NOTE TO FILE

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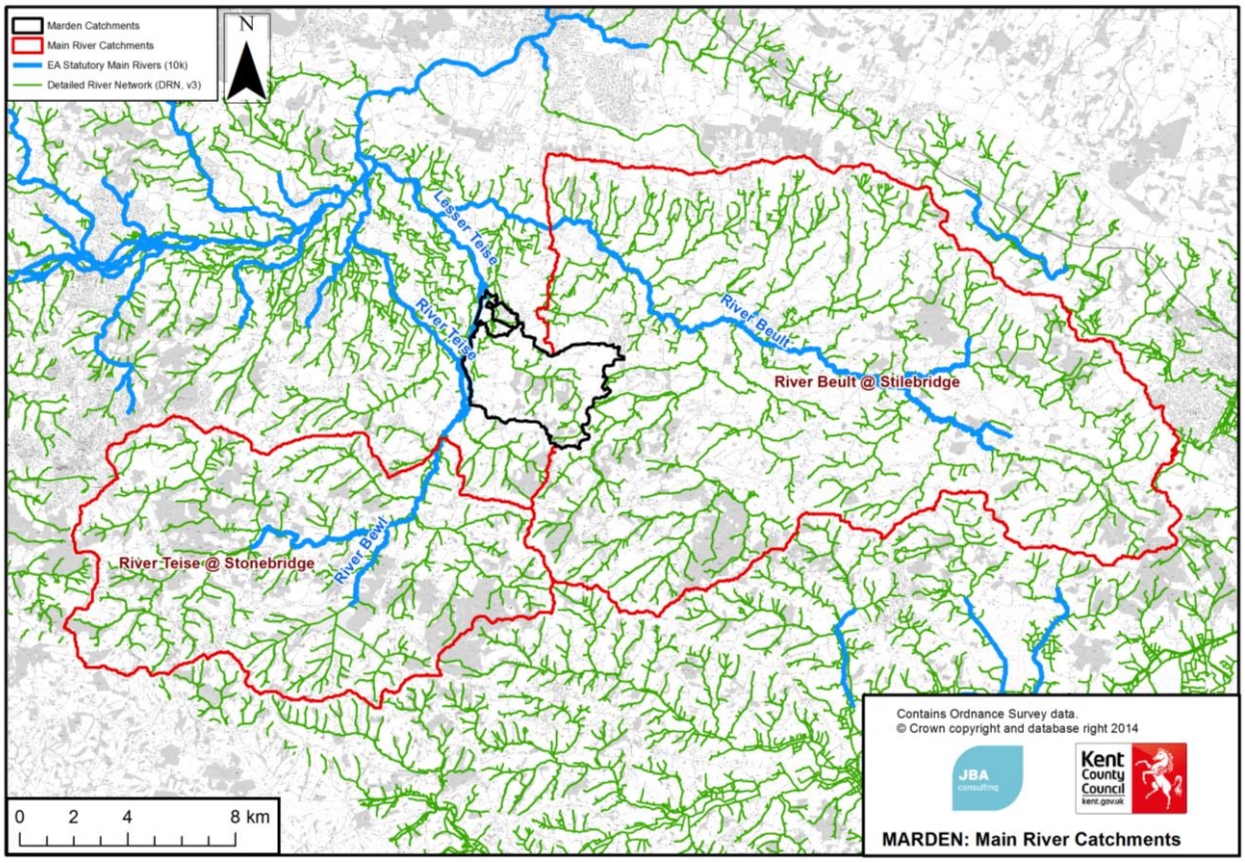
1 Introduction

The purpose of this report is to better understand the rainfall events that lead to flooding within Marden in order to determine any potential interactions between adjacent Main River levels (River Beult and River Teise) and the surface water drainage network within Marden.

The village of Marden is located near the topographic boundary between the Lesser Teise and River Beult catchments. The Stilebridge gauging station is located nearly 4km to the north of Marden and the Stonebridge gauging station is located approximately 5km to the south of Marden. Figure 1-1 below illustrates the Marden drain catchments in relation to the gauged catchments at Stilebridge and Stonebridge GS.

