Final Technical Report

Lancing Surface Water Management Plan

Prepared for

West Sussex County Council

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Contents

Acronyms and Abbreviations

BH	Borehole
BHAFC	Brighton and Hove Albion Football Club
Defra	Department for Environment, Food and Rural Affairs
EA	Environment Agency
EAP	Emergency Action Plan
FEH	Flood Estimation Handbook
FCRM GiA	Flood and Coastal Erosion Risk Management Grant in Aid
FRA	Flood Risk Assessment
GIS	Geographic Information System (ArcGIS used in this study)
IRP	Infiltration Reduction Plan
LIDAR	Light Detection and Ranging
LFRMS	Local Flood Risk Management Strategy
mAOD	metres Above Ordnance Datum
SFRA	Strategic Flood Risk Assessment
SoP	Standard of Protection
SW	Southern Water
SWMP	Surface Water Management Plan
WSCC	West Sussex County Council
1D	One Dimensional (hydraulic model)

Introduction

1.1 Project context

Lancing Surface Water Management Plan (SWMP) has been undertaken as part of a commission to develop SWMPs for five areas of West Sussex which have a history of significant flooding from surface water, groundwater and drainage systems. The five study areas were:

- Easebourne;
- Lancing;
- Manhood Peninsula;
- Upper Lavant Valley, and;
- West Chichester, including Fishbourne and Parklands.

These areas were selected as part of West Sussex County Council's (WSCC) response to the severe flooding in the summer of 2012, known as Operation Watershed[1], although it is recognised that many of these areas have suffered flooding on multiple occasions.

A SWMP is described as a framework through which key local partners with a responsibility for surface water and drainage in their area work together to understand the causes of surface water flooding and agree the most cost effective way of managing that risk. The purpose is to make sustainable surface water management decisions that are evidence based, risk based, future proofed and inclusive of stakeholder views. Managing surface water flooding requires a range of partners, organisations and individuals to work together. The roles and responsibilities for those involved in helping to manage surface water flooding are described in Appendix A.

1.2 Background to Lancing SWMP

Lancing is an area which is exposed to flooding from a range of sources including pluvial, overtopping of watercourses (including the River Adur), sewers, and groundwater. In addition, there are tidal influences within the catchment which affect discharge from the Lancing Brooks and discharge of regional groundwater to the sea. Due to the relatively flat gradient within the system and the influence of groundwater on flooding, Lancing is particularly vulnerable to flooding during winter months. Flooding is generally confined to highways and gardens, and there are few properties which flood internally. Nevertheless, given the complexities of flooding mechanisms in Lancing this SWMP has been undertaken to understand the causes of flooding and identify any capital improvements or ongoing maintenance needed to reduce the impacts of flooding to people and infrastructure.

1.2.1 Objectives

The primary objectives of the Lancing SWMP were to:

- confirm the catchment boundaries and comment on any differences with previous studies;
- gain a better understanding of the existing drainage network, connectivity, and ownership;
- understand the causes of flooding across Lancing from a range of sources including surface water, foul water, groundwater, watercourses, and tidal influence;
- understand the performance of the Lancing Brooks ditch network and identify how and when future maintenance of the ditches needs to be undertaken, and;
- identify any capital works required to mitigate flooding in Lancing.

1.2.2 Scope

The scope for this SWMP was established during the early part of the overall project programme through discussions with WSCC, a rapid assessment of available data, and early establishment of the flooding issues and mechanisms. A scoping document was prepared in March 2014 and agreed by WSCC. The scope is outlined in detail below. It should be noted that the scope of work broadly follows the SWMP

[1] For more information on Operation Watershed see: http://www.westsussex.gov.uk/default.aspx?page=36724

Technical Guidance published by Defra in 2010, ensuring the work was aligned with the national best practice. The SWMP Technical Guidance describes a four step process, as outlined in Figure 1-1.

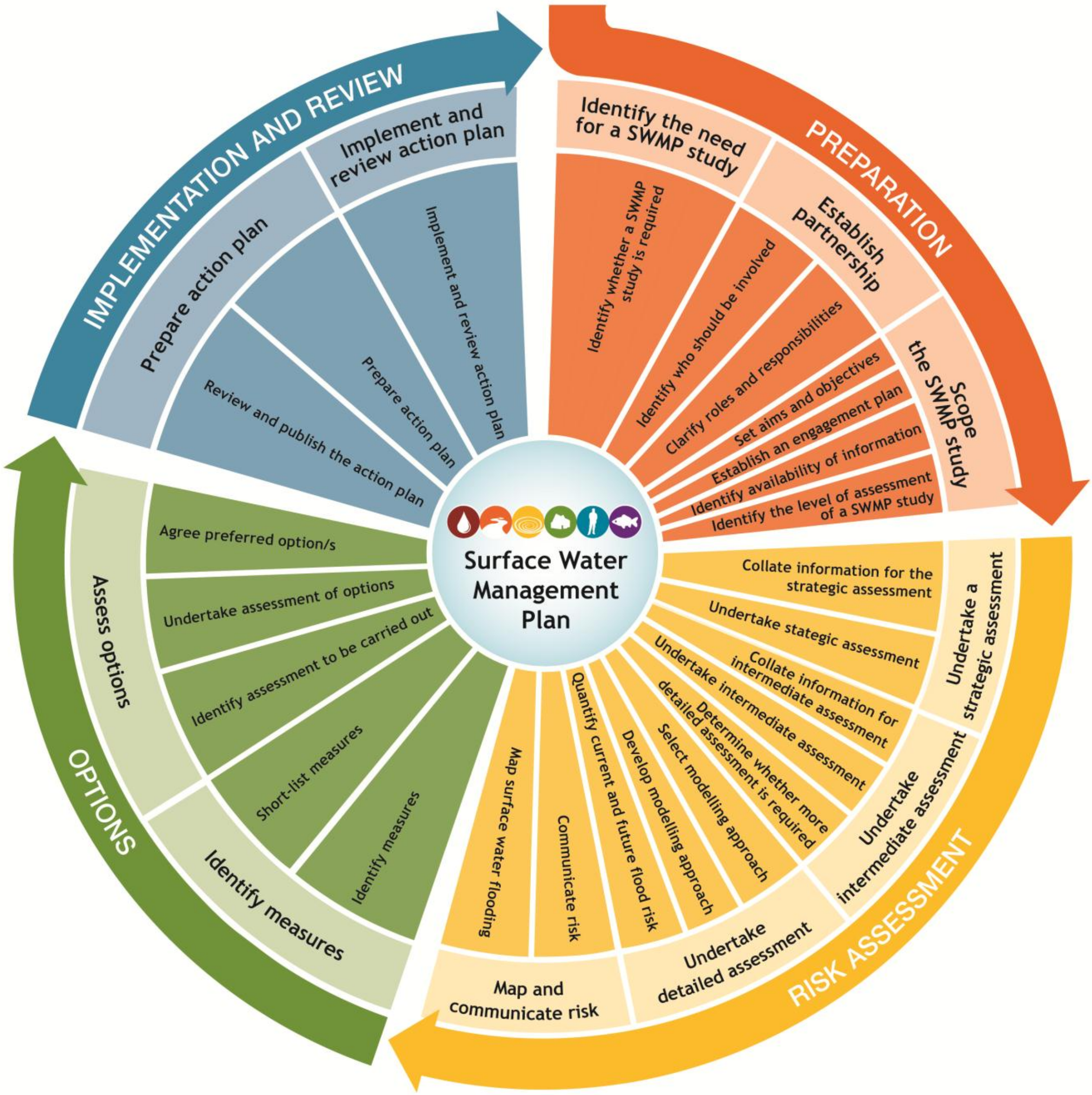

Figure 1-1 *SWMP Process*

Stage 1 – Data collection & review

Stage 1 consisted of data collection, compilation, and review. This included collecting and compiling flood incident data, obtaining third party data sets (e.g. Southern Water, WSCC, Highways Agency, Shoreham Airport drainage data, and any borehole data), and reviewing existing studies and reports relevant to Lancing (e.g. Monson Engineering study, Royal Haskoning study). During this stage, the extent of the drainage catchment was established.

Stage 2 – Understanding the water balance of the system

To investigate the capacity of the drainage networks, it is important to understand the magnitude of flows arising from the catchment. A conceptual hydrological and hydro-geological analysis was undertaken to understand the inflows and outflows from the drainage system and possible conveyance measures in “pinch point” locations.

Stage 3 – Undertake surveys

Following data review and site specific investigation, surveys were undertaken in key areas of Lancing, including:

- walkover and connectivity surveys in October 2014;
- cross-section survey of the entire ditch network in December 2014 and January 2015, and;
- limited manhole and level survey in West Beach Estate in March 2015 and April 2015.

Analysis undertaken during the first three stages was used to establish a comprehensive understanding of the causes and effects of flooding in Lancing.

Stage 4 – Identify options to mitigate flooding

The final stage of the study identified proportionate and cost effective mitigation measures to alleviate flooding in Lancing. It included a water level management plan, which included operational rules for ditch clearances, dredging, vegetation management and future maintenance recommendations.

1.2.3 Study area

The study area covers the entire catchment from the west which drains towards the Lancing Brooks. The most northerly location of the study area is the open space to the north of Firle Road (in North Lancing). To the east the River Adur forms a natural catchment boundary and the Lancing Brooks discharge into the Adur. To the south the sea forms another natural catchment boundary. A map of the study area is provided in Figure 3-1 and Appendix B.

1.2.4 Key stakeholders

A stakeholder engagement strategy was prepared which identified who to engage with, when, and how. Stakeholder engagement is an important part of the overall approach to the development of the Surface Water Management Plan and is integral to the agreed methodology for the study as a whole. The approach aimed to ensure that professional stakeholders, landowners, parish councils and other relevant groups were given an opportunity to help shape the study. Engagement, in different forms, was undertaken throughout the study to:

- ensure the study was robust and that the data used to underpin it were as accurate as possible
- ensure that best use is made of local knowledge and that the analysis of flood risk matches local experience;
- ensure the study addresses the key problems that are of the most concern to local communities;
- generate greater understanding about, and support for, the way in which local flooding will be managed, and;
- help to encourage stakeholders and the general public to take actions to help protect themselves against flooding.

The key stakeholders identified for this SWMP are:

- West Sussex County Council as the Lead Local Flood Authority and Highways Authority;
- Adur and Worthing Councils as the Land Drainage Authority and Local Planning Authority;
- The Environment Agency in relation to springs and groundwater issues in the catchment;
- Riparian owners and local flood action groups particularly at Mash Barn Lane, Manor Close (known as the Lancing Manor (S.E) Residents Network) and West Beach and Widewater;
- Shoreham airport;
- Highways England, and;
- Southern Water as the statutory sewerage undertaker.

A list of engagement activities undertaken during the Lancing SWMP are described in Table 1-1.

Table 1-1 Engagement activities for Lancing SWMP

Activity	**Purpose/Detail**	**Timescale**
Initial meeting with WSCC and Adur and Worthing Councils	To agree the scope of the work	March 2014
Technical discussions with WSCC	To understand the function of the highways drainage system	Throughout study
Technical discussions with representatives from Adur and Worthing Councils	To understand local land drainage constraints	Throughout study
Technical discussions with Environment Agency Staff	To understand groundwater issues, and ongoing capital/maintenance work in the catchment	Throughout study
Engagement with Southern Water	To understand operational issues in the foul sewer network due to infiltration, actions taken over the recent wet winters, and future plans to manage infiltration	Throughout study
Meeting with local representatives	To understand local flooding issues and gain an insight into current measures being taken to alleviate flooding	October 2014
Attendance and presentation at Adur Floodwatch event	To give an overview of the SWMP to the Adur Floodwatch event and seek feedback on local flooding issues	October 2014
Walkover survey and site visits (with representatives from Adur and Worthing Councils)	To understand the catchment flows and local issues	October 2014
Discussions with local representatives	To gain a continued understanding of flooding issues throughout the study	Throughout study

SECTION 2

Review of existing data, studies and actions

2.1 Data collected for SWMP

2.1.1 Data collected for SWMP

A summary and analysis of the data received for the Lancing SWMP is provided in Table 2-1. It includes a summary of data quality issues.

Table 2-1 Data received for Lancing SWMP

Dataset	Data received from	Comments	Data Quality Issues
Common data received across all five study areas			
Bedrock and Superficial Geology	British Geological Society	Maps of the bedrock and superficial geology	-
Digital Terrain Model (DTM)	EA	This is a model of the ground surface, used by the Environment Agency for their national surface water mapping	The data is a composite of LiDAR and NextMap. The NextMap has a much lower accuracy which makes it less reliable as a data source
Flooded Properties Register (DG5)	Southern Water	This is the register of flooded properties held by Southern Water which are the result if hydraulic capacity issues in the public sewer network	-
Flood Map for Planning	EA	National fluvial flood map provided by the EA	Only shows flooding from watercourses where the upstream catchment is >3km^2
Flood Map for Surface Water	EA	National surface water flood mapping provided by the EA for the 1 in 30 year, 1 in 100 year and 1 in 1000 year rainfall probability events	This is the most comprehensive surface water mapping available, but given the mapping is at a national scale there are a number of generic assumptions which may not be locally relevant.
Groundwater Susceptibility Mapping	WSCC	A groundwater flood risk map provided by WSCC, dividing areas into low, moderate and high groundwater flood risk	
Highway drainage data	WSCC	Details of the public highway network	This dataset only contains the location of highway gullies, but does not include details of the pipework
Historic Flood Outlines	EA	Recorded flood outlines from fluvial flooding collated by the EA	
Historic flooded properties	WSCC	A point dataset showing the location of flooded properties	Known limitations with this dataset, as there are many properties not recorded on this dataset which have flooded. The data goes back to 2012
Historic flooded roads	WSCC	A point dataset showing the location of flooded roads	Known limitations with this dataset, as there are many roads not recorded on this dataset which have flooded. The data goes back to 2012
June 2012 Flood Investigation	WSCC	Investigation into June/July 2012 flooding incidents across West Sussex	-

Local Flood Risk Management Strategy	WSCC	A statutory document produced by WSCC as part of their responsibility as a LLFA	-
National Receptor Dataset	EA	Provides location and details of residential, non-residential properties, and critical infrastructure	-
Operation Watershed details	WSCC	Details of the schemes completed or ongoing as part of Operation Watershed	-
Public Sewer Network data	Southern Water	Location, connectivity and details of the public sewer network	Asset details of the surface water sewer system are generally of poorer quality than for the foul or combined system
River network	EA	Location of watercourses	This is a national dataset and there are some assumptions about the routes of watercourses, especially where watercourses go into culverted sections
Data received bespoke to Lancing SWMP			
A27 design drawings	Highways Agency	Design drawings from improvement works on A27	Thought to be missing 1 x outfall from the A27
Brighton and Hove Albion Planning Information	Adur and Worthing Councils	Borehole report and drainage design	-
Borehole information	Environment Agency	Borehole information for Daniels Barn and Sussex Pad	No data available for Daniels Barn since 2010
DG5 Register	Southern Water	Details of the foul flooding in Lancing	-
Evidence from local residents	Local residents	Information on flooding locations and times from local residents. Included pictures and videos where relevant	-
Golf course planning application	Local residents	Details on the planning application for the golf course development	
Haskoning Study	Adur and Worthing Councils	Royal Haskoning Study on Lancing Brooks	-
Historic Maps and books	Various	Range of historic maps and historical information about Lancing	-
Lancing Brook Outfalls	Halcrow	Information on the hydrology, modelling and design for the re-design of the Lancing Brook Outfalls	-

Monson Report	Adur and Worthing Councils	1994 Monson Report into the Lancing Brooks, including recommendations about future capital and maintenance needs	-
Network Rail Culverts	Network Rail	Details of Network Rail culverts in the study area	-
New Monks Farm hydro-geology report	WSCC	Report for New Monks Farm development on Hydro-geology of proposed development	-
Rainfall data	Environment Agency / WSCC	Rainfall data from Applesham Farm, and Skyview dataset	-
Shoreham Airport drainage	Adur and Worthing Councils	Details of drainage at Shoreham Airport	-
Surveys from WSCC	WSCC	WSCC surveys of West Beach/Widewater and Manor Way	-
Tidal data	-	Tide levels at Shoreham	-
Watercourse clearance details	Adur and Worthing Councils	Details on the Lancing Brooks ditch clearance undertaken by Adur and Worthing District Councils (2010-2014)	-
West Beach survey	WSCC	A survey of roads levels on West Beach Estate, using temporary benchmark datum	
Widewater	WSCC	Information on the operation and monitoring of Widewater Lagoon	-

2.2 Existing studies

2.2.1 Strategic Flood Risk Assessment

An update of the Strategic Flood Risk Assessment (SFRA) was produced by Adur and Worthing Councils in January 2012, and is available via the following link:

http://www.adur-worthing.gov.uk/planning-policy/adur-and-worthing-background-studies-and-info/floodrisk/#sfra.

The SFRA provides an overview of all sources of flood risk including fluvial, tidal, surface water, groundwater and sewer flooding. It also summarises the key flood risk issues for all development sites identified in the Core Strategy (e.g. Shoreham Airport).

Relevant extracts from the SFRA are provided in Table 2-2. The SFRA identifies Lancing as being at risk from tidal, surface water, groundwater and sewer flooding. The findings of the SFRA must be considered in the context of other local investigations (e.g. New Monks Farm hydrogeological investigations which is described in Section 2.3.3) and actions already taken by relevant organisations to reduce flood risk (see Section 2.4).

Table 2-2 Extracts from SFRA relevant to Lancing

Source of flood risk	Extract from SFRA
Tidal	"In Adur, the tidal flood zones are more extensive, covering parts of South Lancing, Shoreham by Sea, Shoreham Harbour and Shoreham Airport. The tidal flood zones continue north of the A27 along the River Adur." With respect to Shoreham Airport: "The Adur Tidal Walls scheme will improve the defences along the west bank and the standard of protection afforded to the area. Following construction the area will no longer be inundated during the 1 in 20-year flood event, the extent of the area no longer inundated is shown in Map 17. Consequently, in the future it will be appropriate for this area to be considered non-functional and will lead to the redefinition of Flood Zone 3b. It is understood that the impact of the scheme on flood risk on the east bank will be mitigated through local improvements to the east bank defences." With respect to the new Adur Tidal Walls: "From information provided during the preparation of this SFRA it is suggested that the SoP of these defences will decrease under the impacts of climate change with some inundation of the floodplain behind the defences expected in a future (2115) 1 in 200 year return period event."
Surface water	"The area to the south of the A27 is affected by surface water ponding along roads and streets. The significant areas include, immediately south of the Old Shoreham Road in North Lancing…" "The Lancing Brook Flood Investigation report (2010) also assessed the potential consequences of flooding from surface water sources in the Lancing area. The areas at shown to be at risk in the Lancing Brook study largely agreed with the area identified in the FMfSW. The receptors that were highlighted as having experienced flooding were mainly agricultural and scrub land, local residential roads and the gardens of a small number of residential properties. However, it was highlighted that anticipated changes in climate may increase the risk of localised flooding and may increase the flood risk to Shoreham Dogs Trust and several residential properties. An update to this report stated that the cause of flooding referred to in the report was identified during dredging to be a

	manmade dam immediately east of the northeast property in Willowbrook Park, which was erected to hold water in the ditches of Willowbrook Park as a water feature and as a consequence raised water levels considerably upstream."
Groundwater	"The majority of Adur District is susceptible to groundwater flooding. The only areas that don't appear to be susceptible to groundwater flooding are the north west and north east parts of the district which are mainly rural. The central area of the district between the A27 and to Shoreham-by-Sea is more susceptible to groundwater flooding with a high-risk category (>=75%); the rest of the area is covered by a range of risk categories (< 25% to <75%)."
Sewer	"There have been recorded incidences of sewer flooding in Adur and Worthing. The lack of any significant gradient in the low-lying coastal areas means that sewer networks often rely on pumping to drive flow. Consequently, failure of pumping stations can lead to rapid sewer flooding."

2.2.2 Local Flood Risk Management Strategy

Under the Flood and Water Management Act (2010) WSCC is required to develop, maintain, apply and monitor a Local Flood Risk Management Strategy (LFRMS) for the county. The LFRMS sets out WSCC's objectives for managing flood risk from surface water, ordinary watercourses and groundwater, an understanding of the current level of flood risk, roles and responsibilities of organisations, and the actions required to manage flood risk from surface water, ordinary watercourses and groundwater. The LFRMS has identified that over 100,000 properties are in areas susceptible to flood risk within the county.

The LFRMS has identified Lancing as one of the area's most susceptible to surface water flooding. It also recognises the vulnerability of North Lancing to groundwater flooding. The LFRMS action plan identifies a series of actions in Lancing, including the need for a Surface Water Management Plan in North Lancing.

A full copy of the LFRMS is available via WSCC's website: https://www.westsussex.gov.uk/media/1595/local_flood_risk_management_strategy.pdf.

2.2.3 Monson Engineering study

The Monson Engineering study was prepared in 1994 for Adur District Council. The study included cross-sections of the drainage ditches to establish the hydraulic capacity of the system and to identify local options to reduce flood risk. Cross-sections of the drainage ditches were taken every 100m or where there were changes in cross-sections[2]. Furthermore spot levels of land were taken 30m either side of ditch centre lines. Subsequently the report calculated inflows and outflows from the system to understand the water balance and hydraulic capacity of the network. Key findings from the study are:

- the outfall from the system to the estuary of the River Adur has sufficient capacity to discharge flows;
- flooding therefore arises due to hydraulic deficiency in the upstream network;
- the maximum time of flow from the most northerly to southerly points in the catchment was estimated to be 7 hours, which demonstrates the slow velocities of the network in this area;
- the risk of flooding could be reduced up to and including the 1 in 10 year design event through the following works at an estimated cost of £160,000:
    1. clearance of ditches and obstructions in vicinity of Manor Close and Manor Way;
    2. construction of a relief culvert south of New Salts Farm Road bridge, and;
    3. general improvements over the longer term to ditches through regrading, upsizing of culverts at farm crossings, and removal of vegetation.

[2] We recognise that given the surveys were undertaken in 1994 the bed levels of the ditch network will have changed due to siltation and/or maintenance over this period.

