Southern Staffordshire Surface Water Management Plan Phase 2

Lichfield City

Stafford Borough, Lichfield District, Tamworth Borough, South Staffordshire District, Cannock Chase District and Staffordshire County Councils
January 2011

Final Report

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ROYAL HASKONING

Lichfield district council

Staffordshire County Council

raa
Richard Allitt Associates Ltd
CONSULTING ENGINEERS

A COMPANY OF

ROYAL HASKONING

HASKONING UK LTD.
COASTAL & RIVERS

5th Floor, Radcliffe House
Blenheim Court
Solihull B91 2AA
United Kingdom
+44 (0)121 709 6520 Telephone
Fax
info@solihull.royalhaskoning.com E-mail
www.royalhaskoning.com Internet

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Drafted by	R Ranger	
Checked by	D Worth	
Date/initials check	14/1/2011	D Worth.
Approved by	M Stringer	
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GLOSSARY

Annual Exceedence Probability (AEP)	The probability associated with a *return period* (T). An event of return period 50 years has an AEP of 1/T, 0.02 or 2%.
Antecedent Conditions	The pre-existing condition before a rain event (e.g. waterlogged soil)
Brownfield site	Any land or site that has been previously developed.
Catchment	The area contributing flow or *runoff* to a particular point on a watercourse.
Climate change	Long-term variations in global temperature and weather patterns both natural and as a result of human activity, primarily greenhouse gas emissions.
Culvert	Covered channel or pipe that forms a *watercourse* below ground level, or through a raised embankment.
Defra	UK Government department responsible for policy and regulations on the environment, food and rural affairs.
Development	The carrying out of building, engineering, mining or other operations in, on, over or under land or the making of any material change in the use of any buildings or other land.
Enmained	Watercourse designated as a *Main River*
Environment Agency	Government Agency charged with the protection of the environment.
Flood probability	The estimated likelihood of a flood of a given magnitude occurring or being exceeded in any specified time period.
Flood risk	An expression of the combination of the *flood probability* and the magnitude of the potential consequences of the *flood event*.
Flood risk assessment	A study to assess the risk of a site or area flooding, and to assess the impact that any changes or development in the site or area will have on *flood risk*.
Flood Zones	Flood Zones are defined in Table D.1 of Planning Policy Statement (PPS) 25: Development and Flood Risk. They indicate land at risk by referring to the probability of flooding from river and sea, ignoring the presence of defences.

Fluvial Water	Water contained or flowing within a river or stream.
Greenfield	Previously undeveloped land.
InfoWorks	Modelling software used to simulate surface water and drainage networks in 2D.
LiDAR	Data set that provides a 3D image of the surface of the earth.
Local Planning Authority	Body responsible for planning and controlling development, through the planning system.
Main River	A watercourse designated on a statutory map of Main rivers, maintained by the Environment Agency.
Mitigation measure	A generic term used in this guide to refer to an element of *development* design which may be used to manage some *risk* to the *development*, or to avoid an increase in *risk* elsewhere.
Ordinary watercourse	A watercourse which is not a private drain and is not designated a *Main river*.
Outfall Height	Level at which a sewer or drain discharges into a watercourse.
Overland Flow	Water flowing over the surface of the land, originating from direct rainfall runoff or other drainage networks (e.g. watercourses or underground drainage) that have exceeded their capacity).
Return Period	The return period of a flood (T) is a measure of its rarity, defined as the average interval in years between occurrence of floods that exceed it.
Risk	The probability of an event occurring multiplied by the consequence of such an event.
Runoff	Water flow over the ground surface to the drainage system.
Surface Water	Water collected or flowing over the ground not contained within a watercourse. Usually results from heavy rainfall.
Sustainable Drainage Systems (SUDS)	A sequence of management practices and control structures, often referred to as SUDS, designed to drain surface water in a more sustainable manner. Typically, these techniques are used to attenuate rates of runoff from potential development sites.
Watercourse	Any natural or artificial channel that conveys surface water.

Water Cycle Strategy (WCS)	Provides a plan and programme of Water Services Infrastructure implementation. It is determined through an assessment of the environment and infrastructure capacity for: water supply; sewage disposal; flood risk management; and surface water drainage.
Watershed	Line depicting the area within which all surface water will drain into an area of interest, such as a town or village. For the assessment of surface water this boundary is defined from the topography.

ABBREVIATIONS

AAD	Average Annual Damages
AEP	Annual Exceedence Probability
AStSWF	Areas Susceptible to Surface Water Flooding
CSO	Combined Sewer Overflow
Defra	Department for Environment Flood and Rural Affairs
FEH	Flood Estimation Handbook
FMfSWF	Flood Map for Surface Water Flooding
GIS	Geographical Information System
LiDAR	Light Detecting and Ranging
MCM	Multi Coloured Manual
NPD	National Property Dataset
NVZ	Nitrate Vulnerable Zone
STWL	Severn Trent Water Limited
SUDS	Sustainable Drainage Systems
SWMP	Surface Water Management Plan
WCS	Water Cycle Study
WFD	Water Framework Directive

EXECUTIVE SUMMARY

Introduction

In November 2009 Royal Haskoning was appointed by Stafford Borough, Lichfield District, Tamworth Borough, Cannock Chase District and South Staffordshire District Councils to produce a Phase 1 and Phase 2 Surface Water Management Plan (SWMP) and a Phase 1 and Phase 2: Scoping and Outline Water Cycle Study (WCS). This report relates to the production of the Phase 2 SWMP for Lichfield District, relating specifically to Lichfield City. It has been written with reference to Defra's latest SWMP guidance. The Phase 2 SWMP covers all the required elements of an Intermediate study and many of the elements of a Detailed study.

Modelling

An integrated model has been constructed for Lichfield City using the latest Infoworks ICM (Integrated Catchment Modelling) software, covering the area contained within the watershed of the city. It has been constructed to include overland flow, fluvial flows affected by surface water and the underground drainage network (i.e. sewers), producing outputs of flood extent, depth and velocity for a variety of annual probabilities of flooding, including three climate change scenarios. This model is considered the best available tool to define surface water flooding, given the current data limitations (please see Section 3.2.6 for more information).

Verification of the modelling outputs has been undertaken using the historic flooding information identified as part of the Phase 1 SWMP and through comparison with the Environment Agency's Areas Susceptible to Surface Water Flooding (AStSWF). Both forms of verification have provided a good match with the Lichfield City model outputs.

Quantification of Flood Risk

Average Annual Damages (AAD) have been calculated for both the current and future flood risk scenarios, using basic available information, accounting for damages to property, stress related impacts and emergency costs. Key potential sources of pollution damage to the environment have been identified as direct runoff into watercourses (from both rural and urban areas), surface water sewer outfalls and Combined Sewer Overflow (CSO) spills. These have not been quantified within this assessment. Potential impacts of surface water flooding on critical infrastructure have also been identified.

Outputs

In addition to the model, mapping has been provided to the Steering Group in the form of Interactive PDFs to show:

- ✓ the extent of the modelled flooding for each return period (including the climate change scenarios);
- ✓ the predicted depth of flooding;
- ✓ the associated hazard; and
- ✓ the historical flood locations (from Phase 1).

The following key surface water flooding issues and hotspots within Lichfield City have been identified, alongside key mitigation strategies and partnership actions:

Key Surface Water Flooding Issues for Lichfield City

1. Flooding across the city originates, and is exacerbated, through a combination of overland flow and a lack of drainage capacity (from both sewers and watercourses);
2. Flooding in the urban area is closely linked to overland flow originating from rural runoff (most notably to the west and south of the City);
3. Flooding initiates during the 1 in 2 year flood event;
4. In current situation, the 5 year flood event generates the greatest average annual damages;
5. The total AAD for the current situation is approximately £13.9m, including an allowance for stress and emergency costs;
6. The total AAD for future flood scenarios (based on three flood probabilities) is approximately £45m, indicating that climate change poses a significant increase to surface water flood risk in the City;
7. Surface water flood depths are generally low in all return periods, although increase to a maximum of 2m (0.79m at residential property boundaries) in the 1 in 200 year flood event;
8. Flood hazard within Lichfield City is limited, although some low lying areas (including roads around critical infrastructure locations) are classified as 'Moderate' hazard and some areas of open space are classified as having 'significant' hazard in the lower probability flood events;
9. Risk of pollution is closely linked to surface water flood risk and should be reduced to assist in meeting the Water Framework Directive (WFD) targets downstream (details of sources of pollution are provided in **Table 3.3**);
10. Critical infrastructure is at risk of surface water flooding, affecting boarding schools, care homes, ambulance stations, police stations, power stations, railway stations, schools and waste management sites;

Key Mitigation Strategies for Lichfield City

1. Regular monitoring, clearance and maintenance of key drainage routes, including highways drains and culverts;
2. Maintenance of Leamonsley Brook to enable efficient surface water flow through the City centre;
3. Investigation of the potential to alter land management practices to reduce/slow surface water runoff from the surrounding countryside;
4. Investigation of the potential to reinstate and utilise the Lichfield canal to accommodate surface water runoff;
5. Installation of Sustainable Drainage Systems (SUDS) in all new developments, with the aim to reduce runoff below Greenfield rate in the key drainage areas to the south and west of the City (please see Section 4.3 of the Southern Staffordshire WCS for further information regarding individual SUDS techniques);
6. Retrofitting of SUDS in existing developments, where feasible;
7. Investigation of potential to install storage ponds to accommodate surface water runoff at the City boundaries and upstream of flow constrictions, perhaps through dual use of parkland/ playing fields;
8. Preparation of emergency plans to accommodate road closures and the evacuation of vulnerable populations from hazardous areas;
9. Maintenance of sewer network to allow effective CSO operation and reduce backing up of network below the design capacity (1 in 30 year flood event);
10. Promotion of Codes of Good Agricultural Practice and recognition of Nitrate Vulnerable Zone (NVZ) status to reduce pollution from direct runoff in rural areas;
11. Partnership working between the following organisations to implement the most beneficial and cost effective solutions: Lichfield District Council; Staffordshire County Council; Highways Agency; Environment Agency; Severn Trent Water; Farmers and Landowners; Developers; Civil Contingencies Unit; Lichfield and Hatherton Canal Trust (specific actions are listed in **Table 5.1**).

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1 INTRODUCTION

1.1 General Overview

In November 2009 Royal Haskoning was appointed by Stafford Borough, Lichfield District, Tamworth Borough, Cannock Chase District and South Staffordshire District Councils to produce a Phase 1 and Phase 2 Surface Water Management Plan (SWMP) and a Phase 1 and Phase 2: Scoping and Outline Water Cycle Study (WCS).

The WCS and Phase 1 SWMP reports were published in July 2010 and each covered all five Local Authority Boroughs/Districts. This report relates to the production of the Phase 2 SWMP for Lichfield District, relating specifically to Lichfield City. It has been written with reference to Defra's latest SWMP guidance[1].