Figure 1-1: Main River catchments



The majority of the historical flood information available within Marden, Headcorn and Staplehurst is qualitative data i.e. reported flood incidents, highways records, flood hotspots, sources of flooding and occasionally observed flood extents. There are no flow or level gauges within the Marden Drain catchments and therefore Tipping Bucket Raingauges (TBRs) will form the basis of the quantitative assessment of event rarity within Marden. Marden is located within the Lesser Teise catchment which is a tributary of the River Beult. Upstream of Marden (NGR: TQ 72498 42766), the River Teise splits into the lower section of the River Teise and the Lesser Teise catchment.

Surface water flooding events are often as a result of convective summer storms i.e. short intense rainfall events, and therefore 'higher peaked' rainfall profiles would usually be expected if a convective summer event is the main cause of the surface water flooding. These convective summer events also tend to be more critical in urbanised areas.

2 Catchment characteristics

The catchments within Marden are underlain predominantly by mudstone deposits (Weald Clay formation) and therefore the catchments are quite impermeable and consequently a more flashy response to rainfall is expected. There are a few outcrops of limestone (Weald Clay formation) to the east of Marden, although these deposits are fairly limited in extent. This is supported by fairly low BFIHOST values in the range of 0.281 to 0.302; the average SPRHOST value is 47%. These geological formations are overlain by superficial deposits of Alluvium and River Terrace deposits which mainly consist of sands, gravel, clays and silts. The superficial deposits are mostly confined to the centre of Marden and along some of the river reaches. The River Teise catchment covers approximately 180km^2 to Laddingford and it drains an essentially rural catchment that is underlain with Wealden Group sandstone, siltstone and mudstones overlain by Alluvium and River Terrace deposits along river reaches.

The soils within the Marden catchment predominantly consist of slowly permeable wet clayey soils with impeded drainage. There are freely draining loamy soils to the east of Marden (associated with the Limestone outcrop) but these are fairly limited in extent. Given that Marden is slightly urbanised and the underlying soils and geology and are fairly impermeable, it is likely that Marden is more susceptible to short intense rainfall events. There is a fairly shallow gradient across the catchment with the highest elevation point at approximately 97mAOD (Foxridge Wood) and the lowest elevation point at approximately 15mAOD at the downstream model extent.

3 Data availability

There is data available for seven Tipping-Bucket Raingauges (TBRs) in and around Marden, Staplehurst and Headcorn: Staplehurst, Horsmonden STW, Headcorn, Sutton Valance, Charing PS, Bethersden STW and Hollingbourne (Table 3-1 and Figure 3-2). A brief analysis of rainfall data coverage in the catchment was undertaken using Thiessen polygons and the most representative TBRs for the catchment within Marden are Horsmonden STW and Staplehurst TBR.

Table 3-1: Tipping-bucket raingauge information

Gauge	Altitude (m)	Aspect
Staplehurst	19.5	NE
Horsmonden STW	34.5	ENE
Headcorn	20.5	SSE

Staplehurst

The Staplehurst TBR has a slightly shorter record than Horsmonden and rainfall data is only available up until 19th January 2014. The gauge appears to be fairly reliable and compares well with Horsmonden. There are no periods of data flagged as missing but between March 2000 and March 2001 the gauge is recording zero rainfall. There is one potential outlier in May 2003 where 63mm of rain was recorded in 2 hours which was not observed at the other gauges. Staplehurst has quite low annual totals when compared against the other gauges.

