Great Yarmouth Borough

Surface Water Management Plan

Stage 2 Report

Final
July 2014

Prepared for:

Norfolk County Council

Great Yarmouth Borough Council

love every drop
anglianwater

Revision Schedule

DOCUMENT INFORMATION

Title:	Great Yarmouth Borough Surface Water Management Plan
Owner:	Norfolk County Council / Great Yarmouth Borough Council / Anglian Water
Version:	0.4
Status:	Final
Project Number:	CS/058209
File Name:	GreatYarmouth_SWMP_v0.4_Final.docx

REVISION HISTORY

Details and Summary of Changes	Completed By	Date of Issue	Version
Original	Capita Symonds URS	01/07/2013	0.1
Update following review by SWMP Steering Group	Capita Symonds URS	08/10/2013	0.2
Update following final review by SWMP Steering Group	Capita Symonds URS	29/11/2013	0.3
Update following final review by SWMP Steering Group	Norfolk County Council	18/07/14	0.4

AUTHORS

Name	Organisation
Michael Arthur	Associate Director, Capita Symonds Ltd
Georgia Athanasia	Graduate, Capita Symonds Ltd
Sarah Kelly	Senior Water Specialist, URS Infrastructure & Environment UK Limited

APPROVALS

Name	Title	Signature	Date
Mark Ogden	Surface Water Project Officer (Norfolk County Council)		
Jan Davis	Emergency Planning Manager (Great Yarmouth Borough Council)		
Andy Bird	Senior Wastewater Asset Modeller (Anglian Water)		

This document and related appendices have been prepared on behalf of Norfolk County Council, Great Yarmouth Borough Council and Anglian Water by:

CAPITA SYMONDS | URS
Procter House, 1 Procter Street, London WC1V 6DW
www.capitasymonds.co.uk

Acknowledgements

A number of people and organisations outside Norfolk County Council, Great Yarmouth Borough Council and Anglian Water have contributed to this Surface Water Management Plan. Their assistance is greatly appreciated. Particular inputs and information has been provided by:

- Environment Agency
- Broads (2006) Internal Drainage Board
- Waveney, Lower Yare & Lothingland Internal Drainage Board

Executive Summary

Purpose

This document forms the Surface Water Management Plan (SWMP) for Great Yarmouth Borough. The SWMP investigates the risks of surface water flooding and proposes a surface water management strategy for Great Yarmouth Borough. Surface water flooding describes flooding from sewers, drains, groundwater, runoff from land, small watercourses and ditches that occurs as a result of heavy rainfall (as illustrated in Figure ES1 below).

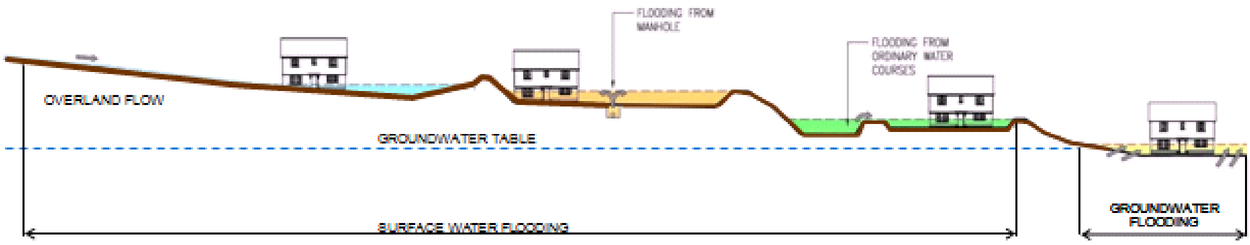


Figure ES1: Surface Water Flooding

The SWMP is being undertaken in Great Yarmouth Borough as a result of Norfolk County Councils Preliminary Flood Risk Assessment (PFRA) work. The PFRA identified Great Yarmouth Borough as a priority area. In an extreme rainfall event, approximately 7,000 people could be affected by flooding, along with over 700 non-residential properties and more than 30 critical service locations (schools, utilities services (water/power) and hospitals). The level of risk was also validated by significant flooding occurring in 2006 due to prolonged rainfall. More than 90 properties in Great Yarmouth and Lowestoft were affected.

The aim of a SWMP is to understand and resolve complex, high risk surface water flooding problems in urbanised areas. A SWMP brings together key local partners, with responsibility for surface water and drainage in their areas, to collaborate to investigate the causes of surface water flooding and agree the most cost effective way of managing surface water flood risk.

Partnership

The project is jointly funded by Norfolk County Council, Great Yarmouth Borough Council and Anglian Water Services. These organisations form the leadership of the project Steering Group that is actively supported by the Environment Agency, local Internal Drainage Boards (IDBs) and representatives from the Broads Authority. In order to provide an integrated approach to surface water management, it is important that key stakeholders with responsibility for different flood mechanisms are able to work together in a holistic manner.

Risk Assessment

The purpose of the risk assessment phase is to determine the level of probable future risk within Great Yarmouth Borough, prioritise higher risk areas for further investigation and identify ‘quick win’ flood mitigation actions.

<u>Strategic Assessment</u>

An initial strategic assessment of risk completed by the Steering Group identified the following settlements as being vulnerable to surface water flooding:

- Martham
- Winterton-on-Sea
- Caister-on-Sea
- Great Yarmouth

- Hemsby
- Ormesby-St-Margaret
- Hopton-on-Sea
- Gorleston
- Bradwell
- Belton

Intermediate Assessment

This assessment used existing flood risk information combination with a series of site visits to assess probable surface water flood risk to the above ten settlements within Great Yarmouth Borough. The purpose of this assessment was to correlate historic incident information with the national level Flood Map for Surface Water (FMfSW) and determine the priority for further investigation work. Priority for detailed assessment was determined using a combination of known historic incidents, potential for future development, potential environmental impacts and predicted number of buildings flooded (using the national FMfSW).

The prioritisation process identified the following settlements for further detailed assessment:

- Great Yarmouth inc. Gorleston (south of River Yare) – Detailed Modelling
- Great Yarmouth (north of River Yare) – Detailed Modelling
- Bradwell – Detailed Modelling
- Caister-on-Sea – Engineering Judgement Based Detailed Assessment
- Hemsby - Engineering Judgement Based Detailed Assessment

The remaining settlements (Martham, Hopton-on-Sea, Winterton-on-Sea and Belton) have been assessed at the intermediate level only and have flood risk management actions defined for each based on local conditions. They have not been progressed for detailed assessment as the available flood risk information is judged sufficient to be able to make effective risk management decisions.

Detailed Assessment

Detailed risk assessment using a combination of computer modelling and engineering judgement based methods identified eight (8) Critical Drainage Areas (CDAs) as shown in Figure ES2. The risk assessment process identifies the areas of probable flooding (the 'impacts') and the surrounding area that contributes runoff (the 'catchment') - the combination of these areas is defined for the purposes of this study as a CDA. The definition of a CDA in this context is:

> *'a discrete geographic area (usually a hydrological catchment) where multiple or interlinked sources of flood risk cause flooding during a severe rainfall event thereby affecting people, property or local infrastructure.'*

Approximately 342 properties could be at risk of flooding during a rainfall event with a **1** in **100** probability of occurrence in any given year with the CDAs in the Great Yarmouth urban areas. Table ES1 summarises the types of properties predicted to be flooded. Approximately 1,042 properties could be at risk of flooding during a rainfall event with a **1** in **200** probability of occurrence in any given year with the CDAs in the Caister and Hemsby areas. It should be noted that two different probabilities have been used for the CDA assessment as each relies on a different flood risk data set. Computer modelling was completed for the Great Yarmouth urban areas while Hemsby / Caister were assessed using a nation wide surface water flood risk map. The nation wide surface water flood risk map was used for Hemsby / Caister as this was judged to be a good representation of local flood risk without the need for computer modelling as part of this study.

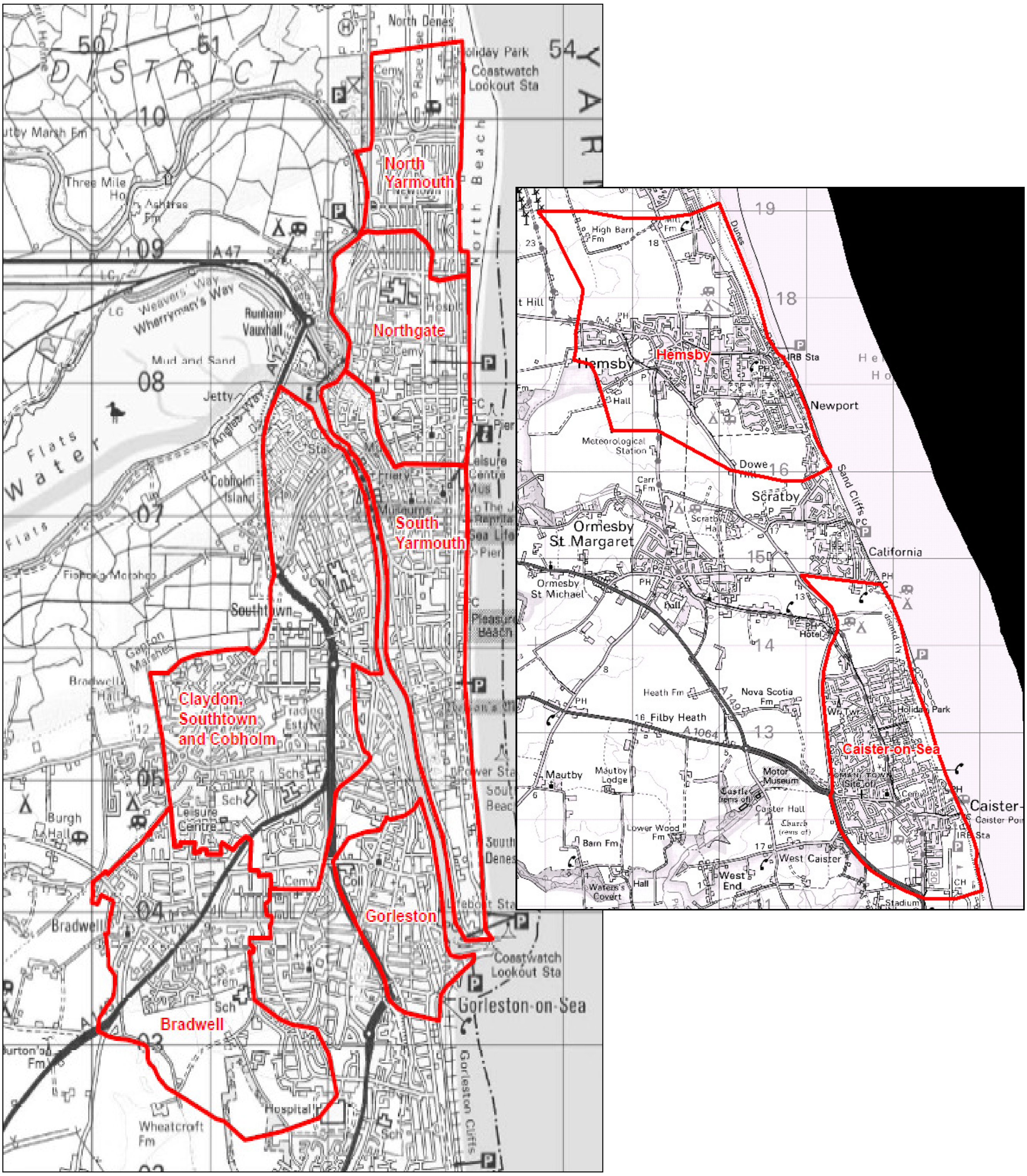


Figure ES2: Critical Drainage Areas

Table ES1: Predicted Flooded Properties Summary – 1 in 100 Year Flood Event (Great Yarmouth Urban Area CDAs)

Property Type	Flood Risk Vulnerability Classification	Number of flooded properties above depth threshold	
		>0.1m	>0.5m
Infrastructure	Essential Infrastructure	0	0
	Highly Vulnerable	3	1
	More Vulnerable	4	0
Households	Non-Deprived	73	0
	Deprived	173	14
Commercial / Industrial	Units (All)	40	4
Others	Other Flooded Properties	48	4
	Unclassified Flooded Properties	0	0
	Infrastructure Other	1	0
Total		**342**	**23**

Table ES2: Predicted Flooded Properties Summary – 1 in 200 Year Flood Event (Caister and Hemsby CDAs)

Property Type	Flood Risk Vulnerability Classification	Number of flooded properties above depth threshold	
		>0.1m	>0.3m
Infrastructure	Essential Infrastructure	0	0
	Highly Vulnerable	2	0
	More Vulnerable	4	0
Households	Non-Deprived	601	137
	Deprived	0	0
Commercial / Industrial	Units (All)	22	7
Others	Other Flooded Properties	404	137
	Unclassified Flooded Properties	0	0
	Infrastructure Other	9	4
Total		**1042**	**285**

Refer Table 6-7 (Infrastructure Sub-Categories) in Section 6.3 (Flood Risk Summary) for an explanation of infrastructure class types

Options Assessment

The options assessment defines which options are generally available for reducing flood risk within the study area and specific concept level mitigation solutions for each of the CDAs. As well as surface water, consideration is given to other sources of flooding and their interactions with surface water flooding, with particular focus on options which will provide flood alleviation from combined flood sources. Approximate capital cost estimates of the potential CDA options have been determined, but it should be noted that no funding has been confirmed or is guaranteed at present. Potential funding opportunities are still to be explored by the Steering Group.

To assist with prioritisation and programming of further work on all CDAs, a basic prioritisation methodology based on the number of properties predicted to be at risk was applied to the CDAs. At this stage of flood risk investigation and mitigation it is important to keep this method simple and transparent to ensure clear interpretation of the decision making process to prioritise one area over another. This will aid in demonstrating that future spending on surface water management is distributed equitably around the study area. The high priority CDAs were identified to be South Yarmouth, Northgate, Caister-on-Sea and Hemsby. For each High Priority CDA, it is recommended that the Steering Group:

- Undertake a detailed feasibility study
- Complete further public consultation
- Review all benefits of proposed schemes and identify links with partner organisation goals

Medium and Low Priority CDAs do not justify immediate further investigation, but should have the following actions considered for implementation. Evidence gathered from these actions may increase the level of priority or identify quick win actions in the future.

- Monitor flood risk related problems and manage future development using proposed CDA preferred options to minimise impact on flood risk
- Work proactively to monitor the condition of ordinary watercourses and associated culverts and review maintenance practices as required.
- Work proactively with the EA and local IDBs to monitor the condition of Main Rivers, culverts and defences.
- Engage NCC Highways and the Highways Agency to monitor any future flooding and assess the associated risk on all Major Roads

Action Plan

The Action Plan outlines a wide range of recommended measures that could be undertaken to manage surface water within the study area more effectively by each of the Steering Group members. The Action Plan identifies:

- General flood risk management actions to integrate outcomes, recommendations and new information from this study into the practices of all Steering Group organisations
- Strategic Planning Policy actions to assist NCC and GYBC to manage future developments in the context of local flood risk management
- Maintenance actions to prompt possible review of current schedules in the context of new information presented in this study
- High priority CDA actions to be considered to better understand flood risk in specific areas and proactively manage operational risks
- All CDA actions to be considered across all CDAs identified within this study
- Transport infrastructure risk assessment actions to investigate at risk major roads and pedestrian underpasses to understand the potential risk associated with each

The SWMP Action Plan is a 'living' document and should be reviewed / updated regularly. Triggers could include the occurrence of a surface water flood event, when additional data or modelling becomes available, following the outcome of investment decisions by partners and following any additional major development or changes in the catchment which may influence the surface water flood risk within the study area.

Implementation

Implementation of the Action Plan will require continued work within the Steering Group. NCC should coordinate with relevant internal and external partners in order to ensure a holistic approach to the implementation of outputs and actions from the SWMP. The sections below summarise the implementation actions that should be considered by each of the Steering Group partners:

Anglian Water

Consider how the outputs from this SWMP could be used to influence investment and funding schedule for drainage improvements and maintenance programmes across the study area

Strategic Planning (NCC and GYBC)

There are three key avenues by which the findings of this SWMP are recommended to be taken forward through the planning system:

1. The SWMP maps which identify potential areas that are more vulnerable to surface water flooding should be used in addition to information in SFRAs
2. The SWMP maps which identify potential areas that are more vulnerable to surface water flooding should be used to update/prepare policies in the Local Plan
3. The SWMP maps which identify potential areas that are more vulnerable to surface water flooding should be used to inform development decisions for sites or areas by either:
    - Resulting in modifications to strategies, guidance, or policies for major development locations (e.g. through Area Action Plans and Supplementary Planning Guidance); or
    - Influencing planning decisions in relation to the principle, layout or design of particular development proposals.

Emergency Planning (NCC and GYBC)

The SWMP surface water flood maps can be used to:

- Identify vulnerable people or groups of vulnerable people who are at risk of flooding
- Identify critical transport routes that could be subject to flooding
- Understand how emergency response infrastructure (fire stations, ambulance stations, police stations, hospitals and command centres) and related access routes may be impacted by flooding
- Estimate the overall cumulative impact of a significant rainfall event (i.e. the combined impact of access route blockage, flooding of significant infrastructure and impact to groups of properties)
- Identify groups of buildings that are potentially at risk of significant flooding
- Hazard rating and predicted depth maps show clear differentiation of level of risk that may be encountered within each area of predicted flooding

Review

Timeframe

It is recommended that the Action Plan is regularly reviewed and updated to reflect any necessary amendments. In order to capture the works undertaken by Steering Group members, it is recommended that the Action Plan review should be on an annual basis.

Monitoring

The SWMP Action Plan should be reviewed and updated annually as a minimum, but there may be circumstances which might trigger a review and/or an update of the SWMP and/or the Action Plan in the interim. Examples of events which would likely trigger a review include:

- Occurrence of a surface water flood event
- Additional data or modelling becoming available, which may alter the understanding of risk within the study area
- Outcome of investment decisions by partners is different to the preferred option, which may require a revision to the action plan
- Additional (major) development or other changes in the study area which may affect the surface water flood risk

Glossary and Abbreviations

Term	Definition
AEP	Annual Exceedance Probability (represented as a %)
Aquifer	A source of groundwater comprising water bearing rock, sand or gravel capable of yielding significant quantities of water.
Anglian Water Services (AWS)	The Water and Sewerage Company for the study area.
Asset Management Plan (AMP)	A plan for managing water and sewerage company (WaSC) infrastructure and other assets in order to deliver an agreed standard of service. This is Anglian Water Services within the study area.
Areas Susceptible to Groundwater Flooding (AStGWF)	A national data set held by the Environment Agency identifying the risk of groundwater emergence within an area.
Areas Susceptible to Surface Water Flooding (AStSWF)	A national data set held by the Environment Agency and based on high level modelling which shows areas potentially at risk of surface water flooding.
Bank Full	The flow stage of a watercourse in which the stream completely fills its channel and the elevation of the water surface coincides with the top of the watercourses banks.
BGS	British Geological Survey
Catchment Flood Management Plan (CFMP)	A high-level planning strategy through which the Environment Agency works with their key decision makers within a river catchment to identify and agree policies to secure the long-term sustainable management of flood risk.
Critical Drainage Area (CDA)	A discrete geographic area (usually a hydrological catchment) where multiple and interlinked sources of flood risk (surface water, groundwater, sewer, Main River and/or tidal) cause flooding during severe weather thereby affecting people, property or local infrastructure.
CIRIA	Construction Industry Research and Information Association
Civil Contingencies Act	This UK Parliamentary Act delivers a single framework for civil protection in the UK. As part of the Act, Local Resilience Forums have a duty to put into place emergency plans for a range of circumstances including flooding.
Climate Change	Long term variations in global temperature and weather patterns caused by natural and human actions.
Community Resilience	A measure of the sustained ability of a community to utilise available resources to respond to, withstand, and recover from adverse situations
Culvert	A channel or pipe that carries water below the level of the ground.
DCLG	Government Department for Communities and Local Government
Defra	Government Department for Environment, Food and Rural Affairs
DEM	Digital Elevation Model: a topographic model consisting of terrain elevations for ground positions at regularly spaced horizontal intervals. DEM is often used as a global term to describe DSMs (Digital Surface Model) and DTMs (Digital Terrain Models).
Dendritic	Irregular stream branching, with tributaries joining the main stream at all angles. e.g. drainage networks converge into larger trunk sewers and finally one outfall.
DG5 Register	A water-company held register of properties which have experienced sewer flooding due to hydraulic overload, or properties which are 'at risk' of sewer flooding more frequently than once in 20 years.
Digital Surface Model (DSM)	A topographic model of the bare earth/underlying terrain of the earth's surface including objects such as vegetation and buildings.

Term	Definition
Digital Terrain Model (DTM)	A topographic model of the bare earth/underlying terrain of the earth's surface excluding objects such as vegetation and buildings. DTMs are usually derived from DSMs.
Environment Agency (EA)	Government Agency reporting to Defra charged with protecting the environment and managing flood risk in England.
Flood and Coastal Erosion Risk Management Strategy. (FCERMS)	Prepared by the Environment Agency in partnership with Defra. The strategy is required under the Flood and Water Management Act 2010 and will describe what needs to be done by all involved in flood and coastal risk management to reduce the risk of flooding and coastal erosion, and to manage its consequences.
Flood defence	Infrastructure used to protect an area against floods such as floodwalls and embankments; they are designed to a specific standard of protection (design standard).
Flood Risk Area	Areas determined by the Environment Agency as potentially having a significant flood risk, based on guidance published by Defra and WAG and the use of certain national datasets.
Flood Risk Regulations (FRR)	Transposition of the EU Floods Directive into UK law. The EU Floods Directive is a piece of European Community (EC) legislation to specifically address flood risk by prescribing a common framework for its measurement and management.
Flood and Water Management Act (FWMA)	An Act of Parliament which forms part of the UK Government's response to Sir Michael Pitt's Report on the Summer 2007 floods, the aim of which is to clarify the legislative framework for managing surface water flood risk in England. The Act was passed in 2010 and is currently being enacted.
Fluvial Flooding	Flooding resulting from water levels exceeding the bank level of a watercourse (river or stream). In this report the term Fluvial Flooding generally refers to flooding from Main Rivers (see later definition).
Flood Map for Surface Water (FMfSW)	A national data set held by the Environment Agency showing areas where surface water would be expected to flow or pond, as a result of two different chances of rainfall event, the 1 in 30yr and 1 in 200yr events.
GYBC	Great Yarmouth Borough Council
Hyetograph	A graphical representation of the variation of rainfall depth or intensity with time.
Integrated Urban Drainage (IUD)	A concept which aims to integrate different methods and techniques, including sustainable drainage, to effectively manage surface water within the urban environment.
Internal Drainage Board (IDB)	An independent body with powers and duties for land drainage and flood control within a specific geographical area, usually an area reliant on active pumping of water for its drainage.
LP	Local Plan
Lead Local Flood Authority (LLFA)	Local Authority responsible for taking the lead on local flood risk management. The duties of LLFAs are set out in the Flood and Water Management Act. This is Norfolk County Council within the study area.
LiDAR	Light Detection and Ranging, a technique to measure ground and building levels remotely from the air, LiDAR data is used to develop DTMs and DEMs (see definitions above).
Local Planning Authority (LPA)	The local authority that is empowered by law to exercise planning functions for a particular area.
Local Resilience Forum (LRF)	A multi-agency forum, bringing together all the organisations that have a duty to cooperate under the Civil Contingencies Act, and those involved in responding to emergencies. They prepare emergency plans in a co-ordinated manner and respond in an emergency. Roles and Responsibilities are defined under the Civil Contingencies Act. This is the Norfolk Resilience Forum within the study area.

Term	Definition
Main River	Main Rivers are a statutory type of watercourse in England and Wales, usually larger streams and rivers, but also include some smaller watercourses. A Main River is defined as a watercourse marked as such on a Main River map, and can include any structure or appliance for controlling or regulating the flow of water in, into or out of a Main River. The Environment Agency's powers to carry out flood defence works apply to Main Rivers only.
Norfolk County Council (NCC)	The Lead Local Flood Authority in the area.
NPPF	National Planning Policy Framework (replaces PPS25)
National Receptor Dataset (NRD)	A collection of risk receptors produced by the Environment Agency. A receptor could include essential infrastructure such as power infrastructure and vulnerable property such as schools and health clinics.
Ordinary Watercourse	All watercourses that are not designated Main River, and which are the responsibility of Local Authorities or, where they exist, IDBs are termed Ordinary Watercourses.
Partner	A person or organisation with responsibility for the decision or actions that need to be taken.
Pitt Review	Comprehensive independent review of the 2007 summer floods by Sir Michael Pitt, which provided recommendations to improve flood risk management in England.
Pluvial Flooding	Flooding from water flowing over the surface of the ground; often occurs when the soil is saturated and natural drainage channels or artificial drainage systems have insufficient capacity to cope with additional flow.
Policy Area (PA)	One or more Critical Drainage Areas linked together to provide a planning policy tool for the end users. Primarily defined on a hydrological basis, but can also accommodate geological concerns where these significantly influence the implementation of SuDS
PPS25	Planning and Policy Statement 25: Development and Flood Risk (replaced by NPPF in March 2012)
Preliminary Flood Risk Assessment (PFRA)	Assessment required by the EU Floods Directive which summarises flood risk in a geographical area. Led by LLFAs.
Resilience Measures	Measures designed to reduce the impact of water that enters property and businesses; could include measures such as raising electrical appliances.
Resistance Measures	Measures designed to keep flood water out of properties and businesses; could include flood guards for example.
Risk	In flood risk management, risk is defined as a product of the probability or likelihood of a flood occurring, combined with the consequence of the flood.
Risk Management Authority (RMA)	As defined by the Floods and Water Management Act. These are (a) the Environment Agency, (b) a lead local flood authority (NCC), (c) a study area council for an area for which there is no unitary authority (GYBC), (d) an internal drainage board, (e) a water company (AWS), and (f) a highway authority (Norfolk County Highways and the Highways Agency)
Sewer flooding	Flooding caused by a blockage or overflowing in a sewer or urban drainage system.
Stakeholder	A person or organisation affected by the problem or solution, or interested in the problem or solution. They can be individuals or organisations, includes the public and communities.

Term	Definition
Strategic Flood Risk Assessment (SFRA)	SFRAs are prepared by local planning authorities (in consultation with the Environment Agency) to help guide local planning. They allow them to understand the local risk of flooding from all sources (including surface water and groundwater). They include analysis and maps of the impact of climate change on the extent of future floods. You can find these documents on the website of your local planning authority.
Sustainable Drainage Systems (SuDS)	Methods of management practices and control structures that are designed to drain surface water in a more sustainable manner than some conventional techniques. Includes swales, wetlands, bioretention devices and ponds.
Surface water runoff	Rainwater (including snow and other precipitation) which is on the surface of the ground (whether or not it is moving), and has not entered a watercourse, drainage system or public sewer.
Surface Water Management Plan (SWMP)	This document – refer Section 1.1 (What is a Surface Water Management Plan?)
UKCIP	The UK Climate Impacts Programme. Established in 1997 to assist in the co-ordination of research into the impacts of climate change. UKCIP publishes climate change information on behalf of the UK Government and is largely funded by Defra.
WaSC	Water and Sewerage Company. This is Anglian Water Services in the study area.

Table of Contents

1 Introduction

Capita Symonds URS have been commissioned by Norfolk County Council, Great Yarmouth Borough Council and Anglian Water Services (hereinafter referred to as NCC, GYBC and AWS respectively or the 'Steering Group' collectively) to prepare a Surface Water Management Plan (SWMP) for the Great Yarmouth Borough Council administrative area.

1.1 What is a Surface Water Management Plan?

A Surface Water Management Plan (SWMP) outlines the preferred surface water management strategy in a given location. In this context surface water flooding describes flooding from sewers, drains, groundwater, runoff from land, small water courses and ditches that occurs as a result of heavy rainfall.

This SWMP study has been undertaken in partnership with key local stakeholders who are responsible for surface water management and drainage in the Great Yarmouth Borough area – including Anglian Water and the Environment Agency. The Steering Group have worked together to understand the causes and effects of surface water flooding and agree the most cost effective way of managing surface water flood risk for the long term.

This document also establishes a long-term action plan to manage surface water and will influence future capital investment, maintenance, public engagement and understanding, land-use planning, emergency planning and future developments.

1.2 SWMP Process

The Defra SWMP Technical Guidance (2010) provides the framework for preparing SWMPs. This report has been prepared to reflect the four principal stages identified by the guidance (refer below):

1. Preparation: Identify the need for a SWMP, establish a partnership with the relevant stakeholders and scope SWMP (refer to Section 3)

2. Risk Assessment: Select an appropriate level risk assessment and complete it – a combination of risk assessment methods were selected for this study (refer to Section 6)

3. Options: Identify options/measures (with stakeholder engagement) which seek to alleviate the surface water flood risk within Critical Drainage Areas (refer to Section 7)

4. Implementation and Review: Prepare Action Plan and implement the monitoring and review process for these actions (refer to Sections 8 and 9)

The scope of this study includes elements of all phases of the process. These phases and their key components are illustrated in the figures below.

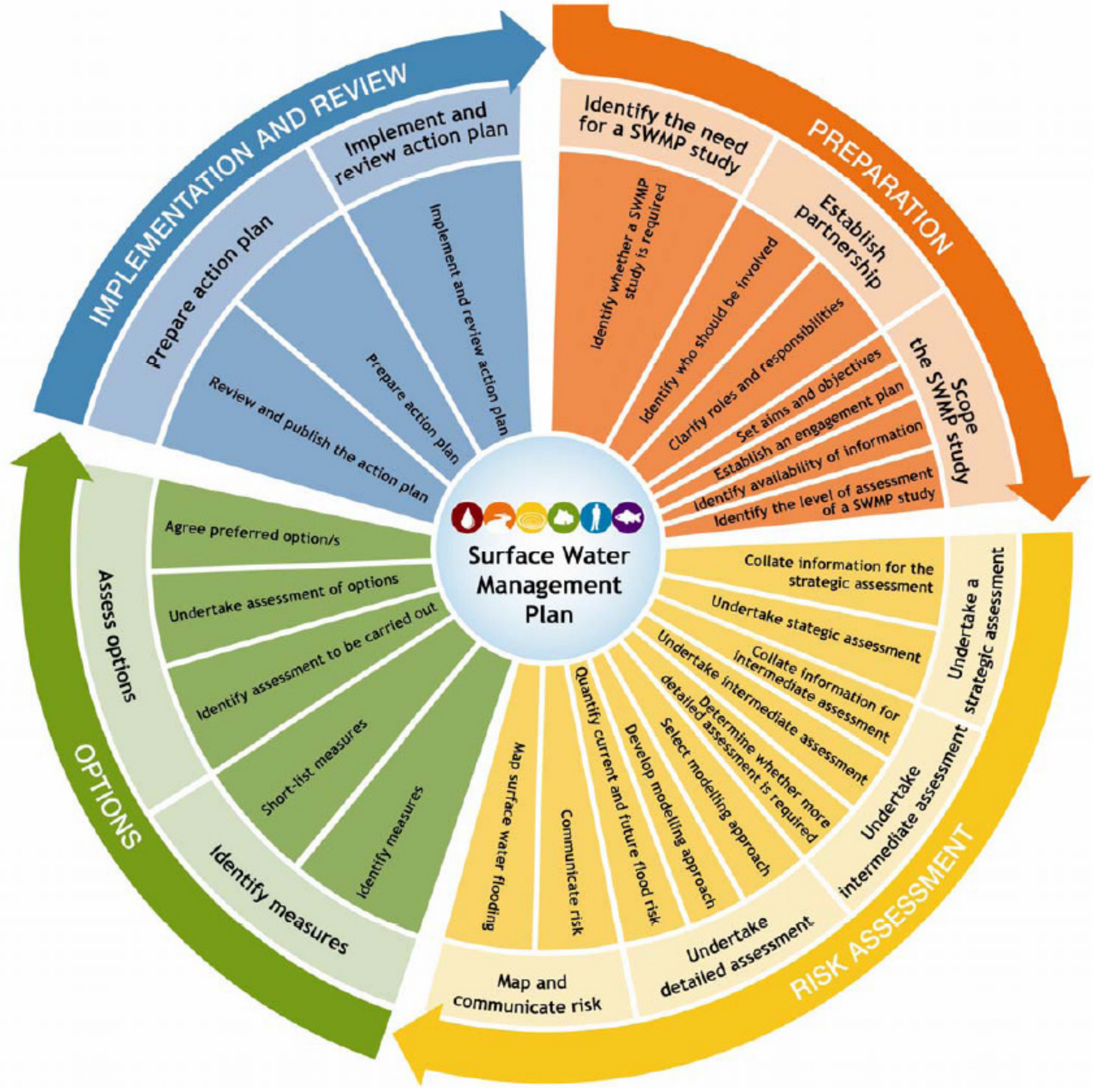


Figure 1-1 Recommended Defra SWMP Process (Source Defra 2010)

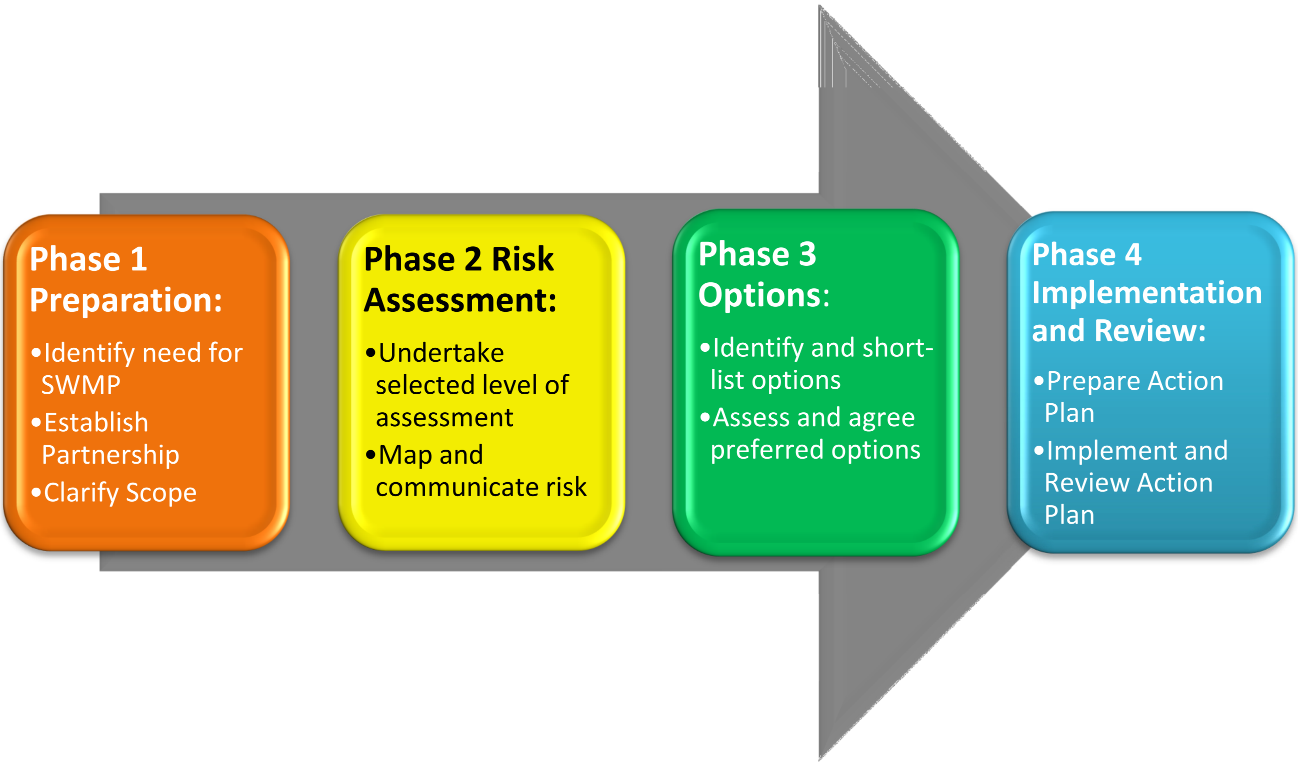


Figure 1-2 Summary of the Defra SWMP Phases

1.3 Objectives

The objectives of the SWMP are to:

- Develop a thorough understanding of surface water flood risk in and around the study area, taking into account the implications of climate change, population and demographic change and increasing urbanisation in and around Great Yarmouth Borough;
- Identify, define and prioritise Critical Drainage Areas and map areas of potential flood risk;
- Make recommendations for holistic and integrated management of surface water management which improve emergency and land use planning, and support better flood risk and drainage infrastructure investments;
- Establish and consolidate partnerships between key stakeholders to facilitate a collaborative culture, promoting openness and sharing of data, skills, resource and learning, and encouraging improved coordination and collaborative working;
- Engage with stakeholders to raise awareness of surface water flooding, identify flood risks and assets, and agree mitigation measures and actions; and
- Deliver outputs to enable practical improvements or change where partners and stakeholders take ownership of their flood risk and commit to delivering and maintaining the recommended measures and actions.

1.4 Sources of Flooding

Surface water or pluvial flooding occurs when water flows over the surface of the ground and ponds in low lying areas. It is usually a result of runoff associated with high intensity, short duration, rainfall events and can be exacerbated when the ground is saturated (or baked hard) and the drainage network has insufficient capacity to manage the additional flow. Surface water flooding is grouped with flooding from ordinary watercourses, sewers and groundwater. Under the FWMA this group of flood sources is defined as **'local flooding'** and is the general responsibility of the LLFA (NCC in this case).

- **Pluvial Flooding**: High intensity storms (often with a short duration) are sometimes unable to infiltrate into the ground or be drained by formal drainage systems since the capacity of the collection systems is not large enough to convey runoff to the underground pipe systems (which in turn might already be surcharging). The pathway for surface water flooding can include blockage, restriction of flows (elevated grounds), overflows of the drainage system and failure of sluice outfalls and pump systems.
- **Sewer Flooding**: Flooding which occurs when the capacity of the underground drainage network is exceeded, resulting in the surcharging of water into the nearby environment (or within internal and external building drainage networks). The discharge of the drainage network into waterways and rivers can also be affected if high water levels in receiving waters obstruct the drainage network outfalls.
- **Ordinary Watercourses (including IDB managed drains)**: Flooding from small open channels and culverted urban watercourses (which receive most of their flow from the urban areas) can either exceed their capacity and cause localised flooding of an area or can be obstructed (through debris or illegal obstruction) and cause localised out of bank flooding of nearby low lying areas. Many of the IDB drainage systems are dependent on pump stations and can flood if these fail.
- **Groundwater Flooding:** Flooding occurs when the water level within the groundwater aquifer rises to the surface. In very wet winters these rising water levels may lead to flooding of areas that are normally dry. This can also lead to streams that only flow for part of the year being reactivated. These intermittent streams are typically known as 'bournes'. Water levels below the ground can rise during winter (dependant on rainfall) and fall during drier summer months as water discharges from the saturated ground into nearby watercourses.

Figure 1-3 provides an illustration of these flood sources. Each of these sources of flood risk are further explained within Section 4 of this report.

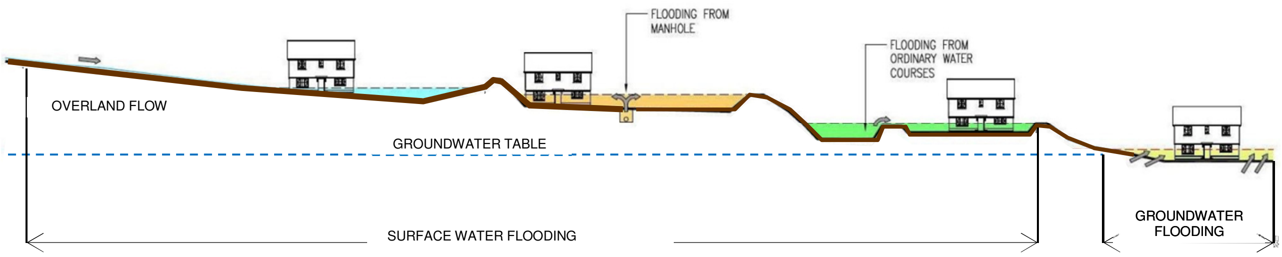


Figure 1-3 Illustration of Flood Sources[1]

Flooding from Main Rivers and tidal sources are addressed through the EA Catchment Flood Management Plans and Shoreline Management Plans, respectively. The interactions of Main River / tidal flooding with local flooding are considered by this assessment, but not explicitly described or assessed in their own right.