1.2 Study Area

The Phase 1 SWMP covered the study area enclosed by the administrative boundaries of Stafford Borough, Lichfield District, Tamworth Borough, South Staffordshire District and Cannock Chase District, as outlined in red in **Figure 1.1** on the following page. The Phase 2 SWMP has focussed upon one settlement within each of the Local Authority boundaries: Lichfield City; Stafford town; Cannock town; Tamworth town; and Penkridge village. These locations have been selected from the Phase 1 SWMP using the following criteria:

1. High incidence of historical surface water flooding;
2. High number of houses located within the Environment Agency's First Edition Surface Water Flood Map 'less than' flood zone; and
3. A potential for future growth.

To provide a comprehensive assessment of surface water flooding within these settlements, the study area of each SWMP extends beyond the residential boundary to cover the geographical area, defined by topography, in which all surface water runoff flows towards the settlement (the watershed). The outlines study areas are outlined in green on **Figure 1.1** and a separate Phase 2 SWMP report has been produced for each watershed.

1.3 Scope of the SWMP

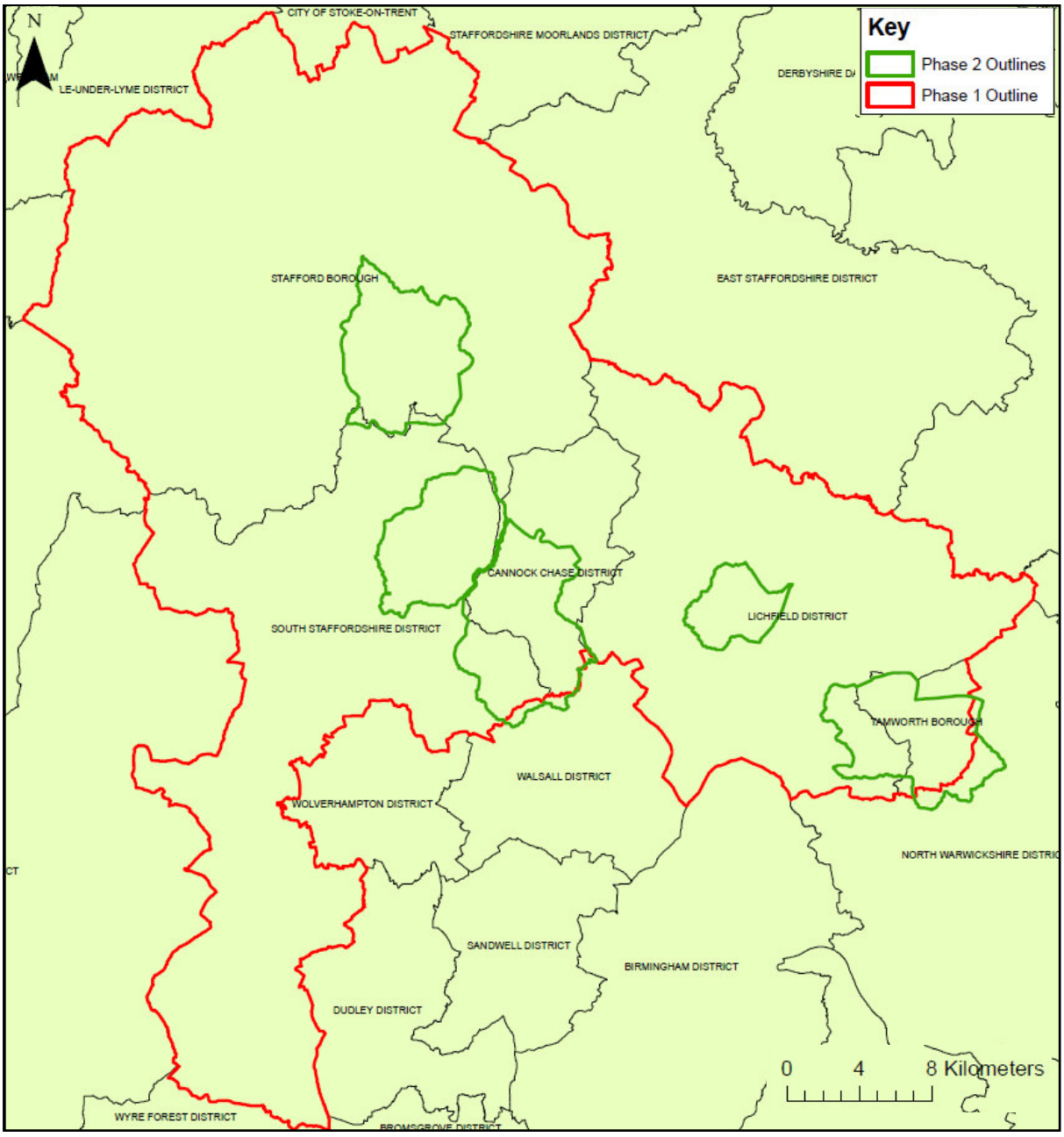
Defra's SWMP guidance states there are four main stages and a number of sub stages to producing a SWMP, interlinked into a linear process that extends from the identification of a problem through to the implementation of actions to resolve the situation. This study was commissioned, and the Phase 1 SWMP completed, to the specifications of the draft SWMP guidance[2] (dated February 2009). However, the guidance was updated in March 2010 and the four stages, and their associated sub stages, have been adjusted between the two versions. To assist the Councils with the progression of this SWMP at a later date (i.e. through Phases 3 and 4, if required), this

[1] Surface Water Management Plan Technical Guidance, Defra, March 2010

[2] Surface Water Management Plan Technical Guidance, Living Draft Version 1, Defra, 2009

Phase 2 report has been written with reference to the latest, 2010, guidance. The stages specified within this guidance are shown in **Figure 2.1**.

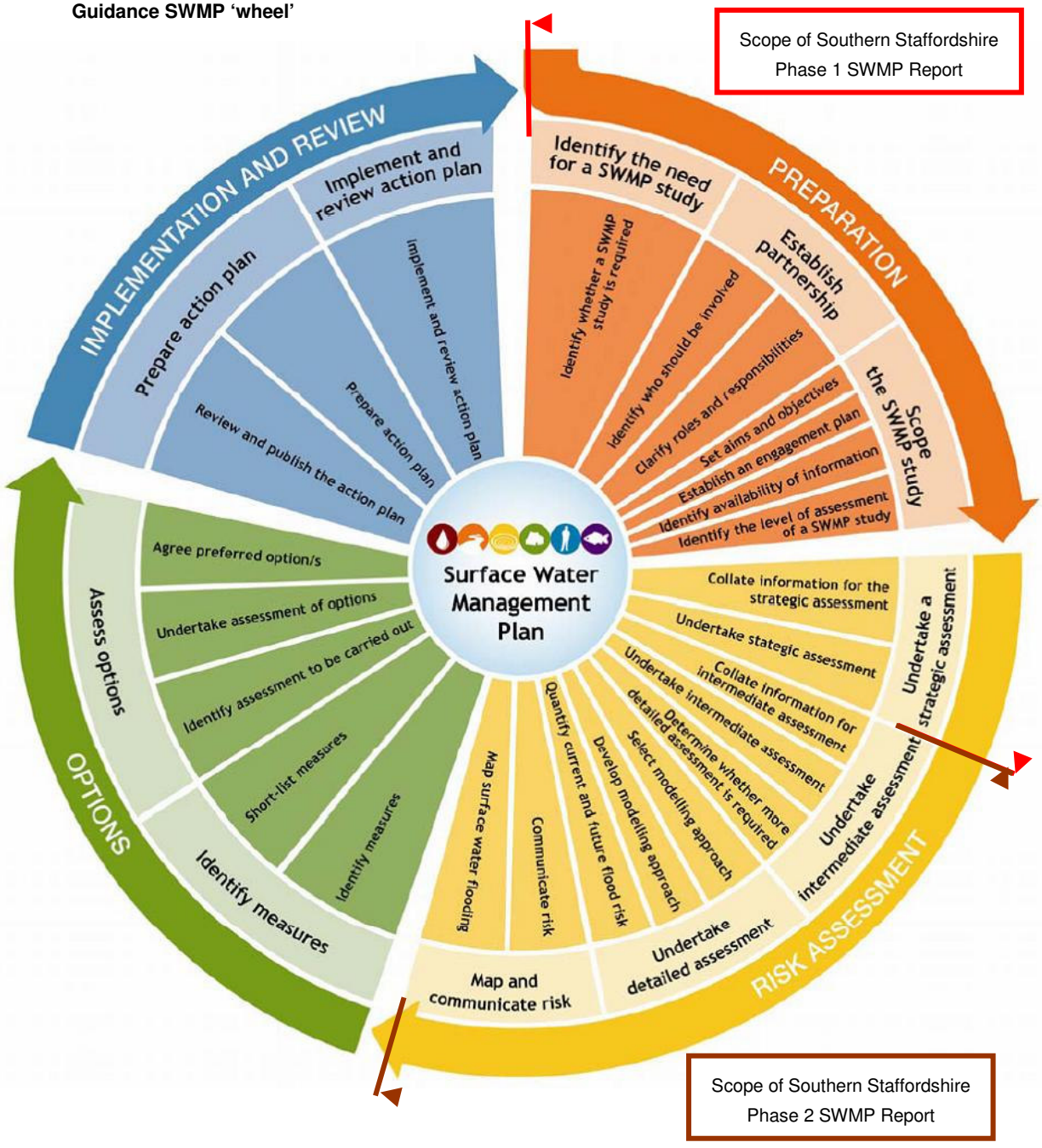
Figure 1.1 - SWMP Study Area - Phase 1 and Phase 2



2 OUTPUTS FROM PHASE 1

The adjustments to the Defra 'wheel' between the draft and latest guidance have resulted in a degree of overlap between the scope of the completed Phase 1 SWMP report and the current requirements of a Phase 2 SWMP. To provide clarification, a comparison of the latest SWMP 'wheel' with the scope of the Southern Staffordshire Phase 1 and Phase 2 studies is illustrated in **Figure 2.1** below. The remainder of this section reviews the stages covered within the Phase 1 SWMP report.

Figure 2.1 - Scope of Southern Staffordshire Phase 1 and Phase 2 SWMPs Overlaid onto Defra's Final Guidance SWMP 'wheel'



2.1 Preparation

All the requirements of the Preparation stage of the latest Defra 'wheel' were covered in the Southern Staffordshire Phase 1 SWMP, namely:

- ✓ Identification of the need for a SWMP;
- ✓ Identification of partners to be involved;
- ✓ Clarification of partner roles and responsibilities;
- ✓ Determination of aims and objectives;
- ✓ Establishment of an engagement plan;
- ✓ Identification of information availability; and
- ✓ Identification of the level of assessment required.

2.2 Strategic Assessment

Phase 1 of the draft Defra SWMP guidance specified a requirement for collating, analysing and mapping surface water flooding information. Within the latest guidance, this requirement is included within Phase 2 and referred to as the 'strategic assessment'.

The outputs from the Southern Staffordshire Phase 1 SWMP included maps of the entire study area (all five Districts/Boroughs) showing locations and frequency of historic surface water flooding events, the risk of future surface water flooding (based upon the Environment Agency's AStSWF) and the locations of potential future development. From this information the Phase 1 report concluded that the following settlements were 'hotspots' for historic and, potentially future, surface water flooding and, as such required further investigation within a Phase 2 SWMP:

- ✓ Stafford town;
- ✓ Lichfield City;
- ✓ Cannock Chase town;
- ✓ Tamworth town; and
- ✓ Penkridge village.

