxford has a complicated history of land ownership, surrounding the university colleges and contains a rich historical and archaeological interest. The western floodplain is also the site of numerous environmentally protected areas.

2.3.5 The floodplain consists of a gravel braided river system, with the River Thames as its centrepiece. Flooding into the floodplain occurs during storm events because the river network has insufficient capacity and the water-bearing gravel layers are saturated. Flooding is significantly increased due to the man-made restrictions to flow caused by local road / rail embankments and landfill sites.

2.3.6 Given the large size of the upstream catchment areas, most major floods on the River Thames and River Cherwell in the Oxford area occur as a result of heavy, persistent and widespread rainfall, perhaps combined with snowmelt. These events normally occur during the winter months but there are exceptions to this, as experienced in the July 2007 flood event.

2.3.7 The catchments are more likely to be saturated before the onset of the rainfall that causes the flooding. Due to the size of the River Thames and Cherwell, there is often a delayed response of 48 to 72 hours between the onset of rain and a noticeable increase in flows through Oxford.

2.3.8 As the River Thames flows increase, the Oxford lock keepers on the River Thames (at Kings, Godstow, Osney, Iffley and Sandford locks) progressively open the weirs and sluice gates to maintain the river level in the vicinity of the locks at a constant level, with the result that, during the early stages at least, the flows generally remain within banks.

2.3.9 However, once the flow control structures have been fully opened there is little more that can be done to directly affect water levels.

2.3.10 In events with return periods greater than 1 in 2 years, water will overtop the banks in numerous places filling the floodplain and finding an alternative flow route downstream.

2.3.11 During flood events, spillages from the River Thames channel can be observed flowing from both the left and right banks of the River Thames, immediately upstream of Kings Lock. Flooding from the north bank is contained by the nearby A40, flooding the historical flood meadows of Pixey and Yarnton Mead.

2.3.12 This flooding is then directed to rejoin the main channel of the River Thames at Kings Lock and the Wolvercote Stream north of Kings Lock. Some floodwater then follows the Wolvercote Stream through lower Wolvercote village and onto Port Meadow; parts of Wolvercote village are at flood risk being directly in the floodplain.

2.3.13 Floodwater that spills from the River Thames right bank (in the Kings Lock area) flows southwards following the line of the Seacourt Stream. As this floodwater flows along the western floodplain it comes constrained (at the Wytham villages) and affects a number of properties alongside the raised embankment of the A34 ring road.

2.3.14 Having passed through the bridge, beneath the A34, the Seacourt Stream, when in flood, then flows across the western side of the River Thames floodplain, continuing southwards towards the Botley Road.

2.3.15 A proportion of this flow follows the Seacourt Stream; whilst a similar proportion follows the line of the Botley Stream and heads toward the Bulstake Stream area, upstream of the Botley Road.

2.3.16 Similarly, on the eastern side of the floodplain the River Thames flows through Binsey village and in particular when out of banks, flows west and overspills into the Bulstake Stream through the Tumbling Bay area. Port Meadow is on the far west bank of the River Thames and floods often, as it forms part of the natural floodplain.

2.3.17 Floodwater backs up across a large area of floodplain to the north of the Botley Road as the road impedes flow. The five watercourses that flow beneath the Botley Road have a combined capacity of 125 cumecs before floodwater encroaches across the road itself, disrupting communication. Many properties both immediately to the north and south of this road are flooded when flows exceed this amount, particularly Duke and Earl Street, Old Botley and Bulstake Close. The Botley Road over-tops in a 1 in 10 to 1 in 15 year event.

2.3.18 Flood flows continue southwards along and beside the watercourses, south of the Botley Road especially along the western edge of the floodplain. These flows generally follow the route of the Seacourt Stream, which becomes the Hinksey Stream at North Hinksey.

2.3.19 The floodwater, especially at South Hinksey becomes contained between the railway and the A34 southern by-pass. At this point development across the floodplain north and beside Kennington, including: the mainline railway; the southern section of the A34; Redbridge 'Park & Ride'; and localised landfill sites, restrict clear passage of floodwater across this western side of the River Thames floodplain. This contributes to the flood risk of the Abingdon Road properties, which are mainly domestic residences.

2.3.20 Flood flows pass through and beneath the railway line, either within the Hinksey Stream or via any available route, such as the ballast supporting the railway line or smaller culverts; this supplements the ground water within and around Hinksey Lake.

2.3.21 This flow is eventually funneled towards Kennington by the Abingdon Road and high ground further to the west. At this point however, relatively recent development across the floodplain north of Kennington, which includes: the mainline railway; the southern section of the A34 ring road; the Redbridge 'Park & Ride' area; and localised landfill sites, appear to cause backing up of the floodwater across the River Thames floodplain.

2.3.22 The flood flows along the eastern part of the River Thames floodplain follows the main channel of the river through Osney and downstream to Iffley, this is joined by the floodwater from the River Cherwell, before flowing downstream to Sandford Lock. The Weirs Mill Stream links the River Thames directly to the lower part of the Hinksey Stream, generating additional flows in this very constricted area of Oxford.

2.3.23 During the peak of any flood greater than a 1 in 5 year event, significant overland flows bypass most, if not all, of the lock and sluice complexes on the River Thames within the Oxford area.

2.3.24 Many residential and commercial properties to the west of Oxford are adversely affected by flooding. This forces the closure of the Oxford to London railway line for several days by spilling across the track in the Redbridge area. It also causes major traffic disruption to south Oxford closing the Abingdon Road through New Hinksey, and the Kennington Road north of Kennington for several days.

2.3.25 In addition, if the River Cherwell catchment is affected, the River Cherwell will also burst its banks, as experienced during the January 2003 event. However, the flooding mechanism was less complex and significantly fewer properties and roads were affected.

2.3.26 The River Cherwell floodplain lies to the east of Oxford city and separates Headington from the city. At this point, the floodplain is approximately 500m wide but it narrows to approximately 50m wide where it passes under Magdalen Bridge before joining the River Thames near Grandpont.

2.3.27 There are very few properties at risk in the River Cherwell floodplain, except for a few at New Marston. Therefore, the impact of flooding from the River Cherwell is much less severe than in the River Thames floodplain to the west of Oxford.

2.3.28 From design hydrographs the River Cherwell contributes approximately 27% of the flow of the River Thames at Sandford Lock.

2.4 History of Flooding

2.4.1 The worst flood event in living memory occurred in 1947 when over 3,000 properties (as reported at the time) and numerous roads were badly affected by floodwater. The estimated return period of the 1947 flood was 1 in 75 years. Since then, there has been significant development on and adjacent to the floodplain, which has led to increasing vulnerability to flooding in the Oxford area. A prominent example of this is the Botley Road, an important transport route into Oxford, which is sited on a raised bank running across the floodplain to the west of Oxford. As discussed above, the Botley Road acts as a low dam causing flood damage by impeding flood water and overtopping.

2.4.2 In recent years, Oxford has experienced three floods: December 2000; January 2003; and July 2007, with the latest being the fourth significant flood event in the last 100 years.

Photo 1 - Low level flooding in West Oxford, July 2007

2.4.3 During the 2007 flood event, flows in the River Thames and River Cherwell increased gradually, raising water levels in both rivers through the afternoon of 20th July. During the late evening and into the early hours of the 21st July, the water level and the flow in the tributaries of the River Thames upstream of Oxford increased. Flows continued to build and the braided secondary watercourses that network through the Oxford floodplain were inundated. The Seacourt Stream, Hinksey Stream and Bulstake Stream were particularly affected. The return period of this flood event was 1 in 20 years and over 200 properties suffered from internal flooding. The return periods of the December 2000 and January 2003 events were 1 in 5 to 10 and 1 in 15 years respectively.

2.4.4 Table 2.1 shows significant recorded flood events in Oxford, and Table 2.2 indicates the approximate current standards of protection in Oxford.

Table 2.1 – Major Floods within the study area (Ranked according to peak discharge)

Years	Estimated Return Period	Peak discharge at Sandford Lock (m^3/s)
1894	1 in 100 years	278
1947	1 in 75 years	267
1903	1 in 20 years	229
1929	1 in 20 years	229
2007	1 in 20 years	225
1900	1 in 20 years	222
1904	1 in 15 years	217
1910	1 in 15 years	214
1933	1 in 15 years	214
1915	1 in 15 years	212
2003	1 in 15 years	212
1926	1 in 15 years	210

Table 2.2 – Current Standard of Protection in Oxford

Area*	Current Standard of Protection (Years)
Wolvercote	25-50
Binsey	5
Botley/Osney	5-10
Grandpont	5-10
South Hinksey	20-50
New Hinksey	10
River Cherwell Catchment	50-75
North Kennington	10-25

**Note - these areas are listed from north to south through Oxford*

2.5 The Area covered by the Strategy

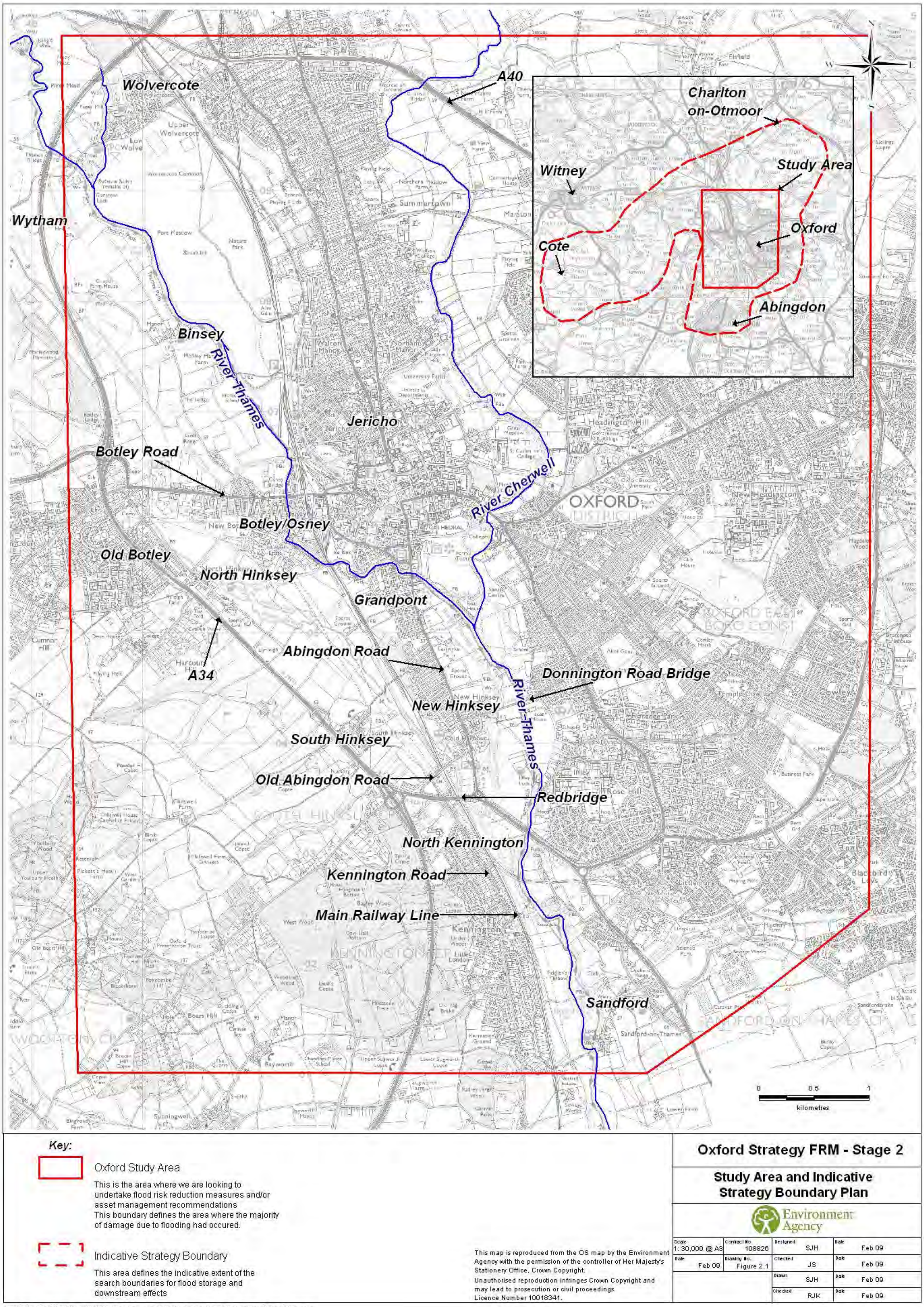
2.5.1 The Strategy study area (Figure 2.2) is bounded by Sandford Lock on the River Thames (south of Oxford), Kings Lock on the River Thames (north-west of Oxford) and the floodplain boundaries of the river as defined on the Environment Agency's flood map.

2.5.2 The Strategy study area also includes the floodplain of the River Cherwell between the A40 Oxford ring road and its confluence with the River Thames south of the city centre. The overall size of this area is approximately 30km², whilst the approximate lengths of the River Thames and the River Cherwell within the study area are 15km and 6km respectively.

2.5.3 A wider area, known as the indicative Strategy boundary (Figure 2.2) was considered to identify the impacts of the various strategic Flood Risk Management (FRM) measures. The indicative Strategy boundary is larger than the study area for the following reasons:

- The footprint of the potential engineering interventions considered in the strategic options needs to cover a wider area than the study area;
- Potential zones of influence (where there is the potential for increased or reduced flood risk). This has been taken to be the floodplain extent of a flood with a 1% (1 in 100) chance of happening in a year;
- Areas of potential enhancement (a 500m buffer either side of the River Thames and River Cherwell where this is larger than the floodplain as described above);
- To ascertain visual impacts, there is a requirement to look further than the study area. For example, any changes to the landscape and visual amenity may be viewed from further afield than the study area.

Figure 2.2 Oxford study area and indicative Strategy boundary



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3. Previous Investigations and Studies

3.1 Background Investigations

3.1.1 Investigations of flood risk management in Oxford have been on-going since the early 1990s.

3.1.2 Within the early stages of these investigations, the focus was on the flood mechanisms within Oxford and in particular why certain areas were more at risk of flooding than others.

3.1.3 By the start of 2000 the focus had moved towards putting together a Strategy Plan for Oxford to identify a preferred option to reduce the impact of flooding in the area.

3.1.4 Table 3.1 provides a brief history of all the previous investigations undertaken for Oxford. More details are given in Appendix A.

Table 3.1 – Previous Investigations for Oxford

Period	Study Stage
1992 – 2001	A series of hydraulic modelling studies (Peter Brett Associates)
May 2002	Oxford Flood Defence Strategy - Inception Stage (Black and Veatch)
Dec 2003	OFRMS - Strategy Plan (Black and Veatch)
Oct 2004	OFRMS Interim Strategy Report (Black and Veatch)
Nov 2004	Start OFRMS "Feasibility Study" - Stage 1 (Black & Veatch)
Apr 2006	Change "Feasibility Study" to OFRMS Strategy – Stage 2
2007	Interdependencies between surface and groundwater in Oxford (BGS/EA/Black & Veatch)
2007	Oxford City Council's Strategic Flood Risk Assessment (Oxford West End) (WS Atkins)
2008	Oxford City Council's Strategic Flood Risk Assessment (for all of Oxford) (WS Atkins)
2008	Report on flood risk in the west Oxford floodplain – for private clients (CE Rickard)
2009	Complete OFRMS Strategy – Stage 2 (Black & Veatch)

3.1.5 In February 2002, a FRM Strategy for the Oxford area commenced. This was necessary due to the lack of a Catchment Flood Management Plan (CFMP) and the size and relative complexity of the study area due to a variety of flooding mechanisms, environmental sensitivities and land use issues. The Inception Report for the OFRMS was issued in May 2002, and established the need for and strategic approach for the consideration of flood alleviation measures in the River Thames floodplain west of Oxford.

3.1.6 The study was carried out in stages, with the results of the first stage being presented in December 2003 in a Strategy Plan, which included a Strategic Environmental Assessment (SEA). The Strategy Plan identified that up to £7.2M might be needed to complete the study and produce subsequent Project Appraisal Reports (PARs).

3.1.7 Following internal and external consultation, in October 2004 the Interim Strategy Report was presented to and agreed by the National Review Group (NRG). The

Thames Regional Director subsequently gave a Scheme of Delegation (SoD) approval to undertake a "Feasibility Study", as a separate project.

3.1.8 This feasibility study and other subsequent phases were intended to develop the preferred option, which would be presented in a PAR. However, reconsideration of the risks to the preferred option, which had the capacity to alter its preferred status, became apparent.

3.1.9 Therefore, the Project Team met with the NRG Chairman on the 20th April 2006, to discuss the most appropriate way to advance the next stage of the Strategy to its conclusion in the most efficient way. The team decided to re-focus on submission of the Strategy, rather than through a phased feasibility study as originally proposed in order to mitigate the key outstanding risks. It was agreed to submit a Strategy Approval Report (StAR) with the supporting SEA to NRG in June 2009. The OFRMS StAR was developed in two stages: Stage 1 covers the work done under the "Feasibility Study" from November 2004 to April 2006 whilst Stage 2 covers the work done from November 2006 until the StAR was completed in 2009.

3.2 Flood Risk Management Measures considered in Stage 1

3.2.1 The focus of the OFRMS Stage 1 studies was to identify the most appropriate core engineering measures that would either function as a stand-alone or as a portfolio of measures to form the preferred flood risk management solution in Oxford over the next 100 years. Table 3.2 lists all of the reports that were prepared as part of the Stage 1 OFRMS:

Table 3. 2 – Stage 1 Reports

Title	Description	Date issued
Recreation Scoping Study	Study to develop an understanding of the use of the study area for recreational purposes, including type of recreation, location and level of usage and to develop a baseline recreational study which can be used to compare recreational impacts and potential benefits associated with the various flood risk management options.	Jul 05
Phase 1 River Habitat and River Corridor Survey	Study to establish the areas of conservation interest and provide baseline information.	Feb 06
Geomorphology Scoping Study	Study to develop an understanding of the geomorphology history of the study area, and to develop a baseline from which flood risk management options can be assessed.	Sep 05
Landscaping Study	Study which defines the baseline of the landscape of the study area so that the impact on the landscape of the options investigated can be assessed.	Jan 2006
Archaeological Report	Desktop study which identifies Scheduled Monuments within the study area.	June 2006
Do Nothing and Do Minimum Report	Report which defines the do nothing and do minimum options to be used for the OFRMS.	Jul 05
Option Identification Report	Report which identifies the flood risk management options to be considered during Stage 1 of the OFRMS.	Jul 05

Title	Description	Date issued
Summary of Upstream Storage Option Appraisal carried out during the Strategy Study	Report that investigates the upstream storage options identified in the Strategy Plan. It also recommends further work on upstream storage to be undertaken in Stage 2.	Jan 05
Economic Assessment Report and Western Conveyance Options	Report which analyses the costs and benefits of the "western" do something options.	Jan 2006
Risk Register	Stage 1 risk register listing risks, and costs associated with the risks.	Feb 06
Model Review Report – Feasibility Stage 1	Report which details the changes to be made to the hydraulic model used during the Strategy Plan and gives recommendations for future stages.	Aug 05
Report on Modelling of Western Options	Report which details the findings of the modelling carried out during Stage 1 of the OFRMS.	June 2006
Land Use Management Options for Oxford and Upper Thames	Report which includes a comprehensive review of recent and ongoing land use management research, with particular reference to the FD2114 – Review of Impacts of Rural Land Use and Management of Flood Generation, Sep 04	Feb 2006

3.2.2 The Foresight Future Flooding Report (Office of Science & Technology, 2004) was to be used as a framework to ensure all engineering and non-engineering measures were considered as a way to reduce flood risk in Oxford (refer to Appendix A).

3.2.3 The Foresight Report refers to flood reduction measures as 'Responses' and identified 21 possible responses, which it grouped into six themes, these are:

- Managing the Rural Landscape,
- Managing the Urban Fabric,
- Managing Flood Events,
- Managing Flood Losses for Existing Developments,
- Managing Flood Losses for New Developments, and
- Engineering Interventions.

3.2.4 Under the Foresight structure over 100 different engineering and non-engineering measures were considered in Stage 1. These ranged from minor works on locks and sluices to major works enlarging streams and providing new sections of channel to convey flood water.

3.2.5 Stage 1 involved a high level appraisal process which involved a series of three workshops with key people within the wider OFRMS project team. The objective of these workshops was to identify potential core engineering measures that would significantly reduce flood risk in Oxford.

3.2.6 As a result of these workshops and further consideration, the majority of these engineering measures were discounted for various reasons (refer to Table 3.3).

3.2.7 The main reasons for being discounted were that measures were either not technically feasible or that, by further inspection/engineering judgement it was concluded that they did not provide sufficient benefit in reducing flood risk. Wholesale provision of flood defences was discounted due to the high capital costs and potential of groundwater flooding on the dry side of the defence.

