Final Report

Upper Lavant Valley Flood Risk Management Study

Prepared for

West Sussex County Council

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Contents

Acronyms and Abbreviations

Defra	Department for Environment, Food and Rural Affairs
EA	Environment Agency
FEH	Flood Estimation Handbook
GIS	Geographic Information System
IRP	Infiltration Reduction Plan
MAFP	Multi Agency Flood Plan
SEA	Strategic Environmental Assessment
SW	Southern Water
SWMP	Surface Water Management Plan
WSCC	West Sussex County Council

SECTION 1

Introduction

1.1 Project context

This 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 and winter of 2012, although it is recognised that many of these 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 Upper Lavant Valley study

Within this context the Upper Lavant Valley consists of the main settlements of Charlton, Chilgrove, East Dean, East and Mid Lavant, Singleton and West Dean. The River Lavant flows through all of the settlements (with the exception of Chilgrove). Due to the underlying chalk the River Lavant is primarily a groundwater fed stream, and therefore responds to changes in groundwater levels through the year. It frequently runs dry during summer months when groundwater levels within the chalk catchment are lower.

Flooding within the Upper Lavant Valley occurs primarily when high groundwater levels cause over topping of the River Lavant and the local ditch networks which connect to it. Flooding also occurs after heavy rainfall when the catchment is already saturated. In addition, the foul sewer network can become overloaded by high groundwater levels which inundate and infiltrate the sewer network affecting its operation. Within the last 20 years flooding in the Upper Lavant Valley has occurred in in the winters of 1993/1994, 2000/01, 2012/13 and 2013/14. Further information on the flooding mechanisms and history is provided in Section 2.

WSCC has drafted a Lavant Valley Groundwater Multi-Agency Flood Plan (MAFP) to outline the actions and responsibilities for each identified organisation in response to high groundwater levels. This SWMP has provided a further, more detailed analysis of groundwater levels and their impacts on flooding within the catchment. The purpose has been to provide additional evidence to inform the MAFP. The findings of this study will be used to update the MAFP, and provide locally specific capital, maintenance and emergency management approaches to minimise the impact of flooding to people, properties and infrastructure within the Upper Lavant Valley.

1.2.1 Objectives

The primary objectives of this study are to:

- understand the flooding issues within the catchment, including flooding from the River Lavant, the foul sewer network, and high groundwater levels;
- consider current flood risk management practices within the Upper Lavant Valley, including how actions are taken in response to groundwater levels at Chilgrove;
- identify localised capital and maintenance measures which can be taken to reduce flood risk to people, property and infrastructure, and;
- provide evidence to support WSCC, the Environment Agency, Southern Water and local residents to prepare for, and respond to, flooding incidents.

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 identification 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 Surface Water Management Plan (SWMP) 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.

Stage 1 - Data Collection & review

During this stage we collected and mapped flood incident data and all other relevant flood risk management information. We engaged with WSCC and the Environment Agency to investigate current flood risk management practices, identify properties that were affected by flooding, and identify properties that received flood alerts/warnings from the Environment Agency.

Stage 2 - Understand Southern Water actions

Subsequently, we engaged with Southern Water to establish the impacts of recent winter flooding on the function of the foul sewer network, and to consider plans to mitigate groundwater ingress into the network. During development of the Upper Lavant Valley study Southern Water issued their draft Infiltration Reduction Plan (IRP), which set out how Southern Water are planning to reduce infiltration into their sewer network. The IRP was used as the primary evidence base to support this study.

Stage 3 – Local walk over-survey

In July 2014 we undertook a walkover surveys to understand the drainage system within the key areas of flooding as highlighted above. The purpose was to improve our understanding of the areas at risk of flooding, any pinch points within the drainage and watercourse network, and consider suitable mitigation measures to reduce property and highway flooding. We undertook the walkover with representatives from Mid Lavant Parish Council, Singleton Parish Council, and West Dean Parish Council.

Step 4 – Engagement with locals and production of groundwater management action plan

The outputs from this study will become part of the evidence base of the Lavant Valley Groundwater MAFP currently being prepared by WSCC. Our evidence will add support to the actions already identified in the draft MAFP. Local residents will be engaged by WSCC through presentation of the SWMP to the Lavant Valley Partnership.

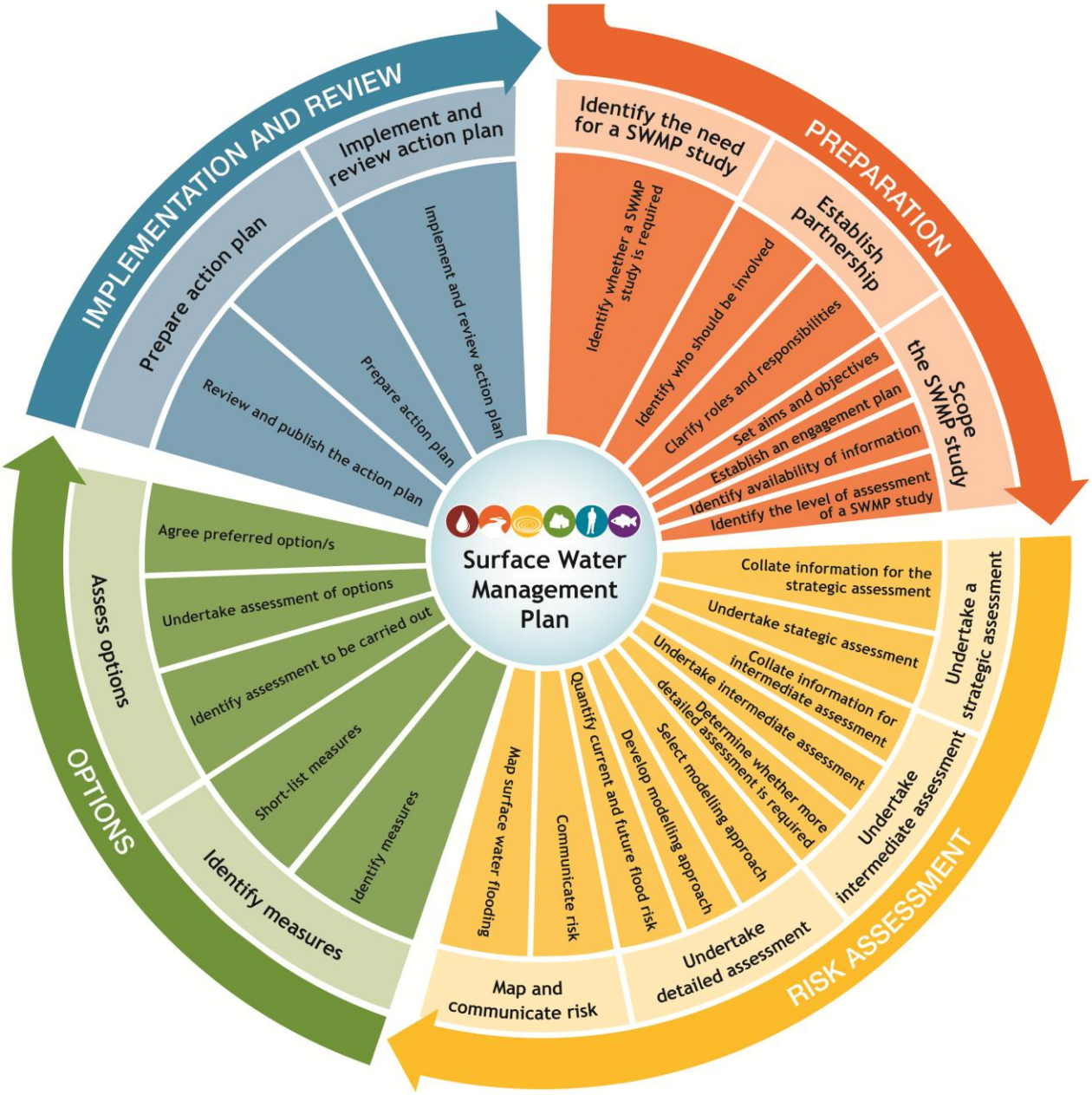


Figure 1 SWMP Process

1.2.3 Study area

The study area was based on an estimate of the River Lavant catchment using the Flood Estimation Handbook (FEH). This included all the inflows and tributaries of the River Lavant from the head of the catchment, and included the main settlements of Charlton, Chilgrove, East Dean, East and Mid Lavant, Singleton and West Dean. The downstream boundary of the study area was considered to be the River Lavant at Westhampnett Mill, which is approximately the location of the diversion channel of the Lavant constructed by the Environment Agency to reduce flood risk to Chichester. The agreed study boundary is provided in Appendix B.

1.2.4 Key stakeholders

For each of the five SWMP areas a stakeholder engagement strategy was prepared which identified who to engage with and when and how this should be done. Stakeholder engagement is an important part of our

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 with a view to helping to:

- ensure the study was robust and that the data used to underpin it were as accurate as possible - ensuring that best use is made of local knowledge and that our 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 buy in for, the way in which local flooding will be managed going forward, and;
- help to encourage stakeholders and the general public to take actions to help protect themselves against flooding.

The key stakeholders identified for the Upper Lavant Study are:

- West Sussex County Council as the Lead Local Flood Authority and Highways Authority;
- Chichester District Council as the Land Drainage Authority
- The Environment Agency to understand groundwater levels and flow and the issues these generate in the catchment;
- Southern Water;
- Parish Councils, and;
- Lavant Valley Partnership

A list of engagement activities undertaken during the Upper Lavant Valley study are described in Table 1

Table 1 Engagement activities for Upper Lavant Study

Activity	**Purpose/Detail**	**Timescale**
Initial meeting with WSCC	To agree the scope of the work	March 2014
Technical discussions with Environment Agency Staff	To understand how the Environment Agency issue flood alerts/warnings, how trigger levels are set, 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 past 2 wet winters, and future plans to manage infiltration	Throughout study
Walkover survey and site visits	To ensure problems from a local perspective are understood. Representatives from various parish councils and WSCC were in attendance	July 2014
Presentation to Lavant Valley Partnership	To report back on the results of the analysis and modelling and share the emerging Surface Water Management Plan, and the MAFP.	November 2014

1.2.5 Data collected for study

A summary and analysis of the data received for the Upper Lavant Study is provided in Table 2, and includes a commentary of any known data quality issues.

Table 2 Data received for Upper Lavant Study

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)	Environment Agency	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	Environment Agency	National fluvial flood map provided by the Environment Agency for Flood Zone 3 (1 in 100 chance of occurring in any given year) and Flood Zone 2 (1 in 1000 year)	Only shows flooding from watercourses where the upstream catchment is >3km^2
Flood Map for Surface Water	Environment Agency	National surface water flood mapping provided by the Environment Agency 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	Environment Agency	Recorded flood outlines from fluvial flooding collated by the Environment Agency	

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 in 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	Environment Agency	Provides location and details on 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 the foul or combined system
River network	Environment Agency	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 Upper Lavant Study			
Infiltration Reduction Plan	Southern Water	Summarises infiltration issues in the catchment, and how Southern Water plan to mitigate infiltration	-
Overpumping and tankering	Southern Water and Environment Agency	Dates of overpumping and tankering in the catchment over the winter 2013/14	-
Lavant Groundwater Alerts Recipients	Environment Agency	Location of residents who receive groundwater flood alerts in the study area	-

Highway works logs	WSCC	Details of customer enquiries to WSCC about flooding to highways from 2012-2014	-
Incident logs	WSCC	Incident logs from resilience and emergency team about winter 2013/14 flooding	-
Flood Reports from EA	Environment Agency	Recorded flood calls from the Environment Agency January to February 2014	-
Draft Lavant Valley Groundwater MAFP	WSCC	Draft version of the Lavant Valley Groundwater MAFP	-
Summary of flooding by parish	WSCC	Summary spreadsheet from Communities team outlining the key flooding issues by parish	-
Borehole data	Environment Agency	Historic borehole data for Chilgrove, East Dean (Butchers Lane and Droke Lane), Charlton (North Lane and Charlton Road) and West Dean Colworth Farm	Whilst Chilgrove is a continuous dataset the other boreholes are manual dip and sampling regime is often not detailed enough to understand the timing of fluctuations in groundwater levels
Rainfall data	Environment Agency	Historic rainfall data for Chilgrove	
River flow data	Environment Agency	River flow data at Graylingwell	There are some periods of missing flow data
Local information from parish councils	Singleton PC	Summary map of flooding problems in Singleton, and records of site walkover with parish councils, Environment Agency and WSCC in 2013 in East Dean, Charlton and Singleton	

SECTION 2

Flooding History and Impacts

2.1 Flooding History

The association between high groundwater levels and flooding in the Lavant valley has been recognised at least since 1994 when there was extensive flooding in the valley (and serious fluvial flooding in Chichester itself) prompted by exceptional winter rainfall (610mm, October 1993- Jan 1994). At that time groundwater levels monitored at Chilgrove became artesian (a level of 77.18mAOD) on 7 January 1994 and remained at that level for 18 days. During the 2013/14 event, Chilgrove borehole was artesian for five days during January 2014, but levels remained above 76m AOD (sufficient to cause flooding throughout the Upper Lavant Valley) for nearly 50 days from 7th January 2014 to 22nd February 2014.

Further incidents of flooding associated with high groundwater in the Lavant were recorded in 1994, in 2000/2001 (when this type of flooding was widespread across the chalk strata in the south of England), to a lesser extent in 2003 and 2012/2013 and then again with widespread flooding in the winter of 2013/14.

Unfortunately, other than a good hydrological and meteorological record, there appears to be a paucity of reliable historic information which would allow a better correlation between rainfall, fluvial flow and groundwater levels and the occurrence, timing, frequency and significance of resultant flood events.

On this basis it has been necessary focus investigation and analysis on the winter of 2013/2014, which although broadly similar to these earlier events in most respects, was characterized by the most extreme rate of rise of groundwater levels, nearly 6m/day at one point, ever recorded (refer Appendix C Table 6)[1].

A further more detailed description of the timing of flood events during winter 2013/2014 is provided in a number of charts provided with Appendix C and the issues arising are described in each village in Table 5 to Table 9.

2.2 Flooding Impacts

Villages along the Upper Lavant Valley Body (East Dean, Charlton, Singleton, West Dean); the road to Chilgrove (B2141) including Chilgrove village itself, and parts of Mid Lavant and East Lavant are susceptible to a number of flooding impacts caused by high groundwater levels within the permeable chalk catchment. A summary of the flooding impacts by village are described in Table 3.

Typically the effects of flooding in the catchment are:

(i) Enhanced flows in the ephemeral parts of the catchment (i.e. along the winterbournes), which may exceed bank capacity and lead to fluvial flooding events, causing both widespread road flooding and some property flooding.

(ii) Significant inundation and infiltration into the foul sewer network causing sewer flooding. Surcharged sewers prevent toilets flushing, require pumping to tanker or overpumping into the River Lavant and may lead to flows of foul water along roads.

(iii) Some, but not extensive, direct groundwater flooding caused by emergence beneath houses.

Flooding in the lower parts of the valley in Mid Lavant and East Lavant is primarily fluvial in nature, although there appears to be a fairly consistent relationship between groundwater levels in the upper parts of the catchment (i.e. as monitored at Chilgrove) and flows in the river recorded at Graylingwell gauging station.

[1] The Environment Agency has confirmed that during the winter of 2013/14 there was some surface water ingress into the borehole which could have caused levels to rise artificially. This is important to note but not considered critical to the analysis of groundwater rise

Table 3 Properties and infrastructure affected by flooding

Village	**Properties / Infrastructure affected by flooding**
East Dean	Several properties suffer basement flooding Butchers Lane and Main Road are flooded (not impassable)
Charlton	Charlton Road flooded along various sections from East Dean to Charlton Flooding also occurs at both bridges through Charlton
Singleton	2-5 properties flooded due to direct groundwater flooding, overtopping of the River Lavant and sewer flooding Charlton Road flooded along various sections from Charlton through to Singleton Flooding also occurs on the A286 and Cobbler's Row
Chilgrove & Chilgrove Road	Extensive flooding on Chilgrove Road which causes dangerous driving conditions
West Dean	2-3 properties at risk of flooding from overtopping of River Lavant and direct groundwater flooding (only one property suffered basement flooding in 2013/14 event)
Mid & East Lavant	3 properties on Pook Lane and memorial hall at risk of flooding from overtopping of River Lavant (no property flooding in 2013/14) Sheepwash Lane and Pook Lane flooded

NB: Sewer flooding not listed above as it affects all of the settlements listed above (excluding Chilgrove)

SECTION 3

Analysis of flooding

3.1 Introduction

A full and detailed technical analysis of flooding in the study area, is provided in Appendix C. This gives details of the data used in the analysis and provides appropriate charts and other forms of data interpretation. The data analysis is used to identify and establish relationships between recorded groundwater level, river flow monitoring, rainfall and other monitored parameters and the occurrence of different types of flooding in the Catchment. These relationships are then used to evaluate a refinement in the use of trigger levels to prompt actions that may be taken to ameliorate the impacts of flooding within the Lavant valley, which are further developed in Section 4. Based on the data set available, and in particular the timing of flood events, the focus of the analysis is the winter of 2013/2014. Within this report the most salient points for discussion have been considered, with more detail and evidence provided in Appendix C.

3.2 Catchment boundary and characteristics

The catchment boundary used for the study area is as identified in Appendix B, however the focus of the investigations and analysis has been the most heavily impacted settlements and the roads and sewer infrastructure in the upper parts of the catchment. The northern groundwater catchment boundary, as identified on hydrogeological mapping, is slightly further south than the surface water catchment defined by the FEH (see section 1.2.3) and the eastern and western groundwater boundaries are primarily defined by the configuration of dry valleys in the upper catchment. In the unconfined upper catchment of the chalk aquifer, it is reasonable to use the surface water catchment as the boundary.

The catchment is somewhat asymmetric, with a broad, East West orientated upper catchment narrowing significantly in the vicinity of East Lavant and toward Chichester. The southward dipping chalk has been impacted by structural folding which significantly influences the geometry of the drainage. A further element of the geological setting of the catchment, is the occurrence of superficial “head” deposits, found aligned east west, south of Mid/East Lavant. This deposit acts to confine the chalk, such that south of this area, direct emergence of groundwater from the chalk is unlikely to occur – i.e. from the East Lavant/ Mid Lavant area southward any flooding is fundamentally fluvial (overtopping of the watercourse), albeit driven by high groundwater levels and heavy rainfall in the upper catchment. The geological characteristics of the Upper Lavant Valley are discussed further in Section 4.1 and 4.2 of Appendix C.

3.3 Analysis of groundwater flooding

The behavior of chalk catchments in particular and the characteristics of groundwater flooding generated within these catchments are somewhat different to fluvial flooding. Typically the factors that influence the high discharge from the chalk and the development of groundwater flooding are:

- the timing, duration and frequency of recharge by rainfall;
- antecedent groundwater level (storage) conditions in the chalk;
- shallow zones of high chalk transmissivity, particularly along valley bottoms that provide a focus for preferential flow;
- increased hydraulic gradients from interfluvial areas to valley bottoms (and generally across the catchment) that generate increased groundwater flows to the valleys;
- activation of the ephemeral drainage networks, and;
- the change in behaviour of chalk when groundwater levels are nears surface such that semi direct runoff may occur (i.e. the chalk catchment starts to behave in a “flashy” manner).

In the Lavant catchment previous studies suggest that when groundwater levels at Chilgrove reach 69.5 mAOD (the threshold used by the Environment Agency to consider issue of groundwater flood alerts) the chalk catchment response changes from the more typical “buffered” response of chalk catchments to the flashier, near direct runoff response. This is accompanied by a rapid rise of groundwater levels throughout the catchment and increased sensitivity of all areas to flooding following large storms. These typical characteristics were all demonstrated during the winter 2013/2014.

As noted in Section 2.2, groundwater flooding manifests in a number of ways. During 2013/2014 the most dominant of these mechanisms were the significantly enhanced flows in the River Lavant due to high groundwater levels (leading to emergency of groundwater and fluvial flooding) and infiltration and inundation into the foul sewer network causing sewer surcharge and flooding (see Section 3.4). There are a few recorded incidents of direct groundwater emergence through property floors (and these were limited to a few properties in West Dean, East Dean and Singleton), on or around the 8th January 2014. The continuously recorded groundwater level data (daily, logged) at Chilgrove provides an opportunity to compare the timing of these flood events with respect to groundwater levels, as illustrated by Figure 2.

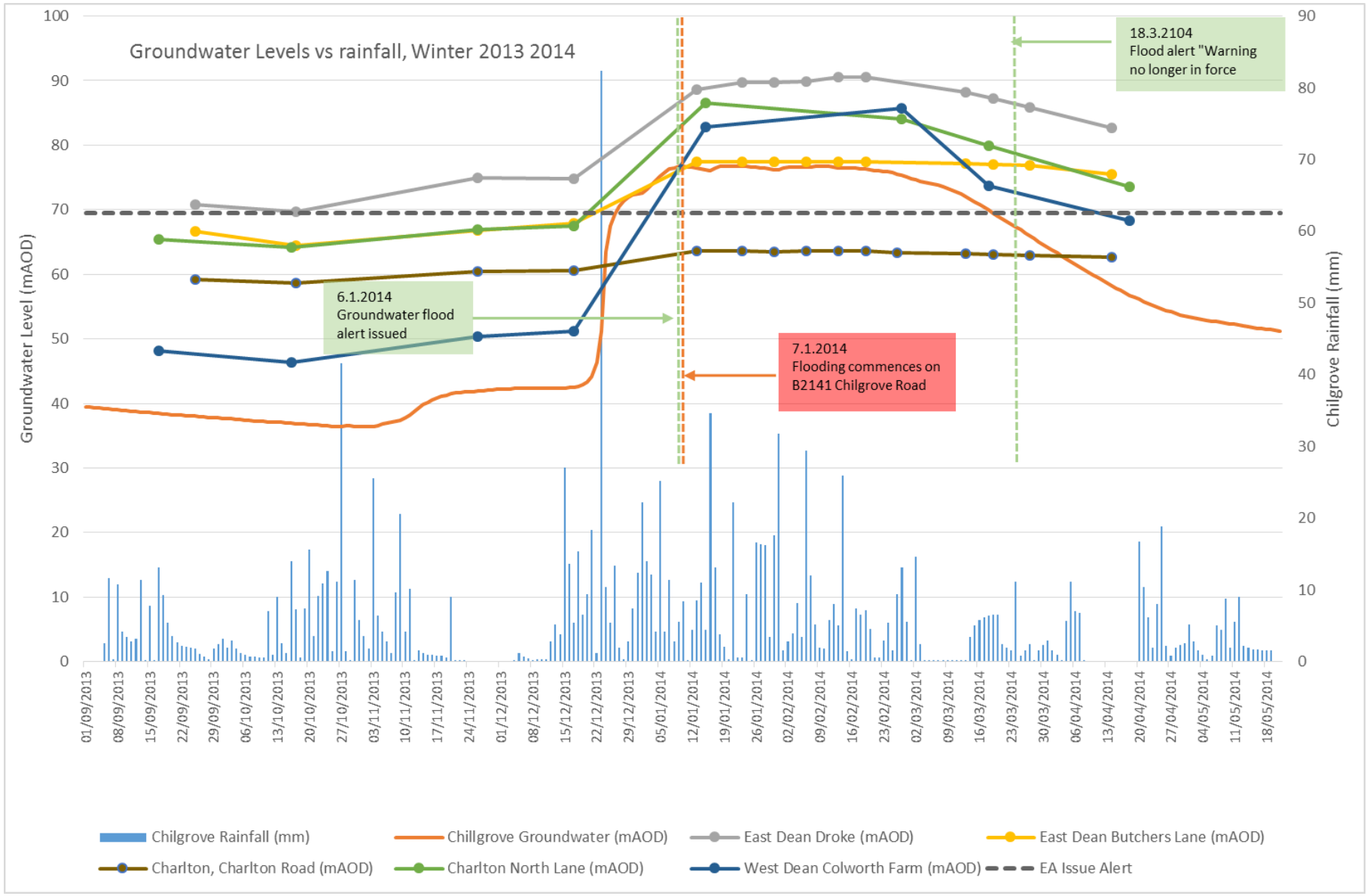


Figure 2 Graph showing relationship between groundwater level, rainfall and commencement of flood events

These relationships, described further in Appendix C, may be used to predict the future occurrence of such events. This allows a development of a series of trigger levels to prompt actions that may prevent or reduce damage arising from the flood events.

The Environment Agency already provides groundwater briefing notes and also flood alerts to the residents of the Upper Lavant Valley (see Appendix C for details) however there is an opportunity to refine these warnings and develop a series of (other) actions prompted by recorded groundwater levels. In Appendix C, these have been shown as a timeline of flood events vs. the groundwater level.

The broad relationship between flooding and groundwater levels at Chilgrove is summarised below:

Table 4 Flood and groundwater levels at Chilgrove

Groundwater level at Chilgrove (mAOD)	Catchment groundwater response
57mAOD	River Lavant flowing/rising groundwater levels (Environment Agency considers issuing groundwater briefing note)
69.5mAOD	Catchment behavior becomes more flashy, significant further rainfall likely to lead to flooding (Environment Agency considers issuing groundwater flood alert, subject to a range of factors including antecedent conditions, rate of rise and predicted rainfall)
76.3 mAOD	Flooding occurs on Chilgrove road, and basement flooding will occur in West Dean, Singleton and East Dean. Fluvial flooding in Singleton, Mid/East Lavant will occur following heavy rainfall events (estimated to be >20mm in a day)

Once the 69.5m AOD threshold is exceeded, whether groundwater and fluvial flooding occurs (and how rapidly afterward) will depend upon:

- antecedent rainfall conditions and ongoing recharge;
- the antecedent and ongoing rate of rise of groundwater in response to the recharge, and;
- continued rainfall and recharge following the threshold being reached.

As a result, the exceedance of this threshold does not guarantee that flooding will occur.

Flooding also occurred as a result of heavy rainfall on saturated catchments which caused river levels to rise rapidly and flow out of bank, most notably in Singleton and Mid/East Lavant. Discussions with staff at the Environment Agency suggested that flooding on 17th January was as a result of heavy rainfall on 16th January (+30mm in one day) causing fluvial flooding, rather than due to rising groundwater levels. This was also repeated on 14th February 2014 following a rainfall event >20mm on the same day. This supports the evidence that when groundwater levels are above a certain threshold fluvial flooding will occur following heavy rainfall events. Based on a comparison of rainfall records and groundwater levels during the 2013/14 winter (see Appendix C) there is no recorded evidence of fluvial flooding prior to 17th January 2014. At this point (17th January) groundwater levels were above 76m AOD. On the contrary there was heavy rainfall on 5th January 2014 (>25mm) but this did not prompt fluvial flooding, and groundwater levels were c.75m AOD. Equally no fluvial flooding was documented following extreme rainfall on 23rd December 2013 (>80mm), when groundwater levels at Chilgrove were at 51m AOD. Based on this evidence it seems likely that once groundwater levels are above approximately 76m AOD this causes base river levels to be so high that fluvial flooding will occur within 24-48 hours following rainfall in excess of 25mm in a single day. Therefore threshold levels for villages affected by fluvial flooding (Singleton and Mid/East Lavant) should be linked to groundwater levels and rainfall.