2.2.4 Royal Haskoning study

In 2010 Royal Haskoning were commissioned by Worthing Borough Council to undertake a detailed investigation of the Lancing Brook ditch network south of the railway line. The work considered the existing condition of the drainage system using the Environment Agency's Condition Assessment Manual (2006). Using this approach Royal Haskoning identified 8 of the 17 reaches to be in 'very poor' condition and a further 4 to be in 'poor' condition. The report cited heavy vegetation, siltation and blockages caused by trees. Subsequently the report outlined a series of remedial measures to restore the performance of the drainage network, which included localised clearance, vegetation clearance, silt removal, re-grading, structural improvements, and re-instating disused ditches and outfalls.

2.2.5 National surface water mapping

In December 2013 the Environment Agency produced and published updated national surface water mapping to identify areas which were naturally susceptible to surface water flooding. This mapping is based on a modelling approach which applies rainfall onto the surface and allows runoff to be routed depending on the natural topography of the land. The rainfall is factored to account for losses to the ground, and the presence of existing drainage systems which will capture some rainfall. The model was simulated for three rainfall probabilities to comply with the Flood Risk Regulations 2009 (1 in 30 year, 1 in 100 year, 1 in 1000 year). In Lancing the national surface water mapping indicates that North Lancing is most significantly at risk of surface water flooding to properties, gardens and the highway. In Barfield Park and Monks Avenue predicted flooding is limited to the highway and gardens of residential properties.

The national surface water map can be accessed via the Environment Agency's website: http://watermaps.environment-agency.gov.uk/wiyby/wiyby.aspx?topic=ufmfsw#x=357683&y=355134&scale=2. An extract of the national surface water mapping for Lancing is shown in Figure 2-1. This includes the predicted flooding for the 1 in 30 year ("High") and 1 in 100 year ("Moderate") rainfall probabilities.

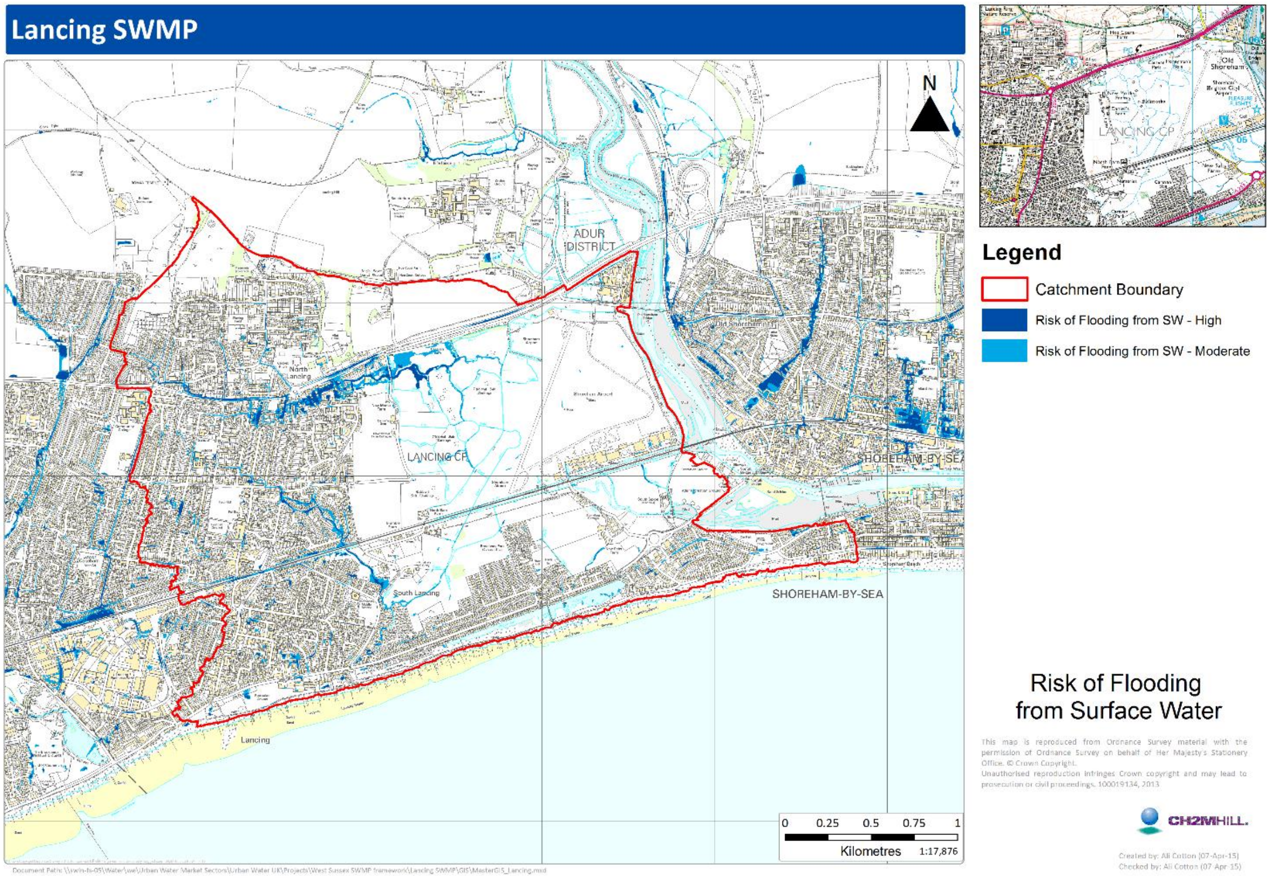

Figure 2-1 Risk of Flooding from Surface Water

2.3 Recent development in the catchment

2.3.1 Golf course development

In 2005 planning permission was granted for an 18 hole golf course east of Mash Barn Lane. The golf course has not been completed at the time of writing this report, although the ground level has been raised by 1m-3m with inert waste material in preparation for the golf course. With respect to drainage and flood risk management one of the schedule of conditions attached to the planning permission was that:

"No development approved by this permission shall be commenced until a scheme for the provision and implementation of compensatory flood storage works has been submitted and approved in writing by the Local Planning Authority. The scheme shall be implemented in accordance with the approved programme and details prior to use of the golf course"[3].

In 2006 a water level management plan was prepared which identified the proposals to provide compensatory flood storage once the golf course was constructed[4] to mitigate for the impact of raised ground levels. This water level management plan estimated that during a high spring tide where there is no discharge from the site, the 100 year flood storage volume would be in the region of 37,000 m^3. The proposals to achieve this (and whether they have been implemented) are described in Table 2-3.

[3] Adur District Council Planning Permission, Application Number L/87/00/TP

[4] Stuart Michael Associates (2006), New Monks Farm, Lancing, Water Level Management Plan

Table 2-3 Proposals and implementation of the water level management plan

Proposal from Water Level Management Plan	Consideration whether the proposal has been implemented
Clear, widen and re-profile the existing ditches in the golf course, and where backfalls exist these were to be re-graded[5]	The watercourses have been widened, deepened and well maintained. Indeed, the landowner undertakes maintenance of the watercourses on an annual basis, with the most recent works undertaken in January 2015.
Control flows at the downstream end of the site to mitigate the improved hydraulic capacity of ditches[6]	The water level management plan identifies that "it was recommended within Stuart Michael Associates' 1999 report that in order to mitigate downstream flooding stop logs should be installed in the control structure where the ditches enter the airfield site. These were introduced during watercourse mitigation proposals within the airfield and this has increased water levels within the Golf Course site by 500mm." However, these have now been permanently removed at the Environment Agency's request[7].
Provision of flood storage in 12 offline balancing ponds[8]	The proposed balancing ponds have not been constructed

Because of the complexities of the Lancing Brooks network it is difficult, without detailed 1D/2D hydraulic modelling, to fully evaluate the impacts of the water level management plan not being fully implemented to date. This is outside the scope of this SWMP. However, it is possible to qualitatively describe the potential impacts. The clearance, widening and re-profiling of the ditches will increase peak flow rates through the golf course site[9], thus enabling flows to drain away from Manor Close more effectively. During more frequent rainfall events flow in the ditches will remain 'in bank'. The widening, deepening and improved maintenance of the ditches will ensure flows can be conveyed away without an increase in flood risk upstream. It remains unclear how an increase in flows through the site will affect downstream flood risk.

During more extreme rainfall events, where the watercourses would naturally flow out of bank, this is no longer possible because of the loss of floodplain storage. Without the compensatory balancing ponds, water could back up in the ditch network and may increase flood risk to properties upstream.

Despite two of the wettest winters on record in recent years there is no confirmed evidence that flooding has increased upstream or downstream of the development site. Analysis of rainfall data from Applesham Farm over these winters indicates that the most rainfall in a single day was 30mm on 12th January 2015. The theoretical depth of a 1 in 10 year rainfall event with a 7 hour duration[10] in this location is 44mm. This

[5] Stuart Michael Associates (1999), New Monks Farm, Lancing Proposed Golf Couse, Land Drainage Considerations (appended to Water Level Management Plan (2006)

[6] *Ibid.*

[7] Ken Argent, *pers. comm*.

[8] Stuart Michael Associates (2006), New Monks Farm, Lancing, Water Level Management Plan

[9] The 1999 Stuart Michael Associates report considered the cleared, widened and re-profiled ditches would have capacity to convey more than 4 m^3/s, which is greater than the capacity of the upstream ditches in Manor Close

[10] This has been assumed to be the critical duration event in line with the Monson Engineering Report

analysis indicates that the ditch system may not yet have been tested for an extreme rainfall event since the development of the golf course site.

2.3.2 Brighton and Hove Albion development

In 2013 Brighton and Hove Albion Football Club (BHAFC) completed construction of a new training ground near Mash Barn Lane. The drainage strategy for the development was outlined in the flood risk assessment (FRA) for the planning application. The proposals in the FRA outlined a combination of drainage direct to ground (e.g. car parking areas, grass pitches and training areas) to mimic the natural drainage, and water storage onsite to store (and reuse) surface water runoff from the main training facility building, the maintenance building and the covered indoor pitch.

Linked to the surface water drainage strategy was the irrigation strategy for the pitches. This comprises of water from a grey water recycling facility, an abstraction borehole, and water stored from surface water runoff. It is supplemented by a mains water supply in periods of insufficient rainfall.

Since the construction of the training ground there have been concerns from local residents that it has increased local flooding and the volume of water within the Lancing Brook ditches. The concerns have centred on two elements: onsite drainage issues, and changes to the groundwater regime as a result of the development.

Appendix E provides a detailed summary of the investigation into geology and hydrogeology in Lancing. With respect to the BHAFC training ground nine boreholes were installed by Soils Limited to assess the geology and monitor groundwater levels. At all but one of these boreholes there were clayey head deposits overlying the chalk at various levels of thickness (2.5-4m). Only in BH3, in the extreme south east, are Raised Beach Deposits (1.8m thick) identified between the overlying Head (1.3m thick) and underlying Chalk. These clayey head deposits form an “aquiclude” which acts as a confining layer and prevents or limits movement between the two aquifers. Owing to the depths of the clayey head deposits, and the ground raising (between 1-2m) undertaken during construction of the training ground it is not considered that the site is affected by, nor influences, the flow of regional chalk groundwater.

Local residents have raised concerns to BHAFC about onsite tankers and overpumping into local ditches. BHAFC responded to these concerns identifying that the additional tankering, observed by local residents, was to bring more water onto the site and not related to drainage issues on site. This is a matter for further consideration by the local planning authority and is not considered any further in this report.

2.3.3 New Monks Farm hydrogeological investigations

As part of a proposed development at New Monks Farm the site developer commissioned a detailed hydro-geological investigation into the groundwater levels and other influences[11]. The purpose of the investigation was to test whether the site would be at high risk of groundwater flooding, as identified in preliminary mapping undertaken by the Environment Agency, and in the SFRA. The report is primarily based on the findings from ten boreholes drilled at the site between the 23rd January 2014 and 5th February 2014. In boreholes BH1, BH2, BH4, BH6, BH7 and BH10 water monitors were placed to measure ground water level in both the underlying bedrock (Chalk) and superficial layer (clay and alluvium).

The geology was found to be consistent with that shown on the British Geological Survey (BGS) online database. Typically this consisted of 0.5-2.0m of made ground underlain by 2.5-4.0m of clay/alluvium underlain by chalk bedrock. During drilling, in all boreholes, groundwater was struck in the Chalk only after the superficial layers had been penetrated. Where groundwater was also encountered in the Superficial Deposits (in 7 of the boreholes) this was in addition and separate to the water strikes in the Chalk. It was concluded that the clay/alluvium layer acts as an aquiclude to groundwater contained within the underlying Chalk. This conclusion was made based on the drilling record and on the two distinct water levels observed

[11] Capita Symonds Ltd (2014), New Monks Farm, Interpretive Hydrogeological Report on Groundwater Levels and Influencing Factors

in the aquifers during the period of groundwater measurement. The monitoring showed that the aquifers layers respond separately to the influence of recharge and discharge, with a time lag in response between the two layers. Additionally, due to the clay/alluvium acting as an aquiclude the pressure in the Chalk aquifer was found to be artesian after the period of heavy rainfall during February. The Chalk aquifer in this location was therefore behaving as a confined aquifer with groundwater in the superficial layer acting as a perched water table. Based on this evidence, there is no significant contribution to surface water flows from the underlying Chalk in this location. There was found to be a tidal influence in the Chalk aquifer at BH07. The groundwater level was found to react quickly to the diurnal tidal cycle. Elevated levels of sodium and chloride were recorded for BH07D only. It was concluded that this was representative of a more direct and deeper hydraulic link to groundwater in the Chalk beneath the Adur estuary or beneath the coast.

The report recommended that the development site was not at risk of groundwater flooding, provided that the development did not disturb the geological units (i.e. development did not extend into the Chalk formation. As part of the review for the SWMP there is no evidence that would counter the conclusions of the New Monks Farm hydrogeological investigations. A summary description of the geology in the area can be found in Section 3.4.

2.4 Actions taken to alleviate flooding in the catchment

2.4.1 Clearance of Lancing Brooks

Collectively, the Monson and Royal Haskoning studies have considered the drainage ditch network in considerable detail to understand pinch points and remedial works required. Significant ditch clearance work was carried out by Adur and Worthing Councils and landowners in 2010 and 2013. In 2010 extensive ditch clearance was undertaken on the northern floodplain east of Mash Barn Lane[12], and on the southern floodplain south of the railway line (downstream of Barfield Park). Furthermore in 2013 the ditch sections which run through residential areas were dredged and cleared (beds lowered by up to 500mm)[13]. The ditch clearance work addresses most of the recommendations of the Monson and Royal Haskoning reports.

As part of the SWMP new and comprehensive cross-section survey of the ditch network was undertaken in in December 2014 and January 2015 to understand the current flow regime and levels of siltation and vegetation. The purpose of this was to assist WSCC and Adur and Worthing District Councils in identifying an optimal maintenance regime. The findings of the cross-section survey are described in Section 6. In January 2015 the landowner of the golf course development undertook a comprehensive clearance of the ditches.

2.4.2 Improvements to foul sewerage network

Since the winters of 2013/13 and 2013/14 Southern Water have undertaken a number of actions to reduce the risk of foul sewer flooding, including:

- developing an Infiltration Reduction Plan (IRP) for North Lancing which sets out the strategy for managing infiltration into the sewer network;
- sealing of the sewer network to reduce infiltration;
- installation of a level alert system which triggers a tanker call out when sewer levels go above a certain threshold, and;
- production of an Emergency Action Plan (EAP) which identifies trigger levels and associated actions depending on sewer levels and forecast flooding.

12 In January 2015 the landowner also undertook ditch clearance of the northern floodplain within the golf course area

13 Ken Argent, *pers. comm.*

2.4.3 Improvements to surface water drainage network

There is a 300mm pipe which flows through the garden of No. 4 Old Shoreham Road (where it becomes open for a short section[14]) and then discharges to the ditch known locally as the 'doctors ditch' to the rear of number 9 Manor Way. Historically there has been flooding from the 300mm pipe, caused by a blockage. This was cleared by WSCC following the winter 2013/14 flooding.

Historically, flooding on The Paddocks occurred regularly following heavy rainfall, affecting garages and the highway. During the past 18 months WSCC has de-silted the storage tanks under The Paddocks, cleared root infestation in the surface water drainage pipes, and de-silted the stream to which the drainage discharges into. It is understood that this has significantly mitigated the flooding at this locations

Furthermore, following flooding on the A27 in 2012 the Highways Agency have undertaken significant remediation work, which was completed in 2013. This has included pipe remediation, patch lining, lateral grinding and root cutting, to improve conveyance capacity of the system.

2.4.4 Shoreham Adur tidal walls scheme

The Environment Agency is currently developing a scheme to improve the standard of protection from the Adur tidal walls. This will reduce tidal flood risk to Shoreham-by-Sea and Lancing. Further details on this scheme are available at: https://www.gov.uk/government/publications/shoreham-adur-tidal-walls-scheme/shoreham-adur-tidal-walls-scheme.

[14] It becomes an open section due to damage to the pipe, Ken Argent, *pers. comm.*

SECTION 3

Catchment characteristics

3.1 Catchment boundary

The Monson and Royal Haskoning studies have identified different catchment boundaries, particularly to the west. The Royal Haskoning catchment boundary was derived from FEH analysis, as there was no LiDAR available at the time, whilst the Monson report used contoured Ordnance Survey maps.

To define the natural catchment boundary an extension tool in ArcGIS software was used. The analysis is based on LiDAR data. This analysis was used to create a refined catchment boundary and flow pathway. A map of the revised catchment boundary is included in Appendix B and Figure 3-1. This analysis shows the catchment boundary is a further 1km west than the Monson catchment boundary. The western edge of the catchment boundary is the college on Upper Boundstone Lane. These findings have been verified against Highways Agency (flow direction) and Southern Water data (cover levels of manholes), which corroborates the revised catchment boundary. It is worth noting two issues:

- surface water from the business park at the far north-east of the catchment may drain to the River Adur directly, and;
- the area at the far south-east of the catchment is on a shingle spit and is believed to discharge surface water direct to the sea

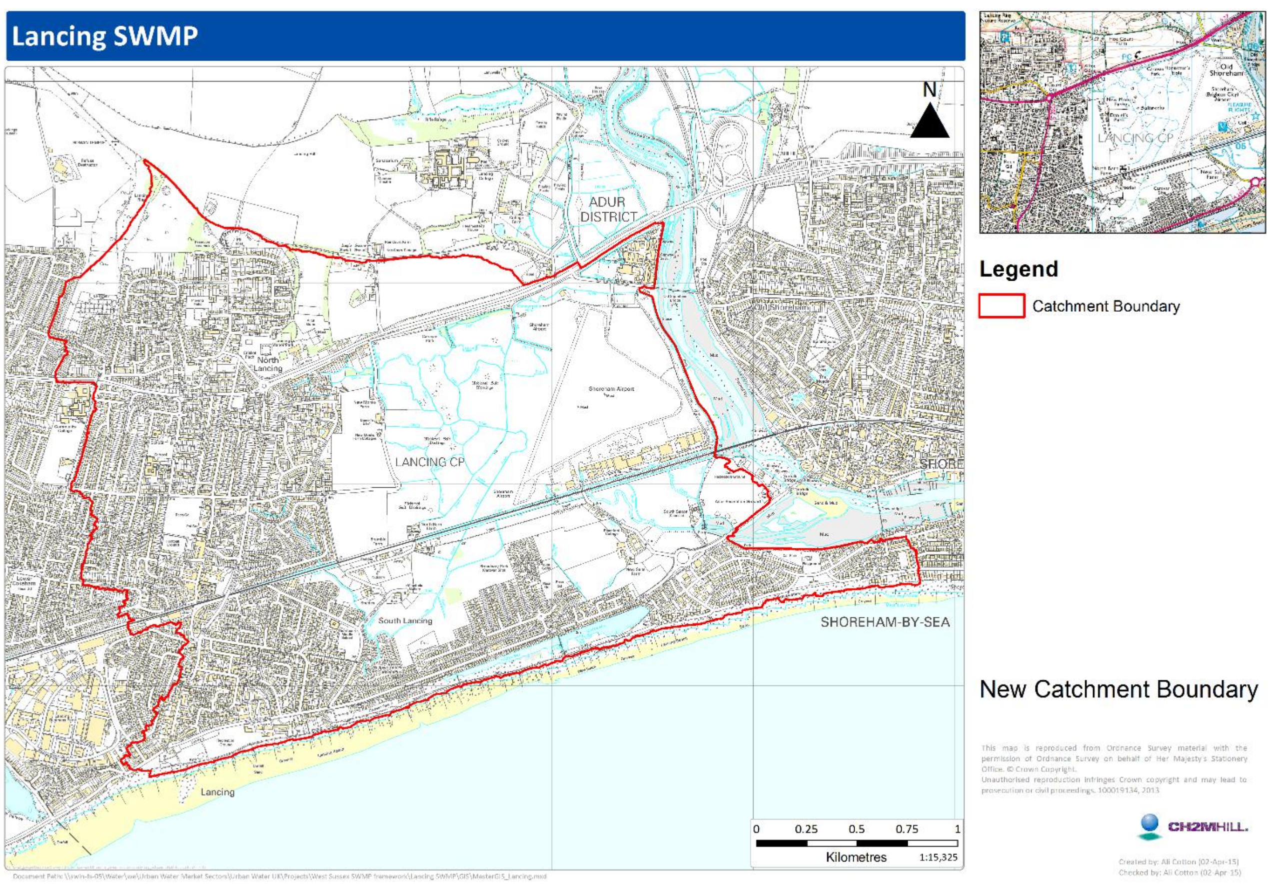

Figure 3-1 *Catchment Boundary*

3.2 General description of catchment and drainage

An overview of the key drainage features of the Lancing catchment is shown in Figure 3-2. Surface water runoff from residential areas to the west of the catchment boundary drain to the Lancing Brooks via soakaways (which will discharge to ground and ultimately flow towards the Brooks) or piped drainage. In addition, surface water runoff from the A27 drains via a series of outfalls into the Lancing Brooks.

The Lancing Brooks flow via a series of ditches which all ultimately drain to an outfall downstream of the Dogs Trust rehoming centre near New Salts Farm Road. North of the railway the Brooks flow through the golf course development, before discharging into a twin 900mm culvert under the airport. The Brooks emerge for a short section before re-entering a culvert to take flows under the railway. South of the railway the Brooks emerge from Barfield Park and flow in a south easterly direction until Willowbrook Caravan Park. Downstream of the caravan park the Brooks flow in a generally easterly direction before joining flows from the northern floodplain near New Salts Farm Road. Outflows from the Lancing Brooks is dependant on tide levels.