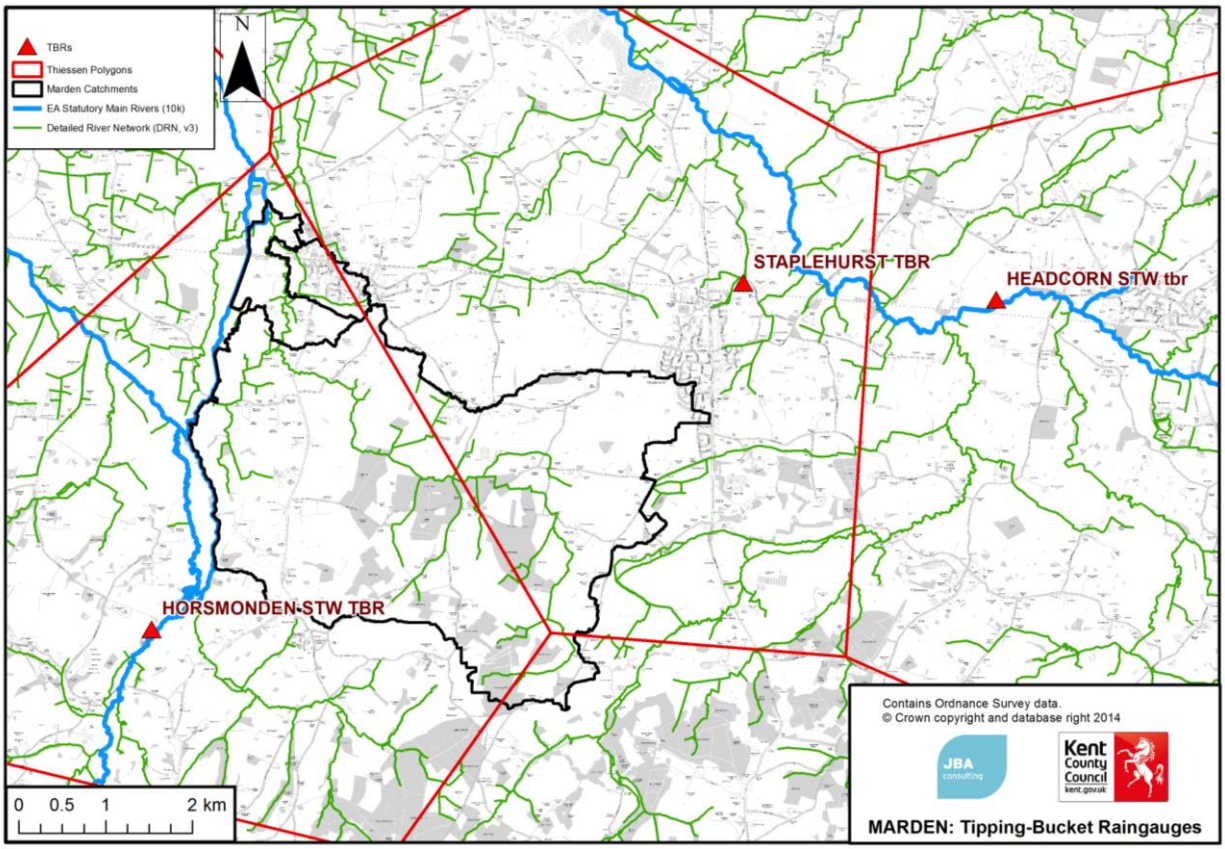
Horsmonden

Overall the Horsmonden TBR looks reasonably reliable. There is a period of missing data from November 1996 until July 1997 with another brief gap in August 1997. Between November 2001 and March 2002 the gauge is recording zero rainfall but this has not been flagged as missing. There are no data points associated with unduly high rainfall intensities. The yearly totals from Horsmonden are quite high but appear to match well with a nearby rainfall storage gauge at Pembury. In the earlier years Horsmonden observed 5 to 10% less rainfall than Pembury but in later years (2003 onwards) Horsmonden has been recording slightly more rainfall than Pembury; this may be a result of a recalibration or re-siting of the gauge. The gauge also appears to significantly under record during the October 2000 event.

Headcorn

Overall, the Headcorn TBR appears to be good. There are no prolonged periods of missing data. However, the gauge was decommissioned in 2011 and therefore did not record the most recent winter events. As the other two TBRs were either not recording (Staplehurst) or under-recording (Horsmonden) for the Autumn 2000 events, the Headcorn raingauge has been used to determine the rarity of this event.