Based upon the available information it was determined that an integrated model was the most suitable assessment method, with a separate model constructed for each of the five watersheds. As surface water flooding is not connected between these five areas, a separate model and Phase 2 SWMP report has been produced for each watershed. **This report relates to the Lichfield City watershed only.**

3 PHASE 2 SWMP: RISK ASSESSMENT

3.1 Level of Assessment

As noted, this assessment was not commissioned under the latest Defra SWMP guidance. However, it has been determined that the level of this Phase 2 SWMP covers all the required elements of an Intermediate study and many of the elements of a Detailed study. Checklists identifying which elements are included within this report are shown in **Appendix A**.

3.2 Modelling

An integrated model has been constructed for Lichfield City by our specialist sub consultant, Richard Allitt Associates, using the latest Infoworks ICM (Integrated Catchment Modelling) software. The model covers the area contained within the watershed of the city, as shown in **Figure 3.1** (**Appendix B**). The model has been constructed to include overland flow, fluvial flows affected by surface water and the underground drainage network (i.e. sewers), producing outputs of flood extent, depth and velocity for a variety of annual probabilities of flooding.

3.2.1 Overland Flow

The surface topography has been represented in the Infoworks model as a triangular mesh, varying in grid size to reflect the required level of detail of the land surface. In the open countryside the mesh is large to reduce model run-time, whereas in the centre of the city the mesh is much smaller to represent the roads and drainage pathways between buildings.

LiDAR has been procured for the entire watershed at a resolution of 1m, enabling detailed representation of the topography, including road networks, railway embankments, bridges and underpasses. Within the urban area the Council's Mastermap data has been used to depict the footprint of buildings. These footprints have been artificially raised in height to force the surface water to flow around the structures. Where information was available, openings through embankments, such as culverts, have also been included.

Overland flow is simulated in the model by applying rainfall outputs, which are then routed across the mesh, flowing down slope, along drainage routes and collecting in depressions.

3.2.2 Fluvial Flows

The Main Rivers and larger ordinary watercourses have been defined within the model as routes of surface water flow. As none of the watercourses within Lichfield City are classified as Main River, no Environment Agency models were available for inclusion within this model. Instead, the watercourses were defined through the extraction of cross sections from the LiDAR. However, as LiDAR does not penetrate water, the bed level of the watercourse channels is not accurately represented using this technique, requiring manual modification. As such, the model would be improved through the inclusion of channel survey data, if undertaken in the future.

The watercourses receive outfalls from the sewer network, in addition to surface water runoff entering along the length of their banks. Where flows exceed the capacity of the watercourse, the water overtops the banks and is routed back into the surface mesh.

A baseflow provision for the fluvial watercourses has been included, but a detailed assessment of fluvial flows, included tributary inflows, water levels and downstream boundaries was not included. The resulting flooding modelled along these watercourses is therefore purely related to surface water flooding and not fluvial flooding, which may occur in parallel, resulting in a much larger flood extent.

3.2.3 Underground Drainage

Severn Trent Water Limited (STWL) acts as the sewerage undertaker for Lichfield City. They periodically assess the capacity and simulate the operation of their network. Their latest model was incorporated into this integrated surface water model, representing foul, combined and some surface water sewers. The model enables surface water flows to flow in to and out of the sewerage network. Flows enter the network where the model predicts there is capacity and leave the underground network at outfall locations (into the watercourses), combined sewer overflows (CSOs) and manholes (details of both the location and invert levels of such structures were included in the model).

STWL's model was produced for use within their Drainage Area Planning and, as such was only intended to be used for strategic planning purposes. The models used within this SWMP have not been subject to detailed local verification and, in some locations, have not been verified at all by STWL. As a result, the degree of verification and model confidence varies both within and between the different models used within this SWMP. STWL therefore cannot guarantee the accuracy and correction of the models provided and this may affect the confidence of the model outputs, including flood depths and velocities.

Where known surface water sewers were omitted from STWL's model, they were manually added to this combined model. These sewers have not, however, been verified by STWL.

For urban areas not served by the sewerage network, or where the location of the sewer network was unknown, the rainfall runoff was routed over the surface. To offer the most conservative scenario, existing SuDS schemes located within new developments were not included. Highway and private drains have also not been included.

3.2.4 Rainfall

A volume of rainfall has been assigned across the watershed using the FEH rainfall runoff volume method and the model run for the critical storm duration[3]. For Lichfield City the critical storm duration was defined as the 60minute event and this was applied to all annual probabilities of flooding.

[3] The length of storm that results in the highest peak flow of surface water runoff

To provide a representation of infiltration, the rainfall was factored down to give 17%[4] runoff in rural areas. In urban areas it was maintained as 100% runoff. A value of 10mm of antecedent rainfall was applied over all surfaces in the model to fill surface depressions and storage areas.

The climate change scenarios were simulated by increasing the current rainfall intensity by 30%, as per current Defra guidance[5]. This represents the predicted scenario 75 - 105 years in the future (2085 - 2115).

3.2.5 Model Verification

Verification of the modelling outputs has been undertaken using the historic flooding locations identified as part of the Phase 1 SWMP and through comparison with the Environment Agency's AStSWF. No formal verification was undertaken of the rainfall events.

Both forms of verification have provided a good match with the Lichfield model outputs. The results follow similar flow paths as the Environment Agency's maps, but offer significant refinement of the routes and reduction of flooded area. All the historic flooding points correlate with the modelled flood outlines.

3.2.6 Model Assumptions and Limitations

The model has been constructed using the best available information, including:

- ✓ LiDAR (flown in 2010);
- ✓ Mastermap;
- ✓ STWL Sewer model;
- ✓ STWL manhole locations and invert levels;
- ✓ River Centrelines;
- ✓ FEH rainfall;
- ✓ Culvert size and location information from Lichfield District and Staffordshire County Councils; and
- ✓ Proposed development site locations

The model, as it stands at present, is considered fit for purpose. However, due to data, budget and time restrictions there are some limitations to the outputs, which must be appreciated when interpreting the model results. These are summarised in the information box below and could be modified in any future adjustments to the model.

[4] This figure has been calculated as a benchmark through previous SWMP studies.

[5] See SWMP guidance (March 2010): pp37 and PPS25 (March 2010): pp16

Model Limitations / Assumptions

1. Flow routes through buildings have not been included, with buildings represented as solid objects;
2. Individual property sewer connections have not been included;
3. Road and pavement curbs have not been included;
4. Garden walls, fences and gates have not been included;
5. As channel survey and models were not available, watercourses have been represented using LiDAR and a degree of manual interpretation for channel depths;
6. Fluvial flow has not been fully represented;
7. Surface water sewers omitted from STWL's model have been manually added and, as a result, have not been verified by STWL;
8. Rainfall inputs have not been verified;
9. Model verification is limited by the data collected in Phase 1; and
10. A number of assumptions have been made regarding culvert sizes, river reaches, trash screens and weirs[6].

3.3 Model Runs

The model has been run for the following annual probabilities of surface water flooding:

- 50% *(there is a 1 in 2 chance of flooding in any given year)*;
- 20% *(there is a 1 in 5 chance of flooding in any given year);*
- 10% *(there is a 1 in 10 chance of flooding in any given year);*
- 5% *(there is a 1 in 20 chance of flooding in any given year);*
- 4% *(there is a 1 in 25 chance of flooding in any given year);*
- 3.33% *(there is a 1 in 30 chance of flooding in any given year);*
- 2% *(there is a 1 in 50 in chance of flooding in any given year);*
- 1.33% *(there is a 1 in 75 chance of flooding in any given year);*
- 1% *(there is a 1 in 100 chance of flooding in any given year);*
- 0.5% *(there is a 1 in 200 chance of flooding in any given year);*

In addition, the following climate change scenarios have been simulated (by increasing the current associated rainfall intensity by 30%):

- 5% + CC *(projected to the year 2100, there is a 1 in 20 chance of flooding in any given year);*
- 2% + CC *(projected to the year 2100, there is a 1 in 50 in chance of flooding in any given year); and*
- 1% + CC *(projected to the year 2100, there is a 1 in 100 chance of flooding in any given year).*

The outputs from these simulations have included flood extent, depth and velocities and have been used to inform the quantification of current and future surface water flood risk, outlined below.

[6] Shapefiles and associated databases of all assumptions within the modelling have been included with the GIS deliverables.

3.4 Quantifying Current Risk

The process included within the Defra guidance for quantifying current flood risk has been followed to identify the Average Annual Damages (AAD) due to surface water flooding. The guidance recommends the consideration of the damages to property, people, the environment and critical infrastructure/services. As depth information was provided from the model simulations, a depth-damage relationship was applied, utilising the depth-damage curves and estimates included within the 'Multi-Coloured Manual'[7]. Limitations to this approach are summarised in the following box.

Limits of Depth-Damage Calculations

Although considered to be the approach which provides the best representation of damage to properties, depth-damage curves are known to be highly sensitive to low depth predictions, introducing uncertainty to the results. Almost all the flood depths simulated within Lichfield City are considered 'low depth' (<0.4m) and should therefore be viewed with caution.

In addition, the calculation of damages is limited to the property/infrastructure information readily available at the time of analysis. This assessment has utilised the National Property Dataset and Critical Infrastructure information provided by the Environment Agency. This information has not been verified through site visits or surveys. It must also be noted that, as threshold surveys were not available for use, the calculations assume all property thresholds to be at ground level. As such they provide a very conservative estimate of total damages.

As a result of the limitations mentioned here, the damage calculations included in this report should not be considered prescriptive, but used as a rough comparative guide. More detailed depth-damage calculations are recommended as part of a cost-benefit assessment when considering particular mitigation options within Phase 3 of the SWMP (if progressed). For more information regarding the calculation of damages using depth-damage curves, please refer to the Defra SWMP and MCM guidance.

3.4.1 Damages to Property

To calculate the damages to properties, the depth of flooding was extracted from the model results at the property boundary (where a variety of depths were measured around the property, the deepest was selected for this calculation). The National Property Dataset (NPD) was used as the basis for locating affected properties and determining their use (i.e. residential or commercial). As no threshold data was available for use in this study, all thresholds were assumed to be at ground level, although the model results do not include depth simulations below 10mm.

Damage to residential properties was calculated using the MCM depth-damage tables, accounting for depth of flooding and property type (e.g. detached, semi-detached, terraced etc). The inclusion of social class and a social weighting (as discussed in the Defra guidance) was considered too detailed for this city-wide assessment. Damage to commercial properties was included through identification of use and floor area from the NPD (e.g. office, warehouse, retail etc) and comparison with the appropriate MCM depth-damage tables. All flood events were assumed to be less than 12 hours in duration.

[7] 'The Benefits of Flood and Coastal Risk Management: A Manual of Assessment Techniques', Flood Hazard Research Centre (FHRC), Defra, Environment Agency (2005) - *the 'Multi-Coloured Manual' (MCM).*

The number of properties, types of commercial property and vulnerable population affected by each flood event are summarised in **Tables 3.1** and **3.2** below.

