Weston-super-Mare
Level 2 Strategic Flood Risk Assessment and further works: Technical Element

North Somerset Council

July 2010

Final Report

9V0839

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GLOSSARY OF TERMS

ABD	Areas Benefiting from Defences
AEP	Annual Exceedence Probability. The estimated probability of a flood of given magnitude occurring or being exceeded in any year.
Catchment	The area contributing surface water flow to a point on a drainage or river system (the area drained by that river, including areas away from the watercourse network). Can be divided into sub-catchments.
CIL	Community Infrastructure Levy
DEM	Digital Elevation Model
Design Event	A historic or notional flood event of a given annual flood probability, against which the suitability of a proposed development is assessed and mitigation measures, if any, are designed.
DTM	Digital Terrain Model
EA Flood Zone 1	Low Probability of flooding
EA Flood Zone 2	Medium Probability of flooding. Probability of fluvial flooding is 0.1 – 1% and probability of tidal flooding is 0.1 – 0.5%
EA Flood Zone 3a	High Probability of Flooding. Probability of fluvial flooding is 1% (1 in 100 years) or greater and probability of tidal flooding is 0.5% (1 in 200 years) or greater.
EA Flood Zone 3b	Functional floodplain.
Environment Agency	Non-departmental public body responsible for the delivery of government policy relating to the environment and flood risk management in England and Wales.
FAS	Flood Alleviation Scheme
FEH	Flood Estimation Handbook. The Environment Agency approved method of estimating flood flows in the UK.
Flood Defence	A structure (or system of structures) for the alleviation of flooding from rivers or the sea to a specified design standard.
Flood Estimation Handbook	The Environment Agency approved method of estimating flood flows in the UK.
FMS	Flood Management Study
FMS – Post development flows (P2)	These flows recalculated rates of runoff assuming 75% impermeable land and 25% permeable in order to model development.
Flood Risk	The level of flood risk is the product of the frequency or likelihood of the flood events and their consequences (such as loss, damage, harm, distress and disruption).
Flood Risk Assessment	Considerations of the flood risks inherent in a project, leading to the development of actions to control, mitigate or accept them.
Floodplain	Any area of land over which water flows or is stored during a flood event, or would flow but for the presence of flood defences.
Fluvial	Pertaining to a watercourse (river or stream).
Freeboard	The difference between the design flood level and the lowest point on the flood defence.

GIS	Geographical Information System. A computer-based system for capturing, storing, checking, integrating, manipulating, analysing and displaying data that are spatially referenced.
Greenfield run-off rate	The rate of run-off that would occur from the site in its undeveloped state.
Groundwater	Water occurring below ground in natural formations (typically rocks, gravels and sand).
Hazard	A situation with the potential to result in harm. A hazard does not necessarily lead to harm.
Hydraulic model	A computerised model of a watercourse and floodplain to simulate water flows in rivers to estimate water levels and flood extents.
iSIS	One dimensional hydraulic modelling software.
LiDAR	Light Detection And Ranging - The Environment Agency's digital terrain mapping data
Main River	Watercourses defined on a 'Main River Map' designated by DEFRA. The Environment Agency has permissive powers to carry out flood defence works, maintenance and operational activities for Main Rivers only.
QMED	Mean annual maximum flood
mAOD	Metres Above Ordnance Datum. Elevations use Ordnance Datum Newlyn.
NFCDD	National Flood & Coastal Defence Database. Environment Agency asset management system database.
NSC	North Somerset Council
PPS25	Planning Policy Statement 25; 'Development and Flood Risk'.
Probability	The likelihood of an event occurring.
Residual Flood Risk	The remaining flood risk after risk reduction measures have been taken into account.
Return Period	The average time period between rainfall or flood events with the same intensity and effect.
RSS	Regional Spatial Strategy
SLR	Sea Level Rise.
Standard of protection	The level of flood that a defence is designed to protect against before it is exceeded.
Surface Run-off	Water flowing over the ground surface to the drainage system. This occurs if the ground is impermeable, is saturated or if rainfall is particularly intense.
Sustainable Drainage Systems (SuDS)	A sequence of management practices and control structures designed to drain surface water in a more sustainable fashion than some conventional techniques.
Time to peak	The time from the centroid of the total rainfall to the peak of the run-off hydrograph, i.e. the length of time it takes to convert rain into river flow.
Topography	The shape and form of the land, in terms of hills, steepness of slopes, or flat land.
Water Level Management Plans (WLMPs)	Water Level Management Plans (WLMPs) are required for all areas which have a conservation interest and where the control of water is important for the maintenance or rehabilitation of that interest.

1 INTRODUCTION

1.1 Commission award

Royal Haskoning were commissioned in December 2009 by North Somerset Council (NSC) to produce a Level 2 Strategic Flood Risk Assessment (SFRA) for Weston-super-Mare.

1.2 Background

1.2.1 Flood risk in the Weston-super-Mare area originates from a number of sources including river, tidal, surface water and groundwater flooding. This Level 2 SFRA examines the risk from fluvial (river) and tidal flooding. The scope of this study does not include modelling of groundwater or surface water flooding with the exception of an overview of surface water susceptibility within the study area using the recently published EA Areas Susceptible to Surface Water Flooding maps. Further information pertaining to surface water and groundwater flood risk can be found in the NSC Level 1 SFRA. Developers should be aware of the risk presented by groundwater flooding due to high water tables which would impact the design and deliverability of surface water drainage schemes and floor levels. The risk of groundwater and surface water flooding should therefore be assessed in detail by a site-specific Flood Risk Assessment (FRA) prior to development.

1.2.2 The government guidance document 'Planning Policy Statement; Development and Flood Risk' (PPS25) outlines the requirements for the production and use of SFRAs and site-specific FRAs. PPS25 aims to reduce the risks from flooding to people and the development and natural environment by discouraging further built development within floodplain areas and by promoting best practice for the control of surface water runoff. When planning for development, the flood risk management hierarchy within PPS25 (shown below) should be used to ensure that planning at all levels delivers sustainable development which avoids or reduces the risk of flooding.

Step 1 – Assess
Appropriate flood risk assessment

↓

Step 2 – Avoid
Apply the Sequential approach

↓

Step 3 – Substitute
Apply the Sequential Test at site level.

↓

Step 4 – Control
e.g. SUDS, design, flood defence

↓

Step 5 – Mitigate
e.g. Flood resilient construction

Flood Risk Management Heirarchy: Extract from PPS25 – Practice Guide (Dec 2009)

1.2.3 This Level 2 SFRA for Weston-super-Mare follows on from the Level 1 SFRA completed by Royal Haskoning or the whole of the NSC mainland area in October 2008. The aim of the Level 1 SFRA was to examine the flood risk within the NSC area and to provide general guidance to local authority planners, developers and other interested people, including the general public about locations where flood risk is a potential issue. This should be used by NSC and developers to determine sites of lower risk.

1.2.4 Both the Level 1 and Level 2 SFRA's should be used to facilitate the Sequential Test and Exception Test in accordance with PPS25 (Para 3.58 of the PPS25 Practice Guide). The 'Sequential Test' is a procedure set out in PPS25 that aims to ensure land is allocated for development in lower flood risk zones in preference to high risk zones. If NSC decides that the development needs to be located in WSM and they can justify the socio-economic benefits that out weight flood risk, then the more detailed Level 2 should be used to apply the sequential approach within Weston Super Mare and inform the FRA.

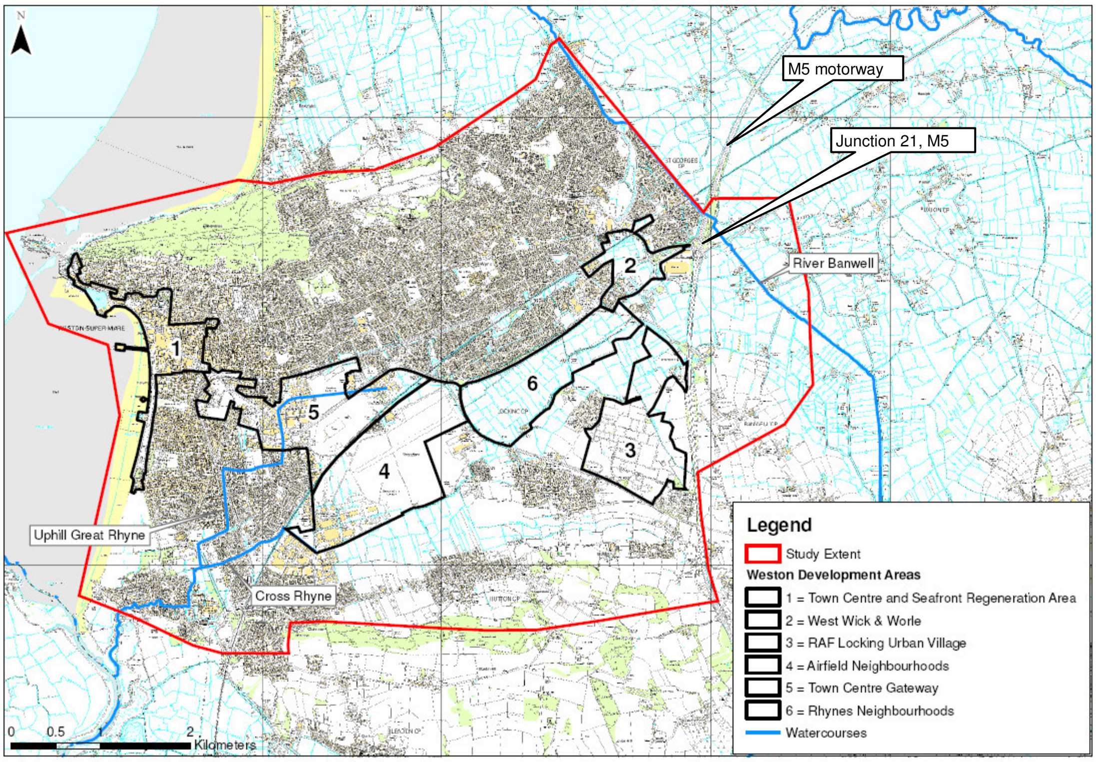
1.2.5 It is not always possible to allocate all proposed development and infrastructure in accordance with the 'Sequential Test' for various reasons and it may be necessary to extend the scope of the SFRA. PPS25 therefore sets out another procedure called the Exception Test, which if passed means that subject to a satisfactory site specific Flood Risk Assessment detailing appropriate mitigation measures which make the proposal acceptable, development can take place in higher flood risk areas.

1.2.6 In order to undertake the Exception Test for the locations identified through information provided in the Level 1 SFRA, PPS25 requires quantifiable information regarding flood risk and, where necessary, possible mitigation measures, to understand the flood risks at each site and drainage requirements. This is to assess whether it is appropriate for proposed development to take place. The technical information provided in this Level 2 report will enable NSC to draft criteria based policies for the local development Framework (LDF), which is used to consider planning applications for these sites. This will be done by outlining policies in the Level 2 SFRA that the supporting Flood Risk Assessments (FRAs) should adhere to in order to satisfy criterion (c) in paragraph D9 (The Exception Test) in PPS25; "a FRA must demonstrate that the development will be safe, without increasing flood risk elsewhere, and, where possible, will reduce flood risk overall".

1.2.7 Throughout this study the Level 1 SFRA data and the existing 1D fluvial model (created for the Weston-super-Mare Flood Management Study (FMS) produced for NSC by Royal Haskoning, 2007) and the 2D tidal modelling (created for the Environment Agency's North Wessex Area Tidal Areas Benefitting from Defences Project, 2007) results have been used with permission from the Environment Agency and NSC as a basis for the assessment, in order to make the best use of existing data and provide consistency between flood risk studies within the Weston-super-Mare area.

1.3 Study Area

Figure 1.1 - Level 2 study areas



This Level 2 SFRA focuses on locations (as shown in Figure 1.1) where there is a need to consider additional development on land within existing flood risk areas or where development could increase run-off affecting existing floodplains and vulnerable land. This comprises the current urban area of Weston-super-Mare and the proposed Weston Development Area (WDA). The six sub-areas that make up the WDA to be assessed during this study are:

Site 1: Town Centre and Seafront Regeneration Area
Site 2: West Wick & Worle
Site 3: RAF Locking Urban Village
Site 4: Airfield Neighbourhoods
Site 5: Town Centre Gateway
Site 6: Rhynes Neighbourhoods

Figure 1.1 shows the study area extends slightly east of the M5 opposite West Wick and Worle and RAF Locking Urban Village. This is to incorporate the development of the proposed new junction 21 bypass.

1.3.1 Coastal areas

Middle Hope – North of the study area, extending from St. Thomas Head south to Sand Point. The area has steep cliffs interspersed with narrow intertidal areas. There are no low-lying areas in this section of the coastline.

Sand Bay – At the northern end of the study area this bay faces westwards and has a wide inter-tidal area of sand banks and mud flats extending from Sand Point in the north to Birnbeck Island in the south. Sand dunes form the backshore and part of the sea defences. There is a large salt marsh at the northern end of the bay. Residential development is situated behind the sand dunes with agricultural land located inland of this development.

Weston Bay - The most southerly section of coastline within the NSC boundary extends from Birnbeck Head to Brean Down in the south. The bay is western facing with a sandy coastline defined by the hard rock headlands of Birnbeck in the north and Brean Down in the south. There is a wide mud inter-tidal area and sandy foreshore. Weston-super-Mare is the primary developed section of coastline with residential, commercial, recreational and tourist interests. It has a wide sandy beach with a new seawall defence. Uphill lies to the south and is defended by an embankment, uphill sluice and high ground.

1.3.2 River Catchments

The North Somerset Levels (Avon Levels) are located between the Gordano Levels to the north and the Somerset levels to the south. Water Level Management Plans (WLMPs) have been adopted to regulate water levels across the North Somerset levels. The water levels in the Levels and Moors are controlled and drained by a network of channels known as rhynes, and the use of sluices and pumping stations. The area is mainly used for grazing but some peat extraction is also carried out. Some parts are allowed to flood in winter.

The Uphill Great Rhyne is approximately 4.5km in length and drains water from the area of Weston airfield. Uphill Great Rhyne runs from Wyvern School through the residential areas of southern Weston-super-Mare and Uphill to a discharge at Uphill Sluice. A 1.6km culvert feeds surface water into the head of Uphill Great Rhyne. A second major channel, Cross Rhyne, joins Uphill Great Rhyne upstream of the hospital site. Cross Rhyne drains water from the Weston Airfield area. The channel outfalls into Uphill Pill, via Uphill Sluice, which was newly constructed in 2004, is a tidal sluice which prevents tide water entering Uphill Great Rhyne at high tide and allows the Rhyne to drain at low tide. There is a period of approximately 3 hours on each tide when the Uphill Great Rhyne is tide locked and cannot drain.

The River Banwell is a largely artificial channel 9km in length, located to the east of Weston-super-Mare. The river rises at a spring at Banwell Village, drains the surrounding agricultural land and discharges through New Bow Sluice, a tidal defence structure. The current sluice was constructed in 1990, replacing an earlier sluice of inadequate capacity and is 0.8km upstream of the confluence with the Severn Estuary. The gradient of the river channel is very shallow (approximately 1 in 3300 or 2.7m over 9km) and the flow in the river is consequently dominated by daily tide locking at the New Bow sluice. Ground water levels are reported to be very close to ground level in some of the developed areas. This causes problems with constructing local sustainable urban drainage attenuation measures and results in the potential for problems with water logging issues. In one area, due to development it has been necessary to pump surface water into the River Banwell and construct a number of small storage facilities to counteract the increased flood risk. However, the potential for use of sustainable urban drainage systems (SuDS) should still be investigated for new developments.

West Mendip Internal Drainage Board (IDB) operates and maintains the rhyne system. This includes water control structures which are used to control water levels in the area. Typically, during the summer months, water in the River Banwell is held back or penned to provide water for irrigation, wet fencing and general amenity. During the winter months these various water level control structures are opened to allow the free discharge of flow and to reduce flooding risks. The IDB also operate control structures as part of local flood storage systems in the area of the Locking Castle development.

1.4 Scope of Work

1.4.1 Overview

Environment Agency Flood Zones have been used in the Level 1 SFRA to determine Sequential Testing and which sites require further analysis in the Level 2 SFRA in order to undertake the Exception Test. Environment Agency Flood Zones do not consider the beneficial effects of existing flood risk management infrastructure, such as raised defences, in influencing the extent and severity of flooding from rivers and the sea.

The Level 2 SFRA does consider the beneficial effects of existing flood risk management infrastructure in order to further understand the flood risks to each site.

The majority of the sites covered by this Level 2 study are within the Environment Agency Flood Zones. For these areas the Level 2 SFRA will enable the production of mapping showing flood outlines for different probabilities, impact, speed of onset, depth and velocity variance of flooding taking account of the presence and likely performance of flood risk management infrastructure.

The information in the SFRA level 2 will not be sufficient to be used to support individual planning applications; rather it will provide the background information necessary that FRAs can draw upon to inform planning applications in the future. The information will also allow NSC to assess criterion c) of the Exception Test at a strategic level for the lifetime of a proposed development through the provision of high-level information on flood risk now and in 100 years time to account for climate change. Climate change assessments will be based on the shelf life of the Core Strategy i.e. up to 2026, plus the required 100 year design life for residential development. The assessment will therefore consider levels for 2126.

This SFRA Level 2 takes into account paragraph D4 contained in annex D of PPS25 which advises that the SFRA refines information on the probability of flooding, taking the impacts of climate change into account. The SFRA provides the basis for applying the Sequential Test, using the zones in Table D1 of PPS25. Where Table D3 of PPS25 indicates the need to apply the Exception Test, the SFRA considers the impact of the flood risk management infrastructure on the frequency, impact, speed of onset, depth and velocity of flooding both now and in the future.

1.4.2 Data sources

All of the data collected and produced as part of the Level 1 SFRA has been utilised during this study. Two of the main sources of information were the Environment Agency Flood Zones, which were re-issued for this study to ensure that the most up-to-date information was being used, and LiDAR data. LiDAR stands for Light Detection and Ranging and provides a Digital Terrain Model (DTM) for an area. It was used to provide an idea of the topography and to create the grids which were used to display the model results.

Historic flood records have been sourced from NSC and the EA (data from the Flood Reconnaissance Information System), and supplemented with information from Parish Councils, local residents and Wessex Water. The historic information has been used in conjunction with other data such as Flood Maps detailing extents of flood risk and information about the location of defences, provided by the EA.

Information about the management of flooding has been provided including surface water flooding information as this is a major cause of flooding incidents in the North Somerset District.

The Weston-super-Mare FMS Phase II Options Report written by Royal Haskoning, October 2007, focused on two main catchments at risk of flooding within the Weston Vision area, these are the River Banwell and the Uphill Great Rhyne. Two pre-feasibility reports were delivered as part of the initial stage (Phase I) of the Weston FMS, focusing on the above catchments. These pre-feasibility reports form the basis for more detailed investigations carried out, under the Weston FMS Phase 2, into flooding mechanisms, potential flood extents and sustainable flood management options.

As part of the FMS study a preferred option for flood mitigation due to increased development was agreed by the Weston Partnership. This involved a 'Super Pond' adjacent to Cross Rhyne and a compound channel on the River Banwell. A study is underway to assess the design of this preferred option in more detail. The idea of the 'Super Pond' is to ensure that a strategic approach to flood mitigation is taken for the area as a whole rather than piece-meal site specific infrastructure. Appendix F provides the outline process for delivering Weston-super-Mare's flood risk management infrastructure.

The following information has been used with permission from the Environment Agency and North Somerset Council as a basis for the assessment:

- Light Detection and Ranging (LiDAR) DTM data supplied by NSC for the use in the Level 2 SFRA.
- River Banwell and Uphill Great Rhyne 1D HEC-RAS hydraulic models supplied by NSC.
- North Wessex Area Tidal Areas Benefitting Defences 2D TUFLOW model supplied by the Environment Agency (2007).
- Areas Susceptible to Surface Water Flooding maps supplied by the Environment Agency (2009)
- Information on Flood Warning areas supplied by the Environment Agency
- Information on Flood Defences from NSC and from the National Flood and Coastal Defence Database (NFCDD) supplied the Environment Agency (NFCDD).
- Ordnance Survey Mastermap and 1:10,000 scale mapping provided be NSC.
- Hazard Assessment based Flood Risks to People Phase 2 FD2321/TR1 The Flood Risks to People Methodology (DEFRA, 2006).
- Planning information including the proposed Weston Development Area provided by NSC.

- Information on predicted tide levels for extreme events from the SW Regional Extreme Tide Report 2003, which was prepared by Royal Haskoning on behalf of the Environment Agency.
- Information and outputs from the Weston Flood Management Study Phase I and II (2007) which was prepared by Royal Haskoning on behalf of NSC.
- Information on required allowances for sea level rise obtained from Planning Policy Statement 25: (PPS25) Development and Flood Risk.
- Environment Agency Flood Zone extents (2008) for the area supplied by the Environment Agency.
- Different sources of flooding for geo-referenced features affected by flood incidents. Derived from the EA Flood Reconnaissance Information System (FRIS). Supplied by the Environment Agency.

2 METHODOLOGY

This section provides an overview of the methods and data used in the Level 2 SFRA to undertake the tasks necessary to provide information about each site to meet the requirements of PPS25.

2.1 Overview of existing flood risk and inundation

The Environment Agency Flood Zones 2 and 3 have been used to assess the current risk of flooding at the development sites. Flood Zones 2 and 3 represent areas of medium and high flood risk respectively due to fluvial and tidal flooding. The medium flood risk refers to areas that may flood from a 1 in 1000 year event i.e. with an annual probability of 0.1%, whilst high flood risk represents areas that may flood from a 1 in 100 year fluvial or 1 in 200 year tidal event, i.e. with an annual probability of 1% or 0.5% respectively. Any areas not shown as Environment Agency Flood Zones 2 or 3 are classed as Environment Agency Flood Zone 1, low fluvial and tidal flood risk. The Environment Agency Flood Zones do not take account of the beneficial impacts of flood risk management infrastructure or sources of flooding other than fluvial and tidal.

The historic flooding information detailed in the North Somerset Levels 1 and 2 SFRA has also been considered when reviewing the flood risk to the areas. This historic data is not conclusive and only indicates data recorded by NSC or the Environment Agency. Other incidents of flooding may have occurred but not been recorded and are therefore not detailed in this assessment.

2.2 Existing defences, Verification of Defences and Areas Benefiting from Defences (ABDs)

Information in the Level 2 SFRA regarding existing tidal and fluvial defences has been obtained from the Level 1 SFRA and the National Flood and Coastal Defence database (NFCDD). NFCDD highlights all information regarding the structure of watercourses in the area. It therefore shows areas of natural or maintained channel as well as raised defences or culverts.

Defences comprise a structure (or system of structures) for the alleviation of fluvial or tidal flooding. The SFRA level 1 has identified existing defences that are maintained by the Environment Agency. It also highlights a number of privately maintained defences that are currently within NFCDD. It should be noted that there may be additional private defences that have not been included in NFCDD. Private walls may also exist in the area but are not classed as ‘flood defences’. Furthermore, not all banks are flood defences.

Defences are designed to protect from flooding of a certain level - a standard of protection. The standard of protection is the maximum flood event that the defence can protect against before it is breached or overtopped.

It cannot be assumed that the level of defence is still at the original design standard because of changes to the way floods are estimated, the effects of climate change and deterioration of the structure.

Changes to the land use in areas near to defences can also have an effect on the standard of protection provided by the defence by changing the flow patterns of groundwater and surface water runoff. Therefore any proposed development must be closely examined during a detailed FRA to ensure that the existing and future development has the appropriate level of protection. PPS25 suggests that the appropriate level of defence against fluvial floods should be a 1 in 100 year standard (1% probability flood) and against tidal floods should be a 1 in 200 year standard (0.5% probability flood).

NFCDD highlights all information regarding the structure of watercourses in the area. It therefore shows areas of natural or maintained channel as well as raised defences or culverts.

Within Section 4.1, defences are identified and where they are present on or adjacent to development areas, figures have been produced illustrating their location and standard of protection. Where defences constitute small culverts under roads, figures have not been included. In addition there may be other private or informal defences not included in NFCDD, which are therefore not shown on the figures.

2.2.1 Verification of defences using model results

Using the fluvial and tidal hydraulic models, we have assessed the standards of protection recorded by the Environment Agency within NFCDD for the study area. We have supplemented this assessment with analysis of 'with defences' scenarios within the hydraulic models discussed in Section 4.2 where appropriate. Standards of protection have been summarised across the Weston Development Area.

Using the modelling results we have created mapped extents of tidal flooding with the new sea defence as designed to identify residual risk areas and made an assessment of the level the raised defences would need to be extended to in order to provide a 1 in 200 year standard of protection within the study area for both the current and future scenarios (up to 2126).

There is a small section of reach along the River Banwell with raised defences adjacent to St Georges. The Standard of Protection of this defence is assumed to be 1 in 25 years or greater (see section 4.1). Royal Haskoning have previously made an assessment of the effect of removing these defences on fluvial flooding and found the differences to be minimal.

2.3 Assessment of flood probability, depth and velocity

2.3.1 Hydrological overview

We have used the existing tidal and fluvial models to assess maximum water levels to determine the probability of the onset of flooding for the current defended situation. We have used 3D GIS techniques and LiDAR DTM data to interpolate grid based maps of depth, velocity and hazard from the 2D tidal model outputs and grids of depth and hazard for the 1D fluvial model outputs. We have also considered the impact of climate change on fluvial and tidal flood risk in 2126 to provide quantification of flood depth and velocity in the future.

Information about existing defences in the current fluvial and tidal models has been taken from a number of sources. These are the National Flood and Coastal Defence database (NFCDD), crest level surveys (Halcrow, on behalf of the Environment Agency) and the new Weston-super-Mare defence level was determined by modelling undertaken for the Weston-super-Mare Sea Defences project, Royal Haskoning, 2008 and LiDAR DTM for the study area.

Fluvial

Permission was obtained from the Weston Partnership to use the results of a 1D HEC-RAS model developed by Royal Haskoning for Weston-super-Mare FMS in 2007 which represents channel and floodplain flow for three watercourses, Uphill Great Rhyne, Cross Rhyne and the River Banwell. Figure 2.1 displays the catchment areas of the Uphill Great Rhyne and River Banwell. The three hydraulic models cover each study area in the Weston development area.

The objective of the hydraulic modelling was to provide a tool to assist the estimation of water levels for the preparation of flood risk maps for both catchments. An unsteady-flow model was used to allow for the spatial and temporal distribution of flood water volume, thereby giving greater confidence in the results. The model was built using HEC-RAS, an industry-standard package used to model open channel and floodplain flow, whilst incorporating hydraulic units such as bridges, weirs and sluices. HEC-RAS computes flow depths and discharges using a method based primarily on sub-critical flow regime calculations. This enables an accurate representation of the flow into and out of the storage areas.

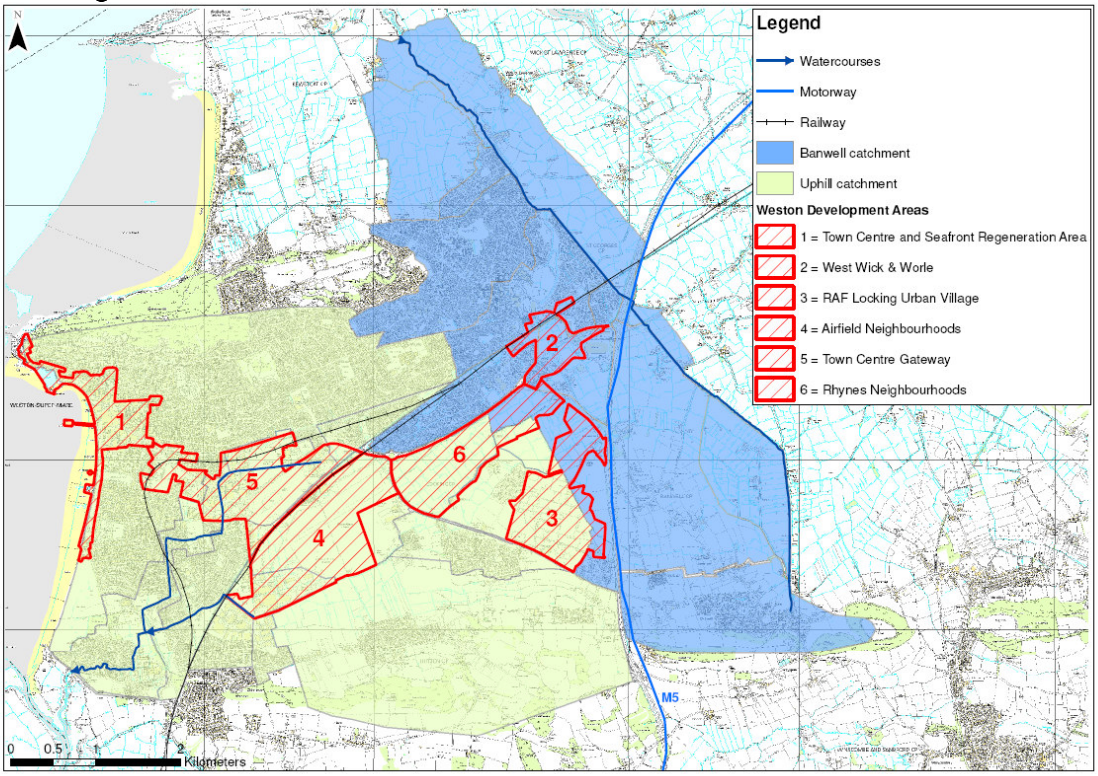
Three separate HEC-RAS models were used to provide an estimation of water levels for Uphill Great Rhyne, Banwell and Banwell Tributary. The aim of the hydrological study was to obtain the most realistic flows possible using available observed flow, stage and rainfall data for each model. The differing characteristics of the sub-catchments require an approach that simulates the relative timings of the response to rainfall on the Uphill Great Rhyne and Banwell catchments. This enables representation of the development of the event hydrograph storm throughout the catchment, as well as showing the affects of attenuation and potential tide-locking. Therefore inflow hydrographs were produced for each of the significant sub-catchments draining to Uphill Great Rhyne and Banwell watercourses.

Hydrological inflows were derived using the Flood Estimation Handbook (FEH) Rainfall runoff technique. Flows were determined for a range of scenarios and return periods: the 1 in 20 year event (20% AEP lowest modelled event), 1 in 100 year (1% AEP) flood event, present and future scenario 2126 which represented in the model with an increase in flows of 20%. The downstream extent of both models is tidal, the tidal still water level used for to day was 7.29mOD and with sea level rise is 7.72mOD for each model.

The overbank flooding was simulated in the HEC-RAS models through the use of storage areas which were determined using the LiDAR DTM and are connected to the channel and where appropriate to each other. These storage areas can be seen in Figure 4.12 for the River Banwell and 4.13 for Uphill Great Rhyne.

Since the model was built in 2007 the Uphill Great Rhyne model has been extended for NSC to include an additional section at the upstream end of Uphill Great Rhyne (Royal Haskoning, 2009 and 2010).

Figure 2.1 - Catchment overview & Location of modelled watercourses



Tidal

For the tidal scenarios wave overtopping rates were calculated using Royal Haskoning in-house software AMAZON. These results were then input into a 2D tidal model called TUFLOW in order to establish the tidal flood extent from a combined water level and wave event.

The extreme tide levels that were calculated by Royal Haskoning in 2003 have been adjusted to take account of sea level rise for up to the next 200 years in order to undertake analysis of the effects of climate change. This has been carried out with reference to the Defra FCDPAG3 Economic Appraisal Note to Operating Authorities – Climate Change Impacts October 2006, which equates to the following net sea level rise allowances for the South West of England:

- 3.5mm per year for 1990 to 2025
- 8.0mm per year for 2025 to 2055
- 11.5mm per year for 2055 to 2085
- 14.5mm per year for 2085 to 2126

The tidal still water levels used for each return period in the model are displayed in Table 2.1. These water levels were scaled to the peak of the tide curve and input to the TUFLOW model.

