Broadland Futures Initiative

The Sources and Nature of Flood Risk within the Plan Area

Contents

Coversheet image: flooding along Postwick Marshes © Jeremy Halls

1. Introduction

The Broadland Futures Initiative

The **Broadland Futures Initiative** (BFI) is a partnership for future flood risk management in the Broadland area. Our main goal is to agree a plan for future flood risk management that better copes with changing climate and rising sea level (see later pages for project information). The focus will be on what will happen from the mid-2020s onwards, however we need to start planning now to secure support and make well-informed decisions.

This document aims to inform you about the sources and nature of flood risk within the BFI plan area. Additionally, the document provides an overview of how flood risk is assessed and describes past flood events.

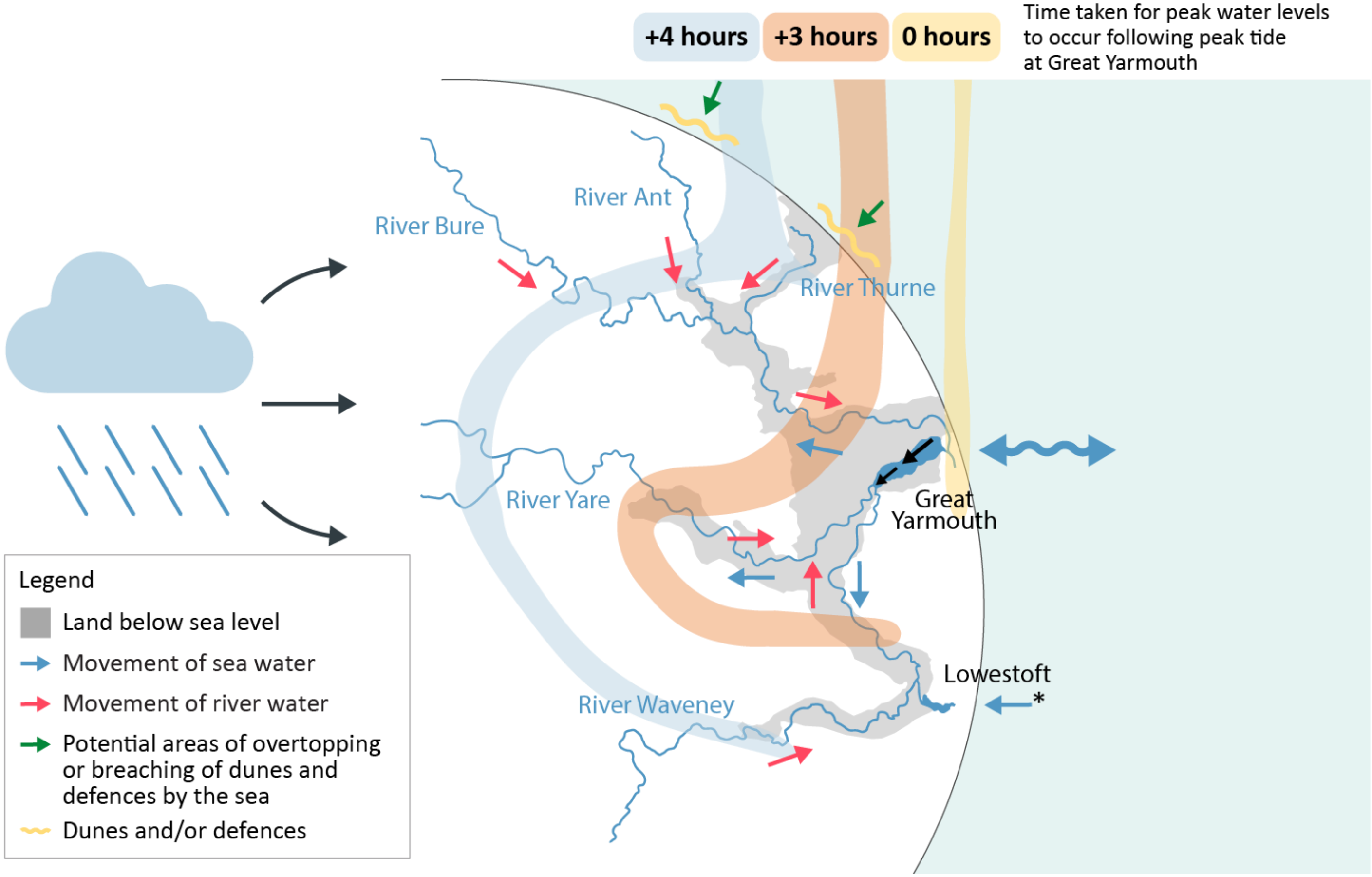
Specific organisations are responsible for managing flood risk depending on the source of flooding. The local community also has the ability to manage flood risk related to their properties and land.

The BFI plan area includes the full extent of the Broads Authority executive area and key stretches of the coast which could influence flooding in the Broads. Refer to the map on page 2. The plan area is predominantly in east Norfolk but also crosses into north east Suffolk.

Saltmarsh at Breydon Water © Jeremy Halls

BFI plan area extent. The figure contains OS data © Crown copyright [and database right] 2020

A generalised summary of the key flooding mechanisms and processes that are discussed in this document can be seen below. Rain and groundwater from the large catchment, some of which is outside the plan area, drains to the rivers flowing through the plan area. The rivers flow out to sea at Great Yarmouth and the tide travels up the rivers; there is a time lag for tide levels to peak inland. Note that tidal events entering the broad at Lowestoft is rare due to Mutford Lock and therefore is denoted on the map with a smaller one headed arrow. Breydon Water acts to buffer this exchange of flows on the River Yare. If dunes are breached or overtopped at some locations on the coast, then the sea could flood the land behind and also flow into the river network.



**Note that it is rare/unlikely for the tide to enter, or rivers to flow out of, the system at Lowestoft owing to Mutford Lock, therefore this entry point has been denoted by a smaller arrow.*
Also, a tidal barrier is currently proposed at Lowestoft.

The black arrows of decreasing size on Breydon Water represent the reduction in water level and flow compared to the tide at the coast- due to Breydon Water acting as a store.

2. The Sea, Main Rivers and Water Features

North Sea

The North Sea forms the eastern-most boundary of the plan area. The position of the coast has changed dramatically since the last glaciation. Even over the last 100 years, the combination of sea level rise and the land continuing to sink as a result of glacial rebound (the ice sheet was over the north of the UK and when it melted the north began to rise and the south east began to lower slowly as a result) has influenced sediment build up and erosion. This combined with natural processes, as well as subsequent storm surges, has led to parts of the soft and mobile coast eroding landward.

The North Sea tide rises and falls with a peak (highest point) and trough (lowest point) twice daily. This time varies from day to day, with each high and low tide advancing by approximately 50 minutes each day. The difference in level between high and low tides is termed the tidal range.

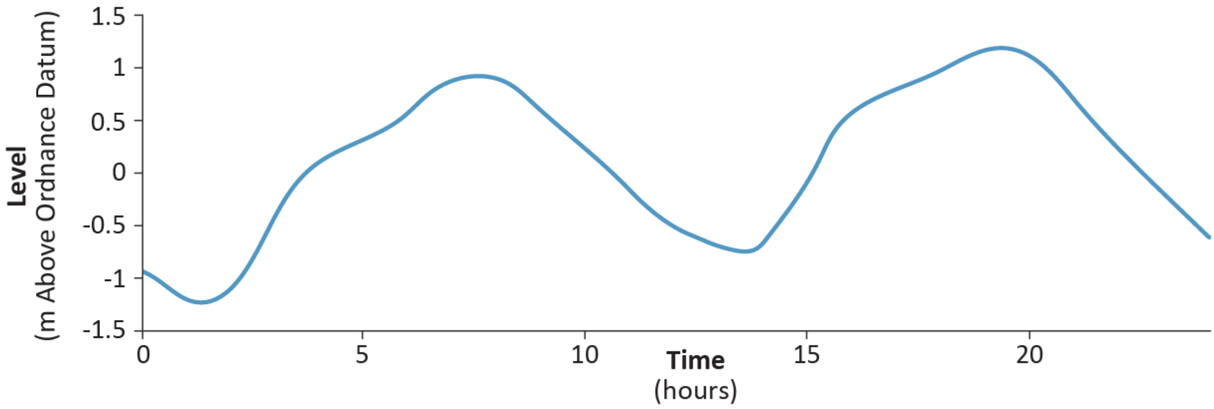
Tides are the rise and fall in sea level caused by the rotation of the earth and the gravitational influence of the sun and moon.