Table 3.1 - Property Numbers within Each Flood Extent

Flood Event (1 in…)	Residential			Commercial	
	Number of Properties	Population (Number of People)[1]	Water Depths (m)	Number of Properties	Water Depths (m)
2	111	233	0.01 - 0.2	7	0.02 - 0.6
5	429	901	0.01 - 0.31	34	0.01 - 0.67
10	777	1,632	0.01 - 0.4	75	0.01 - 0.7
20	1,242	2,608	0.01 - 0.44	139	0.01 - 0.73
25	2,655	5,576	0.01 - 0.47	268	0.01 - 0.77
30	2,655	5,576	0.01 - 0.47	268	0.01 - 0.77
50	2,830	5,943	0.01 - 0.49	279	0.01 - 0.78
75	3,864	8,114	0.01 - 0.67	330	0.01 - 0.88
100	3,866	8,119	0.01 - 0.74	330	0.01 - 0.88
200	4,768	10,013	0.01 - 0.79	380	0.01 - 0.98
20CC[2]	2,655	5,576	0.01 - 0.47	268	0.01 - 0.77
50CC	2,864	6,014	0.01 - 0.67	330	0.01 - 0.88
100CC	4,767	10,011	0.01 - 0.79	380	0.01 - 0.98

[1] Number of properties multiplied by 2.1 [2] CC represents Climate Change scenario

Table 3.2 - Types of Commercial Property and Vulnerable Populations within Each Flood Extent

Commercial Building* (Red indicates Vulnerable Populations/ Critical Infrastructure)	Flood Event Probability (1 in …)												
											Climate Change		
	2	5	10	20	25	30	50	75	100	200	20	50	100
AMBULANCE STATION										✓			✓
ART GALLERY								✓	✓	✓	✓	✓	✓
BANK			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
BAR			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
BETTING OFFICE										✓			✓
BUILDING SOCIETY										✓			✓
CAFÉ				✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
CAR DEALER		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
CARAVANNING					✓	✓	✓	✓	✓	✓	✓	✓	✓
CATHEDRAL		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
CEMETERY	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
GOVERNMENT OFFICE		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
CHEMIST					✓	✓	✓	✓	✓	✓	✓	✓	✓
CHURCH			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
CLINIC					✓	✓	✓	✓	✓	✓	✓	✓	✓
COMMUNITY CENTRE			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
DAIRY			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
DENTAL SURGERY					✓	✓	✓	✓	✓	✓	✓	✓	✓
DEPOT								✓	✓	✓		✓	✓
ESTATE AGENCY								✓	✓	✓		✓	✓

Commercial Building* (Red indicates Vulnerable Populations/ Critical Infrastructure)	**Flood Event Probability (1 in …)**												
											Climate Change		
	2	**5**	**10**	**20**	**25**	**30**	**50**	**75**	**100**	**200**	**20**	**50**	**100**
FACTORY		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
FILLING STATION					✓	✓	✓	✓	✓	✓	✓	✓	✓
FINANCIAL SERVICES					✓	✓	✓	✓	✓	✓	✓	✓	✓
FIRE STATION										✓			✓
COLLEGE								✓	✓	✓		✓	✓
GARAGE			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
GARDEN CENTRE				✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
GENERAL COMMERCIAL	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
HAIRDRESSER			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
HALL		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
HEALTH CENTRE					✓	✓	✓	✓	✓	✓	✓	✓	✓
HIGH SCHOOL			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
HOTEL					✓	✓	✓	✓	✓	✓	✓	✓	✓
INN				✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
LEISURE CENTRE	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
LOCAL GOVERNMENT OFFICE	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
MUSEUM				✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
NURSING HOME				✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
OFFICE			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
POLICE SERVICES					✓	✓	✓	✓	✓	✓	✓	✓	✓
POST OFFICE			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
PRE SCHOOL			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
PRIMARY SCHOOL		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
PUBLIC HOUSE		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
REPAIR CENTRE					✓	✓	✓	✓	✓	✓	✓	✓	✓
RESTAURANT				✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
RETAIL WAREHOUSE					✓	✓	✓	✓	✓	✓	✓	✓	✓
SANDWICH BAR				✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
SCHOOL	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
SCOUTS MEETING PLACE										✓			✓
SHOPPING		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
SOCIAL CLUB					✓	✓	✓	✓	✓	✓	✓	✓	✓
SPECIAL SCHOOL		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
STEEL WORKS										✓			✓
SUPERMARKET					✓	✓	✓	✓	✓	✓	✓	✓	✓
SURGERY										✓			✓
TAKE AWAY					✓	✓	✓	✓	✓	✓	✓	✓	✓
TELECOMMUNICATIONS					✓	✓	✓	✓	✓	✓	✓	✓	✓
THEATRE											✓		✓
TRAVEL AGENCY				✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
TYRE DEPOT								✓	✓	✓	✓	✓	✓
UNDERTAKERS					✓	✓	✓	✓	✓	✓	✓	✓	✓
WORKS		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

3.4.2 Damages to People

The impacts of flooding on householders include stress, health effects and the loss of possessions. The Defra guidance recommends the consideration of the following two components when considering damages to health:

1. Stress-related impacts - As per the MCM, an allowance of £200 for flooding per year per household has been included in the AAD calculations to account for stress related impacts.

2. Loss of life and injury - As water velocities and depths are generally fairly low across Lichfield City it was not considered necessary to include an allowance in the damage calculations for loss of life or injury.

To provide a broad estimate of the number of people potentially affected by each model simulation, an average household size of 2.1 people has been applied and included within **Table 3.1** above.

3.4.3 Damages to the Environment

Surface water runoff from the urban environment can have a significant impact on receiving water quality, especially where the flood waters interact with the sewer network.

The ordinary watercourses within Lichfield City have not been reviewed within the River Basin Management Plan (RBMP). However, as stated in the Water Cycle Study, the River Trent, downstream of Lichfield City, has been identified as having a 'poor' ecological status. In addition, it has been assigned protected status under the Freshwater Fish, Nitrates and Urban Wastewater Treatment Directives (see the associated Southern Staffordshire WCS[8] for further information). As a result, significant improvement is necessary to meet the required 'good' ecological status required under the Water Framework Directive (WFD) by 2015 and a reduction in pollution entering the watercourse from its tributaries will be essential.

Table 3.3 summarises the main sources of pollution likely to affect watercourses as a result of surface water flooding within Lichfield City and suggestions for mitigating this risk.

If a detailed cost-benefit assessment is undertaken during any future SWMP stages, damages to environmental assets resulting from the surface water flooding will require quantification within the damage calculations. They have not been included within the high level AAD calculations within this report.

[8] Southern Staffordshire Outline Water Cycle Study Final Report, Royal Haskoning, 2010

Table 3.3 - Sources of Surface Water Pollution and Potential Mitigation Measures

Source of Pollution	Modelling Outputs	Mitigation Suggestions	Partnership
Direct runoff into watercourses			
- from rural areas	Surface runoff from extensive rural areas to the west, north and south of Lichfield City drain into the urban areas and, subsequently, into the sewer and watercourse networks.	Promotion of Codes of Good Agricultural Practice and recognition of designation as Nitrate Vulnerable Zones (see Southern Staffordshire WCS).	→ *Farmers* → *Lichfield District Council* → *Environment Agency*
- from urban areas	Surface water drains along roads and between buildings to the low lying watercourses. In some locations surface/combined sewers are present along these drainage routes.	Implementation of filtering SUDS schemes to trap pollution along key drainage paths and along the banks of watercourses.	→ *Lichfield DC* → *Highways Agency* → *Severn Trent Water* → *Developers*
Surface Water Sewer Outfalls	At numerous places along the watercourses (the Leamonsley Brook in particular), the surface water sewers outfall directly to the watercourse, having collected drainage from large areas of the city.	Implementation of filtering SUDS schemes to trap pollution on a property or street scale, before the water enters the sewer network. Promotion of reed beds within the Minster and Stowe Pools.	→ *Lichfield District Council* → *Developers* → *Severn Trent Water*
CSO spills	Although some surface sewers are present the centre of Lichfield City is drained by combined sewers, which run beneath the roads acting as key surface water flow routes. If the water on the surface enters the sewer network (i.e from surface drains), the additional water may place additional pressure on the CSOs and, as a result, increase the risk of effluent discharging into the watercourses.	Promotion of SUDS schemes to reduce surface water discharge and cease the connection of surface water discharges into the combined sewer network.	→ *Lichfield District Council* → *Developers* → *Severn Trent Water*

3.4.4 Damages to Critical Infrastructure, Disruption to Services and Emergency Service Costs

The commercial AAD calculations within this report have made an allowance for critical infrastructure, where it is included within the NPD. A full level cost benefit assessment would refine this data by ascertaining that it is up to date and accurate. It should also consider the indirect costs of the disruption caused by the flooding and the cost of service disruption (e.g. the inability of a water treatment works to supply water, an electricity sub station to function or the closure of the road network). Such an assessment should be undertaken by an appropriately trained person or organisation following the latest nationally recognised guidance (currently the MCM).

In addition to the NPD, the Environment Agency has supplied a dataset of critical infrastructure locations. **Table 3.4** below summarises the key elements of critical

infrastructure within Lichfield City and the surface water flood risk posed to each. Please note this table only records flooding to the buildings and not the access and egress routes, which may be affected for many of these locations. All the flood depths are very shallow measured as less than 250mm (the typical threshold level), with the exception of two of the schools.

Table 3.4 - Summary of Flood Risk to Critical Infrastructure within Lichfield City

Critical Infrastructure	Number Affected	Vulnerability	Onset of Flooding	Maximum Flood Depth
Boarding School	1	High	1 in 25 year	0.06m
Care Home	2	High	1 in 25 year	0.02m
Emergency Response				
Ambulance	1	High	1 in 200 year	0.02m
Police	2	High	1 in 20 year	0.04m
Hospital				
IPCC Registered Sites				
Power Stations	3	High	1 in 20 year	0.12m
Radioactive Sites				
Railway Station	2	Medium	1 in 20 year	0.02m
School	11	High	1 in 2 year	0.27m *(2 above 0.25m)*
Wastewater Treatment Works				
Telephone Exchange				
Waste Management Sites	1	Low	1 in 20 year	0.02m

N.B. White squares indicate infrastructure that is <u>not</u> affected by the modelled flood outlines.

The direct cost of the flooding of emergency services (such as fire and ambulance stations) has been included within the AAD calculations using the costings provided in the MCM. The Defra guidance also recommends the inclusion of the costs of emergency services responding to flooding incidents. The MCM recommends the inclusion of a multiplier of 10.7% in addition to property damages to account for emergency costs. This has been included in Section 3.4.5 below.

3.4.5 Average Annual Damages

The methodology for calculating Annual Average Damages (AAD) utilises the information obtained from all modelled flood events, calculating and summing the integrals between the damage calculations. Inclusion of stress related impacts calculates and sums the integrals of property numbers between the flood events. The methodology is summarised in **Appendix C**.

