URS

Southend-on-Sea 11th October 2013 Flood Investigation Report

Final

March 2015

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UNITED KINGDOM & IRELAND

Prepared for:

southend on sea BOROUGH COUNCIL

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REVISION SCHEDULE

Rev	Date	Details	Prepared by	Reviewed by	Approved by
1	October 2014	1st Draft for Client Comment	Danielle Skilton Flood Risk Consultant	Sarah Kelly Principal Consultant	Elizabeth Gent Principal Consultant
2	February 2015	Final Draft	Danielle Skilton Flood Risk Consultant	Elizabeth Gent Principal Consultant	Elizabeth Gent Principal Consultant
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EXECUTIVE SUMMARY

This report constitutes the findings of the flood investigation completed for the flooding event of the 11th October 2013 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 on the 11th October 2013 as a result of heavy rainfall coinciding with high tides resulting in 20 recorded incidents of flooding. Three areas saw repeated flooding on the 13th October 2013 following further rainfall.

At its peak, 37 mm of rain was recorded to fall over a 17 hour period on the 11th October. This has been estimated to between the equivalent of a 1 in 1 year and a 1 in 3.3 year rainfall return period event. Rainfall for the 13th October totalled 11.2 mm within 12 hours and 25 minutes. The intensity of this rainfall is estimated to be a "commonplace" event with a return period of less than 1 month.

The flood investigation examined specific sites in more detail to determine the likely mechanisms of flooding, Risk Management Authority (RMA) responsibilities and responses and suggest actions. The sites examined have been limited to those that have suffered repeated flooding and include:

- Chalkwell Esplanade and Chalkwell Avenue;
- Clifton Drive and Western Esplanade;
- Victoria Avenue;
- Warners Bridge Roundabout;
- Rodbridge Drive;
- Thorpe Hall Avenue;
- Wakering Road;
- Campfield Road and Ness Road; and,
- Ness Road and Shoebury Common Road.

The investigation determined that flooding incidents predominantly resulted from issues associated with maintenance of assets. This resulted in the impeded function of inflow of water to highways gullies and restriction of flow from drainage network outfalls.

In most instances, the responsible RMAs (Southend-on-Sea Borough Council as the Highways Authority and Anglian Water as the drainage authority), attended the sites and resolved the issues at the time, or shortly after the flooding.

In the short term, it is recommended that maintenance of assets within areas prone to flooding is prioritised to ensure the continued performance of the drainage network. In the longer term, it is recommended that there is wide scale implementation of Sustainable Drainage Systems (SuDS) to attenuate surface water at the source and reduce the rate of runoff from the urban catchment areas. This will act to reduce the pressure on the drainage network and reduce the risk of flooding from more frequent rainfall events.

The mechanisms for flooding at Rodbridge Drive could not be determined from the data available. It has therefore been recommended that the Anglian Water and Southend-on-Sea Borough Council undertake surveys of the drainage network in this area to determine the cause of the flooding and improve understanding of the flooding mechanisms.

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 and Essex & Suffolk Water),
- Highways Authority (SBC).

1.2 Criteria for Investigating Flood 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 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 an investigation into the flooding incidents across Southend-on-Sea on 11th October 2013 as disruption occurred across the Borough within a relatively short timeframe since the last flooding incident on the 24th August 2013.

This report will focus on areas which have seen repeated flooding either following the 24th August event or flooding on both the 11th and 13th October. This report constitutes a record of this investigation.

1.3 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

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.

SBC hold quarterly Flood Group Meetings with the RMAs to discuss and report on flood management.

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

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. 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 (highway drains, road gullies and gully leads).

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 1.2) 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. 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. As part of the AW network with Southend-on-Sea, there are a number of culverted watercourses that fall under AW's jurisdiction.

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

[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

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.

1.3.4 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 to managing and repair this as the water undertaker.

1.3.5 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 riparian 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 EA's document, 'Living on the Edge' (2012)[x].

1.3.6 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.

1.4 Consultation

Investigation of flooding at Southend-on-Sea on 11th October 2013 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 2013 flooding event[xi]. As a result, much of the previous discussion also applied to the 11th October 2013 event.

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

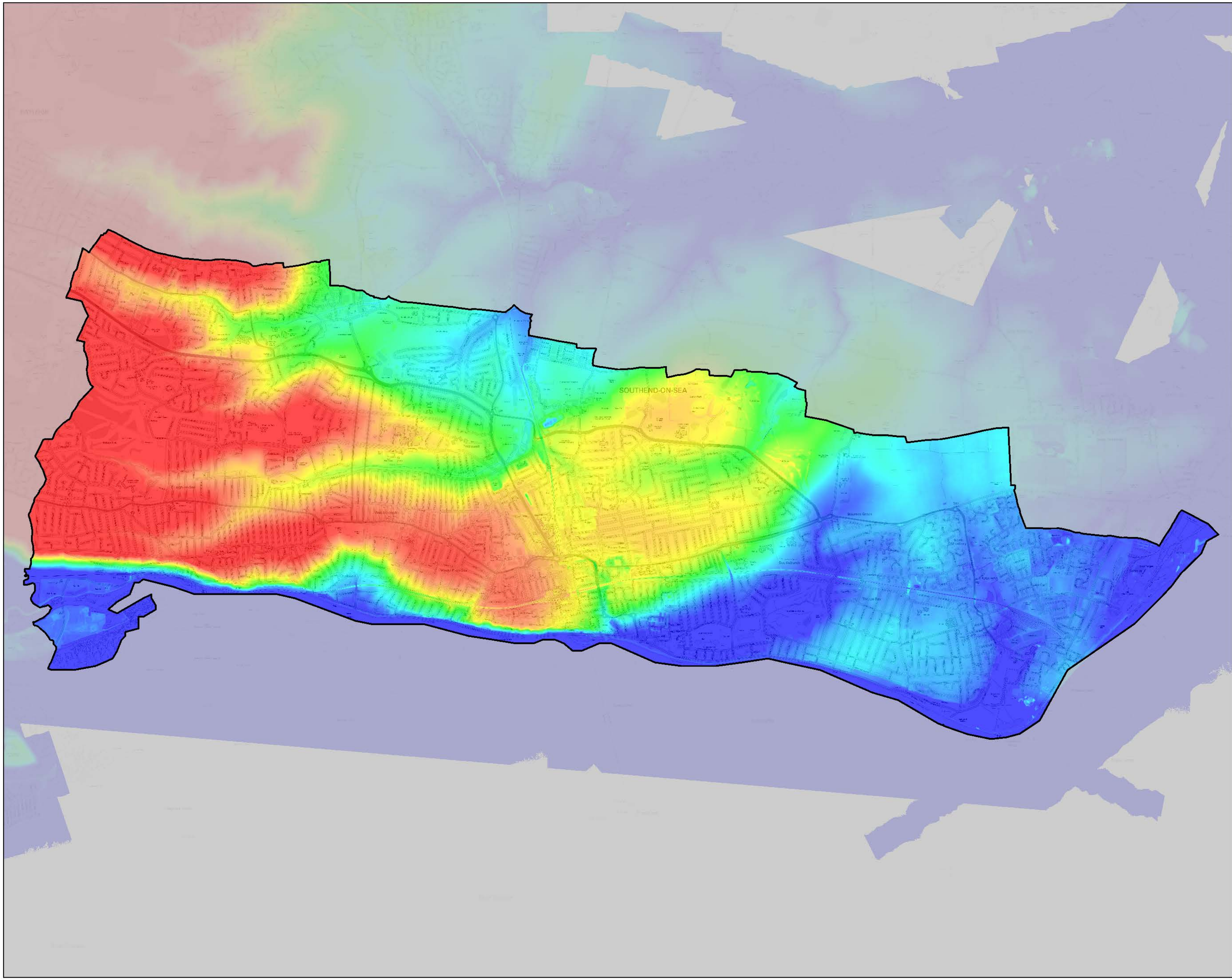
1.5 Site Description

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.

[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
[xi] Southend-on-Sea 24th August 2013 Flood Investigation Report (URS, 2014)

Southend-on-Sea is heavily urbanised with dense residential and commercial development. The topography of the borough can be seen in Figure 1-1. 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 Figure 1-2 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.



Legend

Southend-on-Sea Borough Extent

Elevation (mAOD)

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

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Purpose of Issue: FINAL

Client: southend on sea

Project Title: SOUTHEND-ON-SEA 11TH OF OCTOBER 2013 FLOOD INVESTIGATION REPORT

Drawing Title: SOUTHEND-ON-SEA TOPOGRAPHY

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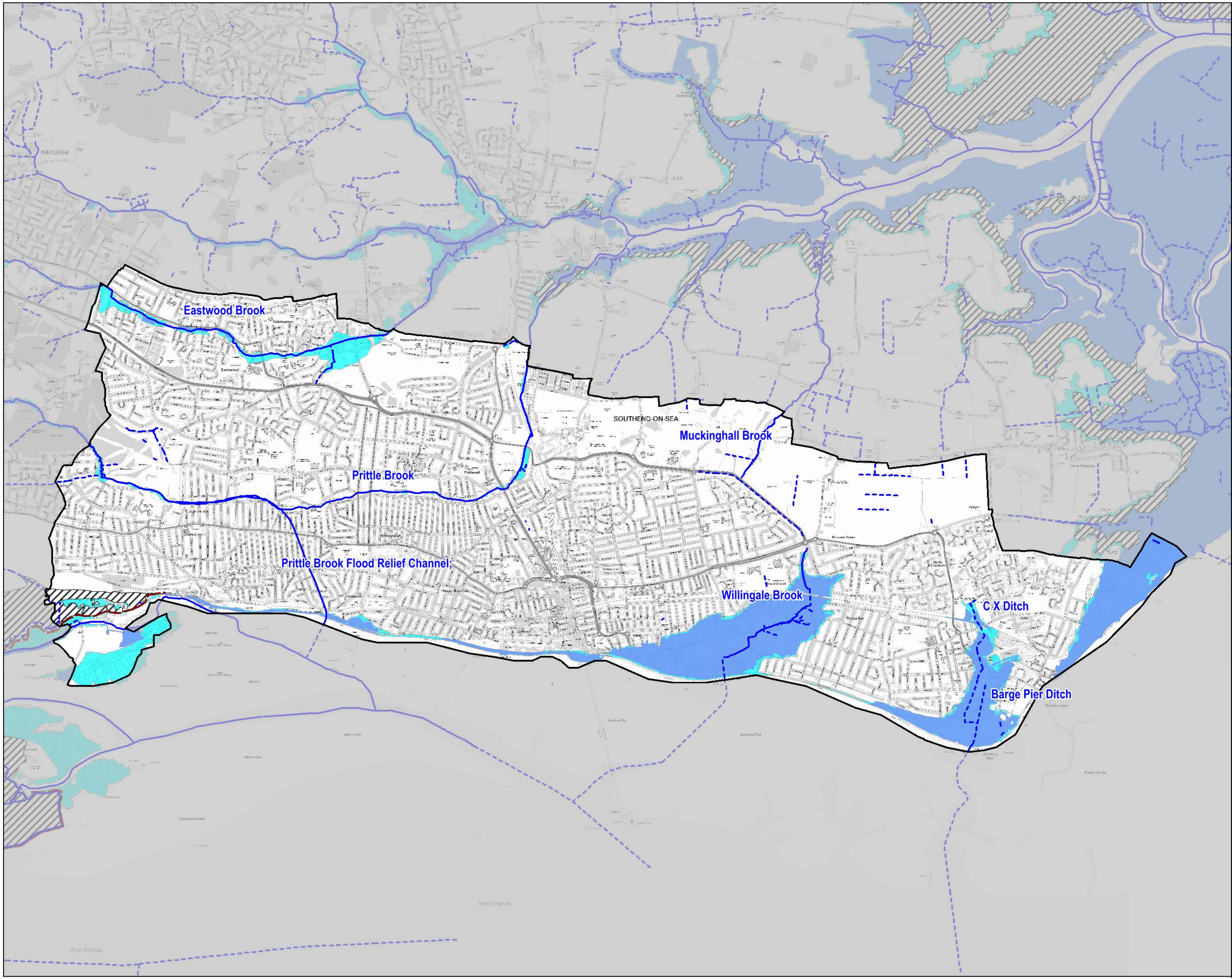
Drawing Number	Rev
Figure 1-1	3



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	Check Date	Suffix

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Drawing Number: Figure 1-2
Rev: 3

2 FLOOD INCIDENT DETAILS

SBC was subject to widespread flooding on the 11th October 2013 as a result of heavy rainfall coinciding with high tides. Manor Road, Wakering Road and Ness Road saw repeated flooding on the 13th October 2013 following further rainfall. The following section details the conditions leading up to the flood event and the resulting impacts.

2.1 Weather Warnings and Flood Alerts

The Met Office[xii] describes the weather observed on the 11th October to be as a result of a low pressure, centred in the North Sea. This resulted in rain and strong winds for the south and south-eastern areas of the country. Rain continued on the 12th and 13th in eastern and southern areas of the UK.

A Flood Alert[xiii] was issued by the Environment Agency for the River Roach, Prittle Brook and Eastwood Brook at 16:48 on the 11th October. On the 13th of October, a Flood Alert for the same area was issued at 10:05.

Figure 2-3 details the areas within Southend-on-Sea which receive these flood alerts.

2.2 Recorded Rainfall

The EA tipping bucket rain gauge located in Southchurch Park (Ordnance Survey National Grid Reference: 589992, 184988) recorded 38.6 mm of rain to have fallen between 03:00 to 23:15 on the 11th October. At the peak rainfall intensity, 37 mm of rain fell over 17.75 hours (between 03:00 – 20:45), with 4.2 mm falling within 15 minutes at 16:00. This is plotted in Figure 2-1. By comparison, the average monthly rainfall for this area in October is approximately 59.9 mm.

Radar data supplied by the Environment Agency shows a peak rainfall intensity of 3.4 mm to fall at 15:15, 2.6 km to the west of the Southchurch park rain gauge. Between the times of 03:00 to 23:15, a rainfall depth of 32.4 mm was recorded. The total rainfall between 15:00 and 16:00 is presented in Figure 2-2a. This shows a band of intense rainfall passing across Southend-on-Sea in a north westerly direction with a total of 11mm of rainfall falling within the hour.

It should be noted that rainfall intensity recorded using tipping bucket rain gauges tends to be more accurate than radar, which is often susceptible to interference. Radar data however provides a good spatial coverage of rainfall intensity, whereas rain gauges only provide details of intensity at that location. The EA however have stated that on this occasion, the rain gauge was found to be under reading by 8.49% compared to the adjacent check gauge.

The Flood Estimation Handbook (FEH) CD-ROM (version 3) 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 between 100% AEP (1 in 1 year) and 30% AEP (1 in 3.3 years). Further details can be found in Appendix A. Figure 2-2 shows the 15 minute rainfall data recorded by the Southchurch Park rain gauge.

Rainfall for the 13th October totalled 11.2 mm within 12 hours and 15 minutes (02:30 – 14:45). At its peak, 1.2 mm was recorded to fall over 15 minutes at 08:00.The FEH CD-ROM determined this volume and intensity of rainfall to be a "commonplace" event with a return

xii Met Office, Regional values – October 2013 http://www.metoffice.gov.uk/climate/uk/summaries/2013/october/regional-values
xiii Flood Alert: Flooding is possible. Be prepared.

period of less than 1 month. This however followed the more intense storm on the 11th October, the effects of which may still be notable though saturated soils.

Radar data for the 13th October recorded a peak rainfall of 2.1mm to be recorded over 15 minutes at 08:15 at Delaware Road, approximately 2.5 km to the east of the Southchurch Park rain gauge. The Radar imagery, Figure 2-2b, shows the rainfall on this occasion to be widely spread across the Borough.

The tidal levels recorded at Southend Pier are also shown in Figure 2-1. The spring tide was recorded on the 11th October at 04:15, reaching a level of 3.07m AOD. This coincided with the first period of heavy rainfall of 3.8 mm at 04:30. The second high tide, recorded at 16:30 again coincided with the main rainfall event, where the peak intensity of 4.2 mm was recorded at 16:00 on the 11th October.

The 13th October rainfall commenced at 06:00 am, coinciding with the high tide of 2.07m at 06:00 am.

Figure 2-1: Recorded rainfall (mm) at Southchurch Park and tide levels at Southend Pier from the 11th to 13th October 2013.

