URS

Southend-on-Sea Flooding on the 20th July 2014

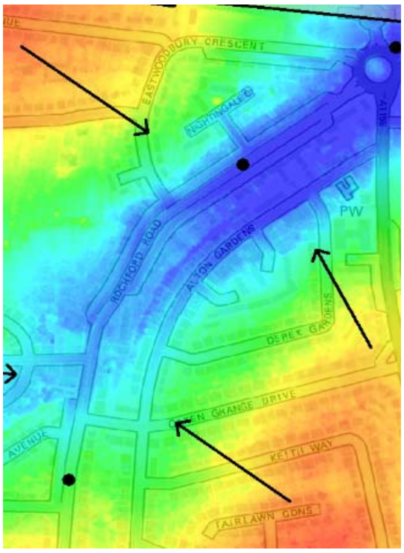
Flood Investigation Report

Final

March 2015

47071307

UNITED KINGDOM & IRELAND



Prepared for:

southend onsea BOROUGH COUNCIL

REVISION SCHEDULE					
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Forecast cost estimates do not include such costs associated with any negotiations, appeals or other non-technical actions associated with the agreement on measures to meet the requirements of the authorities, nor are potential business loss and interruption costs considered that may be incurred as part of any technical measures.

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EXECUTIVE SUMMARY

This report constitutes the findings of the Flood Investigation completed for the flooding event of the 20th July 2014 within Southend-on-Sea. This has been completed under Section 19 of the Flood and Water Management Act 2010.

Southend-on-Sea was subject to widespread flooding, particularly within the western areas, on the 20th of July as a result of heavy rainfall. In total 30 incidents of flooding were recorded, including the internal flooding of Southend General Hospital.

A total depth of 16.6 mm of rain was recorded to fall within 3 hours, between 13:30 and 16:30 on the 20th July 2014. At the peak intensity, 8.2 mm was recorded to fall within 15 minutes. This rainfall event has been estimated to be less than a 1 in 2 year rainfall event. However it should be noted that the rain gauge was noted to be under recording rainfall. Therefore, it is considered that the calculated frequency is likely to be an underestimation for this rainfall event.

The Flood Investigation focuses on the incidents of flooding recorded at the Southend General Hospital as well as in areas where flooding had also been recorded to occur previously on the 24th August or 11th October 2013. The areas being investigated are:

- Southend General Hospital,
- Glenwood Avenue,
- Throndon Park Drive and Park View Drive,
- Highlands Boulevard,
- Prince Avenue,
- Rochford Road,
- Cavendish Gardens,
- Chalkwell,
- Manor Road,
- Queensway, and,
- Lifstan Way.

The investigation concluded that the majority of incidents were either associated with:

- the public surface water network - the responsibility of Anglian Water Services as the sewerage company for Southend-on-Sea,
- the highways drainage network - the responsibility of Southend-on-Sea Borough Council as the Highways Authority, or,
- private drainage networks – the responsibility of individual property or land owners.

The primary mechanisms of flooding on the 20th July 2014 can be broadly defined into the following categories:

- **Network capacity** – For the majority of incidents, flooding was associated with lifted or surcharging manholes. At Southend General Hospital, it is thought that the manhole had not been bolted down, therefore the sewer surcharged more easily. For the instances at Prince Avenue, Rochford Road, Chalkwell, Manor Road and Lifstan Way the cause of flooding is thought to be due to capacity issues within the surface water network.

- **Gully capacity** - For many of the incidents, it is thought that the capacity of the network was overwhelmed by the intensity of the rainfall. As a result, surface water was not able to enter the drainage network and so accumulated in areas of low-lying topography. This occurred in areas such as Thorndon Park Drive, Highlands Boulevard and at Prince Avenue.

- **Maintenance issues** - flooding at the Queensway underpass and Harp House Roundabout was considered to be a result of maintenance issues, restricting the function of the highway drainage.

- **River channels -** the water level of Prittle Brook was recorded to respond rapidly to rainfall. It is also considered that the Eastwood Brook demonstrates the same rapid response. Following the rainfall, the water levels within the channels of these rivers rose rapidly. In the case of the Eastwood Brook, this resulted in flooding at Glenwood Avenue as water overtopped the channel at the head of a culverted section beneath Glenwood Avenue and Grovewood Avenue. Along Prittle Brook, this high water level restricted the discharge of surface water outfalls draining into the river, resulting in water backing up the network within the Cavendish Gardens area.

As part of the investigation, a number of actions have been identified to assist with the ongoing flood management across the Borough. Many of the actions should be implemented by Southend-on-Sea Borough Council along with Anglian Water, the Environment Agency, riparian owners, residents and developers.

1. INTRODUCTION

1.1 Background

Section 19 (1) of the Flood and Water Management Act (FWMA, 2010)[i] places a duty on Lead Local Flood Authorities (LLFAs), including Southend-on-Sea Borough Council (SBC), to investigate flood incidents from surface water, groundwater and ordinary watercourses[ii], where it considers it 'necessary and appropriate'.

Section 19 of the FWMA states that:

(1) On becoming aware of a flood in its area, a LLFA must, to the extent that is considers it necessary or appropriate, investigate:

    (a) which risk management authorities (RMAs) have relevant flood risk management functions, and

    (b) whether each of those RMAs has exercised, or is proposing to exercise, those functions in response to the flood.

(2) Where an authority carries out an investigation under sub-section (1) it must:

    (a) publish the results of its investigation, and

    (b) notify any relevant RMAs in accordance with Section 19(2) of the FWMA.

The FWMA (Section 6 (13)) states RMAs to be:

- the LLFA (SBC) and neighbouring LLFAs (Essex County Council (ECC)),
- the Environment Agency (EA),
- Internal Drainage Boards (not applicable within SBC),
- Water Company (Anglian Water (AW) as the sewerage undertaker,
- Highways Authority (SBC).

1.2 Criteria for Investigating Flooding Incidents

SBC has developed a set of criteria in order to determine if a flooding event requires investigation. This is based on the assessment of the consequences of flooding that are considered to be sufficiently serious.

Where any of these criteria are met, an investigation will be undertaken:

Is there, or have there been:

- more than four reports of the interior of a single residential property flooding,
- any reports of the interior of critical infrastructure flooding,

[i] Flood and Water Management Act 2010: http://www.legislation.gov.uk/ukpga/2010/29/contents
[ii] An ordinary watercourse includes every river, stream, ditch, drain, cut, dyke, sluice, sewer (other than public sewer) and passage through which water flows which does not form part of a Main River.

- flooding of a transport link such that it has been made impassable for a significant amount of time,
- more than 14 reports of flooding within 50m of the receptor in the past three years,
- potential for accidents or health implications, or
- effects on vulnerable people through service or amenity impacts.

Where the answer to any of the below is 'yes', the need for a Flood Investigation will be considered based on a risk based approach:

- Has there been more than one report of the interior of a commercial property flooding?
- And has this had an economic impact?
- Has the natural environment been affected?
- And is there a threat to a local ecosystem?
- Is the localised flooding known to occur according to historic records?
- Has a request for investigation been received?
- Is a single source of flooding evident?
- Are other flood risk management authorities investigating?

Following the above set of criteria, it was deemed necessary to complete a Flood Investigation as internal flooding of critical infrastructure (Southend General Hospital) was recorded. In addition, the report will also investigate flooding in areas that have seen repeated flooding on either the 24th of August 2013 or 11th October 2013. This report constitutes a record of this investigation.

1.3 Risk Management Authority Duties and Responsibilities

The legal framework for managing flooding lies with a number of different agencies; the key responsibilities for each are outlined below. Reference should be made to the relevant legislation and the Local Flood Risk Management Strategy (LFRMS)[iii], once complete, for further information.

1.3.1 Southend-on-Sea Borough Council (LLFA)

SBC, as the LLFA, has a strategic overview role and a responsibility to investigate flood incidents from surface water, groundwater and ordinary watercourses where it is considered necessary and appropriate. As part of this role, SBC hold quarterly Flood Group Meetings with the RMAs to discuss and report on flood management.

SBC has a consenting and enforcement responsibility for ordinary watercourse regulation for those ordinary watercourses within the administrative area.

The FWMA outlines that the LLFA has powers to designate structures and features that affect flooding in order to safeguard assets that are relied upon for flood risk management of surface

[iii] URS (2014) Draft Southend-on-Sea Borough Council Local Flood Risk Management Strategy

water, groundwater and ordinary watercourses. Once a feature is designated, the owner must seek consent from the authority to alter, remove or replace it (FWMA Schedule 1, Section 1).

SBC as the Highway Authority also has the duty to maintain adopted highways within their administrative area under Section 41 of the Highways Act 1980[iv]. Highway maintenance includes that of the road drainage networks (drains and gullies).

Under the Civil Contingencies Act (2004)[v], SBC are a Category 1 Responder and therefore have the duty to put in place emergency plans and assess local risks to inform the emergency planning. SBC are also required to make information available to the public about civil protection matters and maintain arrangements to warn and advise the public in the event of an emergency.

1.3.2 Environment Agency

The EA has a strategic overview role and responsibility to investigate flooding from Main Rivers and the sea. The EA has permissive powers to carry out maintenance work on Main Rivers[vi] (see Figure 1.1) under Section 165 of the Water Resources Act (1991)[vii].

The FWMA outlines that the EA has powers to designate structures and features that affect flooding in order to safeguard assets that are relied upon for flood risk management for fluvial and tidal sources. Once a feature is designated, the owner must seek consent from the authority to alter, remove or replace it (FWMA Schedule 1, Section 1).

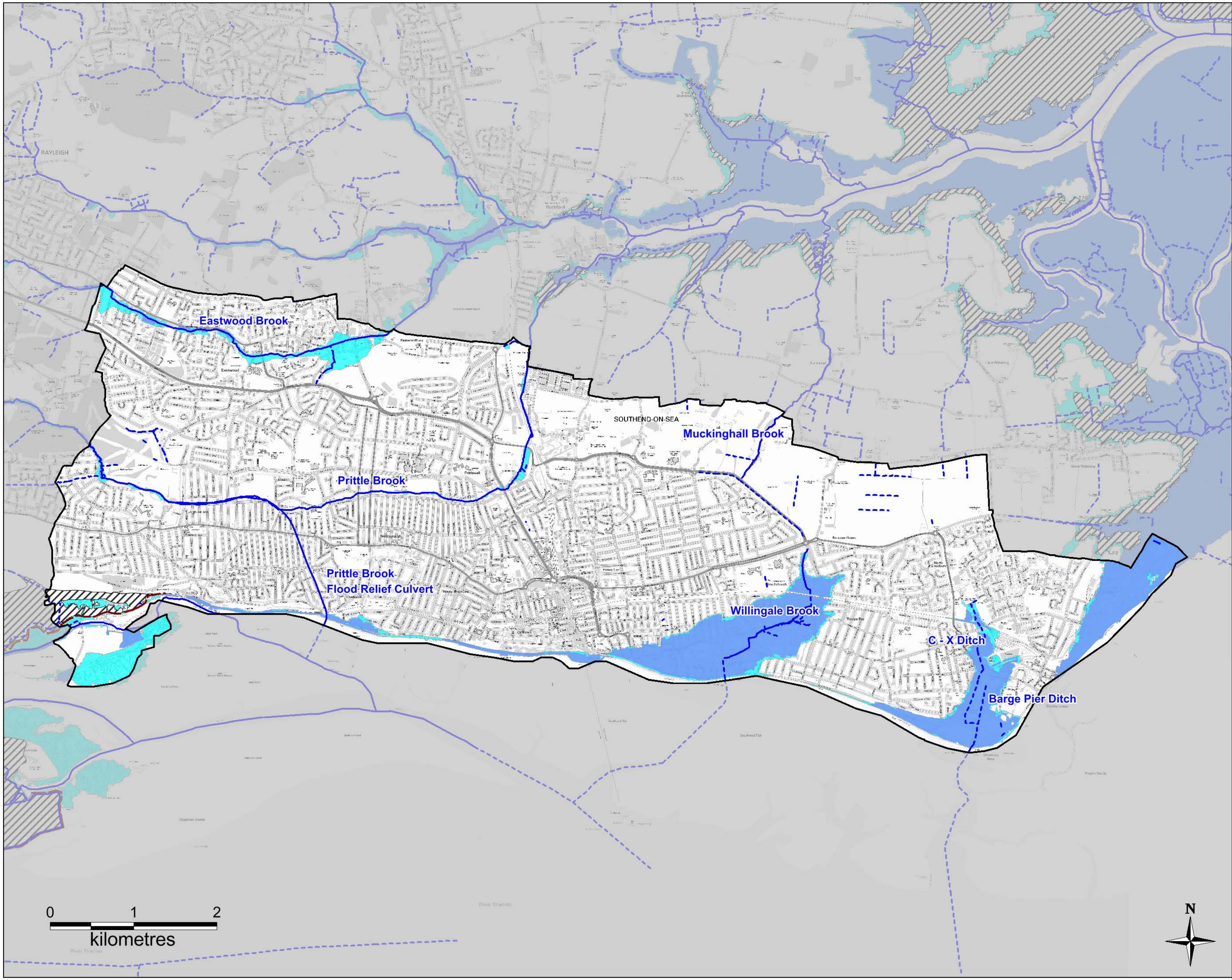
1.3.3 Anglian Water

Under the FWMA, AW is responsible for managing the risks of flooding from surface water, foul and/or combined sewer systems where the sewer flooding is wholly or partly caused by an increase in the volume of rainwater (including snow and other precipitations) entering or otherwise affecting the system. Within Southend-on-Sea there are sections of culverted watercourse that also fall under AW responsibility.

AW has a duty to provide and maintain a system of public sewers so that the areas for which they are responsible are effectually drained (Water Industry Act, 1991[viii]). Sewerage systems are not, however, designed to accommodate flows from severe weather events. AW's level of service is set by Ofwat, the industry regulator. In the context of drainage, severe weather is considered to be 'rainfall events having a storm return period that is less frequent than a rainfall event with an Annual Exceedance Probability (AEP) of 5% (1 in 20 years)'. Therefore, rainfall events with a lower annual rainfall probability than 5% would be expected to result in surcharging of some of the sewer network.

As part of AW's obligation to Ofwat, they are required to undertake capacity improvements to alleviate sewer flooding problems to properties on their 'at risk register', with priority being given to more frequent property internal flooding problems. AW prioritises this programme of work on the basis of customers willingness to pay and cost benefit analysis; the benefits to customers must be greater than the whole life cost of the scheme.

[iv] Highways Act 1980: http://www.legislation.gov.uk/ukpga/1980/66/contents
[v] Civil Contingencies Act 2004: http://www.legislation.gov.uk/ukpga/2004/36/pdfs/ukpga_20040036_en.pdf
[vi] Main Rivers are watercourses shown on the statutory main river maps held by the Environment Agency, the Department of Environment, Food and Rural Affairs (in England) and the Welsh Assembly Government (in Wales). They can include any structure or appliance for controlling or regulating the flow of water into, in or out of the channel.
[vii] Water Resources Act (1991): http://www.legislation.gov.uk/ukpga/1991/57/contents
[viii] Water Industry Act (1991): http://www.legislation.gov.uk/ukpga/1991/56



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Legend

- Southend-on-Sea Borough Extent
- Flood Zone 3
- Flood Zone 2
- Flood storage areas
- Areas benefiting from flood defences
- Defences

Watercourses

- Main River
- Ordinary Watercourse

Revision Details	By	Check	Date	Suffix

Purpose of Issue
FINAL

Client
southend onsea

Project Title
SOUTHEND-ON-SEA
20TH JULY 2014 FLOOD
INVESTIGATION REPORT

Drawing Title
RIVERS AND
FLOOD ZONES

Drawn	Checked	Approved	Date
DS	EG	EG	March 2015

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Figure 1-1	3

1.4 Other Stakeholder Duties and Responsibilities

1.4.1 Essex and Suffolk Water

Essex and Suffolk Water is responsible for maintaining, improving and extending the water mains and other pipes under Section 37(1)(b) of the Water Industry Act 1991. If a water main bursts, it is Essex and Suffolk Waters responsibility, as the water undertaker, to manage and repair this.

1.4.2 Riparian Owners

Riparian owners are those that own land or property adjacent to a watercourse. Riparian owners have a responsibility to maintain the bed and banks of the watercourse; this includes maintenance of any owned structures, such as trash screens or culverts.

Section 25 of the Land Drainage Act (1991)[ix] outlines that where the flow of a watercourse is obstructed; the riparian owner is responsible to resolve the condition. Section 28 of the Land Drainage Act (1991) outlines the responsibility of the riparian owner to undertake maintenance of their watercourse if it is impeding the flow of water.

Riparian owners must let water flow through their land without obstruction and must accept flood flows through their land. Riparian owners have no duty in common law to improve the drainage capacity of a watercourse. Further information can be found in the Environment Agency's document 'Living on the Edge' (2012)[x].

1.4.3 Local Residents

Residents who are aware that they are at risk of flooding should take action to ensure that they and their properties are protected.

Residents should report flooding incidents or potential problems (such as blockages) to the LLFA or appropriate organisation if known.

1.5 Consultation

Investigation of the flooding at Southend-on-Sea on 20th July 2014 has been undertaken in consultation with the key stakeholders and RMAs.

The RMA discussion and consultation process was already in place as a result of the preceding 24th August and 11th October 2013 flooding events. As a result, much of the previous discussion applied to the 20th July 2014 event.

The EA and AW have provided information on flooding records obtained through their organisations and clarification of response procedures and asset locations.

1.6 Site Description

Southend-on-Sea Borough is located in the south of Essex and is bordered by the neighbouring boroughs of Castle Point to the west, and Rochford to the north. The Thames Estuary is to the south of the borough.