The AAD have been calculated for the following three scenarios:

1. Residential property building damages;
2. Residential property total damages; and
3. Commercial property damages

The annualised damages and property numbers for each return period for these three scenarios are also included in **Appendix C**. The AAD for each are summarised in **Table 3.5** below:

Table 3.5 - AAD Calculations for Current Flood Risk Scenarios

Damage Calculation	AAD	Annualised Property Numbers	AAD including Stress Impacts	Onset of Flooding	Event with Greatest Annual Damages
Residential Building only	£846,224	328	£911,904	1 in 2 year	1 in 5 year
Residential Total[1]	£4,183,666	328	£4,249,346	1 in 2 year	1 in 5 year
Commercial Total	£7,345,780	26	£7,350,978	1 in 2 year	1 in 5 year
Residential + Commercial	**£12,375,669**	**354**	**£12,512,228**	**1 in 2 year**	**1 in 5 year**
Emergency Costs (10.7%)	£1,324,197		£1,338,808		
Total Including Emergency Costs	**£13,699,866**		**£13,851,036**		

[1] Total damages includes an allowance for property contents

In all three cases the onset of flooding is in during the 1 in 2 year event, during which 110 residential properties and 6 commercial properties are flooded (it must be noted that the depth of flooding is very low). For all three scenarios the annual average damages calculations indicate that the flood event which generates the greatest damages is the 5 year storm.

This calculation accounts for both the size of the event (i.e. the resulting cost of flooding) and the probability of the event occurring in any one year to provide a potential 'per year' cost of each event. A 1 in 100 year event may have an estimated damage cost of £20million, but may only occur once in a fifty year period, resulting in £20million damages. A 1 in 5 year event may only cause £5million damages, but may occur more than ten times in a fifty year period, resulting in over £50million damages. It is therefore more cost effective to mitigate against the 1 in 5 year event than the 1 in 100 year event. AAD calculations scale this type of comparison down to a one year period, providing a comparative cost estimate of each event occurring in any one year. The event identified as potentially being the most expensive in any one year is the most cost effective to mitigate against. Interventions which limit flooding from this event are therefore likely to prove the most cost-beneficial overall.

A second peak in the damages occurs in the 50 year storm, reflecting the exceedence of sewer capacity. However, due to the limitations of depth-damage curves for low water depths, these results are highly likely to be significantly inflated and should reduce with a more robust damage calculation.

3.5 Quantifying Future Risk

3.5.1 Climate Change

To quantify future flood risk and to assist the Councils with their development control processes, the model has also been run for three climate change scenarios - the 1 in 20 year, 1 in 50 year and 1 in 100 year scenarios. These scenarios are set 100 years in the future, accounting for a 30% increase in rainfall intensity.

3.5.2 Urbanisation and Urban Creep

The Defra guidance recommends that future surface water flood risk scenarios include allowances for new development and urban creep. Such impacts may increase flood risk through decreased infiltration area and sewer capacity exceedence, but may also provide opportunities to decrease flood risk through implementation of SUDS schemes. Urban creep often occurs in the form of extensions and garden paving, which is hard to monitor and the Floods and Water Management Act, when implemented, will require that all new development proposals include a SUDS design. To provide a more detailed representation of future flood risk periodic assessments of urban creep can be made, accounting for the location, size and SUDS design of any confirmed development sites and the model adjusted and re-run.

3.5.3 Annualised Average Damages

Using the same methodology as outlined for the current scenarios, above, the AAD for the three climate change scenarios has also been calculated, as outlined in **Table 3.6** These show a substantial increase in the AAD totals, implying that surface water flooding will become more of a significant issue within Lichfield City in the future unless appropriate mitigation measures are installed.

Table 3.6 - AAD Calculations, Including Climate Change

Damage Calculation	AAD	Annualised Property Numbers	AAD including Stress Impacts	Event with Greatest Annual Damages
Residential Building only	£3,628,129	1,365	£3,901,189	1 in 20 year + CC
Residential Total	£17,487,244	1,365	£17,760,304	1 in 20 year + CC
Commercial Total	£19,188,786	144	£19,217,554	1 in 20 year + CC
Residential + Commercial	**£40,304,159**	**1,509**	**£40,879,047**	**1 in 20 year + CC**
Emergency Costs (10.7%)	£4,191,632		£4,251,421	
Total Including Emergency Costs	**£44,495,791**		**£45,130,467**	

4 PHASE 2 SWMP: MAP AND COMMUNICATE RISK

4.1 Surface Water Flood Maps

Mapping has been provided to the Steering Group in the form of Interactive PDFs to show:

- ✓ the extent of the modelled flooding for each return period (including the climate change scenarios);
- ✓ the predicted depth of flooding;
- ✓ the associated hazard; and
- ✓ the historical flood locations (from Phase 1).

4.1.1 Flood Hazard Maps

Flood Hazard Mapping brings information on flood depth and velocity (speed) of floodwater together to create a hazard rating to people within each area that could experience flooding. The hazard rating used is set out in Defra's FD2320 guidance[9]. The hazard rating is calculated using the following equation and categorises flood risk in terms of Caution, Danger for Some, Danger for Most and Danger for All, with the hazard becoming dangerous to more people as depths and velocities increase.

Hazard Rating = d * (v+0.5) + DF
Where d = depth (m), v = velocity (m/s), DF = debris factor

The results from this equation are grouped into bands, as illustrated in **Table 4.1** and **Table 4.2** below.

Table 4.1 – Description of Hazard Categories

Degree of Flood Hazard	Colour Code	Description
Low		**Caution / Low Hazard**
Moderate		**Danger for Some** (includes children, the elderly, and the infirm)
Significant		**Danger for Most** (includes the general public)
Extreme		**Danger for All** (includes the emergency services)

[9] Flood Risk Assessment Guidance for New Development Phase 2, Framework and Guidance for Assessing and Managing Flood Risk for New Development (FD2320/TR2) HR Wallingford (October 2005)

Table 4.2 – 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												
0.10												
0.25												
0.50												
1.00												
1.50												
2.00												
2.50												
3.00												
3.50												
4.00												
4.50												
5.00												

* The green colour code is not specified in FD2320/TR2 and has been employed within the mapping in order to show maximum flood extent.

Surface water flood hazard within Lichfield City is limited, due to low depths and velocities. In all return periods, the majority of the flooded area is classified as 'Low' or 'No' hazard. The hazard does increase as flood probability decreases, but even in the 1 in 200 year event the hazard is limited. Some low lying areas of residential roads are classified as 'moderate' hazard, as are the areas around the watercourses and behind constrictions, such as embankments and culverts. The extent of 'significant' hazard is limited and generally confined to non residential playing fields, gardens and allotments. However some areas of significant hazard do occur in some residential roads and parts of the central shopping area. The hazard is not particularly high around the critical infrastructure locations, although it is considered as Moderate close to one of the schools, one of the railways stations and the emergency response units in the centre of town. These are areas which should be focussed upon when considering emergency planning, especially with regards to their access and egress routes.

4.2 High Risk Areas and Mitigation Suggestions

4.2.1 Current Risk

Overall the current risk (accounting for probability and consequence) from surface water flooding within Lichfield City is relatively low, especially for the higher probability (more frequent) flood events. Where flooding does occur the water depths are generally low (less than 0.25m). However, as witnessed in July 2007, certain parts of the town have a higher risk of surface water flooding and, if flow routes become blocked, the water depths may increase dramatically.

Tables 4.3-4.8 on the following pages summarise: the key surface water hot spots identified within six broad high risk areas of the City; potential mitigation measures to improve the situation; and the stakeholders from which a partnership approach would be beneficial when considering mitigation. **Figure 4.1** in **Appendix B** shows the broad high risk areas (identified through interpretation of the modelling results) and key flow routes and is annotated with references to the flooding hot spots within them.

The overarching key mitigation strategies and quick wins are summarised for the City as a whole in the box below. Please note these are initial suggestions and require further discussion and development with all surface water partners as part of a Phase 3 SWMP, if undertaken. Please also note that many of the partners (including STWL, the Highways Agency and the Councils) already undertake a number of the routine maintenance tasks identified below. Where this is the case, this report encourages the continuation of such tasks.

Key Management Themes and Quick Wins for Lichfield City

- Regular monitoring, clearance and maintenance of key drainage routes, including highways drains and culverts;
- Maintenance of Leamonsley Brook to enable surface water to flow efficiently through the City centre;
- Investigate the potential to alter land management practices to reduce/slow surface water runoff from the surrounding countryside;
- Investigate the potential to reinstate and utilise the Lichfield canal to accommodate surface water runoff;
- Installation of SUDS in new developments (please see Section 4.3 of the Southern Staffordshire WCS for further information regarding individual SUDS techniques);
- Retrofitting of SUDS in existing development, where feasible;
- Investigation of potential to install storage ponds to accommodate surface water runoff in key areas, perhaps through dual use of parkland or playing fields;
- Preparation of emergency plans to accommodate road closures and the evacuation of vulnerable populations from hazardous areas;
- Maintenance of sewer network to allow effective CSO operation and minimise backing up of network below the design capacity (1 in 30 year flood event);
- **Partnership working between organisations to implement the most beneficial and cost effective solutions - all mitigation options to be identified, discussed and agreed as part of a Phase 3 SWMP, if undertaken.**

Table 4.3 - City Centre

City Centre - Map Area 1		
Issues	**Mitigation**	**Partnership**
♦ Areas of 'moderate' to 'significant' flood hazard.	♦ Draw up appropriate emergency plans and prioritise evacuation from these areas in times of flood, especially for vulnerable populations. ♦ Educate local population. ♦ Implement resilience measures for affected properties.	→ *Lichfield District Council* → *Staffordshire County Council* → *Civil Contingencies Unit*
♦ Flooding of southbound access route from 1 in 20 year flood event and western access route from 1 in 50 year flood event.	♦ Draw up appropriate emergency plans and be prepared for road closures in times of flood. ♦ Ensure highway drains are kept clear from debris along these routes. ♦ Regular maintenance of combined sewers to ensure sufficient capacity is available for surface water.	→ *Lichfield District Council* → *Staffordshire County Council* → *Civil Contingencies Unit* → *Highways Agency* → *Severn Trent Water**
♦ Restriction of flow through culvert upstream of Minster pool in low return periods (1 in 5 and 1 in 10 year flood events)	♦ Regular maintenance to keep culvert clear. ♦ If flooding still occurs, investigate potential to increase culvert size or investigate the potential to utilise Beacon Park as a water storage area during a flood event. ♦ Improve drainage so water does not collect and pool. ♦ Reduce surface water flow from upstream through installation of SUDS in any new developments. ♦ Investigate potential to reduce surface water flow from upstream through adjustment of land management practices to reduce run off (e.g. ploughing parallel to contours, not leaving fields fallow etc).	→ *Lichfield District Council* → *Staffordshire County Council* → *Developers* → *Farmers/Land Owners*
♦ Restriction of flow through culvert downstream of Festival gardens from 1 in 5 year flood event.	♦ Regular maintenance to keep culvert clear. ♦ If flooding still occurs, investigate potential to increase culvert size or install a balancing pond upstream of the culvert to contain surface water. ♦ Be prepared for high flood hazard in this area for the lower flood probability events.	→ *Lichfield District Council* → *Staffordshire County Council* → *Civil Contingencies Unit*
♦ Flooding of many access and egress routes from 1 in 25 year flood event.	♦ Draw up appropriate emergency plans and be prepared for road closures in times of flood. ♦ Ensure highway drains are kept clear from debris along these routes ♦ Regular maintenance of combined sewers to ensure sufficient capacity is available for surface water.	→ *Lichfield District Council* → *Staffordshire County Council* → *Civil Contingencies Unit* → *Highways Agency* → *Severn Trent Water**

NOTES: * STWL are currently only funded to address the more severe incidents of known reported sewer flooding, as recorded on their sewer flooding register. Drainage systems are designed to have a finite capacity and upsizing the underground system to cope with extreme rainfall events may not be the most cost effective means of managing surface water, with the potential to increase the risk of flooding downstream. All actions stated within this table require discussion between the partnership organisations during a Phase 3 SWMP, if undertaken.