3.4 Analysis of sewer flooding

The elevated levels through the upper catchment led to the inundation and infiltration of the sewer network throughout much of the Upper Lavant Valley. The draft IRP identifies that tankering and overpumping operations were carried out at eight locations. These are listed below:

- tankering in Mid and East Lavant at Potnore (MH3303) and MH0301
- tankering in West Dean at Harcourt House (MH8302) and 127 West Dean (MH5701);
- overpumping in Singleton at overpumping at The Leys (MH 0101);
- overpumping in Charlton at Charlton East (MH0001) and Charlton Knights Hill (MH7005), and;
- overpumping in East Dean at East Dean village pond (MH3801).

We understand that overpumping commenced in East Dean and Charlton on 18th January 2014, and 2 days later in Singleton, with further overpumping at Charlton on 1st February 2014, as illustrated in Figure 3.

Analysis of local groundwater levels at Charlton and East Dean suggests that groundwater levels were above the downstream invert levels in these villages on 23 December to 10/11 January respectively. Whilst the infiltration of groundwater into sewers will require some head difference between groundwater levels and the sewer level (i.e. to "drive" the groundwater into the sewer via discontinuities, cracks and joints), there appears to be a relatively long time between the invert level being exceeded in Charlton and the onset of overpumping (over 3 weeks) during which time groundwater levels rose rapidly.

There is no evidence that Southern Water used groundwater levels (at Chilgrove or elsewhere in the catchment) to develop a proactive response to sewer flooding over the winter 2013/14. The ongoing actions of Southern Water identified as part of their IRP include capital works (e.g. replacing. refurbishing or sealing pipework, sealing manholes and other access points). However the IRP recognises that in certain extreme events that "emergency response" tankering and overpumping will become necessary (i.e. it is impractical to wholly seal the sewage system). On this basis, and as part of the monitoring of the success of their capital works, it would be sensible to identify groundwater level based thresholds (whether at Chilgrove or at more local boreholes) that can be used to prompt those actions.

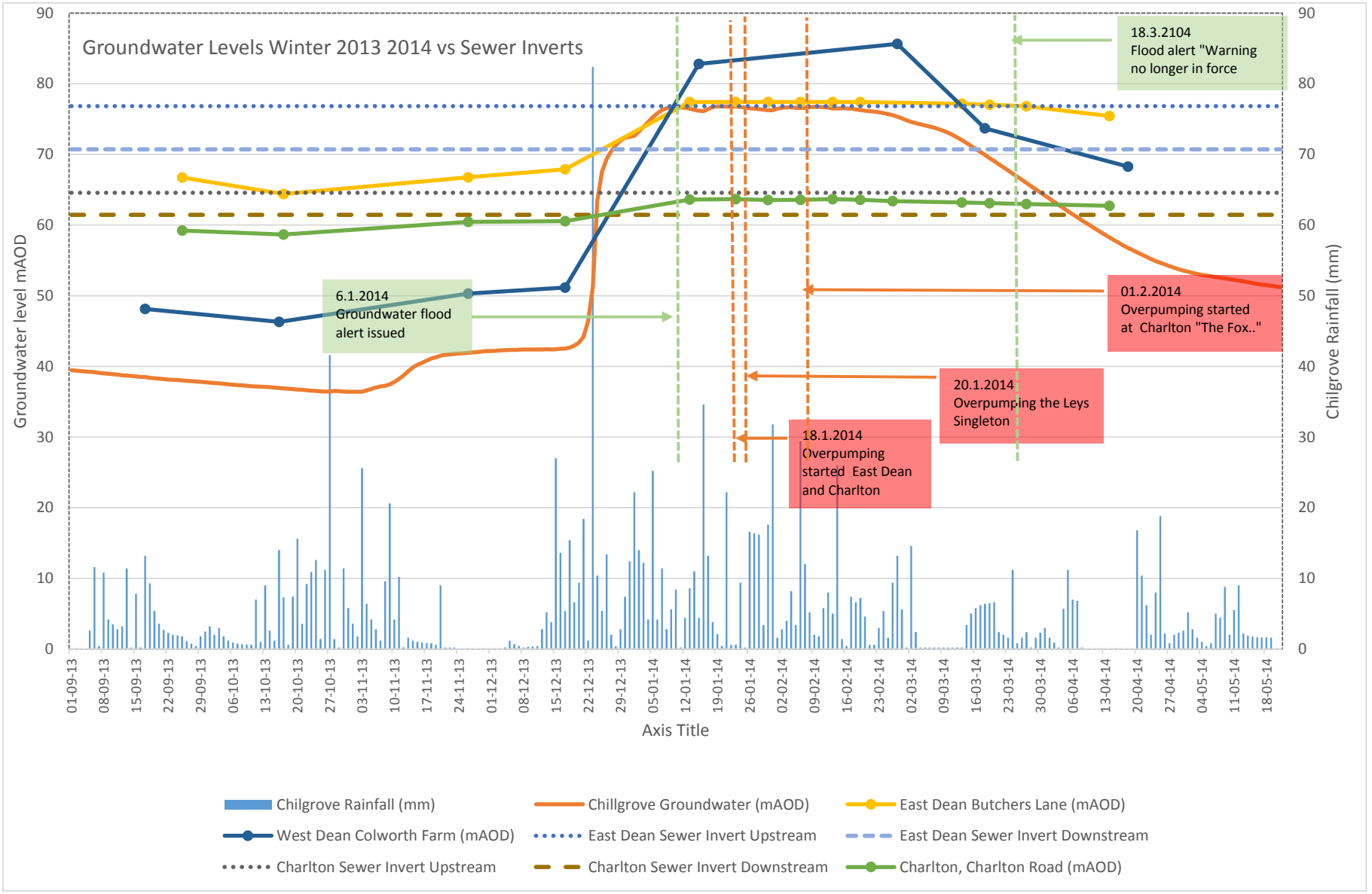


Figure 3 Graph showing dates of overpumping in relation to groundwater levels

SECTION 3

3.5 Setting thresholds and trigger levels

Appendix C identifies how threshold trigger levels can be set for prompting actions on groundwater , fluvial and sewer flooding. These trigger levels consider:

- the rate of rise of groundwater;
- predicted rainfall;
- the appropriate period for advance warning;
- avoidance of false alarms, and;
- clear and unequivocal thresholds.

The trigger levels can be used to prompt necessary actions and emergency measures that form part of this study and that are highlighted in Table 5 to Table 9.

Although the selected thresholds should also take into account other contributory factors to groundwater flooding, such as ongoing rainfall and recharge and antecedent conditions (see Section 3.3), it is not appropriate at this stage to quantify these other factors, and a certain level of judgment will be needed in the application of these threshold levels. It is recommended that consultation with the Environment Agency should be undertaken as soon as the "Groundwater Flood Alert" threshold (i.e. 69.5 mAOD at Chilgrove) is exceeded, to determine whether ongoing conditions in the catchment warrant action based on the application of the later threshold trigger levels.

Based on the available evidence presented in Appendix C the following threshold levels and actions are recommended:

(i) Trigger groundwater levels at the Chilgrove borehole should continue to be the basis for prompting actions in the Lavant valley.

(ii) Groundwater briefing notes should be considered for issue at 57m AOD and 67m AOD to encourage initial actions to be taken. The threshold trigger level for the Environment Agency considering the issue of a flood alert should remain at 69.5 mAOD. When this level is reached the following actions should take place:

- Issue of groundwater flood alerts, subject to other conditions (e.g. forecast rainfall, rate of rise) [Environment Agency]
- Enhanced level monitoring (daily) in supplementary boreholes at East Dean (Droke and Butchers Lane) and at Charlton (North and Charlton Road) [Environment Agency, WSCC or local community - to be determined][2]

(iii) Based on our analysis of the average rate of rise and to allow a 2 day 'lead in' time before flooding commences on Chilgrove Road a further trigger at 70.3m AOD would be helpful (flooding on Chilgrove Road commences when groundwater levels at Chilgrove reach 76.3m AOD and the average rate of rise if 3 metres/day. However, given that the level of 70.3m AOD is so close to the level at which the Environment Agency will consider issuing a groundwater flood alert (at 69.5m AOD) there does not seem merit in having two trigger levels at very similar levels. Therefore, we propose that at 69.5m AOD a further set of actions are required which should include:

- Issue of road flood warning signs along Chilgrove Road, prepare other measures (temporary traffic signals, ensure diversion routes clear), considering the rate of rise [WSCC]
- Initial preparation to issue sandbags for other Lavant villages [WSCC]
- Prompt actions from Southern Water to prepare for sewer flooding including overpumping permissions from the Environment Agency [WSCC/ Southern Water/ Environment Agency]

[2] It may be possible to install loggers at these boreholes to provide continuous readings

- Advise local communities in East Dean, Singleton and West Dean of likely groundwater flooding [through issue of Environment Agency Flood Alert]
- Prepare local communities for action [WSCC/ Parish councils]
- Continue/ enhance local monitoring of flooding [WSCC/ Parish councils, Environment Agency]
- Monitor Environment Agency Flood Warnings ref. Mid and East Lavant [WSCC/ Parish councils]

(iv) Once the Chilgrove boreholes reaches 76.3 mAOD, if groundwater continues to rise and based on rainfall forecasts, the following actions should be undertaken:

- Prepare for or deploy more significant traffic management along Chilgrove Road, including possible road closures and diversions [WSCC]
- Deploy and emplace sandbags for other Lavant villages (Singleton, Charlton, East Dean) in line with rainfall forecasts >25mm [WSCC]
- Confirm actions to be taken by Southern Water with respect to sewer flooding [WSCC/ Southern Water/ EA]
- Ensure local communities remain vigilant and aware [WSCC/ Parish councils]
- Continue local monitoring of flooding [WSCC/ Parish councils, Environment Agency]
- Monitor Environment Agency Flood Warnings ref. Mid and East Lavant [WSCC/ Parish councils]

More detail on where specific actions should be taken within each village are outlined in Table 5 to Table 9.

SECTION 4

Options and Action Plan for Main Settlements

4.1 Introduction

Our approach to the development and appraisal of suitable mitigation measures is based around the concept shown in Figure 4, which although not wholly applicable to the groundwater sourced flooding that occurs in the catchment, remains relevant. This concept defines different flood risk management approaches dependant on the rainfall event within a catchment (or in this catchment a combination of rainfall and groundwater levels). For 'everyday rainfall' the drainage system (including both the natural drainage through the valley and the sewer network) should function according to its natural or designed capacity to limit the impact of any flooding. Conversely during extreme events, in this case combinations of high groundwater levels and extreme rainfall (or cumulative rainfall), it is recognised that drainage systems (both natural and man-made) and any other flood risk infrastructure will be completely overwhelmed and therefore emergency response is the most appropriate management technique to reduce the impacts of flooding.

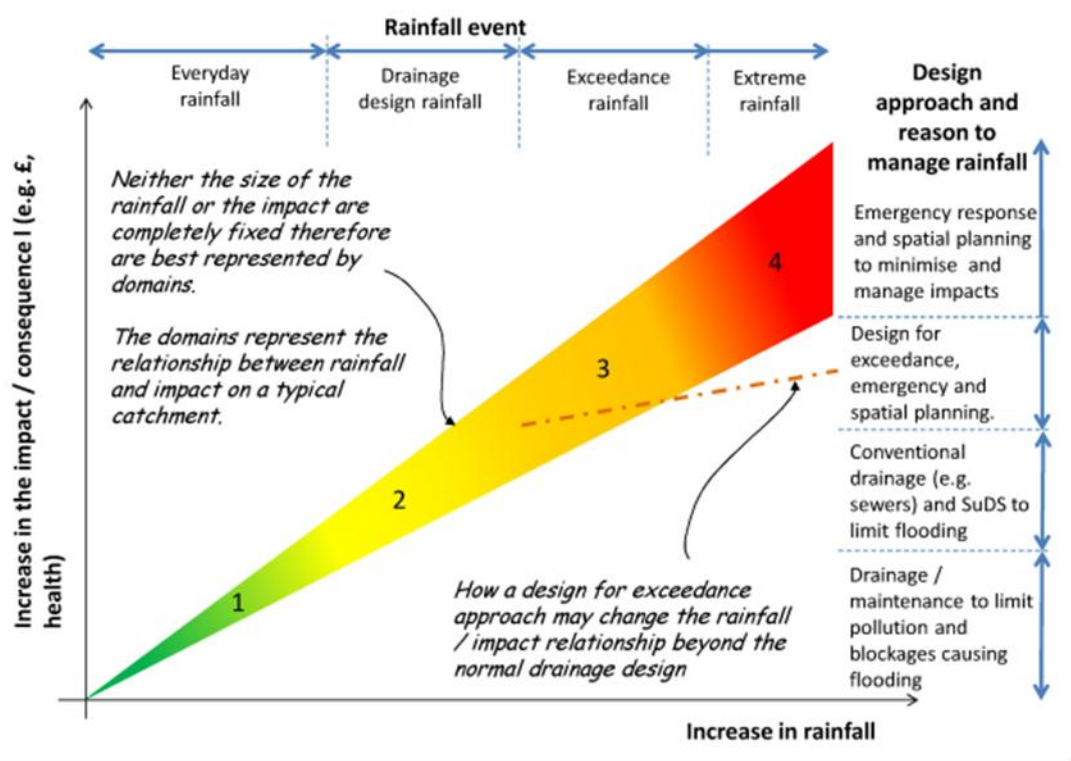


Figure 4 Flood risk management concept applied in the Upper Lavant Valley (taken from CIRIA's Designing for Exceedance guidance[3])

[3] 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.

For the Upper Lavant Valley study we have identified capital works, maintenance measures and emergency management approaches to reduce the impacts of flooding to people, property and infrastructure. In the Lavant valley, the capital works and maintenance measures are designed to deal with identified and known flooding hotspots wherein such measures will either increase conveyance or reduce the potential for out of bank flow. The emergency management approaches seek to reduce the impact where such measures are impractical or are less likely to be effective, and will also manage the impact where the flood event reflects the 'extreme' combination of rainfall and groundwater level, such as those seen during the winter of 2013/14.

4.2 Initial options considered

Initially over 30 flood risk measures were considered to manage flood risk within the Upper Lavant Valley based on our understanding of flooding mechanisms and impacts. The full list of options considered are outlined in Appendix D. Some of the initial options considered were excluded from further analysis because they were considered technically infeasible, cost prohibitive, or a disproportionate response given the nature and scale of flooding impacts in this catchment. The capital, maintenance and emergency management approaches taken forward as part of the action plan for each village are outlined in Section 4.3.

4.3 Short-listed options for main settlements

In Sections 4.3.1 to 4.3.5 below an action plan has been drafted for each of the main settlements affected by flooding in the Upper Lavant Valley, based on the short-listed options. In each settlement the key flooding issues affecting people, property and infrastructure have been described, with accompanying actions. Actions have been broken down into:

- capital measures, where investment in infrastructure is required to improve conveyance of flows or protect properties;
- enhanced maintenance measures to ensure that the conveyance of drainage and watercourses is effective during times of flooding incidents, and;
- emergency management approaches, which consider what local authorities, parish councils, Southern Water and homeowners need to do to reduce the impacts of flooding when certain threshold levels are reached in the catchment.

A table of actions has been provided for each settlement, and there is an accompanying map for the settlements in Appendix E which indicate the locations of the proposed actions. A reference system has been used for consistency across the settlements[4]. To date the costs and benefits of the proposed measures have not been quantified as it is not considered appropriate for the types of measures proposed.

[4] A five or six letter code to identify which settlement, followed by a "1" to indicate capital measures, a "2" to indicate maintenance measures, and a "3" to indicate emergency management

4.3.1 Mid and East Lavant

Table 5 Proposed actions for Mid and East Lavant

Flood Issue / Concern	Potential Measures			Comments
	Capital Improvements (1)	**Enhanced Maintenance (2)**	**Emergency Planning and Actions (3)**	
• Risk of flooding to properties on Lavant Down Road – following the 1994 floods on the estate a twin culvert and small bund were established at the north-east corner of Lavant Down Road where there is a track along the disused railway. Residents remain concerned about the maintenance of that twin culvert and the possibility of exceedance causing a residual risk to properties on Lavant Down Road.	• MELAV_1a. Create an exceedance route along the track to the north-east of Lavant Down Road to divert water away from properties if the new twin culverts are exceeded. This should be done by lowering the road immediately south of the twin culverts so it will act as an exceedance route **[EA/WSCC/Chichester DC (who own the access road)]**	• MELAV_2a. Establish annual maintenance and vegetation clearance of the River Lavant at key structures (bridges and culverts to maximise conveyance), in particular the twin culverts to the north-east of Lavant Down Road, and the river as it runs parallel to Sheepwash Lane . **[EA]** • MELAV_2b. Lower bed level of River Lavant near Manor Farm which is silted **[EA]** • MELAV_2c. Establish annual maintenance of ditch along Marsh Lane Track **[WSCC/Riparian Owner]**	With respect to the River Lavant, once the Environment Agency flood warning is issued[5]: • MELAV_3a. Properties on Pook Lane should be sandbagged to protect flooding of properties (a permanent sandbag store could be established in the village) **[Local residents/Parish council]** • MELAV_3b. Existing property level protection measures at Lavant Village Hall should be put up when the clerk is notified of a flood warning being issued **[Parish council]** • MELAV_3c. Traffic management should be established on Pook Lane and Sheepwash Lane to divert traffic away where possible or to advise proceeding with caution (NB: it is not believed the roads needs to be closed) **[WSCC]** **Note: Preparations for the above deployment actions should be discussed with Environment Agency when Chilgrove borehole reaches 76.3mAOD.**	• Local residents are concerned that any conveyance improvements or changes to the flood plain storage upstream may exacerbate flooding in Mid and East Lavant. • The EA Flood Warning Area "the River Lavant at Mid Lavant and East Lavant" covers this area. Local residents should be encouraged to sign up to flood warnings, and encourage awareness about how to respond to flood alerts/warnings • Environmental issues to be considered (e.g. Vole habitats) with respect to maintenance and clearances
• Flooding to properties on Pook Lane and Memorial Hall – in the winter of 2013/14 sandbags were placed by the properties on Pook Lane and the memorial hall flooded. This is a repeated issue and the memorial hall has installed property level protection measures	• MELAV_1b. Re-design/Re-build the furthest downstream bridge along Sheepwash Lane which causes backing up due to restricted capacity. **[WSCC/Riparian Owner]**			
• Function of the foul sewer network during the winter – Southern Water were tankering on Lavant Down Road because of problems with sewer backing up and toilets flushing over the winter 2013/14	-	-	With respect to function of the foul sewer network: • MELAV_3d. Southern Water should make preparation for tankering at Potnore (MH3303) and MH0301 as per winter 2013/14 5-10 days following levels at Chilgrove reaching 76.3mAOD **[SW]**	• Actions for Southern Water will be reviewed in light of other actions they are taking as part of the IRP **[SW]** • Communities should be pre-warned when tankering will be taking place **[SW]**
• Resilience of Portsmouth Water pumping station to flooding	• MEL_1c. Increase level of resilience at Pumping Station to the north-east of Lavant Down Road **[Portsmouth Water]**	-		• This is a decision for Portsmouth Water depending on the business case for investment. Any bunds to keep water out of the site may result in loss of flood plain, so building and borehole specific measures would be more appropriate

[5] Mid and East Lavant are in the River Lavant at Mid Lavant and East Lavant flood warning area. Flood warnings are based on flows and levels at nearby Graylingwell, and are therefore more suitable to act as a trigger for action than the Chilgrove borehole which is 5km away (as the crow flies). In addition the flooding mechanism in Mid and East Lavant is fluvial, and therefore a flood warning linked to levels at Gralingwell is a more robust indicator of forecast flooding.

4.3.2 West Dean and Chilgrove

Table 6 Proposed actions for West Dean and Chilgrove

Flood Issue / Concern	Potential Measures			Comments
	Capital Improvements (1)	**Enhanced Maintenance (2)**	**Emergency Planning and Actions (3)**	
• Harcourt Farm - in the winter of 2013/14 sandbags were placed by the property because of concerns about flooding from the River Lavant • Groundwater flooding to some properties in West Dean	• WDCHIL_1a. Homeowners would need to consider property protection measures if they are concerned about internal flooding **[Home owners]**	-	When borehole levels at Chilgrove reach 76.3 mAOD, preparations should be made to take actions within West Dean. These actions should take place within 12 hours of rainfall >25mm within the catchment (or based on rainfall forecasts from Met Office) • WDCHIL_3a. Deploy sandbags at Harcourt Farm **[WSCC/Parish Council]**	• Local residents should be encouraged to sign up to flood warnings, and encourage awareness about how to respond to flood alerts. When Chilgrove groundwater levels reach 69.5mAOD The Environment Agency consider issuing a groundwater flood alert [Groundwater flooding expected in West Dean once groundwater levels reach 76.3m AOD at Chilgrove] • It would be useful for the Parish Council to establish a sandbag store in West Dean which can be accessed quickly during flooding incidents **[Parish council]**
• Function of the foul sewer network during the winter – Southern Water were tankering from Harcourt House (MH8302) and 127 West Dean (MH5701 in the winter of 2013/14. In addition there was surcharging from a manhole (private) near West Dean College.	-	• WDCHIL_2a. Through the IRP will identify any improvements to the sewer network will be identified **[SW]**	With respect to function of the foul sewer network: • WDCHIL_3b. Southern Water should make preparations for tankering at Harcourt House (MH8302) and 127 West Dean (MH5701) as per winter 2013/14 5-10 days following levels at Chilgrove reaching 76.3mAOD **[SW]** **NB: PROVISIONAL PENDING FURTHER DATA FROM SOUTHERN WATER ON TIMING OF TANKERING OPERATIONS DURING 2013/2014**	• Actions for Southern Water will be reviewed in light of other actions they are taking as part of the IRP **[SW]** • Communities should be pre-warned when tankering will be taking place **[SW]**
• Flooding along the A286 near the turn off for West Dean College – this is believed to be due to blockages in the highway drainage system	• WDCHIL_1b. Subject to highway drainage investigations **[WSCC]**	• WDCHIL_2b. Investigate and unblock the highway drainage system along the A286 **[WSCC]**	-	
• Flooding of the Chilgrove Road (B2141) – residents have expressed concerns about the lack of ditch maintenance in the area	-	• WDCHIL_2c. Undertake one off ditch clearance on either side of Chilgrove Road and establish annual vegetation clearance **[Riparian Owner/Parish Council]** • WDCHIL_2d. Install signage at key points on Chilgrove Road to make users aware the road is liable to flooding **[WSCC]**	• WDCHIL_3c. Once levels at Chilgrove borehole are above 76.3 m AOD the road is flooded and largely impassable. Therefore traffic management and warnings should be implemented on this road 2-5 days before flooding occurs, when levels at Chilgrove borehole reach 69.5m AOD **[WSCC/Parish Council]** • WDCHIL_3d. Inform emergency services that they may have difficulty responding to incidents in the area due to flooded roads. Advise them again once the road	

			becomes largely impassable (when Chilgrove reaches 76.3m AOD) **[WSCC]**	

4.3.3 Singleton

Table 7 Proposed actions for Singleton

Flood Issue / Concern	Potential Measures			Comments
	Capital Improvements (1)	**Enhanced Maintenance (2)**	**Emergency Planning and Actions (3)**	
• On the Ley's Meadow there is a risk of hedge collapse into the watercourse on the right bank to the east of Bankside properties • Maintenance of the grid near The Leys – local residents have to clear the grid frequently during high flows to prevent overtopping of the watercourse (NB: if the watercourse overtops it flows down the A286) • Backing up at the A286 bridge – once backing up occurs it overtops the bank and causes flooding to the A286 and Cobblers Row • From the A286 bridge to near Brook House the watercourse has significant overgrowth, detritus and trees which is reducing the conveyance potential of the watercourse. There is also a water service pipe which catches debris and exacerbates backing up. Overtopping of the watercourse at this point results in flooding to properties on Groom's Yard (NB: part of the issue at Groom's Yard is that SW discharge backs up during high river levels, as well as bow waves caused by drivers) • On the frontage to Cowper Lodge/A286 there is a redundant bridge which causes backing up and overtopping of the watercourse • There are concerns about the gradient of the River Lavant near the cricket pitch which will reduce conveyance.	• SING_1a. Consider reinforcement of banking and hedgerow along Ley's Meadow and cut pathways to relieve pressure of flood water in extreme conditions **[WSCC/Parish Council through Operation Watershed]** • SING_1b. Install property protection for properties on Cobbler's Row (either at property entrance or front doors/airbricks) **[WSCC/Home owners / Parish Council through Operation Watershed]** • SING_1c. Remove redundant bridge at Cowper Lodge **[WSCC/ Home owners]** • SING_1d. Raise left bank of Lavant downstream of the A286 bridge by semi-permanent sandbags, and provide sandbags to residents to put on access bridges during high flows **[WSCC/EA/Home owners/Parish Council through Operation Watershed]**	• SING_2a. Removal of detritus and trees along section of watercourse through Singleton will help to reduce water **[EA/WSCC]** • SING_2b. Seasonal vegetation clearance of the River Lavant along the section from Charlton to the culvert inlet near The Leys • SING_2c. Maintenance of the grid at The Leys as required by local residents **[WSCC/ Parish Council/FAG/RO]** • SING_2d. Check whether the railway sleepers towards the western end of Singleton can be removed, and rehabilitate the bolts which appear to have rusted	When borehole levels at Chilgrove reach 76.3 mAOD, preparations should be made to take actions within Singleton. These actions should take place within 12 hours of rainfall >25mm within the catchment (or based on rainfall forecasts from Met Office) • SING_3a. Walk the length of the River Lavant through from Bankside to downstream of Singleton to check it is flowing freely and there are no restrictions at culvert inlets or bridges **[WSCC/Parish Council/EA]** • SING_3b. Sandbag access points on the left bank of the River Lavant to complement Option 1d. **[Parish council/WSCC/EA]** • SING_3c. Deploy sandbags to properties on Cobbler's Row (a permanent sandbag store could be established in the village). **[Parish council]** • SING_3d. Implement traffic management (traffic lighting or closure) on A286 through Singleton **[WSCC]**	• Need to ensure conveyance improvements through Singleton will not cause more significant issues for downstream villages. • Environmental issues to be considered with respect to maintenance and clearances. • Road safety (e.g. pedestrian walkways, lines of sight) must be considered in any permanent change • Under Operation Watershed it would be useful for local residents to be provided with tools and guidance on clearing trash screens. This could be part of a wider initiative to re-instate local 'lengthsmen' along key stretches of the watercourse to monitor the need for clearing. **[WSCC/Parish council]** • It may be worthwhile installing a simple gauge board at the A286 bridge to monitor the rise of the River Lavant **[Parish council]** • It would be useful for the Parish Council to establish a sandbag store in West Dean which can be access quickly during flooding incidents **[Parish council]** • More frequent borehole monitoring at Charlton Lane during high groundwater events would provide additional granularity as to trigger levels and response time in Singleton and Charlton. • The apparently unusual (for a chalk catchment) rate of rise of groundwater in the Upper Lavant during 2013/2014 gives difficulties in terms of trigger levels, these should be continuously reviewed.
• Groundwater flooding at specific properties	-	-	• Homeowner has established a borehole in their garden to be prepared for high groundwater, and has installed resilience measures in their property **[Home owner]**	• Local residents should be encouraged to sign up to flood warnings, and encourage awareness about how to respond to flood alerts. When Chilgrove groundwater levels reach 69.5mAOD The Environment Agency consider issuing a groundwater flood alert [Groundwater and basement flooding expected in Singleton once groundwater levels reach 76.3m AOD at Chilgrove]

