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

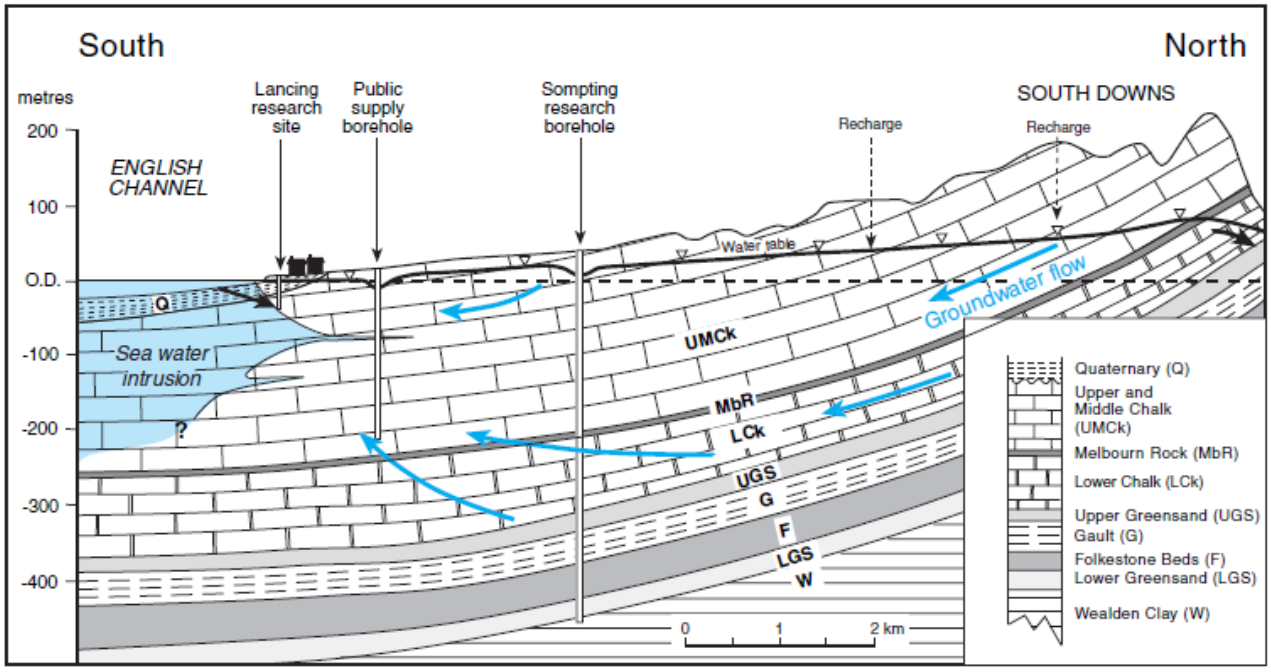


Figure 3-4 Generalised regional geological section. Note that the Chalk nomenclature used on the cross section has now been superceded. (From: "The Chalk Aquifer of the South Downs". Hydrogeological Report Series of the British Geological Survey. British Geological Survey 1999

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.