Figure 3-1: TBR coverage in Marden



4 Historical flood events

This section looks at the flood events in Marden as identified during the flood history search.

There are limited reports of flooding within Marden to base this assessment on. However, all of the observed flood events are fairly recent and the source of flooding has also been reported (see Table 4-1).

Table 4-1: Reported flood history within Marden

Date	Source
2000 (Autumn)	Fluvial
February 2009	Fluvial and Surface Water
March 2012	Surface Water
December/January 2013-2014	Foul Sewer
February 2014	Sewer

Based on the reported flood events within Marden, it appears as though all of the flood events occur during the winter season (October – March); even the surface water/sewer flood events appear to be during the winter months. Given that the catchments within Marden are generally impermeable and

slightly urbanised, it would be expected that Marden would be more susceptible to short intense rainfall events which are typically observed during the summer months. Therefore this suggests that Marden may be more susceptible to flooding based on elevated Main River levels in the River Teise and Lesser Teise which would prevent excess surface water from being cleared from the surface water drainage network i.e. a rise in the water table and nearby Main River levels during periods of higher than normal rainfall may mean that land drainage networks, such as storm sewers, will be unable to discharge excess surface water properly if the water table is higher than normal. Therefore flooding within Marden may be as a result of the inability to discharge excess surface water during Main River flood events.

4.1 Rainfall analysis

This section summarises analysis into the return period and duration of rainfall which lead to flooding in Marden.

In order to estimate the order of magnitude of the main flood events within Marden, the same TBR should be used across all of the reported events to enable consistency between return period estimates. Therefore as the rainfall data recorded at the Horsmonden gauge is available up until February 2014, the Horsmonden TBR will be used to assess event rarity for the reported events (Table 4-2). In addition, rainfall totals at Horsmonden correlate well with the local rainfall storage raingauge at Pembury. However, there is a period of missing data during 2000 which means that the October 2000 rainfall event was not recorded at Horsmonden. Therefore, the TBR at Headcorn was used to inform event rarity of the October 2000 event.

Table 4-2: Rainfall analysis

Date	Rainfall Depth (mm)	Duration (hours)	Rainfall profile	Return Period (years)	Raingauge
12/10/2000	73.2	16.25	Winter	35	Headcorn
10/02/2009	34.6	24.00	Mixed profile	2	Horsmonden
March 2012		Non-event; no peak flows observed in the Main Rivers			
24/12/2013	48.2	24.75	Multi-peak	6	Horsmonden
January 2014		Smaller rainfall totals			
	Other peak rainfall events (no significant flooding reported within Marden) – but raised levels in the River Teise at Stonebridge)				
January 2008	34.4	22.00	Summer	2	Horsmonden
December 1999	30.4	9.00	Summer	3	Horsmonden