Groundwater is a key feature of the drainage system in Lancing. Regional groundwater flows are predominantly towards the east and south, as shown in Figure 3-2. The flow and influence of groundwater is complicated in Lancing, and the geological characteristics are described in detail in Section 3.4.

A more detailed description of the drainage system and associated flood risk issues is provided in Section 5 of this report.

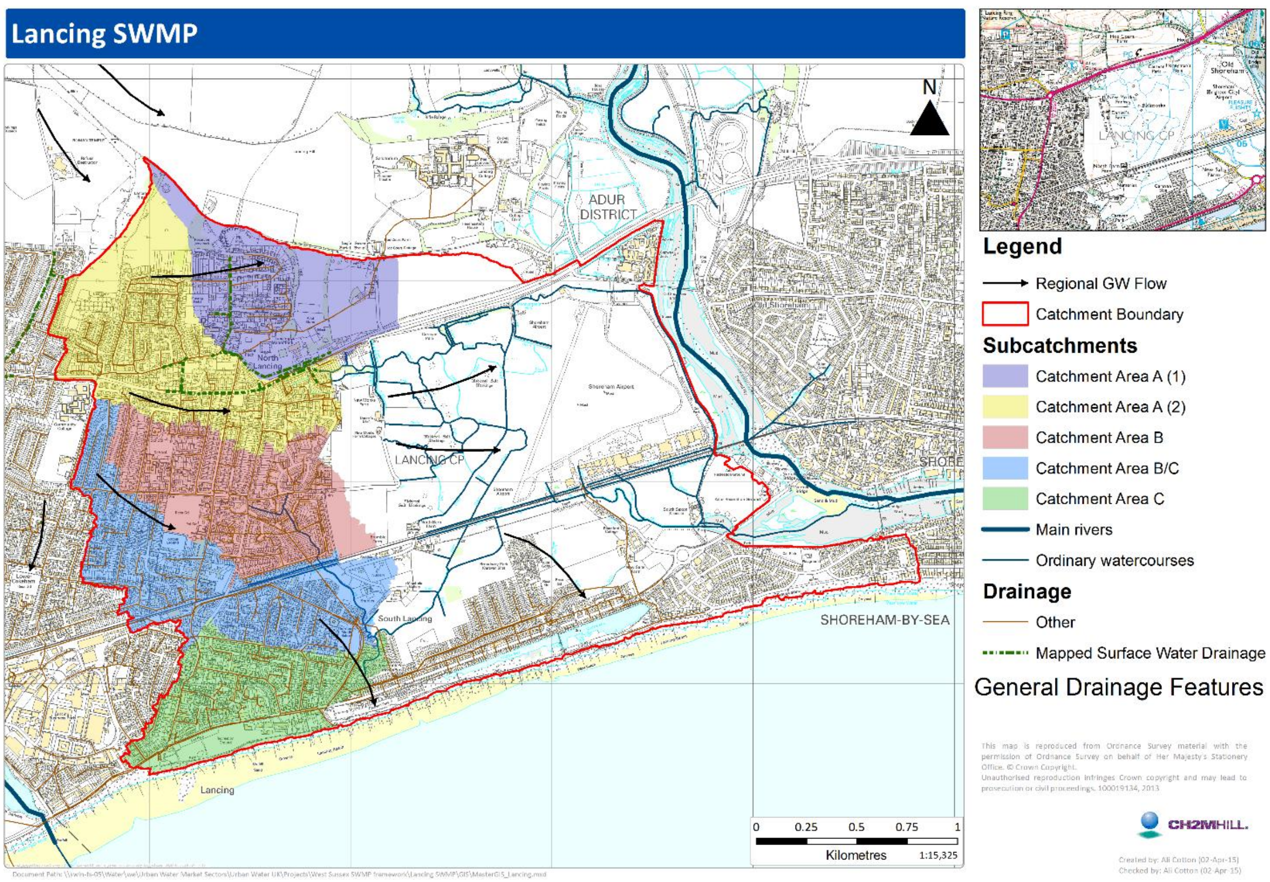

Figure 3-2 General drainage features of Lancing

3.3 Rainfall

There is a rain gauge at Applesham Farm (519486, 107183) which has captured daily rainfall totals since 1964. Based on these recorded data the average annual rainfall is nearly 820mm, with the wettest year on record seeing more than 1200mm of rain (2000). Given recent wet weather and flooding in this catchment it has been decided to specifically consider the rainfall over the past two wet winters, 2012/13 and 2013/14. Based on the rain gauge data, the total rainfall from December to February over these two winters was far in excess of the long term winter average for the same period. A summary of the key statistics is shown in Table 3-1. In fact the winter of 2013/14 was the wettest winter over the 50 year record from the Applesham rain gauge, with over 470mm of rainfall falling over this period.

Table 3-1 Rainfall totals at Applesham rain gauge over past two winters

Date	**Rainfall total (mm)**		**% of long-term average (1964-2014)**	
	2012/13	**2013/2014**	**2012/13**	**2013/14**
December	206	159	222%	172%
January	107	168	121%	190%
February	58	146	93%	237%
Sum	**371**	**473**	**153%**	**195%**

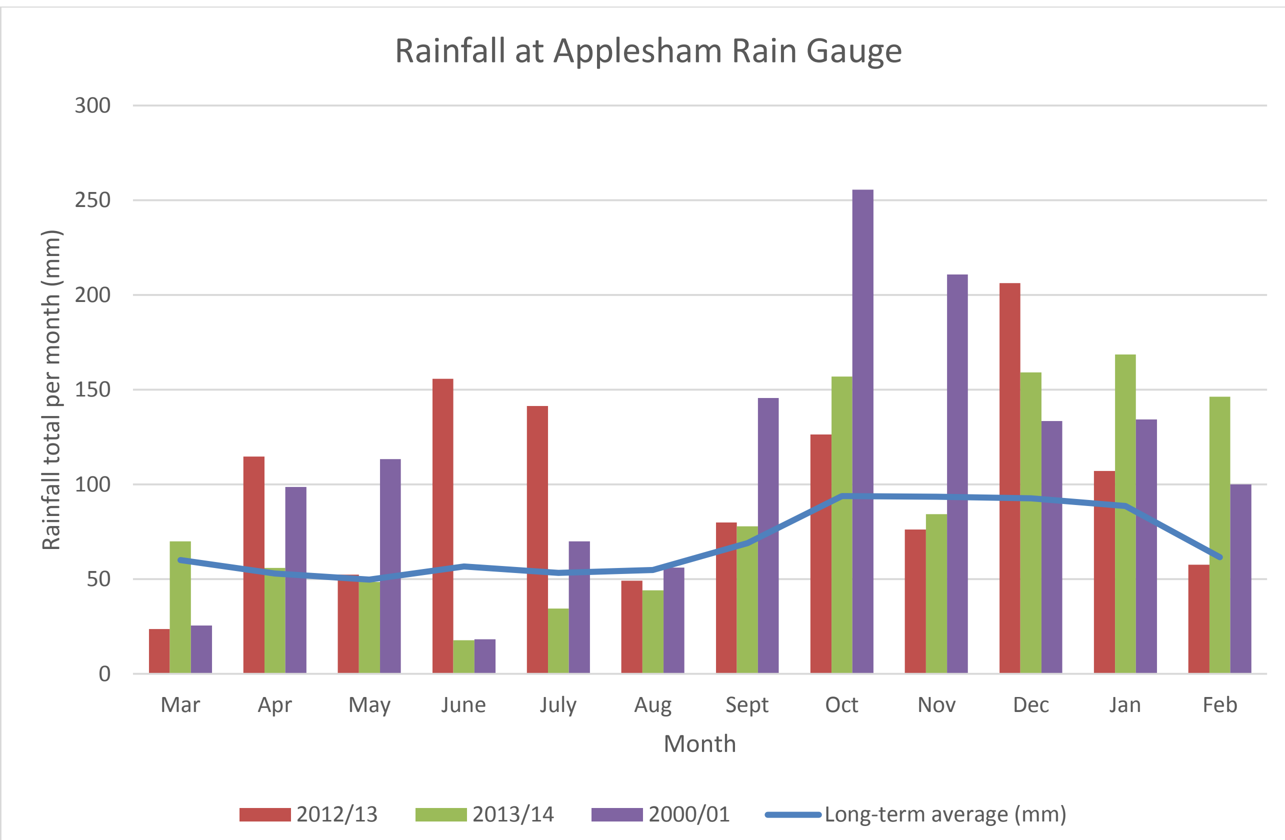

Figure 3-3 Rainfall at Applesham Rain Gauge for 2000/01, 2012/13 and 2013/14 compared to long-term average

The heavy summer rainfall in June and July 2012 is also evident from Figure 3-3 above, and the total monthly rainfalls are similar to those experienced in the recent 2013/14 winter. However, the winter events are associated with elevated groundwater levels, and flooding in Lancing predominantly occurs during winter when groundwater levels in the alluvial deposits and the underlying Chalk are high. There is some anecdotal evidence of flooding during the summer 2012 storms on the West Beach Estate, however it is not as widespread as during winter events. This indicates flooding is not wholly the result of short duration intense rainfall events (which would normally overwhelm urban drainage systems), but rather the result of the impact of long duration events over the winter. The superimposition of shorter term rainfall over these longer term events exacerbates any flooding condition.

3.4 Geology and hydrogeology

A detailed technical note about the geology and hydrogeology in Lancing is included in Appendix E. The most salient points model are described in Sections 3.4.1 to 3.4.2.

3.4.1 Geological setting

3.4.1.1 Solid Strata

The whole of the study area is underlain by Chalk strata of Cretaceous age. Influenced by regional structural trends, these strata dip down toward the coast from the South Downs in the north, as illustrated by the regional cross section below (Figure 3-4). This structure has implications for regional groundwater flow

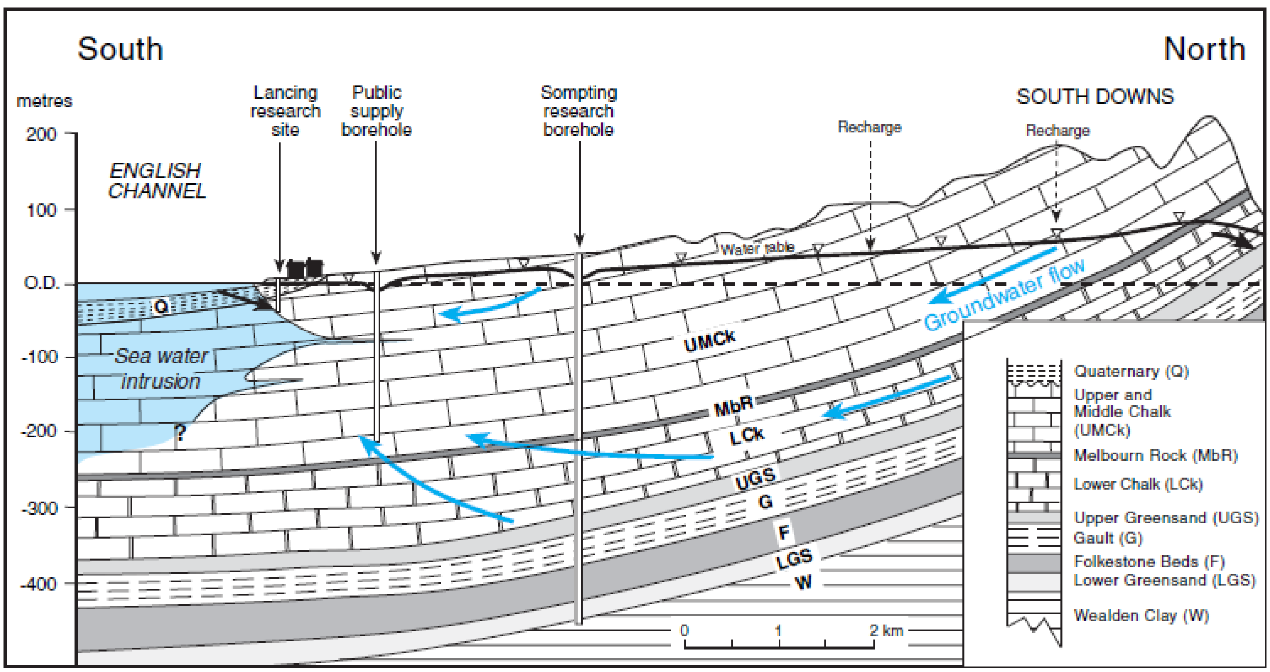

Figure 3-4 Generalised regional geological section. Note that the Chalk nomenclature used on the cross section has now been superceded. (From: "The Chalk Aquifer of the South Downs". Hydrogeological Report Series of the British Geological Survey. British Geological Survey 1999

To the extreme south of the study area beneath the West Beach Estate and Widewater Lagoon, the younger (Palaeogene) Lambeth Formation occurs. This overlaps the Newhaven Chalk, and thins rapidly northward. Based on BGS borehole evidence, this formation may be up to about 10-15m thick toward the coast particularly at the western end of West Beach estate and Widewater.

3.4.1.2 Superficial Deposits

Although the underlying strata have a significant bearing on groundwater flow through the study area, they are not exposed at outcrop, other than to the north of the A27, as the hills rise to the Chalk downs. Younger, unconsolidated Superficial Deposits occur right across the study area. These are the result of more recent geological and geomorphological processes (Quaternary age up to circa 3 Million years ago) and comprise a number of different deposits. The age relationships between these deposits is not always clear, particularly between alluvium and tidal flat deposits. The Head and Raised Beach Deposits are more prevalent underlying the higher ground to the west of the study area.

In addition to the above natural Superficial Deposits, there is some Made Ground present. This is material reworked or deposited by man's activities and may have been emplaced for ground levelling or other landscaping, engineering or development purposes. It is most prevalent in the north, beneath the golf course, where it is between 2.2 and 3.5m thick. The area developed as part of BHAFC training grounds has been levelled using found material[15], although borehole evidence suggest no Made Ground occurred in this area before the development. There also appears to be Made Ground to the west beneath the housing estates, presumably as a result of ground levelling associated with the historic development of housing. It is also likely to be moderately widespread beneath Shoreham Airport.

3.4.2 Hydrogeological conceptual model

The hydrogeology is described in detail in Appendix E. This section includes an overview of the hydrogeological conceptual model, which is used to express the characteristics and processes inherent in the groundwater system based on evidence accumulated from geological and hydrogeological mapping, site observations and investigations, groundwater monitoring, rainfall and other data sources. The model identifies the broad understanding of how groundwater beneath the site behaves. Based on the evidence provided above, the conceptual model can be summarised as follows, and in the schematic cross section in Figure 3-5.

Groundwater occurrence	Groundwater is present in the "regional" Chalk aquifer and in more permeable localised and discontinuous layers in the Superficial Deposits, primarily Alluvium. Across the central and western parts of the study area these lower (Chalk) and upper (Alluvium) aquifers are separated by layers of clay forming an "aquitard" which acts as a confining layer and prevents or limits movement between the two aquifers. There may be areas across the study area wherein this separation is less marked, i.e. in permeable "windows" between the Chalk and upper aquifers.
Recharge/ Discharge	Groundwater in the Chalk is recharged across the Downs to the north and west. The recharge, topography and Chalk structure imparts a west to east regional groundwater gradient towards the River Adur, which acts as an area of regional groundwater discharge. There is a more southerly element to this gradient near the coast.
Groundwater levels, flow and emergence	Groundwater flow in the Chalk occurs primarily from west to east in response to regional groundwater gradient. The rate of flow depends upon both the gradient and the permeability of the Chalk, which tends to be at its greatest at shallow depths where the Chalk has been subject to dissolution in areas of water level fluctuation. These areas are often associated with the boundary between different Superficial Deposits and the boundaries of Superficial Deposits with the Chalk. Under conditions of high winter recharge and elevated groundwater levels in the Chalk and in response to upward groundwater pressure from the underlying Chalk, there may be upward leakage from the Chalk to the upper aquifer and surface water. This occurs through more permeable windows in the Superficial Deposits (as described above). Where there is partial connectivity between the two aquifers, the upper alluvial aquifer may become

[15] This is imported fill

more permanently saturated, leading to areas of marshy ground. These mechanisms are most likely to occur in the southern part of the study area.

The upward groundwater movement is primarily a response to pressure (piezometric) differentials established in the Chalk, where the confining layer is absent, Chalk groundwater will rise to the piezometric level, which, when this is above the surface, can lead to emergence of groundwater.

The upper superficial aquifer is recharged directly from rainfall and discharges through evapotranspiration and through lateral flow to surface waters. The characteristics of the Superficial Deposits suggest that although this shallow aquifer may provide some baseflow to the surface water channels, this is likely to be only a relatively small contribution to the overall flow in the surface water channels. There may also be some emergence of shallow groundwater at boundaries with less permeable deposits.

Tidal influence

The tide prompts a pressure response in the Chalk groundwater towards the coast, which causes diurnal changes in the Chalk piezometric surface such that groundwater levels near the coast rise and fall in response to tide levels.

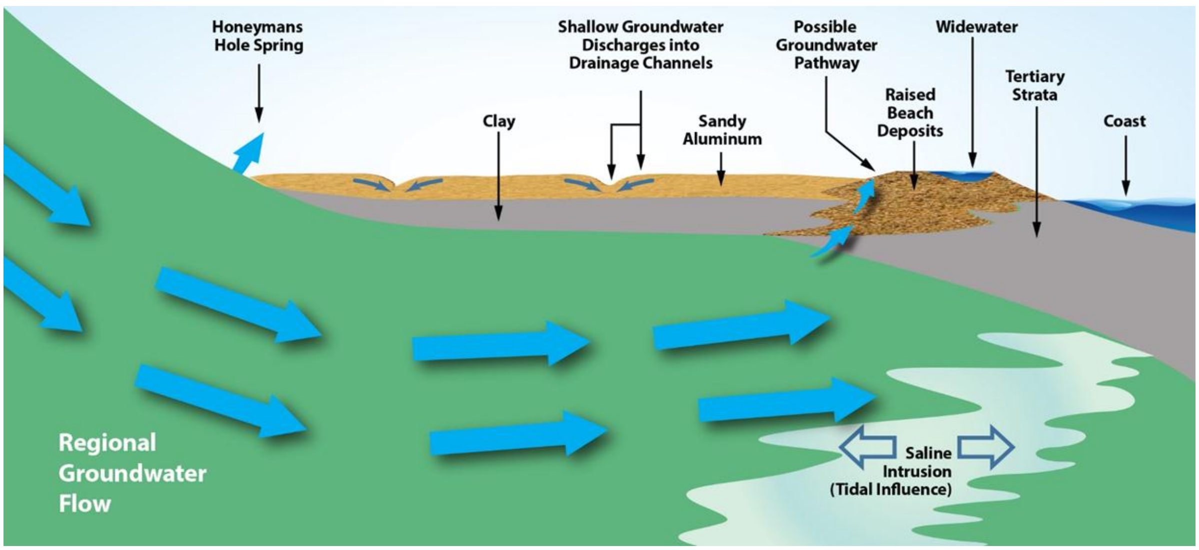

Figure 3-5 Conceptual Model- Sectional view showing interaction between regional flow in Chalk, shallow groundwater and groundwater emergence

3.5 Environmental characteristics

A summary of the environmental constraints based on a preliminary desk-based study are provided in Appendix I. This enables an assessment of the environmental effects of the drainage and flood management strategy for Lancing. An Environmental Features Plan has been created to show the environmental constraints and opportunities in and around the study area for the Lancing SWMP. This can also be found in Appendix I.

SECTION 4

Flooding history

4.1 Summary of flooding

There is good anecdotal evidence of flooding within Lancing from the wet winters of 2012/13 and 2013/14, and ongoing reporting from local residents throughout 2014 and 2015. Local residents have provided detailed information on the timing, location and impacts of flooding in Lancing. This has enabled a comprehensive picture of flooding to be established over the past two to three years. Flooding in Lancing has been a long-standing problem, but the best anecdotal evidence of flooding is from the last two to three years. Given that 2013/14 was the wettest winter on record it is reasonable to assume that the available anecdotal evidence from the past two to three years provides a good basis to assess the flooding impacts. Table 4-1 provides an overview of the key locations affected by flooding in Lancing.

Table 4-1 Locations affected by flooding in Lancing

Location	No. properties flooded internally[16]	Other impacts	Dates of flooding
Grinstead Lane, Manor Way, Manor Close	Two garages flooded in Manor Way	Extensive flooding on Grinstead Lane (impassable), restricted toilet use, garden flooding, and overpumping of foul network into ditch network	December 2012 and December 2013 January 2015 although flooding impacts significantly reduced
Old Shoreham Road[17]	None	Flooding on Old Shoreham Road Garden flooding	December 2012 and December 2013, January 2014 and 2015
Barfield Park and Monks Avenue	1 home affected on Barfield Park 1 property flooded near Monks Avenue/Hadlow Way	Garden flooding in other locations	December 2013, Summer 2014
The Paddocks	None, but some garages affected	Flooding on the highway	Flooding occurred regularly following heavy rainfall (until work completed (see Section 2.4.3)
West Beach Estate	None	Flooding across most of The Broadway, and parts of Westway and Prince Avenue	Flooding occurs regularly
A27	None	Northern carriageway of A27 flooded	December 2013
Shoreham Airport	None	Airport flooded, although main runway was still operational	December 2013

[16] Defined as flooding within a building, and includes the main buildings / garages of a property

[17] This refers to the cul-de-sacs south of the A27 (NB: The A27 is also known as Old Shoreham Road)

SECTION 5

Description of drainage system and associated issues

5.1 Inflows

This section focuses on inflows to the Lancing Brooks watercourse network from the residential estates, the A27, Honeyman's Hole and Widewater Lagoon. The residential areas to the west of the study area all drain towards the Lancing Brooks via either positive drainage (e.g. highway drainage) or soakaways which will discharge to the ground and ultimately flow towards the Brooks. The residential areas have been divided into three principal catchments based on the location of discharge to the Lancing Brook ditches, as illustrated in Figure 5-1.

