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Kings Lynn Ordinary Watercourses Study

Technical Note
October 2015

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Job No	CS072082		
Project	Kings Lynn Ordinary Watercourses Study		
Location	Kings Lynn		
Title	Technical Report		
Document Ref	N/A	**Issue / Revision**	2
File reference	Kings Lynn Ordinary Watercourses Study Report 01Oct_2015_v4.docx		
Date	October 2015		
Prepared by	Georgia Athanasia	Signature (for file)	
	Mohammed Mamun	Signature (for file)	
Checked by	Nicole Shamier	Signature (for file)	
Authorised by	Kerry Foster	Signature (for file)	

Revision Status / History

Rev	Date	Issue / Purpose/ Comment	Prepared	Checked	Authorised
1	August 2015	Draft for Comment	GA / MM / NS	MM/NS	KF
2	October 2015	Final	GA/MM/NS	MM/NS	KF

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Contents

Figures

Tables

Appendices

1. Introduction

1.1 Background

The Kings Lynn and West Norfolk Settlements Surface Water Management Plan (SWMP) was completed in January 2012. The study assessed pluvial flood risk to 16 settlements across West Norfolk for a range of flood events. Due to project constraints, the flood risk associated with ordinary watercourses was not specifically assessed. Norfolk County Council commissioned Capita to undertake a more detailed assessment of flood risk from ordinary watercourses within Kings Lynn and its interaction with surface water flooding. The existing SWMP hydraulic models were updated to meet the requirements of this study.

This Technical Report provides an update to the assessment of flood risk flood risk from ordinary watercourses within Kings Lynn and its interaction with surface water flooding. It should be read in conjunction with the January 2012 Kings Lynn and West Norfolk Settlements SWMP Report. This report also comprises the surface water flood mitigation options assessment for Kings Lynn.

1.2 Project Aims and Work Areas

The purpose of the project is to determine the potential impact of 'combined' surface water and ordinary watercourse flooding. This report aims to provide Norfolk County Council (NCC) with supporting evidence on the feasibility of the development of potential flood risk management measures within the study area. The work scope below is broken into three Work Areas as requested by NCC.

Work Area 1 – Update SWMP Model and Run Specified Scenarios
This work area comprises of the following sub-tasks:

- Assessment of existing studies by Norfolk County Council and King's Lynn IDB
- Model flood risk scenarios including asset failure and significant rainfall events
- Assess the impacts on people, properties and critical infrastructure
- Production of a Technical Note

Work Area 2 - Map, Measure and Assess 'Critical Structures' and Features
This work area comprises of the following sub-tasks:

- Site surveys of the watercourses and associated flood risk structures and features
- Mapping and detailing of structures and features associated with ordinary watercourses that have an effect on flood risk

Work Area 3 – Options Assessment
This work area comprises of the following sub-tasks:

- Options assessment of flood mitigation measures
- Develop Action Plan

2. SWMP Model Update

2.1 Modelling software

The model constructed for this study was simulated using the latest versions of ISIS and TUFLOW available at the time of the project start up (ISIS version 3. 7.0.110 and TUFLOW version 2013-12-AD-iDP). This will allow for use of the latest functionality available in each software package specifically the enhanced representation of soils infiltration. The mathematical solver for more recent versions of TUFLOW (as used for this study) also offers significant improvements in the stability of direct rainfall models.

2.2 Availability of existing models

2.2.1 SWMP TUFLOW models

Four 2D TUFLOW hydraulic models were constructed by Capita in 2012 to inform the SWMP study. The model named “Kings Lynn” covers the area of interest for this additional work and will be used to represent the 2D floodplain of a new model to be constructed for this study. Amendments and updates to certain model features are discussed in the subsequent sections of this document.

2.2.2 IDB studies

1D ISIS models of a number of the ordinary watercourses within Kings Lynn were commissioned by the Internal Drainage Board (IDB) in 2004 and 2009. These models were constructed for River Gaywood Strategic Review and for the Pierrepoint District Strategic Review and have been provided for use in this study. Table 2-1 below provides further details on these existing ISIS models. The model extents are shown in Figure 1-1.

Table 2-1: Existing ISIS models

Model Name	Description
River Gaywood and North Lynn ISIS model	The model has been has been developed by Hannah Reed (now part of PBA) in 2004 for the River Gaywood Strategic Review. The model includes River Gaywood (from the A149 to the tidal outfall into the River Great Ouse), Bawsey Drain (from Spring Lane to the tidal outfall into the River Great Ouse), Black Drain (from A149 to its confluence with the Bawsey Drain) and North Lynn Drain (from the culvert outlet north to Reid Way to the Tidal Outfall into the River Great Ouse, see Figure 1). The model has 961 nodes and since 2004 the model has been updated with recent survey data.
Pierrepoint ISIS model	The model has been developed by Hannah Reed (now part of PBA) in 2006 for the Pierrepoint District Strategic Review. The model includes Pierrepoint Drain (from north of Fair Green to its pumped outfall into the River Nar) and Middleton Stop Drain (from Station Road at Middleton Towers to its confluence with Pierrepoint Drain)-(see Figure 1). Model has 504 nodes and since 2006 the model has been updated for different development projects. The railway bridge on Middleton Stop Drain has not been modelled due to lack of survey data

2.3 Model extent

The existing extent of the 2D Kings Lynn SWMP TUFLOW model includes an area to the south that is not of interest as part of the Kings Lynn Ordinary Watercourse (KLOW) Study. This extent was trimmed as shown in Figure 1.1 in order to reduce model simulation times. The extent of the existing IDB's ISIS models remains same as shown in the Figure 1.1. More information about the modelling methodology can be found in Appendix A.