Table 4.4 - South Lichfield City

South Lichfield City - Map Area 2		
Issues	**Mitigation**	**Partnership**
♦ Significant runoff from agricultural land, impacting upon urban area and sewer network. Flow routes extend from this area into other parts of Lichfield City.	♦ Investigate potential to reduce surface water flow from upstream through adjustment of land management practices to reduce run off (e.g. ploughing parallel to contours, not leaving fields fallow etc).	→ *Lichfield District Council* → *Staffordshire County Council* → *Farmers/Land Owners*
♦ Numerous occurrences of historic flooding (highways and surface water) along east-west periphery road.	♦ Regular maintenance and clearance of highway drains. ♦ Maintenance of surface water sewer to retain maximum capacity. ♦ Awareness of other mitigation suggestions above and below to reduce inflow of surface water from upstream.	→ *Lichfield District Council* → *Staffordshire County Council* → *Highways Agency* → *Severn Trent Water**
♦ Lack of capacity in existing sewer network to accommodate additional surface water drainage from Greenfield development.	♦ Implementation of SUDS in new development to reduce runoff below Greenfield values. ♦ Current east-west surface water sewer is located in bed of original Lichfield canal. Investigate potential for using developer funding to reinstate canal to accommodate surface water flow.	→ *Lichfield District Council* → *Staffordshire County Council* → *Developers* → *Lichfield and Hatherton Canal Trust* → *British Waterways* → *Severn Trent Water**
♦ Constriction in flow route at railway culvert resulting in potentially significant flooding of properties (moderate flood hazard).	♦ Investigate flow route under railway (assumed to be road). ♦ Install a drainage ditch separate to the road to route flows under the railway. ♦ Keep highways drains clear. ♦ Investigate potential to reduce volume of surface water draining into area through installation of a surface water pond upstream of development. ♦ Awareness of potential flood hazard arising from flood depths and velocities and prepare appropriate emergency plan.	→ *Lichfield District Council* → *Staffordshire County Council* → *Civil Contingencies Unit* → *Highways Agency*

NOTES: * STWL are currently only funded to address the more severe incidents of known reported sewer flooding, as recorded on their sewer flooding register. Drainage systems are designed to have a finite capacity and upsizing the underground system to cope with extreme rainfall events may not be the most cost effective means of managing surface water, with the potential to increase the risk of flooding downstream. All actions stated within this table require discussion between the partnership organisations during a Phase 3 SWMP, if undertaken.

Table 4.5 - West Lichfield City

West Lichfield City - Map Area 3		
Issues	**Mitigation**	**Partnership**
♦ Significant runoff from agricultural land feeding into flow route.	♦ Investigate potential to reduce surface water flow from upstream through adjustment of land management practices to reduce run off (e.g. ploughing parallel to contours, not leaving fields fallow etc)	→ *Lichfield District Council* → *Staffordshire County Council* → *Farmers/Land Owners*
♦ Flow route from this area extends into city centre.	♦ Keep an awareness of interconnectivity of flow routes when planning mitigation measures.	→ *Lichfield District Council* → *Staffordshire County Council*
♦ Capacity constriction of Western bypass culvert.	♦ Regular maintenance and clearance of culvert. ♦ Potential to investigate benefits from a flood storage area upstream of culvert (increasing flow through culvert will negatively impact upon Beacon Park and flood risk downstream).	→ *Lichfield District Council* → *Staffordshire County Council* → *Highways Agency*
♦ Leamonsley Brook required to take significant proportion of runoff flow from this area through the city centre.	♦ Ensure flow route of Brook is kept clear and culverts are properly maintained and monitored throughout the city. ♦ Reduction of surface water drainage entering Brook through retrofitting of SUDS into existing development (wherever possible) and inclusion of SUDS in new developments/ redevelopments. ♦ Effective CSO operation along watercourse through reduction in surface water drainage entering sewer network.	→ *Lichfield District Council* → *Staffordshire County Council* → *Developers* → *Severn Trent Water**
♦ Moderate - Significant flood hazard along course of Leamonsley Brook and behind Western bypass.	♦ Awareness of potential flood hazard arising from flood depths and velocities and prepare appropriate emergency plan.	→ *Lichfield District Council* → *Staffordshire County Council* → *Civil Contingencies Unit*
♦ Flooding of rural roads.	♦ Preparedness for installation of diversions during flood events. ♦ Maintenance and regular clearance of road-side drainage ditches in affected areas.	→ *Lichfield District Council* → *Staffordshire County Council* → *Civil Contingencies Unit* → *Highways Agency.*

NOTES: * STWL are currently only funded to address the more severe incidents of known reported sewer flooding, as recorded on their sewer flooding register. Drainage systems are designed to have a finite capacity and upsizing the underground system to cope with extreme rainfall events may not be the most cost effective means of managing surface water, with the potential to increase the risk of flooding downstream. All actions stated within this table require discussion between the partnership organisations during a Phase 3 SWMP, if undertaken.

Table 4.6 - North Lichfield City

North Lichfield City - Map Area 4		
Issues	**Mitigation**	**Partnership**
♦ Moderate - Significant flood hazard along course of Brook.	♦ Awareness of potential flood hazard arising from flood depths and velocities and prepare appropriate emergency plan. ♦ Ensure flow route of Brook is kept clear and culverts are properly maintained and monitored.	→ *Lichfield District Council* → *Staffordshire County Council* → *Civil Contingencies Unit*
♦ Flooding of industrial estate from 1in 20 year flood event.	♦ Application of appropriate development control and flood resilience if redevelopment occurs / has occurred.	→ *Lichfield District Council* → *Staffordshire County Council* → *Developers*
♦ Flooding of Eastern Avenue from 1 in 75 year flood event.	♦ Maintenance and regular clearance of highways drains. ♦ Maintenance of surface water sewer to transmit flows without capacity exceedence.	→ *Lichfield District Council* → *Staffordshire County Council* → *Highways Agency* → *Severn Trent Water**

NOTES: * STWL are currently only funded to address the more severe incidents of known reported sewer flooding, as recorded on their sewer flooding register. Drainage systems are designed to have a finite capacity and upsizing the underground system to cope with extreme rainfall events may not be the most cost effective means of managing surface water, with the potential to increase the risk of flooding downstream. All actions stated within this table require discussion between the partnership organisations during a Phase 3 SWMP, if undertaken.

Table 4.7 - Northern Lichfield City

Northern Lichfield City - Map Area 5		
Issues	**Mitigation**	**Partnership**
♦ Historic and modelled sewer capacity exceedence.	♦ Review capacity of surface water and combined sewers. ♦ Remove surface water entering systems through installation/ retrofitting of SUDS and rainwater harvesting where possible. ♦ Limit new connections to the surface water and combined sewer networks. ♦ Keep Leamonsley Brook clear to enable surface water outfall from sewers to enter watercourse.	→ *Lichfield District Council* → *Staffordshire County Council* → *Developers* → *Severn Trent Water**

NOTES: * STWL are currently only funded to address the more severe incidents of known reported sewer flooding, as recorded on their sewer flooding register. Drainage systems are designed to have a finite capacity and upsizing the underground system to cope with extreme rainfall events may not be the most cost effective means of managing surface water, with the potential to increase the risk of flooding downstream. All actions stated within this table require discussion between the partnership organisations during a Phase 3 SWMP, if undertaken.

Table 4.8 - East Lichfield City

East Lichfield City - Map Area 6		
Issues	**Mitigation**	**Partnership**
♦ Historic highways flood event and high hazard area to east.	♦ Keep highways drainage routes maintained and clear. ♦ Ensure combined sewer does not exceed capacity.	→ *Lichfield District Council* → *Staffordshire County Council* → *Highways Agency* → *Severn Trent Water**
♦ Flow routes draining between residential properties.	♦ Adjust residential roads to act as drainage routes to route water away from properties. ♦ Property specific resilience measures.	→ *Lichfield District Council* → *Staffordshire County Council* → *Developers* → *Highways Agency.*

NOTES: * STWL are currently only funded to address the more severe incidents of known reported sewer flooding, as recorded on their sewer flooding register. Drainage systems are designed to have a finite capacity and upsizing the underground system to cope with extreme rainfall events may not be the most cost effective means of managing surface water, with the potential to increase the risk of flooding downstream. All actions stated within this table require discussion between the partnership organisations during a Phase 3 SWMP, if undertaken.

4.2.2 Future Risk

The impact of climate change on the 1 in 20 year, 1 in 50 year and 1 in 100 year events has been included in the model runs and mapped outputs. A comparison between the climate change scenarios and the current day scenarios results in the following similarities:

- → 1 in 20 year with climate change scenario is similar to the 1 in 25 year current scenario;
- → 1 in 50 year with climate change scenario is similar to the 1 in 75 year current scenario; and
- → 1 in 100 year with climate change scenario is similar to the 1 in 200 year current scenario.

The future risk of flooding will also be impacted by any other changes in the catchment, such as new development, alterations to land management practices and adjustments to flow regimes (e.g. culvert widening and the installation of flood storage areas). It is recommended that the models are adjusted and rerun, either to predict the impacts of alterations in the catchments, or to update the results to the latest situation.

4.3 Communication of Risk

As outlined in the Engagement Plan, drawn up as part of the Phase 1 SWMP, numerous stakeholders have an interest in surface water flooding. However, due to the nature of the outputs and the potential for property blight, the Councils will need to decide upon the most suitable method of dissemination to each group. The key groups identified as part of this study and the recommended order in which the findings should be disseminated are illustrated in the summary box below.

Dissemination of Surface Water Findings

1. Core Steering Group
- → Stafford Borough Council;
- → Lichfield District Council;
- → Tamworth Borough Council;
- → South Staffordshire District Council;
- → Cannock Chase District Council;
- → Staffordshire County Council (Lead Local Flood Authority);
- → Environment Agency; and
- → Severn Trent Water Limited.

2. Additional Surface Water Mitigation Partners
- → Lichfield and Hatherton Canal Trust;
- → British Waterways;
- → Farmers/Land Owners;
- → Civil Contingencies Unit; and
- → Highways Agency

3. Other Stakeholders
- → Natural England
- → Environmental Groups
- → Public Flood Risk Forums
- → Public
- → Riparian Owners; and
- → Developers

5 CONCLUSIONS AND NEXT STEPS

5.1 Conclusions

This Phase 2 SWMP study and associated modelling have defined the surface water flood risk to Lichfield City, based upon the best available current information. The model results have substantially refined the extent of surface water flooding from the Environment Agency's AStSWF and been verified by the historical data collected during Phase 1. It must be noted that there are limitations in the modelling techniques and depth damage calculations utilised within this study - these are summarised within the text above.