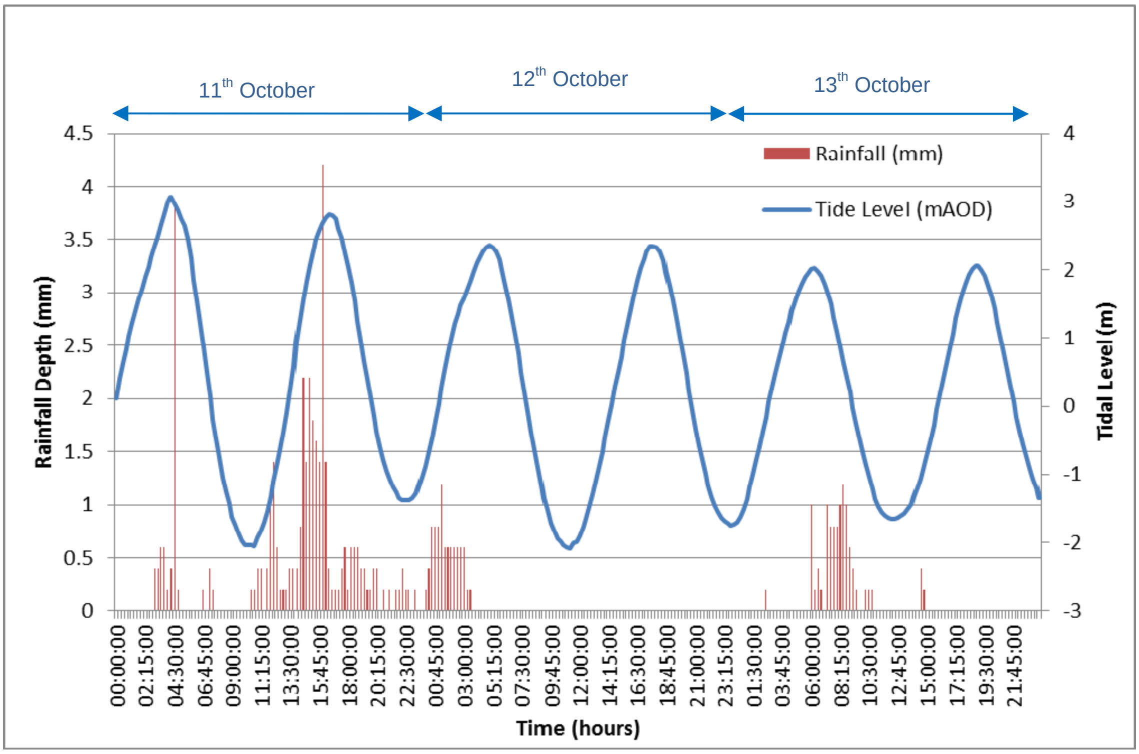
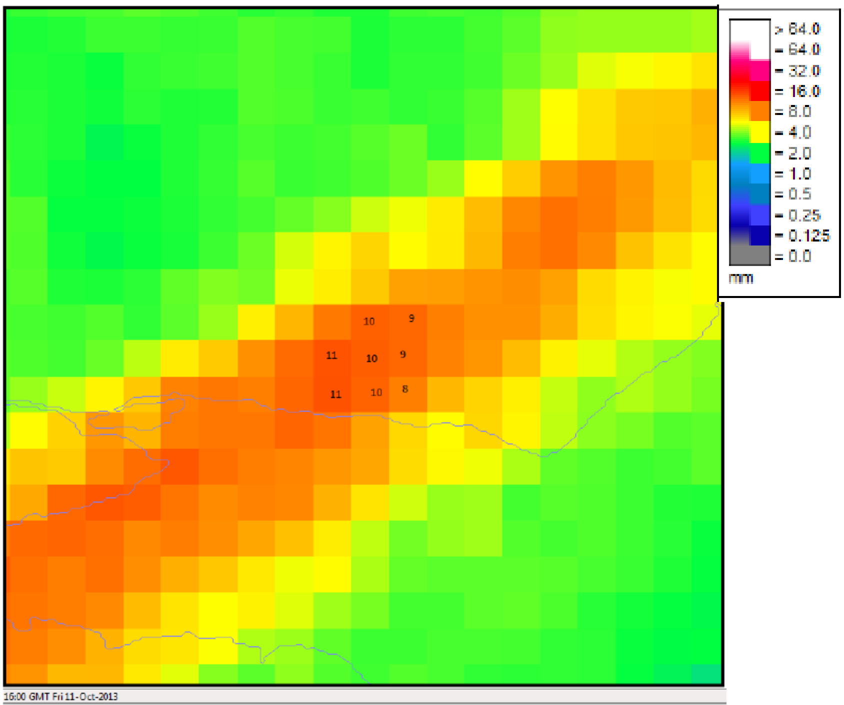
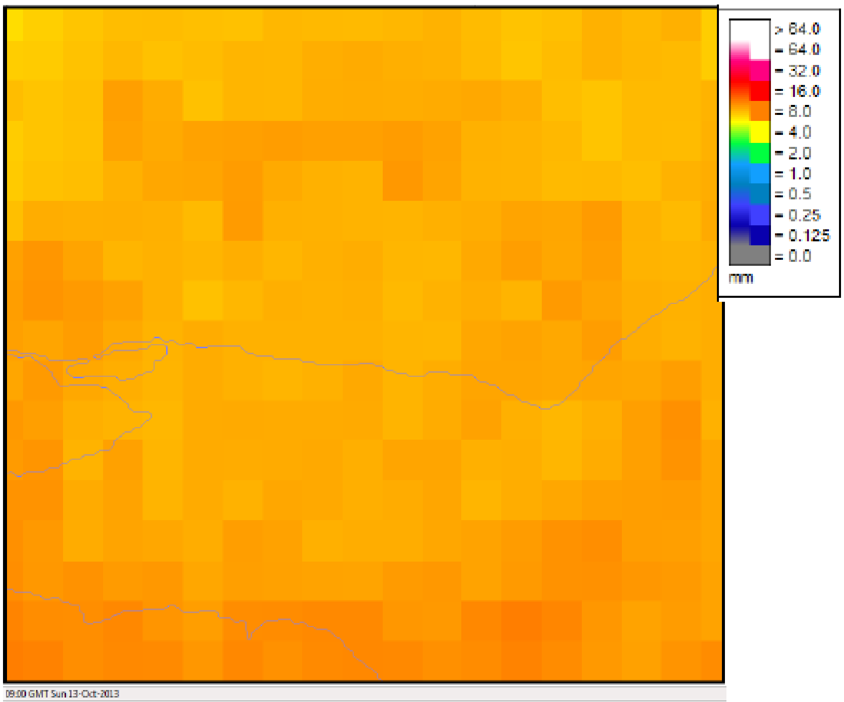


Figure 2-2

a) Environment Agency Radar imagery showing the 60 minute accumulation between 15:00 and 16:00 on the 11th October 2013. Rainfall depths are in mm.



b) Environment Agency Radar imagery showing the 60 minute accumulation between 08:00 and 09:00 on the 13th October 2013. Rainfall depths are in mm.



2.3 Flood Records

Figure 2-4 shows the location of flood records across Southend-on-Sea. It can be seen that there is a wide spatial distribution of the flooding incidents recorded on the 11th October. In total 20 incidents of flooding were recorded on the 11th October. Of these:

- 4 records were associated with flooding of roads;
- 5 records were flooding from manholes and gullies;
- 2 records of property flooding; and
- 9 records were of flooding with no further details.

Following the 11th October event, three areas were recorded to flood again on the 13th October. Whilst the 13th October event alone would not warrant a formal Flood Investigation, as the event occurred within a short time of the 11th October event, it has been considered to be related. The locations of the incidents recorded on the 13th October are also shown in Figure 2-4.

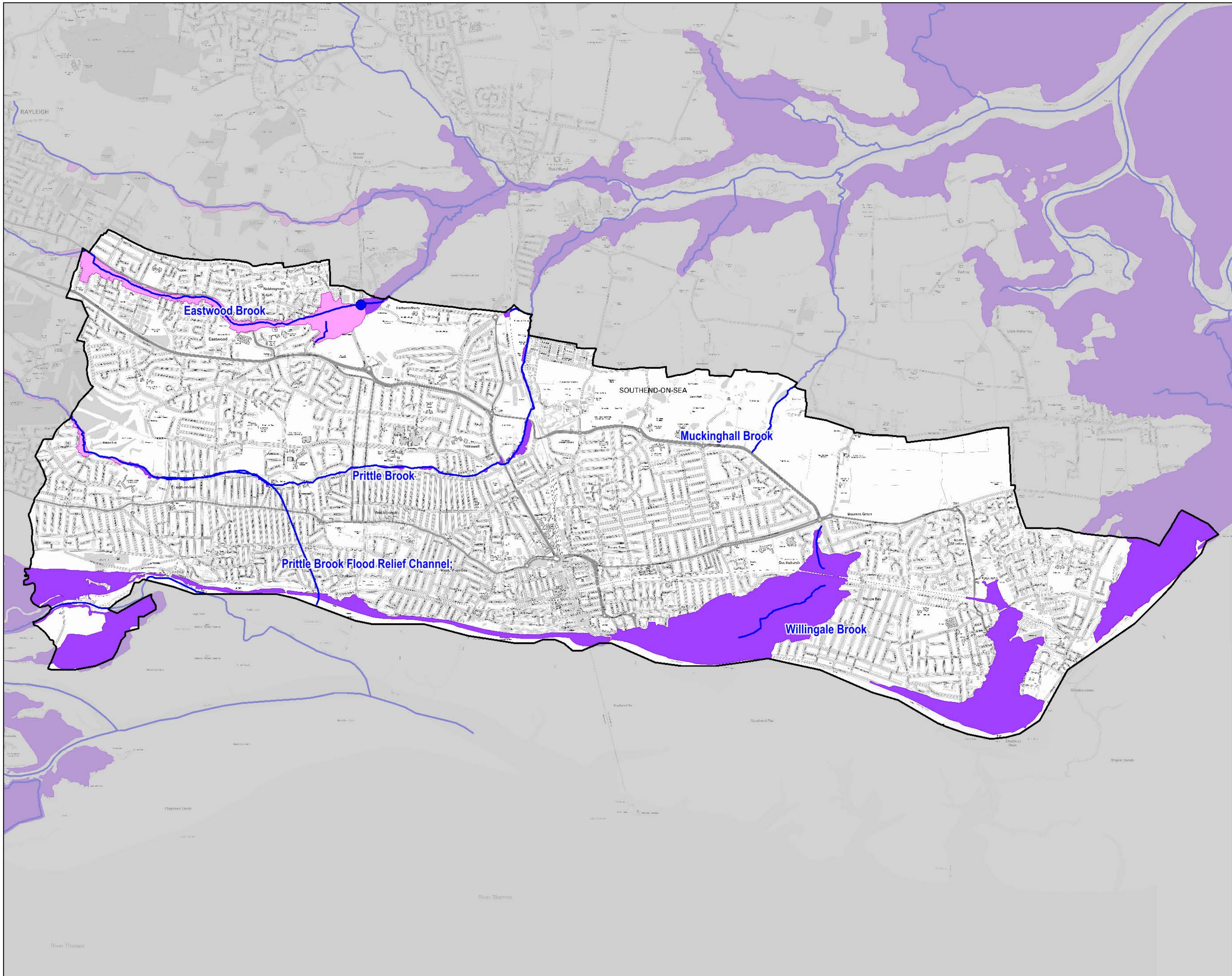
Records of flooding relating to this incident have been gathered from a number of organisations. The records have been complied into one database which is currently held and managed by the SBC Emergency Planning officer. Many of the records were gathered at the time of the flood event; however a number of flooding incidents were also reported following the event. It is likely that many flooding incidents may not have been recorded.

Records have been gathered from the following organisations and SBC departments:

- SBC Environmental Care Team,
- SBC Parks,
- SBC Out of Hours,
- SBC Emergency Planning,
- SBC Survey (December 2014)
- Essex County Fire and Rescue,
- Local Councillor, and,
- Evening Eco (Local newspaper).

The EA has confirmed that no calls were received on the 11th or 13th October relating to flooding or blockages of the channels and trash screens of the rivers within Southend-on-Sea.

AW has no records of internal flooding having occurred on the 11th or 13th October, resulting from issues with hydraulic capacity of the drainage network.



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

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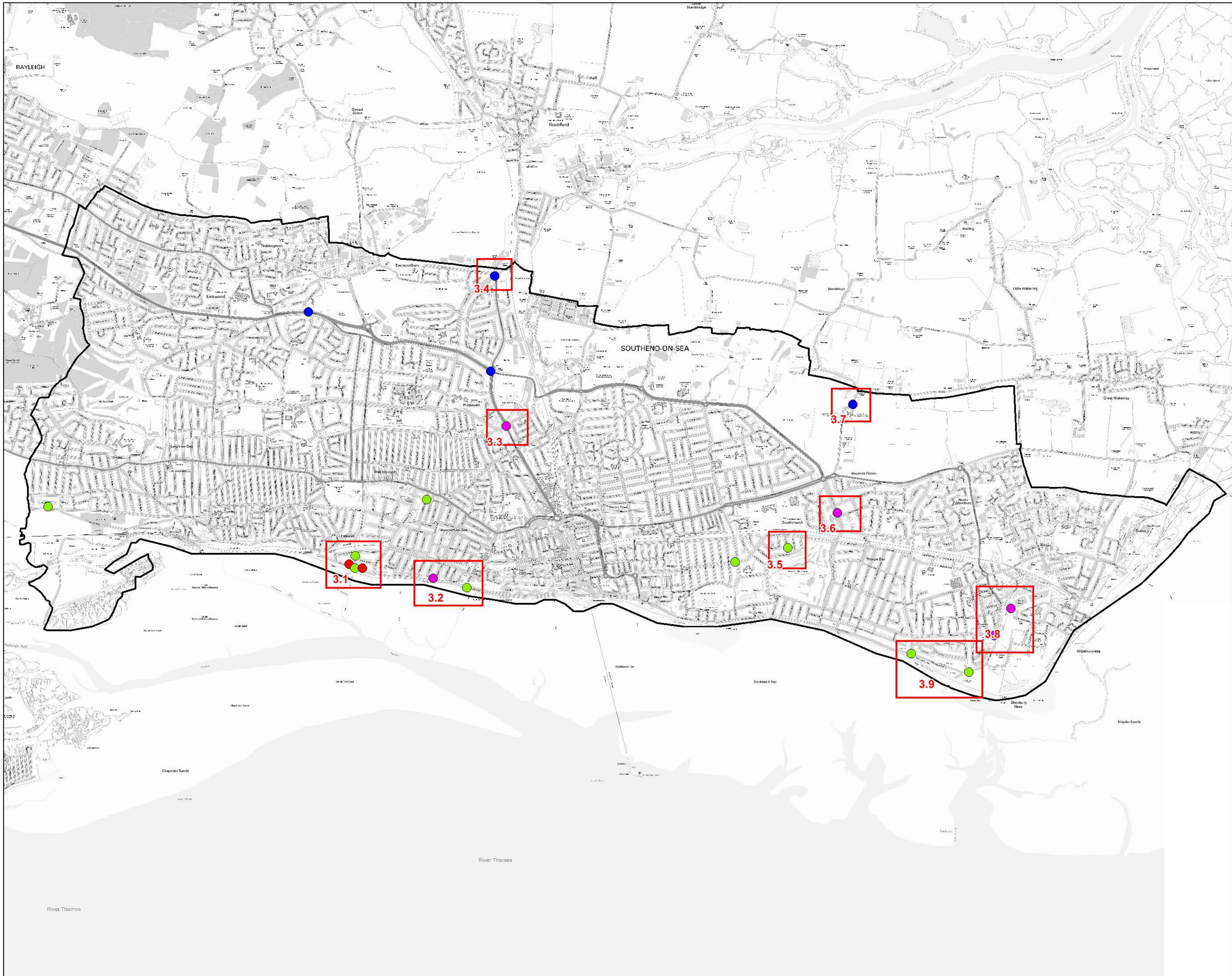

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Southend-on-Sea Borough Extent

Recorded Flooding 11th October
- Property flooding
- Road flooding
- Manhole and gully flooding
- Flooding (source unknown)

Recorded Flooding 13th October
- Flooding (source unknown)

Areas of detailed investigation

Revision Details	By / Check	Check Date	Suffix

Purpose of Issue: FINAL

Client: southend on sea BOROUGH COUNCIL

Project Title: SOUTHEND-ON-SEA 11TH OF OCTOBER 2013 FLOOD INVESTIGATION REPORT

Drawing Title: RECORDED FLOODING 11TH & 13TH OCTOBER 2013

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Drawing Number: Figure 2-4 | Rev: 3

3 FLOODING MECHANISMS

The following chapter summarises the flooding investigation for the areas identified to have been subject to repeated flooding, either following the 24th August event or on both the 11th and 13th October.

For each site, an overview is provided, flooding mechanisms discussed, RMA responses outlined and actions for flood management suggested.

The potential flooding mechanisms described for each area are based on observations from the site walkover, review of data available and information provided by stakeholders. A site visit was undertaken between the 26th and 28th August 2014.

3.1 Chalkwell Esplanade and Chalkwell Avenue

3.1.1 Overview

Within this area there were four recorded incidents of flooding on the 11th October 2013, one of which of which was of property flooding. This area had previously suffered extensive flooding on the 24th August 2013.

3.1.2 Mechanisms for Flooding

Within the Chalkwell area, Chalkwell Esplanade is at a low elevation of around 4 to 5 mAOD when compared to the surrounding area (Figure 3-1). When looking at the slope of the land locally to Chalkwell Esplanade, as shown Photograph 3-1, it can be seen that there is a slight camber in the road, with the northern edge (landward edge) lying at a lower elevation. Adjacent to the northern edge of the road there is a raised footpath. Should water accumulating within the road exceed the capacity of the road channel, there is the potential for water to overtop the level of the footpath and flow towards the properties. The presence of traffic calming measures along the road is likely to have a further influence on the accumulation of water within the road.

Within the area, many of the properties have lower ground level access or parking that are more susceptible to flooding. On the 11th October, one property was recorded to flood, affecting the basement.

There are a number of road gullies located along the road, however as there is minimal slope surface water may accumulate in areas where gullies are not present.

The southern extent of Chalkwell Avenue is relatively flat (Photograph 3-2) following the steep drop from the road to the north. If surface water is unable to enter the road gullies, water would follow the path of the road and accumulate within the area to the south. It should be noted that due to the time of year, road gullies may have been partially blocked by leaf litter, reducing their drainage efficiency.

Figure 3-1: Topography of Chalkwell area (black arrows indicate the general overland flow route)
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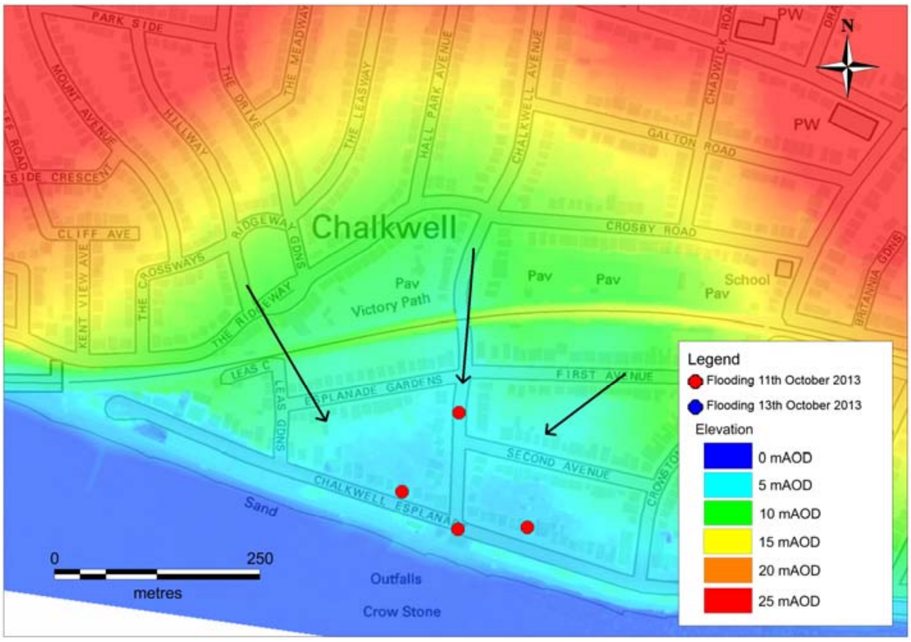

Photograph 3-1: Chalkwell Esplanade (looking west)

Photograph 3-2: Chalkwell Avenue (looking north)

There are numerous surface water sewers that drain Chalkwell Esplanade and Chalkwell Avenue. These drain towards the Chalkwell Pumping Station, before surface water flows by gravity (during low tide conditions) or is pumped (at high tide) to the Thames Estuary.

AW confirms that the Chalkwell Pumping Station was operational on the 11th October. Due to the high tide levels experienced at the time of peak rainfall, surface water would have been pumped from the network. AW indicates that the pumping station discharges water at a rate of 800 l/s.

3.1.3 Response to Flooding

During the flooding incident, the SBC Environment Care Team responded to notification of the internal flooding incident by providing sandbags to alleviate the immediate flood risk.

AW has undertaken the programmed replacement of the existing pumping station equipment at Chalkwell Esplanade following the previous flooding event on the 24th August 2013. .