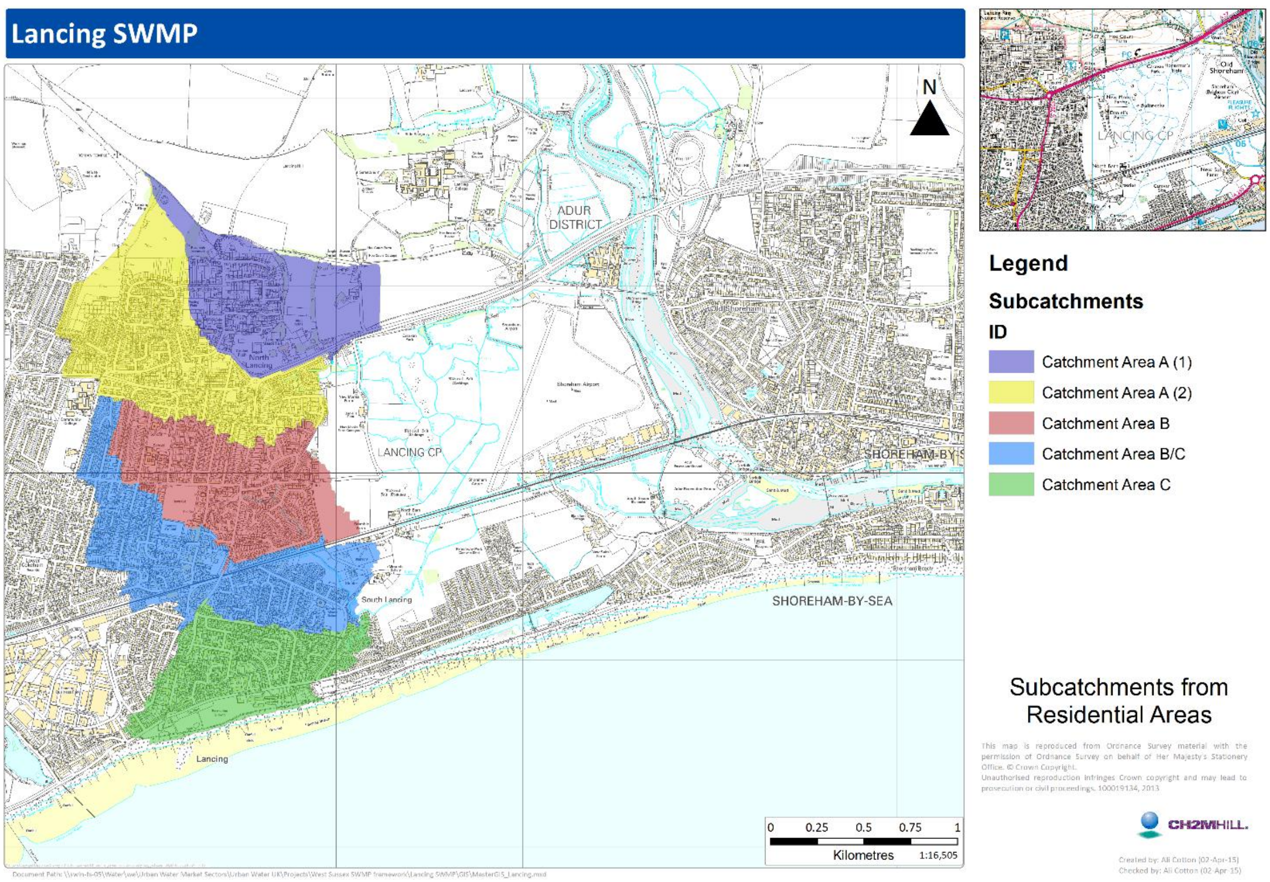

Figure 5-1 Subcatchments from residential areas

5.1.1 Manor Way / Grinstead Lane Area (Catchment Area A)

5.1.1.1 Surface water drainage

This catchment flows from the west of Grinstead Lane and north of the A27 towards the ditch network which runs to the rear of properties on Old Shoreham Road and Manor Close. For the most part residential properties and highways drain via soakaways, but there are locations of piped drainage within this area. It is difficult to understand what proportion of flows in the urban area drain to soakaway without detailed survey of every street.

Surface water piped drainage collects to a 300mm pipe which flows east between numbers 5-7 Grinstead Lane, through the garden of No. 4 Old Shoreham Road (where it becomes open for a short section[18]) There are three connections to the 300mm pipe:

- a 225mm pipe which flows north from Grinstead Lane;
- a 300mm pipe which flows from Manor Road, under the A27 roundabout (NB: there is a 225mm overflow pipe on the Manor Road system which passes excess flows under the northern verge of the A27 via a 225mm system, ultimately discharging to a manhole at the northern end of Manor Close), and;
- part of the A27 drainage from the west flows towards the 300mm although there is also a continuation pipe which flows towards the same manhole at the northern end of Manor Close.

At the end of No.4 Old Shoreham Road there are two outlet pipes, a 225mm and 300mm, which both discharges to the ditch known locally as the 'doctors ditch' to the rear of number 9 Manor Way.

Historically there has been flooding from the 300mm pipe, caused by a blockage. This was cleared by WSCC following the winter 2013/14 flooding. However, analysis undertaken for the SWMP indicates that the pipe size is insufficient to cope with the estimated flows from the upstream catchment. The analysis indicates that the capacity of the 300mm is estimated to be 112 l/s[19]. Using the Rational Method (where Q = 2.78 * coefficient * rainfall intensity * area) to estimate inflows to this network the pipe is likely to be exceeded on a frequent basis, as frequently as during a 1 in 5 year rainfall event[20]. Where the capacity of the 300mm pipe is reached it will cause backing up and flooding on Grinstead Lane and other locations. Options to reduce the risk of flooding from this is described in Section 8.

5.1.1.2 Watercourses

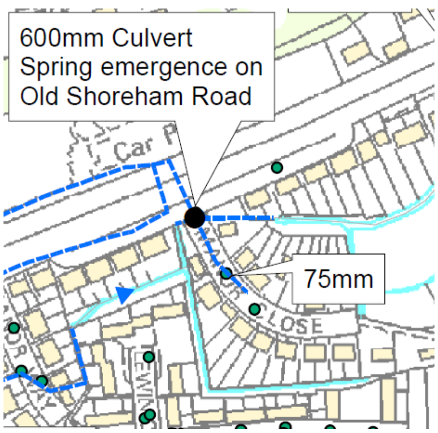

Figure 5-2 Drainage layout on Manor Close

The upstream network discharges into the 'doctors ditch'. This ditch network is initially very constrained but widens further downstream. The ditch then enters a culvert to pass under Manor Close, which has a 450mm opening. During the site visit in October 2014 the manhole in Manor Close was lifted to confirm the location of the culvert. The main line of the culvert passed through the manhole in a 600mm diameter pipe (NB: the manhole was heavily silted). There was an additional pipe entering from the north (which is the overflow pipe from Manor Road system and discharge location from the A27) and a minor 75mm diameter pipe entering from the south (see Figure 5-2). The culvert emerges behind houses on Manor Close and Old Shoreham Road. The ditch in this location varied between 0.5m wide by 0.5m deep and 1.5m wide by 0.5m deep.

The ditch continues to run parallel to Old Shoreham Road until it passes under Mash Barn Lane and enters land owned by a private developer. There are outfall from the A27 along this section.

5.1.1.3 Foul sewerage

Within this area there has also been flooding from the foul sewerage network attributed to groundwater ingress into the sewerage network. During the winters of 2012/13 and 2013/14 this caused the pumping station on Grinstead Lane to cease functioning, which caused restricted toilet use and foul sewer flooding onto Grinstead Lane, Manor Way, Manor Close and Old Shoreham Road. As a mitigation Southern Water

[18] Through No.4 Old Shoreham Road the pipe becomes open because of its condition, Ken Argent, *pers. comm*.

[19] Using Colebrook-White formula to calculate pipe flows for full pipes assuming there are no effects on downstream controls. We have assumed a culvert size of 300mm, a gradient of 1:100, and a roughness of 0.6 which is typical for surface water sewers

[20] Although we note that the Rational Method over-estimates flows because it does not consider headlosses or storage in pipes

over-pumped flows into the ditch network. Since these events Southern Water have undertaken a number of actions to reduce the risk of foul sewer flooding, which have been outlined in Section 2-7.

5.1.1.4 Groundwater influence

Based on the evidence from the local residents and from Southern Water, flooding of the Manor Way/ Old Shoreham Road area commenced in late January 2014 and continued through most of February. As shown in Figure 5-3, this coincided not only with a series of rainfall events of >20mm /day, but also with groundwater levels (at Sussex Pad) in excess of 2.8mAOD (peaking at around 3.2mAOD). The areas of groundwater emergence along the A27 and at the property adjacent to the roundabout at Old Shoreham Road/Grinstead Lane are adjacent to a Chalk/Superficial Deposit boundary. As noted, these boundaries typically represent areas of enhanced and rapid groundwater flow. These areas will always be susceptible to flooding under conditions of high groundwater level.

Flooding recorded in January 2015, appears to represent a slightly different event. Groundwater levels were generally lower (circa 2.6m, peaking at around 2.8mAOD) but there were at least two days of rainfall in excess of 20mm. This demonstrates that groundwater levels locally respond very rapidly to winter rainfall recharge and via west to east regional groundwater flow. It is concluded that groundwater makes a significant contribution to flooding in Manor Way / Grinstead Lane.

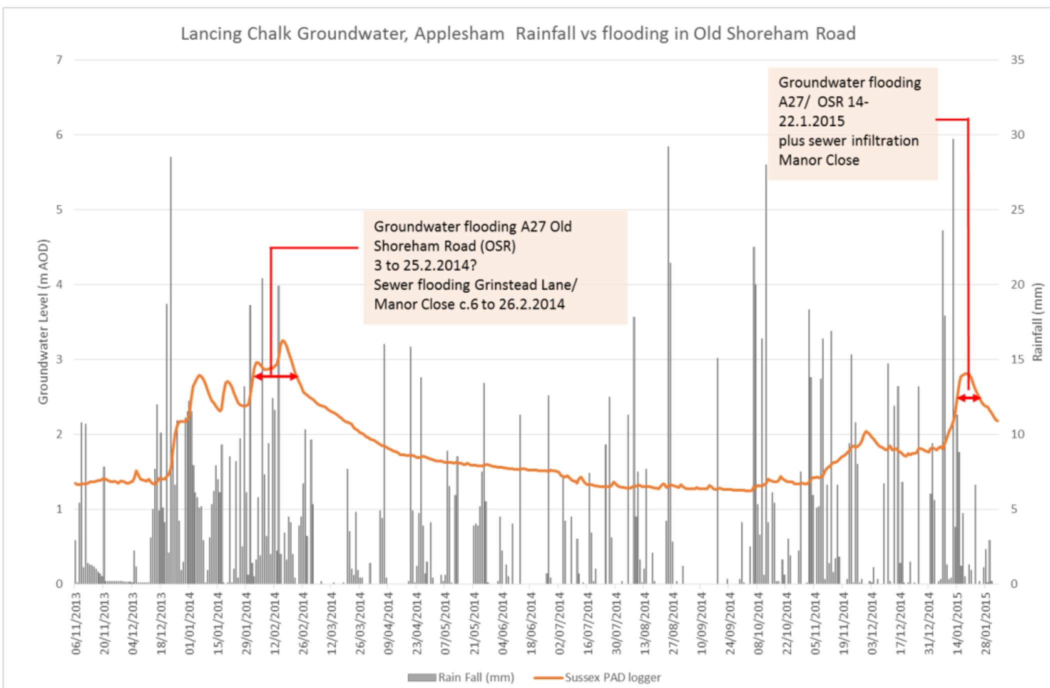

Figure 5-3 Groundwater Levels and Rainfall vs flooding recorded in Old Shoreham Road/ Manor Way area

5.1.2 Barfield Park Area (Catchment Area B)

5.1.2.1 Surface water drainage

Surface water runoff from residential areas west of Grinstead Lane drain to a ditch network which flows through Monks Avenue, Hadlow Way and Barfield Park, before flowing under the railway towards The Paddocks. The majority of runoff from residential properties and highways drain to soakaways, but there is a piped highway drainage system flowing under Grinstead Lane and into the ditch network to the rear of properties on Monks Avenue. This piped highway drainage network was inspected during a site visit in October 2014 near the outlet (adjacent to the ditch headwall opposite the Harvester pub on Grinstead Lane). This identified three inlets draining from Grinstead Lane to the north and the south, and Crabtree

Lane. The contributing area draining to this network compared is unknown. There is no evidence of flooding from this piped highway drainage network at this point, so no mitigation measures are proposed.

On Monks Avenue, Barfield Park and Hadlow Way highway drainage is a mixture of gullies, soakaways and piped drainage to the watercourses. Historically there has been garden flooding near Monks Avenue / Hadlow Way because of blockages to a highway gully and the drainage being unable to discharge into the ditch network.

5.1.2.2 Watercourses

Downstream of Grinstead Lane the ditch is approximately 2m wide by 0.5m deep and flows in an easterly direction along Monks Avenue where it is joined by a further ditch which flows from Mash Barn Lane. The ditch continues to flow under Monks Avenue via two 600mm diameter pipes. The ditch passes behind houses on Hadlow Way.

The ditch continues to flow behind houses to a twin 600mm diameter culvert under North Farm Road. Local residents noted the ditch has flowed out of bank during previous winters however they had not experienced flooding in the house. From this point the ditch runs through a 550mm (high) by 900mm (width) brick arch culvert under the railway to The Paddocks. The existing ditch network seems to be operating effectively. Variations in local maintenance seem to be causing areas of storage of water due to vegetation or overly deep channels.

5.1.2.3 Groundwater influence

One resident in the north east corner of Barfield Park reported significant groundwater emergence from a soakaway in their drive, as well flooding in the rear garden. Other properties in Barfield Park suffer waterlogged gardens. A rapid response to rainfall was reported, with levels remaining high through the winter of 2014/2015. Evaluation of the geology in this area suggests this property lies at or near a geological boundary between Alluvium, Head and Raised Beach deposits. These boundary areas may be associated with high flow zones in the Chalk, with a possible surface exposure to groundwater in the underlying Chalk. Further, it may be that the construction of the soakaway has penetrated the more impermeable clay layers, creating a more rapid flow path from the underlying chalk. In this scenario groundwater emergence may occur as the groundwater pressure surface rises in response to recharge in the Downs.

5.1.3 The Paddocks / Willowbrook Area (Catchment Area C)

5.1.3.1 Surface water drainage

This catchment covers the residential area south of the railway and west of The Paddocks. As in catchment areas A and B the majority of drainage is via soakaways. There was historic flooding at The Paddocks following heavy rainfall. Surface water drainage flows from The Paddocks towards the Lancing Brooks ditches. Clearance work on the surface water drainage network has significantly mitigated the flooding at this location.

5.1.3.2 Watercourses

The ditch system drains in a south-easterly direction past The Paddocks, where it passes under Old Salts Farm Road. The culvert under Old Salts Farm is significantly smaller than the cross-sectional area of the ditches upstream and downstream, which could result in backing up of flows. This is considered further within the hydraulic modelling section of the report (Section 6). Downstream of Old Salts Farm Road the ditch flows east and subsequently north-east through the southern floodplain. A further ditch joins from the Willowbrook Caravan Park[21]. There is a historic pond at the head of this system, which no longer exists. It is possible this is now a spring which contributes flows to the ditch through Willowbrook Caravan Park.

[21] There is repeated blocking of the watercourse near the Willowbrook Caravan Park. This is a local enforcement issue under the Land Drainage Act 1991

5.1.3.3 Groundwater influence

Based on geological data from boreholes in the New Salts Farm and Old Salts Farm areas there is evidence for the occurrence of “windows” in the confining clay layer and hence there is a mechanism for the emergence of “regional” groundwater from the underlying Chalk. This regional groundwater can therefore discharge into the surface water channels across the southern part of the Lancing Brook flood plain. Furthermore, the Old Salts Farm area is also associated with widespread waterlogged ground, further evidence suggestive of emerging groundwater.

5.1.4 West Beach Estate, including A259

5.1.4.1 Surface water drainage

The West Beach Estate suffers regular flooding primarily to The Broadway and Westway, although other parts of the Estate can be affected (e.g. Prince Avenue). Flooding is contained within the highway and no properties are known to have flooded.

The current surface water drainage on West Beach Estate is a combination of soakaways and piped drainage. There are three WSCC highway gullies on The Broadway which drain to a soakaway just north of the A259, via one inlet. WSCC has confirmed (February 2015) that the three gullies and the soakaway are clear (NB: the soakaway was full of water in February 2015, but there was limited silt buildup). North of these gullies, all drainage within West Beach Estate is privately owned and therefore not the responsibility of WSCC to manage and maintain.

Further north on The Broadway there are further gullies draining to a soakaway on the corner of The Broadway/Orient Road. Again a recent survey by WSCC identified that the soakaway was full of water but there was limited silt. The soakaway is more than 2m deep.

On the section of The Westway between The Broadway and Bristol Avenue there is a series of gullies are believed to drain to soakaway. From this point west the drainage is all piped, with the main network flowing underneath the roads which run are believed to flow south to north (e.g. Bristol Avenue, George V Avenue). On each of these roads there are surface water pipes which drain the roads and also take some runoff from The Westway. The drainage plan for West Beach Estate is presented in Appendix D.

Data collected for the SWMP (road levels and pipe depths) indicates that that whilst there is very little gradient on the pipe network (less than 1:1000), the pipes appear to have been designed to flow from south to north. At the southern end of Bristol Avenue the soffit level of the pipe is approximately 0.95m (temporary benchmark datum), whereas at the northern end the soffit level is approximately 0.9m[22]. It is believed that the outfalls from the roads which run south to north were supposed to be connected to the ditch network further north when the estate was built in the 1930s[23]. Local residents have uncovered and cleared the outfalls at Bristol Avenue and George V Avenue, and anecdotal evidence indicates this has alleviated flooding on these roads. Despite limited gradient clearing the outfalls will alleviate flooding because when the pipes are full it allows the system to discharge into the floodplain rather than backing up and flooding out of manholes.

[22] This is within the bounds of survey inaccuracy.

[23] The Second World War meant further development north was never built

Throughout the estate the condition and silt levels in the pipe network varies. On Bristol Avenue and George V Avenue the pipes there was little evidence of silt (October 2014). Along The Westway some pipes were clear and some were almost up to 50% silted, particularly on the far east of the estate. Road gullies were in bad condition throughout, approximately 10% were completely cracked/broken, 10-20% were choked (full of sediment) and a further 30% had standing water (although it had been raining heavily the day before the site visit in October 2014).

Figure 5-4 Photo of manhole on A259 (taken by WSCC)

The A259 is drained via a 300mm pipe system which flows in an easterly direction under the northern pavement of the A259. The system flows past Adur Close where the network drains to a soakaway. A WSCC survey team inspected the A259 drainage near the junction with The Broadway in February 2015. This identified that the gullies were clear of silt, and the network was freely flowing, as shown in Figure 5-4. Water levels in the manhole chambers were approximately 300mm above the invert level of the pipe. This water level corresponds to the water level in the two soakaways on The Broadway.

Because West Beach Estate is lower than the A259 any runoff which exceeds the capacity of the current A259 drainage system will flow onto the West Beach Estate, most noticeably through alleyways (twittens) and on The Broadway north of the junction with the A259. There is some anecdotal evidence of this occurring to a small extent but it is not considered to be a significant contributor to flooding.

5.1.4.2 Groundwater influence

The geological setting beneath the West Beach comprises Chalk at depth, overlain in part (to the south) by Lambeth Group (variously clay and silt) then in turn by superficial deposits, mostly dominated by Alluvium, although there is evidence for the occurrence of River Terrace or Raised Beach Deposits, particularly to the east end of the estate (see further below).

Groundwater may occur in the Raised Beach Deposits, coarser (sandy) horizons in the Alluvium and in the underlying regional Chalk aquifer. The Lambeth Group and more fine grained superficial deposits (clay, silt) prevent upward movement of groundwater from across much of the area. However there is strong circumstantial evidence that there are more permeable windows in the superficial deposits that may allow Chalk groundwater to impact groundwater levels in the area, for example by maintaining high levels in any upper aquifer. Borehole data (see Appendix E for further details) were used to generate a conceptual cross section (refer to Figure 5-5 below). What this section shows is that the gravel (Superficial Deposits) aquifer appears to be in hydraulic continuity with the sea. Groundwater levels in this aquifer will be significantly influenced by tide. Outward (southerly) groundwater discharge will be limited and high tides may cause the groundwater to “back up” at least maintaining groundwater levels at a high level beneath the Broadway area.

In this area groundwater levels in the Chalk will be influenced by a number of factors including:

- the regional southerly and easterly groundwater flow toward the sea;
- diurnal variations caused by the pressure response from tidal influence;

- confined conditions from the cover of Lambeth Group and finer superficial deposits, and;
- possible discharge at the Lambeth Group Boundary and through permeable windows in the superficial deposits.

Groundwater levels in the Superficial Deposits will be influenced by:

- upward groundwater movement from the Chalk brought on by a response to changing groundwater pressure;
- local recharges and discharges (including drainage to soakaways);
- the small amount of groundwater storage available due to the limited extent and nature of the superficial deposits, and;
- response to tidal influence, preventing seaward discharge through the gravels and backing up groundwater levels inland.