[1] Adopted from Thatcham Surface Water Management Plan Volume One

1.5 Partnership

The Flood and Water Management Act 2010 defines the Lead Local Flood Authority (LLFA) for an area as the unitary authority for the area, or if there is no unitary authority, the county council for the area. NCC is the LLFA for the administrative county boundary of Norfolk. Great Yarmouth Borough Council (GYBC) is the lower tier council responsible for the study area.

The Environment Agency (EA) is responsible for flood risk and water quality management of the River Yare, its associated 'Main River' tributaries (the River Bure and River Waveney) and the coastline within the study area. These rivers and coastal waters receive a large proportion of the surface water runoff in this study area and the EA are an essential partner for flood risk management.

Anglian Water is the sewerage undertaker within the GYBC area. The study area also intersects with two Internal Drainage Boards – the Broads (2006) Internal Drainage Board and the Waveney, Lower Yare & Lothingland Internal Drainage Board (WLYL IDB).

The study area also falls within the zone of responsibility for Anglian Eastern Regional Flood and Coastal Committee (RFCC). This committee replaced the previous Regional Flood and Coastal Defence (RFCD) committee that existed until 31 March 2011 as part of national changes initiated by the FWMA 2010.

In order to provide an integrated approach to surface water management, it is important that key stakeholders with responsibility for different flood mechanisms are able to work together in a holistic manner. To this end, key stakeholders have been engaged throughout the duration of this study through the establishment of a Steering Group, which contains representatives from the organisations illustrated in Figure 1-4. These groups have been consulted throughout the SWMP process and have provided key input at a number of stages of the study.

The lead stakeholders (and project funders) within the Steering Group are NCC, GYBC and Anglian Water. Each of these parties has specific responsibilities for management of local flood risk. These responsibilities are summarised in the following sections.

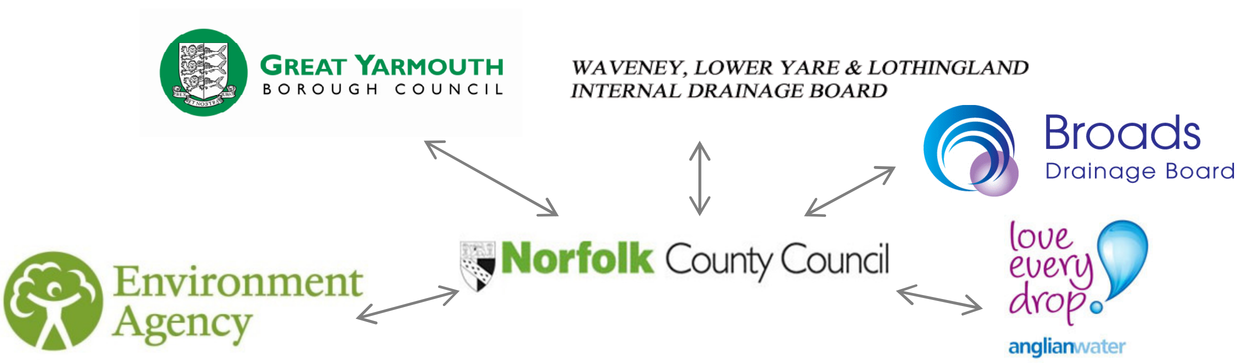


Figure 1-4: Key stakeholders engaged in the SWMP process

1.5.1 Norfolk County Council Responsibilities (LLFA)

In addition to forging partnerships and coordinating and leading on local flood management, there are a number of other key responsibilities that have arisen for Lead Local Flood Authorities from the Flood & Water Management Act 2010. These responsibilities include:

1. **Investigating Flood Incidents** – LLFAs have a duty to investigate and record details of significant flood events within their area. This duty includes identifying which authorities have flood risk management functions and what they have done, or intend to do, with respect to the incident, notifying risk management authorities where necessary and publishing the results of any investigations carried out.

2. **Asset Register** – LLFAs also have a duty to maintain a register of structures or features which are considered to have a significant effect on flood risk, including as a minimum details of ownership and condition. The register must be available for inspection and the Secretary of State will be able to make regulations about the content of the register and records.

3. **SUDS Approving Body** – LLFAs are designated the SUDS Approving Body (SAB) for any new drainage system, and therefore must approve, adopt and maintain any new sustainable drainage systems (SUDS) within their area. This responsibility is anticipated to commence in April 2014.

4. **Local Flood Risk Management Strategy** – LLFAs are required to develop, maintain, apply and monitor a strategy for local flood risk management in its area. The strategy will build upon information such as national risk assessments and will use consistent risk based approaches across different local authority areas and catchments.

5. **Works Powers** – LLFAs have permissive powers to undertake works to manage flood risk from surface runoff and groundwater, consistent with the local flood risk management strategy for the area.

6. **Designation Powers** – LLFAs, as well as Districts, IDBs and the Environment Agency, have powers to designate structures and features that affect flooding in order to safeguard assets that are relied upon for flood risk management.

7. **Regulation of Works on Ordinary Watercourses -** Administration of a consenting system for works and enforcement of non-compliant or un-consented works (including maintenance works where required).

These LLFA requirements have been considered in the production of this document. The SWMP will assist the LLFA in providing evidence for points 1, 2, 3 and 4.

1.5.2 Great Yarmouth Borough Council Responsibilities

In order to assist the LLFA (NCC) in delivering their responsibilities, the GYBC should undertake the following:

- Maintain ditches and other water management features on Council owned land with the exception of SUDS features which is adopted / maintained by another authority;
- Category One Responder to local and national emergencies; and
- Providing temporary accommodation in an emergency.
- Works powers on ordinary watercourses when consistent with the LFRMS

1.5.3 Anglian Water Responsibilities

The water industry is highly regulated. The quality of customer service and the prices they are able to charge their customers are regulated by the Water Services Regulation Authority (WSRA), commonly known as Ofwat. The water industry operates on five-yearly funding cycles called Asset Management Plan (AMP) periods. Prices are set by Ofwat at the beginning of each period, following submissions from each company about what it will cost to deliver their business plans.

When determining price limits Ofwat determines how much water companies can charge its customers to:

- Finance its day to day spending
- Finance its capital investment programme
- Reward outperformance in the previous five-year period
- Continue to finance previous capital investment through the return the company earns on its regulatory capital value (RCV)
- Pay tax it is liable for

Anglian Water Services (and all other water and sewerage companies) has the following responsibilities around flood risk management:

- Respond to flooding incidents involving their assets.
- Maintenance of a register of properties at risk of flooding due to a hydraulic overload in the sewerage network (DG5 register).
- Undertake capacity improvements to alleviate sewer flooding problems on the DG5 register.
- Provide, maintain and operate systems of public sewers and works for the purpose of effectually draining an area.
- Have a duty to co-operate with other relevant authorities in the exercise of their flood and coastal erosion risk management functions.
- Must act in a manner which is consistent to national flood and coastal erosion risk management strategies and have regard to local flood risk management strategies.
- May be subject to scrutiny from Lead Local Flood Authorities' democratic processes.
- Have a duty for the adoption of private sewers.
- Statutory consultee to the SuDS Approval Body (SAB) when the drainage system is proposed to connect with a public sewer

1.6 Public Engagement

Members of the public may also have valuable information to contribute to the SWMP and to an improved understanding and management of local flood risk within the study area. Public engagement can afford significant benefits to local flood risk management including building trust, gaining access to additional local knowledge and increasing the chances of stakeholder acceptance of options, and decisions proposed in future flood risk management plans.

The Steering Group has proactively engaged with the public throughout the preparation of the SWMP. Events include:

- ***Elected Members Workshop (February 2013):*** Elected members from Great Yarmouth Borough Council, Parish Councils within identified higher risk areas (refer Section 5.1), Local Resilience Forum Members and representatives from the local emergency services attended a workshop that covered:
    - A summary of the project to date
    - Details of the risk assessment approach
    - Draft surface water modelling results
    - Potential impacts of infrastructure, critical assets and vulnerable people

- Discussion of potential flood mitigation solutions

- ***Public 'Drop In' Sessions (June 2013):*** The general public was invited to a series of 'drop in' sessions held at Caister Council Hall, Gorleston Library, 'The Pavillion' (Hemsby) and Great Yarmouth Town Hall. The events were publicised through the local paper, Parish Councillors, Local Resilience Forums and a direct mail out to those properties identified as possibly at risk within the study area. Attendees were able to view surface water flood maps of the local area, proposed mitigation solutions and have informal discussions with members of the Steering Group. The Steering Group was able to obtain valuable input on local flooding issues and gauge the general opinion of the possible flood mitigation solutions proposed.

2 Study Area

Great Yarmouth Borough Council is located within Norfolk County and covers an area of 182km^2. It includes the coastal town of Great Yarmouth along with several other smaller settlements along the coast and further inland. The borough is located on the East Coast of the UK between the North Sea and the Norfolk Broads. Great Yarmouth Borough Council (GYBC) is a second tier local authority in which Norfolk County Council (NCC) is the upper tier local authority and responsible for delivering the Lead Local Flood Authority (LLFA) requirements of the FWMA in the Great Yarmouth Borough area. The extent of the study area within this SWMP is illustrated in Figure 2-1.

2.1 Location and Characteristics

Great Yarmouth Borough is a coastal Borough in Norfolk. It has been a seaside resort since 1760 and it is the gateway from the Norfolk Broads to the sea. Great Yarmouth Borough's setting close to both major marine and fluvial environments has influenced its historic development in the past and can be anticipated to do so in the future. The harbour at Great Yarmouth provides an area of sheltered water for shipping and has long been known as a safe haven. For hundreds of years it was a major fishing port but its fishing industry suffered a steep decline in the second half of the 20th century, and has now all but disappeared. The discovery of oil in the North Sea in the 1960s led to a flourishing oil rig supply industry, and today it services offshore natural gas rigs. More recently, the development of renewable energy sources, especially offshore wind power, has created further opportunities for support services.

The main road into Great Yarmouth from the west is the A47 which runs in parallel with the railway line from Norwich. The road and rail route runs south of the River Bure and enters the town from the north side of Breydon Water. The A12 bypasses the main town centre and carries traffic south to Lowestoft. The A12 runs approximately parallel to the coast, approximately 1km inland.

Great Yarmouth Borough is bordered by North Norfolk District Council to the north, Broadland District Council to the west and South Norfolk District Council to the south. The southern boundary of the Borough also adjoins Waveney District Council in Suffolk County. Figure 2-2 (and Figure 3 within Appendix C) provides an overview of the land uses within the study area.

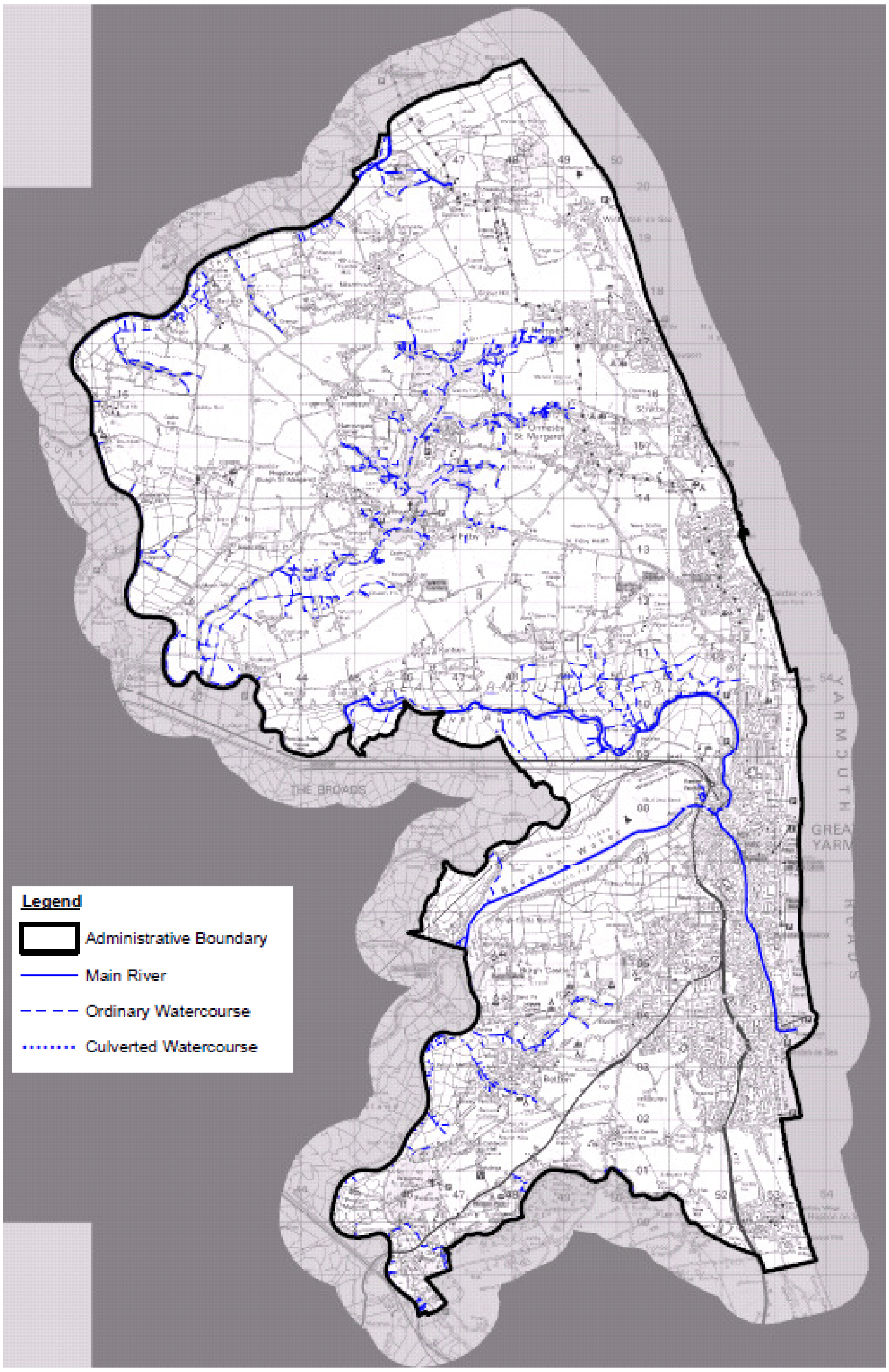


Figure 2-1 Great Yarmouth Borough Administrative Boundary and Study Area

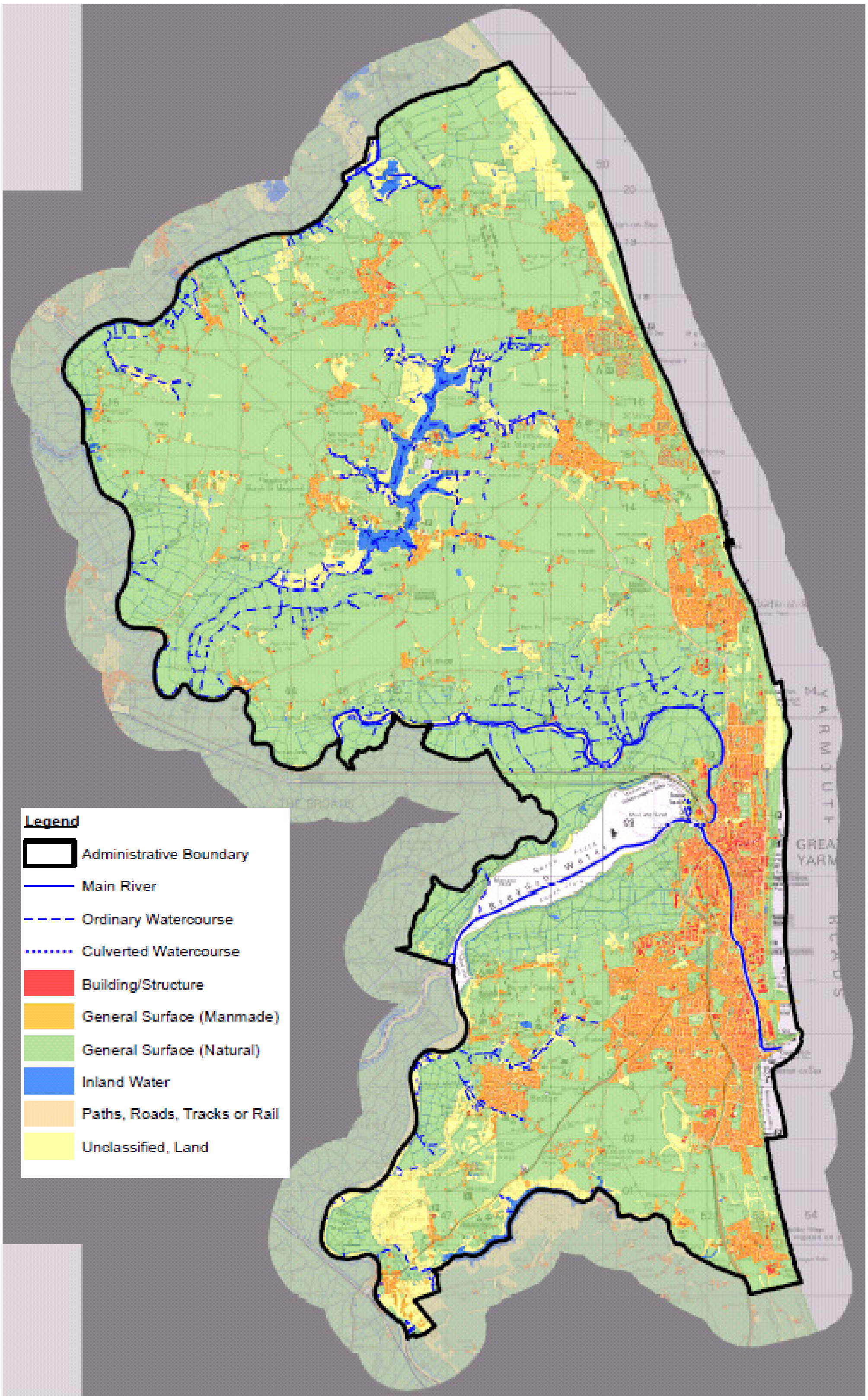


Figure 2-2 Land Uses within the study area

2.2 Major Rivers and Waterways

The Great Yarmouth Borough area is crossed by the Rivers Yare, Bure and Waveney. The River Thurne, a tributary of the Bure, runs along the northern area boundary. The area is bounded in the east by the North Sea. The character of the area and the nature of the flood risk are strongly influenced by the interface between land and sea. The River Yare is the principle of the three main watercourses. Upstream of Great Yarmouth the Yare flows into Breydon Water a large semi natural tidal basin before flowing on through the main urban area of Great Yarmouth and into the Inner Harbour and finally the North Sea.

Upstream of Great Yarmouth the Yare has a predominantly rural character flowing from its headwaters west of Norwich through the Broads and then on to the sea. Major tributaries of the Yare include the Chet and the Wensum, and in its lower reach the River Waveney. The Yare is tidal for much of its length and the tidal influence is observed as far upstream as Norwich (approximately 27 km inland). All principal watercourses within the study area are navigable and are used for both commercial and recreational boating and shipping. Refer to Appendix C for more detailed mapping of the major watercourses.

2.3 Topography and Geology

Great Yarmouth Borough is a generally low lying area and the LiDAR data shows limited variation in ground elevations across the study area. Ground elevations within the main town are typically between 2m AOD and 6m AOD on the northern (coast) side of the river. On the southern side of the river, the areas of Cobholm and Southtown are particularly low with ground levels less than 2m AOD. Further south, ground levels in Gorleston rise to above 10m AOD. The A47 main road into Great Yarmouth is raised above the surrounding area where levels are below 0m AOD. The topography of the study area is presented in Figure 2-3 below.

Great Yarmouth Borough is underlain by superficial drift deposits and deeper solid geology ranging from loose blown sand at the surface to thick Chalk deposits at depths of ~175 m. The drift geology is comprised of sandy, clayey and silty deposits with occasional gravels while the deeper solid geology is comprised of sandstones, mud/siltstones and Chalk. There is little variation in the soils and geology across the study area. Figure 4 in Appendix C shows a geological map of the study area.

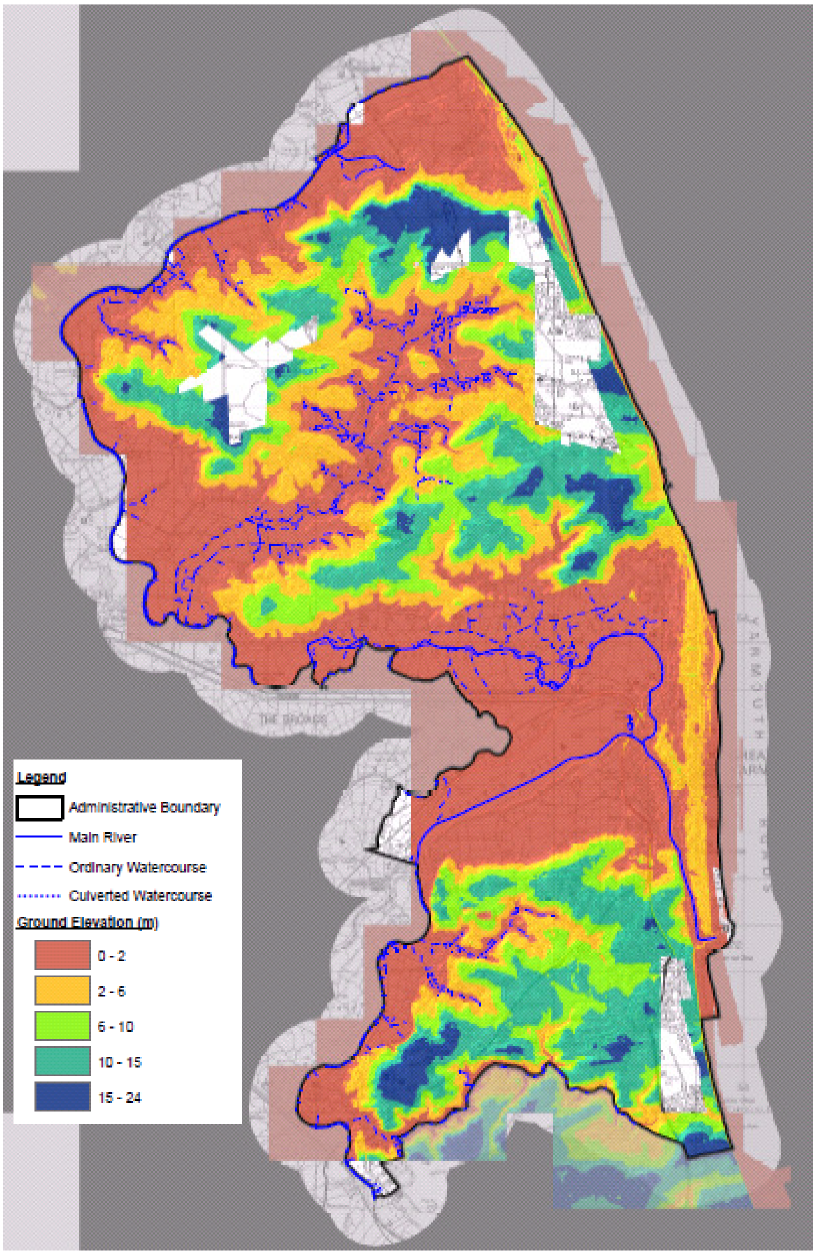


Figure 2-3 DTM Representation of the Topography within the study area

2.4 Significant Future Development Plans

The emerging Local Plan for Great Yarmouth Borough identifies growth and regeneration priority areas within the study area. It sets out how the new neighbourhood areas will be supported by strategic transport infrastructure – roads, rail, as well as other elements essential for a sustainable community - education, water, sewers, shops, energy and green space. Where these growth areas are identified within risk areas (Critical Drainage Areas – refer Section 6), specific management policies and possible surface water flood mitigation options are proposed in the Options Assessment (Refer Section 7). These should be considered by GYBC when allocating development sites or assessing planning applications in these areas.

2.5 Links with Other Studies

It is important that the SWMP is not viewed as an isolated document, but one that connects with other strategic and local plans. It is also important that it fits in with other studies and plans and does not duplicate existing work.

Figure 2-4, shows an interpretation of the drivers behind the Great Yarmouth Borough SWMP, the evidence base and how the SWMP supports the delivery of other key planning and investment processes.

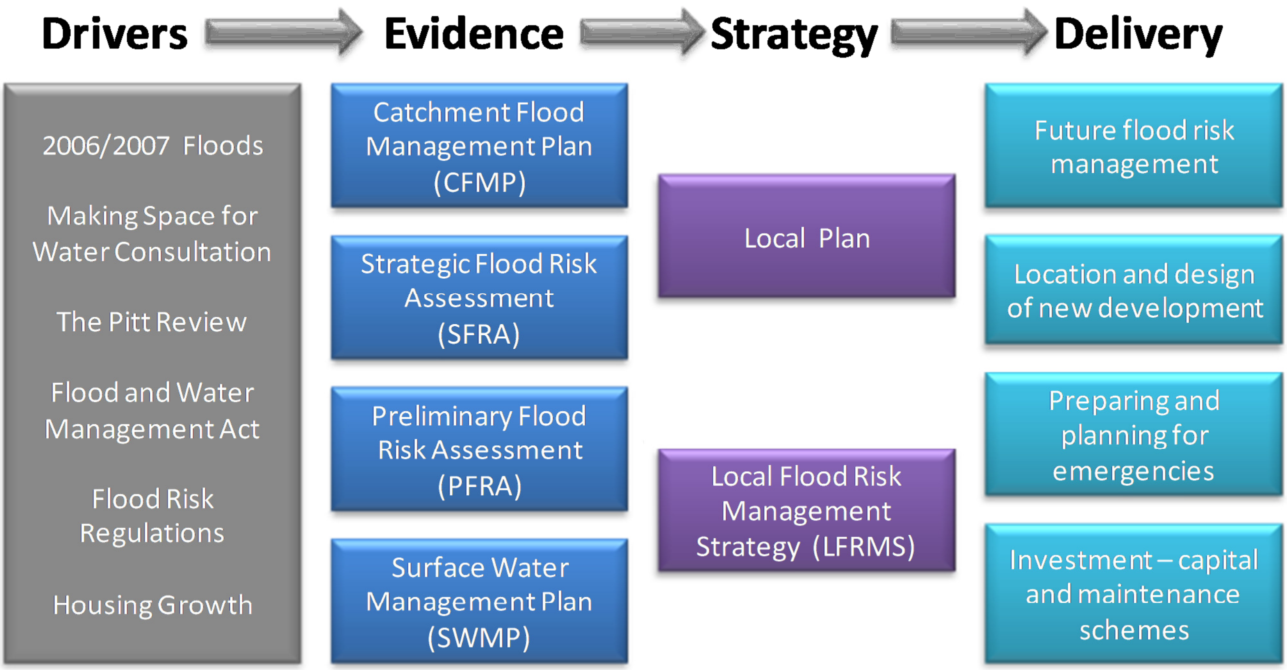


Figure 2-4 Links with Other Studies

Figure 2-4, highlights reports compiling evidence on flood risk (CFMP, SFRA, PFRA and SWMP) and strategy documents (LP and LFRMS). The number of these reports and their nature running parallel to each other has primarily been driven by the timings of their production and data availability; however, the creation and existence of numerous different documents can be confusing. Some key details for these different studies and plans and how they are relevant to the study area are included below:

Regional Flood Risk Appraisal (RFRA)

The East of England RFRA was produced in 2009 by the East of England Regional Assembly (EERA). As of 31 March 2010, EERA was dissolved as an organisation and much of their work is now undertaken by the East of England Local Government Association (East of England LGA). Nevertheless, the RFRA still exists as a document and provides a summary of flood risk in the region with the aim of informing Strategic Flood Risk Assessments and other local development plans. With the introduction of the new National Planning Policy Framework replacing the current Planning Policy Statements, the RFRA is unlikely to be revised in future.

Broadland Rivers Catchment Flood Management Plan (CFMP)

The Broadland Rivers Catchment Flood Management Plan (July 2008) and Summary Report (December 2009) by the Environment Agency includes Great Yarmouth Borough in its study area.

The plan gives an overview of flood risk in the Broadland Rivers catchment and sets out the preferred plan for sustainable flood risk management over the next 50 to 100yrs.

The two relevant policies to this SWMP relate to the River Yare and Great Yarmouth urban area:

- ***Policy 2 (River Yare) - Areas of low to moderate flood risk where we can generally reduce existing flood risk management actions***. This policy will tend to be applied where the overall level of risk to people and property is low to moderate. It may no longer be value for money to focus on continuing current levels of maintenance of existing defences if we can use resources to reduce risk where there are more people at higher risk. We would therefore review the flood risk management actions being taken so that they are proportionate to the level of risk The CFMP is intended to be periodically reviewed, approximately five years from when it was published, to ensure that it continues to reflect land use changes in the catchment.
- ***Policy 5 (Great Yarmouth) - Areas of moderate to high flood risk where we can generally take further action to reduce flood risk.*** This policy will tend to be applied to those areas where the case for further action to reduce flood risk is most compelling, for example where there are many people at high risk, or where changes in the environment have already increased risk. Taking further action to reduce risk will require additional appraisal to assess whether there are socially and environmentally sustainable, technically viable and economically justified options.

Strategic Flood Risk Assessments (SFRA)

Each local planning authority was required to produce a SFRA under Planning Policy Statement 25 (PPS25) – now replaced by National Planning Policy Framework (NPPF). This document provides an important tool to guide planning policies and land use decisions. Current SFRAs have a strong emphasis on flooding from Main Rivers and the sea and are less focussed on evaluating flooding from local sources such as surface water, groundwater and ordinary watercourses. The information from this study will improve this understanding. Great Yarmouth Borough Council produced the Great Yarmouth and Gorleston Strategic Flood Risk Assessment in September 2009. It is recommended that future updates to this document take into account the findings of the SWMP study.

Preliminary Flood Risk Assessment (PFRA)

A Preliminary Flood Risk Assessment (PFRA) Report by NCC, as LLFA, has been prepared as part of the Flood Risk Regulations (FRR). The PFRA process provides a consistent high level overview of the potential risk of flooding from local sources such as surface water, groundwater and ordinary watercourses. The outputs from this SWMP will be able to inform future PFRA cycles, which will benefit from an increased level of information and understanding relating to surface water flood risk within the study area.

Local Plan

The Local Plan will need to reflect the results from this study. This may include policies for large parts of the study area or for smaller specific parts of the study area (Critical Drainage Areas). There may also be a need to review Area Action Plans where surface water flood risk is a particular issue.

National Flood and Coastal Erosion Risk Management Strategy (National FCERM Strategy)

The FWMA 2010 requires the EA to produce a national strategy to inform and guide local flood risk management strategies. This document was consulted upon in early 2011 and became law on 19 July 2011. The strategy's overall aim is to ensure that flooding and coastal erosion risks are well-managed and co-ordinated, so that their impacts are minimised.

The National FCERM Strategy for England stresses the need for risk to be managed in a co-ordinated way across river catchments and along the coast, embracing the full range of practical options and helping local decision-making.

Local Flood Risk Management Strategy (LFRMS)

The Flood and Water Management Act (2010) requires each LLFA to produce a Local Flood Risk Management Strategy (LFRMS) for their administrative area. This SWMP will provide a strong evidence base to support the Norfolk County LFRMS. The Norfolk County LFRMS will go out to public consultation in the Autumn of 2013 and will be completed in 2014. The LFRMS will be available from the NCC website.

Summary of Documents

The schematic diagram (Figure 2-5, below) illustrates how the CFMP, PFRA, SWMP and SFRA link to and underpin the development of a Local Flood Risk Management Strategy.

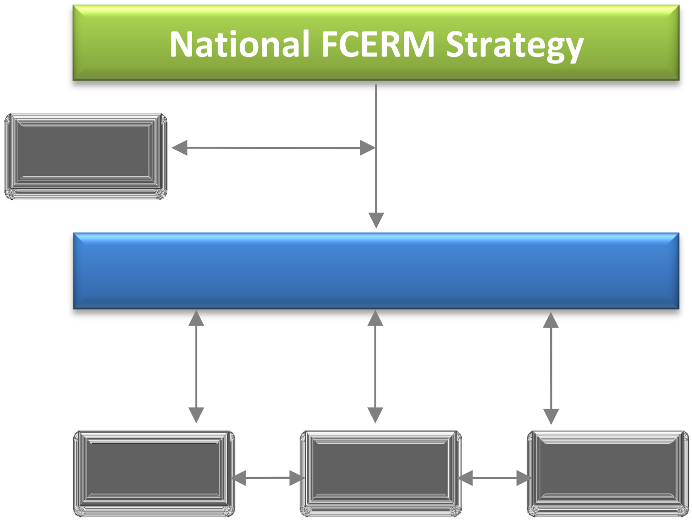
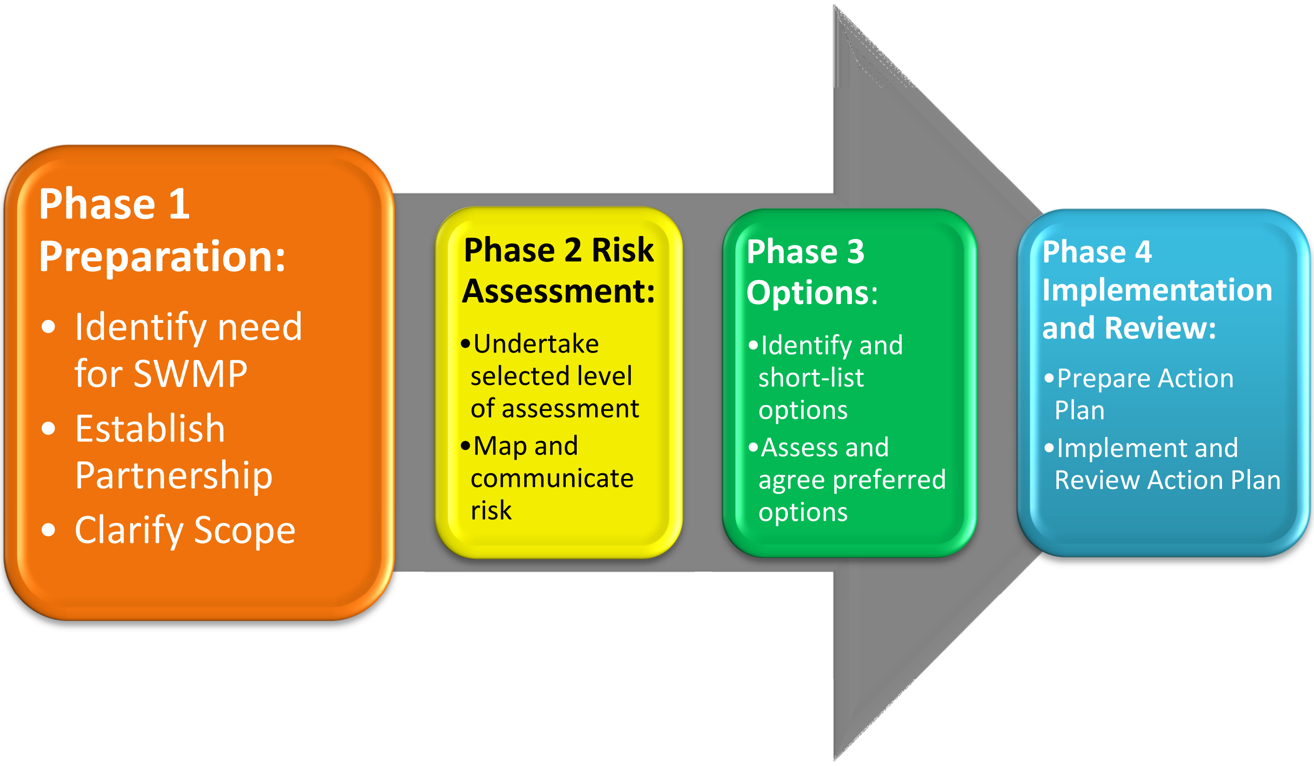


Figure 2-5 Links to local strategies

PHASE 1: PREPARATION



3 Preparation

3.1 SWMP Approach

The initial parts of the SWMP process were delivered by the Steering Group members. The Steering Group achieved the following:

- Concluded that the SWMP should be delivered at an intermediate level, with detailed assessments undertaken in specific areas vulnerable to surface water flooding where funding allowed;
- Established a partnership and clarified the roles of responsibilities of each partner;
- Established the method and timing of stakeholder engagement;
- Set the overall objectives for the Great Yarmouth Borough SWMP;
- Collated and mapped all available data for the SWMP, identified missing data and presented the data in a format that would aid later phases;
- Identified ten areas that are more vulnerable to surface water flooding from existing data:
    - Martham;
    - Winterton-on-Sea;
    - Hemsby;
    - Ormesby-St-Margaret;
    - Hopton-on-Sea;
    - Caister-on-Sea;
    - Great Yarmouth;
    - Gorleston;
    - Bradwell; and
    - Belton.
- Determined the overall approach for Phases 2, 3 and 4 of the Great Yarmouth Borough SWMP.

3.2 Data Collection

Data was collected from each of the following organisations:

- Great Yarmouth Borough Council;
- Environment Agency;
- Broads 2006 Internal Drainage Board;
- Waveny, Lower Yare & Lothingland Internal Drainage Board;
- Norfolk County Council;
- Anglian Water; and
- Norfolk Fire Authority.

Table 3-1 provides a summary of the data sources held by the organisations listed above and provides a description of each dataset, and how the data was used in preparing the SWMP.

Table 3-1 Data Sources and Use

Source	Dataset	Description	Use in this SWMP
Environment Agency	National Receptors Dataset	A nationally consistent dataset of social, economic, environmental and cultural receptors including residential properties, schools, hospitals, transport infrastructure and electricity substations.	Utilised for property/infrastructure flood counts and to determine CDAs.
	Flood Map for Surface Water DTM	The DTM used to produce a the Flood Map for Surface Water – A hybrid DTM of the best available terrain data as collected during 2010 (a combination of LiDAR, IfSAR and Photogrammetry)	Used to fill gaps in the high resolution LiDAR information
	Main River centre lines	GIS dataset identifying the location of Main Rivers across they study area	To define waterway locations within the study area.
	Environment Agency Flood Map (Flood Zones)	Shows extent of flooding from rivers during a 1 in 100yr flood and 1 in 1000yr return period flood. Shows extent of flooding from the sea during 1 in 200yr and 1 in 1000yr flood events. Ignores the presence of defences.	To identify the fluvial and tidal flood risk within the study area and areas benefiting from fluvial and tidal defences.
	Areas Susceptible to Surface Water Flooding	A national outline of surface water flooding held by the EA and developed in response to Pitt Review recommendations.	To assist with the verification of the pluvial modelling
	Flood Map for Surface Water	A second generation of surface water flood mapping which was released at the end of 2010.	To assist with the verification of the pluvial modelling
	Groundwater Flooding Incidents	Records of historic incidents of groundwater flooding as recorded by the Environment Agency.	To identify recorded groundwater flood risk – assist with verifying groundwater flood risk
	LiDAR topographic data.	2m resolution terrain model complied from aerial surveys	Creation of terrain model for pluvial modelling
	Historic Flood Outline	Attributed spatial flood extent data for flooding from all sources.	Used to assist with the verification of modelling results and CDA locations (where available)
	Areas Susceptible to Groundwater Flooding	Mapping showing areas susceptible to groundwater flooding	To assess groundwater flood risk
	Broadland Rivers Catchment Flood Management Plan	Summarises the scale and extent of flooding now and in the future, and set policies for managing flood risk within the catchment.	To ensure a coordinated approach is taken for mitigation solutions
Great Yarmouth Borough Council	Strategic Flood Risk Assessment (SFRA)	Contains useful information on historic flooding, including local sources of flooding from surface water and groundwater.	Provide a background to flood risk in the study area.
	Anecdotal information relating to local flood history and flood risk areas	Records of flooding from surface water, groundwater and ordinary watercourses.	Where available used to assist with the verification of modelling results and CDA locations.