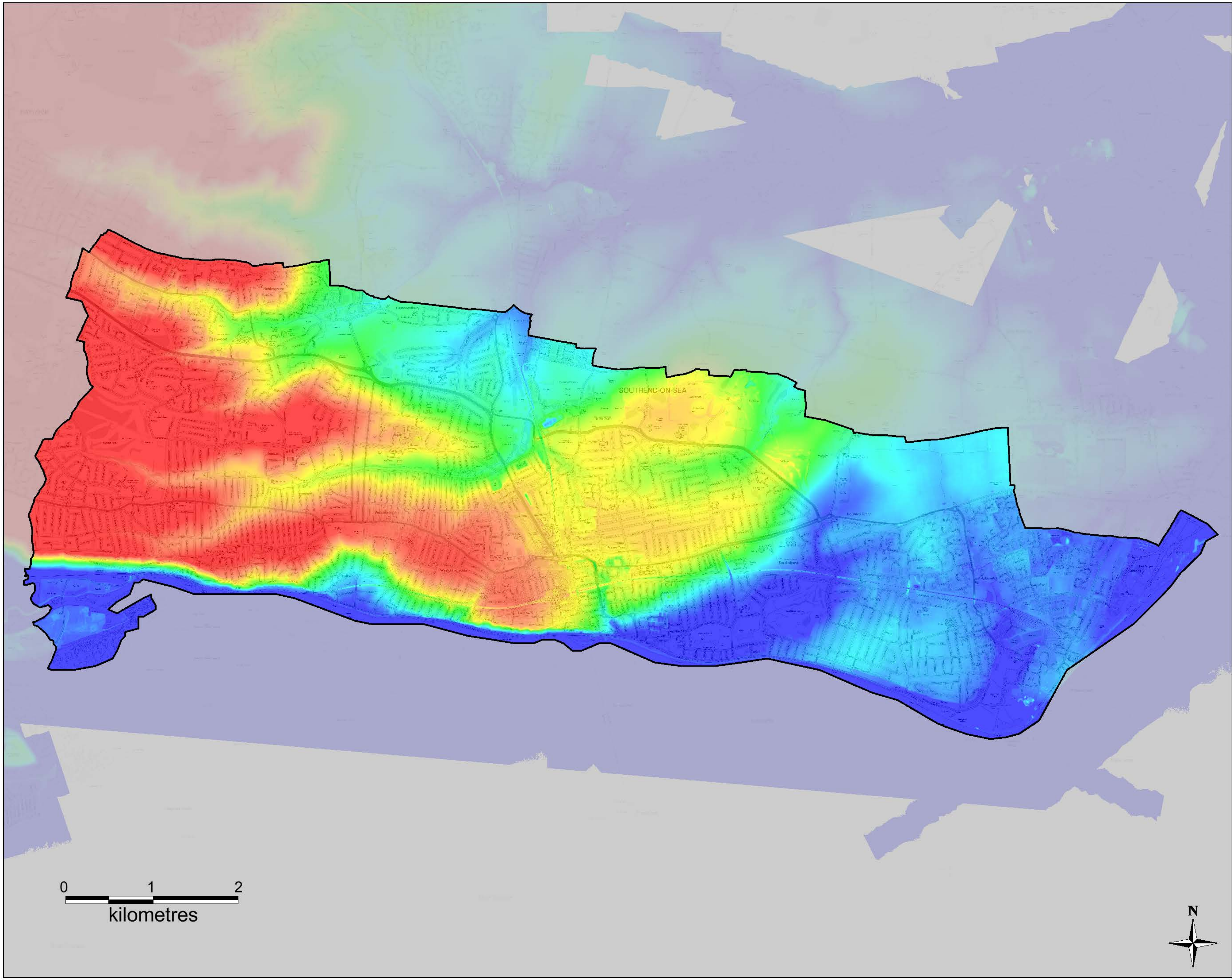
Southend-on-Sea is heavily urbanised with dense residential and commercial development.

[ix] Land Drainage Act (1991): http://www.legislation.gov.uk/ukpga/1991/59/contents
[x] Environment Agency (2012) Living on the edge – A guide to your rights and responsibilities of riverside ownership. http://www.environment-agency.gov.uk/homeandleisure/floods/31626.aspx

The topography of the borough can be seen in Figure 1-2. Elevations are approximately 45 mAOD in the west of the borough decreasing to approximately 7 mAOD in Shoeburyness to the east of the borough. The borough is bisected by a number of river channels which form valleys across the area. These are most notably associated with Eastwood Brook and Prittle Brook to the west of the borough, which drain in a northerly direction towards Rochford. The southern boundary of the borough has steep slopes where the elevation falls from approximately 40 mAOD to 4 mAOD towards the coast.

There are a number of Main Rivers and ordinary watercourses within Southend-on-Sea; these are plotted in previously in Figure 1-1 along with the associated EA fluvial flood zones.

The bedrock geology is predominantly London Clay, with the superficial geology of River Terrace Deposits overlying the bedrock in the east of the borough and along the river channels of the Eastwood Brook and Prittle Brook. Around Shoebury and Southchurch there are superficial deposits of Tidal Flat Deposits overlying the bedrock.



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Legend

Southend-on-Sea Borough Extent

Elevation (mAOD)

- 0 mAOD
- 10 mAOD
- 20 mAOD
- 30 mAOD
- 40 mAOD
- 50 mAOD

Revision Details	By / Check	Check Date	Suffix

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Client: southend on sea

Project Title

SOUTHEND-ON-SEA
20TH JULY 2014 FLOOD
INVESTIGATION REPORT

Drawing Title

SOUTHEND-ON-SEA
TOPOGRAPHY

Drawn	Checked	Approved	Date
DS	EG	EG	March 2015

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Figure 1-2	3

2. FLOOD INCIDENT DETAILS

2.1 Overview

Southend-on-Sea was subject to widespread flooding on the 20th July 2014 as a result of heavy rainfall falling across the borough. The following section describes the conditions leading up to the flood event and the resultant impacts.

2.2 Weather Warnings and Flood Alerts

A flood warning[xi] was issued by the EA on the 20th July at 17:25 BST for Eastwood Brook and Prittle Brook.

Figure 2-3 outlines the areas that received flood alerts[xii] and flood warnings across Southend-on-Sea.

2.3 Recorded Rainfall

The Met Office[xiii] describes the weather on the 20th July as scattered showers and thunderstorms across the south east.

Within Southend-on-Sea, the EA tipping bucket rain gauge in Southchurch Park recorded a total depth of 16.6 mm to fall within 3 hours, between 13:30 and 16:30. At the peak intensity, 8.2 mm was recorded to fall within 15 minutes at 14:00 (Figure 2-1). The tide levels recorded at Southend Pier, show the tide level to be at its lowest just before the peak rainfall.

Environment Agency radar imagery, shown in Figure 2-2 B, details the highest rainfall intensity to have occurred over the area of Canvey Island, Castle Point between 14:00 and 15:00. Within the Southend-on-Sea area, a high intensity of rainfall was recorded across the extent of the Borough. The greatest rainfall intensity within Southend-on-Sea was recorded to the north west of the Borough around Bournes Green Chase and North Shoebury Road, 14km east of Canvey Island (Figure 2-2 A). A total depth of 25 mm fell over the duration of the storm, with a peak intensity of 11.5mm over 15 minutes at 13:30.

It should be noted that rainfall intensity recorded using tipping bucket rain gauges tends to be a more accurate measure of rainfall. On this instance however it was found that the rain gauge was under recording rainfall by 15%. Radar data is often susceptible to interference, reducing its accuracy; however it provides a good spatial coverage of rainfall intensity, whereas rain gauges only provide details of intensity at that location.

The Flood Estimation Handbook (FEH) CD-ROM (version 3)[xiv] has been used to determine the corresponding likelihood of probability for this rainfall event. The rainfall data recorded by the Environment Agency tipping bucket rain gauge has been used as this is considered the more accurate dataset. It has been estimated that the return period for this event is less than a 1 in 2 year event (50% AEP). It should be noted that the FEH methodology is not suitable for estimating return periods for storms of less than 30 minute duration. Therefore the probability of exceedance associated with the peak rainfall over 15 minutes cannot be predicted. Further details can be found in Appendix A.

[xi] Flood Warning: Flooding is expected. Immediate action required.
[xii] Flood Alert: Flooding is possible. Be prepared.
[xiii] Met Office, UK climate summaries, July 2014: http://www.metoffice.gov.uk/climate/uk/summaries/2014/july
[xiv] Centre for Ecology & Hydrology, Flood Estimation Handbook CD-ROM (Version 3), 2009.

Figure 2-1: Recorded rainfall at Southchurch Park and tidal levels and Southend Pier on the 20th July 2014

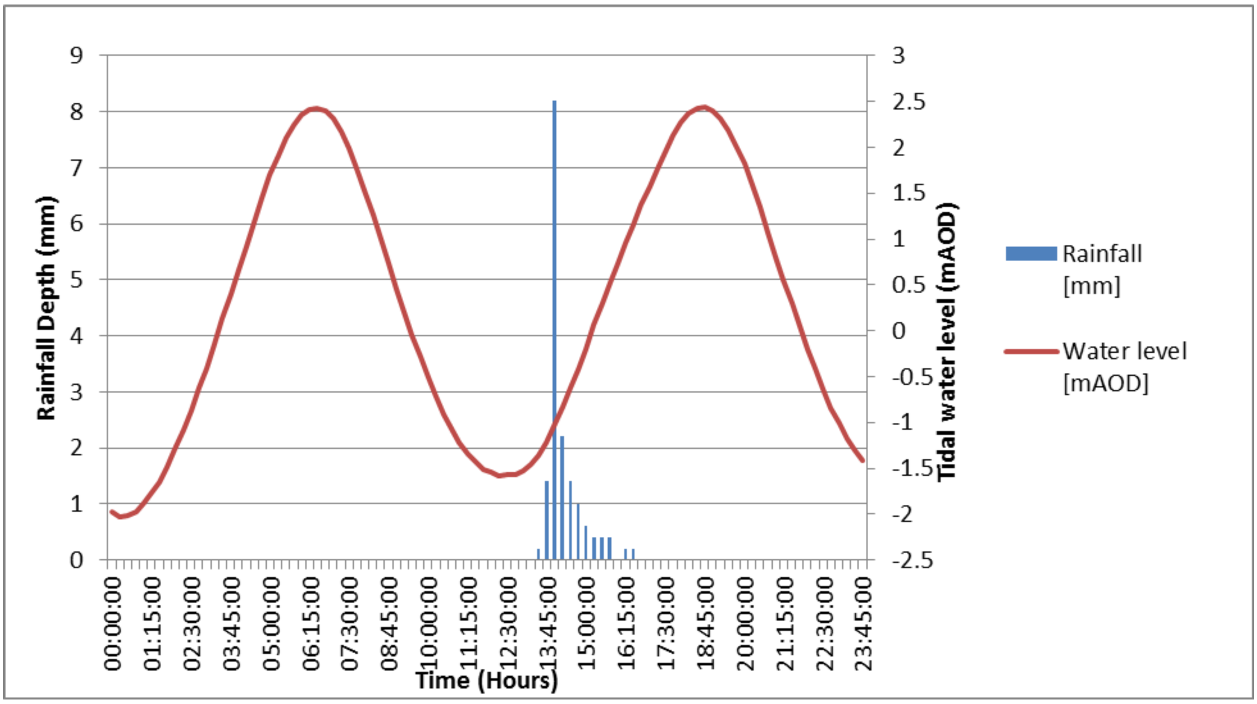


Figure 2-2 A - Environment Agency Radar imagery showing the 60 minute accumulation between 13:00 and 14:00 on the 20th July 2014. Rainfall depths are in mm.

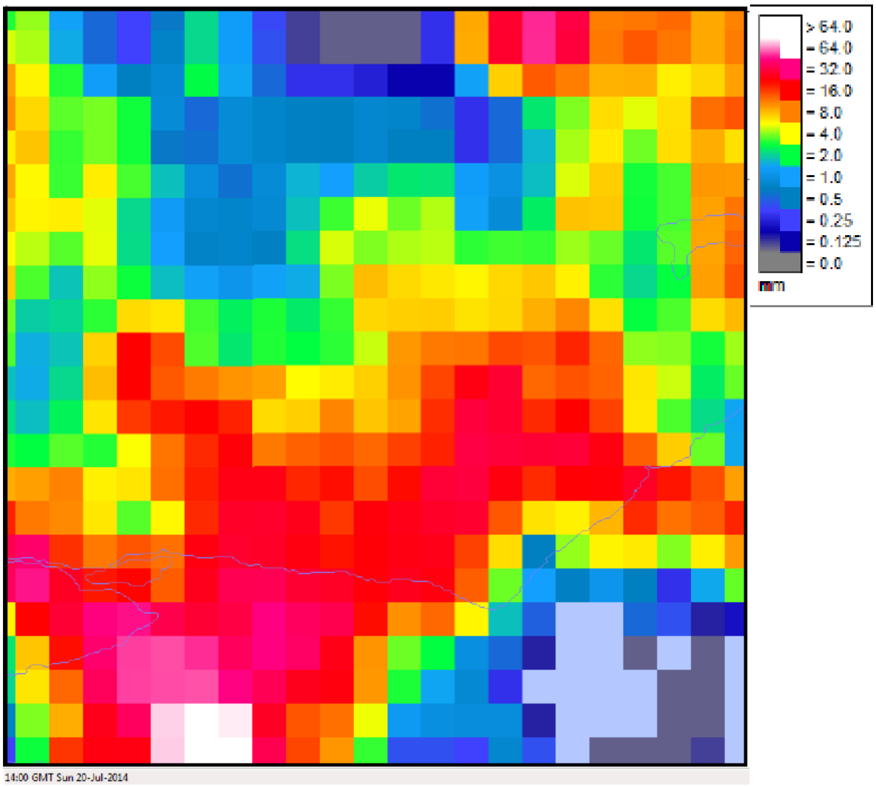
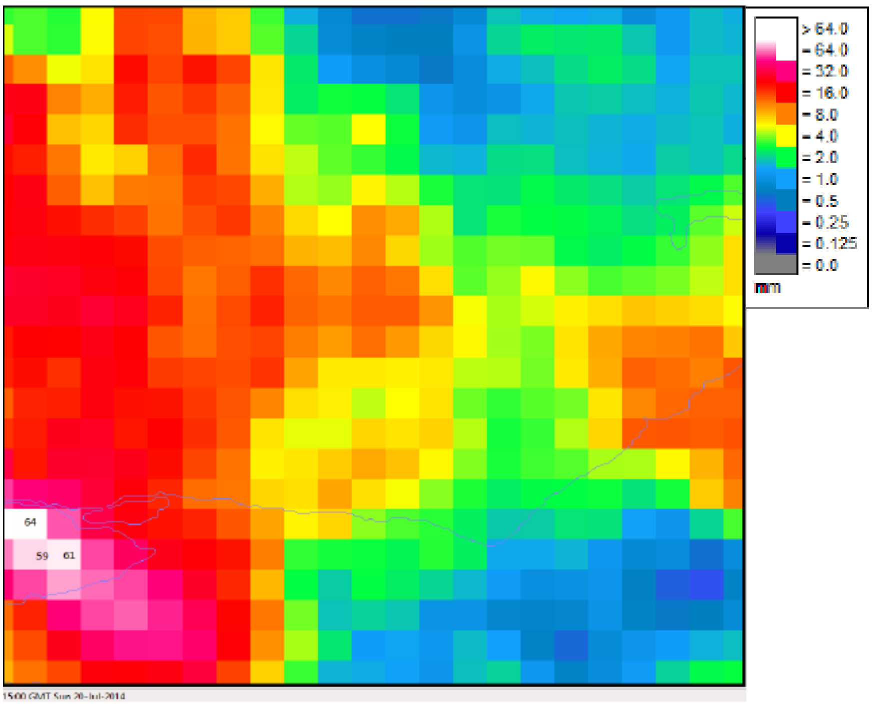


Figure 2-2 B - Environment Agency Radar imagery showing the 60 minute accumulation between 14:00 and 15:00 on the 20th July 2014. Rainfall depths are in mm.



2.4 Flood Records

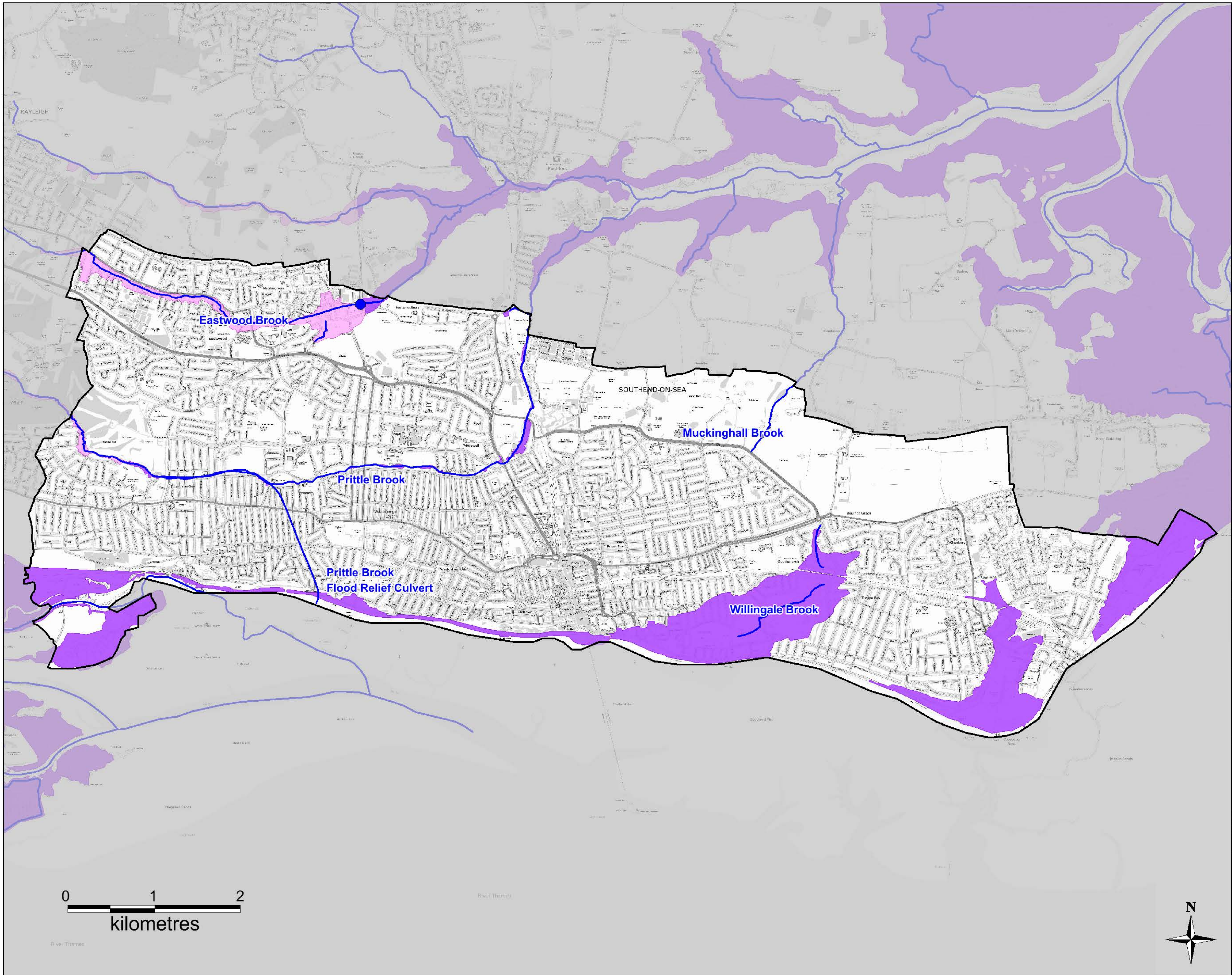
Figure 2-3 shows the locations of flooding recorded flooding across Southend-on-Sea. It can be seen that the distribution of flooding incidents is focussed to the west of the borough.

A total of 30 incidents were recorded. Of these, there were:

- 2 records of property flooding,
- 9 records of manhole covers being lifted,
- 1 record of manhole lifting resulting in property flooding (the hospital),
- 3 records of highways flooding,
- 1 record of water rising in a garden, and
- 14 records with no description.

The EA has detailed that they had no reports of flooding on the 20th July, however they have had unconfirmed reports of flooding along Raleigh Road and at Southend Airport.

In addition, AW has two records of flooding from the 20th of July associated with external flooding at Temple Farm Industrial Estate and Highlands Boulevard.