When the sun and moon align their gravitational influence is larger, which exaggerates the peaks and troughs. This is referred to as a **spring tide**. A spring tide occurs approximately twice every month (during the full moon and then again at new moon). Seven days after a spring tide is a **neap tide**. A neap tide occurs when the sun and moon are pulling the water in different directions to each other which results in more moderate tides (lower high tides and higher low tides).

Tide times are available online for locations along the UK coast (see https://www.bbc.com/weather/coast-and-sea/tide-tables/1)

There is one inlet and outlet to the sea for the BFI plan area rivers at Great Yarmouth, where the River Yare flows into the North Sea and at high tide the sea flows back up into the Broads river system. A typical tidal range for Great Yarmouth is shown in the following diagram. The highest spring tide each year is approximately 1.5m above average sea level (termed Ordnance Datum) and the normal spring tidal range at Great Yarmouth is 1.9m.

Aerial photo of Winterton beach © Mike Page



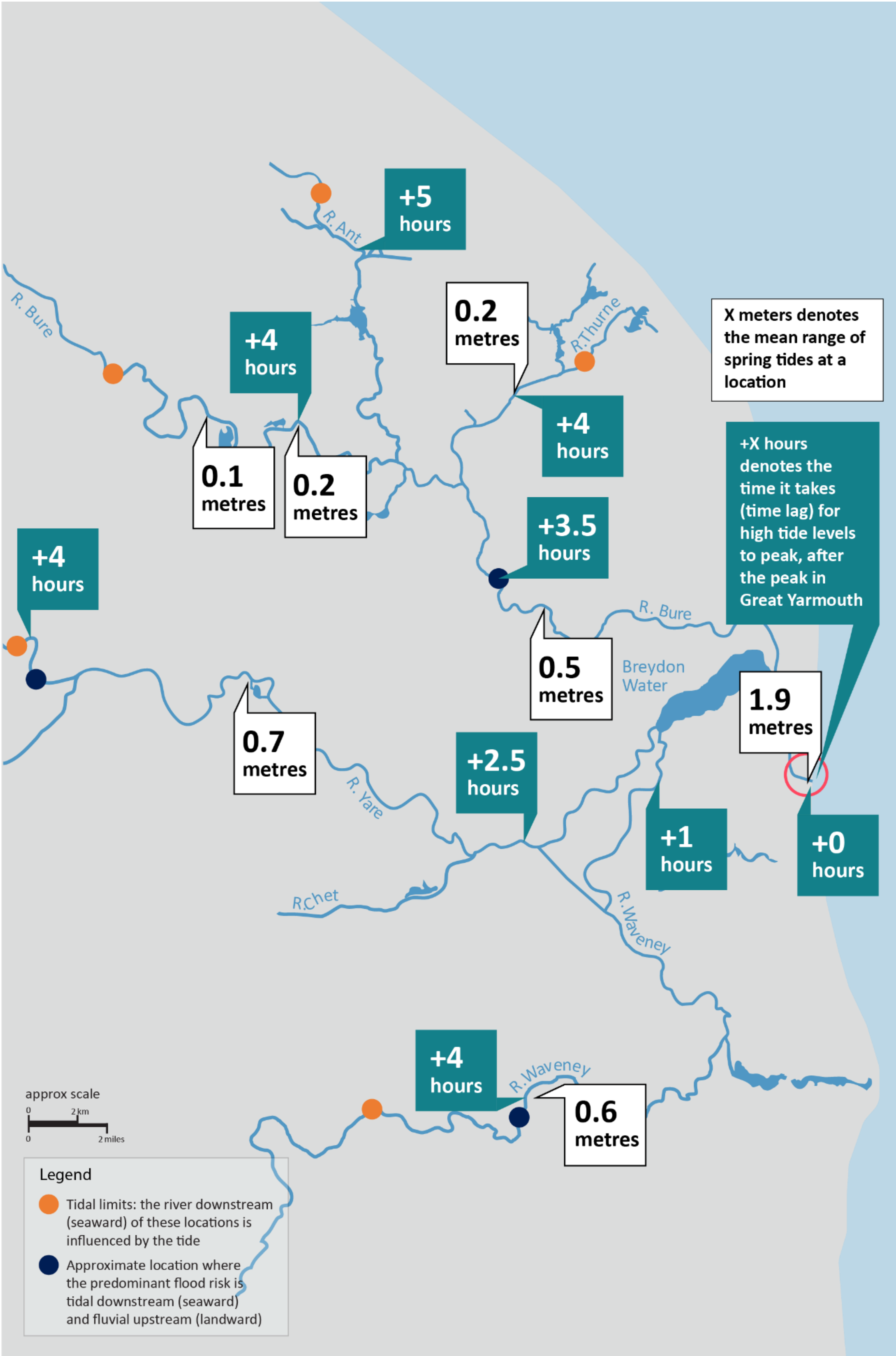
An example of a typical tidal range over 24 hours for Great Yarmouth

At Lowestoft tidal water is prevented from entering the Broads river system due to Mutford Lock- a navigation lock that is between Oulton Broad and Lake Lothing. Additionally, a tidal barrier at Lowestoft is currently proposed. This would be closed during storm surges/tidal events further preventing sea water entering the Broads.

The level of the tide at Great Yarmouth will not be the same as it is in the Broads. This is predominantly due to the large expanse of **Breydon Water**, which acts as a buffer and stores some of the tidal water coming into the system. The shallow land gradients across the plan area mean that the tidal influence extends far up the rivers. The time it takes for the water to travel up the system leads to a time lag between the peak of the tide at Great Yarmouth and peaks on the river levels inland. Approximate time lags in hours can be seen in the next diagram, together with the maximum point upstream where the tide can be detected, termed the tidal limit. **In Broadland, the influence of tides on the rivers can be felt up to 50km inland** in the case of the River Yare. This means that the direction of flow in the river systems can be either inland or seaward, depending on whether tides are rising or falling.

The salinity of the water can vary along the rivers for many kilometres inland from Great Yarmouth, due to this tidal water influence in the BFI area. How far upstream high salinity water penetrates is principally determined by the height of the tide and the amount of freshwater flowing downstream. Salinity in the rivers can vary vertically, with higher salinity water near the river bed and freshwater at the surface, and horizontally, with freshwater often found towards the banks and higher salinity water in the centre of the channel.

The effects of tide levels, and also salinity, decrease further inland as ground levels become more elevated and broads attenuate some of the flow. Tidal influence is larger on the rivers Yare and Waveney than the Bure. In fact, the tidal influence on the Bure and its tributaries is approximately half of the Yare and Waveney at similar distances from the sea. This is partly due to the Bure having a larger number of broads to accommodate water.



Map showing locations in the Broads where the tide has influence (tidal limits) and also approximate location where the risk switches from fluvial to tidal. The figure contains OS data © Crown copyright [and database right] 2020

The Rivers and Broads

The **Rivers Yare, Bure, Waveney, Chet, Ant and Thurne** are within the plan area and large sections of each are navigable. At Reedham, there is a direct navigable link to the River Waveney through the **Haddiscoe Cut** (also known as New Cut), an artificial waterway. The network of the rivers can be seen on the plan area map. These rivers are fed by water outside of the plan area which means that they are already conveying substantial flows by the time they near the influence of the tides. For example, the Bure, Yare and Waveney have a combined catchment area (the area that rainfall and groundwater will drain to a river) of more than 3,200km^2. By comparison, the plan area is just 370km^2.

The wider catchment is not known for being 'flashy'. In other words, there is a time lag between rain on the catchment and rivers levels rising. This is due to the relatively low land gradients upstream, as well as the soils and underlying rock being permeable (especially on the Bure), with the capacity to absorb some of the rainfall before it slowly flows to the rivers.

In comparison to other parts of the country, the east of the UK receives less rainfall. The annual average rainfall in Norfolk is 600mm compared to the national average of 1000mm.