Source	Dataset	Description	Use in this SWMP
Norfolk County Council	OS Mapping / MasterMap	Topographic maps of the study area	Used to derive modelling parameters
	Local Plans	Development plan setting out how the borough will develop	Understanding of areas of future development.
	Flood Alleviation Schemes	Location and description of existing flood alleviation schemes within the study area.	Used in Phase 3: Options Assessment to determine options of each CDA.
	Preliminary Flood Risk Assessment	Summary of known historic flooding and potential future flooding from all sources	Prioritisation of study areas
	Historic Flood Records	Locations of historic flooding	Used to assist with the verification of modelling results and CDA locations (where available)
Anglian Water	Sewer pipe network	GIS dataset providing the geo-referenced location of surface water, foul and combined sewers across the study area. Includes pipe size and some information on invert levels.	Model build, verifying CDA locations and Phase 3:Options Assessment
	DG5 Records	Records of internal and external building flooding caused by the sewer system occurring more than once in 20yrs. Resolution provided was to street level (not individual property)	Validation of modelling results
	Sewer Model Results – Selected rainfall events	As part of the detailed modelling process, a series of rainfall events were agreed with AWS and were run though the AWS sewer models. Results were then provided in the form of outflows from manholes.	Key input to detailed surface water modelling
Norfolk Fire and Rescue Service	Historic flooding records	Locations of historic flooding	Validation of hydraulic modelling results

3.3 Data Review

Historic Records of Local Flooding

Great Yarmouth Borough has the best recent recorded evidence of severe surface water flooding in Norfolk which has been used to verify the flood risk modelling. NCC and GYBC have provided all available historic records that were accessible at the time of request. Where possible, these have been digitised into GIS form, however there is little information on the probability, hazard or consequence of flooding.

Similarly, the Norfolk County Fire and Rescue have recorded incidents of call outs related to flooding, however there is no information on the source of flooding (e.g. pipe bursts or rainfall), or probability, hazard or consequence of the flooding.

Significant flooding occurred in 2006 due to prolonged rainfall. More than 90 properties in Great Yarmouth and Lowestoft were affected. Great Yarmouth railway station was closed and floods also caused one of the pumps at Great Yarmouth Pumping Station to fail (BBC, September 2006).

Other hotspots for surface water flooding over the last 50 years include Southtown around Anson Road, Wolseley Road, Lichfield Road, Mill Road, Bridge Road, Bunns Lane, Ferry Lane and also Northgate Street in Great Yarmouth and the surrounding roads (Great Yarmouth Mercury, 2008).

Hotspot areas for surface water flooding are also known in the Gorleston area around Quay Road and Riverside Road; Hemsby especially on Haycroft Road, Barleycroft Road and Beach Road. Locations in Great Yarmouth include North and South Quay, Marine Parade, Blackfriars Road, North Market Road and Albion Road. There have also been reported incidents of surface water flooding in Caister on Sea along Yarmouth Road and Julian Road.

Flooding Consequences

The National Receptors Database (NRD) was provided by the EA allow property counts to be undertaken for this SWMP. This is the most up to date version available as at October 2012.

Topographic / Elevation Data

Topographic information for the study area was provided in the form of LiDAR data from the Environment Agency Geomatics Group at 1m and 2m resolution, respectively. The coverage of both datasets is comprehensive, but there are gaps adjacent to Hopton on Sea and Gorleston in the south of the borough and adjacent to Hemsby, Martham, Ormesby St. Margaret and Winterton on Sea in the north of the borough. These areas were filled using the Environment Agency Flood Map for Surface Water DTM. The FMfSW DTM is created from the best available terrain information. For the missing areas of LiDAR within the study area, the FMfSW DTM was generated from a combination of IfSAR and Photogrammetry with a 5m resolution. The areas of lower resolution terrain information are highlighted on relevant mapping where they influence hydraulic model outputs.

Main River Information

A substantial quantity of high quality information on the River Yare, its tributaries and associated defences within the study area was provided by the EA. This data provides a good basis for understanding fluvial impacts on flooding.

3.4 Security, Licensing and Use Restrictions

A number of datasets used in the preparation of this SWMP are subject to licensing agreements and use restrictions. The following national datasets provided by the Environment Agency are available to LLFA for local decision making:

- EA Flood Zone Map;
- Areas Susceptible to Surface Water Flooding;
- Areas Susceptible to Groundwater Flooding;
- Flood Map for Surface Water; and

- National Receptor Database.

A number of the data sources used are publicly available documents, such as:

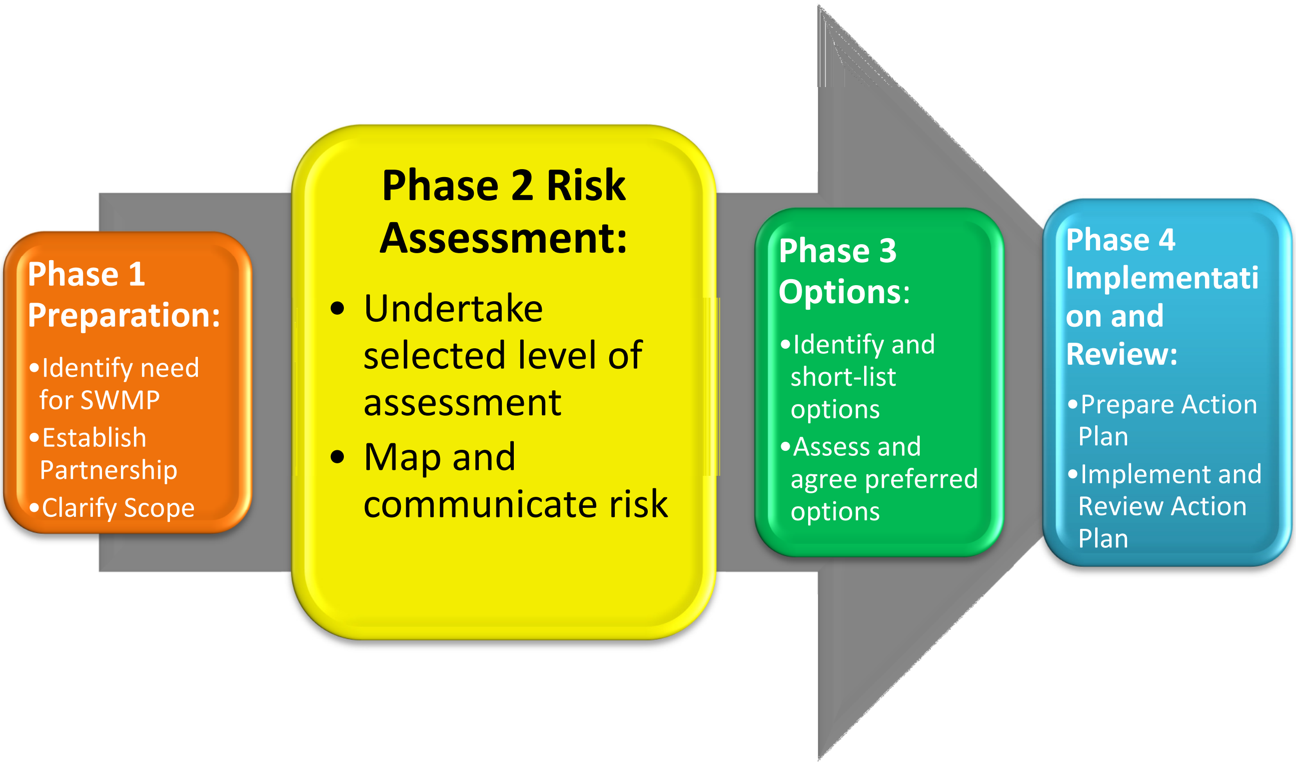
- Strategic Flood Risk Assessment;
- Catchment Flood Management Plan;
- Preliminary Flood Risk Assessment; and
- Index of Multiple Deprivation.

The use of some of the datasets made available for this SWMP have been restricted. These include:

- Records of property flooding held by NCC / GYBC; and
- DG5 register records from Anglian Water.

Necessary precautions must be taken to ensure that all restricted information given to third parties is treated as confidential. The information must not be used for anything other than the purpose stated in the terms and conditions of use accompanying the data. No information may be copied, reproduced or reduced to writing, other than what is necessary for the purpose stated in the agreement.

PHASE 2: RISK ASSESSMENT



4 Flood Sources

4.1 Historic Flooding

The SFRA indicates that there were significant flooding events in the Great Yarmouth area in 2006 due to prolonged rainfall. These events have been recorded by the Great Yarmouth Mercury in 2008. The Environment Agency did not provided any records of historic flood incidents of surface water in the area. Other flood records were collected from a range of sources including:

- Anglian Water
- Great Yarmouth Borough Council
- Norfolk County Council
- Norfolk County Fire and Rescue Service

A summary of key historic events which were provided for this report have been geo-referenced and mapped in Figure 4-1.

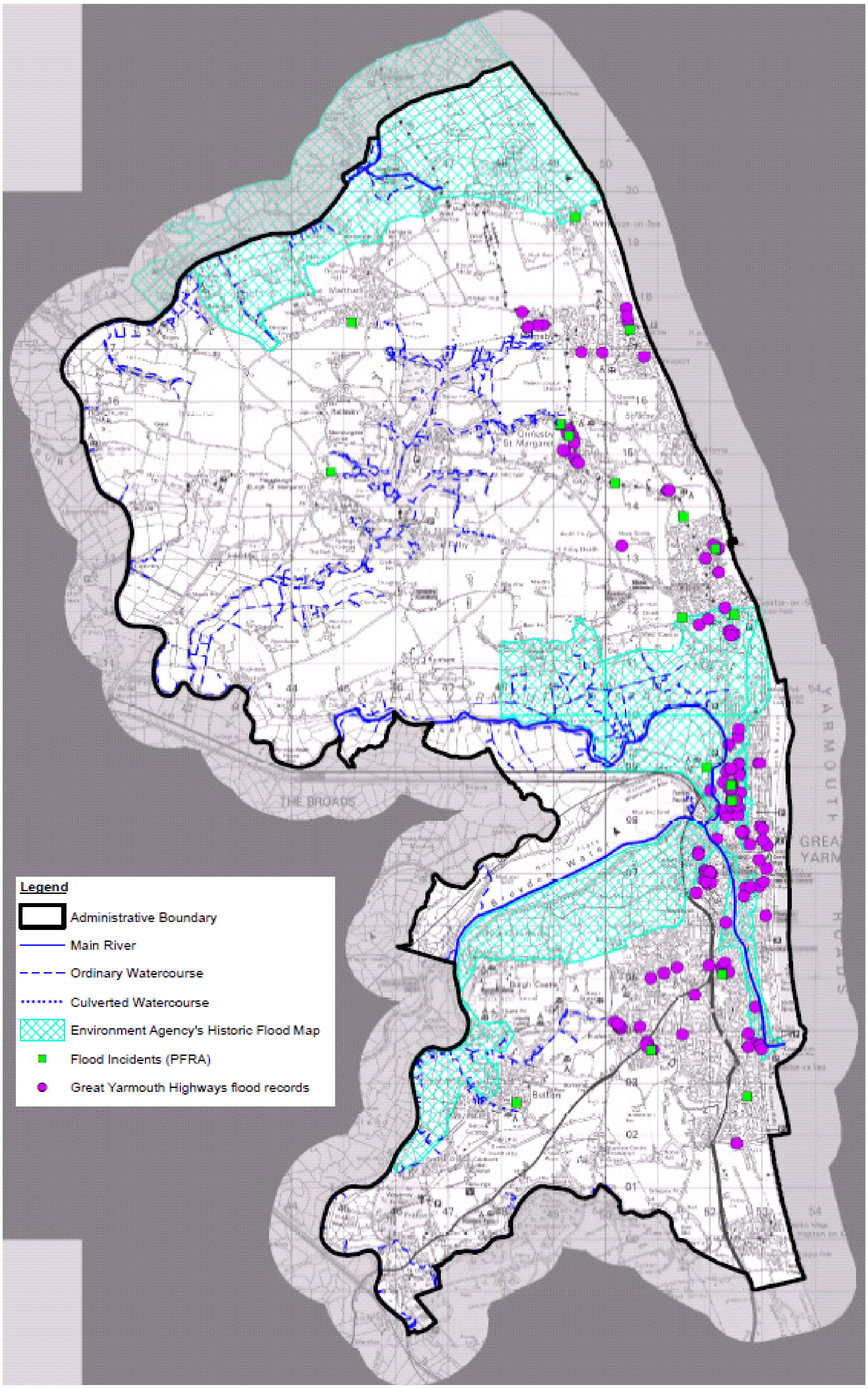


Figure 4-1 Historic Flood Events within the study area

4.2 Pluvial Flooding

4.2.1 Description

Pluvial flooding is the term used to describe flooding which occurs when intense, often short duration rainfall is unable to soak into the ground or to enter drainage systems and therefore runs over the land surface causing flooding. It is most likely to occur when soils are saturated (or baked hard) so that they cannot infiltrate any additional water, or in urban areas where buildings, tarmac and concrete prevent water soaking into the ground. The excess water can pond (collect) in low points and result in the development of flow pathways often along roads but also through built up areas and open spaces. This type of flooding is usually short lived and associated with heavy downpours of rain.

The potential volume of surface runoff in catchments is directly related to the size and shape of the catchment to that point. The amount of runoff is also a function of geology, slope, climate, rainfall, saturation, soil type, urbanisation and vegetation.

4.2.2 Causes and Classifications

Pluvial flooding can occur in rural and urban areas, but usually causes more damage and disruption in the latter. Flood pathways include the land and water features over which floodwater flows. These pathways can include drainage channels, rail and road cuttings. Developments that include significant impermeable surfaces, such as roads and car parks may increase the volume and rate of surface water runoff.

Urban areas which are close to artificial drainage systems, or located at the bottom of hill slopes, or in valley bottoms and hollows, may be more prone to pluvial flooding. This may be the case in areas that are down slope of land that has a high runoff potential including impermeable areas and compacted ground.

4.2.3 Impacts of pluvial flooding

Pluvial flooding can affect all forms of the built environment, including:

- Residential, commercial and industrial properties;
- Infrastructure, such as roads and railways, electrical infrastructure, telecommunication systems and sewer systems (including pumping stations);

It can also impact on:

- Agriculture; and
- Amenity and recreation facilities.

This type of flooding is usually short-lived and may only last as long as the rainfall event. However occasionally flooding may persist in low-lying areas where ponding occurs. Due to the typically short duration, this type of flooding tends not to have consequences as serious as other forms of flooding, such as flooding from rivers; however it can still cause significant damage and disruption on a local scale.

4.3 Ordinary Watercourse Flooding

4.3.1 Description

All watercourses in England and Wales are classified as either 'Main Rivers' or 'Ordinary Watercourses'. The difference between the two classifications is based largely on the perceived importance of a watercourse, and in particular its potential to cause significant and widespread flooding. However, this is not to say watercourses classified as Ordinary Watercourses cannot cause localised flooding. The Water Resources Act (1991) defines a 'Main River' as "a watercourse shown as such on a Main River Map". The Environment Agency stores and maintains information on the spatial extent of the Main River designations. The Flood and Water Management Act (2010) defines any watercourse that is not a Main River an Ordinary Watercourse – including ditches, dykes, rivers, streams and drains (as in 'land drains') but not public sewers.

The Environment Agency has duties and powers in relation to Main Rivers. Local Authorities have powers and duties in relation to Ordinary Watercourses.

Flooding from Ordinary Watercourses occurs when water levels in the stream or river channel rise beyond the capacity of the channel, causing floodwater to spill over the banks of the watercourse and onto the adjacent land. The main reasons for water levels rising in ordinary watercourses are:

- Intense or prolonged rainfall causing rapid run-off increasing flow in watercourses, exceeding the capacity of the channel. This can be exacerbated by wet antecedent (the preceding time period) conditions and where there are significant contributions of groundwater;
- Constrictions/obstructions within the channel causing flood water to backup;
- Blockage/obstructions of structures causing flood water to backup and overtop the banks; and
- High water levels in rivers preventing discharge at the outlet of the Ordinary Watercourse (often into a Main River).

4.3.2 Impacts of Flooding from Ordinary Watercourses

The consequence of Ordinary Watercourse flooding is dependent upon the degree of hazard generated by the flood water (as specified within the Defra/Environment Agency research on Flood Risks to People - FD2321/TR2) and what the receptor is (e.g. the consequence of a hospital flooding is greater than that of a commercial retailer). The hazard posed by flood water is related to the depth and velocity of water, which, in Ordinary Watercourses, depends on:

- Constrictions in the channel causing flood water to backup;
- The magnitude of flood flows;
- The size, shape and slope of the channel;
- The width and roughness of the adjacent floodplain; and
- The types of structures that span the channel.

The hazard presented by floodwater is proportional to the depth of water, the velocity of flow and the speed of onset of flooding. Hazardous flows can pose a significant risk to exposed people, property and infrastructure.

Whilst low hazard flows are less of a risk to life (shallow, slow moving/still water), they can disrupt communities, require significant post-flood clean-up and can cause costly and possibly permanent structural damage to property.

4.4 Groundwater Flooding

4.4.1 Description

Groundwater flooding is water originating from sub-surface permeable strata which emerges from the ground, either at a specific point (such as a spring) or over a wide diffuse location, and inundates low lying areas

The actual flooding can occur some distance from the emergence zone, with increased flows in local streams resulting in flooding at downstream constrictions / obstructions. This can make groundwater flooding difficult to categorise. Flooding from groundwater tends to be long in duration, developing over weeks or months and continuing for days or weeks.

There are many mechanisms associated with groundwater flooding, which are linked to high groundwater levels, and can be broadly classified as:

- Direct contribution to channel flow;
- Springs emerging at the surface;
- Inundation of drainage infrastructure; and
- Inundation of low-lying property (basements).

4.4.2 Impacts of Groundwater Flooding

The main impacts of groundwater flooding are:

- Flooding of basements of buildings below ground level – in the mildest case this may involve seepage of small volumes of water through walls and temporary loss of services. In more extreme cases larger volumes may lead to the catastrophic loss of stored items and failure of structural integrity;
- Overflowing of sewers and drains – surcharging of drainage networks can lead to overland flows causing significant but localised damage to property. Sewer surcharging can lead to inundation of property by polluted water. It is often difficult to separate this type flooding from other sources, notably surface water or sewer flooding;
- Flooding of buried services or other assets below ground level – prolonged inundation of buried services can lead to interruption and disruption of supply;
- Inundation of roads, commercial, residential and amenity areas – inundation of grassed areas can be inconvenient; however the inundation of hard-standing areas can lead to structural damage and the disruption of commercial activity. Inundation of agricultural land for long durations can have financial consequences; and
- Flooding of ground floors of buildings above ground level – can be disruptive, and may result in structural damage. The long duration of flooding can outweigh the lead time which would otherwise reduce the overall level of damages.

In general terms groundwater flooding rarely poses a risk to life. Figure 4-2 shows the Environment Agency Areas Susceptible to Groundwater Flooding. The general trend in the study area is high susceptibility along the Main River corridors with medium to low susceptibility in proportion to the distance from the Main Rivers and increase in elevation.

4.4.3 Groundwater Flooding Risk Assessment

There was only one data source available to review to produce an overall interpretation of groundwater flood risk in the study area. This is the EA Areas Susceptible to Groundwater Flooding Map (EA 2012). This data has used the top two susceptibility bands of the British Geological Society (BGS) 1:50,000 Groundwater Flood Susceptibility Map. It shows the proportion of each 1km grid square where geological and hydrogeological conditions show that groundwater might emerge. This provides an overview of proportional area that is at high or very high risk of groundwater flooding. The categories are as follows:

- $< 25\%$ (Low)
- $\geq 25\% < 50\%$ (Moderate)
- $\geq 50\% < 75\%$ (High)
- $\geq 75\%$ (Very High)

The study area only includes zones of ‘Low’ risk to groundwater flooding.

Groundwater levels rise and fall in response to rainfall patterns and distribution, with a time scale of months rather than days. The significance of this rise and fall for flooding depends largely on the type of ground it occurs in i.e. how permeable the ground is and whether the water level comes close to or meets the ground surface.

Groundwater flooding is often highly localised and complex. Under some circumstances groundwater levels can rise and cause flooding problems in subsurface structures or at the ground surface. The mapping technique adopted by the EA aims to identify only those areas in which there is the greatest potential for this to happen.

There is currently limited research which specifically considers the impact of climate change on groundwater flooding. The mechanisms of groundwater flooding are unlikely to be affected by climate change, however if winter rainfall becomes more frequent and heavier, groundwater levels may increase. Higher winter recharge may however be balanced by lower recharge during the predicted hotter and drier summers.

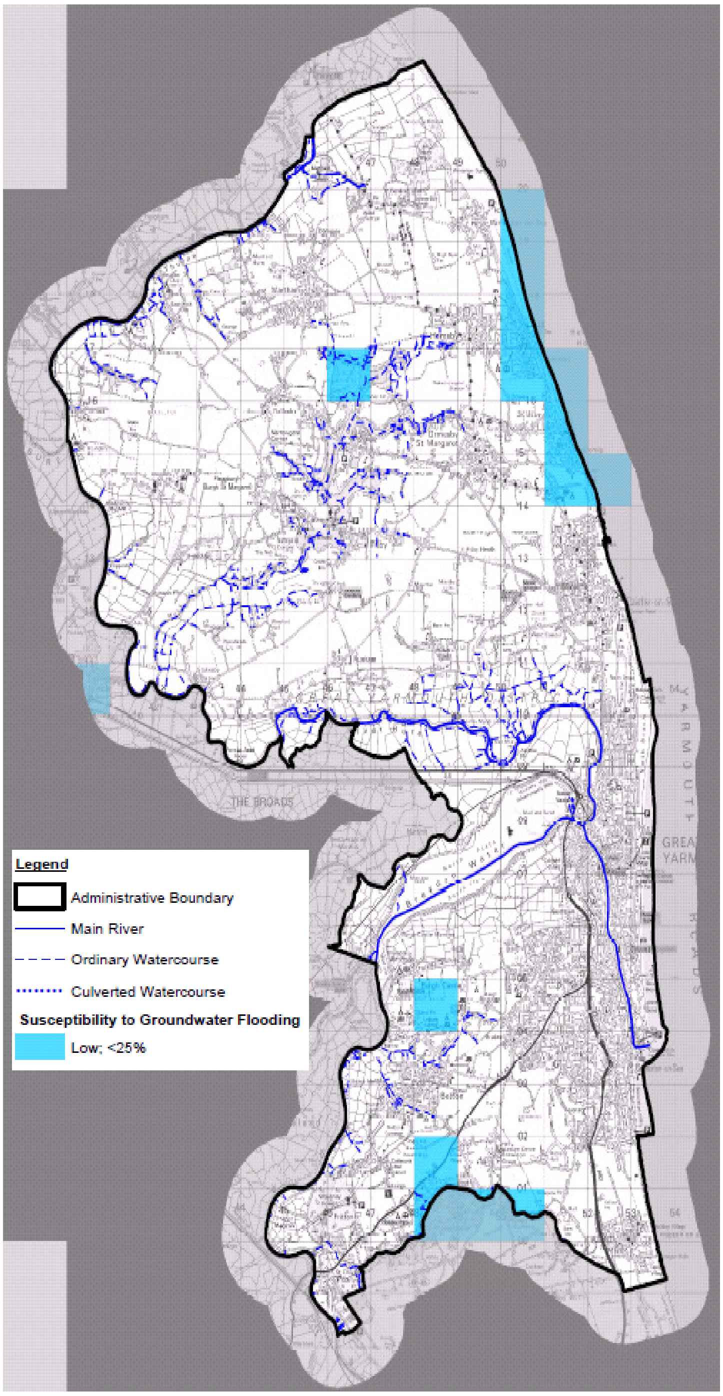


Figure 4-2 Environment Agency Areas Susceptible to Groundwater Flooding Map

4.4.4 Groundwater Flooding Management

Management is highly dependent upon the characteristics of the specific situation. The costs associated with the management of groundwater flooding are highly variable. The implications of groundwater flooding should be considered and managed through development control and building design. Possible responses include:

- Raising property ground or floor levels or avoiding the building of basements in areas considered to be at risk of groundwater flooding.

- Provide local protection for specific problem areas such as flood-proofing properties (such as tanking, sealing of building basements, raising the electrical sockets/TV points etc).
- Replacement and renewal of leaking sewers, drains and water supply reservoirs. Water companies have a programme to address leakage from infrastructure, so there is clear ownership of the potential source.
- Major ground works (such as construction of new or enlarged watercourses) and improvements to the existing surface water drainage network to improve conveyance of floodwater from surface water of fluvial events through and away from areas prone to groundwater flooding.

Most options involve the management of groundwater levels. It is important to assess the impact of managing groundwater with regard to water resources and environmental designations. Likewise, placing a barrier to groundwater movement can shift groundwater flooding from one location to another. The appropriateness of infiltration based drainage techniques should also be questioned in areas where groundwater levels are high or where source protection zones are close by.

4.4.5 Uncertainties and Limitations – Groundwater Flooding

Within the areas delineated, the local rise of groundwater will be heavily controlled by local geological features and artificial influences (e.g. structures or conduits) which are not represented. This localised nature of groundwater flooding compared with, say, fluvial flooding suggests that interpretation of the map should similarly be different. The map shows the area within which groundwater has the potential to emerge but it is unlikely to emerge uniformly or in sufficient volume to have a similar impact to surface water or fluvial flooding. Instead, groundwater emerging at the surface may simply runoff to pond in lower areas.

Locations shown to be at risk of surface water flooding are also likely to be most at risk of runoff/ponding caused by groundwater flooding. Therefore the susceptibility map should not be used as a “flood outline” within which properties at risk can be counted. Rather, it is provided, in conjunction with the surface water mapping, to identify those areas where groundwater may emerge and what the major water flow pathways would be in that event.

It should be noted that this assessment is broad scale and does not provide a detailed analysis of groundwater; it only aims to provide an indication of where more detailed consideration of the risks may be required.

The causes of groundwater flooding are generally understood. However, groundwater flooding is dependent on local variations in topography, geology and soils. It is difficult to predict the actual location, timing and extent of groundwater flooding without comprehensive analysis.

There is a lack of reliable measured datasets to undertake flood frequency analysis on groundwater flooding and even with datasets this analysis is complicated due to the non-independence of groundwater level data. Studies therefore tend to analyse historic flooding which means that it is difficult to assign a level of certainty.

The impact of climate change on groundwater levels is highly uncertain. The UK Climate Impact Programme (UKCIP) model indicates that, in future, winters may be generally wetter and summers substantially drier across the UK. The greater variability in rainfall could mean more frequent and prolonged periods of high or low water levels. The effects of climate change on groundwater in the UK therefore may include increased frequency and severity of groundwater-related floods. It should be noted that although winter rainfall may increase the frequency of groundwater flooding incidents, the potential of drier summers and lower recharge of aquifers may counteract this effect.

4.4.6 Infiltration SUDS

Improper use of infiltration SUDS could lead to contamination of the superficial deposit or bedrock aquifers, leading to deterioration in aquifer quality status or groundwater flooding / drainage issues. However, correct use of infiltration SUDS is likely to help improve aquifer quality status and reduce overall flood risk.

Environment Agency guidance on infiltration SUDS is available on their website at: http://www.environment-agency.gov.uk/business/sectors/36998.aspx. This should be considered by developers and their contractors, and by the Councils when approving or rejecting planning applications.

The areas that may be suitable for infiltration SUDS exist where there is a combination of high ground and permeable geology. However, consideration should be given to the impact of increased infiltration SUDS on properties further down gradient. An increase in infiltration and groundwater recharge will lead to an increase in groundwater levels, thereby increasing the susceptibility to groundwater flooding at a down gradient location. This type of analysis is beyond the scope of the current report, but it could be as significant problem where there is potential for perched water tables to develop.

4.5 Sewer Flooding

4.5.1 Description

Flooding which occurs when the capacity of the underground drainage network is exceeded, resulting in the surcharging of water into the nearby environment (or within internal and external building drainage networks) or when there is an infrastructure failure. The discharge of the drainage network into waterways and rivers can also be affected if high water levels in receiving waters obstruct the drainage network outfalls. In the study area, the sewer network is predominantly a combined (surface water and foul water in the same pipe) sewer system.

4.5.2 Causes of Sewer Flooding

The main causes of sewer flooding are:

- Lack of capacity in the sewer drainage networks due to original under-design – this is a result of the original design criteria requiring a reduced standard of protection which was acceptable at the time of construction;
- Lack of capacity in sewer drainage networks due to an increase in flow (such as climate change and/or new developments connecting to the network);
- Exceeded capacity in sewer drainage networks due to events larger than the system designed event;
- Loss of capacity in sewer drainage networks when a watercourse has been fully culverted and diverted or incorporated into the formal drainage network (lost watercourses);
- Lack of maintenance or failure of sewer networks which leads to a reduction in capacity and can sometimes lead to total sewer blockage;
- Failure of sewerage infrastructure such as pump stations or flap valves leading to surface water or combined foul/surface water flooding (this is only considered in this study if caused by a rainfall event);

- Additional paved or roof areas i.e. paved driveways and conservatories connected onto existing network without any control;
- Lack of gully maintenance restricting transfer of flows into the drainage network;
- Groundwater infiltration into poorly maintained or damaged pipe networks; and
- Restricted outflow from the sewer systems due to high water or tide levels in receiving watercourses ('tide locking').

Sewer flooding is a key issue for Great Yarmouth Borough – most predominantly in the Great Yarmouth urban areas (Great Yarmouth itself, Cobholm, Southtown, Bradwell and Goreleston). Through a combination of the very flat topography and extensive tidal flood defences, these areas rely almost completely on piped drainage systems for managing surface water runoff. The piped systems in these areas are generally 'combined' (surface water and foul water conveyed in the same pipe) and are pumped to the local sewerage treatment plant.

The piped and pumped drainage system is designed to convey foul water and a small volume of surface water. When surface water runoff exceeds the capacity of the drainage system, then surcharging and surface water flooding occurs. The impact of surface water flooding is exacerbated through contamination with foul water and a significant volume of contaminated water is discharged into the River Yare and its tributaries.

The situation is exacerbated further if significant rainfall occurs during a high tide or storm surge as this further limits the capacity of the drainage system to discharge excess flows. In these circumstances, overflows from the drainage system need to be pumped into the river. The pumps have limited capacity and this is often exceeded, resulting in localised surface water flooding.

4.5.3 Impacts of Sewer Flooding

The impact of sewer flooding is usually confined to relatively small localised areas but, because flooding is associated with blockage or failure of the sewer network, flooding can be rapid and unpredictable. Flood waters from this source are also often contaminated with raw sewage and pose a health risk. The spreading of illness and disease can be a concern to the local population if this form of flooding occurs on a regular basis.

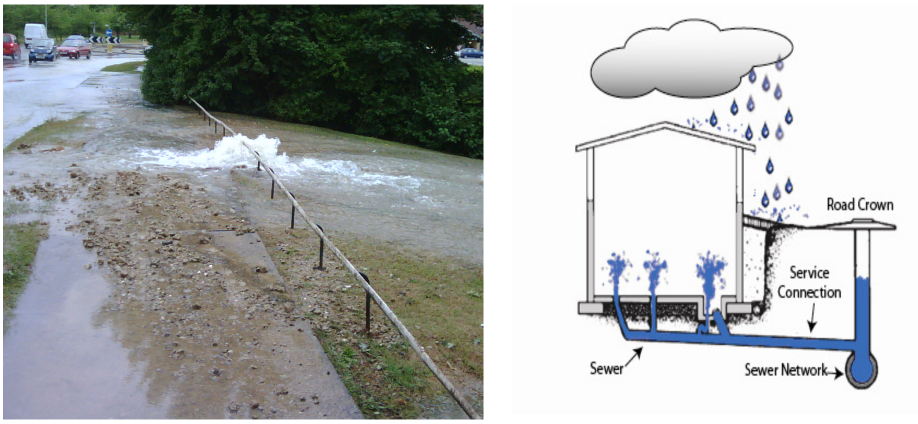


Figure 4-3 Surcharging of the sewer system within a road (left) and internally within a property (right)

Drainage systems often rely on gravity assisted branching systems, which convey water in trunk sewers located at the lower end of the catchment. Failure of these trunk sewers can have serious consequences, which are often exacerbated by topography, as water from surcharged manholes will flow into low-lying urban areas (Figure 4-3).

The diversion of "natural" watercourses into culverted or piped structures is a historic feature of the study area drainage network. Where it has occurred, deliberately or accidentally it can result in a reduced available capacity in the network during rainfall events when the sewers drain the watercourses catchment as well as the formal network. Excess water from these watercourses may flow along unexpected routes at the surface (usually dry and often developed) as its original channel is no longer present and the formal drainage system cannot absorb it.

In order to clearly identify problems and solutions, it is important to first outline the responsibilities of different organisations with respect to drainage infrastructure. The responsible parties are primarily the Highways Authority and Anglian Water.

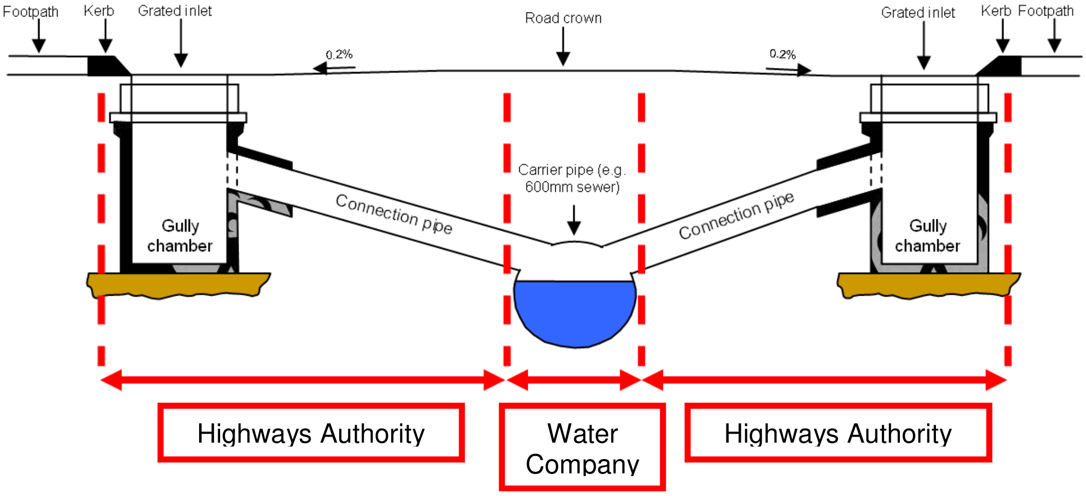


Figure 4-4 Surface water sewer responsibility

As illustrated in Figure 4-4, NCC, as the Highways Authority, is responsible for maintaining an effective highway drainage system including kerbs, road gullies and the pipes which connect the gullies to the trunk sewers and soakaways for all roads except trunk roads. The Highways Agency is responsible for the maintenance of Trunk Roads. The sewerage undertaker, in this case Anglian Water, is responsible for maintaining the trunk sewers.

4.5.4 Drainage Network

A number of different data sources were used to obtain a detailed understanding of the sewer network across Great Yarmouth Borough, primarily through consultation with Anglian Water. Anglian Water is keen to work with Great Yarmouth Borough and the LLFA (NCC), in order to mitigate flood risk issues in an integrated manner. The primary sources of information were:

- Anglian Water – Provided details of the infrastructure network including sewers, manholes, pumping stations and outfalls in GIS format.
- NCC Highways – Supplied details of recently separated surface water road drainage (mainly in the Bradwell area) in AutoCAD format.
- Waveney, Lower Yare and Lothingland Internal Drainage Board – Supplied detailed drainage layouts of IDB controlled assets in the Great Yarmouth area (mainly Bradwell and Cobholm).

4.5.5 Uncertainties in Flood Risk Assessment – Sewer Flooding

Assessing the risk of sewer flooding over a wide area is limited by the lack of data and the quality of data that is available. Furthermore, flood events may be a combination of surface water, groundwater and sewer flooding.

An integrated modelling approach has been used in this study for three distinct, high priority areas of Great Yarmouth Borough to assess the impact of sewer flooding. The modelling methodology is described fully in Section 5.2 and details the relevant uncertainties. In non-modelled areas, the impact of sewer flooding is measured solely by the number of Anglian Water DG5 records (properties that flood more regularly than once in 20 years that can be directly attributed to sewer flooding) in a certain area. This dataset has been provided to street level accuracy (not individual property) and is based on actual flood incidents (not modelled).

4.6 Main River Fluvial and Tidal Flooding

Interactions between surface water and fluvial flooding are generally a result of watercourses unable to receive and convey excess surface water runoff. Where the watercourse in question is defended, surface water can pond behind defences. This may be exacerbated in situations where high water levels in the watercourse prevent discharge via flap valves through defence walls.

Main Rivers have been considered in the surface water modelling by assuming a 'bank full' condition, in the same way that ordinary watercourses have been modelled. Control structures such as weirs, locks and gates along watercourses have not been explicitly modelled.

A network of discrete flood defences has been constructed to reduce flood risk within the study area. Whilst managing flood risk from Main Rivers in some areas, as shown in Figure 4-5, this flood defence infrastructure can increase the residual risk of flooding in these areas due to the possibility of its failure (and can also influence flooding on the upstream side as a result of the unnatural obstruction to surface water flows). There are two primary modes of defence failure; overtopping and breach.

Figure 4-5 displays the Environment Agency's Flood Risk Zones. The outlines indicate that the risk of fluvial flooding from Main Rivers and Tidal sources is largely concentrated around the low lying areas along the coast and the River Yare along with its associated tributaries.

Note that the effects of Main River flooding have not been assessed as part of this study; more information can be found in the CFMP and SFRA documents. Further information on fluvial (Main River) flooding and potential impacts of tidal flood defence breaches can be found in the SFRA.