Table 3.3 - Discounted Measures

Flood Reduction Measures				Reason for Discounting
River Conveyance	***Foresight Response 18** – including: deepening and widening of existing channels; removing obstructions; and, constructing new channels.*	Channel Widening	River Thames	Discounted on the basis that there is insufficient land available for the extent of widening required. Also the widening would require the purchase of properties and the widened River Thames channel would be unacceptable on environmental and landscape grounds.
			River Cherwell	Discounted as the River Cherwell uses its natural floodplain effectively. Widening the channel wouldn't reduce the impact of flooding in Oxford
			Holywell Mill	Discounted due to costs and physical constraints
			Osney Ditch	
			St Clements	
			St Catherine's College	
			Botley	
		Removal of Control Structures	Thames	Discounted due to loss of navigation, possible adverse impact on water levels management of SAC and SSSIs. Also due to high costs of demolition.
			Cherwell	
			Seacourt	Discounted due to high cost of demolition, environmental damage of changing water levels.
			Bulstake	
			Holywell Mill	
			Hinksey	
			Osney ditch	
			St Clements	
			St Catherine's College	
			Botley	
		Enhance control structures	Sandford Lock Sluices	Discounted as the modelling results showed negligible impact on water levels at any return period
			Seacourt Stream Off take	Discounted as video evidence shows the structure is bypassed at high flows rendering any enhancements ineffective
			Bulstake Stream Bathing Weirs	Discounted as modelling results showed no impact on water levels above a 5 year return period
			Iffley Lock Sluices	Discounted as modelling results showed negligible impact on water levels at any return period
			Osney Lock Sluices	
			Kings Weir	
			Godstow Lock	Discounted as it was considered to be a low priority. It was not modelled as Godstow has small number of properties at risk
			Osney Weir B	Discounted as modelling results showed negligible impact on water levels at any return period
			Hinksey Stream Sluice	
			Osney Mill Sluice	
			Weirs Mill Stream Weir	
		New flood channels	Eastern edge of River Thames floodplain	Discounted as too difficult to find route

Flood Reduction Measures				Reason for Discounting
			FRC Binsey to Sandford	Discounted as the environmental and economic cases for extending a new flood channel north of Botley Road weren't favourable.
			Western edge of River Thames floodplain – Godstow to the Seacourt Stream	
			Western edge of River Thames floodplain – Binsey to the Seacourt Stream	
			Western edge of River Thames floodplain – River Cherwell floodplain	Discounted, as no route available in the River Cherwell floodplain
		Reduction of frictional resistance of existing channel - hard engineering solution		Discounted as hard engineering solutions are environmentally unacceptable and the costs would be too high.
		Culverting		Discounted due to high cost, high risk and the Environment Agency's policy regard to culverting watercourses. Although limited culverting might be appropriate
		Enhanced maintenance	River Thames	Discounted as regular maintenance is already taken to maintain navigation.
			River Cherwell	Discounted as there would be little or no benefit
		Reduce Downstream flood levels		Discounted as model shows local improvement upstream of Sandford but nowhere else. Improvements are insignificant.
		Remove localised constrictions in watercourse		Discounted - high headloss areas were modelled with reduced roughness, however results showed insignificant improvements.
		Winter abandonment of River Thames Navigation		Rejected. Due to legal position and technical difficulties with opening lock gates during floods. Also against EA policy to limit use of the Navigation.
Engineering Flood Storage	***Foresight Response 19*** *– includes the creation of storage sites to attenuate flows.*	Upstream Storage	River Cherwell	Discounted on cost grounds. Possible sites but extensive flood banks would be needed to impound the water.
		Storage in study area	River Thames	Discounted as no storage areas capable of storing the required volumes are available on the River Thames in the study area
			River Cherwell	
		Below ground storage		Discounted as potentially major impacts both during and after construction. Very high construction and operating costs.
		Divert to another catchment		Discounted, some routes technically feasible but high costs. High risk as could make problems worse elsewhere.
		Divert from River Thames to River		Discounted, as no viable route available and also high costs

Flood Reduction Measures				Reason for Discounting
		Cherwell		
		Groundwater recharge		Discounted as high construction and operating costs. Benefits not considered significant.
Water Transfer	***Foresight Response 20***	Transferring Flood Water from the River Thames Catchment		Discounted due to the cost and engineering infrastructure required
River Defences	***Foresight Response 21*** *– Includes constructing raised defences, either fixed or demountable.*	Increase height of defences		Discounted as there are no formal flood defences
		Decrease heights of defences		Discounted as there are no formal flood defences
		Localised Permanent flood defences	Wytham	Discounted as the use of localised permanent flood defences wasn't appropriate. This is due to the high level of surface water-groundwater connectivity, leading to a high risk of flooding behind defences.
			North of Botley Road Seacourt Stream to River Thames	
			Binsey	
			New Hinksey	
			North Hinksey	
			Kennington	
			Areas west of Iffley Road	
			Sandford	
			South Hinksey	
			South of Botley Road Seacourt Stream to Bulstake Stream	
			Area east of Binsey between the railway and the canal	
			Grandpont area on opposite bank of River Thames	
			Botley	
			Osney Island	

3.2.8 The conclusion of Stage 1 was that improved flood flow conveyance within the River Thames floodplain west and south west of Oxford and upstream floodplain storage were the feasible core engineering measures that would significantly reduce flood risk in Oxford. It was also concluded that assessment into non-engineering measures would be required as a potential solution to reduce residual flood risk. These were to be studied further in Stage 2.

4. Stage 2 Flood Risk Management Measures

4.1 Flood Risk Management Measures considered in Stage 2

4.1.1 A series of engineering and non-engineering measures from Stage 1 were considered in more detail in Stage 2. These measures are outlined below in Table 4.1.

Table 4.1 Engineering and Non-Engineering Measures that were considered in Stage 2

<table>
<tr><th colspan="4">Flood Reduction Measures</th></tr>
<tr><td rowspan="17">Non-Structural Measures</td><td rowspan="17">Foresight Responses 1 – 17</td><td rowspan="3">Managing the Rural Landscape</td><td>Rural Infiltration (Response 1)</td></tr>
<tr><td>Catchment-Wide Storage (Response 2)</td></tr>
<tr><td>Rural Conveyance (Response 3)</td></tr>
<tr><td rowspan="3">Managing the Urban Fabric</td><td>Urban Storage (Response 4)</td></tr>
<tr><td>Urban Infiltration (Response 5)</td></tr>
<tr><td>Urban Conveyance (Response 6)</td></tr>
<tr><td rowspan="5">Managing Flood Events</td><td>Pre-Event Measures (Response 7)</td></tr>
<tr><td>Flood Forecasting and Warning (Response 8)</td></tr>
<tr><td>Flood Fighting (Response 9)</td></tr>
<tr><td>Collective-Scale Damage Avoidance Action (Response 10)</td></tr>
<tr><td>Individual-Scale Damage Avoidance Action (Response 11)</td></tr>
<tr><td rowspan="2">Managing Flood Losses for Existing Development</td><td>Land-Use Management (Response 12)</td></tr>
<tr><td>Flood Proofing (Response 13)</td></tr>
<tr><td rowspan="4">Managing Flood Losses for New Development</td><td>Land-Use Planning (Response 14)</td></tr>
<tr><td>Building Codes (Response 15)</td></tr>
<tr><td>Insurance, Shared Risk Compensation (Response 16)</td></tr>
<tr><td>Health & Social Measure (Response 17)</td></tr>
<tr><td rowspan="9">Structural (River Conveyance)</td><td rowspan="9">Foresight Response 18 - including: deepening and widening of existing channels; removing obstructions; and, constructing new channels.</td><td rowspan="5">Channel Widening</td><td>Seacourt</td></tr>
<tr><td>Bulstake</td></tr>
<tr><td>Hinksey Stream</td></tr>
<tr><td>Weirs Mill Stream</td></tr>
<tr><td>Osney Mill Race</td></tr>
<tr><td rowspan="4">New Flood Channel</td><td>FRC Cold Harbour to Sandford</td></tr>
<tr><td>Western edge of River Thames floodplain - Kennington to downstream of Sandford Lock</td></tr>
<tr><td>Western edge of River Thames floodplain - South Hinksey to Kennington</td></tr>
<tr><td>Western edge of River Thames floodplain - Southern end of North Hinksey Village to Kennington</td></tr>
</table>

		Enhance Maintenance *Note: this considers desilting of all of the streams within the floodplain network*	Seacourt
			Bulstake
			Holywell Mill
			Hinksey Stream
			Osney drain
			St Clements
			St Catherine's
			Botley
			Hogacre Ditch
			Weirs Mill stream
			Binsey Drain
			Eastwyke Ditch
			Hinksey Ditch
			Osney Stream
			Redbridge Stream
		Enhance Control Structure	Towles Mill Sluice
			Wolvercote Mill
		Clearance of silt and vegetation from all watercourses	Wareham Park End
		Re- instate inoperable control structures	Morrels Brewery Sluice
Structural – (Engineering Flood Storage)	***Foresight Response 19** – includes creation of storage sites to attenuate flows.*	Upstream Storage	River Thames *Note: Stage 1 identified that upstream storage was not a viable stand-alone measure. However, in combination with improve river conveyance, it could potentially be a viable measures*
Structural – (Floodwater Transfer)	***Foresight Response 20***	Floodwater Transfer	Transferring floodwater from the Thames catchment to either the nearby Severn, Avon or Ouse catchments
Structural – (River Defences)	***Foresight Response 21** – includes constructing raised defences, either fixed or demountable.*	Localised Permanent flood defences	Wolvercote
		Localised Temporary flood defences	Osney Island, Vicarage Lane and Lake Street
		Individual property protection	Response 13 (Flood Proofing)

4.2 Technical Studies in Stage 2

Introduction

4.2.1 The technical studies in Stage 2 were carried out to ensure that the engineering interventions proposed under the OFRMS would be technically feasible and would not adversely affect the existing groundwater regime on which the environmentally sensitive Oxford Meadows SAC depends.

4.2.2 The studies comprised hydrology, river modelling, hydrogeology, contaminated land (due to existence of disused landfills in the floodplain), archaeological considerations, physical obstacles in the floodplain and the design of improved conveyance channels. The reports and briefing notes of these studies are included within Appendix B.

Hydrological Assessment

4.2.3 In 2002, Black & Veatch carried out a hydrological study for the Oxford area to derive an updated set of design inflows for the Oxford ISIS model. The design flows from this study have been used in subsequent studies, including the Stage 2 hydrological review, which involved updating flood hydrographs with additional flood events such as July 2007 and new rating curves developed by EdenVale for the Environment Agency's Flood Forecasting project.

4.2.4 The key objective of this hydrological review was to provide design flood hydrographs, for events with return periods ranging from 2 years to 200 years, for those catchments that drain to the River Thames between Eynsham and Sandford. These flood hydrographs were subsequently used in the hydraulic model of the River Thames in the vicinity of Oxford.

4.2.5 The key findings from these studies are:

- Compared with the flood hydrographs used for previous stages of the Strategy, the revised hydrology has resulted higher flows in lower return period (2 to 10 years) and lower flows in higher return period (100 to 200 years). For example, the new maximum peak flow at Sandford Lock for a 2 year storm is 142 m^3/s compared to previous assumptions of 125 m^3/s.
- This is consistent with our observation that the previous modelling work tended to have too high a return period flood as a threshold of flooding.
- All design events are of long duration, supporting the use of a steady state analysis for option testing and initial design.

4.2.6 For further details about the Strategy's hydrological review, refer to the OFRMS Hydrology Report in Appendix B.

Hydraulic Assessment

4.2.7 There have recently been a number of hydraulic assessments of the River Thames at Oxford. These have included the development of the Oxford Flood Forecasting ISIS (1D) model, which was based on the River Thames model initially developed in the 1990s.

4.2.8 As part of the Stage 2 hydraulic assessment, initial works included improving, upgrading and recalibration of the existing Oxford Flood Forecasting model. The reasons for using the Oxford Flood Forecasting model within Stage 2 include:

- It has been based on a long-standing calibrated ISIS model;
- The flood forecasting study further refined and calibrated the model; and

- The current study has again refined the model calibration.

4.2.9 The original ISIS model was constructed by the National Rivers Authority in the early 1990s and over the years various improvements have been made as additional information has become available. The model has remained ‘fit for purpose’ for the Strategy, and flood risk management analysis work throughout its history.

4.2.10 As part of the Stage 2 studies a number of improvements, upgrades and recalibrations of the model were undertaken, these included:

- Upgrading the representation of the floodplain by ISIS reservoir units within the model using the LiDAR survey data flown in 2005 and checking the impact this has on the existing model. We have carried out further hydraulic calculations on a representative sample of critical hydraulic structures, such as bridges and weirs, to check that the model appropriately reflects these structures.
- Rigorous recalibration and verification processes using real data from recent flood events - 1998, 2000, 2003, 2007 and 2008. This calibration has been supplemented by site inspection of actual flood marks on locks/bridges and referring to available photos of flood events where appropriate.

4.2.11 In addition, as part of the Stage 2 assessment we also developed a combined 1D-2D model, which involved replacing the existing flood storage sections with sections of 2D floodplain. The 2-D solutions allow water to find its own path, whereas in a 1D model the user explicitly defines the drainage path. This combined model uses the ISIS-TUFLOW software and is based on the recalibrated ISIS model. The combined 1D-2D model has been used to evaluate the 1D model and provide a visual representation of the flood mechanism. The 2D model gave slightly lower water levels than the 1D ISIS model, but the higher water levels were used in the results on the basis that it is safer to be slightly conservative.

4.2.12 For further details about the Strategy’s hydraulic modelling and results, refer to the OFRMS Hydraulic Reports in Appendix B. These reports detail the modelling scope, verification, assessment and results.

Hydrogeological Assessment

4.2.13 The majority of the study area is covered by alluvial clay with underlying River Terrace Deposits of sands and gravel. The alluvial clay is on average 1m thick and the thickness of the underlying sands and gravel varies from 1m to more than 4m.

4.2.14 The sands and gravel are water bearing and the groundwater level in this strata is generally 1m below ground level. The beds of the existing main river channels are often below the top of the sands and gravel deposits and therefore groundwater is likely to be in hydraulic continuity with those surface water features. Groundwater levels respond quickly to recharge events and surface water level variations.

4.2.15 Because of this close hydraulic continuity within the study area, further investigation into the local hydrogeology was carried out. This investigation expanded on the ongoing groundwater monitoring project in partnership with British Geological Society (BGS). Based on the data collected, BGS have developed a 3-D geological model which has been used to complete a preliminary assessment of the risk of groundwater flooding.

4.2.16 The initial findings from this assessment identified that between 80 and 330 properties are potentially at risk from groundwater flooding (at ground level) as well as fluvial flooding. These are mainly located in the Grandpont area of Oxford (refer to BGS Oxford Groundwater Flooding Report in Appendix B).

4.2.17 In addition to this work, the Strategy completed a hydrogeological review to understand the existing hydrogeological conditions of the River Thames floodplain around Oxford and to assess the potential impacts the Western Conveyance channel may have on groundwater levels. Because of the hydraulic continuity between the river system and groundwater, the proposed Western Conveyance channel will reduce groundwater flood risk by virtue of its higher capacity to drain the floodplain.

4.2.18 The main conclusion from the review indicated that to maintain the groundwater level adjacent to the proposed Western Conveyance channel in non-flood conditions, the normal operational top water level of the channel should be maintained at a similar level to the existing groundwater level. One way this can be achieved is by setting the gradient between the Western Conveyance channel water level and the existing groundwater level by providing a series of flow control structures.

4.2.19 The reason for ensuring that there is minimal impact on the groundwater regime within the area is because there are a number of environmentally sensitive sites, such as the Oxford Meadows SAC which are groundwater dependant.

4.2.20 Based on these conclusions, the Western Conveyance channel will be suitably designed to take into consideration the sensitive groundwater/surface water conductivity regime. The review recommends that further ground investigations works are undertaken at the location of any hydraulic flow structures and infrastructure crossings. This would provide site specific information on ground conditions and geotechnical parameters to be used in the detailed design.

4.2.21 Hydraulic flow structures proposed for the Western Conveyance channel should have adjustable weirs or settings to allow fine tuning of the groundwater/surface water interface.

4.2.22 For further details, refer to the OFRMS Hydrogeological Review in Appendix B.

Contaminated Land

4.2.23 As part of an initial study into the core engineering measures within Stage 1, contaminated land was identified as a key risk to the project. Although the majority of the study area is open or agricultural land, there are some locations that have a long industrial history. Therefore, as part of the OFRMS Stage 2 investigations a contaminated land and geotechnical assessment of the study area was carried out.

4.2.24 The aim of these assessments was to identify any potential contamination constraints that would cause financial and programme risks to the project, in particular the implementation of the Western Conveyance channel.

4.2.25 An initial desk based assessment of potential contamination risk within the study area was completed. This desk study highlighted a number of locations within the area which were of concern and recommended that an intrusive site investigation was carried out to obtain further information on ground and groundwater conditions in the area and to test for the presence of contamination at these locations.

4.2.26 Based on these recommendations, an intrusive site investigation was carried out on areas identified as being the highest risk. In particular, this focussed on the area around Old Abingdon Road where a number of historic landfills are present, although other areas were also investigated. The site investigation fieldwork consisted of twenty boreholes sunk to depths of between 1.20m and 14.10m below ground level and sixteen trial pits excavated to depths of between 0.50m and 3.10m below ground level. 50mm standpipes were installed in most of the boreholes to monitor water levels and ground gas conditions. Samples were taken from the boreholes and trial pits and laboratory tested for contaminants.

4.2.27 The purpose of the investigation was to determine the ground and groundwater conditions for both geotechnical and contamination assessment of the proposed Western Conveyance alignment, in order to allow a preliminary channel design to be completed.

4.2.28 The site investigation showed that there were minor elevations of various contaminants across the assessment area. Some samples exceeded generic residential assessment criteria, but further qualitative assessment showed there to be only a low risk. However, all samples were found to be below industrial/commercial assessment criteria, with the exception of two samples from within the historic landfills which exceeded these for lead concentrations. As expected, landfill gas was found to be elevated within the area of the historic landfills, in particular at the Redbridge Park & Ride.

4.2.29 An assessment of current potential pollutant linkages between contaminants and receptors has shown there to be a low risk. However, any change in land use or removal of cover materials may require a further assessment, and additional protection/remediation may be required. In particular, it is likely that further assessment will be required in order to ensure the safety of groundworkers during any construction works, who are likely to be those most at risk.

4.2.30 For further details, refer to the OFRMS Geotechnical and Contaminated Land Reports in Appendix B.

Archaeology

4.2.31 There is a wealth of cultural and archaeological heritage within the study area. Therefore, as part of the OFRMS Stage 2 investigations, archaeological investigations of the study area were carried out to identify any potential archaeological constraints that would cause financial and programme risks to the project. This work is described more fully in the Strategic Environmental Assessment (SEA) Environmental Report but is mentioned here as it may pose a risk to the proposed flood risk management measures.

4.2.32 A desk based assessment of historical aerial photography, the Oxford County Council Historic Environment Record (HER) and palaeo-environmental records was undertaken and used to produce an archaeological risk map of the western floodplain of the River Thames. The results of these studies are presented in Appendix B. Furthermore, a desk based analysis of the HER for the wider study area was undertaken and this was used to produce an archaeological risk map of the wider study area.

4.2.33 Additional archaeology investigations were undertaken to determine whether there were any archaeological constraints associated with the Old Abingdon Road which is thought to have been built on the site of an old Norman causeway, similar to that discovered at Grandpont. This archaeology assessment included a desk study and a non intrusive Ground Penetrating Radar (GPR) survey on the Old Abingdon Road Bridge and its approaches to determine whether there would be any constraints that would prevent increasing flow conveyance, constructing new structures to convey flood flow or widening of existing structures as part of the Western Conveyance channel. The results of this study is presented in Appendix B.

4.2.34 The archaeology risk mapping has shown that it should be possible to enlarge existing channels and create new channels within the western corridor without adverse impact on areas of high archaeological sensitivity (national designations). The assessment of geophysical survey work and desk based studies have also indicated areas of low archaeological risk along the Old Abingdon Road indicating the potential to enlarge existing structures or create new structures to pass additional flood flows.

4.2.35 English Heritage, Oxfordshire County Council and Oxford City Council archaeologists have been consulted on the archaeology risk mapping and potential channel widening under the Old Abingdon Road. The outcomes were that, although it will be challenging to reach a consensus between interested parties, an acceptable solution can be found.

Landscape Character

4.2.36 The landscape of the OFRMS study area has been almost completely determined by the geomorphology, ecological processes, and human activity associated with the River Thames and its tributaries.

4.2.37 The city of Oxford and its urban fringe form much of the character of the central section of the study area. Upstream of Oxford the landscape is more remote and tranquil and contains flood meadows, small woodlands, pasture, and willows growing on the river banks. However, overhead powerlines are a key detracting feature throughout the study area.

4.2.38 The visual impact of the OFRMS proposals may stretch beyond the extent of the study area. Therefore, a zone of inter-visibility has been developed to assess the impact of the options upon key visual receptors.

4.2.39 Several key statutorily designated landscapes fall within or across the study area. These include the Oxford Green Belt; a number of Built Conservation Areas and Registered Parks and Gardens of Historic Interest; and a series of protected views to the city of Oxford.

4.2.40 We have undertaken a Landscape Character Assessment of the study area following Natural England guidelines and in line with the European Landscape Convention's 'All Landscapes Matter' approach. The resultant Landscape Strategy incorporates the many character areas identified across the study area, the landscape units within them, and their relative sensitivity to change. For further details, refer to the OFRMS Landscape Character Report in Appendix B.

Infrastructure Impediments to Flood Flow

4.2.41 Parts of the western floodplain are heavily developed, and as a result, impede flood flows. There are two areas in particular that cause significant impact on flood flow conveyance; these are the Botley Road causeway and the Redbridge corridor.

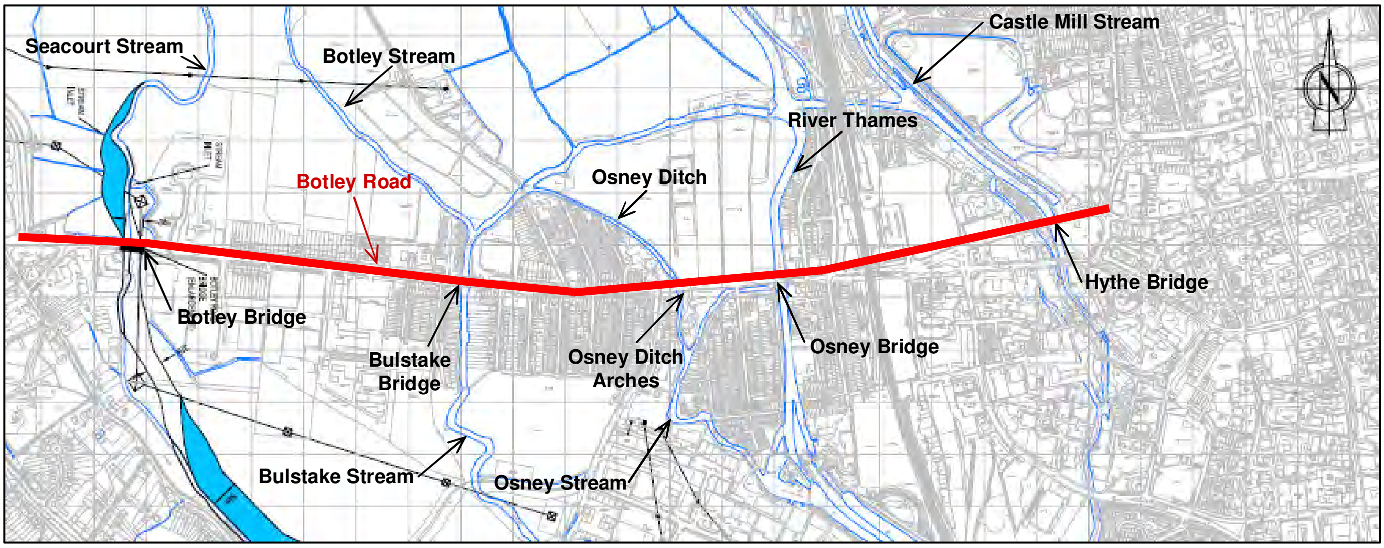
Botley Road causeway

4.2.42 Botley Road is an arterial route into Oxford from the west and is constructed on a causeway through the River Thames western floodplain. The Botley Road area is heavily developed with both residential and commercial property, which reduces the effectiveness of the western floodplain even further.

4.2.43 Five distinct openings exist through the Botley Road. From west to east, they convey the watercourses of: the Seacourt Stream; Bulstake Stream; Osney Ditch; River Thames; and Castle Mill Stream. These five watercourses provide the essential link between the floodplains to the north and south of the Botley Road. If these floodplains reach their maximum capacity then the only remaining route for flood water is to overtop the Botley Road. This occurred in 2007 and caused flooding to residential and commercial properties and closed the Botley Road for seven days from 21st to 28th July.

4.2.44 As part of the technical assessment for the OFRMS, an investigation has been undertaken of the capacity of the bridges and culverts along Botley Road and where conveyance improvements could be made. Figure 4.1 below shows the location of these bridges and culverts along Botley Road.