Table 2.1 - Summary of Extreme Tide Levels with climate change

	2010		2086		2126	
Location	**25yr**	**200yr**	**25yr**	**200yr**	**25yr**	**200yr**
Wick Warth	8.11	8.49	8.76	9.14	9.34	9.72
Sand Bay	7.85	8.23	8.50	8.88	9.08	9.46
WSM North	7.79	8.16	8.44	8.81	9.02	9.39
WSM South	7.79	8.16	8.44	8.81	9.02	9.39
Uphill	7.78	8.15	8.43	8.80	9.01	9.38

The TUFLOW model was set up to run for 105 hours which equates to approximately 8 tidal cycles, allowing for realistic time frames for large tidal swells to coincide with spring tides.

Coastal hydrodynamic parameters such as astronomic tide, surge shape, offshore storm waves, depth limited waves, modelled nearshore waves and wind direction have been taken from the existing North Wessex Tidal Areas Benefiting from Defences Study; *(Royal Haskoning on behalf of the Environment Agency 2007).* This information has been entered into the AMAZON modelling package in order to generate overtopping volumes for tidal flooding.

Overtopping rates have been calculated at five locations along the coast which have the potential to affect the SFRA study area in terms of flooding. To model in AMAZON a profile of the coastline at each location is required which consists of a cross section of the nearshore bathymetry from offshore to just landward of any defences that may be present. The profiles used have been taken from various sources of existing information, which are summarised in Table 2.2. The overtopping rates are used in combination with the defence length to derive a total volume of water that is estimated to overtop the defence. Five profile locations have been selected and used to run six different scenarios.

AMAZON results have been converted to a rate of overtopping m^3/s and input into a 2D TUFLOW.

For this study we developed the existing 2D TUFLOW model created as part of the North Wessex Tidal Areas Benefiting from Defences Study; (*Royal Haskoning on behalf of the Environment Agency 2007).* The new model includes the geometry of the new sea defence scheme at Weston-super-Mare. This has enabled us to map tidal extents for the current defended situation to show the residual risk areas which take into account the degree of protection granted to different areas. Six scenarios have been used to provide an updated representation of residual risk areas. These runs can be seen in Table 2.3.

Table 2.2 - Sources of Amazon Profile Data

Amazon Profile		Source of Profile	Section Name	Defence Height
1	Uphill	Weston-super-Mare Coastal Flood Warning Review (2009)	Uphill - Profile B	NFCDD Feb 2010
2a	WSM	North Wessex Tidal ABD (2007)	Marine Lake to Grand Pier, Weston-super-Mare	Royal Haskoning
2b	WSM	North Wessex Tidal ABD (2007) with lowering of defence	Tropicana to	Royal Haskoning
Amazon Profile		Source of Profile	Section Name	Defence Height
3	Sand Bay	North Wessex Tidal ABD (2007)	Sand Point to Kewstoke, Sand Bay - Kewstoke	NFCDD Feb 2010
4	Wick Warth	North Wessex Tidal ABD (2007)	Wick Warth	NFCDD Feb 2010

Using the new defence levels ensures that the Standard of Protection of this and other defences are verified. It should be noted that the new defence contains a number of gates which must be closed in certain conditions in order to provide a continuous defence along the length of the sea wall. In order to simulate failure to close the gates during flood conditions two breach scenarios have been modelled.

2.3.2 Flood probability

For this section, flooding has been assessed for the ‘with defences’ scenario. This shows the current situation assuming the defences are maintained at the current crest level for the lifetime of the development and work as designed. The Shoreline Management Plan Review for North Devon and Somerset (SMP2) (expected due for release later in 2010) recommends a present day and medium term preferred plan of hold the line along at Weston-super-Mare (WSM) over the development lifetime of proposed developments and of no active intervention from WSM to Uphill along the dunes. In the longer term, the SMP2 preferred plan recommends holding the line at WSM and of no active intervention from WSM to Uphill but with managed realignment along the dunes if necessary. However, the SMP2 is likely to be reviewed on a regular (10 year) basis and that it should continue to be consulted.

Model outputs were used to map flood probability at each development area for a range of fluvial and tidal flood events as indicated in Table 2.3 below. Fluvial flood events were modelled assuming a 1 in 1 year tidal event. This was to ensure that any tide-locking is taken into account with the model results. **Unless stated otherwise, it should be assumed that model results refer to the defended situation.**

Table 2.3 – Modelled return periods

Return period	Tidal	Fluvial
1 in 20 year*	x	✓
1 in 20 year + climate change (increased river flows)*	x	✓
1 in 25 year	✓	x
1 in 25 year + climate change (sea level rise)	✓	x
1 in 100 year*	x	✓
1 in 100 year + climate change (increased river flows)*	x	✓
1in 100 year + climate change (sea level rise)*	x	✓
1 in 200 year	✓	x
1 in 200 year + climate change (sea level rise)	✓ (to 2086)	x
1 in 200 year + climate change (sea level rise)	✓ (to 2126)	x

* Includes tide locking based on a 1 in 1 year tidal event

2.3.3 Flood Zone 3a & 3b

Environment Agency Flood Zone 3 can be split into Flood Zone 3a (high probability) and Flood Zone 3b (functional floodplain) as detailed in Table D.1 of PPS25. Functional floodplain is defined as land where water has to flow or be stored in times of flood, this includes water conveyance routes and flood storage areas. For this reason it is important that as far as possible development is sited away from areas identified as functional floodplain. Table D.1 in PPS25 advises that only water compatible or essential infrastructure (the latter requiring the Exception Test to be passed) are considered to be suitable development types in the functional floodplain.

For SFRA purposes, the functional floodplain is identified as land which would flood with an annual probability of 1 in 20 (5%) or greater in any year, taking account of local circumstances and as agreed with the Environment Agency. PPS25 states that Local Planning Authorities should identify areas of functional floodplain in their SFRA's through discussion with the Environment Agency. In order to assist NSC in meeting this requirement, we have assessed the split between Flood Zones 3a and 3b based on the North Somerset Level 1 SFRA and the modelling results, details of which can be found in Section 4.2.

Areas defined as functional floodplain take into account the effects of defences and other flood risk management infrastructure. Where raised defences are present, the river channel up to the top of the banks or flood defence is classified as functional floodplain (Flood Zone 3b).,Providing the defences are of a high enough standard, the land behind the defences is classified as Flood Zone 3a. It should be noted that some areas behind defences which are currently classed as Flood Zone 3a become functional (3b) when taking climate change into account.

Both fluvial and tidal flood extents have been mapped in terms of Flood Zone 3a (High Probability) and Flood Zone 3b (Functional Floodplain). This was carried out for the whole of the NSC area and delivered as part of the North Somerset Council Level 1 Strategic Flood Risk Assessment; *Royal Haskoning 2009*. These extents have been compared to the 1D and 2D model results extracted for this Level 2 SFRA and modifications to the Flood Zone 3a / 3b classification made where necessary. This is detailed in Section 4.2.

2.3.4 Flood depth

Flood depths have been assessed 'with defences' to represent the current situation and unless stated otherwise, it should be assumed that model results refer to the defended situation. Grids of maximum depth were extracted from the hydraulic model to enable mapping of flood depth for each return period across the development sites.

2.3.5 Flood Hazard

Flood Hazard Mapping combines information on flood depth and speed (velocity) of floodwater with a debris factor to create a hazard rating for people for each area that experiences flooding. The hazard rating we have used is set out in the report Flood Risks to People Phase 2: FD2321/TR1. The Flood Risks to People Methodology (DEFRA, March 2006). The hazard rating categorises flood risk in terms of Caution, Danger for Some, Danger for Most and Danger for All, with the hazard becoming dangerous to more kinds of people as depths and velocity increase. This is described in Table 2.5.

The tidal Flood Hazard Mapping presented in this report is based on the hazard rating calculated by the 2D modelling outputs using the hazard equations stated in FD2321/TR1 and colour coding as shown in Tables 2.4 / 2.5 and is given below;

Table 2.4 – Flood Hazard Coding used in Level 2 SFRA

Hazard rating	Colour	Hazard value	Danger
Low	green	0* – 0.75	**Caution**
Moderate	yellow	0.75 – 1.25	**Danger for Some** (includes children, elderly and the infirm)
Significant	orange	1.25 – 2.5	**Danger for Most** (includes the general public)
Extreme	red	> 2-5	**Danger for All** (includes emergency services)

*The hazard "Caution" (green) is not specified in FD2321/TR1 and has been employed within this SFRA to show maximum flood extents.

Table 2.5 - Flood Hazard Matrix*

Velocity (m/s)	Depth (m)											
	0.05	0.10	0.20	0.30	0.40	0.50	0.60	0.80	1.00	1.50	2.00	2.50
0.00	Green	Green	Green	Yellow	Yellow	Yellow	Orange	Orange	Orange	Orange	Red	Red
0.10	Green	Green	Green	Yellow	Yellow	Orange	Orange	Orange	Orange	Orange	Red	Red
0.25	Green	Green	Green	Yellow	Orange	Orange	Orange	Orange	Orange	Red	Red	Red
0.50	Green	Green	Green	Orange	Orange	Orange	Orange	Orange	Orange	Red	Red	Red
1.00	Green	Green	Yellow	Orange	Orange	Orange	Orange	Red	Red	Red	Red	Red
1.50	Green	Green	Yellow	Orange	Orange	Orange	Red	Red	Red	Red	Red	Red
2.00	Green	Yellow	Yellow	Orange	Orange	Red	Red	Red	Red	Red	Red	Red
2.50	Green	Yellow	Yellow	Orange	Red	Red	Red	Red	Red	Red	Red	Red
3.00	Green	Yellow	Yellow	Red	Red	Red	Red	Red	Red	Red	Red	Red
3.50	Green	Yellow	Orange	Red	Red	Red	Red	Red	Red	Red	Red	Red
4.00	Green	Yellow	Orange	Red	Red	Red	Red	Red	Red	Red	Red	Red
4.50	Yellow	Yellow	Orange	Red	Red	Red	Red	Red	Red	Red	Red	Red
5.00	Yellow	Yellow	Orange	Red	Red	Red	Red	Red	Red	Red	Red	Red

*The hazard "Caution" (green) is not specified in FD2321/TR1 and has been employed within this SFRA to show maximum flood extents.

A modified approach was employed for the fluvial Flood Hazard Mapping presented in this report. This is because information regarding fluvial flood velocity was unavailable from the 1D modelling. The hazard rating was therefore estimated using the depth results from the 1D modelling and an average, constant velocity across the study area derived from the 2D tidal modelling. This approach was adopted because the tidal results displayed flood velocities in the flood plain and it was assumed that once the flood waters spread across the fields both tidal and fluvial flood extents would behave in the same way. It was also considered that the land comprising the Weston Development Area is very flat which means that generally velocities will be low and depth will be the more influential factor with regard to flood hazard. Therefore, based on the tidal results, a conservative velocity of $0.03m^3/s$ was used in combination with the 1D depth results to produce a fluvial hazard rating using the equation in FD2321/TR1 and colour coding as shown in Tables 2.4 / 2.5 above.

2.3.6 Speed of onset of flooding

The speed of onset of flooding is an important factor in flood management as a rapid onset of flooding increases risk to life. The speed of onset affects how much time people have to react to rising water levels and possible flooding. The speed of onset has been assessed using the results of the hydraulic modelling (where appropriate) to determine the time of onset for a design event. It has been based on the lowest return period design event that results in the overtopping of the man-made or natural defences. This gives an indication of the time it could take following the peak of a rainfall event for flooding to occur. In general as event severity increases, flooding will occur earlier and for longer. The study areas and their catchments have been classified into ranges according to the speed of onset. The ranges are given below:

- **Fast onset:** <1.5 hours time to flooding onset
- **Moderate onset:** 1.5 – 4 hours time to p flooding onset
- **Slow onset:** >4 hours time to flooding onset

Where tidal flooding is dominant over fluvial flooding it is considered a moderate onset. This is because it would be reasonable to expect at least 6 hours forecast of a significant tide level, although the actual tide and wave condition will be determined closer to the time of high tide.

2.4 Impact of climate change

PPS25 states that climate change needs to be considered in terms of both fluvial and tidal flooding.

In order to model the climate change scenario for fluvial flooding the model flows were increased by 20% following guidance from PPS25. In addition an extra 10% increase in flows has been included as a precautionary approach and to provide allowance for uncertainties of modelling a rhyne system.

Climate change has also been accounted for in the 2126 model run scenarios with an adjustment for predicted sea level rise (SLR) being incorporated in the downstream tidal boundary. Due to the increase in the tide level caused by this sea level rise the downstream tidal gates on the River Banwell and Uphill Great Rhyne were adjusted to mitigate from additional tidal inundation.

Sensitivity testing for climate change within the modelling was represented by an increase in sea level rise according to the guidance set out in Defra FCDPAG3 *Economic Appraisal Supplementary Note to Operating Authorities – Climate Change Impacts* (see table 2.6). The impact of these increased flows on flood extents, depths and velocities has been assessed for the 1 in 100 year return period fluvial flows and 1 in 200 year tidal flows. A comparison has been made with the 1 in 100 and 1 in 200 year extents respectively for the current defended situation (it is assumed that defences will continue to be maintained to their current standard of protection). This is to allow us to assess the impact of the 1 in 100 year fluvial and 1 in 200 year tidal flood events now, and to use this as a baseline through which we can then make judgements about current flood risk and how this may change in the future with climate change.

The Shoreline Management Plan Review proposes a ‘hold the line policy throughout the study area except along the undefended dunes. The climate change modelling uses current defence crest levels for all modelled events. This can help to identify areas where in the future defences may need to be raised in order to ‘hold the line.

Note that the tidal climate change for 2126 modelling takes into account still tidal levels only in all areas except Sand Bay as the water level is above the height of the sea wall and therefore the tide level is the dominant flooding mechanism. A detailed site Flood Risk Assessment may need to consider wave action and surge if an area is particularly vulnerable to the effects of climate change. The tidal climate change for 2086 includes for wave overtopping of all the defences in the model though surge is not included in these results.

Table 2.6 – Sea level rise allowance

Administrative Region	Net Sea Level Rise (mm/yr) Relative to 1990			
	1990 to 2025	2025 to 2055	2055 to 2085	2085 to 2115
South West	3.5	8.0	11.5	14.5

Source: Table B.1 Planning Policy Statement 25: Development and Flood Risk

The 2D modelling described in Section 2.3 was used to model the effects of climate change on tidal flooding for the area for the 1 in 200 year event, the 1 in 200 year event plus climate change up to 2086 to account for the life of commercial development, and the 1 in 200 year event with climate change up to 2126 to account for the life of residential development.

The climate change allowance can produce dramatic changes in inundation extent in flat areas. Changes in sea level and fluvial flows will increase the frequency at which potential flood levels will be reached, with increased storminess creating wave conditions that could exacerbate this. The resulting frequency and depth of flooding can have implications for the type of development that is appropriate, according to its vulnerability to flooding, due to the potential re-classification of the level of flood risk. The assessment of climate change has been made using the 'with defences' scenario to represent the current situation. It is assumed that defences will continue to be maintained to their current standard of protection.

The impact of increased tidal levels on flood extents, depths and velocities has been assessed for the 1 in 200 year return period event and then compared with the current situation. This allowed us to assess the impact of an extreme flood event on the site now, and to use this as a baseline through which we can then make judgements about current flood risk and how this may change in the future with climate change.

2.5 Access and Egress

PPS25 states that development in flood risk areas should be protected from fluvial and/or tidal flood risk over the lifetime of the development (100 years for residential development and 60 years for commercial development). Access and egress routes should be above likely flood levels, and therefore access to any development areas should be considered with dry alternatives offered if appropriate to ensure safe access and egress for emergency vehicles and residents. Specific safe routes for access and egress from the development areas have been identified as part of the SFRA, whilst links within the development are to be addressed as part of a site specific FRA.

Where the risk has been assessed and development in flood risk areas cannot be avoided, appropriate flood warning and emergency plans need to be provided so that users and residents are safe or can move safely should a flood occur. Flood warning systems (such as Flood Warnings Direct operated by the Environment Agency) should not be solely relied upon, as responses to flooding should also be a result of active planning. Planning conditions can be used to cover the maintenance of signs and keeping evacuation routes clear, details of which should be provided in a site specific FRA.

The 1 in 200 year with climate change was considered comparable to 1 in 1000 year event of today; it was these results that were used to assess access and egress. Using the velocity, depth and hazard maps generated from model results, safe access and egress routes have been identified for the SFRA Level 2 development areas. These should be investigated further as part of a detailed site Flood Risk Assessment. The potential for safe access and egress specific to each area is identified in Section 4.6.

2.6 Overview of impact of development on flood risk elsewhere

Hydrological assessments for the study area have previously been undertaken in detail during the Weston FMS Phase 2: Options Report (Royal Haskoning, 2007).

As the proposed developments in the study area would lead to an increase in impermeable land, this increase in urbanisation was factored into the Weston FMS Phase I hydrology to produce post-development flows. For the Weston FMS Phase 2 study a hybrid methodology was used through the assessment of land use coefficients from the Modified Rational Method and application of an adjusted Standard Percentage Runoff (SPR) value to the runoff rates already identified in Phase I using the Flood Estimation Handbook Rainfall Runoff Method. A more detailed methodology can be found in the Weston FMS modelling reports.

The results of this assessment have been used in this Level 2 SFRA in order to assess the current potential impact of development within the Weston Development Area on flood risk to the surrounding areas. This was carried out to show at a strategic level which sites could have the most impact on flood risk elsewhere (i.e. away from the development area itself). This approach involved an assessment of pre and post development flows to be made at each area. This information was then used to understand the relative level of mitigation measures that each area may need to use in order to meet the requirements of PPS25.

2.7 Surface water drainage

Surface water flooding is difficult to predict and often occurs rapidly. Areas Susceptible to Surface Water Flooding (ASSWF) maps relevant to the study area are held by NSC. These are not flood risk maps but can be used to indicate potential surface water problem areas and highlight whether further work such as a FRA might be required. Susceptibility to surface water flooding across the study area has been evaluated using these maps in Section 4.8.

For new developments, the best way of avoiding and managing surface water flooding is to manage the water at source through the use of Sustainable Drainage Systems (SuDS).

SuDS are designed to mimic natural drainage processes, along with treating the surface water to reduce the amount of pollutants entering the watercourse. They can be located as close as possible to where the rainwater falls (at 'source') and provide varying degrees of treatment for the surface water, using the natural processes of sedimentation, filtration, adsorption and biological degradation. Guidance about the use of SuDS techniques has been appended to this report (see Appendix A).

The development of Surface Water Management Plans (SWMPs) is being explored by the Government as part of the Flood and Water Management Act (2010). SWMPs will focus on managing flood risk and optimising the provision of SuDS and are envisaged to inform Local Planning Authorities in their preparation of the Core Strategy document, allowing appropriate policies on flooding and surface water drainage to be incorporated. The need for SWMPs and identification of critical drainage areas will be highlighted, where appropriate, for each development area.

2.8 Consequences of infilling on the floodplain

An assessment of the consequences of infilling of the floodplain is a requirement under criterion c) of the Exception Test, “a FRA must demonstrate that the development will be safe, without increasing flood risk elsewhere, and where possible, will reduce flood risk overall” and should be undertaken as part of the detailed site specific Flood Risk Assessment. We have undertaken an assessment of this at a strategic level for the Level 2 SFRA for fluvial sites.

Under a fluvial or tidal event, the effects of raising land for development in order to mitigate flood risk could increase flood risk elsewhere. The Environment Agency will oppose any infilling of the fluvial floodplain on grounds of loss of conveyance and / or loss of flood storage unless suitable compensation storage / conveyance is carried out. At a local level, under any flooding scenario, raising the ground levels may change the flow direction of floodwater.

2.9 Potential mitigation and management of residual risk

According to the flood risk management hierarchy set out in PPS25 and the North Somerset Level 1 SFRA, if the risk of flooding has been assessed and cannot be avoided, mitigation measures are a final option. Where possible, land allocated for development should be located where minimal mitigation will be required. If they are necessary, mitigation measures for development at any of the sites would need to be considered within a site specific FRA to demonstrate the site will be safe, without increasing flood risk elsewhere, and, where possible will reduce flood risk overall, therefore satisfying criteria c) of the Exception Test. The adoption of flood resilient design and construction, where appropriate, should also be included as part of the site specific FRA in order to manage residual flood risk. Specific resilience measures that can be undertaken are detailed in Appendix A.

PPS25 states that the volume of run-off leaving a site should not increase after development, and where possible the drainage should mimic that of the natural drainage of the area. SuDS will therefore be required for all developments, although the type and space required will be dependent on the effect the development has on the volume of surface water leaving the site. Where the impact is small only minor work will be required e.g. permeable paving and vegetation where possible, whereas in areas where the impact is higher storage and attenuation may be required which could affect the viability of the site.

Even where a high frequency of flooding exists across the site, sufficient economic benefit for the justification of further mitigation works needs to be identified in order to apply for Government funding. The Environment Agency’s remit relates to the provision of defences which protect existing assets. They do not provide defences to facilitate new development. Should new or improved defences be required to allow development to occur, the provision of these works would be the responsibility of the developer or the local authority if they wish to promote the development. Further measures to manage residual risk could include the use of developer contributions towards flood mitigation schemes and the management of surface water discharge from the site. These contributions are normally achieved through Section 106 agreements implemented by the Local Planning Authority. Specific mitigation measures would be identified through a site specific FRA.

3 OVERVIEW OF PROPOSED DEVELOPMENT

3.1 Weston Development Area

3.1.1 The Weston Area Development Framework (June 2005) set out a vision for regeneration within Weston-super-Mare. Development of a number of sites within the Weston Development Area was key to this framework with residential and commercial development planned within both Uphill and Banwell catchments. Some 9,000 new dwellings were expected in Weston-super-Mare by 2021. Figure 3.1 shows the extent of key development areas within the study area as outlined in the Weston Area Development Framework and as agreed with NSC for the purpose of the Level 2 SFRA.

3.1.2 Following the abandonment of the RSS, the projected level of growth is under review. Figure 3.2 shows the July 2010 proposal for two new villages in areas3, 4 and part of 6. Master planning for these villages should make use of the information provided for the relevant areas.

3.1.3 For the Banwell catchment both commercial and residential development is planned in the RAF Locking area, whereas development in the West Wick, Worle and St Georges area will be predominantly residential.

3.1.4 Within Uphill Great Rhyne catchment, both commercial and residential development is planned in the RAF Locking area (which falls within both catchments) and the Airfield Neighbourhoods. Based on information received from NSC, approximately 2,000 to 2,400 dwellings and part of 38.5ha of employment land are proposed for the Airfields Neighbourhoods. A further 2,800 dwellings are estimated to be sited at Locking Parklands along with the remaining employment land.

3.1.5 An extensive seafront regeneration programme is also linked to the current Weston Sea Defences project.

3.1.6 Government guidance, PPS25 exists to assist planning officers making decisions about land allocation in terms of flood risk. Any new development within the catchment will require a flood risk assessment as defined by PPS25. The flood risk assessment will have to demonstrate that the development does not put people or assets connected with the development at risk of flooding. It also has to demonstrate that, as a result of development, flood risk is not increased anywhere else in the catchment.

Figure 3.1 - Weston Development Area: key areas

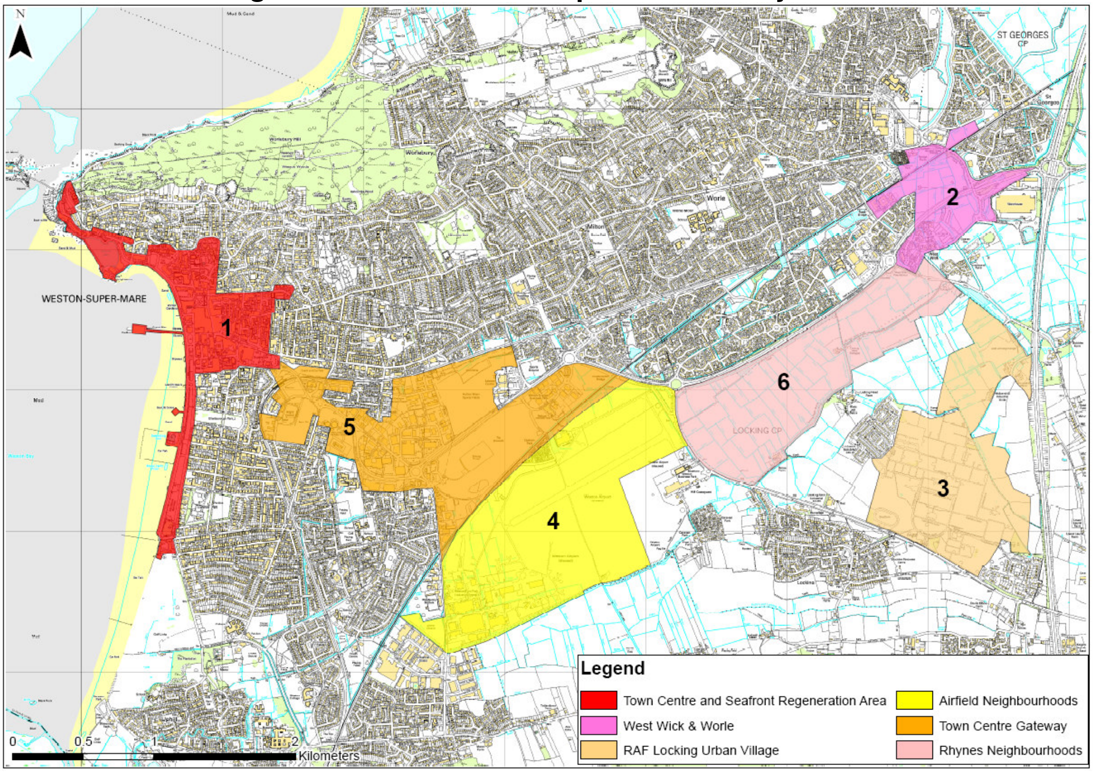


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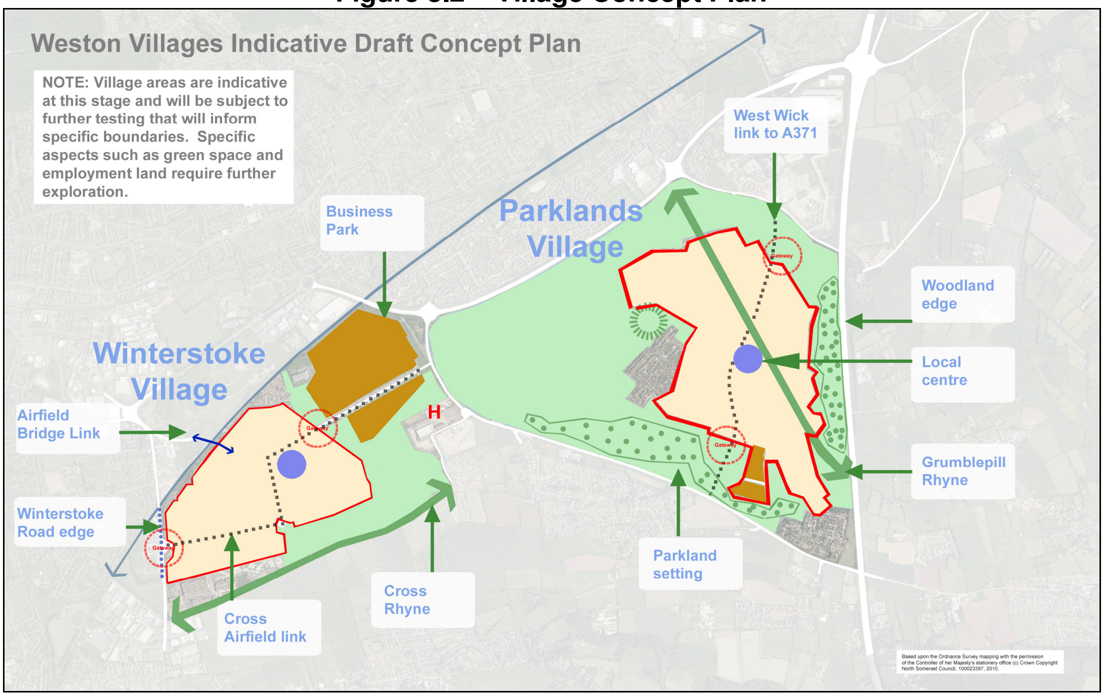
Figure 3.2 – Village Concept Plan



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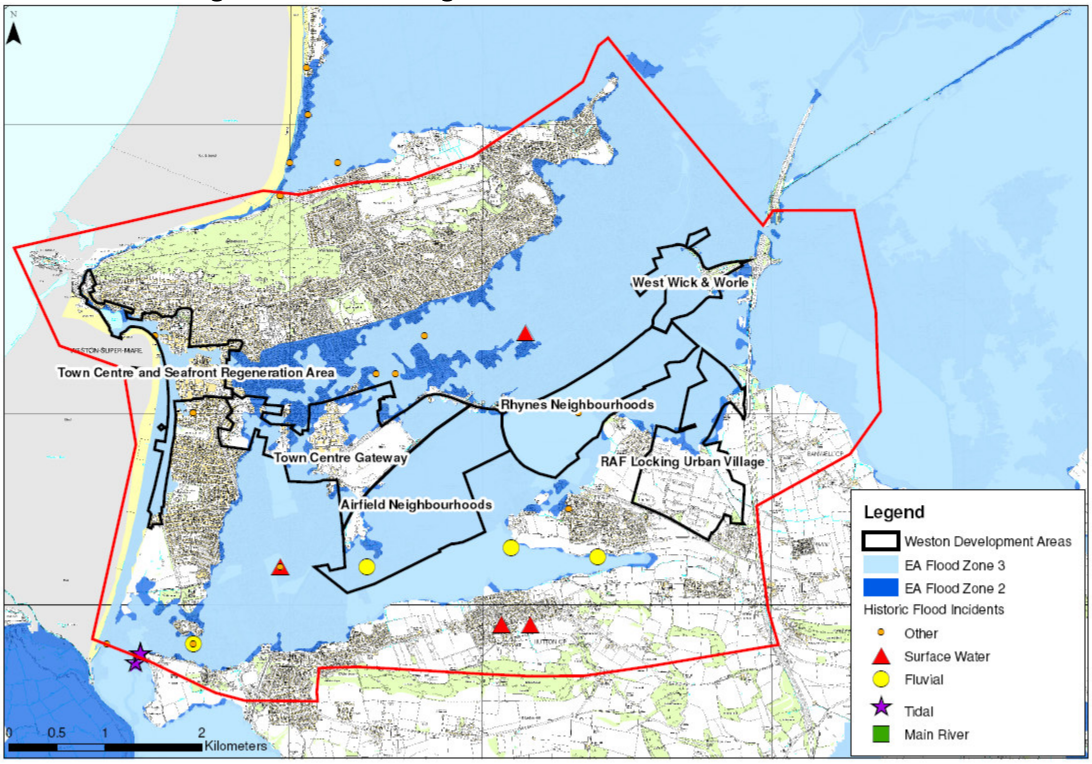
4 ASSESSING THE FLOOD RISKS IN WESTON-SUPER-MARE

Figure 4.1 – Existing Flood Risk to SFRA Level 2 areas



Flooding is an issue with varying levels of severity across most of the study area. In some locations flooding is made worse by tide locking, with fluvial and coastal flooding leading to significant and at times extensive damage. Less severe flooding in the town and the highway network is predominantly from overtopped defences (both tidal and fluvial) surface water runoff, and the blockage of drains and culverts.