3.1.4 Suggested Actions

This area will remain susceptible to surface water flooding from extreme rainfall events due to the topography of the surrounding area. A number of quick win solutions could be implemented to assist in flood risk management within the short term, 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 Chalkwell Esplanade and Chalkwell Avenue are frequently inspected and maintained, if needed.

In the long term, SBC could investigate the potential for implementing source control Sustainable Drainage Systems (SuDS) within the area to alleviate the volume of water draining to the road channel. This should be implemented, where possible, across the area of Chalkwell to have maximum benefit. Local to Chalkwell Esplanade, SuDS could be incorporated, including the gradual replacement of parking areas with permeable paving, or modifying the landscape to provide temporary flood storage areas. Any potential measures would need to be developed through further investigation and feasibility studies prior to implementation.

AW should assist in understanding the surface water flood risk through monitoring the performance of the pumping station and network to ensure that surface water is drained as required.

3.2 Clifton Drive and Western Esplanade

3.2.1 Overview

There are three reported incidents of flooding located between Clifton Drive and Western Esplanade on the 11th and 13th October, with records of water flowing down the slope from Clifton Drive to Western Esplanade. Previous flooding on the 24th August 2013 resulted in a landslip within the cliffs to the south of Clifton Drive.

Photographs 3-3 to 3-6 below detail the flooding at Clifton Drive at approximately 16:50 on the 11th October, as provided by the SBC Environmental Care Team. These demonstrate the source of flooding to be water surcharging from manholes and gullies within Clifton Drive. The water then runs down the cliff towards Western Esplanade.

Photograph 3-3: Runoff from Clifton Drive (looking north from Western Esplanade)

Photograph 3-4: Runoff from Clifton Drive (looking west from Clifton Drive)

Photograph 3-5: Surcharging manhole at Clifton Drive

Photograph 3-6: Surcharging gully at Clifton Drive

3.2.2 Mechanisms for Flooding

There is a considerable drop in elevation from Clifton drive to the Western Esplanade and the sea front (from 12.5 mAOD to 4.5 mAOD) as shown in Figure 3-2.

Figure 3-2: Topography of Clifton Drive (black arrows indicate the general overland flow route)
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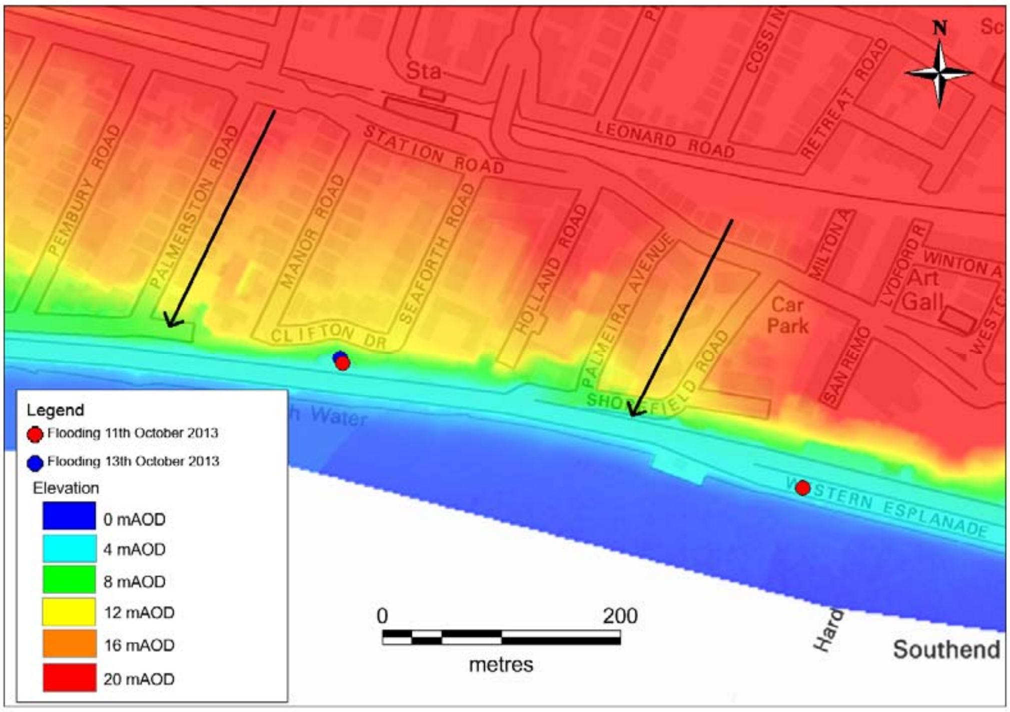

Surface water from Clifton Drive and the residential area of Westcliff-on-Sea, drains via a separate surface water network that discharges by a gravity outfall to the Thames Estuary. A 300 mm and 225 mm diameter sewers drain from Clifton Drive and Manor Road respectively, joining at the junction of the two roads before draining via a 300 mm pipe to the Estuary. Examination of the AW network suggests that the catchment area of the sewer network draining towards Clifton drive is approximately 0.2 km^2.

The foul sewer network drains towards the Western Valley Pumping Station.

Due to the high tides, it is likely that the capacity of the network was further reduced by tide locking of the outfall. Water would therefore not have been able to discharge freely from the network. As the drainage area is heavily urbanised, runoff would be rapid. The capacity of the network would therefore reach capacity shortly after the rainfall. Photographs 3-3 to 3-6 were taken at approximately 16:50, 50 minutes after the peak rainfall was recorded and at the time of the high tide.

High-level hydraulic calculations using MicroDrainage WinDES software indicate that the surface water sewer within Clifton Drive would reach capacity following 9.9 mm of rain, 60 minutes after the onset of rain, assuming there is a free outfall to the Thames Estuary. Flooding is thought to be a result of the pinch point created at the junction of the two surface water sewers, causing water to back up within the 300 mm pipe in Clifton Drive. Further details of the hydraulic calculations are provided in Appendix B.

Additionally, AW confirmed that there was a partial collapse of the 300 mm pipe discharging surface water to the Estuary. This collapse would have further reduced the capacity of the surface water network, causing water to back up and surcharge from the network.

The incident on the 13th October is likely to have been runoff from the elevated land to the north. The soils are likely to have been saturated following the 11th October rainfall, reducing the infiltration potential of the ground.

3.2.3 Response to Flooding

The stability of the cliffs is being investigated by SBC following the 24th August 2013 rainfall event and ground stabilisation works were commenced following the 24th of August event.

AW replaced the partially collapsed section of pipe in November 2013.

Measures to manage overland flow resulting from Clifton Drive are currently being investigated. These will function to channel flood waters from Clifton Drive to Western Esplanade so as to minimise flooding of properties.

3.2.4 Suggested Actions

Remediation works have been commenced to stabilise the land and the replace the collapsed pipe. However, reports of flooding in September 2014 suggest there are still capacity issues with the network. It is therefore suggested that AW should undertake a survey of the network to determine if the current infrastructure is adequate for managing rainfall in this area.

Due to the topography of the area, Clifton Drive will be more susceptible to surface water flooding. SBC should ensure highways gullies remain clear within this area to prevent water accumulating within the road.

At the moment the property at the base of the cliff is unoccupied. Should the use of this change, SBC should work with the developer to implement water resilient measures so as to minimise any damage should flooding occur in the future.

3.3 Victoria Avenue

3.3.1 Overview

Victoria Avenue (A127) is a major transport route to and from the central area of Southend-on-Sea. The road was observed to flood on the 11th October as a result of water overflowing from manholes and gullies. The road flooded previously on the 24th August 2013 event.

3.3.2 Mechanisms for Flooding

There is a dip in the elevation of Victoria Avenue just to the north of the junction of Priory Crescent and Fairfax Drive as shown in Figure 3-3. Just beyond this point, Victoria Avenue crosses the channel of Prittle Brook. Prittle Brook is culverted for a short section underneath the road and flows in a north easterly direction towards Prittlewell Priory.

The surface water drainage network is comprised of a number of surface water sewers draining the areas to the north and south of the crossing. All of the surface water sewers discharge to the Prittle Brook, below the river bank level (as shown in Photograph 3-8).

Figure 3-3: Topography of Victoria Avenue (black arrows indicate the general overland flow route)
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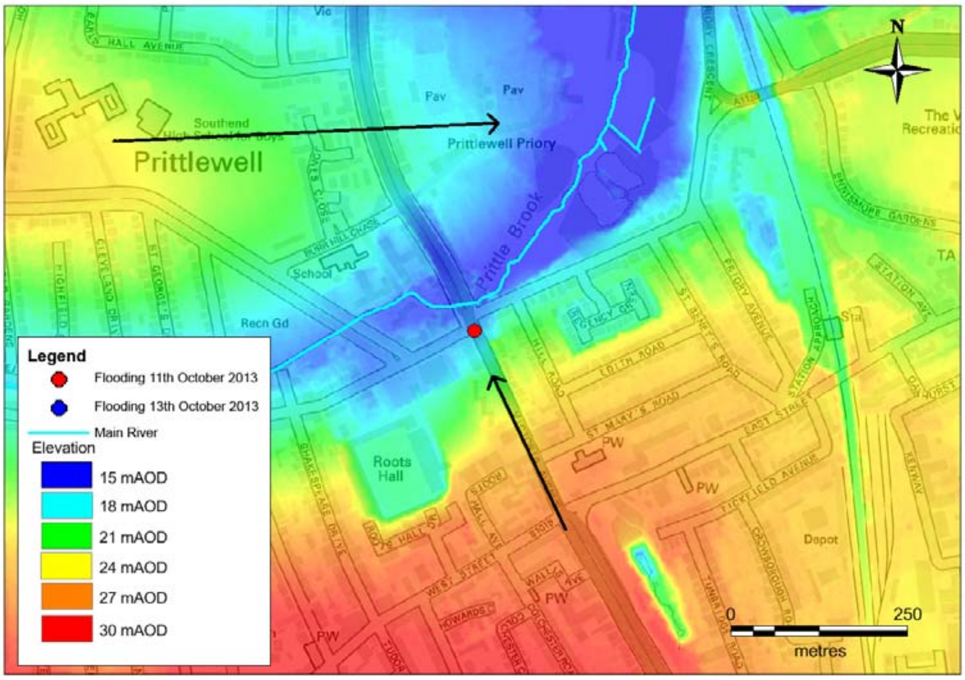
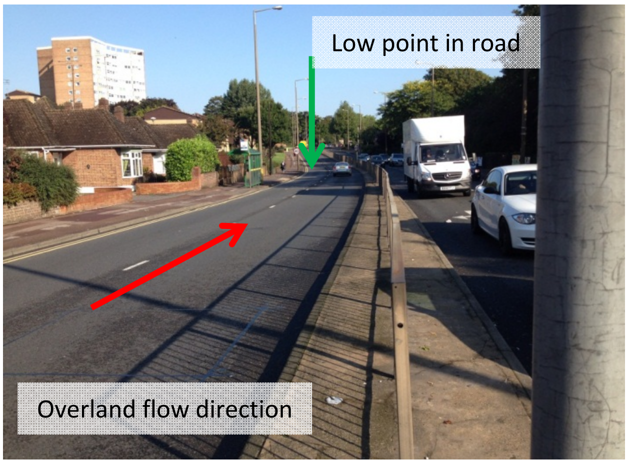




Photograph 3-7: Victoria Avenue (looking north)

Photograph 3-8: Surface Water to the Prittle Brook

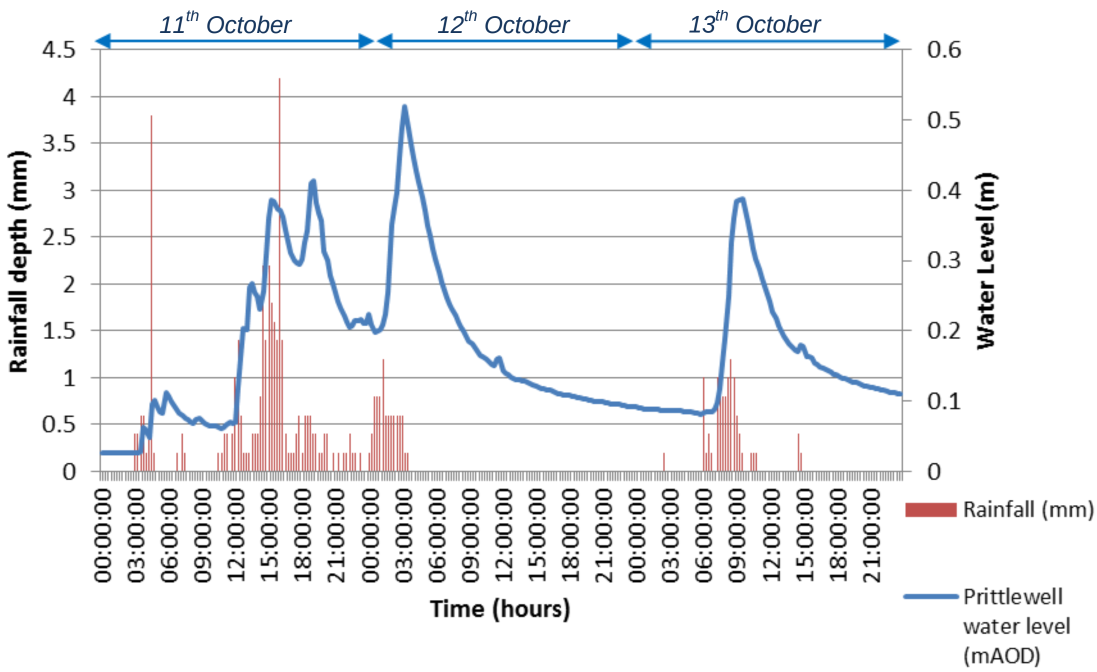
Flooding within this area is likely to be due to the presence of the lower elevation of the road. The source of flooding is considered to be surface water, which is exacerbated by high water levels of the Prittle Brook flood-locking the surface water outfalls.

The water levels of the Prittle Brook respond rapidly to rainfall as can be seen in Figure 3-4. In this instance, there are two peaks in the river levels on the 11th October in response to the rainfall. This would have been likely to rise above the outfall level of the surface water sewers.

The capacity of the surface water sewers discharging to the Prittle Brook is therefore dependent on the water levels within the Prittle Brook. Should the water levels of the Prittle

Brook exceed the channel capacity, there is the potential for water to back-up through the surface water outfalls.

Figure 3-4: Recorded Prittle Brook water levels (at Prittlewell) and rainfall (at Southcurch Park) - from 00:00 11/10//13 to 23:34 13/10/13



3.3.3 Response to Flooding

The SBC Environmental Care Team provides the first response to reports of flooding. In this instance, as water was overflowing from the manholes and gullies due to the high water levels of Prittle Book, it was not possible to pump the water away from the highway until water levels in the Prittle Brook subsided.

Warning signs were set up to indicate the flood risk at the junction and the risk of flooding to adjacent properties was assessed.

3.3.4 Suggested Actions

As the outfalls of the surface water sewers are below the flood levels of the Prittle Brook, the option to install flap values on the surface water outfalls could be considered to ensure that water from the Prittle Brook does not propagate up the sewer network when river levels are high. This will maximise the storage available within the system.

There will however remain the issue of the reduced capacity of the surface water network to drain the carriageway. In the short term, measures should be taken to implement road closures and diversions around the junction of Victoria Avenue, Fairfax Drive and Priory Crescent during times of flooding.

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

Alternatively, to alleviate the flood risk to more vulnerable areas, flood storage could be implemented in the open area of Prittlewell Park.

3.4 Warners Bridge Roundabout

3.4.1 Overview

Flooding was recorded on the roundabout of the A1159, Rochford Road, Eastwoodbury Crescent and Warners Bridge on October 11th. The roundabout had been recorded to flood previously on the 24th August 2013.

3.4.2 Mechanisms for Flooding

There are numerous surface water drains within the roads leading to the roundabout from the adjoining roads. These ultimately discharge to a tributary of Prittle Brook to the south of Southend Road, Rochford.

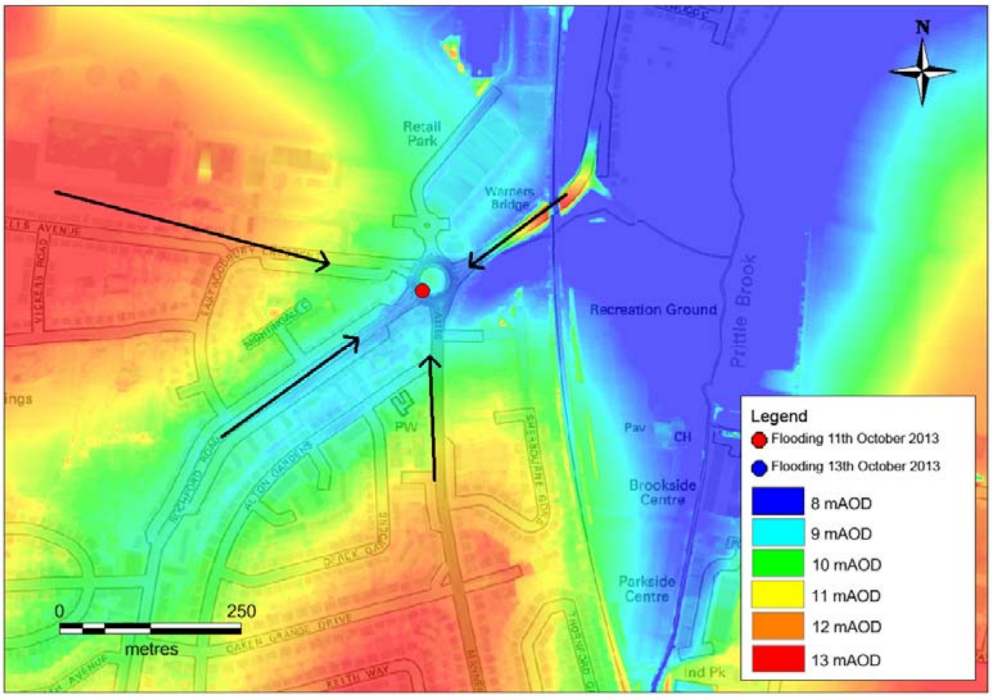
During the site walkover on the 28th August 2014, it was observed that there is a slight camber of the road towards the centre of the roundabout. The roundabout is drained through a series of kerb gullies.

Discussions with SBC have indicated that the Warners Bridge roundabout had been resurfaced prior to the 11th October event. As a result of the resurfacing, a kerb gully, located on the inner lane of the roundabout, became partially obstructed, restricting the volume of water draining from the area.

SBC contractors attended the site, and upon lifting the kerb gully, water was able drain freely from the highway.

Flooding in this area is likely to have been exacerbated by the topography of the land. Figure 3-5 shows that the roundabout and Rochford Road is at a relatively low elevation in relation to the surrounding area. Surface water, as overland flow, will tend to flow towards the low point of the roundabout. If there is insufficient highway drainage, or the capacity of the drains is reduced though blockages, surface water will remain within the road channel. As the roundabout is within an overland flow path, debris will be deposited within the road channel where water accumulates, potentially causing the more rapid siltation and blockage of the highways gullies.