Figure 4.1 Bridges, Culverts and Watercourse along Botley Road



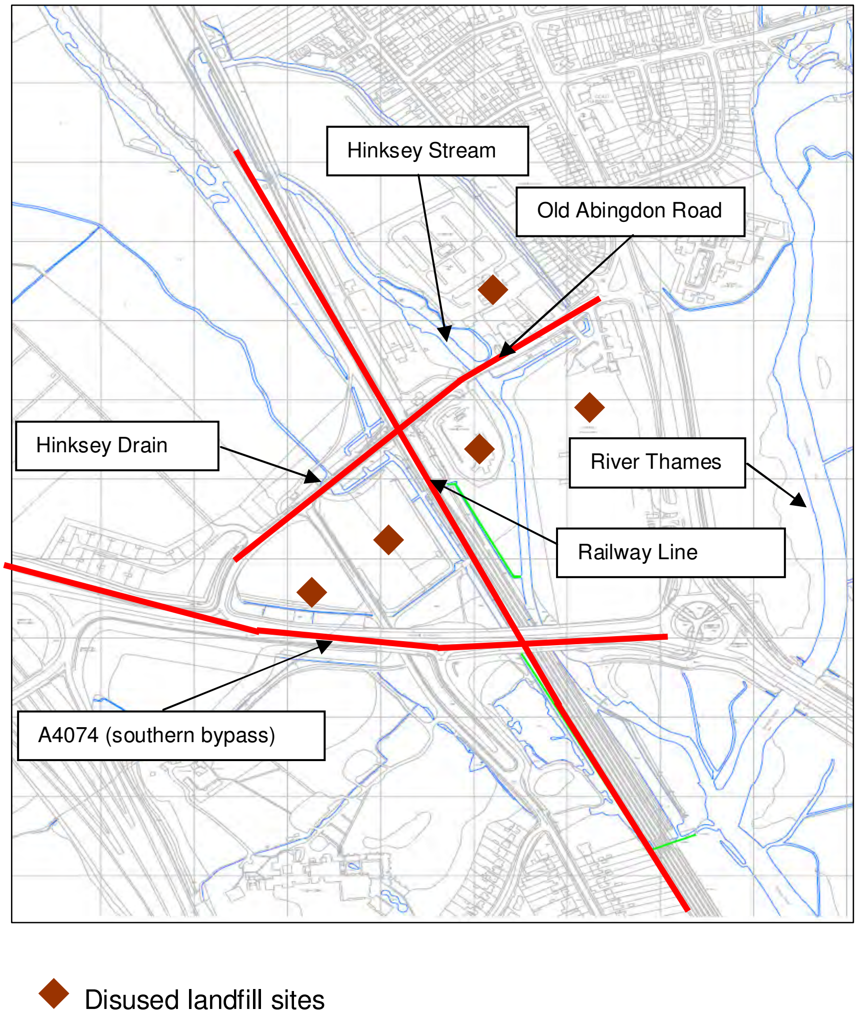
4.2.45 This study concluded that in general the Botley Road bridges have a greater capacity than the streams that flow under them. This study also concluded that widening of the Seacourt Stream and the associated Botley Bridge (which carries Botley Road over the Seacourt Stream) would provide the most economically viable opportunity to increase the flood flow conveyance through this area. The existing Botley Bridge has a significant span which would allow the capacity of the Seacourt Stream to be substantially increased at this point. Further hydraulic modelling work would be needed to confirm the required structure size; however this initial assessment identified the potential to widen by 10m on the right bank and 5m on the left bank. Furthermore, the Seacourt Stream is furthest from the city centre and has the least amount of development on the adjacent banks. This indicates that widening the stream in this location would be both practical and cost effective.

4.2.46 For further details about the flow conveyance at Botley Road, refer to the OFRMS Botley Road Conveyance Briefing Note in Appendix B.

Redbridge Corridor

4.2.47 The Redbridge area refers to the southern part of Oxford city where the A4074 southern bypass road crosses the River Thames floodplain. The area is immediately identifiable as the major arteries of the Old Abingdon Road, the A4074 southern bypass road, and the main railway line from Southampton to Birmingham form an elongated triangle of land. Figure 4.2 shows the location of these features.

Figure 4.2 Bridges and Streams in the Redbridge Area



4.2.48 The flood water which spills out of the banks of the River Thames and its secondary watercourses onto the western floodplain must be conveyed through this area in order that it can rejoin the River Thames in the Sandford area.

4.2.49 Like the Botley Road, the flood flow conveyance in this area is poor due to a number of constrictions to flow. A study of these constraints identified four main factors:

- The railway line which runs through the corridor is the main freight link from Southampton to the Midlands. The railway currently has only three culverts with limited capacity to convey flows from the west side of the railway back to the River Thames.
- Old Abingdon Road has limited capacity to convey flows from the western floodplain back into the River Thames. Also, parts of this road have been identified as being of potential high archaeological sensitivity.
- Disused landfill sites south of the Old Abingdon Road pose issues with constructing or enlarging channels due to the potential for leaching into the water system. Furthermore, the landfills have built up the existing floodplain by approximately 1.3m which has reduced storage volume and conveyance in this area.
- The Southern Bypass Road (A4074) currently passes the western flows from the north to the South of the western area by channels that run parallel with the main railway route under the A4074.

4.2.50 The study recommends: a widened channel under the A4074; a new culvert under Old Abingdon Road; a new culvert under Kennington Road; and a new culvert pipe-jacked under the railway.

4.2.51 For further details about flow conveyance at Redbridge, refer to the OFRMS Redbridge Briefing Note in Appendix B.

4.3 Improved Flow Conveyance

Introduction

4.3.1 The studies carried out under the Strategy conclude that an improved flood flow conveyance within the River Thames western and south western floodplain would significantly reduce flood risk in Oxford. The flow improvements could be achieved by the construction of a new or enlarged watercourse in this part of the floodplain.

4.3.2 This engineering measure is known as "Western Conveyance" within the OFRMS and will be referred to as this within this report.

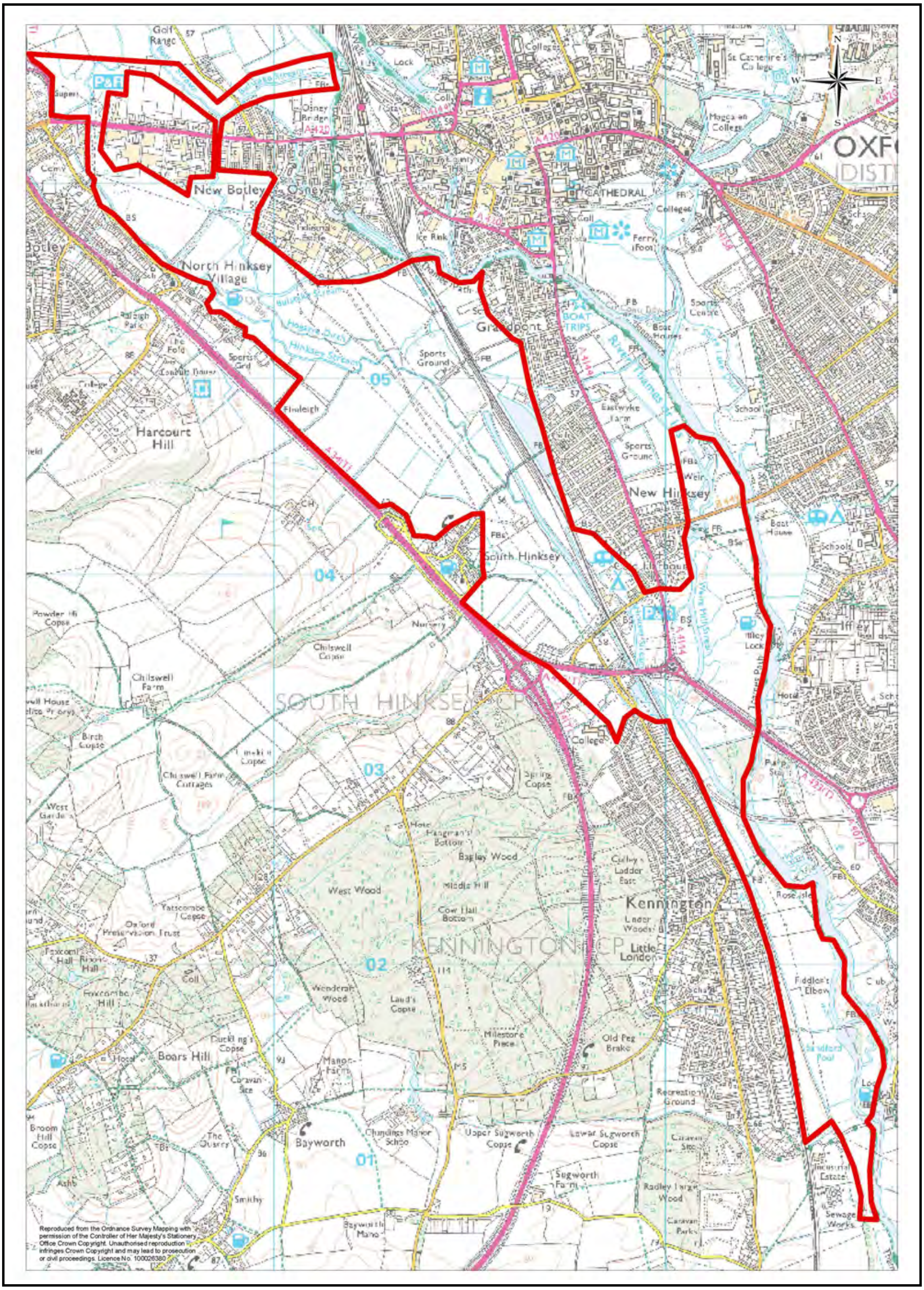
4.3.3 Western Conveyance will be made up of the following components:

- Enlargement of existing channels.
- Creation of a new channel where enlargement is not possible.
- Creation of second stage channel in some locations (on both new and existing channels).
- Installation and operation of two off-take structures; one on the Seacourt Stream and one on the River Thames.
- Five tilting weirs along the course of the conveyance channel which will be used to maintain high water levels in the channel to prevent drawdown of surrounding groundwater.

4.3.4 To reduce land take, where possible the Western Conveyance will firstly be improved through the enlargement of existing channels and then by a new channel. Enlargement of existing channels will result in some adverse impacts on riparian habitat but these can be mitigated by re-planting and selection of an alignment involving least disturbance.

4.3.5 An indicative corridor for the alignment of the Western Conveyance channel has been identified in the western area of Oxford, which extends south from Botley Road to past Sandford Lock. Refer to Figure 4.3 which shows the red line boundary map of the conveyance corridor. The exact alignment of the Western Conveyance within this corridor has not been determined in the OFRMS; this will be determined at PAR stage.

Figure 4.3 – Red line Boundary Map



4.3.6 Western Conveyance will not extend northwards of Botley Road, as a channel in this location may have an adverse affect on the environmentally sensitive Oxford Meadows SAC. Refer to the OFRMS Briefing Note on excluding a channel north of Botley Road in Appendix B.

4.3.7 The conveyance channel will have two off-take structures; one on the Seacourt Stream at Botley Road; and the second at Rose Island on the River Thames. Under normal conditions, base flow in the conveyance channel will be from groundwater, which will be supplemented by a sweetening flow from other watercourses when possible (i.e. not in very low flow conditions).

4.3.8 The off-take structure on the Seacourt Stream at Botley Road will be an in-line control structure that allows flood flows to pass down the Western Conveyance channel, but will hold river and groundwater at existing levels upstream, so as not to adversely affect the Oxford Meadows SAC.

4.3.9 The off-take structure at Rose Island will be a side weir that will take flood flows from the River Thames opposite Rose Island down a new channel that will form the last section of the Western Conveyance. This new channel will re-join the River Thames after Sandford Lock thus bypassing the existing bottleneck there.

4.3.10 Western Conveyance will have two parts:

- The improved conveyance from Botley Road to below Sandford Lock; and
- Enlargement of the existing Weirs Mill Stream where pinch-points restrict flow. This watercourse will be widened to convey an extra $25m^3/s$ above its existing capacity of $47m^3/s$. A top width of 28m for this channel is required to meet this additional flow capacity and this means that the channel has to be widened (on one side only) in three locations totaling approximately 900m of bank length. Refer to the OFRMS Briefing Note on widening Weirs Mills Stream in Appendix B.

4.3.11 Widening of the Weirs Mill Stream will reduce flood risk in Grandpont and North Hinksey caused by flood flows coming down the River Cherwell and joining the River Thames at this location. Modelling of the widening of Weirs Mill Stream showed benefits with all Western Conveyance channel options. It is therefore, an important feature of the Western Conveyance proposal.

4.3.12 Any enlargement of watercourses would be achieved by widening the main channel and adding a second higher stage channel where there are no constraints. Where there are constraints the channel will be either a simple trapezoidal section, or if there are severe constraints the channel will have a rectangular section. The new higher secondary stages will have their beds above normal groundwater level so that for most of the year they remain dry.

4.3.13 It is estimated that five tilting weirs will be used to maintain a base flow in the channel under normal conditions in order to preserve existing groundwater levels. The tilting weirs will have fish and canoe passes.

4.3.14 Modelling studies were used to predict the impact on downstream water levels due to Western Conveyance. These are described in detail in the Downstream Effects Briefing Note in Appendix B. The results compare the water levels just downstream of the study area before and after making conveyance improvements in the floodplain to the west of Oxford. The difference in the water levels indicates that there are extremely small increases of less than 6mm before and after the improvements.

Typical Channel Cross Sections

4.3.15 For the purposes of hydraulic modelling and cost estimates we have assumed that the Western Conveyance channel will be made up of three typical cross sections (refer to Figure 4.4a-b) each with an average depth of 2.5m to 3.0m:

- **Constrained channel** – used for areas that have physical constraints that do not allow for widening and based on a channel with vertical sides;
- **Semi-constrained channel** – a typical trapezoidal shape with landscaping; and
- **Unconstrained channel** – a two stage channel with a higher stage that would remain dry under normal conditions and would be nominally 1m deep. On average the slopes of the second stage will be 1:10.

4.3.16 Three sizes of channel have been considered as options for Western Conveyance (again refer to Figure 4.4a-b):

- Figure 4a - Western Conveyance small channel (WC Small) with a trapezoidal cross section area of 25m^2;
- Figure 4b - Western Conveyance medium channel (WC Medium) with a trapezoidal cross section area of 50m^2; and
- Figure 4c - Western Conveyance large channel (WC Large) with a trapezoidal cross section area of 70m^2.

Figure 4.4a - Western Conveyance Typical Channel Cross Sections

WC Small = 25m^2

Not to scale

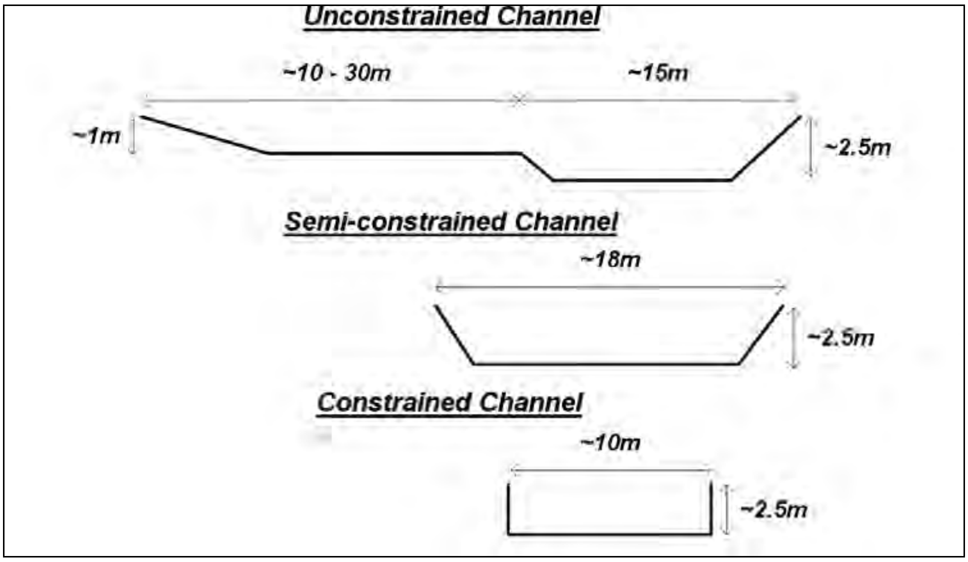


Figure 4.4b - Western Conveyance Typical Channel Cross Sections (Medium)

<u>WC Medium = 50m²</u>

Not to scale

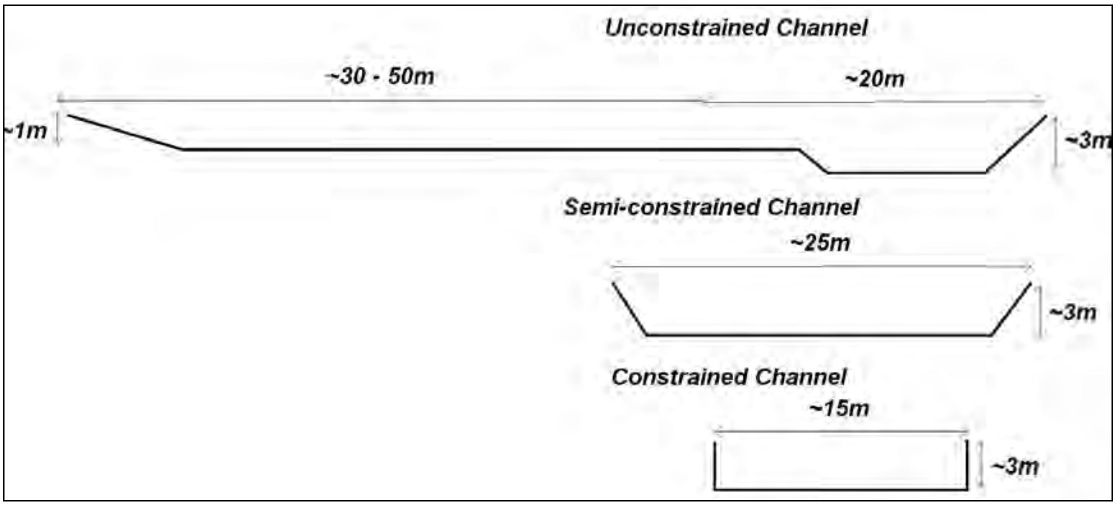
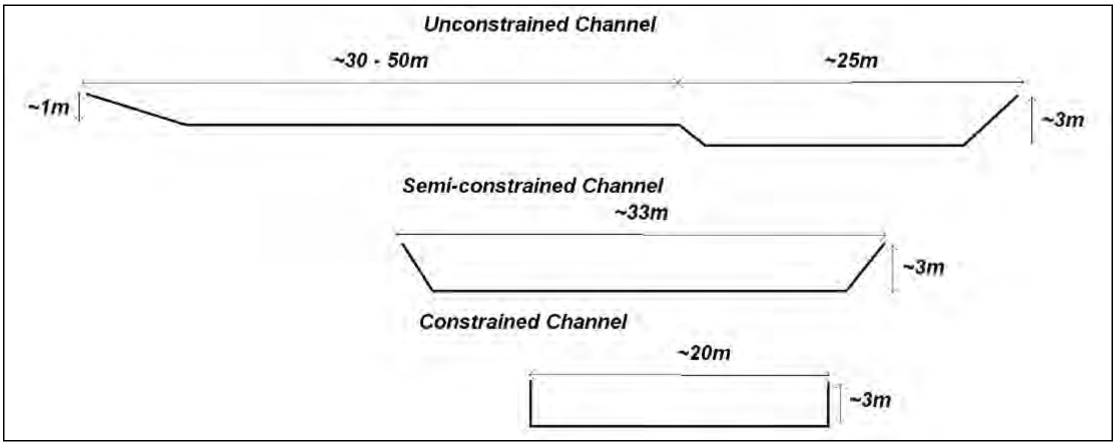


Figure 4.4c - Western Conveyance Typical Channel Cross Sections (Large)

WC Large = 70m²

Not to scale



4.3.17 The indicative widths of the channel cross sections shown above are from modelling results and are for strategic level assessment only.

Modelling Results

4.3.18 The three sizes of channel have been hydraulically modelled to determine their capacity. Assuming the channel shapes as shown in Figure 4.5, the modelling results indicate that the estimated maximum in-bank flows are:

- WC Small: 18 – 20 m^3/s;
- WC Medium Channel: 35 – 40 m^3/s; and
- WC Large: 55 – 60 m^3/s.

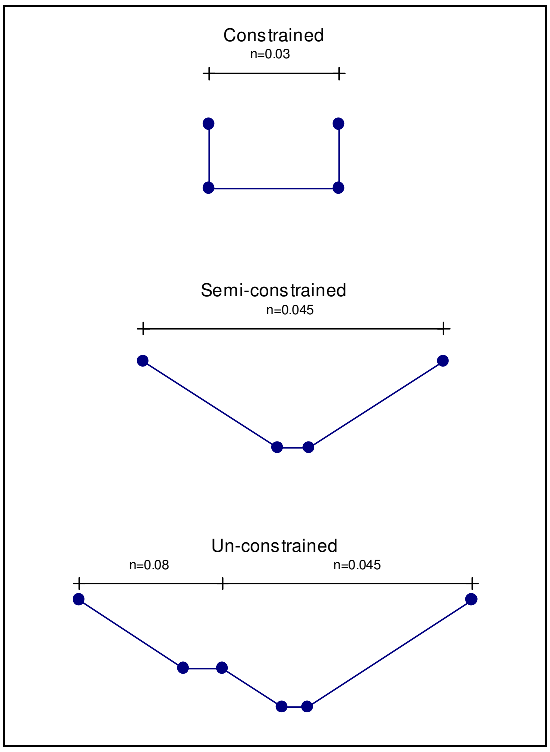


Figure 4.5 – Western Conveyance Channel Types

4.3.19 The flows have been estimated using Manning's equation for uniform flow in open channels with n varying from 0.03 to 0.08 depending on the channel roughness.

4.3.20 Modelling has been used to establish flood levels at nodes throughout the study area for 1 in 2, 5, 10, 25, 50, 75, 100 and 200 year flood events.

4.3.21 The longitudinal gradient has been assumed as 1:1355 for the upper part of the Western Conveyance and 1:1216 for the lower section that starts at Rose Island.

4.3.22 It was assumed in the hydraulic model that the Western Conveyance channel runs parallel to the existing water courses with 'glass wall' banks (i.e. no connection to the floodplains). This is a reasonable assumption as the flood flows remain in-bank during the modelling runs. Details of the assumptions for these models are given in the 'Hydraulic Modelling Reports' in Appendix B.

4.3.23 The groundwater in the Western Conveyance area is high at approximately 1m below the ground level. Due to the high hydraulic conductivity of the gravels a channel in the area during low flow periods would draw down the ground water level. To avoid this effect weirs will be used to maintain a high water level in the channel during low flow periods, and prevent a draw down in groundwater levels.

4.3.24 The model has been run in steady state conditions so that any changes in channel storage between options will not affect the model results.

4.3.25 Another channel option was considered. This was to widen the River Thames from Botley Road to Sandford Lock by about 20m to give an extra capacity of 40m^3/s. Physical and environmental constraints affecting this proposal meant that it was not feasible. More details of this proposal refer to the Briefing Note on Widening of the River Thames in Appendix B.