4.2 Main River analysis

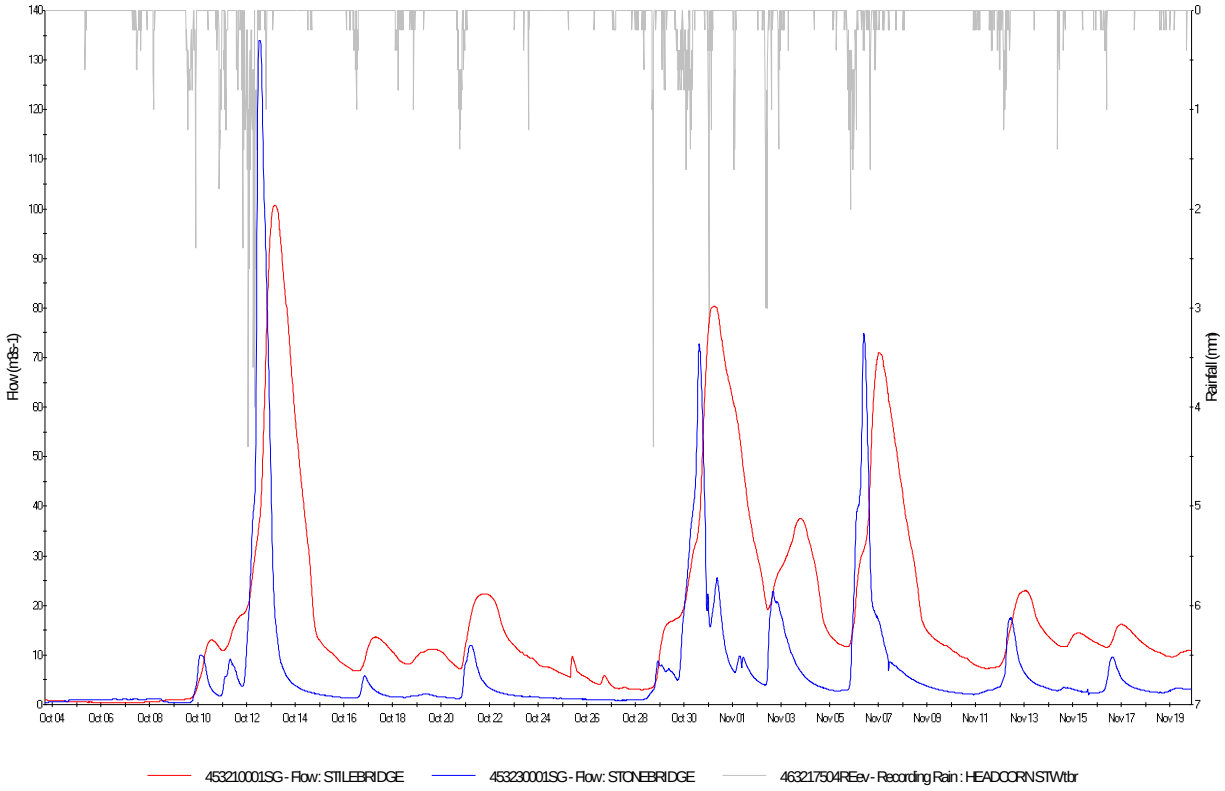
The purpose of this section is to analyse flow patterns on the Main Rivers of the River Beult and Lesser Teise at the time when flood events have occurred in Marden. This analyses will test our hypothesis that local flooding events in Marden, coincide with high water levels on the Main Rivers.

Observed hydrographs for the Stilebridge and Stonebridge gauging stations are shown for each of the reported flood events within Marden. Also included on these hydrometric plots is a continuous rainfall record from nearby representative raingauges (dependent on data availability at the TBRs).

4.2.1 Autumn 2000

In autumn 2000, fluvial flooding was reported at Marden. Rainfall recorded at Headcorn STW TBR and the flow on the River Beult recorded at Stilebridge and flow on the River Teise at Stonebridge are shown in Figure 4-1.

Figure 4-1: Autumn 2000 events



For the Autumn 2000 events, the River Teise and Beult were characterised by numerous storm events that led to fluvial flooding. The largest peak flows were seen on 12-13 October 2000 (at Stonebridge these were significantly higher than at other times during the winter). Smaller peaks were seen following the storms of 30 October 2000 and 7 November 2000. The Autumn 2000 events (particularly the October 13th event) are the highest ranked events at Stilebridge and Stonebridge.