The North Somerset district experiences regular flooding of land without risk to property, and in parts of the low lying North Somerset levels, controlled flooding of agricultural land forms part of the catchment management processes. There are, however areas that are at a greater risk to fluvial and coastal flooding as indicated by the Environment Agency Flood Zones in Figure 4.1. A significant proportion of the Weston Development Area is within the EA Flood Zone 3. Therefore in accordance with PPS25, if no suitable alternatives for development can be identified, the exception test will have to be passed in these areas where development is proposed on Greenfield land.

Figure 4.1 also highlights that there have been a number of historic flood incidents in the Weston area, although only three are located within the Weston Development Area comprising, fluvial (Airfields neighbourhood), coastal (Town centre and seafront) and an unknown source of flooding (Rhynes neighbourhood). Note that to date there are no recorded incidents of flooding from ‘Main River’ within the study area in the FRIS database.

There is a history of fluvial and tidal flooding within the study area. The north of Weston-super-Mare is affected by flooding which results from overtopping of the sea defence wall between Marine Lake and Grand Pier. Work to build a new sea defence scheme is currently being undertaken to address these tidal flooding issues. In addition, anecdotal reports indicate that in recent years minor flooding has also occurred in the low lying areas (such as the airfield and railway triangle, Banwell Moor and St Georges Village). Significant tidal flooding has also been recorded in the past at Uphill as a result of the failure of the previous Uphill tidal sluice. Defences in this area have been repaired however the potential for failure and the consequence of such an event should be considered if development is proposed in an area that would be affected by flooding from this source.

The Level 1 SFRA (October 2008) identifies a number of flood events that have occurred in the study area over the last 100 years.

There are many other sources of flooding other than rivers and the sea within the study area that are beyond the scope of this study to evaluate but that should be taken into account prior to development, including;

- Groundwater flooding through the recharge of ephemeral (seasonal) streams
- Blockages in culverts, gutters and drains (sometimes due to inadequate maintenance) leading to surcharged drains and surface water flooding
- Field runoff due to catchment land management practices leading to overland flow

4.1 Existing defences, Verification of Defences and Areas Benefiting from Defences (ABDs)

With the exception of the seafront, all watercourses across the Weston study area are shown by NFCDD to have a standard of protection of less than 1 in 5 years. The majority of channel along the Uphill Great Rhyne and Cross Rhyne (along the southern boundary of the Airfields Neighbourhoods region) comprises maintained and natural channel interspersed with sections of culvert. A considerable stretch of the Uphill Great Rhyne is culverted through the Town Centre Gateway.

At the coast there is a mixture of man-made and natural defences with primarily a 1 in 200 year standard of protection, reducing to 1 in 50 years for a section along the coast between ends of Quantock road and Moorland road south of the town centre. This section comprises of a masonry wall built to protect the private development Royal Sands.

Figure 4.2 – Standard of Protection of Defences

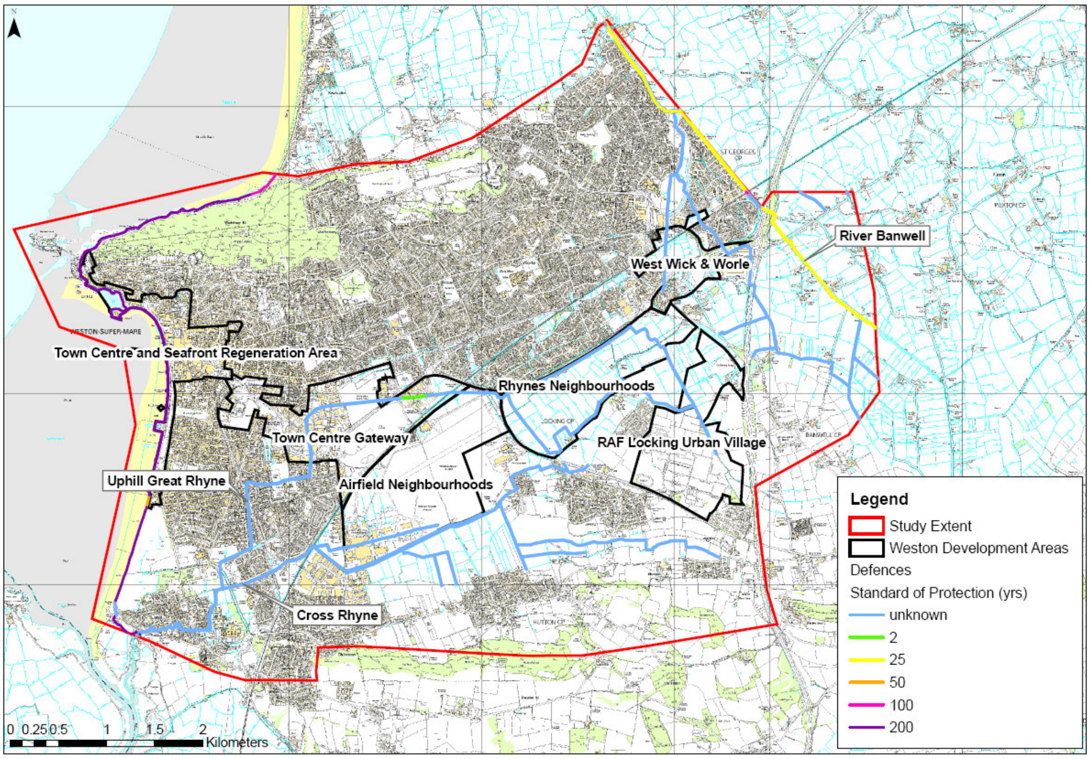
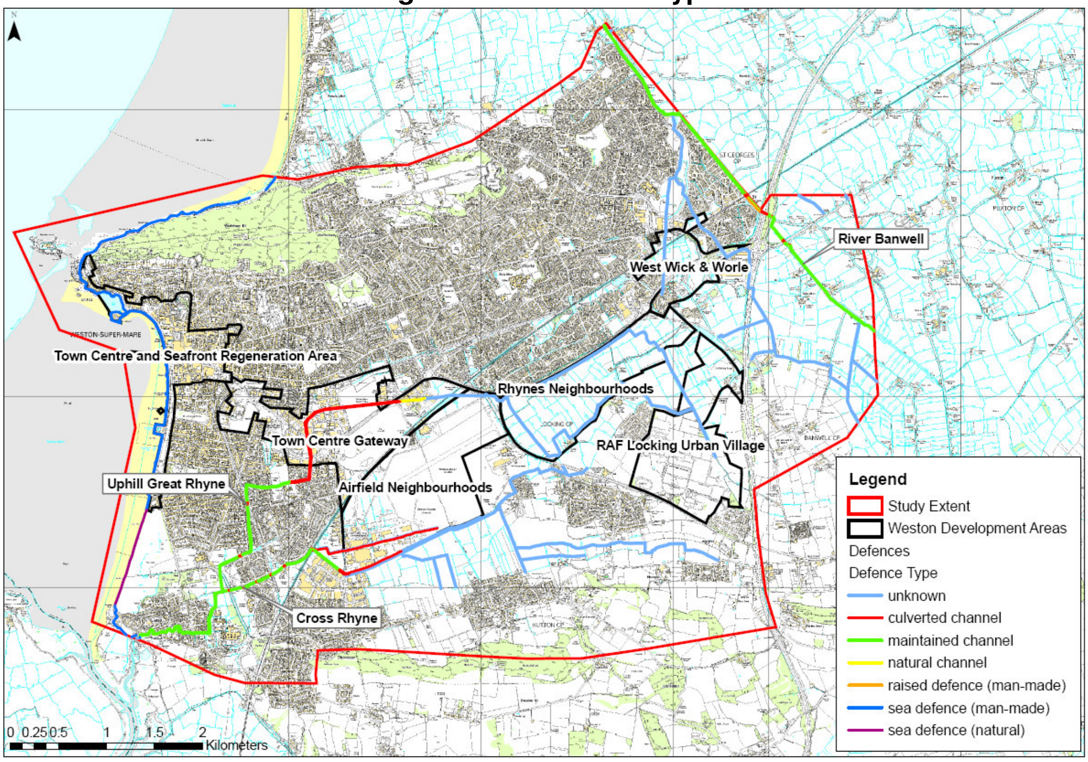


Figure 4.3 – Defence Type



As stated in Section 2.2.1 there is a small section of reach along the River Banwell with raised defences adjacent to St Georges. The standard of protection (SoP) stated by NFCDD is unknown, however the maintained channel either side of the defence has a SoP of 1 in 25 years therefore, when considered in combination with the model results, it is reasonable to assume that the raised defence has a SoP of 1 in 25 years or greater. However Royal Haskoning have previously made an assessment of the effect of removing these defences on fluvial flooding and found the differences to be minimal. As part of the proposed mitigation options outlined in the Weston-super-Mare FMS Phase II (Royal Haskoning, October 2007) report the standard of protection offered by the defences at St. Georges was investigated. As part of the preferred option for the River Banwell three locations where the bank was low were identified adjacent to St Georges, with the total length of bank to be raised around 200m. The option included raising the existing embankments by 300mm to ensure that the freeboard is not compromised.

In the east of the study area, the maintained channel along the River Banwell provides a 1 in 25 year standard of protection along the reach of the watercourse displayed in Figures 4.2 and 4.3.

Figure 4.5 in Section 4.2.1 shows the extent of tidal flooding, taking defences into account, at present, and in the future in 2086 and 2126 as a result of climate change. In 2086 the model outputs show that there is no flooding from Weston seafront. In 2126 flooding occurs as the still tide level of 9.39mAOD is above the height of the seawall provided by the current scheme (9.07mAOD). However the seawall has been designed so that an additional 0.5m can be added which will take the wall up to 9.57mOD, enough to prevent still water inundating the area by 2126. Flooding will still occur as a result of wave overtopping but this is designed to be managed through adequate surface drainage design within the seawall and promenade design to prevent flooding extending into the urban area.

In 2100 the tide level is 9.01mAOD (below the wall level) and by 2110 it is up to 9.16mOD (overtopping the wall) so according to current predictions and taking wave action into account the wall will need to be raised around the end of the century in order to maintain a 1 in 200 years standard of protection.

Breach analysis has been undertaken at two locations within the seawall (one at the northern end and one at the southern end of the scheme) and the associated results and risks to people are detailed in Section 4.6.

4.2 Assessment of flood probability and hazard

4.2.1 Flood probability

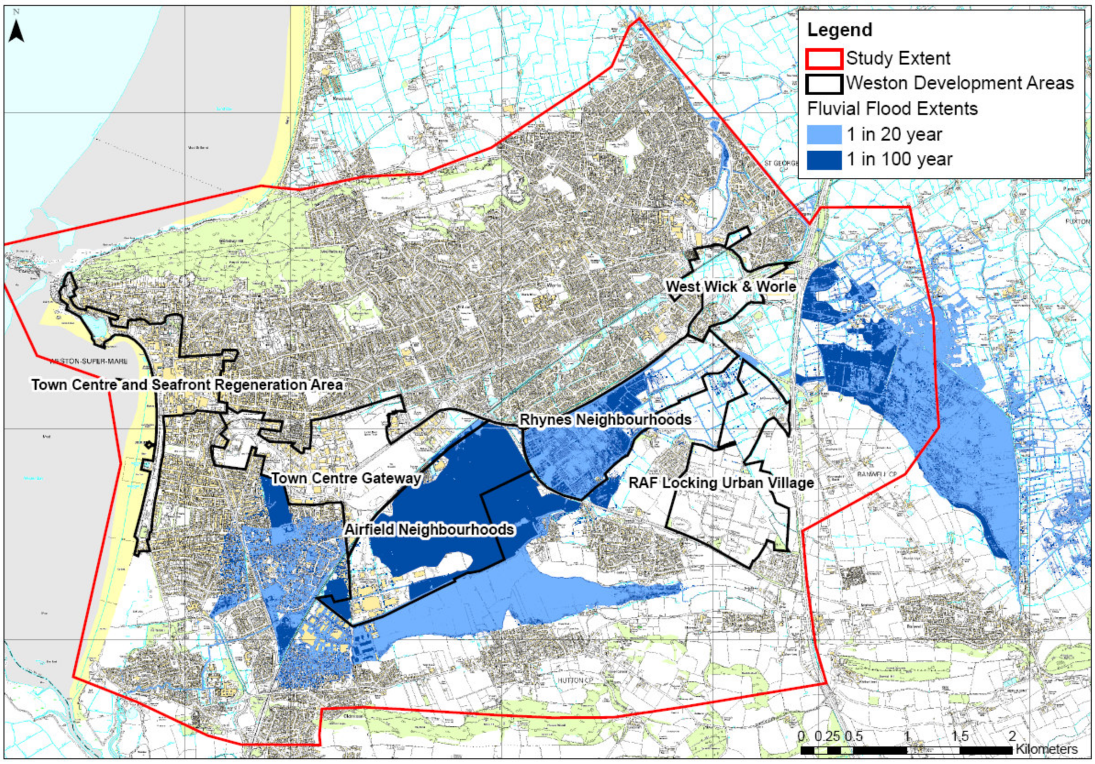
Fluvial

Modelling results shown in Figure 4.4 show that although considerable flooding is experienced across the study area during the 1 in 20 year fluvial event, only the Rhynes Neighbourhoods region of the Weston Development Area is anticipated to flood to any significant extent. NFCDD reports the stretch of maintained channel around St. Georges as having a 1 in 25 year standard of protection, the model results for the 1 in 100 year event suggest the flow of water remains in channel and it is thought that this is due to the channel geometry at this point. Model results indicate that more than 50% of the

Rhynes Neighbourhood experiences flooding at the 1 in 20 year event. Figure 4.4 also demonstrates that extensive flooding occurs at the 1 in 20 year event at the following locations:

- Along the River Banwell, east of the M5,
- South of the Airfields Neighbourhoods in relation to Cross Rhyne
- SW of both the Airfields Neighbourhoods and Town Centre Gateway from the Uphill Great Rhyne. This extends across a large residential area.

Figure 4.4 – Fluvial Flood Extents (with defences)



Fluvial modelling Includes tide locking based on a 1 in 1 year tidal event.

A comparison of Figure 4.4 and Figure 4.6 shows that all of the study area which is within Flood Zone 3 is at risk from fluvial flooding and that there are no areas benefitting from defences. Ponding occurs in the north east of the Airfields Neighbourhood but the flow routes are only noticeable on the A1 maps. This suggests that the whole area will actually be wet and therefore at risk.

Results indicate that extents do not significantly increase with increasing return period because in general flooding at the 1 in 100 year event is not much more extensive than at the 1 in 20 year event (Figure 4.4). Additional flooding at the 1 in 100 year event is observed in the north and SE of the Airfields Neighbourhoods. Extents are also seen to increase in and SE of the Rhynes Neighbourhoods.

Limited flooding at both 1 in 20 and 1 in 100 year fluvial flood events was also observed in the north of the study area at St Georges.

Appendix B contains four maps showing Depth and Hazard maps for scenario 2010 and 2126 with Sea Level rise and climate change.

Tidal

Figure 4.5 shows a large 'Area Benefiting from Defences' and no residual risk areas behind the sea wall. Tidal flooding is generally negligible across the study area and does not occur within the Weston Development Area at either the 1 in 25 or 1 in 200 year flood events. Figure 4.5 demonstrates that considerable flooding is expected at Uphill in the SW of the study extent at the 1 in 200 year event. Flood depth and hazard in relation to this are discussed in subsequent sections. Flooding is indicated along the Seafront, however this is in front of the defences and therefore only affects the beach.

Figure 4.5 – Tidal Flood Extents (with defences)

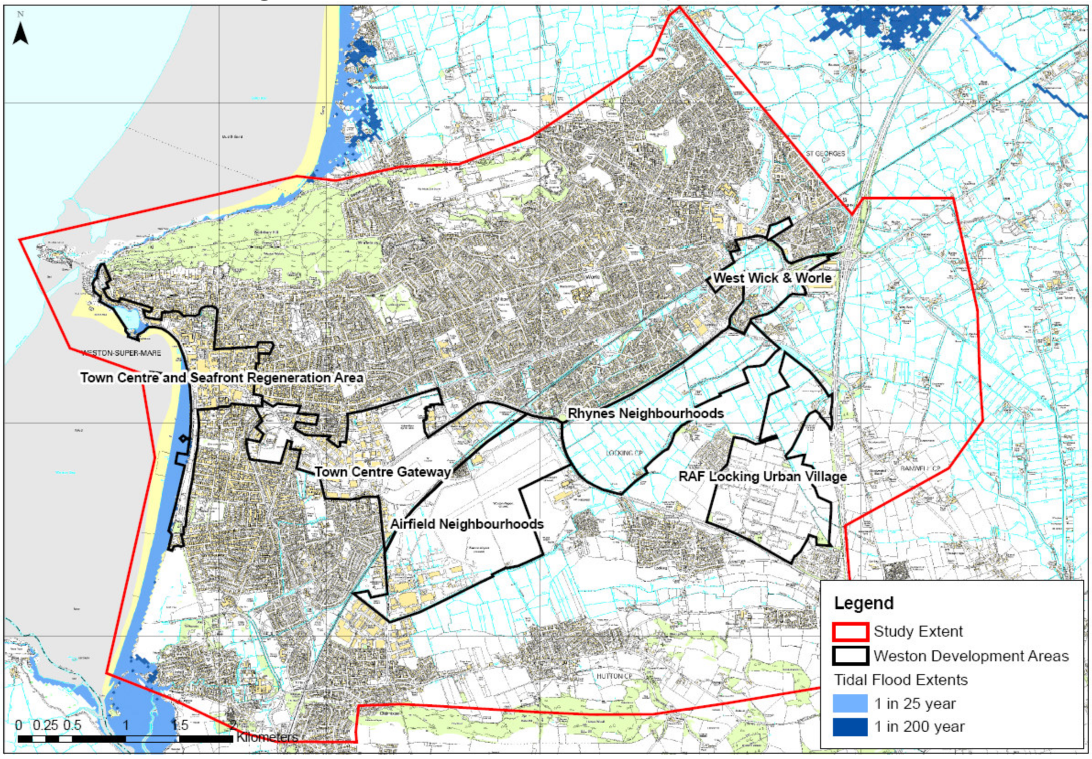


Figure 4.5 shows that with the new seawall at Weston in place, along with the other existing defences, the whole of the tidal Flood Zone 3 within the study area is classed as an Area Benefitting from Defences (ABD) and therefore for the current situation there is no residual risk.

Appendix C contains a series of 18 maps showing Depth and Hazard and Velocity for the 25 and 200 year return period event for the following years 2010, 2086 and 2126.

4.2.2 Flood Zone 3a and 3b

As part of this Level 2 SFRA, Royal Haskoning have undertaken an exercise to define the function floodplain. The division of Flood Zones 3a and 3b has been based on the model results. Maps have been produced of both tidal and fluvial Flood Zones 3a / 3b.

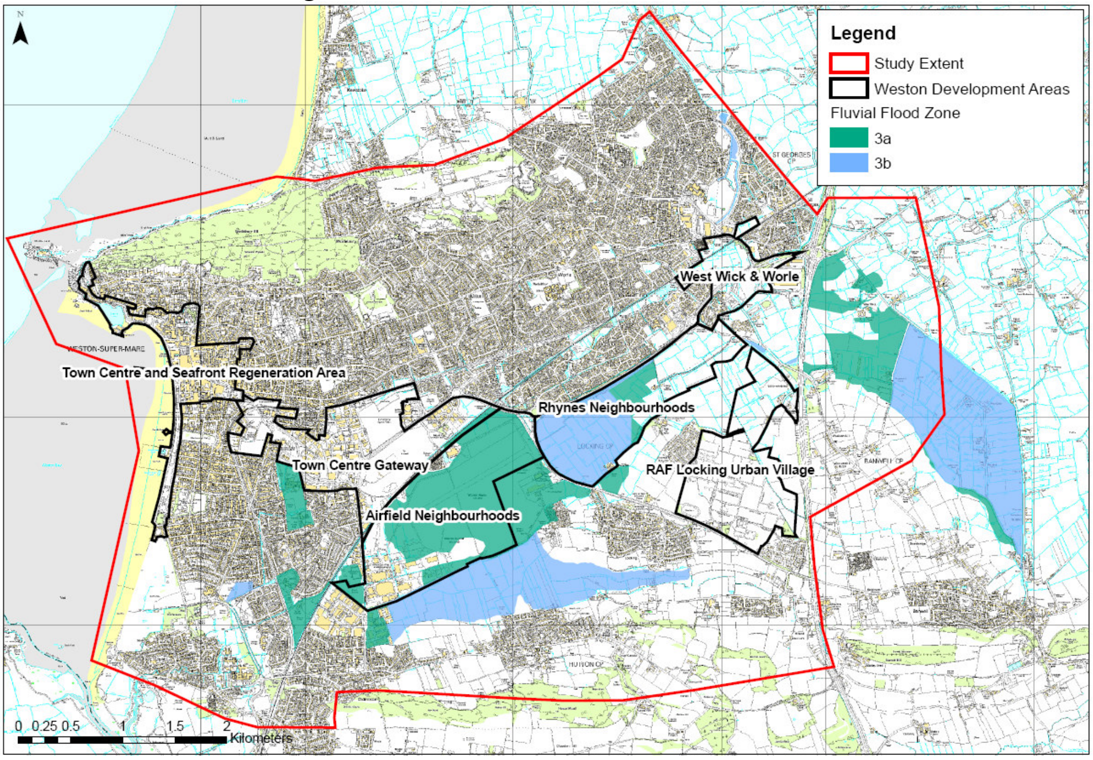
For the purposes of this SFRA we have used the Flood Zone split produced for the NSC Level 1 SFRA and verified the extents using the 1 in 20 year fluvial and 1 in 25 year tidal flood extents. The fluvial Flood Zone 3a and 3b split was discussed and agreed with the Weston Partnership as part of the FMS study. This was based on model results and local knowledge. For the tidal Flood Zone split, in general the coastal strip along the western edge of the study area is defended therefore for the tidal Flood Zone split, we have classified Flood Zone 3 landwards of the defences as Zone 3a and seawards of the defences as Zone 3b. These flood extents have been determined as a result of the modelling available to this study in agreement with NSC and the Environment Agency no modifications have been required. Figure 4.6 below shows the fluvial split for the Weston Development Area.

Figure 4.6 indicates that most of the Weston Development Area is outside of fluvial Flood Zone 3. The Town Centre Gateway area has a very small section of fluvial Flood Zone 3a along the eastern edge associated with Uphill Great Rhyne. There is also an area of fluvial Flood Zone 3a to the south of the Town Centre Gateway which should be considered when planning development for this section of the Weston Development Area to ensure that flood risk is not increased to this area. It should be noted that the extents of the fluvial flood zones 3a and 3b were discussed and agreed with NSC and the Environment Agency who has specialist knowledge and understanding of the flow routes and flooding within the study area.

Other regions within the Weston Development Area that the fluvial modelling has shown to be in fluvial Flood Zone 3 comprise the Airfields Neighbourhoods which is nearly all fluvial Flood Zone 3a and the Rhynes Neighbourhoods, the SW third of which is classed as Flood Zone 3b adjacent to land classed as Zone 3a. This has implications for development because The Sequential Test in PPS25 states that only water compatible or less vulnerable development should take place in Flood zone 3a and only when no suitable alternative can be found in a zone of lower flood risk. Table D.1 of PPS25 also advises that only water compatible development or essential infrastructure is suitable for location with Flood Zone 3b and this form of development must be able to operate in times of flood.

Across the Airfields and Rhynes Neighbourhoods, and the Weston Development Area in general, there is a significant proportion of land currently outside of Flood Zones 2 and 3 that should be evaluated first for its development potential. It should also be noted that the effects of climate change could affect the extent of the current Flood Zones 3a and 3b which should therefore be considered prior to development.

Figure 4.6 - Fluvial Flood Zone 3a and 3b



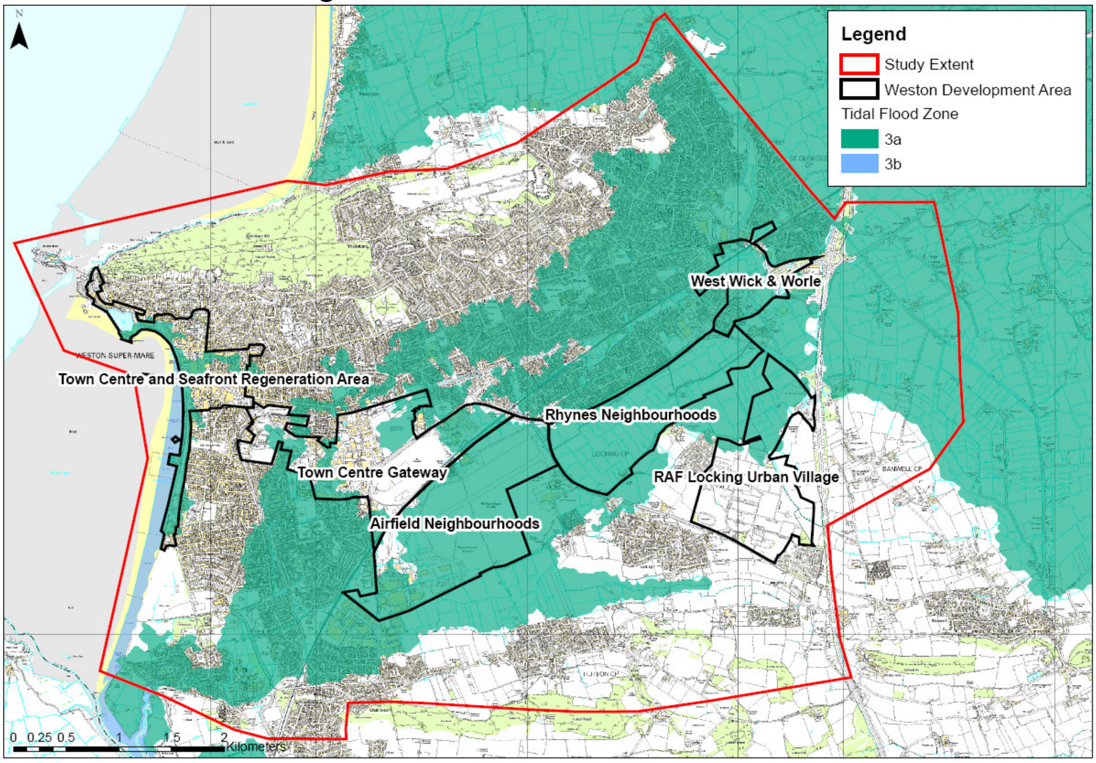
Fluvial modelling includes tide locking based on a 1 in 1 year tidal event.

Figure 4.7 shows that due to the presence of defences along the Weston area coastline, where the tidal Flood Zone 3 extends across the study area it is almost all classed as tidal Flood Zone 3a. This affects all of the regions within the Weston Development Area to varying degrees. Most of the Airfields and Rhynes Neighbourhoods, and West Wick & Worle regions lie in the tidal Flood Zone 3a as well as half of the RAF Locking Urban Village and parts of the remaining two areas, the Town Centre Gateway and the Town Centre and Seafront. Table D.1 of PPS25 states that only water compatible development or less vulnerable development is appropriate in Flood Zone 3a unless the Exception Test is passed to allow more vulnerable (for example residential) development.

Therefore if development is proposed within the areas of tidal (or fluvial) Flood Zone 3a it will need to meet the criteria of the Exception Test by demonstrating that 'the development provides wider sustainability benefits to the community that outweigh flood risk', 'the development is on developable previously-developed land or, if not on previously developed land, that there are no reasonable alternative sites on developable previously-developed land' and that 'a FRA must demonstrate that the development will be safe, without increasing flood risk elsewhere, and, where possible, will reduce flood risk overall'.

The only areas of tidal Flood Zone 3b are seawards of the defences to the west of the study area and do not affect the Weston Development Area.

Figure 4.7- Tidal Flood Zone 3a and 3b



4.2.3 Flood depth

Flood depths have been assessed 'with defences' to represent the current situation and unless stated otherwise, it should be assumed that model results refer to the defended situation. Using the modelled outputs from the hydraulic models maximum depth grids were used to map flood depth for each return period across the development sites.

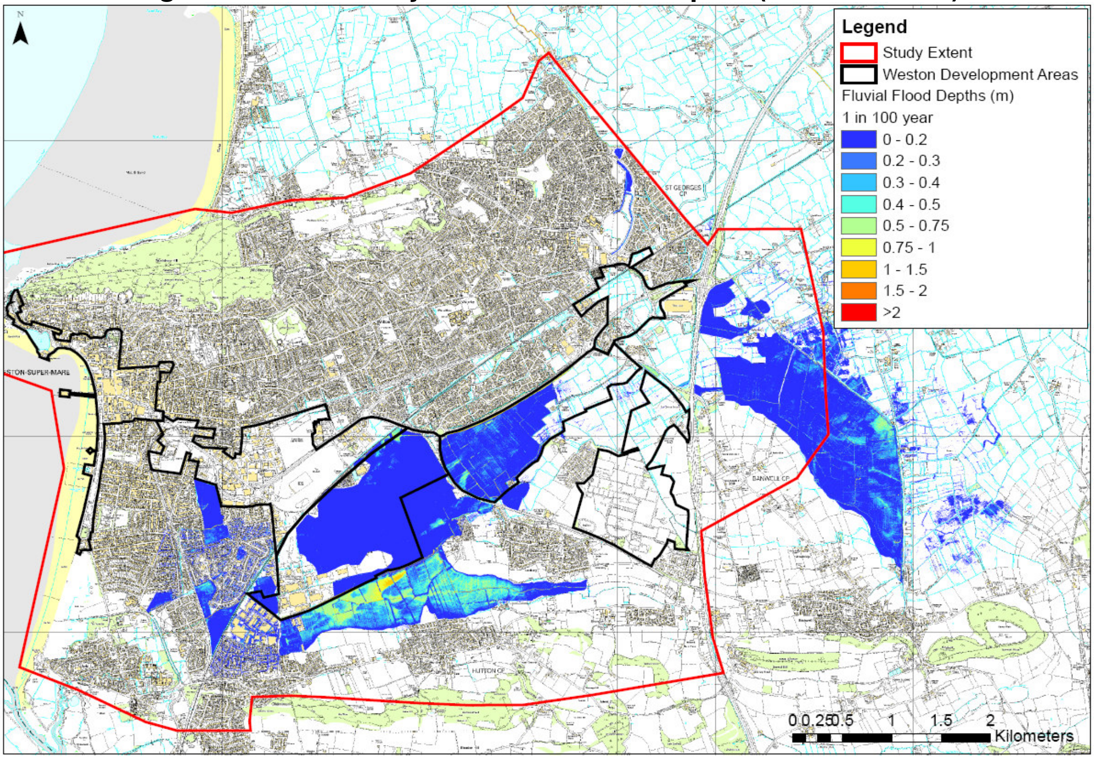
In general, the deeper the flood waters the higher the hazard. To help put the depths into context, assuming low velocities of flow, the hazard rating discussed in Section 4.2.4 has been used to assign low, medium and high depth classifications to the varying depth levels. Note that the hazard rating discussed in Section 4.2.4 considers both the modelled tidal depth and velocity where possible.

- No flooding, route remains dry – No Danger
- Low flood depth < 0.3m – Very low hazard
- Moderate flood depth between 0.3 and 0.6m – Danger for some – includes children, the elderly and the infirm
- High flood depth between 0.6 and 2m – Danger for most – includes the general public
- Extremely high flood depth > 2m – Danger for all - includes emergency services

Fluvial

Figure 4.8 shows that fluvial flood depths at the 1 in 100 year event are generally low to moderate. East of the M5 average flood depths are low at less than 0.3m. This is also the case in the Rhynes Neighbourhoods with the exception of the SE border where depths are recorded to increase to 0.5-0.75m. Flooding in the Airfields Neighbourhoods is also anticipated to be less than 0.3m except along the Uphill Great Rhyne in the north of the area where maximum depths are in the order of 0.5-0.75m. The most significant flood depths are along the southern border of the Airfields Neighbourhoods associated with the Cross Rhyne where flood depths of 1-1.5m are observed. Flood depths in the residential area SW of the Town Centre Gateway are moderate, in the order of 0.2-0.4m. The Junction 21 bypass is affected by fluvial flooding in a 100 year tidal event in 2010 to depths of less than 0.15m.