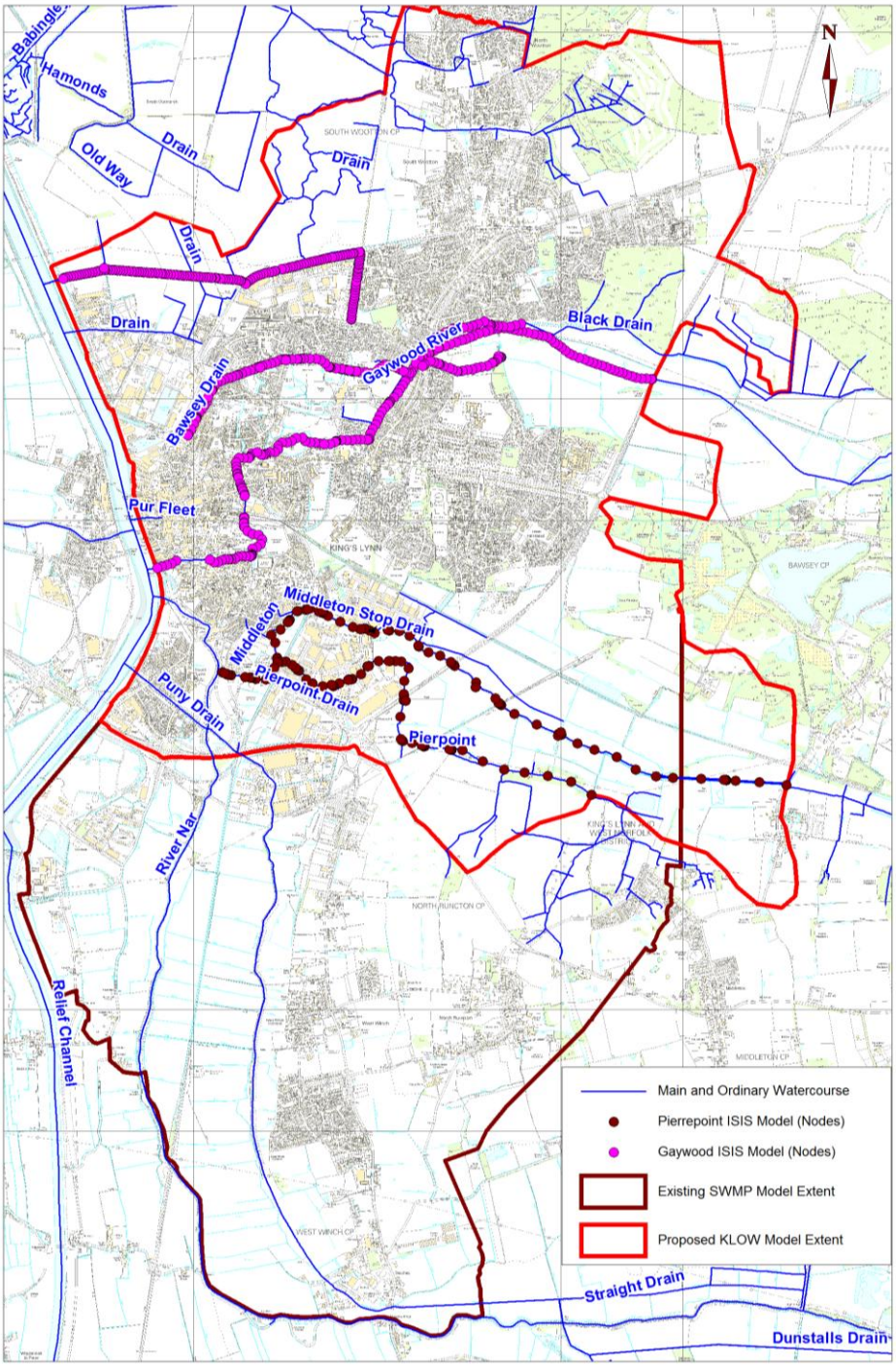

Figure 2-1: Model extents (existing SWMP and proposed KLOW model)

2.4 Additional survey requirements

A site walkover survey was carried out with stakeholders (NCC, Borough Council of Kings Lynn and West Norfolk (BCKLWN) and IDBs officials) on the 7th October 2014. During the site visit it was discussed that additional survey of the structures might not be required as most structures within the modelled reach have already been included in the existing IDB's ISIS models. The only structure not included in the existing model is the Railway Bridge on Middleton Stop Drain, (NGR562939, 319284). The Client (NCC) agreed and confirmed that no additional survey would be required for this project. The dimensions of the Railway Bridge on Middleton Stop Drain were measured during the site visit and the structure has been included in the KLOW model.