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



3.4.3 Response to Flooding

SBC subcontractors attended the site upon becoming aware of flooding and resolved the immediate problem by lifting the kerb gully to allow water the drain freely from the carriageway.

Following the flooding SBC undertook works to clear the road surface directly in front of the gully to remove the restriction. SBC are investigating completing further works to modify or replace the kerb gully within this area.

3.4.4 Suggested Actions

In the short-term SBC are considering further works to modify the kerb gully. In the longer term, options could be considered for flood storage within the immediate area, such as within the roundabout itself, or at the land to the north east, where the sewer outfalls.

3.5 Rodbridge Drive

3.5.1 Overview

There is a record of flooding in Rodbridge Drive on the 11th October. Prior to this, there were several records of flooding in Rodbridge Drive and Wyatts Drive associated with the 24th August 2013 event.

3.5.2 Mechanisms for Flooding

There is a slight slope along the length of the Rodbridge Drive from the north to the south, where the elevation of the land is around 2.5m AOD, as shown in Figure 3-6. The elevated railway embankment, located to the north of Woodgrange Drive, forms a barrier to overland flow from the area of higher elevation to the north.

The surface water drainage network that serves Rodbridge Drive and the surrounding area discharges into the Willingale Brook to the southwest. A 225 mm diameter sewer, at the top of the network, drains Rodbridge Drive.

Figure 3-6: Topography of Rodbridge Drive (black arrows indicate the general overland flow route)
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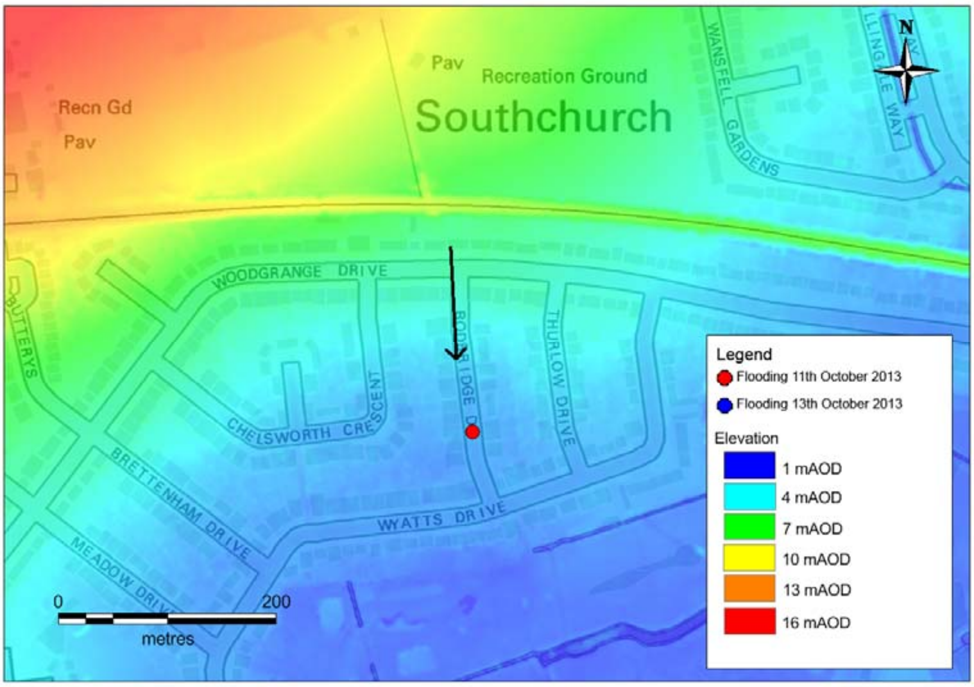

Due to the topography, surface water runoff from the north would be likely to flow along the road towards Wyatts Drive in the south.

Observations from the site walkover on the 28th August 2014 showed there to be a number of road gullies on both sides of the road. Should these be blocked or obstructed, surface water would tend to accumulate within the channel of the road.

AW are not aware of any past sewer flooding incidents or capacity issues within this area.

3.5.3 Response to Flooding

The flooding incident was reported to Essex Fire & Rescue who provided an emergency response.

SBC became aware of the incident during the data gathering exercise completed following the event.

3.5.4 Suggested Actions

It is recommended that SBC with support from AW undertake an investigation into the sewer network within this area to see if there is any capacity issues associated with the highways gullies or surface water sewer network respectively.

It is recommended that the road gullies and drains within this area are considered for more frequent cleaning and maintenance to ensure the drainage network functions as designed.

3.6 Thorpe Hall Avenue

3.6.1 Overview

Thorpe Hall Avenue runs in a north-south direction across Thorpe Bay, to the east of Southend-on-Sea.

Flooding within Thorpe Hall Avenue was recorded on the 11th October as a result of a manhole overflowing within the carriageway. Similar flooding was observed on the 24th August 2013.

3.6.2 Mechanisms for Flooding

There is a 300 mm diameter surface water sewer that runs in a southerly direction down Thorpe Hall Avenue. Along the length of the sewer, there are number connections from the adjacent road. This sewer ultimately discharges into the Willingale Brook (a Main River) that runs to the west of Thorpe Hall Avenue. This sewer and the Willingale Brook drain surface water from the catchment extending to the A13 and A1159 roundabout to the north. In addition, Thorpe Hall Avenue is the route of the main outfall from the Sewage Treatment Works to the north. The outfall consists of a 1,500mm diameter pressurised sewer that discharges to the Thames Estuary beyond Thorpe Esplanade.

As shown in Figure 3-7, the elevation of Thorpe Hall Avenue declines in both a northerly and southerly direction. Water overflowing from the manhole would follow the path of Thorpe Hall Avenue to the south, towards Acacia Drive.

Overland flow within this area would run predominantly towards the course of the Willingale Brook, along Thorpe Hall Avenue.

Figure 3-7: Topography of Thorpe Hall Avenue (black arrows indicate the general overland flow route)
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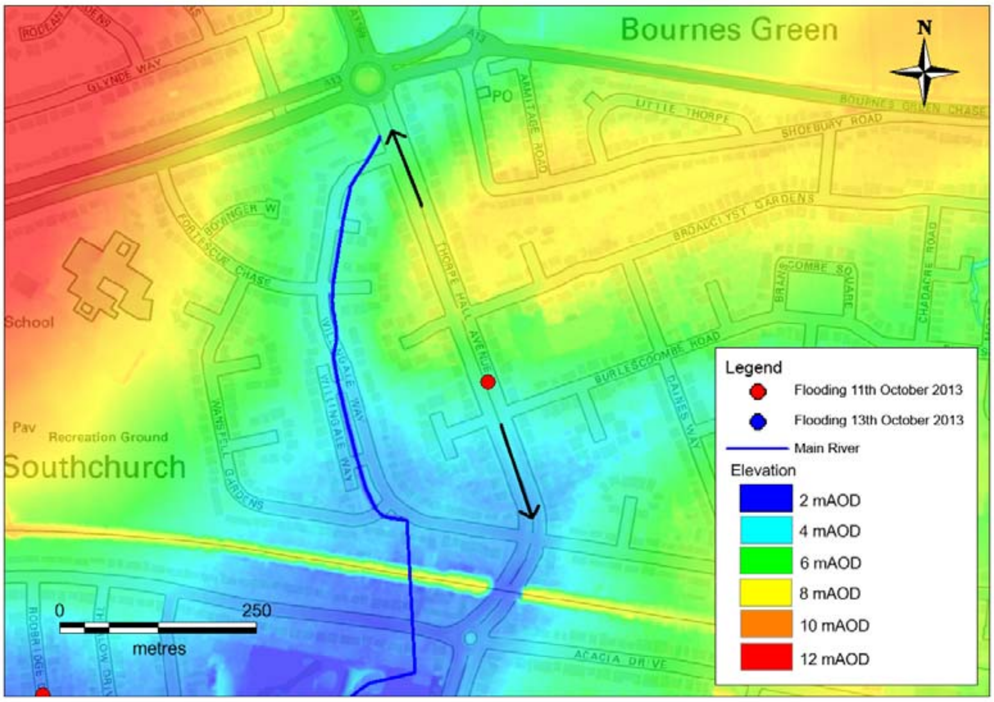


Discussions with AW have indicated that in this instance, the manhole cover within Thorpe Hall Avenue, associated with the surface water network, had not been bolted down following inspections completed prior to the event. Therefore, the higher flows within the network as a result of the rainfall would have caused water to surcharge and lift the cover.

It is likely, that should the cover had been secured, there would not have been flooding within the carriageway.

3.6.3 Response to Flooding

On becoming aware of the flooding, AW representatives attended the site and secured the manhole cover.

3.6.4 Suggested Actions

It is considered that flooding at this location was a one off event. No specific actions are considered to be required.

3.7 Wakering Road

3.7.1 Overview

Wakering Road provides a connection between the A13 (Bournes Green Chase) and the B1017 (Southend Road).

Flooding of Wakering Road was recorded on the 11th and 13th October. There have been no other recorded instances within this area.

There are no public sewers draining the road within this area, therefore the road is served by highways drainage only. The highways system in this area discharges to a lake within the grounds of the Alleyn Court Preparatory School, to the south of Wakering Road.

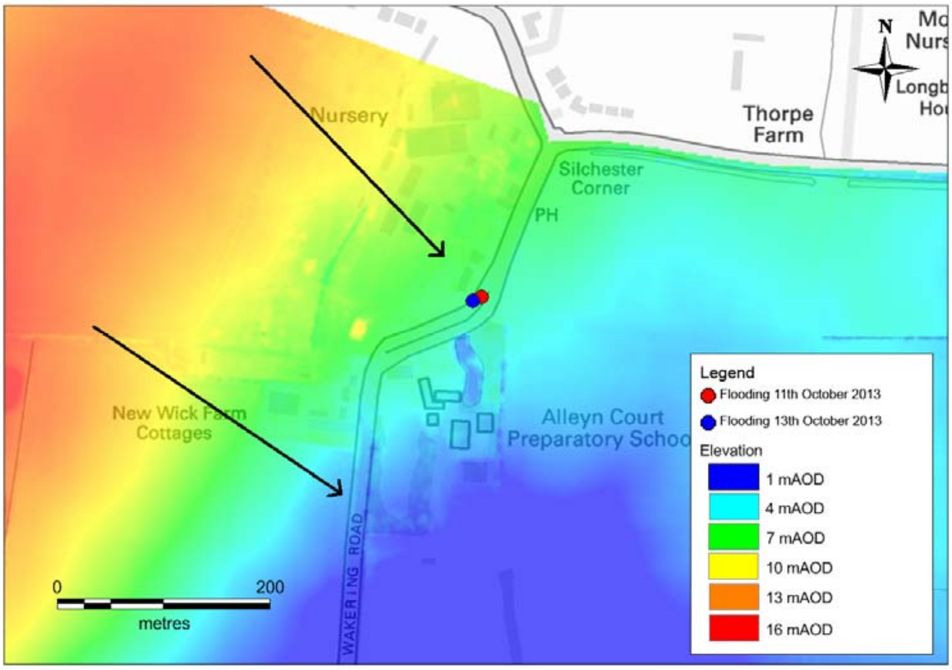
3.7.2 Mechanisms for Flooding

The flooding is considered to have resulted from the collapse of a section of pipe forming the gully connection, restricting the flow within the highways draining network.

Flooding is likely to have been further exacerbated by the local topography of the area, as shown in Figure 3-8. The road is split into two levels around the bends as the road approaches Southend Road. As a result of this split, the south bound carriageway is estimated to be 75cm below the northbound carriageway. In addition, the south bound carriageway has a notable camber, sloping towards the centre of the road. The north bound carriageway by contrast slopes outwards, towards the driveway entrances of the properties adjacent.

There are numerous road gullies located along the road in both directions.

Figure 3-8: Topography of Wakering Road (black arrows indicate the general overland flow route) Contains Ordnance Survey data © Crown copyright and database right 2014



3.7.3 Response to Flooding

On becoming aware of the flooding, SBC contractors attended the site and determined the cause of flooding to be due to lack of capacity created by the collapsed gully connection. Measures were taken by SBC to clear the network and replace the broken section of pipe.

3.7.4 Suggested Actions

The measures taken to restore the network are considered to have resolved the flooding risk in this area. No further actions are suggested.

3.8 Campfield Road and Ness Road

3.8.1 Overview

There were two reported incidents of flooding from manholes around Campfield Road and Ness Road, adjacent to Gunners Park on the 11th October, as shown in Photographs 3-9 and 3-10.

Photograph 3-9: Flooding from manhole in Campfield Road (picture from SBC Environmental Care team)

Photograph 3-10: Manhole flooding on footway adjacent to Ness Road (picture from SBC Environmental Care team)

3.8.2 Mechanisms for Flooding

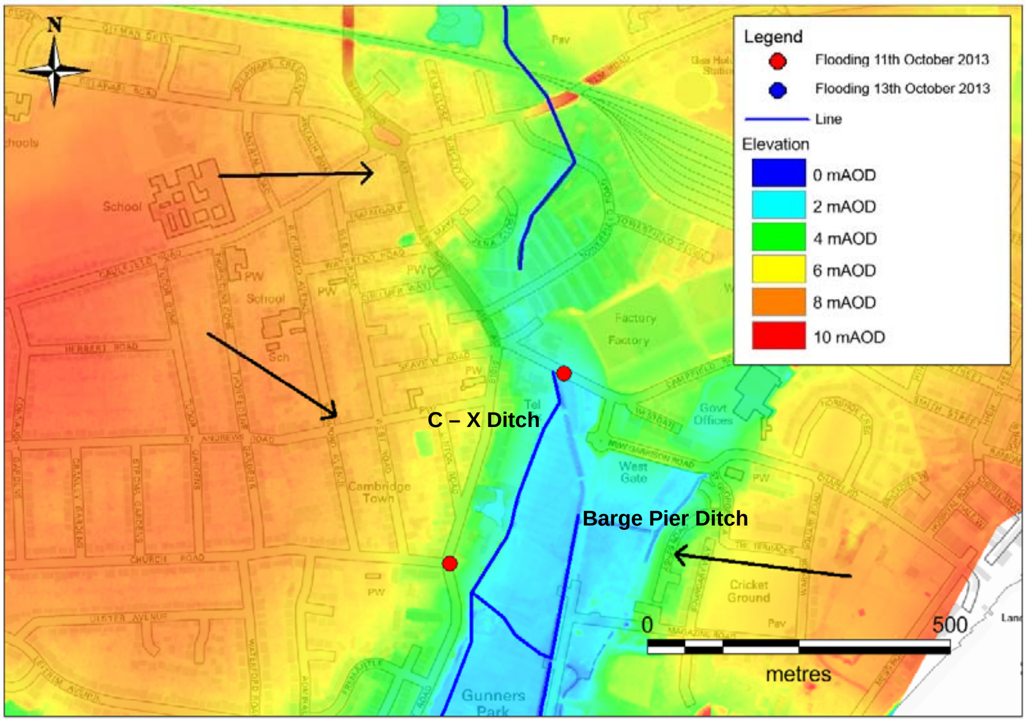
The topography of the area, and the location of the drainage ditches, can be seen in Figure 3-9.

The first incident (Photograph 3-9) of flooding is associated with the drainage of the C-X Ditch. The C-X Ditch (an ordinary watercourse) runs beneath Campfield road through a 1,300 mm diameter culvert. The watercourse (formally the River Shoe) is culverted from the north of Towerfield Road to the outfall south of Campfield Road in Gunners Park.

The second incident (Photograph 3-10) is associated with the surface water drainage network that discharges into the C-X Ditch within Gunners Park, to the east of Ness Road. The surface water outfall discharges three surface water drains that convey surface water from the Cambridge Town area and Thropdene Gardens.

The C-X Ditch drains into downstream extremity of the Barge Pier Ditch. The Barge Pier Ditch (an ordinary watercourse) is connected to the tidal lagoon and functions as an attenuation area for fluvial water when the outfall to the Thames Estuary is tide locked.

Figure 3-9: Topography around Campfield Road and Ness Road (black arrows indicate the general overland flow route) Contains Ordnance Survey data © Crown copyright and database right 2014



It is considered likely, that there would be high water levels within the C-X Ditch at the time of the flooding incidents as the outfall to the Estuary would have been tide-locked around the time of the peak rainfall. In addition, it was reported that there was extensive vegetation growth within the river channel at the time. Therefore, the capacity of the channel downstream of the culvert may have been reduced.

In both instances, the surface water networks discharge to the ditches within Gunners Park. As a result of the impeded outfalls and high water levels in the drainage ditch, surface water discharge may have been restricted resulting in water backing up within the networks.

In addition, there would have been large quantities of surface water draining from the urban areas. As the flow capacity of the drainage ditches may not have been sufficient, this would have caused water to back-up through the network and surcharge from the gullies and manholes.

Ditch clearance works within Gunners Park had not yet been carried out by SBC (the riparian owner) therefore the storage capacity of the channel could have been limited at the time of the flood event.

SBC has reported that an examination of the AW outfall at the junction of Ness Road and Church Road, found that the outlet and headwall had partially collapsed within this area, which may have further reduced the capacity of the outfall.

High level hydraulic calculations using MicroDrainage WinDES software have been completed. These show that the manhole at the junction of Church Road and Ness Road would have surcharged, as a result of the network reaching capacity, following 7.56 mm of rain. Flooding would occur approximately 56 minutes following the onset of rain. This is assuming a free discharge from the outfall. If the capacity of the outfall was reduced by 50%, flooding would be expected after 4.56 mm of rain, 48 minutes after the onset of rain. Further details are provided in Appendix B.

3.8.3 Response to Flooding

The SBC Environmental Care Team attended the site following the report of flooding. The manhole cover had been broken and lifted at Campfield Road; therefore barriers were placed around the hole to prevent vehicles driving into it.

Following the incident, AW were notified of the lifted manhole.

Following the flooding event, SBC as the riparian owner of the ordinary watercourse, has included the C-X Ditch in the borough-wide maintenance schedule. Vegetation clearance will be completed on a bi-annual basis to ensure the capacity of the channel is maintained.

3.8.4 Suggested Actions

To reduce the risk of the surface water network becoming overwhelmed within this area following rainfall, the surface water outflows and channels need to be maintained to provide maximum capacity.

It is recommended that AW survey the outfall of the drainage networks in this area to ensure there are no blockages that may have influenced the flooding.

SBC, as riparian owners, should continue to maintain the channel capacity of the C-X Ditch and Barge Pier Ditch.

3.9 Ness Road and Shoebury Common Road

3.9.1 Overview

Ness Road is located to the west of Gunners Park. Shoebury Common Road runs to the north, parallel to Shoebury Common. Both roads are at a low elevation in relation to the surrounding area, with a level of approximately 2.5m AOD (Figure 3-10).