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Legend

- Southend-on-Sea Borough Extent
- Flood Alert area only
- Flood Warning area
- Main River
- Flow gauging station

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Drawing Title: RIVER AND SEA FLOOD ALERT AND WARNING AREAS

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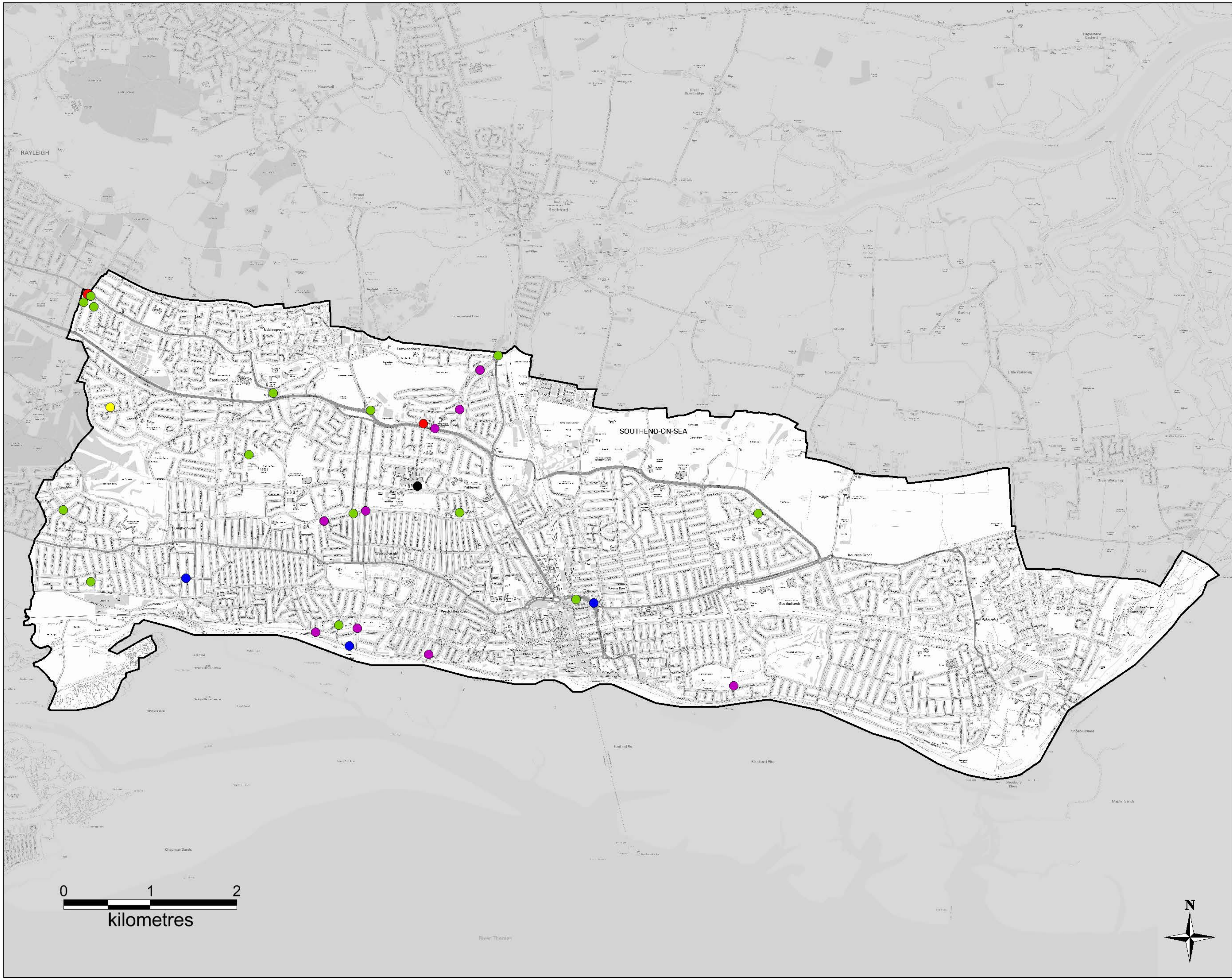
Figure 2-3	3



Legend

Southend-on-Sea Administrative Area

20th July 2014 Flood Records

- Critical Infrastructure Flooding
- Property flooding
- Flooding (source unknown)
- Road flooding
- Manhole and gully flooding
- Water rising in garden

Revision Details	By	Check	Date	Suffix

Purpose of Issue
FINAL

Client
southend on sea

Project Title
SOUTHEND-ON-SEA
20TH JULY 2014 FLOOD
INVESTIGATION REPORT

Drawing Title
FLOODING INCIDENTS
20TH JULY 2014

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Figure 2-4	3

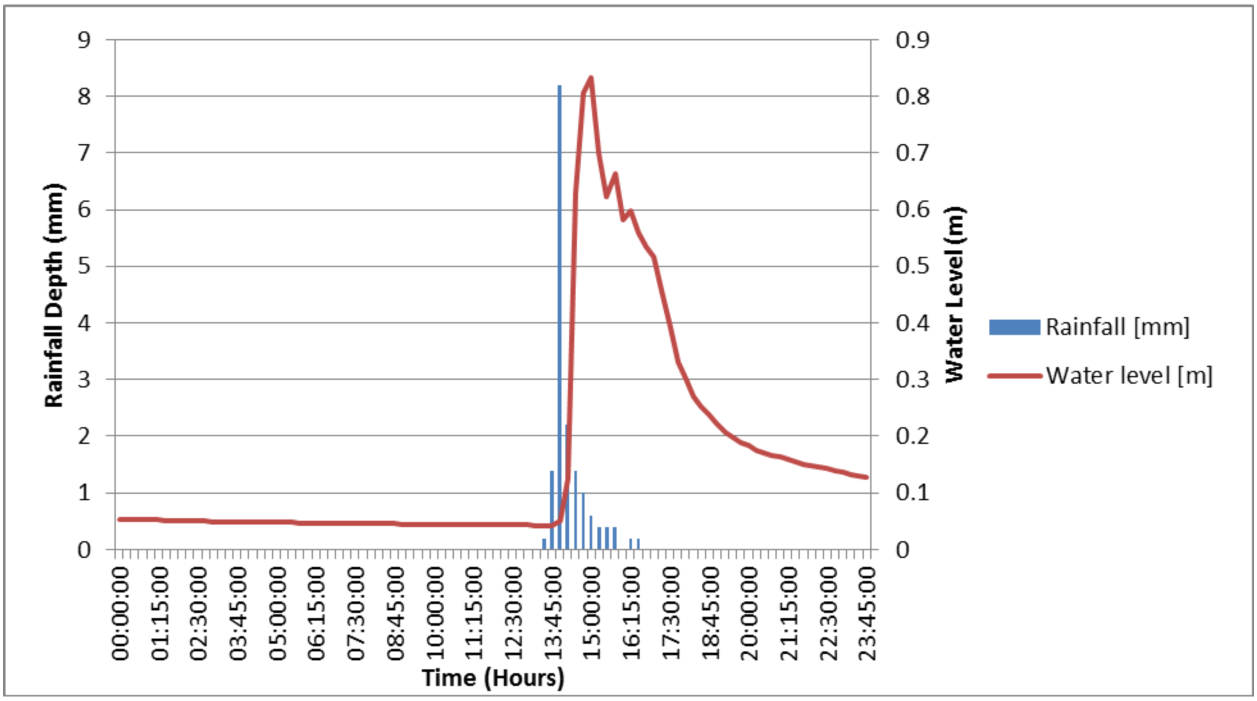
2.5 Recorded River Levels

As can be seen in Figure 2-4, five incidents have been recorded along the length of Prittle Brook and its tributaries. Water levels within Prittle Brook are recorded at a gauging station within Belfrairs Park (NGR: 583292, 187035). Figure 2-5 shows the water levels of Prittle Brook on the 20th July along with the recorded rainfall.

It can be seen that Prittle Brook responded rapidly to rainfall across the catchment, with approximately a 30 minute delay (lag) between the peak rainfall and peak river flows.

It should be noted that Prittle Brook drains from Hadleigh in Castle Point to the west of Southend-on-Sea. As the focus of the storm occurred to the west of Southend-on-Sea, the resultant flows within Prittle Brook through Southend-on-Sea are likely to have been of a greater magnitude than would result from the rainfall recorded at Southchurch Park.

Figure 2-5: Recorded rainfall at Southchurch Park and river levels at Belfairs Park on the 20th July 2014



3. FLOODING MECHANISMS

The following chapter summarises the flooding investigation for Southend General Hospital and for areas identified to have been subject to repeated flooding. For each site, an overview will be provided, flooding mechanisms discussed, RMA responses outlined and actions for flood management suggested.

A site walkover was undertaken on the 28th of August 2014 in order to assess the potential flooding mechanisms at the affected sites.

3.1 Southend General Hospital

3.1.1 Overview

Southend General Hospital is located within the central part of the borough, to the north of Prittlewell Chase and south of Carlingford Drive. The hospital is an emergency response centre.

3.1.2 Mechanisms for Flooding

Prittle Brook runs in an easterly direction, approximately 260 m to the south of the hospital. The AW public surface water drainage network, consists of 225 mm diameter surface water sewers which drain Prittlewell Chase from the west and east, before running south, converging and discharging via a single outfall to Prittle Brook.

As shown in Figure 3-1, the hospital is at a relatively high elevation of approximately 27 mAOD. The land to the north and south of the hospital falls to a lower elevation. Prittle Brook to the south is at a level of approximately 19 mAOD.

Figure 3-1: Topography around Southend General Hospital
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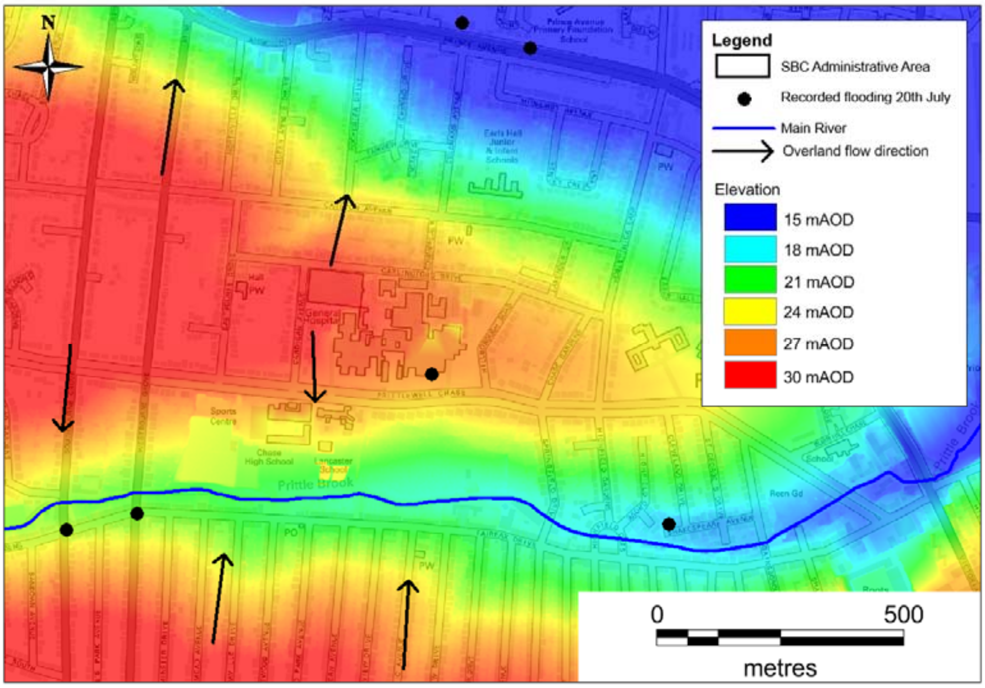

Flooding on the 20th July occurred within the A&E resuscitation room in the southeast of the hospital building. Flooding was observed to have occurred from a surcharging manhole, located centrally within the room. As a result, the A&E department was partially evacuated for the duration of the flooding and all emergencies were diverted from the hospital.

A meeting was held with the Hospital Facilities Management, the SBC Emergency Planner and URS on the 16th September 2014 to clarify details of flooding. Discussions further revealed that flooding was also observed within the car park to the south of the A&E entrance and Prittlewell Chase.

Descriptions of the sewer network provided by hospital staff outline that there is a large (150mm diameter) private surface water sewer that collects rainfall from the roof area of the main hospital building and runs in a westerly direction across the front of the hospital (under the A&E department), before connecting into the public sewer network in Prittlewell Chase.

High level hydraulic calculations have been completed to analyse the potential for surcharging to have occurred as a result of high intensity rainfall. Considering the peak rainfall occurring over 15 minutes, it has been estimated that the manhole would have surcharged shortly after the peak rainfall.

A CCTV survey of the drainage network serving the hospital, competed in November 2014 following the flooding event, showed that the surface water drainage network, within this location, is in a suitable condition.

Investigations completed at the time of the flooding by hospital staff did not specify if the manhole cover had been bolted down prior to the flooding.

It is likely that the short spell of intense rain would have caused the rapid runoff of surface water from the roof area to the drainage network. The sudden increase in inflow may have caused the surface water sewer to become overwhelmed and surcharge. Should the manhole cover not have been secured, this could have lifted with the increased water pressure.

In addition to the drainage network within the hospital, high level hydraulic calculations of the public sewer network have been completed (see Appendix B). This has identified that the public surface water sewer network in Prittlewell Chase (not including the drainage network within the hospital) would reach capacity after approximately 5.8 mm of rainfall, and would result in flooding after 81 minutes, assuming a 50% blockage (flood-locking) of the outfall. Assuming there is no restriction to the outfall at Prittle Brook, the network would not surcharge.

It is possible that the high water levels of Prittle Brook would have contributed to flooding by causing water to back up within the surface water network, leading the sewer system to surcharge within the hospital. Further investigation would be needed to confirm this.

During the site walkover on the 28th August 2014, it was observed that many of the road gullies draining the hospital car park were silted, therefore their potential to drain surface water would have been compromised (Photographs 3-1 and 3-2). The flooding of the car park is likely to have been a result of water not being able to enter the drainage network. Due to the topography of the area, surface water would have flowed towards Prittlewell Close at a lower elevation.

Photograph 3-1: Entrance to Southend A & E (looking north), detail of gully at entrance.

Photograph 3-2: Car park and Prittelwell Close (looking west) including detail of car park drainage

3.1.3 Response to Flooding

As a result of flooding, the hospital's A&E department was partly evacuated, and emergencies were diverted to other hospitals. The department was closed for 1.5 hours whilst flood water was cleared away.

A CCTV survey of the hospital drainage network has been undertaken and has identified a number of sections where remedial actions are necessary. These will be addressed within the coming months.

The manhole is now confirmed to be bolted down.

3.1.4 Suggested Action

As the hospital grounds form a considerable area of hard standing surfaces, measures could be taken in the long term to implement source control Sustainable Drainage Systems (SuDS) in order to reduce the rate and volume of surface water runoff. Measures such as using permeable paving in the car parking areas, or installation of green roofs could be developed. These will act to retain and attenuate surface water at the source, reducing the rate of runoff from hard-standing surfaces across the area of the hospital.

Staff at Southend General Hospital should undertake frequent inspections of the manhole covers within the hospital to ensure they are correctly fixed, especially following inspections or maintenance work.

3.2 Glenwood Avenue

3.2.1 Overview

Within this area there were four recorded incidents of flooding on the 20th July, one of which was property flooding. This area has previously suffered extensive flooding on the 24th August 2013 and details of this are provided in the Southend-on-Sea 24th August 2013 Flood Investigation Report[xv].

3.2.2 Mechanisms for Flooding

The topography around Glenwood Avenue is shown in Figure 3-2. The elevation of Glenwood Avenue falls in a northerly direction to its junction with Rayleigh Road. A low point in the carriageway is located at the northern end of Glenwood Avenue, highlighted in Photograph 3-3.

At the junction of Glenwood Avenue and Rayleigh Road, Eastwood Brook, which flows in an easterly direction, enters a 1,500 mm culvert that flows to the south of Rayleigh Road, before emerging to the east of Grovewood Avenue. The culvert inlet is fitted with a trash screen and both the screen and the culverted section of watercourse are owned and maintained by AW.

Within this area, many of the properties on Glenwood Road have thresholds below the level of the road and driveways which slope down towards the properties. On Rayleigh Road, the properties on the southern side of the road immediately downstream of the culvert inlet are located at the base of a steep bank below the level of the footpath.

There is a gauging station at the downstream end of the Eastwood Brook but the upstream section is not currently monitored. It is assumed, as with Prittle Brook described in Section 2-5, that flow within the Eastwood Brook is likely to be of high magnitude due to higher rainfall falling within the upper catchment of the Eastwood Brook.

It is believed that high flows within Eastwood Brook exceeded the capacity of the river channel as it entered the culvert. This may have been exacerbated by debris from upstream causing a partial blockage of the trash screen. It is unknown if this occurred. As a result, the hydraulic capacity of the culvert inlet was reduced and flow backed up and spilled onto both Rayleigh Road and Glenwood Avenue.

Water emerging from the river would have flowed overland towards the low point at the northern end of Glenwood Avenue according to the local topography. Due to the low lying nature of the properties adjacent to Glenwood Avenue and Rayleigh Road, water flowed into the gardens of properties on both roads. In one instance, on Rayleigh Road, the property threshold level was exceeded and internal flooding occurred.

[xv] URS 2014, Southend-on-Sea Borough Council – Flood Investigation Report 24th August 2013.

Figure 3-2: Topography of Glenwood Avenue
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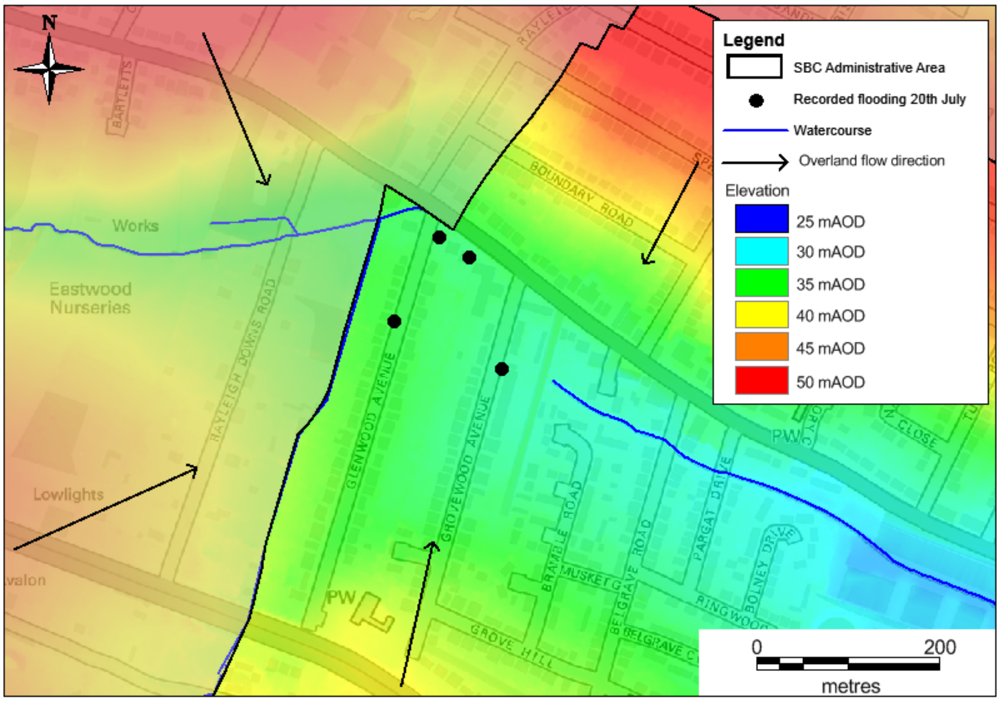

There is a further reported incident of flooding towards the centre of Glenwood Avenue. The topography of the area suggests that this flooding was likely to be a direct result of flood water emerging from the river channel. The surface water sewer on Glenwood Avenue however falls in a northerly direction to meet the culverted watercourse at the junction with Rayleigh Road. Therefore, it is possible that the standing water present at the low point of Glenwood Avenue caused the sewer system to become surcharged. As a result, rainwater falling on Glenwood Avenue would have been unable to enter the sewer system and therefore ponded in local depressions along the carriageway. Due to the fall of many driveways along Glenwood Avenue, standing surface water could have flowed towards properties on the western side of the road.