The key outcomes/conclusions from this study are as follows:

Key Surface Water Flooding Issues for Lichfield City

1. Flooding across the city originates, and is exacerbated, through a combination of overland flow and a lack of drainage capacity (from both sewers and watercourses);
2. Flooding in the urban area is closely linked to overland flow originating from rural runoff (most notably to the west and south of the City);
3. Flooding initiates during the 1 in 2 year flood event;
4. For the current situation, the flood event that generates the greatest annualised damages is the 5 year storm;
5. The total AAD for the current situation is approximately £13.9m, including an allowance for stress and emergency costs;
6. The total AAD for the future flood scenarios (based on three flood probabilities) is approximately £45m, indicating that climate change poses a significant increase to surface water flood risk in the City;
7. Surface water flood depths are generally low in all return periods, although increase to a maximum of 2m (0.79m at residential property boundaries) in the 1 in 200 year flood event;
8. Flood hazard within Lichfield City is limited, although some low lying areas (including roads around critical infrastructure locations) are classified as 'Moderate' hazard and some areas of open space are classified as having 'significant' hazard in the lower probability flood events;
9. Risk of pollution is closely linked to surface water flood risk and should be reduced to assist in meeting the WFD targets downstream (details of sources of pollution are provided in **Table 3.1**);
10. Critical infrastructure is at risk of surface water flooding, affecting boarding schools, care homes, ambulance stations, police stations, power stations, railway stations, schools and waste management sites;

Key Mitigation Strategies for Lichfield City

1. Regular monitoring, clearance and maintenance of key drainage routes, including highways drains and culverts;
2. Maintenance of Leamonsley Brook to enable surface water to flow efficiently through the City centre;
3. Investigation of the potential to alter land management practices to reduce/slow surface water runoff from the surrounding countryside;
4. Investigation of the potential to reinstate and utilise the Lichfield canal to accommodate surface water runoff;

5. Installation of SUDS in all new developments, with the aim to reduce runoff below Greenfield rate in the key drainage areas to the south and west of the City (please see Section 4.3 of the Southern Staffordshire WCS for further information regarding individual SUDS techniques);
6. Retrofitting of SUDS in existing developments, where feasible;
7. Investigation of potential to install storage ponds to accommodate surface water runoff at the City boundaries and upstream of flow constrictions, perhaps through dual use of parkland or playing fields;
8. Preparation of emergency plans to accommodate road closures and the evacuation of vulnerable populations from hazardous areas;
9. Maintenance of sewer network to allow effective CSO operation and minimise backing up of network below the design capacity (1 in 30 year flood event);
10. Promotion of Codes of Good Agricultural Practice and recognition of NVZ status to reduce pollution from direct runoff in rural areas ; and
11. Partnership working between organisations to implement the most beneficial and cost effective solutions (the main actions required from the key partners identified within this report are summarised in **Table 5.1** below - these require review, discussion and agreement as part of a Phase 3 SWMP, if undertaken).

Table 5.1 - Key Partnership Actions

Partner	Partnership Actions	
	To Reduce Surface Water Flooding / Risks from Surface Water Flooding	**To Reduce Pollution Resulting from Surface Water Flooding**
Lichfield District Council	♦ Appropriate emergency planning and road diversions; ♦ Education of local population; ♦ Property specific resilience measures; ♦ Regular maintenance of drains in key flood risk areas; ♦ Regular maintenance/improvement of key watercourses and culverts ♦ Improved drainage of areas at risk of surface water 'pooling' ♦ Promotion of SUDS ♦ Regular clearance of rural ditches ♦ Investigation of potential to utilise Lichfield canal to reduce surface water flood risk ♦ Awareness of interconnectivity of flow routes when considering development control. ♦ Investigation into alternative drainage routes/storage options	♦ Promotion of Codes of Good Agricultural Practice; ♦ Recognition of NVZ designation; ♦ Alteration in land management practices to reduce rapid surface water runoff; ♦ Promotion of SUDS schemes
Staffordshire County Council	♦ Preparation of appropriate emergency planning and road diversions ♦ Education of local population ♦ Regular maintenance of drains in key flood risk areas; ♦ Regular maintenance/improvement of key watercourses and culverts ♦ Improved drainage of areas at risk of surface water 'pooling' ♦ Promotion and approval of SUDS ♦ Awareness of interconnectivity of flow routes when	

Partner	Partnership Actions	
	To Reduce Surface Water Flooding / Risks from Surface Water Flooding	**To Reduce Pollution Resulting from Surface Water Flooding**
	considering development control. ♦ Investigation into alternative drainage routes/storage options	
Highways Agency	♦ Preparation of appropriate road diversions ♦ Regular maintenance of highways drains in key flood risk areas; ♦ Regular clearance of rural ditches ♦ Investigation into alternative drainage routes/storage options	♦ Promotion of SUDS schemes
Environment Agency	♦ Appropriate review of FRAs; ♦ Promotion of SUDS.	♦ Promotion of Codes of Good Agricultural Practice; ♦ Recognition of NVZ designation; ♦ Land Management to reduce rapid surface water runoff in rural areas.
Severn Trent Water Limited*	♦ Regular maintenance of combined sewers to provided maximum capacity; ♦ Resolution of sewer flooding/capacity issues	♦ Promotion of SUDS schemes ♦ Effective CSO operation
Farmers	♦ Adjustment of land management practices; ♦ Regular maintenance of ditches/drains	♦ Promotion of Codes of Good Agricultural Practice; ♦ Recognition of NVZ designation; ♦ Land Management to reduce rapid surface water runoff in rural areas.
Developers	♦ Installation of SUDS ♦ Investigation of potential to utilise Lichfield canal to reduce surface water flood risk	♦ Promotion of SUDS schemes
Civil Contingencies Unit	♦ Appropriate emergency planning ♦ Education of local population ♦ Identification of vulnerable population at risk of flooding/moderate to significant flood hazard. ♦ Awareness of risks associated with flood hazard.	
Lichfield and Hatherton Canal Trust	♦ Investigation of potential to utilise Lichfield canal to reduce surface water flood risk.	

NOTES: * STWL are currently only funded to address the more severe incidents of known reported sewer flooding, as recorded on their sewer flooding register. Drainage systems are designed to have a finite capacity and upsizing the underground system to cope with extreme rainfall events may not be the most cost effective means of managing surface water, with the potential to increase the risk of flooding downstream. All actions stated within this table require discussion between the partnership organisations during a Phase 3 SWMP, if undertaken.

5.2 Next Steps

5.2.1 SWMP Phase 3 and 4

The Defra guidance recommends that once the surface water flood hazard has been modelled and mapped, the SWMP should be progressed to identify and assess options for surface water mitigation (Phase 3) and prepare an action plan for their implementation (Phase 4).

This Phase 2 assessment has identified a number of potential surface water mitigation actions and the key partners to be involved in implementing these actions. However, to progress this SWMP it is recommended that the AAD calculations are refined to include a full cost-benefit assessment to accurately assess options. At this stage it would be useful to refine the modelling to simulate the impact of such options.

5.2.2 Model Refinement

A number of limitations and assumptions relating to this modelling have been highlighted within this report. When new or updated information becomes available it is recommended that the model is refined and rerun.

5.2.3 Model Use

The model developed for use in this SWMP has been commission by the Local Authorities, but contains STWL's current drainage model. As such, ownership should be viewed as a partnership. Any adjustments or amendments made to the model should be undertaken with the consent of, and reviewed by, both partners.

It has currently not been defined how this model can be used by developers and consultants for the assessment of individual development sites. Advice will be forthcoming and should be sought from either Lichfield District Council or Staffordshire County Council.

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Appendix A
Defra SWMP Guidance Check Lists

Table A.1 - Requirements of an Intermediate Assessment (Defra SWMP Guidance, March 2010)

Criteria	Description	Included within this Phase 2 SWMP?
Purpose	To: ♦ gain an improved understanding of surface water flooding; ♦ to identify localised flood hotspots and support decisions on whether these may require further assessment; and ♦ to identify mitigation measures to reduce surface water flooding.	 ✓ ✓ ✓
Scale	♦ Town, city or London Borough	✓
Inputs (data and information)	♦ Information from the strategic assessment ♦ Existing asset data or models (drainage, 'ordinary' watercourses, highway drainage, rivers, coast, groundwater levels) ♦ Location of proposed new development ♦ Additional evidence collated from site visits, surveys or modelling ♦ Local knowledge (EA / LPA)	✓ ✓ ✓ ✓ ✓
Process	♦ More detailed information is collated and analysed to improve the understanding of surface water flooding and to identify flood hotspots	✓
Outputs	♦ Improved mapping to support spatial and emergency planning ♦ Identification of flood hotspots which may require further, more detailed assessment (possibly through modelling approaches) ♦ Identification of plausible mitigation measures, including quick wins or immediate measures which can be put in place	✓ ✓ ✓
Benefits	♦ Improved understanding of surface water flooding within the study area ♦ Improved mapping which can be used to support spatial and emergency planning functions ♦ Identification of mitigation measures to reduce surface water flooding; in particular 'quick win' (or immediate) actions which can be taken by partners and stakeholders ♦ As the intermediate assessment identified flood hotspots, the detailed assessment can be focussed on the hotspot locations, ensuring greatest value for money.	✓ ✓ ✓ ✓

Table A.1 - Requirements of a Detailed Assessment (Defra SWMP Guidance, March 2010)

Criteria	Description	Included within this Phase 2 SWMP?
Purpose	♦ To understand the causes, probability and consequences of surface water flooding in a greater level of detail; and ♦ To test mitigation measures to reduce surface water flooding	✓
Scale	♦ In flood hotspot locations; generally considered to be at sub-settlement scale	*Larger Scale*
Inputs (data and information)	♦ Existing asset data or models (drainage, 'ordinary' watercourses, highway drainage, rivers, coast, groundwater levels) ♦ Location of new development ♦ Additional evidence collated from site visits or surveys *NB: Majority of information already collated in intermediate assessment, but additional data may need to be collected to support modelling approach (e.g. survey data, rainfall data)*	✓ ✓ *Where already available*
Process	♦ Use of modelling approaches to assess surface water flood risk (where risk = probability x consequence). ♦ The same modelling approach is used to test mitigation measures.	✓ *Not undertaken*
Outputs	♦ Understanding of 'annualised' surface water flood risk, both now and in the future. ♦ Understanding the benefits and costs of mitigation measures to reduce surface water flooding. ♦ Detailed mapping of flood risk and flood hazard (partners should consider the emerging requirements of Part 3 of the Flood Risk Regulations [2009]).	✓ *Benefit/costs not calculated* ✓
Benefits	♦ Improved understanding of the probability and consequences of flooding. ♦ Detailed understanding of the flood risk will enable informed judgements to be made of the benefits and costs of potential mitigation measures. ♦ Can assess benefits of mitigation measures (where a benefit is a reduction in damages due to surface water flooding). ♦ Can help to fulfil the requirements of the Floods Risk Regulations to produce flood risk and flood hazard maps. ♦ Can provide justification for mitigation measures based on benefits and costs.	✓ ✓ *Flood risk and flood hazard maps produced*