• There is significant infiltration into the foul sewer network, and in the winter 2013/14 a manhole near the A286 bridge blew causing exceedance from the network		• SING_2e. Through the IRP will identify any improvements to the sewer network will be identified **[SW]**	With respect to function of the foul sewer network: • SING_3e. Southern Water should make preparations for overpumping at The Leys (MH 0101) 5-10 days following levels at Chilgrove reaching 76.3mAOD **[SW]**	• Actions for Southern Water will be reviewed in light of other actions they are taking as part of the IRP **[SW]** • Communities should be pre-warned when tankering will be taking place **[SW]**
• Foul flooding at Key Cottage and No.1 Cobblers Row (garage)	• SING_1e. Southern Water will need to identify any capital options to alleviate flooding to these properties	• SING_2e. Through the IRP will identify any improvements to the sewer network will be identified **[SW]**		

4.3.4 Charlton

Table 8 Proposed measures for Charlton

Flood Issue / Concern	Potential Measures			Comments
	Capital Improvements (1)	**Enhanced Maintenance (2)**	**Emergency Planning and Actions (3)**	
• From East Dean to Charlton the main road is prone to flooding, although the road has not been closed • Maintenance of the River Lavant East Dean and Charlton, and as the river passes through Charlton (e.g. Charlton Barns) is required • There is evidence of silting of the culvert which runs immediately south of Fox Goes Free, which would reduce flows through the culvert • The brick bridge over the river just east of Fox Goes Free car park is known to be in poor condition • There is a ditch along North Lane which flows into the Lavant; this is considered to be in poor condition and in need of clearance (removal of Ash tree) and provision of a new grille	• CHARL_1a. Clearance of the ditch along North Lane, and installation of new grille at outfall **[WSCC]**	• CHARL_2a.Cut grips on the north side of the road from East Dean to Charlton to allow more water on the road to discharge to the Lavant (NB: because water and road levels are similar in wet periods we need to carefully plan the locations where grips are cut to ensure we do not exacerbate flows from the river onto the road) **[WSCC]** • CHARL_2b. Annual seasonal clearance of vegetation/obstructions the Lavant from East Dean to Charlton, and through Charlton **[WSCC/Riparian Owner/Parish Council through Operation Watershed]** • CHARL_2c. Identify silt levels at the culvert to the south of Fox Goes Free and clear as required **[WSCC]**	When the EA issue the groundwater alert the following actions should be taken: • CHARL_3a. Enhance local groundwater level monitoring to obtain daily readings at Charlton North Lane. **[WSCC/Parish Council/EA]** When borehole levels at Chilgrove reach 76.3 mAOD, preparations should be made to take actions within Singleton. These actions should take place within 12 hours of rainfall >25mm within the catchment (or based on rainfall forecasts from Met Office) • CHARL_3b. Walk the length of the River Lavant through Charlton and check it is flowing freely and there are no restrictions at culvert inlets or bridges **[WSCC/Parish Council/EA]** • CHARL_3c. Install traffic warnings at east and west of Charlton to make road users aware the road is liable to imminent flooding **[WSCC]**	• Local residents should be encouraged to sign up to flood warnings, and encourage awareness about how to respond to flood alerts. When Chilgrove groundwater levels reach 69.5mAOD The Environment Agency consider issuing a groundwater flood alert • Need to ensure grips on the north side of the road from East Dean to Charlton do not allow reverse flow from River Lavant to the road • Environmental issues to be considered with respect to maintenance and clearances. • More frequent borehole monitoring at Charlton Lane during high groundwater events would provide additional granularity as to trigger levels and response time in Singleton and Charlton. • Under Operation Watershed it would be useful for local residents to be provided with tools and guidance on clearing trash screens. This could be part of a wider initiative to re-instate local 'lengthsmen' along key stretches of the watercourse to monitor the need for clearing. **[WSCC/Parish council]**
• There is significant infiltration of groundwater into the sewer network in this location, resulting in two over-pumping locations at the eastern and western (Knight's Hill) edge of the village (residents reported damage to the grass verge where pumping occurred at Knight's Hill). To the east the sewer runs parallel to the river and significant infiltration will occur along this length. Furthermore groundwater levels at the Charlton lane borehole were higher than sewer inverts in the western edge of the village over the winter which would cause further infiltration. There is also likely to be infiltration as the sewer runs along Ley's Meadow	-	• CHARL_2d. Through the IRP will identify any improvements to the sewer network will be identified **[Southern Water]**	With respect to function of the foul sewer network: • CHARL_3d. Southern Water should make preparations for overpumping at Charlton East (MH0001) and Charlton Knights Hill (MH7005) 5-10 days following levels at Chilgrove reaching 76.3mAOD **[SW]**	• Actions for Southern Water will be reviewed in light of other actions they are taking as part of the IRP **[SW]** • Communities should be pre-warned when tankering will be taking place **[SW]**

4.3.5 East Dean

Table 9 Proposed measures for East Dean

Flood Issue / Concern	Potential Measures			Comments
	Capital Improvements (1)	**Enhanced Maintenance (2)**	**Emergency Planning and Actions (3)**	
• Butcher's Lane borehole went artesian from 13/01/14 to 19/02/14 which resulted in overflow down Butcher's Lane, but also from emergent springs. Groundwater caused flooding to cellar of Star and Garter pub and other basements in the village. In addition it caused overland flows towards pond at lowest point of village. Overland flows were also noted from road junction on Main Road/Droke Road • Local residents concerned about a blocked culvert which runs west from bridleway at end of Butcher's Lane and emerges at eastern end of Chapel Row	-	• EDEAN_2a. Clear blocked culvert which runs west from bridleway at end of Butcher's Lane and emerges at eastern end of Chapel Row **[WSCC]**	When the EA issue the groundwater alert the following actions should be taken: • EDEAN_3a. Enhance local groundwater level monitoring to obtain daily readings at Butchers Lane and Droke Lane. **[WSCC/Parish Council/EA]** And the following actions should be taken within 2-5 days of groundwater levels reaching 69.5m AOD at Chilgrove (NB: based on documented evidence from 2013 flooding occurs on the road when Chilgrove levels are above 75m AOD) • EDEAN_3b. Open additional valves on outlet pipe into village pond **[Parish Council]** • EDEAN_3c. Walk the length of the River Lavant from Chapel Row to downstream of the village to check it is flowing freely and there are no restrictions at culvert inlets or bridges **[WSCC/Parish Council/EA]** • EDEAN_3d. Install traffic warnings at all entry points to East Dean to make road users aware the road is liable to imminent flooding **[WSCC]**	• Local residents should be encouraged to sign up to flood warnings, and encourage awareness about how to respond to flood alerts. When Chilgrove groundwater levels reach 69.5mAOD The Environment Agency consider issuing a groundwater flood alert [Groundwater and basement flooding expected in East Dean once groundwater levels reach 75m AOD at Chilgrove] • Environmental issues to be considered with respect to maintenance and clearances. • More frequent borehole monitoring at East Dean (Butcher's Lane) during high groundwater events would provide additional granularity as to trigger levels and response time in East Dean and throughout the valley • Under Operation Watershed it would be useful for local residents to be provided with tools and guidance on clearing trash screens. This could be part of a wider initiative to re-instate local 'lengthsmen' along key stretches of the watercourse to monitor the need for clearing. **[WSCC/Parish council]** • WSCC have already implemented some mitigation measures in this location, by providing an enhanced outfall to the pond
• When Butcher's Lane borehole goes artesian (ground level 77.43m AOD) Southern Water sewers become inundated with groundwater. Overpumping at the Pond is required to alleviate pressure on the foul network	-	• EDEAN_2B. Through the IRP will identify any improvements to the sewer network will be identified **[Southern Water]**	With respect to function of the foul sewer network: • EDEAN_3e. Southern Water should make preparations for overpumping at East Dean village pond (MH3801) 5-10 days following levels at Chilgrove reaching 76.3mAOD **[SW]**	• Actions for Southern Water will be reviewed in light of other actions they are taking as part of the IRP **[SW]** • Communities should be pre-warned when tankering will be taking place **[SW]**

SECTION 4

4.4 Environmental considerations

It is understood that West Sussex County Council has made a 'screening decision' in relation to the requirement for a Strategic Environmental Assessment (SEA) of the Upper Lavant Study, and determined that a statutory SEA is not required for the plan. This section of the SWMP therefore summarises the environmental considerations of the SWMP and describes any further actions required to ensure that implementation of the measures and actions outlined in the SWMP will not adversely impact on the environment.

4.4.1 Environmental Baseline

Table 10 provides a summary of the key baseline environmental characteristics of the Lavant Valley SWMP study area (see Appendix B) identified from a preliminary desk-based study using various internet websites. Potential environmental receptors have been identified for a range of topics, against which the potential environmental effects of the proposed SWMP measures can be assessed.

Table 10 Environmental Baseline Characteristics of the Lavant Valley SWMP Study Area

Baseline	Environmental Issues
Local Community	
• Settlements within the study area comprise five rural nucleated villages strung along the Lavant valley between Mid/East Lavant and East Dean. Some properties in the villages experience flooding from surface water • Community assets include West Dean college, Lavant and Singleton CE primary schools, Lavant village hall, playing fields, public houses, St Mary's Church in East Lavant • Areas of employment include the Eastmead industrial estate in Mid Lavant and numerous small commercial enterprises, including visitor accommodation • The key visitor attraction in the study area is the South Downs National Park, which offers recreational and leisure opportunities. It is estimated that around £464.4 million was spent by visitors (excluding residents) during their visit to the South Downs in 2011/12, supporting approximately 8,194 local jobs (Tourism South East 2013). Features within the study area include an Open air museum at Singleton, an arboretum and college at West Dean and Goodwood racecourse • Numerous long distance trails within the river valley: the New Lipchis Way, the West Sussex Literary Trail, Monarch's Way; and numerous public rights of way	• Direct effects on the population, properties and community/tourism assets within flood risk areas, including businesses and visitors to the South Downs • Quality of life is affected by flooding
Material Assets	
• The A286 runs in a north-south direction and from West Dean in an east-west direction through the centre of the study area • The B2141 (Chilgrove Road) extends in a north-west direction from the A286 at Mid Lavant to Chilgrove • Critical infrastructure includes electricity sub-stations, pumping stations, sewage works	• Flood risk to critical and transport infrastructure which provide essential services to the local community
Biodiversity, Flora and Fauna	

Baseline	Environmental Issues

• Internationally and nationally designated nature conservation sites within the study area:
  ○ Singleton and Cocking Tunnels Special Area of Conservation (SAC) and Site of Special Scientific Interest (SSSI): hibernating bats
  ○ Levin Down SSSI: chalk grassland and heath
  ○ East Dean Park Wood SSSI: chalk dry valley wood supporting a nationally important epiphytic flora
  ○ Kingley Vale SSSI and National Nature Reserve (NNR): yew woodland
• Woodland Biodiversity Action Plan (BAP) priority habitats present including: deciduous woodland; traditional orchard; and wood pasture and parkland (especially around West Dean)
• Areas of Ancient Woodland present
• The clear, chalk river flows in a narrow floodplain, which is characterised by small permanent pastures divided by hedgerows, wet woodland, water meadows, and open water, all of which are of great ecological interest (South Downs: Integrated Landscape Character Assessment)
• Part of the river is designated as a Site of Importance for Nature Conservation (SINC), being particularly notable for its rich aquatic plant communities and associated invertebrates
• The presence of other sites of local wildlife importance (e.g. SINCs) and non-statutory nature reserves within and around the study area (available from the Sussex Biodiversity Records Centre), would need to be taken into consideration for any option taken forward to detailed appraisal.
• There are likely to be rare, notable and/or protected species within the study area in terrestrial, riverine and aquatic environments. Such species may be sensitive to changes in hydrology, flood regime and water quality. Details will need to be obtained from the Sussex Biological Records Centre and through site surveys
• Details of any Tree Preservation Orders (TPO) will need to be confirmed with Chichester District Council prior to implementation of any SWMP measures. Where possible, the detailed design of a scheme should seek to avoid the loss of and damage to trees, particularly those protected by TPOs. However, where works to a tree designated by a TPO are required, this will need to be consented by the local planning authority.
	• Potential for effects on nationally and internationally designated sites need to be considered, although distant from the floodplain
	• Potential for negative or positive effects on local conservation sites; terrestrial, aquatic or riparian habitats; and associated species of conservation concern and/or attracting legal protection, if present
	• Opportunities for habitat improvement and creation during surface water flood management works

Soil, Geology and Land Use	
• The Lavant valley follows the lines of faults in the underlying chalk and the river is a winterbourne in its upper reaches • There are shallow well drained, calcareous silty soils on the valley sides supporting intensive arable cultivation on shallower slopes and pasture, calcareous grassland, scrub and woodland on steeper slopes • There are no known active or historic landfill sites • There is unknown potential for other contaminated land • Forms part of the South Downs Environmentally Sensitive Area	• Geology can influence the extent and likelihood of an area to flooding and/or the suitability of options • Potential for changes in land use as a result of flooding and flood risk management actions • Potential to uncover areas of unknown contamination
Water	
• The River Lavant is a chalk stream that typically only flows during winter when groundwater levels are high	• Direct and indirect effects on water resources, both surface and ground

Baseline	Environmental Issues
• Upstream of Mid Lavant, the river is classified under the EU Water Framework Directive (WFD) as the River Lavant (Upper) (GB107041012360) water body and is currently of good ecological status. Chemical quality does not require assessment. Forms part of a Protected Area designated under the EU Nitrates Directive • Including and downstream of Mid/East Lavant, the river is classified as Pagham Harbour (GB107041012880) river water body which is of moderate ecological potential and good chemical quality. This water body is heavily modified due to flood protection. Specific issues include fish (poor), dissolved oxygen (bad), phosphate (poor) and hydrology (not high). Forms part of Protected Areas designated under the following EU Directives: Bathing Water Directive, Freshwater Fish Directive, Natura 2000 (Habitats and/or Birds Directive), Nitrates Directive, Urban Waste Water Treatment Directive • Underlying groundwater body is the Chichester-Worthing-Portsdown Chalk (GB40701G500700). Currently classified as poor quantitative and chemical quality. Objective is to reach good status by 2027. Forms part of Protected Areas designated under the following EU Directives: Drinking Water Protected Area and Nitrates Directive • Groundwater Nitrate Vulnerable Zone (NVZ) at the downstream end of the study area and an Eutrophic NVZ to the west of Mid Lavant • Groundwater source protection zones (GSPZ) – Zones 1 to 3 – present within the study area • Three medium licensed groundwater abstractions in the study area – one for amenity purposes and two for agriculture	water, which could affect their chemical and ecological status as required by the WFD • Potential requirement for a preliminary WFD Assessment
Historic Environment	
• Number of Scheduled Monuments within the study area reflecting its historic interest – in particular parts of the Devil's Dyke extending through Mid/East Lavant • Numerous listed buildings within the five villages – mainly Grade II, but with a Grade I church in Mid/East Lavant • Two Registered Parks and Gardens within the study area: Goodwood House (Grade I) and West Dean (Grade II*) • The historic landscape of the valley, including its historic land use and water management, has been characterised at a county level • There are likely to be non-designated sites and Historic Environment Records (HER) sites of importance within the study area and potential for as yet undiscovered features of archaeological interest	• Potential to reduce flood risk to known archaeological assets • Potential for impacts on the character of the historic landscape and the setting of archaeological/architectural assets
Landscape	
• The entire study area lies within the South Downs National Park – an area of national landscape significance • The Lavant Valley is identified as a chalk valley system – landscape character area in the Integrated Landscape Character Assessment (South Downs National Park Authority, 2011)	• Measures to reduce flood risk need to be sympathetic to the character of the designated landscape and surrounding landscape character.

4.4.2 Potential environmental impacts

The potentially significant environmental impacts of the potential measures identified in this SWMP, whether capital improvements, enhanced maintenance or emergency planning and actions, are presented in Appendix F. Where appropriate, recommendations to address identified adverse impacts are made for

subsequent stages of detailed appraisal/implementation of proposed measures. Similar types of measures have been grouped together for ease of assessment and presentation.

Appendices

Appendix A Roles and Responsibilities

1. Roles and Responsibilities for Local Flood Risk Management

Appendix B Study Boundary

1. Lavant Study Boundary

Appendix C Technical analysis of flooding in the Lavant Study area

1. Lavant Groundwater Analysis FINAL

2. Figures 2-8

Appendix D Initial Measures Considered

1. Initial measures considered

Appendix E Drawings

1. East Dean Measures
2. Charlton Measures
3. Singleton Measures
4. West Dean Measures
5. Chilgrove Road Measures
6. Mid and East Lavant Measures

Appendix F Environmental Constraints Plan

1. Lavant Constraint Plan
2. Environmental Assessment of Options

Roles and Responsibilities for Local Flood Risk Management

Overview

Under the Flood and Water Management Act 2010 West Sussex County Council has the responsibility for developing, maintaining and applying a local flood risk management strategy within the county. It is intended that local authorities should reflect the content, guiding principles, aims and objectives of the national strategy in the development of their local flood risk management strategies.

West Sussex County Council will not be working in isolation. A range of partner authorities known as risk management authorities also have flood and coastal erosion management duties, powers and responsibility. The development of the local flood risk management strategy required input from designated 'flood management authorities'. In West Sussex the other flood risk management authorities are the Environment Agency, the five Internal Drainage Boards (Upper Medway, Ouse, Arun, Adur and South West Sussex), the Highways Agency, Southern Water Services Ltd, Thames Water Utilities Ltd and the seven District and Borough Councils.

In West Sussex, Southern Water Services Ltd and Thames Water Utilities Ltd are responsible for managing public sewers, and for resolving flooding issues where there is no significant interaction with other types of flooding. The seven District and Borough Councils in the county are an important part of flood risk management are risk management authorities in their own right, and, all take an active role in assisting the Lead Local Flood Authority in performing some Flood and Water Management Act duties.

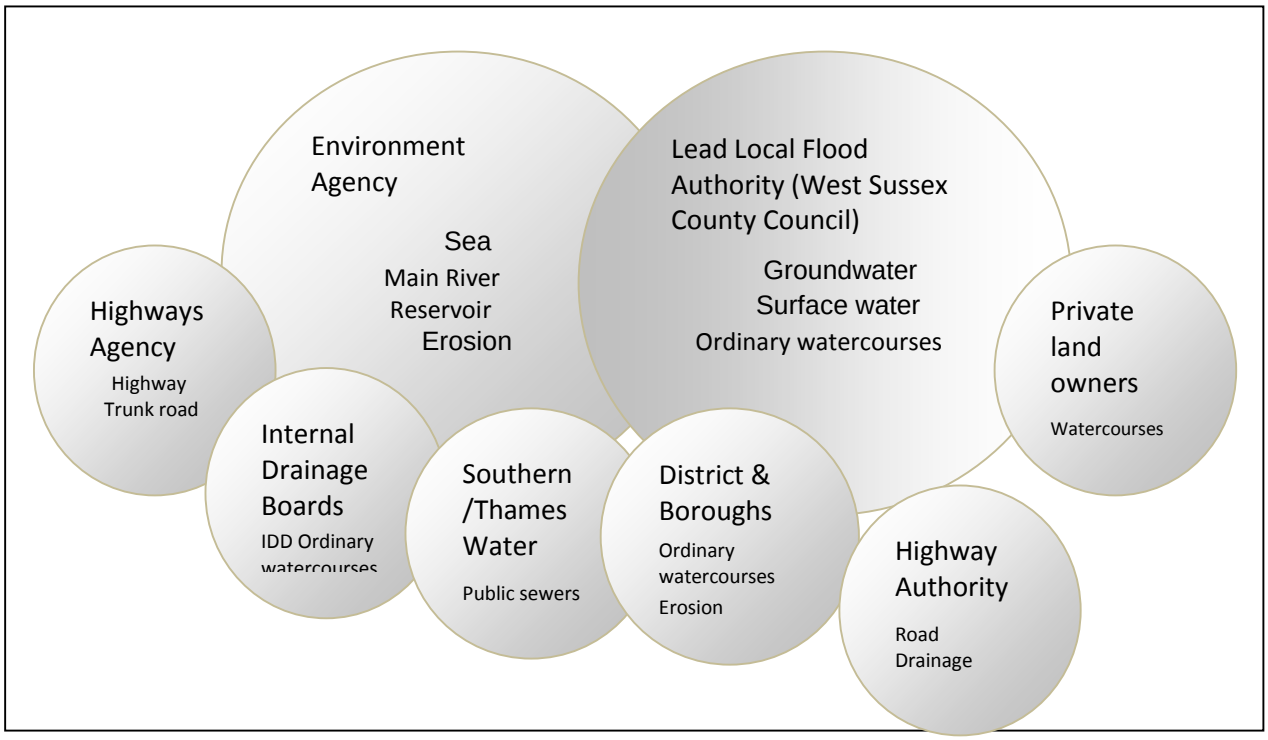


Figure 9: Who manages what within West Sussex?

The Internal Drainage Boards (IDBs) carry out maintenance works within their Internal Drainage District (IDD). Four of the five IDBs are operated by the Environment Agency (the Ouse, Arun, Adur and South West Sussex). The fifth IDB (Upper Medway) covers a small area within the county near East Grinstead and is

independently managed. At the time of writing in 2013 an Environment Agency review into the management of Internal Drainage Districts was underway which may change the current set up.

Under the provisions of the Flood and Water Management Act the following duties are common to all risk management authorities:

- Duty to cooperate with other risk management authorities
- Duty to act consistently with the national and local strategies
- Powers to take on flood risk functions from another risk management authority
- Duty to contribute towards the achievement of sustainable development
- Duty to be subject to scrutiny from the Lead Local Flood Authority's democratic process.

Responsibilities of different organisations

West Sussex County Council (Lead Local Flood Authority)

The responsibilities of the county council as Lead Local Flood Authority and as a risk management authority are to:

- Provide leadership of local flood risk management authorities;
- Develop, maintain, apply and monitor a strategy for local flood risk;
- Permissive power to do works to manage flood risk from surface water runoff or groundwater;
- Permissive power to request information from any person in connection with the authorities flood risk management functions;
- Permissive power to exercise the Land Drainage Act 1991;
- Perform as a Category 1 responder to flood incident under the Civil Contingencies Act 2004, including dealing with recovery and resulting homelessness;
- A duty to investigate and publish reports on flood incidents in West Sussex (where appropriate and necessary) to identify which authorities have relevant flood risk management functions, and what they have done or intend to do;
- A duty to maintain a register of structures or features that have a significant effect on flood risk;
- Permissive power to designate structures and features with flood risk significance;
- Responsibility (once enacted) for the sustainable drainage systems approving body with responsibility for approval, adoption, inspection and maintenance of new sustainable drainage systems;
- Decision making and enforcement responsibility for whether third party works on ordinary watercourses by third parties, that may affect water flow, can take place;
- A duty to contribute towards the achievement of sustainable development in the exercise of flood risk management functions and to have regard to any ministerial guidance on this topic.

West Sussex Highways Authority (part of West Sussex County Council)

The responsibility of the West Sussex Highways Authority is to:

- Undertake routine and reactive maintenance on all roads (except the A27 and M23/A23 that are the responsibility of the Highways Agency), including associated drainage provided by gullies, drains and culverts.
- Provide advice on road and road drainage issues associated with proposed development, ensuring any impact on the road network is taken into account;
- Decide whether improvements to the transport network are needed, based on access to local facilities, and the possible effects of a development on road safety and congestion.

Environment Agency

The Environment Agency has the following roles and responsibilities as a risk management authority:

- A strategic overview of all types of flooding;

- Responsible for flood risk management on main rivers and the coast;
- A coastline erosion risk management authority, under the Flood and Water Management Act 2010;
- Responsible for Environment Agency reservoirs, and, to regulate and enforce the Reservoirs Act 1975 on other reservoirs with capacity over 10000m^3;
- Duty to be subject to scrutiny from Lead Local Flood Authorities;
- Carrying out flood risk management functions in a consistent manor with the national and local strategies, reporting to ministers on flood risk management and implementation of strategies;
- Permissive power to request information for any person in relation to flood risk management concerning Environment Agency functions;
- Permissive power to designate structures and features with flood risk significance;
- To be a statutory consultee to the Sustainable Drainage Systems Approving Body;
- To be a statutory consultee to local planning authorities on flood risk matters;
- Perform as a Category 1 responder to flood incident under the Civil Contingencies Act;
- Consent and enforce applications for works on main river;
- A duty to contribute to sustainable development through flood risk management functions.

Internal Drainage Boards

Internal Drainage Boards have the following roles and responsibilities as a risk management authority:

- Carry out maintenance work to maintain drainage;
- Use statutory powers to ensure those responsible maintain the flow of water in a watercourse and to modify or remove inappropriate structures within channels. Take the appropriate action against those who inappropriately modify the watercourse;
- Responsible for reservoirs over 10000m^3 capacity;
- Permissive power to exercise the Land Drainage Act 1991;
- A duty to contribute towards sustainable development;
- Permissive power to undertake flood risk management works;
- Undertake consenting on ordinary watercourse within their boundary;
- Be a statutory consultee on the Sustainable Drainage Systems Approving Body;
- Work alongside and together with neighbouring Internal Drainage Districts;
- Duty to be scrutinised from Lead Local Flood Authority democratic processes;
- Duty to act consistently with the Local and National Strategy;
- Permissive power to designate structures and features with flood risk significance.

Southern Water and Thames Water

Southern Water and Thames Water have the following roles and responsibilities as a risk management authority:

- Duty to adopt new build sewers;
- Manage public sewer flooding;
- Duty to subject to scrutiny from Lead Local Flood Authority democratic process;
- Duty to have regard for the National and Local Strategies;
- Perform as a Category 2 responder to flood incidents under the Civil Contingencies Act.

The District and Borough Councils (Second Tier Authorities)

The Districts and Boroughs have the following roles and responsibilities as a risk management authority:

- Permissive power to designate structures and features with flood risk significance;
- Duty to act consistently with the Local and National Strategy;
- A coastline erosion risk management authority, under the Coastal Protection Act 1949;
- Duty to be subject to scrutiny from Lead Local Flood Authority democratic process;

- Permissive power to exercise parts of the Land Drainage Act 1991 (except in an Internal Drainage District) area;
- Perform as a Category 1 responder to flood incidents under the Civil Contingencies Act 2004, including dealing with recovery and resulting homelessness;
- Perform as the local planning authority and a duty to encourage the appropriate development and promote sustainable development;
- Under delegated powers, use statutory powers to ensure those responsible maintain the flow of water in a watercourse and to modify or remove inappropriate structures within channels. Take the appropriate action against those who inappropriately modify the watercourse.

Highways Agency

The Highways Agency has the following roles and responsibilities as a risk management authority:

- Duty to have regard for the National and Local Strategies;
- Responsibility to maintain the highway trunk road network under the Highways Act (in West Sussex the A23, M23 and A27) and for these roads;
- Duty to regularly inspect and maintain highways structures;
- Permissive powers to deliver works to protect the highway from flooding (for example, draining roads into private watercourses);
- Carry out maintenance and improvement works to maintain existing standards of protection for highways;
- A duty to contribute towards sustainable development.

Other Stakeholders

While not designated flood risk authorities, stakeholders such as infrastructure providers, riparian owners, parishes and residents have a key part to play in flood risk management.