Photograph 3-3 –Looking north along Glenwood Avenue to junction with Rayleigh Road.

3.2.3 Responses to Flooding

Following the flooding, SBC undertook work to check and clear all the gullies in the area.

AW currently complete weekly inspections of the trash screen. AW operatives are also dispatched to inspect the trash screen following the receipt of weather warnings for heavy rainfall.

Since the flood incidents occurred, AW has replaced fencing surrounding the trash screen to prevent dumping of rubbish directly onto the screen. Photograph 3-4 shows the sign now present at the time of the site visit on the fencing which provides the public with contact details for AW to report any problems noticed with the channel, screen or culvert.

Photograph 3-4 –New sign providing Anglian Water emergency contact details

In the longer term, as stated within the 24th of August Flood Investigation Report, the EA is looking into installing a gauging station to the west of Dawes Heath Road, along Eastwood Brook, upstream of Southend-on-Sea. This would be used to provide flood alerts and flood warnings to the area downstream, including Eastwood. The EA is working with Rochford District Council in the development of this scheme. It is anticipated that the gauging station will be installed within the next 6 months.

Additionally, the EA proposes to commence an investigation into the existing fluvial flood risk to people and property along the Eastwood Brook in 2015. However, this is dependent upon securing the necessary funding. The EA propose to develop this project in conjunction with SBC, other risk management authorities and the local community.

3.2.4 Suggested Action

AW should continue to maintain and clear the trash screen on a regular basis, and with SBC should encourage residents in the local area to report blockages of the screen to AW via the number provided.

SBC, the EA and AW could work with residents to form a community flood group, with the intention of providing an effective route for communication and flood responses. The role of the community group could be further developed to ensure residents are able to help themselves in the event of flooding.

3.3 Thorndon Park Drive & Park View Drive

3.3.1 Overview

There was one recorded incident of flooding during the 20th July event, however there were multiple properties flooded during the 24th August 2013 event. During the 20th July event, flooding was limited to gardens and no internal flooding was reported.

3.3.2 Mechanisms for Flooding

Figure 3-3 shows that the affected area lies on a relatively steep slope (1:35) in a predominantly residential area. A large percentage of the ground is covered by impervious drives and roadways, which combined with slope of the land, can lead to rapid runoff and surface water flooding.

Figure 3-3: Topography of Park View Drive and Thornond Park Drive
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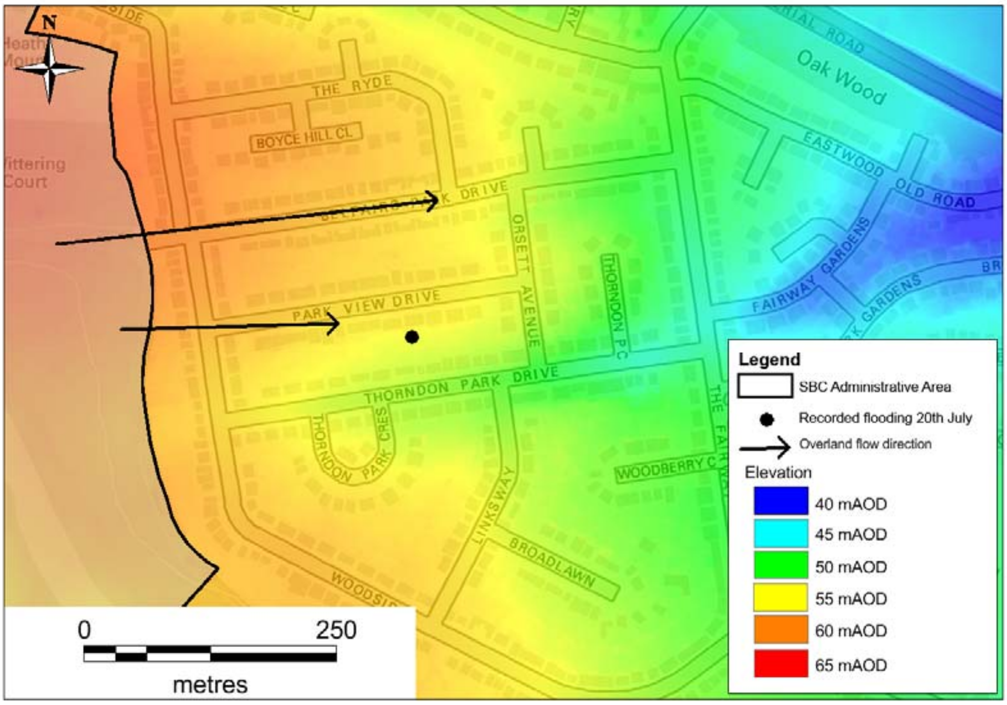


Park View Drive and Thorndon Park Drive are drained by 225 mm and 300 mm diameter sewers respectively, that run in an easterly direction. The sewer network at this point is at the top of the catchment i.e. there is little area to the west, upstream of the site that drains to the network. It is therefore unlikely that there are issues with the capacity of the sewer network.

Reports from residents stated that water emerged within the rear garden of a property on Park View Drive; this could suggest that flooding in this area was driven by groundwater sources. However, this is unlikely, as groundwater flooding tends to occur after extended periods of heavy rainfall and in areas underlain by highly permeable soils. The topsoil and bedrock geology within this area is largely clay based soils, clayey soils are generally highly impermeable and do not hold or convey significant volumes of water. Ground investigations would be needed to determine if this flooding is a result of groundwater emergence.

Alternatively, flooding in this area could have occurred as a result of the local topography and rainfall runoff from the surrounding steep areas. The garden affected on Park View Drive may be located within a local topographic depression, or on the course of a filled ditch or watercourse in which water was able to pond.

3.3.3 Response to Flooding

SBC checked the gullies and carried out a review of the surface water drainage infrastructure and general drainage investigation. As a result, 7 new gullies are to be provided in this area.

3.3.4 Suggested Action

This area is likely to remain susceptible to surface water flooding during rainfall events due to the steep topography of the surrounding area. A number of quick win solutions could be implemented to assist in managing the flood risk, such as:

- SBC should continue to work with residents to inform them of the flood risk in the area, and outline property protection measures that can be implemented.
- SBC should ensure that as part of the highways maintenance programme, the gullies and highway drains of Park View Drive and Thorndon Park Drive are frequently inspected and maintained, if needed.

In the long term, SBC could investigate the potential for implementing source control SuDS across the urban area to alleviate the volume of water draining to the road channel. This should be implemented, where possible, across the surrounding area to have maximum benefit. Local to Park View Drive, SuDS could be incorporated, including the gradual replacement of parking areas with permeable paving, or modifying the kerb to provide rain gardens. Any potential measures would need to be developed through further investigation and feasibility studies prior to implementation.

3.4 Highlands Boulevard

3.4.1 Overview

Highlands Boulevard is located to the west of Southend-on-Sea. Flooding was recoded previously on the 24th August 2013. Flooding was recorded again on the 20th July 2014 by SBC and AW.

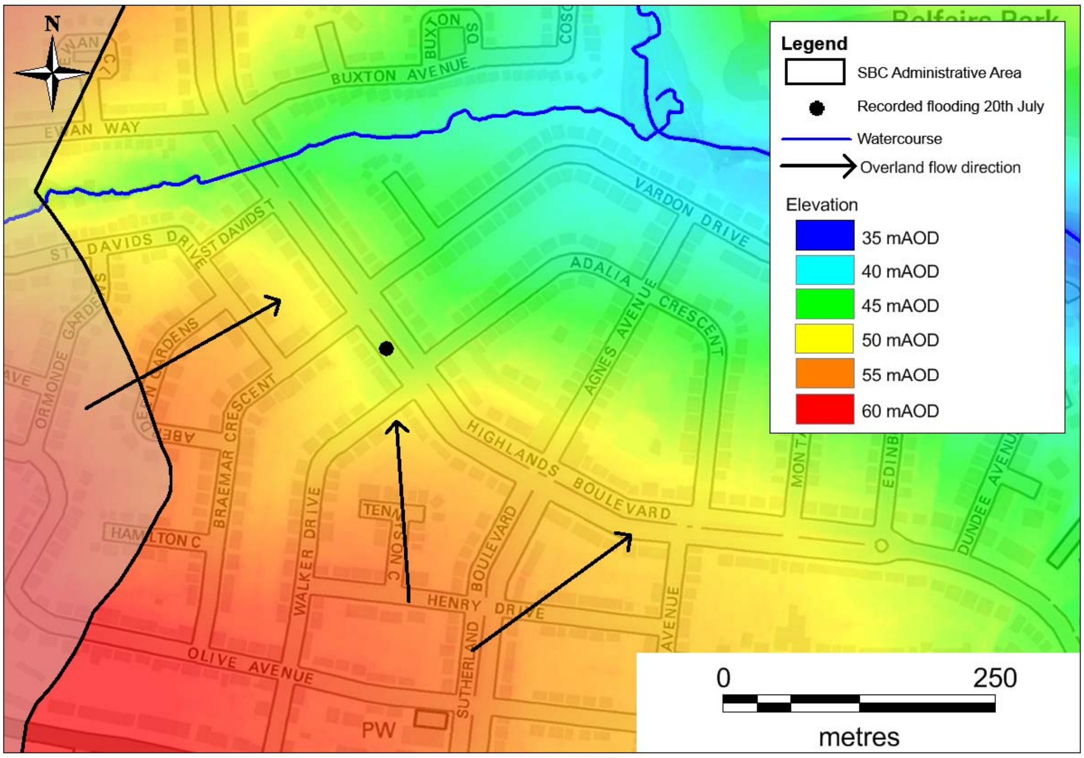
3.4.2 Mechanisms for Flooding

As shown in Figure 3-4 and Photographs 3-5 and 3-6, Highlands Boulevard slopes in a northerly direction towards the river channel of a tributary of Prittle Brook. There is a second dip in the elevation as the road bends to the north, where flooding was observed.

Observations from the site walkover on the 28th August 2014 showed that there is a considerable slope across the width of the road. Surface water runoff, generated from hard standing surfaces, would follow the channel of the road. In the event that the rate or volume of flow is increased, such as during an intense rainfall event, it is likely that water would exceed the capacity of the road channel and flow towards the properties on the northern side.

Prior to recent highways drainage improvements (discussed in further detail in section 3.4.3); there were limited road gullies or kerb gullies serving the area. This would have further reduced the potential for surface water to enter the drainage network.

Figure 3-4: Topography of Highlands Boulevard
Contains Ordnance Survey data © Crown copyright and database right 2014



The surface water drainage network within this area consist of a 375 mm diameter pipe that runs within Highlands Boulevard, and discharges to the river channel (as shown in Photograph

3-7). This surface water network drains the area of Braemar Crescent and its adjoining roads. The southern part of Highlands Boulevard is drained in a north easterly direction.

It is possible that, if the water level of the tributary of Prittle Brook rises above that of the surface water outfall, the discharge of surface water would be restricted and would back-up within the network. High level hydraulic calculations, presented in Appendix B, show that the manhole at the junction of Braemar Crescent and Highland Boulevard would have surcharged following 9.7 mm of rainfall, 90 minutes after the onset of rain, assuming a 50% blockage (flood locking) of the outfall. Assuming there is no restriction at the outfall, the manhole would not surcharge during the simulated rainfall event.

It is considered that the cause of flooding in this instance was as a result of the topography of the land channelling surface water towards the property, exacerbated by the potential reduced capacity within the surface water drainage network.

Photograph 3-5: Crossing at Highlands Boulevard at the junction of Adalia Crescent and Walker Drive (looking south). Detail of new gullies.

Photograph 3-6: Drop in elevation along Highlands Boulevard (looking north).

Photograph 3-7: Surface water outfalls to the tributary of Prittle Brook

3.4.3 Response to Flooding

AW responded to residents' concerns of flooding by carrying out a CCTV survey of the drainage network within this area. This confirmed partial siltation of the sewer network, which was then cleared.

SBC has regular communication with the residents within this area and has subsequently completed (September 2014) a number of local highways drainage improvements, including:

- The installation of additional gullies in the central road crossing opposite Walker Drive and an additional gully further to the west of the road crossing to improve the capture of surface water runoff,
- The installation of a new road gully at the junction of Adalia Crescent and Highland Boulevard and a linear drain across the footway to reduce the surface water runoff towards the properties, and
- Modification of existing kerb gullies to improve the efficiency of receiving surface water runoff.

As part of the highways improvements, it has been agreed with the residents, that water from the linear drains will be diverted to the rear gardens of the properties affected. This will help to alleviate the volume of water entering the surface water drainage network.

3.4.4 Suggested Action

The improvements in the highway drainage described may alleviate the risk of overland flow from rainfall events of similar magnitude. However, if the outfall of the surface water sewer is flood-locked by high water levels in the river, it is likely that the capacity of the system will be exceeded during extreme rainfall events.

SBC should ensure that residents are aware of this risk. Residents should consider the use of property protection measures to implement in the event of a flood.

In the longer term, the central verge between the carriageways could be considered to provide a flood conveyance route to attenuate the peak runoff from the road area. The feasibility of this would need to be examined prior to any implementation.

3.5 Prince Avenue

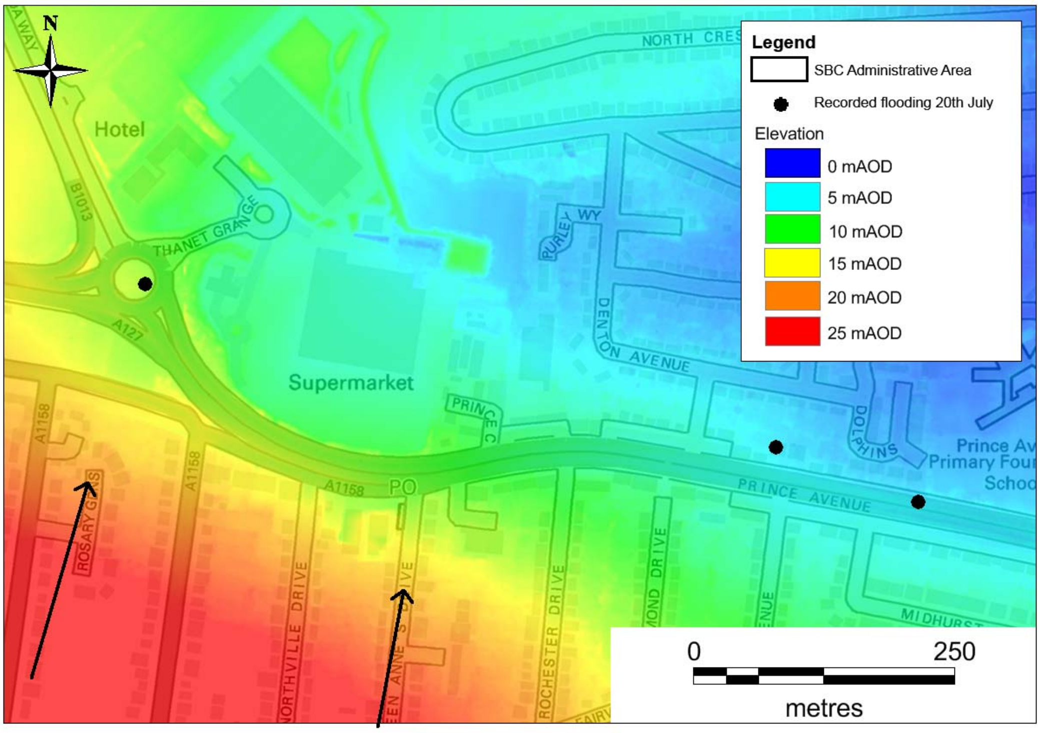
3.5.1 Overview

Prince Avenue (A127) forms a key access route to and from central Southend-on-Sea. Within this area there were three recorded incidents of flooding during the 20th July event, one of which was property flooding. There were two records of carriage way damage from the 24th August 2013 event along Princes Avenue.

3.5.2 Mechanisms for Flooding

The topography in Figure 3-5 shows that there is a fall in elevation from the south towards Prince Avenue. There would therefore be a tendency for surface water to run, as overland flow, towards Prince Avenue. The public surface water sewer network, consists of a large surface water sewer (increasing from 675 mm to 900 mm) running in an easterly direction along the length of Prince Avenue. Surface water sewers from the lateral roads to the south join along the length of the sewer.

Figure 3-5: Topography of Prince Avenue (black arrows indicate the general overland flow route) Contains Ordnance Survey data © Crown copyright and database right 2014



It is considered that the cause of flooding at each of the locations is not related. Reports received from Essex Police and SBC Highways department state that the manhole cover 300 m from The Bell traffic lights, opposite Prince Avenue Primary Foundation School, was lifted and water was emerging from the sewer causing disruption to the carriageway. The manhole cover which lifted is likely to form part of the 900 mm diameter surface water sewer which flows east along Prince Avenue.

High level hydraulic calculations, presented in Appendix B, show that the manhole would have surcharged following 7.4 mm of rainfall, 84 minutes after the onset of rain. This is assuming there is no restriction on the outflow. This indicates that the surface water drainage network may not have sufficient capacity to drain the area to the required return period.

The property on Prince Avenue which reported internal flooding is located on the northern side of the carriageway. The property is located below the level of the carriageway and is connected to the road by a driveway which slopes towards the property and has no protective measures to prevent surface water runoff from the road flowing towards the property. It is likely that surface water runoff from the carriageway flowed down the driveway to pond in front of the property. As water levels increased, water would have overtopped the building threshold. It is unlikely that water from the surcharging manhole would have contributed to flooding, as the road at this point is at a slightly lower elevation that at the property.

The incident of flooding reported at the Tesco roundabout is not believed to be connected to the surcharging manhole. A site walkover on the 28th August 2014 revealed that there are a large number of road gullies on the roundabout. AW records do not show that there is a surface water sewer network within this area; it is believed that surface water from the roundabout is drained by a private system. The operation and standard of design of this system is not known. It is most likely that flooding occurred on the roundabout due to blockages of the road gullies preventing water draining from the road surface or a blockage within the private drainage system causing flow to back up onto the road.

3.5.3 Response to Flooding

During the flood event, in response to the broken and lifted manhole cover on Prince Avenue, Essex Police requested that SBC Highways department remove a lane of traffic from the carriageway. This prevented traffic driving over or close to the lifted manhole and through the deepest areas of flooding surrounding the manhole.

The broken and lifted manhole was also reported to AW by SBC. Since the flood event, AW has replaced the manhole cover.

With the aim of preventing surface water from the carriageway flowing onto the driveway of the flooded property, SBC has installed a linear drain across the driveway entrance and has connected this to the highway drainage system.

3.5.4 Suggested Action

It is recommended that SBC and AW investigate why the highway drainage system and the surface water sewer system within Prince Avenue were unable to drain the surface water runoff during this event. A CCTV survey should be undertaken to determine if there are any blockages or features of the sewer which are likely to reduce its hydraulic capacity. SBC should assist in this through assessment of the highway drainage system which connects to the surface water sewer.

On completion of such a survey, remediation work should be carried out to these systems to remove any blockages.