3. Baseline Assessment

3.1 Baseline Results

The detailed model built for this study provides an enhanced baseline representation of surface water flooding across the study area. Following the updates to the models (refer to Chapter 2 and Appendix A for more information), the baseline simulation was run to produce revised flood depth outputs for the area of interest. The model has been run for the following rainfall return periods:

- 3.3% Annual Exceedance Probability (AEP) (1 in 30 year);
- 1.33% AEP (1 in 75 year);
- 1% AEP (1 in 100 year)
- 1% AEP (1 in 100 year) including the effects of climate change; and
- 0.5% AEP (1 in 200 year).

The modelling outputs for the 100 year event are presented in Figure 3.1 below. Refer to Appendix D (Figures 1-5) for the other return periods.

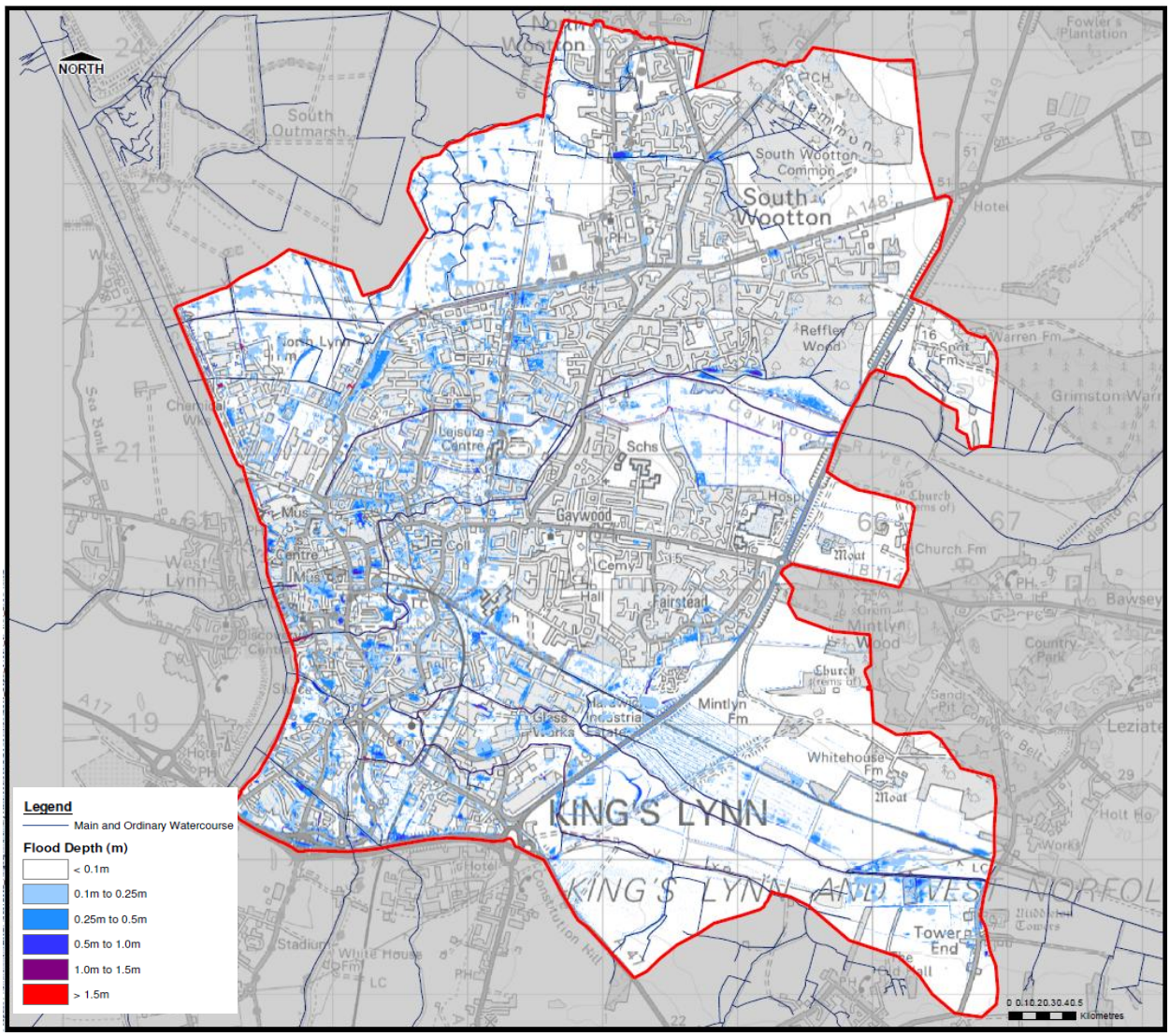

Figure 3-1: Baseline results (1 in 100 year event - pluvial)

In order to assess the fluvial impact in the area the baseline model was also run with fluvial inflow only (no rainfall was applied). The model results for the 1 in 100 year fluvial event are presented in Figure 3.2. Refer to Figures 6-10 in Appendix D for the remaining return periods.