Catchment area flowing into the Broadland and Great Yarmouth. The figure contains OS data © Crown copyright [and database right] 2020

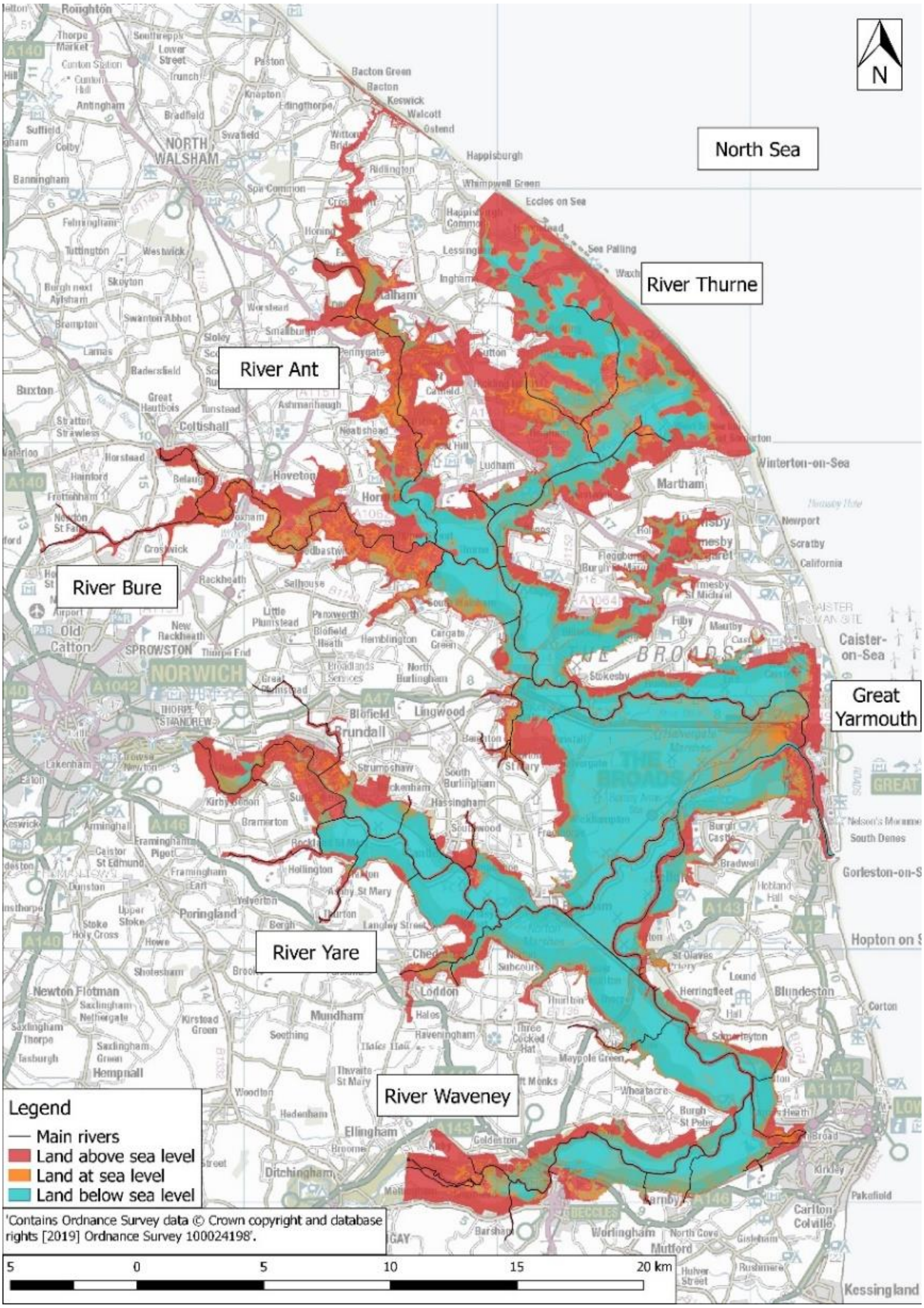
The Broads are areas of open water which were formed by the flooding of peat diggings following sea level rise. There are approximately 50 broads, ranging in size from small pools to large expanses such as Hickling Broad or Barton Broad. Most of the broads lie in the northern part of the BFI plan area. Rivers may flow directly through a broad or the broad could be situated to one side and connected to the river by an artificial channel or dyke. Some of the broads are navigable and are important for sailing, fishing and other recreational activities.

Upper Thurne and Hickling Broad © Mike Page

Low-lying Areas

The plan area is low-lying with approximately **60% at or below mean sea level** and therefore vulnerable to flooding (see map opposite). The majority of this low land was once an estuary and covered with water during part of the Roman period.

Since the majority of the land in the plan area is at or lower than sea level, large areas cannot drain effectively by gravity. This means that on a day-to-day basis, as well as particularly during any flood events, the land has to be both kept dry and returned to being dry once flood levels have receded. Indeed, most of the lowland plan area has a pumped drainage system managed by the Internal Drainage Boards (IDBs). Together with the embankments along many of the rivers, it is this network of pumps that prevents many villages from regular flooding and enables the low-lying land to be farmed and used productively.



Approximate elevation of land in the plan area

Groundwater

It can be easy to overlook the groundwater underlying the whole plan area in permeable soils and rocks. The plan area lies on top of a larger chalk basin which is filled with Crag; muddy and sandy sediments deposited when shallow waters covered the area. Crag is known as a locally important aquifer, and groundwater provides vital baseflow to many of the rivers in the plan area. Indeed, much of the area is underlain by peat, loamy and clayey soils with naturally high groundwater. Near to the coast, the Crag will exchange fresh and saline water with the sea, with the risk that the interface between fresh and saline water will move inland due to water abstractions and sea level rise.

There are other water features in the plan area, such as reservoirs, which pose a smaller flood risk. These risks are addressed through separate regulations and strategies.

A marsh dyke, part of the Broadlands wetland habitat © Jeremy Halls

Although groundwater is important for water supply in the area, and supports the many wetland habitats, upward movement of groundwater following prolonged above-average rainfall is limited. Therefore, widespread flooding caused by exceptionally high groundwater levels has not been observed in the plan area and is not currently seen as a key source of flood risk. However, groundwater levels near the coast are anticipated to rise with sea level which could lead to shallower groundwater across large areas of the low lying flat land in the future.

3. Flooding and Flood Risk

Introduction

Flooding is a natural process and, in certain locations across the plan area, is important to maintain wetland habitats. However, flooding can have serious consequences when it occurs outside these benefitting locations. Each river or floodplain has a limited capacity to pass flood water without overflowing the river banks and high ground, whether natural or raised by embankments or walls (called **flood management structures**). Likewise, coastal features such as dunes or artificial flood management structures cannot prevent overtopping by the sea in all storm conditions. Below is an introduction to the different sources of flooding possible within the plan area and some of the information available to understand where, and how frequently, flooding can occur.

A number of organisations are responsible for the management of flood risk, depending on the location and source of flooding. Further details will be provided in a separate document detailing the current approaches to flood risk management within the plan area.

Flood risk is the likelihood of flooding occurring together with the consequence of the flood event, such as something valuable being flooded or a potential threat to life. Things of value can include land (that is environmentally or agriculturally valuable), property or infrastructure (such as road networks). There are a number of techniques available to understand the consequences of flooding which are introduced below.

Sources of Flooding

Flooding can occur for a number of reasons, but often follows a period of intense rainfall and/or high water levels in rivers and the sea due to high spring tides and or the addition of storm surges.

Flooding from the sea can be separated into the following two types. **Tidal flooding** is seawater overtopping the natural coast or flowing up estuaries (where rivers meet the sea) where it can also impede the seawards flow of rivers and drains. **Coastal flooding** occurs from breaches or overtopping of natural or artificial structures at the open coast by abnormally high waves. The open coast is areas that experience direct waves from the North Sea rather than, for example, a harbour or tidal Broadland river.

For clarity, tidal and coastal sources will often be referred to simply as **flooding from the sea**, although the distinction is important when considering how to manage flooding. Flooding from breaching is different to other sources as it can happen very suddenly leading to high velocity flood water flooding the area immediately behind the breach with very little warning.

Erosion of beaches and dunes can cause breaches of structures and flooding

Higher than usual tides can exceed embankment levels and lead to flooding

Concrete sea wall at Walcott © Katy Walters-Geograph.org.uk

Flooding during high spring tide adjacent to River Yare at Reedham © Jeremy Halls

Storm surges can form when a significant low-pressure weather system (called a ‘depression’) and strong winds adjacent to the coast (northerly or north westerly winds) combine with high tides. This can lead to substantially higher tide levels than normal, and large powerful waves creating significant danger along vulnerable parts of the coast. Since monitoring began, the highest recorded level at Great Yarmouth was 3.3m above Ordnance Datum (this level is not taking into account waves on top of the water) which occurred on the 5th December 2013.