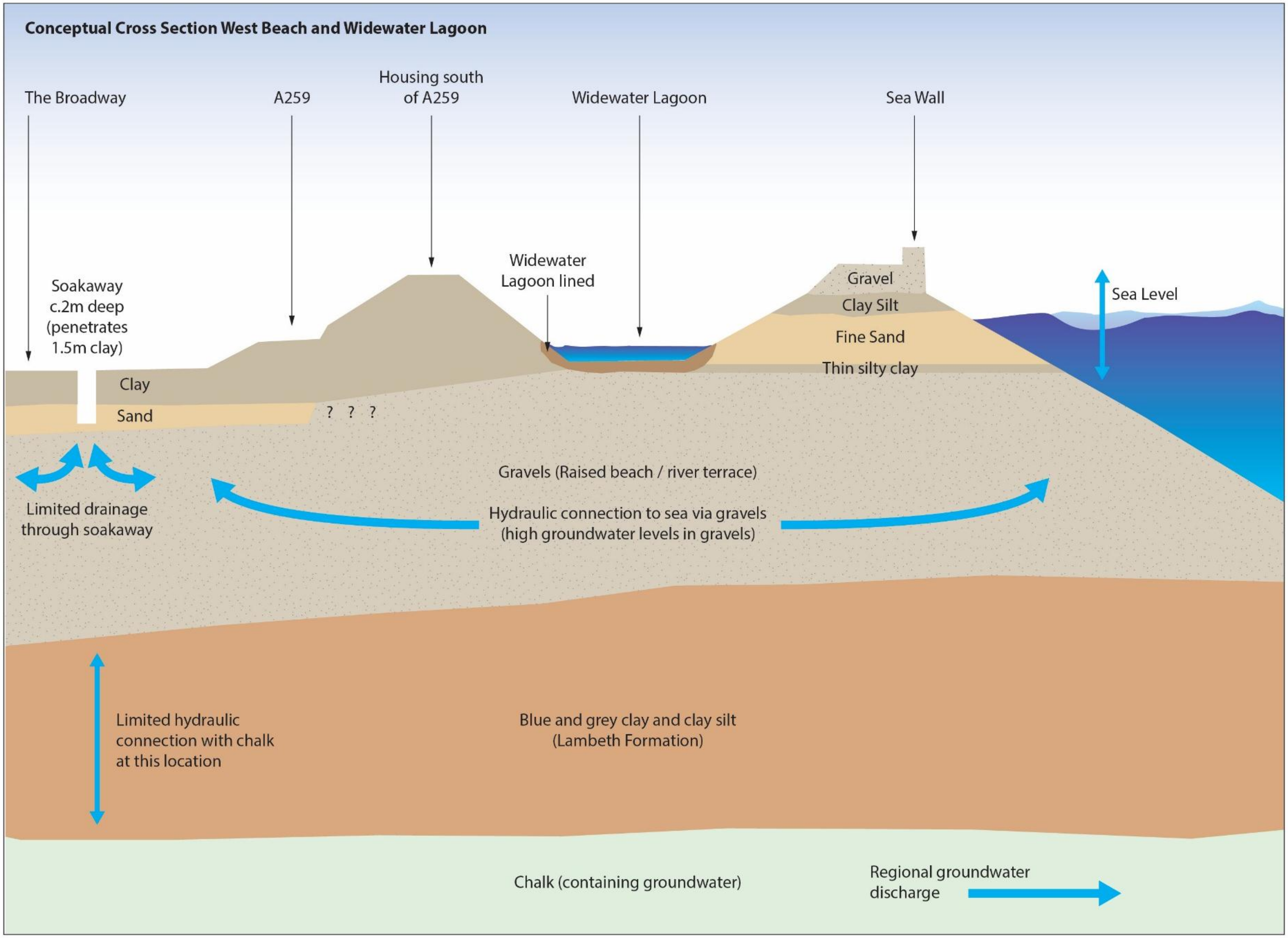

Figure 5-5 Cross-section of geology near Widewater Lagoon and West Beach Estate

Seasonal groundwater level variation in the area (particularly in the Chalk) is most likely to occur as a pressure response, but as this is an area primarily of discharge of regional groundwater flow , these seasonal variations are likely to be less marked than further inland (i.e. there will be a lesser variation between maximum and minimum levels). Supported both by upward leakage from the Chalk and local recharge, groundwater levels in the superficial deposits are likely to remain high most of the year, although there will be some recession through the autumn months. On this basis, groundwater levels recorded at Sussex Pad may not be wholly representative of groundwater behaviour in the Chalk beneath West Beach Estate. However, there remains value in comparing monitored groundwater levels with tidal levels, rainfall and the occurrence of flooding (see Figure 5-6 below).

These hydrograph data suggest that groundwater levels are not the sole influence on flooding at West Beach, which appears to be combined with the response to rainfall and surface water flooding. However, where drainage is to soakaways (as along Broadway), which discharge directly into the underlying sands and gravels, high groundwater levels will prevent the soakaways from functioning and prevent any surface water from draining away. It is evident that diurnal water level variations and raised groundwater levels brought on by high tides also impact significantly on the ability for these areas to drain. There is likely to be a lag time between the tidal high and any high in the groundwater levels.

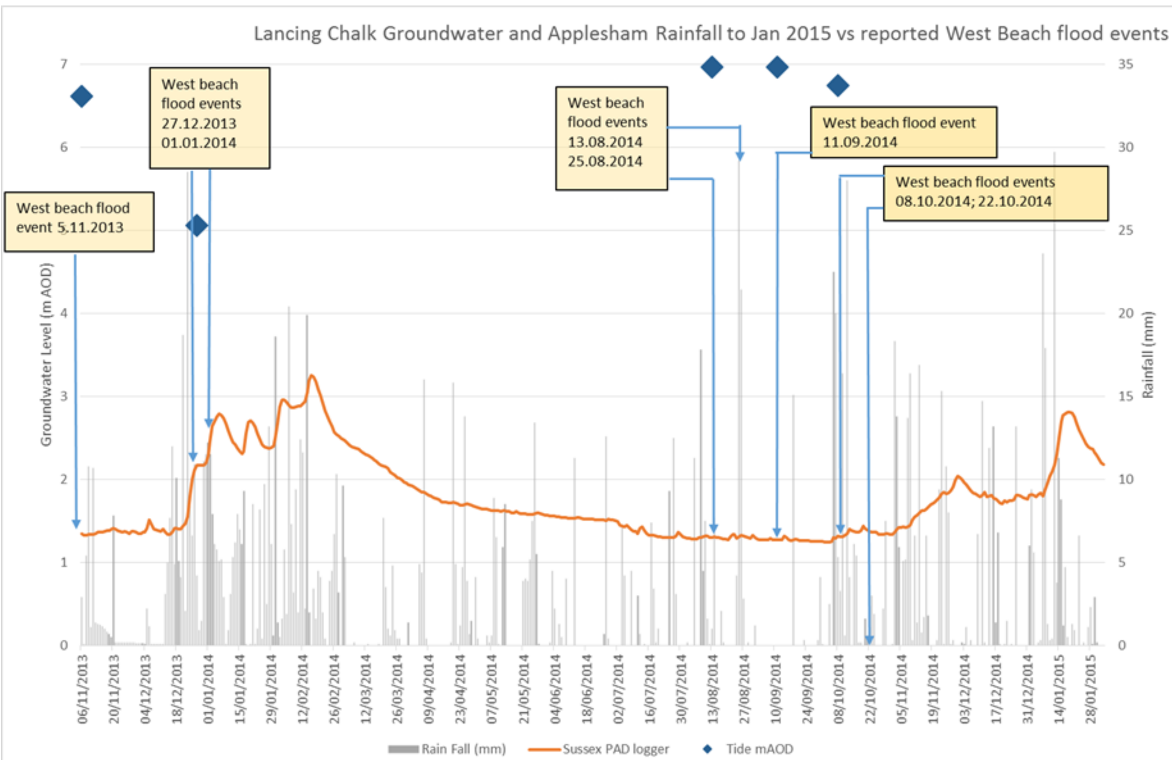

Figure 5-6 Groundwater and Tidal Levels and Rainfall vs flooding recorded in West Beach Area (NB: not all reported flood records are displayed on this graph)

5.1.4.3 Causes of flooding

There are a number of local drainage issues that are playing a significant role in flooding on the West Beach Estate. These include:

- a significant number of gullies which are cracked/broken, or full of sediment, siltation in the surface water pipes along Westway, and potential siltation of soakaways;

- blocked surface water drainage outfalls – local residents have confirmed that since the outfalls on Bristol Avenue and George V Avenue were cleared the flooding has reduced, but other outfalls remain blocked, and;
- high groundwater levels (as demonstrated by the water level in the soakaways) which means that water cannot drain away after heavy rainfall events (for further details see Section 5.1.4.2).

The high water levels encountered in the soakaways (and the A259 pipe) supports the view that there is a high water table beneath the Estate. With consistently high groundwater levels, there is no capacity for water to drain away from the gullies during rainfall events, which will therefore contribute towards flooding on The Broadway. In addition the soakaways are likely to be acting as conduits for groundwater to come towards the surface. A local history book notes that "much of the development *[West Beach Estate]* was over the beds of beach, and when soak-pits were dug to take away the reverse took place at high tide, when water came out of the gullies instead of running into them. The water went down with the tide"[24]. As the soakaways have limited capacity to drain more surface water (due to the high water table) the result is that flooding remains on The Broadway for several days following heavy rainfall. In addition, heavy rainfall will also cause significant problems on the estate because the main surface water drainage pipes do not have functioning outfalls for the most part.

24 reports of flooding from residents of West Beach Estate since November 2013 has been analysed for this SWMP, although most of the evidence is related to Autumn 2014 and Winter 2014/15, as shown in Table 5-1. Because flooding in the West Beach Estate lasts for several days due to reasons noted above flooding reports within five days of each other have been grouped. These are shown in bold, italic type font in Table 5-1, resulting 16 unique flooding incidents reported by local residents. For each of these flooding incidents we have examined the level and timing of high tides, groundwater levels in the Chalk at Sussex PAD, and rainfall data at Applesham Farm (NB: antecedent rainfall up to two days was also considered).

Of the 16 unique flooding incidents, 12 of these are related to wet weather (>10mm rainfall) on the day of flooding and often also due to antecedent rainfall in the preceding two days. High tides can exacerbate the flooding. Of the remaining four unique flooding incidents, there is no rainfall data for two of the incidents and there are two incidents associated with very high tides and no rainfall (11th September 2014 and 23rd January 2015). For the incidents associated with very high tides and no rainfall, water was observed to be 'bubbling up' through the tarmac on Westway (near George V Avenue), causing isolated flooding to the parts of the highway. There was no documented flooding on The Broadway.

In summary, flooding primarily occurs following heavy rainfall. A combination of rainfall and high tides will exacerbate flooding because it will cause the groundwater table to rise and reduce the capacity of the drainage system (gullies, soakaways and pipes) to discharge surface water. Very high tides during dry conditions (>6.8m AOD) can also cause isolated flooding because the water table rises above the surface.

[24] Kerridge, R.G., (1979), A History of Lancing

SECTION 5

Table 5-1 Summary of flooding reports from residents of West Beach Estate (bold & italic text identifies a linked event)

ID	Date/Time flooding	Date/time high tide	What is flooded? And to what extent? (All are quotes from local residents)		Other useful information	Level of high tide (mAOD)	Groundwater level at Sussex PAD (mAOD)	Rainfall total (Applesham Farm)	Dry / Wet	Tide level at time of flood
			The Broadway	The Westway						
1	05/11/2013 2:30pm	05/11/2013 12:05pm				6.61	1.36	25.6mm two days earlier2.2mm	Wet	High
2	27/12/2013 7:00am	27/12/2013 05:43am	The Broadway is continually flooded from the entrance to the crossroads 6-9 inches deep		The flood Plain behind West Beach is pooling on Old Salts Farm	5.06	2.17	4.2mm on 27/11, 10.9mm on 26/11	Wet	Low
3	01/01/2014 2:00pm	01/01/2014 10:49am	Was flooded to the centre of the road but numerous cars including a lowered mini was able to enter/exit the estate area		All areas were deep, making it difficult to drive through	6.51	2.29	12.2mm on 01/01, 11.5mm on 31/12	Wet	High
4	10/08/2014 Time Unknown		The Broadway is continually flooded	West beach is continuing to flood badly all this week		Tide >6m	1.31	17.8mm on 08/08 and 4.5mm on 09/08 and 7.5mm on 10/08	Wet	High
4a	***13/08/2014 4:10pm***	***13/08/2014 1:59pm***	***Unknown***	***Flooding either side of Westway above ankle deep, but not to middle of road***		***6.96***	***1.30***	***1mm on 13/08, 12/08 dry***	***Dry***	***High***
5	25/08/2014 7:00am				Flooding of woodland area	Tide <6m	1.31	29.2mm on 25/08	Wet	Low
6	11/09/2014 3:00pm	11/09/2014 1:38pm		Flooding either side of Westway limited to one side of the road	Water bubbling up onto Westway (video). Water drained away by 5.30	6.96	1.27	Dry	Dry	High
7	08/10/2014 1:00PM	08/10/2014 11:50am	Unknown	Flooding across most of width of Westway. Fairly deep in places	The flood plain behind west beach is now flooded. Prince Avenue flooded	6.74	1.32	5.3mm 08/10 and 20.0mm on 07/10	Wet	High
8	22/10/2014 1:30PM	22/10/2014 11:06am			Prince Avenue flooded across whole width of road	5.66	1.37	Unknown	Unknown	Low
9	03/11/2014 09:00am	03/11/2014 7:50am	Broadway flooded, extent / depths unknown	Westway also flooded, extent unknown?	Roads were at 9am. About a foot of concrete was not under water. Water still sitting in Westway and Broadway at 6pm	5.62	1.40	18.3mm on 02/11 and 13.8mm 03/11	Wet	Low
9a	***07/11/2014 12:15pm***	***07/11/2014 11:13am***	***Broadway flooded, extent / depths unknown***	***Westway flooded, half way across the road but quite deep. Also looks to be flowing***		***6.54***	***1.42***	***5.1mm on 06/11 and 5.2mm on 07/11***	***Dry***	***High***
9b	***08/11/2014 1:30pm***	***08/11/2014 11:54am***	***Broadway flooded, extent / depths unknown***	***Flooding across most of width of Westway. Fairly deep in places***	***Also flooded 9th November 2014, high tide was 6.32m AOD***	***6.49***	***1.43***	***13.7mm on 08/11***	***Wet***	***High***

ID	Date/Time flooding	Date/time high tide	What is flooded? And to what extent? (All are quotes from local residents)		Other useful information	Level of high tide (mAOD)	Groundwater level at Sussex PAD (mAOD)	Rainfall total (Applesham Farm)	Dry / Wet	Tide level at time of flood
			The Broadway	The Westway						
9c	***10/11/2014 3.25pm***	***10/11/2014 1:13pm***	***Broadway badly flooded across whole length of road, buses couldn't stop at edge of road***		***Orient Road flooded near junction with Broadway***	***6.05***	***1.51***	***0.3mm on 10/11***	***Dry***	***High***
10	23/11/2014 1:00pm	23/11/2014 11:26am	The Broadway / Orient Rd are flooding badly again. Flooding almost across the total width of the road	Limited flooding on Westway?	Broadway north of junction also flooded one side of the road	6.24	1.83	9.4 on 22/11 and 15.3mm on 23/11	Wet	High
10a	***28/11/2014 Time Unknown***		***Refer to previous photographs of the flooding on the Broadway and crossroads of Westway / Orient Road***		***The flooding has been constant and not abated ,yesterday it was across the entire road and causing problems with the flow of traffic especially smaller cars which have to travel down the centre of the road***	***Tide <6m in afternoon***	***1.91***	***10.8mm on 25/11, .88mm on 26/11 and 0.3mm on 28/11***	***Wet***	***Low***
11	12/12/2014 09:30am		Broadway and crossroads Orient Road and Westway almost across road near junction with A259		Just to keep you informed The Broadway is still partially flooded 2 days after the precipitation	Not linked to high tide	1.85	14.7mm on 11/12 and 0.2mm on 12/11	Wet	Low
11a	***17/12/2014 3:30pm***		***The Broadway is badly flooded nearly to the middle of the road but still passable. Corner of Orient Flooded***	***No flooding on Westway***	***Low tide but heavy precipitation.***	***Tide <5m***	***1.76***	***13.2mm on 16/12 and 1.4mm on 17/12***	***Wet***	***Low***
11b	***19/12/2014 12:00pm***		***Broadway flooded, but less water compared to 2 days earlier. Still across most of road***			***Tide <5.5m***	***1.72***	***6.8mm on 18/12 and 0.1mm on 19/12***	***Dry***	***Low***
12	03/01/2015 Time Unknown		The Broadway badly flooded , cascading water off A 259 , reaching middle of road etc as previous	No flooding on Westway	Unsure of time of flood, email was as 12:47pm	Tide <5.75m	1.81	9.4mm on 02/01 and 5.6mm on 03/01	Wet	Low
13	08-01-2015 11:00am		The Broadway badly flooded , cascading water off A 259 , reaching middle of road etc as previous	Flooding Westway half way across road, focussed on area between George V and Bristol Avenue		Not related to tide level	1.88	23.6mm on 07/01 and 17.9mm on 08/01	Wet	Low
14	14-01-2015 3:35pm		The Broadway junction floods in all four directions (into Orient Rd, up and down Broadway as well as into the Westway). If it rains heavily, the whole junction floods heavily	Not flooded		Low tide 2 hours earlier	2.50	11.3mm on 14/01	Wet	Low
14a	***17-01-2015 11.30am***		***Majority of Broadway flooded***	***Not flooded***		***High tide @ 8am, only 5.2m AOD***	***2.79***	***4.7mm on 17/01***	***Dry***	***Low***
15	23-01-15 2.30pm	23-01-15 @1.30pm	Flooding but still receding	Water bubbling up through Westway, but only isolated flooding		6.83	2.60	6.6mm on 23/01	Dry	High

ID	Date/Time flooding	Date/time high tide	What is flooded? And to what extent? (All are quotes from local residents)		Other useful information	Level of high tide (mAOD)	Groundwater level at Sussex PAD (mAOD)	Rainfall total (Applesham Farm)	Dry / Wet	Tide level at time of flood
			The Broadway	The Westway						
16	13-02-2015 4.00pm		The Broadway is flooded to about a quarter due to surface water runoff from the A 259 after precipitation this	pooling significantly along the curbs to a quarter of the Broadway and orient / Westway		High tide 4.97 @ 5pm	Data not yet available	Data not yet available	Unknown	Unknown

5.1.5 A27 Drainage

The A27 catchment which contributes flows towards Lancing Brook ditches is in proximity to the junction with Berriedale Drive to the west and the crossing over the River Adur to the east. The A27 drains to the ditches via kerb offlets, gullies, edge and surface channels, filter drains and pipework to a series of outfalls into the Lancing Brook ditches. The outfalls from the A27 are outlined below (from west to east):

- south of the Manor Road / Grinstead Lane roundabout where flows drain to the 300mm pipe which flows through No.4 Old Shoreham Road;
- on Manor Close where the A27 drainage flows into a manhole which also conveys the flows from the ditches under Manor Close;
- into a small ditch near 68A Old Shoreham Road[25];
- two outfalls into the ditch immediately east of Mash Barn Lane;
- outfall into the lagoon south of the A27, which is known to be heavily silted, and;
- a further unknown outfall into Withy Patch caravan park.

Following flooding on the A27 in 2012 the Highways Agency undertook significant remediation work, which was completed in 2013. This has included pipe remediation, patch lining, lateral grinding and root cutting, to improve conveyance capacity of the system.

5.1.6 Honeyman's Hole

Honeyman's Hole is a spring located immediately south of the A27 (co-ordinates 519088, 105881). It is not possible to quantify its contribution of flow to the Lancing Brooks with any certainty, but it flows all year round. Honeyman's Hole discharges into a ditch network which runs both east towards a sluice gate into the tidal Adur, and south into a culvert which runs under Shoreham Airport (via a large brick arch culvert[26], as shown in Figure 5-7). During low tide approximately 50% of flows from Honeyman's Hole drains towards the sluice gate, with the remainder flowing south. During tide-lock situations all flows from Honeyman's Hole will flow south towards the brick arch culvert.

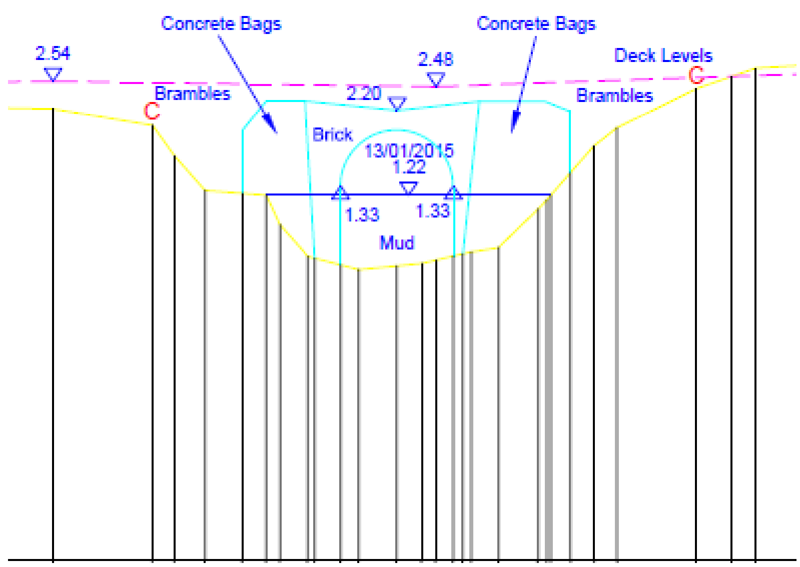

Figure 5-7 Culvert under Shoreham Airport from Honeyman's Hole (from Cross-Section Survey)

5.1.7 Widewater lagoon

Widewater is a shallow lagoon approximately 1.1km long and up to 80m wide at the eastern end. It is an important location for nature with many rare species and attracts a wide range of interest from the general

[25] This is the cul-de-sac on the southern side of the A27

[26] Approximately 3m into the culvert it appear to change to a 1m diameter culvert, but this could not be confirmed during the survey without confined space entry.

public for recreation. The Widewater Management Plan (2009-2014) contains a significant level of background information about Widewater which is not repeated in this report[27].

For the SWMP the key issue is whether Widewater Lagoon contributes to flooding at West Beach Estate. WSCC undertook a survey from the Widewater Lagoon to the junction of The Broadway with Orient Road/Westway in April 2014 to establish ground levels across the section (using Temporary Benchmark Datum). The bed of Widewater Lagoon was approximately 150mm lower than the low point on The Broadway (near the local shops). The water level in April 2014 was approximately 500mm higher than the low point on The Broadway. The water level in the Lagoon is affected by:

- seawater percolation through the shingle bank;
- overtopping of the defences during storms;
- inlet pipe, which can increase salinity where required;
- rainfall and surface water runoff from properties adjacent to the Lagoon, and;
- water loss via evaporation, and some percolation through the lagoon bed[28].