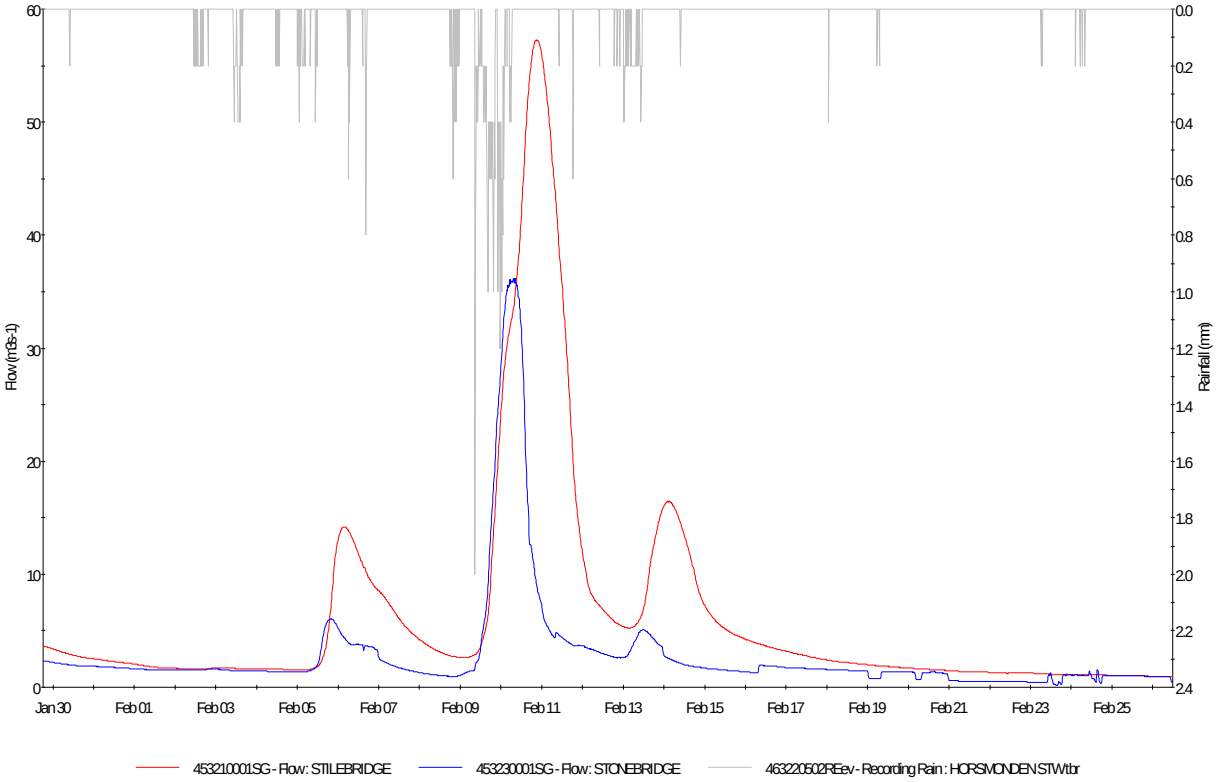
Therefore it is expected that these events were also significant for the Marden Drain catchments. Unfortunately, there is no information on severity or magnitude within the reported flood history in Marden. However, the return period for the rainfall that fell on the 12th October is approximately 35 years.

4.2.2 February 2009

In February 2009, fluvial and surface water flooding was reported at Marden. Rainfall recorded at Horsmonden STW TBR and the flow on the River Beult recorded at Stilebridge and flow on the River

Teise at Stonebridge are shown in Figure 4-2.