Utility and infrastructure providers

While not risk management authorities, utility companies play an important role in flood risk management. Many assets of utility companies are in areas prone to flooding. Ensuring that the service the company provides is resilient to flooding can save the company money in the long term, so flooding is an important factor in investment and planning. Companies can achieve savings if they contribute to partnership schemes. This approach provides mutual benefit for those involved and ensures services for the public and businesses are more resilient.

Riparian Owners

Home or business owners that live close to a river or ditch are likely to be riparian owners with maintenance rights and responsibilities. If the watercourse borders the property it is normal for the boundary of responsibility to extend to half way across the channel. Maintenance responsibilities include keeping the channel clear of obstructions, and maintaining a free flow of water in the watercourse. Land drainage management and maintenance is vital to ensuring that surface water is adequately managed across the county.

The key message to riparian owners is, you must let water flow through your land without any obstruction that may affect the rights of others. Importantly, you should keep the banks and bed of the ditch clear of anything that could cause an obstruction and increase flood risk. More details can be found on the West Sussex County Council or Environment Agency websites by searching for ‘riparian ownership’. The Environment Agency’s ‘Living on the Edge’ document provides a full guide and is available online.

Risk management authorities take every opportunity to communicate publically about riparian responsibilities. The Parish and Town Councils can play a key role in supporting local knowledge and communicating the rights and responsibilities to communities. If you have a watercourse within your

property boundary, such as river, brook, beck, ditch, mill stream or culvert, and are unsure on its maintenance please seek advice via the Living on the Edge document. Full contact details are available should you wish to speak to an advisor.

Any works to construct in or over a watercourse or alter the channel may require Ordinary Watercourse Consent. Please contact your local District or Borough Council for more information, or visit the West Sussex County Council website.

Parish and Town Councils

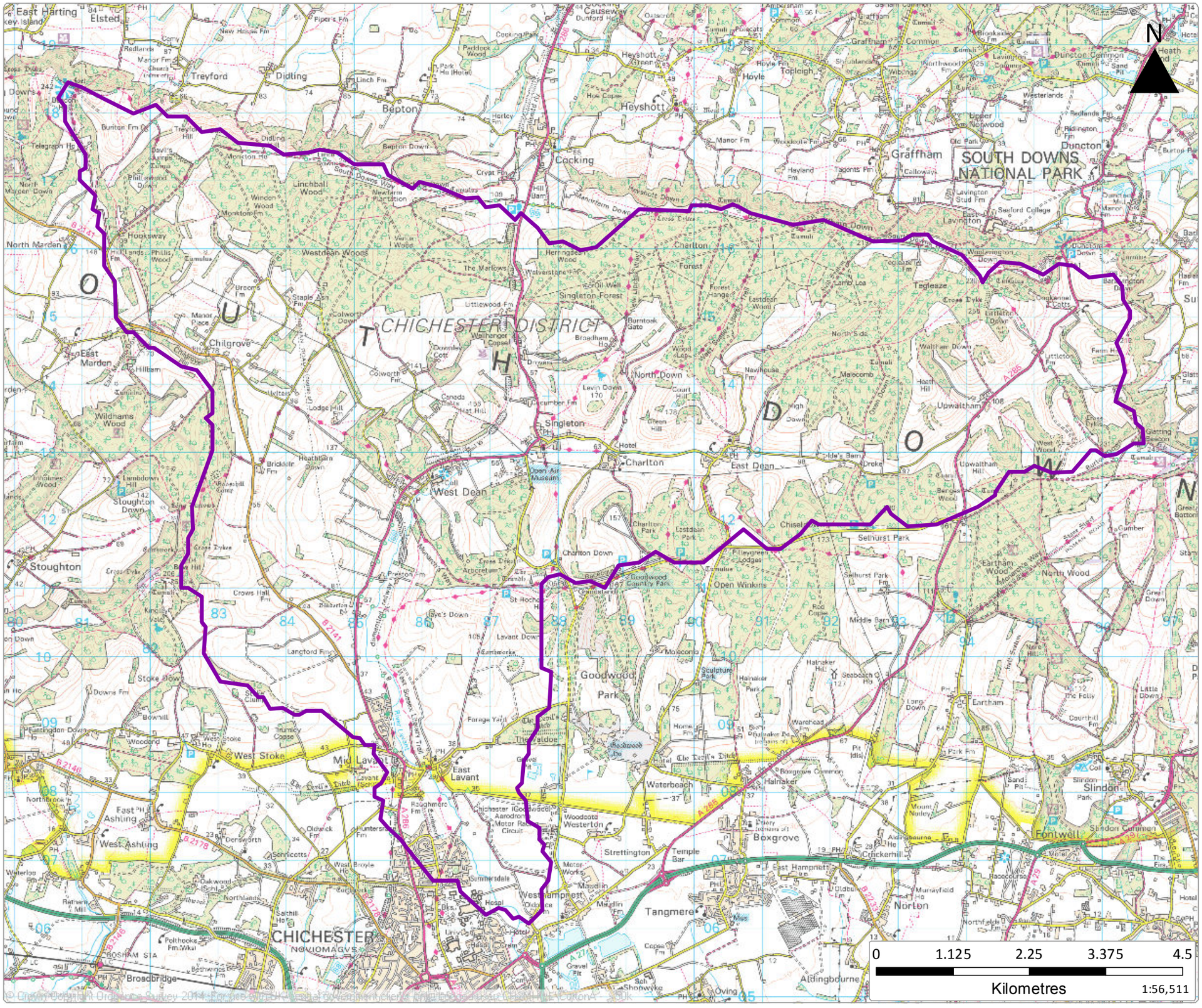
Town and Parish Councils can make a significant contribution before and during a flood event. Coordinated assistance can be critical in supporting local residents and in providing the shelter for neighbours who have experienced flooding. Parish and Town Council members can also play a crucial role in the dissemination of flood alerts and flood warnings, as they have the local knowledge of the community. This local knowledge can also be used to inform the District or Borough Council or County Council about sources of flooding.

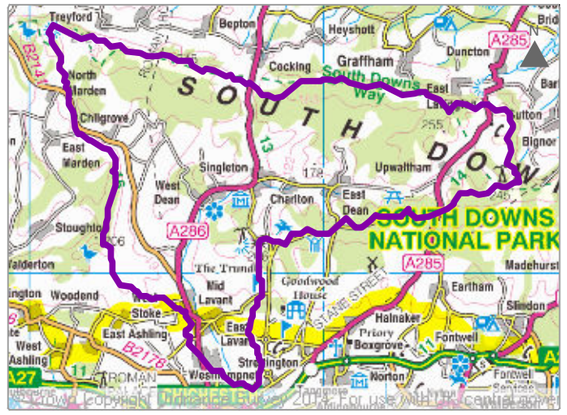
An affective Parish or Town Council will have an emergency plan, and an agreed process in place to react to a natural disaster. For more information please contact your District or Borough Emergency Planning Officer who will be able to provide guidance. For other advice please contact the West Sussex County Council Community and Economic Development Team (please see page 60 for areas covered) who will direct your query to the appropriate lead officer.

Property owners and residents

It is home owners and business owner's responsibility to protect their property from risks, including flood water protection. It's impossible to completely flood-proof a property but there are lots of things that can be done to reduce flood damage. More details can be found on the Environment Agency website by searching for 'prepare your property for flooding'.

Lavant SWMP





Legend

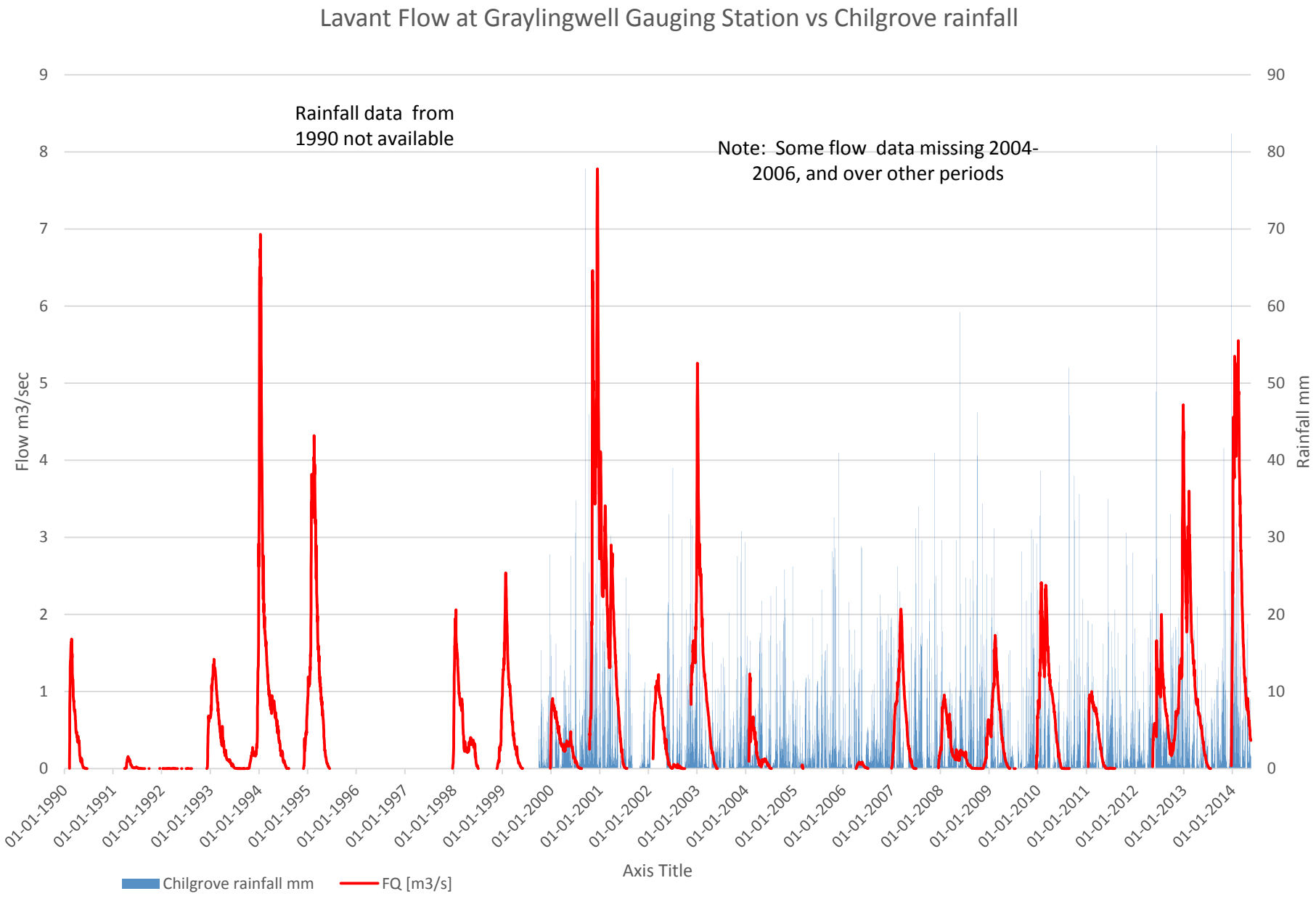
Lavant Study Boundary

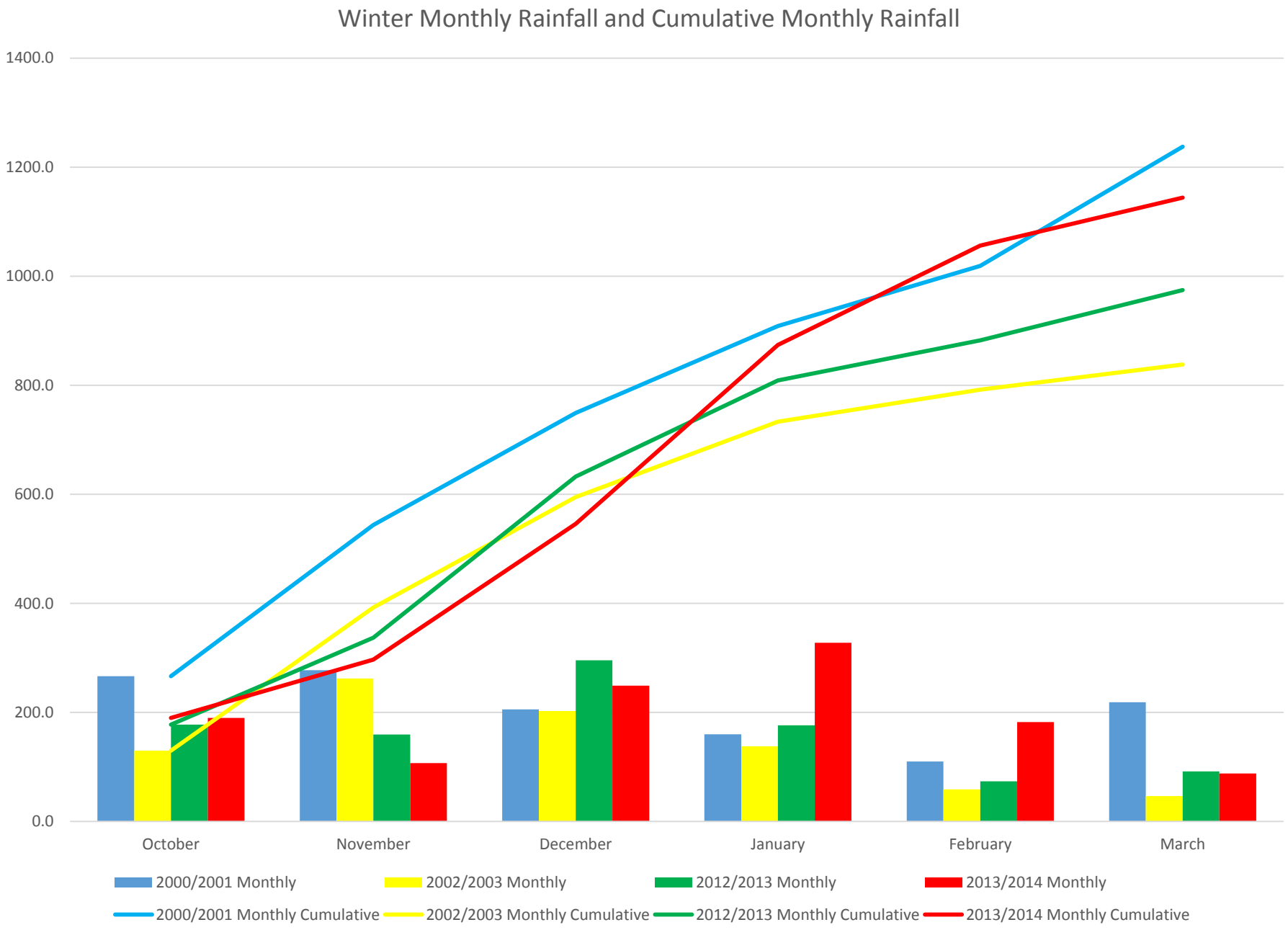
Upper Lavant Study Boundary

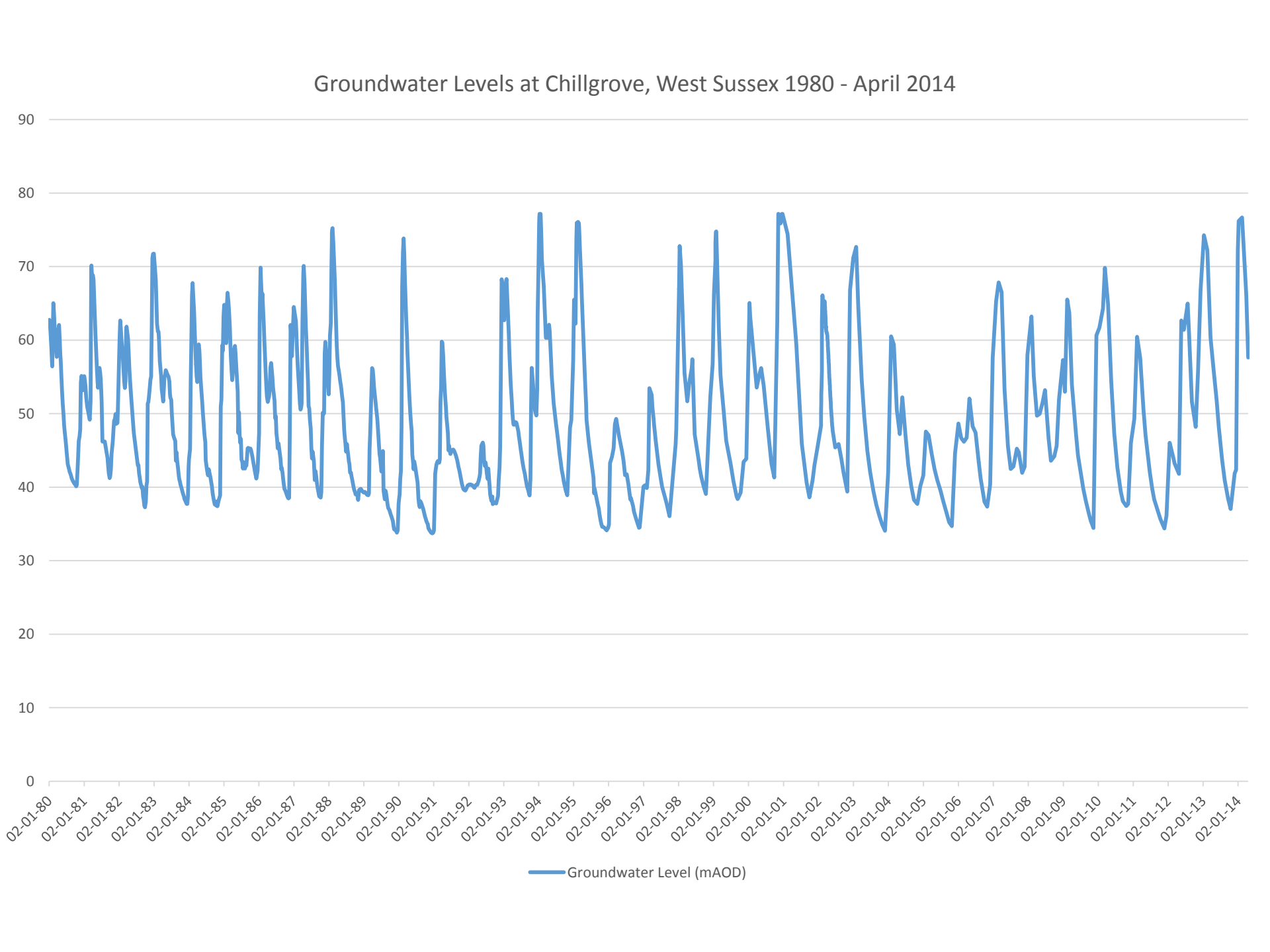
CH2MHILL.

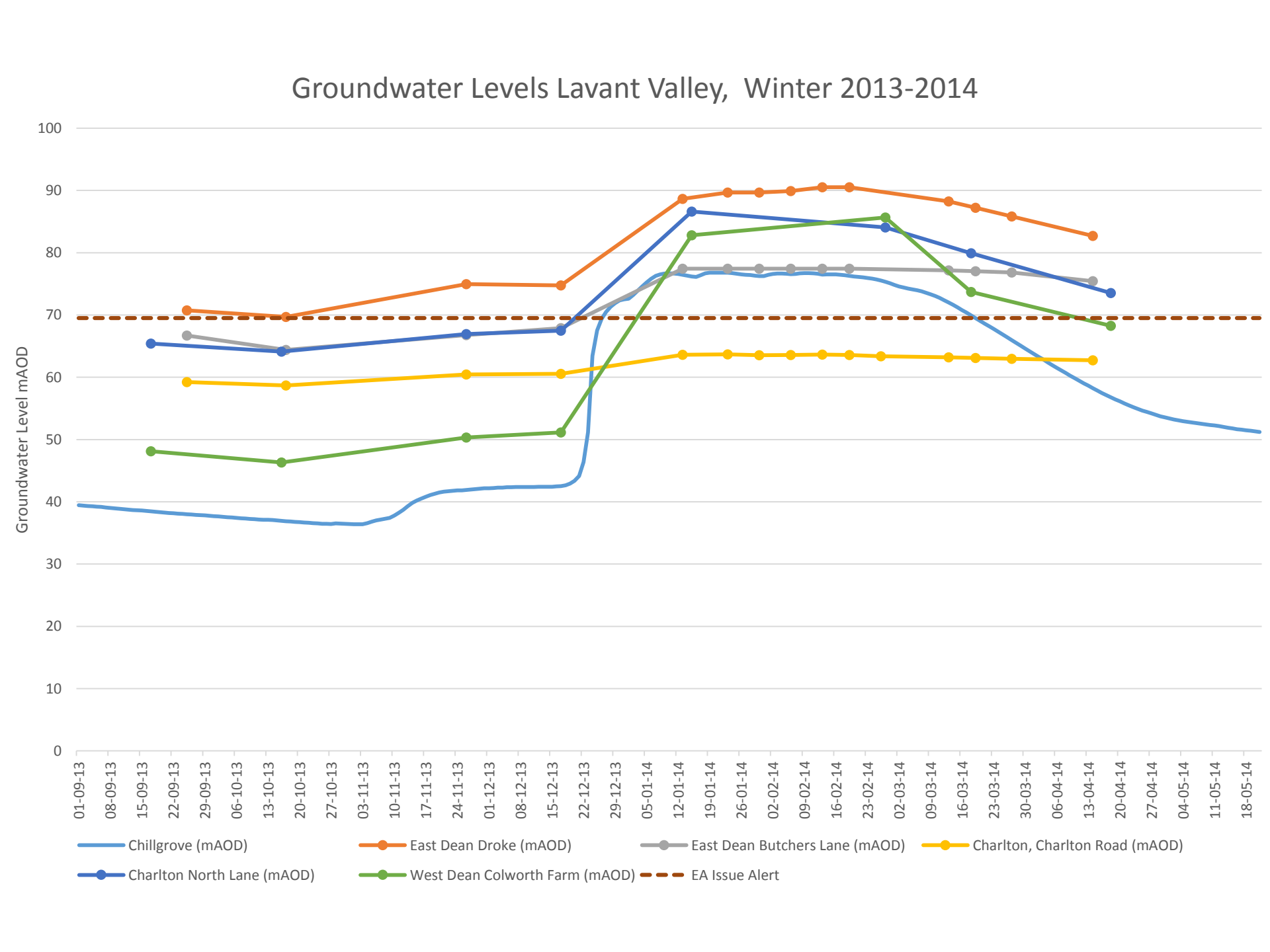
Created by: Lizzie Shipman (09-Sep-14)
Checked by: Ali Cotton (09-Sep-14)

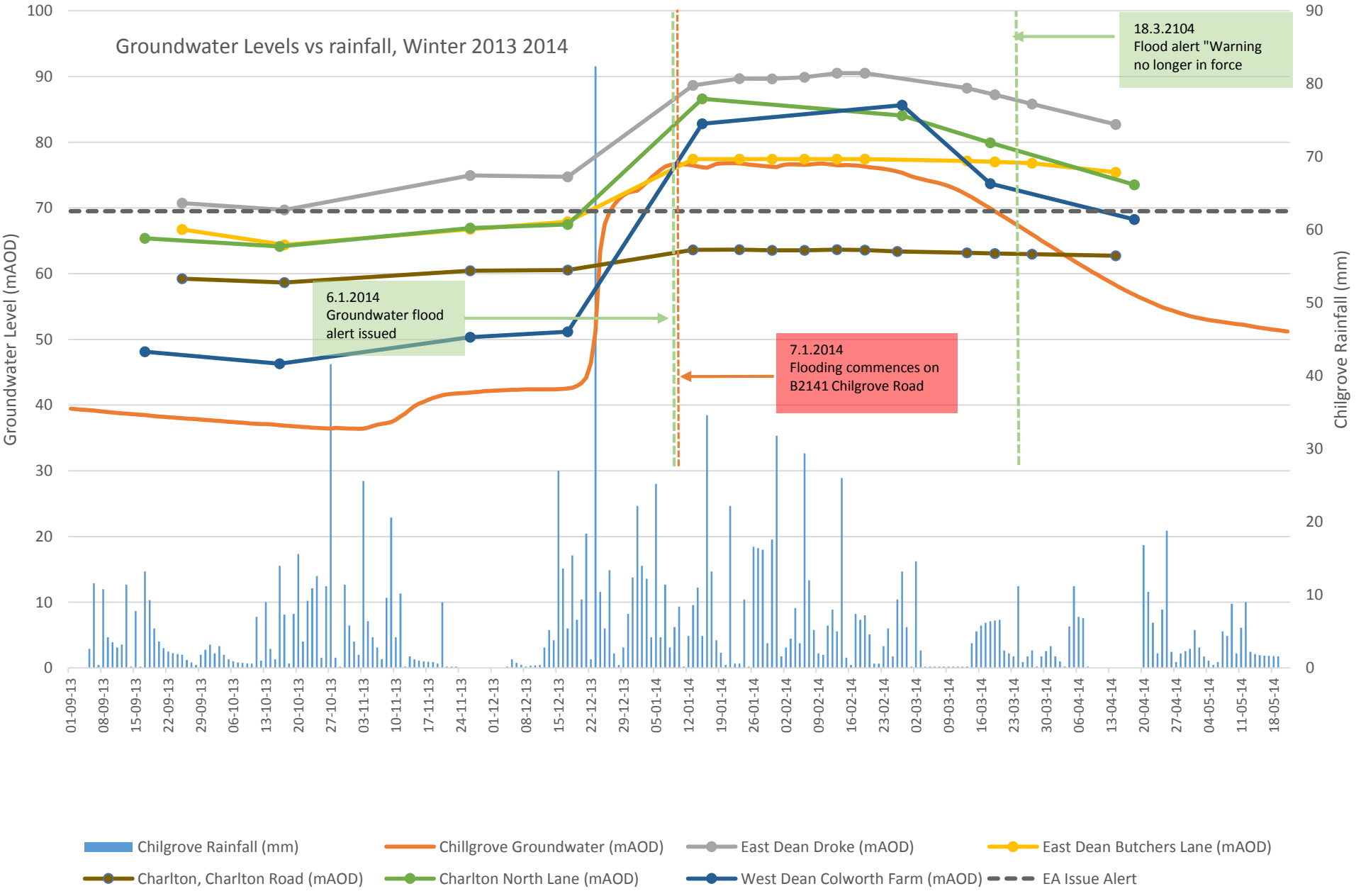
Document Path: \\swin-fs-05\Water\we\Urban Water Market Sectors\Urban Water UK\Projects\West Sussex SWMP framework\Lavant SWMP\GIS\MasterGIS_Lavant.mxd