Whole Life Costs

4.3.26 The whole life costs for the three different channel sizes of Western Conveyance were calculated. These costs were based on a number of assumptions on the construction of the channels. These assumptions are:

- Site clearance required;
- Haul roads;
- Volume of top soil to be excavated, stored and removed;
- Length and types of fencing that will be required temporarily and permanently;
- Presence of contaminated land'
- Excavation volumes;
- Disposal of acceptable and unacceptable material;
- Landscaping;
- Groundwater levels;
- Potential diversions required around listed structures;
- Structures required e.g. flow control structures, weirs, culverts, footbridges, road bridges; and
- Scour protection.

4.3.27 For details about these assumptions, please refer to the cost spreadsheets in Appendix C.

4.3.28 Maintenance costs have been included as part of Western Conveyance and comprise the following components:

- Staff requirements to carry out additional routine maintenance work;
- Civil engineering requirements – maintenance of the new structures e.g. replacement of hand railing or routine repair work. This is estimated to be 0.50% per annum of the construction cost of each structure;
- M&E requirements – general maintenance for the operation of the new control structures e.g. replacement of seals, telemetry, operation gear and gates;
- Channel requirements – general maintenance and weed cutting of the new two-stage channels; and
- Landscaping - for 4 years after completion of the works.

4.3.29 The whole life costs are outlined in Table 4.2 below. An optimism bias of 42%, which was calculated using the EA standard risk table, has been included. It should be noted that the cost of the Weirs Mill Stream enlargement is included in the total scheme capital cost. For further details about the costs, refer to Appendix C.

Table 4.2: Western Conveyance Whole Life Costs

Size	Total Scheme Capital Cost (2008) (£M)	Optimism Bias (42%) (£M)	Total Scheme Capital Cost (2008) incl. OB (£M)	Freeboard (6%)	Total Scheme Maintenance Costs over 100yrs (£M)	Whole Life Scheme Cost With Freeboard (£M)
Small	59.6	25	84.6	3.6	96.7	184.9
Medium	84.7	35.6	120.4	5	57.3	182.8
Large	96.9	40.7	137.6	5.8	124.8	268.2

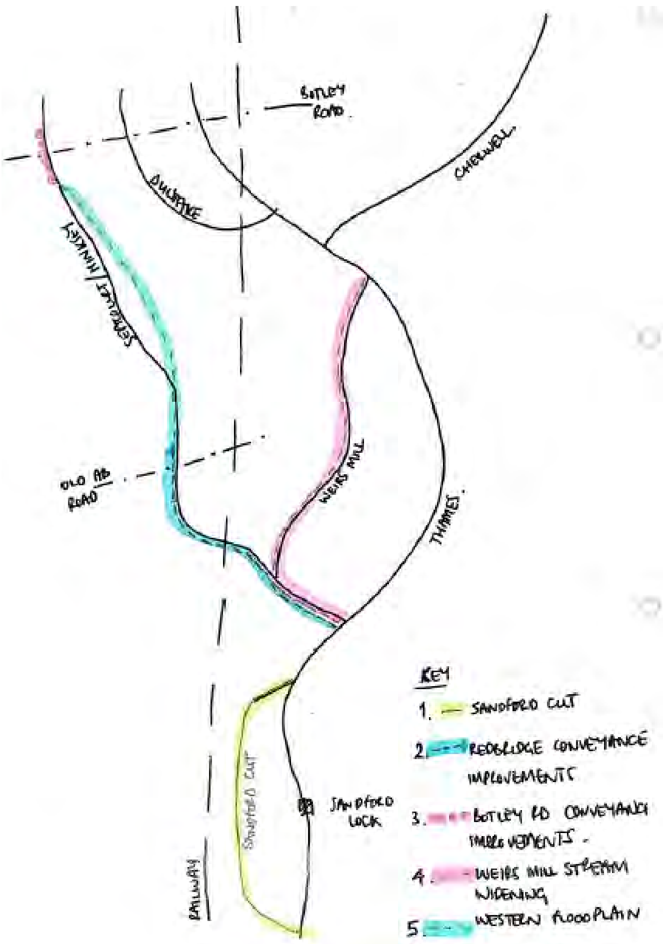
Splitting Up of the Channel

4.3.30 As part of the technical appraisal of the western conveyance, the channel was split into several reach which were appraised individually and in various combinations to identify whether it was economically justifiable to:

- Implement individual or combinations of reaches instead of the full Western Conveyance option, or
- Construct the lower reaches of the channel prior to the upstream reaches in a phased construction implementation plan (refer to Appendix B.16 for further details).

4.3.31 These reaches were (refer to Sketch 4.1):

1. Sandford Cut,
2. Redbridge conveyance improvement
3. Botley Road conveyance improvements,
4. Weirs Mill Stream widening and Western floodplain channel.
5. Western floodplain



Sketch 4.1 - Western Conveyance Model Components

4.3.32 As part of this exercise a high level costs review was undertaken to identify the costs associated with each of component. The estimate costs are provided in Table 4.3.

Table 4.3: Costs per reach within Western Conveyance

Component No.	Component	Costs
1	Sandford Cut	~ £22.6M
2	Redbridge conveyance improvements	~ £33M
3	Botley Road conveyance improvements	~ £7.8M
4	Weirs Mills Stream widening	~ £2M
5	Western floodplain channel	~ £52M

Note 1. these costs are based on WC50 (Option 6)
Note 2. refer to Appendix B.19 for an illustrated map showing the key benefit areas and the cost for each of the above western conveyance components.

4.3.33 To determine whether it would be economically advantageous and technically feasible to implement parts or all of the Western Conveyance option, we modelled the five reaches identified in Section 4.3.31 (based on WC50) in various combinations (refer to Appendix B.19 for further details).

4.3.34 This high level screening exercise, identified that the most attractive combinations for phasing in western conveyance would be: Sandford Cut or Sandford Cut and Redbridge or Sandford Cut, Redbridge and Weirs Mill Stream.

4.4 Upstream Flood Storage

Introduction

4.4.1 As described in Section 3, upstream flood storage in combination with improved flood flow conveyance could be an effective engineering measure to reduce flood risk in Oxford. Therefore, based on the investigation completed in Stage 1 on upstream storage, further assessment has been undertaken to identify the preferred location of any upstream storage.

4.4.2 The previous investigation identified five upstream storage areas: four on the River Thames; and one on the River Cherwell, all of these are upstream of Oxford.

4.4.3 The aim of the flood storage is to reduce and control the downstream flows by temporarily storing water upstream during the peak of the flood. This is achieved by controlling the maximum discharge passed downstream to a predetermined amount.

4.4.4 The stored floodwater in the storage area is typically released downstream after the flood peak has passed, at a rate to prevent flooding and which leaves the storage area once again dry (Figure 4.6).

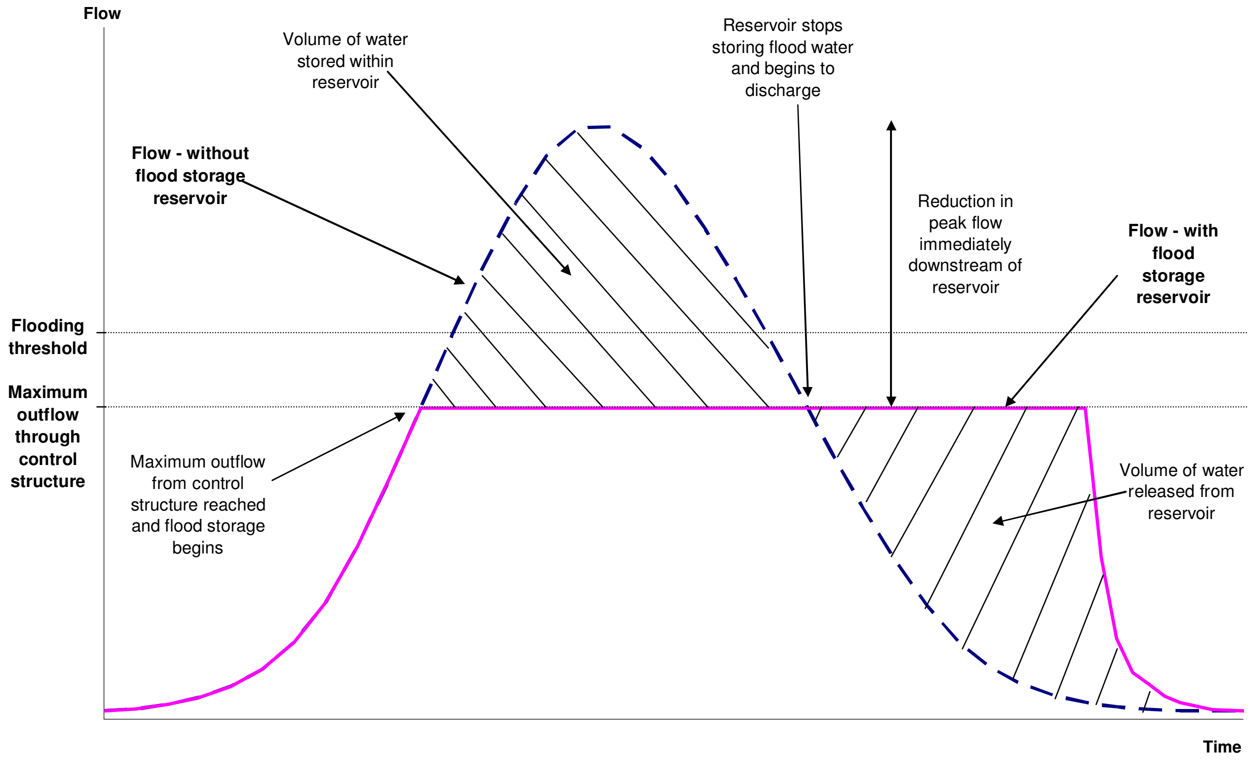


Figure 4.6 - Generalised hydrograph - Flow downstream of an effective flood storage area

Upstream Storage Options

4.4.5 Five storage area options upstream of Oxford were considered and although none of these are suitable as a standalone option they could be used in conjunction with the Western Conveyance option. These sites were chosen based on:

- Available land (i.e. pastoral land with a limited number of properties);
- Distance upstream of Oxford so that the storage area captures a minimum of 1/3

of the catchment above Botley Road for the River Thames options, and 1/3 of the Cherwell catchment for the River Cherwell option;

- Large volume to store flood waters to reduce the flood flows to an acceptable level; and
- Consideration of environmental and social issues.

4.4.6 The approximate locations of the five storage areas are shown on Figure 4.7.

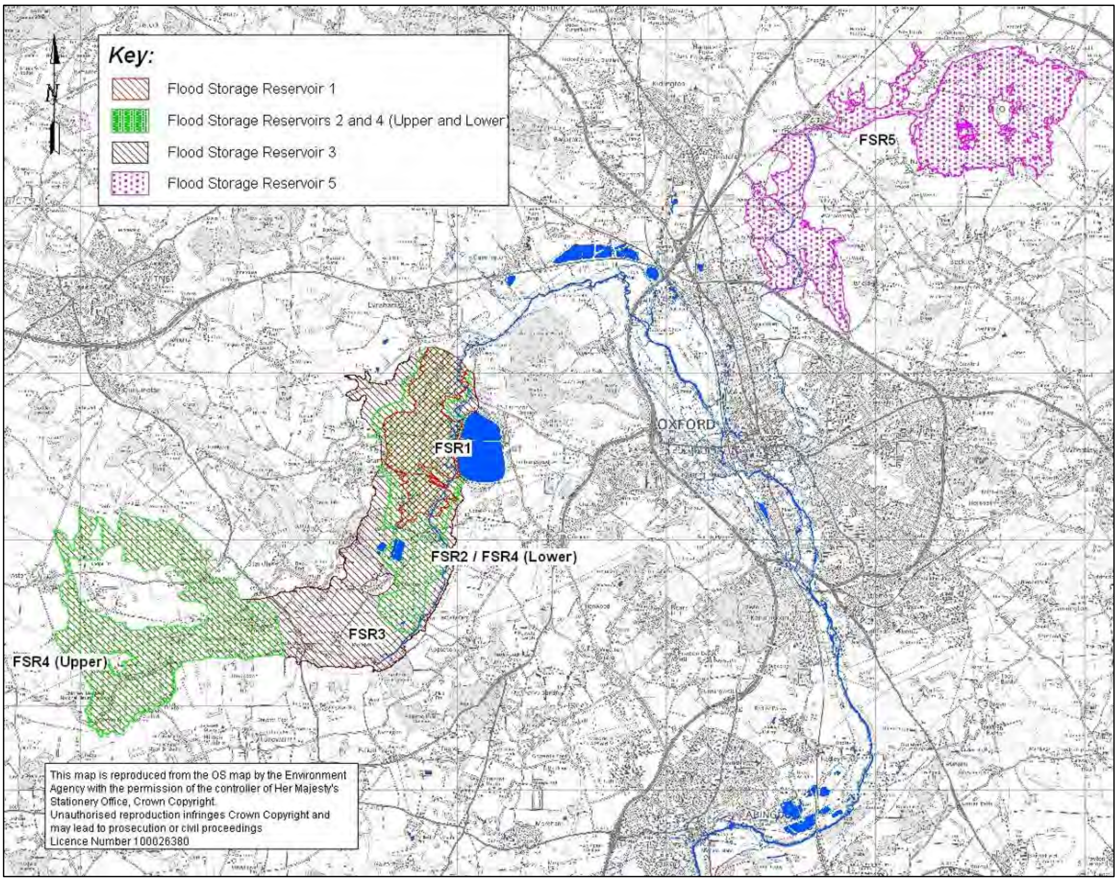
4.4.7 Table 4.3 provides a summary of the five storage options and reasons why they were not considered further. The peak flow downstream of the Evenlode confluence for a 100 year event without storage would be 193m^3/s. Table 4.3 illustrates the attenuating effect of each storage option.

4.4.8 For further details about each of the storage area options, refer to the Upstream Storage Briefing Note in Appendix B.

Table 4.3 – Five Upstream Storage Options

Flood Storage Area (FSA)	Volume (Mm^3)	Area (km^2)	Revised 1 in 100 year Peak Flow on the River Thames (m^3/s)*	Appraisal points	Preferred Option
FSA 1	2	4.8	173	No significant reduction in flood risk	X
FSA 2 (Lower)	8.7	10	148	Effects on Farmoor reservoir embankments Inundation of 90 properties and a caravan park	X
FSA 3	45.2	31.6	92	Large storage area Effects on Farmoor reservoir embankments Large number of properties would be inundated, including the villages of Northmoor and Newbridge	X
FSA 4 (Combined)	8.7	10	127	FSA	X
FSA 4-a (Upper)	9.9	12	160	Only affects 4 properties	✓
FSA 5	5	21	N/A	Effect stability of railway embankment No significant reduction in flood risk	X
*existing peak flow on the River Thames = 191m^3/s					

Figure 4.7 - Locations of the Five Upstream Storage Areas



Selecting the Preferred Storage Area Option

4.4.9 As illustrated in Table 4.3 above, Flood Storage Area (FSA) 1 was excluded based on the small effect it would have on reducing flood flows, and thus the cost benefit would be small. FSA 5 was excluded due to its impacts on environmental receptors, its uncertain technical viability, and the relatively small reduction in flood flows upstream of the River Cherwell confluence. FSA 3 was also excluded based on its large storage area footprint which not only inundates a large number of properties but also isolates a village which results in a very high cost.

4.4.10 Three options were taken to the second stage of appraisal: FSA 4 lower (same as FSA 2); FSA 4 upper; and FSA 4 tiered storage.

4.4.11 From the flood storage environmental appraisal (these section 6.2 of the SEA Environmental Report) the tiered storage (upper and lower combined) would have the greatest environmental impact. This is primarily because a larger area will be temporarily affected, thus potentially impacting upon an increased number of environmental receptors. Therefore, a single storage area is the environmentally preferred option.

4.4.12 From the environmental appraisal it was determined that although the lower storage area would have a greater impact upon the built environment (within its storage footprint) than the upper storage area, it would have a lesser impact compared to the upper storage area on the natural environment. Neither of the single storage area options has been ruled out on the grounds of environmental impact.

4.4.13 The main difference between the upper and the lower storage area is that the lower storage area inundates a greater number of properties (i.e. 94 properties in the lower storage area and only 4 for the upper storage area). This results in a much higher cost to remove or relocate the properties for the lower storage area. As a result, the upper storage area (located above the A414 at Newbridge) has been selected as the preferred engineered storage location.

4.4.14 In addition, FSA 4 upper was also the most appropriate choice for the OFRMS because:

- It captures at least a 1/3 of the catchment area for Oxford (applies to both River Thames and River Cherwell);
- The volume of the storage area is sufficient to reduce the flood flows;
- There are only 4 properties that are in the storage area envelope;
- The existing area is predominantly pastoral land where the current land use may continue (outside of times of flood).

4.4.15 Consideration of the storage area options is given in the Upstream Storage Briefing Note in Appendix B.

Preferred Storage Area

4.4.16 The storage area will have one main embankment, which will be located above the A415 with a maximum height of 1.5m and a length of 2km. There will be four secondary embankments also with a maximum height of 1.5m that will protect houses at the outer extent of the storage area envelope. The downstream embankment will be designed so that it can be safely overtopped in flood events above 100 year flood event. Table 4.4 below outlines the main key elements of the storage area.

Table 4.4: FSA 4 Upper Storage Area Details

Upper Storage Area Elements	Details*
Top water level (AOD)	65m
Catchment area	1226km^2 (32% of Sandford catchment area)
Storage Area	1217 hectares
Main Embankment – Height	1.6m
Main Embankment - Length	2000m
Maximum floodplain depth	Ranges between 1m – 3m (Maximum 3m)
Auxiliary Spillway	Downstream embankment designed to be safely overtopped in an event over a 1 in 100 year (1% AEP) flood event
Volume of Storage Area	9.89M.m^3
Inundated properties	4
Additional flood defences required to protect local settlements Properties at risk:	Shifford, Cote, 4 additional embankments Also raising a section of the B4449 to ensure access to Cote during flood events
Control structure	Three radial gates with widths 5m by 4m high
Navigation	Open gate only closed during flood events

**Note: these figures and the storage design are indicative for the OFRMS. Further assessment of the storage area will be undertaken during scheme appraisal.*

4.4.17 Table 4.5 provides a summary of the flood flow reduction (on the River Thames at Eynsham and after the confluence with the Evenlode) prior to the storage area being built and post completion.

Table 4.5 - Peak flows prior to storage area and after implementation

Return period	River Thames at Eynsham		River Thames after Confluence with Evenlode	
	Pre Scheme Peak Flow (m^3/s)	Post Scheme Peak flow (m^3/s)	Pre Scheme Peak Flow (m^3/s)	Post Scheme Peak Flow (m^3/s)
10	116.6	116.6	142.8	142.8
20	129.1	113.8	158.0	142.8
50	145.5	114.2	178.1	146.8
75	151.7	119.5	158.0	153.5
100	157.4	124.0	192.7	159.3

4.4.18 Table 4.6 provides a summary of the change in return period of flows at Sandford Lock as a result of the upstream storage area.

Table 4.6 - Changes in Return Period at Sandford Lock

Return period	Peak Flows at Sandford Lock		New Return period
	Pre Scheme (m^3/s)	Post Scheme (m^3/s)	
2	142	142	2
5	183	183	5
10	206	206	10
20	228	213	13
50	257	226	19
75	268	236	24
100	**278**	**245**	**37**
200	299	264	57

Whole Life Costs

4.4.19 The whole life costs for the upstream storage area were based on a number of different projects with similar characteristics such as the Banbury flood storage project. All of the costs for the upstream storage area were inflated to 2008 prices (Refer to the costs spreadsheets in Appendix C for details) and assumptions on the following aspects were made:

- Construction Costs;
- Operation and Maintenance Costs;
- Staff Requirements;

- M&E Requirements (specialist maintenance costs for control structures);
- Landscaping; and
- After flood event costs (possible additional maintenance).

4.4.20 The present value (PV) whole life costs are outlined in Table 4.7 below. The standard factor for optimism bias for large public procurement projects in the UK is 60%, however, this has been reduced to 55% in this case using the EA standard risk table. For further details about this optimism bias reduction, refer to the cost details in Appendix C.

Table 4.7: Upstream Storage 100 Year PV Whole Life Costs

Total Scheme Capital Cost (2008) PV	Optimism Bias (55%)	Total Scheme Capital Cost (2008) incl. OB, PV	Total Scheme Maintenance Costs over 100yrs, PV	100 Year PV Whole Life Costs
£ 36,686,031	£ 20,177,317	£ 56,863,348	£ 5,278,994	£ 62,142,342

Summary

4.4.21 An engineered FSA upstream of Oxford could be constructed and operated to help alleviate floods downstream in Oxford. However, it has been identified that a storage area could not be a standalone engineering measure as it only attenuates flood events with a return period greater than 1 in 10 years, but flooding of property occurs at Binsey with a return period of 5 years.

4.4.22 Therefore, this measure should be combined with other engineering measures such as the Western Conveyance to alleviate the risk of flooding in Oxford. The preferred FSA is situated above Newbridge with the downstream embankment (1.5m high) parallel to the A415. The storage area would have a top water level of 65m AOD with a storage volume of 9.9Mm3. For a 100 year event this storage area would reduce the River Thames flow that enters Oxford at the northern end by approximately 33m^3/s to help reduce flood risk in Oxford city.

4.5 Water Transfer

Introduction

4.5.1 This section provides a discussion on whether flood water transfer from the River Thames catchment to a nearby catchment is a feasible option for alleviating the problem of flooding in Oxford. Water transfer involves the engineered relocation of water from one river catchment to another. This engineering intervention is usually used as a response to irrigation water supply and water scarcity issues. However, theoretically it has the potential of being used to reduce the flood impact on one catchment by transferring flood waters to another catchment, which is not simultaneously experiencing flooding. However, this would mean significant alterations to the catchments natural hydrological regime, major engineering works to physically transfer the flood water and potentially significant environmental impacts during and post construction and also during operation.

Discussion

4.5.2 A flood water transfer scheme to alleviate the flood risk to Oxford would involve diverting flood water from the River Thames (upstream of the city) to an adjacent catchment, either the River Severn, River Avon or Great Ouse catchments. Although this option is theoretically possible, in reality there are several factors that would render this option technically, economically or environmentally non viable. The key factors are described below:

- The River Thames catchment above Oxford has a catchment area of 3,806km^2 (measured at Sandford lock). The 3 nearest (and largest) catchments to which water could be transferred are shown in Table 4.8.

Table 4.8 - Large river catchments nearest to Oxford

River	Location	Catchment Area (km^2)	Distance from Oxford (km)
Severn	Gloucester	9,970	65
Ouse	Milton Keynes	500	45
Avon	Chippenham	560	68

- It is clear from the figures in the Table 4.8 that two of the catchments are too small (considering proportions of catchment areas). All three neighbouring catchments are a significant distance away.
- Due to the climate and general topography of the UK, the catchments adjacent to the River Thames are likely to experience some degree of flooding simultaneously. Therefore, transferring flood water from the River Thames may increase the flood risk to people and property in the adjacent catchments.
- To transfer water effectively would require one or several large diameter tunnels or large diameter pumped transfer pipelines. The volume of water to be transferred in a 1:100 year event is estimated to be in the region of 80Mm^3. With a flood duration of 9 days, this would require the transfer system to discharge at approximately 100m^3/s.
- Both capital and operating costs of transferring this volume of water over this length of distance would be extremely expensive (it would be significantly more expensive than more localised options).
- The risks to achieving implementation would be extremely high as it could impact on existing infrastructure, environmental sensitivities, cross administrative boundaries, and negotiate urban areas to name some of the many constraints.