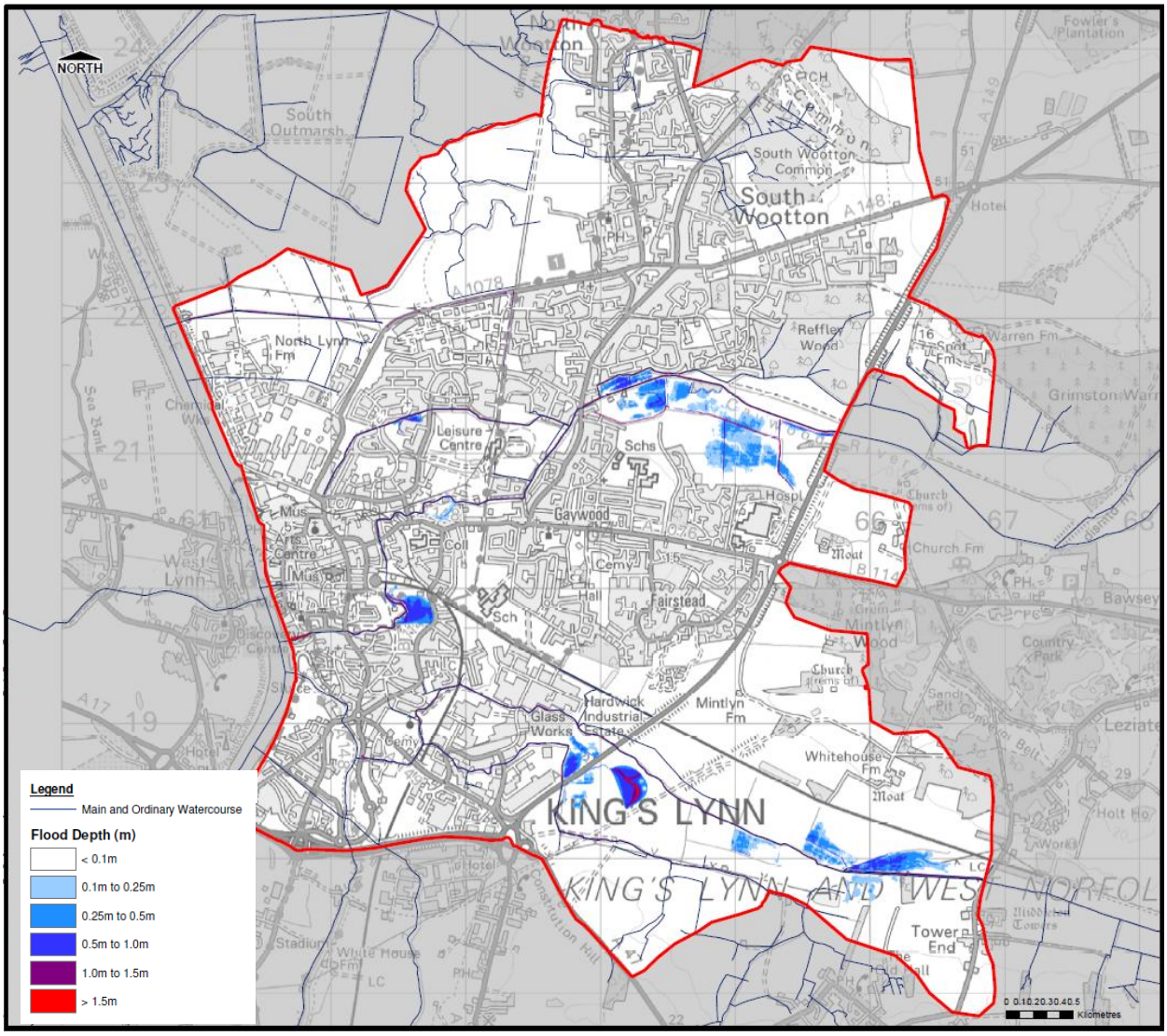

Figure 3-2: Baseline results (1 in 100 year event - fluvial)

The pluvial model shows more severe flooding within the area of interest therefore these outputs were used to identify the Critical Drainage Catchments (CDCs) and the recommended appraisal options, which are described in the sections below.

A Blockage scenario was run for some key structures in the area of interest. However, the model results of this scenario did not show any significant increase in flooding within the study area (refer to Appendix D for the model results of the Blockage scenario – Figures 11-22).