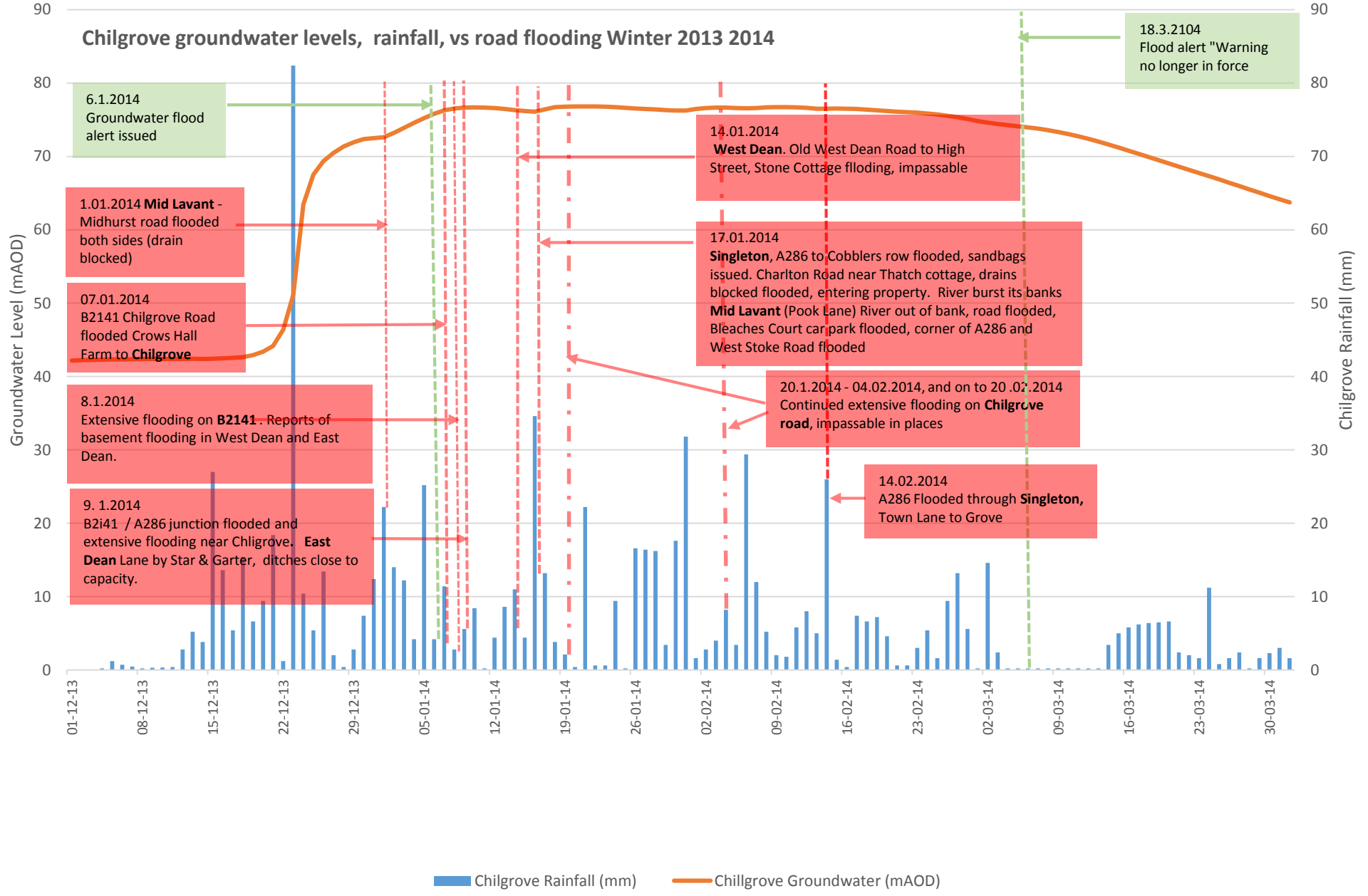

Lavant Flow at Graylingwell Gauging Station vs Chilgrove rainfall
Rainfall data from 1990 not available
Note: Some flow data missing 2004-2006, and over other periods
Flow m3/sec
Rainfall mm
Axis Title
Chilgrove rainfall mm
FQ [m3/s]
0
1
2
3
4
5
6
7
8
9
10
20
30
40
50
60
70
80
90
01-01-1990
01-01-1991
01-01-1992
01-01-1993
01-01-1994
01-01-1995
01-01-1996
01-01-1997
01-01-1998
01-01-1999
01-01-2000
01-01-2001
01-01-2002
01-01-2003
01-01-2004
01-01-2005
01-01-2006
01-01-2007
01-01-2008
01-01-2009
01-01-2010
01-01-2011
01-01-2012
01-01-2013
01-01-2014

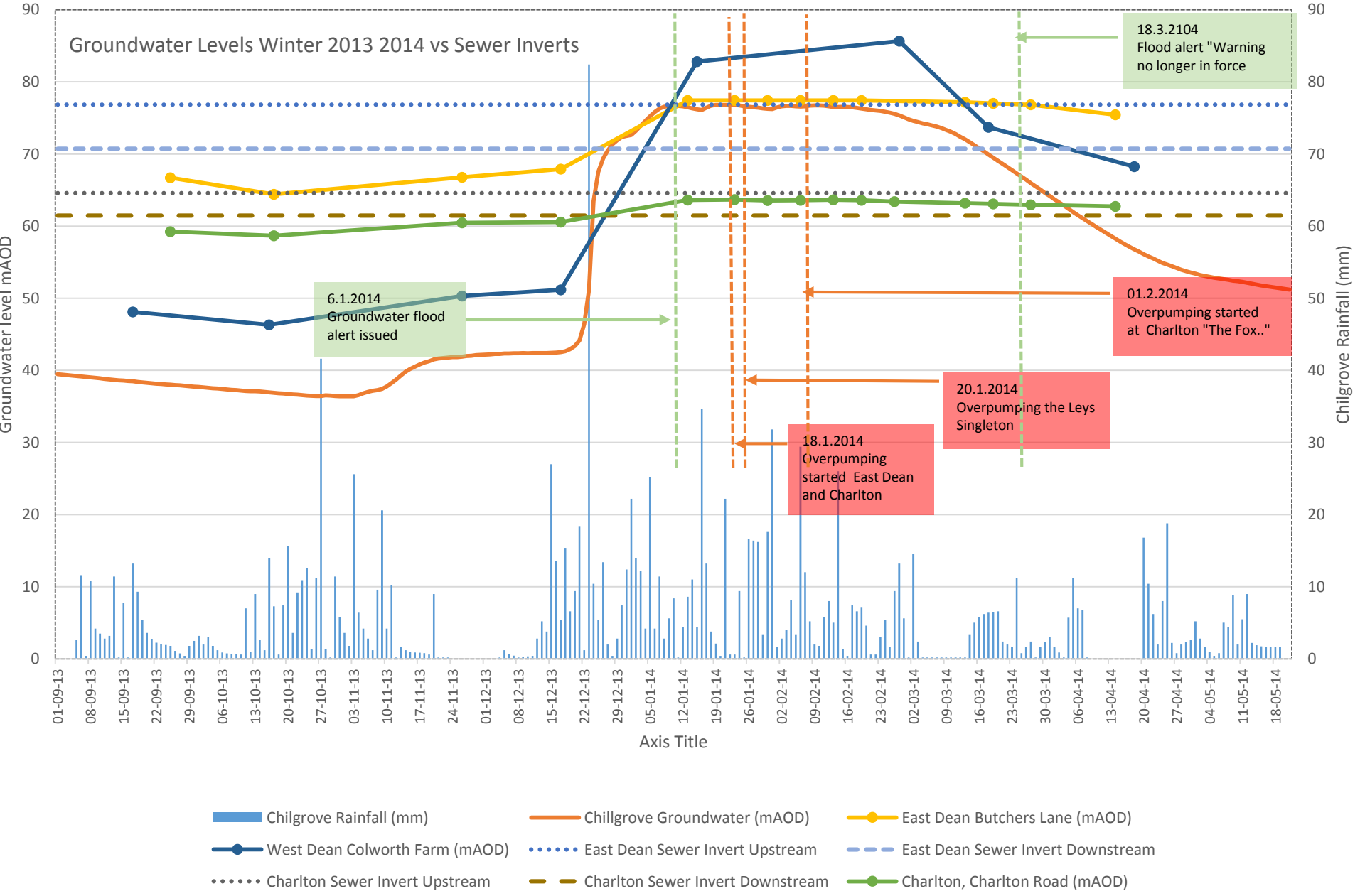

Winter Monthly Rainfall and Cumulative Monthly Rainfall
1400.0
1200.0
1000.0
800.0
600.0
400.0
200.0
0.0
October
November
December
January
February
March
2000/2001 Monthly
2002/2003 Monthly
2012/2013 Monthly
2013/2014 Monthly
2000/2001 Monthly Cumulative
2002/2003 Monthly Cumulative
2012/2013 Monthly Cumulative
2013/2014 Monthly Cumulative


Groundwater Levels at Chillgrove, West Sussex 1980 - April 2014
90
80
70
60
50
40
30
20
10
0
02-01-80
02-01-81
02-01-82
02-01-83
02-01-84
02-01-85
02-01-86
02-01-87
02-01-88
02-01-89
02-01-90
02-01-91
02-01-92
02-01-93
02-01-94
02-01-95
02-01-96
02-01-97
02-01-98
02-01-99
02-01-00
02-01-01
02-01-02
02-01-03
02-01-04
02-01-05
02-01-06
02-01-07
02-01-08
02-01-09
02-01-10
02-01-11
02-01-12
02-01-13
02-01-14
Groundwater Level (mAOD)


Groundwater Levels Lavant Valley, Winter 2013-2014
Groundwater Level mAOD
100
90
80
70
60
50
40
30
20
10
0
01-09-13
08-09-13
15-09-13
22-09-13
29-09-13
06-10-13
13-10-13
20-10-13
27-10-13
03-11-13
10-11-13
17-11-13
24-11-13
01-12-13
08-12-13
15-12-13
22-12-13
29-12-13
05-01-14
12-01-14
19-01-14
26-01-14
02-02-14
09-02-14
16-02-14
23-02-14
02-03-14
09-03-14
16-03-14
23-03-14
30-03-14
06-04-14
13-04-14
20-04-14
27-04-14
04-05-14
11-05-14
18-05-14
Chillgrove (mAOD)
East Dean Droke (mAOD)
East Dean Butchers Lane (mAOD)
Charlton, Charlton Road (mAOD)
Charlton North Lane (mAOD)
West Dean Colworth Farm (mAOD)
EA Issue Alert


Groundwater Levels vs rainfall, Winter 2013 2014
Groundwater Level (mAOD)
Chilgrove Rainfall (mm)
18.3.2104
Flood alert "Warning no longer in force
6.1.2014
Groundwater flood alert issued
7.1.2014
Flooding commences on B2141 Chilgrove Road
01-09-13
08-09-13
15-09-13
22-09-13
29-09-13
06-10-13
13-10-13
20-10-13
27-10-13
03-11-13
10-11-13
17-11-13
24-11-13
01-12-13
08-12-13
15-12-13
22-12-13
29-12-13
05-01-14
12-01-14
19-01-14
26-01-14
02-02-14
09-02-14
16-02-14
23-02-14
02-03-14
09-03-14
16-03-14
23-03-14
30-03-14
06-04-14
13-04-14
20-04-14
27-04-14
04-05-14
11-05-14
18-05-14
Chilgrove Rainfall (mm)
Chillgrove Groundwater (mAOD)
East Dean Droke (mAOD)
East Dean Butchers Lane (mAOD)
Charlton, Charlton Road (mAOD)
Charlton North Lane (mAOD)
West Dean Colworth Farm (mAOD)
EA Issue Alert


Chilgrove groundwater levels, rainfall, vs road flooding Winter 2013 2014
Groundwater Level (mAOD)
Chilgrove Rainfall (mm)
90
80
70
60
50
40
30
20
10
0
01-12-13
08-12-13
15-12-13
22-12-13
29-12-13
05-01-14
12-01-14
19-01-14
26-01-14
02-02-14
09-02-14
16-02-14
23-02-14
02-03-14
09-03-14
16-03-14
23-03-14
30-03-14
6.1.2014
Groundwater flood alert issued
18.3.2104
Flood alert "Warning no longer in force
14.01.2014
West Dean. Old West Dean Road to High Street, Stone Cottage flloding, impassable
1.01.2014 Mid Lavant - Midhurst road flooded both sides (drain blocked)
17.01.2014
Singleton, A286 to Cobblers row flooded, sandbags issued. Charlton Road near Thatch cottage, drains blocked flooded, entering property. River burst its banks Mid Lavant (Pook Lane) River out of bank, road flooded, Bleaches Court car park flooded, corner of A286 and West Stoke Road flooded
07.01.2014
B2141 Chilgrove Road flooded Crows Hall Farm to Chilgrove
20.1.2014 - 04.02.2014, and on to 20 .02.2014
Continued extensive flooding on Chilgrove road, impassable in places
8.1.2014
Extensive flooding on B2141 . Reports of basement flooding in West Dean and East Dean.
14.02.2014
A286 Flooded through Singleton, Town Lane to Grove
9. 1.2014
B2i41 / A286 junction flooded and extensive flooding near Chligrove. East Dean Lane by Star & Garter, ditches close to capacity.
Chilgrove Rainfall (mm)
Chillgrove Groundwater (mAOD)


Groundwater Levels Winter 2013 2014 vs Sewer Inverts
Groundwater level mAOD
Chilgrove Rainfall (mm)
Axis Title
18.3.2104
Flood alert "Warning no longer in force
6.1.2014
Groundwater flood alert issued
01.2.2014
Overpumping started at Charlton "The Fox.."
20.1.2014
Overpumping the Leys Singleton
18.1.2014
Overpumping started East Dean and Charlton
Chilgrove Rainfall (mm)
Chillgrove Groundwater (mAOD)
East Dean Butchers Lane (mAOD)
West Dean Colworth Farm (mAOD)
East Dean Sewer Invert Upstream
East Dean Sewer Invert Downstream
Charlton Sewer Invert Upstream
Charlton Sewer Invert Downstream
Charlton, Charlton Road (mAOD)

Lavant SWMP – Technical analysis of flooding in the Lavant study area

1 Introduction

1.1 Background

Villages along the Upper Lavant Valley Body (East Dean, Charlton, Singleton, West Dean); the road to Chilgrove (B2141) including Chilgrove village itself, and parts of Mid Lavant and East Lavant are susceptible to a number of flooding incidents caused by high groundwater levels within the permeable chalk catchment.

Typically the effects of groundwater flooding in the catchment are as follows:

(i) Enhanced flows in the ephemeral parts of the catchment (i.e. along the winterbournes), which may exceed bank capacity and lead to fluvial flooding events, causing both widespread road flooding and some property flooding.

(ii) Significant infiltration into the foul sewer network causing sewer flooding. Surcharged sewers prevent toilets flushing, require pumping to tanker or overpumping into the River Lavant and may lead to flows of foul water along roads.

(iii) Some, but not extensive, direct groundwater flooding caused by emergence beneath houses (e.g. in Singleton and East Dean).

Flooding in the lower parts of the valley in Mid Lavant and East Lavant is primarily fluvial in nature, although there appears to be a fairly consistent relationship between groundwater levels in the upper parts of the catchment (i.e. as monitored at Chilgrove) and flows in the river recorded at Graylingwell gauging station (see further below).

1.2 Objectives

The purpose of this technical note is to describe, where possible, relationships that can established between records of groundwater level, river flow monitoring and other monitored parameters (such as rainfall) and the occurrence of these different types of flooding. Further, to use these relationships to evaluate a refinement in the use of trigger levels to prompt actions that may be taken to ameliorate the impacts of flooding within the Lavant valley.

2 Data Collection and Collation

2.1 Data Sources

a) Environment Agency.

(i) Groundwater level data

Groundwater level data was provided for a number of Environment Agency monitoring (observation) wells in and around the Lavant valley, as shown in Figure 1 and as described in Table 1 below:

TABLE 1
Groundwater Level Monitoring Locations

Location (NGR)	Available Data Record (period/ frequency)	Comment
Chilgrove House (SU 8352 1438)	1999 - 21 May 2014 Daily	Longest continual groundwater level record in the UK (since 1835). Records from 1980, better than weekly, daily level data from 1999.

TABLE 1
Groundwater Level Monitoring Locations

Location (NGR)	**Available Data Record (period/ frequency)**	**Comment**
		Used as basis for trigger levels for existing groundwater flood alert service (see below).
East Dean - Droke (SU 9246 1275)	1976 – 14 April 2014 Monthly	Monthly record, increased frequency (circa weekly) for period 13.1.2014- 27.3.2014 and Nov- Dec 2000. Up gradient (circa 1.75 km) from East Dean, not wholly representative of groundwater levels in East Dean village but indicative of potential flow at the eastern source of the Lavant river.
East Dean - Butchers Lane (SU 9062 1286)	1982 - April .2014	Data frequency very variable, artesian through Jan 2014. Datum change July 2003, levels used in analysis post July 2003. At eastern end of village within 500m of main part of village, so representative of groundwater levels within the village and good groundwater level indicator for East Dean. Increased monitoring only appears to have been undertaken when artesian conditions already occurred – may not be wholly appropriate for setting trigger levels
Charlton - North Lane (SU 8948 1448)	1982 – April 2014	Approximately every 2 months, occasionally monthly. Some higher frequency readings though these not obviously related to high groundwater level periods. This data may represent a good indicator of up catchment groundwater levels (similar to those at Chilgrove).
Charlton - Charlton Road (SU 88690 13020)	1981- April 2014	Approximately every 2 months, occasionally monthly. Some higher frequency readings e.g. winters 1994/5, 2000/01, 2002/03, 2010. Increase frequency through Feb 2014 but still some gaps in data. Located down gradient of Charlton, just on village boundary hence good groundwater level indicator for Charlton – may not be wholly appropriate for trigger levels.
West Dean - Colworth Farm (SU 8527 1516)	1982 – April 2014	Monthly record. No increased frequency during high groundwater level periods. Too far (>1.25km and "up valley") from village to be of great value in assessing conditions within West Dean and with the given frequency of monitoring
Graylingwell Farm (SU8706 0643)	1995- April 2014	Very variable record frequency, circa monthly 2000 to 2008, more frequent during winter 2000/01, low frequency during winter 2013/14. Too far down gradient from upper Lavant valley to be of value in setting thresholds and trigger levels, though may be used to compare d/stream Lavant flows with d/stream groundwater levels. Groundwater logger data (daily) is also available for the period October 2010 – 13 January 2014

(ii) Stream flow continuous gauging data

Graylingwell Gauging Station (NGR SU 87062 06450) provides flow data (daily, 3.12.1970 - 19.5.2014) downstream on the Lavant. This provides flow being derived from the wider total upstream catchment.

Stream flow – spot gauging data

Spot gauging data is available at 5 locations in the catchment (from Chilgrove to East Lavant) for the period 2006- 2011, as shown in Table 2 below:

TABLE 2
Spot river gauging locations

Site name	Location NGR	Period
Singleton Cricket	SU 8756 1309	Mar 2006-May 2011
Preston Farm	SU 8547 1112	Mar 2006- May 2008
Chilgrove Stream Confluence	SU 8547 0985	May 2006- July 2011
Lavant Old Railway Bridge	SU 8536 0994	Apr 2006-Jul 2011
Sheepwash Lane	SU 8591 0840	Jan 2010- July 2011

This monitoring occurs over periods of relatively low flow in the Lavant which does not cover any peak flow periods and therefore does not provide useful information for this study.

(iii) Rainfall Data

Daily rainfall data (from a tipping bucket rain gauge) was provided for Chilgrove House for the period October 1999 – 19 May 2014.

(iv) Groundwater Briefing Notes, Flood Alert and Warning Area Areas

Information on current groundwater briefing notes is found at:

https://www.gov.uk/government/collections/groundwater-current-status-and-flood-risk

The Environment Agency also publish the groundwater levels recorded at Chilgrove house (see above) at:

https://www.gov.uk/government/publications/weekly-water-levels-hampshire-west-sussex-and-isle-of-wight

Information on Groundwater Flood Alert and Flood Warning areas is available on the Environment Agency website (in particular What's in your backyard? or "WIYBY").

There is a (fluvial) Flood Warning Area established for:

"The River Lavant at Mid Lavant and East Lavant"

This warning area extends from the Portsmouth Water water works (approximately NGR SU 8530 0979) downstream to the North east of Chichester at Graylingwell Farm Gauging Station (approximately NGR SU 8706 0643) where a further Flood Warning Area commences.

No formal river "Flood warning" is issued for the Upper Lavant catchment, although a Groundwater Flood Alert Area has been established for: *"Communities at risk from groundwater flooding to the north of Chichester including West Dean , Singleton, Charlton, East Dean and Chilgrove"*

Recent flood warning issues from EA website, are as follows (note that the web site only reports the most recent issued warnings, it is presumed that flood warnings were issued prior to 6 February 2014):

TABLE 3

Flood Warnings and Flood Alerts

Warning type	Target Area Name	Issued	Warning No Longer in Force
Briefing Note	Groundwater briefing note for Sussex	27/12/2013	26/04/2014

TABLE 3

Flood Warnings and Flood Alerts

Warning type	Target Area Name	Issued	Warning No Longer in Force
Flood Alert	Groundwater flooding in West Dean, Singleton, Charlton, East Dean and Chilgrove	06/01/2014	18/03/2014
Flood Warning	Mid and East Lavant	06/02/2014	09/02/2014
Flood Warning	Mid and East Lavant	14/02/2014	15/02/2014

Note: The issue dates are also identified in the WSCC emergency Incident log over this period. Note that only "Flood Alerts" and not "Flood Warnings" are issued for areas affected by groundwater as these terms have specific meanings in the Environment Agency hierarchy of flood warning information.

A similar alert is issued to an adjacent catchment (Finchdean and Dean Lane End) in the Chalk of Hampshire. It is notable that despite its proximity (circa 12 km due west of West Dean) that the alert (for 2014) in Finchdean was issued around the same time (07.1.2014), but stayed in force for a longer period, until 03.04.2014 (i.e. groundwater levels remained elevated in that neighbouring catchment for about 2 weeks longer). This suggests that this catchment (The "Hampshire Lavant) drains considerably more slowly than the Lavant and demonstrates how groundwater flood alerts must be tailored to the individual chalk catchment. Notably groundwater flooding in the Finchdean and Dean Lane End area is consistently more widespread and damaging than contemporaneous events in the Lavant valley.

The Environment Agency also provided some information on flood calls they received directly during January to February 2014.

(v) Current Trigger levels

Discussions with the EA have indicated that they set alarm thresholds (trigger levels) at Chilgrove borehole as follows[1]:

Threshold	Status	Comments (EA commentary)
H1 (High 1)	57mAOD - consider issuing groundwater briefing note	River Lavant flowing/rising groundwater levels
H2 (High 2)	67mAOD- consider issuing groundwater briefing note	Groundwater levels becoming more significant
H3 (High 3)	69.5mAOD - consider issuing groundwater flood alert	Significant rainfall with groundwater levels above 69.5mAOD is more likely to cause flooding (fluvial, and groundwater). Stay vigilant
H4 (High 4)	72.85mAOD - consider fluvial actions through Chichester	Groundwater levels high, nearing surface, if not already disruption

b) WSCC Emergency Planning and Highways.

Flood incident logs (groundwater and severe weather) and traffic incident logs were obtained from WSCC for the winter of 2012/13 and 2013/2014. These have been used to help build a timeline analysis of flood incident through the winter that can be related to recorded groundwater levels and other hydrological and climatic data.

[1] Richard Eastaff (Environment Agency), *pers. comm.*

c) Southern Water Sewer Network Data.

Mapping of the Southern Water foul sewer network was provided by Southern Water as GIS files. This provides, for example, details of pipe sizes, manholes locations and upstream/ downstream invert levels. We also received details of dates and locations of overpumping and tankering within the catchment from Southern Water and the EA. Furthermore, during the period of this study Southern Water issued their draft Infiltration Reduction Plan which identifies their proposals to reduce infiltration into the sewer network in the Upper Lavant catchment. As part of their IRP Southern Water will be developing location-specific action plans, but these were not completed at the time of this report being published.

2.2 Data Coverage

a) Data availability

In broad terms, sufficient data are available to analyse the relationship between groundwater levels and flooding incidents recorded during 2013/2014. However, although groundwater level, river flow and rainfall data is available for earlier years wherein groundwater related flood issues were encountered (including, for example the winters of 2012/2013; 2006/2007; 2002/2003; 2000/2001; 1993/94) there is little available recorded incident data to allow correlation between this hydrological data and actual flood events. The focus of this analysis has therefore been the winter of 2013/14.

b) Data quality

The quality of the hydrological data is mostly very good, particularly the continuously logged groundwater and rainfall data from Chilgrove and the (similarly logged) data for surface water flow at Graylingwell. In some locations there are issues regarding changing measuring datums, although in general terms these were not prevalent in the winter 2013/2014 data that was subjected to the most detailed analysis. Although there are a number of data gaps (see Table 1) and the frequency of observations in some locations is relatively poor, the overall hydrological picture can be evaluated.

The data from the flood incident recording is reasonable for 2013/2014, although more details of the type of flooding would be an improvement. This may be a reflection of the relatively few numbers of properties that were flooded, however it is not wholly clear (if and) when road closures or traffic management measures were introduced. The data from Southern Water was limited to the sewer mapping and some information derived from their draft IRP which although provided some detail (tankering and overpumping locations) did not provide either timescales of implementation (e.g. when tankering started/stopped) or the extent of these operations (e.g. frequency of tanker visits). The dates of overpumping were provided by the Environment Agency.

c) Extent of data cover

The geographical spread of data was sufficient to allow analysis of flood conditions throughout the study area.

3 Data Analysis

3.1 Results and data plots

Timeseries data were converted into spreadsheet format, the data cleaned and used to develop a number of charts as follows:

- Graylingwell flows vs rainfall and vs Chilgrove groundwater levels
- Chilgrove Rainfall vs groundwater levels
- Groundwater Levels vs recorded flood events
- Groundwater Level vs sewer Inverts
- Groundwater Level vs Highways management and other emergency actions
- Groundwater – rate of rise at Chilgrove for the most extreme winters
- Monthly rainfall and cumulative rainfall

3.2 Analysis and evaluation

(a) Rainfall and Surface flow analysis

Figure 2 is a graph of daily river flow data from 1990 to May 2014, with rainfall data from 1999. Although this data set is incomplete, with periodic gaps it does demonstrate that:

- winter 2013/2014 flows were not as extreme as winter 2000/2001 or winter 1994, and only marginally above winter 2003;
- the peak flow in winter 2013/2014 occurred on 14 February 2014, although there was a rapid rise in flow over the period 25 December 2013 to 19 January 2014, when the flow increased from 0.345 to 5.35 m^3/sec which was a fifteen fold increase in just 25 days and a reflection of the prolonged high rainfall, and in particular a response to the high rainfall day of 23 December;
- there appears to be a moderate correlation of winter rainfall with streamflow response, although there is a generally a lag time between "down catchment" flow response at Graylingwell and rainfall at Chilgrove, and;
- this buffering of rainfall response is typical of chalk catchments due to recharge of the aquifer, however, notably the lag time appears to depend upon antecedent groundwater conditions (see Box 1 below).The change in time lag between rainfall and down catchment flow appears to be a reflection of the "saturated" nature of the chalk catchment when "buffering" of rainfall by recharge of the chalk becomes less prominent and a more direct response to rainfall occurs in the catchment and is supported by the work of others in the area (see Box 2 below)

(b) Cumulative rainfall

On the basis of the above, the buffering capacity of the Chalk and the antecedent groundwater conditions has a significant influence on the occurrence of groundwater flooding. Further, this suggests that it is not single rainfall events but the cumulative rainfall that have the greatest impact on the occurrence of groundwater flooding. Table 5 and Figure 3 provide a comparison the monthly and cumulative monthly rainfall for a 6 monthly period over 4 wet winters (amongst the wettest on record).

Box 1

The **lag time** between rainfall (at Chilgrove) and down catchment flow response in the River Lavant depends upon antecedent conditions in the aquifer. This can be demonstrated by different events in winter 2012/2013 and winter 2013/2014:

After 7 days of rain (totaling 158mm) on 16-22 December 2012, peak flow (4.74m^3/sec) was measured 6 days later on 28 December. Over this period, already high groundwater levels at Chilgrove rose from 63.5mAOD to 71.4 mAOD.