Conclusion

4.5.3 The option of water transfer is not considered viable for managing flood risk in Oxford.

4.6 Non-structural methods

4.6.1 The Foresight Report's non-structural responses (1 – 17) were considered as part of the Strategy to manage flood risk in Oxford 'Non-structural responses'. The approaches (of the responses) generally refers to the management actions to reduce either the extent or the impact of flood events, rather than major structural interventions (such as the construction of large flood channel, flood storage or flood defence schemes) to achieve these ends. Refer to Tables 4.1 & 4.9.

4.6.2 Each of these responses was investigated and assessed in regard to their suitability as part of the Oxford Strategy (refer to the 'Foresight Response Summary and Responses 1 -17 Briefing Notes' in Appendix B).

4.6.3 The results of this assessment concluded that the following responses should be included in the Strategy:

- Response 7 – Pre-Event Measures
- Response 8 – Flood Forecasting and Warning
- Response 9 – Flood Fighting
- Response 10 – Collective-Scale Damage Avoidance
- Response 11 - Individual-Scale Damage Avoidance
- Response 13 – Flood Proofing
- Response 17 – Heath & Safety Measures

4.6.4 For further details about this assessment and its recommendations, refer to Table 4.9 which provides an overall summary of the assessments. Table 4.9 gives a description of the summary table headings.

Table 4.9 - Response Summary Table

	Response	Strategic / Local	Reduction in Probability	Reduction in Consequence	When benefits are achieved	Certainty	Cost	Economic Benefit	Environment	Social Perception of Impact	Implemented by	Department within EA responsible	Recommendation in StAR
1	Rural Infiltration	Strategic	Medium	Medium	Long Term	Low	High	Medium	High	Low	Defra	Regional FRM	Review in future Strategy review
2	Catchment-Wide Storage	Strategic	Medium	Medium	Long Term	Medium	High	Medium	High	Medium	Defra	Regional FRM	Review in future Strategy review
3	Rural Conveyance	Strategic	Medium	Medium	Long Term	Medium	High	Medium	High	Medium	Defra	Regional FRM	Review in future Strategy review
4	Urban Storage	Local	Medium	Medium	Medium Term	Medium	High	Medium	Low	Medium	LPA/Thames Water	Area FRM	Non-EA investment required
5	Urban Infiltration	Local	Medium	Medium	Medium Term	Low	High	Medium	Medium	Medium	LPA	Area FRM	Non-EA investment required
6	Urban Conveyance	Local	Medium	Medium	Medium Term	Medium	High	Medium	Low	Medium	LPA/Thames Water	Area FRM	Non-EA investment required
7	Pre-event Measures	Strategic	Low	High	Short Term	Medium	Medium	High	Low	High	LPA/EA/Local flood groups	Area FRM	Promote MFAP
8	Flood Forecasting and Warning	Strategic	Low	High	Short Term	High	Medium	High	Low	High	EA	Flood Warning	Framework For Action / PAR (EA Investment)
9	Flood Fighting	Local	Medium	Medium	Short Term	Medium	Medium	Medium	Low	High	LPA/EA/Local flood groups	Area FRM	Promote MFAP
10	Collective-scale damage avoidance actions	Strategic	Low	High	Short Term	Medium	Medium	Medium	Low	High	LPA/EA	Area FRM	Promote MFAP
11	Individual-scale damage avoidance actions	Local	Low	High	Short Term	Medium	Medium	Medium	Low	Medium	LPA/EA/Local flood groups	Area FRM	Promote MFAP
12	Land-use Management	Strategic	High	High	Long Term	High	Low	High	High	Low	LPA/ EA	Development Control	Strategy Recommendation (EA investment unlikely)
13	Flood Proofing	Local	Medium	Medium	Medium Term	High	High	Medium	Low	High	LPA	Area FRM	Strategy Recommendation
14	Land-use Planning	Strategic	Low	Low (high if PPS25 not adhered to)	Medium Term	High	Low	Low	High	Low	LPA	Development Control	Business as Usual
15	Building Codes	Strategic	Low	High	Medium Term	High	Low	Low	Low	Low	LPA	Development Control	Business as Usual
16	Insurance, Shared Risk and Compensation	Strategic	Low	Low	Medium Term	Medium	Low	Low	Low	Medium	ABI/Defra	Regional FRM	Business as Usual
17	Health & Social Measures	Strategic	Low	Medium	Short Term	Medium	Medium	Low	Low	High	LPA/County/EA	Area FRM	Promote MFAP

Table 4.10 - Description of summary table headings

Heading in Table	Description
Response	As defined in the Flood Foresight Report. For this purpose we have only considered Responses 1 - 17; the remaining responses (18-21) deal with specific engineering intervention.
Strategic / Local	This distinguishes between responses that are likely to be implemented across the study area and those that may apply only to local areas or buildings.
Reduction in Probability	Defines the potential for the response to reduce the probability of a flood event
Reduction in Consequence	Defines the potential for the response to reduce the consequence of a flood event, i.e. the damage, loss, disruption or risk to life that a flood causes.
When benefits are achieved	Indicates how long it is likely to take from the implementation of the response until the benefits are achieved. Short-term = less than 5 years Medium-term = 5 to 15 years Long-term = more than 15 years
Certainty	Indicates the degree of certainty of achieving the perceived benefits through implementation of a response.
Cost	PV Cost of actually implementing the response. High = > £2 million Medium = £0.5 million to £2 million Low = < £0.5 million
Benefit	High-level assessment of economic benefits relative to costs to be achieved through implementing the response.
Environment	An estimate of the overall environmental net gain that may be achieved through implementation of the response.
Social Perception of Impact	A measure of the unquantifiable benefits whereby communities perceive a meaningful change that benefits them.
Implemented by	Denotes the organisation that is responsible for delivering the recommendation.
Department within EA responsible	Denotes the key stakeholder group within the Environment Agency.
Recommendation in StAR	Indicates how the response may be taken forward in the StAR i.e. PAR, future review, revenue requirement.

4.7 Additional Measures

4.7.1 As part of the Strategy investigation, it was identified that Additional Measures would complement or support the core engineering elements.

4.7.2 Additional Measures are either:

a) measures to manage flood risk at areas / properties that would have a residual flood risk once the core engineering measure(s) were implemented; or,

b) measures that can be economical justified to be implemented in the short term in advance of core engineering measures.

4.7.3 The following Additional Measures were identified;

Short term measures

4.7.4 As part of the Strategy investigation, it was identified that a number of measures (interim works) could be implement (ahead of the completion of the core engineering element) that reduce the level of flood risk within certain areas of Oxford from low order events.

4.7.5 These measures would include a range of flood reduction, however the main measures would be de-silting and vegetation clearance on key watercourses at certain pinch point locations. Phase 1 of this work (known as STM1) was completed in November 2009 (refer to STM1 PAR) and will benefit 96 properties that will not longer be at risk of flooding in a 1 in 20 year event.

4.7.6 Further works are current being appraised (STM2) with proposed implementation in late summer 2010.

Improved watercourse maintenance

4.7.7 The Area Operational Delivery team will undertake double the existing channel maintenance on a proactive basis.

Flood resilience measures

4.7.8 Flood resilience measures involve taking actions to limit the consequences of flooding on existing properties located within the floodplain. The most common flood resilience measures are installation of concrete floors, the use of water resistant materials in wall and floor construction, and the raising of electrics and other appliances above flood level.

4.7.9 As part of the appraisal process, these measures have been evaluated across the entirety of the Strategy study area. All those properties within the 1 in 10 year (10% AEP) flood plain in the Strategy study area were considered. This assessment identified that these measures could be installed within 112 properties within Oxford.

4.7.10 For further details refer to the Target Response and Response 13 – Flood Proofing briefing note included in Appendix B.

Raised defences

4.7.11 As part of the appraisal process, it was identified that raised flood defences would be a suitable solution to reduce the level of flood risk at Wolvercote. As it was identified that this area will not fully benefit from the core engineering elements.

4.7.12 This appraisal identified that a raised flood defence will protect up to 83 properties in a 1 75year (1.33 AEP) flood event. The raised flood defence would be in the form of either an embankment or wall, or a combination of both. It would need to be 1.2m in high, 12 metres wide with a total length of approximately 950 metres.

4.7.13 For further details about the raise defences at Wolvercote, refer to the Target Response Note included in Appendix B.

Multi-Agency Flood Plan

4.7.14 In response to the review of the Foresight Responses, it was identified that having a Mutli-Agency Flood Plan reduces the consequential flood risk. Therefore based on Responses 9, 10, 11 & 17 this plan would provide scope and direction for local partners to improve the planning for, and management of flood events.

4.7.15 For further details about the Mutli-Agency Flood Plan, refer to Responses 9, 10, 11 & 12 briefing notes included in Appendix B.

5. Short List of Options

5.1 Compiling the short list

5.1.1 Based on the assessment described above in Section 4, a short list option has been compiled. This includes the core engineering measures and Additional Measures.

5.1.2 The short list of the options is shown in Table 5.1 below.

Table 5.1: Short List of Core Engineering Options

Options	Description
Option 1	Do Nothing – undertake no further operation works, flood warning, maintenance and improvement activities whatsoever on the watercourses or existing flood projection measures.
Option 2	Do Minimum – continue to undertake present operation works, flood warning, maintenance and improvement activities throughout the 100 year appraisal period.
Option 3	Do Minimum (sustain) - continue to undertake present operation works, flood warning, maintenance and improvement activities throughout the 100 year appraisal period. Replacement of flow control structures after 60 years.
Option 3b	Do Minimum (sustain) & Additional Measures – as above in Option 3, however including additional measures; STM 1 & STM2, improve watercourse maintenance, flood resilience measures, raised defences (Wolvercote) and Mutli-agency Flood Plan.
Option 4	Enhanced Maintenance + (Option 3b) - continue to undertake present operation works, flood warning, maintenance and improvement activities throughout the 100 year appraisal period. Increased frequency and extent of maintenance activities to improve the standard of service. Replace control structures after 60 years.
Option 5	Western Conveyance (small channel) + (Option 3b) - increased flood flow conveyance to the west and south west of Oxford by constructing sections of new channel and/or enlargement of existing channels to convey an estimated maximum in bank flow of 18 – 20 cumecs. Widening pinch-points on Weirs Mill Stream.
Option 6	Western Conveyance (medium channel) + (Option 3b) - increased flood flow conveyance to the west and south west of Oxford by constructing sections of new channel and/or enlargement of other channels to convey an estimated maximum in bank flow of 35 – 40 cumecs. Widening pinch-points on Weirs Mill Stream.
Option 7	Western Conveyance (large channel) + (Option 3b) - increased flood flow conveyance to the west and south west of Oxford by constructing sections of new channel and/or enlargement of other channels to convey an estimated maximum in bank flow of 55 – 60 cumecs. Widening pinch-points on Weirs Mill Stream.
Option 8	Western Conveyance (small channel) & Upstream Storage + (Option 3b) - increased flood flow conveyance to the west and south west of Oxford by constructing sections of new channel and/or enlargement of other channels to convey an estimated maximum in bank flow of 18 – 20 cumecs. Widening pinch-points on Weirs Mill Stream. Providing a temporary on-line FSA (controlled by gated structures) upstream of Oxford.
Option 9	Western Conveyance (medium channel) & Upstream Storage + (Option 3b) - increased flood flow conveyance to the west and south west of Oxford by constructing sections of new channel and/or enlargement of other channels to convey an estimated maximum in bank flow of 35 – 40 cumecs. Widening pinch-points on Weirs Mill Stream. Providing a temporary on-line FSA (controlled by gated structures) upstream of Oxford.

5.2 Option 1: Do Nothing

Description

5.2.1 Do Nothing in flood risk management terms means that no new flood alleviation schemes would be promoted, and no maintenance works would be carried out to the channels or the existing flood protection measures. Do Nothing has formed the baseline which all other options are assessed against in order to identify the preferred option.

Technical

5.2.2 Do Nothing would involve the Environment Agency ceasing all flood management activities with respect to operation, flood warning, maintenance and improvement activities within the study area.

5.2.3 This option would lead to gradual deterioration of the watercourses and the flow control structures, which would not be replaced. There would be no damage limitation or flood alleviation measures during a flood event. In time, the standard of protection would reduce and further reduction would occur with the predicted impacts of climate change.

Cost and Economics

5.2.4 The number of properties at risk from flooding for the 1 in 75 year event in Oxford is over 3,156. There are no costs associated with this option and there are no economical benefits, as all operation and maintenance works would be stopped and the level of flood risk would increase over time. The approach adopted aligns with both the Lower Thames and Thames Weir Strategies.

Environmental

5.2.5 The main beneficial effects that this option would provide are a more naturalised river environment and geomorphological processes in the long term.

5.2.6 With this option the adverse environmental effects would be:

- Increased flood risk and deterioration over time for residential and commercial properties, urban areas and other commercial assets (including services and utilities, agricultural land, and planned development) within the western floodplain;
- Increased stress for residents and associated adverse effects on health and social well being;
- Increased flood risk and deterioration over time for roads, the railway line, footpaths and cycle paths in the western floodplain. Reduced access to employment;
- Inconsistent water depths and inability to navigate watercourses. Reduced access to recreational pursuits. Increased flood risk of recreational sites;
- Increased flood risk of undeveloped land leading to water logged soils, soil erosion and leaching;
- Shading and sedimentation of channels. Increased potential for transfer of contaminants into surface and with adverse impact for aquatic ecosystems;
- Increased flooding of designated sites and terrestrial ecosystems altering habitats over time;
- Use of energy resources for post-event clean-up operations;

- Impact on landscape character where this relies on a certain flooding regime, and potential adverse impact on visual amenity due to deterioration over time of control structures; and
- Increased flood risk for cultural heritage assets and potential impact on known archaeology.

5.3 Option 2 – Do Minimum

Description

5.3.1 Do Minimum in flood risk management terms means that only continuation of operation and maintenance activities at their current level would be undertaken by the Environment Agency and Operating Authorities.

Technical

5.3.2 With this option there would be no improvement to the standard of protection provided or any major capital construction works. This option represents the continuation of existing flood risk management activities to maintain existing conditions of locks and control structures until a point in time (for our assessment purposes we have assumed year 60 as assets are currently in a good state of repair) when they fail and are not replaced. Therefore, over time the standard of protection would reduce, and this reduction would be further increased by the predicted impacts of climate change.

5.3.3 Ongoing flood management activities that would continue throughout the 100 year appraisal period are:

- Periodic debris removal (obstructions to flow) and vegetation clearance. Reactive in hotspots;
- Reactive de-silting for navigation or other reasons;
- The continued operation, maintenance and repair of all locks and flow control structures; and
- Carrying out any damage limitation or flood alleviation measures during flood events (i.e. pumping, placing of sand bags, flood warnings, etc).

Costs and Economics

5.3.4 The whole life PV (100yrs) cost for this option is £9.9M. Refer to Appendix C for further details about this cost. The approach adopted aligns with both the Lower Thames and Thames Weir Strategies.

5.3.5 Table 5.2 and Figure 5.1 below identifies the number of properties that benefit from this option, including the number of properties that have a residual flood risk.

Table 5.2 Number of Properties that Benefit – Option 2

Number of properties (1 in 75 year event)*		Percentage against "Do Nothing" (3,156 at risk in the 1 in 75yr event) – refer to pie chart below
With Protected from this Option	1,559	50%
With Reduced Flood Risk from this Option	1,412	44 %
With No Benefit from this Option	185	6 %

* The number of properties protected and with a reduce flood risk are estimates due to the uncertainty of the type of works. The number of properties protected are the same until failure of assets by year 60.

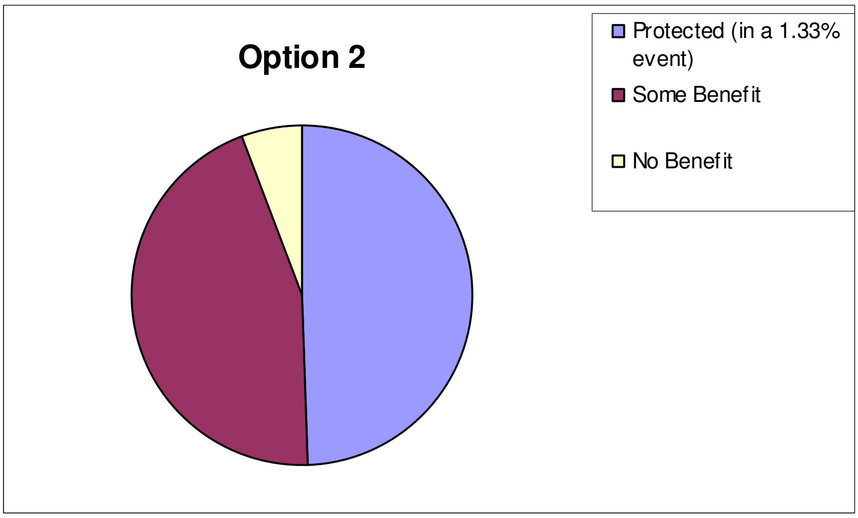


Figure 5.1 – Pie Chart for Option 2

Environmental

5.3.6 With this option, the beneficial environmental effects would be:

5.3.7 Very small reduction in flood risk in the long term to residential and commercial properties, urban areas and other commercial assets within the western floodplain;

5.3.8 Very small reduction in flood risk in the long term to roads, the railway line, footpaths and cycles paths in the western floodplain;

5.3.9 In the long term, absence of control structures will result in increased fish migration and opportunities for angling over a wider area;

5.3.10 In the long term, a more naturalised river environment will develop, benefiting the aquatic environment;

5.3.11 Ongoing maintenance activities will protect 'Conserve' units of landscape character; and

5.3.12 Repeat flooding and subsequent erosion may uncover unknown archaeological sites.

5.3.13 With this option the adverse environmental effects would be:

- No reduction in flood risk to residential and commercial properties, urban areas and other commercial assets (including services and utilities, agricultural land, and planned development) within the western floodplain in the short to medium term;
- Increased stress for residents and associated adverse effects on health and social well being;
- No change in flood risk in the short to medium term and deterioration over time of roads, the railway line, footpaths and cycle paths in the western floodplain;
- Reduced access to recreational pursuits in the short – medium term. In the long term, inconsistent water depths and inability to navigate watercourses;
- Continued potential for transfer of contaminants into surface water with adverse impact for aquatic ecosystems;
- In the long term, failure of control structures will result in mobilisation of sediments and increased erosion within channels;

- Use of energy resources for post-event clean-up operations;
- Potential adverse impact on visual amenity through deterioration of control structures; and
- Deterioration of cultural heritage assets and potential impact on known archaeology.

5.4 Option 3 – Do Minimum 'Sustain'

Description

5.4.1 Do Minimum 'Sustain' in flood risk management terms means the continuation of existing operational and maintenance activities, and replacement of flow control structures by year 60 on watercourses within the study area. These activities would be undertaken by the Environment Agency and Operating Authorities on a regular basis throughout the 100 year appraisal period.

Technical

5.4.2 This option represents the continuation of existing flood risk management activities (including the replacement of structures). Ongoing flood management activities include:

- Periodic debris removal (obstructions to flow) and vegetation clearance, reactive in hotspots;
- Reactive de-silting for navigation or other reasons;
- The continued operation, maintenance and repair of all locks and flow control structures;
- Carrying out any damage limitation or flood alleviation measures during flood events (i.e. pumping, placing of sand bags, flood warnings, etc); and
- The repair of breaches, if appropriate.

5.4.3 This option does not include improvements to the standard of service provided by major capital construction works. Over time the standard of protection may reduce with the predicted impacts of climate change.

Costs and Economics

5.4.4 The whole life PV (100yr) cost for this option is £14.1M. Refer to Appendix C for further details about this cost. The approach adopted aligns with both the Lower Thames and Thames Weir Strategies.

5.4.5 Table 5.3 below identifies the number of properties that benefit from this option, including the number of properties that have a residual flood risk. This information is also illustrated in a pie charge, refer to Figure 5.2.

Table 5.3 Number of Properties that Benefit – Option 3

Number of properties (1 in 75 year event)		Percentage against "Do Nothing" (3,156 at risk in the 1 in 75yr event) – refer to pie chart below
With Protected from this Option	1,559	50%
With Reduced Flood Risk from this Option	1,412	44 %
With No Benefit from this Option	185	6 %

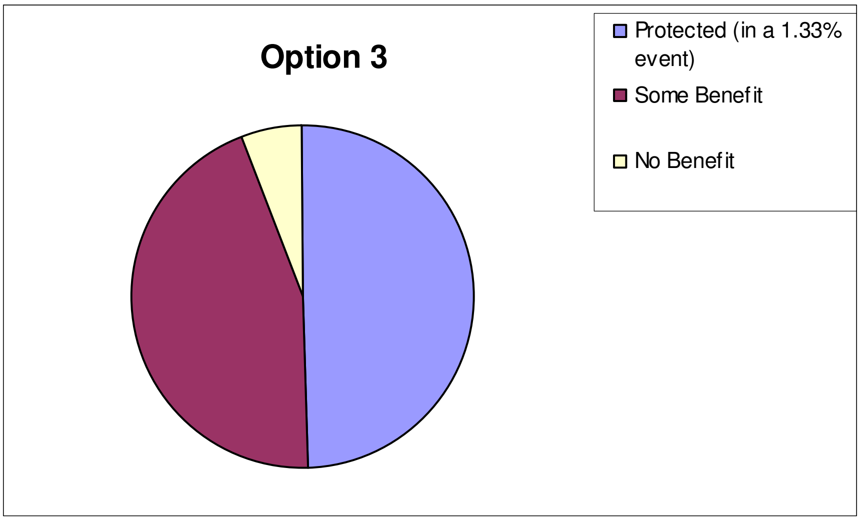


Figure 5.2 – Pie Chart for Option 3

Environmental

5.4.6 This is the option against which the other options are assessed within the SEA Environmental Report. The beneficial environmental effects of this option would be the potential to may uncover unknown archaeological sites through continued flooding and subsequent erosion.

5.4.7 With this option the adverse environmental effects would be:

- No change in flood risk to residential and commercial properties, urban areas and other commercial assets (including services and utilities, agricultural land, and planned development) within the western floodplain;
- Increased stress for residents and associated adverse effects on health and social well being;
- No change in flood risk to roads, the railway line, footpaths and cycle paths in the western floodplain;
- Works to replace locks, sluices and control structures may have temporary impacts on navigation. Continues flood risk will result in reduced access to recreational pursuits;
- Continued potential for transfer of contaminants into surface water with adverse impact for aquatic ecosystems;
- Reduced quality of agricultural land and allotments due to repeat flooding;
- Continued flood events will require use of energy resources. Replacement of locks, sluices and control structures will result in waste generation;
- Temporary impacts on 'Conserve' units of landscape character and visual amenity; and
- Deterioration of cultural heritage assets and potential adverse impact on known archaeology. Potential for impacts on historically important navigation structures.