With respect to the latter point the Widewater Management Plan notes that "there has been bubbling observed from the base of the lagoon at normal high tides, indicating that some flow of air and/or seawater occurs through the shingle bank and via the bed of the lagoon"[29]. However, the clay layer at the bottom of the Lagoon will have a significant effect of limiting the amount of seepage into the Lagoon during high tides, and limiting seepage out of the lagoon during low tides. There is no evidence of significant reductions in water levels during low tides which would occur each and every time if there was significant seepage through the lagoon bed. The majority of seepage into and out of the lagoon will be via the shingle bank.

The evidence available does not suggest that there is significant seepage through the lagoon bed. Any minor seepage would be discharged into underlying strata beneath Widewater, which will flow towards the sea in keeping with the regional groundwater flows (as described in Section 3.4). Widewater Lagoon is not considered to be a contributory factor in flooding on West Beach Estate.

5.2 Lancing Brooks watercourses

Due to the presence of the railway line the catchment can broadly be divided into the northern floodplain and southern floodplain, before converging south of the railway near Shoreham Airport.

The route and connectivity of the Lancing Brooks has changed on several occasions over the past 400 years, based on analysis of historic maps dating back to 1622. Historically the Teville Stream, which now flows through Worthing (discharging to the sea) used to flow east and discharge into the tidal Adur. The Lancing Brooks connected to the Teville Stream south of Old Salts Farm and New Salts Farm. This was the case until between 1870 and 1898 when Widewater Lagoon was constructed and the Teville Stream was diverted to outfall to the sea further west. Historically, the lost ditch north of Adur Close is likely to have been the ditch that discharged flows from Teville Stream into the tidal Adur although this cannot be confirmed based on the resolution of the historic mapping. The railway also seems to have affected the Lancing Brooks. Before the railway there is evidence of a flow connection from the southern floodplain towards the northern floodplain east of Old Salts Farm. This no longer occurs as the ditches south of the railway do not flow into the northern floodplain. Development during the 20th century has also affected the route of the ditches, which have at times been altered. In addition, this development has constrained the natural floodplain of the ditches, which are now heavily constrained through the urban areas of Lancing.

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27 http://www.lancingparishcouncil.gov.uk/council/item/21

28 *Ibid.*

29 *Ibid.*

In the subsequent sections a brief overview of the connectivity and outfall of the Lancing Brooks is provided, as it flows today.

5.2.1 Northern floodplain

The ditches west of Mash Barn Lane have been described in Section 5.1.1.2. East of Mash Barn Lane the ditches flow through the golf course development. The primary ditch runs east until near the boundary with Shoreham Airport where the ditch flows south towards the twin 900mm culvert, which flows under Shoreham Airport, before emerging for a short open section and then flowing under the railway via a brick arch culvert. Immediately upstream of the twin 900mm culvert is a small pond. At various points throughout the golf course there are connecting ditches. This includes a ditch network which drains flows from the Brighton and Hove Albion football club development. The landowners of the golf course clear the ditches on an annual basis to maximise conveyance through the ditches. In addition to flows from the Manor Way area and the golf course, the northern floodplain also includes flows from Honeyman's Hole, as described in Section 5.1.6. Figure 5-8 provides an overview of the northern floodplain.

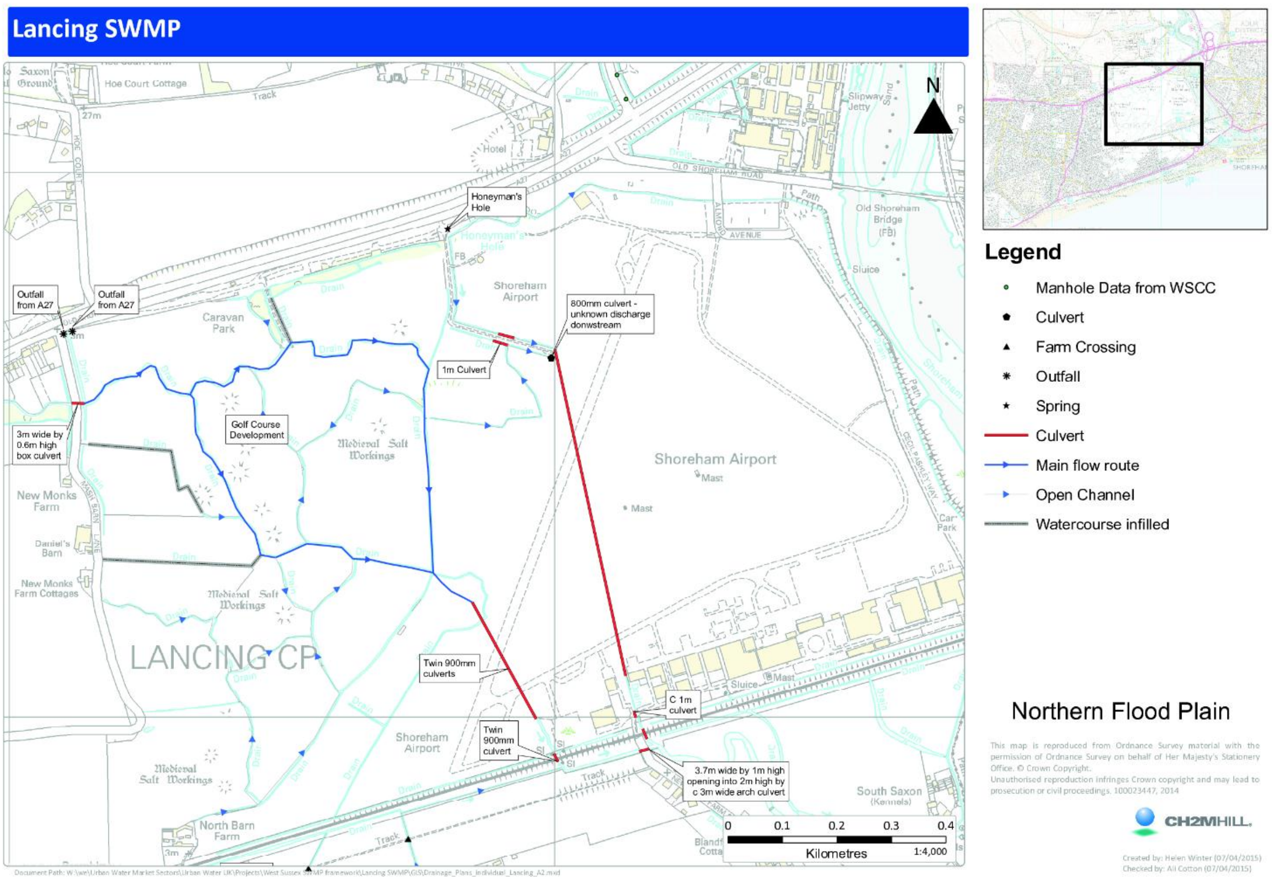

Figure 5-8 Northern floodplain layout

5.2.2 Southern floodplain

Inflows to the southern floodplain are primarily from the ditch which flows from Barfield Park, the ditch which flows from Willowbrook Caravan Park, and groundwater emergence. With respect to Barfield Park, Section 5.1.2 describes the connectivity of ditches. Downstream of the railway the Brooks continue to flow in a southerly direction where it is joined by flows from Willowbrook Caravan Park. At this point the ditch turns to flow in a north-easterly direction until a bifurcation in flow north of the West Beach Estate. The primary flow pathway is east until the ditch reaches the end of Broadway Park Homes where the ditch turns abruptly north towards the railway. The ditch continues to flow along the southern edge of the railway before crossing under New Salts Farm Bridge (NB: two bridges at this location), before flowing towards the Lancing Brooks outfall by the Dogs Trust.

5.2.3 Outflows

The Lancing Brooks Outfall collates all flows from the northern and southern floodplain and discharges into the tidal Adur[30]. The outfall was re-built in 2010. Prior to this the twin northern outfalls had failed completely due to siltation. The report[31] prepared to support the business case notes: "the existing trash screens are not effective, causing debris to be caught in the flap valve in the past. Access to maintain the trash screen is very poor, and there is no access to maintain or clear the tidal flap valves." To alleviate the problem a series of options were considered:

1. Do nothing
2. Do minimum
3. Option D; replace southern outfall and decommission northern outfall
4. Option D(s); as option D with additional flood plain storage
5. Option E; Replace southern outfall with increased capacity and decommission northern outfall
6. Option F; Pumping station with 3 x 250 l/s pumps to lift water from Lancing Brook into tidal lagoon

Option D was the preferred option and taken forward for design and construction in 2009 and 2010. Local residents have expressed concerns that the new outfall is insufficient and causes backing up of the water into the floodplain. The hydraulic modelling and design of the outfall has therefore been considered, in the context of its impact on discharge from the Brooks.

When the Lancing Brooks Outfall was re-designed the capacity of the discharge was increased, and the invert level at the outfalls was also lowered. The invert levels for construction were lowered by 100mm to -0.25m AOD at the inlet and -0.31m AOD at the outlet. During initial design the proposal was to do a like for like replacement of the twin 900mm culverts on the southern outfall. However, during construction the twin culverts were actually upsized to 1200mm culverts, thus increasing the peak flow discharge from the outfall. The pipe full capacity pre and post scheme is shown in Table 5-2, which have been calculated using *Tables for Hydraulic Design of Pipes and Sewers*, By HR Wallingford.

Table 5-2 Capacity of the Lancing Brooks Outfall pre and post scheme

Parameter	Pre-scheme (southern outfall)	Post-scheme (southern outfall)
Gradient, S_0	1/300	1/300
Hydraulic roughness, k_s, mm	0.03	0.03
Pipe diameter, mm	2 x 900	2 x 1200
Pipe full flow, m^3/s	1.438	3.053
Pipe full velocity, m/s	2.26	2.70

This calculation assumes that the flap valves at the downstream end of the twin 1200mm culverts are full opened, which will only occur if there is sufficient hydraulic head within the system to force the flap valves open. If the hydraulic head in the system is insufficient to fully open the flap valves then upsizing or lowering the invert level of the culverts would not be effective in increasing the discharge capacity. It is not

30 With the exception of some flow from Honeyman's Hole which drain east towards the tidal sluice, and some flows from the airport which drain to a surface water pumping station (which in turn pumps flows into the tidal Adur).

31 Halcrow Group Ltd (2008), Lancing Brook Outfalls, Project Appraisal Report

considered that any changes to the Lancing Brooks Outfall is required to mitigate flood risk to people and property in Lancing.

The change in upstream water level in the hydraulic model used to support the re-design of the outfall has also been considered. The results of modelling demonstrate a reduction in peak water level post-development of between 11 and 15 cm. This is as expected due to the lowering of the southern outfall allowing more water to drain from the catchment on the low tide.

SECTION 6

Modelling of Lancing Brooks

6.1 Introduction

A comprehensive cross-section survey was undertaken, which was used to develop a simplified 1D ISIS hydraulic model. The purpose of the modelling was to provide an overview of the conveyance of flows through the ditch system, and identify locations where there are pinch points in the system. However, the hydraulic model is not intended to be a verified flooding model, principally because of the complexities of accurately representing inflows to the ditch system, as noted in the Monson Engineering study report[32].

6.2 Cross-section survey

During December 2014 and January 2015 a comprehensive cross-section survey was undertaken of the Lancing Brooks. More than 85 cross-section surveys were taken of the Lancing Brooks from its emergence in the urban areas around Manor Close and Barfield Park, to the outfall east of New Salts Farm. The location of cross-sections for the survey were determined in collaboration with the district drainage engineer from Adur and Worthing Councils, and experience of the survey team.

Cross-sections were surveyed at all key structures (e.g. bridges, farm crossings, culverts), where ditches converged, and at other suitable locations throughout the network. Cross sections extended 10m beyond the river bank into the flood plain, wherever possible although in some of the residential areas the channel was heavily constrained and the top of the watercourse bank was deemed acceptable. For upstream elevations of bridges and culverts, the downstream soffit, top of parapet, invert, bed level and bank crests were surveyed. Weirs, drop structures and all other structures were also surveyed. Outputs from the survey were in ISIS format, and XYZ files. Long sections were provided for any structures which are considered to effect flow and CAD format drawings of hydraulic structures were supplied by the survey contractor. The outputs from the survey are provided in Appendix F.

6.3 Hydraulic model build

The cross-section survey was used to build a one-dimensional (1D) ISIS hydraulic model of the Lancing Brooks ditches. The 1D model represents changes in water levels throughout the system and locations where this may cause flows to reach the top of the bank of the watercourse or overtop the bank. However, a 1D model does not seek to represent the flows once they are out of bank (i.e. how water travels over the floodplain, causing flooding to properties and infrastructure). All structures from the cross-section survey were represented in the model to assess the impact of these on water levels. At all structures a ‘spill’ unit was included in the model, with the level set to road or bank level. The spill unit represents out of bank flow at these key structures, which is subsequently discharged to the downstream section.

As the purpose of the model was to broadly understand the conveyance of flows through the ditches, the model was run with nominal steady state inflows, rather than based on detailed FEH rainfall-runoff calculations. Inflows were provided at head of each reach into the system. To ensure that the total inflows into the ditch system were broadly appropriate previous work was considered, which has quantified the total inflows to the system for a range of design storm events.

The Monson Engineering study estimated that on average runoff arriving at the New Salts Farm Road culvert was approximately 1.25 m^3/s during a 1 in 10 year design storm with a 7 hour critical duration. Furthermore, to support the re-design of the Lancing Brooks Outfall total flows arriving at the outfall were estimated to be

[32] Monson Engineering (1994), Report on the Survey and Hydraulic Analysis of Lancing Drainage Ditches

approximately 1 m^3/s during a 1 in 10 year design storm (with a critical duration of 12 hours[33]), and 1.5 m3/s for a 1 in 100 year design storm[34].

The hydraulic model has been run with two sets of steady state inflows of 1 m^3/s and 1.5m^3/s to test the conveyance of flows through the network. These have been applied proportionately at the head of each reach, with the largest inflows included at the head of the ditch system at Manor Way and Barfield Park.

6.4 Model simulations

The hydraulic model was simulated for a range of scenarios to understand pinch points in the system, and the effectiveness of different mitigation measures on water levels across the Lancing Brooks. The following scenarios were run in the hydraulic model.

- Baseline (BL) – this scenario is based on bed and bank levels from the cross-section survey, and are considered to represent the current day scenario.
- Scenario 0 (SC_0) – this scenario represents the impact of no maintenance on water levels. For this scenario a range of increased bed levels were represented in the residential areas and southern floodplain ditches to identify what the optimal maintenance regime would be for the ditches. The ditches within the Golf Course are maintained on an annual basis and were therefore left unchanged for this scenario. No change was made to culverted sections, because in many places there is already significant increases in bed levels at culvert inlets under roads/bridges due to siltation.
- Scenario 1 (SC_1) – this scenario represents maintenance improvements at key structures which have the greatest impact on water levels. The bed levels for road bridges at Mash Barn Lane and Old Salts Farm were lowered to provide a consistent bed level upstream and downstream of these structures.
- Scenario 2 (SC_2) – this scenario represents capital improvements at key structures which have the greatest impact on water levels. The culvert inlet on Manor Close was increased from a 450mm to a 600mm, and 600mm diversion culverts were implemented parallel to the Old Salts Farm Road Bridge and Mash Barn Lane. For these scenarios the bed levels at Mash Barn Lane and Old Salts Farm Road bridges were unchanged from the baseline scenario, to identify mitigation options for upgrading the road bridges in case it is not possible to lower the bed levels without affecting the structural integrity of the bridges.

The model simulations are identified in Table 6-1. A summary of the modelling results are presented in the subsequent sections, and full modelling results are presented in Appendix G. All modelling results have been compared against Scenario 0 (no maintenance) to represent the effects of a 'do nothing' scenario[35].

Table 6-1 Baseline model scenarios

Scenario ID	Total inflows to model		Outfall condition	
	1 m^3/s	1.5 m^3/s	Outfall open	Outfall closed
SC_0a	✓		✓	
SC_0b	✓			✓
SC_0c		✓	✓	
SC_0d		✓		✓
BL_a	✓		✓	
BL_b	✓			✓

[33] Initially a critical storm duration of 6 hours was used, however this is subject to change when tide-lock conditions were considered.

[34] Halcrow Group Ltd (2007), Lancing Brook Outfall, Hydrology Technical Note

[35] As per Environment Agency (2010), Flood and Coastal Erosion Risk Management appraisal guidance, http://webarchive.nationalarchives.gov.uk/20131108051347/http:/a0768b4a8a31e106d8b0-50dc802554eb38a24458b98ff72d550b.r19.cf3.rackcdn.com/geho0310bsdb-e-e.pdf

Scenario ID	Total inflows to model		Outfall condition	
	1 m^3/s	1.5 m^3/s	Outfall open	Outfall closed
BL_c		✓	✓	
BL_d		✓		✓
SC_1a	✓		✓	
SC_1b	✓			✓
SC_1c		✓	✓	
SC_1d		✓		✓
SC_2a	✓		✓	
SC_2b	✓			✓
SC_2c		✓	✓	
SC_2d		✓		✓

6.4.1 Scenario 0 - Do nothing scenario

This scenario seeks to investigate the impact of a lack of maintenance on water levels in the Lancing Brooks. The following adjustments were made to the open channel cross-sections within the baseline model:

- bed levels were increased in the residential areas were increased by 150mm, and 250mm to represent different levels of siltation buildup, and;
- bed levels were increased in the southern floodplain (from the railway culvert to New Salts Farm Road bridge) were increased by 150mm and 250mm.

Culverts and farm crossings were not adjusted because in most cases there is existing siltation at these structures, which causes constrictions to flows.

Table 6-2 summarises the changes in water level across the Barfield Park and Manor Way reaches with 150mm and 250mm siltation, compared to the baseline scenario. With 150mm siltation in the system the maximum increase in water levels in upstream of Mash Barn Lane, and downstream of the railway bridge near Old Salts Farm was approximately 80mm.

However, for the same reaches siltation in the order of 250mm resulted in increases in maximum water levels of 150mm downstream of the railway bridge near Old Salts Farm and more than 200mm upstream of Mash Barn Lane. This will increase the risk of overtopping of the watercourses because the conveyance capacity is reduced in the channels. The evidence from the modelling therefore suggests that siltation of up to 150mm will have a limited impact of water levels, but siltation up to 250mm will have a more significant impact.

Table 6-2 Changes in water level under Scenario 0 compared to the baseline results

Reach	Maximum increase in Water Level (mAOD) compared to Baseline scenario			
	150mm siltation		250mm siltation	
	1 m^3/s inflows	1.5 m^3/s inflows	1 m^3/s inflows	1.5 m^3/s inflows
Barfield Park – Lancing Brooks Outfall	0.081	0.033	0.148	0.069
Manor Way – Lancing Brooks Outfall	0.082	0.03	0.222	0.065

6.4.2 Baseline scenario

The model results indicate that for the low tide baseline scenario with 1 m^3/s inflows (BL_a) there are numerous structures (e.g. bridges, culverts) which have a significant impact on upstream water levels, due to headloss in the system at these structures. This is demonstrated by sharp increases in water levels upstream of some key structures, including the Old Salts Farm Road Bridge and Mash Barn Lane Road Bridge.

The cross-section survey identified significant constrictions at these road bridges due to siltation which has elevated the bed level, and pipe crossings which affect the soffit level. The effect of siltation and pipe crossings is to reduce the cross-sectional area of these road bridges significantly, compared to the upstream and downstream open channel sections. Appendix E contains the cross-section survey data, which demonstrates the constrictions in flows at these road bridges.

Under scenario BL_c (low tide baseline scenario with 1.5 m^3/s inflows) there are additional structures which have a more significant impact on upstream water levels, most notably at the 450mm Manor Close culvert inlet, the twin 600mm culverts under Monks Avenue and North Farm Road culvert, and the brick arch culvert under the railway south of North Farm Road. At these structures the cross-section survey did not identify significant siltation, therefore any flow constriction is related to the sizing of these structures, rather than maintenance and sediment buildup. The Manor Close culvert has a more significant impact on upstream water levels than either of the twin 600mm culverts at Monks Avenue and North Farm Road, and the railway culvert. Whilst the twin 600mm culverts at Monks Avenue and North Farm Road and the railway culvert do effect water levels and cause some constriction in flow, there is no evidence from this modelling that they contribute to out of bank flooding from the ditches. Therefore improvement works should focus on the Manor Close culvert.

The Monson Engineering study identified the New Salts Farm Road Bridge to be a major restriction in the system. The model results presented in this study do suggest some increase in water levels upstream of this structure, but it is less significant that the effects of structures further upstream. There is also evidence of siltation around at the New Salts Farm road bridge[36]

The bed levels from the cross-section survey suggest a relatively good gradient from the upper parts of the ditches to the outfall. There are some sections which have been over-deepened through ditch clearance (e.g. southern floodplain to the north of the West Beach Estate, and sections of the golf course), but these will not serve to restrict flow. More importantly, there appear to be few sections of open channel where the bed level increases sharply, which would have an impact on upstream water levels. In summary, the baseline model scenarios suggest structures are having a greater impact on water levels than the current maintenance of the Lancing Brooks.

With the Lancing Brooks Outfall closed, to represent a high tide scenario (BL_b), the model results show a significant rise in water levels throughout the ditch network. This corroborates local evidence that water levels as far north as Mash Barn Lane rise during high tide. In addition, during a high tide the water level is significantly less affected by flow restrictions at structures, because water level equalises over the whole ditch network in the absence of any discharge from the system.

6.4.3 Scenario 1 – Maintenance improvements at structures

This scenario represents maintenance improvements at key structures which have the greatest impact on water levels, namely the Mash Barn Lane and Old Salts Farm road bridges. Within the ISIS model the bed levels at these structures was lowered to provide an improved gradient upstream and downstream of these structures. At this stage no consideration has been made of the structural integrity of the road bridges, and

[36] Bed levels at the downstream face of New Salts Farm road bridge were 0.25m AOD at the time of survey. The bed levels at the nearest surveyed upstream section (just before the Brooks flow alongside the railway) were 0.991m AOD. Downstream of the bridge bed levels drop to below sea level as the Brooks flow through open fields, although these sections appear to be over-deepened.

the potential impact of de-silting, although it may be possible to re-design the bridges at the point of maintenance to make them easier to clear and reduce silt buildup through their design.