The high water levels are pushed towards the coast by the wind, where the sea floor becomes increasingly shallow. This causes water in contact with the sea bed to slow more than the water at the surface so that the water bunches up and surges onto the coast. At vulnerable locations, this can lead to **erosion** of beaches and dunes and possible breaching of the natural coast and defence structures. Erosion on this coast can be worse in conditions such as prolonged periods of easterly winds even if no flooding occurs. As noted previously extreme tide levels will also extrend up the rivers, although the maximum water level reached due to the tide will decarease the further inland you go. Additionally, water that spills out of the river onto marshland can reduce the water levels upstream.

A storm surge is higher than usual tides and strong winds exacerbate and push the waves onto the beach

Tidal flooding is the predominant risk in the majority of the BFI plan area. Not only can it affect the coast directly but also, as noted in earlier sections, tidal influence can extend far up the rivers inland. Modelling work has shown that even at locations inland, the largest risk is from the sea- as shown on the previous map with tidal limits.

Additionally, even without directly causing flooding, high sea levels can prevent river flows from draining away and cause them to back up, resulting in **'tide locking'.** Tide locking affects many riverside settlements, including Wroxham, Hoveton and Horning along the River Bure. Tide locking does not necessarily need extreme water levels to occur. In October 2014 for example there were high levels in the Broads system following a storm surge occurring during low tide which raised tide levels at Great Yarmouth for longer than usual.

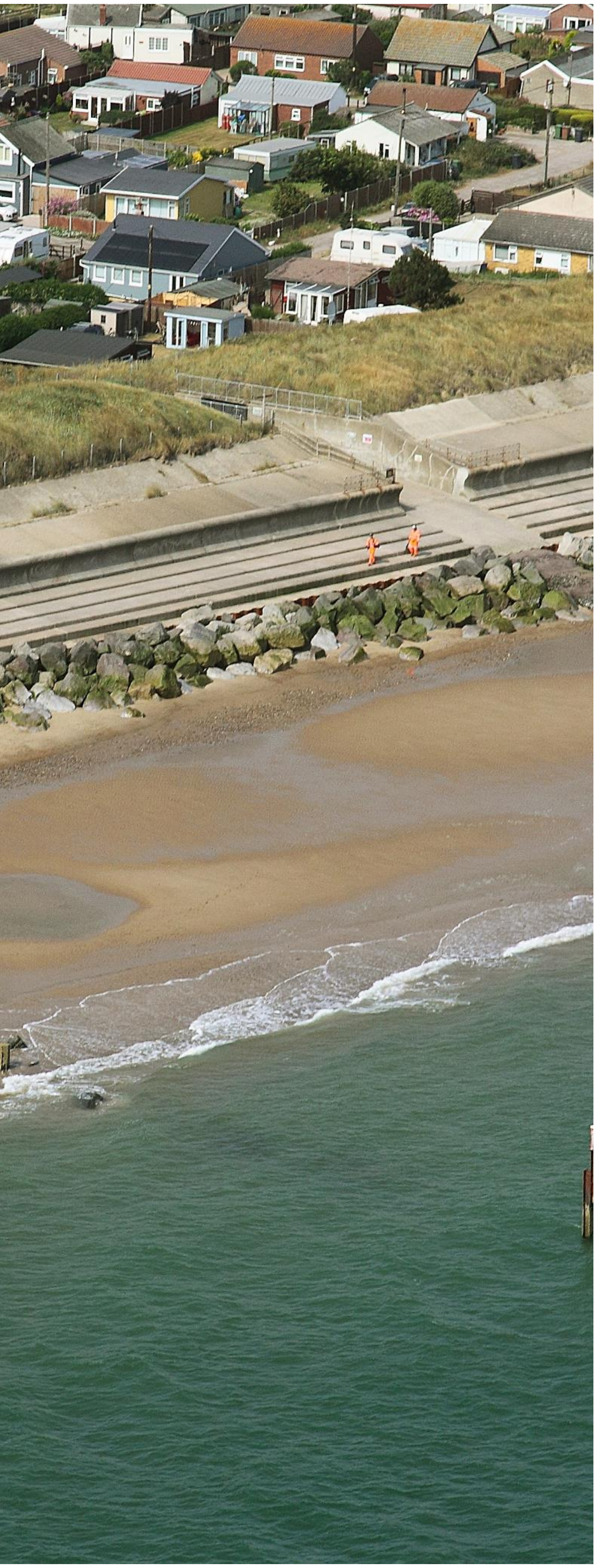
Areas inland can flood during abnormally high tides/tidal storm events. However, the long travel times from Great Yarmouth provides a few additional hours warning if the tides are predicted to cause or increase flooding.

It is also important to note that overtopping or breaching along the coast can lead to coastal flooding in the Broads system that usually would not be reached by the tide.

Tide locking can lead to high water levels in rivers for a prolonged period and potential flooding if **combined with high rainfall**. However, floods due to high rainfall and storm surges occurring at the same time in the BFI plan area, are rare. Although we cannot precisely predict flooding, scientists use historic data, statistical analysis and computer models to assess existing and future flood risk. This includes data such as rainfall or surge levels and climate change predictions. The rarity of events being caused by coincident flood sources has been confirmed by previous investigations.

Rivers are the result of springs, base flow from groundwater and rainfall that has fallen on the catchment. Rivers flow downstream out to sea, usually merging with other rivers beforehand, as the water seeks to find the path of least resistance downhill to the sea. When the volume of water exceeds the volume that the channel can hold, the water spills over the land adjacent to the river, hence why the land surrounding rivers are called floodplains. Flooding from high river levels caused by abnormally high rainfall and large volumes of water being discharged into the river channel is referred to as **fluvial flooding**.

Tide Locking – Prolonged high sea levels can prevent river flows and drainage networks from discharging



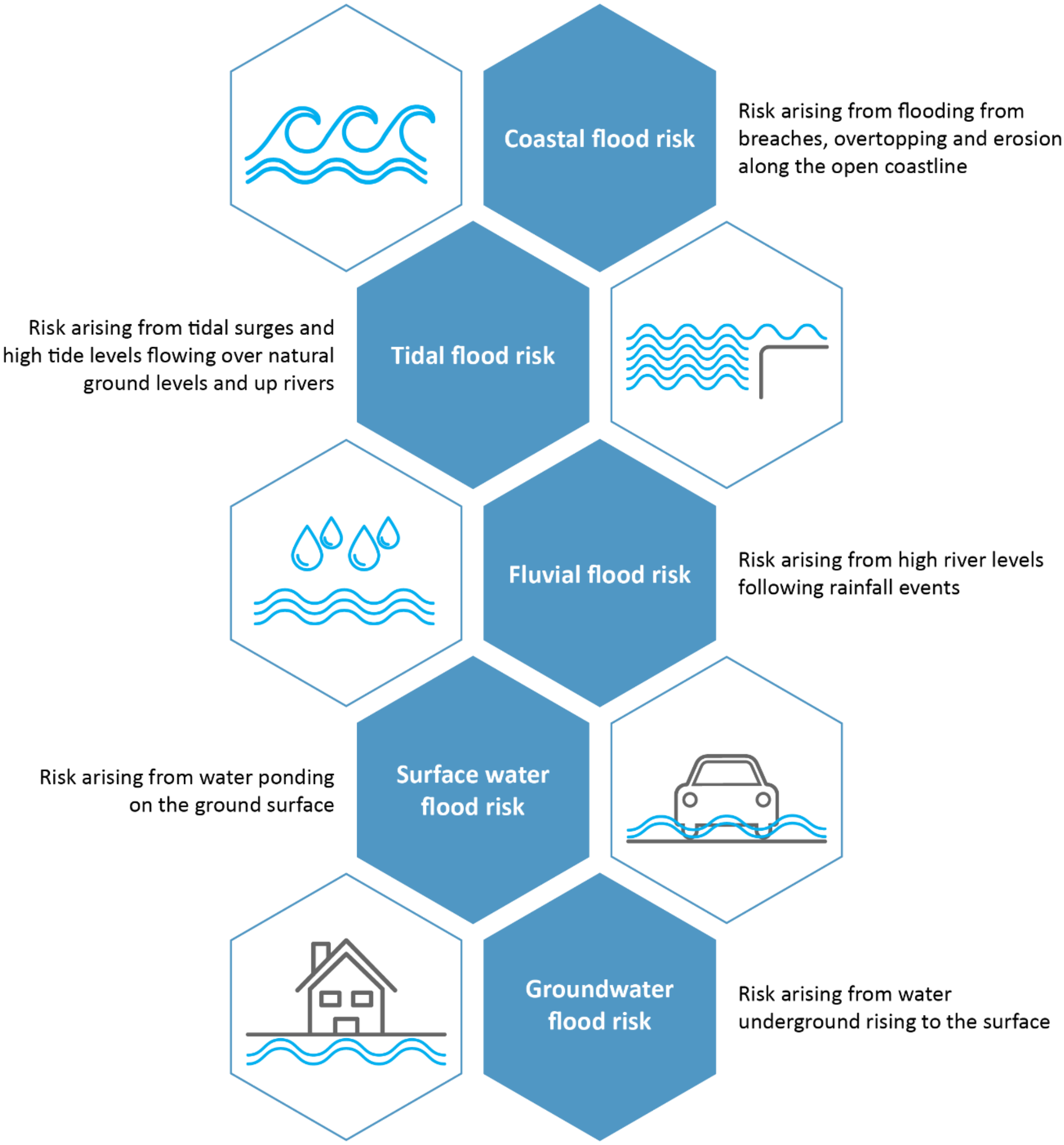
Stretch along Eccles beach front © Mike Page