5.5 Option 3b – Do Minimum 'Sustain' & Additional Measures

Description

5.5.1 Do Minimum 'Sustain' and Additional Measures includes all elements on Option 3 (as describe above in Section 5.4) and Additional Measures, which are:

- Short Term Measures 1 & 2
- Improve Watercourse Maintenance
- Flood Resilience Measures
- Raised Defences at Wolvercote
- Multi-Agency Flood Plan

Technical

5.5.2 As outlined above in Section 5.4 (Do Minimum Sustain) and the Additional Measures are:

5.5.3 *Short Term Measures 1& 2* – measures that could be implemented in the short term that would reduce the level of flood risk within certain areas of Oxford from low order events. These measures would include a range of flood reduction, however the main measures would be de-silting and vegetation clearance on key watercourses at certain pinch point locations.

5.5.4 *Increased watercourse maintenance* – undertake double the existing channel maintenance on a proactive basis.

5.5.5 *Flood Resilience Measures* – taking action to limit the consequences of flooding on existing properties located within the floodplain.

5.5.6 *Raised Defences at Wolvercote* - raised flood defence will protect up to 83 properties in a 1 75year (1.33 AEP) flood event.

5.5.7 *Multi-Agency Flood Plan* – scope and direction for local partners to improve the planning for, and management of flood events.

5.5.8 For further details, refer to Section 4.

Costs and Economics

5.5.9 The whole life PV (100yr) cost for this option is £24.6M. Refer to Appendix C for further details about this cost.

5.5.10 Table 5.4 and Figure 5.3 below identifies the number of properties that benefit from this option.

Table 5.4 Number of Properties that Benefit – Option 3b

Number of properties (1 in 75 year event) *		Percentage against "Do Nothing" (3,156 at risk in the 1 in 75yr event) – refer to pie chart below
With Protected from this Option	1,642	52%
With Reduced Flood Risk from this Option	1,412	45 %
With No Benefit from this Option	102	3 %

Note - the above numbers do not include those properties (~ 112) with reduced flood damage as a result of resilience measures

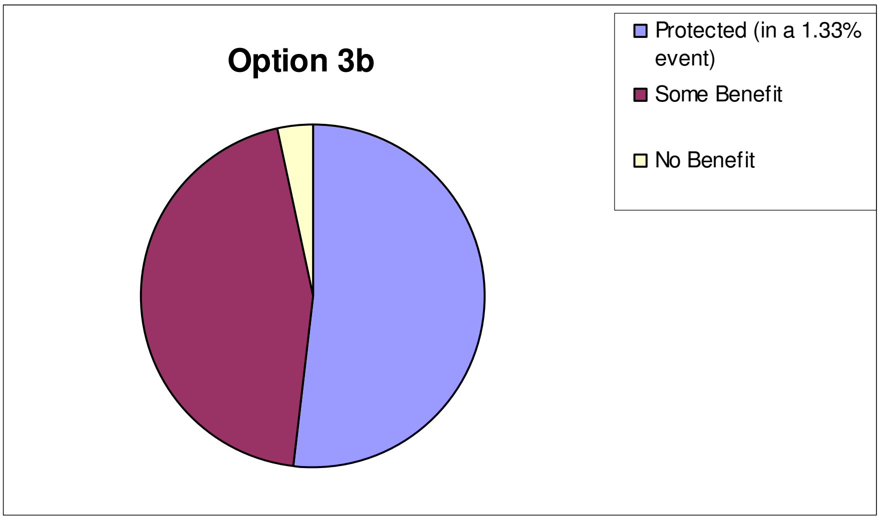


Figure 5.3 – Pie Chart for Option 3b

Environmental

5.5.11 Option 3b it was not environmentally appraised as a stand alone strategic option.

5.6 Option 4 – Enhanced Maintenance

Description

5.6.1 Enhanced Maintenance in flood risk management terms means over and above the current standard of service. The aim is to maximise flow capacity by removing silt, vegetation and other debris to reinstate the river cross section and reduce roughness (without altering the existing bed and banks). It also includes the replacement of flow control structures by year 60 on watercourses within the study area. These activities would be undertaken by the Environment Agency and Operating Authorities.

5.6.2 This option also includes Do Minimum Sustain and Additional Measures (refer to Section 5.5).

Technical

5.6.3 This option represents the continuation of existing flood risk management activities (including the replacement of structures). Ongoing flood management activities that would continue throughout the 100 year appraisal period include (for timing of these activities, refer to the cost breakdown in Appendix C:

- Periodic debris removal (obstructions to flow) and vegetation clearance; reactive in hotspots;
- Reactive de-silting for navigation or other reasons;
- The continued operation, maintenance and repair of all locks and flow control structures;
- Carrying out any damage limitation or flood alleviation measures during flood events (i.e. pumping, placing of sand bags, flood warnings, etc); and

- The repair of breaches, if appropriate.

5.6.4 The aim of Option 4 is to increase the flood flow capacity of the existing watercourses without substantially altering the existing river bed and banks. This option would include the following measures, known as proactive watercourse maintenance:

- Annual scrub and vegetation clearance with partial de-silting (key reaches and silt shoaling "hot spots") every 5 years and full de-silting in all watercourse every 10 years;
- Tree trimming where branches overhang the channel and possible tree removal (only where this is considered to restrict flow conveyance); and
- Debris clearance from culverts, bridges and flow control structures along channel reaches.

5.6.5 With this option there would be no improvement to the standard of protection provided by major capital construction works. Therefore, over time this may reduce with the predicted impacts of climate change.

5.6.6 This option was modelled (28km of the entire secondary watercourses) and the following assumptions were made:

- There is continued operation, maintenance and repair of all structures;
- An efficient programme of maintenance commensurate with asset type and consequence of flooding;
- Carrying out any damage limitation or flood alleviation measures during flood events (i.e. pumping, placing of sand bags, flood warnings, etc); and
- The repair of breaches damage as necessary, if appropriate.

5.6.7 This option was modelled and assessed as a series of sub-options with enhanced maintenance of various combinations of individual channel reaches, a similar approach as described in Section 4 (refer to Appendix B.19 for further details).

Costs and Economics

5.6.8 The costs associated with this option are:

- Operational and maintenance costs of the civil structures on the River Thames and its tributaries;
- Bank clearance operations of the River Thames and its tributaries; and
- Dredging of the tributaries, inspection activities, repair and refurbishment and/or replacement costs of the civil structures on the River Thames and its tributaries.

5.6.9 The civil structures operation and maintenance forms the major component of the cost. However, these costs do not include those associated with reinstating existing access routes and/or services.

5.6.10 The whole life PV (100yr) cost for this option is £70.1M. Refer to Appendix C for further details about this cost.

5.6.11 Table 5.5 below identifies the number of properties that benefit from this option, including the number of properties that have a residual flood risk. This information is also illustrated in a pie charge, refer to Figure 5.4.

Table 5.5 Number of Properties that Benefit – Option 4

Number of properties (1 in 75 year event)		Percentage against "Do Nothing" (3,156 at risk in the 1 in 75yr event) – refer to pie chart below
With Protected from this Option	1,795	57 %
With Reduced Flood Risk from this Option	1,170	37 %
With No Benefit from this Option	199	6 %

Note - the above numbers do not include those properties (~ 112) with reduced flood damage as a result of resilience measures

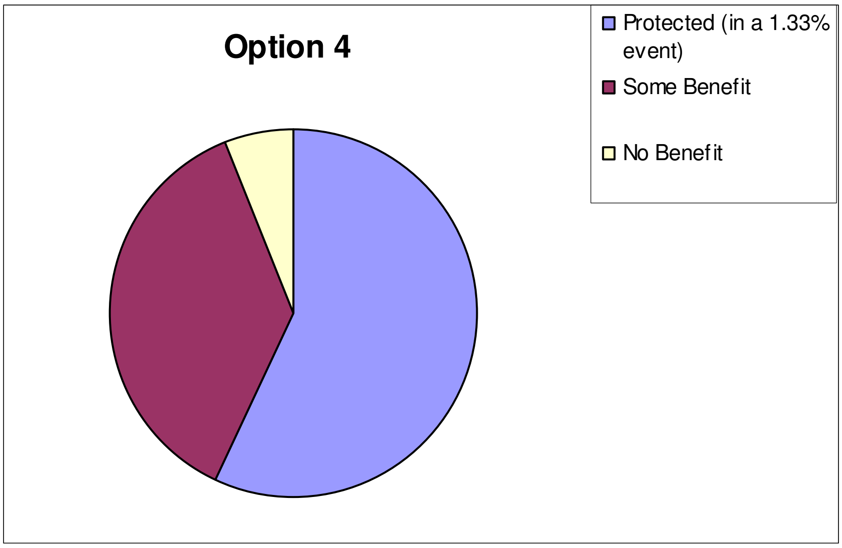


Figure 5.4 – Pie Chart for Option 4

Environmental

5.6.12 With this option the beneficial environmental effects would be:

- Small reduced flood risk for residential and commercial properties, urban areas and other commercial assets within the western floodplain;
- Reduced risk to life and improved health and social well being of residents of the western floodplain;
- Reduced flood risk for roads, the railway line, footpaths and cycle paths in the western floodplain;
- Increased navigational opportunities for small craft and improved access to recreational pursuits;
- Reduced potential for transfer of contaminants into surface water. Reduced flood risk of discharge points with beneficial impact on aquatic ecosystems; and
- Reduced flood risk for cultural heritage assets within the western floodplain. .

5.6.13 With this option the adverse environmental effects would be:

- Mobilisation of sediments during desilting and channel clearance works;
- Temporary but repeated impact on aquatic and terrestrial habitats and associated species as a result of repeated maintenance;
- Regular vegetation clearance and desilting of channels will result in regular use of machinery and associated use of energy resources;
- Temporary impact on landscape character and visual amenity; and
- Potential impact on areas of archaeological risk and unknown buried archaeology through changing groundwater and surface water regime.

5.7 Option 5 – Western Conveyance (small channel)

Description

5.7.1 The core engineering measure in this option is to substantially increase the flood flow capacity of the river system to the west and south west of Oxford (refer to Section 4.3).

Technical

5.7.2 This will involve construction of new sections of channel and/or enlargement of existing channels between Botley Road and downstream of Sandford Lock. It is proposed that Western Conveyance would increase the river systems capacity to pass flood flows by a maximum in bank flow of 18 – 20 cumecs. The pinch points in the Weirs Mill Stream will be widened to increase it's within banks capacity to $80m^3/s$. Refer to Appendix B for more details.

5.7.3 This option also includes Do Minimum Sustain and Additional Measures (refer to Section 5.5).

Costs and Economics

5.7.4 The whole life PV (100yrs) cost for this option is £123M. Refer to Appendix C for further details about this cost.

5.7.5 Table 5.6 below identifies the number of properties that benefit from this option, including the number of properties that have a residual flood risk. This information is also illustrated in a pie charge, refer to Figure 5.4.

Table 5.6 Number of Properties that Benefit

Number of properties (1 in 75 year event)		Percentage against "Do Nothing" (3,156 at risk in the 1 in 75yr event) – refer to pie chart below
With Protected from this Option	2,212	70 %
With Reduced Flood Risk from this Option	795	25 %
With No Benefit from this Option	149	5 %

Note - the above numbers do not include those properties (~ 112) with reduced flood damage as a result of resilience measures

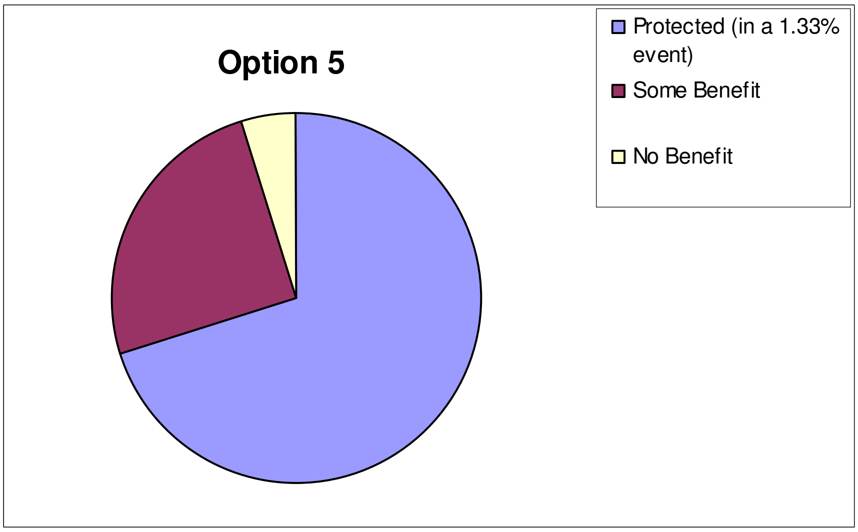


Figure 5.4 - Pie Chart for Option 5

Environmental

5.7.6 With this option the beneficial environmental effects would be:

- Reduced flood risk for residential and commercial properties, urban areas and other commercial assets (including services and utilities, agricultural land, and planned development) within the western floodplain. Reduction in business interruption;
- Reduced risk to life and improved health and social well being of residents of the western floodplain. Recreational opportunities associated with conveyance channel;
- Reduced flood risk to roads, the railway line, footpaths and cycle paths in the western floodplain;
- Increased navigational opportunities for small craft and improved access to recreational pursuits;
- Reduced potential for waterlogged soils, soil erosion and leaching. Reduced potential for transfer of contaminants into surface water with beneficial impact on aquatic ecosystems and angling;
- Creation of aquatic habitat;
- Opportunities for enhancement of landscape character; and
- Reduced flood risk for cultural heritage assets within the western floodplain. Construction of conveyance channel may provide opportunities to discover unknown buried archaeology.

5.7.7 With this option the adverse environmental effects would be:

- Elevated flow rates where new channel re-joins the River Thames may make navigation slightly more difficult;
- Potential for loss of locally designated sites, terrestrial ecosystems and habitats for protected species;
- Land take potentially impacting residential gardens, agricultural land, allotments, recreational facilities, planned developments, commercial and industrial assets, services and utilities and PRoW and cycle paths;
- Potential for pollution of surface water and groundwater during construction;
- Potential for sediment deposition and algal growth in enlarged or new channels;
- Excavation of a large quantity of gravel, alluvium and topsoil. Permanent loss of soil resource. Potential for contaminated arisings requiring treatment and disposal;
- Use of energy for construction of conveyance channel, operation of low flow weirs and control structures;
- Impact on landscape character and the protected views of Oxford city. Potential for visual detraction from the River Thames; and
- Potential for impacts on known areas of archaeological risk and unknown buried archaeology.

5.8 Option 6 – Western Conveyance (medium channel)

Description

5.8.1 The core engineering measure in this option is to substantially increase the flood flow capacity of the river system to the west and south west of Oxford (refer to Section 4.3).

5.8.2 This option also includes Do Minimum Sustain and Additional Measures (refer to Section 5.5).

Technical

5.8.3 This will involve construction of new sections of channel and/or enlargement of existing channels between Botley Road and downstream of Sandford Lock. It is proposed that Western Conveyance would increase the river systems capacity to pass flood flows by a maximum in bank flow of 35 - 40 cumecs. The pinch points in the Weirs Mill Stream will be widened to increase it's within banks capacity to $80m^3/s$. Refer to Appendix B for more details.

5.8.4 This option was modelled and assessed as a series of sub-options with enhanced maintenance of various combinations of individual channel reaches, refer to Section 4.3.30 and Appendix B.19 for more details.

Cost and Economics

5.8.5 The whole life PV (100yr) cost for this option is £163M. Refer to Section 4.3 and Appendix C for further details about this cost.

5.8.6 Table 5.7 below identifies the number of properties that benefit from this option, including the number of properties that have a residual flood risk. This information is also illustrated in a pie charge, refer to Figure 5.5.

Table 5.7 Number of Properties that Benefit – Option 6

Number of properties (1 in 75 year event)		Percentage against "Do Nothing" (3,156 at risk in the 1 in 75yr event) – refer to pie chart below
With Protected from this Option	2,436	77%
With Reduced Floor Risk from this Option	584	19 %
With No Benefit from this Option	136	4 %

Note - the above numbers do not include those properties (~ 112) with reduced flood damage as a result of resilience measures

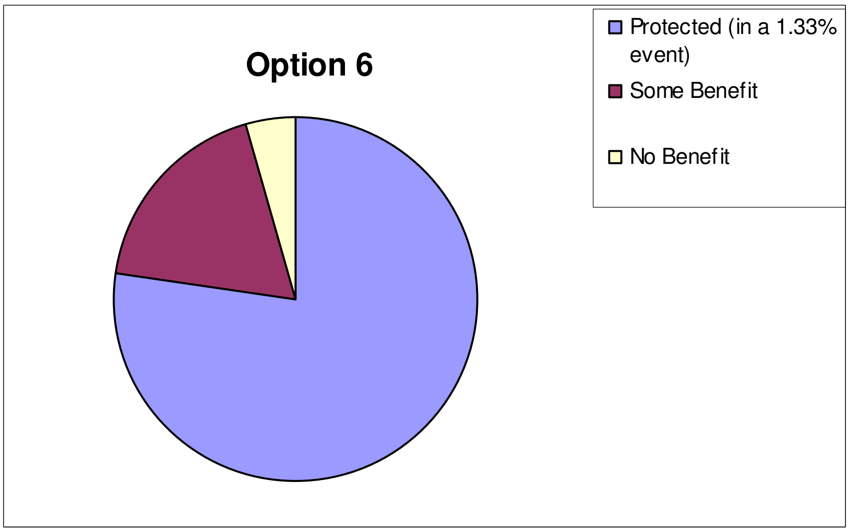


Figure 5.5 – Pie Chart for Option 6

Environmental

5.8.7 The beneficial and adverse environmental effects would be similar to those for Option 5 (see sections 5.6.5 and 5.6.6). However, option 5 is a smaller channel which will be narrower and thus have a smaller land take and less excavated material. It is therefore likely to have fewer impacts than a wider channel which will have a larger land table and produce more excavated material. A narrower channel is likely to have a narrower second stage and thus perhaps fewer opportunities for natural features; although all channel widths will have some opportunity for in-channel related features.

5.8.8 Option 6 is a wider channel than option 5 and thus has a greater opportunity for a wider second stage and the ecological and recreational features associated with this. The wider the second stage, the easier it will be to facilitate grazing activities and land use management practices and to include diverse and more channel associated features. Thus, a larger channel (which has a wider second stage when unconstrained) has a greater potential for environmental benefits.

5.9 Option 7 – Western Conveyance (large channel)

Description

5.9.1 The core engineering measure in this option is to substantially increase the flood flow capacity of the river system to the west and south west of Oxford.

5.9.2 This option also includes Do Minimum Sustain and Additional Measures (refer to Section 5.5).

Technical

5.9.3 This will involve construction of new sections of channel and/or enlargement of existing channels between Botley Road and downstream of Sandford Lock. It is proposed that Western Conveyance would increase the river systems capacity to pass flood flows by a maximum in bank flow of 55 - 60 cumecs. The pinch points in the Weirs Mill Stream will be widened to increase it's within banks capacity to $80m^3/s$. Refer to Appendix B for more details.

5.9.4 This option was modelled and assessed as a series of sub-options with enhanced maintenance of various combinations of individual channel reaches, refer to section 4.3.30 for more details.

Cost and Economic

5.9.5 The whole life PV (100yr) cost for this option is £182M. Refer to Appendix C for further details about this cost.

5.9.6 Table 5.8 below identifies the number of properties that benefit from this option, including the number of properties that have a residual flood risk. This information is also illustrated in a pie charge, refer to Figure 5.6.

Table 5.8 Number of Properties that Benefit

Number of properties (1 in 75 year event)		Percentage against "Do Nothing" (3,156 at risk in the 1 in 75yr event) – refer to pie chart below
With Protected from this Option	2,517	80 %
With Reduced Flood Risk from this Option	502	16 %
With No Benefit from this Option	137	4 %

Note - the above numbers do not include those properties (~ 112) with reduced flood damage as a result of resilience measures

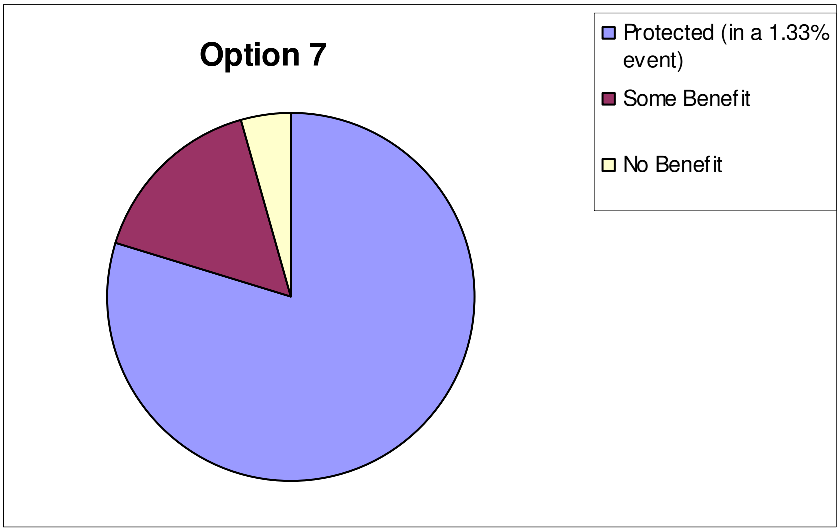


Figure 5.6 – Pie Chart for Option 7

Environmental

5.9.7 See sections 5.7.5 and 5.7.6.

5.10 Option 8 – Western Conveyance (small channel) with upstream storage

Description

5.10.1 Option 8 comprises two main engineering elements:

1. Improved Conveyance

5.10.2 To substantially increase the flood flow capacity of the river system to the west and south west of Oxford.

5.10.3 This will involve construction of new sections of channel and/or enlargement of existing channels between Botley Road and downstream of Sandford Lock. It is proposed that Western Conveyance would increase the river systems capacity to pass flood flows by a maximum in bank flow of 18 – 20 cumecs.

5.10.4 The pinch points in the Weirs Mill Stream will be widened to increase its within banks capacity to $80m^3/s$.

2. Flood Storage

5.10.5 Provide upstream storage in conjunction with increasing the flood flow capacity of the river system to the west and south west of Oxford.

5.10.6 The proposed FSA will be sited on the River Thames just upstream of the confluence of the River Thames and the Windrush rivers. The FSA will be 'on-line' (meaning that the River Thames will flow through the FSA) and will require a flow control structure and barrier at its downstream extent to allow the area to be filled and emptied. This element would only be implemented if future climate change predictions, that increase the flood risk in Oxford, are realised. This provides us with an adaptive approach to managing flood risk in the future.

5.10.7 The flow levels would be controlled by an outlet structure in the embankment on the current River Thames path. It is expected that 3 radial gates will control flows during flood events. Navigation will be maintained with a gate beside the radial gates that will remain open during normal conditions and only close during flood events.

5.10.8 Pumping will be required at the secondary embankments to prevent build up of surface runoff on the dry side of the embankments during flood events. During flood events the roads that run in the flood envelope will be required to be closed and traffic diverted through alternate routes. For a more detailed technical description refer to Appendix B.

5.10.9 When developing the hydrographs to represent the operation of the upstream storage, only 80% of the determined FSA volume has been assumed to allow for uncertainties. A major consideration in the operation of the storage area is the Oxford Meadows SAC downstream of the proposed storage area site. Oxford Meadows SAC relies on frequent (up to 1 in 10 year flood events, but potentially reducing to 1 in 4 year flood events in the future to allow for the effects of climate change) to maintain nutrient deposition in relation to favourable conditions. Therefore, the storage area would only retain flood flows above a 1 in 10 year event (peak flow of 142.8m^3/s at the confluence with the Evenlode) for the present. This means that the minimum required flooding regime for the Oxford Meadows SAC will not change. Refer to Appendix B for the hydrographs showing the operation of the storage area.