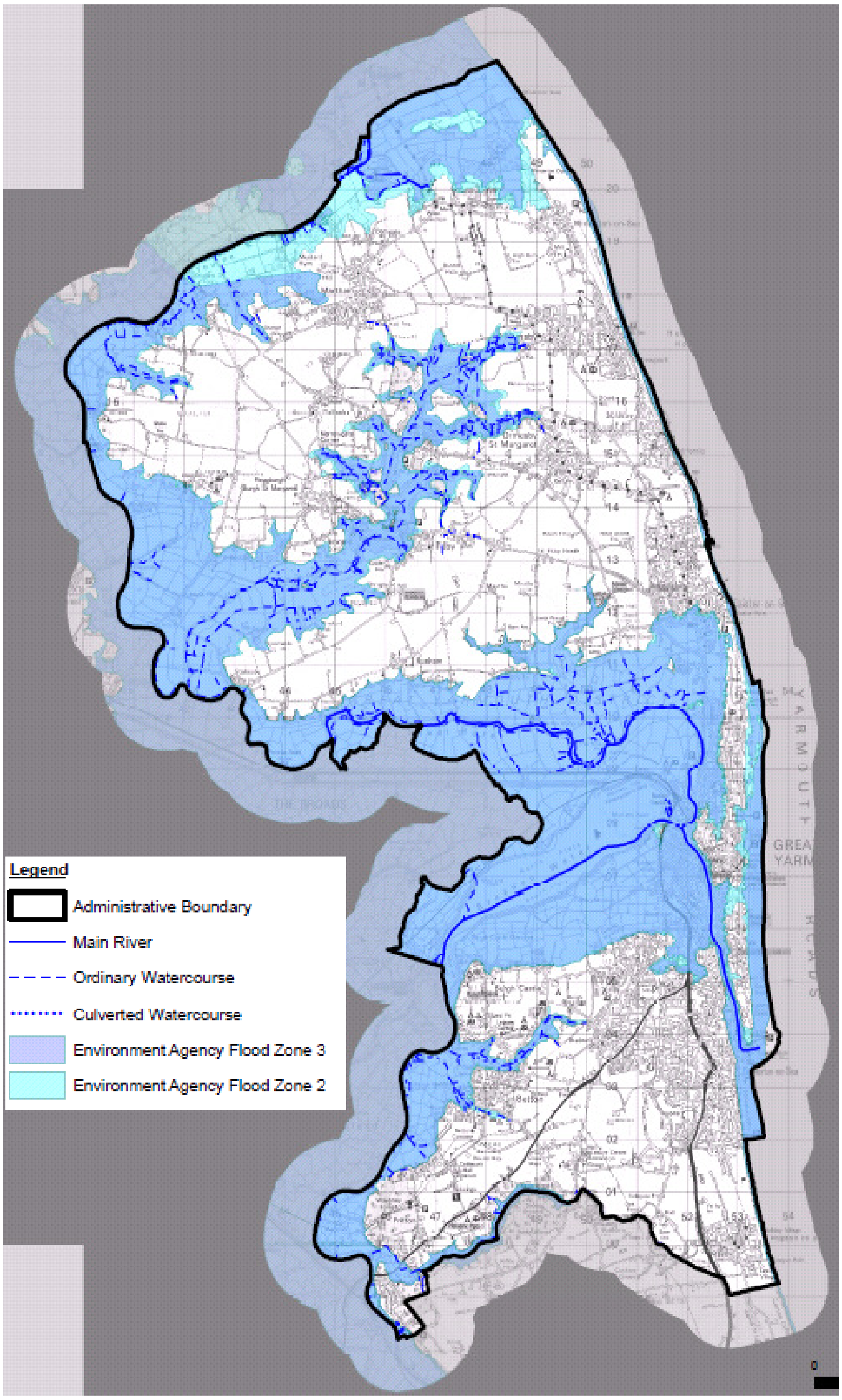


Figure 4-5 Flood Zones within Great Yarmouth Borough

5 Assessment Methodology

SWMPs can function at different geographical scales and as a result of this differing levels of detail may be necessary. Table 5-1 defines the levels of assessment that can be used within a SWMP (**bold** style font).

Table 5-1: Level of assessment (adapted from Defra SWMP Guidance, March 2010)

Level of Assessment	Appropriate Scale	Outputs
Strategic Assessment	County or large conurbation (e.g. Norfolk County area)	• Broad understanding of locations that are more vulnerable to surface water flooding. • Prioritised list for further assessment. • Outline maps to inform strategic and emergency planning.
Intermediate Assessment	**Large town or district (e.g. Great Yarmouth Borough)**	• **Identify flood hotspots which might require further analysis through detailed assessment.** • **Identify immediate mitigation measures which could be considered.** • **Inform strategic and emergency planning.**
Detailed Assessment	**Known flooding hotspots (e.g. Critical Drainage Areas)**	• **Detailed assessment of cause and consequences of flooding.** • **Use to understand the mechanisms and test potential mitigation measures.**

Two levels of assessment have been applied for this SWMP. An Intermediate Assessment was applied across the study area and used to identify the areas that required a Detailed Assessment. These two processes are detailed in the following sections.

5.1 Intermediate Assessment

The purpose of the intermediate assessment was to further identify areas within Great Yarmouth Borough that are likely to be at greatest risk of surface water flooding and which required further analysis through more detailed assessment.

A thorough review of available relevant flood risk data for the study area was carried out. This included a desktop review of historic flood information, asset data, future development plans and previous studies in consultation with relevant Steering Group members to ensure full coverage and comprehensive understanding of the local issues was achieved.

Flood risk maps using the EA Flood Map for Surface Water (FMfSW) were prepared and site visits were completed to each of the ten nominated settlements (as identified in Phase 1). The purpose of these visits was to ground truth the FMfSW, determine flooding mechanisms, consult with local residents, identify opportunities for flood mitigation, review local vulnerability to flooding and assess the potential local impacts of surface water flooding. The notes made during these site visits are located in Appendix A.

The desktop review and site visit information were then combined to form a prioritised list of areas for detailed assessment based on flood impact (no. of receptors at risk in 1 in 200yr event and actual historic impacts), vulnerability, potential future development and environmental impacts. The prioritised list is summarised below and further details are available in Appendix A.

1. Great Yarmouth inc. Gorleston (South of River Yare);
2. Great Yarmouth (North of River Yare);
3. Bradwell;
4. Hemsby;
5. Caister-on-Sea;
6. Ormesby St Margaret;
7. Martham;
8. Hopton-on-Sea;
9. Winterton-on-Sea; and
10. Belton.

Through discussion with the Steering Group, it was agreed that the five highest priority areas would be taken further into the Detailed Assessment phase. The top three areas were assessed using detailed hydraulic modelling, while the fourth and fifth ranked areas were further assessed using engineering judgement. The justifications for each of these approaches are detailed in the table below.

The remaining settlements (Martham, Hopton-on-Sea, Winterton-on-Sea and Belton) have been assessed at the intermediate level only and have flood risk management actions defined for each based on local conditions (refer Appendix A for details). They have not been progressed for detailed assessment as the available flood risk information is judged sufficient to be able to make effective risk management decisions.

In general, the detailed assessment process was undertaken using one of the two methods depending on the quality of available information and the level of flood impact estimated by the Intermediate Assessment. Detailed modelling assessments were completed for the highest priority areas that had suitable supporting data (such as good LiDAR coverage and pipe network asset data) and had a clear justification for improving on the national FMfSW. Engineering judgement based detailed assessments were completed for areas where the national FMfSW showed good correlation with local information and detailed modelling was not justifiable.

Table 5-2: Justification for Detailed Assessment Approach

Settlement	Assessment Type	Justification	Outcomes
Hemsby Caister-on-Sea	Complete Engineering Judgement based detailed assessment – focussing on: • Review of previous capital works • Estimating soakage capacity • Assessment of flood impact on non-residential properties • Review of complex geological conditions to assess groundwater flood risk • Identification of opportunities for flood mitigation through future development	• Piped surface water sewer system is limited in size and extent • Surface water relies mostly on soakage systems • Flood Map for Surface Water represents current flood risk well • Level of groundwater flood risk is poorly understood	• Understanding of net impact of recent works • Understanding of groundwater flood risk • Identified opportunities to manage flood risk through future development
Bradwell	Build Integrated Urban Drainage model (overland and surface water drainage only) to: • Assess impacts of rainfall events that exceed the design capacity of surface water drainage system • Understand impact of downstream water levels on flooding in Bradwell	• Significant investment already made in understanding and improving highways drainage system • Consequences of capacity exceedance are not well understood • Impact of downstream controls on overall system are not well understood	• Understanding of residual flood risk following recent drainage works
Great Yarmouth inc. Gorleston (south of River Yare) Great Yarmouth (north of River Yare)	Build detailed overland flow only (no pipe network) model using Anglian Water modelled overflow points to[2]: • Assess impacts of rainfall events that exceed the design capacity of drainage system • Improve surface water flood risk map of the whole area (detailed 2D model can represent influence of buildings and subtle changes in local topography)	• Anglian Water already have a detailed combined system pipe model of these areas – this can be used to assess how much runoff enters the pipe network and how much remains on the surface • Using the Anglian Water model to generate point inflows implicitly allows for hydraulic controls (pump station, control valves etc).	• Identified targeted areas that require detailed modelling to understand complex flood mechanisms • Improved understanding of flood mechanisms in area • Overland flow model is available for future working with AWS

[2] Further detail on the modelling methodology is provided in Section 5.2

5.2 Detailed Assessment – Modelling

5.2.1 Methodology – Overview

In order to continue developing an understanding of the causes and consequences of surface water flooding in the highest priority parts of the study area, hydraulic modelling has been undertaken for a range of rainfall event probabilities. The purpose of this modelling is to provide additional information where local knowledge is lacking and forms a basis for future detailed assessments in areas identified as high risk.

To facilitate the accurate identification, retrieval and review of model data a number of actions were undertaken, including:

- The use of a standard folder structure for all model files;
- A standardised naming convention that included the model name, scenario and version number;
- A model log was initiated at the start of the modelling process that provides a clear and concise record of model development; and
- The model was reviewed by a senior modeller following Capita Symonds URS standard Quality Assurance protocol. This review incorporated all the model files that were used in the model set-up.

A combination of modelling approaches has been selected (see Table 5-3) which models direct rainfall (pluvial flooding) and the sewer system. The approach for Great Yarmouth Borough uses a combination of direct rainfall and Anglian Water drainage system models as follows:

- Areas served by the Anglian Water combined drainage system were modelled by Anglian Water for an agreed set of five rainfall events (refer to Table 5-4). As the Anglian Water model only includes the pipe system, it is assumed that all rainfall enters the pipe system and then overflows via manholes where the system capacity is exceeded. The hydrographs from each overflowing manhole were exported and provide to the Capita Symonds URS team to use as 'point inflows' for the overland flow model.
- Areas not served by the Anglian Water combined drainage system were modelled by Capita Symonds URS using a direct rainfall approach. The same five agreed rainfall events are applied to the overland flow model.

Table 5-3: Levels of pluvial modelling

Rolling Ball	Surface water flow routes are identified by topographic analysis, most commonly in a GIS package
Direct Rainfall	Rainfall is applied directly to a surface and is routed overland to predict surface water flooding
Drainage Systems	Based around models of the underground drainage systems
Integrated Approach	Representing both direct rainfall and drainage systems in an integrated manner, or through linking different models together dynamically

The 'overland flow' model represents the local topography – including ordinary watercourses. With two flow inputs (direct rainfall and overflows from the drainage system), this provides a detailed representation of local surface water flooding.

Hydraulic modelling of the pluvial and ordinary watercourses component of surface water flooding was undertaken using InfoWorks Integrated Catchment Management (ICM) software (Version 3). InfoWorks ICM simulates water level variations and flows for depth-averaged, unsteady two-dimensional (2D), free-surface flows and has been used successfully for many SWMPs to capture the hydrodynamic behaviour and flow patterns in complex urban environments.

The extent of the hydraulic model was based upon catchment boundaries as agreed with the SWMP Steering Group with a variable resolution of between $5m^2$ and $30m^2$. Figure 5-1 indicates the extent of the models utilised within the risk assessment.

Figure 5-1 Model Boundaries

5.2.2 Rainfall Events

The selected return periods were chosen through consultation with the Steering Group. As part of this report, figures have been prepared for the modelled settlements based on the 1 in 100 year rainfall event (1% AEP). All relevant figures can be found in Appendix D. Additionally, ASCII grids and ESRI Shape files have been created and distributed to the Steering Group for use within their in-house GIS system. Table 5-4 provides details of the return periods that have been selected and the suggested uses of the various modelling outputs.

Table 5-4: Selected return periods and suggested use of outputs

Modelled Return Period	Suggested use
1 in 30 year event *(3.3% AEP)*	This is the design level of service for new sewers and matches with the events selected for the other SWMPs completed to date in Norfolk (Norwich, Kings Lynn and West Norfolk). The event also matches with the requirements of the Flood Risk Regulations and the national Environment Agency Flood Map for Surface Water (for model validation purposes).
1 in 75 year event *(1.3% AEP)*	In areas where the likelihood of flooding is 1 in 1 year to 1 in 75 years insurers may not guarantee to provide cover to property if it is affected by flooding. This layer should be used to inform strategic planning as if property cannot be guaranteed insurance, the development may not be viable.
1 in 100 year event *(1% AEP)*	Can be overlaid with Environment Agency Flood Zone 3 layer to show areas at risk under the same return period event from surface water and Main River flooding. Can be used to advise planning teams – please note that the pluvial 1 in 100 year event may differ from the fluvial event due to methods in runoff and routing calculations.
1 in 100 year event (plus 30% climate change)	NPPF requires that the impact of climate change is fully assessed. Reference should be made to this flood outline by the strategic planning teams to assess the sustainability of developments.
1 in 200 year event *(0.5% AEP)*	To be used by emergency planning teams when formulating emergency evacuation plans from areas at risk of flooding. It also matches with the national Environment Agency Flood Map for Surface Water (for model validation purposes).

A summer rainfall profile was selected as it produces a higher intensity storm event in comparison to a winter profile, which is considered to be the worst-case scenario. Models simulations were run at double the critical duration in order to allow runoff to be conveyed down overland flow paths.

5.2.3 Hydrology

An important aspect of establishing suitable rainfall profiles is to estimate the critical storm duration for the study area. In order to ensure that the most appropriate scenario is assessed and the entire catchment is contributing surface water runoff, the critical storm duration must be estimated.

Two methods were used to calculate an estimate of the critical storm duration for the rainfall profiles used in the model. A summary of these methods is given below:

- The Bransby-Williams formula was used to derive the *time of concentration,* defined as the time taken for water to travel from the furthest point in the catchment to the catchment outfall, at which point the entire site is considered to be contributing runoff; and
- The Flood Estimation Handbook (FEH) equation for critical storm duration - the standard average annual rainfall (SAAR) value for each catchment has been extracted from the FEH CD-ROM v3 and the Revitalised Flood Hydrograph method (ReFH) model has been used to derive the time to peak (Tp) from catchment descriptors.

Based on this assessment a critical storm duration of three (3) hours was utilised within the direct rainfall model, with the model simulation being run six (6) hours to capture the impacts of ponding and overland flow after a storm has passed.

The catchment descriptors for the study area were exported from FEH and used in the InfoWorks ICM rain generator to derive rainfall hyetographs for a range of return periods. The hyetographs generated using this methodology, and incorporated within the pluvial model, can be located within Appendix C.

5.2.4 Model Topography

The boundary of the models was based on a review of the topographical information available for the area. This included the following information (in order of preference):

- Light Detecting and Ranging data (LiDAR) was used as the base information for the model topography. LiDAR data is an airborne survey technique that uses laser to measure the distance between an aircraft and the ground surface, recording an elevation accurate to ±0.15m at points between 0.25m and 2m apart (depending in the intended accuracy of the survey). The technique records elevations from all surfaces and includes features such as buildings, trees and cars. This raw data is then processed to remove these features and provide values of the ground surface, which is merged to create a Digital Terrain Model (DTM) of the ground surface itself.
- IFSAR (Interferometric Synthetic Aperture Radar) - An aircraft-mounted sensor designed to measure surface elevation, which is used to produce topographic imagery. Depending on the terrain and vegetation, IFSAR can have a vertical accuracy of ±1m.

Figure 5-2 displays the variation in level of detail available between these datasets.

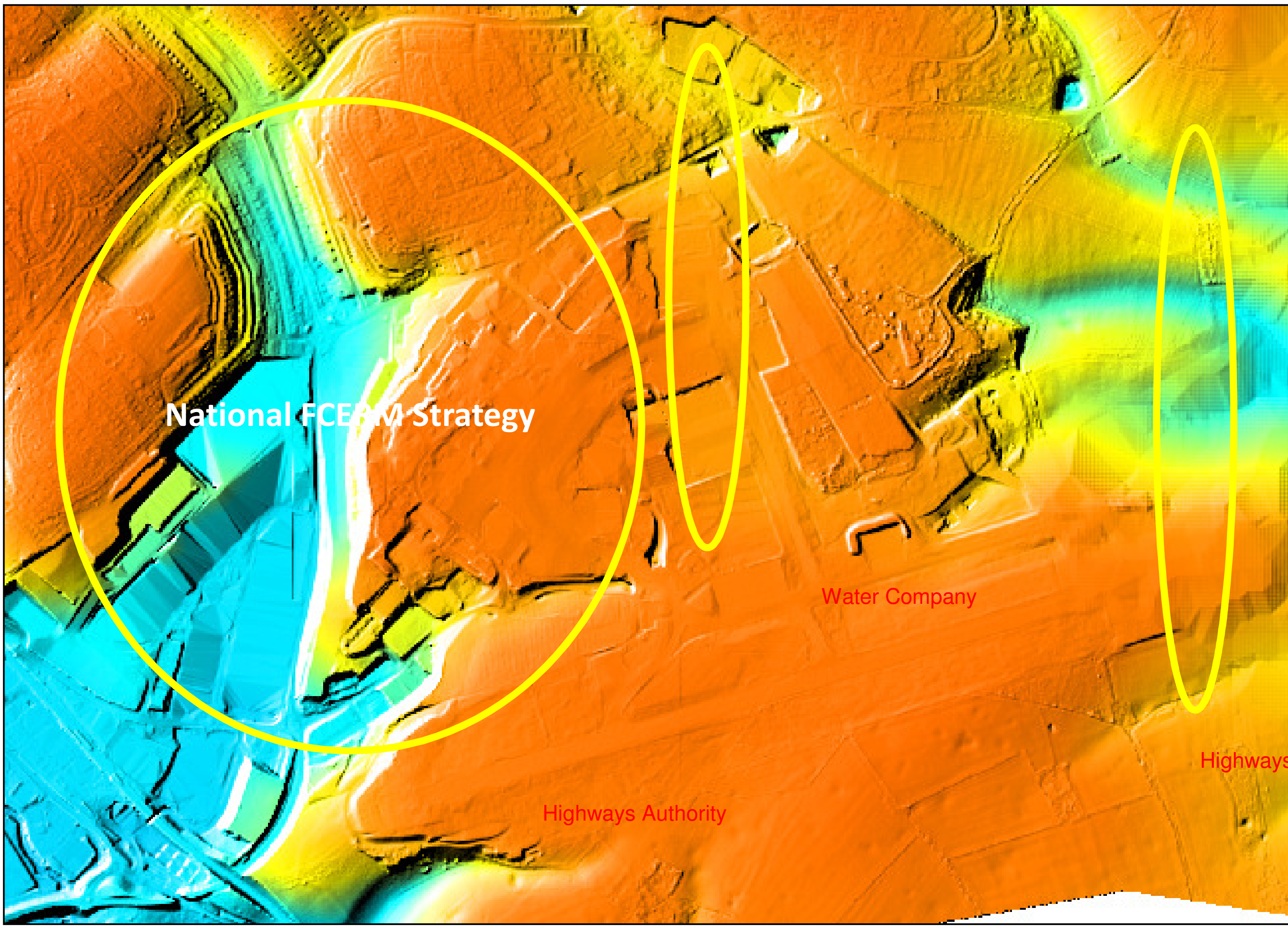


Figure 5-2 Variation in Information utilised to Create the Model DTM

LiDAR data was available at a 1m resolution for the majority of the study area. Where LiDAR was not available, for a small area (1.2km^2) to the south of Gorleston, IFSAR data was obtained and used. Filtered LiDAR (and IFSAR) data, in preference to unfiltered data, has been used as the base topography to provide the model with a smoother surface to reduce the potential instabilities in the model and areas of unexpected ponding. The filtered data represents the 'bare earth' topography and does not include vegetation or buildings. The general topography of the study area generated from the combined LIDAR and IFSAR data can be seen in Figure 2-3.

The ground elevations were represented in InfoWorks ICM using variable triangular mesh. This approach allows small topographic features to be represented in detail with other large features represented in lower resolution. The decision to use a 5m^2 to 30m^2 mesh size is an optimisation of the computational time required due to the size of the study area and the need for accuracy in the model in order to resolve features in the urban environment.

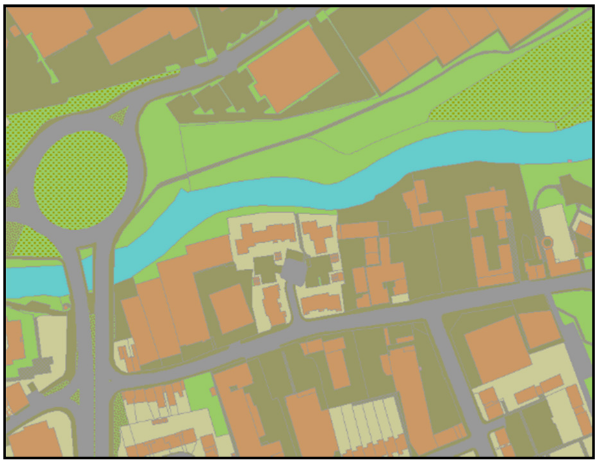
Three catchments were modelled as illustrated in Figure 5-1:

- GRY1 - Great Yarmouth (North of River Yare), covering the urban extent of Great Yarmouth, bounded by the coast to the east, River Yare to the south and west and Fremantle Road to the north. Modelled catchment area is approximately 5.1km^2.

- BRG1 – Bradwell, Gorleston and Southtown, covering the urban extent, bounded to north and east by the River Yare, to the north and west by the WLY&L IDB Burgh Castle Catchment and to the south by the BRG2. Modelled catchment area is approximately 11.9km^2.

- BRG2 – Bradwell and south Gorleston, covering the urban extent, bounded to the east by the River Yare, to the west and south by fields and to the north by the catchment boundary of BRG1. Modelled catchment area is approximately 8.1km^2.

5.2.5 Land Surface



The type of land surface has a significant effect on the flow of water along surface water flow paths due to the relatively shallow depths of flooding. As such, a number of roughness coefficients have been specified in order to accurately represent different land types within the hydraulic model and the effect they have on the flow of water.

OS MasterMap data has been used to produce different land type layers (such as roads, grass, water, etc, as shown in Figure 6-7), for which different Manning's roughness coefficients have been specified. These layers have been applied across the modelled areas and included within the InfoWorks ICM model in order to represent the different behaviour of water as it flows over different surfaces.

5.2.6 Anglian Water Sewer Network

Model Representation

The sewer network, as modelled by Anglian Water Services (AWS), was not included in the models as:

- AWS has existing models of their sewer catchments and are in the process of updating these;
- AWS cannot release their models for consultant use and it is considered that any attempt to represent the AWS model within this study is unlikely to accurately replicate the complexities of the network;
- Modelling undertaken as part of the SWMP looks at the higher intensity rainfall runoff events (1 in 30 year and greater) which are in exceedance of the AWS sewer network capacity;
- AWS are interested in understanding the flood risk from the larger return period events and will use the outputs from the modelling to compare with, or include within, their sewer model updates (due for completion by October 2014); and
- The aim of the detailed 2D modelling is to assess the impacts of rainfall events that could exceed the capacity of the drainage system.

It was agreed that the AWS models would be run for one storm duration for the agreed rainfall runoff events (5 in total). Capita Symonds with URS provided the FEH rainfall events and duration to AWS for input to their model. The outputs from the AWS models (surcharging manhole locations and volumes) were provided by AWS for inclusion in the 2D surface water models.

Sewer Infiltration Rates

There is a large uncertainty and variation in sewer infiltration rates used within surface water models to represent losses to the sewer. The modelling approach used in this study negates the need for inclusion of assumptions in infiltration rates, through incorporating the AWS model outputs (at manholes) for the agreed rainfall runoff events.

Pumping Failure Scenarios

Following discussion with AWS it was agreed that pumping stations and pumping station failure scenarios should not be included in the modelling at this stage, as:

- There are several pumps across the proposed modelling catchments and it would be difficult at this stage to identify which pumps (or combination of pumps) to show as failing as part of any pumping failure scenarios;
- There would be considerable effort involved for AWS in rerunning their models for any proposed pump failure scenarios to generate outputs for the SWMP modelling – the effort and time incurred in undertaking this would likely delay the overall project timescales; and
- It would be better to review the need or benefit for modelling pumping station failures following undertaking the surface water modelling to identify specific areas for further consideration / modelling of any pumping failures.

5.2.7 Internal Drainage Board Networks

These are not explicitly considered within the 2D surface water model due to:

- The number of drains in the catchment and lack of information available for the majority of these (dimensions and water levels);
- The different pumping / abstraction regimes depending on season (summer and winter) and the impact these have on flows;
- The different operating practices (dependent on whether it is an IDB, NCC or private drainage area);
- The number of assets that would require modelling e.g. pumping station, culverts, sluice, penstocks to try to represent the catchment; and
- The presence of underground seepage routes and springs along the marshland area.

Where IDB drains clearly appear in LIDAR topographic data, they have been included in the model by default. Where significant culverts influence overland flow, these have been included using size and grade information provided by the WLY&L IDB (the modelled areas do not include a substantial area within the Broads IDB). There is no explicit representation of each individual drain.

5.2.8 Model Verification

It is important to ensure that the outputs from the modelling process are as reliable as possible. To this end, a number of actions and data sources have been used to check the validity of the model outputs, including the following:

Ground-truth Model

This stage of verification involved reviewing the hydraulic model outputs against the initial site inspections/assessment to ensure that the predictions were realistic and considered local topography and identified drainage patterns. Where previous site inspection data did not provide sufficient information on a specific area within the study, the model outputs were assessed against photography from third party sources (e.g. Google and Bing maps) to assist in the model verification.

EA National Surface Water Mapping

The Environment Agency has produced two national surface water datasets using a coarse scale national methodology:

- Areas Susceptible to Surface Water Flooding (AStSWF); and
- Flood Map for Surface Water (FMfSW).

As a method of validation, the outputs from these datasets have been compared to the SWMP modelling outputs to ensure similar flood depths and extents have been predicted. There are slight variations, due to the more accurate methodology used in the SWMP risk assessment, but generally the outputs with relation to ponding locations and flow paths are very similar.

Flood History and Local Knowledge

Recorded flood history has also been used to verify areas which are identified as being at risk of flooding with previous known flood events. As discussed in Section 4.1, information on historical flood events were collected from a number of sources. In addition to this, members of the SWMP Steering Group, have an extensive knowledge of the study area and the drainage and flooding history through living locally.

The use of a Steering Group workshop and public 'drop in' sessions was also an effective way to validate the model outputs. The attendees of the events examined the modelling outputs and were able to provide anecdotal information on past flooding which confirmed several of the predicted areas of ponding.

5.2.9 Uncertainty

The surface water modelling provides the most detailed information to date on the mechanisms, extent and hazard which may result from high intensity rainfall across the study area. However, due to the strategic nature of this study and the limitations of some data sets, there are limitations and uncertainties in the assessment approach of which the reader should be aware.

There is a lack of reliable measured datasets, therefore the estimation of the return period (probability) for flood events is difficult to verify. The broad scale mapping provides an initial guide to areas that may be at risk, but there are a number of limitations to using the information:

- The mapping should not be used in a scale to identify individual properties at risk of surface water flooding. It can only be used as a general indication of areas potentially at risk; and
- Whilst modelled rainfall input has been modified to reflect the possible impacts of climate change it should be acknowledged that this type of flooding scenario is uncertain and likely to be very site specific. More intense short duration rainfall and higher volume more prolonged winter rainfall are likely to exacerbate flooding in the future.

5.2.10 Key Assumptions

The surface water modelling methodology for the study area has used the following key assumptions:

- It has been assumed that land roughness varies with land type (e.g., roads, buildings, grass, water, etc) and therefore different Manning's roughness coefficients have been specified for different land types to represent the effect different surfaces have on the flow of water;
- Tidal defences were included and it was assumed that tidal impacts do not affect surface water flooding mechanisms or depths;

- Building thresholds have been included in the model in order to represent the influence they have on surface water flow paths. All building footprints within the model were raised by 0.1m, meaning they act as barriers to flood waters in the model, up until the water depth becomes greater than 0.1m where it is assumed that the building would flood and water would flow through the building, as would be the case in an actual flood event; and
- Fences and other minor obstructions have not been considered to influence overland flow paths.

5.2.11 Model Outputs

Overview

Maps of maximum water depth and hazard for each of the return periods above have been prepared and are presented in Appendix D of this report. When viewing the maps, it is important that the limitations of the modelling are considered.

InfoWorks ICM outputs data in a format which can be easily exported into GIS packages. As part of the surface water modelling exercise MapInfo TAB files have been created including:

- Flood depth;
- Flow velocity; and
- Flood hazard.

The model outputs are also used to delineate Critical Drainage Areas as described in Section 6.

Flood Hazard Rating

Flood hazard is a function of the flood depth, flow velocity and a debris factor (determined by the flood depth). Each cell generated by InfoWorks ICM been assigned one of four hazard rating categories: 'Extreme Hazard', 'Significant Hazard', 'Moderate Hazard' and 'Low Hazard'. Guidance on the depths and velocities (hazard) of floodwater that can be a risk to people is shown within Figure 5-3 (overleaf).

The hazard rating (HR) at each point and at each time step during a flood event is calculated according to the following formula (Defra/Environment Agency FD2320/TR1 report, 2005):

$$HR = d\,(v + 0.5) + DF$$

Where:
HR = flood hazard rating
d = depth of flooding (m)
v = velocity of floodwater (m/s)
DF = Debris Factor, according to depth, d (see below)

Guidance within the FD2320 report recommends the use of a Debris Factor (DF) to account for the presence of debris during a flood event in the urban environment. The Debris Factor is dependent on the depth of flooding; for depths less than 0.25m a Debris Factor of 0.5 was used and for depths greater than 0.25m a Debris Factor of 1.0 was used.

The maximum hazard rating for each point in the model is then converted to a flood hazard rating category, as described in Table 5-5, below. These are typically classified as caution (very low hazard), moderate (danger for some), significant (danger for most), extreme (danger for all).

HR	Depth of flooding - d (m)												
	DF = 0.5				DF = 1								
Velocity v (m/s)	0.05	0.10	0.20	0.25	0.30	0.40	0.50	0.60	0.80	1.00	1.50	2.00	2.50
0.0	0.03+0.5= 0.53	0.05+0.5 = 0.55	0.10+0.5 = 0.60	0.13+0.5 = 0.63	0.15+1.0 = 1.15	0.20+1.0 = 1.20	0.25+1.0 = 1.25	0.30+1.0 = 1.30	0.40+1.0 = 1.40	0.50+1.0 = 1.50	0.75+1.0 = 1.75	1.00+1.0 = 2.00	1.25+1.0 = 2.25
0.1	0.03+0.5= 0.53	0.06+0.5 = 0.56	0.12+0.5 = 0.62	0.15+0.5 = 0.65	0.18+1.0 = 1.18	0.24+1.0 = 1.24	0.30+1.0 = 1.30	0.36+1.0 = 1.36	0.48+1.0 = 1.48	0.60+1.0 = 1.60	0.90+1.0 = 1.90	1.20+1.0 = 2.20	1.50+1.0 = 2.55
0.3	0.04+0.5= 0.54	0.08+0.5 = 0.58	0.15+0.5 = 0.65	0.19+0.5 = 0.69	0.23+1.0 = 1.23	0.30+1.0 = 1.30	0.38+1.0 = 1.38	0.45+1.0 = 1.45	0.60+1.0 = 1.60	0.75+1.0 = 1.75	1.13+1.0 = 2.13	1.50+1.0 = 2.50	1.88+1.0 = 2.88
0.5	0.05+0.5= 0.55	0.10+0.5 = 0.60	0.20+0.5 = 0.70	0.25+0.5 = 0.75	0.30+1.0 = 1.30	0.40+1.0 = 1.40	0.50+1.0 = 1.50	0.60+1.0 = 1.60	0.80+1.0 = 1.80	1.00+1.0 = 2.00	1.50+1.0 = 2.50	2.00+1.0 = 3.00	2.50+1.0 = 3.50
1.0	0.08+0.5= 0.58	0.15+0.5 = 0.65	0.30+0.5 = 0.80	0.38+0.5 = 0.88	0.45+1.0 = 1.45	0.60+1.0 = 1.60	0.75+1.0 = 1.75	0.90+1.0 = 1.90	1.20+1.0 = 2.20	1.50+1.0 = 2.50	2.25+1.0 = 3.25	3.00+1.0 = 4.00	3.75+1.0 = 4.75
1.5	0.10+0.5= 0.60	0.20+0.5 = 0.70	0.40+0.5 = 0.90	0.50+0.5 = 1.00	0.60+1.0 = 1.60	0.80+1.0 = 1.80	1.00+1.0 = 2.00	1.20+1.0 = 2.20	1.60+1.0 = 2.60	2.00+1.0 = 3.00	3.00+1.0 = 4.00	4.00+1.0 = 5.00	5.00+1.0 = 6.00
2.0	0.13+0.5= 0.63	0.25+0.5 = 0.75	0.50+0.5 = 1.00	0.63+0.5 = 1.13	0.75+1.0 = 1.75	1.00+1.0 = 2.00	1.25+1.0 = 2.25	1.50+1.0 = 2.50	2.00+1.0 = 3.00	3.50	4.75	6.00	7.25
2.5	0.15+0.5= 0.65	0.30+0.5 = 0.80	0.60+0.5 = 1.10	0.75+0.5 = 1.25	0.90+1.0 = 1.90	1.20+1.0 = 2.20	1.50+1.0 = 2.50	1.80+1.0 = 2.80	3.40	4.00	5.50	7.00	8.50
3.0	0.18+0.5= 0.68	0.35+0.5 = 0.85	0.70+0.5 = 1.20	0.88+0.5 = 1.38	1.05+1.0 = 2.05	1.40+1.0 = 2.40	1.75+1.0 = 2.75	3.10	3.80	4.50	6.25	8.00	9.75
3.5	0.20+0.5= 0.70	0.40+0.5 = 0.90	0.80+0.5 = 1.30	1.00+0.5 = 1.50	1.20+1.0 = 2.20	1.60+1.0 = 2.60	3.00	3.40	4.20	5.00	7.00	9.00	11.00
4.0	0.23+0.5= 0.73	0.45+0.5 = 0.95	0.90+0.5 = 1.40	1.13+0.5 = 1.63	1.35+1.0 = 2.35	1.80+1.0 = 2.80	3.25	3.70	4.60	5.50	7.75	10.00	12.25
4.5	0.25+0.5= 0.75	0.50+0.5 = 1.00	1.00+0.5 = 1.50	1.25+0.5 = 1.75	1.50+1.0 = 2.50	2.00+1.0 = 3.00	3.50	4.00	5.00	6.00	8.50	11.00	13.50
5.0	0.28+0.5= 0.78	0.60+0.5 = 1.10	1.10+0.5 = 1.60	1.38+0.5 = 1.88	1.65+1.0 = 2.65	3.20	3.75	4.30	5.40	6.50	9.25	12.00	14.75

Figure 5-3 Combinations of flood depth and velocity that cause danger to people (Source: DEFRA/Environment Agency research on Flood Risks to People - FD2320/TR2)

Table 5-5: Derivation of Hazard Rating category

Degree of Flood Hazard	Hazard Rating (HR)		Description
Low	<0.75	Caution	Flood zone with shallow flowing water or deep standing water
Moderate	0.75b – 1.25	Dangerous for some (i.e. children)	Danger: Flood zone with deep or fast flowing water
Significant	1.25 -2.5	Dangerous for most people	Danger: Flood zone with deep fast flowing water
Extreme	>2.5	Dangerous for all	Extreme danger: Flood zone with deep fast flowing water

5.2.12 Area Specific Considerations

GRY1 – Great Yarmouth
Baseline modelling for this area includes the Northgate Flood Alleviation Scheme to ensure appropriate representation of current and future risk in this area.

BRG1 and BRG2 – Bradwell, Gorleston & Southtown
This catchment is particularly important with regards to future development in the area and potential impacts on the WLY&L IDB Burgh Castle catchment. The WLY&L IDB Burgh Castle catchment has not previously been modelled, though several studies exist which have been produced by consultants in support of planning applications for development (which have now been constructed).

The WLY&L IDB also hold some topographical surveys in support of these applications (unknown whether these are available electronically) and further planning applications which include a survey of the Main Drain between the developed area and the Burgh Castle IDB pumping station. There is a lagoon near the pumping station used as a flow management device, though the effectiveness of this is unknown.

The WLY&L IDB see the main value of any model to be (a) to improve the case for funding flood defence improvements and (b) to deter development in unsuitable places. However, having reviewed the available datasets and complexity of the system (which has several small and larger drains, different pumping / abstraction regimes depending on season, a number of different operating practices and a number of assets that would require modelling e.g. pumping station, culverts, sluice, penstocks to try to represent the catchment) it was concluded that it would be difficult to provide an accurate representation of this within the surface water model without significant effort and cost.

The substantial highways surface water drainage system recently installed along Lord's Lane in Bradwell has been included in the model. This system has been designed to a 1 in 10yr standard and is likely to have a significant impact on local surface water flood mechanisms for lower return period rainfall events.

Following model verification of the BRG1, it was determined that predicted flooding depths in the Southtown and Cobholm area were under predicted compared to local and historical knowledge. Further model runs were undertaken, applying a percentage of direct rainfall to the Southtown and Cobholm subcatchment in addition to the Anglian Water sewer outputs, to determine a predicted level of flooding that was considered to be in conformity with local and historical knowledge. The outputs were discussed with the SWMP Steering Group and it was agreed that 30% direct rainfall should be applied to the Southtown and Cobholm subcatchment.

5.3 Detailed Assessment – Engineering Judgement

5.3.1 Methodology

Engineering Judgement based assessments focus on the historic and predicted flood risk to the area in question for local sources of flooding (surface water runoff, groundwater and ordinary watercourse) alongside sewer and fluvial flooding. Information available at the time of the study has been used to inform identification of the historic flooding mechanisms, future flood risk and key infrastructure in place to manage surface water flooding both now and in the future.

The assessments were done through a combination of desktop review of available data and comprehensive site visits – including meetings with local residents to discuss historic flooding issues. Each assessment was completed using this structure:

- Flood Sources and Mechanisms: A settlement wide review of flood risk from surface water, groundwater, ordinary watercourses and sewers along with an analysis of possible interactions with Main River / tidal flooding;
- Flood Risk Assessment by Area: An area by area assessment of local flood risk combined with information provided by residents and observations during site visits;
- New Development: A summary of possible development areas and what impact they may have on local flood risk; and
- Environment and Heritage: A review of local flood risk impacts on local significant environment and heritage sites.

5.3.2 Area Specific Considerations

Caister-on-Sea

The settlement of Caister-on-Sea is a town to the north of Great Yarmouth. It is identified as a Key Service Centre in the Borough's emerging Local Plan. Holiday Camps can bring in a significant increase in summer population to the area.

Hemsby

The village of Hemsby is located to the north east of Great Yarmouth Borough. It contains several Holiday Villages, Caravan Parks and Chalet Centres, to the east of the settlement, which brings in a large holiday population to the area during the summer months.

6 Identification of Critical Drainage Areas

6.1 Definition of a 'Critical Drainage Area'

One of the purposes of the risk assessment is to identify those parts of the study area that are likely to require more detailed investigation to gain an improved understanding of the causes and consequences of surface water flooding. The risk assessment process identifies the areas of probable flooding (the 'impacts') and the surrounding area that contributes runoff (the 'catchment') - the combination of these areas is defined for the purposes of this study as a Critical Drainage Area (CDAs). The definition of a CDA in this context is:

> *'a discrete geographic area (usually a hydrological catchment) where multiple or interlinked sources of flood risk cause flooding during a severe rainfall event thereby affecting people, property or local infrastructure.'*

The CDA comprises the upstream 'contributing' catchment, the actual area of predicted flooding and the immediate downstream area if this can have an influence on the localised flooding (this is often the case in flat, low lying areas). In defining a CDA, the following has been taken into account:

- **Flood depth, extent, overland flow paths and velocities** – As predicted by pluvial modelling or derived from the EA FMfSW
- **Flood hazard** – a function of flood depth and velocity
- **Potential impact on people, properties and critical infrastructure** – including residential properties, main roads (access to hospitals or evacuation routes), rail routes, rail stations, hospitals and schools
- **Groundwater flood risk** – based on groundwater assessment and EA AStGWF dataset identifying areas most susceptible to groundwater flooding
- **Sewer capacity issues** – based on sewer flooding assessment and information obtained from Anglian Water
- **Significant underground linkages** – including underpasses, tunnels, large diameter pipelines (surface water, sewer or combined) or culverted rivers
- **Cross boundary linkages** – CDAs are not curtailed by political or administrative boundaries
- **Historic flooding** – areas known to have previously flooded during a surface water flood event
- **Definition of area** – including the hydraulic catchment contributing to the CDA and the area available for flood mitigation options
- **Source, pathway and receptor** – the source, pathway and receptor of the main flooding mechanisms should be included within the CDA

6.2 CDA Assessment

Eight (8) CDAs have been identified in the study area and are reviewed within the following sections. In order to quantify the risk across the CDAs an assessment has been carried out to determine the quantity of properties and critical infrastructure at risk from surface water flooding during a range of flood events. Details on this assessment are included in the following sections. Figure 6-1 identifies the location of the CDAs within Great Yarmouth Borough.