Flooding can arise from rainfall ponding on, or flowing over, the ground surface which is termed **surface water flooding**. Surface water flooding occurs when intense rainfall exceeds the capacity of drainage systems or when soil is too saturated to absorb remaining water. Urban land use (paving, roofs etc.) reduces the amount of natural land available to absorb rainfall. However, new developments consider surface water runoff and are being encouraged to implement Sustainable Drainage Systems (SuDS) which seek to mimic natural drainage by both storing and reducing rainfall runoff.

Following periods of prolonged, above-average, rainfall, groundwater can rise to exceptionally high levels to cause **groundwater flooding**. At the ground surface, flooding from groundwater is caused by water emerging either from point (e.g. springs) or diffuse (e.g. general emergence) locations. Groundwater flooding can go unnoticed if it is masked by flooding from rivers occurring at the same time and/or in similar locations. The impacts of groundwater flooding can include flooding of basements and ground level floors of buildings, buried services or other assets below ground level, inundation of farmland, roads and amenity areas as well as overflowing of sewers and drains. Unlike flooding from other sources, groundwater can remain near the ground surface for long periods.

Coastal, tidal and fluvial floods pose a risk that can result in extensive flooding due to the flat nature and low elevation of large areas of the BFI plan area. Surface water and groundwater flood risk, by comparison, are typically more localised. There are other sources of flood risk, for example from reservoirs and sewers, that pose a smaller risk and are addressed by other strategies and so will not be further explored in this document.

An area may be prone to more than one type of flood source. This can lead to a larger area being affected (possibly for a longer time) and flooding occurring more frequently.



Flood risks sources summarised into categories

Understanding the Likelihood of Flooding

The size (or, **magnitude**) of a flood event relates primarily to its scale, measured as flood extent and depth. Smaller magnitude flood events have a higher chance of occurring than larger events. Larger magnitude flood events are rare, and so have a small likelihood of occurrence. This is why we only see larger floods like December 2013 infrequently. The **likelihood** (or, **probability**) of a particular magnitude flood is now commonly expressed as the annual chance of it occurring. For example, a relatively small flood event which could be expected about once a year would have a 100% chance of occurring in any particular year. Conversely, an extremely large flood event would only occur rarely, for example every few decades, and so would have a much lower chance of occurring in any given year. We used to express the likelihood of flooding in 'return periods' but this was often misinterpreted as suggesting that once a flood event had occurred, it would not 'return' for a given period of years. Therefore, what may have previously been referred to as a '1 in 100 year return period' flood is now referred to as a flood which has a 1% chance of occurring in any year.

One important reason for understanding the likelihood of flood events is so that maps can be produced to show how likely different areas of land are to flood. The Environment Agency has two main ways in which it maps areas at risk from flooding: Flood Zones and the National Flood Risk Assessment (NaFRA).

Flood Zones are used across England to categorise areas that have a similar probability of flooding, with the source being fluvial (rivers) and tidal (sea). Because of the historic levels of protection offered against fluvial flooding compared with tidal flooding, the maps show different likelihood events depending on the source. Maps showing Flood Zones can be found at https://flood-map-for-planning.service.gov.uk/.

Importantly, Flood Zones are not intended to suggest that all land within the zone would be flooded at the same time. Rather, they are intended to steer development away from areas of high flood risk to areas of lower flood risk. For this reason, the flood zones **do not take into account any flood risk management structures** because the development could exist after the structures has reached the end of its useful life (see glossary for Flood Zones). There are three main Flood Zones:

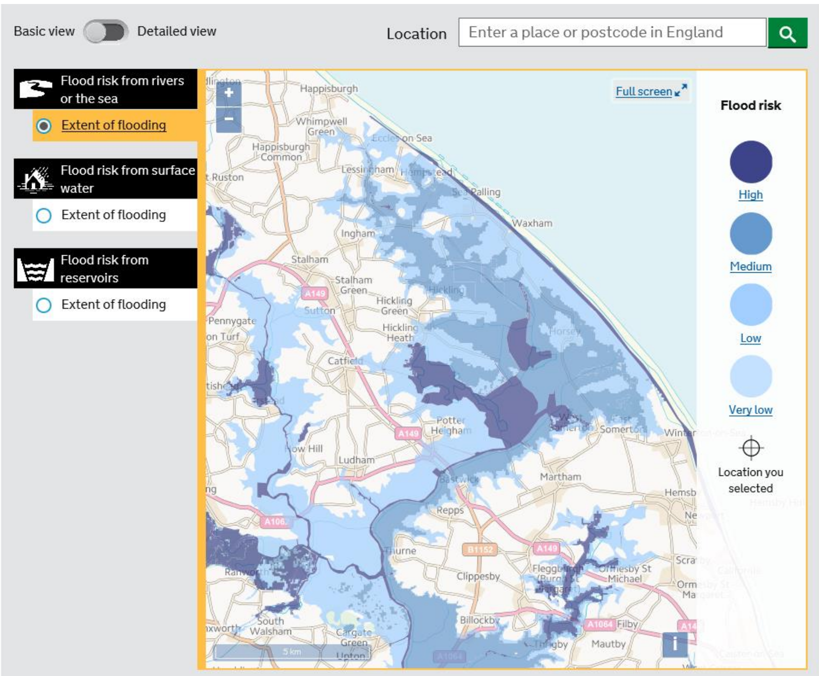
- **Zone 1** is land with a low probability of flooding, i.e. less than 0.1% annual chance for river and sea flooding
- **Zone 2** is land with a medium probability of flooding, i.e. between a 1% and 0.1% annual chance for river flooding, or between a 0.5% and 0.1% annual chance for sea flooding
- **Zone 3** is land with a high probability of flooding, i.e. more frequent than a 1% annual chance for river flooding, or more frequent than a 0.5% annual chance for sea flooding.

> The probability of a large magnitude fluvial flood event happening at the same time as a large magnitude tidal/coastal event is low in the plan area.