5.10.10 This option also includes Do Minimum Sustain and Additional Measures (refer to Section 5.5).

Cost and Economic

5.10.11 The whole life PV (100yr) cost for this option is £18M. Refer to Section 4.3 and Appendix C for further details about this cost.

5.10.12 Table 5.9 below identifies the number of properties that benefit from this option, including the number of properties that have a residual flood risk. This information is also illustrated in a pie charge, refer to Figure 5.7.

Table 5.9 Number of Properties that Benefit

Number of properties (1 in 75 year event)		Percentage against "Do Nothing" (3,156 at risk in the 1 in 75yr event) – refer to pie chart below
With Protected from this Option	2,661	84 %
With Reduced Flood Risk from this Option	366	12 %
With No Benefit from this Option	129	4 %

Note - the above numbers do not include those properties (~ 112) with reduced flood damage as a result of resilience measures

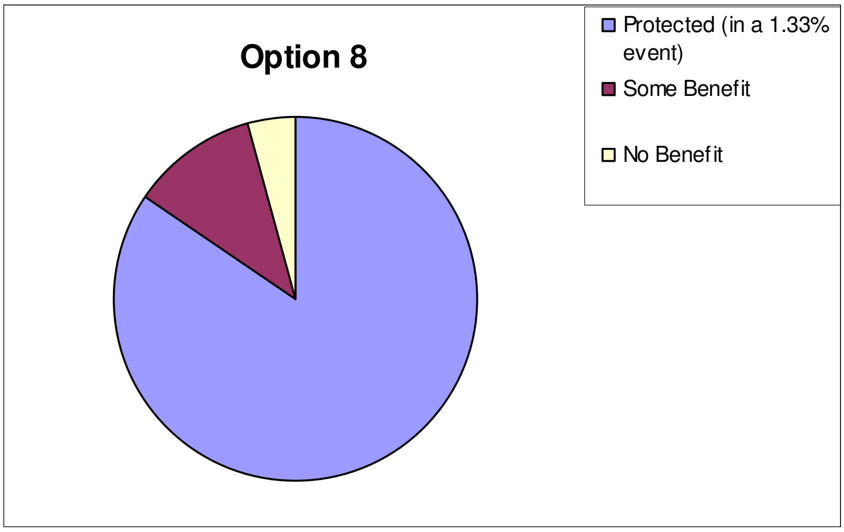


Figure 5.7 – Pie Chart for Option 8

Environmental

5.10.13 With this option the beneficial and adverse environmental effects of Western Conveyance are as set out for option 5.

5.10.14 The beneficial environmental effects of Flood Storage would be:

- Contribution to reduced flood risk for residential and commercial properties, urban areas and other commercial assets (including services and utilities, agricultural land, and planned development) within the western floodplain. Reduction in business interruption;
- Contribution to reduced risk to life and improved health and social well being of residents of the western floodplain;
- Contribution to reduced flood risk to roads, the railway line, footpaths and cycle paths in the western floodplain;
- Contribution to improved access to recreational pursuits in western floodplain;
- Potential to contribute to landscape and biodiversity improvements;
- Contribution to reduced potential for waterlogged soils, soil erosion and leaching in western floodplain. Contribution to reduced potential for transfer of contaminants into surface and groundwater in western floodplain with beneficial impact on aquatic ecosystems;
- Opportunities for the creation of BAP habitat; and
- Contribution to reduced flood risk for cultural heritage assets within the western floodplain. Construction of embankments and the downstream barrier may provide opportunities to discover unknown buried archaeology.

5.10.15 The adverse environmental effects of Flood Storage would be:

- Increased flood risk to 4 properties within storage area footprint;
- Temporary deeper or new inundation through FSA operation could have an adverse impact on designated conservation sites and BAP habitats within FSA;
- Longer restrictions to navigation along the River Thames downstream of the

storage area;

- Temporary restrictions on access routes within storage area footprint;
- Increased potential for waterlogged soils, soil erosion and leaching in FSA;
- Temporary deeper or new inundation of agricultural land within storage area footprint resulting in crop loss and necessitating relocation of livestock;
- Embankments and the downstream barrier may impact the relatively flat, rural and unspoilt landscape; and
- Potential for impact to areas of known archaeological risk and unknown buried archaeology.

5.11 Option 9 - Western Conveyance (medium channel) with upstream storage

Description

5.11.1 Option 9 comprises of two main engineering elements:

1. Improved Conveyance

5.11.2 To substantially increase the flood flow capacity of the river system to the west and south west of Oxford.

5.11.3 This will involve construction of new sections of channel and/or enlargement of existing channels between Botley Road and downstream of Sandford Lock. It is proposed that Western Conveyance would increase the river systems capacity to pass flood flows by a maximum in bank flow of 35 - 40 cumecs.

5.11.4 The pinch points in the Weirs Mill Stream will be widened to increase it's within banks capacity to $80m^3/s$.

2. Flood Storage

5.11.5 Provide upstream storage (refer to Section 4.4) in conjunction with increasing the flood flow capacity of the river system to the west and south west of Oxford. See description for Option 8.

5.11.6 This option also includes Do Minimum Sustain and Additional Measures (refer to Section 5.5).

Cost and Economic

5.11.7 The whole life PV (100yrs) cost for this option is £225M. Refer to Section 4.3 and Appendix C for further details about this cost.

5.11.8 Table 5.10 below identifies the number of properties that benefit from this option, including the number of properties that have a residual flood risk. This information is also illustrated in a pie charge, refer to Figure 5.8.

Table 5.10 Number of Properties that Benefit

Number of properties (1 in 75 year event)		Percentage against "Do Nothing" (3,156 at risk in the 1 in 75yr event) – refer to pie chart below
With Protected from this Option	2,776	88 %
With Reduced Floor Risk from this Option	247	8 %
With No Benefit from this Option	133	4 %

Note - the above numbers do not include those properties (~ 112) with reduced flood damage as a result of resilience measures

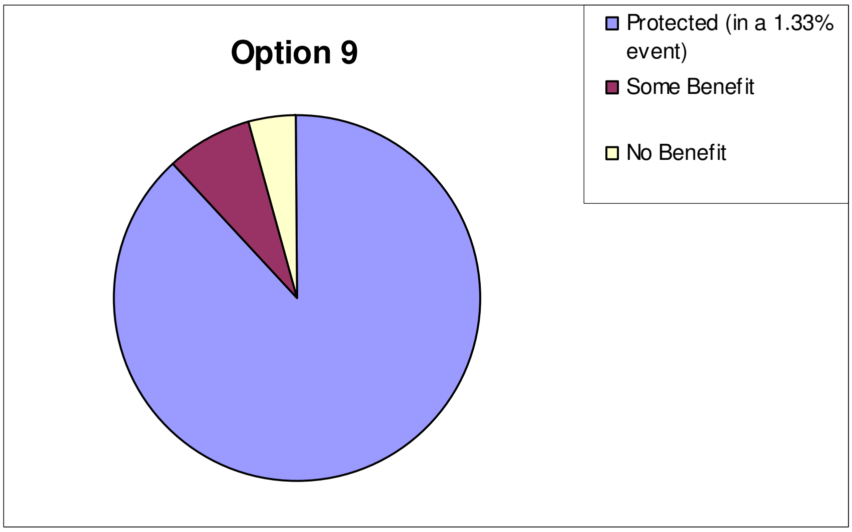


Figure 5.8 – Pie Chart for Option 9

Environmental

5.11.9 With this option the beneficial and adverse environmental effects would be as for Option 8 above, taking in to consideration the discussion regarding channel capacity as set out in section 5.7.5 and 5.7.6.

6. Selection of the Preferred Option

6.1 Introduction

6.1.1 In order to select the preferred option we have compared each option in the following ways:

- Is it technically satisfactory?
- Is it economically viable, with relevant outcome measures?
- Is it environmentally acceptable?

6.1.2 The following summary tables (Tables 6.1, 6.2 & 6.3) were produced to present the results for each option and provide an indication of the effects of climate change (Table 6.2).

6.1.3 When viewing the tables bear in mind the following points:

- Each option was subject to a technical assessment.
- For the environmental assessment, we grouped the options in to three categories:
  - Very little flood risk reduction
  - Residual adverse impacts which outweigh the flood risk reduction
  - Good level of flood risk reduction which can outweigh residual adverse impacts

6.1.4 An economic appraisal has been undertaken for all options listed in the summary tables. Details are included in the Economics Appraisal Report.

6.1.5 The PV Costs listed in the tables are the present value of the total capital and operating expenditure over the next 100 years. The present value is calculated using the 'discount rate' specified by Defra.

6.1.6 Tables 6.1 and 6.2 below provide a summary of the Options, whilst Table 6.3 provides an individual summary of the Additional Measures.

Table 6.1 Summary of Option <u>without</u> Climate Change

Option	Description	Technical	Environmental	Economic					Strategy Recommends
				Properties Protected 1 in 75yrs (1.33%)***	PV Costs (£M)	BCR	IBCR	**	
Option 1 Do Nothing	No Nothing - no further operation works, flood warning, maintenance and improvement activities whatsoever on the watercourses or existing flood projection measures.	Gradual deterioration of the watercourses and the flow control structures, which would not be replaced. Standard of protection would reduce and further reduction with the predicted impacts of climate change.	Increase in flood risk	Nil	-	-	-	-	×
Option 2 Do Minimum	Do Minimum – continue to undertake present operation works, flood warning, maintenance and improvement activities throughout the 100 year appraisal period.	Continuation of existing flood risk management and maintenance activities. When assets fail, they will not be replaced. Standard of protection would reduce eventually over time and further reduction with the predicted impacts of climate change.	Continued flood risk to assets and people within flood plain.	1,559	9.9	105		-	×
Option 3 Do Minimum - Sustain	Do Minimum – Sustain - continue to undertake present operation works, flood warning, maintenance and improvement activities throughout the 100 year appraisal period. Replace flow control structures after 60 years.	Continuation of existing flood risk management and maintenance activities. Assets will be replaced by year 60 Standard of protection remain the same, but would reduce with the predicted impacts of climate change.	Continued flood risk to assets and people within flood plain	1,559	14.1	74.5	3.1	2	×
Option 3b* Do Minimum – Sustain and Additional Measures + Additional Measures	Do Minimum – Sustain & Additional Measures- continue to undertake present operation works, flood warning, maintenance and improvement activities throughout the 100 year appraisal period. Replace flow control structures after 60 years. Additional Measures (refer to Table 6.3)	Continuation of existing flood risk management and maintenance activities. Assets will be replaced by year 60 Standard of protection remain the same, but would reduce with the predicted impacts of climate change.	Continued flood risk to assets and people within flood plain	1,642	24.6	44.2	3.4	3	✓
Option 4 Enhanced Maintenance + Additional Measures	Enhanced Maintenance - continue to undertake present operation works, flood warning, maintenance and improvement activities throughout the 100 year appraisal period. Increase the frequency and extent of maintenance activities to improve the standard of service. Replace control structures after 60 years. Additional Measures (refer to Table 6.3)	Continuation and improvement of existing flood risk management and maintenance activities. Assets will be replaced by year 60.	<u>Enhanced Maintenance & Additional Measures</u> a) Repeated temporary minor adverse impacts on flora and fauna, aquatic environment, landscape and buried archaeology across all watercourses in the study area. There is uncertainty in the frequency at which maintenance is required. However, there will be an increase in annual vegetation clearance with partial de-silting every 5 years and full de-silting in all watercourses every 10 years. A greater frequency of maintenance works will result in greater adverse impacts. b) Minor flood risk reduction to localised assets and people within floodplain.	1,795	70.1	15.8	0.4	3b	×
Option 5 Western Conveyance (Small channel) + Additional Measures	Western Conveyance (small channel) – increased flood flow conveyance to the west and south west of Oxford by constructing sections of new channel and/or enlargement of existing channel. Additional Measures (refer to Table 6.3)	Conveys an estimated maximum in-bank flow of 18 – 20 cumecs.	<u>Western Conveyance Channel (small) & Additional Measures</u> a) Moderate flood risk reduction to assets and people within floodplain. b) Adverse impact on flora and fauna, land use, landscape and buried archaeology. Many of these can be avoided through good channel design. c) No adverse impacts on	2,212	123	9.3	0.6 0.8	3b 4	×

			SSSIs, SAC or Scheduled Monuments. d) Opportunities for environmental enhancements. e) The smallest footprint of Western Conveyance alternatives and thus fewest adverse impacts						
Option 6 Western Conveyance (Medium channel) + Additional Measures	Western Conveyance (medium channel)* – increased flood flow conveyance to the west and south west of Oxford by constructing sections of new channel and/or enlargement of other channels. Additional Measures (refer to Table 6.3)	Conveys an estimated maximum in bank flow of 35 – 40 cumecs.	Western Conveyance Channel (medium) & Additional Measures As for option 5 but larger channel resulting in greater flood risk reduction and greater opportunities for environmental enhancements but potential for greater adverse impacts on flora and fauna, land use, landscape and buried archaeology.	2,436	163	7.2	0.7	5	×
Option 7 Western Conveyance (Large channel) + Additional Measures	Western Conveyance (large channel) – increased flood flow conveyance to the west and south west of Oxford by constructing sections of new channel and/or enlargement of other channels. Additional Measures (refer to Table 6.3)	Conveys an estimated maximum in bank flow of 55 – 60 cumecs.	Western Conveyance Channel (large) & Additional Measures* a) Adverse impact on flora and fauna, land use, landscape and buried archaeology as a result of large footprint of channel. The largest footprint of Western Conveyance alternatives and thus the most adverse impacts b) Flood risk reduction benefits and opportunities for environmental enhancements.	2,517	182	6.5	0.4	6	×
Option 8 Western Conveyance (Small channel) + Upstream Storage + Additional Measures	Western Conveyance (small channel) – increased flood flow conveyance to the west and south west of Oxford by constructing sections of new channel and/or enlargement of other channels. Upstream Storage - on-line FSA (controlled by gated structures) upstream of Oxford. Additional Measures (refer to Table 6.3)	Conveys an estimated maximum in bank flow of 18 – 20 cumecs. Storage capacity 9.9M.m^3. Will impound flood water at flows greater than 142 m^3/s (1 in 10 year event) at Eynsham.	Western Conveyance Channel (small), Upstream Storage & Additional Measures a) As for option 5. b) In addition, potential impact of Upstream Storage on designated sites (further research prior to implementation is required). c) High flood risk reduction benefits and opportunities for environmental enhancements..	2,661	185	6.4	0.6	5	×
Option 9 Western Conveyance (Medium channel) + Upstream Storage + Additional Measures	Western Conveyance (medium channel) – increased flood flow conveyance to the west and south west of Oxford by constructing sections of new channel and/or enlargement of other channels.	Conveys an estimated maximum in bank flow of 35 – 40 cumecs.	Western Conveyance Channel (medium), Upstream Storage & Additional Measures* a) As for option 6. b) In addition, potential impacts of Upstream Storage on designated sites. c) High flood risk reduction benefits and opportunities for environmental enhancements.	2,776	225	5.4	0.5	6	×
	Upstream Storage - on-line FSA (controlled by gated structures) upstream of Oxford. Additional Measures (refer to Table 6.3)	Storage capacity 9.9M.m^3. Will impound flood water at flows greater than 142 m^3/s (1 in 10 year event) at Eynsham.					0.4	8	

* Option 3b it was not environmentally appraised as a stand alone strategic option

** This states which option has been referenced to calculate the IBCR

*** These are the number of properties that are protected against do nothing and they do not include those properties (~112) which, as part of Additional Measures, will have resilience.

Table 6.2 Summary of Option with Climate Change (20% increase in flows)

Option	Description	Technical	Environmental	Economic					Strategy Recommends
				Properties Protected	PV Costs (£M)	BCR	IBCR	**	
Option 1 Do Nothing	No Nothing - no further operation works, flood warning, maintenance and improvement activities whatsoever on the watercourses or existing flood projection measures.	Gradual deterioration of the watercourses and the flow control structures, which would not be replaced. Increased level of flood risk compared to current situation	Increase in flood risk	-					×
Option 2 Do Minimum	Do Minimum – continue to undertake present operation works, flood warning, maintenance and improvement activities throughout the 100 year appraisal period.	Continuation of existing flood risk management and maintenance activities. When assets fail, they will not be replaced. Increased level of flood risk compared to current situation	Continued flood risk to assets and people within flood plain.	-	10	134.0			×
Option 3 Do Minimum – Sustain	Do Minimum – Sustain and Additional Measures- continue to undertake present operation works, flood warning, maintenance and improvement activities throughout the 100 year appraisal period. Replace flow control structures after 60 years.	Continuation of existing flood risk management and maintenance activities. Assets will be replaced by year 60 Standard of protection remain the same, but would reduce with the predicted impacts of climate change.	Continued flood risk to assets and people within flood plain	-	14	95.4	3.1	2	×
Option 3b* Do Minimum – Sustain + Additional Measures	Do Minimum – Sustain +Additional Measures Continue to undertake present operation works, flood warning, maintenance and improvement activities throughout the 100 year appraisal period. Replace flow control structures after 60 years. Additional Measures (refer to Table 6.3)	Continuation of existing flood risk management and maintenance activities. Assets will be replaced by year 60 Increased level of flood risk compared to current situation	Continued flood risk to assets and people within flood plain	-	25	56.5	4.3	3	×
Option 4 Enhanced Maintenance + Additional Measures	Enhanced Maintenance - continue to undertake present operation works, flood warning, maintenance and improvement activities throughout the 100 year appraisal period. Increase the frequency and extent of maintenance activities to improve the standard of service. Replace control structures after 60 years. Additional Measures (refer to Table 6.3)	Continuation and improvement of existing flood risk management and maintenance activities. Assets will be replaced by year 60. Erosion of SoP overtime as climate change is realised	Enhanced Maintenance & Additional Measures a) Repeated temporary minor adverse impacts on flora and fauna, aquatic environment, landscape and buried archaeology across all watercourses in the study area. There is uncertainty in the frequency at which maintenance is required. However, there will be an increase in annual vegetation clearance with partial de-silting every 5 years and full de-silting in all watercourses every 10 years. A greater frequency of maintenance works will result in greater adverse impacts. b) Minor flood risk reduction to localised assets and people within floodplain.	-	70	20.3	0.6	3b	×
Option 5 Western Conveyance (Small channel) + Additional Measures	Western Conveyance (small channel) – increased flood flow conveyance to the west and south west of Oxford by constructing sections of new channel and/or enlargement of existing channel. Additional Measures (refer to Table 6.3)	Conveys an estimated maximum in-bank flow of 18 – 20 cumecs. Erosion of SoP overtime as climate change is realised	Western Conveyance Channel (small) & Additional Measures a) Moderate flood risk reduction to assets and people within floodplain. b) Adverse impact on flora and fauna, land use, landscape and buried archaeology. Many of these can be avoided through good channel design. c) No adverse impacts on	-	123	12.4	1.3 2.3	3b 4	×

			SSSIs, SAC or Scheduled Monuments. d) Opportunities for environmental enhancements. e) The smallest footprint of Western Conveyance alternatives and thus fewest adverse impacts						
Option 6 Western Conveyance (Medium channel) + Additional Measures	Western Conveyance (medium channel)* – increased flood flow conveyance to the west and south west of Oxford by constructing sections of new channel and/or enlargement of other channels. Additional Measures (refer to Table 6.3)	Conveys an estimated maximum in bank flow of 35 – 40 cumecs. Erosion of SoP overtime as climate change is realised	Western Conveyance Channel (medium) & Additional Measures As for option 5 but larger channel resulting in greater flood risk reduction and greater opportunities for environmental enhancements but potential for greater adverse impacts on flora and fauna, land use, landscape and buried archaeology.	-	163	9.8	1.7	5	×
Option 7 Western Conveyance (Large channel) + Additional Measures	Western Conveyance (large channel)* – increased flood flow conveyance to the west and south west of Oxford by constructing sections of new channel and/or enlargement of other channels. Additional Measures (refer to Table 6.3)	Conveys an estimated maximum in bank flow of 55 – 60 cumecs. Erosion of SoP overtime as climate change is realised	Western Conveyance Channel (large) & Additional Measures a) Adverse impact on flora and fauna, land use, landscape and buried archaeology as a result of large footprint of channel. The largest footprint of Western Conveyance alternatives and thus the most adverse impacts b) Flood risk reduction benefits and opportunities for environmental enhancements.	-	182	8.9	1.1	6	×
Option 8 Western Conveyance (Small channel) + Upstream Storage + Additional Measures	Western Conveyance (small channel) – increased flood flow conveyance to the west and south west of Oxford by constructing sections of new channel and/or enlargement of other channels. Upstream Storage - on-line FSA (controlled by gated structures) upstream of Oxford. Additional Measures (refer to Table 6.3)	Conveys an estimated maximum in bank flow of 18 – 20 cumecs. Storage capacity 9.9M.m^3. Will impound flood water at flows above 142 m^3/s (1 in 4 year flood event). Implementation of upstream storage will reverse the erosion of SoP and mitigate the effects of climate change	Western Conveyance Channel (small), Upstream Storage & Additional Measures a) As for option 5. b) In addition, potential impact of Upstream Storage on designated sites (further research prior to implementation is required). c) High flood risk reduction benefits and opportunities for environmental enhancements..	-	185	8.8	1.8	5	×
Option 9 Western Conveyance (Medium channel) + Upstream Storage + Additional Measures	Western Conveyance (medium channel) – increased flood flow conveyance to the west and south west of Oxford by constructing sections of new channel and/or enlargement of other channels. Upstream Storage - on-line FSA (controlled by gated structures) upstream of Oxford. Additional Measures (refer to Table 6.3)	Conveys an estimated maximum in bank flow of 35 – 40 cumecs. Storage capacity 9.9M.m^3 Storage capacity. Will impound flood water at flows above 142 m^3/s (1 in 4 year flood event). Implementation of upstream storage will reverse the erosion of SoP and mitigate the effects of climate change	Western Conveyance Channel (medium), Upstream Storage & Additional Measures* a) As for option 6. b) In addition, potential impacts of Upstream Storage on designated sites. c) High flood risk reduction benefits and opportunities for environmental enhancements.	2,776	225	7.4	1.3 1.0	6 8	✓

* Option 3b it was not environmentally appraised as a stand alone strategic option
** This states which option has been referenced to calculate the IBCR

Table 6.3 Additional Measures Costs and Benefits (£M) [A]

<table>
<tr><th rowspan="2"></th><th rowspan="2">Description</th><th rowspan="2">Technical</th><th rowspan="2">Environmental</th><th colspan="3">Economic</th></tr>
<tr><th>Properties Protected or Reduce flood Risk</th><th>PV Costs (£M)</th><th>BCR</th></tr>
<tr><td rowspan="6">Additional Measures</td><td>Short Term Measures Phase 1</td><td rowspan="2">These are measures that can be implemented in a short space of time and would complement the medium to long term strategic solution. They would include de-silting and vegetation clearance on key watercourses as well as other flood flow improvements.
Phase 1 of the STM work has been completed in November 2009.
Phase 2 STM PAR has started and it is proposed to be approved by August 2010 to facilitate construction by December 2011</td><td rowspan="2">Contributes to reduced flood risk to properties and access within the floodplain and reduced risk to life. Contributes to increased navigational opportunities, reduced potential for transfer of contaminants and reduced flood risk for cultural heritage assets.
Temporary but repeated impact on aquatic and terrestrial habitat and associated species. Temporary impact on landscape character and visual amenity and contribution to potential adverse impact on areas of archaeological risk and unknown buried archaeology.</td><td>96[B]</td><td>4.76</td><td>18</td></tr>
<tr><td>Short Term Measures Phase 2</td><td>63[C]</td><td>4.46</td><td>19.5</td></tr>
<tr><td>Raised Defences at Wolvercote</td><td>These permanent defences (which could comprise of a grass embankment and/or flood walls) are proposed to provide protection to approximately 83 properties against the 1 in 75yr (1.33% AEP).</td><td>Contributes to reduced flood risk to residential properties, cultural heritage and infrastructure, and improved health and social well-being.
Impact on visual amenity to the rear of residents' properties in Wolvercote.</td><td>83[E]</td><td>1.94</td><td>7.22</td></tr>
<tr><td>Oxford Multi Agency Flood Plan</td><td>A Plan that will provide more closer working relationship with our local partners to improve the planning for, and manage of, flooding</td><td>Improved warnings and co-ordination of response contributing to reduced risk to life and improved health and social well-being of residents. Limiting damage to residential and commercial properties and assets.</td><td>0[F]</td><td>0.334</td><td>140</td></tr>
<tr><td>Improved Watercourse Maintenance</td><td>Double the existing annual operation and maintenance regime to optimise flow capacity within existing channel dimensions of key secondary watercourses River Thames floodplain. This measures include: desilting, debris removal and channel clearance.</td><td>Contributes to reduced flood risk to properties and access within the floodplain and reduced risk to life. Contributes to increased navigational opportunities, reduced potential for transfer of contaminants and reduced flood risk for cultural heritage assets.
Temporary but repeated impact on aquatic and terrestrial habit and associated species.
These measures will not alter the existing bed and banks</td><td>0[G]</td><td>1.55</td><td>9.61</td></tr>
<tr><td>Flood Resilience Measures</td><td>There will still be properties at risk from more infrequent flooding. To prevent this, we propose to provide flood resilience measures to individual residential properties</td><td>Contribution to reduced risk to life and damage to residential properties and improved health and social well-being of residents.</td><td>112[H]</td><td>3.5</td><td>1.86</td></tr>
</table>

[A] Interim works have an 8 year appraisal period. The Do Nothing PVd over 8 years used to determine PVb is £128.6M.
[B+C] Numbers quoted are properties with improved SoP to 1 in 20 (5% AEP) in the short term.
[D] Includes PVc for Do Minimum Sustain (to provide realistic BCR as Do Minimum Sustain is the basis of STM1 and STM2).
[E] Number of properties with improved SoP to 1 in 75 (5% AEP).
[F] Multi Agency Flood Plan reduces the consequences of flooding but not the probability.
[G] Improved maintenance further improves the SoP to those properties already benefiting.
[H] Assumes 40% uptake from 279 eligible properties in the 1 in 10 year (10%) floodplain.