Figure 4.8 – 1 in 100 year Fluvial Flood Depths (with defences)



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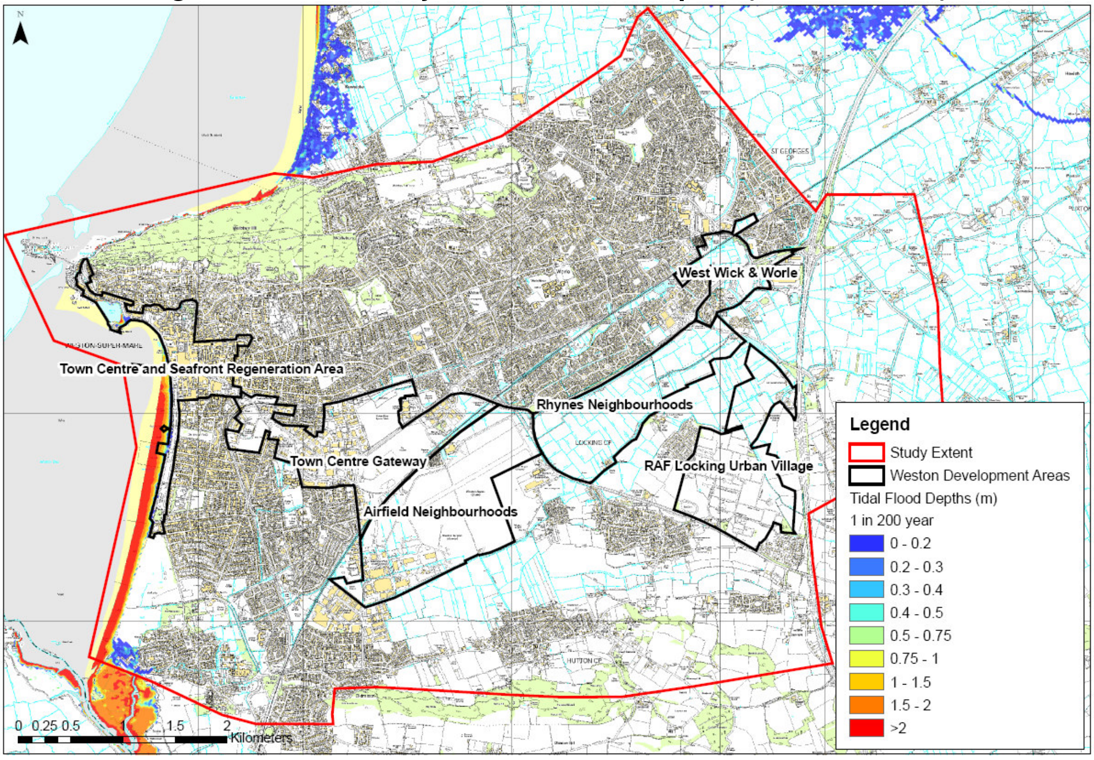
NB Fluvial modelling includes tide locking based on a 1 in 1 year tidal event.

Tidal

Tidal flooding at the 1 in 200 year event is limited in the study area and does not affect the Weston Development Areas (Figure 4.9).

The most extensive area of tidal flooding in the study area occurs at Uphill. Where this affects properties, the 1 in 200 year depth is mostly less than 0.2m. However there are a number of patches where this increases to 0.5 – 0.75m such as along Berkerley Crescent and Thornbury Road. Adjacent to this and outside the study area, tidal flood depths of more than 1m are recorded, although this appears to only affect the boat yard and marshes at Uphill. Significant flooding is observed north of the study area at Wick St Lawrence but this does not affect the Weston Development Area or any land within the Level 2 SFRA study area and is therefore not discussed further in this report. The Junction 21 bypass is not affected by tidal flooding in a 200 year tidal event in 2010.

Figure 4.9 – 1 in 200 year Tidal Flood Depths (with defences)



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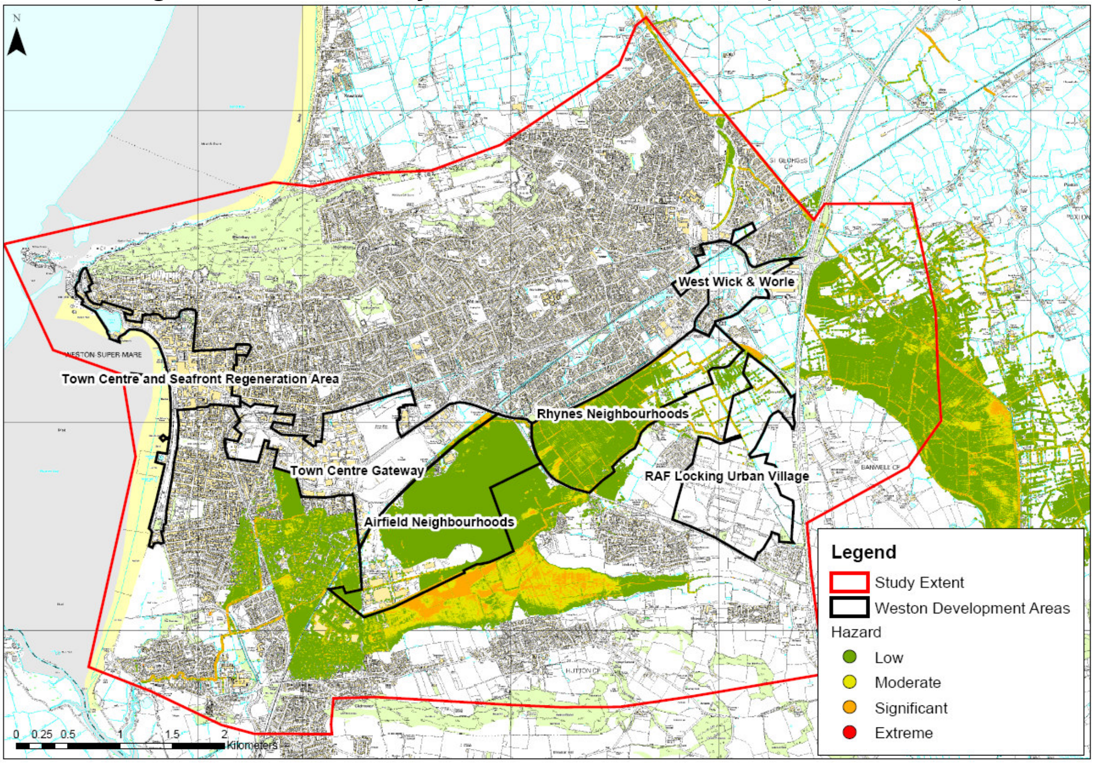
4.2.4 Flood hazard (including speed of onset)

Fluvial

As shown by Figure 4.10, fluvial flooding across the study area is generally of low hazard except in the area to the south of the airfield and north of Hutton village. This area which forms an area of naturally low lying topography has a mainly moderate hazard with internal areas of significant hazard where the water depth is above 0.6m. This reflects the depths of water as shown in Figure 4.8 and means that in certain areas the flood hazard is sufficient to cause danger for most, including the general public.

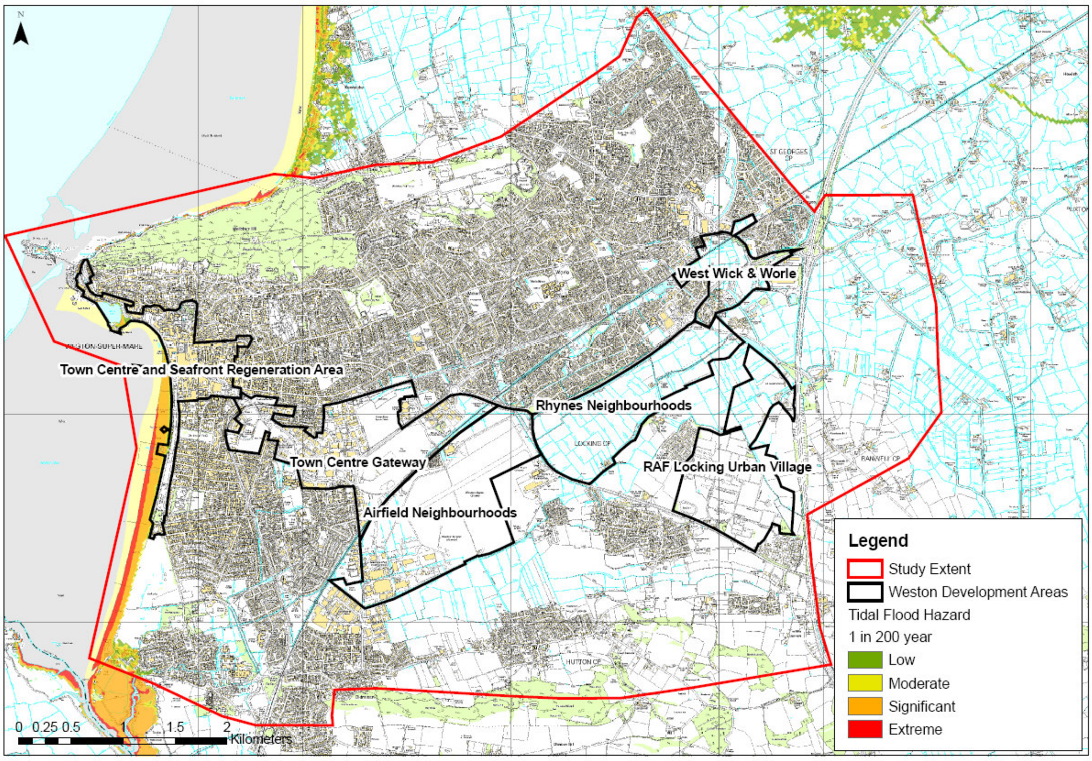
Figure 4.10 – 1 in 100 year Fluvial Flood Hazard (with defences)



Fluvial modelling includes tide locking based on a 1 in 1 year tidal event.

Tidal

Figure 4.11 – 1 in 200 year Tidal Flood Hazard (with defences)



Tidal flood hazard at the 1 in 200 year event is minimal in the study area and does not affect any of the Weston Development Areas (see Figure 4.11).

At Uphill, where the largest expanse of tidal flooding occurs, the tidal flood hazard at the 1 in 200 year event ranges from Low to Extreme. On Thornbury Road and Berkeley Crescent tidal flood hazard is recorded to be significant in places, representing danger for most.

Speed of Onset

Where tidal flooding is the dominant risk such as along the Seafront and at Uphill in the SW of the study area, the speed of onset is considered to be moderate.

After a rainfall event the Banwell catchment responds with two peaks. The first peak is the direct result of the rainfall event and the delayed second is due to the spring fed nature of this catchment.

Both Banwell and Uphill catchments are large, relatively flat catchments where flood levels rise slowly and remain flooded for long periods of time. The model results show that generally the speed of onset for the storage areas in both areas is greater than 4 hours, with some being as long as 70 hours (see Tables 4.1 and 4.2). Based on the classifications in FD2320 the onset of flooding is therefore slow. For storage Area locations see Figure 4.12 for the River Banwell and 4.13 for Uphill Great Rhyne.

Figure 4.12 - River Banwell Modelled Storage Areas

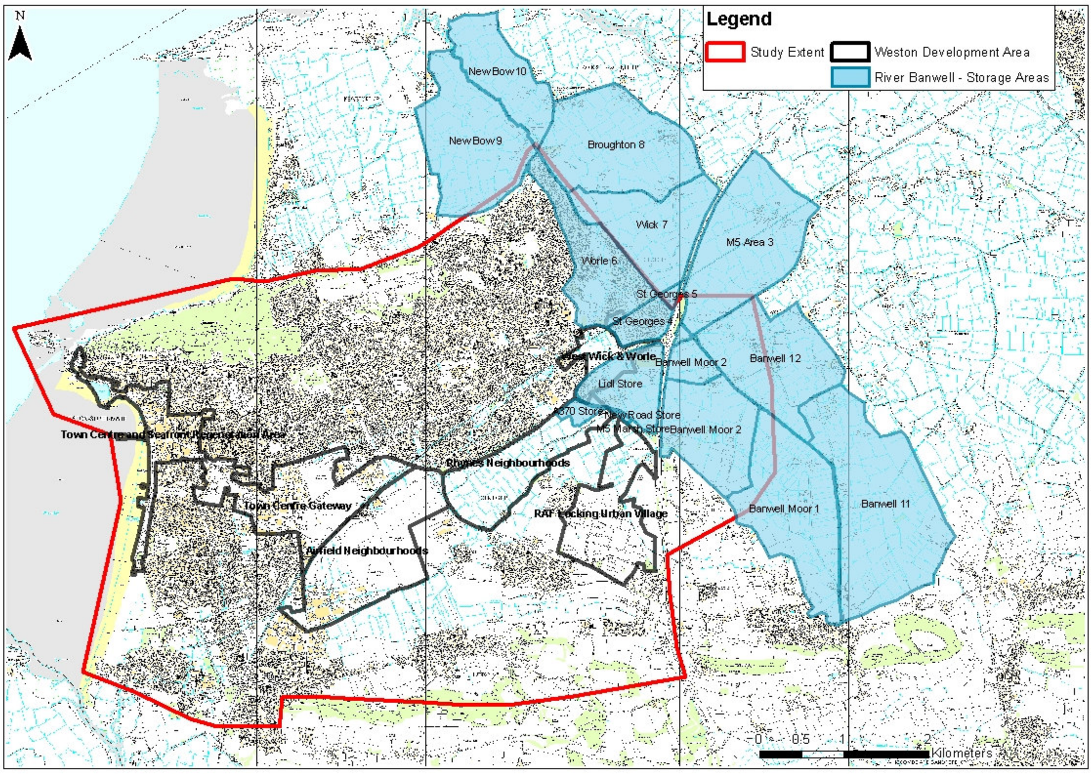
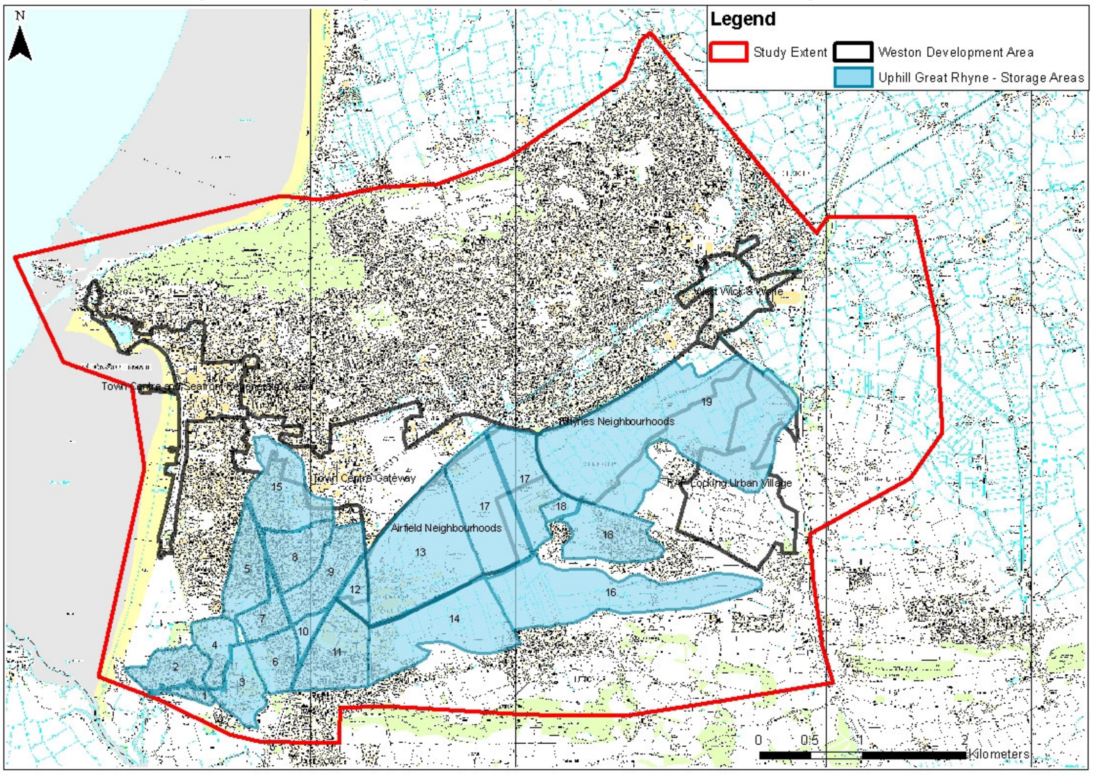


Table 4.1 - Banwell: Speed of onset

Slow Rising		Quick Rising	
Storage Area	Speed of Onset	Storage Area	Speed of Onset
Banwell 11	48h	Wick 7	5h
Banwell Moor 1	65h	Worle 6	3h
Banwell moor 2	72h	New Bow 10	2.5h
New Road Sluice	36h	Moor Drove Store	11h
M5 Marsh Store	43h		

Figure 4.13 - Uphill Great Rhyne Modelled Storage Areas



N.B. Reservoir 20 is not shown on the map but is a very small reservoir within what is shown as reservoir 8 and is located adjacent to Bournville School.

Table 4.2 - Uphill Great Rhyne Speed of onset

Slow Rising		Quick Rising	
Storage Area	Speed of Onset	Storage Area	Speed of Onset
10	12.5h	5	3h
11	12h	8	3h
12	11h	9	3.5h
14	20h	13	3.5h
16	12.5h	15	4h
17	12h	20	3h
18	16h		
19	38h		

The only area where onset is faster is in the New Bow area of the Banwell catchment (New Bow 10 storage area). Here the onset is 2.5 hours which would therefore be classed as moderate.

Areas behind flood defences are at particular risk from rapid onset of fast-flowing and deep water flooding, with little or no warning, if defences are overtopped or breached. If development is proposed adjacent to raised flood defences, detailed breach analysis should be undertaken as part of a site specific Flood Risk Assessment.

4.3 Impact of climate change

The tidal modelling described in Section 2.3 was used to model the effects of sea level rise as a result of climate change on tidal flooding for the 1 in 200 year event, the 1 in 200 year event plus climate change up to 2086 to account for the life of commercial development, and the 1 in 200 year event with climate change up to 2126 to account for the life of residential development.

The combined effect of fluvial and tidal flooding has been accounted for through the inclusion of a tidal downstream boundary in the fluvial model representing the effect of tide locking at the 1 in 1 year tidal event both now and in the future. Fluvial flooding has not been included with the tidal model because the effect of the tide is expected to dominate any fluvial flow. It should be noted that although the combined effect of increased sea level rise and river flows has been modelled, the joint probability of high order return period events such as the 1 in 100 year fluvial and 1 in 200 year tidal has not been modelled and could result in a higher level of flood risk than shown. These types of scenarios have not been modelled due to the extremely low probability of those two events combining.

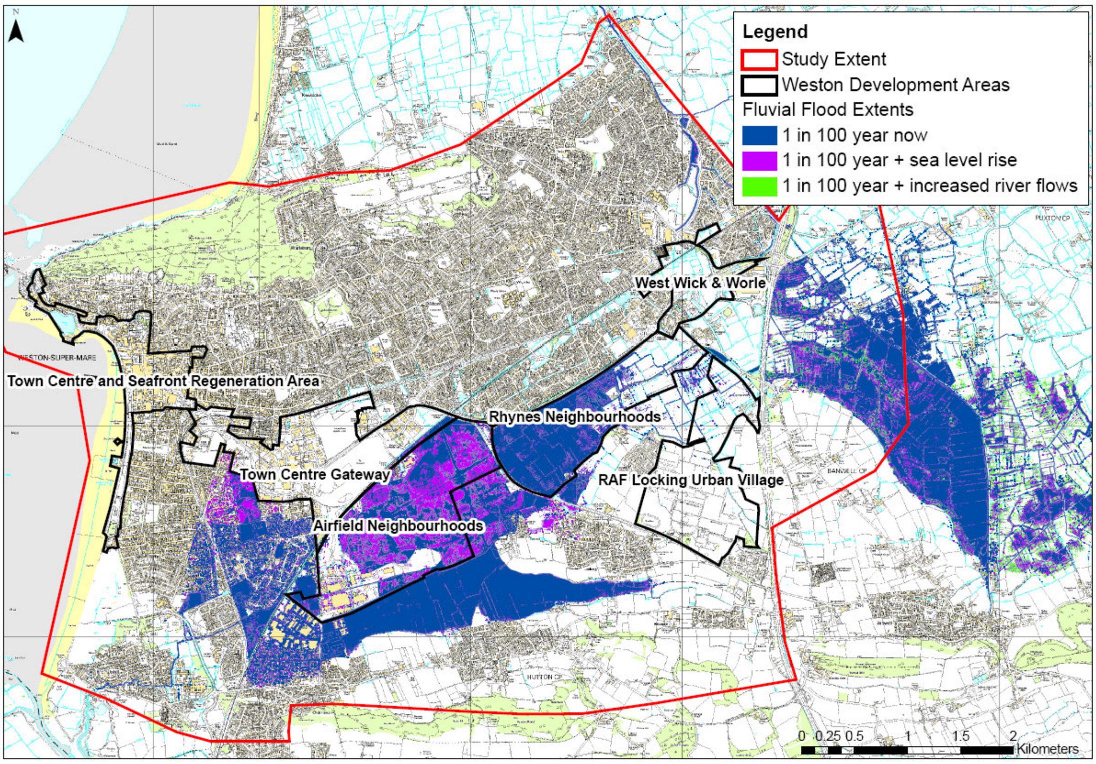
Fluvial

The effect of climate change on 1 in 100 year fluvial flood extents across the study area is displayed in Figure 4.14. Model results that include an increase in flows of 20% to allow for climate change indicate that the effects of climate change on fluvial flood extents across the Uphill catchment has a relatively minor impact on the Weston Development Area, with the exception of the Airfields Neighbourhoods where extents expand to cover up to 60% of the area. Increases in extent as a result of climate change are also observed immediately south of the Town Centre Gateway.

In 2126 a large area will be at risk from fluvial flooding and there are no ABDs.

In general it is noted that the effect of sea level rise on the Uphill catchment is greater than that of increased river flows due to the increased tide-locking. The opposite effect is observed across the Banwell catchment where the effect of increased flows is greater than that of sea level rise demonstrated by a greater fluvial flood extent in the order of 10-15m. However, this is anticipated to have a negligible impact on the Weston Development Area where extents are not shown to increase significantly from those of the current 1 in 100 year fluvial flood event.

Figure 4.14 – Effects of climate change on fluvial flood extents

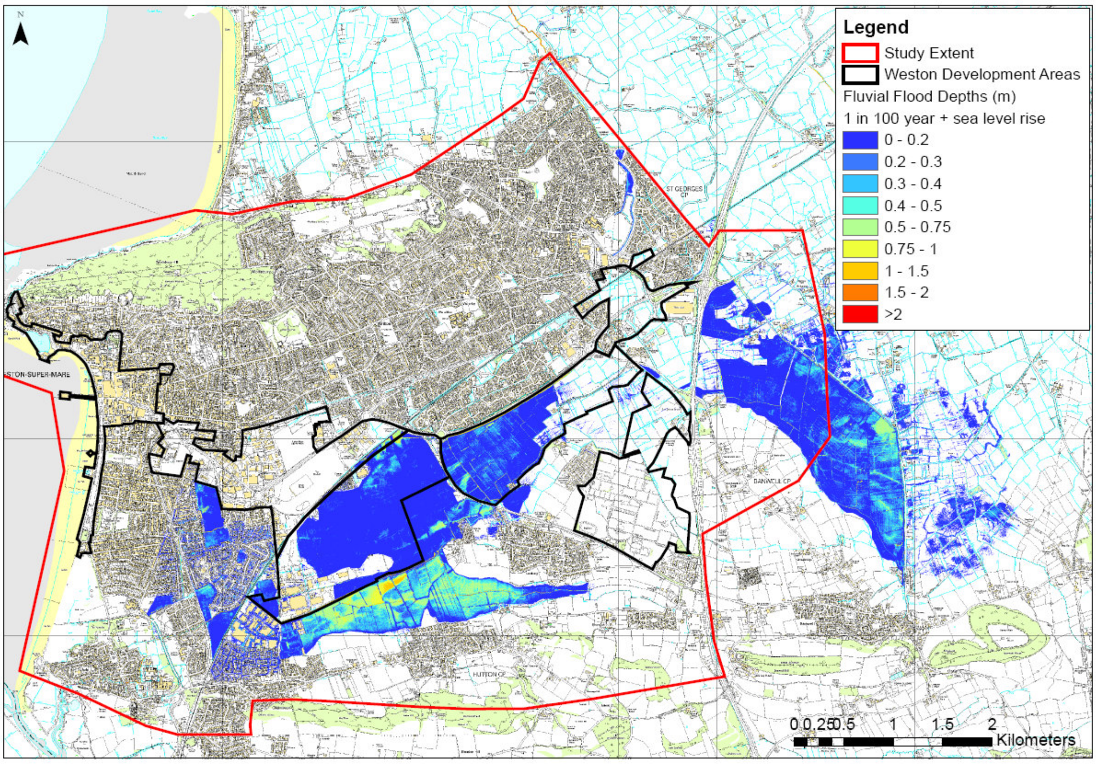


Fluvial modelling includes tide locking based on a 1 in 1 year tidal event with sea level rise up to 2126.

The effects of increased flood flows due to climate change with and without sea level rise on at the downstream boundary were generally observed to have much the same effect on flood depth. Therefore only the map of flood depths with sea level rise is shown below (Figure 4.15) as the extents of flooding resulting from the effects of sea level rise are slightly greater than those expected from the effects of increased river flows only.

Fluvial flood depths are not expected to significantly increase as a result of climate change across the Uphill and Banwell catchments, with the exception of where flooding occurs where it has not previously occurred as described above. There is one area outside of the Weston Development Area where the increase in fluvial flood depth is worth noting, this is the residential area south west of the Town Centre Gateway. In this area average depths are anticipated to increase up to 0.4m with areas of maximum depths of 0.5-0.75m.

Figure 4.15 – Effects of sea level rise on fluvial flood depths

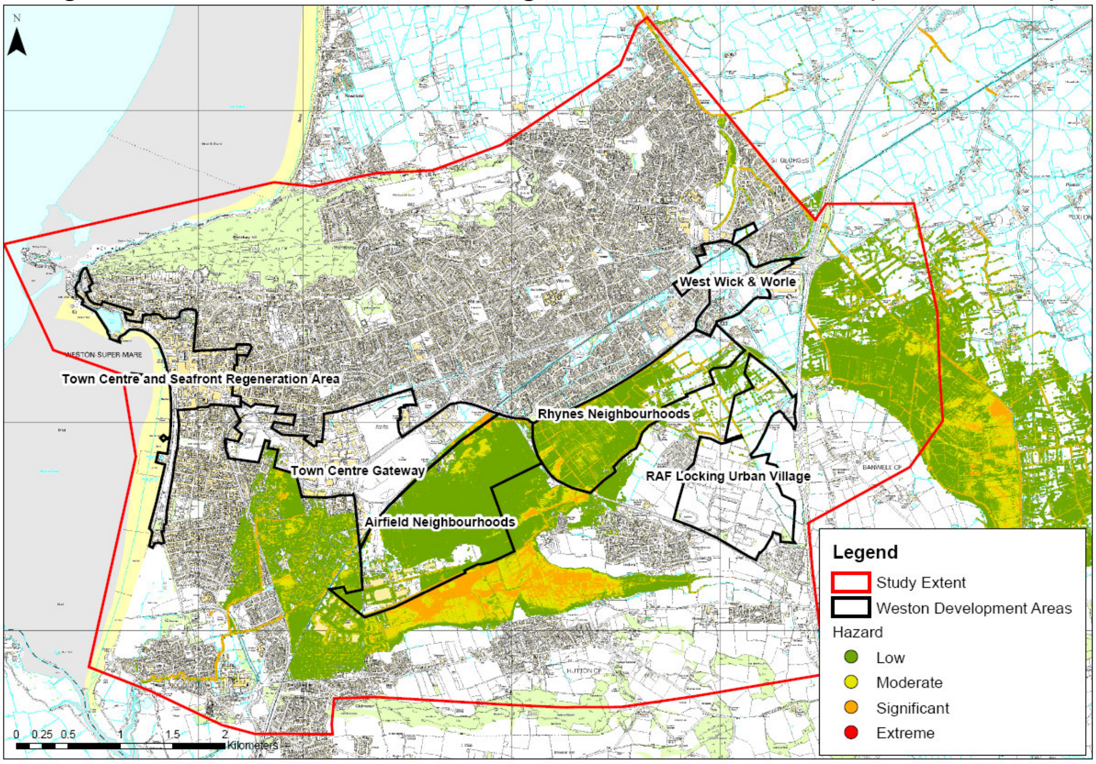


Fluvial modelling includes tide locking based on a 1 in 1 year tidal event,

In the future fluvial flooding across the study area is still generally of low hazard (see Figure 4.16) although there are some areas of moderate hazard (other than those to the south of the airfield and north of Hutton village) within the northeast of the Airfields neighbourhood, the southwest of the Rhynes neighbourhood and the Bourneville area of Weston-super-Mare. The extent of moderate hazard and significant hazard to the south of the airfield has increased which would be expected with the overall increase in water depths.

The Junction 21 bypass is at risk of flooding in a 100 year fluvial event in 2126. However, the flooding due to the 200 year tidal event in 2126 gives greater depths. The minimum levels required to keep this road above the flood levels are therefore outlined in the tidal section below.

Figure 4.16 – Effects of climate change on fluvial flood hazard (sea level rise)



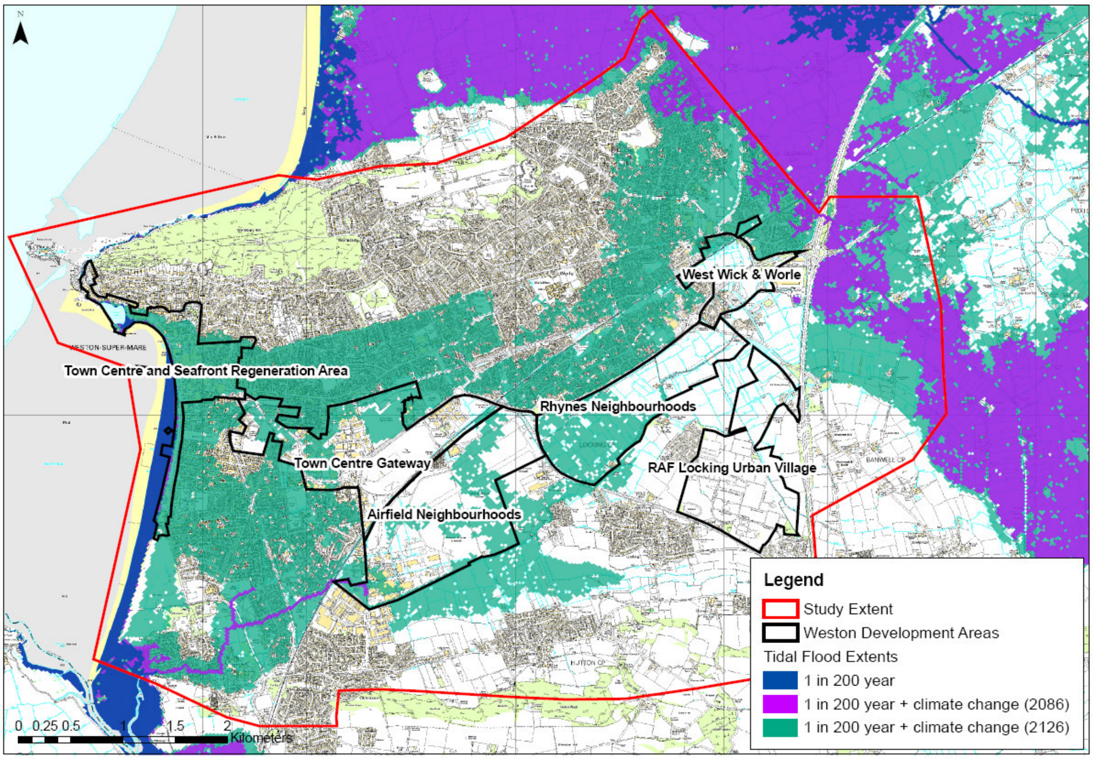
Fluvial modelling includes tide locking based on a 1 in 1 year tidal event with sea level rise up to 2126

Tidal

The effect of climate change on tidal flood extents, taking into account sea level rise and wave overtopping, is shown in Figure 4.17. It can be seen that in the Banwell catchment to the north of the study area, and to the east along the River Banwell, tidal flood extents are anticipated to increase considerably by 2086. However, this has little impact on the Weston Development Area. There is also an increase in tidal flood extent along the Uphill Great Rhyne and Cross Rhynes in the Uphill catchment. This extends into the SW of the Weston Development Area via the Airfields Neighbourhoods and could affect a small number of properties at Uphill in Thornbury Road and Berkeley Crescent.