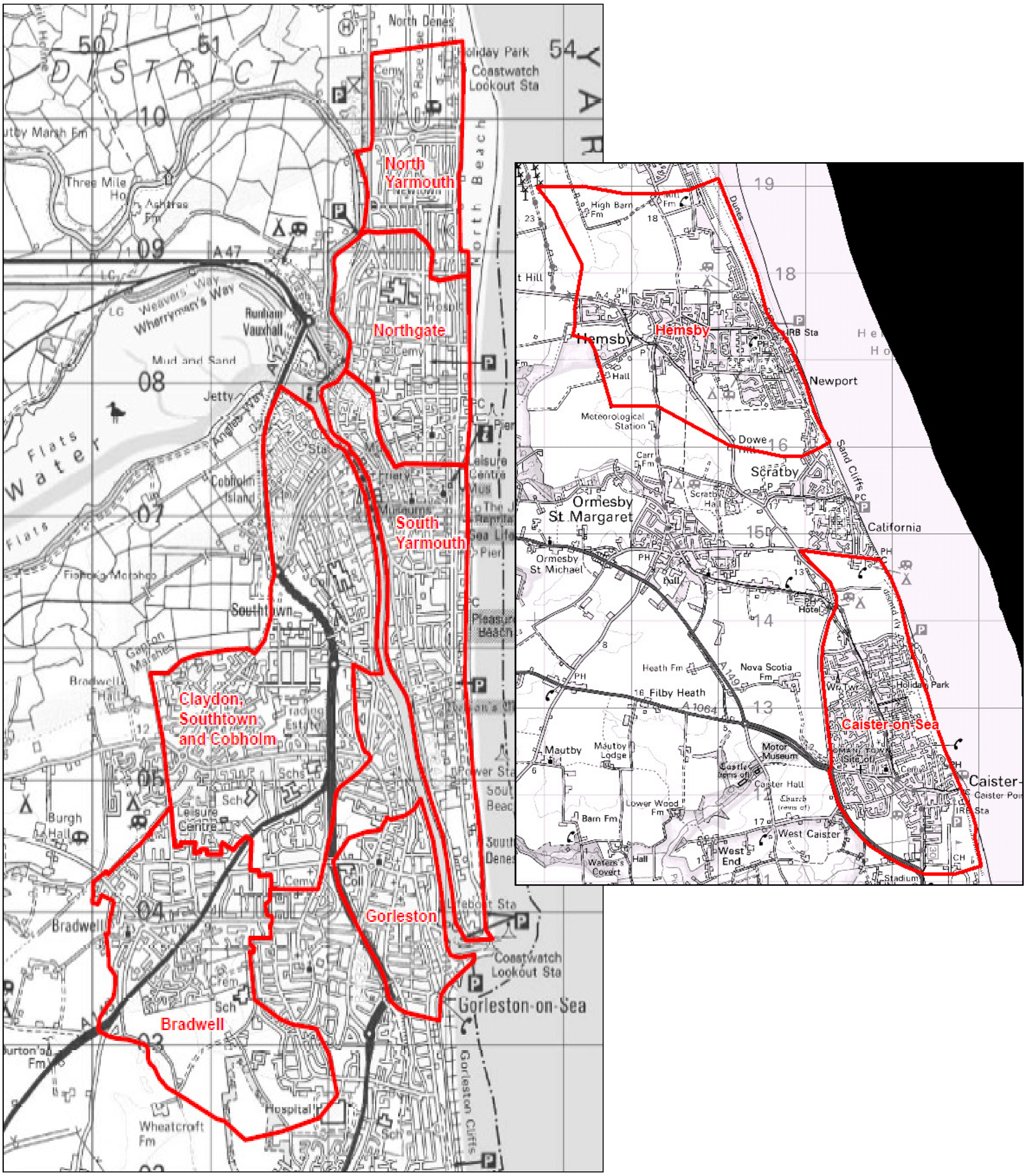
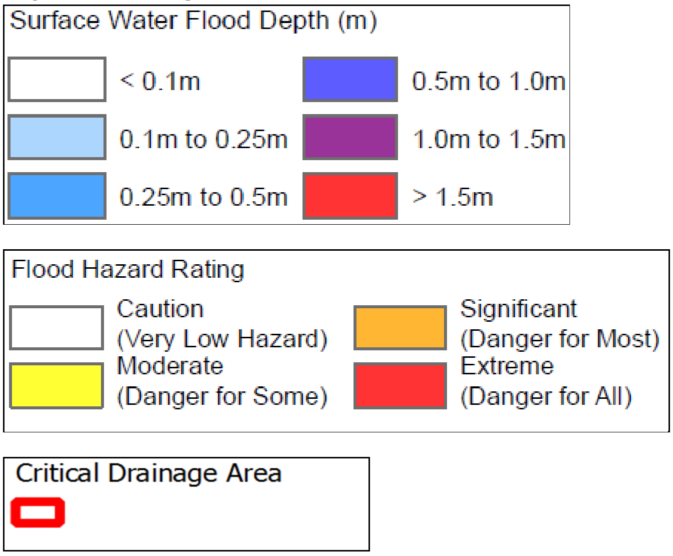


Figure 6-1 Critical Drainage Areas within Great Yarmouth Borough

6.2.1 Modelled Areas

The following pages summarise the flood mechanisms and possible impacts identified in each of the six (6) CDAs within the modelled area. The following legend applies to all of the CDA summaries. All maps show the 1 in 100year event without an allowance for climate change.

Figure 6-2 **Legends Used for CDA Risk / Hazard Mapping**



CDA 001 – Claydon, Cobholm and Southtown

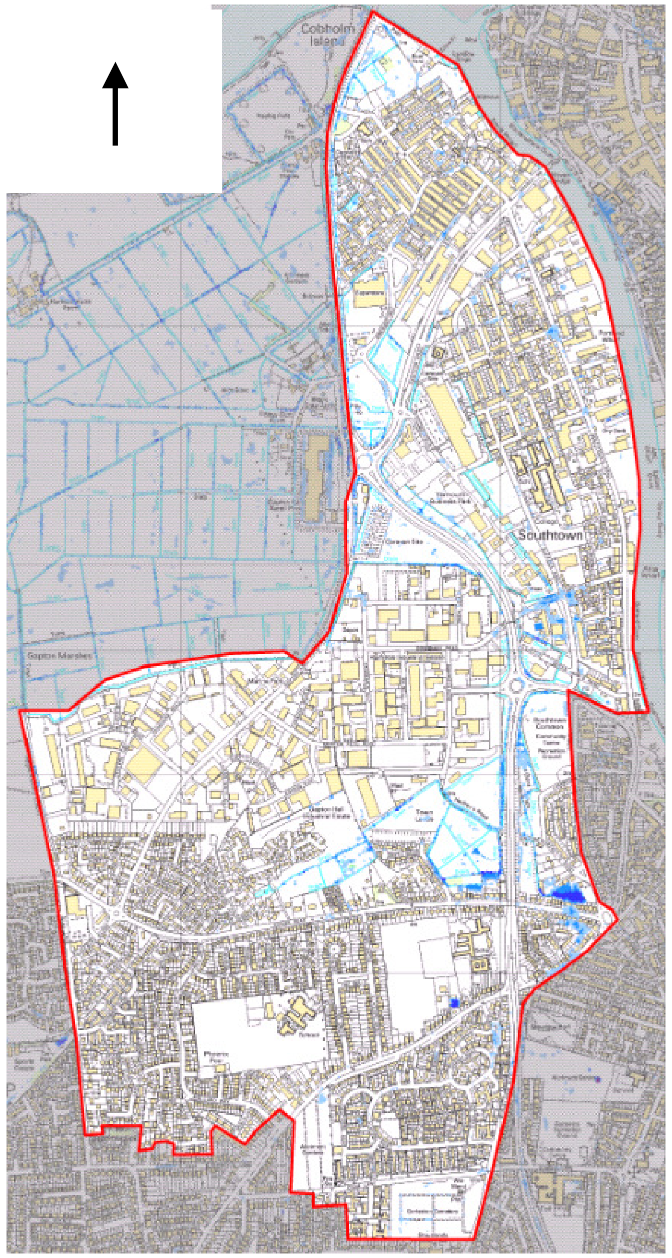


Figure 6-3 CDA 001 - 1 in 100 year Depth Results

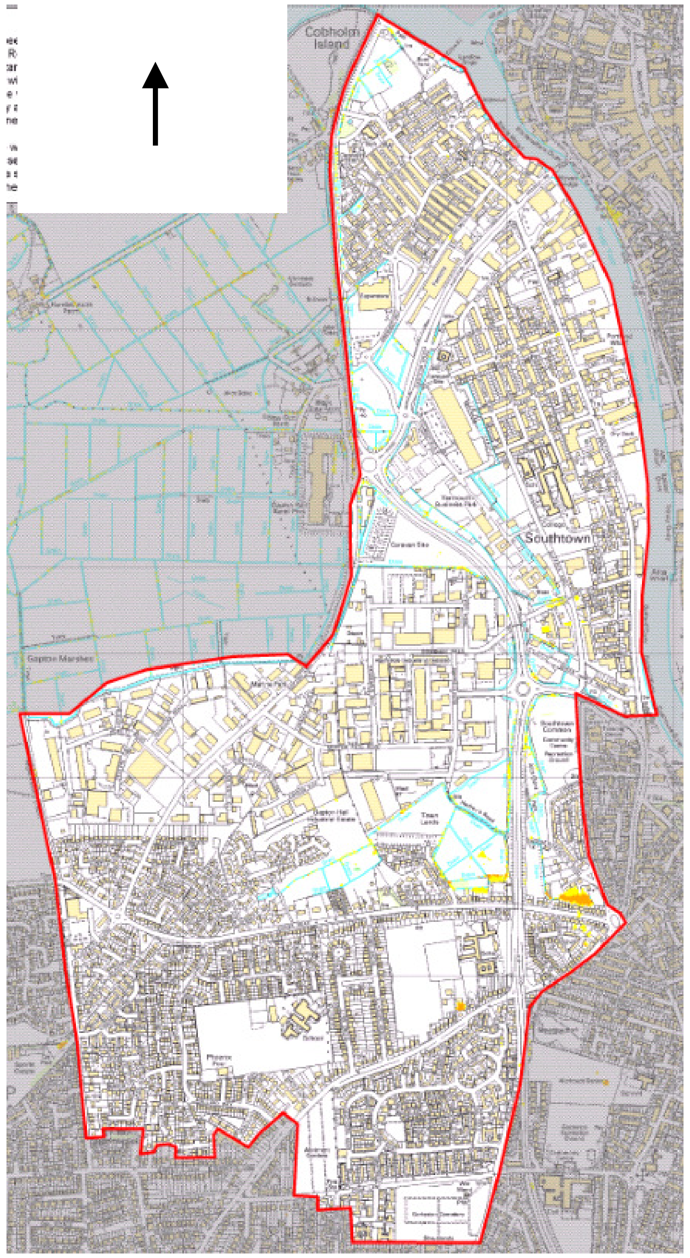


Figure 6-4 CDA 001 - 1 in100 year Hazard Results

Table 6-1 Summary of local flood risk within the CDA 001 – Claydon, Cobholm and Southtown

Flood Classification/ Type	Source	Pathway	Receptor
Overland flow	Runoff from the commercial area to the north and residential areas to the south	The CDA topography has been heavily modified – overland flows are impacted by road embankments and buildings	Open space, residential properties, commercial properties, gardens and roads.
Ponding of surface water	Natural valleys, depressions and topographic low spots.	The main area of ponding is located within the topographic low areas along the overland flow path	Open space, residential properties, commercial properties, gardens and roads.
Hazard	Moderate and significant hazards are expected within the CDA.		
Sewer	The drainage network within the CDA is a combined system (surface water and foul in the same pipe).		
Validation	Wolseley Road / Lichfield Road / Suffolk Road / Goring Road – properties were previously flooded (date unknown). The Southtown Resilience Group is looking into property level protection and is exploring options to buy supplies in bulk. Mill Road – flooding has been reported outside the Convenience Store to the Chip Shop and roundabout. Flooding was reported as being the depth of the kerb stone and was still accessible to vehicles.		
Groundwater	Available data shows that the CDA is not susceptible to groundwater flooding		

Summary of Risk:

The CDA is located in the centre of the Great Yarmouth urban area. Overland flows from both the north and south converged around the Southtown Common before being conveyed through a series of culverts under the A12 towards the Burgh Castle area. The open channels and culverts in the area are managed by a combination of the WLY&L IDB and riparian owners. This often leads to miss-understandings around maintenance responsibilities and the ditches / open channels are often poorly maintained leading to exacerbation of local flood risk. Flooding from surface water and sewers along Burgh Road is a common occurrence. Surface water flooding around the Southtown area is also common, but is not well represented in the model results. The reason for this is not clear and further work is required to determine the exact flood mechanism in this area. Approximately the northern two thirds of the CDA is classified as Flood Zone 3 (Main River and Tidal Flooding).

CDA 002 – Bradwell

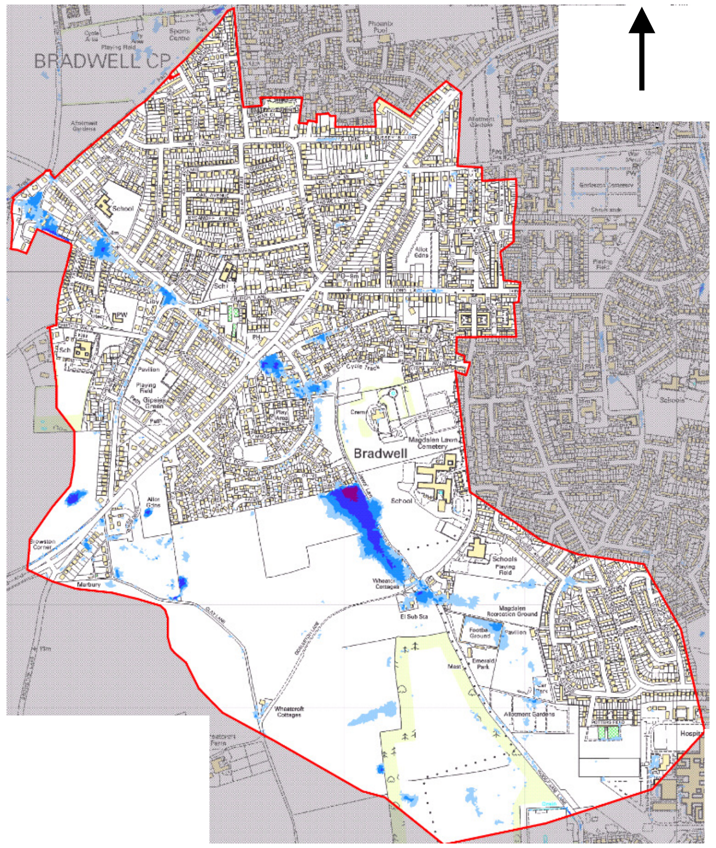


Figure 6-5 CDA 002 - 1 in 100 year Depth Results

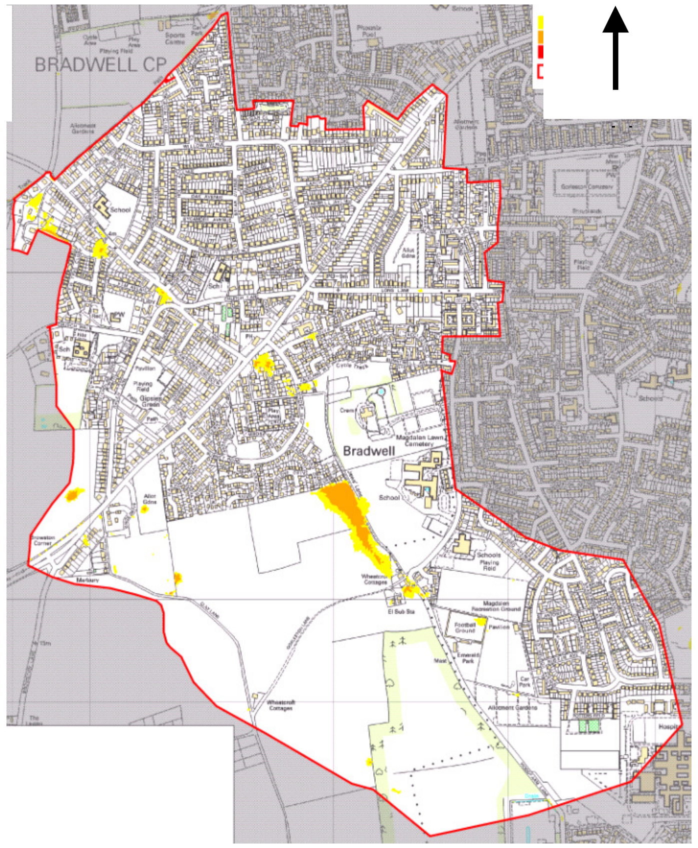


Figure 6-6 CDA 002 - 1 in100 year Hazard Results

Table 6-2 Summary of local flood risk within the CDA 002 – Bradwell

Flood Classification/ Type	Source	Pathway	Receptor
Overland flow	In extreme rainfall events surface water runoff from both greenfield and urban areas converge at low points within the natural valleys and form clear overland flow paths	Due to the topography of the area a natural overland flow path is along the natural valley floors	Open space, residential properties, gardens and roads.
Ponding of surface water (within topographic low spots)	Natural valleys, depressions and topographic low spots.	The main area of ponding is located within the topographic low areas along the overland flow path	Residential properties, roads, open space
Hazard	Moderate and significant hazards are expected within the CDA predominantly along the overland flow route.		
Sewer	The drainage network within the CDA is a combined system (surface water and foul in the same pipe) – with a small reach of separated surface water sewer serving the highways as described in the 'Summary of Risk'		
Validation	The CDA has an extensive flooding history with multiple reports of surface water and sewer flooding along Yew Tree Close, Lords Lane (including the library), Wheatcroft Cottages and Green Lane.		
Groundwater	Available data shows that the CDA is not susceptible to groundwater flooding		

Summary of Risk:

This CDA is in Bradwell which forms part of the Great Yarmouth urban area. The CDA is formed from a natural valley that has been heavily modified in the lower parts by residential development. The predicted flood extents clearly show the path of a historic ordinary watercourse that extends from Woodfarm Lane, along Primrose Way, through Sun Lane and Lords Lane, ending at Yew Tree Close before joining the IDB managed drainage system to the west. The EA Main River Flood Zones do not encroach on the CDA – but do extend close to the western boundary at Doles Farm.

There is a long record of flooding issues in the CDA. These include incidents at Yew Tree Close, Lords Lane and Wheatcroft Cottages. In response to these historic issues, Norfolk County Highways have installed a new surface water drainage system extending from Primrose Way to Yew Tree Close. This has mitigated some risk, but up to it's designed level of service (1 in 10year flooding). The model clearly shows the extent of the residual risk. The Anglian Water DG5 register also shows more than 15 properties at risk of sewer flooding.

CDA 003 – Gorleston

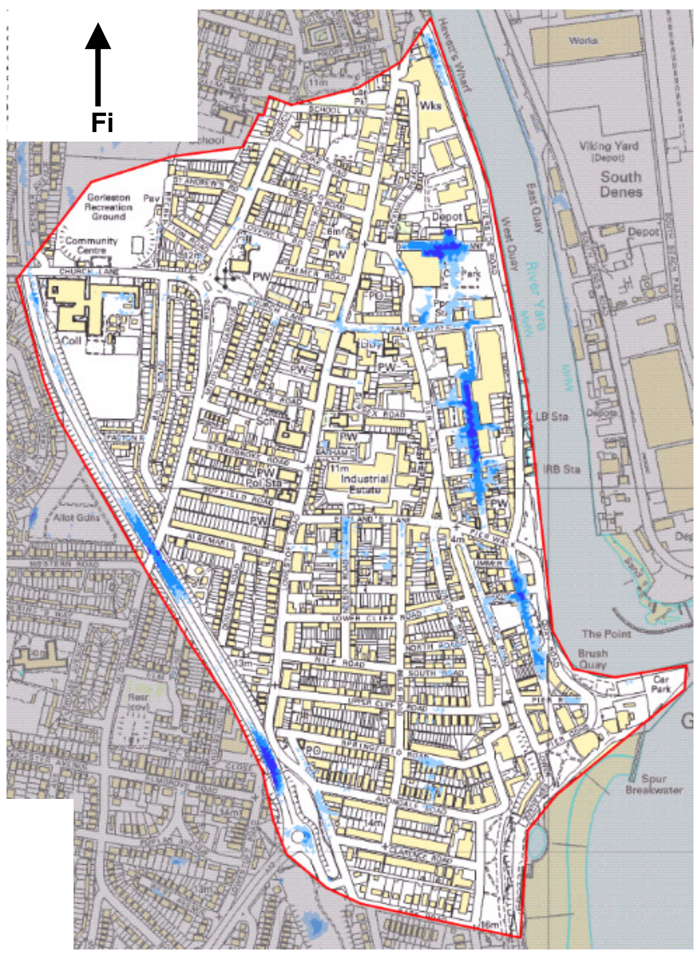


Figure 6-8 CDA 003 - 1 in 100 year Depth Results

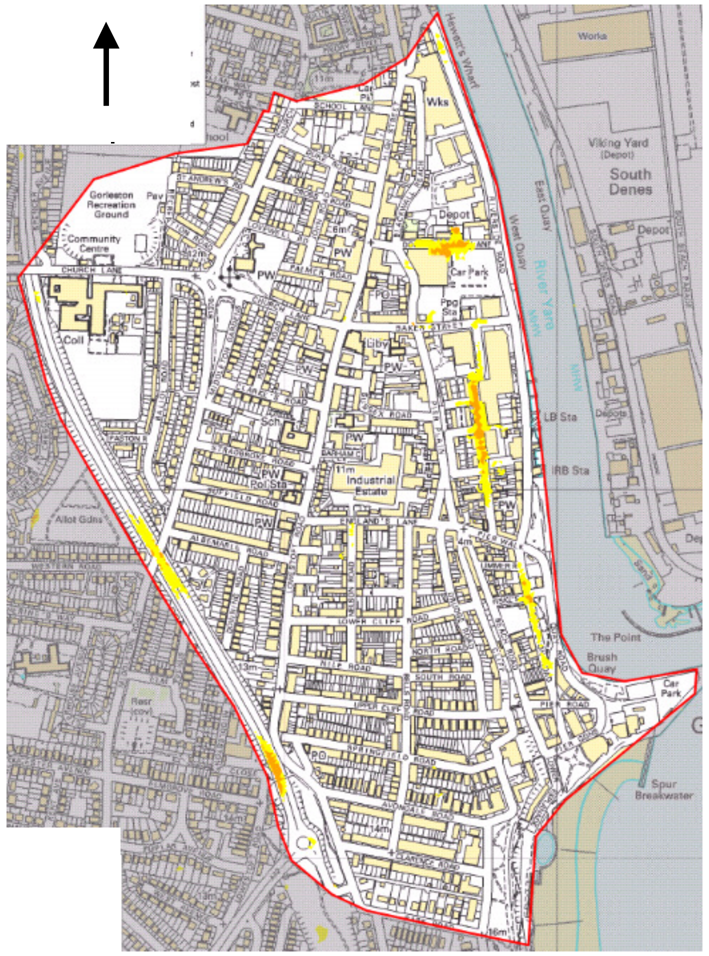


Figure 6-9 CDA 003 - 1 in100 year Hazard Results

Summary of Risk:

There are two distinct areas of surface water flood risk in this CDA – along the A12 road cutting to the west and adjacent to the River Yare in the east. The flood risk predicted along the A12 road cutting has not been validated by any historic incidents. It is thought that the highways drainage has sufficient capacity to manage regular rainfall events, but the modelled results predict that more extreme rainfall events may cause significant flooding along this corridor.

The second area of predicted surface water flooding is along Beach Road, Pavilion Road, Bell's Marsh Road, Baker Street and Dock Tavern Lane. Flooding in this area has been confirmed by incident reports along Beach Road and Dock Tavern Lane. The Beach Road to Dock Tavern Lane area is also classified as Flood Zone 3 by the Environment Agency. This area is defended from river / tidal flooding, but the defences also act as a barrier to overland flows that would otherwise enter the river. The Anglian Water DG5 register shows two properties within Beach Road.

It is noted that Anglian Water has recently completed works along Quay Road and Dock Tavern Lane to fit combined sever overflow tanks. These are targeted at improving bathing water quality under the Water Framework Directive. They could help alleviate flooding in regular rainfall events, but are unlikely to have a significant impact on extreme rainfall events.

Table 6-3 Summary of local flood risk within the CDA 003 – Gorleston

Flood Classification/ Type	Source	Pathway	Receptor
Overland flow	The area is predominantly flat – so runoff accumulates in the lower lying portions of the CDA	The flat topography leads to low velocity, poorly defined overland flows that accumulate in low lying areas.	Open space, residential properties, commercial properties, gardens and roads.
Ponding of surface water	Topographic low spots.	The main area of ponding is located within the topographic low areas	Open space, residential properties, commercial properties, gardens and roads.
Hazard	Moderate and significant hazards are expected within the CDA predominantly in the deeper areas of flooding.		
Sewer	The drainage network within the CDA is a combined system (surface water and foul in the same pipe).		
Validation	Several historic events validate the surface water flood risk in this area – including: • Flooding has occurred this year on Beach Road (behind Quay Road) where surface water overtopped the kerb and • Previous flooding incidents have been reported in the vicinity of Dock Tavern Lane.		
Groundwater	The eastern half of the CDA is classified as high vulnerability to groundwater flooding due to superficial deposits.		

CDA 004 – South Yarmouth

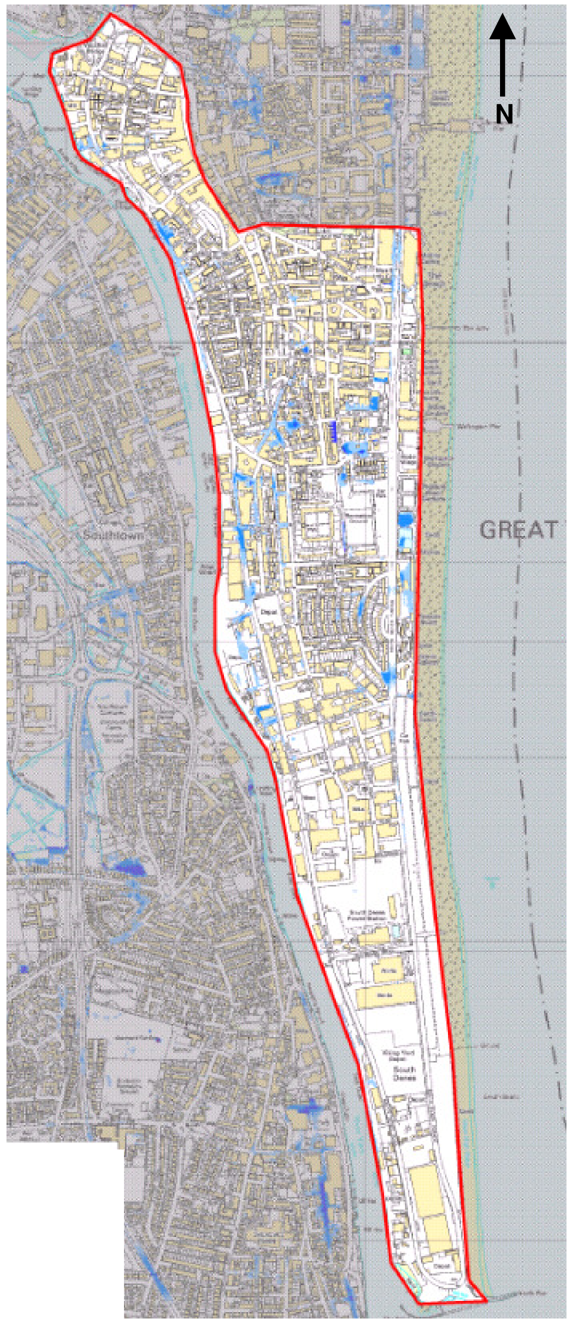


Figure 6-10 CDA 004 - 1 in 100 year Depth Results

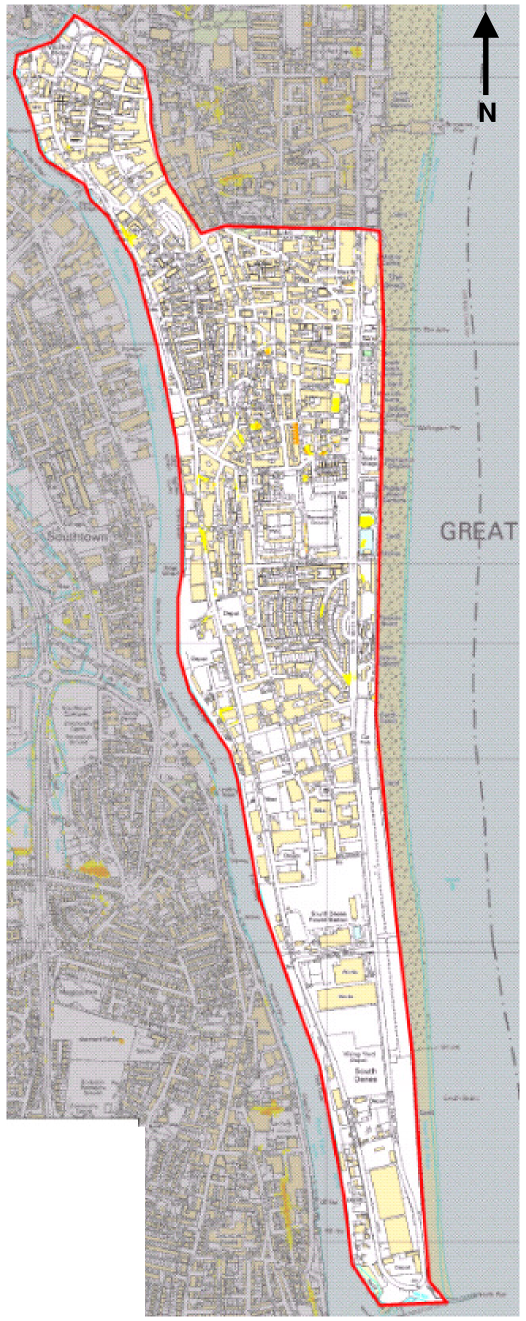


Figure 6-11 CDA 004 - 1 in100 year Hazard

Summary of Risk:

This CDA covers the majority of the southern area of the Great Yarmouth urban area between the River Yare and the coast. The area is predominantly flat and surface water accumulates in topographic low spots with only a minority of areas showing a clear overland flow path. South Yarmouth is heavily urbanised with a mix of commercial / residential in the northern half and heavy industrial use in the southern half. While the southern half does not show a significant level of surface water flood risk, it does contribute surface water flows to the northern half via the combined drainage system and is therefore included in the CDA. Several basement properties are also predicted to be at risk in this CDA.

Environment Agency Flood Zones 2 and 3 show extensive coverage in the northern part of the CDA – predominantly from flooding from the River Yare. This area is defended from river / tidal flooding, but the defences also act as a barrier to overland flows that would otherwise enter the river. Anglian Water DG5 records show that no properties in the CDA are currently at risk of sewer flooding.

Table 6-4 Summary of local flood risk within the CDA 004 – South Yarmouth

Flood Classification/ Type	Source	Pathway	Receptor
Overland flow	The area is predominantly flat – so runoff accumulates in the lower lying portions of the CDA	The flat topography leads to low velocity, poorly defined overland flows that accumulate in low lying areas.	Open space, residential properties, commercial properties, gardens and roads.
Ponding of surface water	Topographic low spots.	The main area of ponding is located within the topographic low areas	Open space, residential properties, commercial properties, gardens and roads.
Hazard	Moderate and significant hazards are expected within the CDA predominantly in the deeper areas of flooding.		
Sewer	The drainage network within the CDA is a combined system (surface water and foul in the same pipe).		
Validation	Town Hall - Surface water flooding has been reported at the bottom of a slope. The area adjacent to South Quay has had recent flooding from a blocked drain. A resident in Albert Square noted that their property had suffered from minor surface water flooding previously.		
Groundwater	Available data shows that the CDA is not susceptible to groundwater flooding		

CDA 005 – Northgate

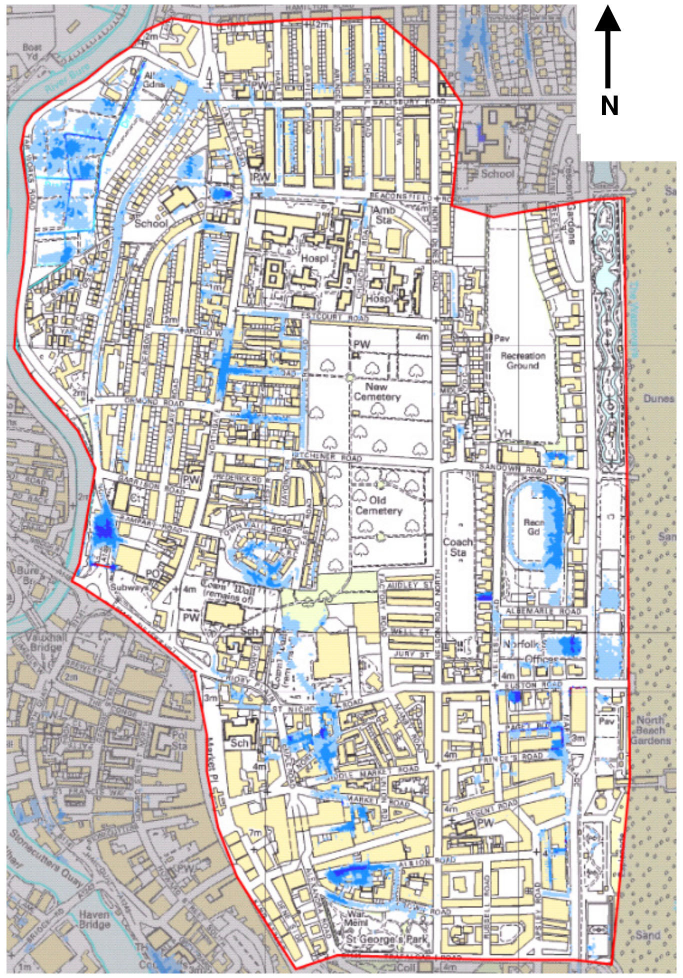


Figure 6-12 CDA 005 - 1 in 100 year Depth Results

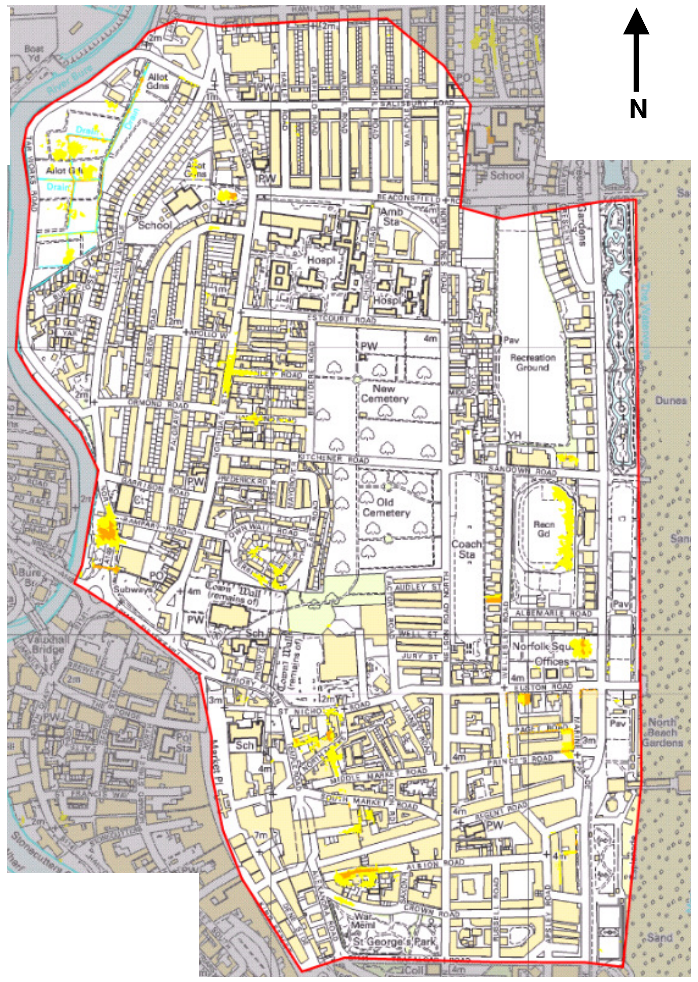


Figure 6-13 CDA 005 - 1 in100 year Hazard Results

Summary of risk:

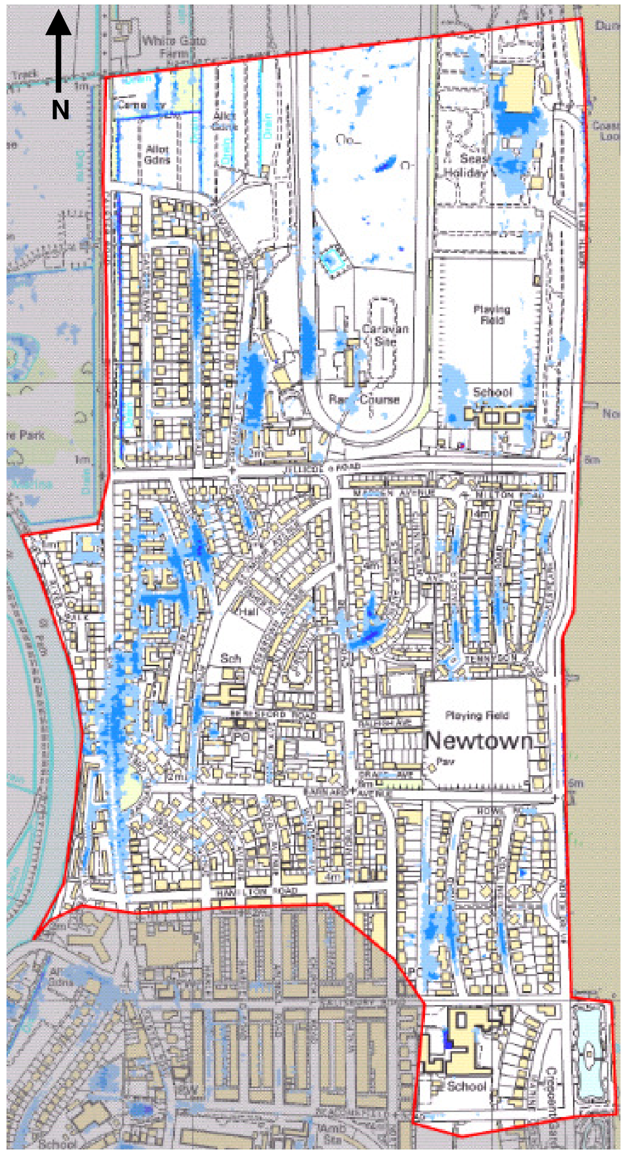
The Northgate CDA is very similar to South Yarmouth and Gorleston – it is generally very flat with no clear overland flow routes. Surface water tends to accumulate in topographic low points. It should be noted that during the 2006 flood event, the area around Northgate Street, Nursery Terrace, Stanley Road and Hammond Road suffered significant flooding. Anglian Water has since installed a scheme that is designed to mitigate risk in this area for rainfall events of similar magnitude to the one in 2006 (approximately 1 in 95 year return period). The model includes an allowance for this scheme, but it is evident that some residual risk remains in the Northgate area for rainfall events that exceed the design capacity of the scheme.