There are two records of flooding on the 11th October at the junction of Ness Road and Shoebury Common Road and at the junction of Shoebury Common Road and Maplin Way. Flooding was recorded again at the junction of Ness Road and Shoebury Common Road on the 13th October.

3.9.2 Mechanisms for Flooding

Though in close proximity to the south west of the Campfield Road and Ness Road flooding incidents, the surface water network within these areas is drained separately and discharges to the Thames Estuary. Surface water from Shoebury Common Road, Maplin Way and the residential land to the north, drains via gravity through a 975 mm diameter outfall to the Estuary.

Surface water from Ness Road and the residential area to the north drains via the Shoebury Ness Road Pumping Station to the Thames Estuary. At low tide, surface water can discharge by gravity. During high tides, there is the potential for the surface water network to be tide locked.

Figure 3-10: Topography of Ness Road and Shoebury Common Road (black arrows indicate the general overland flow route)
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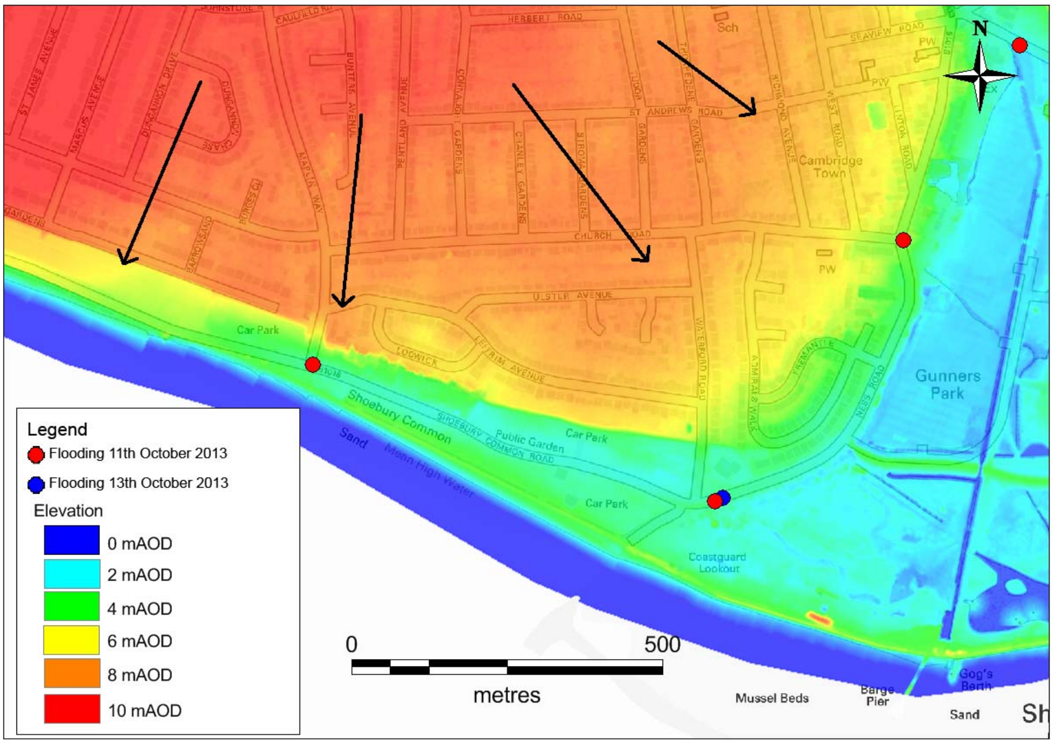


Flooding at the junction of Maplin Way is reported to have occurred as a result of the failure of the tidal flap valve allowing sea water ingress up the network as the tidal levels increased. This would have resulted in flooding from the restriction of the outflow and the reduced capacity of the network. Water would therefore have surcharged from the network through gullies and manholes as the water level at the end of the network increased.

High level hydraulic calculations undertaken using MicroDrainage WinDES software, show that the Ness Road surface water network would not flood providing there is free discharge from the outfall. A 50% reduction in the outfall capacity would however result in flooding of the network following 0.93 mm of rain, 16 minutes following the onset of rain. Further details are provided in Appendix B.

Based on the data available, the flooding within Ness Road is thought to be as a result of the failure of the Shoebury Common Pumping Station on this event. This would result in water backing up within the network and overflowing through gullies and manholes.

3.9.3 Response to Flooding

AW has replaced the flap valve at the outfall of Maplin Way.

The Maplin Way outfall has been prioritised within AW's regular maintenance programme.

3.9.4 Suggested Actions

SBC, along with AW, should investigate highways drainage within the southern section of Ness Road to determine if drainage to ditches within Gunners Park could be developed as an option to alleviate pressure on the surface water network within this area. This would rely on the continual maintenance of the drainage ditches to maintain capacity.

Alternatively, AW could potentially examine the possibility to increase the capacity of the Shoebury Common Pumping Station as a potential way to reduce the pressure on the system within this area.

3.10 Other incidents

In addition to the incidents described in Sections 3.1 – 3.10, isolated flooding was recorded at:

- Cotswold Road (flooding);
- Marine Close (flooding);
- Cuckoo corner (roundabout of A127 and A1159, road flooded);
- Prince Avenue (flooding in dip of road); and
- Woodgrange Drive (flooding).

As there are no previous incidents of flooding within these areas, it is considered that there is less susceptibility to flooding. It is likely, that due to the time of year, there may well have been issues with gully blockages from leaf debris.

Should flooding within these areas be recorded again, it is recommended that a more detailed investigation of the area is undertaken.

3.11 Summary of Flooding

The flooding incidents on the 11th October and 13th October primarily resulted from issues associated with inflow to gullies, restriction of outfalls and the condition of the drainage networks. The majority of the issues can be attributed to inadequate maintenance of assets resulting in their restricted function.

In the case of Chalkwell Esplanade and Warners Bridge Roundabout, flooding primarily resulted from water being unable to enter the drainage network, either due to the structure of local topography, or the partial blockage of the gullies.

The incidents at Victoria Avenue, Campfield Road and Ness Road, and Maplin Way and Shoebury Common Road are associated with restricted outfalls of the surface water drainage network. In the case of Victoria Avenue, the outfalls are susceptible to flood locking from the Prittle Brook, whereas for the outfalls at Maplin Way and Shoebury Common Road, and Campfield Road and Ness Road, discharge from the outfalls was restricted as a result of inadequate maintenance. Hydraulic calculations suggest that the surface water network at Campfield Road and Ness Road is potentially under capacity. The network at Maplin Way and Shoebury Common Road surcharged as a result of the restricted discharge.

Two incidents were identified to result from obstructions of flows due to the partial collapse of the pipes. In the case of Wakering Road, this was the gully lead that drained the highway. At Clifton Drive, this was associated with the partial collapse of the outfall as well as the influence of tide locking. Hydraulic calculations suggest there may be insufficient capacity within the Clifton Drive network should the same rainfall event occur again.

Thorpe Hall Avenue was an isolated incident as a result of the manhole cover not being secured.

The cause of flooding at Rodbrige Drive could not be determined from the information available. It is recommended the AW and SBC survey the gullies and surface water networks in this area to discount potential blockages.

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

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, in repairing the kerb gully at the Warners Bridge Roundabout and the collapsed gully lead at Wakefield Road.

The SBC Environmental Care team provided the first response to flooding in most incidents reported to SBC. SBC operatives attended calls, assessed the risk and determined appropriate responses. For many of the incidents, pumping flood water was not viable, therefore cones, barriers and warning signs were set up as needed and sandbags distributed.

During the flooding SBC operatives were not able to implement road closures or diversions; this could only be done though Essex Police. SBC are however considering completing the required training in order to implement this responsibility.

SBC operate a bi-annual clearing of the gully pots, however gully leads are not regularly inspected. SBC operate a reactive approach to the maintenance of gully leads, 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.

4.2.3 … as Riparian Owner

SBC is the riparian owner for the downstream reaches of the Barge Pier Ditch and C-X Ditch within Gunners Park. At the time of flooding, it was considered that the drainage ditches had not been maintained and as a result, there was reduced capacity. SBC has since addressed this and undertaken maintenance. The drainage ditches should be incorporated into the SBC asset maintenance schedule to prevent future capacity issues.

4.3 Environment Agency

The EA has confirmed that debris runs and trash screen clearances are undertaken every week within Southend-on-Sea and EA Flood Incident Duty officers instruct the field teams to check all known ‘hotspots’ prior to any forecasted heavy rainfall.

The EA has outlined that within Southend-on-Sea, these hotspots include the Prittle Tunnel Intake, Glenwood Avenue Debris Screen (now under Anglian Water's jurisdiction (transferred in early 2014) and the debris screen at Manchester Drive along the Prittle Brook.

The EA will also respond to calls received detailing any blockages.

4.4 Anglian Water

AW is not aware of any internal property flooding to have occurred on the 11th or 13th October, resulting from flooding of the sewer network, which would prompt the need for further investigation.

Following the flooding event, AW has undertaken a number of actions including:

- Replacing the section of pipe at Clifton Drive;
- Replacing the section of pipe at the outfall of Church Road and Ness Road;
- Replacing the tidal flap valve on the outfall at Maplin Road; and
- Inspecting the outfalls along the sea front.

There are however concerns with a number of areas as to the function and suitability of the drainage network, especially at Clifton Drive, Rodbridge Drive, Campfield Road and Ness Road. As flooding on this incident resulted from a frequent rainfall event, AW should ensure these areas are investigated to determine condition and potential problems with the network. Where the network is not found to be suitable, necessary measures should be implemented.

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. The assessments of flooding mechanisms highlight several issues that could be applied across the borough.

As described in Section 3.11, the majority of the flooding can be attributed to inadequate maintenance of assets, resulting in their restricted function. It is understood that the maintenance of all assets (outfalls, gullies, sewers, river etc.) across the borough is an on-going task for all RMAs using a risk based approach.

An action plan has been developed and is shown in Table 5-1. This incorporates the suggested actions for each of the areas investigated as well as providing broad scale and borough-wide actions for flood management.

Table 5-1: Action Plan

ID	Action	Lead RMA (support)	Area to be Implemented
1	Communication with residents, property owners and businesses to increase understanding of flood risk and measures individuals could take to protect themselves and their properties.	SBC (EA, AW)	Borough Wide
2	Prioritisation for more frequent gully inspections and maintenance.	SBC Highways	Chalkwell Esplanade, Clifton Drive, Rodbridge Drive
3	Implementation of SuDS to manage surface water at the source.	SBC (developers)	Borough Wide
	a) Controlled storage at Chalkwell Esplanade to attenuate surface water runoff prior to discharge (eg permeable paving).	SBC (residents & businesses)	Chalkwell Esplanade
	b) Storage for floodwaters alongside the	SBC	Victoria Avenue/ Priory

	Prittle Brook in Priory Park.		Park
	c) Flood storage around the Warners Bridge Roundabout area or within the roundabout itself.	SBC	Warners Bridge
4	Complete investigations of the sewer network function and condition. Where necessary, monitor performance to ensure network is function as intended.	AW	Chalkwell Esplanade, Clifton Drive, Rodbridge Drive and Campfield Road.
5	Plan for the implementation of road closures and diversions for areas prone to flooding. Consider this for areas where property risk is increased as a result of bow waves created by vehicles.	SBC (Essex Police)	Victoria Avenue
6	Investigate the feasibility of installing flap values on surface water outfalls discharging to rivers. Determine the contribution river levels backing up within the network could have on the magnitude of flooding at surface level.	AW (SBC, EA)	Victoria Avenue (Prittle Brook)
7	Ensure frequent maintenance of ordinary watercourses to provide the maximum storage potential.	SBC, Riparian Owners	Campfield Road and Ness Road
8	Ensure tidal flap valves are inspected and maintained frequently to prevent the ingress of tidal sea water within the network.	AW	Sea front
9	Investigate potential of linking the southern Ness Road surface water sewers to drainage ditches within Gunners Park.	SBC, AW	Ness Road
10	In areas with a single incident of flooding, prioritise investigation should flooding occur again within the future.	SBC (EA, AWS)	Cotswold Road, Marine Close, Cuckoo Corner, Prince Avenue and Woodgrange Drive
11	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)	Borough Wide

APPENDIX A – RAINFALL ANALYSIS

The rainfall return period has been estimated in order to determine the relative magnitude of the event of 11th and 13th October events. 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 11th October 18 hour rainfall event, the maximum rainfall depth is the equivalent of a 1 in 3.3 chance of occurring 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 between 1 in 1 and 1 in 3.3 within any given year.

The 13th of October rainfall is considered to be “commonplace” with an event return period of less than 1 month.

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 - 11th October Rainfall (EA data, recorded at Southchurch Park)

Southchurch Park Rain Gauge Data			**Calculation of peak rainfall depths: duration (hours)**										
Date	**Time**	**Rainfall [mm]**	**0.5**	**1**	**2**	**3**	**4**	**5**	**6**	**9**	**12**	**18**	**24**
11/10/2013	00:00:00	.											
11/10/2013	00:15:00	.	0										
11/10/2013	00:30:00	.	0										
11/10/2013	00:45:00	.	0	0									
11/10/2013	01:00:00	.	0	0									
11/10/2013	01:15:00	.	0	0									
11/10/2013	01:30:00	.	0	0									
11/10/2013	01:45:00	.	0	0	0								
11/10/2013	02:00:00	.	0	0	0								
11/10/2013	02:15:00	.	0	0	0								
11/10/2013	02:30:00	.	0	0	0								
11/10/2013	02:45:00	.	0	0	0	0							
11/10/2013	03:00:00	0.4	0.4	0.4	0.4	0.4							
11/10/2013	03:15:00	0.4	0.8	0.8	0.8	0.8							
11/10/2013	03:30:00	0.6	1	1.4	1.4	1.4							
11/10/2013	03:45:00	0.6	1.2	2	2	2	2						
11/10/2013	04:00:00	0.2	0.8	1.8	2.2	2.2	2.2						
11/10/2013	04:15:00	0.4	0.6	1.8	2.6	2.6	2.6						
11/10/2013	04:30:00	3.8	4.2	5	6.4	6.4	6.4						
11/10/2013	04:45:00	0.2	4	4.6	6.6	6.6	6.6	6.6					
11/10/2013	05:00:00	.	0.2	4.4	6.2	6.6	6.6	6.6					

Southchurch Park Rain Gauge Data			Calculation of peak rainfall depths: duration (hours)										
Date	Time	Rainfall [mm]	0.5	1	2	3	4	5	6	9	12	18	24
11/10/2013	05:15:00	.	0	4	5.8	6.6	6.6	6.6					
11/10/2013	05:30:00	.	0	0.2	5.2	6.6	6.6	6.6					
11/10/2013	05:45:00	.	0	0	4.6	6.6	6.6	6.6	6.6				
11/10/2013	06:00:00	.	0	0	4.4	6.2	6.6	6.6	6.6				
11/10/2013	06:15:00	.	0	0	4	5.8	6.6	6.6	6.6				
11/10/2013	06:30:00	.	0	0	0.2	5.2	6.6	6.6	6.6				
11/10/2013	06:45:00	0.2	0.2	0.2	0.2	4.8	6.8	6.8	6.8				
11/10/2013	07:00:00	.	0.2	0.2	0.2	4.6	6.4	6.8	6.8				
11/10/2013	07:15:00	0.4	0.4	0.6	0.6	4.6	6.4	7.2	7.2				
11/10/2013	07:30:00	0.2	0.6	0.8	0.8	1	6	7.4	7.4				
11/10/2013	07:45:00	.	0.2	0.6	0.8	0.8	5.4	7.4	7.4				
11/10/2013	08:00:00	.	0	0.6	0.8	0.8	5.2	7	7.4				
11/10/2013	08:15:00	.	0	0.2	0.8	0.8	4.8	6.6	7.4				
11/10/2013	08:30:00	.	0	0	0.8	0.8	1	6	7.4				
11/10/2013	08:45:00	.	0	0	0.6	0.8	0.8	5.4	7.4	7.4			
11/10/2013	09:00:00	.	0	0	0.6	0.8	0.8	5.2	7	7.4			
11/10/2013	09:15:00	.	0	0	0.2	0.8	0.8	4.8	6.6	7.4			
11/10/2013	09:30:00	.	0	0	0	0.8	0.8	1	6	7.4			
11/10/2013	09:45:00	.	0	0	0	0.6	0.8	0.8	5.4	7.4			
11/10/2013	10:00:00	.	0	0	0	0.6	0.8	0.8	5.2	7.4			
11/10/2013	10:15:00	.	0	0	0	0.2	0.8	0.8	4.8	7.4			
11/10/2013	10:30:00	0.2	0.2	0.2	0.2	0.2	1	1	1.2	7.6			

Southchurch Park Rain Gauge Data			Calculation of peak rainfall depths: duration (hours)										
Date	Time	Rainfall [mm]	0.5	1	2	3	4	5	6	9	12	18	24
11/10/2013	10:45:00	0.2	0.4	0.4	0.4	0.4	1	1.2	1.2	7.8			
11/10/2013	11:00:00	0.4	0.6	0.8	0.8	0.8	1.4	1.6	1.6	8.2			
11/10/2013	11:15:00	0.4	0.8	1.2	1.2	1.2	1.4	2	2	8.6			
11/10/2013	11:30:00	.	0.4	1	1.2	1.2	1.2	2	2	8.6			
11/10/2013	11:45:00	0.4	0.4	1.2	1.6	1.6	1.6	2.2	2.4	9	9		
11/10/2013	12:00:00	1	1.4	1.8	2.6	2.6	2.6	3.2	3.4	9.6	10		
11/10/2013	12:15:00	1.4	2.4	2.8	4	4	4	4.2	4.8	10.6	11.4		
11/10/2013	12:30:00	0.6	2	3.4	4.4	4.6	4.6	4.6	5.4	10.6	12		
11/10/2013	12:45:00	0.2	0.8	3.2	4.4	4.8	4.8	4.8	5.4	10.2	12.2		
11/10/2013	13:00:00	0.2	0.4	2.4	4.2	5	5	5	5.6	10.2	12.4		
11/10/2013	13:15:00	0.2	0.4	1.2	4	5.2	5.2	5.2	5.4	10	12.6		
11/10/2013	13:30:00	0.4	0.6	1	4.4	5.4	5.6	5.6	5.6	6.6	13		
11/10/2013	13:45:00	0.4	0.8	1.2	4.4	5.6	6	6	6	6.8	13.4		
11/10/2013	14:00:00	0.4	0.8	1.4	3.8	5.6	6.4	6.4	6.4	7.2	13.8		
11/10/2013	14:15:00	0.8	1.2	2	3.2	6	7.2	7.2	7.2	8	14.6		
11/10/2013	14:30:00	2.2	3	3.8	4.8	8.2	9.2	9.4	9.4	10.2	16.8		
11/10/2013	14:45:00	1.4	3.6	4.8	6	9.2	10.4	10.8	10.8	11.6	18.2		
11/10/2013	15:00:00	2.2	3.6	6.6	8	10.4	12.2	13	13	13.8	20		
11/10/2013	15:15:00	1.8	4	7.6	9.6	10.8	13.6	14.8	14.8	15.6	21.4		
11/10/2013	15:30:00	1.6	3.4	7	10.8	11.8	15.2	16.2	16.4	17.2	22.4		
11/10/2013	15:45:00	1.4	3	7	11.8	13	16.2	17.4	17.8	18.4	23.2		
11/10/2013	16:00:00	4.2	5.6	9	15.6	17	19.4	21.2	22	22.6	27.2		