By 2126, tidal flooding at the 1 in 200 year event is much more extensive across the entire study area. Flooding is anticipated to occur across most of the Town Centre and Seafront area, and across up to half of the land in the Town Centre Gateway and Airfields and Rhynes Neighbourhoods. Outside of the Weston development Area tidal flooding is considerable at the 1 in 200 year event in 2126 and is expected to extend north from the Weston Development Area up to Milton Road, south towards Hutton and west of the Development Area affecting most of the residential area between the Airfields Neighbourhoods and the coast (Figure 4.17 below). The level of the defence used to produce the results for figure 4.17 is the height of the wall constructed for the new sea wall scheme at Weston-super-Mare and that the level of this defence is planned to be raised in the future.

Figure 4.17 – Effects of climate change on tidal flood extents



The modelling shown in Figure 4.17 is with the current defences in place. This includes the new sea wall at its existing level. By 2126 the area shown in green or purple is at residual risk, i.e there is a risk of flooding even with defences in place. There are no longer any areas of ABD. As part of the design of the sea wall an allowance for an additional 0.5m of height was included for. If the defences are raised along the seafront at Weston-super-Mare, as they are designed to be, then this residual risk will be significantly reduced. This scenario has not been modelled for this SFRA but is based on an assessment of the 1 in 200 year still tide level in 2126 compared to the raised defence height..

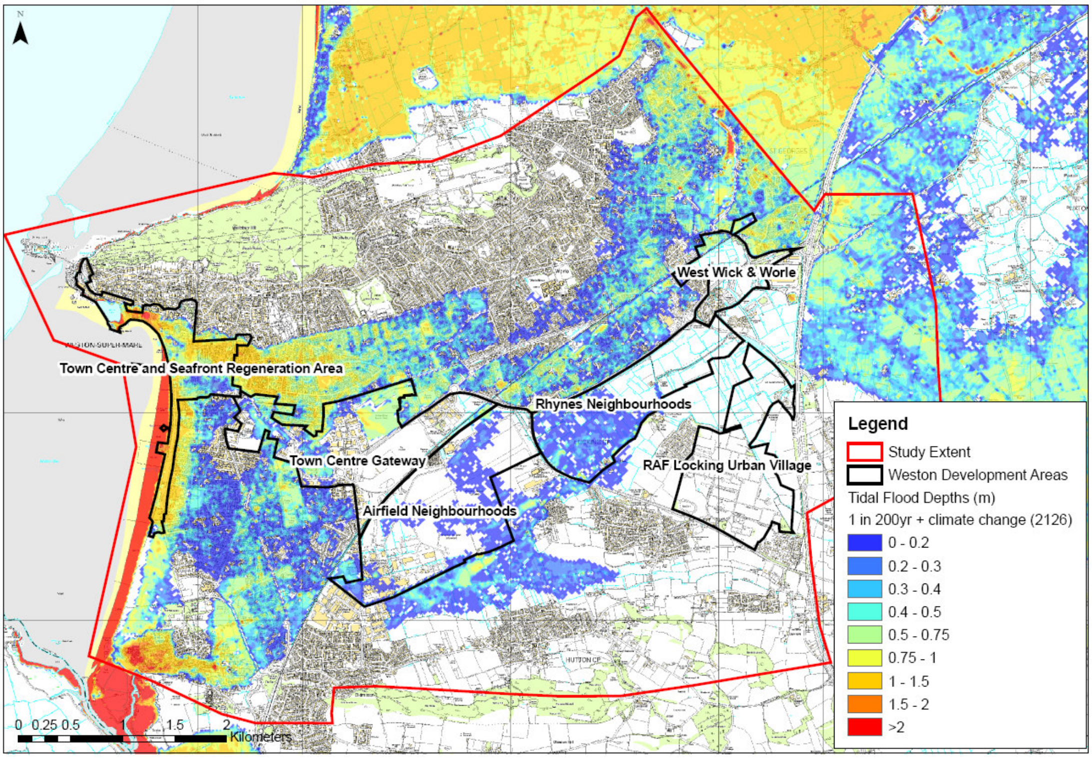
Tidal flood depths at the 1 in 200 year event increase significantly outside of the study area by 2086 although this does not affect the Weston Development Area or existing development within the study area. By 2126, 1 in 200 year tidal flood extents and therefore depths are considerably greater than at the 1 in 200 year event in both 2010 and 2086. Across the Town Centre and Seafront area tidal flood depths are expected to range from 0.2m in the vicinity of Locking Road and Station Road to over 1m along the seafront and in the NE in the region of the Boulevard (see Figure 4.18). Flooding is only predicted to occur in the north and west of the Town Centre Gateway zone with depths of up to 1.5m at the Hutton Moor Sports Fields and 0.5-0.75m adjacent to the Gas Depot. Where tidal flooding occurs in the Airfields and Rhynes Neighbourhoods, depths are low on average at less than 0.2m with areas of greater depth up to 1m.

To the north of the Weston Development Area tidal flood depths at the 1 in 200 year event are on average 0.5-1m representing a high flood depth and danger to most people. This affects the residential area from the Development Area up to Milton Road and the residential area north of West Wick & Worle. Between the Airfields

Neighbourhoods and the seafront flood depths vary, ranging from 0.2m to over 1.5m increasing to over 2m in the south of the study area at Uphill.

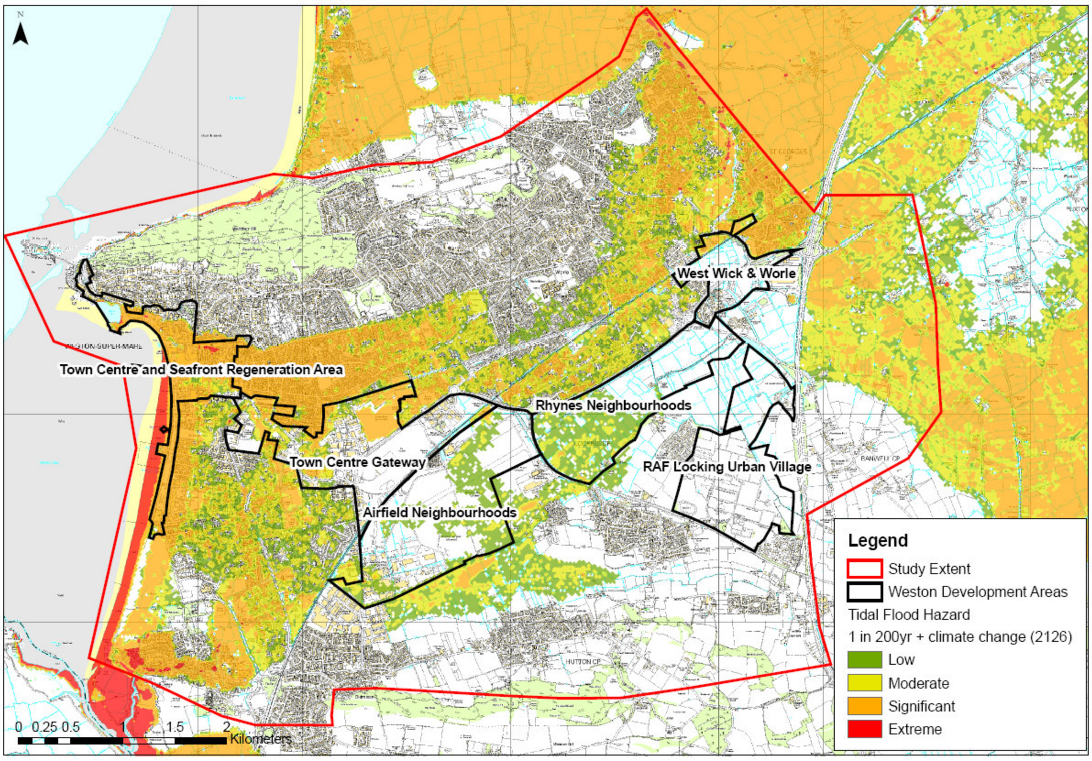
The Junction 21 bypass is at risk of flooding in a 200 year tidal event in 2126 and would need to be above a level of 5.65mAOD at its southern end near Gobbles Farm rising to 5.95m at the northern end near Doubleton Farm.

Figure 4.18 – Effects of climate change on tidal flood depths (2126)



The tidal flood hazard at the 1 in 200 year event in 2126 reflects these flood depths as shown in Figure 4.19. Tidal hazard is moderate to significant where flooding occurs across the Weston Development Area and study area as a whole. As with flood depth, the hazard increases to extreme in the vicinity of Uphill affecting a number of residential roads including Thornbury Terrace, Rhyne Fields, Thornbury Drive, Berkeley Crescent and Westfield Close. Although this is a sizeable distance from the Weston Development Area, it should be considered that any development must not inadvertently increase the risk of flooding to the surrounding area especially where risk is already classed as significant, as at Uphill.

Figure 4.19 – Effects of climate change on tidal flood hazard (2126)



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4.4 Risk of flooding to the Railway Line

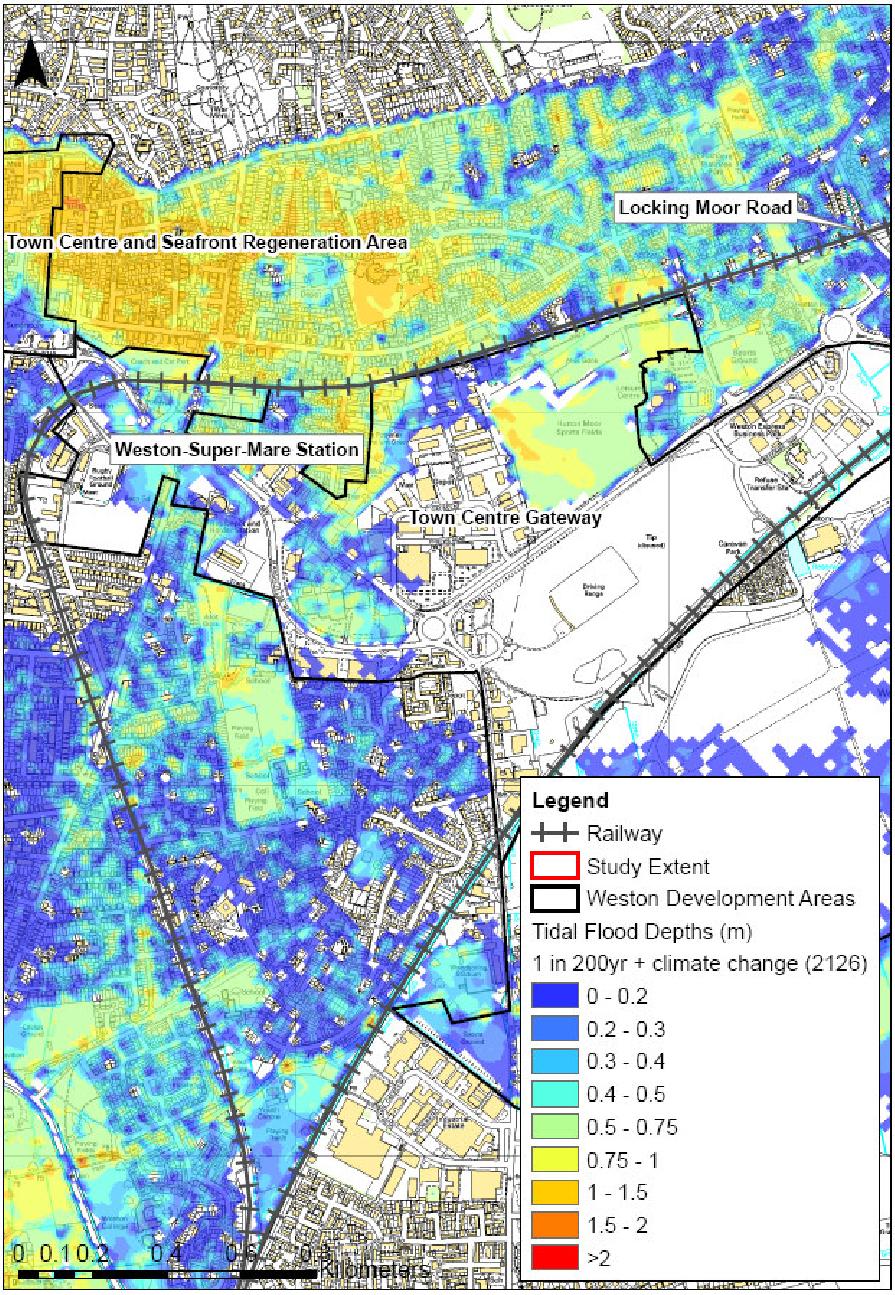
The railway line runs through the study area from the south west to north east with an additional line branching off to Weston-super-Mare station. The fluvial and tidal models have been used to assess flood risk to these routes where they are within the study area both now and in the future.

Under current conditions, the defended model results indicate that there is no tidal or fluvial flood risk to the railway lines as they are suitably raised above the predicted water levels. However, adjacent to the line at Flowerdown Bridge (NE of the Airfields Neighbourhoods) fluvial flooding is recorded to occur at a depth of 0.5-0.75m resulting in a significant fluvial flood hazard to the land surrounding the railway at the 1in 100 year event.

The effects of climate change are not expected to increase the risk of fluvial flooding to the railway lines. The risk of tidal flooding by 2086 is also negligible. By 2126 tidal flooding is anticipated to present a risk of flooding to the lines in two locations.

Figure 4.20 shows tidal flood depths for the first of these locations at the 1 in 200 year event in 2126 from where the branch line to Weston-super-Mare station diverts from the main line, to Locking Moor Road near Flowerdown Bridge. Maximum flood depths are expected to be in excess of 1m across the railway line both east and south of the station.

Figure 4.20 – 1 in 200 year Tidal Flood Depths plus climate change (with defences)



Tidal flood hazard (Figure 4.21) is shown to be low to significant where flooding occurs across the railway line east and south of the station.

Figure 4.21 – 1 in 200 year Tidal Flood Hazard plus climate change (with defences)

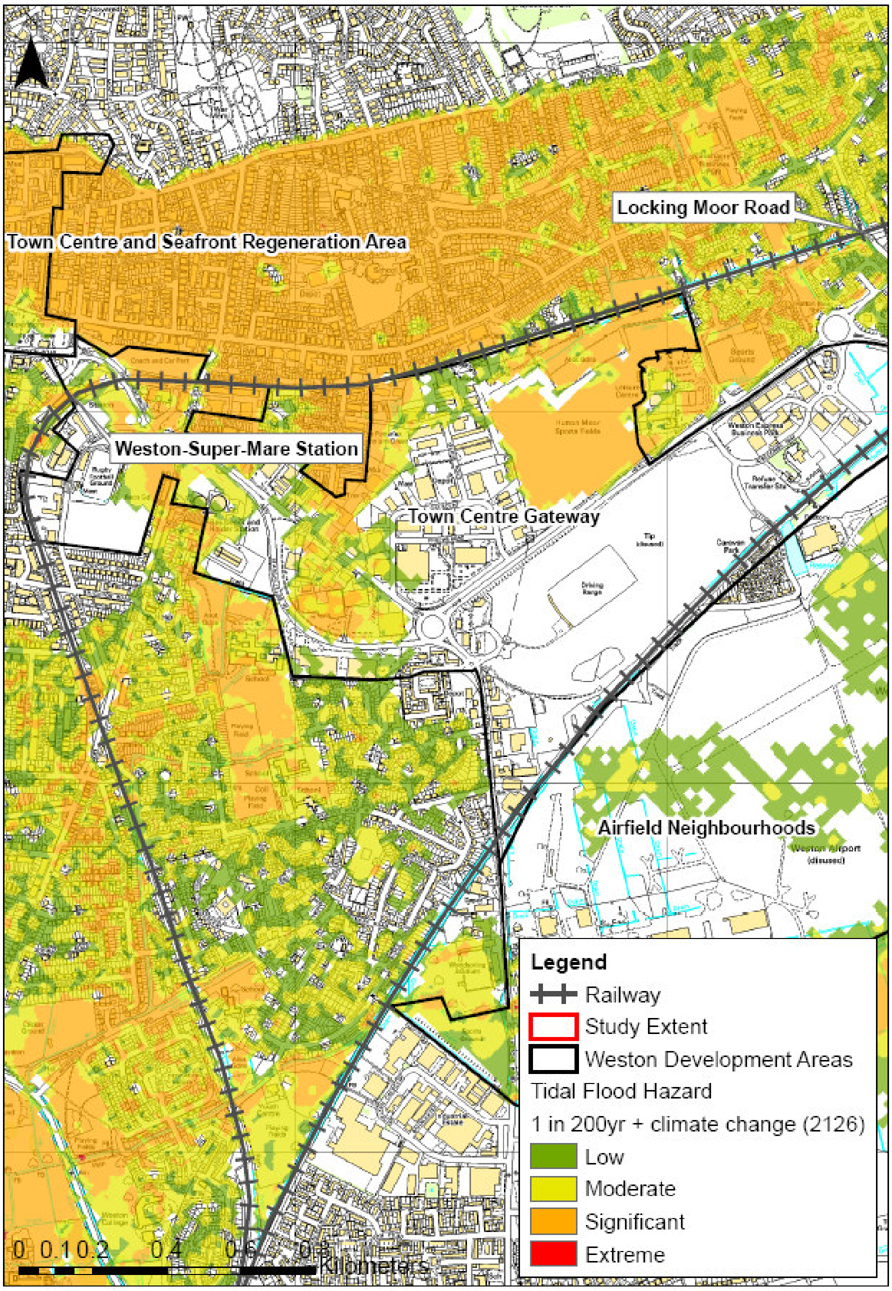


Figure 4.22 shows tidal flood depths for the second area of flooding relating to the railway line at the 1 in 200 year event in 2126 between Flowerdown Bridge and Banwell Road Bridge. Flood depths are generally expected to be shallow in this location at less than 0.25m across the railway line. The tidal flood hazard associated with this flooding is anticipated to be low to moderate with areas of significant hazard adjacent to the railway line as shown by Figure 4.23.

As shown by figures 4.20 to 4.23, the risk of tidal flooding across and surrounding the railway line by 2126 is considerable. NSC should therefore take account of this in any plans for future improvements to the railway infrastructure in this area.

Figure 4.22 – 1 in 200 year Tidal Flood Depths plus climate change (with defences)

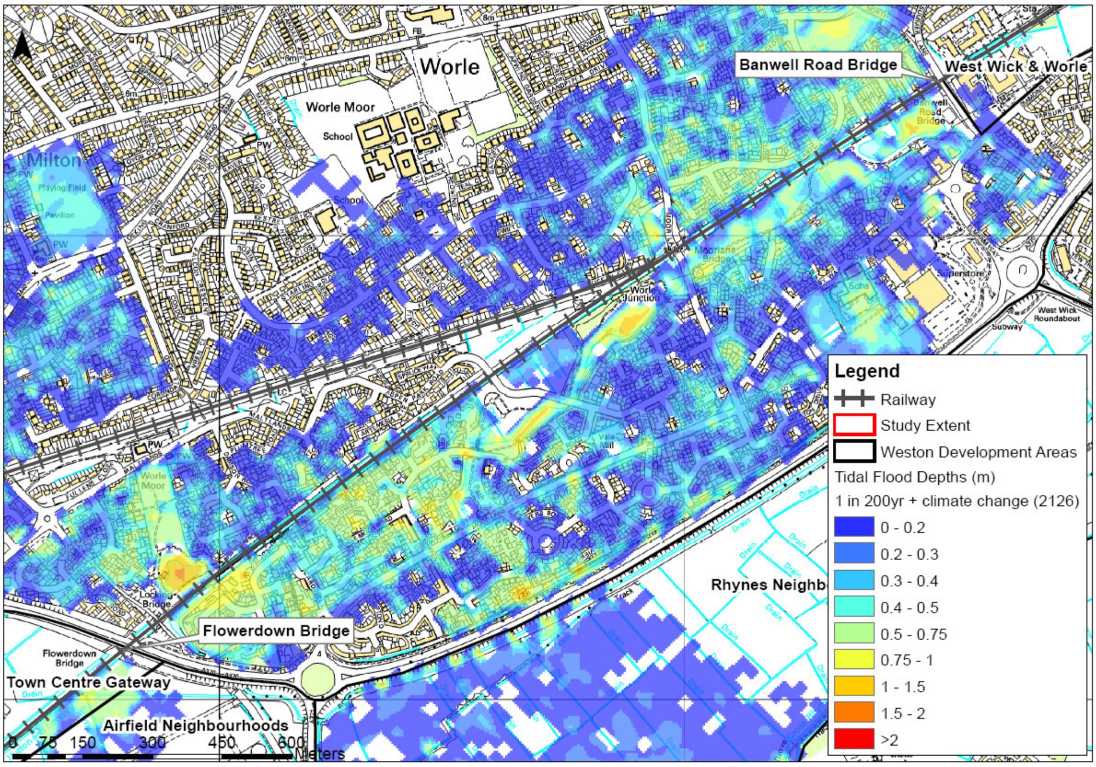
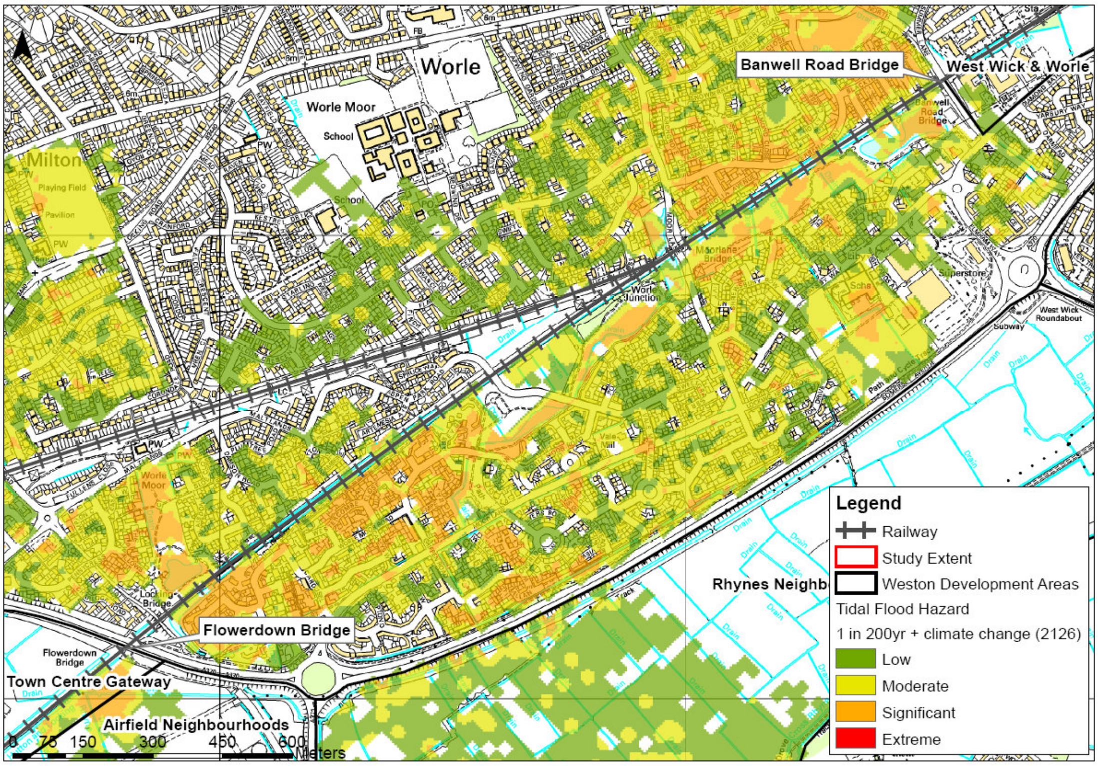


Figure 4.23 – 1 in 200 year Tidal Flood Hazard plus climate change (with defences)

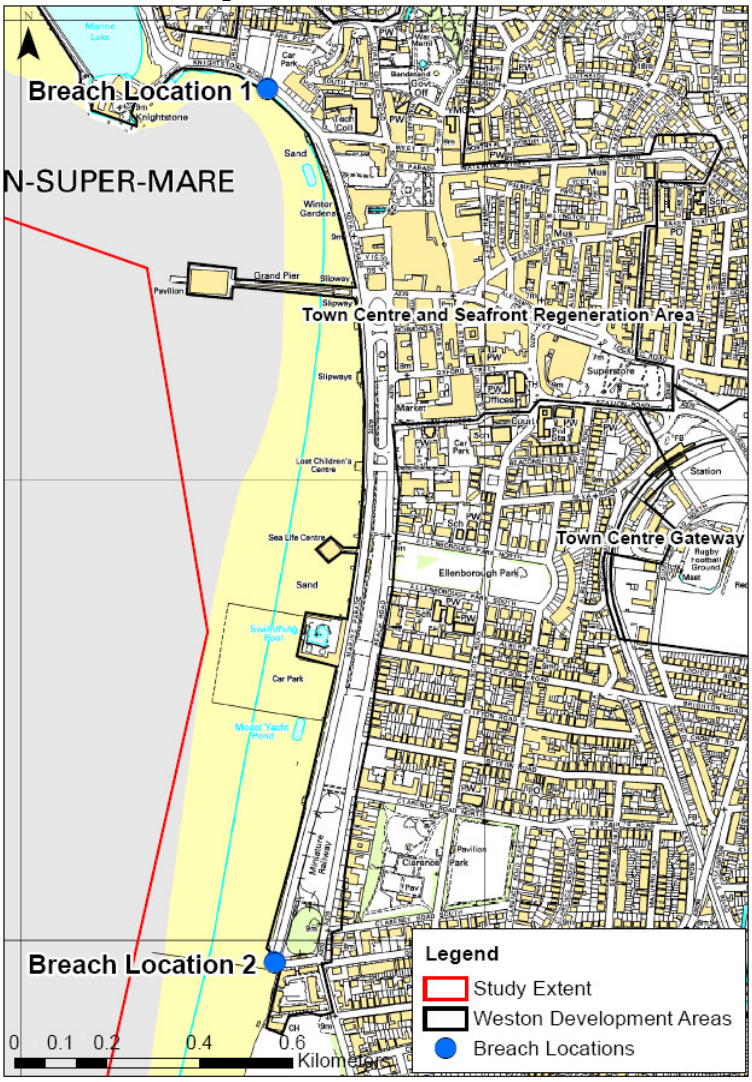


4.5 Breach Analysis

Additional modelling was undertaken using the 2D tidal model in order to assess the impact of a breach in flood defences at one of two locations identified by NSC along the Weston-super-Mare seafront (Figure 4.24). The following figures displaying these results can be found in Appendix D:

- Figure D_1 Breach Location 1, 2010 depth and hazard
- Figure D_2 Breach Location 2, 2010 depth and hazard

Figure 4.24 – Breach Locations



Breach during 1 in 200 year tidal flood event (current, 2010)

Breach Location 1

Under current defended conditions model results indicate that if a breach in defences occurs adjacent to Knightstone Road in the north of the study area, an increase in the 1 in 200 year flood extent of approximately 100m laterally could be observed in the vicinity of the breach. This has the potential to affect the car park, a small number of properties along Knightstone Road, and extends to Greenfield Place and Park Place. The depth of flooding is low, less than 0.3m, however as a result of the flood velocity, the tidal flood hazard averages between moderate and significant representing danger to the general public should a breach in defences occur.

Breach Location 2

Model results show that under current defended conditions a breach in defences opposite Quantock Road would have no discernable effect on flood risk to the area.

The effect of a breach in defences at either location has a limited impact because in both cases the tide level does not exceed the height of the first of the two walls comprising the defence. The only water that gets through the breach is therefore any volume that overtops due to wave action. This is not a significant amount and therefore only minimal additional extents are observed in comparison to those without a breach.

Breach during 1 in 200 year tidal flood event (future, 2126)

Breach Locations 1 and 2

A breach in either of the two locations was shown to result in a smaller flood extent and lower depths than the 1 in 200 year event in 2126 without a breach in defences. This is because the breach occurs when tide level is high. The tide then continues to increase and therefore water can overtop at the same time as it enters through the breach. The volume through the breach is insignificant compared to the volume that overtops, therefore showing little difference in flood extent. As the tide level decreases the breach allows water behind the defence to escape back to the sea. This therefore reduces the water that ponds before the next high tide. The impact of this is that less ponding of flood water occurs overall and so the maximum depths are actually less if a breach occurs.

4.6 Access and Egress

Under current defended conditions, access and egress does not present a problem for the Weston Development Area for either tidal or fluvial flooding. The effects of climate change are not anticipated to further affect access and egress for fluvial flooding as all development areas have access and egress to routes outside of areas of flooding. In the Rhynes Neighbourhoods, access routes within the development area may need to be considered as part of a site specific FRA.

By 2126 tidal flooding is extensive across the study area, results indicate a range of flood hazard from low (caution) to significant (danger for most). In general, access and egress is retained for all development areas (except the town centre and seafront) with the A370 providing a route to land outside the flooded areas.

Model results show that the town centre and seafront area is expected to experience a significant tidal flood hazard by 2126. Access and egress is possible to the north of the area (Birnbeck Road / Upper Church Road) and to the east of the area (Station Road / A370). Access is more of a problem for the development area south of Carlton Street, however areas of none or low hazard are relatively close to the edge of the development area although new routes may need to be created to reach these areas.

Where flooding occurs in Weston-super-Mare outside the Weston Development Areas there are a number of routes above the level of flooding (see Figure 403_H – A1 map showing the 1 in 200 year tidal flood hazard in 2126) for example, the south of Weston has access to the A370 at Oldmixon.

In areas where tidal flooding is anticipated to occur within the lifetime of the development (100 years for residential, 60 years for commercial) and affects safe access and egress, evacuation plans and flood warning systems should be created and designed in to the development at the site-specific FRA stage. This is likely to be necessary for any residential development in the Town Centre and Seafront and the Town Centre Gateway.

4.7 Overview of impact of development on flood risk elsewhere

PPS25 requires that development should not increase flood risk elsewhere, and, where possible, reduce flood risk overall. The Weston Development Area comprises a mixture of previously developed and greenfield land and where land has been previously developed, it is likely that the existing surfaces will be predominantly impermeable. In these locations development is unlikely to adversely affect flow or run-off volume since the surface is already impermeable. Development in these areas could be used to improve the flow regime and lower flood risk to the surrounding area by incorporating Sustainable Drainage Systems (SuDS) to reduce overland flow and surface water ponding.