3.2 Critical Drainage Catchments

The results of this modelling have been used to identify Local Flood Risk Zones (LFRZs) where surface water flooding affects properties, businesses and/or infrastructure. Those areas identified to be at more significant risk have been delineated into Critical Drainage Catchments (CDCs) representing one or more LFRZs as well as the contributing catchment area and features that influence the predicted flood extent.

Within the study area, twelve (12) final CDCs have been identified which have discussed and agreed with NCC, and are presented in Figure 3.3. The dominant mechanisms for flooding can be broadly divided into the following categories:

- Topographical low lying areas – are more susceptible to surface water flooding particularly where obstructions impede flow; and
- Topographical low points – areas which are at topographical low points throughout the Borough (predominantly from basement properties) which result in small, discrete areas of deep surface water ponding.

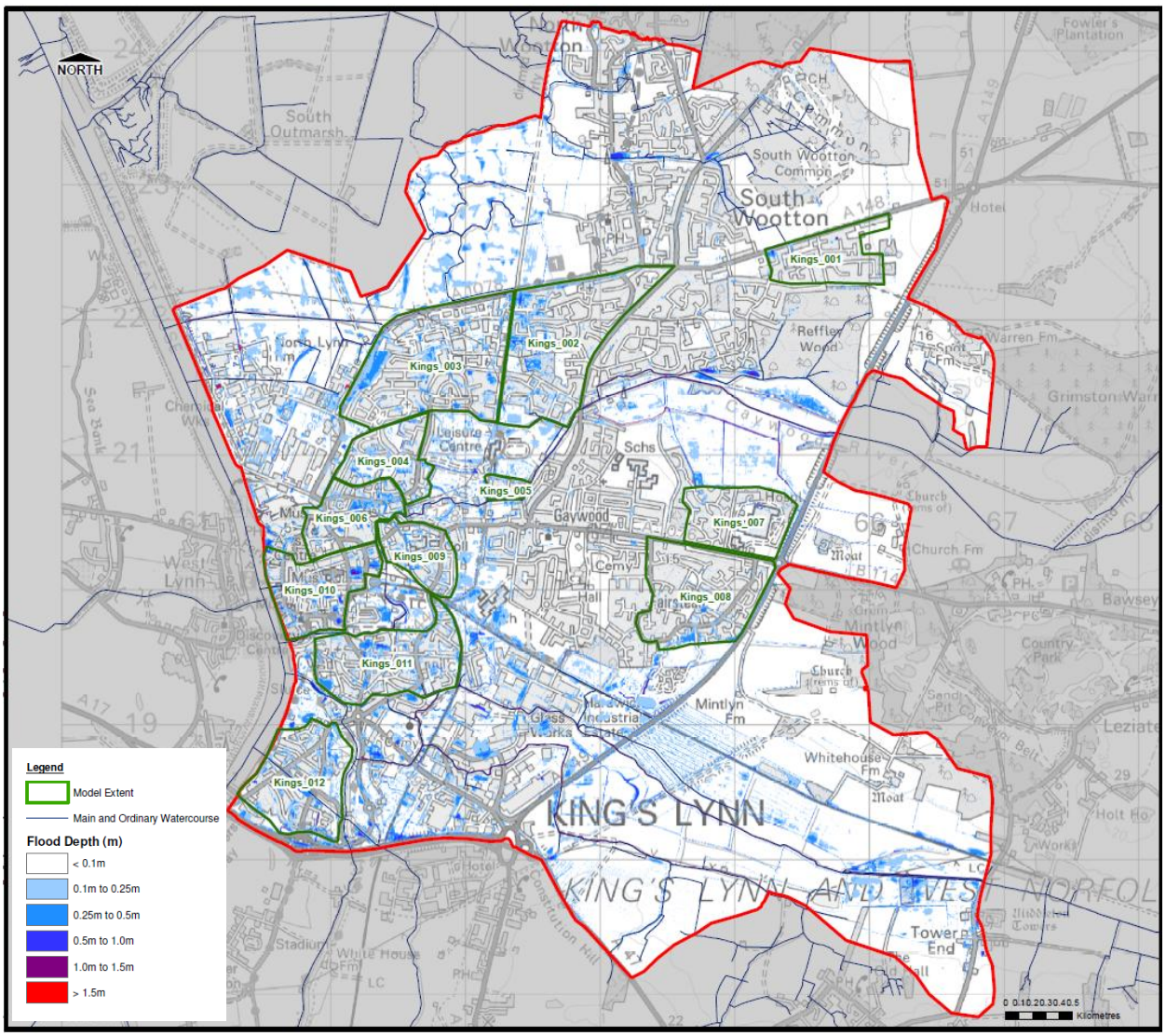

Figure 3-3: Critical Drainage Catchments.

3.3 Baseline Damage Assessment

A damage assessment was undertaken based on the Environment Agency's Flood and Coastal Erosion Risk Management Appraisal Guidance (FCERM-AG) and the Multi Coloured Manual (Middlesex, 2014). The methodology for the damage assessment is outlined in Appendix B.