Southchurch Park Rain Gauge Data			Calculation of peak rainfall depths: duration (hours)										
Date	Time	Rainfall [mm]	0.5	1	2	3	4	5	6	9	12	18	24
11/10/2013	16:15:00	1.4	5.6	8.6	16.2	18.2	19.4	22.2	23.4	23.6	28.2		
11/10/2013	16:30:00	0.4	1.8	7.4	14.4	18.2	19.2	22.6	23.6	23.8	24.8		
11/10/2013	16:45:00	0.2	0.6	6.2	13.2	18	19.2	22.4	23.6	24	24.8		
11/10/2013	17:00:00	0.2	0.4	2.2	11.2	17.8	19.2	21.6	23.4	24.2	25		
11/10/2013	17:15:00	0.2	0.4	1	9.6	17.2	19.2	20.4	23.2	24.4	25.2		
11/10/2013	17:30:00	0.4	0.6	1	8.4	15.4	19.2	20.2	23.6	24.8	25.6		
11/10/2013	17:45:00	0.6	1	1.4	7.6	14.6	19.4	20.6	23.8	25.4	26.2	32.8	
11/10/2013	18:00:00	0.2	0.8	1.4	3.6	12.6	19.2	20.6	23	25.6	26.4	33	
11/10/2013	18:15:00	0.6	0.8	1.8	2.8	11.4	19	21	22.2	26.2	27	33.6	
11/10/2013	18:30:00	0.6	1.2	2	3	10.4	17.4	21.2	22.2	26.8	27.6	34.2	
11/10/2013	18:45:00	0.6	1.2	2	3.4	9.6	16.6	21.4	22.6	27.4	28	34.8	
11/10/2013	19:00:00	0.4	1	2.2	3.6	5.8	14.8	21.4	22.8	27.8	28.4	35.2	
11/10/2013	19:15:00	0.4	0.8	2	3.8	4.8	13.4	21	23	28.2	28.4	35.6	
11/10/2013	19:30:00	0.2	0.6	1.6	3.6	4.6	12	19	22.8	28.2	28.4	35.8	
11/10/2013	19:45:00	0.2	0.4	1.2	3.2	4.6	10.8	17.8	22.6	28.2	28.6	36	
11/10/2013	20:00:00	0.4	0.6	1.2	3.4	4.8	7	16	22.6	28.2	29	36.4	
11/10/2013	20:15:00	0.4	0.8	1.2	3.2	5	6	14.6	22.2	28.2	29.4	36.8	
11/10/2013	20:30:00	.	0.4	1	2.6	4.6	5.6	13	20	28.2	29.4	36.8	
11/10/2013	20:45:00	0.2	0.2	1	2.2	4.2	5.6	11.8	18.8	28	29.6	37	
11/10/2013	21:00:00	.	0.2	0.6	1.8	4	5.4	7.6	16.6	27	29.6	36.6	
11/10/2013	21:15:00	0.2	0.2	0.4	1.6	3.6	5.4	6.4	15	25.8	29.8	36.4	
11/10/2013	21:30:00	.	0.2	0.4	1.4	3	5	6	13.4	25.2	29.8	35.8	

Southchurch Park Rain Gauge Data			Calculation of peak rainfall depths: duration (hours)										
Date	**Time**	**Rainfall [mm]**	**0.5**	**1**	**2**	**3**	**4**	**5**	**6**	**9**	**12**	**18**	**24**
11/10/2013	21:45:00	0.2	0.2	0.4	1.4	2.6	4.6	6	12.2	25.2	30	35.4	
11/10/2013	22:00:00	0.2	0.4	0.6	1.2	2.4	4.6	6	8.2	25.2	30.2	35.4	
11/10/2013	22:15:00	0.4	0.6	0.8	1.2	2.4	4.4	6.2	7.2	25.4	30.6	35.4	
11/10/2013	22:30:00	0.2	0.6	1	1.4	2.4	4	6	7	25.2	30.6	31.8	
11/10/2013	22:45:00	0.2	0.4	1	1.4	2.4	3.6	5.6	7	25	30.6	31.8	
11/10/2013	23:00:00	.	0.2	0.8	1.4	2	3.2	5.4	6.8	24.6	30.2	31.8	
11/10/2013	23:15:00	0.2	0.2	0.6	1.4	1.8	3	5	6.8	24	30	32	
11/10/2013	23:30:00	.	0.2	0.4	1.4	1.8	2.8	4.4	6.4	21.8	30	32	
11/10/2013	23:45:00	.	0	0.2	1.2	1.6	2.6	3.8	5.8	20.4	29.6	32	38.6
Max			**5.6**	**9**	**16.2**	**18.2**	**19.4**	**22.6**	**23.8**	**28.2**	**30.6**	**37**	**38.6**
Return period (point)			**1yr**	**1.1yr**	**1.8yr**	**1.8yr**	**1.7yr**	**2.1yr**	**2.2yr**	**2.5yr**	**2.6yr**	**3.3yr**	**2.9yr**

Table A-2: 13th October 2013 Rainfall (EA data, recorded at Southchurch Park)

Southchurch Park Rain Gauge Data			Calculation of peak rainfall depths: duration (hours)										
Date	**Time**	**Rainfall [mm]**	**0.5**	**1**	**2**	**3**	**4**	**5**	**6**	**9**	**12**	**18**	**24**
13/10/2013	00:00:00	.											
13/10/2013	00:15:00	.	0										
13/10/2013	00:30:00	.	0										
13/10/2013	00:45:00	.	0	0									
13/10/2013	01:00:00	.	0	0									

Southchurch Park Rain Gauge Data			Calculation of peak rainfall depths: duration (hours)										
Date	Time	Rainfall [mm]	0.5	1	2	3	4	5	6	9	12	18	24
13/10/2013	01:15:00	.	0	0									
13/10/2013	01:30:00	.	0	0									
13/10/2013	01:45:00	.	0	0	0								
13/10/2013	02:00:00	.	0	0	0								
13/10/2013	02:15:00	.	0	0	0								
13/10/2013	02:30:00	0.2	0.2	0.2	0.2								
13/10/2013	02:45:00	.	0.2	0.2	0.2	0.2							
13/10/2013	03:00:00	.	0	0.2	0.2	0.2							
13/10/2013	03:15:00	.	0	0.2	0.2	0.2							
13/10/2013	03:30:00	.	0	0	0.2	0.2							
13/10/2013	03:45:00	.	0	0	0.2	0.2	0.2						
13/10/2013	04:00:00	.	0	0	0.2	0.2	0.2						
13/10/2013	04:15:00	.	0	0	0.2	0.2	0.2						
13/10/2013	04:30:00	.	0	0	0	0.2	0.2						
13/10/2013	04:45:00	.	0	0	0	0.2	0.2	0.2					
13/10/2013	05:00:00	.	0	0	0	0.2	0.2	0.2					
13/10/2013	05:15:00	.	0	0	0	0.2	0.2	0.2					
13/10/2013	05:30:00	.	0	0	0	0	0.2	0.2					
13/10/2013	05:45:00	.	0	0	0	0	0.2	0.2	0.2				
13/10/2013	06:00:00	1	1	1	1	1	1.2	1.2	1.2				
13/10/2013	06:15:00	0.2	1.2	1.2	1.2	1.2	1.4	1.4	1.4				
13/10/2013	06:30:00	0.6	0.8	1.8	1.8	1.8	1.8	2	2				

Southchurch Park Rain Gauge Data			Calculation of peak rainfall depths: duration (hours)										
Date	Time	Rainfall [mm]	0.5	1	2	3	4	5	6	9	12	18	24
13/10/2013	06:45:00	0.2	0.8	2	2	2	2	2.2	2.2				
13/10/2013	07:00:00	.	0.2	1	2	2	2	2.2	2.2				
13/10/2013	07:15:00	1	1	1.8	3	3	3	3.2	3.2				
13/10/2013	07:30:00	0.8	1.8	2	3.8	3.8	3.8	3.8	4				
13/10/2013	07:45:00	0.8	1.6	2.6	4.6	4.6	4.6	4.6	4.8				
13/10/2013	08:00:00	0.8	1.6	3.4	4.4	5.4	5.4	5.4	5.6				
13/10/2013	08:15:00	1	1.8	3.4	5.2	6.4	6.4	6.4	6.6				
13/10/2013	08:30:00	1.2	2.2	3.8	5.8	7.6	7.6	7.6	7.6				
13/10/2013	08:45:00	1	2.2	4	6.6	8.6	8.6	8.6	8.6	8.8			
13/10/2013	09:00:00	0.6	1.6	3.8	7.2	8.2	9.2	9.2	9.2	9.4			
13/10/2013	09:15:00	0.4	1	3.2	6.6	8.4	9.6	9.6	9.6	9.8			
13/10/2013	09:30:00	0.2	0.6	2.2	6	8	9.8	9.8	9.8	10			
13/10/2013	09:45:00	.	0.2	1.2	5.2	7.8	9.8	9.8	9.8	10			
13/10/2013	10:00:00	.	0	0.6	4.4	7.8	8.8	9.8	9.8	10			
13/10/2013	10:15:00	0.2	0.2	0.4	3.6	7	8.8	10	10	10.2			
13/10/2013	10:30:00	0.2	0.4	0.4	2.6	6.4	8.4	10.2	10.2	10.4			
13/10/2013	10:45:00	0.2	0.4	0.6	1.8	5.8	8.4	10.4	10.4	10.6			
13/10/2013	11:00:00	.	0.2	0.6	1.2	5	8.4	9.4	10.4	10.6			
13/10/2013	11:15:00	.	0	0.4	0.8	4	7.4	9.2	10.4	10.6			
13/10/2013	11:30:00	.	0	0.2	0.6	2.8	6.6	8.6	10.4	10.4			
13/10/2013	11:45:00	.	0	0	0.6	1.8	5.8	8.4	10.4	10.4	10.6		
13/10/2013	12:00:00	.	0	0	0.6	1.2	5	8.4	9.4	10.4	10.6		

Southchurch Park Rain Gauge Data			Calculation of peak rainfall depths: duration (hours)										
Date	**Time**	**Rainfall [mm]**	**0.5**	**1**	**2**	**3**	**4**	**5**	**6**	**9**	**12**	**18**	**24**
13/10/2013	12:15:00	.	0	0	0.4	0.8	4	7.4	9.2	10.4	10.6		
13/10/2013	12:30:00	.	0	0	0.2	0.6	2.8	6.6	8.6	10.4	10.6		
13/10/2013	12:45:00	.	0	0	0	0.6	1.8	5.8	8.4	10.4	10.6		
13/10/2013	13:00:00	.	0	0	0	0.6	1.2	5	8.4	10.4	10.6		
13/10/2013	13:15:00	.	0	0	0	0.4	0.8	4	7.4	10.4	10.6		
13/10/2013	13:30:00	.	0	0	0	0.2	0.6	2.8	6.6	10.4	10.6		
13/10/2013	13:45:00	.	0	0	0	0	0.6	1.8	5.8	10.4	10.6		
13/10/2013	14:00:00	.	0	0	0	0	0.6	1.2	5	10.4	10.6		
13/10/2013	14:15:00	.	0	0	0	0	0.4	0.8	4	10.4	10.6		
13/10/2013	14:30:00	0.4	0.4	0.4	0.4	0.4	0.6	1	3.2	10.8	10.8		
13/10/2013	14:45:00	0.2	0.6	0.6	0.6	0.6	0.6	1.2	2.4	11	11		
13/10/2013	15:00:00	.	0.2	0.6	0.6	0.6	0.6	1.2	1.8	10	11		
13/10/2013	15:15:00	.	0	0.6	0.6	0.6	0.6	1	1.4	9.8	11		
13/10/2013	15:30:00	.	0	0.2	0.6	0.6	0.6	0.8	1.2	9.2	11		
13/10/2013	15:45:00	.	0	0	0.6	0.6	0.6	0.6	1.2	9	11		
13/10/2013	16:00:00	.	0	0	0.6	0.6	0.6	0.6	1.2	9	11		
13/10/2013	16:15:00	.	0	0	0.6	0.6	0.6	0.6	1	8	11		
13/10/2013	16:30:00	.	0	0	0.2	0.6	0.6	0.6	0.8	7.2	11		
13/10/2013	16:45:00	.	0	0	0	0.6	0.6	0.6	0.6	6.4	11		
13/10/2013	17:00:00	.	0	0	0	0.6	0.6	0.6	0.6	5.6	11		
13/10/2013	17:15:00	.	0	0	0	0.6	0.6	0.6	0.6	4.6	11		
13/10/2013	17:30:00	.	0	0	0	0.2	0.6	0.6	0.6	3.4	11		

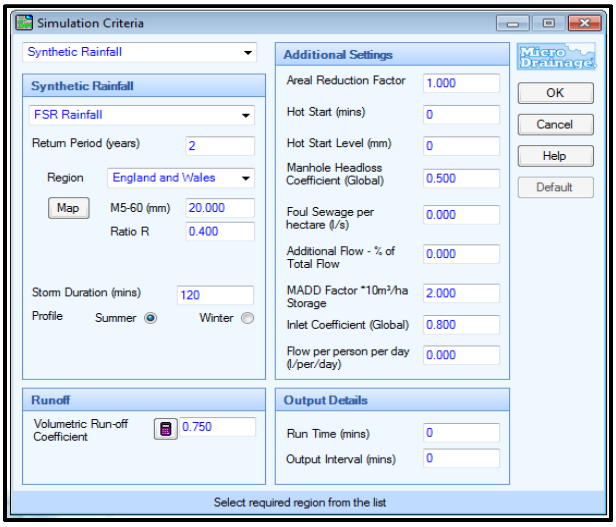
Southchurch Park Rain Gauge Data			Calculation of peak rainfall depths: duration (hours)										
Date	Time	Rainfall [mm]	0.5	1	2	3	4	5	6	9	12	18	24
13/10/2013	17:45:00	.	0	0	0	0	0.6	0.6	0.6	2.4	11	11.2	
13/10/2013	18:00:00	.	0	0	0	0	0.6	0.6	0.6	1.8	10	11.2	
13/10/2013	18:15:00	.	0	0	0	0	0.6	0.6	0.6	1.4	9.8	11.2	
13/10/2013	18:30:00	.	0	0	0	0	0.2	0.6	0.6	1.2	9.2	11.2	
13/10/2013	18:45:00	.	0	0	0	0	0	0.6	0.6	1.2	9	11.2	
13/10/2013	19:00:00	.	0	0	0	0	0	0.6	0.6	1.2	9	11.2	
13/10/2013	19:15:00	.	0	0	0	0	0	0.6	0.6	1	8	11.2	
13/10/2013	19:30:00	.	0	0	0	0	0	0.2	0.6	0.8	7.2	11.2	
13/10/2013	19:45:00	.	0	0	0	0	0	0	0.6	0.6	6.4	11.2	
13/10/2013	20:00:00	.	0	0	0	0	0	0	0.6	0.6	5.6	11.2	
13/10/2013	20:15:00	.	0	0	0	0	0	0	0.6	0.6	4.6	11.2	
13/10/2013	20:30:00	.	0	0	0	0	0	0	0.2	0.6	3.4	11	
13/10/2013	20:45:00	.	0	0	0	0	0	0	0	0.6	2.4	11	
13/10/2013	21:00:00	.	0	0	0	0	0	0	0	0.6	1.8	11	
13/10/2013	21:15:00	.	0	0	0	0	0	0	0	0.6	1.4	11	
13/10/2013	21:30:00	.	0	0	0	0	0	0	0	0.6	1.2	11	
13/10/2013	21:45:00	.	0	0	0	0	0	0	0	0.6	1.2	11	
13/10/2013	22:00:00	.	0	0	0	0	0	0	0	0.6	1.2	11	
13/10/2013	22:15:00	.	0	0	0	0	0	0	0	0.6	1	11	
13/10/2013	22:30:00	.	0	0	0	0	0	0	0	0.6	0.8	11	
13/10/2013	22:45:00	.	0	0	0	0	0	0	0	0.6	0.6	11	
13/10/2013	23:00:00	.	0	0	0	0	0	0	0	0.6	0.6	11	

Southchurch Park Rain Gauge Data			Calculation of peak rainfall depths: duration (hours)										
Date	**Time**	**Rainfall [mm]**	**0.5**	**1**	**2**	**3**	**4**	**5**	**6**	**9**	**12**	**18**	**24**
13/10/2013	23:15:00	.	0	0	0	0	0	0	0	0.6	0.6	11	
13/10/2013	23:30:00	.	0	0	0	0	0	0	0	0.2	0.6	11	
13/10/2013	23:45:00	.	0	0	0	0	0	0	0	0	0.6	11	11.2
Max			**2.2**	**4**	**7.2**	**8.6**	**9.8**	**10.4**	**10.4**	**11**	**11**	**11.2**	**11.2**
Return period (point)			**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Total: 11.2mm			"This event is commonplace with a return period < 1 month"										

APPENDIX B – HYDRAULIC CALCULATIONS

47061441 Clifton Drive and Eastern Esplanade, Southend, Microdrainage Surface Runoff Calculations

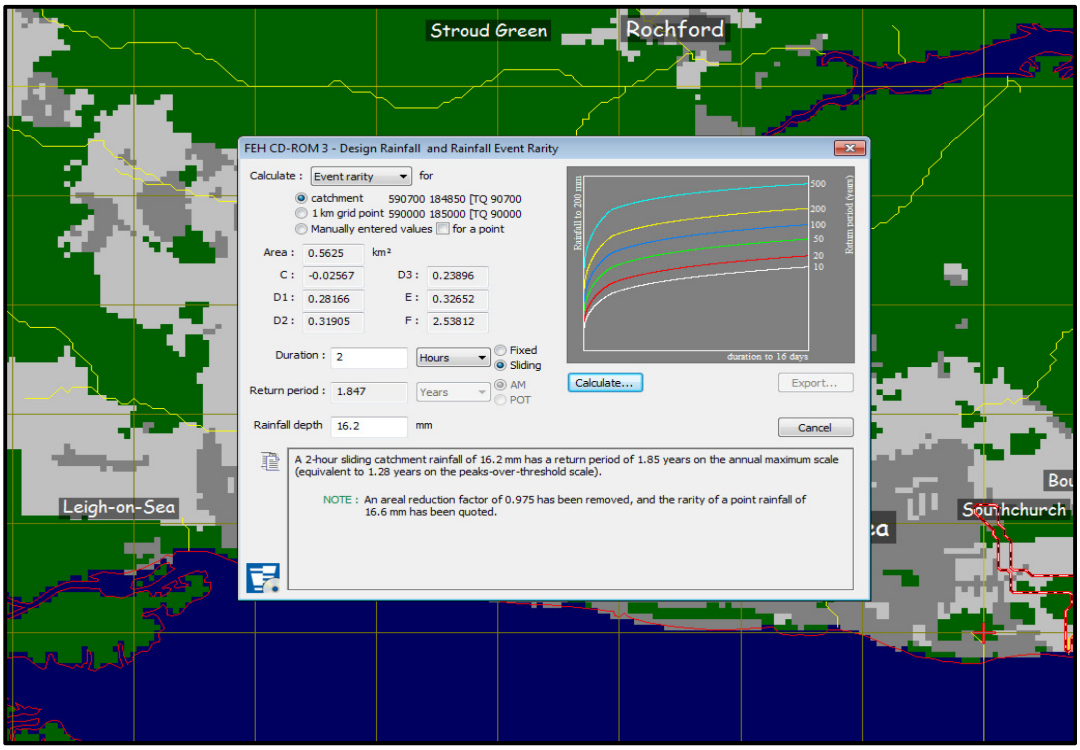
1. Model Parameters Summary



The catchment area is around 0.2km2. a total of 16.2 mm of rain fell over 2 hours (8.1mm/hr).