Flood Zones 2 and 3 are predicted to cover the western half of the CDA with flooding from the River Bure. The Anglian Water DG5 register shows property level sewer flooding in Priory Plain, Hammond Road, Lawn Avenue, Apollo Walk, Caister Road, Britannia Road and Harley Road. Numerous historic flood incident records are available for this CDA and are summarised in Table 6-5.

Table 6-5 Summary of local flood risk within the CDA 005 – Northgate

Flood Classification/ Type	Source	Pathway	Receptor
Overland flow	The area is predominantly flat – so runoff accumulates in the lower lying portions of the CDA	The flat topography leads to low velocity, poorly defined overland flows that accumulate in low lying areas.	Open space, residential properties, commercial properties, gardens and roads.
Ponding of surface water	Topographic low spots.	The main area of ponding is located within the topographic low areas	Open space, residential properties, commercial properties, gardens and roads.
Hazard	Moderate and significant hazards are expected within the CDA predominantly in the deeper areas of flooding.		
Sewer	The drainage network within the CDA is a combined system (surface water and foul in the same pipe).		
Validation	Northgate Street - Adjacent streets including Nursery Terrace, and properties along it flooded in 2006. Heavy rain resulted in drains being overwhelmed and an AWS pump failing, all of which caused surface water flooding in the Northgate Street area. Minor surface water flooding has also been observed at: • Subway near Staples / White Swan Pub (North Quay); • School crossing near Garrison Road on Northgate Street; • Adjacent to Stanley Road on Northgate Street; • Pedestrian crossing near Apollo Walk on Northgate Street; • Pedestrian crossing on Northgate Street; and • Escort Road (at south end of Northgate Street). Lawn Avenue / Caister Road Intersection – since 2004 there have been reports of flooding on Caister Road and on Lawn Avenue, opposite the Bus Depot.		
Groundwater	Available data shows that the CDA is not susceptible to groundwater flooding – with the exception of a report of groundwater leaking from the River Bure through pilings into the car park on North Quay (Haven House).		

CDA 006 – North Yarmouth



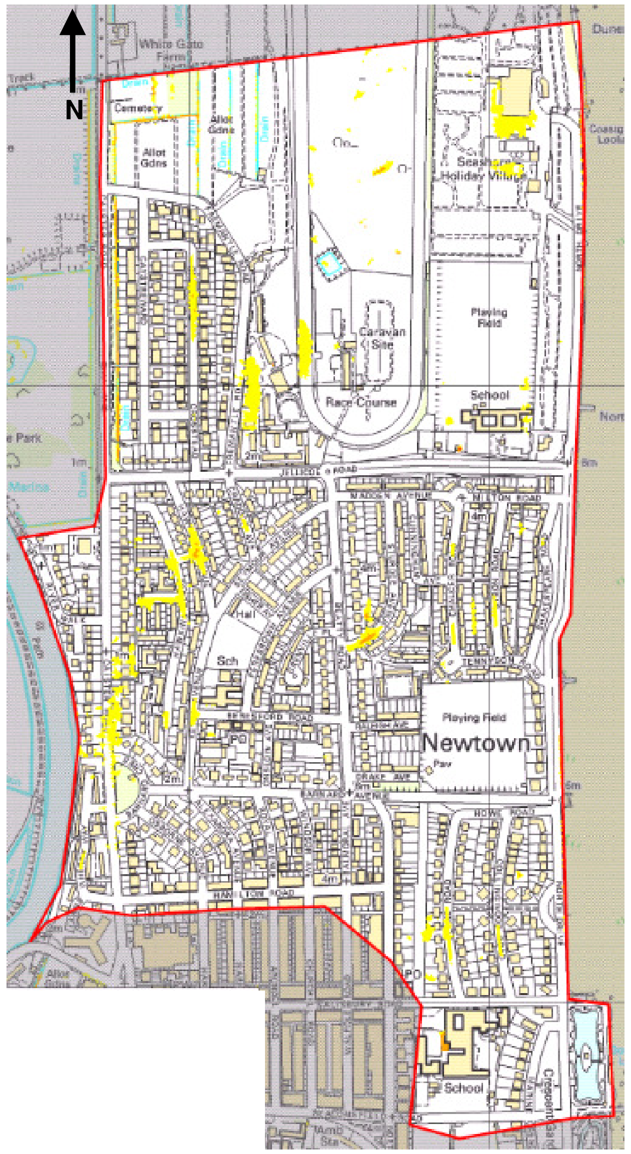


Figure 6-14 CDA 006 - 1 in 100 year Depth Results **Figure 6-15** CDA 006 - 1 in100 year Hazard Results

This CDA is located in the northern part of the Great Yarmouth urban area. It shows a combination of flood mechanisms. An overland flow path originates in the north part of the CDA near to the race course, then flows in a south westerly direction through various residential blocks before ponding at a low point in Caister Road just to the north of Barnard Crescent. The other areas of surface water flooding predicted in the CDA are a result of surface water ponding in topographic low points. The topography is generally very flat and no other clear overland flow routes are evident. Predicted flood extents in this CDA are predominantly within road corridors.

Flood Zones 2 and 3 extend into approximately the western one third of the CDA. Anglian Water DG5 records show property level sewer flooding in Caister Road and Barnard Crescent.

Table 6-6 Summary of local flood risk within the CDA 006 – North Yarmouth

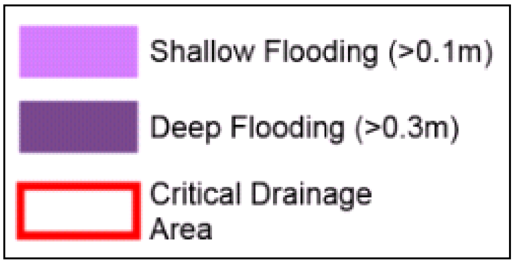
Flood Classification/ Type	Source	Pathway	Receptor
Overland flow	A small overland flow is evident in the north east of the CDA – Runoff originates from the race course area and adjacent residential properties	The flat topography leads to a low velocity, poorly defined overland flow that accumulates in low lying areas.	Open space, residential properties, commercial properties, gardens and roads.
Ponding of surface water	Topographic low spots.	The main area of ponding is located within the topographic low areas	Open space, residential properties, commercial properties, gardens and roads.
Hazard	Moderate and significant hazards are expected within the CDA predominantly in the deeper areas of flooding.		
Sewer	The drainage network within the CDA is a combined system (surface water and foul in the same pipe).		
Validation	Cradock Avenue – it has been reported that the road opposite the racecourse was 'very wet' in August 2012. A property in Craddock Avenue itself has reported regular sewer flooding.		
Groundwater	Available data shows that the CDA is not susceptible to groundwater flooding		

Summary of Risk:

6.2.2 Engineering Judgement

Engineering judgement based assessments were completed for Caister-on-Sea and Hemsby. The full assessments are presented in Appendix F. The following sections summarise the two detailed assessments. It should be noted that these assessments are based on national scale data sets provided by the Environment Agency as no detailed modelling has been completed for these areas as part of this study. The primary dataset for assessment of surface water flooding is the Flood Map for Surface Water (FMfSW). Symbology used on mapping in this section is defined by the legend below and are for the 1 in 200 year return period rainfall event.

Figure 6-16 **Legend Used for Engineering Judgement Assessments**



CDA 007 – Caister-on-Sea

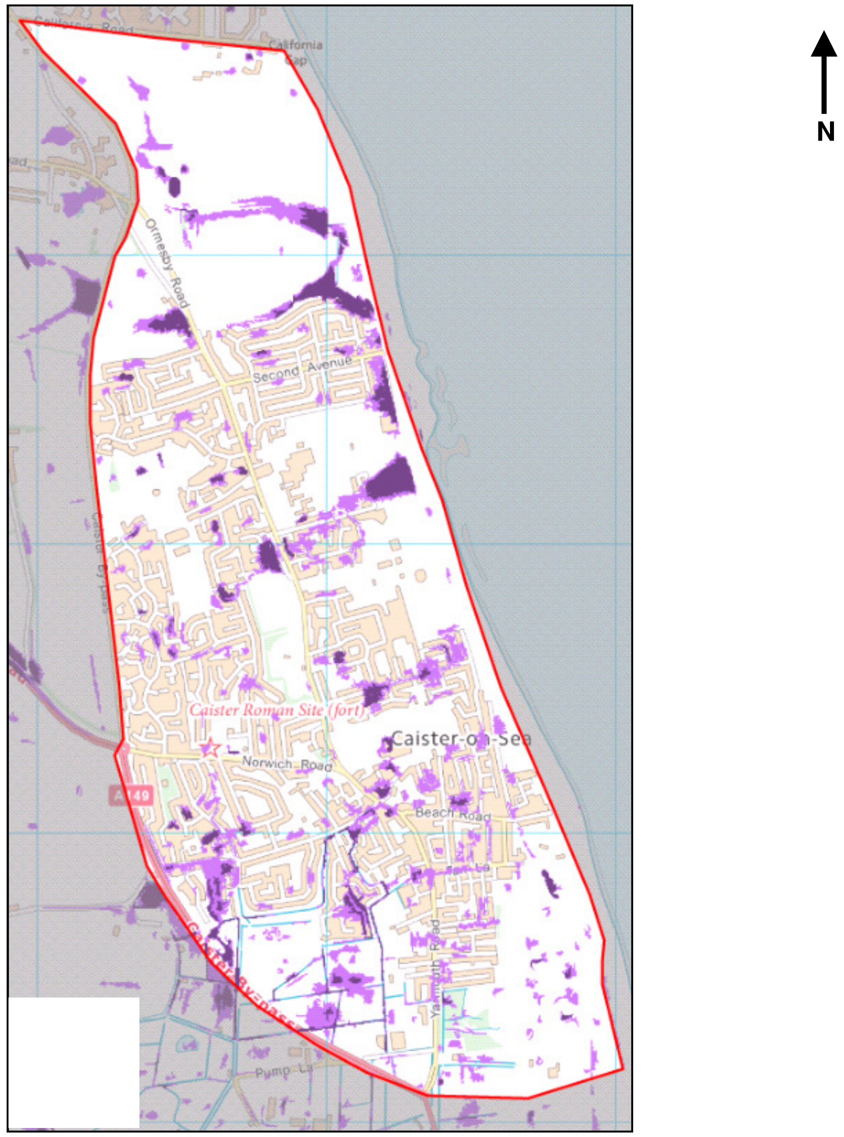


Figure 6-17 CDA 007 - 1 in 200yr Depth

North Caister-on-Sea

The north of Caister-on-Sea, particularly in the vicinity of Winifred Way and Ormesby Road, is susceptible to flooding from surface water runoff (from adjacent fields) and from Ordinary Watercourses (drainage ditches). There were several reports of flooding in the vicinity of Winifred Way (back gardens) in December 2012.

There is a drainage ditch and piped drain to the north of Winifred way which flows eastwards through a County Wildlife Site before discharging into the sea. This system has several features including:

- An inspection chamber north of Winifred Way receives drainage from the ditch and the housing estate to the south;
- A grill and culvert upstream of the inspection chamber (submerged). There could be further pipe drainage from the fields to the north (not confirmed);
- An Inspection Chamber located to the east of the ditch, at the beach front; and
- It is understood that the farmer clears fields prior to flooding to ensure the runoff from the field can be drained to the ditch.

It is considered that the purpose and maintenance of the ditch north of Winifred Way requires clarification as it serves an important surface water management function in the north of Caister-on-Sea. It is understood that the beach / sea outfall may be too low or blocked and this should be investigated.

Additionally, there is a ditch located to the west of Ormesby Road which has previously had flooding problems and is located within an area at risk of surface water ponding (based on FMfSW outputs). The ownership and maintenance regime for this drainage ditch should be confirmed.

South East Caister-on-Sea

There have been several instances of flooding in the vicinity of south east Caister, including;

- The High Street, associated with a pump failure;
- The northern end of the High Street following heavy rainfall, near a pedestrian crossing. Flooding (up to 0.05m) causes pedestrians to step around the designated crossing area and water is displaced by the traffic onto footpaths and in the vicinity of shop frontages;
- Tan Lane in 2004, associated with a collapsed pipe, causing internal flooding of properties. Some properties along this road have subsequently raised their property thresholds to avoid future flooding. Additionally, Anglian Water replaced the drainage pipes from Tan Lane to Ambrose Road Pumping Station following this event and
- Sewer flooding the vicinity of Yarmouth Road and St Julian Road in September 2006.

The majority of predicted flood risk across this area is shallow flooding, though this is predicted to be widespread, likely due to the impermeable nature of the area.

South West Caister-on-Sea

South west Caister is the natural drainage point for surface water in Caister and includes a number of IDB drains which receive surface water discharges from other areas in Caister. As would be expected, this area is naturally wet and standing water was observed in the field to the south of Westerley Way during the site visit in January 2013. This corroborates the FMfSW predictions for surface water ponding across much of the area during the higher rainfall events.

In recent years there has been development in this area and with limited space elsewhere in Caister, it is likely that this area may be subject to further development in the future. SUDS measures have been installed in many of these developments, for example, in the vicinity of West Road and Meadowsweet Road. However, the nature of the land in this area, being at the low point and the drainage outlet means that careful consideration needs to be given to any new development and drainage strategy.

The site visits identified that many of the land drains to the south west of Caister were heavily vegetated and will need to be regularly maintained to ensure that they function as required. It is recommended that discussions are undertaken with the Broads (2006) IDB and the EA to agree a maintenance regime and understand the drainage system in this area in consultation with GYBC and NCC.

CDA 008 – Hemsby

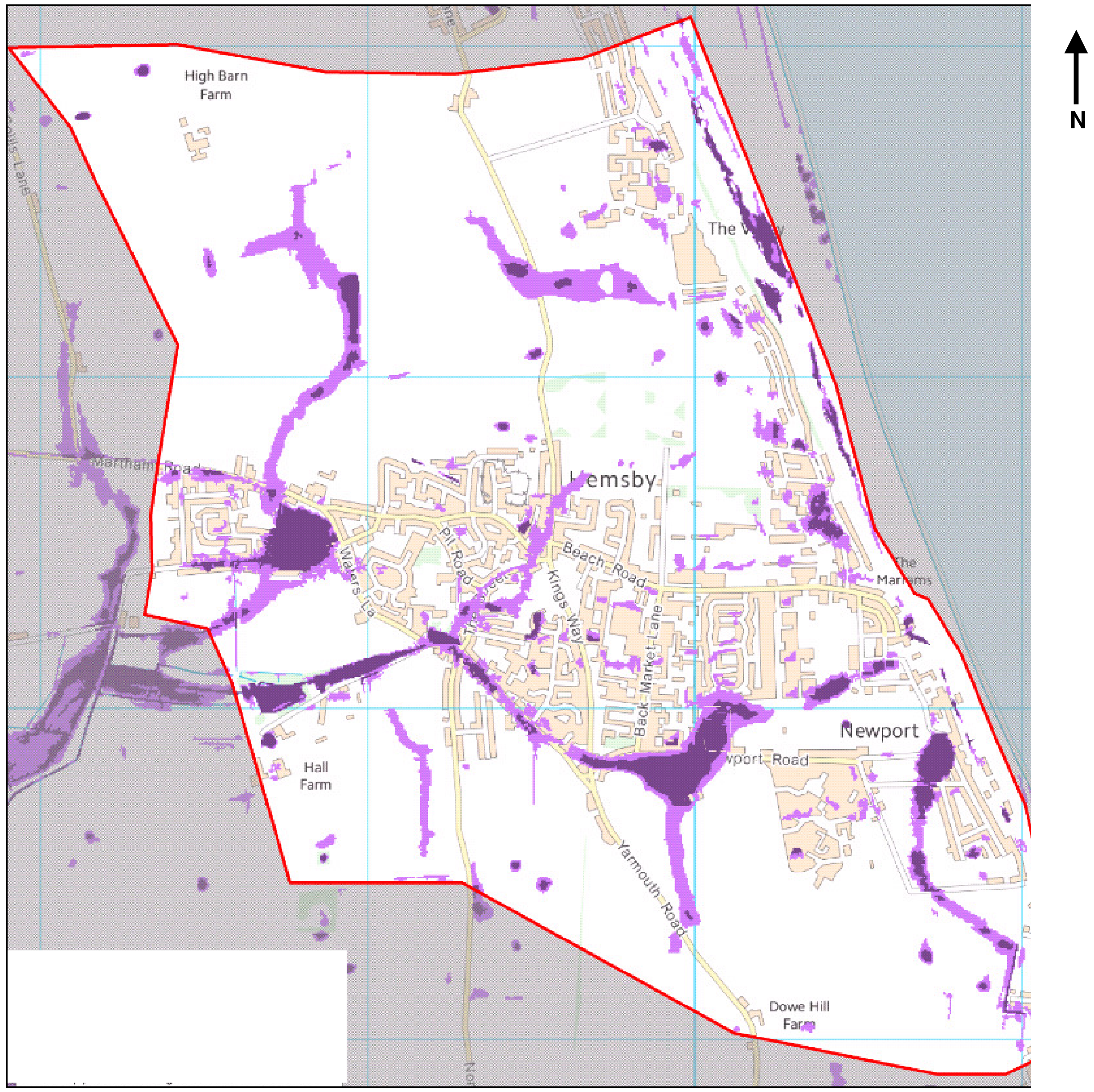


Figure 6-18 CDA 008 - 1 in 200yr Depth

North West Hemsby

North West Hemsby is located in an area identified to be at risk from deep (>0.3m) surface water flooding. It has historically experienced flooding from;

- Surface water runoff from fields to the north of Martham Road;
- Ponding in low spots;
- Areas close to watercourses and drainage ditches; and
- Sewers.

The area experienced flooding during the September 2006 rainfall event.

Following the September 2006 event;

- NCC has implemented a scheme in Common Road to improve drainage in the area. Surface water collected in the catchment upstream of Common Road discharges to the Town Drain and
- Land drains to the north of Martham Road, designed to collect field runoff from the north, have been built or enlarged.

Standing water has previously been observed to the west of Mill Road, also shown as an area of deep surface water ponding in the FMfSW. This area is the course of the old railway line from Winterton to the Broads and flooding issues started in this location following the removal of the railway bridge to the north (under Martham Road).

New development is planned in the open space to the east of Summerfield Road, which overlaps with the area of deep flooding to the north of Common Road. This development includes a separate surface water drainage system that discharges to the Town Drain.

South West Hemsby

- Flooding has occurred multiple times in the vicinity of Waters Lane and Yarmouth Road and resulted in sewage and surface water flooding to properties, including the Post Office;
- There has previously been internal flooding of two (2) properties along Yarmouth Road;
- The Post Office marks the low point in the settlement and Anglian Water foul manholes have previously surcharged in this location. Surface runoff is directed here down Waters Lane, The Street and Ormesby Road. It is understood that a ditch was previously located to the north of the Post Office, but this has be infilled / covered but still within an area of predicted deep flooding;
- Field runoff from the southwest of Yarmouth Road (at junction with Barleycroft) is believed to have contributed to flooding of a Care Home on Yarmouth Road in September 2006; and
- There is a deep ditch to the west of Yarmouth Road (east of the farmland). NCC check grips and the pipe at end of the ditch. However, during prolonged rainfall the ditch fills and can spill onto the road. Under normal conditions there is no water in the ditch.

Measures have been undertaken to address flooding in this area, including Anglian Water fitting three (3) new pumps in Yarmouth Road and non-return valves to several properties in area.

The NCC drainage system drains (gravity fed) north along Yarmouth Road and then west along Hall Road. It should be noted that there is unlikely to be capacity in this system for any drainage from any new development and therefore it is important that a flood risk assessment (incorporating a drainage strategy) is carried out for all developments in this area.

South Central Hemsby

There is a history of surface water flooding in this area;

- Surface water flooding has been reported to Council / ex-Council houses in Newport Road (dates unknown). It is suspected this is due to a lack of gullies along the south of the road, and the road cambering in this direction. Flooding has been reported to kerb height but has not entered properties;
- Flooding was reported in the area in September 2006;
- The ditch to the south of Newport Road has historically flooded.

Following flooding in September 2006, NCC has installed additional gullies along Newport Road, but as illustrated by the FMfSW mapping, it is likely that properties in the area are still at risk of flooding from larger rainfall events.

There is a piped ditch located behind properties to the north of Newport Road (South of the Pontin's Site). Records exist to show that this was cleared in 2006, but current maintenance regimes are unknown.

New development is planned near the Equestrian Centre. Land in this area slopes towards Newport Road properties and has been known to flood road, so surface water management will be important for any new development.

East Hemsby

Historically there has been surface water flooding reported in East Hemsby in the vicinity of Beach Road, The Glebe and Seadell Chalet Park. The FMfSW modelling identifies this as an area at risk of deep (>0.3m) surface water flooding during a rainfall event with a 1 in 200 chance of occurring in any given year. The area is flat and water is likely to pond in this area, particularly where property thresholds are sited below the adjacent road surface level. The area is also within an area at greater risk of groundwater flooding.

In recent years The Glebe has been resurfaced, and property thresholds to the north of the road are now below the level of the road itself, creating a potential flow path for surface water runoff. The road has not been adopted by the Council and is under private ownership. The presence of gullies and a drainage system for the road were noted during site visits, though it is unknown where these discharge.

6.3 Flood Risk Summary

6.3.1 Overview of Flood Risk

The results of the risk assessment, combined with site visits and a detailed review of existing data and historical flood records, indicate that there is moderate to high risk from surface water, groundwater, ordinary watercourses and sewer flooding within the study area. The results indicate that the flood risk is very widely dispersed across the study area with areas with low elevations within the catchment and / or adjacent to obstructions to flow (raised road, embankments etc) being at the greatest risk. It is acknowledged that flooding within the study area is not limited to the identified CDAs; in fact there are several small areas of localised risk of surface water flooding.

In general, flooding across the study area is moderate in the lower order rainfall events (such as the modelled 1 in 30 year event) and is predicted to experience more severe flooding across the study area during higher order events (such as a 1 in 100 year event). This is reflected in the analysis of risk to properties, businesses and infrastructure that is discussed below.

6.3.2 Predicted Risk to Existing Properties & Infrastructure

Maps of predicted flood depths and extents which have been generated from the surface water modelling results and third party data sources are included in Appendix C. In order to provide a quantitative assessment of potential risks, building footprints (taken from the OS MasterMap dataset) and the National Receptor Dataset have been overlaid onto the flood depth maps to estimate the number of properties at risk within the study area. The National Receptor Dataset is not entirely comprehensive and may not include all known or recent properties (and may contain properties that no longer exist). The tables below identify the categories used in the assessment of flooded properties.

Table 6-7 Infrastructure Sub-Categories

Category	Description
Essential Infrastructure	• Essential transport infrastructure which has to cross the area at risk • Mass evacuation routes • Essential utility infrastructure which has to be located in a flood risk area for operation reasons • Electricity generating power stations and grid and primary substations • Water treatment works
Highly Vulnerable	• Police stations, Ambulance stations, Fire stations, Command Centres and telecommunications installations • Installations requiring hazardous substances consent
More Vulnerable	• Hospitals • Health Services • Education establishments, nurseries • Landfill, waste treatment and waste management facilities for hazardous waste • Sewage treatment works • Prisons

Table 6-8 Household Sub-Categories

Category	Description
Households	• All residential dwellings • Caravans, mobile homes and park homes intended for permanent residential use • Student halls of residence, residential care homes, children's homes, social services homes and hostels
Deprived Households	• Those households falling into the lowest 20% of ranks by the Office of National Statistics' Indices of Multiple Deprivation.
Non-Deprived Households	• Those households not falling into the lowest 20% of ranks by the Office of National Statistics' Indices of Multiple Deprivation

Table 6-9 below, indicates the approximate number of predicted properties and critical infrastructure which may be affected within the ***modelled CDAs*** during a 1 in 100 year probability rainfall event (1% AEP) <u>without</u> an allowance for climate change.

Table 6-9 Summary of Flooded Properties within **Modelled CDAs**: 1 in 100 year probability event

Property Type	Flood Risk Vulnerability Classification	Number of flooded properties above depth threshold	
		>0.1m	>0.5m
Infrastructure	Essential Infrastructure	0	0
	Highly Vulnerable	3	1
	More Vulnerable	4	0
Households	Non-Deprived	73	0
	Deprived	173	14
Commercial / Industrial	Units (All)	40	4
Others	Other Flooded Properties	48	4
	Unclassified Flooded Properties	0	0
	Infrastructure Other	1	0

6.3.3 Risk to Future Development

The emerging Local Plan for Great Yarmouth Borough identifies sites for potential development. It is therefore important that surface water flood risk identified within the report should be a consideration in the assessment of detailed development proposals for these areas.

6.3.4 Effect of Climate Change

The effect of climate change on surface water flood risk has also been analysed through the risk assessment phase of this study. Based on current knowledge and understanding, the effects of future climate change are predicted to increase the intensity and likelihood of summer rainfall events, meaning surface water flooding may become more severe and more frequent in the future.

To analyse what impact this might have on flood risk across the study area in the future, the surface water model was run for a 1 in 100 year probability event (1% AEP) to include the effect of climate change. Based on current guidance (taken from Table 2 of NPPF) an increase in peak rainfall intensity of 30% was assumed for this model scenario. The depth grids for these model runs are included in Appendix D along with the other mapped outputs from the modelling process. The main differences caused by climate change are most obvious in areas that have flow obstructions (raised ground downstream) and where urbanisation has impacted the flowpaths of historic watercourses.

This comparison highlights that although the predicted effects of climate change may increase the flood risk within certain areas of Great Yarmouth Borough, the predicted impacts from the 1 in 100 year are suitable for assessing the risk to Great Yarmouth Borough. Minimal variance in predicted flood extents and depths is anticipated as a result of climate change.

6.4 Summary of Risk - CDAs

The tables below summarise the surface water flood risk to infrastructure, households and commercial/industrial receptors for each of the CDAs.

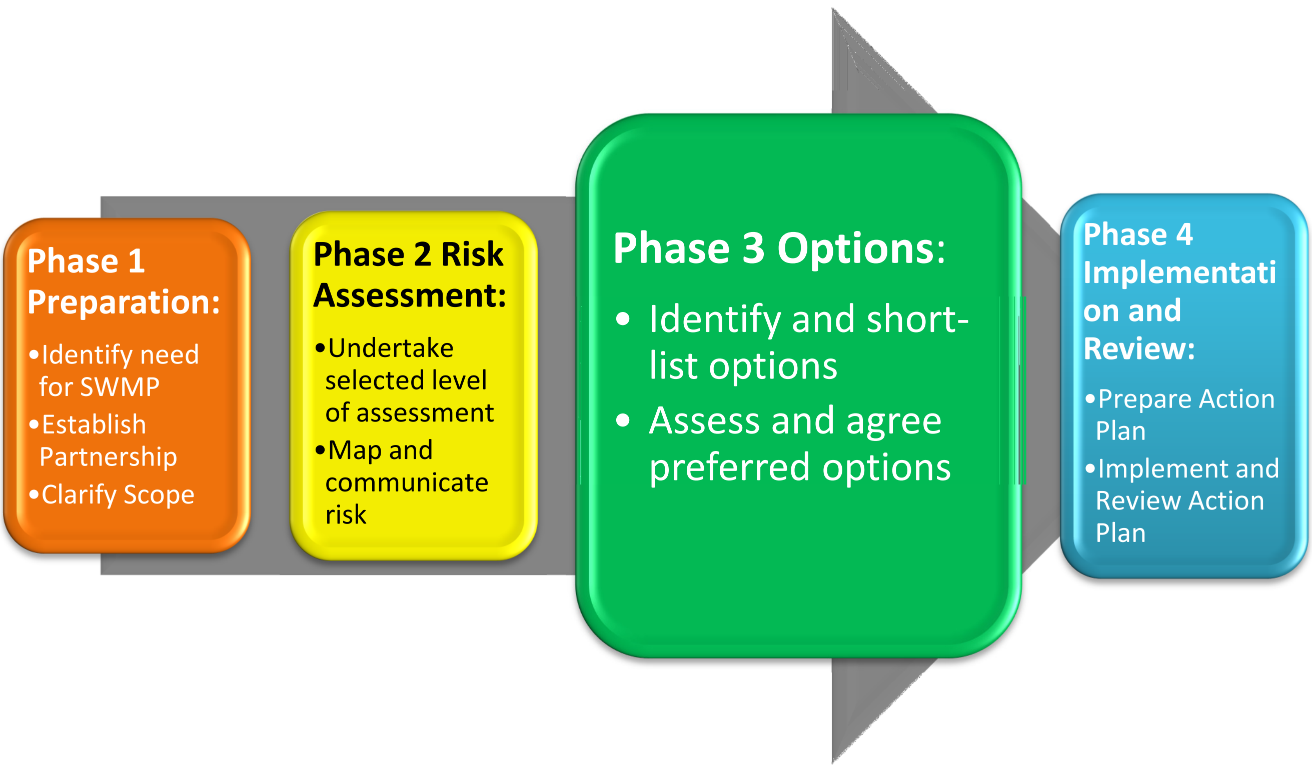
Table 6-10: Summary of Surface Water Flood Risk in Modelled CDAs for a 1 in 100 year event without climate change

Property Type	Flood Risk Vulnerability Classification	Critical Drainage Areas											
		Bradwell		Claydon, Southtown and Cobholm		Gorleston		North Yarmouth		Northgate		South Yarmouth	
		>0.1 m deep	>0.5m deep	>0.1m deep	>0.5m deep	>0.1m deep	>0.5 m deep	>0.1m deep	>0.5m deep	>0.1 m deep	>0.5m deep	>0.1m deep	>0.5m deep
Infrastructure	Essential Infrastructure	0	0	0	0	0	0	0	0	0	0	0	0
	Highly Vulnerable	2	0	0	0	0	0	1	1	0	0	0	0
	More Vulnerable	2	0	1	0	0	0	1	0	0	0	0	0
	Sub-total	4	0	1	0	0	0	2	1	0	0	0	0
Households	Non-Deprived (All)	28	0	0	0	16	0	13	0	13	0	0	0
	Non-Deprived (Basements Only)	0	0	0	0	0	0	0	0	0	0	0	0
	Deprived (All)	4	0	15	0	0	0	4	0	103	7	47	7
	Deprived (Basements Only)	0	0	0	0	0	0	0	0	0	0	0	0
	Sub-total	32	0	15	0	16	0	17	0	116	7	47	7
Commercial / Industrial	Units (All)	0	0	4	0	1	0	1	0	20	1	14	3
	Units (Basements Only)	0	0	0	0	0	0	0	0	0	0	0	0
Others	Other Flooded Properties	8	0	16	3	3	1	6	0	8	0	7	0
	Unclassified Flooded Properties	0	0	0	0	0	0	0	0	0	0	0	0
	Infrastructure Other	1	0	0	0	0	0	0	0	0	0	0	0
Total		45	0	36	3	20	0	26	1	144	8	68	10

Table 6-11: Summary of Surface Water Flood Risk in Non-Modelled CDAs for a 1 in 200 year event without climate change

Property Type	Flood Risk Vulnerability Classification	Critical Drainage Areas			
		Caister – on - Sea		Hemsby	
		>0.1m deep	>0.3m deep	>0.1m deep	>0.3m deep
Infrastructure	Essential Infrastructure	0	0	0	0
	Highly Vulnerable	1	0	1	0
	More Vulnerable	4	0	0	0
	Sub-total	5	0	1	0
Households	Non-Deprived (All)	404	73	197	64
	Non-Deprived (Basements Only)	0	0	0	0
	Deprived (All)	0	0	0	0
	Deprived (Basements Only)	0	0	0	0
	Sub-total	404	73	197	64
Commercial / Industrial	Units (All)	6	2	16	5
	Units (Basements Only)	0	0	0	0
Others	Other Flooded Properties	59	22	345	115
	Unclassified Flooded Properties	0	0	0	0
	Infrastructure Other	4	2	5	2
Total		**478**	**99**	**564**	**186**

PHASE 3: OPTIONS



7 Assessment Methodology

7.1 Objectives

Phase 3 delivers a high level options assessment and indicates what options are generally available for reducing flood risk within the study area. This involves identifying a range of structural and non-structural options for alleviating flood risk and assessing the feasibility of these options. As well as surface water, consideration is given to other sources of flooding and their interactions with surface water flooding, with particular focus on options which will provide flood alleviation from combined flood sources.

The purpose of this phase of work is to assess and shortlist options in order to eliminate those that are not feasible or cost beneficial. Options which are not suitable are discarded and the remaining options are developed and tested against their relative effectiveness, benefits and costs. Measures which achieve multiple benefits, such as water quality, biodiversity or amenity, are encouraged and promoted. The target level of protection is typically set as the 1 in 75 year probability event (1.3% AEP); this will allow potential solutions to be aligned with the current level of insurance cover which is available to the public.

The flow chart below (Figure 7-1) presents the process of identifying and short-listing options as part of the Phase 3.

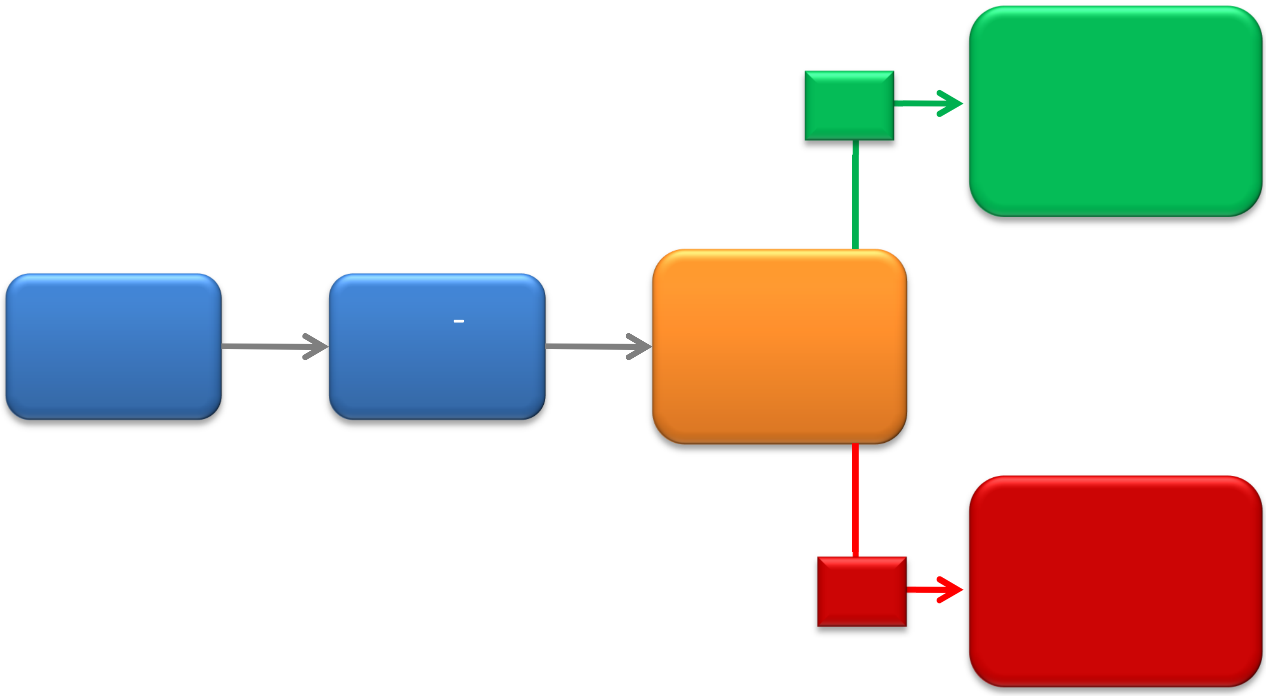


Figure 7-1 Process of identifying and short-listing options and measures (adapted from Defra SWMP Guidance)

To maintain continuity within the report and to reflect the flooding mechanisms within the study area, the options identification process has been undertaken at two levels – study area wide and Critical Drainage Area (as defined by the Phase 2 risk assessment). The options assessment presented here follows the high level methodology described in the Defra SWMP Guidance and is focussed on highlighting areas for further analysis and immediate ‘quick win’ actions.

The study area has several locations where existing development is located in the lower, downstream sections of sub-catchments and the upper parts of the sub-catchments are currently undeveloped. This presents an opportunity to manage existing flood risks in the lower sub-catchment by carefully managing future development in the upper catchment.

7.2 Links to Funding Plans

It is important to consider local investment plans and initiatives and committed future investment when identifying measures that could be implemented within the study area. The following schemes could provide linked funding solutions to flood alleviation work in the study area, which would provide a cost effective and holistic approach to surface water flood risk management:

- Local Green Infrastructure Delivery Plans;
- The Environment Agency Medium Term Plan (MTP) and associated Flood Defence Grant in Aid (FDGiA) / Local Levy opportunities;
- Local Investment Plan and Programme (funding plan for delivery of the Local Plan);
- Major commercial and housing development is an opportunity to retro-fit surface water management measures (housing associations and private developers);
- NCC highways department and Highways Agency investment plans; and
- Anglian Water Business Plan / Asset Management Plan

Although costing estimates of the potential options measures have been provided, no funding has been confirmed or is guaranteed at present. Potential funding opportunities are still to be explored by the Steering Group.

7.3 Options Identification

The Defra SWMP Technical Guidance defines measures and options as:

> *"A measure is defined as a proposed individual action or procedure intended to minimise current and future surface water flood risk or wholly or partially meet other agreed objectives of the SWMP. An option is made up of either a single, or a combination of previously defined measures."*

This stage aims to identify a number of measures and options that have the potential to alleviate surface water flooding across the study area. It has been informed by the knowledge gained as part of the Phase 1 and Phase 2 assessment. Where possible, options have been identified with multiple benefits such as also alleviating flooding from other sources or delivering environmental benefits. At this stage the option identification pays no attention to constraints such as funding or delivery mechanisms to enable a robust technical assessment. The assessment considers all types of options including[3]:

- Options that change the source of risk;
- Options that modify the pathway or change the probability of flooding;
- Options that manage or modify receptors to reduce the consequences;
- Temporary as well as permanent options;
- Options that work with the natural processes wherever possible;

[3] Environment Agency (March 2010) *'Flood and Coastal Flood Risk Management Appraisal Guidance',* Environment Agency: Bristol.

- Options that are adaptable to future changes in flood risk;
- Options that require actions to be taken to deliver the predicted benefits (for example, closing a barrier, erecting a temporary defence or moving contents on receiving a flood warning);
- Innovative options tailored to the specific needs of the project; and,
- Options that can deliver opportunities and wider benefits, through partnership working where possible.

7.4 Identifying Measures

7.4.1 Tool Box of Measures

Surface water flooding is often highly localised and complex. There are few solutions which will provide benefits in all locations, and therefore, its management is largely dependent upon the characteristics of the CDA. This section outlines potential measures which have been considered for mitigating the surface water flood risk within the study area.

The SWMP Plan Technical Guidance (Defra 2010) identifies the concept of Source, Pathway and Receptor as an appropriate basis for understanding and managing flood risk. Figure 7-2 identifies the relationship between these different components, and how some components can be considered within more than one category.