In a similar period in December 2013 (16-22), the 7 day rainfall of 70mm was followed by a huge rainfall event (82mm) on 23 December. However, despite similar total rainfall over the period, the "first" peak flow following this event did not occur until 8 January 2014, some 16 days later. However antecedent groundwater levels were initially much lower (42.5 mAOD on 16 December) and it appears that significant buffering of the rainfall occurred as recharge into groundwater storage in the catchment took place. Groundwater levels increased to 46.4mAOD to 22 December then rose at unprecedented rates from 51.5 mAOD on 23 December to 70.5 mAOD by 27 December, as recharge was absorbed into groundwater storage.

The groundwater levels then remained high, at or near artesian conditions at Chilgrove (76.8mAOD) - until around 17 February 2014. Over this period, the lag between significant rainfall events (nominally over 20mm /day) and down catchment flow was much lesser, as little as 1-2 days.

TABLE 5
Monthly Rainfall Totals
Wet "winter" comparison of monthly and [monthly cumulative] rainfall (mm)

Month	2000/2001		2002/2003		2012/2013		2013/2014	
	month	monthly cumulative	month	monthly cumulative	month	monthly cumulative	month	monthly cumulative
October	266.3	266.3	130.0	130.0	177.5	177.5	189.8	189.8
November	277.4	543.7	262.4	392.4	159.4	336.9	107.0	296.7
December	205.5	749.2	202.7	595.1	295.6	632.5	249.2	545.9
January	159.7	908.9	138.0	733.1	176.5	808.9	327.9	873.8
February	110.1	1019.0	58.7	791.8	73.7	882.6	182.2	1056.0
March	218.6	1237.6	46.4	838.2	91.8	974.4	88.2	1144.2
Oct- Dec	749.2		595.1		632.5		545.9	
Oct- Mar	1237.6		838.2		974.4		1144.2	

Note: Rainfall Oct- Dec 1993 was 420mm, with a further 190 mm falling January 1994. The 1961-1990 Average for the same period is 280mm.

Of note is the following:

- overall the "winter" of 2001/2002 is by far the wettest, particularly over the autumn period;
- January 2013/2014 was the single wettest month;
- cumulatively, 2001/2002 was the wettest for most of the period, except for cumulative rainfall in February (wettest 2013/2014), and;
- 2013/2014 shows the most rapid rise in cumulative rainfall.

In part, these rainfall data explain the different nature of the significant groundwater flooding incidents in 2001/2002 and 2013/2014; the former extensive and drawn out, the latter occurring much more rapidly, but lasting over a shorter period. This is also reflected in recorded groundwater levels (see below).

Previous studies (Taylor 1994) suggest that when groundwater levels at Chilgrove reach 69.5 mAOD (the threshold used by the Environment Agency to issue groundwater flood alerts) the chalk catchment response changes from the more typical "buffered" response to the more flashy, near direct runoff response experienced. This is accompanied by a rapid rise of groundwater levels throughout the catchment and increased sensitivity of all areas to flooding following large storms.

(c) Groundwater Level Analysis

As noted above, the Chilgrove data provide a very full record with daily data logger information available from June 1999. This data forms the basis of most of the analyses carried out. The data record and well hydrograph from Chilgrove from 1980 is shown on Figure 4.

Of note is the following:

- the "winter" of 2001/2002 has the highest recorded levels for longest duration;
- the winter of 1993/94 also had very high groundwater levels, and;
- all the wet winters identified above have correspondingly high groundwater levels.

To assist in developing an understanding of groundwater flooding events in the winter of 2013/ 2014, groundwater data from additional (manually recorded) monitoring boreholes in the Lavant valley were also

analysed. The well hydrographs for these monitoring points are given on Figure 5. Other than Chilgrove, only monitoring at Charlton (Charlton Lane) and East Dean (Droke and Butchers Lane) has sufficient sampling frequency to see how groundwater levels behaved over the winter. Even in these the frequency of monitoring (approximately weekly from the beginning of January) was insufficient to capture the extraordinarily rapid rise of groundwater in the catchment during late December, evident from the Chilgrove record. The graph also identifies the levels at which the Chilgrove borehole becomes artesian (77.18mAOD) and the level at which the Environment Agency "consider issuing groundwater flood alerts (69.5 mAOD).

There are a number of observations (allowing for the different frequency of the records) that may be made:

- monitoring boreholes within a valley setting (e.g. Charlton Road) have a much flatter response – (i.e. groundwater levels fluctuate less as would be expected);
- similar to above, the East Dean Butchers Lane (valley "floor") has a much flatter response than East Droke ("up catchment");
- the length of the groundwater "peak" and the response during the recession (i.e. as groundwater levels decline) occurs over much the same period in all the monitoring wells (including Chilgrove), and;
- although there is an incomplete record covering the rise in groundwater levels, the hydrographs throughout the valley suggest that the Chilgrove borehole is reasonably representative of groundwater level behavior within the Upper Lavant valley as a whole. Therefore it is reasonable to use Chilgrove as an indicator borehole for groundwater levels in this part of the Lavant valley (see further below regarding selection of appropriate monitoring boreholes).

3.3 Relating groundwater levels to flood events

Flood event data obtained from WSCC and the Environment Agency has been used to generate a timeline of flood events during the winter of 2013/2014, to help establish how the groundwater level and rainfall record may be related to different flood events.

These have been plotted as the following charts:

- Figure 6 - Groundwater levels vs rainfall
- Figure 7 - Groundwater levels vs road flooding and related incidents
- Figure 8 -Groundwater levels vs sewer inverts and flooding

Each of these charts identified the date of particular flood events as recorded by the Environment Agency, and WSCC incident and highway incident logs. These are shown relative to the recorded groundwater levels both at Chilgrove and at more local monitoring wells.

A number of observations may be made about the winter 2013/14 flooding incidents:

- The groundwater flood alert was issued by the EA on 6 January 2014 (see Figure 6), at this time Chilgrove groundwater levels (75.81 mAOD) were considerably above the (previously established) EA guidance trigger level for issuing an alert (69.5mAOD, see above) – these levels were reached some 11 days, earlier on 26 December 2014. The Environment Agency had issued a groundwater briefing note at Christmas 2013.
- Flooding on Chilgrove road commenced in 7 January 2014, (only a day after the issue of the alert) when Chilgrove groundwater levels were approximately 76.3mAOD (see Figure 6). Road flooding became progressively more widespread, affecting West Dean and Singleton about a week to 10 days later on 14th January and 17th January, respectively.
- Over this period (7 – 17th January) there was relatively little change in groundwater levels at Chilgrove with levels fluctuating between a high of 76.69 mAOD (10 January) and 76.11 mAOD (16 January).
- Levels at Chilgrove hit a maximum of 76.8 mAOD between 20-22 January 2014 and did not decline below 76mAOD until 25 February 2014, when groundwater levels in other boreholes also appeared to start to decline.

- During the 2013/14 event, Chilgrove borehole was artesian for five days during January 2014, but levels remained above 76m AOD (sufficient to cause flooding throughout the Upper Lavant Valley) for nearly 50 days from 7th January 2014 to 22nd February 2014.
- Based on the local groundwater records, the downstream sewer invert levels at Charlton (circa 61.5mAOD) were exceeded by groundwater from about 23 December (or possibly before), and those at East Dean (70.72mAOD) from about 10/11 January. We understand over pumping did not occur until about 18 January (at East Dean and Charlton) and later at Singleton and Charlton (see Figure 9). Further information is needed from Southern Water regarding when surcharging of sewers becomes a significant issue, when tankering operations commenced and the decision making process that leads to overpumping.

Flooding also occurred as a result of heavy rainfall on saturated catchments which caused river levels to rise rapidly and flow out of bank. Discussions with staff at the Environment Agency indicated that fluvial flooding that occurred from 17th January was as a result of heavy rainfall on 16th January (+30mm in one day), rather than due to rising groundwater levels. This was also repeated on 14th February 2014 following a rainfall event >20mm on the same day. This supports the evidence that when groundwater levels are above a certain threshold fluvial flooding will occur following heavy rainfall events. Based on a comparison of rainfall records and groundwater levels during the 2013/14 winter (see Appendix B) there is no recorded evidence of fluvial flooding prior to 17th January 2014 following the heavy rainfall on 16th January 2014. At this point groundwater levels were above 76m AOD. On the contrary there was heavy rainfall on 5th January 2014 (>25mm) but this did not prompt fluvial flooding, and groundwater levels were c.75m AOD. Equally no fluvial flooding was documented following extreme rainfall on 23rd December 2013 (>80mm), when groundwater levels at Chilgrove were at 51m AOD. Based on this evidence it seems likely that once groundwater levels are above 76m AOD fluvial flooding will occur within 24-48 hours following rainfall in excess of 25mm in a single day. Therefore threshold levels for villages affected by fluvial flooding (Singleton and Mid/East Lavant) should be linked to groundwater levels and rainfall.

4 Discussion

4.1 Geological and Hydrogeological setting

The upper Lavant valley forms part of the chalk landscape of the South Downs. The chalk strata dip southward (toward Mid Lavant). From mid Lavant southward, the chalk is overlain by superficial head deposits (mixed deposits comprising clays, silts, sands and gravels), which confine groundwater in the chalk. This superficial cover make the areas from Mid Lavant southward less susceptible to direct groundwater flooding (although it is still susceptible to fluvial flooding flows generated from groundwater discharge up catchment). Further south (between Chichester and Summersdale, the chalk aquifer is confined by the Lambeth Group Strata (clay, silt and sand).

Toward Chilgrove (up the B2141) the chalk comprises the youngest chalk strata, the Seaford Chalk. Within the (normally dry) valley floor, this chalk is covered by residual head deposits. In this location these head deposits may be more gravelly in nature (typically the floors of chalk dry valleys may have residual gravel deposits). Towards the junction with the A286 and the River Lavant, this superficial cover comprises predominantly sand and gravel river terrace deposits.

From West Dean eastwards, the interfluvial areas to south and north still comprise the Seaford Chalk, but the Lavant valley cuts deeper in to older rocks in the chalk succession comprising (younger to older) the Lewes Nodular Chalk, The New Pit Chalk and the Holywell Nodular Chalk. The chalk sequence and outcrop in the area is influenced by east west folds in the chalk structure through Singleton and further major fold structures further to the south through Chichester.

In the valley floor the chalk is overlain by alluvium and river terrace sand and gravel deposits, to a point about 2 km east of East Dean. The valley sides also have some cover from head deposits.

BGS hydrogeological mapping shows a groundwater catchment divide, running approximately east west (parallel to the line of the downs) about 2km north of Chilgrove and 3km north east of East Dean. Based on the hydrogeological mapping, groundwater flow is typically southward, although there will be some diversion of flow into and along the Lavant valley. Recharge of groundwater from rainfall will occur widely and across the upper catchment, particularly where there is little cover from superficial deposits and sols are thin and readily permeable.

The geology of the valley and the hydrogeological characteristics of the chalk are such that the most permeable parts of the chalk strata are likely to be at shallow depth along the valley floors, in the zones of (normal) groundwater fluctuation. These preferred locations for groundwater flow give rise to the ephemeral "winterbourne" nature of the Upper Lavant Catchment.

4.2 Groundwater Flooding in the Chalk

When groundwater levels are at extreme highs, "new" springs may occur along the valley sides. There is some anecdotal evidence of "overland" flow between Singleton and Charlton that may have been formed by new emergent springs and seepage lines along the valley sides. These may have formed at the junction between different chalk units or by interaction with the overlying and relatively impermeable head deposits.

Under these extreme high level conditions, groundwater levels can rise rapidly within the valley bottom. This is driven by the increased groundwater levels and hydraulic head from up catchment and surrounding higher land. The highly permeable valley floor effectively acts as a conduit draining the chalk throughout the (upper) groundwater catchment. Groundwater will emerge at the surface as the flow capacity within the chalk itself is exceeded. Increased flows in the valley can be closely correlated to groundwater rise in the upper catchment

Bradford and Croker (2007) identify a number of conditions that influence high groundwater discharge and potential flooding (see Section 3.2 Box 2). All these conditions were evident during the winter of 2013/2014.

4.3 Identification of monitoring locations and setting threshold (trigger) levels

(a) Monitoring borehole selection

The selection of appropriate trigger levels relies upon identifying relationships between the monitoring borehole and the onset of groundwater flooding (or fluvial flooding initiated by groundwater emergence)

The key attributes of monitoring wells to be used as a basis for groundwater flood warnings are as follows;

- Location up catchment from receptors susceptible to groundwater flooding.
- A well hydrograph response that does not wholly flatten at peak groundwater levels and that has a moderate range of level fluctuation in response to recharge.
- A long (historic record) with good monitoring frequency (preferably weekly or better).
- Good correlation with a long downstream flow record.
- Away from the influence of groundwater pumping (such as major public supplies).
- Good access (including during flood event).

Most of these attributes apply to Chilgrove and it is considered that this monitoring borehole (as previously selected by the Environment Agency) remains sufficiently appropriate as a means to provide flood warning information for groundwater flooding in the Lavant valley as a whole. The flattening of the Chilgrove well hydrograph as artesian conditions are approached is such that consideration of other more local monitoring boreholes may be of benefit in refining thresholds for more localised responses.

In the Lavant valley, both East Dean (Droke) and Charlton (North Lane) may meet these criteria once a longer, more frequent monitoring record can be developed. The flat well hydrograph at Charlton Lane is such that this monitoring well is inappropriate for anything other than extremely localised warnings (which

may be better served by Charlton North Lane). The borehole at East Dean (Butchers Lane) may have more merit in identifying local thresholds. Daily monitoring during future groundwater flood events would be beneficial in developing and refining local response trigger levels.

(b) Review of Thresholds and Trigger Levels

Selection of warning thresholds

Warning thresholds are to be based on groundwater levels in Chilgrove. Selection of these thresholds should consider a number of factors:

- What is an appropriate rate of rise of groundwater to consider?
- How much advance warning is required?
- How can we avoid false alarms so devaluing the impact of any associated "alerts" or warnings?
- Threshold setting should be clear and unequivocal.

These are discussed below.

What is an appropriate rate of rise to consider?

Even when compared with other wet winters where flooding occurred in the Lavant valley, the winter of 2013/2014 was extreme. It is considered pragmatic not to use this rate of rise to identify alert levels, as this would seem to be wholly unrepresentative and a more conservative approach is recommended. On this basis a rate of rise of 3m/day (which is approximately the average of all the above wet winters) has been selected, based on evidence in Table 6.

TABLE 6

Groundwater rate of rise – extreme winters

Year	Period		Water Level		No. of days	Water rise (m)	Rate of Rise (m/day)
	From	To	From	To			
1993/1994	16/12/1993	5/01/1994	53.32	75.58	20	22.48	1.12
2000/2001	19/10/2000	13/10/2000	40.9	56.3	4	15.4	3.85
2002/2003	12/11/2003	17/11/2003	43.9	58.6	5	14.7	2.94
2012/2013	17/12/2012	26/12/2012	63.5	76.1	9	12.6	1.4
2013/2014	21/12/2013	25/12/2013	44.2	67.5	4	23.3	**5.83**
Average rate							3.03

How much advance warning is required?

The requirement for advance warnings in some respects depends upon the level of preparation effort required and the response needed. It is considered that an advance warning of 3 days offers the best compromise between a timely response and over sensitivity. The issue of groundwater flood alerts (which is issued by the Environment Agency) is likely to remain based on current trigger levels. Based on events in 2013/14, this trigger should have been issued on 26 December 2013, which would have been about 12 days before the onset of road flooding along the B2141 in Chilgrove.

On the basis of recorded flood events in the upper Lavant valley, the first real flooding issue (Chilgrove road flooding) occurred on 7 January 2014, when the Chilgrove Borehole was at 76.3mAOD.

If a threshold is set 3 days in advance of this, based on the average rate of rise of 3m/day, an initial threshold of 67.3 (76.3mAOD – 9m rise over 3 days) is identified, or 70.3mAOD if a 2 day advance warning is adopted. The advance warning threshold needs to be agreed with WSCC.

How can we avoid false alarms?

Looking at (part of) the historic groundwater level record allows us to determine where thresholds set at these levels would have led to "false" alarms (on the premise that unless a level of 76.3mAOD occurs at Chilgrove, there will be no significant flooding). This analysis, shown on Table 7 below was undertaken using the daily logger record (1999 onward) to ensure there were no missed events due to an incomplete groundwater level record.

TABLE 7

Threshold Levels and potential false alarms
(1999 onward logger data)

Threshold	No. of events > threshold	No events that would lead to flooding (level >76.3mAOD)	% "false alarms"
67.3mAOD	10	4	60%
70.3mAOD	9	4	55%

There seems to be little difference, between the two thresholds, however, when a longer (but not daily) data record there is a more evident departure (see Table 8 below).

TABLE 8

Threshold Levels and potential false alarms
(data 1980 to present)

Threshold	No. of events > threshold	No events that would lead to flooding (level >76.3mAOD	% "false alarms"
67.3mAOD	19	3	84%
70.3mAOD	11	3	73%

On this basis, using an action threshold of 70.3 mAOD at Chilgrove would lead to about a 75% "false alarm" rate. This is considered more acceptable, although with more extreme rates of water level rise this might represent a shorter warning (2 days or even less given an average rate of rise of 3m/day).

During 2013/2014, a trigger level set at 70.3 mAOD would have prompted action on or around the 27 of December 2013. This apparent "early warning" for the 2013/14 event is a reflection of the extreme rate of rise (5.8m/day) over that period.

Using other criteria

Whilst trigger levels are most appropriately set to groundwater levels, in reality there should be a consideration of the rainfall/ recharge over this period, as it may be that even after the trigger level has been reached, no further rainfall may lead to a decline of groundwater levels, if not immediate then soon after the threshold has been reached. The antecedent rainfall (i,e. before the trigger is reached), the ongoing rainfall and its duration and intensity will all influence continued rise (or otherwise) in groundwater level and consequent groundwater flooding. However, adopting these further considerations becomes a little more complex and less easy to translate into action, so for the present it is considered appropriate to adopt trigger levels based wholly on groundwater levels.

Predicted rainfall in the catchment becomes critical once Chilgrove levels exceed 76.3m AOD. Heavy rainfall (<25mm) is likely to cause out of bank fluvial flooding in Singleton, Charlton and Mid/East Lavant

Developing triggers based on more localised monitoring

As noted above, (Section 4.3 (a) there is some potential for using more locally based trigger levels using the monitoring wells at Charlton and East Dean. The frequency of the data record during winter 2013/2014 in these boreholes was insufficient to set definitive local triggers during the groundwater level rise period, particularly from 23 December onward, however based on an estimated rate of rise (over this period) in these boreholes, some provisional triggers could be set, assuming the same "2 day" advance warning as adopted above and assuming this will be based on the first incidence of flooding in West Dean and Singleton (i.e. 14 January and 17 January respectively, by reference to Figure 8). As there is an actual data record for 13/15 January in these boreholes, this has been used to back calculate a local trigger.

Monitoring location	Level on 13/15 Jan 2014	Estimated rate of rise (m/day)	Local trigger level (based on 2 day advance warning)
East Dean Droke	88.64	1.5	85.6
East Dean Butchers Lane	77.43	1.2	75.0
Charlton North Lane	86.61	2.3	82.0

Based on these levels and an estimated rate of rise during 2013/2014 "Butchers Lane" would have reached the trigger level by about 26 December and Droke and North Lane a day or so later. As above, this "early warning" reflects the extreme rise in 2013/14.

More frequent monitoring during periods of high groundwater will be required to be able to use and refine these triggers. Although monitoring at Charlton Lane is unlikely to form the basis of refined trigger levels, enhanced monitoring during a flood event may prove useful in future.

6 Recommendations

(i) Trigger groundwater levels at the Chilgrove borehole should continue to be the basis for prompting actions in the Lavant valley.

(ii) Groundwater briefing notes should be considered for issue at 57m AOD and 67m AOD to encourage initial actions to be taken. The threshold trigger level for the Environment Agency considering the issue of a flood alert should remain at 69.5 mAOD. When this level is reached the following actions should take place:

- Issue of groundwater flood alerts, subject to other conditions (e.g. forecast rainfall, rate of rise) [Environment Agency]
- Enhanced level monitoring (daily) in supplementary boreholes at East Dean (Droke and Butchers Lane) and at Charlton (North and Charlton Road) [Environment Agency, WSCC or local community - to be determined][2]

(iii) Based on our analysis of the average rate of rise and to allow a 2 day 'lead in' time before flooding commences on Chilgrove Road a further trigger at 70.3m AOD would be helpful (flooding on Chilgrove Road commences when groundwater levels at Chilgrove reach 76.3m AOD and the average rate of rise if 3 metres/day. However, given that the level of 70.3m AOD is so close to the level at which the Environment Agency will consider issuing a groundwater flood alert (at 69.5m AOD) there does not seem merit in having

[2] It may be possible to install loggers at these boreholes to provide continuous readings

two trigger levels at very similar levels. Therefore, we propose that at 69.5m AOD a further set of actions are required which should include:

- Issue of road flood warning signs along Chilgrove Road, prepare other measures (temporary traffic signals, ensure diversion routes clear), considering the rate of rise [WSCC]
- Initial preparation to issue sandbags for other Lavant villages [WSCC]
- Prompt actions from Southern Water to prepare for sewer flooding including overpumping permissions from the Environment Agency [WSCC/ Southern Water/ Environment Agency]
- Advise local communities in East Dean, Singleton and West Dean of likely groundwater flooding [through issue of Environment Agency Flood Alert]
- Prepare local communities for action [WSCC/ Parish councils]
- Continue/ enhance local monitoring of flooding [WSCC/ Parish councils, Environment Agency]
- Monitor Environment Agency Flood Warnings ref. Mid and East Lavant [WSCC/ Parish councils]

(iv) Once the Chilgrove boreholes reaches 76.3 mAOD, if groundwater continues to rise and based on rainfall forecasts, the following actions should be undertaken:

- Prepare for or deploy more significant traffic management along Chilgrove Road, including possible road closures and diversions [WSCC]
- Deploy and emplace sandbags for other Lavant villages (Singleton, Charlton, East Dean) in line with rainfall forecasts >25mm [WSCC]
- Confirm actions to be taken by Southern Water with respect to sewer flooding [WSCC/ Southern Water/ EA]
- Ensure local communities remain vigilant and aware [WSCC/ Parish councils]
- Continue local monitoring of flooding [WSCC/ Parish councils, Environment Agency]
- Monitor Environment Agency Flood Warnings ref. Mid and East Lavant [WSCC/ Parish councils]

(v) There are opportunities to set local trigger levels based on supplementary boreholes to Chilgrove. These include Charlton North Lane and East Dean Droke. Based on evidence from winter 2013/14 when the above trigger levels were exceeded at Chilgrove (76.3m AOD) levels were 82m AOD at Charlton North Lane and 85.6m AOD at East Dean Droke. At these levels flooding would be expected after heavy rainfall (>25mm in one day) in a similar way to how the Chilgrove borehole responds. These may be more appropriate to set local thresholds but require more monitoring over 2-3 wet winters to understand how groundwater levels fluctuate.

7 References

Lavant Valley Groundwater Multi-Agency Flood Plan (Draft 2013). West Sussex County Council.

Environment Agency: Website.

Application of head-flow responses to groundwater floods in Chalk catchments. R B Bradford and KM Croker. Quarterly Journal of Engineering Geology. V 40 2007

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Hydrogeological Map of the South Downs and Adjacent Parts of the Weald. 1:100,000 scale. Institute of Geological Sciences/ Southern Water Authority 1978

Figure 1 *Observation Well and Gauging Station Locations*

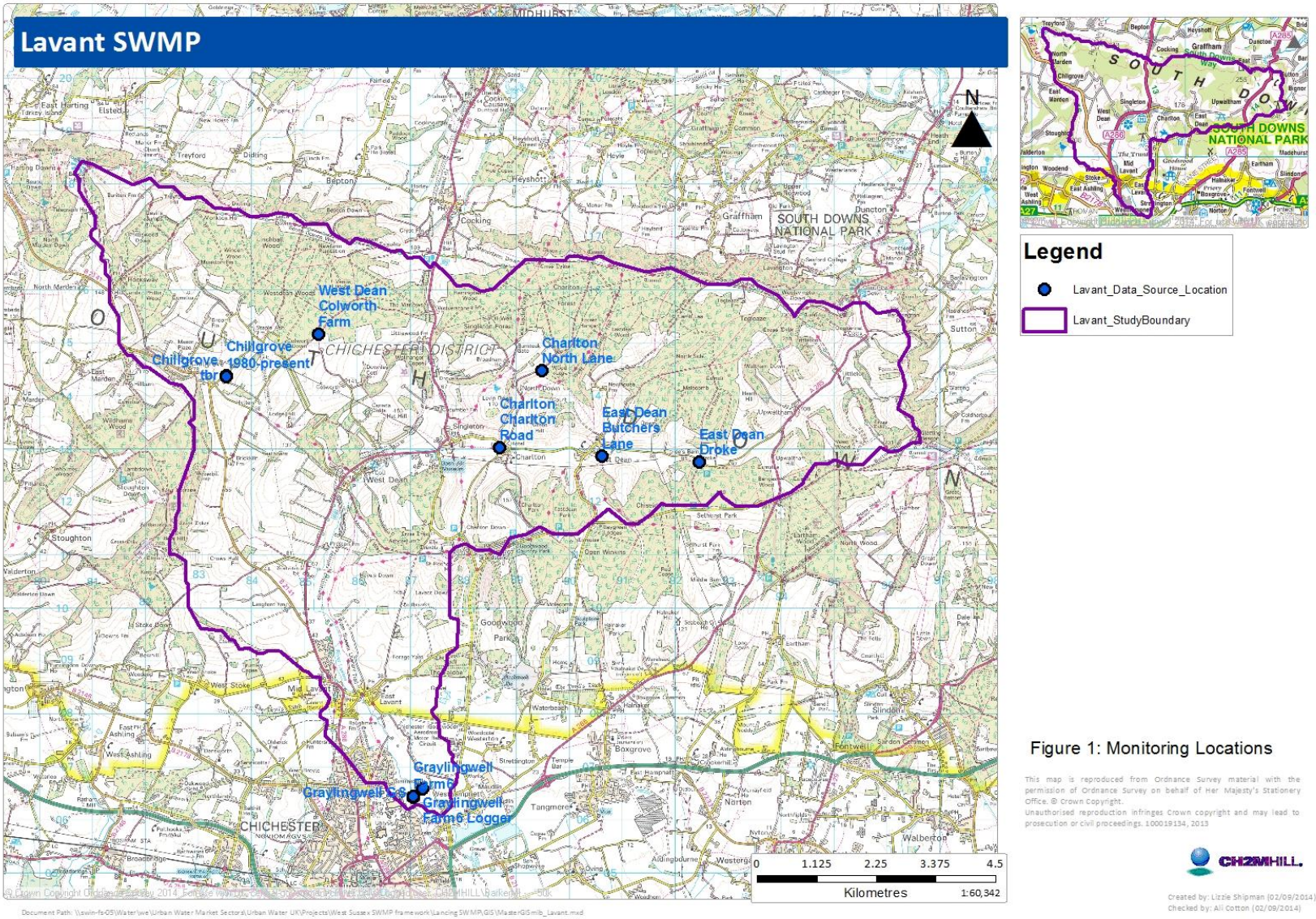


Figure 1: Monitoring Locations

CH2MHILL.