With respect to Barfield Park the model results indicate a significant drop in water levels in the ditches upstream of Old Salts Farm Road bridge. Under scenario SC_1a (low tide scenario with 1 m^3/s inflows) the water level drops by more than 300mm (compared to scenario 0 with a 250mm silt buildup) in the cross-section immediately upstream and downstream of the railway, because of the reduction in headloss when the cross-sectional area of the road bridge is increased by lowering of the bed level. The impact of improving the conveyance capacity of the Old Salts Farm Road bridge extends to the head of the ditch network on Barfield Park, which is the headwall to the east of Grinstead Lane. Under scenario SC_1c (low tide scenario with 1.5 m^3/s inflows) lowering the bed level at Old Salts Farm Road bridge is less significant (c.150mm compared to scenario 0 with 250mm silt buildup). Therefore, the modelling indicates that improved conveyance at Old Salts Farm Road bridge will have an impact on upstream water levels, and hence reduce the risk of out of bank flooding. The model results for SC_1b and SC_1d (high tide scenarios) indicate limited reduction in water levels with the improvements to Old Salts Farm Road bridge.

With respect to Manor Way the model results indicate a modest reduction in water levels with the improvement to the Mash Barn Lane bridge. Under scenario SC_1a (low tide scenario with 1 m^3/s inflows) water levels drop by more than 300mm immediately upstream of the bridge (compared to scenario 0 with a 250mm silt buildup), which reflects the constriction of the bridge on local flows. Further upstream, near the Manor Close culvert modelled water levels do not change with these improvements in place. This is because of the further constriction upstream, associated with the Manor Close culvert. Under scenario SC_1c (low tide scenario with 1.5 m^3/s inflows) the improvement works to the Mash Barn Lane bridge have little impact on upstream water levels (c.100mm). The model results for SC_1b and SC_1d (high tide scenarios) indicate limited reduction in water levels with the lowering of bed levels at the Mash Barn Lane bridge.

6.4.4 Scenario 2 – Capital improvements at structures

This scenario represents capital improvements at key structures which have the greatest impact on water levels. The following changes were applied to the model for this scenario:

- the culvert inlet on Manor Close was increased from a 450mm to a 600mm;
- a 600mm diversion culvert was implemented parallel to the Old Salts Farm Road Bridge, and;
- a 600mm diversion culvert was implemented parallel to the Mash Barn Lane bridge.

No change was made to the bed levels at Mash Barn Lane and Old Salts Farm Road bridges.

With respect to Barfield Park the implementation of an additional 600mm culvert adjacent to the Old Salts Farm Road bridge has a similar impact on water levels as scenario 1, where the bed level of the road bridge was lowered. With the tidal gates closed, water levels are unaffected by the proposed mitigation measures, as per scenario 1.

On Manor Way the combined improvement measures at the Manor Close culvert inlet and Mash Barn Lane bridge result in a reduction in water levels from Mash Barn Lane to the head of the model, which is the doctors ditch. Under scenario SC_2a (low tide scenario with 1 m^3/s inflows) the reduction in water levels immediately upstream of Mash Barn Lane are similar to the results from scenario 1. However, further upstream, near the Manor Close culvert, the model results for this scenario suggest a significant reduction in water levels of nearly 500mm as a result of improvements to the Manor Close culvert inlet.

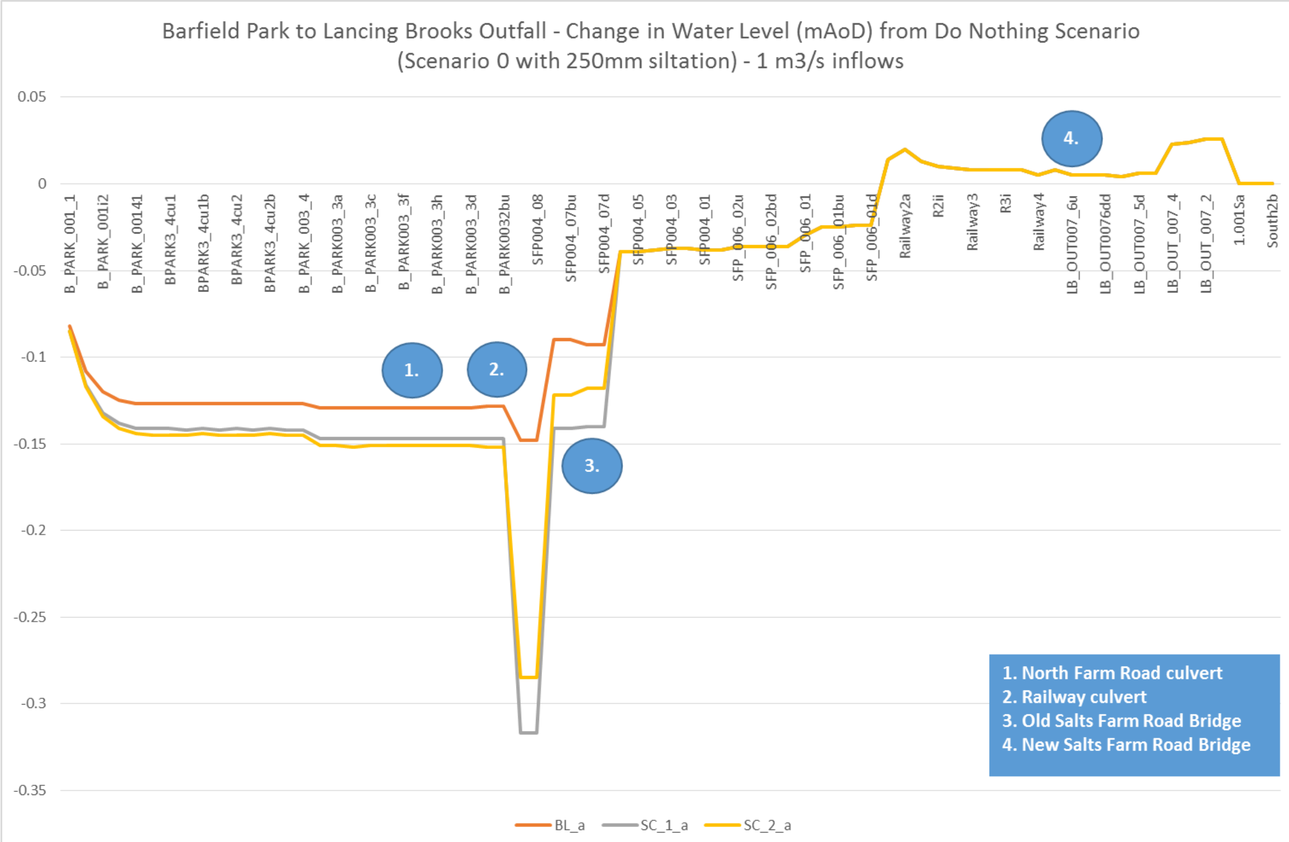

Figure 6-1 Barfield Park to Lancing Brooks Outfall - Change on water level from scenario 0 (250mm siltation) for 1m3/s inflows scenario

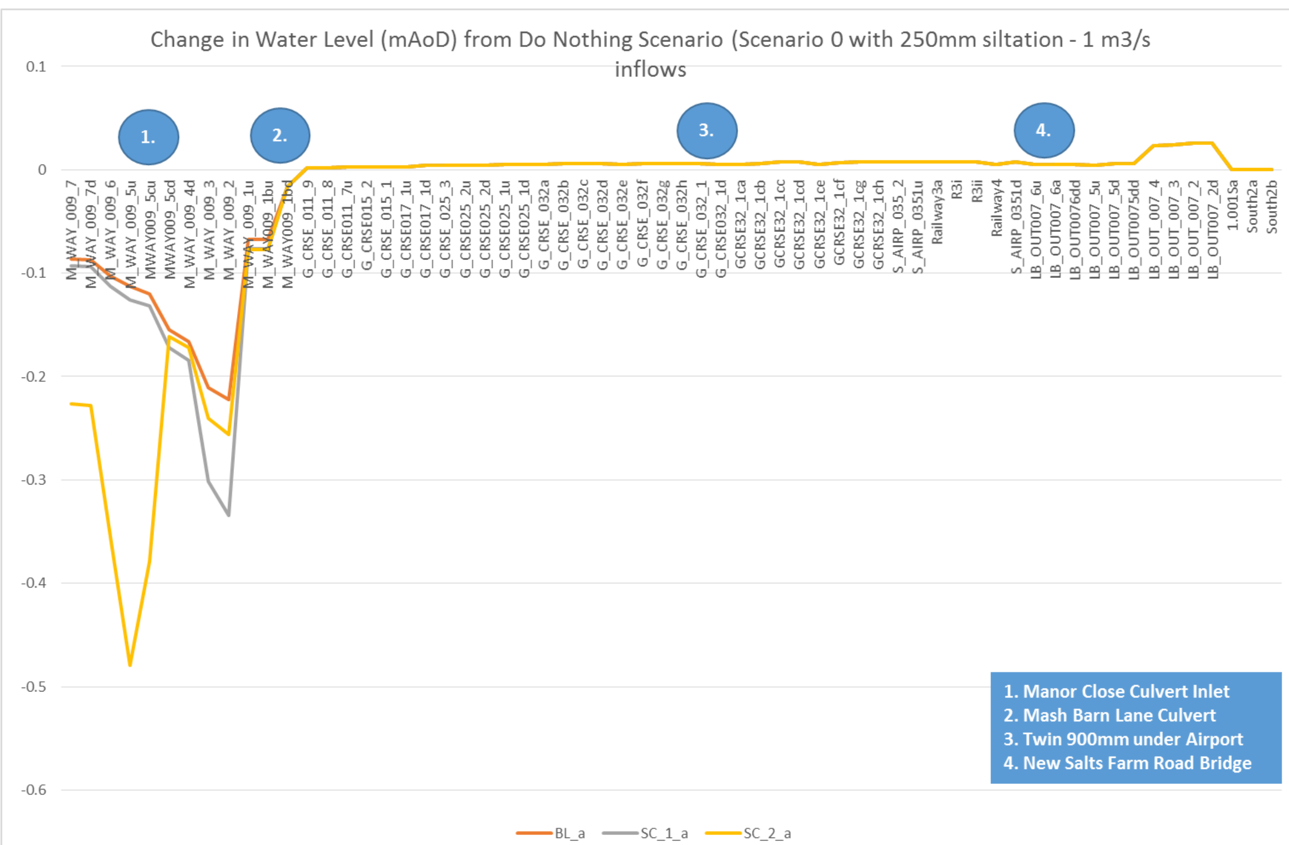

Figure 6-2 Manor Way to Lancing Brooks Outfall - Change on water level from scenario 0 (250mm siltation) for 1m3/s inflows scenario

6.5 Summary of hydraulic modelling

The salient findings from the hydraulic modelling are:

- silt buildup within the ditch network in residential areas and the southern floodplain greater than 150mm will cause a significant impact on water levels;
- there is evidence of significant siltation or capacity constraints at several culverts, bridges, road/farm crossings including Manor Close culvert, Mash Barn Lane road bridge and Old Salts Farm road bridge;
- the twin 600mm culverts under Monks Avenue and North Farm Road, railway culvert to the south of North Farm Road and the New Salts Farm Road Bridge cause some additional backing up of flows and increases in water levels, and;
- improvement works (maintenance and capital) to Manor Close culvert, Mash Barn Lane road bridge and Old Salts Farm road bridge have been modelled and demonstrate reductions in water levels up to 600mm.

SECTION 7

Summary of causes and impacts of flooding

The analysis presented in Sections 5 and 6 have demonstrated the causes of flooding in Lancing. This analysis is summarised in Table 7-1.

Table 7-1 Summary of causes and impacts of flooding

Location	Internal Property Flooding	Garden Flooding	Road Flooding	Other Infrastructure Flooding	Properties at risk of surface water flooding during a 1 in 30 year rainfall probability[37]	Causes of flooding
Grinstead Lane, Manor Way, Manor Close & Old Shoreham Road		✓	✓		15-20 properties	• High sensitivity to groundwater emergence • Influence of high groundwater on the performance of foul and surface water drainage systems, contributing to foul flooding and failure of the Grinstead Lane pumping station. Southern Water has implemented a number of actions following 2012/13 and 2013/14 including: development of a IRP, sealing of some sewers, installation of a level alert and production of an Emergency Action Plan • Culverts on Manor Close and Mash Barn Lane which impede flow of the Lancing Brooks • Maintenance of the Lancing Brooks • Under-sized drainage around Manor Way which can exacerbate flooding along Grinstead Lane • Risk that incomplete water level management plan for golf course development could exacerbate flood risk during extreme flooding events.
Barfield Park and Monks Avenue	✓ (2)	✓	✓		None	• High sensitivity to groundwater emergence • Highway drainage at junction of Monks Avenue / Hadlow Way

[37] Based on the Environment Agency's national surface water flood mapping, http://watermaps.environment-agency.gov.uk/wiyby/wiyby.aspx?topic=ufmfsw#x=357683&y=355134&scale=2

Location	Internal Property Flooding	Garden Flooding	Road Flooding	Other Infrastructure Flooding	Properties at risk of surface water flooding during a 1 in 30 year rainfall probability[37]	Causes of flooding
						• Culverts on Monks Avenue and North Farm Road, and the railway culvert have some impact on water levels, but do not cause out of bank flows. • Maintenance of the Lancing Brooks
The Paddocks	Garages		✓			• Siltation in the storage tanks, root infestation, and siltation in the ditch network. This has been cleared by WSCC during the past 18 months
West Beach Estate			✓		None	• A significant number of gullies which are cracked/broken, or full of sediment, siltation in the surface water pipes along The Westway, and potential siltation of soakaways. • Blocked surface water drainage outfalls • High groundwater levels (as demonstrated by the water level in the soakaways) which means that water cannot drain away after heavy rainfall events
A27			✓		N/A	• Condition of the piped drainage, which has since been addressed through remedial works undertaken by the Highways Agency in 2013. This has included pipe remediation, patch lining, lateral grinding and root cutting, to improve conveyance capacity of the system. It is outside of the scope of this report to recommend additional drainage measures on the A27, and therefore this is not considered further in this report.
Shoreham Airport				✓	N/A	• Failure of the River Adur tidal wall during a tidal surge in December 2013[38]. The Environment Agency is developing the business case for long term improvements to the tidal wall, and therefore this is not considered further in this report.

38 http://www.bbc.co.uk/news/uk-england-sussex-25267611

SECTION 8
Options to mitigate flooding

8.1 Introduction

The level of investment to mitigate flood risk must be proportional to the damage to property and infrastructure caused by flooding. In Lancing few properties are currently affected by internal flooding, and therefore the proposed mitigation measures are reflective of this. Policy, capital and maintenance mitigation measures to alleviate the impacts of flooding in Lancing have been considered and are described in Sections 8.2 to 8.5. It is critical to understand that even with all of these measures in place Lancing will still be at risk of flooding during more extreme weather events. This is because drainage systems (both natural and man-made) and any other flood risk infrastructure will be completely overwhelmed during extreme weather events. This concept is described in Figure 8-1 and defines different flood risk management approaches dependant on the rainfall event within a catchment. For 'everyday rainfall' the drainage system should function according to its natural or designed capacity to limit the impact of any flooding. Conversely during extreme events, it is recognised that drainage systems (both natural and man-made) and any other flood risk management infrastructure will be completely overwhelmed and therefore emergency response is the most appropriate management technique to reduce the impacts of flooding. The measures in this report focus on ensuring the drainage systems are functioning as designed for the 'everyday rainfall' and 'drainage design rainfall' through capital and maintenance investment. For the exceedance rainfall and extreme rainfall scenarios mitigation against flooding will rely on emergency intervention by WSCC, Southern Water and Adur District Council, and local residents taking action to reduce the impacts of flooding to property.

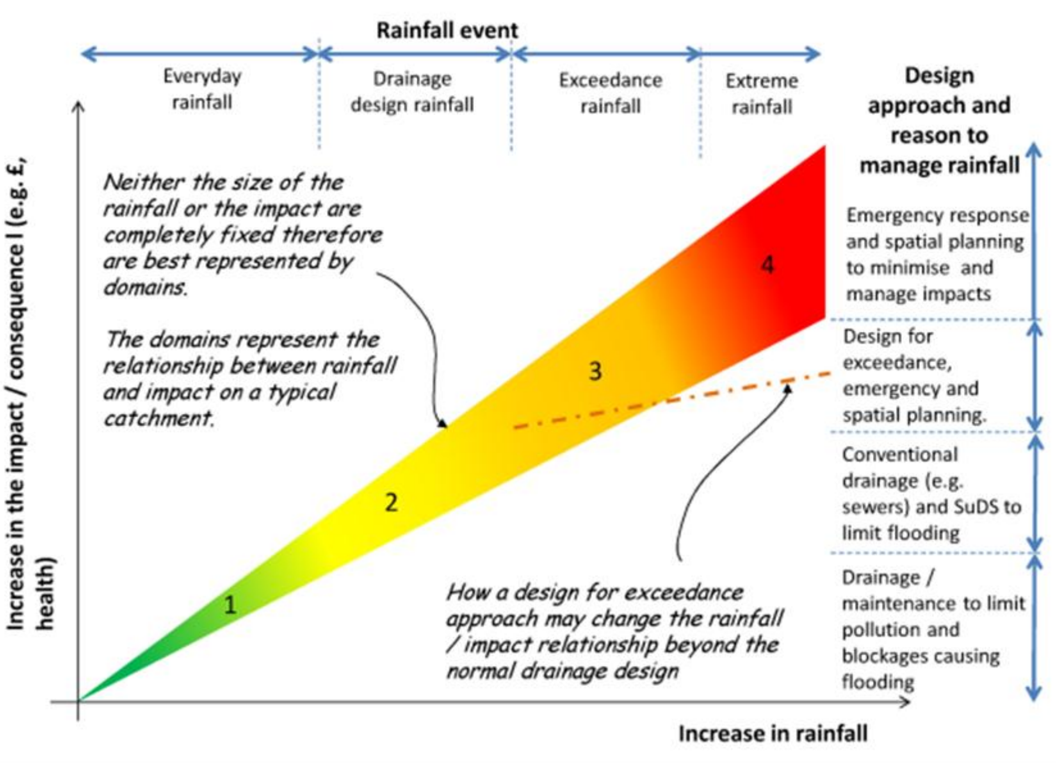

Figure 8-1 Flood risk management concept (taken from CIRIA's Designing for Exceedance guidance[39])

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[39] Digman, C.J., Ashley, R.M., Hargreaves, P. and Gill, E. (2014a) *Managing urban flooding from heavy rainfall - Encouraging the uptake of designing for exceedance – recommendations and summary*, CIRIA, C738a.

8.2 Grinstead Lane, Manor Way, Manor Close & Old Shoreham Road

8.2.1 Under-sized drainage near Manor Way

8.2.1.1 Conceptual options

As identified in Section 5.1.1.1 the 300mm pipe which flows east between numbers 5-7 Grinstead Lane, through the garden of No. 4 Old Shoreham Road has limited capacity to drain surface water flows from the upstream catchment to the doctor's ditch downstream. This will exacerbate surface water flooding in Grinstead Lane and Manor Way. To reduce flood risk at this location the primary option[40] is to disconnect the 300mm pipe which flows from Manor Road, and pass more flows through the existing overflow system which flows along the northern verge of the A27. The existing overflow system will need to be upsized to accommodate the additional flows, and flow control will be required to prevent an increase in flow rates to the Manor Close culvert.

To upsize the existing overflow system there are two options available. Conceptual drawings of these options are provided in Appendix H.

- Option 1 – this option involves constructing a dual pipe system along the route of the current overflow system, with pipe sizes between 600mm to 900mm. The pipes would need to be laid in concrete surround to avoid groundwater infiltration. At the downstream end of the overflow system a flow control device would be constructed to limit flows to the existing discharge rate, hence avoiding any increase in downstream flood risk. There are some constraints to this option because of the proximity of construction to the A27 carriageway, and the possibility of construction temporarily affecting the bus stop.
- Option 2 – this option involves constructing a geocellular attenuation tank (with concrete surround) in the grass verge on the north east of the A27/Manor Road roundabout to store flows. Flows from the geocellular attenuation tank would be limited to avoid any increase in downstream flood risk, and the pipework downstream would also be upsized/re-laid. The pipes would need to be laid in concrete surround to avoid groundwater infiltration. This option avoids the risk of any construction work directly affecting the A27.

There are a large number of assumptions included at this stage, which need to be considered during further design stages. First, the exact catchment area draining to the existing 300mm pipe is unknown, although evidence from Southern Water surface water sewer records suggests the catchment area is in the region of 1 hectare. Secondly the condition or storage capacity within the existing system is unknown. To confirm catchment area, condition and sizes of the upstream network will require a CCTV survey[41]. The CCTV survey should also include the 300mm continuation pipe and the 225mm overflow pipe to confirm condition and levels. Once these data have been collected a hydraulic model should be built to test the capacity of the current system. A further uncertainty at this stage is the presence of utilities and other services along the northern verge of the A27. A services search should be undertaken as a priority action to confirm there is sufficient space to implement the proposed upgrade to the 225mm overflow system.

8.2.1.2 Costs and benefits of options

Due the number of assumptions at this stage it is difficult to provide a cost estimate for these options. However, a provisional construction cost estimate, using bills of quantities and the SPONS pricing book, suggests the construction costs could be in the region of £200,000 for Option A and £100,000 for Option B. This assumes that all pipework and attenuation tanks are laid in concrete surround which approximately

[40] Other options, such as upsizing the pipe are likely to present significant technical challenges because they pass through residential gardens

[41] The manhole survey will capture cover, invert and soffit levels of the network.

doubles the cost estimate for these components of construction. In addition, the cost estimate is based on SPONS pricing books, which are national estimates. Whoever takes this action forward may have access to different construction rates from contractors. An outline of the bills of quantities and construction cost estimates are provided in Appendix H. The cost estimate does not include a consideration of survey and design costs.

It is difficult to monetise the benefits of specific measures in the Lancing catchment, because there is limited property flooding, and it is only a combination of mitigation measures that will reduce flood risk. Qualitatively, the improvement works to the drainage around Manor Road and Manor Way the benefits will be reduced flooding on Grinstead Lane, which has a significant on local residents living in the area. In addition, whilst there has not been any direct internal property flooding there has been garden flooding, which again causes disruption to local residents.