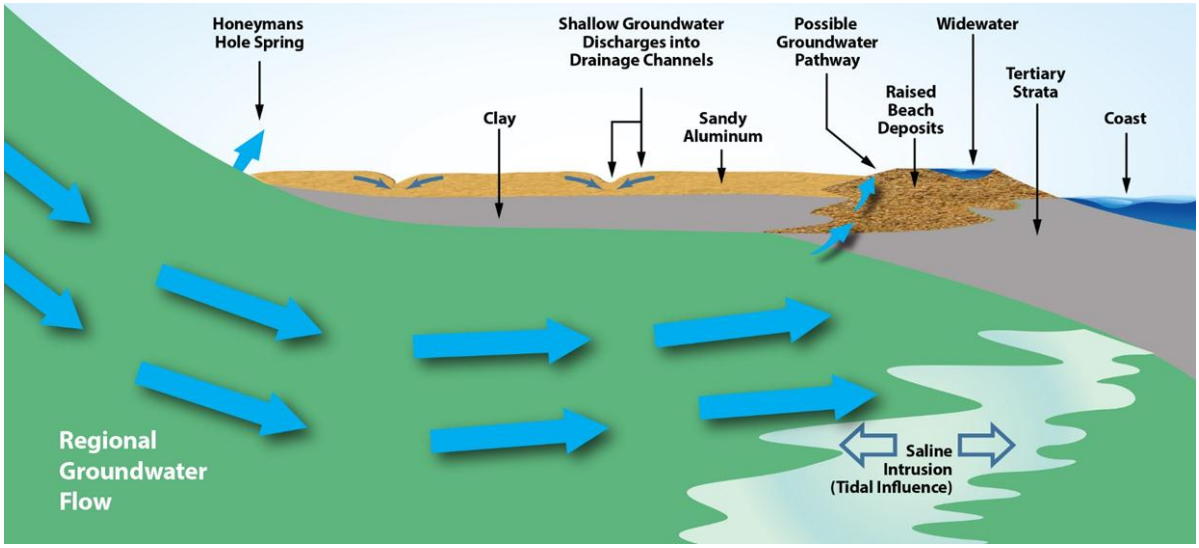


Figure 3-5 Conceptual Model- Sectional view showing interaction between regional flow in Chalk, shallow groundwater and groundwater emergence

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 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.