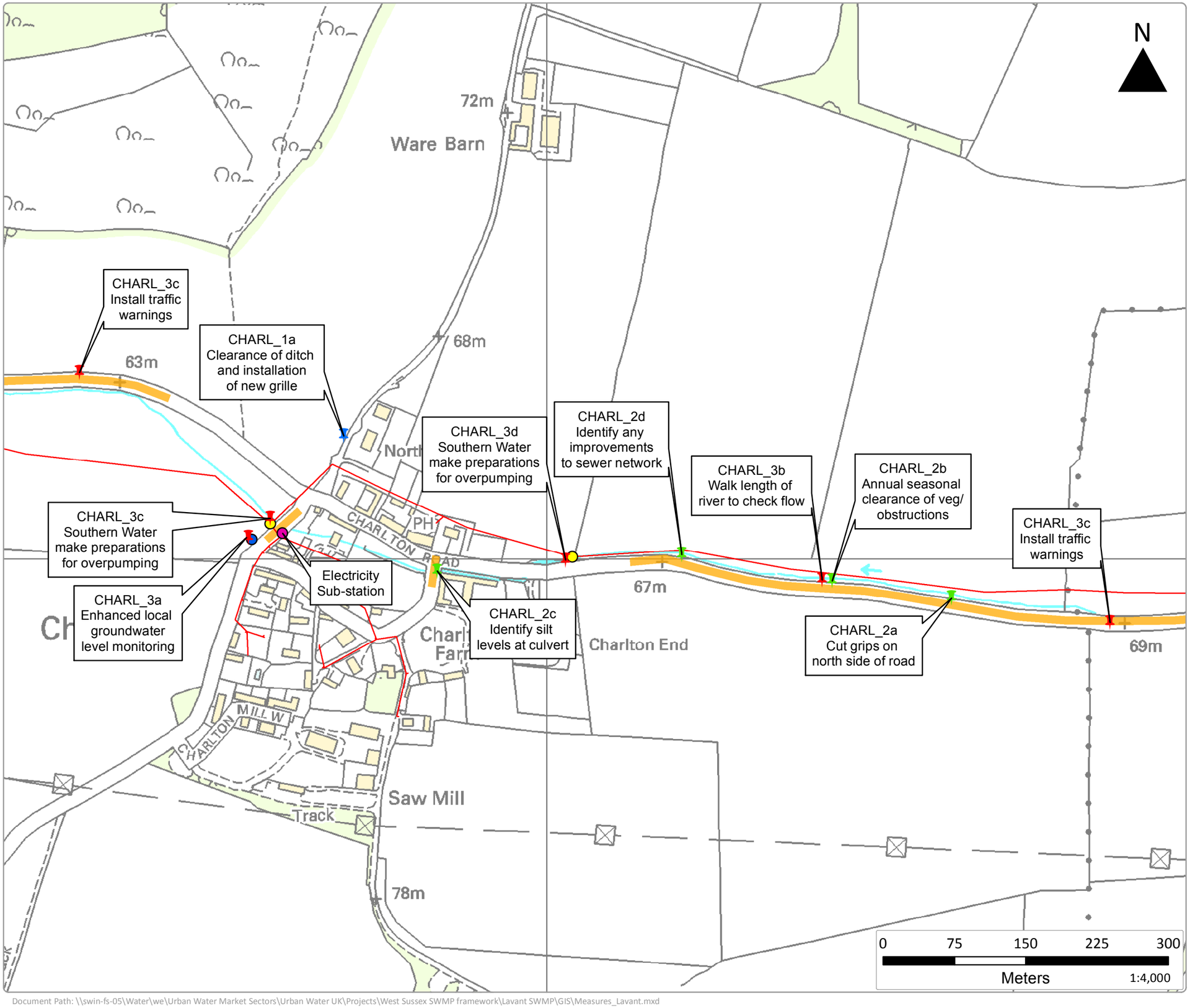
Created by: Lizzie Shipman (02/09/2014)
Checked by: Ali Cotton (02/09/2014)

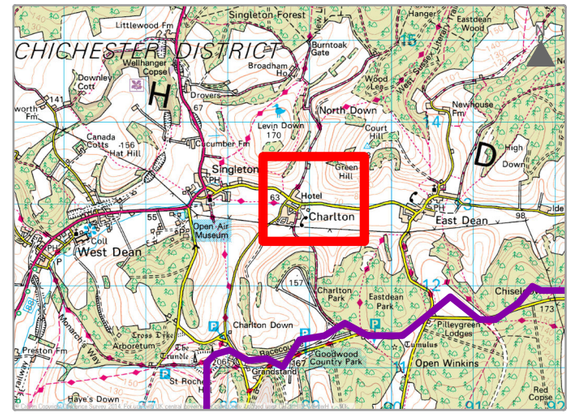
Appendix C Initial Options considered

Theme	Type of measure	Options to use measure in Upper Lavant Valley	Ref in Main Report	Taken forward?	Justification (if excluded from further analysis)
	Survey/Modelling/Design/Consultation	• Consultation of proposed options will be required with local residents.	-	Yes	As there are no major capital or maintenance measures proposed in this area we do not need to undertake any further design work
Source	Land management	• Reinforcement of banking and hedgerow along Ley's Meadow	SING_1a	Yes	
Pathway	Storage above or below ground	• Undertake excavation or bunding to store more flood water in Ley's Meadow more water at Ley's Meadow	-	No	This is unrealistic given levels in the area, any excavation would result in storage being filled up with groundwater
Pathway	Manage exceedance flows (e.g. re-profiling road)	• Create an exceedance route to north east of Lavant Down Road	MELAV_1a	Yes	
		• Cut grips on the north side of the road from East Dean to Charlton to allow more water on the road to discharge to the Lavant	CHARL_2a	Yes	
Pathway	Increase capacity of urban drainage network	• Investigate and unblock highway drainage system along A286 in West Dean (and improve if necessary)	WDCHIL_1b WDCHIL_2b	Yes	
		• Reduce flooding from the foul sewer network through the Infiltration Reduction Plan	WDCHIL_2a SING_2e CHARL_2d EDEAN_2b	Yes	
		• Investigate options to alleviate foul flooding of properties in Singleton	SING_1e	Yes	
Pathway	Increase capacity of watercourses	• Re-design bridge at furthest end of Sheepwash Lane which causes constriction of flows	MELAV_1c	Yes	
		• Lower bed level of River Lavant near Manor Farm which is silted	MELAV_2b	Yes	
		• Remove redundant bridge at Cowper's Lodge	SING_1c	Yes	
		• Raise left bank of Lavant downstream of the A286 bridge by semi-permanent sandbags	SING_1d	Yes	
		• Re-grading of Lavant bed levels near the cricket ground in Singleton to improve conveyance	-	No	Not considered necessary to alleviate upstream flooding problems in Singleton
		• Lower road levels on A286 bridge to permit exceedance flows to re-enter River Lavant rather than flood Cobbler's Row		No	Re-grading the level of the road will be cost prohibitive, and changing conveyance is likely to increase flood risk in other parts of Singleton
		• Clearance of ditch on North Lane in Charlton and installation of new grille	CHARL_1a	Yes	
		• Consider silt levels at culvert to south of Fox Goes Free	CHARL_2c		
Pathway	Raise/create flood defences	• Lower left bank of Springfield Lane in Mid Lavant to allow more water onto floodplain	MELAV_1b	Yes	
Pathway	Maintenance of watercourses/culverts	• Annual maintenance of River Lavant throughout its length	MELAV_2a SING_2b SING_2c	Yes	

			CHARL_2B		
		• Annual maintenance of ditch along Marsh Lane Track	MELAV_2c	Yes	
		• Maintenance of ditch network along Chilgrove Road	WDCHIL_2c	Yes	
		• Removal of detritus and trees along watercourse in Singleton	SING_2b	Yes	
		• Clear blocked culvert which runs west from bridleway at end of Butcher's Lane and emerges at eastern end of Chapel Row	EDEAN_2a	Yes	
Receptor	Individual property level protection	• Increase level of resilience at Portsmouth Water abstraction point north-east of Lavant Down Road	MELAV_1d	Yes	
		• Sandbagging of properties on Pook Lane and install measures at Lavant Village Hall	MELAV_3a and 3b	Yes	
		• Property level protection at low point of West Dean	WDCHIL_1a	Yes	
		• Sandbagging to properties at low point of West Dean in response to flood warning	WDCHIL_3a	Yes	
		• Property level protection on Cobbler's Row	SING_1b	Yes	
		• Sandbagging properties on Cobbler's Row	SING_3c	Yes	
Receptor	Prepare for emergency flooding situation	• Traffic management along key affected routes	MELAV_3c WDCHIL_2d WDCHIL_3c SING_3d CHARL_3b EDEAN_3c	Yes	
		• Prepare and implement tankering and overpumping to alleviate pressure on foul sewer	MELAV_3d WDCHIL_3b SING_3e CHARL_3c EDEAN_3d	Yes	
		• Check whether railway sleepers in Singleton can be removed	SING_2d	Yes	
		• Deploy sandbags along left bank of River Lavant in Singleton	SING_3b	Yes	
		• Open additional valves on outlet pipe into East Dean Village Pond	EDEAN_3a	Yes	

Lavant SWMP





Legend

Type

- Capital Improvements
- Emergency Planning and Actions
- Enhanced Maintenance
- Critical infrastructure
- Overpumping & tankering locations
- EA boreholes locations
- Foul Sewer
- Roads susceptible to flooding

Charlton
Measures to mitigate flood risk

CH2MHILL.

Created by: Helen Winter (10/11/2014)
Checked by: Ali Cotton (10/11/2014)

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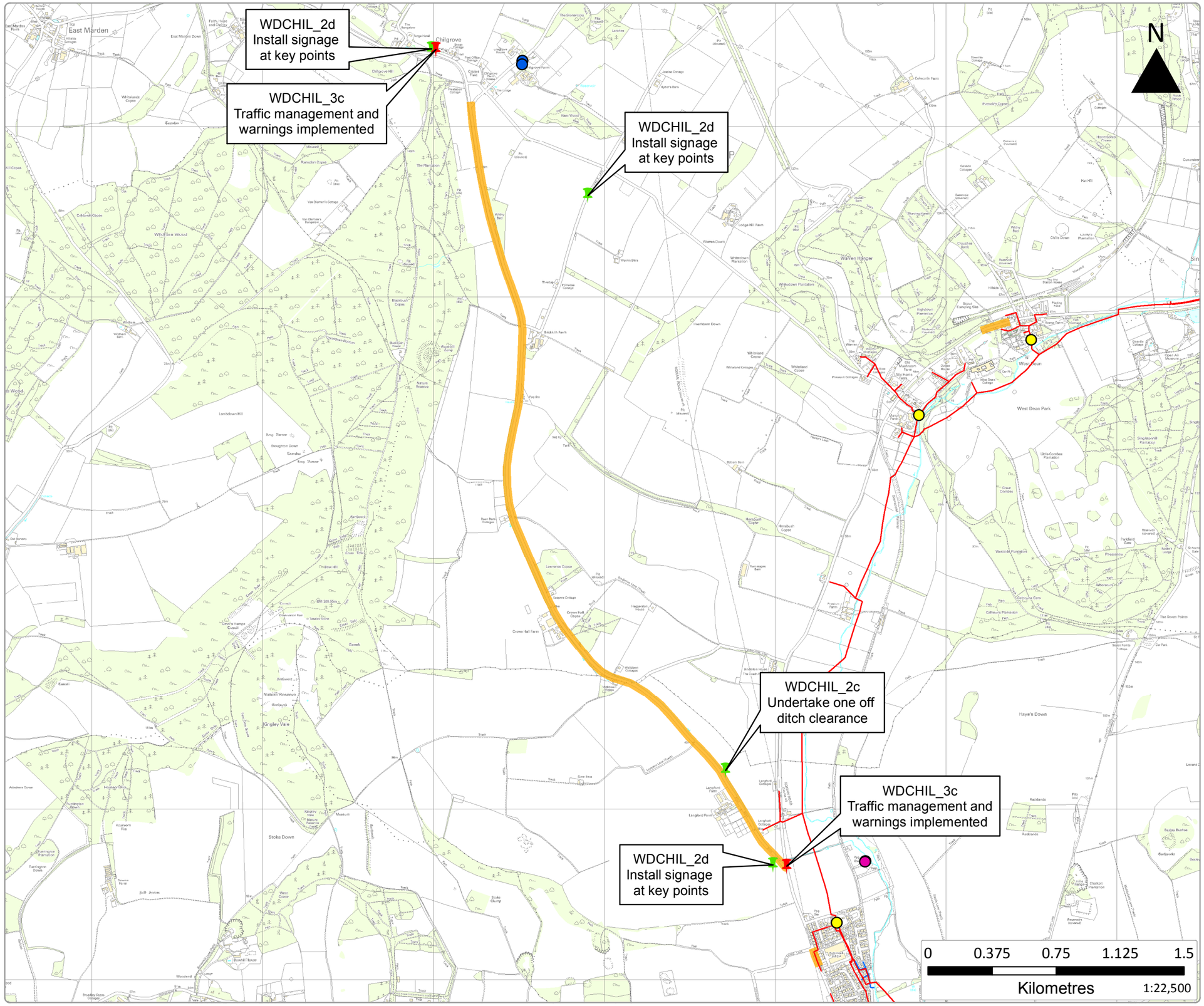
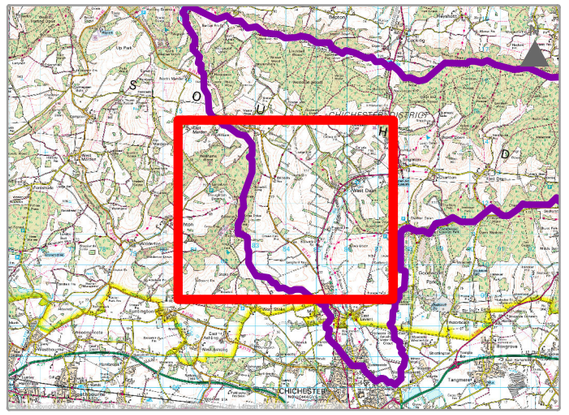
Lavant SWMP





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Type

- Emergency Planning and Actions
- Enhanced Maintenance
- Critical Infrastructure
- Overpumping & tankering locations
- EA boreholes locations
- Foul Sewer
- Surface Water Sewer
- Roads susceptible to flooding

Chilgrove Road
Measures to mitigate flood risk

CH2MHILL.

Created by: Helen Winter (10/11/2014)
Checked by: Ali Cotton (10/11/2014)

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Lavant SWMP

EDEAN_3c
Walk length of river to check flow

EDEAN_3b
Open additional valves on outlet pipe

EDEAN_3d
Install traffic warnings

EDEAN_3d
Install traffic warnings

EDEAN_3e
Southern Water make preparations for overpumping

EDEAN_3a
Enhanced local groundwater level monitoring

EDEAN_2a
Clear blocked culvert

EDEAN_3d
Install traffic warnings

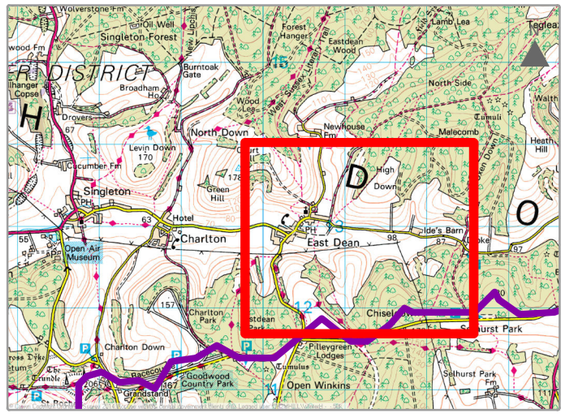
EDEAN_3b
Open additional valves on outlet pipe

EDEAN_3a
Enhanced local groundwater level monitoring

EAST DEAN CP

East Dean

Droke



Legend

Type

- Emergency Planning and Actions
- Enhanced Maintenance
- Overpumping & tankering locations
- EA boreholes locations
- Foul Sewer
- Roads susceptible to flooding

East Dean
Measures to mitigate flood risk

CH2MHILL.

Created by: Helen Winter (10/11/2014)
Checked by: Ali Cotton (10/11/2014)

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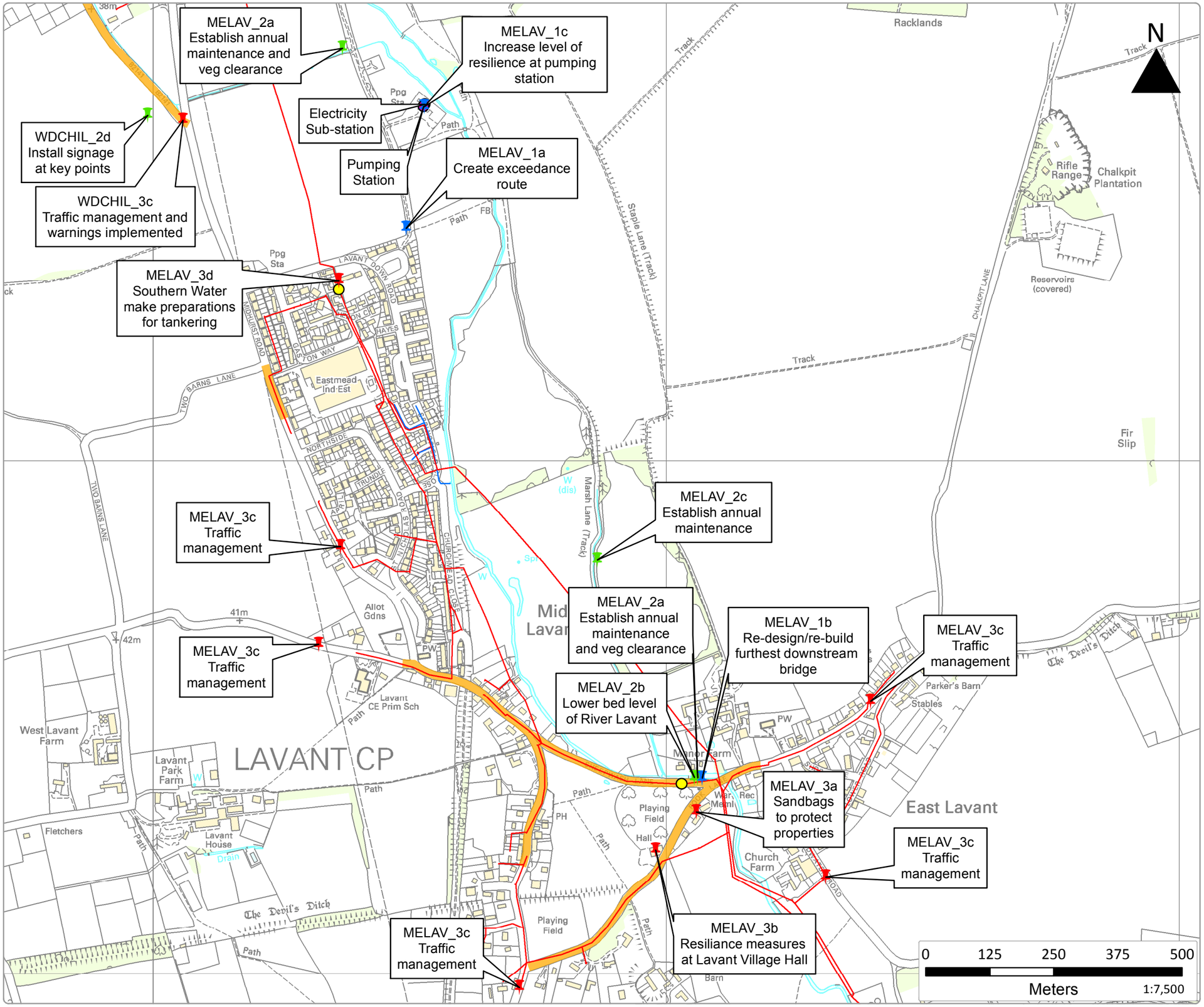
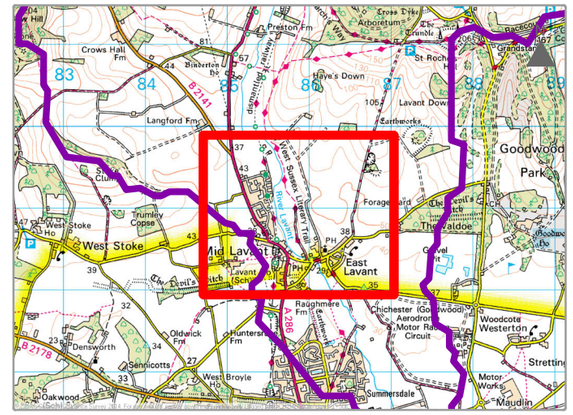
Lavant SWMP





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Type

- Capital Improvements
- Emergency Planning and Actions
- Enhanced Maintenance
- Critical infrastructure
- Overpumping & tankering locations

- Foul Sewer
- Surface Water Sewer
- Roads susceptible to flooding

Mid & East Lavant
Measures to mitigate flood risk

CH2MHILL.

Created by: Helen Winter (10/11/2014)
Checked by: Ali Cotton (10/11/2014)

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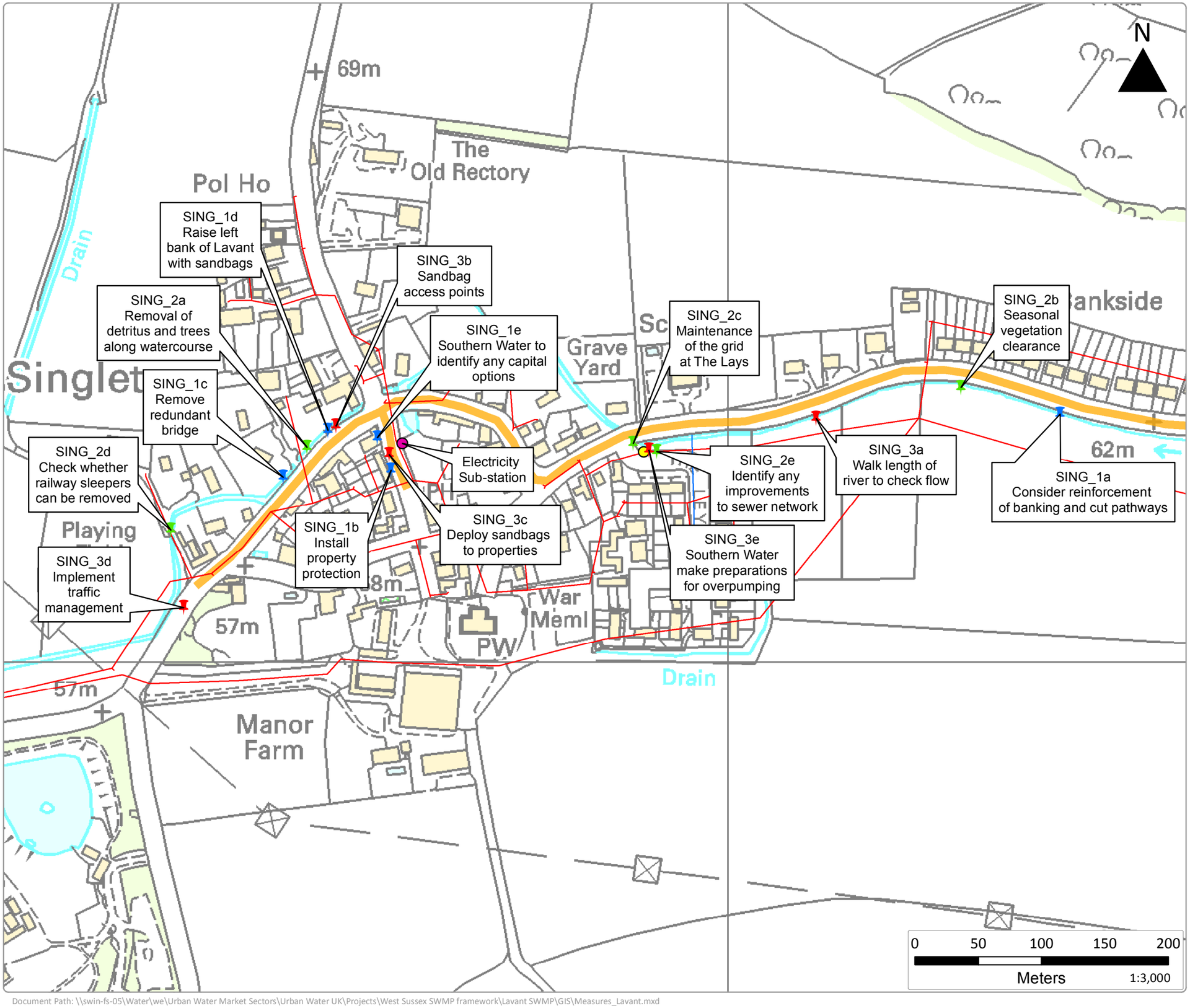
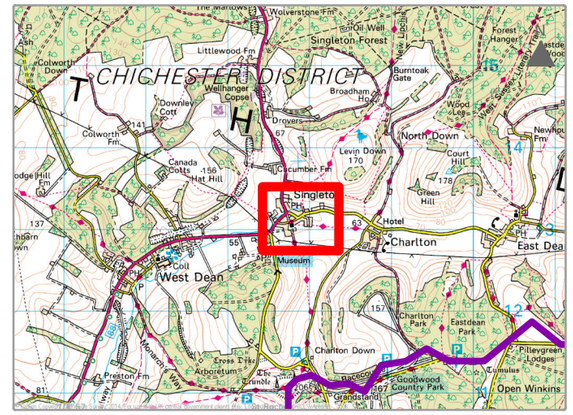
Lavant SWMP





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Type

- Capital Improvements
- Emergency Planning and Actions
- Enhanced Maintenance
- Critical infrastructure
- Overpumping & tankering locations
- Foul Sewer
- Surface Water Sewer
- Roads susceptible to flooding

Singleton
Measures to mitigate flood risk

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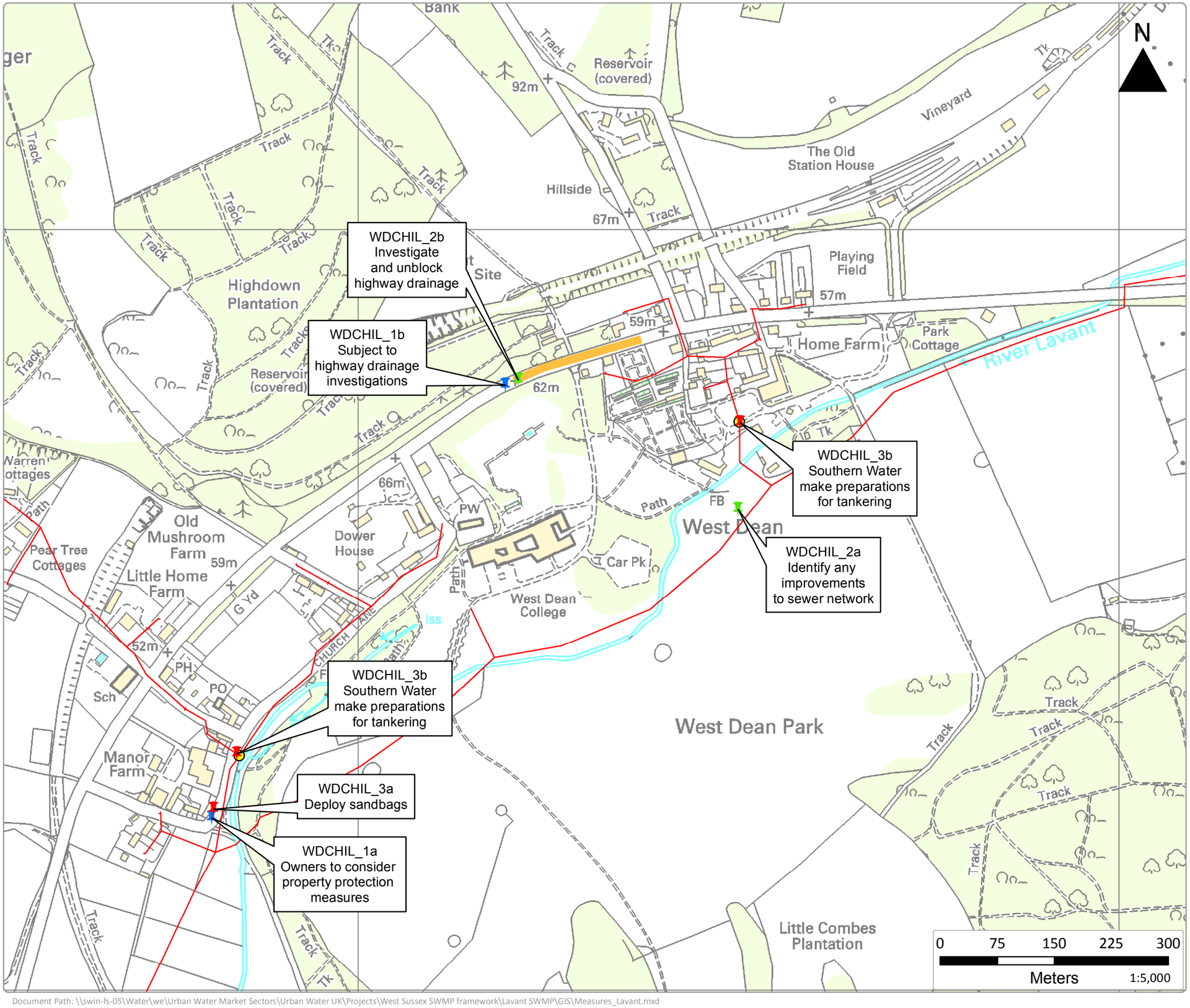
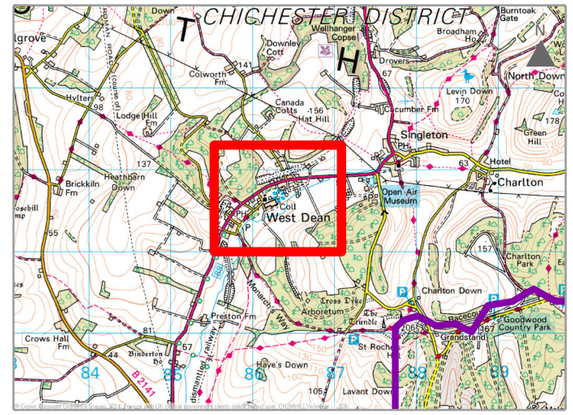
Lavant SWMP





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Type

- Capital Improvements
- Emergency Planning and Actions
- Enhanced Maintenance
- Overpumping & tankering locations
- Foul Sewer
- Roads susceptible to flooding

West Dean
Measures to mitigate flood risk

CH2MHILL.