The hydraulic modelling has estimated the following properties at risk of flooding under each flood event.

Table 3-1: Properties at risk (baseline model)

CDCs	30yr	75yr	100yr	100yrCC	200yr
Kings_001	0	4	6	14	13
Kings_002	18	85	112	202	180
Kings_003	48	101	116	179	160
Kings_004	10	27	28	60	55
Kings_005	2	2	3	5	5
Kings_006	58	98	111	141	132
Kings_007	5	7	7	9	9
Kings_008	4	9	16	50	42
Kings_009	35	54	59	96	85
Kings_010	98	138	143	188	172
Kings_011	57	102	128	241	223
Kings_012	65	98	114	184	164
Out Side	50	81	96	179	154
Total	450	806	939	1548	1394

Expected damage data has been scaled up over the appraisal time period by multiplying the expected annual average damage by 100 years. These were then discounted; discounting is an adjustment which reduces the size of future values to represent, within the appraisal, the preference of society to receive benefits sooner. Discounting is an obligation set out in the Treasury Green Book which influences the expenditure of Grant in Aid to projects with more rapid outcomes. The sum of discounted benefits over the appraisal period is the Present Value Benefits; these are presented in the table below.

Table 3-2: Baseline damages

CDCs	Damage (PVd – Present Value damage) (£)
CDC 01	876,408
CDC 02	3,381,574
CDC 03	2,877,150
CDC 04	1,056,465
CDC 05	147,666
CDC 06	2,233,713
CDC 07	523,659
CDC 08	2,346,919
CDC 09	1,437,247
CDC 10	3,238,672
CDC 11	3,978,479
CDC 12	2,510,125

4. Option Assessment

4.1 Option Identification

A long list of potential flood risk management options for alleviating flooding in the area was developed with reference to the baseline modelling results and knowledge of the study area. The following potential options were discussed with Norfolk County Council during a Progress Meeting (18th March 2015):

Source Measures

- SUDS – Small Scale (Green roofs, rain gardens, permeable paving, soakaways)
- SUDS – Large Scale (Wetlands, ponds, detention basins) - SUDL

Pathway Measures

- Increase drainage capacity (more gullies, bigger pipes, more pipes)
- Separation of sewers
- Managed overland flows
- Improved land management practices

Receptor Measures

- Property level protection (PLP)
- Temporary defence raising
- Resilience and resistance
- Planning policy changes
- Improved emergency response
- Raise Kerbing (RAK)

4.2 Option Selection

From this list above, four of the most suitable options for the area were then selected and included in the hydraulic modelling to provide supporting information for the final choice of options. These four options are:

1. Large Scale SUDS (SUDL) – Ponds and detention basins;
2. Small Scale SUDS (SUDS) – Permeable Pavement;
3. Raise Kerbing (RAK); and
4. Property level Protection (PLP).

In the 3rd progress meeting on 29th April 2015 the model results of the above four options (for all the CDCs) were presented and discussed with the Steering group. Following the progress meeting (April 2015) the Steering group selected a combined option for five of the CDCs. The selected options to be taken forward for assessment are:

- CDC 02: Infiltration Basins and Pond.
- CDC 03: Small infiltration Basins.
- CDC 04: Infiltration Basin off Raby Avenue.
- CDC 06: Infiltration Basin in Loke Park.
- CDC 12: Infiltration Basins.

It was agreed that options would not be selected for the rest CDCs either because there were too few properties benefiting from them to justify works or because there was little space for Sustainable Urban Drainage Systems (SUDS) features.

Further information on the option model results can be found in Figures 23-26 on Appendix D.

4.3 Option Appraisal

All five shortlisted options mentioned above were considered to be technically feasible and progressed for appraisal. Options were packaged together per CDC to form the 'Combined Option' for each individual CDC, as recommended by the client. Although we would usually appraise a number of competing options within the appraisal, in this case, the combined option was judged by the client as the only option which would provide a significant enough reduction in flood risk to make investment worthwhile. Therefore the options appraisal will only consider the combined options as listed in section 4.2.

The table below shows the number of properties which are expected to experience flooding from a 1 in 100 event (moderate), 1 in 30 event (significant) and 1 in 20 event (very significant) under the Do Nothing and the Combined Option Scenarios for each CDC.