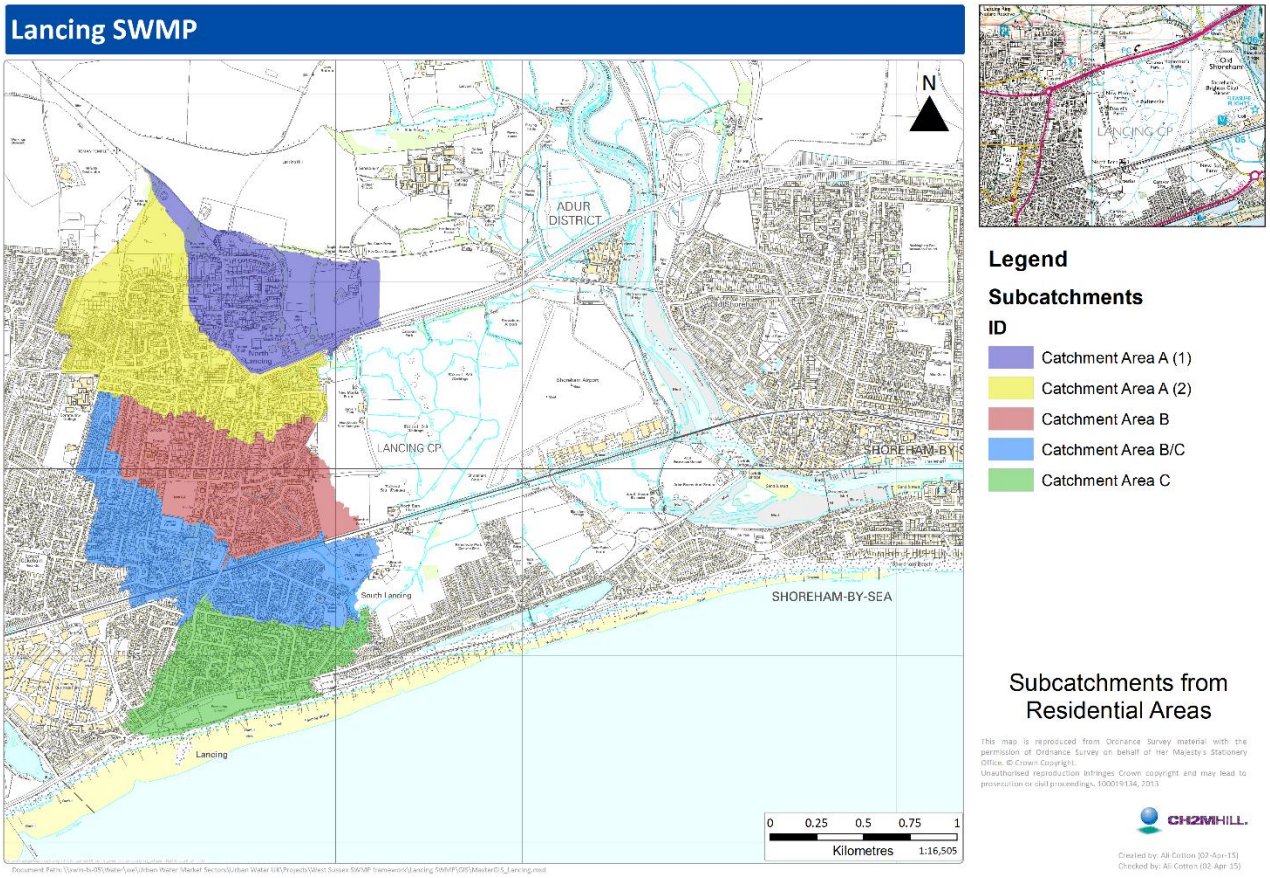


Figure 5-1 Subcatchments from residential areas

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

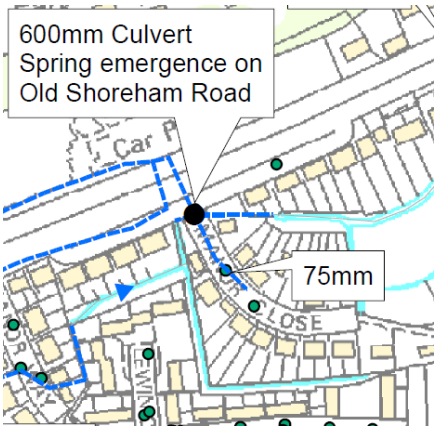


Figure 5-2 Drainage layout on Manor Close

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.

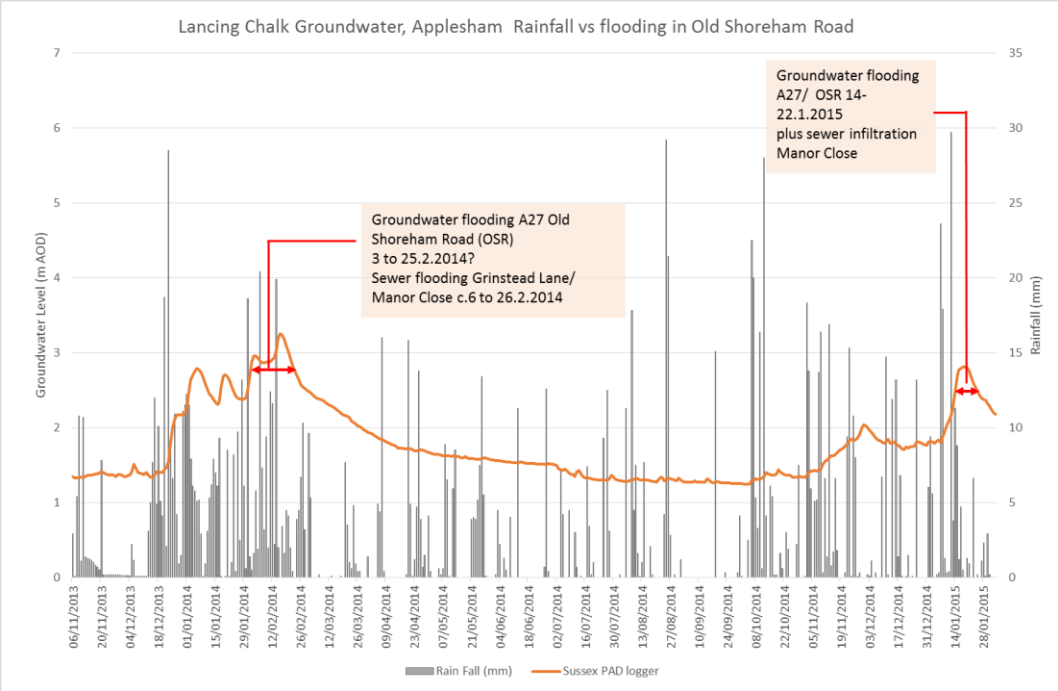


Figure 5-3 Groundwater Levels and Rainfall vs flooding recorded in Old Shoreham Road/ Manor Way area

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

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

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Notes:

1. All dimensions are in millimetres, and all levels are in metres above Ordnance Datum Newlyn, unless stated otherwise.
2. No hydraulic design undertaken on existing arrangements for proposed works.
3. All drainage work shall be in accordance with The Specification for Highways Works 1998 and all subsequent amendments.
4. New manhole and gully covers to be 150mm deep Grade D400 to BS EN 124:1994.
5. All new manholes to be constructed in accordance with WSCC drg. S278/28/13, unless otherwise stated.
6. The abbreviation used for nominal pipe diamater herein is DN.
7. Drawing is for information only, not for construction.
8. Existing services omitted from drawing.
9. Full extents of existing services necessary for outline design.
10. Presence of existing services in verge may restrict feasiblility of proposals.
11. All proposed pipework to be laid with a full concrete surround to prevent ingress of groundwater.