A number of locations within the Weston Development Area, such as the Rhynes neighbourhood and parts of the Airfield neighbourhood, are currently greenfield land. Development at these locations will significantly affect the natural flow regime with the potential to increase flood risk to the site and surrounding area by increasing the proportion of impermeable land. If development is to take place in these areas, as they are currently in Flood Zone 3, it will have to be proved that the development cannot be located in an area of lower flood risk, and the use of SuDS will be required to reduce the risk of increasing runoff to the surrounding areas. In addition, as the Weston Development Area covers a large area of land it is also recommended that should development go ahead a surface water management plan is considered for the area.

The need to consider the additional runoff resulting from the development of land within the Weston Development Area is further highlighted by the following table and figure.

Table 4.3 – Number of properties at risk pre and post development

Location	RH modelled extents	
	Pre-development	Post-development
Banwell catchment	14	14
Uphill catchment	84	188

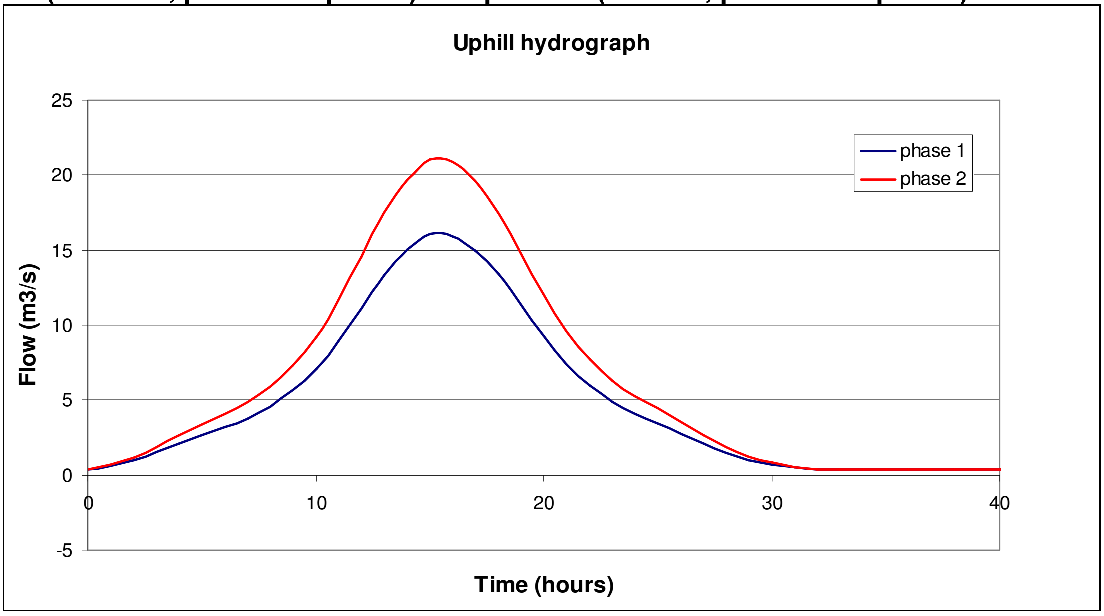
Source: Weston FMS Phase 2: Options Report

Table 4.3 displays the number of properties that could be expected to be affected by the increased runoff caused by development. This does not include the effect of the strategic solutions outlined in the Weston FMS study. In the Banwell catchment, no further properties are likely to be at risk from flooding than at present after development has taken place. However in the Uphill catchment, post development the results of the post development hydrology in the Weston FMS Phase 2 study show that a further 104 properties could be at risk of flooding than under current conditions.

Figure 4.24 shows the hydrographs for Phase 1 (pre-development) and Phase 2 (post-development) scenarios which indicates the considerable increase in peak flows that could be expected as a result of development. It should be noted that the increase of $5m^3/s$ in flow due to development as indicated by Figure 4.24 does not include the strategic solutions suggested in the Weston FMS Study. This increase therefore is the flow that may need to be managed through the use of SuDS should development go ahead within the Uphill Great Rhyne catchment.

It should be noted that the assessment of the effect of development on flood risk elsewhere has not taken account of climate change. Further investigation of the future effect of development on the surrounding area should be considered during a site specific FRA.

Figure 4.25 - Hydrographs for Uphill Great Rhyne catchment produced for phase I (blue line, pre-development) and phase II (red line, post development) flows.



4.8 Overview of Surface water flooding

The ASSWF map for the Weston area can be found in Appendix E. This has been used to highlight areas that are more susceptible to surface water flooding and areas where surface water presents less of a risk. For new developments, the best way of avoiding and managing surface water flooding is to manage the water at source through SuDS. For guidance about the use of SuDS techniques see Appendix A.

On the ASSWF map, the colour band indicating ‘more susceptible to surface water flooding’ helps to identify areas that might flood first, deepest or more frequently than other areas. The areas that are ‘more susceptible to surface water flooding’ might therefore require a detailed investigation of surface water risks should development be proposed in or adjacent to these areas. Within the study extent these are generally very small areas, on average 50m across. The main locations in this category are as follows:

- South of Locking along the Hutton & Locking Rhyne
- North East of Locking adjacent to the M5 motorway
- Alongside the A370 at Locking Bridge and Flowerdown Bridge
- A number of small areas near to Hutton Moor, the Gas Depot and Weston-super-Mare Railway Station
- Bushacre Business Park
- North of Worle in the vicinity of Tamar Rd, Gainsborough Drive and Torrington Crescent.

Areas that are 'intermediately susceptible to surface water flooding' are much larger (generally over 150m across) and more numerous across the study area than those that are more susceptible. Areas where the extent of intermediate surface water flooding risk is significantly greater than the extent of 'more' risk are:

- Land between Hutton and Locking
- Between the railway and the A3033
- Uphill
- North of the A370 extending to Baker Street and Milton Road and east to Worle Moor
- Land north of Locking
- Land east of Worle

Areas shown in Appendix E as 'less susceptible to surface water flooding' extend over most of the study area south of Milton Road and east of Worle Hill.

Areas that do not fall into one of the three categories described above could be expected to have a very low risk of surface water flooding, although this would need to be confirmed if development was panned in these areas. The larger of these areas are listed below:

- Land north of Milton Road
- Land between Hutton Moor sports fields and the railway
- Land between the A371 and Locking Head Farm
- Land between West End Farm and Locking
- Elborough
- Lower Canada
- Small patches of land south of Hutton
- Land at Woolvershill Batch, east of the M5 motorway

For all areas, even where the susceptibility to surface water flooding is not mapped and therefore indicated to be low or negligible, risk of flooding from other sources (including fluvial, tidal and groundwater) may still exist and should be taken into consideration prior to allocation of the land for development purposes.

It should be noted that with the exception of land north of Milton Road, the area of Weston encompassed by the study extent is generally very flat. The ASSWF maps represent the risk of surface water flooding better in steeper catchments, therefore the maps should only be used to indicate where further investigation is required. Environment Agency guidance (Areas Susceptible to Surface Water Flooding: Guidance for Local Resilience Forums and Regional Resilience Teams for emergency planning and other purposes (not land use planning) – v2 July 2009) also states that the maps should not be used in isolation to assess surface water risk. LiDAR data and Environment Agency Flood Reconnaissance Information System data have therefore been used in combination with the maps in order to assess the risk of surface water flooding. It was found that although only five historic incidents of flooding in the study area describe surface water as the cause (see Table 4.4), the LiDAR data highlights the low-lying nature of the area and corroborates the surface water risk indicated by the ASSWF maps.

Table 4.4 - Recorded surface water flood events

Location	Date	Features affected
Hutton	1979, 1986 and 1996	Transport and buildings
Kingsley Road (Weston-super-Mare)	1979	Transport
Ashcombe Gardens / Milton Road	2007	Transport

The Weston Development Area is extensive, low-lying and a mixture of urban (town centre), brownfield (industrial/town centre gateway area) and greenfield land. Where land allocated for potential development is classed as greenfield (such as the Airfield and Rhynes Neighbourhoods), the susceptibility to surface water flooding could be expected to increase as a result of development due to the increase in impermeable surfaces across the area. It is therefore considered that where development is proposed, surface water management plans would be beneficial (either for the development area or on a larger scale depending on the scale of the proposed development) in order to minimise the risk of surface water flooding in and around the development areas.

It is also recommended that any new development should use Sustainable Drainage Systems (SUDS) to control surface water before it enters a watercourse. Within a large urban area such as Weston-super-Mare the combined effect of water discharge from SUDS must also be addressed to prevent further flooding issues downstream.

In June 2010 Royal Haskoning were commissioned to undertake the Weston-super-Mare Surface Water Management Plan (SWMP), with an expected completion date of early 2011. The SWMP will look in much more detail at the surface water flooding risk across the study area, in particular highlighting critical drainage areas. This will involve the adaption of the existing TUFLOW model to include the drainage network and therefore highlighting particularly sensitive areas to surface water flooding. Tide-locking scenarios will also be considered and potential mitigation measures developed where possible.

4.9 Loss of floodplain volume due to infilling of floodplain

As land in the key development areas of the Airfield and Rhynes Neighbourhoods is within the fluvial floodplain (as identified by the hydraulic modelling from this study) an assessment of the volume lost from these storage areas due to development has been made.

The volume lost has been calculated for water levels taken from the 1 in 100 year fluvial event with post development flows included by adjusting the LiDAR DTM data for the proposed development extents and therefore building works above ground level. 100% of the area is assumed to be developed with the expectation that 75% of the developed land will be impermeable (roofs, roads etc) and the remaining 25% will be permeable (gardens, open space etc). These volumes are given in table 4.5 below.

Table 4.5 - Volume lost due to development

Development Area	Water level achieved from 1 in 100 year Post-Development Flow Estimation	Volume lost due to development within the floodplain
Airfield Neighbourhoods	4.94mAOD	69,500m^3
Rhynes Neighbourhoods	5.04mAOD	115,000m^3

This lost volume results in an increased water level and a slightly greater flood extent as shown in the site summary tables in Section 6. This demonstrates that mitigation will be required to account for this lost volume should development go ahead.

5 STRATEGIC FLOOD RISK SOLUTIONS

The flood risks remaining after applying the sequential approach and taking mitigating actions are known as the residual risks. It is the responsibility of those planning development to fully assess flood risk, propose measures to mitigate it and demonstrate that any residual risks can be safely managed.

Planning Policy Statement 25: Development and Flood Risk exists to assist planning officers making decisions about land allocation in terms of flood risk. Any new development under the proposed Core Strategy allocations within the catchment will require a flood risk assessment as defined by PPS25. The flood risk assessment will have to demonstrate that the development does not put people or assets connected with the development at risk of flooding. It also has to demonstrate that, as a result of development, flood risk is not increased anywhere else in the catchment. As it is likely that the proposed developments would lead to an increase in impermeable land, this increase in urbanisation was factored into the hydrology to produce post-development flows to take account of an increase in surface water volumes and runoff rates and therefore an increased flood risk to Weston-super-Mare.

A study of mitigation measures for both the Banwell and Uphill Great Rhyne/Cross Rhyne catchments were undertaken as part of the Weston-super-Mare FMS Phase II and a summary is given below. These options not only look at reducing flood risk as a result of development but also seek to reduce the flood risk for existing settlements promoting sustainability and following Core Strategy aspirations.

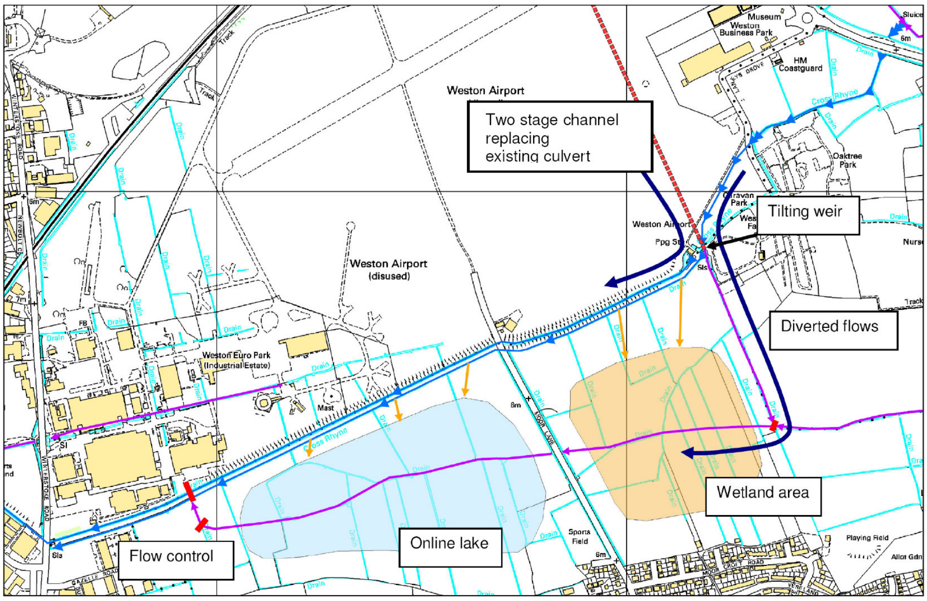
Twenty four options (across both catchment areas) to reduce flooding and flood risk to existing properties, and allow development were examined through the development and assessment of detailed hydraulic modelling to identify a preferred option in terms of flood risk mitigation. These options were then assessed in terms of environmental, human environment and economic impacts to identify preferred overall solution to comply with the aspirations of the Partnership (comprising representatives from North Somerset Council planners and engineers, the Environment Agency and West Mendip Internal Drainage Board (IDB)) and the Weston Vision. Wider consultation was also undertaken with the major developers of the proposed sites through a workshop and discussion meeting.

Within the study area flood management options have been investigated that are strategically planned to improve the current situation and facilitate future development in a coherent and coordinated manner. As well as reducing flood risk, the variety of options examined seeks to meet greater objectives such as enhancing the environment and ensuring long term sustainability. This may take the form of habitat creation and or the creation of amenity open space.

The preferred options have been developed to assess their effectiveness and information regarding costs, properties at risk and changes to flood extents has been provided. The preferred options are given below in Figure 5.1 and 5.2.

The increased flood risk due to development is significantly more apparent within the Uphill and Cross Rhyne catchments. Due to the limitations of building additional and extended defences in the downstream and upstream reaches of Uphill Great Rhyne mitigation options seek to provide sufficient storage to attenuate additional flows due to increased surface water runoff in the areas adjacent to the Airfield Neighbourhoods development area.

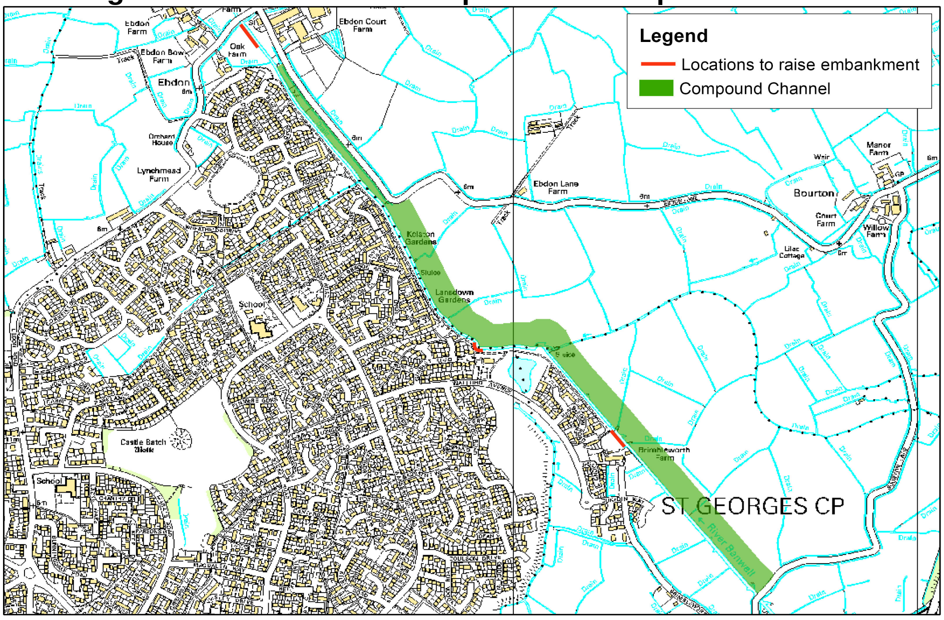
Figure 5.1 - Uphill Great Rhyne: Option 10 - Diverted Cross Rhyne with online lake and wetland areas and culvert works



Flows from Cross Rhyne would be diverted along a new channel starting at the old airfield pumping station and running through an area of wetland and then into a lake providing online storage and recreational facilities. The lake would also be fed from the freshwater stream which flows into Hutton and Locking Rhyne to help to maintain water quality. Flow leaving the lake would be throttled at the downstream end near to Winterstoke Road. Flow from the airfield and former airfield culvert (which would be opened up and replaced with a two stage channel) would drain into the existing Cross Rhyne and Hutton Moor Rhynes running south of the airfield.

The cost of this option has been calculated at £4,900,000 and includes site investigation, set-up and prelims, service diversions and all works including bank raising. This cost assumes that excavated material will be transported and spread on adjacent land to a depth of 500mm approx. The annual maintenance charge is expected to be £70,000. This cost does not include for land purchase and compensation costs. Should the disposal of material off site be necessary, landfill charges are expected to be in excess of £9m which is the potential worst case scenario. Economic and environmental savings may be made through the more sustainable use of excavated material elsewhere.

Figure 5.2 - River Banwell: Option 11 - Compound Channel



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A compound channel would be constructed downstream of the M5 motorway with a lowered bank extending laterally for 50m on the right bank of the channel over a 1900m stretch of channel. This will provide additional storage and lower water levels locally at times of high flow with minimal disruption to the existing agricultural land use (grazing). At certain points along the left bank of this channel the defence is known to have low points which would require a small increase in elevation.

The cost of this option has been calculated at £900,000 and includes site investigation, set-up and prelims, service diversions and all works including bank raising. This cost assumes that excavated material will be transported and spread on adjacent land to a depth of 500mm approx. The annual maintenance charge is expected to be £4,000. This cost does not include for land purchase and compensation costs. Optimism bias is not included in the figure above and if assumed to be at 60% will raise the total cost to £1,440,000. Should the disposal of material off site be necessary, landfill charges are expected to be in excess of £1.9m which is the potential worst case scenario. Economic and environmental savings may be made through the more sustainable use of excavated material elsewhere.

Mitigation measures already under construction as part of the Weston-super-Mare Sea Defences scheme, include raising the parapet wall, improving the drainage, the provision of a secondary flood wall and providing toe protection to the front of the sea wall, where appropriate, to reduce annual flood risk to 1 in 200 years (0.5%). It is proposed that in 25 years the rear wall will be raised so that the 1 in 200 year standard is sustained throughout the 100 year life. This option is the most cost effective, technically sound and environmentally acceptable option. It is estimated that the new sea defence will provide protection to 3830 residential and 637 commercial properties in the developed urban area, including 78 residential basements.

5.1.1 Next stages and funding for flood risk management infrastructure

Construction of flood risk management infrastructure provides benefits to both existing development and new regeneration areas and therefore if any schemes or works are taken forward, then contributions from all parties should be considered. Additionally, in public areas, contributions should be discussed with the local authority where public areas may be enhanced as part of the works.

The cost of future flood risk management infrastructure can essentially be met through either private or public investment and can be viewed in a similar way to other major infrastructure requirements (such as highways) as they are essential for the development of key areas as identified in the Regional Spatial Strategy (RSS) and Core Strategy.

<u>Private Funding</u>
Contributions from the new development areas based on the benefit derived from the flood risk management infrastructure solutions are required to achieve the development obligations under PPS25. These can be raised through a variety of sources including Section 106, Community Infrastructure Levy and Community Benefit funds.

The exact method for assessing the funding requirements will need to be determined based on the development type involved e.g. residential, commercial, employment, and the value of the area of land.

<u>Public Funding for Regeneration</u>
Government funding through various regeneration mechanisms such as Homes and Communities Agency, Regional Funding Allocations and capital borrowing could be appropriate to support future regeneration. Key flood risk management infrastructure could be funded given the identification of Weston-super-Mare as a Strategically Significant Town within the RSS and its primary focus for regional development.

<u>Public Funding for future flood risk management measures</u>
Flood Defence Grant in Aid (FDGiA) is distributed by the Environment Agency on behalf of Defra. Funding provided from third party sources can alter the priority of FDGiA allocations. Funding is generally aimed at schemes that provide the greatest reduction in flood risk for the lowest public contribution.

NSC are currently looking to undertake further work to develop the options for flood risk mitigation works to support and deliver the Core Strategy and Royal Haskoning are currently in the process of agreeing this next project. This work will include further development of a mechanism for developer contributions and further refinement of developer conditions beyond the generic aspects for the development area as a whole and specific to the five key development sites within the Weston Development Area. These conditions have been supplied by the West Mendip Internal Drainage Board, NSC, the Environment Agency and the requirements of Planning Policy Statement 25 (PPS25) which seeks to avoid, mitigate and manage flood risk. NSC needs to establish a clear programme of the Core Strategy with milestones of the flood risk infrastructure.

6 SITE SUMMARY TABLES

As stated in Paragraph D10 of PPS25 a robust Sequential Test must be undertaken by the Local Planning Authority or the developer before seeking planning permission for new developments. The aim of this test is to place new developments onto land with the lowest probability of flooding. Where it is not possible to locate development away from the higher flood risk areas using the sequential test, then the Exception Test should be applied (if applicable).

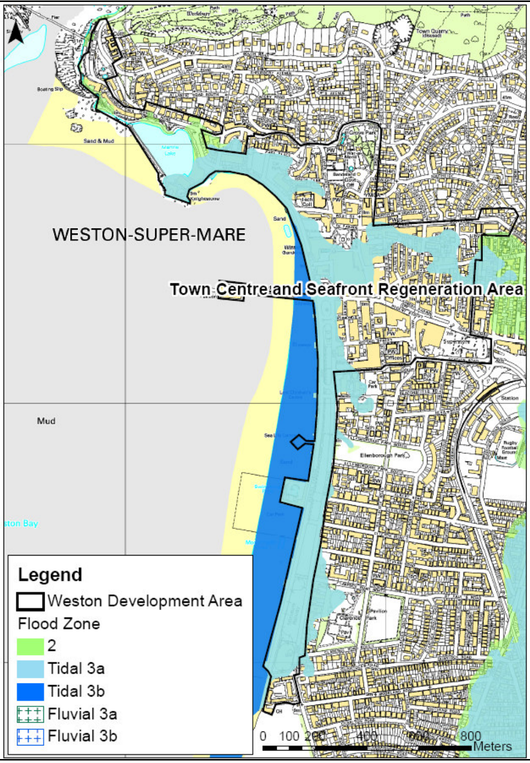
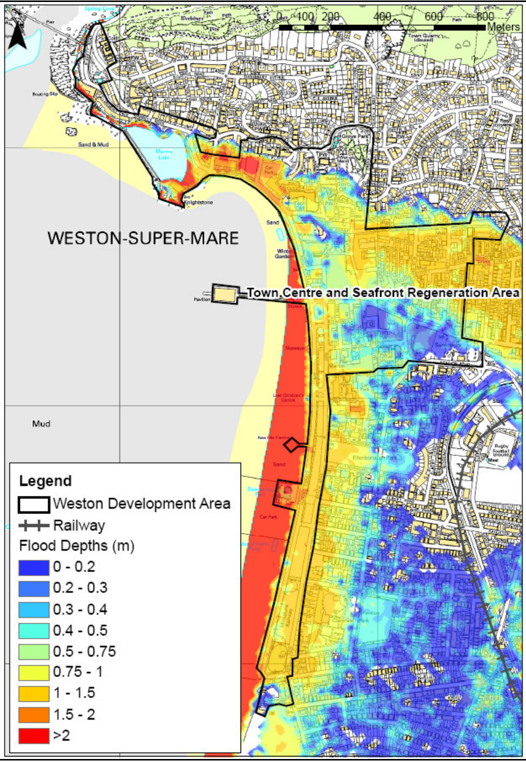
In order to satisfy Part c of the exception test a FRA must demonstrate that the development will be safe, without increasing flood risk elsewhere, and where possible, will reduce flood risk overall. This must be assessed over the lifetime of the development and therefore account for the impacts of climate change.

This includes determining any flood mitigation measures that will need to be used, including the proposed floor levels for a development. With climate change all of the sites are at risk of flooding, therefore all of the areas will need to consider the impacts of climate change over the lifetime of the development. Access and egress routes also need to take into account climate change.

Note that for the following tables Hazard Rating is based on categories from Flood Risk to People Phase 2 (FD2321/TR1) The Flood Risks to People Methodology (DEFRA, 2006).

The following site summary tables bring together the findings of the Level 2 assessment for each area in a consistent way so that flood risk and the potential for development at each site can be compared. The summary table maps showing future flood risk display both tidal and fluvial flood depths for the 1 in 200 year + climate change (2126) event and the 1 in 100 year + sea level rise events respectively. The “Level 1 Flood Zones (undefended)” shows the published flood zone where as the future scenario show the results of the modelling undertaken. The detailed discussion regarding the assessment for each area is presented in section 4. A1 maps showing the modelling results used for this assessment; fluvial flood depth and hazard, and tidal flood depth, velocity and hazard for the entire study area can be found in Appendices B and C respectively.

Note that for any new development exemplar SuDS should be utilised.

<table>
<tr><th>Site</th><th>Level 1 Flood Zones (Undefended)</th><th>Future Flood Risk with Defences</th></tr>
<tr><td>Town Centre and Seafront Regeneration Area</td><td>
</td><td>
</td></tr>
<tr><td>Summary of Risk</td><td>

Tidal flooding dominant.
Approximately 40% of area in Flood Zone 3a.
Defended model results show no flooding at 1 in 200 year event.
Variable susceptibility to surface water flooding across area, intermediate susceptibility in N and NE.
</td><td>

Tidal flooding dominant.
Sea defence scheme currently provides 200yr standard of protection (SoP).
Results indicate defence will need to be raised around the end of the century to maintain a 200yr SoP.
Sea wall has been designed to allow this.
</td></tr>
<tr><td>Hazard Rating</td><td>

No tidal hazard
No fluvial hazard
</td><td>

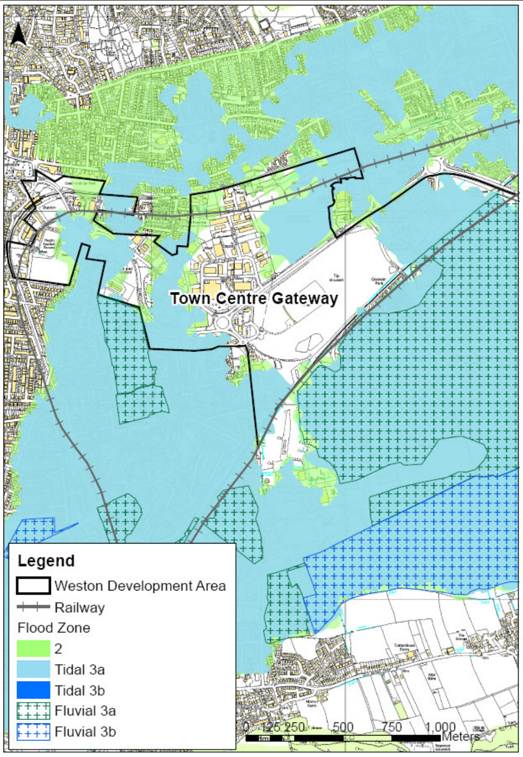
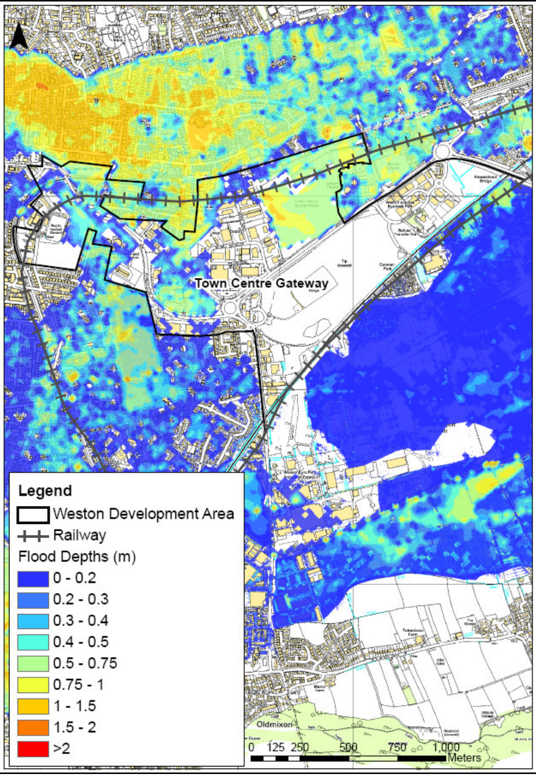
Significant tidal hazard
No fluvial hazard
</td></tr>
<tr><td>Access & Egress</td><td>

Safe for all modelled fluvial and tidal events under current defended conditions
</td><td>

Access/egress possible north of the area on existing routes (Birnbeck Road / Upper Church Road) and east (Station Road / A370).
South of Carlton Street new routes may need to be created.
</td></tr>
<tr><td>Potential for Development</td><td colspan="2">

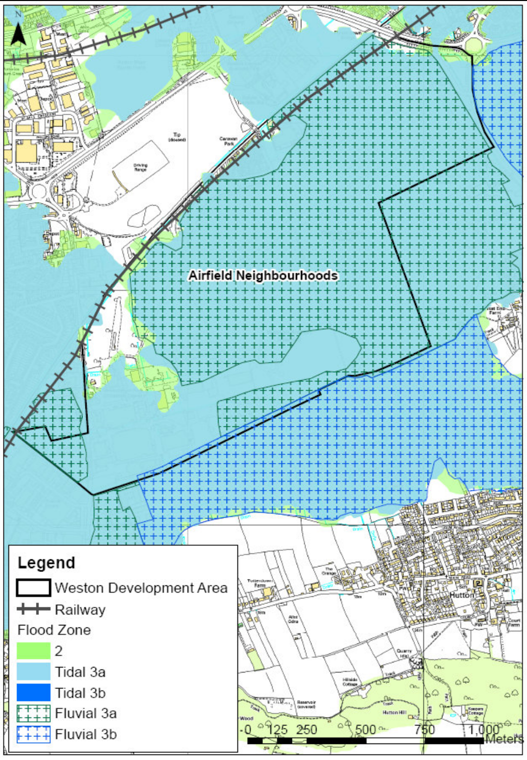
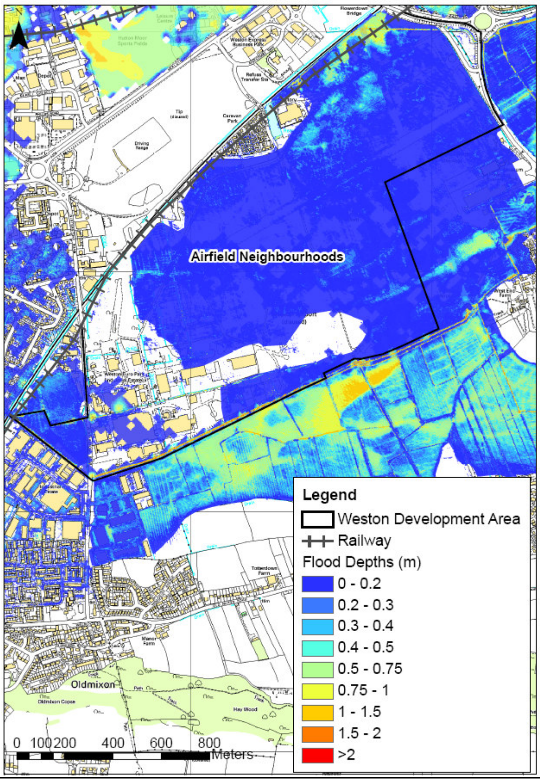
Development area of 0.8km2.
Previously developed land.
Proposed redevelopment of key sites and landmark buildings in addition to residential infill within the town centre.
Much of the area is in Flood Zone 1 where all types of development suitable.
Results indicate minimal flooding under current conditions.
Effects of climate change have little effect until 2126 when most of the area is expected to experience significant tidal flooding of over 1m in depth. This is based on current defence height.
SMP policy to ‘hold the line’, therefore reasonable to assume the 1 in 200yr SoP will be maintained into the future. This could reduce the risk of flooding portrayed above.
A ‘strategic solution’ is not practical for the town centre since development is generally infill, so new or re-development must seek opportunities to reduce overall level of flood risk at the site for example by:
</td></tr>
</table>

	• raising floor levels, • relocating development to zones with lower flood risk, • creating space for flooding. • New developments should adopt exemplar source control SuDS techniques to reduce the risk of frequent low impact flooding due to post development run-off.
Types of Development	• Flood Zone 3a therefore only less vulnerable or water compatible development suitable unless Exception Test passed. • Commercial development is most appropriate given the future flood risk across the area. • If residential development proposed, Exception Test must be passed, therefore safe access/egress routes must be identified or new routes created above flood levels and development must be safe for the lifetime of the development. • Most of the area is immediately behind defences therefore detailed breach analysis should be carried out prior to development during an FRA.
Finished Floor Levels	• These finished floor levels are only a guide and when conducting site specific FRA's they will need to be confirmed and agreed with the Environment Agency. • In line with the FMS study post development flows have been used for fluvial flows when assessing finished floor levels. • For both residential and commercial properties a freeboard allowance of 300mm has been included in the finished floor levels. • Current Levels: At present there is no flooding in this area. • Residential: Based on 2126 modelling, finished floor levels will need to be 9.7mAOD (including 300mm freeboard) along the seafront dropping to 7.3 mAOD (including 300mm freeboard) at the most landward extent of the area. • Commercial: Based on the 2086 modelling there is no tidal flooding in this area, finished floor levels should not be lower than present floor levels.