Should it be found that the drainage and sewer systems beneath the carriageway are operating as designed, surface water flooding is likely to continue occurring in this area. SBC should inform residents of the likelihood of flooding and should recommend the use of property level protection measures.

Regarding the flood incident which occurred on the Tesco roundabout, SBC have confirmed that this junction is currently undergoing reconstruction. A survey of the drainage infrastructure in connection with this work has revealed partial blockages due to shingle intrusion possibly related to pipeline construction. It is recommended that, following the completion of required repairs to the drainage infrastructure at this junction, the maintenance regime for the road gullies on the roundabout is investigated and if necessary, the frequency of gully clearance and maintenance should be increased.

3.6 Rochford Road

3.6.1 Overview

Within this area there were three recorded incidents of flooding on the 20th July 2014. This area previously suffered from flooding on the 24th August and 11th October 2013. There are no recorded incidents of flood water entering properties in this area on the 20th July. Two manhole covers on Rochford Road were lifted by water surcharging from the surface water network and surface water ponded on the Harp House roundabout.

3.6.2 Mechanisms for Flooding

Figure 3-6 shows the local topography. It can be seen that the land to the south west and south east slopes towards Rochford Road and Harp House Roundabout. The topography of the land is associated with a watercourse, which is now culverted and classified as a surface water sewer. This discharges to a tributary of Prittle Brook to the south of Warners Bridge (where Rochford Road passes over the railway line). There are several lateral drains that connect into the culverted watercourse along the length of the surface water sewer.

Figure 3-6: Topography of Rochford Road
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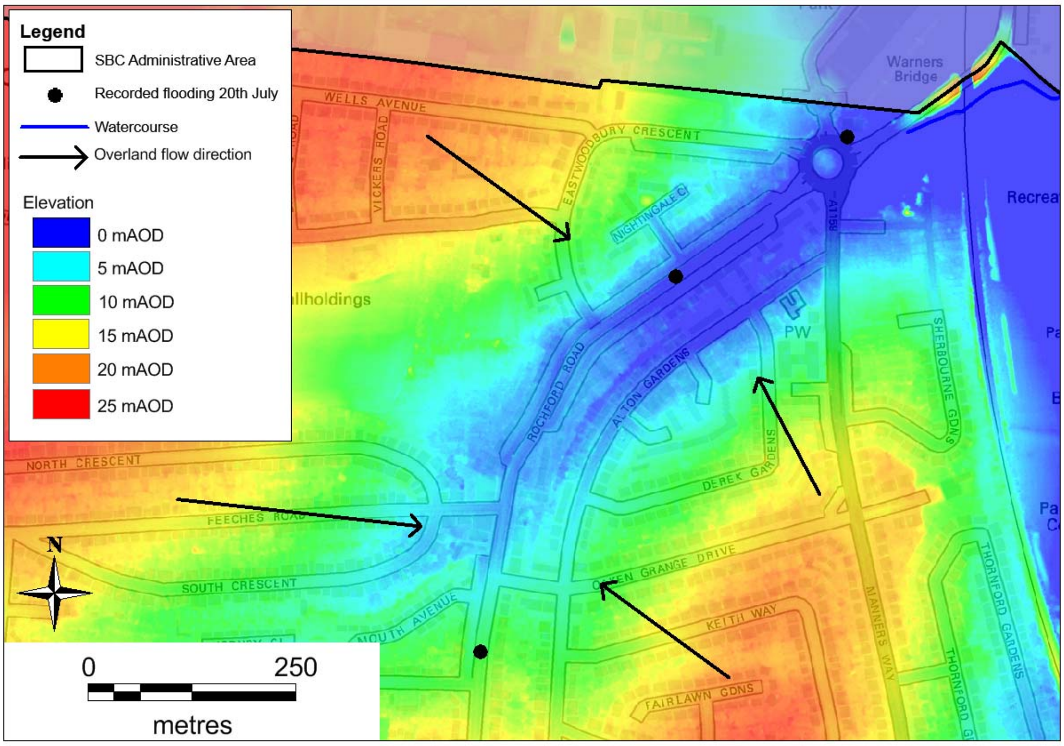

Rochford Road runs along the bottom of a valley which is defined by the flow path of the now culverted watercourse. As a result, surface water runoff from the surrounding areas is directed both overland and within the sewer network towards Rochford Road and the culverted watercourse. Both the surface water and the foul sewer network in this area consist of large diameter pipes (1,800 mm and 675 mm respectively). It is not known whether a spill into the surface water network occurred on the 20th July.

On the 20th July there were reports of two manhole covers on Rochford Road lifting; it is unknown whether these manholes are associated with the foul or the surface water systems. Manhole covers lift when the associated sewers become surcharged and cannot convey flow downstream. Water is forced up through manhole shafts and emerges at ground level.

There are a number of reasons why sewers could become surcharged during these more frequent, lower intensity rainfall events, such as:

- Blockages within, or collapse of, the surface water sewer pipes or manholes could cause the conveyance capacity of the sewer to be reduced, causing flow to back up and surcharge,
- Blockages of, or the drowning of outfalls can cause flow to back up within the network and surcharge manholes, and/or
- Misconnections into foul sewers from surface water sewers or drainage systems can cause the foul system to surcharge during rainfall events, the foul system may not be designed to cope with additional flow during rainfall events. The presence of an overflow from the foul system into the culverted watercourse, suggests that there is a known storm response within the foul system. If the overflow structure were blocked or not functioning as designed, this could cause the foul system to surcharge.

As described previously within Section 1.3.3, the AW surface water network is designed to convey flows without surcharging for rainfall events up to the 5% AEP. Under this standard, the rainfall recorded on the 20th of July should not have resulted in the flooding of the surface water network.

High level hydraulic calculations have been completed for the surface water drainage network at the junction of Nightingale Close and Rochford Road and also at the junction of Sidmouth Avenue and Rochford Road. At the Nightingale Close and Rochford Road junction, assuming there are no restrictions on the outfall, flooding of this manhole should not have occurred during the simulated rainfall event. It is therefore likely that there may be a blockage or obstruction within this part of the network.

At the junction of Sidmouth Avenue and Rochford Road, flooding would be anticipated to have occurred following 7.1 mm of rainfall, resulting in flooding 84 minutes after the onset of rainfall. This suggests that the network may not have sufficient capacity. Calculation details are provided in Appendix B.

On the 20th July 2014, flooding also occurred at the Harp House roundabout where water was reported to pond on the roundabout and was slow to drain away into the highway drainage system. This mechanism for flooding was previously observed on the 11th October 2013.

The 11th October Flood Investigation Report[xvi] found that flooding occurred due to alterations made to the drainage regimes during resurfacing of the roundabout. The resurfaced road was preventing flow entering the kerb gullies. To alleviate the problem on the 11th October 2013,

[xvi] URS 2014, Southend-on-Sea Borough Council 11th October 2013 Flood Investigation Report

SBC subcontractors attended the site and lifted the gully cover, and this allowed water to drain freely from the road surface.

The mechanism for flooding on the 20th July 2014 could therefore be the same as the 11th October 2013 incident. It is also possible that the problems on Rochford Road, which caused manhole covers to be lifted, could have reduced the capacity of the surface water network at the roundabout, causing water to back up onto the road surface. The local topography shows that the roundabout is the low point within the area and as a result surface water would be likely to pond here.

3.6.3 Response to Flooding

The lifted manhole covers and the road flooding was reported to AW.

SBC used cones and barriers to divert traffic from the lifted manholes and flood water to make the area safe for the public.

Following the report, AW completed a camera survey of the network and found no problems.

3.6.4 Suggested Action

It is recommended that AW undertake an investigation to determine why manhole covers were lifted on Rochford Road during a rainfall event with a probability of occurrence greater than 5% AEP.

Regarding the problems at the Harp House roundabout, it is recommended that works are undertaken to the road surface or the gullies to maximise their flow capture.

If the problem persists then further options such as the provision of flood storage areas within the roundabout itself or in the land to the north east where the sewer outfalls should be considered.

3.7 Cavendish Gardens

3.7.1 Overview

Within this area there were three recorded incidents of highway flooding on the 20th July 2014. Two reports were of manholes flooding at the junctions of Cavendish Gardens with Westbourne Grove and Kingsway. A third incident was recorded at the junction with Southbourne Grove; however no further details were recorded.

3.7.2 Mechanisms for Flooding

Figure 3-7 shows that the reported flood incidents are located at the bottom of a valley through which Prittle Brook flows in an easterly direction. The topography indicates that surface water flows would be directed towards Prittle Brook, and as a result Cavendish Gardens.

In addition to overland flow paths, the public surface water sewers within this area also drain towards Prittle Brook. At the location of two of the three flooding incidents, there are outfalls from the surface water network to Prittle Brook.

As described previously within Section 2.5, the water level within the Brook was recorded to peak shortly after the peak rainfall was recorded. It should be noted that Prittle Brook gauging station is located 2 km upstream. The peak water level within Prittle Brook in the vicinity of Cavendish Gardens is not known, however it is assumed that a similar 'flashy' response would have been observed within the river channel adjacent to Cavendish Gardens.

If the water level in Prittle Brook rose above the level of the surface water outfalls, then the discharge from the surface water sewers to the watercourse could be reduced. If the river level were high enough, river water would potentially back up into the sewer system. If the latter occurred, the surface water system could back up and surcharge at low lying manholes. This is the likely mechanism which occurred on the 20th July to cause flooding of the three junctions on Cavendish Gardens.

High level hydraulic calculations of the surface water network draining to Prittle Brook at the junction of Kingsway and Cavendish Gardens show that in the event of the outfall being completely restricted, the surface water network at the junction would reach capacity after 0.2 mm of rain, resulting in surcharging of the network after 9 minutes. Applying the same rainfall profile, but allowing a free discharge to Prittle Book, the network would reach capacity after 13.7 mm of rainfall, resulting in flooding after 99 minutes. This therefore shows that the network is highly susceptible to the rate of discharge to Prittle Brook.

Figure 3-7 Topography in the vicinity of Cavendish Gardens.
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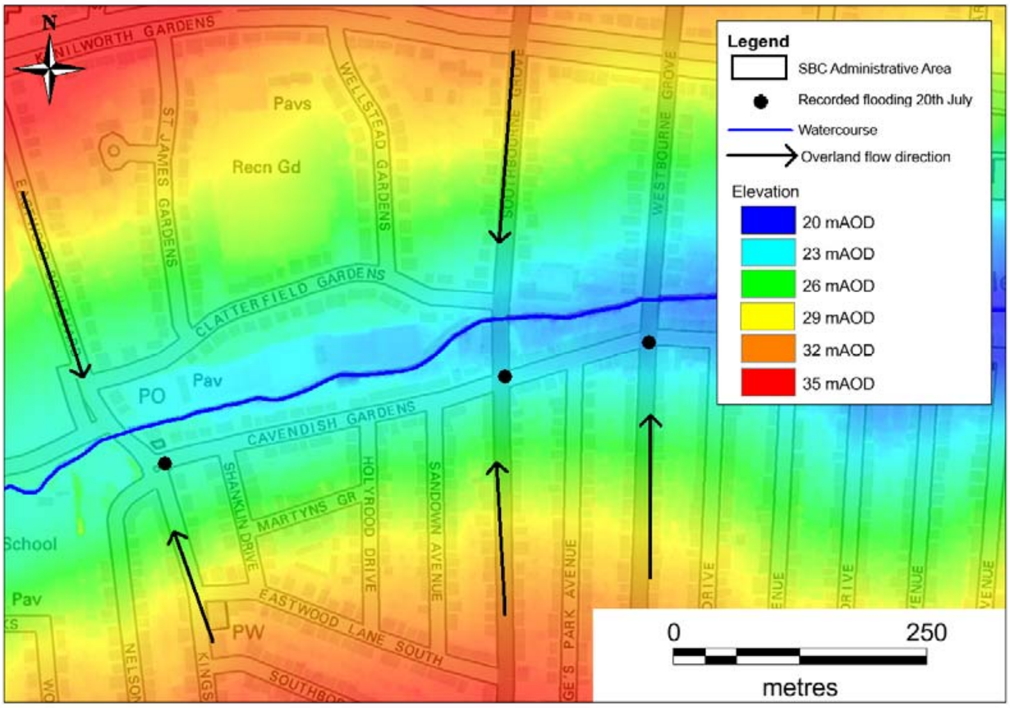


3.7.3 Response to Flooding

SBC checked and cleared the gullies in this area as well as the outfalls to Prittle Brook.

3.7.4 Suggested Action

It is recommended that the effect of non-return valves fitted on the outfalls from the surface water network to Prittle Brook is investigated. These would prevent high flows within Prittle Brook entering the system, which would reduce the likelihood of the sewer network backing up and surcharging.

In the short term, measures should be taken to implement road closures and diversions around the junctions of Cavendish Gardens during times of flooding.

Although the properties adjacent to Prittle Brook in this area are not within the fluvial flood zone (as shown in Figure 1-1), residents should be made aware of the interaction between fluvial and surface water flooding. SBC should work with communities to understand the flood risk and encourage residents to sign up to receive Met Office weather alerts.

In the longer term, actions should be taken to manage surface water runoff across the catchment of Prittle Brook, through the wide scale implementation of SuDS, to reduce the Brook's 'flashy' response to rainfall.

3.8 Chalkwell

3.8.1 Overview

There are four records of flooding within the Chalkwell area from the 20th July 2014. Of these, two are manhole flooding, one is highway flooding and one source of flooding is unknown.

There are multiple records of flooding in the Chalkwell area for the 24th August 2014 event, predominantly around Chalkwell Esplanade and The Ridgeway, as discussed in the Southend-on-Sea 24th August Flood Investigation Report[xv].

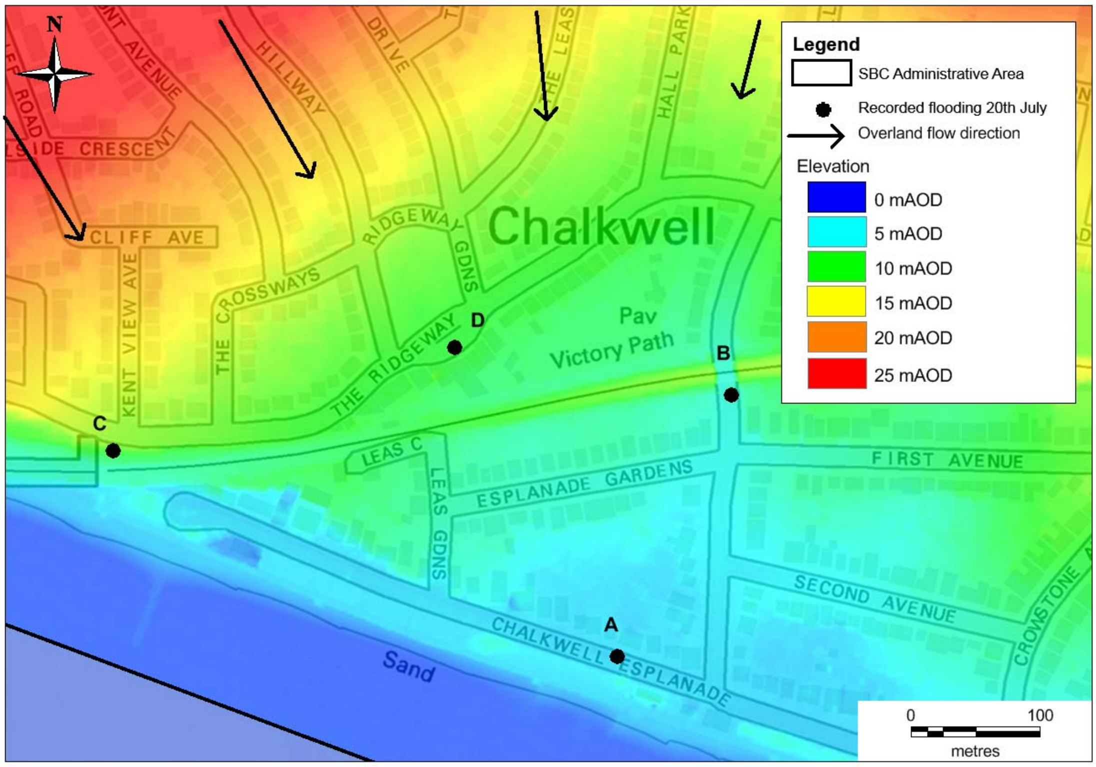
There are also two records from the 11th October 2013 at Chalkwell Esplanade and Chalkwell Avenue. These are discussed in the Southend-on-Sea 11th October Flood Investigation Report[xvi].

3.8.2 Mechanisms for Flooding

The topography of the Chalkwell area is shown in Figure 3-8. It can be seen that there is a considerable slope across the land from the north, around the Chalkwell area, towards the sea front. Overland flow would generally follow the gradient of the land and tend towards the sea front.

The Prittle Brook flood relief channel is culverted and runs beneath the Chalkwell area and discharges to the Thames Estuary at the west end of Chalkwell Esplanade.

Figure 3-8: Topography of Chalkwell
Contains Ordnance Survey data © Crown copyright and database right 2014



The public surface water sewer network within this area drains, via a series of outfalls, to the Thames Estuary. The outfalls are predominantly gravity drained with the exception of the Chalkwell Pumping Station, located at the junction of Chalkwell Esplanade and Chalkwell Avenue.

In addition to the surface water network, there is also a storm overflow protection system. This consists of a large combined sewer that runs from Grand Parade (1,370mm diameter), to the west, before turning southwards towards the sea front and running to the south of Chalkwell Esplanade (1,050mm – 1800mm diameter). The storm overflow protection sewer ultimately discharges at the Western Valley Pumping Station. The relationship between the networks cannot be clearly determined from the data available. For this investigation, it is assumed that the surface water network operates separately from the storm overflow protection sewer.

The flooding at Chalkwell Esplanade (point A) is recorded to be highways flooding. Observations from the site walkover completed on the 28th August 2014 noted that Chalkwell Esplanade is at a lower elevation than the surrounding area. In addition, there are a number of traffic calming measures and road gullies along the length of the road (as shown in Photograph 3-8). It is considered that highway flooding is a result of the reduced ability for water to enter the gullies, either as a result of the road structure impeding the flow of water, or the reduced capacity of the network.

The record of flooding in Chalkwell Avenue (point B) states a manhole cover, located within the road as it passes underneath the railway line, was lifted. This implies that the capacity of the sewer network within this area was exceeded. The surface water drainage network within this area consists of four surface water drains (diameters ranging from 150 mm to 525 mm) converging into two networks beneath the railway line. Two sewers of 675 mm and 375 mm diameter drain to the south before discharging via the Chalkwell Pumping Station. As the tide was low at the time of flooding, surface water would have been able to discharge by gravity. It is considered that the capacity of the network may have been exceeded due to the rapid onset of heavy rainfall, accumulating within this junction. Water surcharging from the manhole would have followed the topography of the road and drained towards Chalkwell Esplanade (as shown in Photograph 3-9).

The flooding in the footway of Chalkwell Station (point C) was due to the manhole cover having lifted. The entrance to the train station is at an elevation of approximately 10 mAOD, 6 m above the level of Chalkwell Esplanade to the south. To the east of the train station, the previously described storm overflow protection tunnel (1200mm diameter), surface water sewer (375 mm diameter) and Prittle Brook flood relief channel cross beneath the railway line. The cause of flooding within this area may be attributed to a blockage or capacity issues within the network. AW has no record of flooding, and is not aware of capacity issues, within this area.