Table 4-1: Number of flooded properties

	Baseline Scenario	Mod	Sig	V. Sig	**Combined Option**	Mod	Sig	V. Sig
CDC 02	20% Most Deprived	0	0	0	20% Most Deprived	0	0	0
	40% Most Deprived	191	81	34	40% Most Deprived	176	56	28
	60% Least Deprived	25	6	4	60% Least Deprived	23	6	4
	Baseline Scenario	Mod	Sig	V. Sig	**Combined Option**	Mod	Sig	V. Sig
CDC 03	20% Most Deprived	184	102	33	20% Most Deprived	170	92	31
	40% Most Deprived	0	0	0	40% Most Deprived	0	0	0
	60% Least Deprived	0	0	0	60% Least Deprived	0	0	0
	Baseline Scenario	Mod	Sig	V. Sig	**Combined Option**	Mod	Sig	V. Sig
CDC 04	20% Most Deprived	61	29	12	20% Most Deprived	61	29	12
	40% Most Deprived	19	4	3	40% Most Deprived	19	4	3
	60% Least Deprived	0	0	0	60% Least Deprived	0	0	0
	Baseline Scenario	Mod	Sig	V. Sig	**Combined Option**	Mod	Sig	V. Sig
CDC 06	20% Most Deprived	69	51	13	20% Most Deprived	68	51	13
	40% Most Deprived	92	59	17	40% Most Deprived	58	51	17
	60% Least Deprived	0	0	0	60% Least Deprived	0	0	0
	Baseline Scenario	Mod	Sig	V. Sig	**Combined Option**	Mod	Sig	V. Sig
CDC 12	20% Most Deprived	103	56	14	20% Most Deprived	95	51	17
	40% Most Deprived	89	44	16	40% Most Deprived	80	43	14
	60% Least Deprived	0	0	0	60% Least Deprived	0	0	0

Note: Indices of Deprivation are produced by Communities and Local Government (CLG) to measure deprivation for every Lower Layer Super Output Area (LSOA) and local authority area in England. 32,482 LSOAs are ranked according to how deprived they are relative to each other.

Assumptions and limitations

The appraisal considered the costs and impacts of options over 100 year timeframe (years 0-99). The base year (year 0) is 2015. All previous prices were uplifted to present day prices and inflation has not been included within forecasts. All future costs and benefits are discounted using the Treasury Social Time Preference rate which is 3.5% for years 0-29, 3% from years 30-74 and 2.5% for years 75-99.

When assessing the costs to implement a scheme, all costs were considered including not only construction costs but also those to promote, design and maintain the scheme. In addition to this, an "optimism bias" was applied to cost evaluations. The optimism bias takes into consideration any potential under estimations of cost that might be made during the early assessment of a scheme and therefore allows for a more conservative and potentially more pragmatic cost assessment. The unit costs and associated assumptions are outlined in Appendix C.

Costs were then inputted into the Defra Appraisal Spreadsheet relating to the year they were expected to be spent. The Defra Appraisal Spreadsheet calculated net present value over the 100 year lifetime of the appraisal, using the Treasury social time preference rate. This rate is 3.5% in years 0 to 30, 3% from years 31 to 75 and 2.5% from year 76 to 99. Discounting is an adjustment used in appraisal to reflect the preference of society to receive benefits (flood risk damage reduction) sooner and pay costs later.

4.4 Option Damage Assessment

A damage assessment was undertaken for the shortlisted options. The methodology for the damage assessment is outlined in Appendix B.

Benefits

Modelling has estimated the following properties at risk of flooding under each flood event.

Table 4-2: Number of flooded properties for the baseline and combined option

	Flood event				
CDC 02 - Residential	Q30	Q75	Q100	Q200	Q100CC
Baseline	18	85	115	186	213
Combined Option	16	61	81	156	197
CDC 02 - Non residential	Q30	Q75	Q100	Q200	Q100CC
Baseline	0	0	0	0	0
Combined Option	0	0	0	0	0

	Flood event				
CDC 03 - Residential	Q30	Q75	Q100	Q200	Q100CC
Baseline	48	102	116	160	179
Combined Option	44	92	109	150	165
CDC 03 - Non residential	Q30	Q75	Q100	Q200	Q100CC
Baseline	0	0	2	2	2
Combined Option	0	0	2	2	2
CDC 04 - Residential	Q30	Q75	Q100	Q200	Q100CC
Baseline	9	29	30	59	64
Combined Option	9	29	30	59	64
CDC 04 - Non residential	Q30	Q75	Q100	Q200	Q100CC
Baseline	2	2	2	8	8
Combined Option	2	2	2	8	8
CDC 06 - Residential	Q30	Q75	Q100	Q200	Q100CC
Baseline	52	94	112	131	140
Combined Option	52	86	94	129	132
CDC 06 - Non residential	Q30	Q75	Q100	Q200	Q100CC
Baseline	2	4	4	6	7
Combined Option	2	4	4	6	7
CDC 12 - Residential	Q30	Q75	Q100	Q200	Q100CC
Baseline	59	92	108	158	182
Combined Option	59	86	101	145	165
CDC 12 - Non residential	Q30	Q75	Q100	Q200	Q100CC
Baseline	0	0	0	0	0
Combined Option	0	0	0	0	0

Expected damage data has been scaled up over the appraisal time period by multiplying the expected annual average damage by 100 years. These were then discounted; discounting is an adjustment which reduces the size of future values to represent, within appraisal, the preference of society to receive benefits sooner. Discounting is an obligation set out in the Treasury Green Book which influences the expenditure of Grant in Aid to projects with more rapid outcomes. The sum of discounted benefits over the appraisal period is the Present Value Benefits; these are presented in the table below.