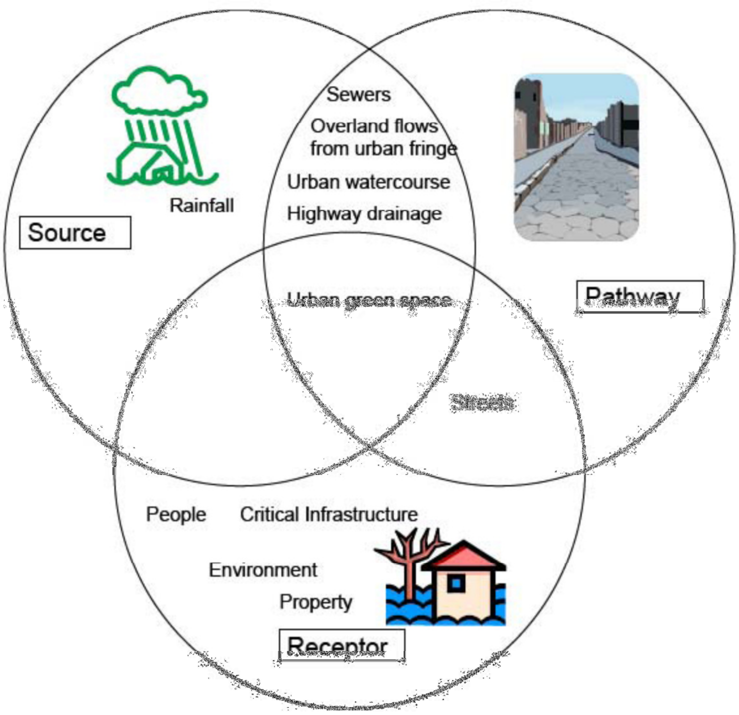


Figure 7-2 Illustration of Sources, Pathways & Receptors
(extracted from SWMP Technical Guidance, Defra 2010)

When identifying potential measures, it is useful to consider the source, pathway, receptor approach (refer to Figure 7-2 and Figure 7-3). Both structural and non-structural measures should be considered in the 'optioneering' exercise undertaken for future CDAs. Structural measures can be considered as those which require fixed or permanent assets to mitigate flood risk (such as a detention basin, increased capacity pipe networks). Non-structural measures may not involve fixed or permanent facilities, and the benefits to flood risk reduction is likely to occur through influencing behaviour (education of flood risk and possible flood resilience measures, understanding the benefits of incorporating rainwater reuse within a property, planning policies etc).

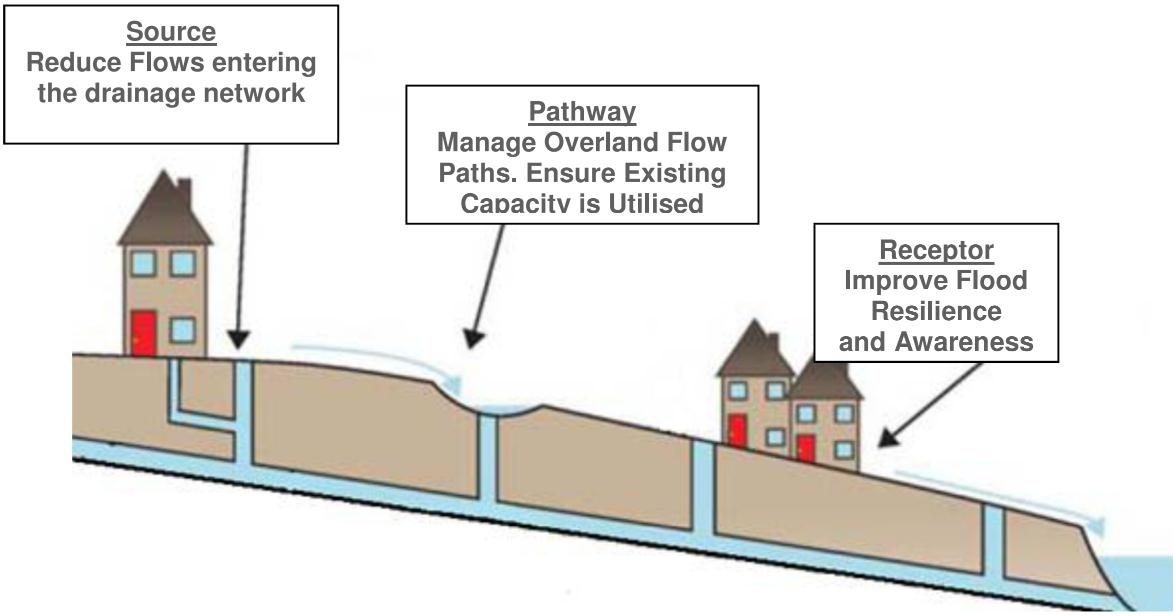


Figure 7-3 Source, Pathway and Receptor Model
(adapted from Defra SWMP Technical Guidance, 2010)

Methods for managing surface water flooding can be divided into methods which influence either the Source, Pathway or Receptor, as described below and detailed in Table 7-1:

- Source Control: Source control measures aim to reduce the rate and volume of surface water runoff through increasing infiltration or storage, and hence reduce the impact on receiving drainage systems. Examples include retrofitting SUDS (e.g. bioretention basins, wetlands, green roofs etc) and other methods for reducing flow rates and volume.

- Pathway Management: These measures seek to manage the overland and underground flow pathways of water in the urban environment, and include: increasing capacity in drainage systems; separation of foul and surface water sewers etc.

- Receptor Management: This is considered to be changes to communities, property and the environment that are affected by flooding. Mitigation measures to reduce the impact of flood risk on receptors may include improved warning and education or flood resilience measures.

Table 7-1 Typical Surface Water Flood Risk Management Measures

	Generic measures	Site specific measures
	• Do Nothing (do not continue maintenance) • Do Minimum (continue current maintenance)	
Source control	• Bioretention carpark pods • Soakaways, water butts and rainwater harvesting • Green roofs • Permeable paving • Underground storage; • Other 'source' measures	• Swales • Detention basins • Bioretention basins; • Bioretention carpark pods; • Bioretention street planting; • Ponds and wetlands
Pathway Management	• Improved maintenance regimes • Increase gulley assets	• Increase capacity in drainage system • Separation of foul & surface water sewers • Managing overland flows • Land Management practices • Other 'pathway' measures
Receptor Management	• Improved weather warning • Planning policies to influence development • Social change, education and awareness • Improved resilience and resistance measures • Raising Doorway/Access Thresholds • Other 'receptor' measures	• Temporary or demountable flood defences - collective measure

7.4.2 High Level Construction Cost Estimates

A high level construction cost estimate is calculated for each flood mitigation solution proposed. *These should be considered as approximate order of magnitude costs only*. Cost estimates are summarised below along with references to relevant industry standard guidance from which they have been adapted. Values have been adjusted to 2013 equivalent values where appropriate.

The following standard assumptions have also been applied:

- The costs are the capital costs for implementation of the scheme only;
- Costs do not include provisions for consultancy, design, supervision, planning process; permits, environmental assessment or optimum bias;
- No provision is made for weather (e.g. winter working);
- No provision is made for access constraints;
- Land acquisition costs are not included;
- No operational or maintenance costs are included; and
- No provision is made for disposal of materials (e.g. for flood storage or soakaway clearance).

Table 7-2 Construction Cost Estimates – Unit Rates

<table>
<tr><th>Classification</th><th>Measure</th><th>Cost Rate (£)</th><th>Unit</th><th>Notes / Source</th></tr>
<tr><td rowspan="8">Source</td><td>Green Roof</td><td>£153</td><td>m^2 of roof</td><td>Greater London Authority - Living Roofs and Walls - Technical Report: Supporting London Plan Policy (2008)</td></tr>
<tr><td>Soakaways</td><td>£267</td><td>m^3 of stored volume</td><td rowspan="3">CIRIA SUDS Manual (2007)</td></tr>
<tr><td>Swales</td><td>£20</td><td>m^2 of swale area</td></tr>
<tr><td>Permeable Paving;</td><td>£54</td><td>m^2 of surface</td></tr>
<tr><td>Rainwater Harvesting</td><td>£1,190</td><td>m^3 of stored volume</td><td>Adapted from: http://www.rainwaterharvesting.co.uk/</td></tr>
<tr><td>Detention Basins</td><td>£27</td><td>m^3 of detention volume</td><td rowspan="2">CIRIA SUDS Manual (2007)</td></tr>
<tr><td>Ponds and Wetlands.</td><td>£40</td><td>m^3 of detention volume</td></tr>
<tr><td>Other 'source' measures</td><td>N/A</td><td>N/A</td><td>Determined on case-by-case basis</td></tr>
<tr><td rowspan="7">Pathway</td><td>Increasing capacity in drainage systems;</td><td>Refer Notes</td><td>m of culvert</td><td>EA FRM Estimating Guide (2010)</td></tr>
<tr><td>Separation of foul and surface water sewers;</td><td>£550</td><td>m^2 of separation catchment area</td><td>Adapted from Thames Water Counters Creek Project (http://www.thameswater.co.uk/cps/rde/xchg/corp/hs.xsl/9344.htm)</td></tr>
<tr><td>Managing overland flows – Non-Road</td><td>£5</td><td>Volume of excavation m^3</td><td rowspan="3">Spon's Civil Engineering and Highway Works Price Book (2008)</td></tr>
<tr><td>Managing overland flows - Roads</td><td>£9</td><td>m of kerb raised</td></tr>
<tr><td>Land management practices.</td><td>£5</td><td>m^3 of ditch created</td></tr>
<tr><td>Improved maintenance regimes</td><td>N/A</td><td>N/A</td><td rowspan="2">Determined on case-by-case basis</td></tr>
<tr><td>Other 'Pathway' measures</td><td>N/A</td><td>N/A</td></tr>
<tr><td rowspan="8">Receptor</td><td>Improved weather warning</td><td>N/A</td><td>N/A</td><td rowspan="4">Pitt Report (2008)</td></tr>
<tr><td>Provide advanced flood warning</td><td>£5,000 to £10,000</td><td>Borough wide</td></tr>
<tr><td>Emergency response (flood) planning and exercising</td><td>£3,000 to £5,000</td><td>Annual borough wide costs</td></tr>
<tr><td>Planning policies to influence development</td><td>N/A</td><td>Borough wide</td></tr>
<tr><td>Temporary or demountable flood defences</td><td>£25,000</td><td>Per property protected</td><td>Adapted from: http://www.floodguarduk.co.uk/ AND http://www.ukfloodbarriers.com/</td></tr>
<tr><td>Social change, education and awareness</td><td>N/A</td><td>N/A</td><td>Determined on case-by-case basis</td></tr>
<tr><td>Improved resilience and resistance measures</td><td>£5,000</td><td>Per property protected</td><td>Defra / EA IPP Scheme from 2009 to 2012 (Presented at Surface Water Management Conference - June 2013)</td></tr>
<tr><td>Other 'Receptor' measures</td><td>N/A</td><td>N/A</td><td>Determined on case-by-case basis</td></tr>
</table>

7.5 Assessment Guidance

A high-level scoring system for each of the options has been utilised to short-list preferred options. The approach to short-listing options is based on the guidance in FCERM and Defra's SWMP guidance. The scoring criteria are provided in the table below.

Table 7-2: Options assessment short-listing criteria

Criteria	Description	Score
Technical	• Is it technically possible and buildable? • Will it be robust and reliable? • Would it require the development of new techniques in order to be implemented?	**U**: Unacceptable (measure eliminated from further consideration) **-2**: High negative outcome **-1**: Moderate negative outcome **0**: Neutral **+1**: Moderate positive outcome **+2**: High positive Outcome
Economic	• Will the benefits exceed the cost? • Is the option within the available budget / funding? (This will depend on available funding, although it must be remembered that alternative routes of funding could be available)	
Social	• Will the community benefit from the option? • Does the option have benefits for local amenity? • Does the option result in any objection from local communities?	
Environmental	• Will the environment benefit from the option? • Will the option provide benefits to water quality or biodiversity?	
Objectives	• Does it help achieve objectives of SWMP partnership? • Does the option meet the overall objective of alleviating flood risk?	

Table 8-1 (Summary of Study Area Wide Options Assessment) shows the application of this scoping system on the study area wide assessment. Any agreed short-listed options can been taken forward for further assessment, possibly detailed modelling if necessary, including an overview assessment of costs, benefits and feasibility. These include the 'Do Nothing' (no intervention and no maintenance) and 'Do Minimum' (continuation of current practice) options which, in line with the Project Appraisal Guidance (PAG), should be taken forward to the detailed assessment stage (even though they might not offer the desired results). The option assessment summary for each CDA can be located within Appendix F of this report.

7.6 CDA Prioritisation

7.6.1 Methodology

To assist with prioritisation and programming of further work on all CDAs, a basic prioritisation methodology was applied to the CDAs identified in Section 5. At this stage of flood risk investigation and mitigation it is important to keep this method simple and transparent to ensure clear interpretation of the decision making process to prioritise one area over another. This will aid in demonstrating that future spending on surface water management is distributed equitably around the study area. The general method proposed is summarised below:

- Use risk assessment outputs to count the number of properties at flood risk within the following general categories for the 1 in 100 year event (for modelled areas) and 1 in 200 year event (for non-modelled areas) :
    - Infrastructure
        - Essential (e.g. water treatment works, primary electricity substations and mass evacuation routes)
        - Highly Vulnerable (e.g. Police stations, fire stations and ambulance stations)
        - More Vulnerable (e.g. Hospitals, retirement homes and schools)
        - Length of Road / Rail impacted by flooding
    - Households (Deprived / Non-Deprived)
    - Commercial / Industrial
    - Environment – Designated Sites (no. of sites impacted by surface water flooding)
- For each category above determine the number of properties which are predicted to be flooded to a depth of:
    - Modelled Areas
        - 0.1m or more
        - 0.5m or more (highest confidence banding of depth)
    - Non-Modelled Areas
        - 0.1m or more
        - 0.3m or more
    - No. of properties on the Anglian Water DG5 Register
- Assign a relative importance weighting associated with each of the above parameters
- Multiply and sum the parameters above to produce a 'total impacts' score.

7.6.2 Outcomes

The outcomes of the above prioritisation process are provided in Appendix D and summarised below in Table 7-3. Based on the final identified score the following range has been applied to these results:

- ≥ 8000 = High priority
- 4000 - 8000 = Medium priority
- ≤ 4000 = Low priority

Table 7-3 Results of Prioritsation Assessment – Modelled CDAs

CDA Name	Total number of units flooded (100yr ARI)	Number of units flooded where depth >0.5m (100yr ARI)	Total Units Flooded	Impacts Score	Priority Rank
South Yarmouth	61	10	71	13,400	High
Northgate	136	8	144	9,400	High
Claydon, Southtown and Cobholm	20	0	20	5,500	Medium
Bradwell	36	0	36	4,600	Medium
Gorleston	17	0	17	3,200	Low
North Yarmouth	20	1	21	2,500	Low

Table 7-4 Results of Prioritsation Assessment – Non-Modelled CDAs

CDA Name	Total number of units flooded (200yr ARI)	Number of units flooded where depth >0.3m (200yr ARI)	Total Units Flooded	Impacts Score	Priority Rank
Caister – on - Sea	415	75	490	13500	High
Hemsby	214	69	283	8200	High

8 Preferred Options

8.1 CDA Options

This section discusses the preferred option identified for each CDA based on the measures discussed earlier within this section. Conceptual option appraisal assessments were undertaken on a range of options for each CDA before the preferred option was chosen. This process was fully documented and details can be located within Appendix E.

The benefits of the combination of options proposed for each **modelled CDA** have been estimated using the hydraulic model. The options have been incorporated into the baseline model using a basic representation methodology to estimate the possible benefits of the preferred scheme. The direct benefits are approximated by a count of the number of properties that are predicted to receive a reduced modelled flood depth compared to the baseline model for the 1 in 75 year rainfall event. The preferred option benefits for the **non-modelled CDAs** have been estimated using engineering judgement.

CDA001 – Claydon, Southtown and Cobholm

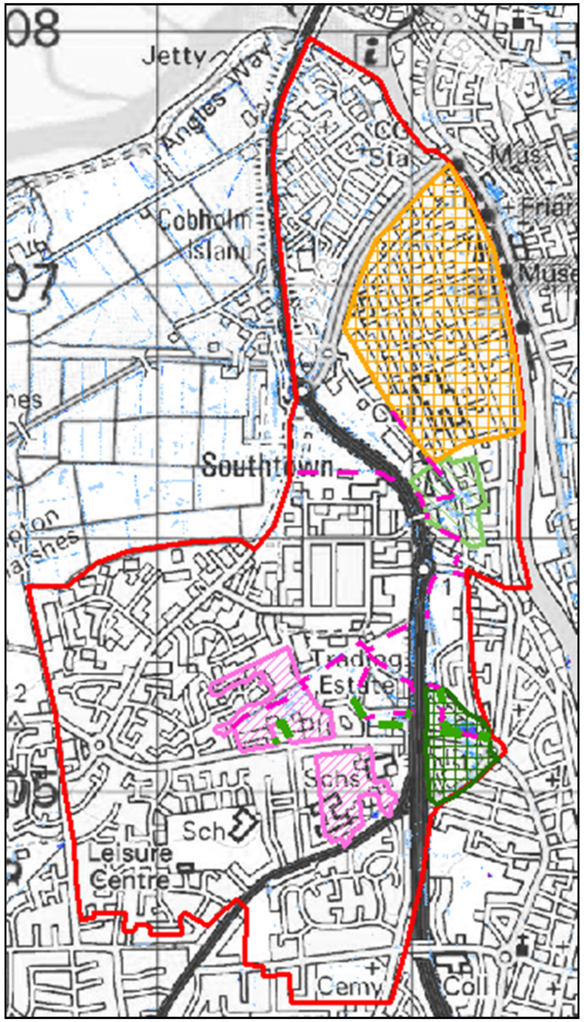


Figure 8-1 CDA001 – Preferred Option Layout

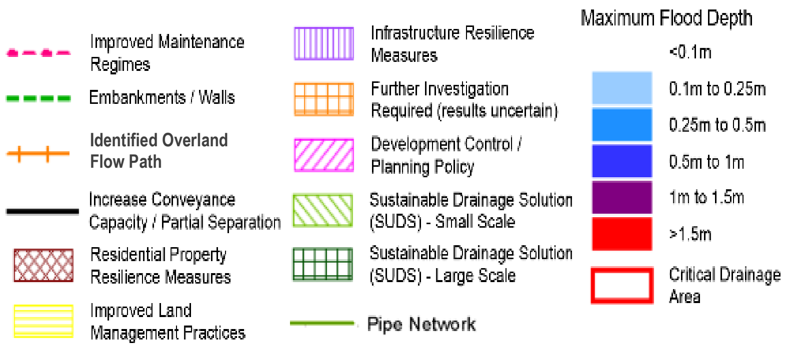
Preferred Option

- SUDS (Large Scale) – Attenuation around open channel area at western end of Burgh Road.
- SUDS (Small Scale) – Property level SUDS schemes (permeable paving) in commercial area in southern part of Southtown.
- Improved Maintenance – All open channels and ditches as indicated in Figure 8-1
- Embankments – Targeted to protect properties located adjacent to existing ditches / open channels;
- Further Investigation – Southtown area
- Planning Policy / Development Control – Consider policies requiring reduction in surface water runoff rates and flood resilient construction.

Approx. Construction Cost = £800,000	**No. Properties Benefitting = 12**

Benefits

- Improved water quality and amenity by treatment of urban runoff through SUDS systems.
- Reduced surface water flows into combined drainage system.
- Significant reduction in modelled flood extents and related residential property flooding around Harferys Road / Burgh Road, Southtown Common and Town Lands (1 in 100 year event).
- Negligible negative impact in downstream areas from increased flows from upper catchment



CDA002 – Bradwell

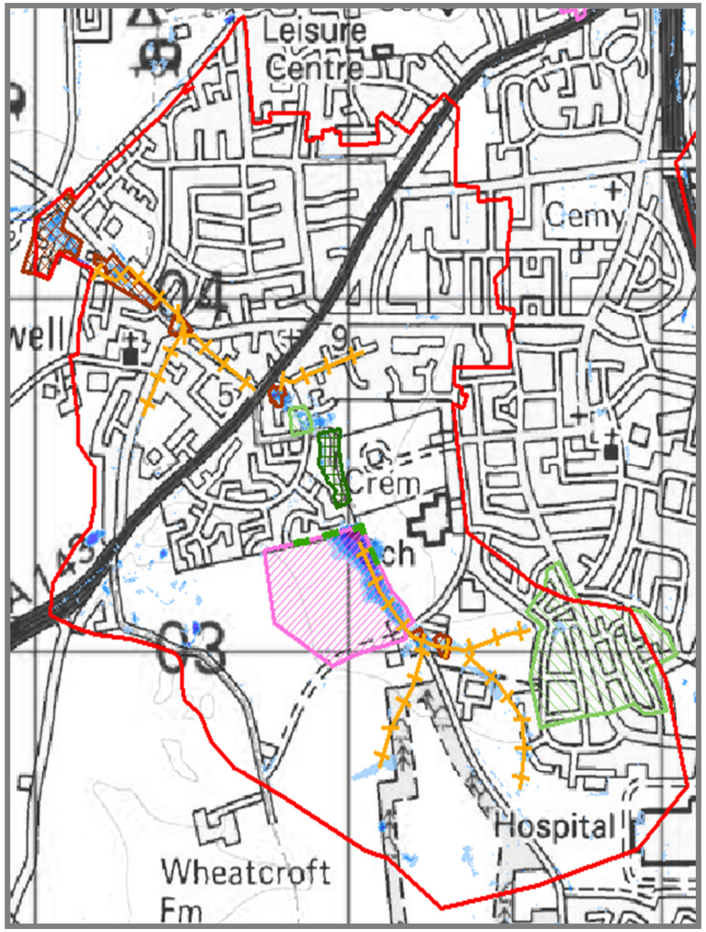


Figure 8-2 CDA002 – Preferred Option Layout

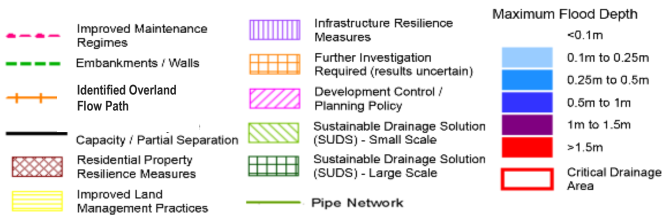
Preferred Option

- SUDS (Large Scale) – Improved attenuation at existing SUDS scheme at Primrose Avenue.
- SUDS (Small Scale) – Property level SUDS schemes (rain gardens and rainwater harvesting) in residential area around Durham Avenue.
- Embankments – To protect properties located in Foxglove Lane, Meadowland Drive and Bluebell Close.
- Planning Policy / Development Control – Consider policies requiring reduction in surface water runoff rates and flood resilient construction.
- Identified Overland Flow Paths – Throughout catchment to ensure existing flow paths are not obstructed.
- Property level resilience – Properties located along Lords Lane, Yew Tree Close, Mageurite Close and Wheatcroft Cottages.

Approx. Construction Cost = £750,000	**No. Properties Benefitting = 34**

Benefits

- SUDS systems improve water quality and amenity.
- Reduced surface water flows into combined drainage system.
- Increased retention volume along Jews Lane
- Substantial mitigation of flood impacts for properties with resilience measures installed (these can provide significant mitigation for flood depths less than 600mm – as mostly occurs in this CDA)
- Retention of overland flow paths lead to improved risk management in future via development control



CDA003 – Gorleston

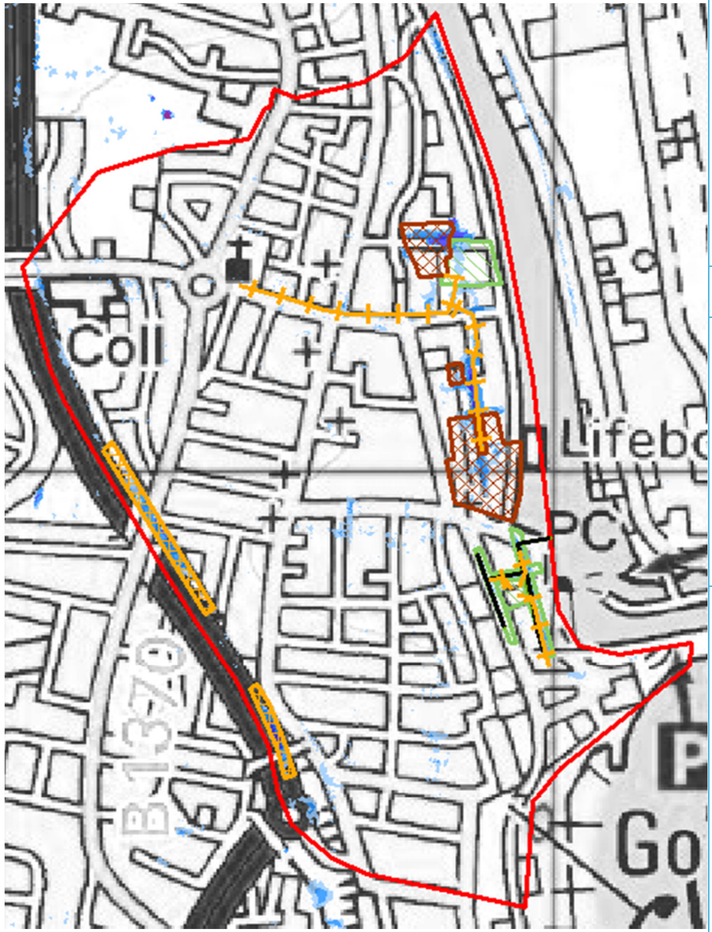


Figure 8-3 CDA003 – Preferred Option Layout

Preferred Option

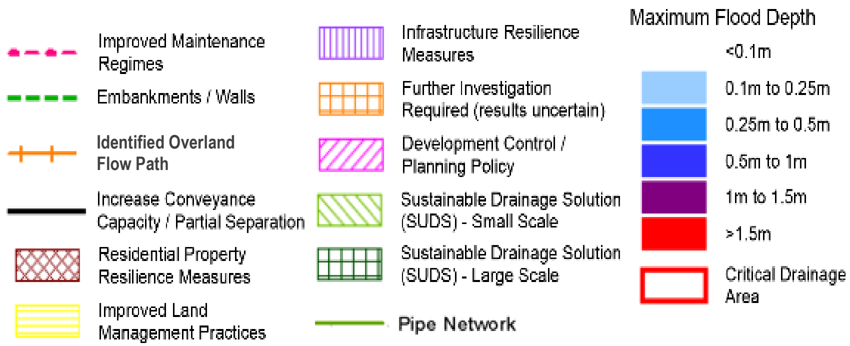
- SUDS (Small Scale) – Property level SUDS schemes (rain gardens and permeable paving) in areas around Beach Road, Pavilion Road and the car park at Dock Tavern Lane.
- Identified Overland Flow Paths – Throughout catchment to ensure existing flow paths are not obstructed and are included in emergency planning.
- Property level resilience – Properties located along Bell's Marsh Road and Dock Tavern Lane.
- Increased Conveyance – Partially separated surface water drainage system along Beach Road and Pavilion Road with enhancements to the existing AWS outfall at Pier Walk / Quay Road.

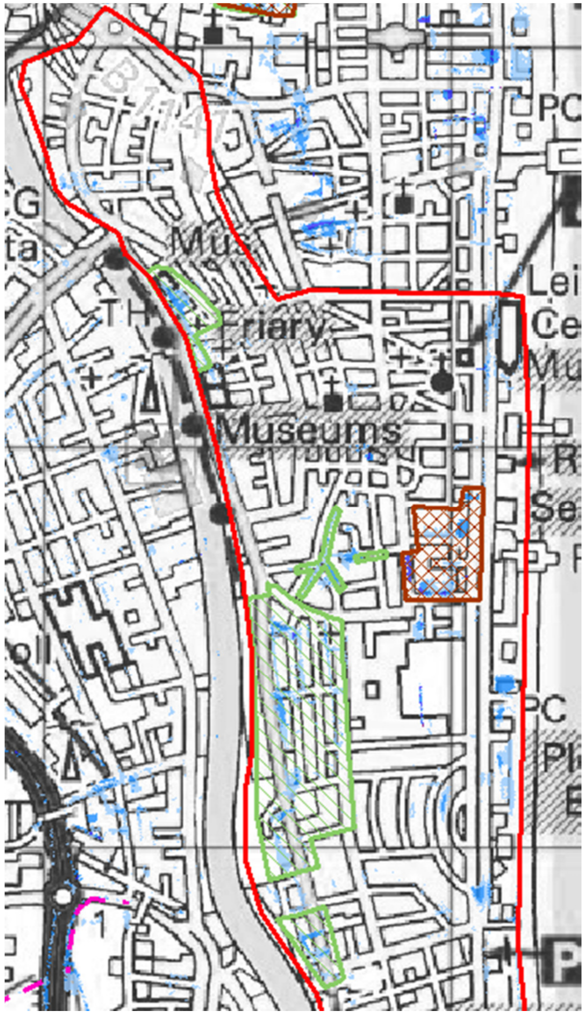
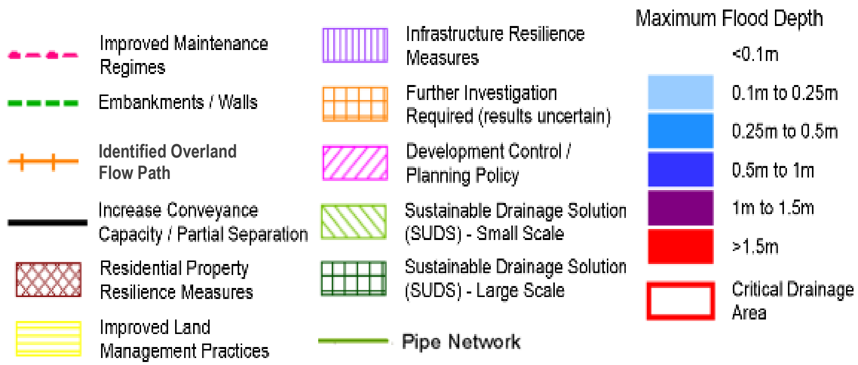
Approx. Construction Cost = £1,140,000

No. Properties Benefitting = 4

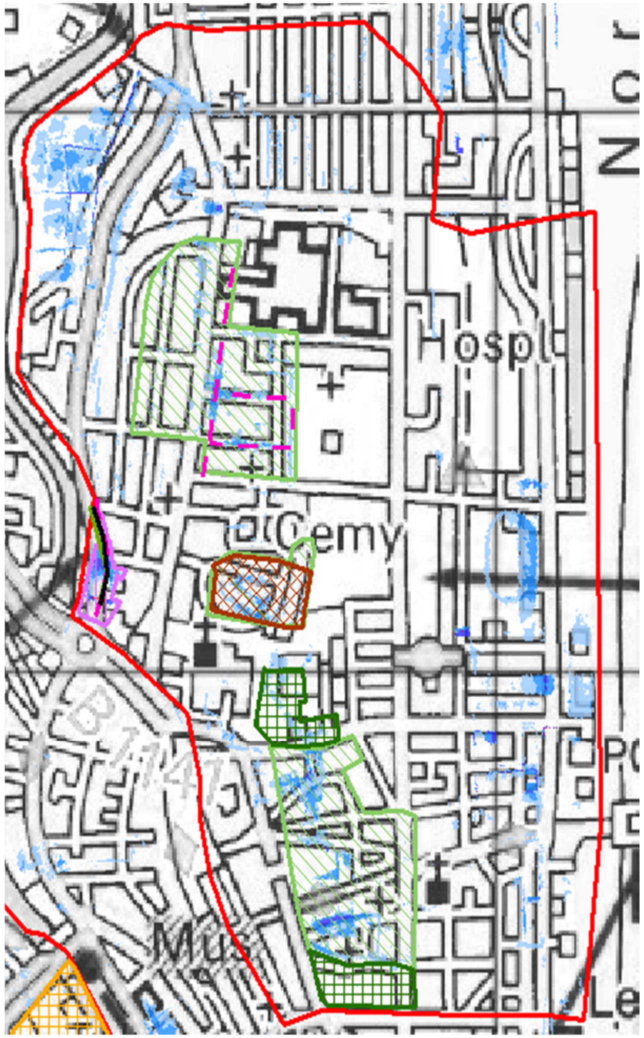
Benefits

- SUDS systems improve water quality and amenity.
- Reduced surface water flows into combined drainage system.
- New pipe system in Pavilion Road / Beach Road substantially reduces predicted flood risk
- Overland flows are conveyed and contained within road corridors
- Property level resilience significantly reduces number of buildings at risk.



CDA004 – South Yarmouth	Preferred Option	
 **Figure 8-4** CDA004 – Preferred Option Layout	• SUDS (Small Scale) – Property level SUDS schemes (rain gardens and permeable paving) in commercial areas around Sutton Road, Barrack Road, Fish Wharf, Exmouth Road, Ordnance Road, Newcastle Road, Blackfriar's Road, Louise Close and the area around the Great Yarmouth Town Hall. • Property level resilience – Basement properties located along Albert Square, Nelson Road South and Shadingfield Close. *Note – No mitigation options are proposed in the southern part of the CDA (not shown in figure)*	
	Approx. Construction Cost = £2,560,000	**No. Properties Benefitting = 15**
	Benefits • SUDS systems improve water quality and amenity. • Reduced surface water flows into combined drainage system. • Property level protection provides significant risk reduction for basement properties	
	 	

CDA005 – Northgate



Preferred Option

- SUDS (Small Scale) – Property level SUDS schemes (rain gardens and rainwater harvesting) in residential areas around Ormind Road, Apollo Way, Palgrave Road, Stanley Street, Hammond Road, Ferrier Road, Town Wall Road, East Road, North / Middle / South Market Road, Regent Road, Alion Road and Crown Road.
- SUDS (Large Scale) – Ponds / wetlands in existing park areas (St Georges Park and Town Wall Park).
- Property level / Infrastructure resilience – Basement properties located around Town Wall Road and Ferrier Close. Pedestrian underpass at North Quay.
- Increased Conveyance – Partially separated surface water drainage system along North Quay.
- Improved Maintenance Regimes – more regular cleaning / inspection of high risk assets.

Approx. Construction Cost = £890,000	No. Properties Benefitting = 91

Benefits

- SUDS systems improve water quality and amenity.
- Reduced surface water flows into combined drainage system.
- New pipe system at North Quay provides significant risk reduction
- Property level protection reduces impact for at risk properties

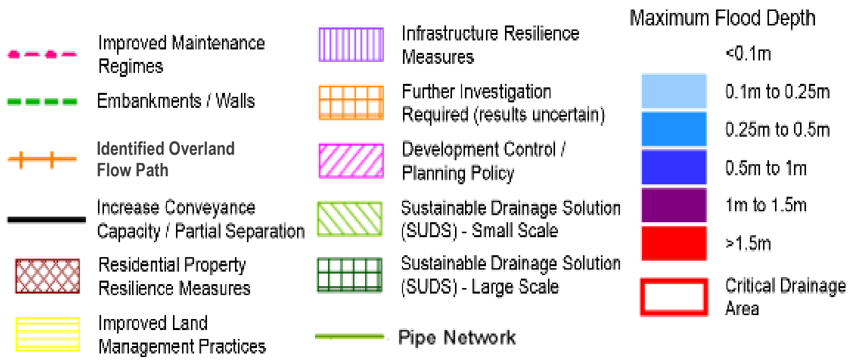
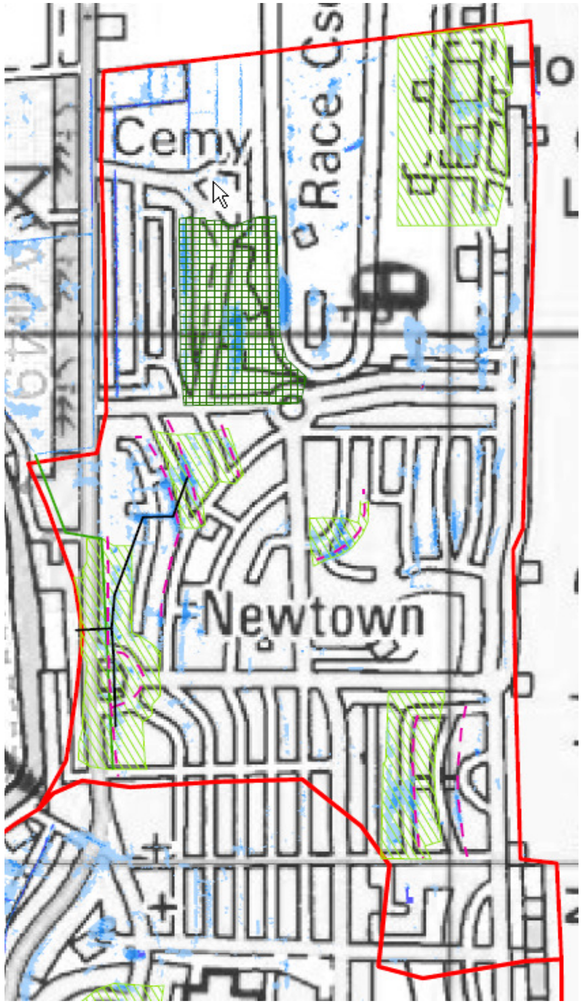


Figure 8-5 CDA005 – Preferred Option Layout

CDA006 – North Yarmouth	**Preferred Option**



- SUDS (Small Scale) – Property level SUDS schemes (Water butts, rainwater harvesting and road side rain gardens) in areas around the Seashore Holiday Village, Craddock Ave, Hawkins Ave, Beatty Road, Sturdee Ave, Blake Road, Caister Road and Barnard Cres.
- SUDS (Large Scale) – Ponds / wetlands in existing park areas adjacent to the race course (Fremantle Road and Crosstead).
- Increased Conveyance – Partially separated surface water drainage system with new outfall into River Bure.
- Improved Maintenance Regimes – more regular cleaning / inspection of high risk assets.