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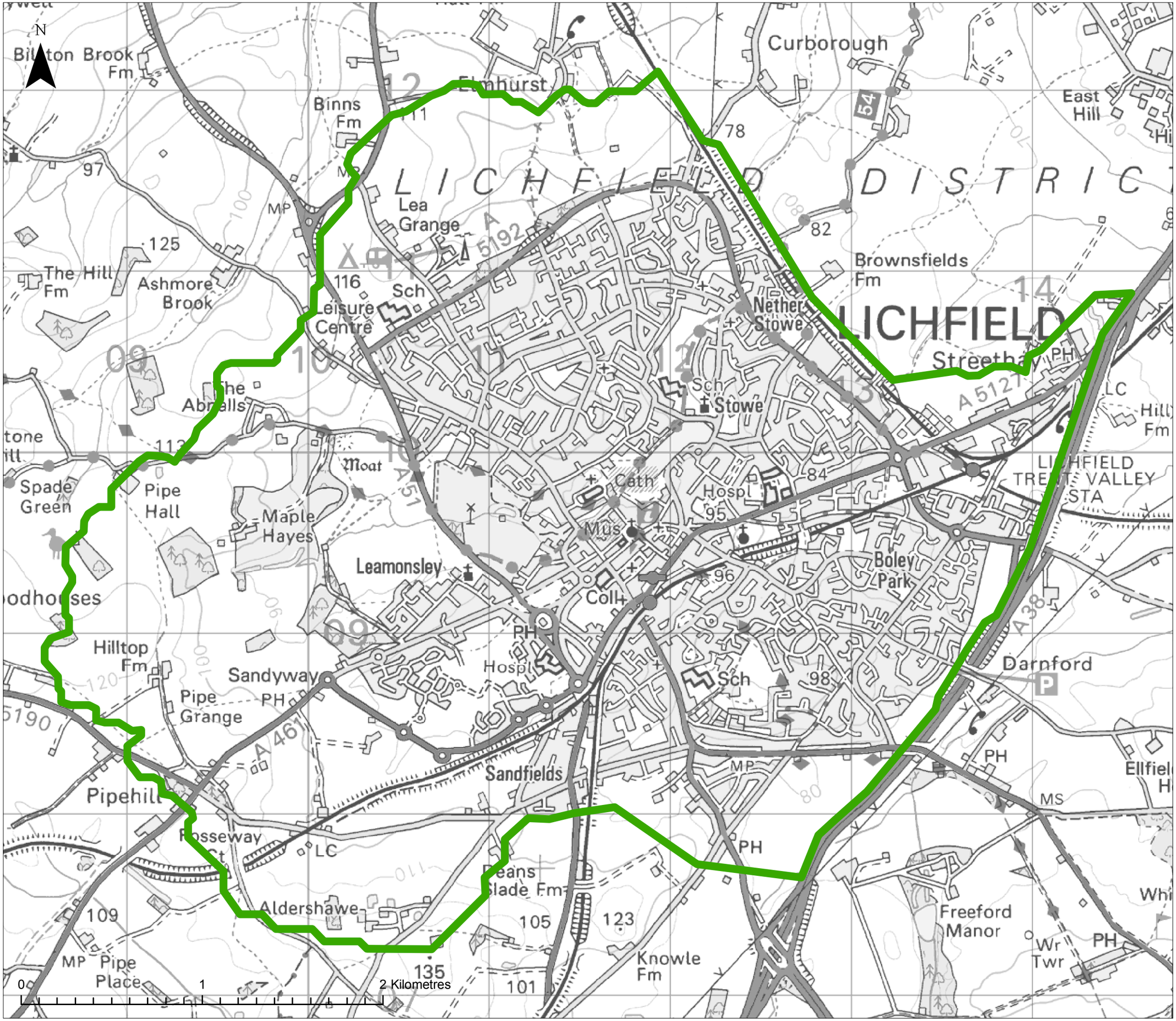
Appendix B
Figures



Key:

Watershed Outline

Title:
Watershed Boundary

Project:
Southern Staffordshire SWMP

Client:
Stafford Borough, Lichfield District, South Staffordshire District, Tamworth Borough and Cannock Chase Councils

Date:
January 2011

Scale:
1:20,000 @ A3

Figure:
3.1

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N

CURBOROUGH AND ELMHURST CP

AND CHORLEY CP

STREETHAY CP

LICHFIELD

LICHFIELD CP

LICHFIELD DISTRICT

WALL CP

Runoff from agricultural land

Areas of Moderate - Significant Hazard

Flow Constriction

4

Flooding of Access Routes

Sewer Capacity Constrictions

5

Significant Flow along Leamonsley Brook

Flooding of Rural Roads

Areas of Moderate - Significant Hazard

Areas of Moderate - Significant Hazard

6

Historic Flooding

3

Runoff from agricultural land

1

Flooding of Access Routes

Culvert Restrictions

Flow Routes through Residential Areas

Historic Flooding

Culvert Restriction

2

Partial Proposed Route of Lichfield Canal

Runoff from agricultural land

0 1 2 Kilometres

N.B ALL ARROWS INDICATE BROAD AREAS AND NOT SPECIFIC LOCATIONS

Key:

- Key Risk Areas
- Ordinary Watercourses
- Main Rivers
- Key Flow Routes

Title:
Key Flood Risk Areas and Hotspots

Project:
Southern Staffordshire SWMP

Client:
Stafford Borough, Lichfield District, South Staffordshire District, Tamworth Borough, and Cannock Chase District Councils

Date:
January 2011

Scale:
1:20,000 @ A3

Figure:
4.1

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Appendix C
Average Annual Damage Calculations

Table C.1 - Methodology for Calculating AAD

Probability of Flood Event (1 in…)	**Flood Probability**	**No of Properties Flooded**	**Damages per Event (£)**	**Annualised Damages (£)**	**Annualised Property Numbers (APN)**
2	0.5	*Extracted using GIS*	*Calculated using NPD and MCM depth-damage curves*	*(1 - 0.5) * (property damage + 0) / 2*	*(1 - 0.5) * (Number of properties flooded) / 2*
5	0.2			*(Previous flood probability - flood probability) * (property damage + property damage from previous flood probability) / 2*	*(Previous flood probability - flood probability) * (Number of properties flooded + number of properties flooded from previous flood probability) / 2*
10	0.1				
20	0.05				
25	0.04				
30	0.033				
50	0.02				
75	0.013				
100	0.01				
200	0.005				
				AAD = *Sum of above*	**Average APN** = *Sum of above*
					Health Weighting = *Average APN * £200*
				AAD including stress impacts = *Health Weighting + AAD*	

Table C.2 - Annualised Damages for Residential Property Building Damages

Probability of Flood Event (1 in…)	Flood Probability	No of Properties Flooded	Damages per Event (£)	Annualised Damages (£)	Annualised Property Numbers (APN)
2	0.5	110	£273,085.13	£68,271.28	28
5	0.2	429	£1,036,992.37	£196,511.62	81
10	0.1	777	£1,885,771.72	£146,138.20	60
20	0.05	1,246	£3,111,965.20	£124,943.42	51
25	0.04	1,993	£5,011,002.91	£40,614.84	16
30	0.033	2,203	£5,546,235.66	£36,950.34	15
50	0.02	2,505	£7,387,105.94	£84,066.72	31
75	0.013	2,982	£9,117,289.47	£57,765.38	19
100	0.01	3,337	£10,411,457.94	£29,293.12	9
200	0.005	4,267	£14,256,074.86	£61,668.83	19
				AAD: £846,223.77	**Average APN:** 328
					Health Weighting: £65,680.20
				AAD including stress impacts = £911,903.97	

(With Climate Change):

.	0.05	2,603	£6,814,715.28	£3,236,989.76	1236
50CC	0.02	3,425	£10,821,786.78	£264,547.53	90
100CC	0.01	4,266	£14,496,614.12	£126,592.00	38
				AAD: £3,771,628.16	**Average APN:** 1,365
					Health Weighting: £273,060.00
				AAD including stress impacts = £3,901,189.30	

Table C.3 - Annualised Damages for Residential Property Total Damages

Probability of Flood Event (1 in…)	Flood Probability	No of Properties Flooded	Damages per Event (£)	Annualised Damages (£)	Annualised Property Numbers (APN)
2	0.05	110	£1,361,780.25	£340,445.06	28
5	0.2	429	£5,222,143.96	£987,588.63	81
10	0.1	777	£9,577,476.75	£739,981.04	60
20	0.05	1,246	£15,485,889.38	£626,584.15	51
25	0.04	1,993	£24,709,067.63	£200,974.79	16
30	0.033	2,203	£27,389,314.93	£182,344.34	15
50	0.02	2,505	£35,540,323.16	£409,042.65	31
75	0.013	2,982	£43,136,047.58	£275,367.30	19
100	0.01	3,337	£48,757,646.22	£137,840.54	9
200	0.005	4,267	£64,641,230.98	£283,497.19	19
				AAD: £4,249,345.89	**Average APN:** 328
					Health Weighting: £65,680.20
				AAD including stress impacts = £4,249,345.89	

(With Climate Change):

20CC	0.05	2,603	£32,967,002.27	£15,659,326.08	1,236
50CC	0.02	3,425	£50,373,136.78	£1,250,102.09	90
100CC	0.01	4,266	£65,189,940.43	£577,815.39	38
				AAD: £17,487,243.55	**Average APN:** 1,365
					Health Weighting: £273,060.00
				AAD including stress impacts = £17,760,303.55	

Table C.4 - Annualised Damages for Commercial Property Total Damages

Probability of Flood Event (1 in…)	Flood Probability	No of Properties Flooded	Damages per Event (£)	Annualised Damages (£)	Annualised Property Numbers (APN)
2	0.5	6	£4,572,958.19	£1,143,239.55	2
5	0.2	22	£11,621,762.14	£2,429,208.05	4
10	0.1	62	£15,817,839.83	£1,371,980.10	4
20	0.05	149	£18,593,842.73	£860,292.06	5
25	0.04	220	£30,498,413.16	£245,461.28	2
30	0.033	236	£32,811,821.90	£221,585.82	2
50	0.02	281	£37,515,441.64	£457,127.21	3
75	0.013	310	£40,818,061.23	£274,167.26	2
100	0.01	318	£41,925,667.42	£124,115.59	1
200	0.005	342	£45,515,388.42	£218,602.64	2
				AAD: £7,345,779.57	**Average APN:** 26
					Health Weighting: £5,198.40
				AAD including stress impacts = £7,350,977.97	

(With Climate Change):

20CC	0.05	277	£36,917,477.61	£17,535,801.86	132
50CC	0.02	320	£43,525,240.86	£1,206,640.78	9
100CC	0.01	342	£45,743,360.46	£446,343.01	3
				AAD: £19,188,785.65	**Average APN:** 144
					Health Weighting: £28,768.00
				AAD including stress impacts = £19,217,553.65	