The record of flooding along The Ridgeway (point D) does not detail a source, however, during the site visit it was observed that a cafe had flooded internally. At this point along The Ridgeway, the road follows the contour of the slope. There is therefore the potential for water, running off the higher land to the north, to accumulate behind structures that obstruct the flow. This is confirmed by residents observations. In this instance, flood waters which exceeded the capacity of the road channel would have continued towards the properties on the southern side of the road. During the site visit it was noted that there were a number of road gullies along the road. These would have been vital in ensuring the drainage of the water, should these have been blocked, and the capacity would have been reduced. Photograph 3-11 shows that sandbags had been placed across the entrance to the building.

Photograph 3-8: Chalkwell Esplanade (looking west)

Photograph 3-9: Chalkwell Avenue (looking north)

Photograph 3-10: Chalkwell Station (looking south)

Photograph 3-11: The Ridgeway (looking south)

High level hydraulic calculations have been completed for two parts of the Chalkwell sewer catchment. These assume that the surface water network drains separately to foul network. Further details are provided in Appendix B.

The first calculations examine the capacity of the network draining the area to the west of Chalkwell, particularly the manhole adjacent to Chalkwell Train Station. The results indicate that no flooding of the network would occur with a free discharge. Therefore, under the 20th July scenario this section of network would have sufficient capacity and would not expect to flood.

The second calculation examines the capacity of the network along Chalkwell Avenue. This assumes the Chalkwell Pumping Station would operate at a maximum rate. For this section of the catchment, it was found that the capacity of the network at Chalkwell Avenue would have been reached after 4.6 mm of rain, resulting in flooding after 72 minutes.

3.8.3 Suggested Action

As described above, the Chalkwell area is very susceptible to flooding, predominantly as a result of the topography. AW already operate a storm overflow protection system within the area, however this will have minimal influence on the flooding across Chalkwell.

In the short term, SBC should advise residents and businesses on property protection measures that they could implement in the event of future flooding. As part of this, residents should be encouraged to sign up to Met Office weather warnings to receive warnings of extreme weather, including the potential for heavy rain.

In the long term, it is recommended that SuDS are implemented within the Chalkwell area to reduce the volumes and rates of runoff leaving the hard standing surfaces. This should be encouraged though communication with residents and business to educate on benefits. Likewise, car parks, or roads receiving low intensities of traffic, could be retrofitted with permeable paving measures during refurbishment works.

3.9 Manor Road

3.9.1 Overview

Within this area there was one recorded incident of flooding on the 20th July 2014. This area previously suffered from flooding on the 24th August and 11th October 2013. During flooding on the 24th August 2013, a land slip occurred on the slope at the south of Manor Road leading down to Western Esplanade which caused the surface water outfall to the Estuary to partially collapse.

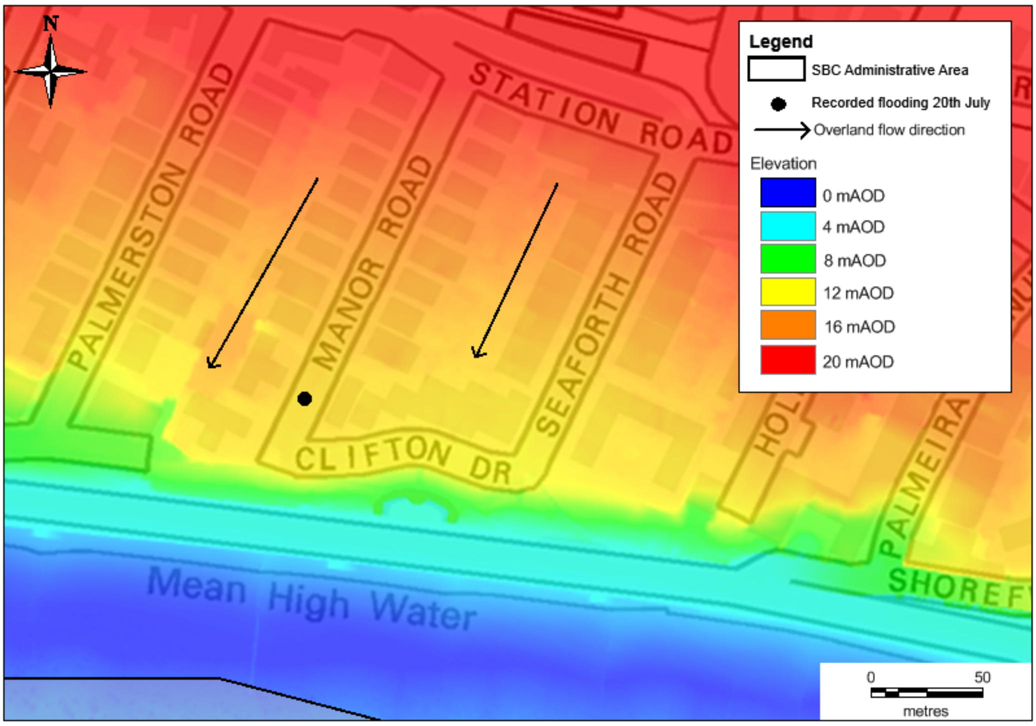
The collapse of the outfall combined with tide locking of the outfall due to a high tide in the Estuary on the 11th October 2013 caused further flooding in the area on Clifton Drive. Surface water surcharged from gullies and manholes on Clifton Drive and flowed down the slope onto Western Esplanade.

In November 2013 AW replaced the surface water outfall pipe from the junction of Clifton Drive and Manor Road which discharges under gravity to the Estuary.

3.9.2 Mechanisms for Flooding

Manor Road is situated on a steep slope in a largely impermeable area. As a result, surface water runoff from the area is less likely to infiltrate into the ground and instead flows overland, largely within the road channels. Figure 3-9 shows the local topography and dominant flow routes in the area.

Figure 3-9: Topography of Manor Road and surrounding area
Contains Ordnance Survey data © Crown copyright and database right 2014



Reports suggest that a manhole cover lifted at the southern end of Manor Road on the 20th July 2014.

Given the steep gradient of Manor Road, if road gully inlets become partially blocked, surface water runoff is likely to bypass the inlet grates. Runoff from Manor Road is likely to pond at the southern end at the junction with Clifton Drive.

The AW surface water sewers on Manor Road and Clifton Drive combine at this location before discharging via a 300 mm diameter pipe under gravity into the Estuary. As the tide was low at the time of the peak rainfall, there would be no restriction on the flow of the outfalls. Flooding is believed to have occurred at this location on the 24th August and 11th October 2013 as a result of high tides within the Estuary locking the outfall and the partial collapse of the outfall pipe further reducing its capacity. During the rainfall event on the 20th July however, there was a low tide within the Estuary and the outfall pipe had been replaced by AW. This suggests that there is a capacity issue within the network at this location even at times when the outfall pipe is operating at its full capacity.

If the capacity of the outfall pipe to the Estuary is unable to convey the incoming flow from the sewers on Manor Road and Clifton Drive, flow will back up in the network and surcharge at manholes as observed on the 20th July 2014.

3.9.3 Response to Flooding

AW has replaced the cover which became dislodged on the 20th July 2014. AW are currently undertaking works in this area and are proposing to complete re-lining work.

SBC are investigation the drainage in this area as part of cliff stabilisation works.

3.9.4 Suggested Action

It is recommended that AW investigate the capacity of this section of the public surface water sewer network. This should determine if there are any underlying causes for the frequent surcharging of the sewer network in this area. It is recommended that this includes:

- Understanding the relationship between the foul and surface water sewers'
- Ascertaining if there are any blockages or collapses which could be reducing capacity' and
- Determining if the outfall pipe configuration is sufficient to discharge flow from the network during rainfall events with a greater than 5% AEP.

3.10 Queensway

3.10.1 Overview

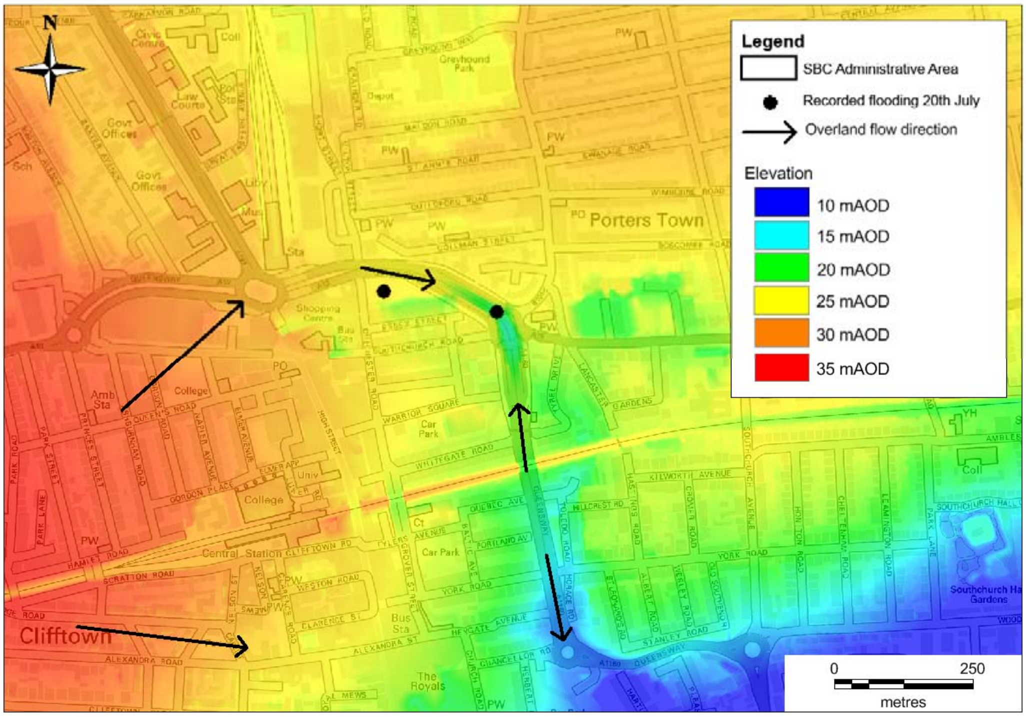
Within this area there was one report of flooding during the 20th July 2014. It is reported that in Queensway underpass at the junction with the A13, water ponded on the road surface and drained slowly into the road drainage systems. The A13 and Queensway is a key access route through Southend-on-Sea. This area previously suffered from flooding on the 24th August 2013.

3.10.2 Mechanisms for Flooding

Reports suggest that flooding occurred when surface water was unable to drain from the road surface into the road gullies in the lowest point of the underpass. As a result water ponded in the road.

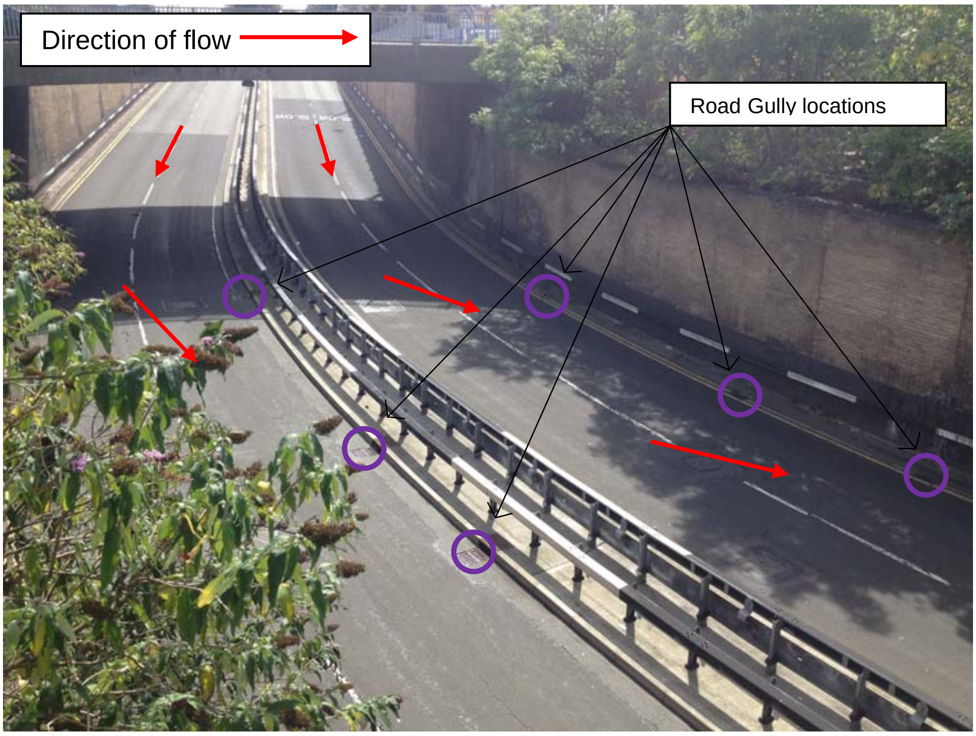
The ground level within the underpass is significantly lower (estimated to be 7m lower according to the LiDAR shown in Figure 3-10) than the surrounding areas. As a result, rainwater falling on the impervious road surface is directed towards the low point of the underpass. The ability of the road drainage to perform its function of removing rainwater from the surface is vital to prevent flooding of the underpass.

Figure 3-10: Topography at the Queensway underpass and surrounding area

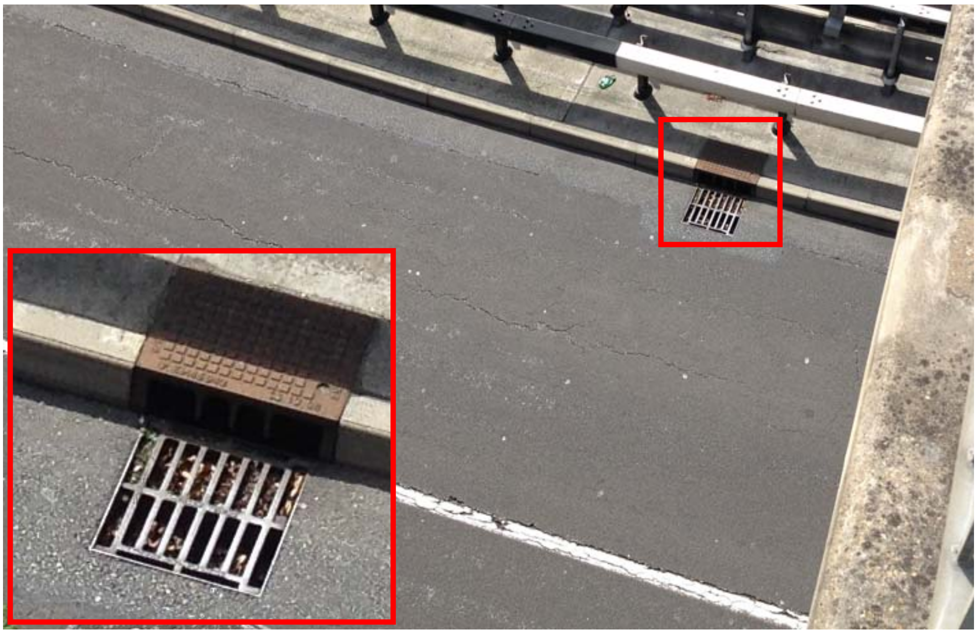


In order to adequately drain the road surface, the gullies need to be correctly placed and sufficient in number to convey the flow falling on the road channel. In addition the gullies need to be cleared of blockages and siltation in order to perform at their maximum capacity.

Observations during a site walkover on the 28th of August 2014 suggest that the problems within this area are likely to be caused by debris within the gullies causing blockages. Photos 3-12 and 3-13 show the location of road gullies and observed conditions.



Photograph 3-12: Photograph showing the number and location of road gullies within the Queensway underpass (looking south)



Photograph 3-13: Photograph showing the blockage of a road gully at the low point of the Queensway underpass (observations from the 28th August 2014 site walkover).

3.10.3 Response to Flooding

The SBC highways department operate a twice yearly cycle of gully cleansing across the borough.

Since the 20th July, SBC highways officers have attended the site to inspect the drainage system. The findings of their inspection are not currently known.

SBC have also checked and cleared the gullies in this area since the 20th July flooding.

3.10.4 Suggested Action

It is recommended that SBC increase the frequency of the clearance of gullies within the underpass. It is further recommended that if advanced weather warnings are received of heavy rainfall, that the gullies are inspected and cleared if required.

SBC should also prepare traffic management plans to divert traffic away from the underpass during flood events to prevent cars driving through flood water, which could be deep.

3.11 Lifstan Way

3.11.1 Overview

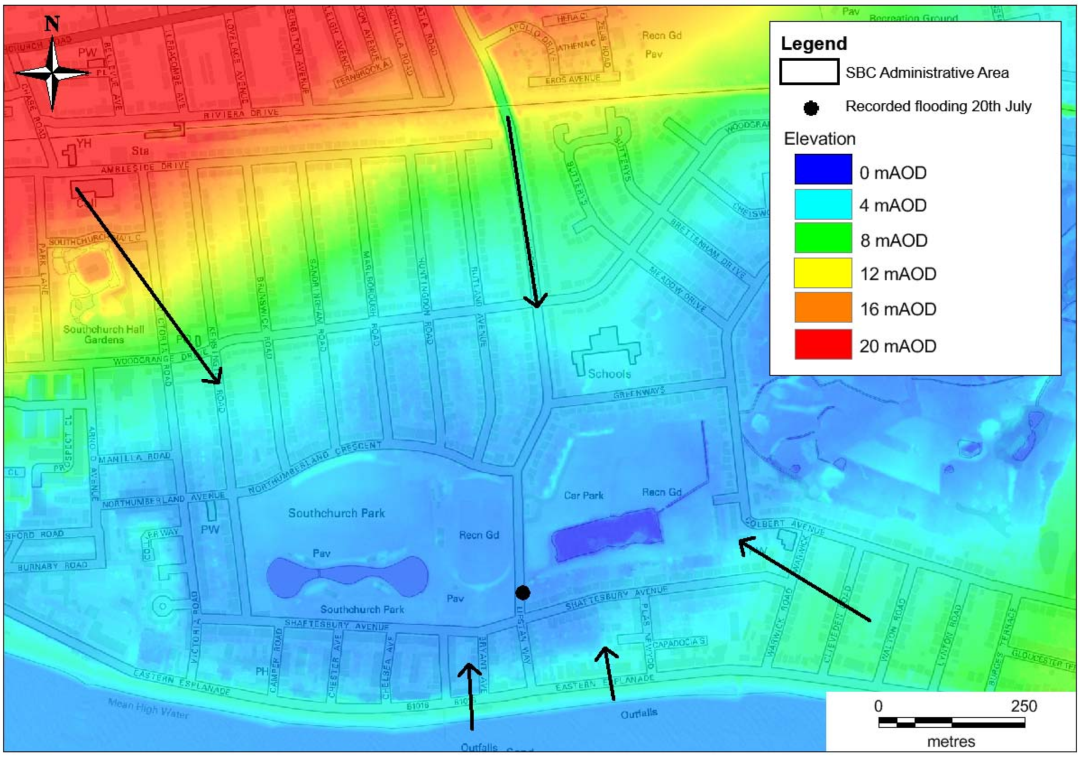
Lifstan Way is located within to the south of the borough and passes between Southchurch Park East and Southchurch Park West.

A manhole was observed to have lifted following rainfall on the 20th July. Three incidents of flooding had previously been recorded on the 24th August 2013 event, one of which was property flooding.