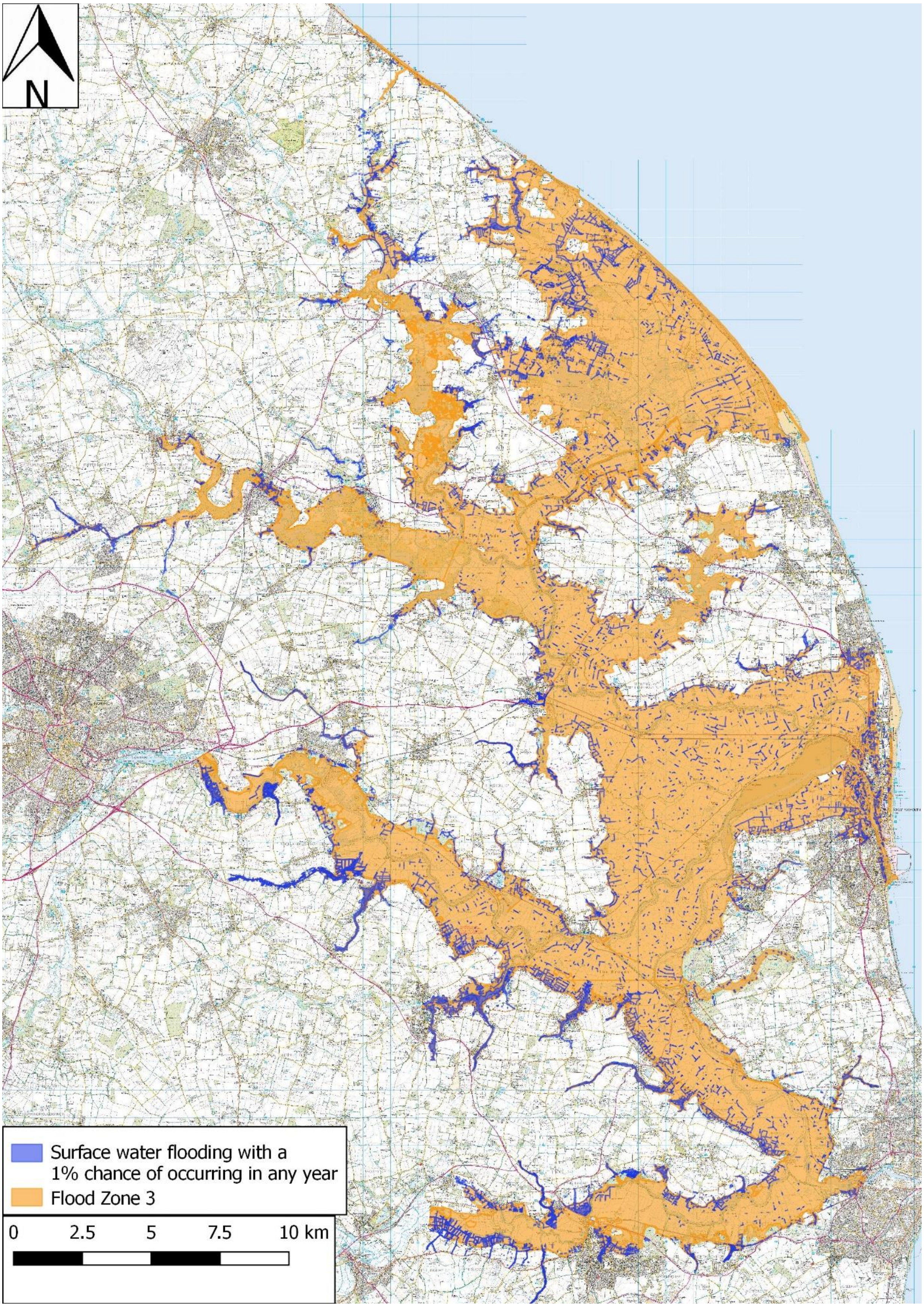
Flood Zones – and most flood maps - are products of **computer models** which estimate water depth in a river and its floodplain based on the physical characteristics (width, depth, shape, surface smoothness, slope etc) of the river. The model can make predictions for flood events of different likelihood and magnitudes. The map on the following page shows Flood Zone 3 for the plan area. **Nearly all of the plan area is within fluvial/tidal Flood Zones 2 and 3**. Importantly, the extent of Flood Zone 2 is only marginally larger than Flood Zone 3 due to the relatively sharp increase in ground levels at the edge of the natural floodplain. However, flood depths within the floodplain will be greater. The map also shows areas at risk of surface water flooding which are clearly more localised, but can be seen particularly in Great Yarmouth and in the upstream reaches of rivers towards the edge of the plan area.

For the **National Flood Risk Assessments** (**NaFRA**) in England and Wales the Environment Agency uses computer modelling to show the chance of flooding from rivers and sea. This information is also available online https://flood-warning-information.service.gov.uk/long-term-flood-risk/map (separate modelling for surface water flood risk and flood extents can also be found at the above link.)

The computer model used to produce NaFRA estimates the likelihood of flooding from rivers and the sea, **taking into account the presence of existing defences** and the chance that they could fail (this is the main difference when compared to Flood Zones). The data is presented in flood risk categories, which indicate the chance of flooding in any given year (see image below taken from the online site).



NaFRA results published by the Environment Agency (16/10/2019). Available online at: https://flood-warning-information.service.gov.uk/long-term-flood-risk/map.



Map showing Flood Zone 3 with surface water with a 1% chance of occurring in any year. Note that Flood Zones do not take into account of flood management structures. Contains Ordnance Survey data © Crown copyright and database rights (2019) Ordnance Survey 100024198

Prediction of areas likely to flood from rising groundwater is different to that of other sources of flooding, and typically considers the susceptibility of locations. From the available geological information, much of the Broads has low susceptibility to groundwater flooding. Indeed, there are few recorded occurrences of groundwater flooding in the plan area, including in past wet winters when flooding occurred elsewhere in the country. The most susceptible areas are in the upper parts of the plan area adjacent to the Bure, Ant, Yare and Waveney, as well as closer to the coast, e.g. at Great Yarmouth. Under normal conditions, groundwater is important to maintaining baseflow in a number of the rivers. It is worth noting that groundwater levels in Great Yarmouth and in part of the Broads are likely to be kept artificially low through the use of pumps which currently reduces susceptibility to groundwater flooding.

Understanding the Impacts of Flooding

Flooding of land along the River Yare 1993 © Mike Page

Flooding can have detrimental impacts and can pose a risk to life and habitat. Flooding can cause disruption and severe stress, lead to local supply shortages and damage assets including agricultural land and environmentally important land. For example, flooding in a home can ruin personal belongings, flooring and the electrics of the house (if sockets are submerged). It could also be contaminated and will leave behind debris and mud, and can affect home insurance in the long-term. Importantly, in our plan area, flooding from saline water can result in greater damage than flooding from fresh water. Flooding from saline water in freshwater locations can cause severe damage to crops/plants and habitats, both in the short and longer-term. Also, the longer the flood waters remain, the greater the damage caused.

Computer modelling is not only used to identify areas likely to flood, but to calculate the damage caused to, for example, properties, road, land and people. This information is used to provide an estimate of the economic damage caused by the flooding. The estimated damages of flooding contribute to understanding the potential benefits (i.e. avoided damages) from schemes that aim to reduce flood risk. More on how the estimated damages and benefits are used can be found in a separate document detailing approaches to flood risk management in the plan area.

It is important to note that some damages can be difficult to quantify. For example, floods put severe strains on people and can significantly disrupt their lives. Attempts can be made to quantify this pressure as a sum of money, in the same way as material damage to a house, so that these impacts can be included when making investment decisions. However, quantifying these impacts in terms of money is not the only, or sometimes most appropriate, way of including these aspects in good decision making.

4. Past Flooding in the Plan Area

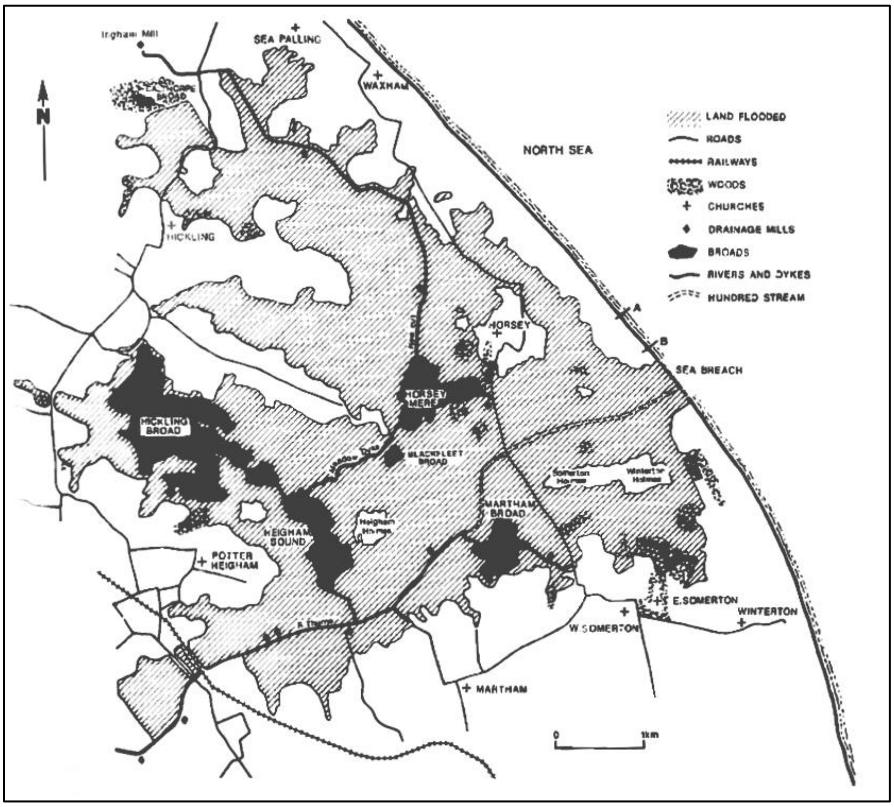
Tidal and fluvial flooding has occurred on numerous occasions in the BFI plan area, whereas coastal flooding is less frequent but has resulted in even more tragic consequences. Analysis of past flood events shows that **flooding of properties can occur even in relatively 'small' events** (e.g. 10% chance in any year) and that **tidal flooding is a more common occurrence than fluvial flooding**. Surface water flooding also occurs in some urbanised areas such as Great Yarmouth.