6.2 Optimisation Process

6.2.1 The first step in selecting the preferred option was to assess the engineering measures to determine which would provide the best economic value, while providing the most appropriate level of protection.

6.2.2 This assessment process (known as Phase 1) consisted of comparing the three Western Conveyance channel sizes (known as small, medium and large) individually and in combination with upstream storage against the Do Nothing option.

6.2.3 At the start of the assessment process, economic analysis showed that regardless of whether or not it was combined with upstream storage, the high cost of construction of the large channel did not return enough benefit compared to the medium channel. Therefore, this option was not included within the Phase 1 assessment.

6.2.4 The outcome of Phase 1 suggested that without the consideration of climate change Option 3b (Do Minimum Sustain & Additional Measures) was the most economically preferred option, with a robust IBCR of 3.4 compared to Option 3. Options 4-9 cannot be preferred under this scenario as they have IBCR's, where compared to Option 3b, in the range of 0.3 to 0.6.

6.2.5 Table 6.4 shows the benefit cost ratios for the options without climate change.

Table 6.4 Benefit cost ratios 'without climate change', by option

	Option	SoP*	PVd (£M)	PVb (£M)	PVc (£M)	BCR	IBCR**	
1	Do Nothing	-	1,243					
2	Do Minimum	<10	205	1,038	9.9	105.0		
3	Do Minimum Sustain	<10	192	1,051	14.1	74.5	3.1	2
3b	Do Minimum Sustain & Additional Measures	<10	157	1,086	24.6	44.2	3.4	3
4	Enhanced Maintenance & Additional Measures	10-20	139	1,104	70.1	15.8	0.4	3b
5	Western Conveyance Small & Additional Measures	20-50	98	1,145	123	9.3	0.6 0.8	3b 4
6	Western Conveyance Medium & Additional Measures	20-50	69	1,174	163	7.2	0.7	5
7	Western Conveyance Large & Additional Measures	20-50	61	1,182	182	6.5	0.4	6
8	Western Conveyance Small, Upstream Storage & Additional Measures	50-75	59	1,184	185	6.4	0.6	5
9	Western Conveyance Medium, Upstream Storage & Additional Measures [preferred option]	50-75	41	1,202	225	5.4	0.5 0.4	6 8

* SoP quoted reflects that provided to 90% of the properties in the key benefit areas.
**The right hand column states which option has been referenced to calculate the IBCR.
NB: The preferred option (without consideration of climate change) is shaded.

6.2.6 The next assessment stage (Phase 2) was then applied to this initial preferred solution for OFRMS. This was an optimisation process that involved the consideration of climate change and identified what influence this would have over the initial selected preferred option. Two scenarios were considered for climate change:

- 10% increase in flows over the 100 year appraisal period;

- 20% increase in flows over the 100 year appraisal period.

6.2.7 When considering climate change and what influence this has over selecting the preferred option, it was concluded that if climate change predictions (assuming 20% increase in flows) are realised, then Option 9 would be preferred option (refer to Table 6.5). For further details of the study on climate change refer to the briefing the 'Climate Change Briefing Note' in Appendix B.

Table 6.5 Benefit cost ratios 'with climate change of 20% increase in flows', by option

	Option	PVd (£M)	PVb (£M)	PVc (£M)	BCR	IBCR**	
1	Do Nothing	1,751					
2	Do Minimum	419	1,332	10	134.0		
3	Do Minimum Sustain	406	1,345	14	95.4	3.1	2
3b	Do Minimum Sustain & Additional Measures	362	1,390	25	56.5	4.3	3
4	Enhanced Maintenance & Additional Measures	326	1,426	70	20.3	0.6	3b
5	Western Conveyance Small & Additional Measures	233	1,519	123	12.4	1.3 2.3	3b 4
6	Western Conveyance Medium & Additional Measures	165	1,586	163	9.8	1.7	5
7	Western Conveyance Large & Additional Measures	149	1,602	182	8.9	1.1	6
8	Western Conveyance Small, Upstream Storage & Additional Measures	120	1,631	185	8.8	1.8	5
9	Western Conveyance Medium, Upstream Storage & Additional Measures	82	1,669	225	7.4	1.3 1.0	6 8

**The right hand column states which option has been referenced to calculate the IBCR.
NB: The preferred option (allowing for 20% increase in flows) is shaded.

6.2.8 Including within this optimisation process, we also review what Additional Measure could support or complement the core engineering elements. These measures are a mixture of specific engineering and non-engineering interventions to areas where neither Western Conveyance nor upstream storage can provide significant flood risk reduction.

6.2.9 In addition to this, a discrete high level assessment of non-structural responses (Responses 1-17 from the Foresight Future Flooding Report) was undertaken to identify what other elements could be taken forward as part of the strategic options.

7. The Preferred Option

7.1 Introduction

7.1.1 Our overall preferred strategic option (Option 9) is a hybrid of engineering and non-engineering elements that reduce the risk of flooding in Oxford. With this option, approximately 2,776 properties (assuming no climate change) will be protected to a 1 in 75 year (1.33% AEP) flood event when all elements are implemented; as a results of resilience measures a further 112+ properties will have an improved standard of protection although not to the 1.33% level.

7.1.2 Table 7.1 below identifies the elements that are associated with the preferred option.

Table 7.1: Elements associated with the preferred option

Description	
Western Conveyance (medium channel)	
Upstream Flood Storage Area	
Priority BAP habitat creation	
Additional Measures	Short Term Measures (1 & 2)
	Improved Watercourse Maintenance Regime
	Flood Resilience Measures
	Raised Defences at Wolvercote
	Multi-Agency Flood Plan

7.2 Western Conveyance Improvements

7.2.1 The Western Conveyance measures will be a combination of new and enlarged sections of channel between Botley Road and downstream of Sandford Lock. Also included in these measures is the widening of the pinch points in the Weirs Mill Stream.

7.2.2 At the current Strategy stage we have not identified the exact alignment of Western Conveyance. Instead, we have identified a potential corridor where these conveyance improvements will be constructed. This corridor is to the west of Oxford and will extend from the Botley Road to past Sandford Lock. The exact alignment will be determined at the Project Appraisal Report stage.

7.2.3 These measures reduce water levels by allowing water to pass through Oxford more efficiently. During flood flows the control gates from the River Thames will be opened to allow excess flood flow through the Western Conveyance channel. In big floods, water will still flow out of bank and make full use of the existing floodplain.

7.2.4 It is proposed that the Western Conveyance will increase the river systems capacity to pass flood flows by a maximum in bank flow of 35 - 40 cumecs. The pinch points on the Weirs Mill Stream will be widened to allow this tributary to achieve about 80 m^3/s in-bank flow.

7.2.5 The cross-sections of the new or enlarged channels will be one of three types depending on the constraints and the nature of the existing landscape at each location. The channel cross-sections are:

- Constrained;
- semi-constrained (typical trapezoidal channel); and
- unconstrained (two stage channel) with gravel beds and an average depth of 3m.

7.2.6 When and where possible, the conveyance will firstly be improved through the enlargement of existing channels (preferably along one side only) and then by a new channel.

7.2.7 An important issue associated with the Western Conveyance element is the maintenance of ground water levels throughout the corridor to the west of Oxford. The construction of additional channels south of the Botley Road and the enlargement of existing channels could draw down the ground water levels throughout the area. To prevent this from happening, a series of low flow control structures will be constructed on the new channel to maintain the existing ground water levels and gradients throughout the western corridor. These structures may be tied into cut-off curtains to prevent significant additional groundwater flow by-passing them. There should be no significant reduction in groundwater levels due to the construction of the Western Conveyance scheme. Further detailed design of these elements will be undertaken before construction.

7.3 Upstream Storage

7.3.1 The aim of the engineered flood storage is to temporarily hold water upstream of Oxford to alleviate flooding downstream. The water would then be released as flood flows subside to leave the storage area dry once again.

7.3.2 Upstream Storage must be used in combination with the Western Conveyance element. It is not suitable as a standalone option as the reduction in flood flows is not sufficient to reduce all the flooding downstream.

7.3.3 The preferred FSA is situated above Newbridge with the downstream embankment (1.5m high) parallel to the A415.

7.3.4 The FSA will be on-line and will only be used when the flood flows are greater than a 10% annual probability (1 in 10 year) event. At this point flow control structures and earth embankments will start impounding water. This will be controlled by an outlet structure in the downstream embankment of the storage area and will be operated based on forecasting and upstream conditions. After the peak flows have subsided the stored water will be released in a controlled manor to ensure that there is no flooding downstream.

7.3.5 The FSA will only operate during large floods greater than the 1 in 10 year return period event. For all smaller floods, the gates will be left fully open and the river flows will not be affected. This will maintain the hydrology and hydrogeology required by the Oxford Meadows SAC downstream of the FSA. During these smaller floods the Western Conveyance element will reduce the flood levels in the critical areas south of the Botley Road.

7.3.6 The main embankment of the FSA would be situated above the A415 with a maximum height of 1.5m and a length is 2000m. There are four secondary embankments that protect houses at the edge of the storage area envelope with a maximum height of 1.5m. The downstream embankment will be designed so that is able to be overtopped in flood events above a 1% annual probability (1 in 100 year return period event).

7.3.7 It should be noted that the FSA is in the natural floodplain and that much of this area will be flooded in events smaller than the 10-year event. The operation of the FSA will increase the depth, extent and duration of inundation of the floodplain.

7.3.8 After the peak of a flood has passed, any stored volume in the storage area will be released. The peak flow in these major events will thus be reduced but the duration of relatively high flows will be prolonged. Refer to the Upstream Storage in Briefing Note in Appendix B for more details on the FSA.

7.3.9 There are some uncertainties regarding the potential adverse impact on designated conservation sites and high quality wildlife sites associated with the temporary FSA and further monitoring is recommended. Subject to the results of further monitoring and research and project level assessment, a FSA could assist in managing the adverse impacts on the socio-economic and built environment associated with increased fluvial flows under a climate change scenario. However, it should be noted that if the monitoring work proposed shows that there would be significant impacts to designated nature conservation sites which could not be mitigated or compensated for, then the FSA will not be implemented.

7.3.10 This element would only be implemented if future climate change predictions, that increase the flood risk in Oxford, are realised. This provides us with an adaptive approach to managing flood risk in the future.

7.4 Additional Measures

7.4.1 Although discounted as standalone solutions, it was recognised that STM1&2, flood resilience measures, raised defences and non-structural measures may be appropriate to implement alongside the core engineering elements of Upstream Storage and Western Conveyance, especially at a local level.

7.4.2 We are proposing to provide raised defences at Wolvercote. These would be permanent defences (which could comprise of a grass embankment and/or flood walls) and will protect an approximately 83 properties against a 1: 75year flood.

7.4.3 We are also implementing a suite of Short Term Measures (STMs) which include de-silting and vegetation clearance on key watercourses as well as other flood flow improvements. Phase 1 of this work (STM1) was completed in 2009 and further works are currently being appraised with proposed implementation in late summer 2010.

7.4.4 Improved watercourse maintenance (double existing annual operational maintenance) will maintain the flow capacities by improving the watercourse maintenance regime in the long term.

7.4.5 As a result of the summer 2007 floods and the recommendations of the Pitt Review, we have acknowledged that we need to work more closely with our local partners to improve the planning for, and management of, flooding. Therefore, we are proposing additional resources to complete and implement the Multi-Agency Flood Plan.

7.4.6 Although the core engineering elements will provide a significant reduction in flood risk, there will still be properties at risk from more infrequent flooding. To prevent this, we propose to provide flood resilience measures to approximately 112 individual residential properties.

7.4.7 Our vision is to create a better place. We have identified that within our study area we can make substantial improvements to the built and natural environment. We propose to improve recreational facilities and landscapes, and enhance habitats to improve the quality of the environment.

7.5 Environmental Enhancements

7.5.1 Environmental enhancements are measures that improve the existing environment to meet our vision: ‘a better place for people and wildlife, for present and for future generations’. These measures are over and above these measures:

- *Mitigation* measures are those which prevent, or reduce as fully as possible, any significant adverse impacts;

- *Environmental off-setting* measures are those which make good for loss or damage to a human or environmental asset without directly reducing that loss or damage. These are appropriate where mitigation measures are not possible; and
- In developing engineering elements, *good environmental design* is expected. This is also distinct from enhancements.

7.5.2 We have considered enhancement opportunities such as improvements to access, landscape, recreation or conservation based on knowledge of the study area and from investigation into other plans (see section 7.5 of the SEA Environmental Report).

7.5.3 The UK Biodiversity Action Plan (BAP) has developed Species and Habitat Action Plans which set priorities for nationally and locally important habitats and wildlife. We have identified areas within the study area which have good potential for land use change in order to create priority BAP habitat. There are:

- Existing non-BAP habitat, which is lost through the enlargement or excavation of channels in the western floodplain, may be enhanced through the creation of BAP habitat in the same location;
- Elsewhere within the western corridor; and
- Elsewhere within the Wider Strategy Boundary. Use of the Oxford Nature Conservation Forum Conservation Target Areas will assist in identifying the most appropriate opportunities.

7.5.4 Priority BAP habitat creation opportunities may include: Ponds; Floodplain Grazing Marsh; and / or Lowland Meadows. Construction of a conveyance channel may result in some small areas of BAP priority habitat loss, potentially fens or lowland mixed deciduous woodland. However, based upon the indicative channel alignment and recommendations for conveyance improvements on the Weirs Mill Stream, these are unlikely to total more than 0.5ha. There is the potential to gain approximately 15ha of BAP priority habitat in the floodplain to the west of Oxford using the higher stage of the unconstrained channels. Table 7.2 shows the breakdown of potential net gain of BAP priority habitat.

Table 7.2: Potential net gain of BAP habitat in the Western corridor

Estimate habitat loss (ha)		Estimated habitat gain (ha)			Net gain (ha)
Footprint of conveyance	**Flood risk reduction**	**Creation on second stage**	**Creation on working strip**	**Other areas of creation***	**Total gain – total loss**
0.5	0	9	6	0	14.5

**There may be other viable areas in the Oxford area but outside of the corridor being considered for conveyance improvements.*

7.5.5 We recommend that 1% of the overall the Strategy budget be allocated to providing some of these enhancements including the creation of BAP priority habitat in the wider study area. This equates to approximately £2.9M.

7.5.6 We recommend that, where BAP priority habitat and other enhancements are in geographical proximity to western conveyance (for example works within the second stage and working strip) that these are delivered as part of any scheme.

7.5.7 Where BAP priority habitat creation opportunities fall across the wider study area, a separate PAR should be commissioned for those opportunities to be fully assessed.

8. Implementation Plan

8.1.1 The Strategy has been appraised against the strategic objectives: to identify a sustainable solution to reduce flood risk to people and property; reduce the disruption and financial loss associated with road and railway flooding; improve the human and natural environment for the quality of life of people and benefit of wildlife; and to be adaptable to future climate change.

8.1.2 A strategic approach to manage the flood risk to property and other assets in Oxford and the surrounding villages has been developed over the next 100 years.

8.1.3 The implementation programme for the Strategy is shown in Table 8.1, outlining activities proposed in the short, medium and long term.

Table 8.1: Strategy Implementation Plan

Strategy Implementation Plan		
Short Term (0 to 9 Years)	**Location**	**Responsible**
Short Term Measures Phase 1 De-silting and removal of vegetation along key reaches. New culverts under Network Rail access track near Old Abingdon Road. Demountable defences at Vicarage Lane and Osney Island. **2008/09: Scheme Implemented.**	Bulstake Stream Hinksey Stream Hinksey Drain Seacourt Stream	Environment Agency
Short Term Measures Phase 2 De-silting and removal of vegetation along remaining key reaches. **2010/11: Scheme Implementation**	Bulstake, Hinksey, Seacourt Streams Hinksey Drain, Osney Ditch	Environment Agency
Raised Flood Defences Raised flood defences to the north and east of Wolvercote **2012: Scheme Implementation**	Wolvercote	Environment Agency
Flood Resilience Measures Provision of flood resilience measures to reduce flood damages at individual residential properties. **2012/16: Scheme Implementation**	Throughout the Study Area	Environment Agency / OCC / VoWH
Multi-Agency Flood Plan (MAFP) Complete MAFP to set out the coordinated approach to responding to floods with other key stakeholders. Provision of additional resources to implement recommendations of MAFP over the long term. **2011: Scheme Implementation**	Throughout the Study Area.	Environment Agency and relevant partners
Improved Watercourse Maintenance Ongoing proactive maintenance through de-silting and vegetation clearance on all watercourses	All watercourses	Environment Agency
Medium Term (10 to 70 years)	Location	Responsible
Western Conveyance Flow conveyance improvements by constructing sections of new channels or enlarging existing channels. It will also include major infrastructure improvements at Botley Rd, Old Abingdon Rd, Southern ring road (A4074) and the main railway line. **By 2079: Scheme Implementation**	Floodplain to the West and South of Oxford. Bulstake, Hinksey, Seacourt Streams River Thames	Environment Agency
Habitat Creation & Environmental Enhancement	Upper Thames	Environment

Strategy Implementation Plan		
Provision of environmental enhancements in the wider Study Area to include creation of BAP habitat **By 2079: Scheme Implementation**	floodplain.	Agency / RSPB / NE / DEFRA / BBOWT / ORPG
Long Term (70 to 90 years)	Location	Responsible
Upstream Storage Provision of a Flood Storage Area in the Upper Thames floodplain if future climate change predictions are realised. Construction of a flow control structure, downstream embankments and secondary bunds. **By 2099: Scheme Implementation**	Upper Thames floodplain	Environment Agency

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Abbreviations

Abbreviation	Full Title
BAPs	Biodiversity Action Plans
BBOWT	Berkshire, Buckinghamshire and Oxfordshire Wildlife Trust
BGS	British Geological Survey
BVL	Black & Veatch Ltd
CFMPs	Catchment Flood Management Plans
Defra	Department of the Environment, Food and Rural Affairs
FSA	Flood Storage Area
FCDPAG	Flood and Coastal Defence Project Appraisal Guidance
OFRMS	Oxford Flood Risk Management Strategy
SEA	Strategic Environmental Assessment
StAR	Strategy Appraisal Report
SSSI	Site of Special Scientific Interest
UK BAP	UK Biodiversity Action Plan

Appendices

Appendix A

A. 1 Previous Oxford Studies and Investigations

A.2 Foresight Report Response Summary

Appendix B

B.1	OFRMS Hydrology Report (2009)
B.2	OFRMS Hydraulic Modelling Reports (2009)
B.3	Oxford Groundwater Flooding and Hydrogeology
B.4	OFRMS Geotechnical and Contaminated Land Reports
B.5	OFRMS Archaeology
B.6	OFRMS Briefing Note – Flow Conveyance at Botley Road
B.7	OFRMS Briefing Note – Redbridge Conveyance
B.8	OFRMS Briefing Note – Excluding a channel north of Botley Road
B.9	OFRMS Briefing Note – Weirs Mill Stream
B.10	OFRMS Briefing Note – Modelling and Downstream Effects
B.11	OFMS Briefing Note – Widening of the River Thames
B.12	OFRMS Briefing Note – Engineered Flood Storage
B.13	OFRMS Briefing Note – Targeted Response_v2
B.14	OFRMS Briefing Note – Foresight Response Introduction & Summary
B.15	OFRMS Briefing Note – Foresight Responses 1 -17
B.16	OFRMS Briefing Note – Flood Water Transfer
B.17	OFRMS Briefing Note – Climate Change
B.18	OFRMS Landscape Character Report
B.19	OFRMS Briefing Note – Western Conveyance Splitting and Enhanced Maintenance Splitting

Appendix C

C.1	Western Conveyance Costs (Small, Medium and Large)
C.2	Upstream Storage Costs
C.3	Do Minimum Costs
C.4	Do Minimum Sustained Costs
C.5	Improved Maintenance Costs
C.6	Enhanced Maintenance Costs
C.7	Environmental Enhancement Costs
C.8	Wolvercote Costs
C.9	Resilience
C.10	STM2 and OMAFP costs
C.11	Preferred option costs