Created by: Helen Winter (10/11/2014)
Checked by: Ali Cotton (10/11/2014)

Appendix E Environmental Assessment of Options

CAPITAL MEASURES								
Proposals	Do Nothing	Create exceedance route	River bank lowering	Bridge works	Increase resilience (of pumping station)	Property protection	Bank reinforce-ments and pathways/ bank raising and sandbags on access bridges	Ditch clearance
Works locations		MELAV_1a	MELAV_1b	MELAV_1c SING_1c	MELAV_1d	WDCHIL_1a SING_1b SING_1d (not assessed)	SING_1a SING_1d	CHARL_1a
Local community	Continued flood risk to population (with associated impacts on quality of life) and properties within flood risk areas, including impacts on businesses, community assets (including public rights of way) and visitors to the South Downs	Contributes to reduction in surface water flood risk to affected people and property	Contributes to reduction in surface water flood risk to affected people and property	Contributes to reduction in surface water flood risk to affected people and property Disruption to local communities in village centres as a result of increased noise and potential access restrictions during works	Enables continued operation of the pumping station and maintenance of services	Contributes to reduction in surface water flood risk to affected people and property Proposed IPP measures may not by acceptable to some property owners	Contributes to reduction in surface water flood risk to affected people and property	Contributes to reduction in surface water flood risk to affected people and property
Material assets	Continued flood risk to critical infrastructure (e.g. electricity sub-stations, pumping stations, sewage works) and road network with associated impacts	Temporary disruption to users of the track to the north-east of Lavant Down Road during construction works and during periods of flooding	No impacts anticipated	Potential contribution to reduction in surface water flood risk to roads and access routes, and associated reduction in traffic disruption Temporary disruption to bridge users during works	Enables continued operation of the pumping station and maintenance of services	No impacts anticipated	Potential contribution to reduction in surface water flood risk to roads and access routes, and associated reduction in traffic disruption Limited disruption to bridge users	No impacts anticipated
Biodiversity, flora and fauna	Potential damage or loss of woodland and other habitats (pasture/ parkland), classified as priority BAP habitat or Ancient Woodland; which may support legally protected species/species of conservation concern, as a result of increased frequency and duration of flood events Potential creation of wetland habitat (and associated species) in the long-term, as flood risk increases as a result of climate change	Potential for impacts on existing terrestrial flora and fauna along the exceedance route. Pre-construction checks will be required to assess suitability of habitat in affected areas to support protected or notable species	Potential for impacts on existing riverine, riparian and terrestrial flora and fauna (e.g. fish and potentially water voles). Pre-construction checks will be required to assess suitability of habitat in affected areas to support protected or notable species Opportunities for ecological improvement integrating new wetland/marginal habitat creation in developing temporary flooded area	Potential for impacts on existing riverine/ riparian flora and fauna (including potentially fish and water voles). Pre-construction checks will be required to assess suitability of habitat (including the bridges) in affected areas to support protected or notable species	Consider potential for impacts on existing flora and fauna; pre-construction checks will be required to assess suitability of habitat in affected areas to support protected or notable species	No impacts on flora or fauna from installation of individual property protection measures	Potential for impacts on existing flora and fauna, including affected hedgerows. Pre-construction checks will be required to assess suitability of habitat in affected areas to support protected or notable species. Works to the hedgerow and any trees will need to be undertaken outside the bird nesting season (March to July inclusive)	Potential to result in the loss of/ disturbance to existing flora and its diversity (in-channel vegetation etc.) and associated impacts on fauna (including fish). Pre-construction checks will be required to assess suitability of habitat in affected areas to support protected or notable species
Soils, geology and contaminated land	Continued loss of agricultural productivity through flooding	Reduction in flood risk to agricultural land Potential for road lowering to expose unknown contaminants, which may require further consideration	Temporary loss of use of field to the east of Springfield Lane during periods of flooding	Potential reduction in flood risk to agricultural land	No impacts anticipated	No impacts anticipated	Potential reduction in flood risk to agricultural land. Potential for any excavation to expose unknown contaminants, which may require further consideration	Potential reduction in flood risk to agricultural land. Potential for ditch excavation to expose unknown contaminants, which may require further consideration

CAPITAL MEASURES								
Proposals	Do Nothing	Create exceedance route	River bank lowering	Bridge works	Increase resilience (of pumping station)	Property protection	Bank reinforce-ments and pathways/ bank raising and sandbags on access bridges	Ditch clearance
Works locations		MELAV_1a	MELAV_1b	MELAV_1c SING_1c	MELAV_1d	WDCHIL_1a SING_1b SING_1d (not assessed)	SING_1a SING_1d	CHARL_1a
Water	Allows the fluvial system to function naturally, which may be beneficial to the hydromorphology of the water bodies (e.g. River Lavant (Upper) and Pagham Harbour), helping to meet the objectives of the WFD Risks to water quality from surface flooding of the foul sewer network	Contributes to reduction in surface water flood risk River water body (Pagham Harbour) already modified for flood protection. Works at Mid/East Lavant will not positively contribute to achievement of WFD objectives, but their small scale will not result in additional adverse impacts No effects on groundwater anticipated	Contributes to reduction in surface water flood risk River water body (Pagham Harbour) already modified for flood protection. Works at Mid/East Lavant will not positively contribute to achievement of WFD objectives, but their small scale will not result in additional adverse impacts No effects on groundwater anticipated	Contributes to reduction in surface water flood risk River water body (Pagham Harbour) at Mid/East Lavant already modified for flood protection. Works will not positively contribute to achievement of WFD objectives for this water body. However, given their small scale, these will also not adversely affect these or those of the River Lavant (Upper) water body No effects on groundwater anticipated	Contributes to reduction in surface water flood risk Potential benefits to water quality through reduced flood risk	Contributes to preparedness in responding to flood events	Contributes to reduction in surface water flood risk Works will not adversely impact on the achievement of WFD objectives for the River Lavant (Upper) water body given their nature and localised scale No effects on groundwater anticipated	Contributes to reduction in surface water flood risk Improved flood conveyance Works will not adversely affect the achievement of WFD objectives for the River Lavant (Upper) water body given their nature and localised scale No effects on groundwater anticipated
Historic environment	Continued flood risk to known and buried heritage assets and archaeology – listed buildings, Registered Parks and Gardens	Potential for long-term reduction in flood risk for any downstream heritage assets Potential for road excavation to affect buried archaeology if present	Potential for long-term reduction in flood risk for any downstream heritage assets Potential for any excavation to affect buried archaeology if present	Potential for works to impact on the listed buildings at Manor Farm in East Lavant and 1-4 Grooms Yard in Singleton that lie in close proximity; the impacts on these buildings and their setting will require further consideration. Potential long-term reduction in flood risk to some heritage assets	No known impacts on heritage assets	Need to consider any impacts of these solutions on setting of listed buildings	Potential for long-term reduction in flood risk for any downstream heritage assets Potential for any excavation to affect buried archaeology if present	Potential for long-term reduction in flood risk for any downstream heritage assets. Potential for any excavation to affect buried archaeology if present
Landscape	Continued natural change to the landscape character of the South Downs National Park through increasing flood risk	Localised change in landscape character as a result of lowering of road and managed flooding. New landscape features will require sympathetic design to ensure careful integration into existing landscape	Localised change in landscape character as a result of changes to existing watercourse. Modifications to existing landscape features will require sympathetic design to ensure careful integration into existing landscape	Localised change in landscape character as a result of removal and, as needed, replacement of bridge structures. Requires sympathetic design to ensure careful integration into existing landscape	No permanent change in landscape character anticipated	No permanent change in landscape character anticipated	Localised change in landscape character as a result of reinforcement of banking and hedgerow and semi-permanent presence of sandbags. Modifications to existing landscape features will require sympathetic design to ensure careful integration into existing landscape	Localised change in landscape character as a result of changes to existing watercourse. Modifications to existing landscape features will require sympathetic design to ensure careful integration into existing landscape

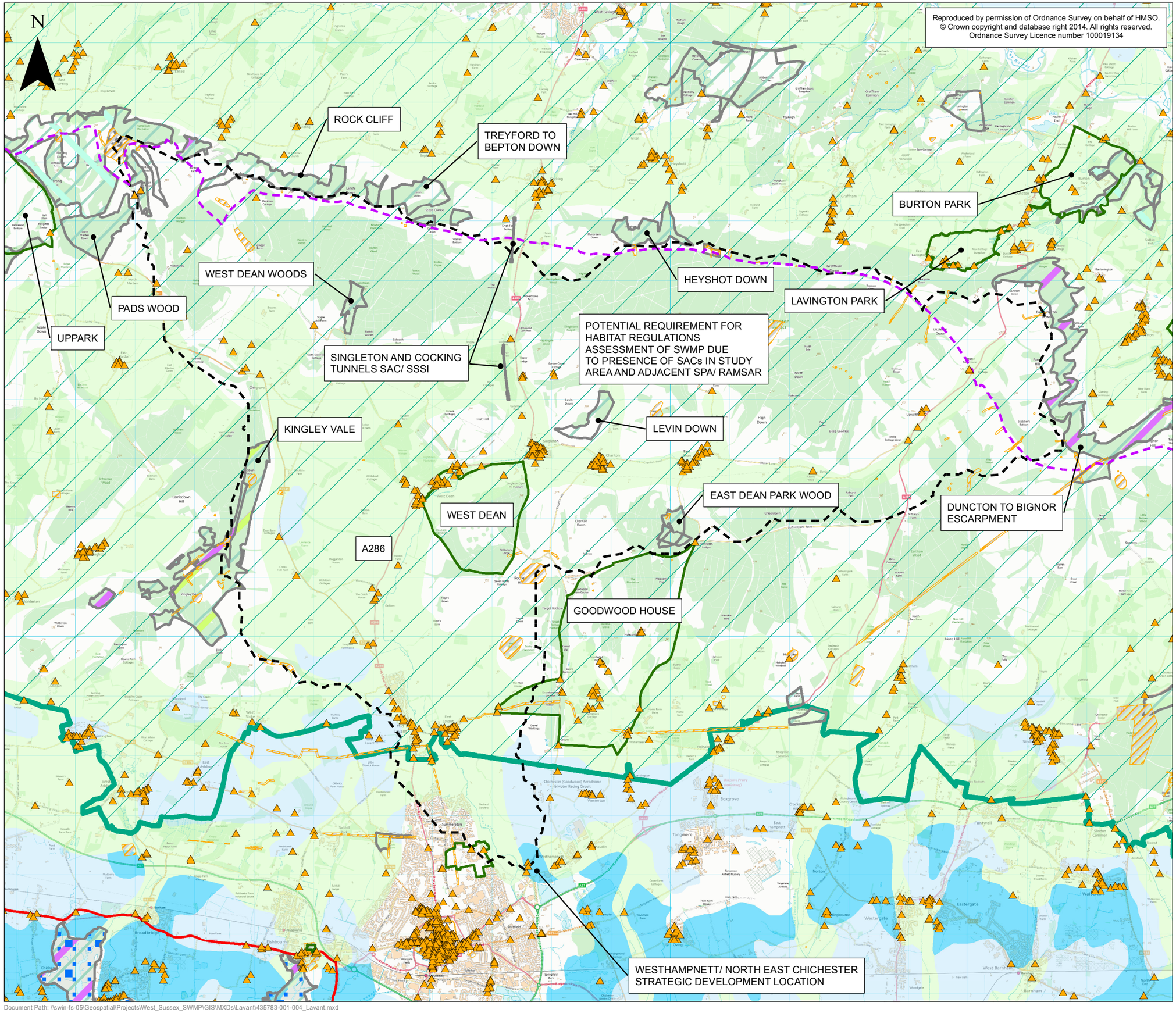
CAPITAL MEASURES								
Proposals	Do Nothing	Create exceedance route	River bank lowering	Bridge works	Increase resilience (of pumping station)	Property protection	Bank reinforce-ments and pathways/ bank raising and sandbags on access bridges	Ditch clearance
Works locations		MELAV_1a	MELAV_1b	MELAV_1c SING_1c	MELAV_1d	WDCHIL_1a SING_1b SING_1d (not assessed)	SING_1a SING_1d	CHARL_1a
Sustainability/climate	No depletion of resources & no greenhouse gas emissions but likely to generate significant safety risks associated with increased flooding	Requires export of excavated material, if it cannot be re-used on-site Requires continued inspection and maintenance, which can be incorporated into general landscape maintenance	Requires export of excavated material, if it cannot be re-used on-site Requires continued inspection and maintenance, which can be incorporated into general landscape maintenance	Requires use of new and export of waste materials, if it cannot be re-used on-site Requires continued inspection and maintenance, which can be incorporated into general landscape maintenance	Likely to require continued inspection and maintenance	Likely to require continued inspection and maintenance by householders	Requires use of new and export of waste materials, if it cannot be re-used on-site Requires continued inspection and maintenance, which can be incorporated into general landscape maintenance	Requires export of excavated material, if it cannot be re-used on-site Requires continued inspection and maintenance, which can be incorporated into general landscape maintenance

ENHANCED MAINTENANCE MEASURES						
Proposals	Do Nothing	Annual maintenance and ditch clearance	Maintain and remove/clear in-channel structures; Lower river bed level	Improvements to sewer network	Unblock highway drainage system	Install signage
Works locations		MELAV_2a, MELAV_2c, WDCHIL_2c, SING_2a, SING_2b, CHARL_2b	SING_2c, SING_2d, CHARL_2c EDEAN_2a MELAV_2b	WDCHIL_2a, SING_2e, SING_2f CHARL_2d, EDEAN_2b	WDCHIL_1b [capital improvement pending further investigation] WDCHIL_2b, CHARL_2a	WDCHIL_2d
Local community	Continued flood risk to population (with associated impacts on quality of life) and properties within flood risk areas, including impacts on businesses, community assets (including public rights of way) and visitors to the South Downs	Contributes to reduction in surface water flood risk to affected people and property	Contributes to reduction in surface water flood risk to affected people and property	Contributes to reduction in surface water flood risk to affected people and property	Contributes to reduction in surface water flood risk to affected people, property and road users	Contributes to reduction in surface water flood risk to road users
Material assets	Continued flood risk to critical infrastructure (e.g. electricity sub-stations, pumping stations, sewage works) and road network with associated impacts	No impacts anticipated	No impacts anticipated	Would facilitate continued functioning of sewer network	Potential contribution to reduction in surface water flood risk to roads and access routes, and associated reduction in traffic disruption	Potential contribution to reduction in surface water flood risk to roads and access routes, and associated reduction in traffic disruption
Biodiversity, flora and fauna	Potential damage or loss of woodland and other habitats (pasture/ parkland), classified as priority BAP habitat or Ancient Woodland; which may support legally protected species/species of conservation concern, as a result of increased frequency and duration of flood events Potential creation of wetland habitat (and associated species) in the long-term, as flood risk increases as a result of climate change	Potential to result in the loss of/ disturbance to existing flora and its diversity (in-channel vegetation etc.) and associated impacts on fauna (including fish). Pre-construction checks will be required to assess suitability of habitat in affected areas to support protected or notable species	Potential to result in the loss of/disturbance to existing flora and its diversity (in-channel vegetation etc.) and associated impacts on fauna (including fish). Pre-construction checks will be required to assess suitability of habitat in affected areas to support protected or notable species	Consider potential for impacts on existing flora and fauna; pre-construction checks will be required to assess suitability of habitat in affected areas to support protected or notable species	Consider potential for impacts on existing flora and fauna; pre-construction checks will be required to assess suitability of habitat in affected areas to support protected or notable species	No impacts anticipated, although impacts of any lighting should be considered if employed
Soils, geology and contaminated land	Continued loss of agricultural productivity through flooding	Potential reduction in flood risk to agricultural land. Potential for ditch excavation to expose unknown contaminants, which may require further consideration	Potential for river bed lowering to expose unknown contaminants, which may require further consideration	No impacts anticipated	No impacts anticipated	No impacts anticipated
Water	Allows the fluvial system to function naturally, which may be beneficial to the hydromorphology of the water bodies (e.g. River Lavant (Upper) and Pagham Harbour), helping to meet the objectives of the WFD Risks to water quality from surface flooding of the foul sewer network	Contributes to reduction in surface water flood risk Improved flood conveyance Works will not adversely affect the achievement of WFD objectives for the River Lavant (Upper) water body given their nature and localised scale No effects on groundwater anticipated	Contributes to reduction in surface water flood risk Improved -flood conveyance Works will not adversely affect the achievement of WFD objectives for the River Lavant (Upper) water body given their nature and localised scale No effects on groundwater anticipated	No impacts anticipated at this stage	Contributes to reduction in surface water flood risk Works will not affect the achievement of WFD objectives for the River Lavant (Upper) However, any potential risks to river water quality will need to be managed	No impacts anticipated
Historic environment	Continued flood risk to known and buried heritage assets and archaeology – listed buildings, Registered Parks and Gardens	Potential for long-term reduction in flood risk for any downstream heritage assets. Potential for any excavation to affect buried archaeology if present	Potential for reduction in flood risk for any downstream heritage assets.	No known impacts on heritage assets	Need to consider any impacts of these solutions on setting of three listed buildings adjacent to the affected stretch of road in West Dean and the adjacent West Dean Registered Park and Garden	Need to consider any impacts of additional signage on setting of listed buildings on Chilgrove Road

ENHANCED MAINTENANCE MEASURES						
Proposals	Do Nothing	Annual maintenance and ditch clearance	Maintain and remove/clear in-channel structures; Lower river bed level	Improvements to sewer network	Unblock highway drainage system	Install signage
Works locations		MELAV_2a, MELAV_2c, WDCHIL_2c, SING_2a, SING_2b, CHARL_2b	SING_2c, SING_2d, CHARL_2c EDEAN_2a MELAV_2b	WDCHIL_2a, SING_2e, SING_2f CHARL_2d, EDEAN_2b	WDCHIL_1b [capital improvement pending further investigation] WDCHIL_2b, CHARL_2a	WDCHIL_2d
Landscape	Continued natural change to the landscape character of the South Downs National Park through increasing flood risk	Localised change in landscape character as a result of minor changes to existing watercourse. Modifications to existing landscape features will require sympathetic design to ensure careful integration into existing landscape	Localised change in landscape character as a result of minor changes to existing watercourse. Modifications to existing landscape features will require sympathetic design to ensure careful integration into existing landscape	No permanent change in landscape character anticipated	No permanent change in landscape character anticipated	Visual intrusion of additional signage will need to be managed
Sustainability/climate	No depletion of resources & no greenhouse gas emissions but likely to generate significant safety risks associated with increased flooding	Requires export of excavated material, if it cannot be re-used on-site Requires continued inspection and maintenance, which can be incorporated into general landscape maintenance	Requires export of excavated material, if it cannot be re-used on-site Requires continued inspection and maintenance, which can be incorporated into general landscape maintenance	Likely to require continued inspection and maintenance	Requires continued inspection and maintenance, which can be incorporated into general highway maintenance	Requires limited inspection and maintenance, which can be incorporated into general highway maintenance

EMERGENCY MANAGEMENT MEASURES					
Proposals	Do Nothing	Preparedness- flood alerts and provision of sandbags; resilience measures; channel inspections	Sewers: tankering and over-pumping	Traffic management	Increased discharge to water bodies
Works locations		MELAV_3a, MELAV_3b, WDCHIL_3a, SING_3b SING_3c, SING_3a, CHARL_3a, EDEAN_3b	MELAV_3d, WDCHIL_3b, CHARL_3b, SING_3e CHARL_3c, EDEAN_3d	MELAV_3c, WDCHIL_3c, SING_3d,, EDEAN_3c	EDEAN_3a
Local community	Continued flood risk to population (with associated impacts on quality of life) and properties within flood risk areas, including impacts on businesses, community assets (including public rights of way) and visitors to the South Downs	Improved preparedness and awareness of flood risk Contributes to reduction in surface water flood risk to affected people, property and community assets (e.g. village hall)	Contributes to reduction in surface water flood risk to affected people and property	Contributes to reduction in surface water flood risk to road users	Contributes to reduction in surface water flood risk to affected people and property
Material assets	Continued flood risk to critical infrastructure (e.g. electricity sub-stations, pumping stations, sewage works) and road network with associated impacts	No impacts anticipated	Would facilitate continued functioning of sewer network	Potential contribution to reduction in surface water flood risk to roads and access routes, Increased journey times for road users during flooding	No impacts anticipated
Biodiversity, flora and fauna	Potential damage or loss of woodland and other habitats (pasture/ parkland), classified as priority BAP habitat or Ancient Woodland; which may support legally protected species/species of conservation concern, as a result of increased frequency and duration of flood events Potential creation of wetland habitat (and associated species) in the long-term, as flood risk increases as a result of climate change	No impacts anticipated	No impacts on flora or fauna from tankering or over-pumping, assuming that all waste is contained	No impacts anticipated	No impacts anticipated on ecology of village pond, but consideration of potential impacts should be made
Soils, geology and contaminated land	Continued loss of agricultural productivity through flooding	No impacts anticipated	Risk of contamination from spillage of sewage effluent needs to be managed	No impacts anticipated	No impacts anticipated
Water	Allows the fluvial system to function naturally, which may be beneficial to the hydromorphology of the water bodies (e.g. River Lavant (Upper) and Pagham Harbour), helping to meet the objectives of the WFD Risks to water quality from surface flooding of the foul sewer network	Contributes to preparedness in responding to flood events	No impacts anticipated	No impacts anticipated	No impacts anticipated on river Effects on water quality and quantity in village pond will need to be considered

EMERGENCY MANAGEMENT MEASURES					
Proposals	Do Nothing	Preparedness- flood alerts and provision of sandbags; resilience measures; channel inspections	Sewers: tankering and over-pumping	Traffic management	Increased discharge to water bodies
Works locations		MELAV_3a, MELAV_3b, WDCHIL_3a, SING_3b SING_3c, SING_3a, CHARL_3a, EDEAN_3b	MELAV_3d, WDCHIL_3b, CHARL_3b, SING_3e CHARL_3c, EDEAN_3d	MELAV_3c, WDCHIL_3c, SING_3d,, EDEAN_3c	EDEAN_3a
Historic environment	Continued flood risk to known and buried heritage assets and archaeology – listed buildings, Registered Parks and Gardens	No anticipated impacts on heritage assets	No known impacts on heritage assets	No known impacts on heritage assets	No known impacts on heritage assets
Landscape	Continued natural change to the landscape character of the South Downs National Park through increasing flood risk	No permanent change in landscape character anticipated	No permanent change in landscape character anticipated	No permanent change in landscape character anticipated	No permanent change in landscape character anticipated
Sustainability/climate	No depletion of resources & no greenhouse gas emissions but likely to generate significant safety risks associated with increased flooding	No new asset or maintenance requirements	No new asset or maintenance requirements	No new asset or maintenance requirements	Requires limited inspection and maintenance, which can be incorporated into general landscape maintenance



KEY

Lavant Study Boundary

NATURE CONSERVATION DESIGNATIONS

- Special Protection Area and Ramsar Site
- Special Area of Conservation
- Site of Special Scientific Interest
- Kingley Vale National Nature Reserve
- Brandyhole Copse Local Nature Reserve

LANDSCAPE DESIGNATIONS

- South Downs National Park
- Chichester Harbour Area of Outstanding Natural Beauty

HERITAGE

- Listed Building
- Registered Park & Garden
- Scheduled Monument

LAND USE

- GRADE 1 Agricultural
- GRADE 2 Agricultural
- GRADE 3 Agricultural
- National Trails

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Kilometres

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Project :
SURFACE WATER MANAGEMENT PLAN

Drawing :
LAVANT ENVIRONMENTAL CONSTRAINTS AND OPPORTUNITIES PLAN

Drawn By :	Tim Hughes	Date: 08/07/2014
Checked By :	Corinna Morgan	Date: 08/07/2014
Approved By :	Ali Cotton	Date: 08/07/2014

Drawing No. : 435783-001-004
Revision : -
Drawing Scale : 1:60,000

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