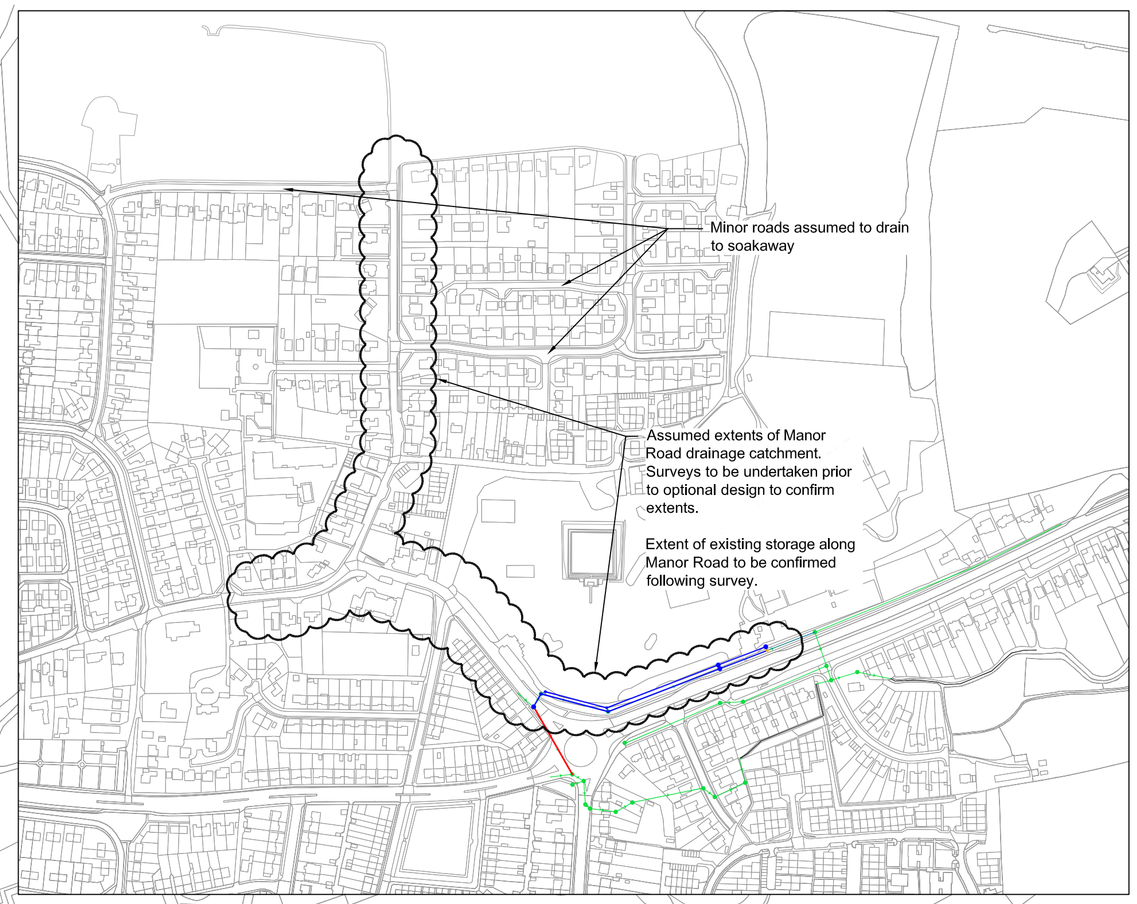
Legend:

Proposed services:

- Surface water sewer
- MH Surface water chamber
- MH Hydrobrake chamber

Existing services:

- Surface water sewer
- Watercourse
- Existing manhole
- Surface water sewer to be abandoned