The outfall sewer has a diameter of 300mm, length of 100m and fall of 11.5m.

2. Rainfall Summary

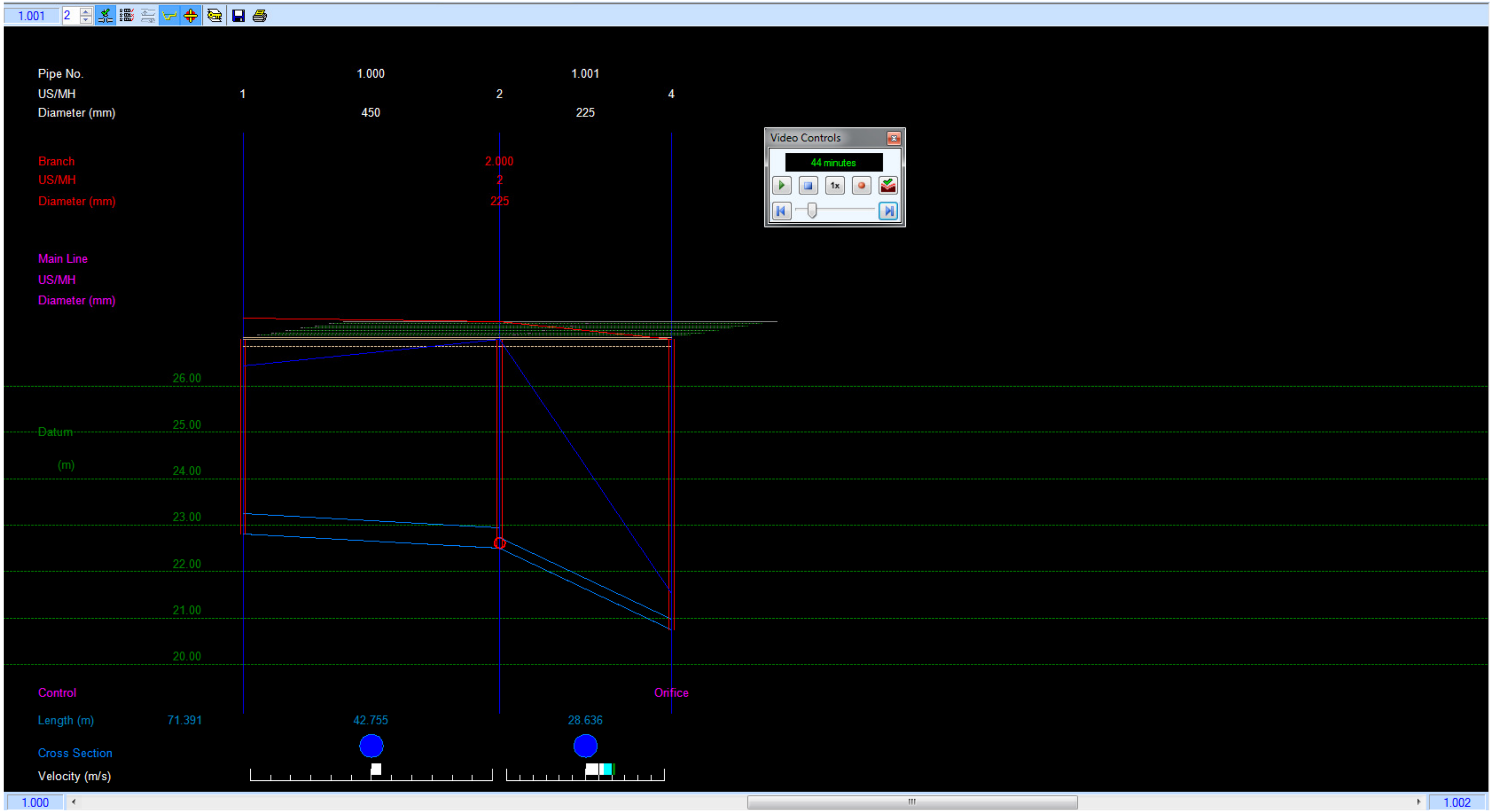


3. Results Summary

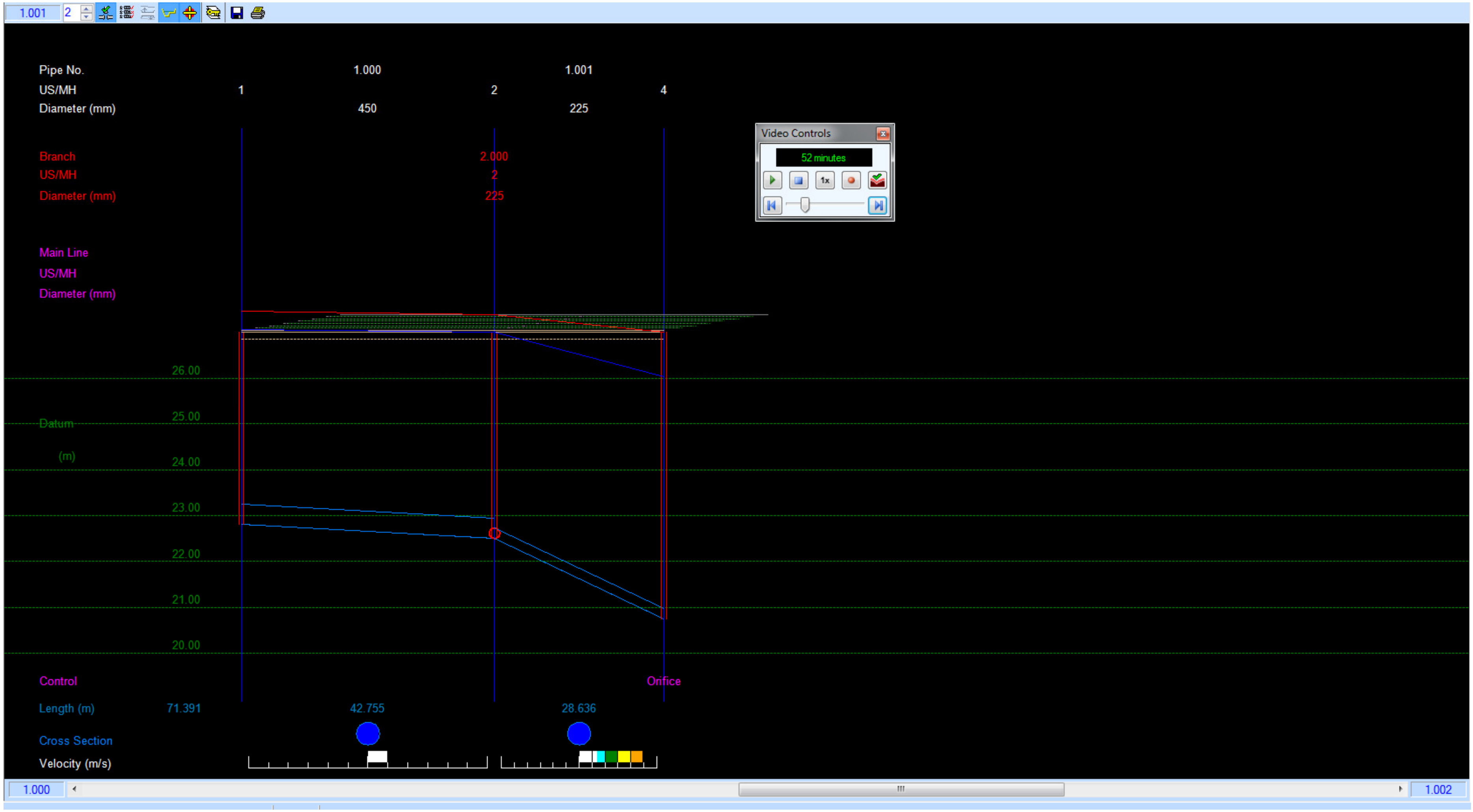
(i) For the 100% discharge reduced tide locked scenario, flooding would occur around 24 mins after the onset of rain. So flooding requires **1.49 mm of rain**

(ii) For the 50% discharge reduced tide locked scenario, flooding would occur around 36 mins after the onset of rain. So flooding requires **2.56 mm of rain**

(iii) For the 0% discharge reduced tide locked scenario, flooding would occur around 60 mins after the onset of rain. So flooding requires **9.90 mm of rain**



(i) 100% tide locked scenario

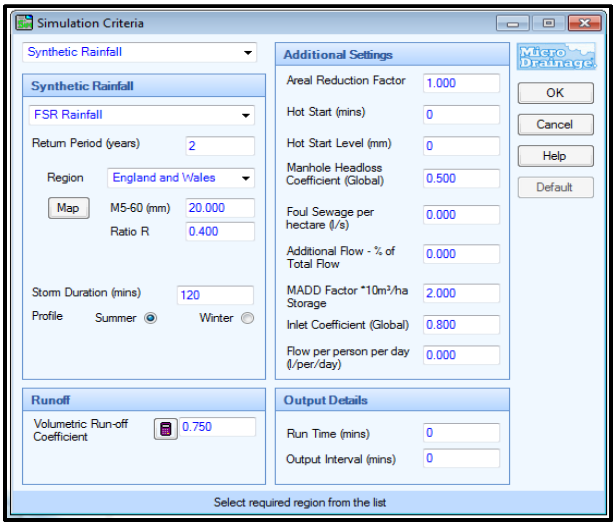


(ii) 50% tide locked scenario

(iii) 0% tide locked scenario

47061441 Campfield Road and Ness Road, Southend, Microdrainage Surface Runoff Calculations

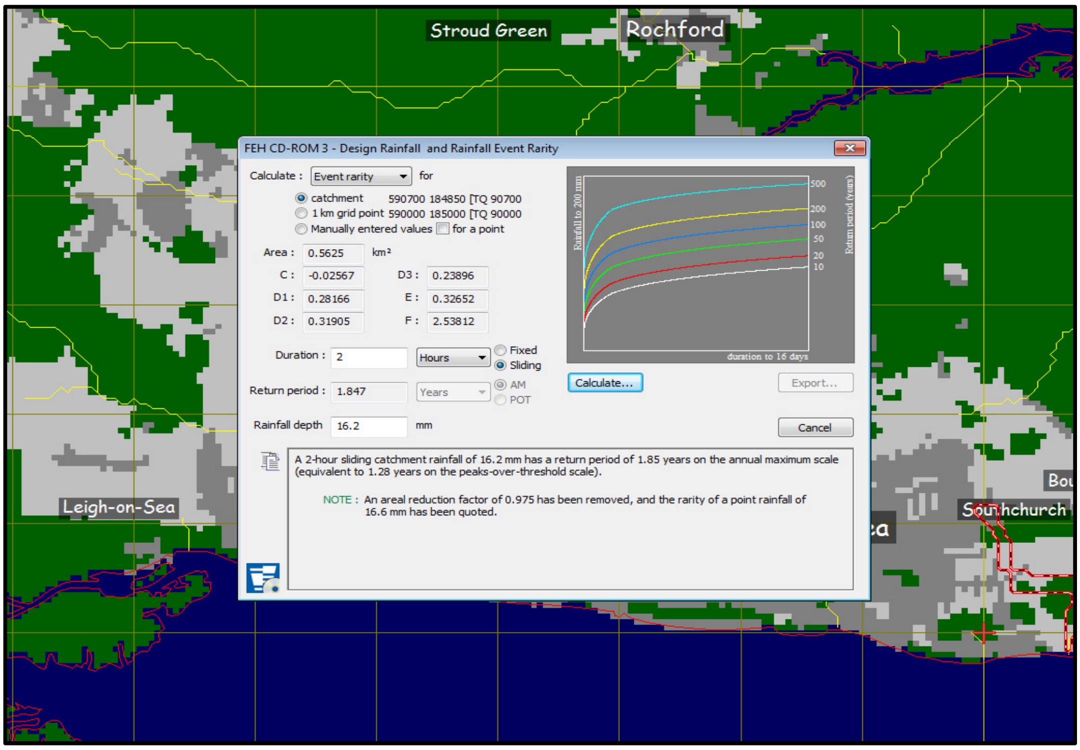
1. Model Parameters Summary



The catchment area is around 0.18km2. a total of 16.2 mm of rain fell over 2 hours (8.1mm/hr).

The sewer upstream of the outfall at the junction of Church Road and Ness Road has a diameter of 225mm, length of 28.6m and fall of 1.75m.

2. Rainfall Summary

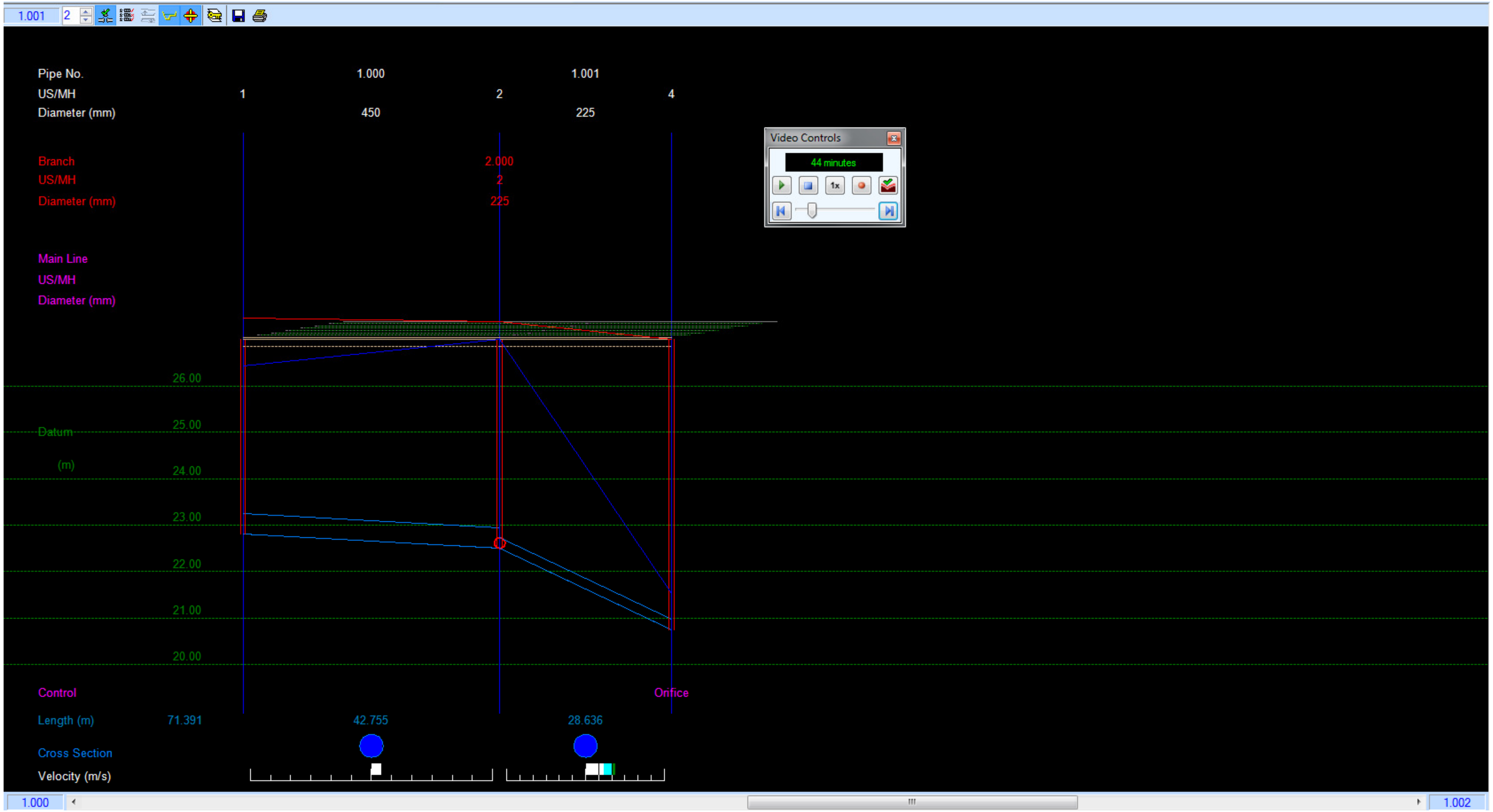


3. Results Summary

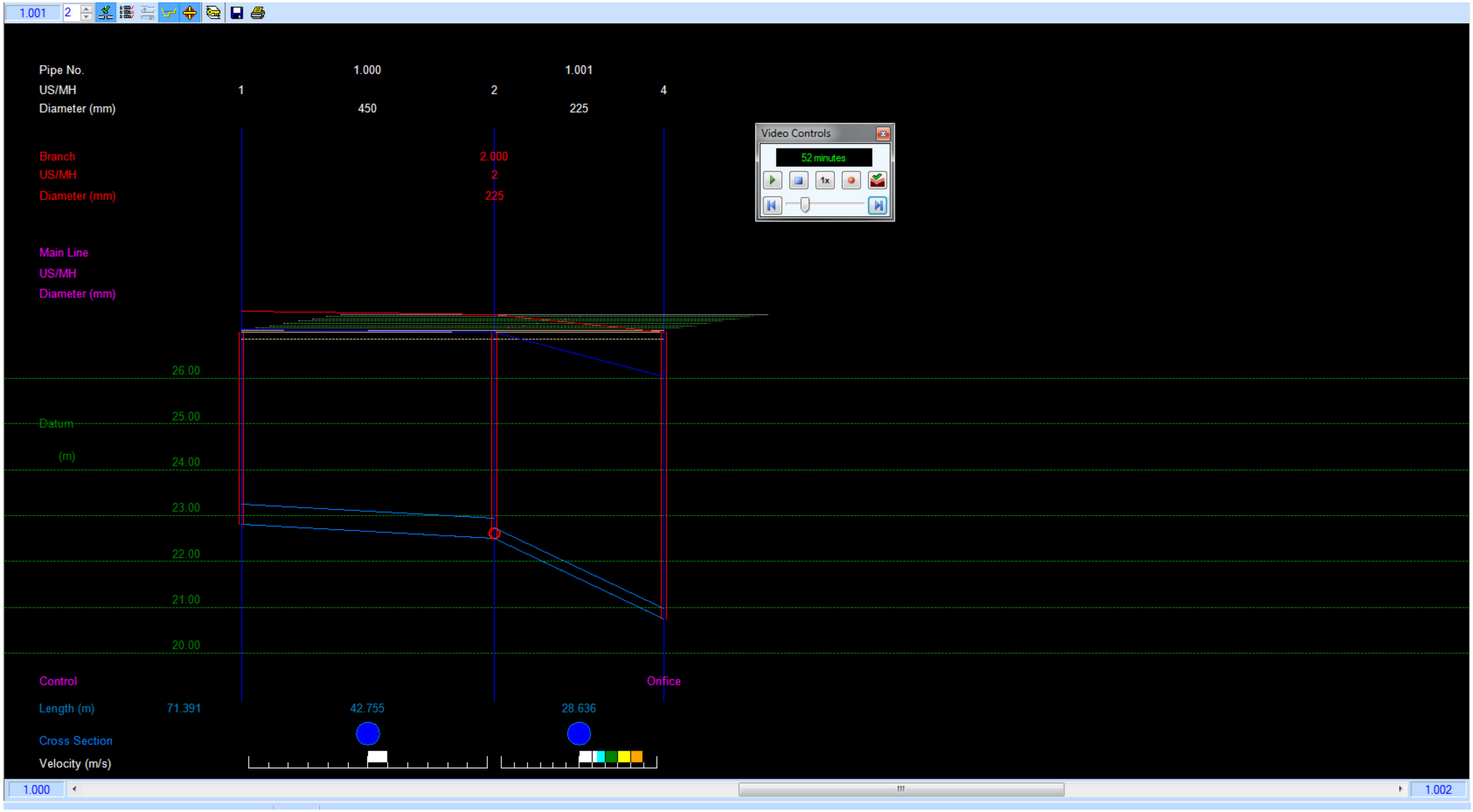
(i) For the 100% discharge reduced tide locked scenario, flooding would occur around 36 mins after the onset of rain. So flooding requires **2.56 mm of rain**