Site	Level 1 Flood Zones (Undefended)	Future Flood Risk with Defences
Town Centre Gateway		
Summary of Risk	• Currently surface water presents greatest risk of flooding • Risk of fluvial flooding along Uphill Great Rhyne in east of area. • 50% of area in tidal FZ3a • No tidal flooding at present due to defences along seafront and elsewhere such as Uphill sluice	• Tidal flooding dominant • Tidal depth and extent greater than fluvial across this area • Depths significant average 0.5-0.75m up to 1-1.5m
Hazard Rating	• No tidal hazard • Fluvial flooding largely not present though there is a small section of significant hazard to the south east of the railway line	• Significant tidal hazard • Fluvial flooding largely not present though there is a small section of significant hazard to the south east of the railway line
Access & Egress	• Safe for all modelled fluvial and tidal events under current defended conditions	• Safe for all modelled fluvial and tidal events under current defended conditions to A370 NE of site and to south of site. • Access within site will need to be identified at FRA stage.

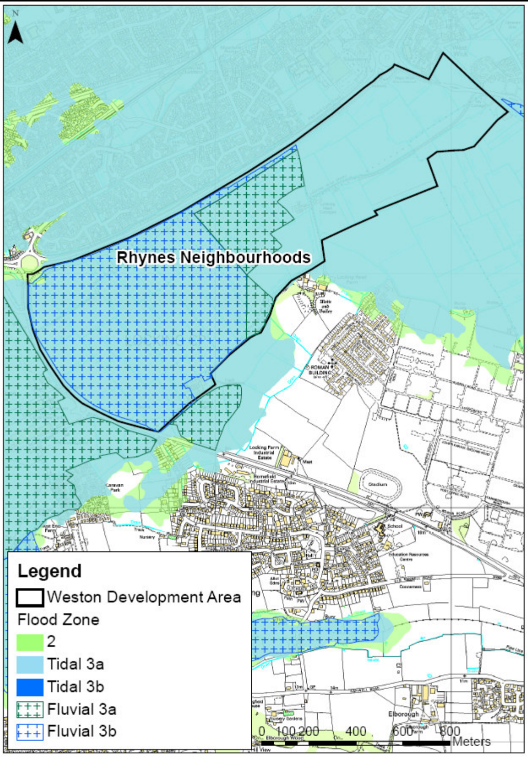
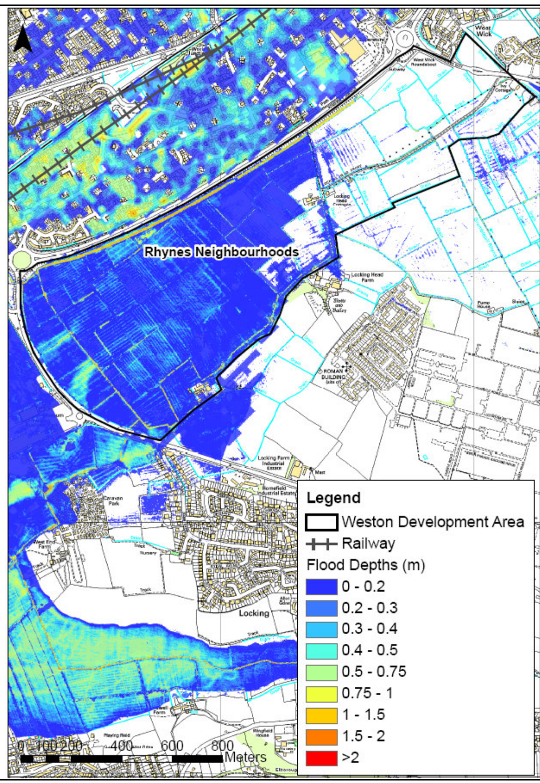
Potential for Development	• Development area of 1.5km2
	• Previously developed land
	• Proposed for mixed use including retail and leisure
	• 50% of area in FZ1
	• Minimal flooding under current conditions
	• Effects of climate change have little effect until 2126
	• In 2126 approximately 50% of area expected to experience tidal flooding with depths over 0.5m
	• New or re-development must seek opportunities to reduce overall level of flood risk at the site for example by:
	  • raising floor levels,
	  • relocating development to zones with lower flood risk,	

	• creating space for flooding. • Strategic Solutions for the Weston development area have been highlighted in the *'Weston FMS – Options report'* and it is this document which should be followed. • New developments should adopt exemplar source control SuDS techniques to reduce the risk of frequent low impact flooding due to post development run-off.
Types of Development	• Where Flood Zone 1, all uses acceptable since the areas currently in Flood Zone 1 are not shown to flood by 2126. • Where Flood Zone 3a only less vulnerable or water compatible development suitable. • Commercial development most appropriate where in FZ3a given the future flood risk. • If residential development is proposed the Exception Test must be passed and safe access/egress routes identified or new routes created above flood levels and the development must be safe for the lifetime of the development.
Finished Floor Levels	• Finished floor levels are only a guide and when conducting site specific FRA's they will need to be confirmed and agreed with the Environment Agency. • In line with the FMS study post development flows have been used for fluvial flows when assessing finished floor levels. • For both residential and commercial properties a freeboard allowance of 300mm has been included in the finished floor levels. • Current Levels: At present there is fluvial flooding to 4.62 mAOD in this area. • Residential: Based on 2126 modelling scenarios finished floor levels will need to be between 5.9 and 6.7mAOD (including 300mm freeboard). • Commercial: Based on 2086 modelling scenarios finished floor levels will need to be 5.9 and 6.7 mAOD (including 300mm freeboard).

<table>
<tr><th>Site</th><th>Level 1 Flood Zones (Undefended)</th><th>Future Flood Risk with Defences</th></tr>
<tr><td>Airfields Neighbour-hoods</td><td>
</td><td>
</td></tr>
<tr><td>Summary of Risk</td><td>Fluvial flooding dominant
All of site in either tidal or fluvial Flood Zone 3a (undefended)
Defended model results show some flooding at 20yr event along Uphill Great Rhyne but no significant flooding until 100yr event (approx. 10% of the area)
No tidal flooding under current defended conditions
Intermediate susceptibility to surface water flooding in centre of area and SE
More susceptible to surface water flooding in the NE.</td><td>Fluvial flooding dominant across area
Tidal flood depths and extents outside area to north significant (more than 0.5m)
Fluvial depths low across area (less than 0.3m) except along Uphill Great Rhyne
Effect of sea level rise shown above, increased flows due to climate change have similar effect.</td></tr>
<tr><td>Hazard Rating</td><td>No tidal hazard
Fluvial flooding largely low hazard across area
Small section of significant fluvial hazard to the north of the site adjacent to the railway line</td><td>Low tidal hazard
Fluvial flooding largely low hazard across area
Small section of significant fluvial hazard to the north of the site adjacent to the railway line</td></tr>
<tr><td>Access & Egress</td><td>Safe for all modelled fluvial and tidal events under current defended conditions.</td><td>Safe access off site to A370/A371 and to Winterstoke Road for all modelled fluvial and tidal events under current defended conditions
Due to flooding within site access within site will need to be identified at FRA stage.</td></tr>
</table>

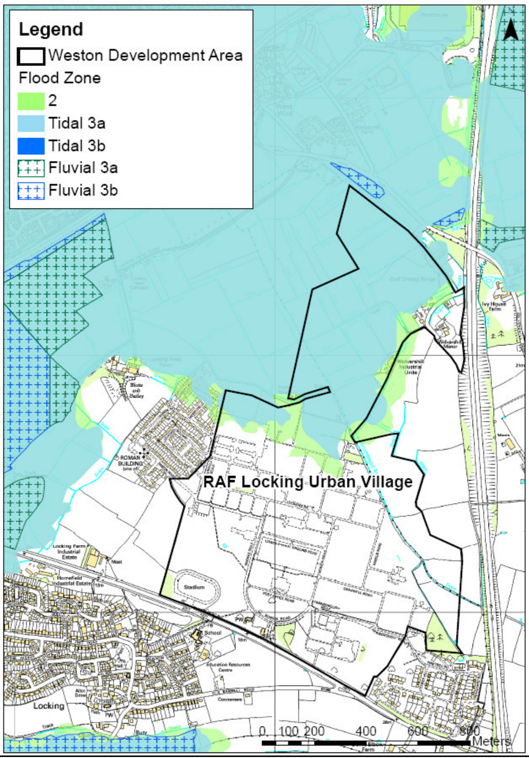
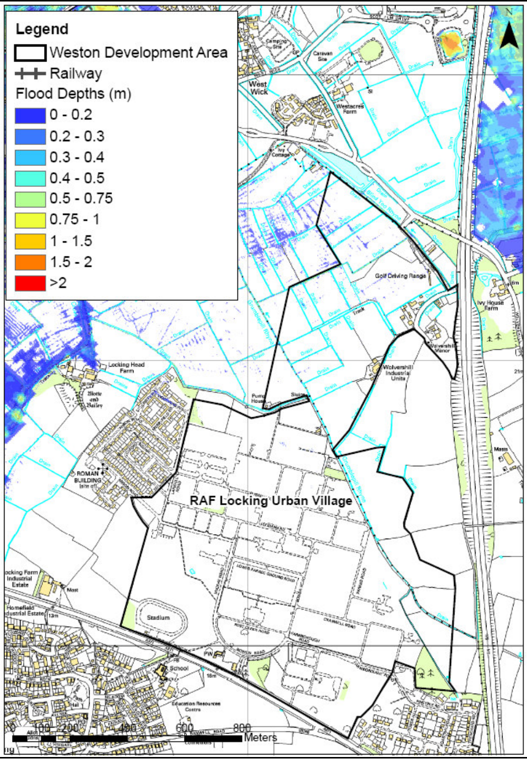
Potential for Development	• Development area of 1.75km2.
	• Mainly undeveloped land
	• Proposed for mixed use including residential, retail and leisure development.
	• Most of area is in Flood Zone 3a although results indicate limited flooding under current conditions.
	• The effects of climate change were shown to have significant effect on fluvial flood extents but little effect on tidal flooding until 2126 when approximately 25% of the area is expected to experience tidal flooding (although this is of less consequence than the expected fluvial flooding).
	• New or re-development must seek opportunities to reduce overall level of flood risk at the site for example by:
	  • raising floor levels,
	  • relocating development to zones with lower flood risk,
	  • creating space for flooding.
	• Strategic Solutions for the Weston development area have been highlighted in the *'Weston FMS – Options report'* and it is this document which should be followed.
	• Risk of surface water flooding requires further investigation at FRA stage owing to presence of area of 'more susceptible to surface water flooding' within site boundary.
	• New developments should adopt exemplar source control SuDS techniques to reduce the risk of frequent low impact flooding due to post development run-off.

Types of Development	• Where in Flood Zone 3a only less vulnerable or water compatible development suitable. • Commercial development most appropriate given the future flood risk. • If residential development is proposed the Exception Test must be passed • Where any Greenfield land is to be developed within the area, due to the its location within Flood Zone 3, the Exception Test must be passed for any type of development. • Mitigation measures will need to be taken to ensure that water flows are not impeded and flood risk is not increased elsewhere to allow development to proceed (see section 4.11). • Due to the flat nature of the area, surface water must also be given consideration prior to development.
Finished Floor Levels	• Finished floor levels are only a guide and when conducting site specific FRA's they will need to be confirmed and agreed with the Environment Agency. • In line with the FMS study post development flows have been used for fluvial flows when assessing finished floor levels. • For both residential and commercial properties a freeboard allowance of 300mm has been included in the finished floor levels. • Current Levels: At present there is fluvial flooding to between 4.81mAOD and 5.1mAOD in this area. • Residential: Based on 2126 fluvial modelling scenarios finished floor levels will need to be between 5.41mAOD and 5.5mAOD (including 300mm freeboard). • Commercial: Based on 2086 modelling scenarios finished floor levels will need to be between 5.41mAOD and 5.5mAOD (including 300mm freeboard).

Site	Level 1 Flood Zones (Undefended)	Future Flood Risk with Defences
Rhynes Neighbour-hoods		
Summary of Risk	• Fluvial and surface water flooding are the dominant risks across this area. • Defended results show no tidal flooding under current conditions. • 50% of the site currently experiences fluvial flooding at the 20yr and 100yr events where fluvial Flood Zone 3b is shown above. • Depths of less than 0.3m except in SE where depths are 0.5-075m. • Intermediate susceptibility to surface water flooding across much of site with more susceptible areas.	• Tidal and fluvial flooding both present risks of future flooding. • Flood depths do not increase significantly as a result of climate change remaining less than 0.3m, across much of the area increasing to 0.5-0.75m in the SE as under current conditions.
Hazard Rating	• No tidal hazard • Fluvial flooding largely low hazard • Isolated areas of significant hazard where current rhyne channels are filled	• Low-moderate tidal hazard • Fluvial flooding largely low hazard • Isolated areas of significant hazard where current rhyne channels are filled. • There are a few areas of moderate hazard to the south western and northern edges of the site.
Access & Egress	• Safe for all modelled fluvial and tidal events under current defended conditions.	• Safe access off site to A370 for all modelled fluvial and tidal events under current defended conditions • Access within site will need to be identified at FRA stage.
Potential for Development	• Development area of 1.2km2. • Mainly undeveloped land • Proposed for residential mixed use with some open spaces. • 50% of the area is in Flood Zone 3b, the remainder in Flood Zone 3a. • The effects of climate change were shown to have little effect on fluvial flood extents but a	

	significant effect on tidal flooding by 2126 when tidal flooding occurs across 50% of the site where previously none had occurred.
	• The combined effect of fluvial and tidal flooding should be further investigated prior to development.
	• New or re-development must seek opportunities to reduce overall level of flood risk at the site for example by:
	  • raising floor levels,
	  • relocating development to zones with lower flood risk,
	  • creating space for flooding.
	• Strategic Solutions for the Weston development area have been highlighted in the *'Weston FMS – Options report'* and it is this document which should be followed.
	• New developments should adopt exemplar source control SuDS techniques to reduce the risk of frequent low impact flooding due to post development run-off.

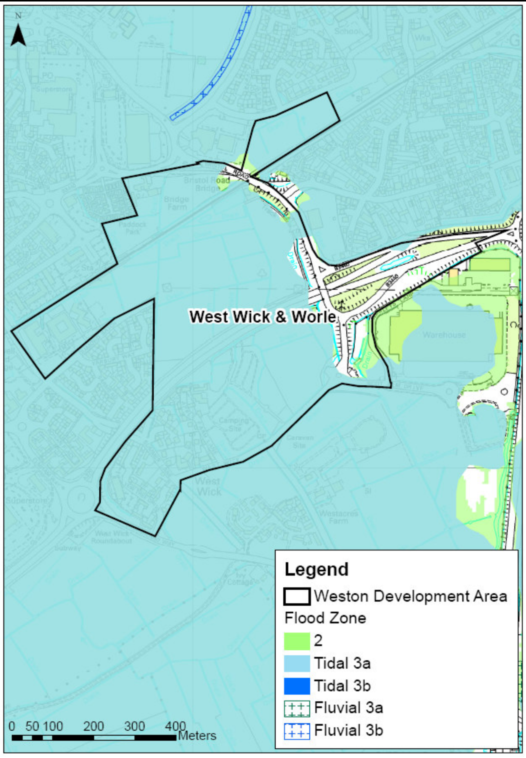
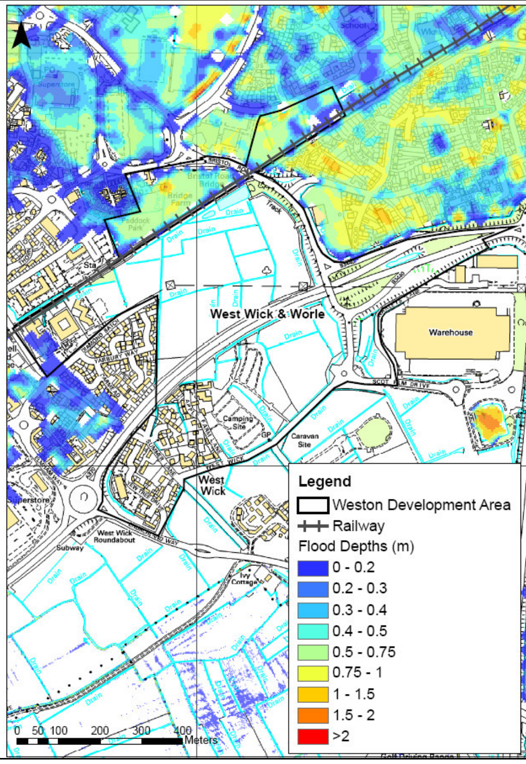
Types of Development	• Where in Flood Zone 3a only less vulnerable or water compatible development suitable. • Commercial development would be most appropriate in these areas given the future flood risk. • Where Greenfield land is to be developed, due to the area's location within Flood Zone 3, PPS25 states that the Sequential and Exception Tests must be passed for all types of development. • Mitigation measures will need to be taken to ensure that water flows are not impeded and flood risk is not increased elsewhere to allow development to proceed (see section 4.10). • Due to the flat nature of the area, surface water must also be given consideration prior to development. • Where in Flood Zone 3b only water-compatible uses and essential infrastructure are appropriate. These areas should be kept as open space where possible.
Finished Floor Levels	• Finished floor levels are only a guide and when conducting site specific FRA's they will need to be confirmed and agreed with the Environment Agency. • In line with the FMS study post development flows have been used for fluvial flows when assessing finished floor levels. • For both residential and commercial properties a freeboard allowance of 300mm has been included in the finished floor levels. • Current Levels: At present there is fluvial flooding to 5.01mAOD in this area. • Residential: Based on 2126 fluvial and tidal modelling scenarios finished floor levels will need to be 5.41mAOD (including 300mm freeboard). • Commercial: Based on 2086 modelling scenarios finished floor levels will need to be 5.41mAOD (including 300mm freeboard).

Site	Level 1 Flood Zones (Undefended)	Future Flood Risk with Defences
RAF Locking Urban Village		
Summary of Risk	• 35% of area in tidal Flood Zone 3a • Defended results show no fluvial or tidal flooding under current defended conditions. • Significant areas of 'more' and 'intermediately susceptible to surface water flooding' in the north of the area.	• Results show no tidal or fluvial flooding across the area in the future • Tidal flooding to east and west of site.
Hazard Rating	• No tidal or fluvial hazard	• No tidal or fluvial hazard
Access & Egress	• Safe for all modelled fluvial and tidal events under current defended conditions.	• Safe for all modelled fluvial and tidal events under existing defended conditions.

Potential for Development	• Development area of 1.2km2.
	• Previously developed land
	• Proposed for residential and employment use with some open spaces.
	• 35% of the area is in Flood Zone 3a.
	• The effects of climate change were shown to have no effect on flood risk to the area.
	• New or re-development must seek opportunities to reduce overall level of flood risk at the site for example by:
	  • raising floor levels,
	  • relocating development to zones with lower flood risk,
	  • creating space for flooding (this includes other forms of flooding such as surface water flooding and others not within the scope of this study such as groundwater).	

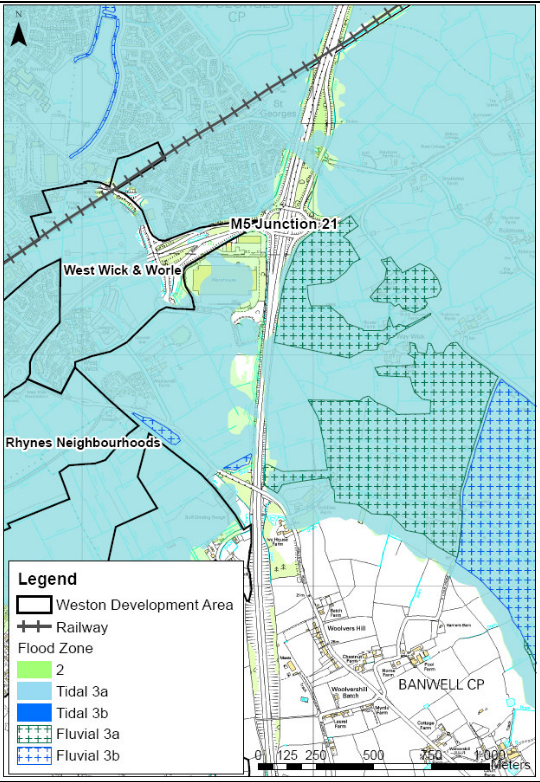
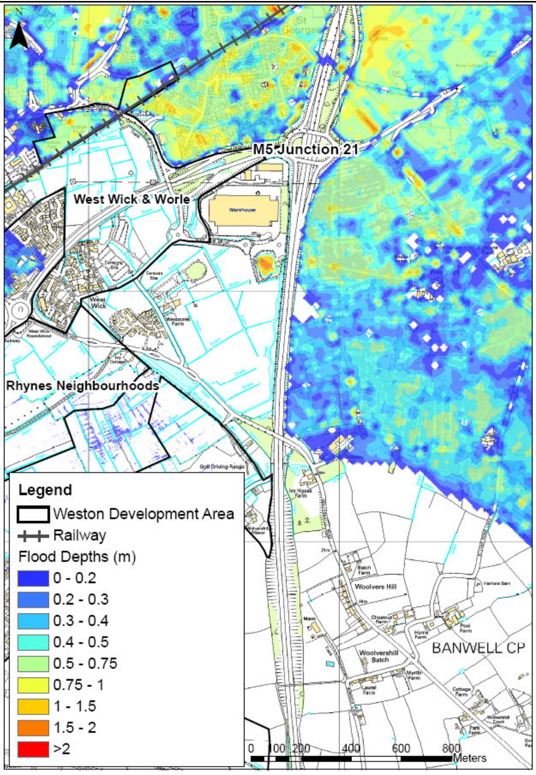
Types of Development	• Where in Flood Zone 1, all uses acceptable since these areas are not shown to flood by 2126. • Where Flood Zone 3a only less vulnerable or water compatible development suitable. • Commercial development would be most appropriate in these areas given the future flood risk. • If residential development is proposed the Exception Test will have to be passed • Where Greenfield land is to be developed, for any type of development, if it is located within Flood Zone 3, the Exception Test must be passed.	

	• Strategic Solutions for the Weston development area have been highlighted in the *'Weston FMS – Options report'* and it is this document which should be followed. • New developments should adopt exemplar source control SuDS techniques to reduce the risk of frequent low impact flooding due to post development run-off.
Finished Floor Levels	• Finished floor levels are only a guide and when conducting site specific FRA's they will need to be confirmed and agreed with the Environment Agency. • In line with the FMS study post development flows have been used for fluvial flows when assessing finished floor levels. • For both residential and commercial properties a freeboard allowance of 300mm has been included in the finished floor levels. • Current Levels: At present there is no flooding in this area. • Residential: Based on 2126 fluvial modelling scenarios finished floor levels will need to be 5.41mAOD (including 300mm freeboard). • Commercial: Based on the 2086 modelling results there is no tidal or fluvial flooding in this area, therefore finished floor levels should not be lower than present floor levels.

Site	Level 1 Flood Zones (Undefended)	Future Flood Risk with Defences
West Wick & Worle		
Summary of Risk	• Most of area in tidal Flood Zone 3a • Due to presence of defences along watercourses downstream of area defended model results show no tidal or fluvial flooding under current conditions. • Surface water flooding is currently dominant risk with much of site intermediately and less susceptible to surface water flooding.	• Model results show no fluvial flooding as a result of climate change however tidal flooding is recorded with significant depths of up to 1m in the north of the area.
Hazard Rating	• No tidal hazard, • No fluvial hazard	• Significant tidal hazard, • No fluvial hazard
Access & Egress	• Safe for all modelled fluvial and tidal events under current defended conditions.	• Safe access/egress (via A370) for all modelled fluvial and tidal events under current defended conditions.

Potential for Development	• Development area of 0.45km2.
	• Mixture of employment and residential development as well as open spaces.
	• 90% of the area is in tidal Flood Zone 3a though under current defended conditions there is no flood risk.
	• In the future there is still no fluvial flood risk but there is an increased risk of tidal flooding in the northern 10% of the site to the north of the railway line.
	• New or re-development must seek opportunities to reduce overall level of flood risk at the site for example by:
	  • raising floor levels,
	  • relocating development to zones with lower flood risk,
	  • creating space for flooding	

Types of Development	• The majority of this site is in Flood Zone 3a and is therefore suitable only for water compatible or less vulnerable development. • Commercial development would be most appropriate given the future flood risk. • If residential (more vulnerable) development or essential infrastructure is proposed the Exception Test must be passed • Developers should seek out opportunities to reduce overall level of flood risk and apply appropriate SUDs* techniques to deal with increased surface water runoff. • Where any Greenfield land is to be developed within the area, due to the its location within Flood Zone 3, the Exception Test must be passed for any type of development. • Strategic Solutions for the Weston development area have been highlighted in the *'Weston FMS – Options report'* and it is this document which should be followed. • New developments should adopt exemplar source control SuDS techniques to reduce the risk of frequent low impact flooding due to post development run-off.
Finished Floor Levels	• Finished floor levels are only a guide and when conducting site specific FRA's they will need to be confirmed and agreed with the Environment Agency. • In line with the FMS study post development flows have been used for fluvial flows when assessing finished floor levels. • For both residential and commercial properties a freeboard allowance of 300mm has been included in the finished floor levels. • Current Levels: At present there is no flooding in this area. • Residential: Based on 2126 tidal modelling scenarios finished floor levels will need to be between 6.01mAOD and 6.32mAOD (including 300mm freeboard). • Commercial: Based on the 2086 modelling results there is no fluvial or tidal flooding in this area, therefore finished floor levels should not be lower than present floor levels.

<table>
<tr><th>Site</th><th>Level 1 Flood Zones (Undefended)</th><th>Future Flood Risk with Defences</th></tr>
<tr><td>M5 Junction 21</td><td>
</td><td>
</td></tr>
<tr><td>Summary of Risk</td><td>• Surface water flooding is the dominant risk.
• Defended results show no tidal flooding under current conditions but east of the M5 currently experiences fluvial flooding at the 20yr and 100yr events.
• Depths generally less than 0.2m.
• Intermediate susceptibility to surface water flooding across much of site with areas that are less susceptible.</td><td>• Tidal flooding dominant in future (2126) due to climate change.
• Tidal flood depth and extent are greater than fluvial across this area.
• Where flooding occurs depths are significant, on average 0.5-0.75m up to 1.5m.</td></tr>
<tr><td>Hazard Rating</td><td>• Low fluvial hazard with isolated areas of significant hazard where current rhyne channels are filled.
• No tidal hazard</td><td>• Low fluvial hazard with isolated areas of significant hazard where current rhyne channels are filled.
• Significant tidal hazard</td></tr>
<tr><td>Access & Egress</td><td>• Safe for all modelled fluvial and tidal events under current defended conditions.</td><td>• Access & egress to the west of the M5 remains safe for all events.
• Access & egress to the east of the M5 will require routes to be raised above the 2126 flood level in order to be safe.</td></tr>
</table>

7 CONCLUSIONS

Flooding is an important issue which must not be ignored. In the future it is likely that flooding will occur more frequently and with more severity due to climate change. By using this SFRA, in combination with site specific FRAs submitted with planning applications for development or change of use, it is possible to allocate land for development in a sustainable way.

This Level 2 SFRA follows PPS25 and its associated Practice Guidance (December 2009), best practice and the guidance provided at all stages by the Environment Agency and North Somerset Council. This Level 2 SFRA is required to assess the flood risk in greater detail than the Level 1 SFRA, because it may be necessary to allocate development or consider windfall development in areas of higher flood risk.

This Level 2 SFRA together with the Level 1 SFRA, provide the necessary information with which to apply the Sequential Test and Exception Test to development proposals for the study area (PPS25, Annex D).

The Levels 1 and 2 SFRA together form part of the evidence base for the Local Development Framework (LDF) and are intended to inform decisions regarding land allocation and policies. The SFRA will also be considered an integral part of the Sustainability Appraisal of relevant component documents of the LDF.

This SFRA investigates six geographical areas under consideration for development, and its output includes flood extent, depth, velocity and hazard maps that represent the current flood risk and with climate change. A summary table has been provided in Section 6 for each of the geographical areas.

A significant number of the sites reviewed have areas of Flood Zone 3a and 3b, which means that they are at least partially unsuitable for development according to PPS25. An indication of these zones was provided in the Level 1 SFRA. The extent of these zones can be challenged via a site specific Flood Risk Assessment (FRA) by a developer when the extent and nature of the potential development is better defined and if more detailed modelling becomes available. This will then need to be agreed with the Environment Agency and North Somerset Council.

The summary tables in Section 6 highlight specific issues for each area that would need to be considered as part of a Flood Risk Assessment. The SFRA maps show that many of the allocated development areas and areas of search for development lie within Flood Zone 3. The Sequential Test should be applied to direct any development away from these higher flood risk areas followed by the sequential approach. Where it is not possible to allocate in lower flood risk areas the Exception Test must be passed.

The confirmation of areas at risk of flooding and measures to reduce flood risk, as highlighted by a FRA, is very important to ensure new development is not at unacceptable risk of flooding in the future and that flood risk is not increased elsewhere. The level of detail for each FRA will vary depending on the risk to that area. Guidance to both planners and developers is appended to this Level 2 SFRA and the North Somerset Level 1 SFRA.

Strategic flood risk management solutions have been identified for both the Uphill Great Rhyne and River Banwell catchment to mitigate development if they cannot be allocated outside the floodplain.

A study is needed to take forward the strategic solutions to an acceptable level of detail, for the North Somerset Council Infrastructure Delivery Plan. This is important to ensure that it meets the requirements of PPS12. Para 4.8 of PPS12 states that the Core Strategy should be supported by evidence of what key infrastructure is needed to enable the amount of development proposed for the area, when it will be delivered and by whom.

The best information is to be used to guide the site selection process for future developments. For this reason, this SFRA is a living document (reports and maps) to be updated as new information becomes available, e.g. further improvements to river models, surface water flooding incidents or revised climate change guidance.