Flood Risk from the Sea and Rivers

The area between Eccles and Winterton is a naturally eroding frontage with a long history of flooding with records dating back to 1287 when 108 people died as a result of storm surge breaking through the dunes.

In August **1912** approximately four months' worth of rain fell in 24 hours resulting in widespread fluvial flooding throughout Norfolk. As a result, four people lost their lives and 3,600 properties were affected. This flood event caused severe flooding both inside and outside of the plan area; for example, in Norwich.

The most extensive recorded coastal flood event in modern times occurred in **1938**, when 3,000 hectares of land flooded, and three deaths occurred following breaching of the dunes at Horsey. There was also a large fish kill and loss of freshwater plants and invertebrates due to sudden salinity increases.



Map showing approximate flood extent from the 1938 flood following breach. Taken from Martin George (1992)

Flooding in Horsey in 1938. Image courtesy of Norfolk County Council Library and Information Service

Following the 1938 flood, salinity levels took a year to re-stabilise and fall to previous levels in part of the broads. Following the 1938 flood the first 'hard' flood management structures were built, comprising a sea wall of concrete filled sand bags at Horsey.

Damage and loss of life also occurred during the **1953** storm surge where approximately 5,950 hectares of the lower reaches of the Broadlands flooded. Some areas in Great Yarmouth were flooded to a depth of over 2m. There were many fatalities along the entire east coast of England with seven people in Sea Palling and ten in Great Yarmouth. In Great Yarmouth, 10,000 people had to be evacuated and could not return until the following week. The devastating effects of the 1953 flood led to the construction of a more substantial concrete seawall, which runs almost the entire length of the Sea Palling to Winterton frontage.

In November **2007**, villagers in Walcott were evacuated due to a storm surge. The waves overtopped and damaged the sea wall, causing extensive damages to properties. River levels were very high throughout the Broads.

November 2007 surge in Reedham © Broadland Environmental Services Limited

Another storm surge in December **2013** also caused damage and erosion along the coast. Large quantities of sand were eroded from the Eccles to Winterton stretch of beach. This left parts of the previously buried sea wall exposed. Flooding occurred along the rivers due to the high tide travelling upstream into the Broads system. A storm surge was forecast in **2017** and occurred between the 13th and 14th January but no flooding was reported in areas included in the BFI plan area.

The aftermath of both the 2013 and 2017 surges was on a smaller scale than the 1953 surge due to flood defence structures, improved risk management, and the development of tidal surge forecasting methods and the flood warning service. Nine thousand homes in Norfolk were contacted ahead of the surge on the 5th and 6th of December 2013. Residents in Great Yarmouth were evacuated, and 20 properties were flooded.

Surface Water Flood Risk

Given the largely rural nature of the area, **property flooding from surface water in the BFI plan area is generally limited, with the exception of Great Yarmouth**. Typically, land drainage in agricultural areas is managed by IDBs and aims to remove standing water from fields and in drains and ditches. Approximately 80% of the plan area is managed by one of the three IDBs: the Norfolk Rivers IDB, Broads IDB and the Waveney, Lower Yare, and Lothingland IDB.

Small IDB pump house at Fritton Marshes next to the River Waveney © Evelyn Simak Geograph.org.uk

In recent years, intense summer rainfall caused flooding in Great Yarmouth in 2006, 2014, 2016 and 2017. According to data collected by Norfolk County Council, Surlingham, Stalham and Wroxham also have had multiple surface water flood events in the past.

In Suffolk, Beccles also experiences surface water flooding. Thirteen of the twenty-three flood incidents recorded by Suffolk County Council (2015-2018) were located in Beccles. These incidents related to roads and pavements flooding from surface water due to either blocked drains or drainage capacity being exceeded. Areas outside of the plan area have also experienced surface water flooding, such as Norwich and Lowestoft.

Summary of Past Flood Events

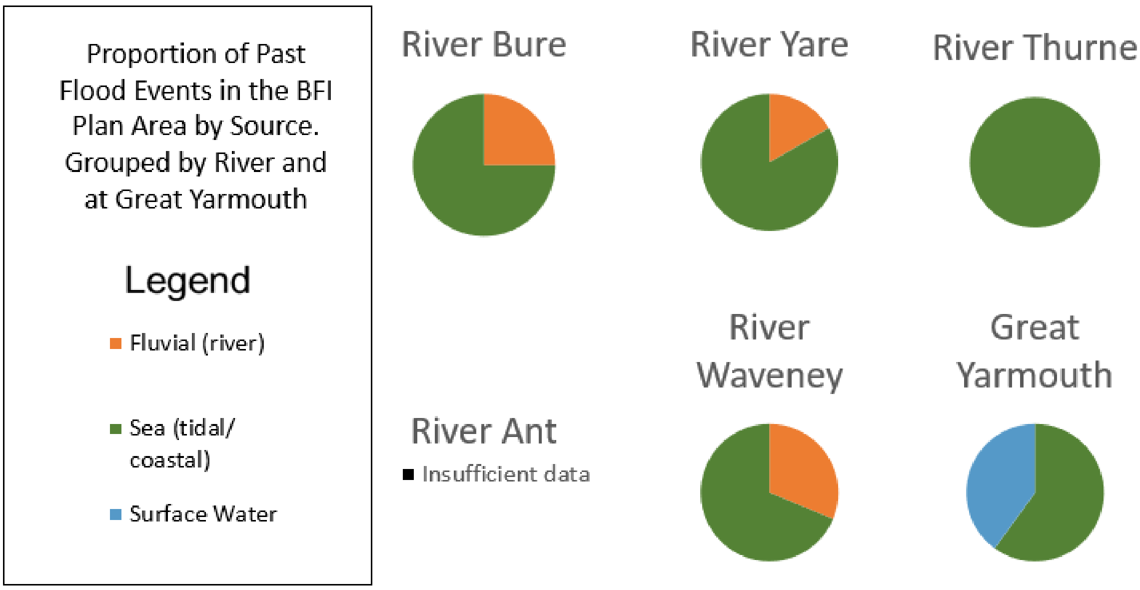
Historically, there has been large flood events within the BFI plan area. The Environment Agency maintain a comprehensive database of past flood events that is updated regularly. Some of the largest events have been mentioned in sections prior to this. The most notable flood events are summarised in the timeline on the following page. Analysis of past flood events corroborates that tidal flooding is a larger risk in the plan area than other flood sources. Additionally, owing to increased urban surface area, surface water floods have become more frequent in modern times.

Historic smaller flood events that do not pose a risk to life or flood properties are less likely to be noted or reported (e.g. flooding of farmland and wildlife habitats). Therefore, there is typically a bias to the location and extent of flooding.

> Flooding from main rivers and sea can be reported to the Environment Agency. Flooding from surface water (e.g. of a road) or groundwater can be reported to your local council.

The pie charts below show past flood events that have occurred in the plan area categorised by flood risk source. Each pie chart indicates the mixture/spread of past flood events according to their source. The flood event locations are grouped by river except for Great Yarmouth, which has a separate pie chart owing to the number of surface water events.

This again corroborates the understanding of the water networks in the plan area gained through modelling and past studies. The charts show that along the Bure, Yare and Thurne the predominant flood risk source is from the sea. This is because high tide levels can travel far up the river network inland for the Yare and Waveney and can affect the lower reaches of the Bure. These high levels can build over several days if there are several high tides in a row preventing the rivers from draining to sea. Past flooding in Great Yarmouth has occurred predominantly due to the sea, with some events caused by surface water.



Timeline Of Notable Flood Events

1912 — Over 3,600 properties affected across the Broadland area. Estimated to have a 0.13% to 0.1% chance of occurring in any year.

1938 — Great Yarmouth and River Thurne affected with 30 properties flooded along the Thurne. Breach along the Eccles to Winterton frontage with 3 deaths recorded.

1953 — Overtopping and breaching of defences throughout the study area. Great Yarmouth experienced 10 deaths and Sea Palling experienced 7 deaths due to the flood.

1976 — Cantley and Burgh Marshes flooded. Flood event on the Bure estimated to have a 10% chance of occurring in any year. 10 properties flooded.

1978 — Flood event with a 12.5% chance of occurring in any year that affected the Bure and Yare. 8 properties flooded along the Bure.