(ii) For the 50% discharge reduced tide locked scenario, flooding would occur around 48 mins after the onset of rain. So flooding requires **4.56mm of rain**

(iii) For the 0% discharge reduced tide locked scenario, flooding would occur around 56 mins after the onset of rain. So flooding requires **7.56 mm of rain**



(i) 100% tide locked scenario

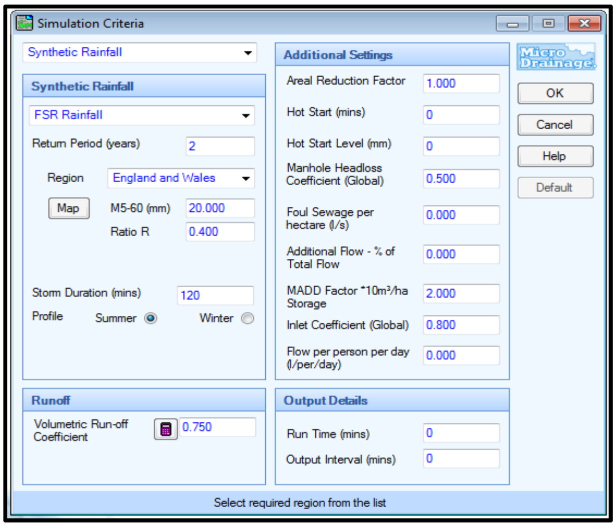


(ii) 50% tide locked scenario

(iii) 0% tide locked scenario

47061441 Ness Road and Shoebury Common Road, Southend, Microdrainage Surface Runoff Calculations

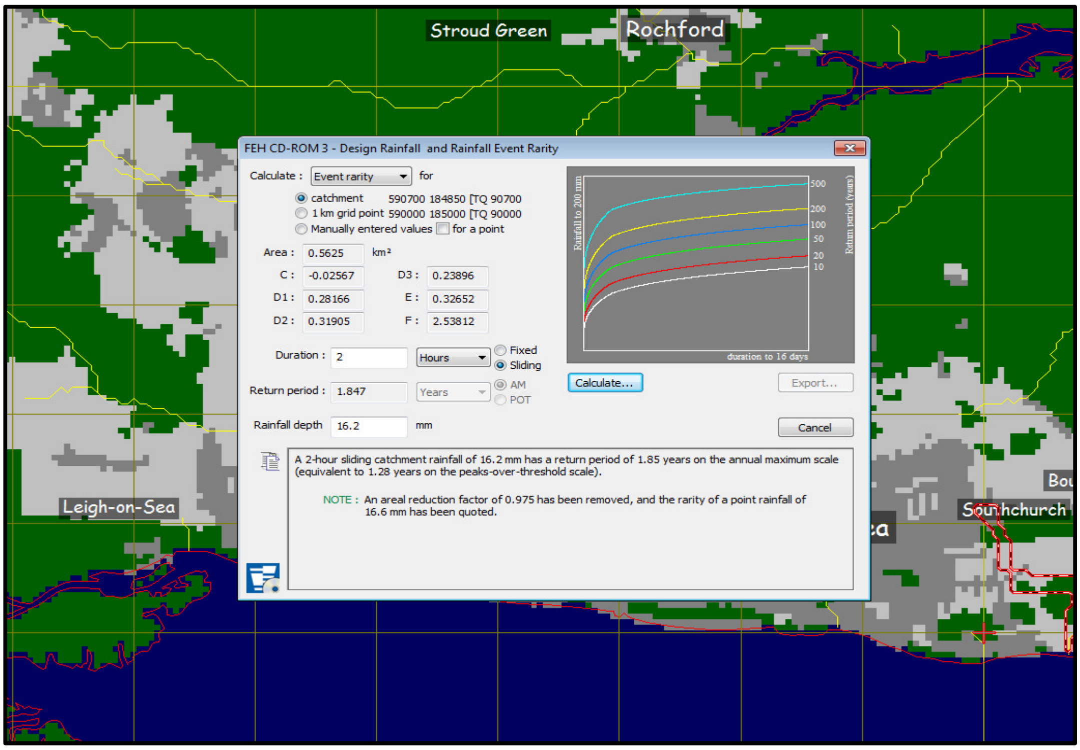
1. Model Parameters Summary



The catchment area is around 0.39km2. a total of 16.2 mm of rain fell over 2 hours (8.1mm/hr).

The Maplin Road sewer upstream of the outfall has a diameter of 975mm, length of 28.636m and fall of 3m.

2. Rainfall Summary

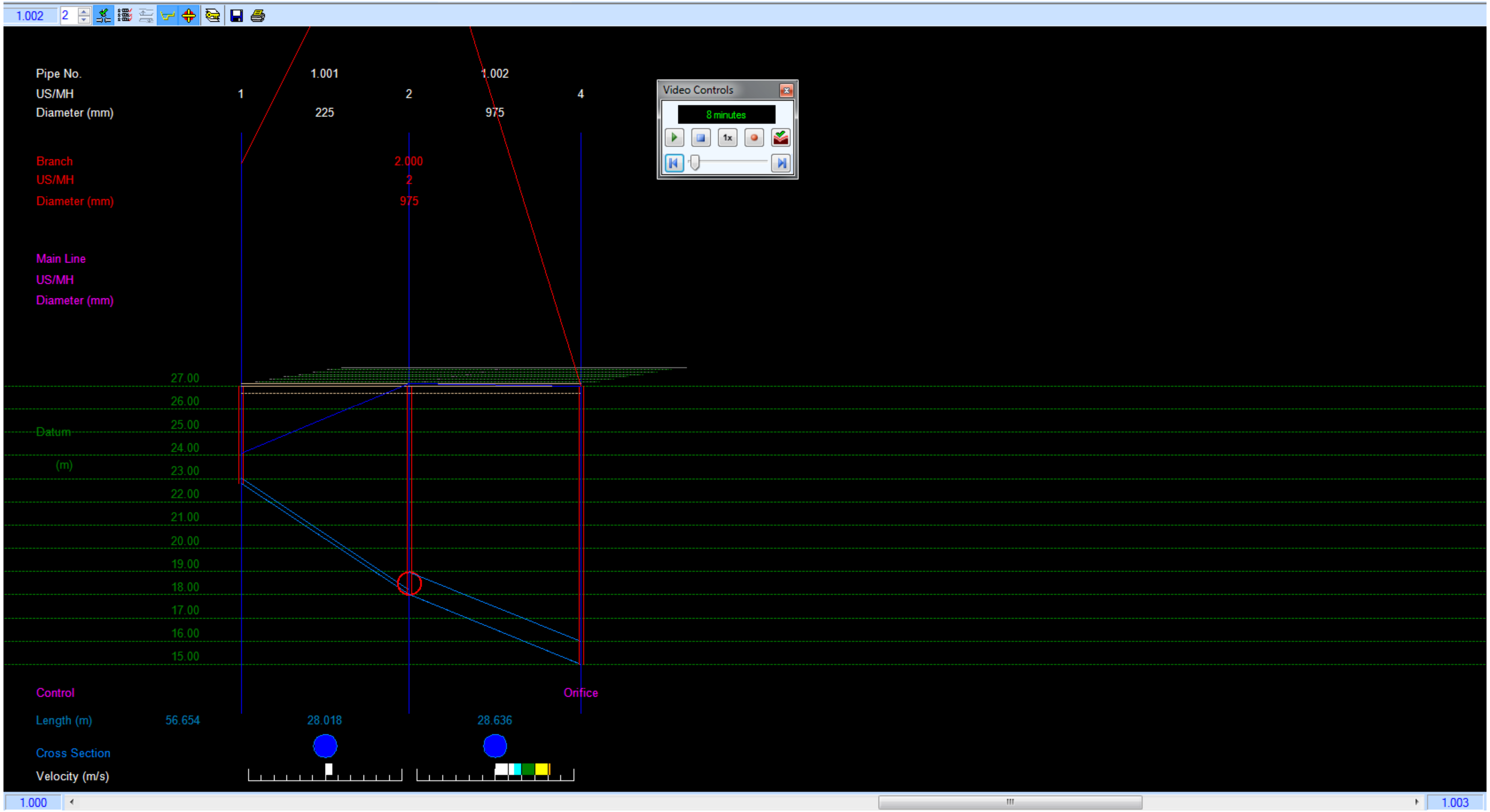


3. Results Summary

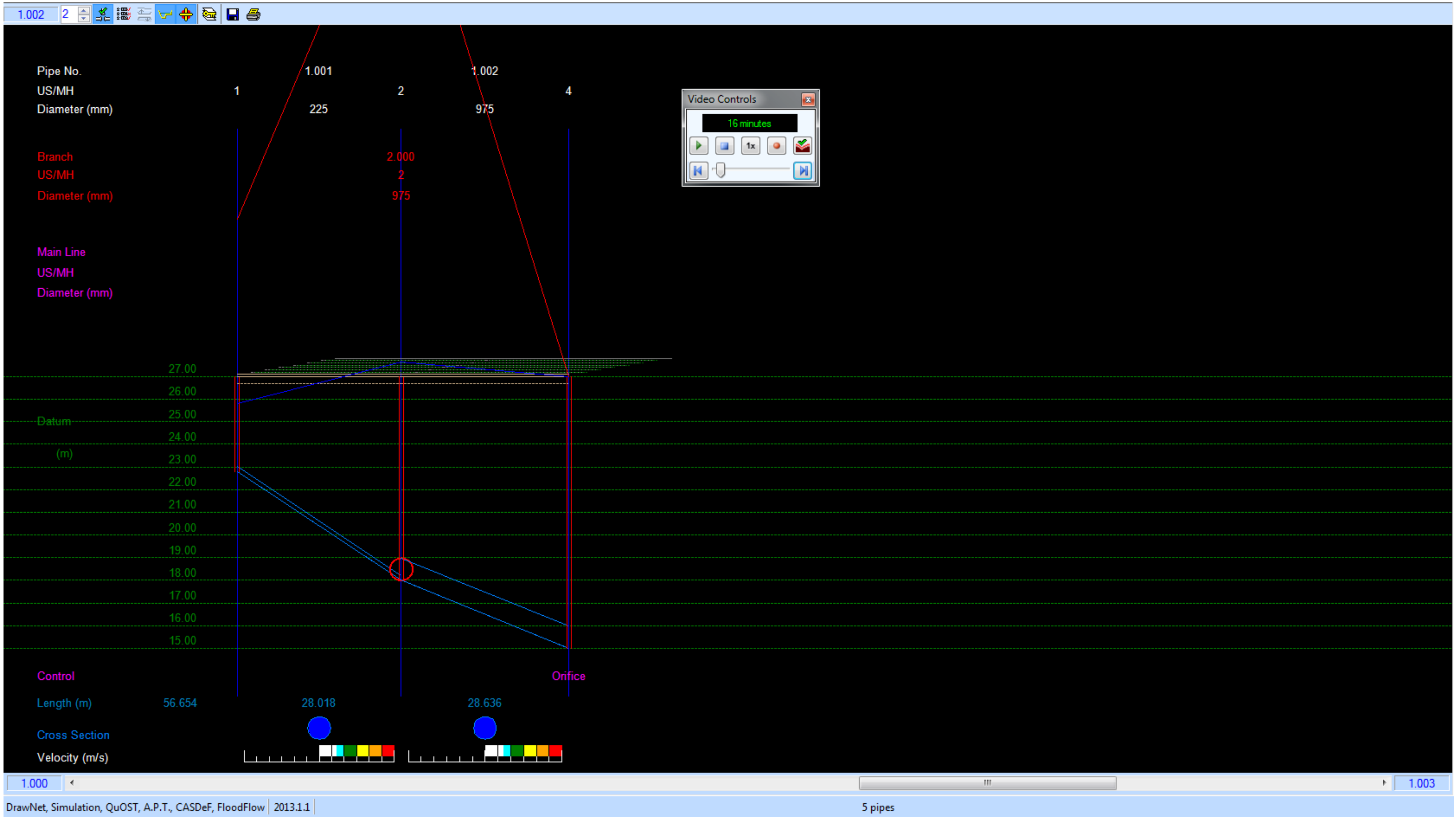
(i) For the 100% discharge reduced tide locked scenario, flooding would occur around 8 mins after the onset of rain. So flooding requires **0.44 mm of rain**

(ii) For the 50% discharge reduced tide locked scenario, flooding would occur around 16 mins after the onset of rain. So flooding requires **0.93 mm of rain**

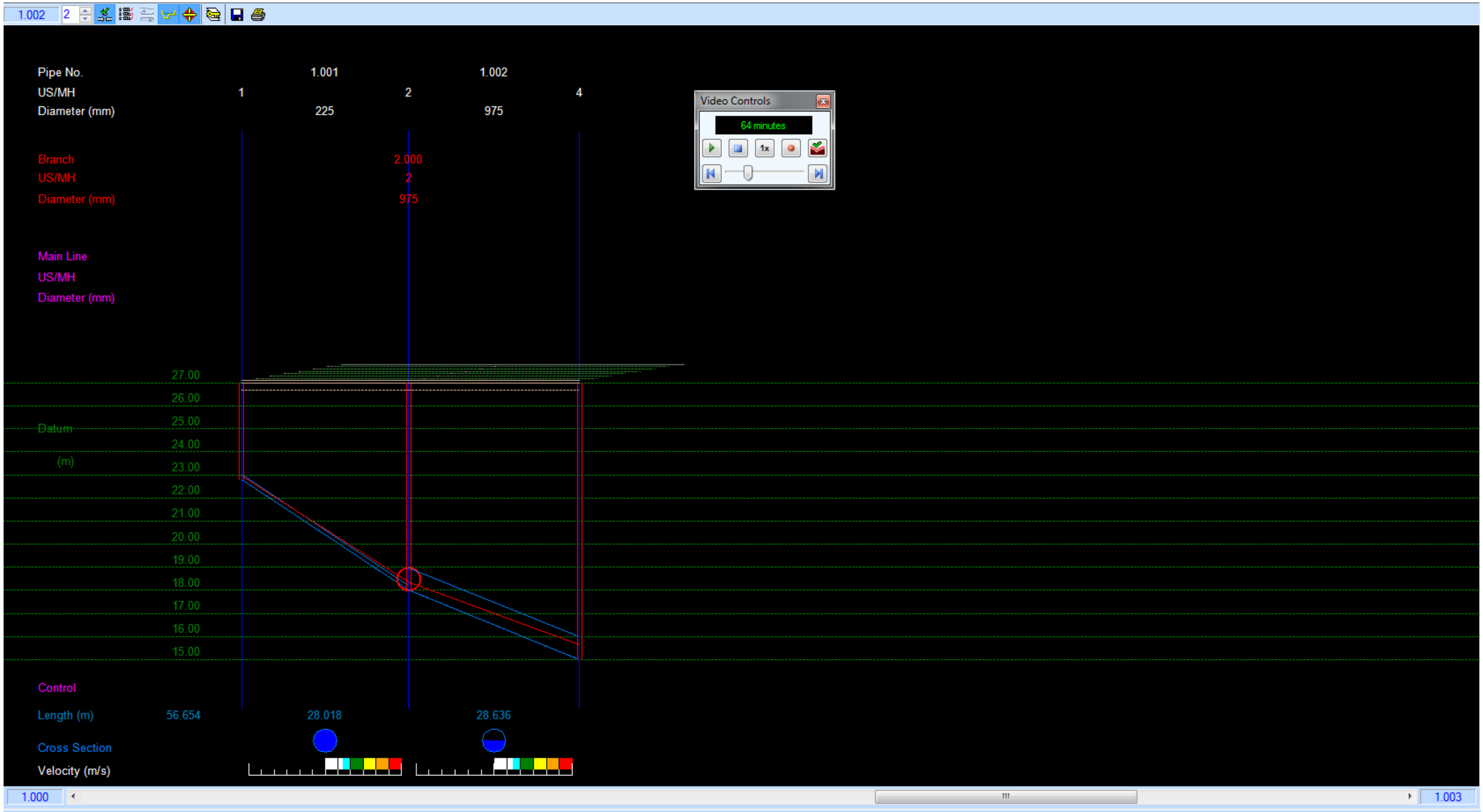
(iii) For the 0% discharge reduced tide locked scenario, flooding would not occur



(i) 100% tide locked scenario



(ii) 50% tide locked scenario



(iii) 0% tide locked scenario