8 RECOMMENDATIONS

8.1 General recommendations

8.1.1 It is recommended that NSC use this document to influence and amend their ongoing masterplans in their Core Strategy, Town Centre Action Plan and Infrastructure Delivery Plan to ensure the sequential test and approach is applied.

8.1.2 It is recommended that across the Weston Development Area a Sequential Test and approach is used to locate potential development in areas of lower flood risk, for example, areas within the town centre and town centre gateway are shown to be in Flood Zone 1 which are therefore suitable for all types of development. The Sequential Test and approach should also be applied within the site boundaries when specifying the Master Plan site.

8.1.3 Safe access and egress should be considered when reviewing the flood risk to proposed sites.

8.1.4 If development plans comprising Change of Use are proposed for the same vulnerability and does not increase flood risk, the development proposal is acceptable provided that the refurbishment uses flood resilient techniques; floor levels are raised if technically possible; flood warnings direct are taken; and there is an evacuation plan. If change of use is to a more vulnerable use, PPS25 states that a site specific FRA will be required where it should be shown that the change of use meets the objectives of PPS25. For example, where mitigation measures are required, how these will be maintained effectively to ensure that the development remains safe with safe access and egress throughout its lifetime.

8.1.5 Where FRA's are required, they should build on the information presented in the Level 2 SFRA for the proposed sites and investigate the potential for reduction of existing flood risk.

8.1.6 A number of requirements and conditions for developers have been identified by the West Mendip Internal Drainage Board, NSC and the Environment Agency as part of the Weston-super-Mare FMS Phase II. These must be adhered to and it is the responsibility of the planning authority to ensure that this is the case.

8.1.7 The outputs of this study should also be used to inform the Weston-super-Mare Surface Water Management Plan.

8.2 Mitigation recommendations

In accordance with the Flood Risk Management Hierarchy in PPS25, where flood risk has been assessed and cannot be avoided, for example development within flood risk areas cannot be located elsewhere, mitigation measures should be investigated as a final option to enable development within areas of flood risk.

8.2.1 Where mitigation will be required for development it is recommended that when requesting an FRA from developers NSC ask that the possible reduction of existing flood risk is investigated. This could be achieved through the Community Infrastructure Levy (CIL). These agreements can act as a main instrument for achieving wider objectives, often requiring developers to minimise the impact on the local community and to carry out tasks which will provide community benefits.

8.2.2 Mitigation measures for Uphill Great Rhyne and Cross Rhyne combine the re-routing of Cross Rhyne and provision of additional storage through the creation of a lake and two stage channel in the location of the former airfield culvert. This provides sufficient attenuation and also reduces levels within the upstream reaches of Uphill Great Rhyne. Future development therefore takes account of PPS25 policy. The potential risk of flooding is reduced from 188 to 4 properties for a 1 in 100 year event.

8.2.3 We recommend that because the Rhynes Neighbourhoods is prone to flooding from both Banwell and Uphill catchments and is permitted to accommodate excess flows from Moorland Drove Rhyne, formalised storage is provided and with further assessments as to the location and volume of storage required, to be carried out as surrounding development progresses.

8.2.4 The smaller scale option (compound channel – see Weston FMS Phase II Study) for the River Banwell is more appropriate for mitigating against the increased level of flood risk and takes account of PPS25 policy. Whilst the number of properties at risk is not reduced, the freeboard adjacent to the St Georges area is within the Environment Agency's recommended level. Whilst the requirement to provide formalised storage within the Banwell catchment is not economically justifiable on flood risk grounds alone, there is however an opportunity for environmental improvement and the enhancement of biodiversity within this area and we recommend that this be explored further, possibly through the commission of a separate study in association with an environment body.

8.2.5 The Weston Vision Partnership have the opportunity to require contributions from developers to allow the implementation of a flood defence scheme that not only meets the requirements of PPS25 for the specific development but also improves the current flood risk throughout the Banwell and Uphill Great Rhyne/Cross Rhyne catchments. Therefore where possible NSC should continue to seek opportunities for combined strategic mitigation measures which may provide a wider benefit than piecemeal development based measures. This could result in the flood risk to existing properties being reduced as well as providing defended land for the development. In addition strategic drainage measures e.g. SUDS can be much more effective over a large area rather than small individual development based schemes. Developer contributions could then be investigated via Section 106 Agreements for the installation and possible maintenance of the defences and/or SUDS.

8.2.6 It is recommended that the Strategic Solutions proposed via the Weston FMS study are implemented and taken through the process of detailed design through the mechanism of the Infrastructure Delivery Plan.

8.2.7 In order to meet the requirements of the Exception Test, climate change needs to be considered for the lifetime of the development (100 years for residential, 60 years for commercial), particularly when considering mitigation measures required. If defences exist, then for development to be permitted, these will need to be maintained at the required standard for the lifetime of the development. It is highly likely that to maintain the required standard of protection defences may need to be raised at some point during the lifetime of the development. It is therefore recommended that a programme is put in place for this maintenance and improvement works along with details of funding.

8.2.8 The issues highlighted in Section 8.2.7 are particularly relevant for the sea defence protecting the town centre. NSC should develop a plan to raise the sea wall in the future (it is thought this will be required in approximately 60 years) in order to 'hold the line' in accordance with SMP policy and to ensure that the wall remains at the required 1 in 200 year standard of protection accounting for the effect of climate change on sea level rise.

8.2.9 For any proposed development within flood risk areas flood warnings should be considered and included as part of the planning application. The impact of the development should also be considered in terms of the existing Flood Warnings for the area.

8.2.10 The Junction 21 bypass is at risk of flooding in a 200 year tidal event in 2126 and would need to be above a level of 5.65mAOD at its southern end near Gobbles Farm rising to 5.95m at the northern end near Doubleton Farm.

8.2.11 Within the Infrastructure Delivery Plan NSC should consider the impact of flooding on the railway line running through the area including the line to Weston-super-Mare station due to the risk of tidal flooding at a 1 in 200 year event by 2126.

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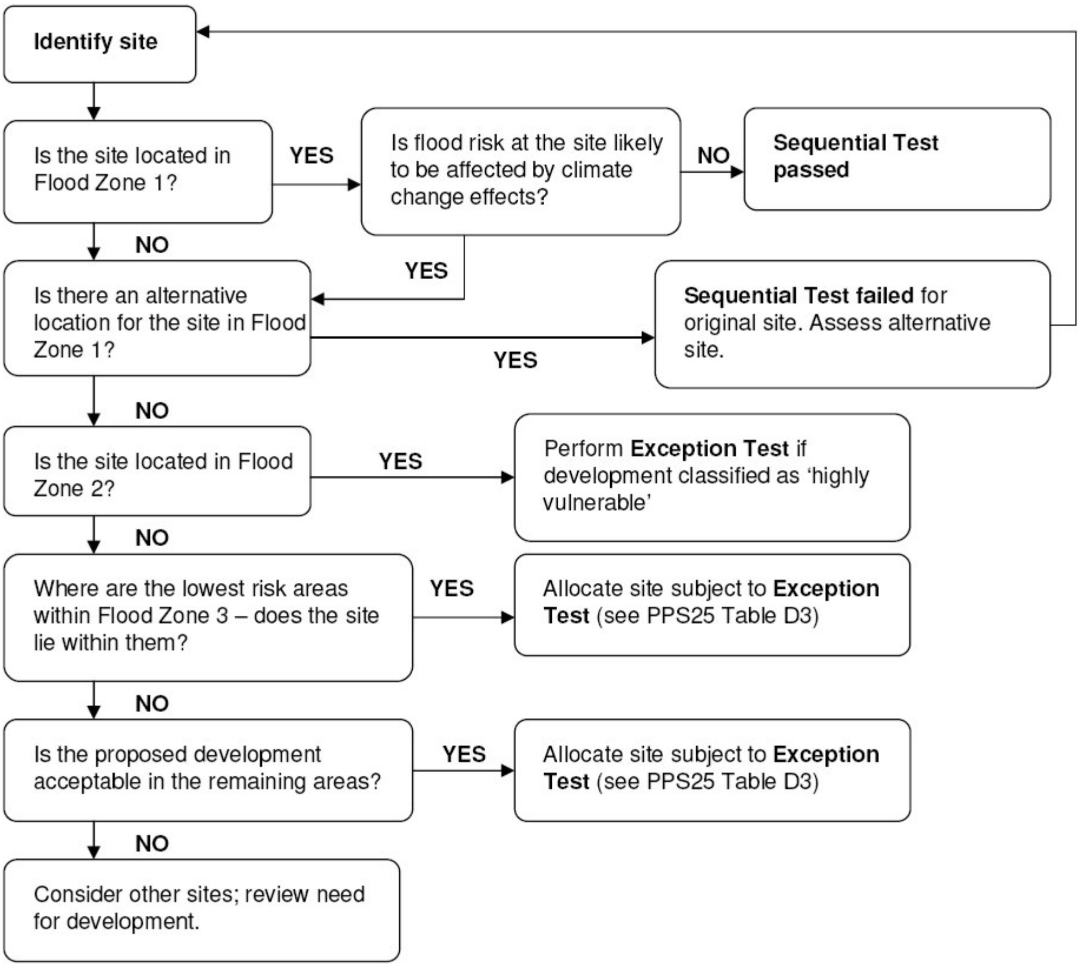
Appendix A

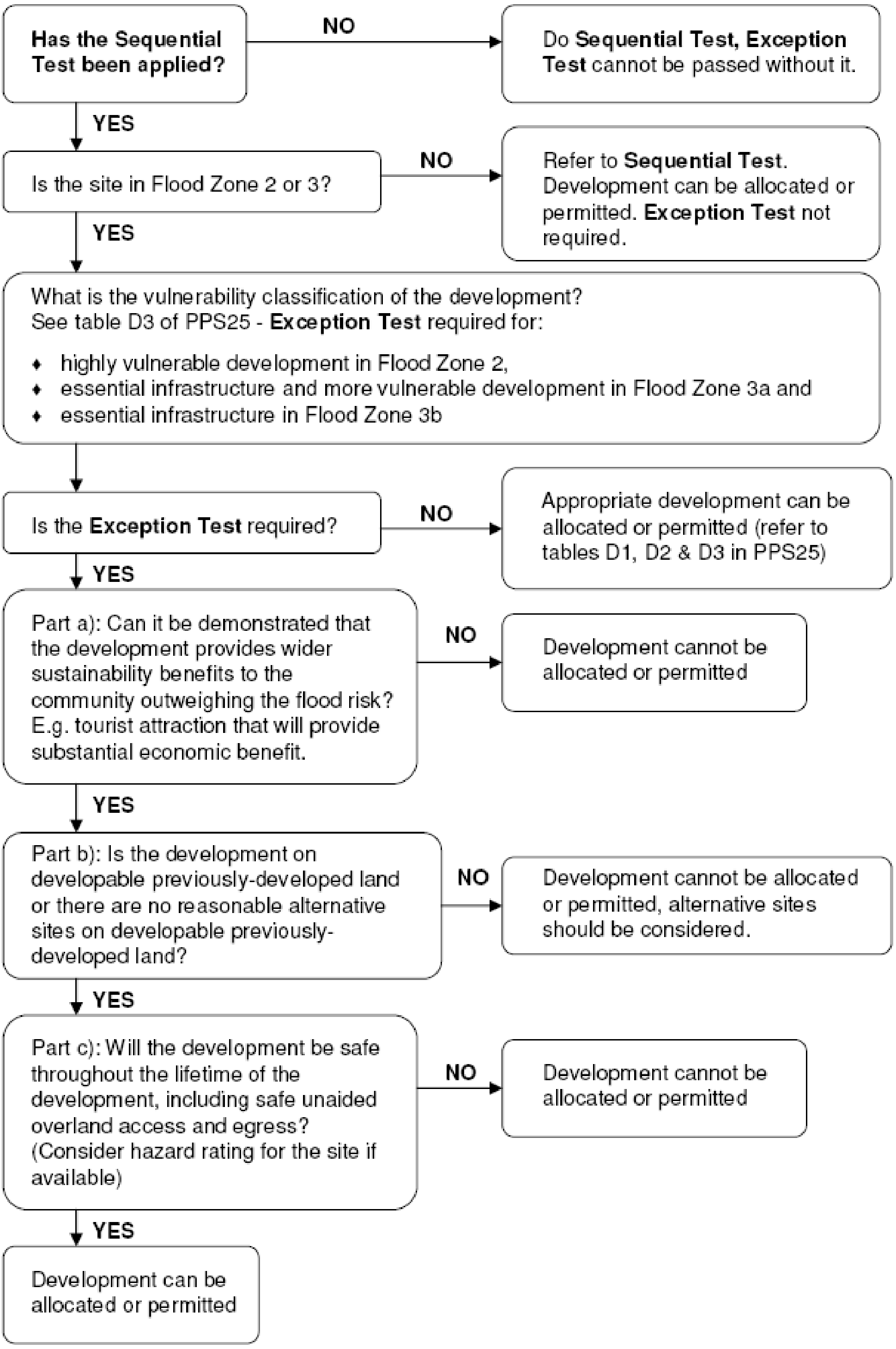
Guidance for site specific FRAs, the use of SuDS techniques and Flood Resilient Construction

Guidance for application of the Sequential and Exception Tests in accordance with PPS25

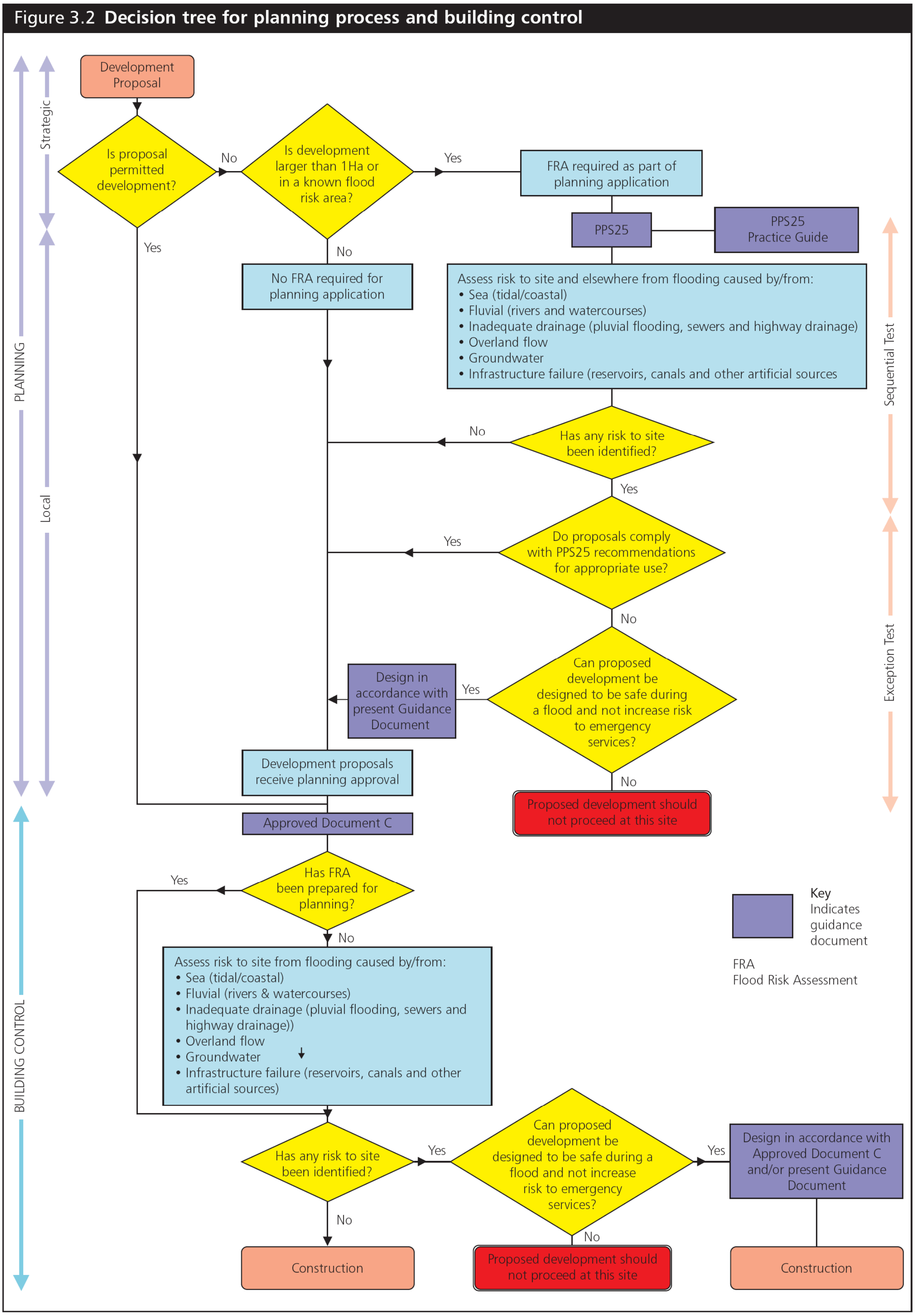
Application of the Sequential Test at the Local Level



Application of the Exception Test at the Local Level



FRA Decision tree and minimum criteria for assessment



Source: Improving the performance of New Buildings: Flood Resilient Construction (Communities and Local Government 2007)

If an FRA is required then the following tick sheet can be used to assess if the minimum criteria have been met…

FRA Criteria	**Included in the FRA?***	**Significant impact?****
Of appropriate detail for the size of the development and risk involved.		
Consider the risk to the development.		
Consider the risk to the surrounding as a result of the development.		
Consider the impacts of climate change.		
Be undertaken by competent people at an early stage in the planning process.		
Consider both the beneficial and adverse effects of any flood risk management infrastructure, along with the consequences of their failure.		
Consider the vulnerability classification of the people who will use the site.		
Put in place safe access to and from the site in times of flood.		
Consider and quantify the existing flood risk from all sources.		
Identify possible measures to reduce the flood risk.		
Consider the effects of a range of flood events on people, property, the natural and historic environment and rivers & coastal processes.		
Include an assessment of the residual risk after flood risk management infrastructure has been put in place and demonstrate that this is acceptable for the development in that particular flood zone.		
Consider how the development may affect how water drains into the ground.		
Consider the effect the proposed development layout may have on the drainage systems.		
Be supported by appropriate data, including historical information on previous events.		

* If any of these are not included in the FRA, return it to the developer for further information.
** If any of these highlight that the impact is significant then further investigation may be required.

If the Exception test is required then more information will need to be collected and analysed.

Surface Water and Sustainable Drainage Systems (SUDS)

Flood risk from surface water flooding is of concern within the study area. A number of flood incidents have occurred within the area caused by surface water alone, or in combination with river flooding. Some of these events are highlighted on the maps as recorded by the EA (FRIS) or historic information. The EA Flood Zone Maps do not show flood risk due to surface water flooding.

Urban developments can have a big effect on the quantity and speed of surface water run-off. By replacing vegetated ground with buildings and paved areas, the amount of water being absorbed into the ground is severely reduced, therefore increasing the amount of surface water present. This additional surface water increases the demand on drainage systems in built up areas. Traditional drainage systems are designed to get rid of the water as quickly as possible to prevent flooding in the built up area. This can cause problems, particularly downstream, by altering the natural flow patterns of the catchment. In addition, water quality can be affected due to pollutants from the built up areas being washed into the watercourse. One technique which can reduce this problem is the use of Sustainable Drainage Systems (SUDS).

Sustainable Drainage Systems (SUDS) are techniques designed to control surface water run-off before it enters the watercourse. They are designed to mimic natural drainage processes, along with treating the water to reduce the amount of pollutants getting into the watercourse. They can be located as close as possible to where the rainwater falls and provide varying degrees of treatment for the surface water, using the natural processes of sedimentation, filtration, adsorption and biological degradation.

CIRIA Guidance (2007) and the SUDS Manual (C687) should be reviewed when the implementation of SUDS is proposed. This will help to ensure that the current guidelines and requirements are met.

SUDS are more sustainable than traditional methods because they can:

- Manage the speed of the run-off
- Protect or enhance the water quality
- Reduce the environmental impact of developments
- Provide a habitat for wildlife
- Encourage natural groundwater recharge.

In addition, they can be used to create more imaginative and attractive developments and are designed so that less damage is done, than conventional systems, if their capacity is exceeded.

Surface water management using SUDS can be implemented at all scales and in most urban settings, ranging from hard-surfaced areas to soft landscaped features, even if there is limited space. Most techniques use infiltration but even if the area has little or no infiltration SUDS can still be used in the form of green roofs, permeable surfaces, swales and ponds.

SUDS are made up of one or more structures built to manage surface water run-off, and used in conjunction with good site management. There are five general methods:

a. Prevention – this can involve minimizing paved areas, replacing tarmac with gravel, rainwater recycling, cleaning and sweeping, careful disposal of pollutants, and general maintenance.

b. Filter strips and swales – these are vegetated surface features that drain water more slowly and evenly off impermeable areas. Swales (figure 4.2) are long shallow channels whilst filter strips (figure 4.3) are gently sloping areas of ground. Both of these mimic natural drainage by allowing rainwater to run in sheets through vegetation, slowing and filtering the flow.

Figure 4.2 - Cross-section of a Swale

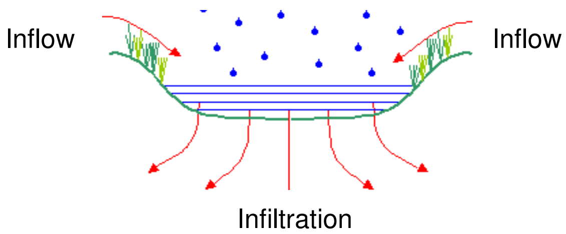
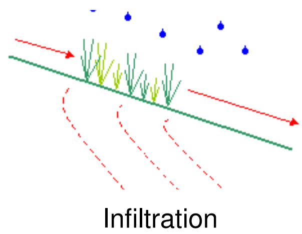


Figure 4.3 - Cross-section of a Filter Strip



c. Permeable surfaces and filter drains – these are devices that have a volume of permeable material below ground to store surface water. Run-off flows to this storage area via a permeable surface.

d. Infiltration devices – these enhance the natural capacity of the ground to store and drain water. They include soakaways, infiltration trenches and infiltration basins. See figure 4.4.

e. Basins and ponds – these are areas for storage of surface run-off e.g. floodplains, wetlands, and flood storage reservoirs. They can be designed to control flows by storing water then releasing it slowly once the risk of flooding has passed. See figure 4.5.

Figure 4.4 - Cross-section through an Infiltration Basin

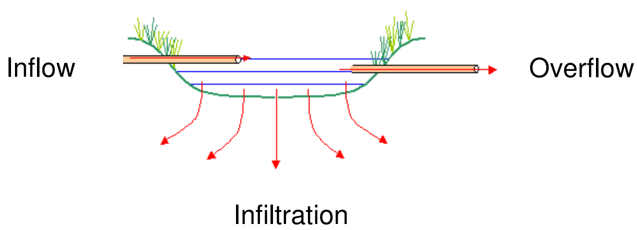
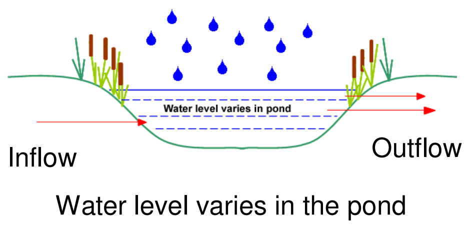


Figure 4.5 - Cross-section of a Pond



SUDS are better suited to areas of new development than in-fill. This is because for new development the drainage system for the whole area can be considered and designed at the same time, ensuring a consistent system across the development area and surroundings. Retro-fitting produces pockets of SUDS which work in isolation and therefore are not as effective as they could be within a SUDS strategy.

It is imperative that when designing SUDS for an area that both the EA and adopting authority are consulted at all stages of the design. This will ensure that the SUDS fit with the existing drainage network.

SUDS need to be regularly maintained to ensure they operate efficiently and effectively. The maintenance regime should be detailed and agreed during the design stage. Different SUDS techniques require different levels of maintenance therefore it is important to make it clear who is responsible for the maintenance at the start of the design and put a programme in place.

Government Guidance has been produced in the new water strategy for England, *Future Water,* which was published in February 2008. This strategy sets out the Government's long-term vision for water management in England. Following this publication, a consultation was carried out regarding policy measures to improve the way that surface water run-off is managed. One of the suggested management tools is the development of Surface Water Management Plans. When completed, these should provide useful guidance for developers and local authorities. More information regarding these strategies and plans can be found on the Defra website, www.defra.gov.uk/Environment/water/strategy/index.htm.

Guidance for developing housing in a flood resistant manner

Setting finished floor levels a minimum of 600m above future design flood levels is considered the minimum mitigation required for new construction. Where the proposal involves a change of use, a reduced freeboard may be acceptable when combined with other flood resistance and resilience measures. Regardless of the flood resistance measures proposed, the development including egress routes must remain safe throughout its design life.

PPS 25 states that development situated in EA Flood Zones 2 or 3 may be required to be built using flood resistant construction.

<u>Exterior Construction</u>
There are several measures to improve flood resistance of a wall using mortar, sealants and fillers. These measures include applying waterproof sealant to the outside face (ideally a breathable sealant), raising the level of the damp proof course, injection of fillers, closing cavities and ensuring there are no cracks or voids in the brickwork.

Excluding water will help reduce damage to the internal fabric of the building and its contents. If water does enter the house, flood resistant building materials will reduce the effects of the water and can reduce the cost of repairs.

<u>Interior Construction</u>
One of the most effective ways of reducing the impact of flooding is to raise the floor level of the property above expected flood levels. If this is not practical, another is to have flooring that can withstand being under water. Chipboard flooring is likely to be damaged by floodwater, so more resistant materials such as treated floorboards, WBP plywood, screed or tiles will be more suitable in flood risk areas. Fixtures that cannot be removed before a flood and might be damaged by exposure to water, such as carpets, parquet and laminate wooden floors should be avoided.

Where internal flooding cannot be avoided, some form of drainage of the water immediately post flood is recommended. In addition to protecting flooring, utility supplies should also be protected so that they can still be used in the event of internal property flooding.

- Electricity
  If there is sufficient space, the meter and fuse box should be positioned at a level which is higher than the expected flood level.
  Modern wiring is not usually affected by flooding, but long immersion may result in the need to replace wiring. Moving the ground floor ring main cables to first floor level could be considered with drop down cables to ground floor sockets. Sockets should also be raised to an appropriate height above flood levels. A further consideration is to have the house wired so that the ground floor main can be switched off, leaving the supply to the upper floors still available.

- Gas supply
  As gas meters can be affected by floodwater it is worth considering raising meters above the expected flood levels. Provision should be made for purging gas supply pipes through the installation of appropriate valves and drain points.

- Central heating systems
  Gas and oil fired boilers and associated pumps and controls should preferably be installed above the maximum expected flood level. Pipe insulation below the expected flood level should preferably be replaced with closed cell insulation. If new heating is being installed, pipework routes should be made easily accessible to allow pipes to be maintained and washed down following flooding.

- Water supply
  Water pipework insulation can be replaced with flood resistant closed cell material below the expected flooding level.

- Telephone and cable services
  Suppliers of the relevant services should be consulted on suitable installation methods in areas liable to flooding. Where possible, incoming telephone lines and internal control boxes should be raised above the expected flood levels.

- Oil storage tanks
  Oil tanks can be damaged during floods and can cause pollution. To avoid this it should be ensured that the tank is anchored down so that it does not float. In addition the oil feed from the tank should incorporate a stop valve at the end nearest the tank so that the tank contents will not be lost if the tank moves and the pipe breaks.

The information above is a summary of the CIRIA Advice Sheets. All the advice sheets, and further guidance for homeowners and developers, can be downloaded from http://www.ciria.org/flooding/advice_sheets.html

In addition, the recently released *Improving the Flood Performance of New Buildings: Flood Resilient Construction,* May 2007, Department for Communities and Local Government provides additional useful information, particularly for properties in low or residual flood risk areas. This can be found at http://www.floodforum.org.uk/improvingfloodresilienceofnewbuildings.pdf

Appendix B

A1 maps showing results of fluvial modelling

List of A1 Maps
B1 – 2010 Fluvial Depth Map
B2 – 2010 Fluvial Hazard Map
B3 – 2126 Fluvial Depth with Sea Level Rise
B4 – 2126 Fluvial Hazard with Sea Level Rise

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Appendix C

A1 maps showing results of tidal modelling

List of A1 Maps
C1 – 2010 – 200year, Depth
C1 – 2010 – 200year, Hazard
C1 – 2010 – 200year, Velocity
C2 – 2086 – 200year, Depth
C2 – 2086 – 200year, Hazard
C2 – 2086 – 200year, Velocity
C3 – 2126 – 200year, Depth
C3 – 2126 – 200year, Hazard
C3 – 2126 – 200year, Velocity
C4 – 2010 – 25year, Depth
C4 – 2010 – 25year, Hazard
C4 – 2010 – 25year, Velocity
C5 – 2086 – 25year, Depth
C5 – 2086 – 25year, Hazard
C5 – 2086 – 25year, Velocity
C6 – 2126 – 25year, Depth
C6 – 2126 – 25year, Hazard
C6 – 2126 – 25year, Velocity

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Appendix D

A1 maps showing results of breach analysis

List of A1 Maps
Breach 1, 200 year - Depth Hazard
Breach 2, 200 year - Depth Hazard

Appendix E

Areas Susceptible to Surface Water Flooding map

<u>List of A1 Maps</u>
Surface water map

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See accompanying A1 map for Weston Areas Susceptible to Surface Water Flooding (ASSWF) Map

ASSWF Guidance

Because of the way they have been produced and the fact that they are indicative, the maps are **not appropriate to act as the sole evidence for any specific planning decision at any scale without further supporting studies or evidence**. Their use in planning will be to highlight areas where more detailed study of surface water flooding may be appropriate as part of a strategic flood risk assessments (SFRA) in England.

The map provides three bandings from ‘less’ to ‘more’ susceptible to surface water flooding. The ‘more’ band will be useful to help identify areas which have a natural vulnerability to:

Flood first;
Flood deepest;
And/or flood for relatively frequent, less extreme events (when compared to the other bands).

LPAs should use local data to assess the bands and then decide which bands are most appropriate for their purposes, noting that surface water flooding can occur outside of the bands.

The map can also be used to help prioritise areas requiring more detailed analysis of surface water flooding.

Note that the susceptibility bandings have been applied nationally. Even if a LPA has no ‘more’ susceptible areas with the national bandings applied, it does not mean that some parts of that LPA area will not be ‘more susceptible’ than others if a local assessment of relative susceptibility were applied.

It should also be noted that the map is **not suitable for identifying individual properties** susceptible to surface water flooding.

For further guidance on the use of the maps refer to the Environment Agency document ‘Areas Susceptible to Surface Water Flooding: Guidance for English LPAs for land use planning and other purposes (not emergency planning)’. V1 July 2009.

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Appendix F

Outline Process delivering WSM Flood Risk Management Infrastructure

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Level 2 SFRA – Outline Process delivering WSM Flood Risk management Infrastructure.

Draft Process for Super Pond.

For the urban extension in the Uphill catchment the process set out below is applicable to the preferred option and any alternative technical strategic solution.

1. North Somerset Council (NSC) to approve/adopt the final "*Weston Super Mare Flood Management Study Phase 2 Options Report*" Dated March 2007. The above strategy sets out the preferred strategic flood risk solution for both the Uphill and Banwell catchments.

2. Royal Haskoning (RH) to take the preliminary design further forward into outline design, which will need to include costs.

3. NSC to secure the land informed by the above works.

4. NSC to obtain planning permission for the works.

5. Further to point 2 NSC to formalise a SPD tariff for delivering the strategic solution.

6. NSC to articulate in Core Strategy as a policy supported by Level 2 SFRA and Infrastructure Plan.

Note: The EA will object in principle to any future planning allocation/application not supported by credible technical evidence on the strategic drainage and flood risk solution within the Weston urban Extension in accordance with PPS12 and PPS25.

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