Table 4-3: Damages avoided compared to the baseline

	Damage (PVd) (£)	**Damage Avoided (£)**	**Benefits (PVb) (£)**
CDC 02 – Combined Option	3,042,833	338,741	338,741
CDC 03 – Combined Option	2,792,812	84,339	84,339
CDC 04 – Combined Option	1,056,465	0	0
CDC 06 – Combined Option	2,055,489	178,225	178,225
CDC 12 – Combined Option	2,439,120	71,005	71,005

The damage avoided as a result of the options developed is greatest in CDC 02, followed by CDC 06 and then CDC 03 and 12. We still expect to see damages from flooding; this is because the options reduce the depth of flooding, but many of the properties are still likely to be flooded but less frequently and to lower depths.

The results of this assessment are shown in the table below. Present Value Costs are the total discounted costs of implementing the chosen flood protection scheme. Present Value Damages are the total discounted damages caused by the effects of flooding. The Net Present Value is the Present Value Benefits (Damages Avoided) less Present Value Costs. The benefit cost ratio is calculated as Present Value Benefits divided by Present Value Costs. Where the Net Present Value is greater than £0 and Benefit Cost Ratio is greater than 1; benefits exceed costs.

Table 4-4: Benefit cost assessment

CDC	PV costs (£)	PV benefits (£)	Average benefit cost ratio (BCR)
02	12,385,798	338,741	0.03
03	7,647,441	84,339	0.01
04	1,286,254	0	0.00
06	1,694,393	178,225	0.11
12	5,248,082	71,005	0.01

The combined option in each CDC has a benefit cost ratio of less than 1. Although the combined option are beneficial in most of the CDCs, the benefit cost ratio is less than 1, meaning that spending more budget on the combined option would not achieve higher benefits per extra pound spent.

5. Action Plan

5.1 Structure and Content

An Action Plan has been developed to outline a range of recommended measures that should be undertaken to manage surface water within Kings Lynn more effectively. It outlines the responsibilities and implications of both structural and non-structural options and details the methods, timescale and responsibility of each proposed action.

Within the Action Plan there are details of general measures that could be implemented across Kings Lynn as well as more specific measures based on the options assessment. The general actions are non-structural and encourage improved surface water management through planning policy and public education and awareness.

The Action Plan should be read in conjunction with details referenced within relevant sections of this document. The Action Plan is included in Appendix E of this report. This is a DRAFT document and it will be revised following client's review.

This Action Plan is a simple summary spreadsheet that has been formulated by reviewing the modelling outputs in order to create a useful set of actions relating to the management and investigation of surface water flooding going forward. It is the intention that the Action Plan is a live document, maintained and regularly updated as actions are progressed and investigated. New actions may be identified by the LLFA, or may be required by changing legislation and guidance over time.

6. Conclusions and Recommendations

6.1 Conclusions

This report comprises the surface water flood mitigation options assessment for Kings Lynn.

As part of the assessment the existing SWMP hydraulic models were updated to incorporate all latest features of the software used. The model constructed for this study was simulated using the latest versions of ISIS and TUFLOW. This allowed for use of the latest functionality available in each software package specifically enhanced representation of soils infiltration.

A pluvial and a fluvial model was run for the area of interest in order to identify the impacts the pluvial and fluvial flood events will have in the study area. Assessment of the model results identified that the pluvial model produces more severe flooding in the Kings Lynn area. Therefore, the pluvial model was used as the baseline model for this study.

Asset failure scenarios for the key structures were also run. The model results indicated that this scenario does not produce any significant changes in flood depth.

Critical Drainage Catchments (CDCs) were identified based on the baseline results. Twelve CDCs were identified in the Kings Lynn area. Following consultation with NCC combined options were developed for five of them.

A damage assessment was performed for the baseline model as well as the combined options. The damage avoided as a result of the options developed is greatest in CDC 02, followed by CDC 06 and then CDC 03 and 12. Damages will still be expected from flooding; this is because the options reduce the depth of flooding, but many of the properties are still likely to be flooded, but less frequently and to lower depths.

The results of this assessment show that the combination of the options chosen to be used in each CDC has a benefit cost ratio of less than 1 for each CDC.

6.2 Recommendations

The updated model used for this study does not include the drainage network. Inclusion of the pipe network in the model might refine the model results for the area of interest.

Action could be taken in order to reduce flood risk within the CDCs. Below are a series of recommendations to further reduce the risk of surface water flooding in the area:

- As part of highways improvement programme include an additional construction task of installing additional gullies or alternative drainage systems to reduce standing water depth and duration.
- Include at least one 'at source' SuDS measure to all proposed developments across the catchment.

- Proposed ‘brownfield’ redevelopments are required to reduce post-development runoff rates for events up to and including the 1 in 100 year return period event with an allowance for climate change. (Refer to Action Plan in Appendix E for more information).

- Focus attention on the maintenance of gully pots in the CDCs which are considered to be high risk.