3.11.2 Mechanisms for Flooding

As shown in Figure 3-11, Lifstan Way is located at a low elevation of approximately 2 mAOD. The land to the north of Lifstan Way is at a higher elevation, resulting in the potential for overland flow to be generated and accumulate within the areas of lower elevation. More locally to Lifstan Way, the sea wall and land to the south east are at a greater elevation. Although to a lesser extent, there is also the potential for surface water runoff from these areas to accumulate within the low lying land around Lifstan Way.

Figure 3-11: Topography of Lifstan Way and surrounding area (black arrows indicate the general overland flow route) Contains Ordnance Survey data © Crown copyright and database right 2014



As a result of the topography, the surface water sewer network within this area is complex. Within Lifstan Way, adjacent to the location of flooding, there are two large surface water sewers. The first is a 750 mm diameter surface water sewer that is pumped to the outfall beyond Eastern Esplanade to the south. The second is a 900 mm outfall from the lake within

Southchurch Park East, which discharges via the Lifstan Way Pumping Station. There are no local surface water connections to these sewers at this point.

In addition, there are two smaller surface water sewers that drain the local area. The first of these is a 225 mm diameter sewer that functions to drain the area local to Lifstan Way, to the north of Shaftesbury Avenue. This drains in a northerly direction before connecting it to a network that discharges to the lake in Southchurch Park East. A second 225 mm diameter sewer drains the length of Lifstan Way between Eastern Esplanade and Shaftesbury Avenue. This drains in a northerly direction before connecting to a westerly flowing 600 mm sewer in Shaftesbury Avenue. The Shaftesbury Avenue sewer is then drained to the Thames Estuary via the Southchurch Park B Pumping Station.

Observations from the site walkover show manholes to be located at the junction of Shaftesbury Avenue and Lifstan Way. From the information available it cannot be determined which section of the surface water sewer exceeded capacity to cause surcharging from the manhole.

As the tide was low at the time of the peak rainfall, there would be no restriction on the flow of the outfalls.

It is considered likely that the surcharging sewer was one of the smaller 225 mm sewers that accept the surface water runoff from the local area. These will have responded rapidly to the intense rainfall resulting in capacity issues where the sewers join the larger network.

3.11.3 Response to Flooding

The flooding incident was recorded by Essex Police. SBC and AW were not aware of flooding within this area at the time of the incident.

SBC are currently undertaking investigations into the function of the drainage network within Southchurch Park. This may determine local causes of flooding, such as the condition of the network that may have contributed to flooding.

3.11.4 Suggested Action

Due to the low lying nature of Lifstan Way, this area will be at a greater risk of surface water flooding. SBC should work with residents to ensure that flood risk is understood and to advise on property level protection measures that can be taken.

In the longer term, options could be considered for providing flood storage within Southchurch Park to alleviate flooding within the residential areas. Additionally, ongoing installation of SuDS across the catchment would assist in reducing the volume and rate of surface water runoff draining towards the Lifstan Way area.

3.12 Other Incidents

In addition to the incidents described in Sections 3.1 – 3.11, isolated flooding was also recorded at:

- Leigh View Drive (flooding – unknown source);
- Rayleigh Road (flooding – unknown source);
- Glendale Gardens (highway flooding);
- Shakespeare Avenue (flooding – unknown source);

- Chichester Road (flooding – unknown source);
- Newington Avenue (flooding – unknown source); and,
- Temple Farm Industrial Estate (external flooding associated with the pumping station at the sewage treatment works).

As there are no previous incidents of flooding within these areas, it is considered that there is less susceptibility to flooding.

Should significant flooding within these areas be recorded again and the Council's criteria triggered, a more detailed investigation of the area should be undertaken.

It is likely that flooding occurred elsewhere across the Borough, but was not recorded. SBC should undertake public communication to ensure that the general public are aware of who to contact in the event of a flood. This will be of benefit to all RMAs as a greater evidence base would allow for further understanding of flooding mechanism, areas at greater risk and areas where funding could be sought.

3.13 Summary of flooding

Flooding on the 20th July 2014 resulted from a short duration of heavy rainfall. The centre of the storm was focused west of Southend-on-Sea, however the rainfall recorded within Southend-on-Sea is equivalent to a 50% AEP (1 in 2 year) event.

The investigation concluded that the majority of incidents were either associated with:

- the public surface water network - the responsibility of Anglian Water Services as the sewerage company for Southend-on-Sea,
- the highways drainage network - the responsibility of Southend-on-Sea Borough Council as the Highways Authority, or
- private drainage networks – the responsibility of individual property or land owners.

The primary mechanisms of flooding on the 20th July can be broadly defined into the following categories:

- **Network capacity** – For the majority of incidents, flooding was associated with lifted or surcharging manholes. At Southend General Hospital, it is thought that the manhole had not been bolted down, therefore the sewer surcharged more easily. For the instances at Prince Avenue, Rochford Road, Chalkwell, Manor Road and Lifstan Way the cause of flooding is thought to be due to capacity issues within the surface water network.
- **Gully capacity** - For many of the incidents, it is thought that the capacity of the network was overwhelmed by the intensity of the rainfall. As a result, surface water was not able to enter the drainage network and so accumulated in areas of low-lying topography. This occurred in areas such as Thorndon Park Drive, Highlands Boulevard and at Prince Avenue.
- **Maintenance issues** - flooding at the Queensway underpass and Harp House Roundabout was considered to be a result of maintenance issues, restricting the function of the highway drainage.

- **River channels -** the water level of Prittle Brook was recorded to respond rapidly to rainfall. It is also considered that the Eastwood Brook demonstrates the same rapid response. Following the rainfall, the water levels within the channels of these rivers rose rapidly. In the case of the Eastwood Brook, this resulted in flooding at Glenwood Avenue as water overtopped the channel at the head of the culvert. Along Prittle Brook, this restricted the discharge of surface water outfalls draining into the river, resulting in water backing up the network within the Cavendish Gardens area.

4. FLOOD INVESTIGATION OUTCOMES

4.1 Overview

This section aims to outline a summary of responses for each of the RMAs that operate within the SBC area and suggested actions for further management of flood risk.

4.2 Southend-on-Sea Borough Council

4.2.1 … as LLFA

As the LLFA, SBC has conducted this investigation into flooding and has consulted with the relevant RMAs. SBC will publish the result of this Flood Investigation and notify the relevant RMAs and stakeholders.

Incidents of flooding have subsequently been reported to the RMAs.

SBC will coordinate with the RMAs areas for further work and investigation.

4.2.2 … as Highways Authority and Emergency Responder

SBC as the Highways Authority is responsible for the maintenance of the highways across the borough. When flooding was observed as a result of failures of highways assets, SBC Highways undertook necessary works to replace or modify these as needed. For example, clearing the highways gullies within the Queensway underpass.

SBC operate a twice yearly clearing of the gully pots, however gully pipes are not regularly inspected. SBC operate a reactive approach to the maintenance of gully pipes, responding when flooding is observed. Although the network is extensive, SBC should consider developing a proactive maintenance strategy, focussing in areas at greatest risk of surface water flooding.

SBC have agreed strategic pumping locations with Essex Fire and Rescue including Victoria Road and Marine Parade. In addition, SBC have plans detailing the procedure required for closing flooded highways where necessary.

SBC have made provision for an additional Environmental Care Officer to be on standby in the event of flooding.

4.3 Environment Agency

Correspondence with the EA has outlined that there were no calls logged within the SBC area for the 20th July.

The EA outline that on a day-to-day basis, calls are often received regarding blockages on Prittle Brook, Eastwood Brook and Nobels Green Ditch (shown in Figure 1-1). Often blockages are a result of fly tipping or areas where riparian owners are not aware of their responsibilities.

EA officers undertake weekly clearances of trash screens across the area. EA Flood Incident Duty Officers will also instruct Field Teams to check all known ‘hotspots’ prior to any forecast heavy rainfall. Such ‘hotspots’ include the Prittle Tunnel intake and debris screen at Manchester Drive on Prittle Brook. The EA will respond to calls of flooding as required.

As described previously in Section 3.2.5, the EA are in the process of installing a gauging station on Eastwood Brook, upstream of Southend-on-Sea. This would be used to provide flood alerts and flood warnings to the residents downstream. Pending funding, the EA will also undertake an investigation into the flood risk associated with Eastwood Brook.

4.4 Anglian Water

AW has stated that no internal property flooding was reported to have occurred on the 20th of July, resulting from flooding from the sewer network.

AW have records of external flooding at Temple Farm Industrial state and Highlands Boulevard.

As part of this investigation, Anglian Water has been informed of the incidents recorded by SBC to result from manhole flooding. As the rainfall event leading to flooding is considerably less than the extreme event threshold set by AW, the incidents of flooding should be investigated further by AW.

In particular, the drainage network at the following locations should be inspected:

- Prince Avenue,
- Rochford Road,
- Chalkwell,
- Manor Road, and
- Lifstan way.

The findings of the investigation should be reported to SBC as the LLFA.

5. NEXT STEPS

SBC's role as LLFA is to coordinate the management of flood risk within their administrative area. A series of actions for SBC and other RMAs, with respect to flood risk across the borough, are outlined below. Each of the RMAs should provide an update on progress at the quarterly flood group meetings.

If following a review of this Flood Incident Report and liaison with RMAs, flood risk is considered to be unacceptable at a site SBC should investigate potential capital schemes which could provide flood alleviation within these areas. A follow-up meeting should be held with RMAs to discuss potential options to be taken forward.

5.1 Actions

Suggested actions for the RMAs have been highlighted within each of the areas investigated within Chapter 3. In addition, the assessments of flooding mechanisms highlight several actions that could be applied across the borough. These are detailed in Table 5-1 below.

Table 5-1: Action Plan

ID	Action	Lead RMA (Support)	Area to be Implemented
1	Communication: Encourage residents to report issues of flooding. Outline who this should be reported to (SBC, AW, EA), and what mechanisms are available to report (phone, email, mobile app etc.). Additional information could be made available through the council website. This would be used to ensure as many records as possible are noted.	SBC (EA, AW, residents, business owners)	Borough Wide
2	Records: Ensure systems are set up at the council to efficiently record details of flooding. This is needed to gather as much information as possible about each incident at the time of flooding. This will be essential in ensuring the correct flooding mechanisms are understood.	SBC	N/A
3	Investigate capacity: As many of the flooding incidents are associated with flooding of the drainage system, actions should be taken to survey and identify potential capacity issues.	AW (SBC)	Prince Avenue, Rochford Road, Chalkwell, Manor Road and Lifstan way
4	Implement SuDS: As part of the investigation, the implementation of SuDS has been suggested as part of a long term approach to reducing the pressure on the surface water drainage network. Further investigation into the feasibility of such schemes would need to be examined prior to implementation.	SBC (residents & businesses)	Borough Wide
5	Investigate the potential for the use of the central verge within Highlands Boulevard as a conveyance route for surface water.	SBC (residents & businesses)	Highlands Boulevard

ID	Action	Lead RMA (Support)	Area to be Implemented
6	Investigate the potential for flood storage within Southchurch Park to alleviate flood risk to Lifstan Way.	SBC (residents & businesses)	Lifstan Way
7	As several issues were associated with poor maintenance, it is recommended that more targetted maintenance is undertaken, especially for highways drainage.	SBC	Thorndon Park Drive, Queensway underpass. Flood Risk Areas generally.
8	SBC should consider methods of liaising with residents to ensure flood risk is understood . This would be beneficial in disseminating information and managing local flood risk.	SBC (EA, AW, residents, businesses)	Glennwood Avenue, Chalkwell Esplanade,
9	Property level protection: Residents should be provided with information and encouraged to consider implementing property level protection where necessary.	residents and businesses (SBC)	Borough wide.
10	Register areas with a single incident of flooding to help identify triggering criteria for future Flood Incident Reports.	SBC (EA, AWS)	Leigh View Drive, Rayleigh Road, Glendale Gardens, Shakespeare Avenue, Chichester Road and Newington Avenue

APPENDIX A – RAINFALL DATA AND RETURN PERIOD CALCULATIONS

The rainfall return period has been estimated in order to determine the relative magnitude of the event of the 20th July 2014 event and allow for the comparison of standards of protection. The assessment of the return period has been made using industry standard techniques outlined in the Flood Estimation Handbook (FEH). The FEH CD-ROM provides catchment descriptors for four million UK catchments that drain an area of 0.5km^2 or more.

The method used involved determining the maximum depth of rain over a range of durations for the 1km^2 in which the rain gauge is situated.

Depth-Duration-Frequency is an empirical model based on the Generalised Extreme Value Distribution and is best used for analysing rainfall duration of between one hour and eight days and such models contain inherent uncertainty. The FEH (Volume 2, Section 2) notes that extrapolation beyond these thresholds (i.e. half an hour) is justified, however the resultant answers should be treated with less confidence due to the extrapolation.

The assessment has found that for the 3 hour rainfall event, a maximum depth of 16.4 mm was recorded, equating to a 1 in 1.46 chance of occurrence in any given year. The greatest intensity recorded over a 1 hour period was 13.2 mm, the equivalent of a 1 in 1.74 chance of occurrence in any given year. Due to the limitations of the methodology used to determine this, it is considered that that the chance of this occurring should be considered to be less than 1 in 2 years.

It should be noted that the methodology used to determine the rainfall return period within FEH cannot be used for rainfall events of 30 minutes or less. As a result, estimating the return period of the storm at its peak (considering only the 8.2mm within 15 minutes) is not possible.

The catchment associated with the Southchurch Park rain gauge is detailed in Figure A-1 below. The catchment descriptors of the 1km^2 area at the rain gauge location were used in these calculations.

Figure A-1 – Southchurch Park Catchment Area as shown in the FEH CD-ROM

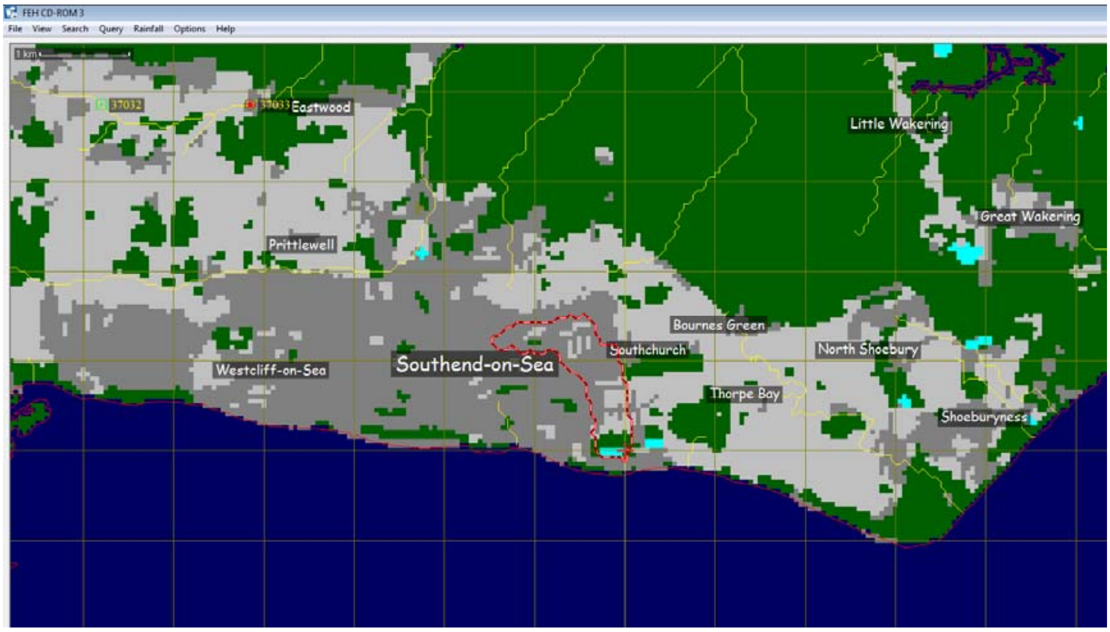


Table A-1 – Calculation of return period based on peak rainfall depths

Southchurch Park rain gauge data			Calculation of peak rainfall depths: duration (hours)					
Date	Time	Rainfall [mm]	0.5	1	2	3	3.5	4
20/07/2014	13:15:00	0						
20/07/2014	13:30:00	0.2	0.2					
20/07/2014	13:45:00	1.4	1.6					
20/07/2014	14:00:00	8.2	9.6	9.8				
20/07/2014	14:15:00	2.2	10.4	12				
20/07/2014	14:30:00	1.4	3.6	13.2				
20/07/2014	14:45:00	1	2.4	12.8				
20/07/2014	15:00:00	0.6	1.6	5.2	15			
20/07/2014	15:15:00	0.4	1	3.4	15.4			
20/07/2014	15:30:00	0.4	0.8	2.4	15.6			
20/07/2014	15:45:00	0.4	0.8	1.8	14.6			
20/07/2014	16:00:00	0	0.4	1.2	6.4	16.2		
20/07/2014	16:15:00	0.2	0.2	1	4.4	16.4		
20/07/2014	16:30:00	0.2	0.4	0.8	3.2	16.4	16.6	
20/07/2014	16:45:00	0	0.2	0.4	2.2	15	16.6	
20/07/2014	17:00:00	0	0	0.4	1.6	6.8	16.4	16.6
20/07/2014	17:15:00	0	0	0.2	1.2	4.6	15	16.6
20/07/2014	17:30:00	0	0	0	0.8	3.2	6.8	16.4
20/07/2014	17:45:00	0	0	0	0.4	2.2	4.6	15
20/07/2014	18:00:00	0	0	0	0.4	1.6	3.2	6.8
20/07/2014	18:15:00	0	0	0	0.2	1.2	2.2	4.6
20/07/2014	18:30:00	0	0	0	0	0.8	1.6	3.2
20/07/2014	18:45:00	0	0	0	0	0.4	1.2	2.2
20/07/2014	19:00:00	0	0	0	0	0.4	0.8	1.6
20/07/2014	19:15:00	0	0	0	0	0.2	0.4	1.2
20/07/2014	19:30:00	0	0	0	0	0	0.4	0.8
20/07/2014	19:45:00	0	0	0	0	0	0.2	0.4
20/07/2014	20:00:00	0	0	0	0	0	0	0.4
20/07/2014	20:15:00	0	0	0	0	0	0	0.2
20/07/2014	20:30:00	0	0	0	0	0	0	0

	0.5	1	2	3	3.5	4
Maximum depth (mm)	10.4	13.2	15.6	16.4	16.6	16.6
Return Period	1.6	1.74	1.65	1.46	1.38	1.3

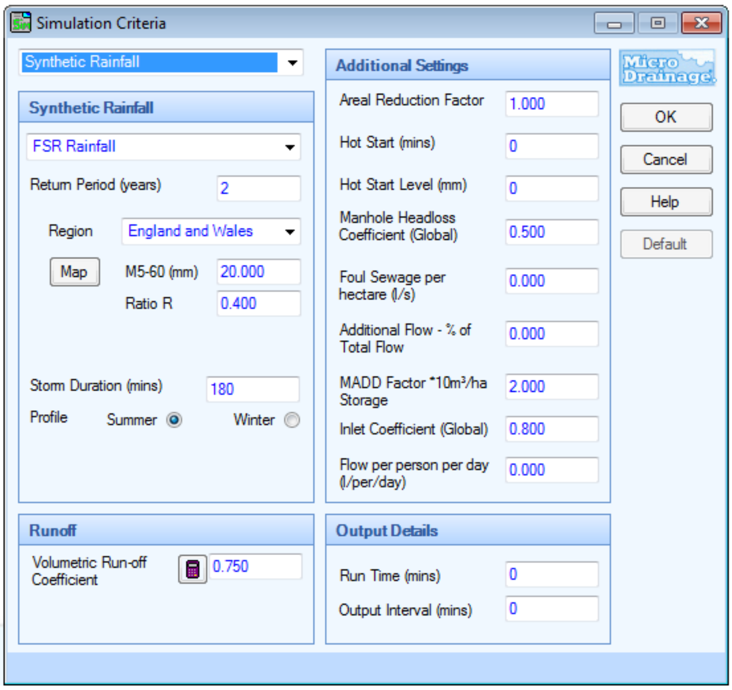
APPENDIX B

B-1 SOUTHEND GENERAL HOSPITAL

1.1 Indicative Catchment Location and Extent

Catchment Area = 0.1452 sq km

1.2 Rainfall and Model Parameters



The rainfall was calculated based on 16.6 mm of rain falling over a 3 hour period.