Approx. Construction Cost = £1,070,000	**No. Properties Benefitting = 14**

Benefits

- SUDS systems improve water quality and amenity.
- Reduced surface water flows into combined drainage system.
- Reduced flooding along Caister Road

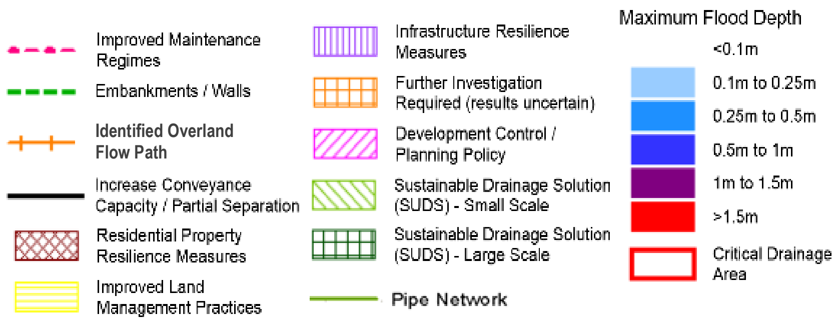


Figure 8-6 CDA006 – Preferred Option Layout

CDA007 – Caister-on-Sea

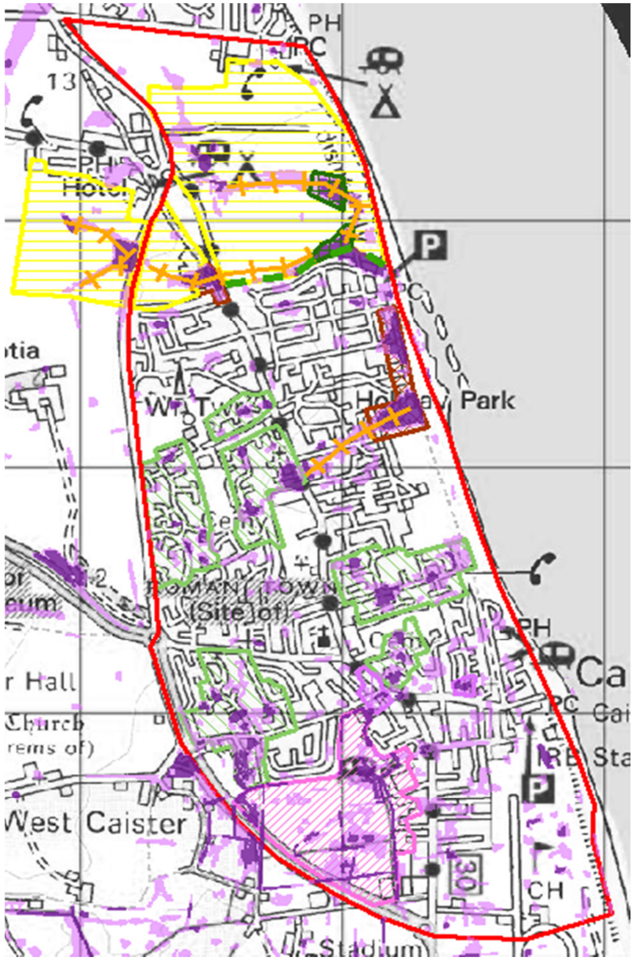


Figure 8-7 CDA007 – Preferred Option Layout

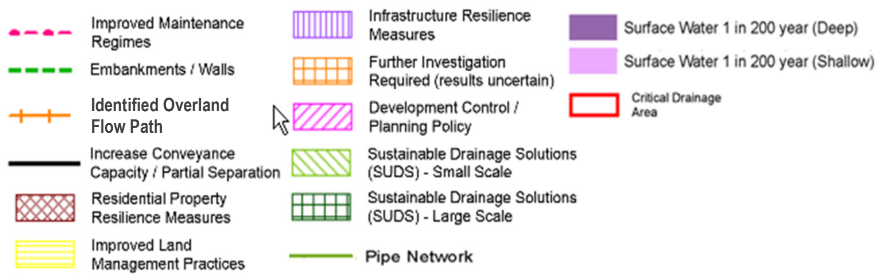
Preferred Option

- SUDS (Small Scale) – Property level SUDS schemes (Water butts, rainwater harvesting and road side rain gardens) in areas around Royal Thames Road, St Nicholas Drive, Diana Way, Braddock Road, Rector Close and Upper Grange Cres.
- Infrastructure / property level resilience – Police Station and telephone exchange on High Street / West Road. Library on Beach Road. Residential and holiday park areas – Silver Sands Holiday Village / Caister Holiday Centre, Marine Drive and Yarmouth Road (adjacent to Reynolds Ave).
- Identified Overland Flow – From Ormesby Road via Branford Road to east.
- SUDS (Large Scale) combined with improved land management practices and an embankment – Area to north of Caister-on-Sea.
- Planning Policy / Development Control – Area to south of Westerly Way.

Approx. Construction Cost = £2,540,000	**No. Properties Benefitting = N/A (not modelled)**

Benefits

- SUDS systems improve water quality and amenity.
- Reduced surface water flows into combined drainage system.



CDA008 – Hemsby

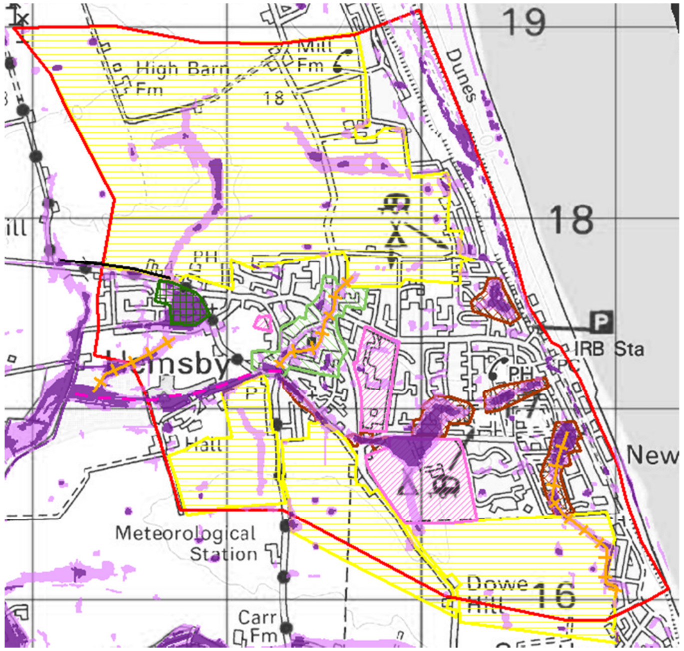


Figure 8-8 CDA008 – Preferred Option Layout

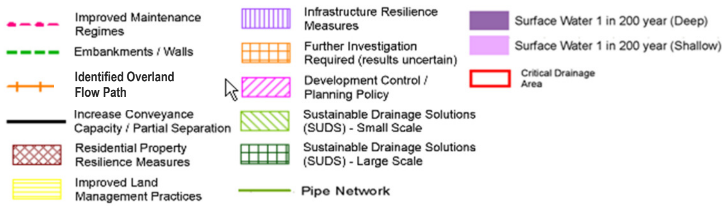
Preferred Option

- SUDS (Small Scale) – Property level SUDS schemes (Water butts, rainwater harvesting and road side rain gardens) in areas around The Street.
- SUDS (Large Scale) - – Ponds / wetlands between Martham Road and Common Road.
- Property level resilience – Permanent habitable buildings located around Hemsby Beach Chalet Centre, Belle Aire Chalet Park, Newport Caravan Park, Sunningdale Caravan Park, Seafields Caravan Site. Residential properties at the corner of Yarmouth Road, Kings Way and Newport Road. Residential properties along Yarmouth Road adjacent to Easterley Way.
- Increased Conveyance / Overland flow diversion – Install new culvert from Martham Road Farm to Collis Lane.
- Planning Policy / Development Control – Reduced runoff rates and flood resilient construction at Pit Road, Hemsby Holiday Centre and the Highfield Equestrian Centre.
- Identified Overland Flow Paths – Tern Road to Bakes Road, Vine Close to Waters Lane and within Fengate Farm.
- Improved Land Management Practices – All farm land immediately to north and south of Hemsby.

Approx. Construction Cost = £1,310,000	**No. Properties Benefitting = N/A (not modelled)**

Benefits

- SUDS systems improve water quality and amenity.
- Reduced surface water flows into combined drainage system.



8.2 High Priority CDA Actions

Before any works are undertaken in a CDA, it is recommended that a combination of actions are undertaken to further confirm the risk, reduce costs of a preferred option / measure and establish the benefit of the proposed scheme. For each High Priority CDA, it is recommended that the Steering Group:

- Undertake a detailed feasibility study which includes:
  - Asset investigations (e.g. Inspection / CCTV of existing infrastructure to confirm condition, size and connectivity)
  - Detailed modelling of the CDA (i.e. refined model grid size, include all pipes and gullies)
  - Initial underground service investigations (obtain and review relevant service plans)
  - Conceptual sizing and locating of proposed measures / options based on updated data and constraints
- Complete further public consultation:
  - Development of a community flood plan
  - Raise awareness of measures that residents can implement themselves (for example water butts, rainwater harvesting and retrofitting permeable surfacing)
  - Review current maintenance practices and adapt where appropriate
- Review all benefits of proposed schemes and identify links with partner organisation goals
  - Water quality benefits (improved water quality in River Yare and related 'blue flag' certifications of local beaches)
  - Reduced surface water runoff volume (lower volume entering Anglian Water systems leading to reduced CSO operation frequency and reduced volume transferred to treatment plant)
  - Improved biodiversity through urban green spaces (improved local amenity and wider ecological benefits)
  - Establish links with local community groups (flood resilience groups, nature groups and make use of local skills / resources for delivery)
  - Increased number of potential funding sources

8.3 Medium / Low Priority CDA Actions

Medium and Low Priority CDAs do not justify immediate further investigation, but should have the following actions considered for implementation. Evidence gathered from these actions may increase the level of priority or identify quick win actions in the future.

- Monitor flood risk related problems and manage future development using proposed CDA preferred options to minimise impact on flood risk
- Work proactively to monitor the condition of ordinary watercourses and associated culverts and review maintenance practices as required.

- Work proactively with the EA and local IDBs to monitor the condition of Main Rivers, culverts and Defences.
- Engage Norfolk Highways to monitor any future flooding and assess the associated risk on all Major Roads

8.4 Study Area Wide Actions

8.4.1 Surface Water Flood and Water Quality Management Policy

CDAs delineate the areas where the impact of surface water flooding is expected to be greatest, it is acknowledged that the CDAs do not account for all the areas that could be affected by surface water flooding. It is therefore recommended that the GYBC and NCC consider implementing planning policies which will reduce the risk from surface water flooding throughout the whole study area. Consistent action will allow both authorities promote and apply current industry best practices with regard to the implementation of SUDS and the reduction of runoff volumes. Where specific 'planning policy / development control' is proposed within specific CDAs, these site specific policies should be applied in parallel with the recommended study area wide policies.

To aid implementation of these proposed policies, GYBC and NCC should consider revision of existing 'permitted development' policies. Certain types of currently permitted development may have a significant long term impact on ground permeability and related surface water runoff into drainage infrastructure. The review should consider the potential impact of the permitted development over the long term and revisions could be made accordingly.

There are four example policies summarised below for consideration by NCC / GYBC as a starting point for development of local strategic planning policy. These example policies set a higher standard that currently required by the National Planning Policy Framework (NPPF). However, the requirements of the NPPF are targeted at managing development in the fluvial and tidal flood plains. It is appropriate that local policies are defined at a local level to manage surface water flood risk based on local conditions. It has therefore been left open for Lead Local Flood Authorities to generate and implement planning policy relating to 'local flood risk' based on local conditions.

Example Policy 1*: All developments across the study area (excluding minor house extensions less than 50m^2) which relate to a net increase in impermeable area are to include at least one 'at source' SUDS measure (e.g. water butt, rainwater harvesting tank, bioretention planter box etc). This is to assist in reducing the peak volume of runoff discharging from the site.*

Example Policy 2*: Proposed 'brownfield' redevelopments of more than one property or area greater than 0.1 hectare are required to reduce post-development runoff rates to of the 50% existing runoff rates for events up to and including the 1 in 100 year return period event with an allowance for climate change. If this results in a discharge rate lower than the Greenfield conditions it is recommended that the Greenfield rates (calculated in accordance with IoH124[4]) are used.*

Example Policy 3: *All new developments and redevelopments of more than one property or area greater than 0.1 hectare located in Critical Drainage Areas (CDAs) should seek betterment to a Greenfield runoff rate (calculated in accordance with IoH124).*

The councils may also wish to consider the inclusion of the following policy to manage the pollutant loads generated from proposed development applications:

[4] Defra/Environment Agency, September 2005, Flood and Coastal Defence R&D Programme: Preliminary Rainfall Runoff Management for Developments (R&D Technical Report W5-074/A/TR/1 Revision D)

Example Policy 4: *Holistic application of Sustainable Urban Drainage Systems (SUDS) is required to be demonstrated for development applications greater than 0.1 hectare within the study area. The following runoff load-reduction targets must be achieved when assessing the post-developed sites runoff water quality (comparison of unmitigated developed scenario versus developed mitigated scenario):*

- 80% reduction in Total Suspended Sediment (TSS);

- 45% reduction in Total Nitrogen (TN);

- 60% reduction in Total Phosphorus (TP); and

- 90% reduction in litter (sized 5mm or greater).

All of the proposed thresholds in the above example policies should be considered in the local context of common development types and the resource available to process planning applications. A review of recent development applications may provide a baseline for setting appropriate thresholds.

The Councils may also wish to consider specific policy relating to site based flood risk assessments for surface water that is similar to the current practice of the Environment Agency for fluvial/tidal/coastal flood risk. The surface water flood risk maps produced as part of the SWMP could be used as an additional trigger for a Flood Risk Assessment under the NPPF in a similar way that development in the EA Flood Zones 2 and 3 are currently used as triggers. Where both forms of flood risk are identified as issues, then they should be managed in an integrated fashion. The level of assessment required could be implemented in a similar fashion to the Environment Agency Flood Zones:

- 100yr Surface Water Flood Depth >0.5m = Assessment similar to Environment Agency Flood Zone 3
- 100yr Surface Water Flood Depth between 0.1 and 0.5m = Assessment similar to Environment Agency Flood Zone 2

NCC (as LLFA) would be responsible for review and approval of FRAs triggered by surface water flooding only as this is classified as a 'local flood risk'. Where flooding from fluvial / tidal sources is also identified, then the review would need to be done in partnership with the EA. Anglian Water would also need to be consulted by the applicant to confirm acceptable discharge rates into the local drainage network (which may be lower than those defined above due to local network capacity issues). The policy applied by NCC in assessing FRAs would be in line with the recommended policies above and the sequential / exception test approach defined by the NPPF.

Implementation of this policy is beyond the scope of this SWMP document. An action has been included in the Action Plan for the Steering Group to undertake internal consultation with their respective strategic planning and development compliance staff to determine how this type of policy could be implemented.

8.4.2 Other Study Area Wide Actions

The table on the following page details the preferred surface water flood risk management options across the entire study area. Further detail on each of the options proposed is included below and on the pages following the table.

Update of strategic planning policy: NCC and GYBC should consider updates to strategic planning policies reflect the CDA specific preferred options in Section 8.1, the example policies outlined in Section 8.4 and the implementation actions in Section 10.3.

Improve maintenance of the drainage network: Drainage maintenance schedules should be reviewed to reflect the findings of this study. The potential for blockages in the drainage network would exacerbate surface water flooding; this would be a particular issue in all the areas identified as being at risk of surface water flooding during an extreme event.

It is recommended that a risk-based approach is applied so that drainage infrastructure in key areas is kept clear and maintained. Such a system is being initiated by NCC Highways, for example highway gullies are scheduled at different frequencies and the levels of silt is recorded in each gully. These systems require an annual review.

Plans should be put in place to warn residents of when the gullies (and land drains/swales) are due to be cleaned and request that cars are parked elsewhere if necessary.

Improve drainage network capacity: A key recommendation of this study is to look at improving the drainage network capacity across the study area, especially within areas that may have capacity issues. When undertaking pipe replacement works it is recommended that an assessment is undertaken to confirm the area can benefit from an increase in pipe size rather than a like-for-like replacement. It is recommended that work is carried out in collaboration with Anglian Water to assess the possibility of upgrading the network capacity in these key areas, which would reduce the risk of surface water flooding in these areas. It is recognised that with current funding levels, additional funding will be required to undertake any significant work.

Table 8-1: Summary of Study Area Wide Options Assessment

Location	Option Category	Option Description	Options Assessment: Technical	Economic	Social	Environmental	Objectives	Overall	Take Forward?	Summary of Scheme
Great Yarmouth Borough Study Area (all areas 'at risk')	Do nothing	Do nothing	-	-	-	-	-	-	✓	Make no intervention or maintenance – no benefit to area
	Do minimum	Do minimum	-	-	-	-	-	-	✓	Continue existing maintenance regimes – minimal benefit and (currently) does not include increased maintenance for the predicted increase in rainfall as a result of climate change.
	Planning Policy	Adapt strategic planning policies	2	2	1	0	2	7	✓	Adapt strategic planning policy for all new developments, especially within areas identified at high risk of surface water flooding in line with recommendations made in Section 8.4.1.
	Improved Maintenance	Improved maintenance of drainage network	2	1	2	1	1	7	✓	Improved and targeted maintenance of the drainage network to avoid potential blockages that reduce the drainage network capacity
	Community Resilience	Improve community resilience to reduce damages from flooding	2	1	2	0	1	6	✓	Improve community resilience to flooding through establishing a flood warning system, reviewing emergency planning practices and encouraging the installation of individual property protection measures (such as flood-gates).
	Source Control, Attenuation and SUDS	Install rainwater harvesting systems water-butts, and bioretention features	2	2	1	1	2	8	✓	Install rainwater harvesting systems, bioretention systems and water-butts in key risk areas in order to reduce the rate and volume of surface water runoff. Upstream attenuation via wetlands and ponds could also be considered where suitable land is available. This option has the added benefit of improving biodiversity
	Flood Storage / Permeability	Install permeable paving in key areas	2	2	1	1	2	8	✓	Install permeable paving systems in key areas and along key overland flow paths in order to reduce local runoff.
	Improvement to Drainage Infrastructure	Improve drainage network capacity within key risk areas	2	1	0	0	2	5	✓	Work collaboratively with Anglian Water to assess the possibility of increasing sewer network capacity in key areas (or those identified as having poor capacity). This could be integrated with the AMP planning process where appropriate.

Location	Option Category	Option Description	Options Assessment							Summary of Scheme
			Technical	Economic	Social	Environmental	Objectives	Overall	Take Forward?	
	Preferential Overland Flow Routes	Increase kerb heights and/or lower road levels along key flow paths	2	1	2	1	1	7	✓	Investigate the potential of increasing footpath heights and/or lowering road levels along key flow paths in order to retain flood water within the roads and channel it away from properties at risk of flowing.
	Other	Hydrometric monitoring	2	2	0	1	2	7	✓	Install hydrometric monitoring equipment in order to gain a better understanding of rainfall patterns and mechanisms that lead to localised flooding across the study area.
	Other	Infrastructure resilience	2	1	2	0	1	6	✓	Identification of at risk infrastructure (electricity sub-stations, telephone exchanges, gas supply manifolds etc) and proactive management of risks
	Other	Community Awareness	2	2	2	0	1	7	✓	Increase awareness of flooding within communities at risk through the use of newsletters, drop-in workshops, websites and social media.

Improve community resilience: It is recommended that a general approach to improving community resilience is adopted across the study area, particularly in areas that have been identified as being at risk. This should include establishing a flood warning system and improving emergency planning procedures (described in more detail below) as well as encouraging property resilience through the installation of individual property protection measures, such as raising property thresholds or installing flood gates or air brick covers.

Emergency planning (flood incident management): Reviewing the emergency planning procedures in areas at risk from surface water flooding will help to ensure the safety of people and to develop additional planning where required.

Due to the rapid nature of surface water flooding following a rainfall event, resources will need to be in place for immediate implementation following a Flood Warning. Within flooded areas, actions such as the closure of roads and diversion of traffic may be required. A strategy for the safe evacuation of residents will also need to be revised based on the surface water modelling outputs contained within this document.

Raising community awareness: Communicating the risk of flooding and raising awareness within local communities across the study area can be implemented in the short-term and provides a 'quick win' measure to surface water management. This will mean residents are more aware of the flood risk across modelled settlements (and wider study area) and can encourage people to become more proactive within their community. Increasing awareness can be achieved through public consultation events, newsletters and online resources such as council websites and social media.

It is also important that technology is fully utilised in order to communicate with the local community. The Environment Agency have produced an iPhone App which delivers data from their online flood warning service straight to people's phones; this is an excellent example of how innovative thinking and technology can be applied to the communication of flood risk. In the first instance, it is recommended that social media platforms such as Google+, Facebook or Twitter are utilised as a way of communicating with local residents and providing information on the council's flood and water management activities.

Improve infrastructure resilience: The surface water flooding risk identified by the SWMP should be provided to local utility operators (electricity, gas, telephone etc). This will ensure they are aware of the potential risk to their assets are able to proactively manage them.

Permeable paving: Installing permeable paving in key risk areas and along key overland flow routes. These systems can assist in reducing the amount of runoff entering the drainage network, and assist in reducing the overall risk of flooding from an extreme rainfall event.

Rainwater harvesting and water-butts: Improving the resilience of local communities to flooding can be achieved through raising awareness of simple measures and systems that can be installed at their homes. Local residents and property owners may, for example, be encouraged to install simple systems such as water butts to capture roof runoff. Alternatively, rainwater harvesting systems could be installed in new developments or schools.

The principle of rainwater harvesting is that rainfall from roof areas is passed through a filter and stored within large underground tanks. When 'grey water' is required, it is delivered from the storage tank to toilets, washing machines and garden taps for use. Any excess water can be discharged via an overflow to a soakaway or into the local drainage network.

One of the preferred options to reduce peak discharges and downstream flood risk is the implementation of water butts on all new development within the existing urban areas, and in addition, retrofitting these to existing properties where possible.

Water butts often have limited storage capacity given that when a catchment is in flood, water butts are often full and have no spare capacity for flood waters. However, it is still considered that they have an important role to play in the sustainable use of water. There is potential to use 'leaky' water butts that provide overflow devices to soakaways or landscaped areas to ensure that there is always some volume available for storage during heavy rainfall events.

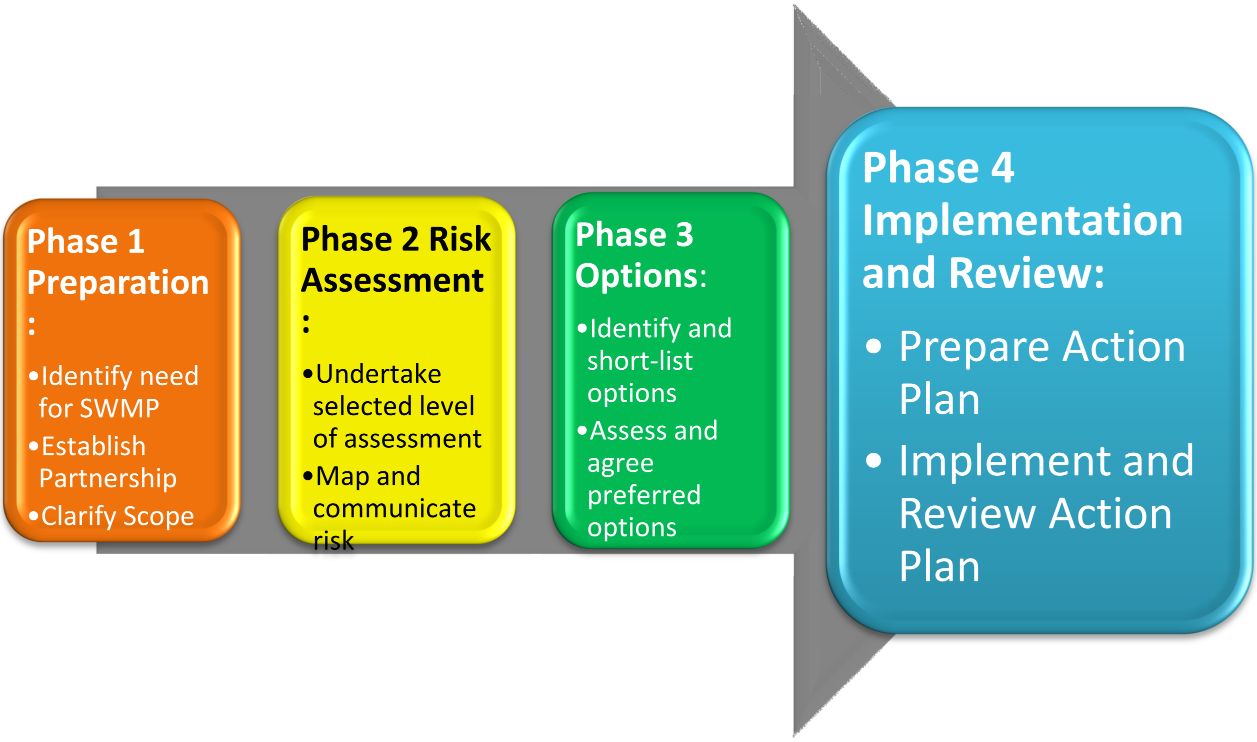
Larger rainwater harvesting systems should also be implemented within suitable developments within the study area (e.g. school facilities, commercial buildings etc)

Retrofitting bioretention/rain gardens car park bays: Retrofitting bioretention features in key risk areas and along key overland flow routes will act as a source control measure to reduce the amount of runoff entering the drainage network, and reducing the overall risk of flooding from an extreme rainfall event. These devices also can enhance the aesthetics and biodiversity of an area due to their landscaping. These devices have been found to assist in reducing the total amount of phosphorus and nitrogen that discharge into downstream waterways as a result of adsorption and absorption processes within the filter media and plant growth and die off and therefore improve the quality of the runoff discharging into the downstream network.

Hydrometric monitoring: It is recommended that installing a series of hydrometric monitoring systems across the study area would provide a stronger understanding of rainfall patterns and flows that lead to surface water flooding across Great Yarmouth Borough. Rain gauges and flow gauges should be installed in targeted areas so that a detailed understanding of the catchment hydrology can be established. This evidence base can be used to inform future studies and flood alleviation projects across the study area. Monitoring stations could also be linked to local flood warning systems to provide some early indication of intense rainfall travelling across the study area.

Norfolk County Council should develop an integrated framework to support emergency response and flood incident management. In conjunction with this, it is recommended that rainfall gauging stations can be used to assist with this aim, as well as to assist with the Council's responsibility of investigating flood incidents as required under the FWMA 2010.

PHASE 4: IMPLEMENTATION AND REVIEW



9 Action Plan

The Action Plan (Appendix B) outlines a wide range of recommended measures that should be undertaken to manage surface water within the study area more effectively. The actions are linked with the recommendations made in Section 8 (Preferred Options) and Section 10 (Implementation). The Action Plan identifies:

- *General flood risk management actions* to integrate outcomes, recommendations and new information from this study into the practices of all Steering Group organisations
- *Strategic Planning Policy actions* to assist NCC and GYBC to manage future developments in the context of local flood risk management
- *Maintenance actions* to prompt possible review of current schedules in the context of new information presented in this study
- *High priority CDA actions* to be considered to better understand flood risk in specific areas and proactively manage operational risks
- *All CDA actions* to be considered across all CDAs identified within this study
- *Transport Infrastructure risk assessment* actions to investigate at risk major roads and pedestrian underpasses to understand the potential risk associated with each

The Action Plan should be read in conjunction with details of the preferred options and recommended actions. It is the intention that the Action Plan is a live document, maintained and regularly updated by the Steering Group, as actions are progressed and investigated.

10 Implementation

10.1 Overview

Implementation of the Action Plan will require continued work within the Steering Group. NCC should coordinate with relevant internal and external partners in order to ensure a holistic approach to the implementation of outputs and actions from the SWMP.

Key internal council partners include emergency planners, highways and strategic planning. Key external partners include GYBC development and regeneration services, environmental health, emergency planning, leisure and public spaces; Anglian Water, and the Environment Agency. The outputs of the SWMP should be used, where appropriate, to update and adjust policies and actions. The following sections summarise the specific recommendations for each of the key Steering Group members.

10.2 Anglian Water

Ofwat, the water company regulator, has also outlined their intention for water companies to work with other key partners to deliver SWMPs. In addition the Flood and Water Management Act (2010) outlines a duty for water companies to provide information and co-operate with such studies. Anglian Water has been extremely helpful throughout the SWMP process and it is important that this partnership is continued into the future.

One example of how the partnership can be developed upon completion of this study is to look at how the outputs from this SWMP could be used to influence Anglian Water's investment and funding schedule for drainage improvements and maintenance programmes across the study area. It would be extremely beneficial if their investments plans can be influenced by this study to target areas which have been identified as being at significant risk of surface water flooding due to drainage capacity issues.

Anglian Water is currently in the AMP5 period of work (set out between 2010 and 2015), and therefore it is recommended that the outputs of the SWMP should be incorporated into the next planning period (AMP6). Anglian Water's Business Plan outlines future investment strategy within the water company. The outputs and recommendations from the SWMP should feed into the decisions made about drainage and sewer flooding in key locations.

The overall aim is for the SWMP outputs to encourage a more holistic approach to future funding arrangements and schemes for drainage improvements within the study area. For example, the SWMP model outputs can feed into the investments plans for areas with an identified flood risk.

10.3 Strategic Planning – NCC and GYBC

There are three key avenues by which the findings of this SWMP are recommended to be taken forward through the planning system:

1. The SWMP maps which identify potential areas that are more vulnerable to surface water flooding should be used in addition to information in SFRAs
2. The SWMP maps which identify potential areas that are more vulnerable to surface water flooding should be used to update/prepare policies in the Local Plan
3. The SWMP maps which identify potential areas that are more vulnerable to surface water flooding should be used to inform development decisions for sites or areas by either:
    - Resulting in modifications to strategies, guidance, or policies for major development locations (e.g. through Area Action Plans and Supplementary Planning Guidance); or
    - Influencing planning decisions in relation to the principle, layout or design of particular development proposals.

Mapping Checklist

The table below indicates the SWMP maps which are of potential use to strategic planning, and indicates which maps may be suitable for superseding existing SFRA maps:

Table 10-1: SWMP maps which are of potential use to strategic planners

Issue	SWMP Map reference	Consider superseding existing SFRA maps?
Surface water flood risk	Appendix D	Yes – more detailed methodology to that used for the SFRA.
Susceptibility to Groundwater Flooding	Appendix D	Yes – more detailed methodology to that used for the SFRA.

Issue	SWMP Map reference	Consider superseding existing SFRA maps?
Recorded incidents of flooding	Appendix D	May include more recent records.

Using the SWMP to Update/Modify Policies in Local Plans

Ideally the SWMP should be used as an evidence base to support significant change to the Local Plan. Where Local Plan documents (e.g. those covering site allocations and development management policies) are yet to be adopted, there is an opportunity to influence both policies and those sites which are being put forward for development.

The production of the SWMP should inform any proposed sites being put forward through the Local Plan and Site Allocations document which are being prepared for the borough. Identification of areas of local flood risk (surface water, ordinary watercourse or groundwater flooding) which have similar levels of hazard significance as the areas identified by the Environmental Agency as Flood Zone 3 should inform the site selection and screening process.

Using the SWMP to Influence Areas of Major Growth and Development

The SWMP should inform consideration of how proposed new development will drain to areas of existing surface water flood risk, and therefore the runoff requirements from those development sites.

The emerging Local Plan will identify a number of areas for major housing growth, associated facilities and employment sites. Where major development proposals are brought forward, these should be examined for:

- Significant surface water flooding issues (regardless of location relative to a defined Critical Drainage Area)
- CDAs that affect the area;
- Susceptibility to Groundwater Flooding; and
- Contribution of run-off to local flood risks beyond the actual redevelopment area.

Local flood risk should not necessarily prevent development from taking place, but it may affect the location, uses, design and resilience of the proposals. Therefore, a Flood Risk Assessment should be undertaken to consider:

- The location of different types of land use within the site(s);
- Application of the sequential approach to development layout and design;
- The layout and design of buildings and spaces to take account of flood risk, for example by dedicating particular flow routes or flood storage areas;
- Measures to reduce the impact of any flood, through flood resistance/resilience measures/materials;
- Incorporating sustainable drainage and rainwater storage to reduce run-off to adjacent areas; and

- Linkages or joint approaches for groups of sites, possibly including those in surrounding areas.

These requirements can be set out in Development Management policies or as site specific policies.

Using the SWMP to Influence Specific Development Proposals

Where allocations are proposed in an area covered wholly or partially by a Critical Drainage Area, this should trigger a Flood Risk Assessment. Whilst some small scale developments may not be appropriate in high risk areas, in most cases it will be a matter of ensuring that the Flood Risk Assessment considers those items listed above and also considers some or all of the following site specific issues:

- Are the flow paths and areas of ponding correct, and will these be altered by the proposed development?
- Has the site been planned sequentially to keep major surface water flow paths clear?
- Has exceedance of the site's drainage capacity been adequately dealt with? Where will exceedance flows run off the site?
- Could there be benefits to existing properties at risk downstream of the site if additional storage could be provided on the site?
- In the event of surface water flooding to the site, have safe access to / egress from the site been adequately considered?
- Have the site levels been altered, or will they be altered during development? Consider how this will impact surface water flood risk on the site and to adjacent areas; and
- Have inter-dependencies between utilities and the development been considered? (for example, the electricity supply for building lifts or water pumps)

10.4 Emergency Planning – NCC and GYBC

The SWMP surface water flood maps can be used to:

- Identify vulnerable people or groups of vulnerable people who are at risk of flooding
- Identify critical transport routes that could be subject to flooding
- Understand how emergency response infrastructure (fire stations, ambulance stations, police stations, hospitals and command centres) and related access routes may be impacted by flooding
- Estimate the overall cumulative impact of a significant rainfall event (i.e. the combined impact of access route blockage, flooding of significant infrastructure and impact to groups of properties)
- Identify groups of buildings that are potentially at risk of significant flooding
- Hazard rating and predicted depth maps show clear differentiation of level of risk that may be encountered within each area of predicted flooding

It is recommended that SWMP surface water flood mapping is made available to:

- Local Resilience Forums

- Emergency Services
- Local / Regional Emergency Management Command Centres

10.5 Highways Authority - NCC

NCC is the highways authority in Norfolk for all roads except trunk roads, and is responsible for managing and maintaining the majority of the road drainage network within the study area. It has a variety of responsibilities ranging from repairing potholes to salting the roads during cold and icy weather. It is also responsible for ensuring that drains and gullies are kept clear from debris such as soil, dead leaves and rubbish.

This type of debris often builds up in drains preventing the flow of water into the surface water or combined sewers and requires frequent maintenance. If drains become blocked during a heavy rainfall event it can exacerbate the severity of flooding that occurs locally.

The NCC highways team is identified as one of the key partners in this SWMP study and its involvement and engagement in the process has been actively encouraged. It is important that the outputs from this SWMP are used effectively in order to support and inform the future management practices of the study area’s road infrastructure.

The main recommendations and actions that NCC highways should consider from the SWMP are:

- The existing schedule of drain and gully maintenance is recommended to be re-evaluated in order to give particular attention to areas considered to be at the highest risk of surface water flooding. This should be undertaken for all settlements within the study area. Drains and gullies in these areas should be kept clear throughout the year to maximise the capacity of the drainage network and reduce the risk of blockages; this should be reflected in the highways maintenance schedule; and
- Opportunities for joint funding on improvement work within the study area should be considered. Highway maintenance and improvement projects could be combined with drainage improvement or flood alleviation projects through a more holistic approach within the council. For example, highways drainage programmes may offer opportunities to incorporate useful changes to overland flow paths or increase drainage capacity within a surface water flood risk hot spot with little extra cost. This would provide a time and cost effective way to manage the resources of the council and ensure different departments are involved in working together to reduce the flood risk across the study area.

11 Review

11.1 Review Timeframe

Proposed actions have been classified into the following categories:

- Short term: Actions to be undertaken within the next one to three years;
- Medium term: Actions to be undertaken within the next three to five years; and
- Long term: Actions to be undertaken beyond five years.

The Action Plan identifies the relevant internal departments and external partnerships that should be consulted and asked to participate when addressing an action. After an action has been addressed, it is recommended that the department responsible for completing the action should review the Action Plan and update it to reflect any issues (communication or stakeholder participation) which arose during the completion of an action and whether or not additional actions are required.

It is recommended that the Action Plan is regularly reviewed and updated to reflect any necessary amendments. In order to capture the works undertaken by the NCC other stakeholders, it is recommended that the Action Plan review should be on an annual basis.

11.2 Ongoing Monitoring

It is intended that the partnership arrangements established as part of the SWMP process, will continue beyond the completion of the SWMP in order to discuss the implementation of the proposed actions, review opportunities for operational efficiency and to review any legislative changes.

The SWMP Action Plan should be reviewed and updated annually as a minimum, but there may be circumstances which might trigger a review and/or an update of the Action Plan in the interim. Examples of events which would likely trigger an Action Plan review include:

- Occurrence of a surface water flood event;
- Additional data or modelling becoming available, which may alter the understanding of risk within the study area;
- Outcome of investment decisions by partners is different to the preferred option, which may require a revision to the action plan, and;
- Additional (major) development or other changes in the study area which may affect the surface water flood risk.

It is in the interest of study area and the residents of the catchment, that the SWMP Action Plan remains current and up-to-date. To help facilitate this, GYBC and NCC should liaise with other flood risk management authorities and monitor progress.

11.3 Incorporating New Datasets

The following tasks should be undertaken when including new datasets in the SWMP:

- Identify new dataset
- Save new dataset/information
- Record new information in log so that next update can review this information

11.4 Updating SWMP Reports and Figures

In recognition that the SWMP will be updated in the future, the report has been structured in chapters according to the SWMP guidance provided by Defra. By structuring the report in this way, it is possible to undertake further analyses on a particular source of flooding and only have to supersede the relevant chapter, whilst keeping the remaining chapters unaffected.

In keeping with this principle, the following tasks should be undertaken when updating SWMP reports and figures:

- Undertake further analyses as required after SWMP review
- Document all new technical analyses by rewriting and replacing relevant chapter(s) and appendices
- Amend and replace relevant SWMP Maps
- Reissue to departments within NCC, GYBC and other stakeholders

12 References

Allen, D J, Brewerton, L J, Coleby, L M, Gibbs, B R, Lewis, M A, MacDonald, A M, Wagstaff, S J, and Williams, A.T. (1997) The physical properties of major aquifers in England and Wales. British Geological Survey Technical Report WD/97/34. 312pp. Environment Agency R&D Publication 8.

Capita Symonds (September 2009) Great Yarmouth and Gorleston Strategic Flood Risk Assessment

Defra (March 2005) Making Space for Water – Taking forward a new Government strategy for flood and coastal erosion risk management in England.

Defra (March 2010) Surface Water Management Plan Technical Guidance.

Environment Agency, (December 2009) River Basin Management Plan Anglian River Basin District

Norfolk Preliminary Flood Risk Assessment (July 2011)

Pitt, M. (2008) Pitt Review - Learning Lessons from the 2007 Floods.

Appendix A: Intermediate Risk Assessment

Appendix B: SWMP Action Plan

Appendix C: Modelling Details

Appendix D: Maps and Figures

Appendix E: CDA Prioritisation

Appendix F: Conceptual Options Assessment

Appendix G: Detailed Assessment – Engineering Judgement

Limitations

Capita Symonds Ltd ("Capita Symonds") has prepared this Report for the sole use of **Norfolk County Council** ("Client") in accordance with the Agreement under which our services were performed. No other warranty, expressed or implied, is made as to the professional advice included in this Report or any other services provided by Capita Symonds. This Report is confidential and may not be disclosed by the Client nor relied upon by any other party without the prior and express written agreement of Capita Symonds.

The conclusions and recommendations contained in this Report are based upon information provided by others and upon the assumption that all relevant information has been provided by those parties from whom it has been requested and that such information is accurate. Information obtained by Capita Symonds has not been independently verified by Capita Symonds, unless otherwise stated in the Report.

The methodology adopted and the sources of information used by Capita Symonds in providing its services are outlined in this Report. The work described in this Report was undertaken between **July 2012** and **September 2013** and is based on the conditions encountered and the information available during the said period of time. The scope of this Report and the services are accordingly factually limited by these circumstances.

Where assessments of works or costs identified in this Report are made, such assessments are based upon the information available at the time and where appropriate are subject to further investigations or information which may become available.

Capita Symonds disclaim any undertaking or obligation to advise any person of any change in any matter affecting the Report, which may come or be brought to Capita Symonds's attention after the date of the Report.

Certain statements made in the Report that are not historical facts may constitute estimates, projections or other forward-looking statements and even though they are based on reasonable assumptions as of the date of the Report, such forward-looking statements by their nature involve risks and uncertainties that could cause actual results to differ materially from the results predicted. Capita Symonds specifically does not guarantee or warrant any estimate or projections contained in this Report.

Unless otherwise stated in this Report, the assessments made assume that the sites and facilities will continue to be used for their current purpose without significant changes.

Costs may vary outside the ranges quoted. Whilst cost estimates are provided for individual issues in this Report these are based upon information at the time which can be incomplete. Cost estimates for such issues may therefore vary from those provided. Where costs are supplied, these estimates should be considered in aggregate only. No reliance should be made in relation to any division of aggregate costs, including in relation to any issue, site or other subdivision.

Copyright