1983 — Beauchamp Arms, Postwick, Haddiscoe/ New Cut and Breydon North Wall affected. Flood event with estimated chance of occurring in any year being between 10% and 20%. 20 properties flooding along the Waveney and eight properties along the Bure.

1993 — 110 properties affected.Estimated to have a 6.7% and 10% chance of occurring in any year. Severe breach at Hassingham.

1993 — A rainfall event caused flooding to part of the Broads and affected 33 properties.

1993 — Heavy rain caused flash flooding to Great Yarmouth. Over 50 properties flooded incl. six schools.

2007 — Low-lying parts of Great Yarmouth flooded by seepage through the food defences and water drains-few properties flooding. Waveney, Yare and Bure river systems also affected. Flooding downstream of Oulton and breach of Haddiscoe bank. Several hundreds of homes evacuated.

2013 — East coast storm surge. 20 properties flooded in Great Yarmouth due to sea level exceeding levels of defences and ground.

2014 — Widespread flooding in Great Yarmouth with multiple properties flooded.

2016 — Torrential rain lasting 90 minutes caused flooding to homes in Gorleston. Drains and pumping systems were unable to cope with the volume of rain.

2017 — Over 20 flooding incidents reported in Norfolk following heavy thunderstorms. Flooding in Great Yarmouth and Caister.

Surface Water source

River source

Sea source

5. Summary

This document informs you about the sources and nature of flood risk within the BFI plan area. The document also provides an overview of how flood risk is assessed, and describes past flood events. This is to enable local communities to understand the issues and to contribute to decision making about managing future flood risk.

There are multiple sources of flood risk in the BFI plan area. The risks which have been investigated in this document are:

- **Coastal** – flooding from breaches, overtopping and erosion along the open coast
- **Tidal** – storm surges and high tide levels flowing over natural ground levels and up rivers
- **Fluvial** – high river levels, following rainfall events, flowing over ground/defence levels
- **Surface water** – inability of water to drain away due to saturated ground, exceeding the capacity or following failure of drainage infrastructure
- **Groundwater** – flood risk arising from exceptionally high groundwater levels

Approximately 60% of land in the plan area is below today's mean sea level. Past flood events and predicted flood extents shows that the greatest risk in the plan area is from the sea (coastal flooding along the Eccles to Winterton frontage and tidal flooding along the Broadland rivers and within Great Yarmouth). Tide locking has also been identified as a particular risk along the river Bure, and also on the rivers Yare and Waveney.

Given the largely rural nature of the BFI plan area, property flooding from surface water is generally limited, with the exception of Great Yarmouth. Several areas of Great Yarmouth have been flooded four times in the last 13 years, all occasions due to surface water. Groundwater flooding currently poses a lower risk across most of the plan area.

It is also important to note that most of the agricultural land within the plan area is artificially drained and managed through the operation of pumping stations and man-made dykes, drains or ditches. This network is managed by the Internal Drainage Boards, who work together with different authorities involved in managing flooding. Current approaches to flood risk management are considered separately in another document.

Thurne Mill and St Benet's Mill © Jeremy Halls

6. What is the Broadland Futures Initiative?

The Broadland Futures Initiative (BFI) is a partnership for future flood risk management in the Broadland area. Our main goal is to agree a framework for future flood risk management that better copes with our changing climate and rising sea level. The focus is to define a flood risk management plan for Broadland over approximately the next 100 years putting people at the heart of decision making.

BFI has been set up by organisations responsible for managing flood risk, working together with partners. The Environment Agency, Natural England, County and District Councils, Internal Drainage Boards, Broads Authority, National Farmers Union, Water Resources East, the Royal Society for the Protection of Birds (RSPB) and the Wildlife Trusts will work together in developing the plan.

Elected members representing local communities will be the decision makers. This will be a democratic process, with local politicians making the core decisions in order to agree the future flood risk management plan, having considered the latest projections on our changing climate.

The plan will be developed over a number of stages. This document is part of establishing the background to the plan. For more information about the BFI and how it's organised see our Frequently asked questions document.

Other documents to be produced during this initial stage are shown below. Some of these are aimed at the general public while others are more technical in nature. They will be available through the BFI website: https://www.broads-authority.gov.uk/looking-after/climate-change/broadland-futures-initiative

- Origins of the plan area
- Coastal processes review
- Current approaches to flood risk management
- The influence of flood risk management
- Strategic plans and documents review
- Existing key data sources and indicators
- The future impacts of climate change
- The result of initial stakeholder survey
- Objectives for the plan
- The methodology for options appraisal and preferred options selection
- Strategic environmental assessment scoping
- Frequently asked questions

7. Glossary

Aquifer: A body of permeable rock which can contain or transmit groundwater.

Breach: A gap in a defence caused by extreme weather conditions such as waves.

Broadland Futures Initiative (BFI): A partnership formed to agree a framework for future flood risk management in the Broadland area. The strategy aims to better cope with our changing climate and rising sea level. Planning has started now with the strategy to be implemented from the mid-2020s onward.

Catchment: Area where water is collected by the natural landscape.

Climate Change: Any significant long-term change in the expected patterns of average weather of a region (or the whole Earth) over a significant period of time.

Defence: Flood defences are structures that act to protect an area from flooding or reduce the likelihood of flooding.

Dyke: Water-filled ditches that provide wet fences and a source of drinking water for livestock in grazing marshes.

Embankment: An artificial, usually earthen, structure, constructed to prevent or control flooding, or for various other purposes including carrying roads and railways.

Erosion: Process by which particles are removed by the action of wind, flowing water or waves (opposite is accretion).

Estuary: The wide mouth of the river where it joins the sea. Seawater and fresh water mixes providing high levels of nutrients making estuaries among the most productive natural habitats in the world.

Floodplain: Area of low-lying ground adjacent to a river, formed mainly of river sediments and subject to flooding.

Flood Zones: Areas that have a similar probability of flooding, with the source being fluvial (rivers) and tidal (sea). They ignore the presence of flood risk management structures/ defences and do not take into account any future changes as a result of climate change. On the online flood zone map there is also a layer that shows 'Areas benefiting from flood defences', this is only used when the areas meet strict guidelines about the protection provided by a flood risk management structure. Therefore, there may be defences in an area that are not included within that layer.

Flood Risk Management: Flood risk management aims to reduce the likelihood and/or the impact of floods. Experience has shown that the most effective approach is through the development of flood risk management programmes incorporating the following elements:

- **Prevention:** preventing damage caused by floods by avoiding construction of houses and industries in present and future flood-prone areas by adapting future developments to the risk of flooding, and by promoting appropriate land-use, agricultural and forestry practices;

- **Protection:** taking measures, both structural and non-structural, to reduce the likelihood of floods and/or the impact of floods in a specific location;
- **Preparedness:** informing the population about flood risks and what to do in the event of a flood;
- **Emergency response:** developing emergency response plans in the case of a flood;
- **Recovery and lessons learned:** returning to normal conditions as soon as possible and mitigating both the social and economic impacts on the affected population.

Habitat: Natural home or environment of an animal, plant, or other organism.

IDB: Internal Drainage Boards are independent locally funded and operated public bodies. There are currently around 100 IDBs in England, each managed by Board members made up of local landowners, Local Authority Councillors and other organisations depending on the needs of that particular drainage district. They are responsible for reducing flood risk for both rural and urban communities (including protection of businesses and infrastructure) and they also have duties in protecting and enhancing valuable wildlife habitats.

Ordnance Datum: When talking about vertical height a common reference point is used. Ordnance Datum is usually mean sea level and therefore height above Ordnance Datum is height above mean sea level.

Peat: Accumulation of partially decayed vegetation or organic matter. It is unique to natural areas called peatlands, bogs, mires, moors, or muskegs.

Receptor (with relation to flooding): Refers to anything or anyone which can be affected by a flooding event e.g. properties, people, environment.

Risk: Combination of the probability that an event will occur and the consequence to receptors associated with that event.

Stakeholder: An individual or group with an interest in, or having an influence over, the success of a proposed project or other course of action.

Storm surge: Rising of the sea as a result of wind and atmospheric pressure changes associated with a storm.

Tide Locking: The phenomena which occurs when the high level of the incoming tide restricts the normal drainage of water out to sea.

Topography: Lay of the land in terms of elevation and physical features.

Tributary: River or stream flowing into a larger river or lake.

Wetland: Transitional habitat between dry land and deep water. Wetlands include marshes, swamps, peatlands (including bogs and fens), flood meadows, river and stream margins.

Cattle grazing on Upton Marshes © Jeremy Halls

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