The FEH event rarity tool was used to calculate the return period for the event was the 1 in 2 year.

The 1 in 2 year 180 minute summer storm was therefore used in the simulation.

1.3 Model Results

The modelling was undertaken on the basis of three separate tidal scenarios. A 100% blockage scenario, a 50% blockage scenario and a 0% blockage scenario.

The scenarios were modelled based on using an orifice to restrict the cross sectional area of the outfall pipe.

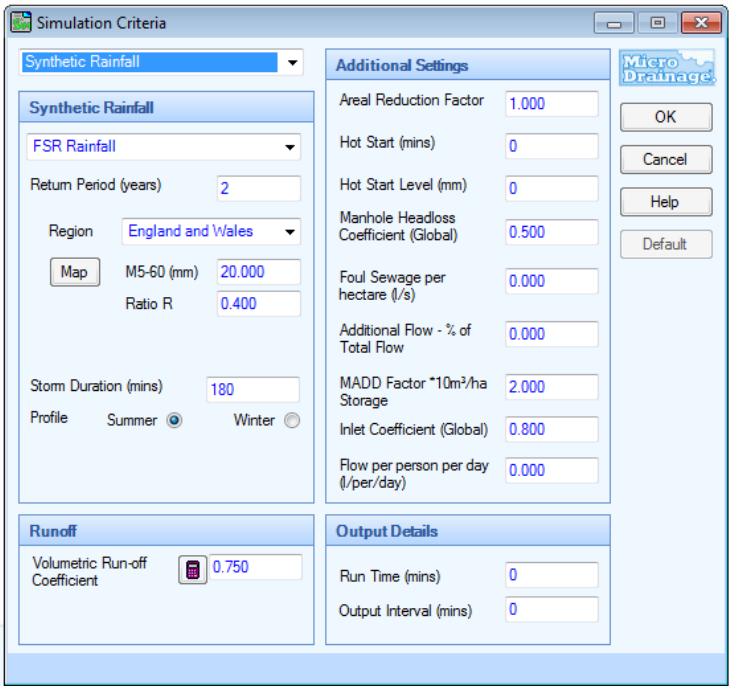
SUMMARY OF MODELLING RESULTS		
Tide Scenario	**Time to onset of flooding (min)**	**Rainfall Depth Required for Flooding (mm)**
100% tide locked	27	0.9
50% tide locked	81	5.8
0% tide locked	No Flooding	-

B-2 HIGHLANDS BOULEVARD

2.1 Indicative Catchment Location and Extent

Catchment Area = 0.0612 sq km

2.2 Rainfall and Model Parameters



The rainfall was calculated based on 16.6 mm of rain falling over a 3 hour period.

The FEH event rarity tool was used to calculate the return period for the event was the 1 in 2 year.

The 1 in 2 year 180 minute summer storm was therefore used in the simulation.

2.3 Model Results

The modelling was undertaken on the basis of three separate 100% restricted flow scenarios. A 100% blockage scenario, a 50% blockage scenario and a 0% blockage scenario. This was to represent the effect of a surcharged system downstream.

The scenarios were modelled based on using an orifice to restrict the cross sectional area of the outfall pipe.

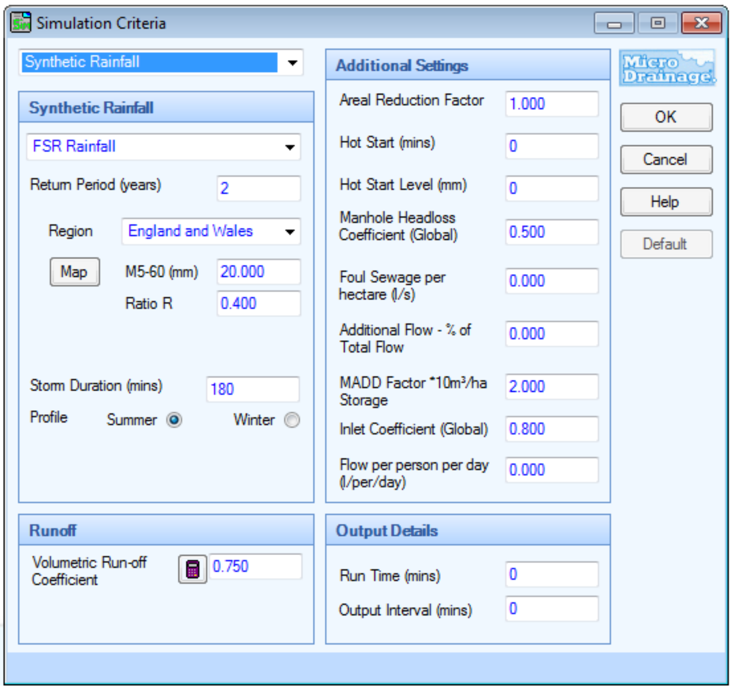
SUMMARY OF MODELLING RESULTS		
Tide Scenario	**Time to onset of flooding (min)**	**Rainfall Depth Required for Flooding (mm)**
100% restricted flow	36	1.5
50% restricted flow	90	9.7
0% restricted flow	No Flooding	-

B-3 PRINCE AVENUE

3.1 Indicative Catchment Location and Extent

Catchment Area = 0.6097 sq km

3.2 Rainfall and Model Parameters



The rainfall was calculated based on 16.6 mm of rain falling over a 3 hour period.

The FEH event rarity tool was used to calculate the return period for the event was the 1 in 2 year.

The 1 in 2 year 180 minute summer storm was therefore used in the simulation.

3.3 Model Results

The modelling was undertaken on the basis of two separate scenarios of restricted flow into the downstream sewer. The scenarios modelled are a 50% blockage scenario and a 0% blockage scenario.

The scenarios were modelled based on using an orifice to restrict the cross sectional area of the outfall pipe.

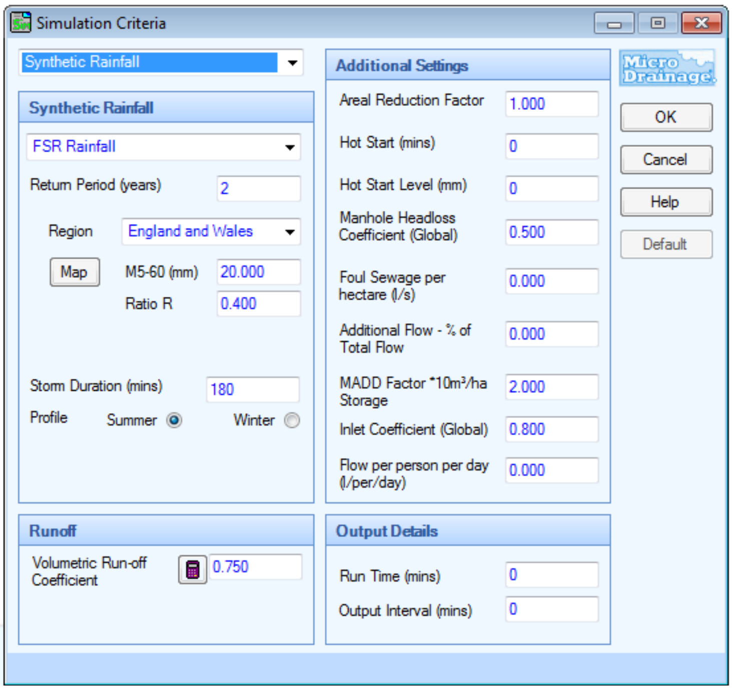
SUMMARY OF MODELLING RESULTS		
Tide Scenario	**Time to onset of flooding (min)**	**Rainfall Depth Required for Flooding (mm)**
50% reduced flow	72	4.6
0% reduced flow	84	7.4

B-4 NIGHTINGALE CLOSE AT ROCHFORD ROAD

4.1 Indicative Catchment Location and Extent

Catchment Area = 0.022 sq km

4.2 Rainfall and Model Parameters



The rainfall was calculated based on 16.6 mm of rain falling over a 3 hour period.

The FEH event rarity tool was used to calculate the return period for the event was the 1 in 2 year.

The 1 in 2 year 180 minute summer storm was therefore used in the simulation.

4.3 Model Results

The modelling was undertaken on the basis of there being no restriction on the outfall.

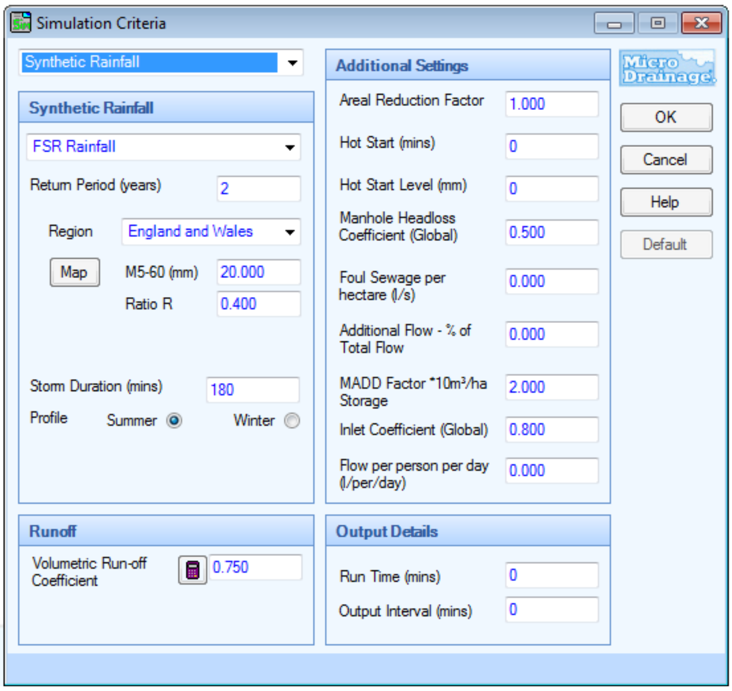
SUMMARY OF MODELLING RESULTS		
Tide Scenario	**Time to onset of flooding (min)**	**Rainfall Depth Required for Flooding (mm)**
No restrictions on outfall	No Flooding	-

B-5 ROCHFORD ROAD AT SIDWORTH AVENUE

5.1 Indicative Catchment Location and Extent

Catchment Area = 0.8785 sq km

5.2 Rainfall and Model Parameters



The rainfall was calculated based on 16.6 mm of rain falling over a 3 hour period.

The FEH event rarity tool was used to calculate the return period for the event was the 1 in 2 year.

The 1 in 2 year 180 minute summer storm was therefore used in the simulation.

5.3 Model Results

The modelling was undertaken to establish the capacity of the sewer in relation to the design storm event. A simple model was developed of the sewer which suffered flooding, and both of the sewers immediately upstream. The catchment area and runoff was calculated to establish whether or not flooding would occur to the pipe for the design storm. No control was placed on the downstream pipe and so the sewer was able to discharge freely.

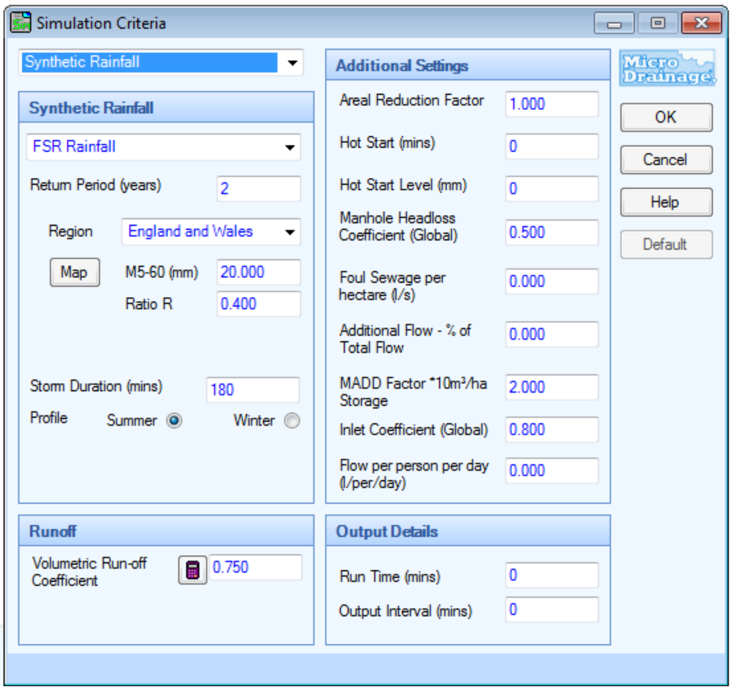
SUMMARY OF MODELLING RESULTS		
Tide Scenario	**Time to onset of flooding (min)**	**Rainfall Depth Required for Flooding (mm)**
0% reduced flow	84	7.1

B-6 CAVENDISH GARDENS

6.1 Indicative Catchment Location and Extent

Catchment Area = 0.1542 sq km

6.2 Rainfall and Model Parameters



The rainfall was calculated based on 16.6 mm of rain falling over a 3 hour period.

The FEH event rarity tool was used to calculate the return period for the event was the 1 in 2 year.

The 1 in 2 year 180 minute summer storm was therefore used in the simulation.

6.3 Model Results

The modelling was undertaken on the basis of three separate tidal scenarios. A 100% blockage scenario, a 50% blockage scenario and a 0% blockage scenario.

The scenarios were modelled based on using an orifice to restrict the cross sectional area of the outfall pipe.

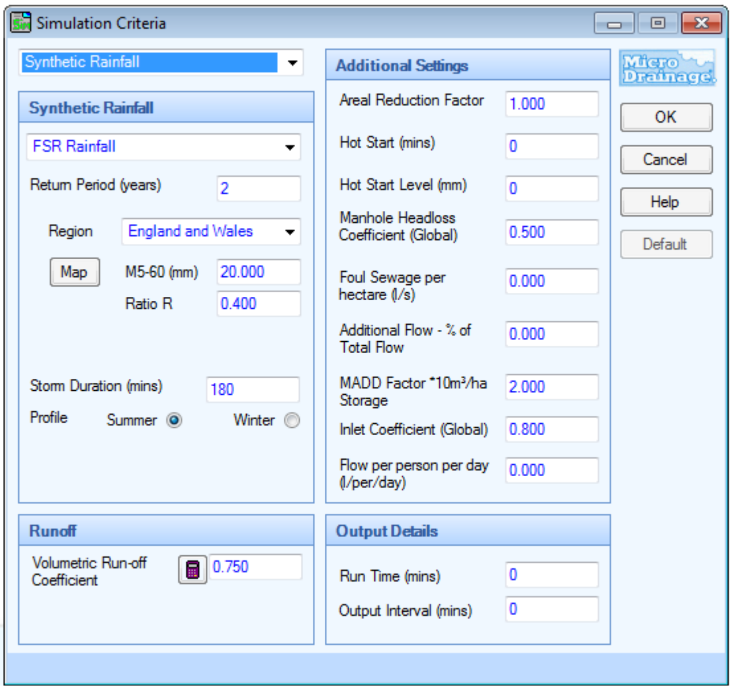
SUMMARY OF MODELLING RESULTS		
Tide Scenario	**Time to onset of flooding (min)**	**Rainfall Depth Required for Flooding (mm)**
100% tide locked	9	0.2
50% tide locked	63	3.4
0% tide locked	99	13.7

B-7 CHALKWELL 1

7.1 Indicative Catchment Location and Extent

Catchment Area = 0.1349 sq km

7.2 Rainfall and Model Parameters



The rainfall was calculated based on 16.6 mm of rain falling over a 3 hour period.

The FEH event rarity tool was used to calculate the return period for the event was the 1 in 2 year.

The 1 in 2 year 180 minute summer storm was therefore used in the simulation.

7.3 Model Results

The modelling was undertaken on the basis of three separate tidal scenarios. A 100% blockage scenario, a 50% blockage scenario and a 0% blockage scenario.

The scenarios were modelled based on using an orifice to restrict the cross sectional area of the outfall pipe.

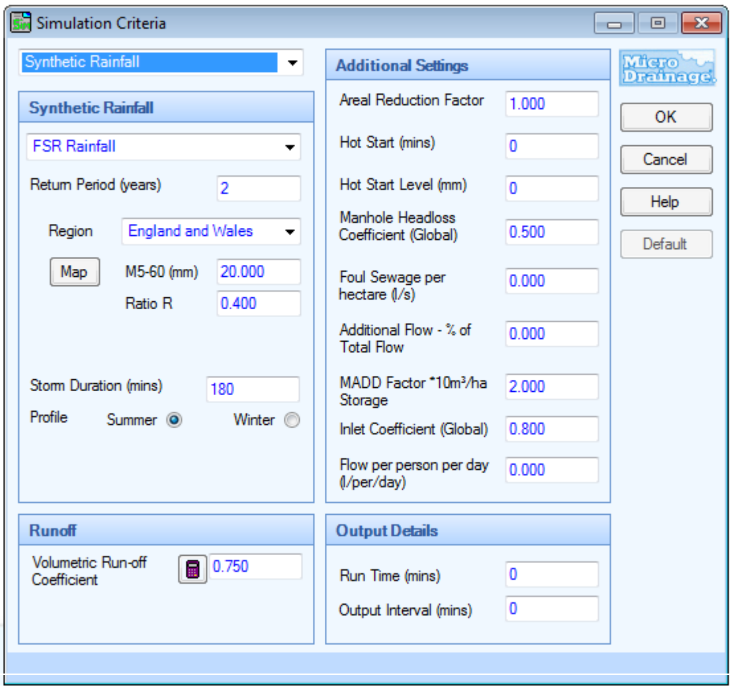
SUMMARY OF MODELLING RESULTS		
Tide Scenario	**Time to onset of flooding (min)**	**Rainfall Depth Required for Flooding (mm)**
100% tide locked	33	1.3
50% tide locked	No Flooding	-
0% tide locked	No Flooding	-

B-8 CHALKWELL 2

8.1 Indicative Catchment Location and Extent

Catchment Area = 0.5687 sq km

8.2 Rainfall and Model Parameters



The rainfall was calculated based on 16.6 mm of rain falling over a 3 hour period.

The FEH event rarity tool was used to calculate the return period for the event was the 1 in 2 year.

The 1 in 2 year 180 minute summer storm was therefore used in the simulation.

8.3 Model Results

The modelling was undertaken on the basis of the outfall into the sea being via a 180 l/s pump. One scenario was therefore modelled in which an orifice plate was attached to the outfall pipe to restrict the outflow to 180 l/s.

As no information regarding the pump station capacity, cut in and cut out levels the pump itself was not explicitly modelled.

SUMMARY OF MODELLING RESULTS		
Tide Scenario	**Time to onset of flooding (min)**	**Rainfall Depth Required for Flooding (mm)**
Restricted to 180 l/s	72	4.6