Figure 4-2: February 2009 event

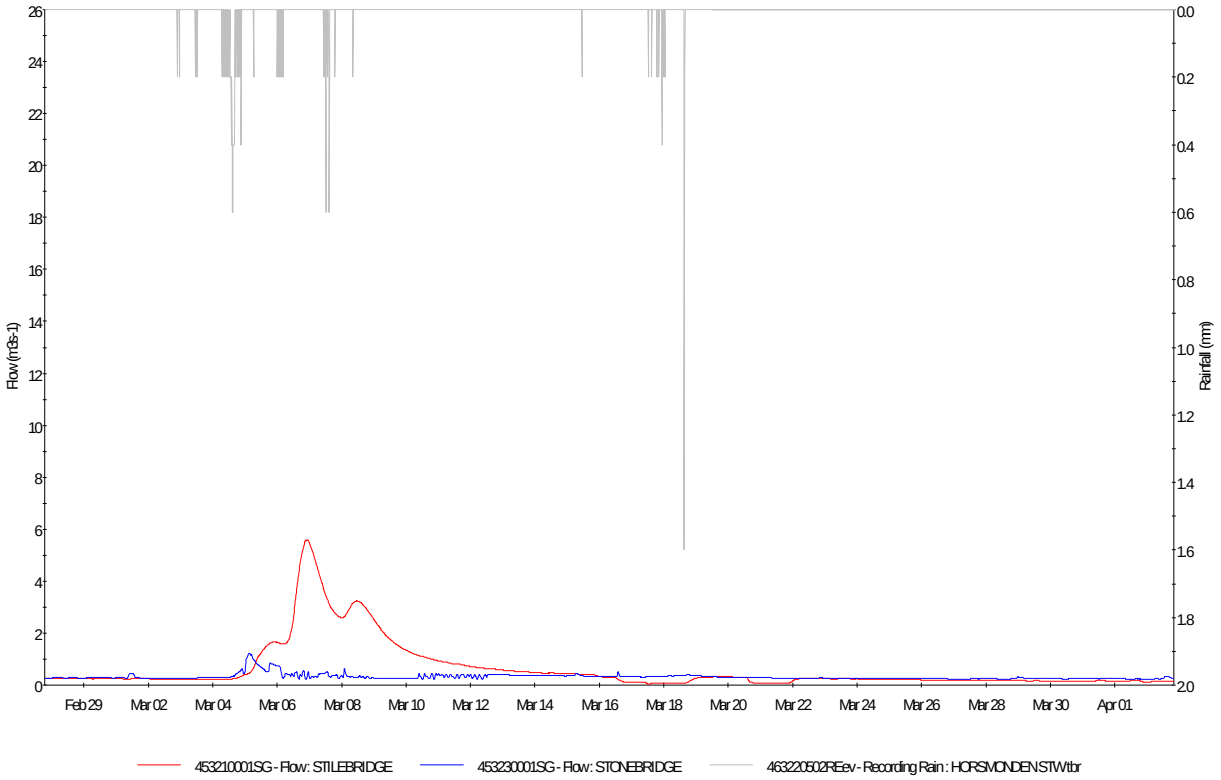


The February 2009 flood event was a result of a period of intense rainfall and levels within the River Beult and Teise rose from approximately 0.5m to 3.2m and 2.3m, respectively. Given the underlying impermeable geology, soil types and urbanised areas within the Marden Drain catchments, it is likely that this intense rainfall event resulted in a combination of fluvial and surface water flooding. This may have also been exacerbated by the elevated Main River levels.

4.2.3 March 2012

In March 2012, surface water flooding was reported at Marden. Rainfall recorded at Horsmonden STW TBR and the flow on the River Beult recorded at Stilebridge and flow on the River Teise at Stonebridge are shown in Figure 4-3.