8.2.2 Other measures required

Mitigation measures for the Lancing Brooks are considered in the water level management plan in Section 8.5. Other mitigation measures relevant to Grinstead Lane, Manor Way, Manor Close & Old Shoreham Road, include:

- Adur District Council to further consider the impact of the golf course water level management plan not being fully implemented as set out by the planning application conditions;
- Southern Water to implement their Infiltration Reduction Plan (IRP) to reduce infiltration into the sewer network, and ensure measures are fully communicated with stakeholders and local residents;
- Southern Water to activate the Emergency Action Plan (EAP) when required;
- Adur Floodwatch Group and Adur District Council to work with local residents and communities to prepare individual and community flood plans, and;
- Adur District Council to discourage the use of new soakaway drainage in the affected area unless site specific investigations demonstrate there is capacity with respect to groundwater levels. In certain areas soakaways will not function during periods of high groundwater levels and may also allow upward emergence of groundwater from the Chalk.

8.3 Barfield Park & Monks Avenue

Within Barfield Park and Monks Avenue there are no significant capital works related to highway or surface water drainage proposed within the SWMP. This is because the majority of flood risk is related to the conveyance capacity of the ditches and emergence of groundwater. For the most part groundwater emergence causes some waterlogging of gardens on Barfield Park, and no mitigation is proposed to these properties. There are one or two properties that experience flooding inside their properties due to groundwater emergence, some of which occurs through soakaways which act as a conduit for groundwater to flow towards the surface. For these properties it is recommended that roof and yard drainage is positively connected to the nearest drainage system (highway drainage or ditches), rather than to soakaways, and that soakaways are infilled to reduce the risk of groundwater emergence.

In addition there is evidence that the highway drainage at the junction of Monks Avenue and Hadlow Way results in garden flooding to one property. WSCC should investigate this further and clear any blocked gullies and/or install a new outlet into the ditch network.

8.4 West Beach Estate

8.4.1 Conceptual options

8.4.1.1 Quick win measures

On the West Beach Estate there are several quick win measures which would alleviate flooding to the roads.

- First, enhanced maintenance of existing road gullies is required. From the site visit in October 2014 10% were completely cracked/broken and 10-20% were choked (full of sediment). These should be prioritised for repair where the gullies are cracked/broken, and jetting where the gullies are full of sediment.

- Secondly, jetting of the pipe network and any soakaways which are heavily silted should be undertaken.
- Thirdly, the outfalls from the piped drainage on Boundary Road and Prince Avenue should be uncovered and cleared, to enable discharge from the network, with permission from the land owner[42]. Uncovering/creation of an outfall at the northern end of roads will help to alleviate flooding. Without any outfalls the piped drainage will become surcharged with surface runoff (and any direct infiltration due to high groundwater levels), and contribute to flooding on the highway. The outfalls will act to relieve surcharging in the piped drainage, and therefore reduce the risk of flooding.
- Fourthly, at the end of each outfall on Bristol Avenue, George V Avenue, Boundary Road and Prince Avenue it is recommended that a shallow depression be constructed to store (and infiltrate, where possible) flows from the Estate, with permission from the land owner. It is not considered necessary to connect the outfalls to the Lancing Brooks directly, via a more extensive ditch network, because:
    - when water levels in the main channel through the southern floodplain are high (during winter months and/or high tides) it would inhibit flows discharging into the main channel from the West Beach Estate[43], and;
    - the costs of a more extensive ditch network are more significant than constructing shallow depressions at the end of each outfall, for little, if any, additional benefit.

8.4.1.2 The Broadway

Figure 8-2 Photo of soakaway near the shops on The Broadway

In addition to the quick win measures, additional capital works may be required to alleviate flooding on The Broadway, which is the most persistent flooding problem affecting the Estate. Evidence from surveys undertaken by WSCC in February 2015 demonstrates that the two existing soakaways on The Broadway can become full of water following heavy rainfall, during winter months when groundwater levels are high, and/or during high tides (which can push groundwater towards the surface). As gullies on The Broadway are connected to the two existing soakaways there is no capacity for water to drain away from the gullies during rainfall events, which will therefore contribute towards flooding on The Broadway. To alleviate this flooding, a proposed option has been considered as part of the SWMP, which is described below. Conceptual drawings of these options are provided in Appendix H. Options which have been discounted are shown in Table 8-1.

The proposed option seeks to reduce flooding on The Broadway through gravity drainage. The three gullies to the north of the shops currently drain to a soakaway on the corner of the crossroads. Under this option these gullies would be connected to a new piped network (c.150mm) which would flow west and connect up

[42] The evidence indicates that piped drainage on West Avenue flows south towards WestWay and then into Prince Avenue. Therefore, it is not considered necessary to locate and create/uncover an outfall on West Avenue.

[43] Based on ground levels at the end of Bristol Avenue (1.62m AOD based on LiDAR) and the data from the cross-section survey (bed level -0.37m AOD, water level 0.66m AOD) any pipe or open channel connection to the main Brooks would be submerged during winter months, thereby rendering any outfall ineffective.

the existing manhole at the southern end of Bristol Avenue. Due to the shallow pipe depth on Bristol Avenue the new piped network would be very shallow, with a relatively flat gradient. The viability of this option would depend on further topographic survey to prove the ground levels and invert levels of the pipe drainage on Bristol Avenue. Due to the shallow gradient or the pipe there would be risks of blockages and/or siltation, which would need to be considered during design.

Further south on The Broadway there is a proposal to install slot drains on the publicly adopted highway to the south of the shops. The slot drains would intercept any localised runoff and any minor exceedance from the A259. The slot drains would be connected via a pipe network (150mm) to the 300mm drainage system on the A259. Further topographical work is required to establish the exact location of the slot drains to enable the system to drain back to the A259 (at the soffit level of the 300mm pipe) via gravity.

Finally, a water level sensor and conductivity meter should be installed in the soakaways on The Broadway to continuously monitor water levels and salinity. This will help to provide further evidence of how water levels are affected by groundwater in the superficial layer (gravels), and the amount of saline influence within the soakaways. It is likely that groundwater levels in the superficial layer remain high most of the year, but monitoring of the soakaways would help to confirm this.

Table 8-1 Discounted options on The Broadway

Description	Reasons for discounting
Provide an overflow piped system from the soakaway near the shops on The Broadway, which flowed north to the cross-roads and then west to connect up to the Bristol Avenue pipe network. The piped network would also include an overflow from the soakaway on the crossroads of The Broadway / WestWay	There is insufficient gradient and pipe depth to create a piped network along this length.
Provision of additional gullies on The Broadway	This will be ineffective at reducing flooding during periods of high groundwater (in winter months), where there is limited capacity for water to drain away
Upsize the 300mm network on the A259	This is not contributing significant flooding to The Broadway, and would not be effective in reducing flooding

8.4.2 Costs of proposed measures

No cost estimate has been prepared for the quick win measures. For the proposed measures on The Broadway a provisional cost estimate suggests the construction costs would be in the region of £70,000, with an appropriate allowance for risk (30%). A breakdown of this cost estimate is provided in Appendix H.

8.4.3 Implementation of proposed measures

On the West Beach Estate the proposed measures within the publicly adopted highway should be added to WSCC’s highways prioritisation log, and funded by WSCC. All proposed measures within the private parts of the Estate should be taken forward the owners of the estate in collaboration with the local residents. In addition the land owners of the fields to the north of West Beach Estate must be engaged to secure agreement to the clearance of the outfalls from the Estate, prior to any works being undertaken.

8.5 Water Level Management Plan for Lancing Brooks

This water level management plan (WLMP) sets out the short-term remedial measures, ongoing maintenance and monitoring which is required to improve the conveyance of the Lancing Brooks. It is based on the findings of the cross-section survey (Appendix F), the hydraulic modelling (Section 6), and observations from site visits. There are necessarily a number of assumptions built into the WLMP, and therefore ongoing monitoring will be required to verify the WLMP, and adjust where necessary. In particular, it is not possible to quantify the rate of sediment buildup within the Lancing Brooks, something which can only be done through establishing a monitoring regime. The monitoring frequency may change as further knowledge is gained about system performance, so annual monitoring could become less frequent.

8.5.1 Short-term remedial measures

The cross-section survey and hydraulic modelling undertaken for this SWMP has identified several constrictions to conveyance of the Lancing Brooks. This is mostly related to culverts and structures under roads throughout the study area. The baseline model scenario (see Section 6.4.2) identified the following key constrictions to flow (in order of impact):

- Old Salts Farm Road bridge, due to significant siltation at the structure, and a pipe crossing under the road bridge;
- Mash Barn Lane bridge, due to significant siltation at the structure, and a pipe crossing under the road bridge;
- the Manor Close culvert has a 450mm inlet structure, which limits the upstream hydraulic capacity;
- the twin 600mm culverts under Monks Avenue and North Farm Road, which cause some flow constriction and increase upstream water levels. Despite this, there is no evidence that the hydraulic capacity of the structure causes out of bank flows;
- the railway culvert to the south of North Farm Road, although this does not cause significant constriction to flow, and;
- the New Salts Farm Road Bridge, which is predicted to have some impact on water levels but these are less significant that the effects of structures further upstream.

As the twin 600mm culverts under Monks Avenue and North Farm Road, and the railway culvert to the south of North Farm Road are not considered to have hydraulic capacity constraints which contribute to a risk of out of bank flows, the WLMP does not consider any short-term remedial measures at these locations.

The hydraulic modelling (Scenario 1 and 2, as outlined in Section 6) has considered the impact of de-silting and upsizing the Old Salts Farm Road bridge, the Mash Barn Lane bridge and the Manor Close culvert. Based on the modelling, and consideration of capital and maintenance costs of different approaches, it is recommended that the following measures are implemented at the Mash Barn Lane and Old Salts Farm Road bridges:

- de-silting, of up to 0.5m, to provide a consistent bed level with upstream and downstream cross-sections,
- development of a hard bed to reduce roughness, increase flow velocity and hence the reduce the potential for silt deposition;
- structural re-inforcement of the bridges, where necessary, once the bed level is lowered;
- construction of a small access track from the roads to the structures, to facilitate future maintenance (including local de-silting), and;
- potential design and construction of silt ponds immediately upstream of the structures to capture sediment, which would be easier to clear than underneath the structure (NB: this is only worthwhile if it can be demonstrated there is a disproportionate buildup of sediment at these structures because of a drop in velocity, compared to other parts of the Brooks and that silt would be deposited preferentially in the silt ponds as opposed to the “main channel”)

Furthermore, it is recommended that the Manor Close culvert inlet is upsized to a 600mm, from a 450mm. The outlet from this 80m long culvert is significantly larger than the 450mm opening, and it is not known how the structure of the culvert changes along its length. At this stage it has been assumed that the 450mm section is for 40m, for the purposes of a provisional cost estimate.

8.5.2 Maintenance of Lancing Brooks

Defining an optimal maintenance regime for the Lancing Brooks is very difficult, in particular because the rate of sediment buildup and the source sediment are unknown. Primarily, it is considered that the sources of sediment to the Lancing Brooks will be due to runoff from hard standing areas (roads in residential areas and the A27), erosion of banks, and decomposition of vegetation following autumn dieback. The area of hard standing area draining to the Lancing Brooks is relatively small, and therefore the sediment contribution from this source is expected to be low. It is more likely that bank erosion and decomposition of vegetation are contributing more significantly to the buildup of sediment and silt.

The rate of sediment buildup is particularly difficult to establish. However, there is some evidence available from the clearance work undertaken by Adur and Worthing District Councils in 2010 (southern floodplain) and 2013 (ditches in residential areas), the clearance work undertaken by the golf course landowner in January 2015, and the cross-section survey undertaken in December 2014 to January 2015. The findings from the cross-section survey suggest a relatively good gradient in the Lancing Brooks from the upper parts of the catchment to the outfall, as described in Section 6.4.2. The hydraulic modelling also suggests that the main channel bed levels of the Lancing Brooks are not currently causing significant changes in upstream water levels, or headloss in the system. Indeed, even with a 150mm increase in bed levels throughout the ditches in the residential areas the net impact on water levels was minimal (up 100mm in the Barfield Park ditches). Further modelling is planned for the final report, to identify the impact of a further increase in bed levels. This evidence suggests that:

- the clearance work undertaken in the recent past remains effective, and;
- some buildup of silt will not have a significant impact on water levels in the ditches, although it remains unclear what is the “tolerance” of the channel flow to the buildup of silt.

This evidence is important because de-silting and disposal of silt from the ditches is a costly activity. Therefore it should be undertaken only when (and where) it is required to reduce flood risk to properties and infrastructures, particularly within the residential areas where the cost for de-silting is very high and the access if extremely difficult.

8.5.2.1 Annual vegetation clearance

As a balanced approach, it is recommended that an annual vegetation clearance is undertaken throughout the Lancing Brooks. Given that vegetation is likely to be a key contributor to silt buildup (as it reduces flow velocity and encourages the deposition of suspended silt load), this will in turn reduce the need for de-silting.

In addition, to reduce silt buildup in the ditches, it is recommended that silt traps are installed on the highway drainage to capture sediment from the hard standing areas before runoff discharges into the ditches. This should be achieved by replacing manhole chambers with catchpits at key locations within the highway drainage that can be maintained as necessary. Maintenance of catchpits is more straightforward than maintenance of the ditches in the residential areas. Three locations have been provisionally identified:

- manhole on Grinstead Lane opposite the Harvester Pub, which is immediately upstream of the discharge of the highway drainage system into the Barfield Park ditches;
- manhole on the pavement outside no.5-7 Grinstead Lane, before discharge into the 300mm pipe which flows through No.4 Old Shoreham Road, and;
- manhole on Manor Close, which takes flows from the A27 and overflows from the Manor Road system.

8.5.2.2 Monitoring and de-silting

On an annual basis (at least) monitoring of silt levels at key locations in the Lancing Brooks should be undertaken to build up a comprehensive picture of the rate of silt buildup across the catchment. The monitoring could be plotted against the cross-section survey undertaken in December 2014 to January 2015, as a means to visualise the silt buildup since the cross-section survey. It is recommended that monitoring is undertaken at the upstream face of structures, where there is readily available access, and in areas most sensitive to silt buildup[44]. This monitoring can be undertaken using simple and readily available equipment (e.g. staff) to measure silt levels. The following structures are considered appropriate locations to measure silt buildup:

- at the end of the doctor's ditch, upstream of the Manor Close culvert;
- upstream of Mash Barn Lane bridge;
- Inlet to the twin 900mm culvert under Shoreham Airport;
- Inlet to the twin 600mm culverts on Monks Avenue and North Farm Road;
- upstream of Old Salts Farm Road bridge;
- at the farm crossing to the north of The Broadway Park Homes;
- upstream of New Salts Farm Road bridge, and;
- upstream of the culvert under the Dogs Home access road (which has not been surveyed as part of the cross-section survey).

It is difficult to ascertain an acceptable level of silt buildup before the hydraulic performance of the Lancing Brooks is compromised, which would increase flood risk to properties and infrastructure. However hydraulic modelling undertaken to support this SWMP has represented silt buildup of 150mm and 250mm. Results suggest a significant increase in water levels with silt buildup of 250mm, and less so with 150mm silt buildup. Therefore, silt buildup between 150-250mm within the channels (in residential areas) is likely to start to affect flood risk.

Given that the majority of structures in the residential area are relatively small (e.g. 450mm on Manor Close, twin 600mm on Monks Avenue) it is logical siltation of more than 150mm is likely to start significantly reducing the conveyance capacity of these structures, causing more backing up of flow, which will increase flood risk and result in more deposition of silt (as velocities decrease). In addition, silt removal within the residential areas will become more difficult as the depths of silt increases, as evidenced during the ditch clearance on Manor Way in 2013. It is therefore recommended that once silt buildup at the structures outlined above becomes greater than 150mm from the bed level identified during the cross-section survey, de-silting is undertaken along the specific reaches affected. Given it has been two years since the last clearance in the residential areas, it is considered that that de-silting may need to take place once every five years. De-silting may not be required across the entire catchment every five years, as some locations may be more susceptible to silt buildup. This can only be confirmed through the annual monitoring. It should be noted that the frequency of ongoing monitoring should also be dictated by the rate of silt buildup. For example, some locations may warrant a more frequent monitoring interval, others less frequent. This frequency may be refined as the evidence base is gathered.

8.5.3 Costs of proposed measures

A provisional construction cost estimate for the short-term remedial measures is £120,000, allowing for a 60% risk contingency at this stage. This cost estimate includes an allowance for the silt ponds upstream of Mash Barn Lane and Old Salts Farm Road bridges, which may not be required. The provisional cost estimates are outlined in Table 8-2. A further breakdown of the costs, by bills of quantities, is provided in Appendix H.

Table 8-2 Provisional cost estimate for short-term remedial works

Item	Provisional Cost Estimate
Manor Close culvert reconstruction	£11,500
Re-design of Mash Barn Lane and Old Salts Farm Road bridges	£36,000

[44] Especially where the cross-sectional area of the structure is less than the upstream open channel

Item	Provisional Cost Estimate
Construction of 2 x silt ponds (if required)	£26,500
Risk Contingency @ 60%	£44,500
Total	**£118,500**

The provisional costs of annual vegetation clearance has been estimated from SPONS[45], with a 2x multiplier added for the ditches in residential areas to account for access difficulties. The provisional cost estimate on an annual basis is illustrated in Table 8-3, based on lengths for different parts of the Lancing Brooks network.

Table 8-3 Estimated annual vegetation clearance costs

Location	Estimated length of ditch (m)	Unit cost £/m	Total (inc. 60% risk contingency[46])
Residential ditches	1000	£1.26	£2,720
Southern floodplain from railway culvert to outfall ditches	2700	£0.63	£4,625[47]
Golf course ditches	5000	£0.63	£8,570
Airport ditches (excluding culverts, which would incur significant additional expense)	1500	£0.63	£2,570
Total	**10,200**	**-**	**£18,485**

A provisional cost estimate for the de-silting is provided in Table 8-4 and includes a 2x multiplier for de-silting in the residential areas. The cost estimate assumes all the ditches will require clearance of 150mm of silt. Further detailed are provided in Appendix H.

Table 8-4 Estimated de-silting costs (per occasion)

Location	Estimated length of ditch (m)	Unit cost £/m[48]	Total (inc. 60% risk contingency[49])
Residential ditches	1000	£21.63	£33,300
Southern floodplain from railway culvert to outfall ditches	2700	£19.03	£75,600
Golf course ditches	5000	£19.03	£140,000

45 SPONS Civil Engineering and Highway Works Price Book 2013, edited by Davis Langdon, an AECOM Company. 27th Edition

46 Includes some mobilisation and de-mobilisation costs

47 Due to higher amounts of reed growth in this section the costs of initial vegetation clearance could be higher than forecast using standard cost estimation methods

48 Includes for disposal of excavated material, which is fixed irrespective of whether the de-silting is from residential areas or other parts of the catchment

49 Includes some mobilisation and de-mobilisation costs

Airport ditches (excluding culverts, which would incur significant additional expense)	1500	£19.03	£42,000
Total	**10,200**	**-**	**£290,900**

8.5.4 Implementation of the WLMP

Different components of the WLMP will be funded by various organisations. With respect to the short-term remedial measures it is recommended that these are funded by WSCC, or the landowners of the structures which need to be upgraded or maintained. It may be possible to attract Flood and Coastal Erosion Risk Management Grant in Aid (FCRM GiA)[50], where it can be demonstrated that the proposed works will reduce flood risk to properties and achieve pre-defined outcomes needed to attract FCRM GiA funding.

With respect to ongoing maintenance (vegetation clearance and de-silting), under the Land Drainage Act (1991) riparian owners are responsible for ensuring the free passage of flow for all watercourses which are within their ownership. Outside of the residential areas in Lancing it is more straightforward for landowners to undertake vegetation and/or de-silting works because access to the ditch is easier, and the land either side of the ditch is often owned by the same landowner.

However, in the residential areas the ditches will have multiple riparian owners, and access to the ditches is extremely difficult. Furthermore, unless clearance work is coordinated across the entire length of the ditches the works will be relatively ineffective. Co-ordinating actions will also reduce the total costs because of efficiencies such as contractor mobilisation/de-mobilisation. It is therefore recommended that local residents who live in the Barfield Park and Manor Way areas, who will benefit from coordinated actions, should work together to fund the vegetation and de-silting. Lancing Parish Council, the Adur Floodwatch Group and/or WSCC Principal Community Officers could play a key role in helping to co-ordinate funding and the de-silting works.

8.6 Next steps

It is recommended that within three months of publication of this report that WSCC produce an implementation plan. WSCC should work with the responsible bodies, landowners and other relevant affected parties to develop this plan. The implementation plan will set out who will undertake the recommended actions from the SWMP, the timetable for doing so, and the possible funding mechanism.

50 https://www.gov.uk/government/collections/flood-and-coastal-defence-funding-for-risk-management-authorities

Appendices

Appendix A Roles and responsibilities

1. Roles and Responsibilities for LFRM

Appendix B Catchment boundary

1. Lancing - Catchment Boundary
2. Lancing - Flow Pathway Analysis

Appendix C Site Visit Notes

1. Site Visit Notes Oct 2014 (Zone A)
2. Site Visit Notes Oct 2014 (Zone B)
3. Site Visit Notes Oct 2014 (Zone D)
4. Site Visit Notes Oct 2014 (Zone F)

Appendix D Drainage Plans

1. Manor Way_OSR Drainage Plan
2. Northern Floodplain Drainage Plan
3. Southern Area Drainage Plan

4a. West Beach Drainage Plan

4b. Lancing_ZoneD_Drainage Plan_v3

Appendix E Geology and Hydrogeology

1. Geology and Hydrogeology Technical Note
2. Figure 3-2 - Solid Geology
3. Figure 3-3 - Superficial Geology
4. Figure 3-4 - Groundwater Flow & Emergence

Appendix F Cross-section survey

1. Cross-Section Survey.zip

Appendix G Hydraulic modelling results

1. Barfield Park (Scenarios).xls
2. Manor Way (scenarios).xls

Appendix H Conceptual drawings and costs

1. Manor Road (Option 1).pdf
2. Manor Road (Option 2).pdf
3. Manor Road construction cost estimates.xls
4. West Beach Estate (Option).pdf
5. West Beach Estate construction cost estimates.xls
6. WLMP Cost Estimates.xls

Appendix I Environmental Constraints

1. Environ. Constraints Plan

2. Environ. baseline and constraints