Plan2
Not to Scale

Plan1
Not to Scale

FOR REVIEW

Rev	By	Chkd	Apprvd	Date	Description
A	MAA	AC		20/03/15	First issue

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Project

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Manor Road Roundabout

Drawing

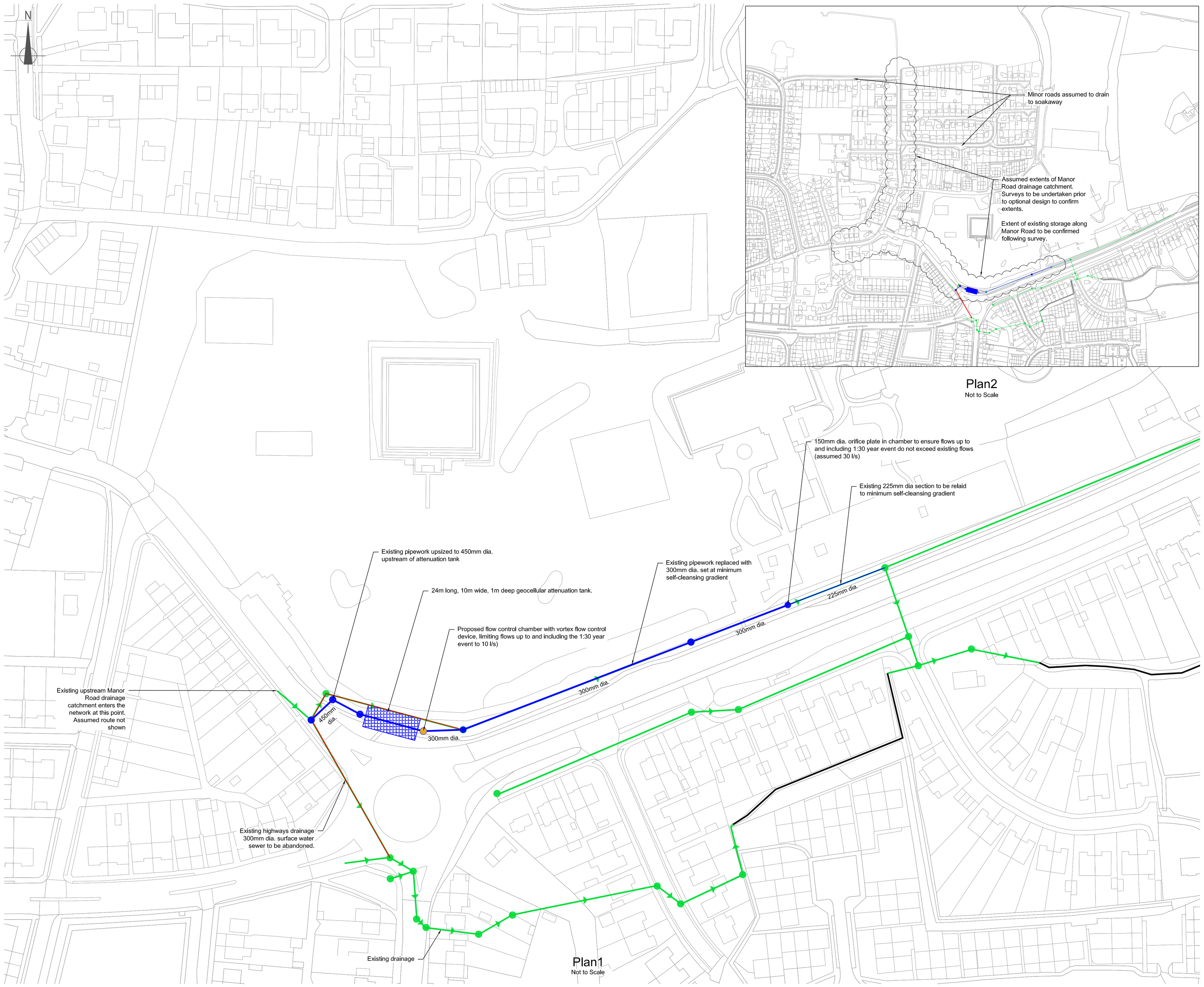
Conceptual Drainage Layout
Option 1

Drawn by: MAA	Date: 20/03/2015
Checked by: Ac	Date: 20/03/2015
Approved by: -	Date: -

Drawing No.	Revision
488929-05-501-C	A

Drawing Scale: NTS

Drawing file path & name : W:\wel\Urban Water Market Sectors\Urban Water UK\Projects\West Sussex SWMP framework\Lancing SWMP\Manor Roundabout Capacity\CAD\ 488929-05-501 - Option 1.dwg



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Legend:

Proposed services:

- Surface water sewer
- MH Surface water chamber
- MH Hydrobrake chamber
- Attenuation tank

Existing services:

- Surface water sewer
- Watercourse
- Existing manhole
- Surface water sewer to be abandoned

FOR REVIEW

Rev	By	Chkd	Apprvd	Date	Description
A	MAA	AC		20/03/15	First issue

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Drawing

Conceptual Drainage Layout
Option 2

Drawn by: MAA	Date: 20/03/2015
Checked by: Ac	Date: 20/03/2015
Approved by: -	Date: -
Drawing No. 488929-05-501-C	Revision A
Drawing Scale: NTS	

Drawing file path & name : W:\wel\Urban Water Market Sectors\Urban Water UK\Projects\West Sussex SWMP Framework\Lancing SWMP\Manor Roundabout Capacity\CAD\ 488929-05-501 - Option 2.dwg