Figure 4-3: March 2012 event

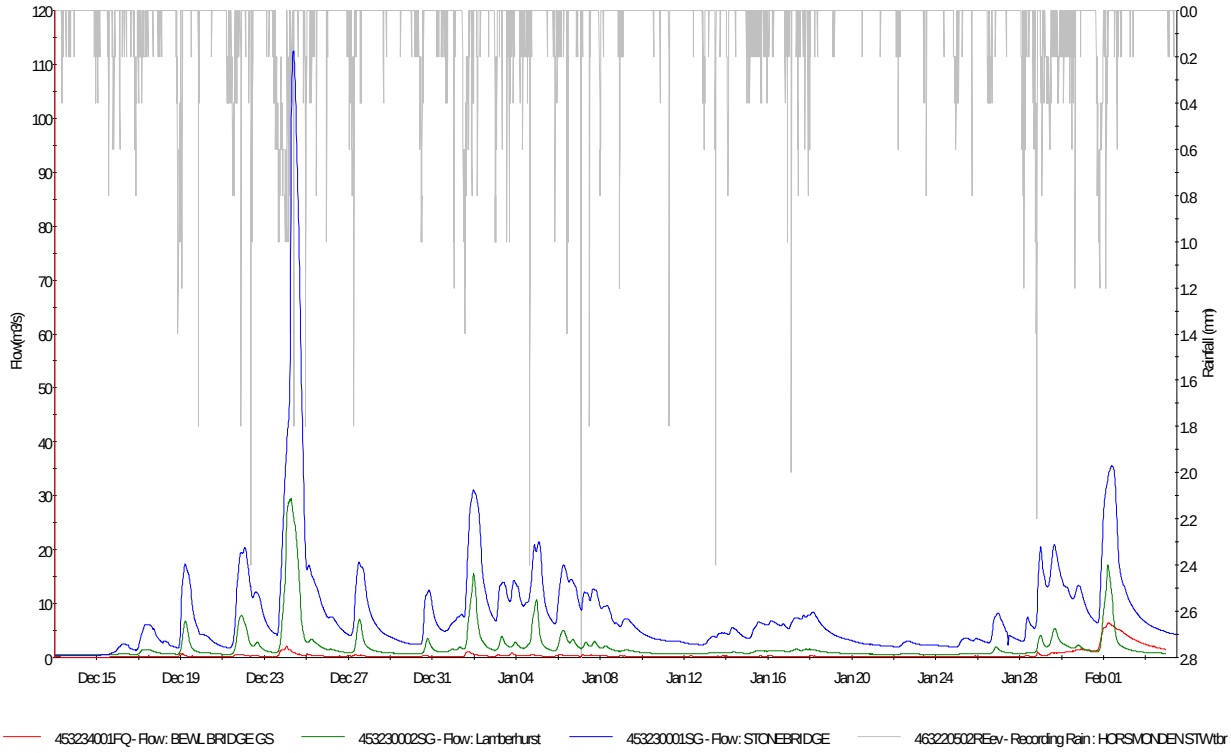


It is likely that this surface water flood event was quite localised and may have been due to a local blockage in the surface water drainage network within Marden. This event has not been included within the analysis.

4.2.4 Winter 2013-14

In December 2013 and January 2014, foul sewer flooding was reported at Marden. Rainfall recorded at Horsmonden STW TBR and the flow on the River Teise at Stonebridge, Lamberhurst and Bewlbridge are shown in Figure 4-4.

Figure 4-4: Winter 2013/14 events



For the winter 2013-14 events, the River Teise was characterised by numerous storm events that led to fluvial flooding. The largest peak flows were seen on 24-25 December 2013 (at Stonebridge these were significantly higher than at other times during the winter). Smaller peaks were seen following the storms of 1 January 2014 and 1 February 2014.

The December 2013 event is the second highest ranked event at Stilebridge and Stonebridge. Therefore it is expected that these events were also significant for the Marden Drain catchments. Unfortunately, there is no information on severity or magnitude within the reported flood history in Marden. The return period for the rainfall that fell on the 24th December is approximately 6 years. However, it is expected that the return period of the sustained rainfall totals across December 2013 – January 2014 would be significantly higher.

5 Conclusions

The majority of the reported flood events are in the winter months and this therefore suggests that the Marden Drain catchments may be more prone to longer duration frontal rainfall events. However, the Marden catchments are also sensitive to short intense rainfall events due to the underlying impermeable geology and urbanised impervious areas. The reported flood events within Marden are generally associated with elevated Main River levels and high flows in the Lesser Teise and the River Beult. Some of the flood events are as a direct result of sewer or surface water flooding and would therefore most likely be due to short intense rainfall events; therefore these events may not always be observed in the Main Rivers.

However, it is highly likely that the catchments within Marden may be more sensitive to short intense rainfall events during periods when there are elevated Main River levels. This would exacerbate the surface water flooding as the excess surface water is unable to be cleared from the surface water drainage network. Therefore flooding within Marden may be as a result of the inability to discharge excess surface water during Main River flood events.