SHERFORD

Flood Risk Assessment

NOVEMBER 2006

FLOOD RISK ASSESSMENT | SHERFORD

FOREWORD

Red Tree (2004) LLP has submitted a planning application for 'Sherford' to both South Hams District Council and Plymouth City Council.

The application is in two parts as follows

Outline for:
- up to 5,500 new dwellings;
- up to 67,000 square metres of business and commercial space;
- up to 16,740 square metres of mixed retail accommodation;
- community, sports and open space facilities, including a Community Park;
- three primary schools and one secondary school;
- one health centre;
- two community wind turbines; and
- a Park and Ride interchange at Deep Lane junction.

Detail for:

- the Main Street link between Deep Lane junction and Stanborough Cross.

The application comprises the following documents (the document you are currently reading is in bold):

- Masterplan Book
- Town Code
- Transport Assessment
- Retail Impact Assessment
- Environmental Statement
- Environmental Statement Non-Technical Summary
- Report to Inform an Appropriate Assessment
- **Flood Risk Assessment**
- Section 106 Agreement: Draft Heads of Terms
- Main Street: Deep Lane Junction to Stanborough Cross

The entire planning application and any supporting documents can be viewed at www.redtreellp.com

If you would like to formally comment on the planning application, please contact the determining authorities – South Hams District Council and/or Plymouth City Council.

If you require any further details, please contact either of the following:

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Additional paper copies of this document can be acquired from Scott Wilson at a price of £15.00 per copy.

Red Tree (2004) LLP
Sherford
Flood Risk Assessment

November 2006

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TABLE OF CONTENTS

1 INTRODUCTION

Scott Wilson were commissioned by Red Tree (2004) LLP (hereafter referred to as Red Tree) in May 2005 to undertake a Environmental Impact Assessment (EIA) for the proposed residential development of the Sherford Valley, Plymouth, Devon.

As part of the EIA a Flood Risk Assessment (FRA) of the proposed development is required so the impact to and from the proposed development can be assessed. The Environmental Impact Assessment and FRA are to be submitted with the planning application.

The FRA has been carried out based on a hydrological analysis and hydraulic modelling specifically undertaken for this study. This report summarises the findings of these assessments and the main assumptions made in arriving at flood estimates. The findings of these assessments are then used to determine the flood risk to the proposed development.

1.1 Project Background

The district of South Hams (Devon) has been identified in the adopted Devon Structure Plan as the location for a new community, as a strategic requirement for the Plymouth sub region. To meet the growth, housing, regeneration, environmental and sustainability requirements, the new community must have high quality public transport links, walkable neighbourhoods, mixed use buildings, be of a high density and create enough employment for local residents and residents of the new community. The new community will be an extension to the eastern edge of Plymouth.

South Hams District Council invited The Prince's Foundation to facilitate an Enquiry by Design to investigate the development of the new community site identified in western South Hams. The Prince's Foundation were asked to examine the potential to develop 4000+ houses, employment and mixed use space in this area. The Enquiry by Design concluded that the Sherford development provided an excellent opportunity to create an exemplar, sustainable new community which is an extension to Plymouth. This would stimulate the local economy and make best use of the distinctive environment.

Red Tree are proposing to take this vision forward on the identified Sherford Valley land to the east of Plymouth and south of the A38(T). The proposal will require outline planning permission from South Hams District Council and Plymouth City Council.

As part of the planning application process, this FRA has been prepared such that it can be included with and inform the Environmental Impact Assessment. This will provide the Environment Agency, South Hams District Council, Plymouth City Council, Devon County Council, other statutory agencies and consultees with the necessary information of the flood risk posed to the development and the surrounding areas. This will allow them to make informed decisions of the application with regards to issues relating to flood risk.

1.2 Project Aims

The aim of this study is to provide an FRA report in accordance with the recommendations of Planning Policy Guidance 25: Development and Flood Risk (PPG25) [DTLR, 2001] and with consideration of the new consultation on Planning Policy Statement 25: Development and Flood Risk (ODPM, 2005). The FRA is to provide information to inform an EIA in support of an outline planning application for the proposed Sherford development. In addition, the study is also required to provide flood levels to assist in the assessment of the extent of flooding so that this can be taken into consideration during later stages of the planning and design process.

1.3 Key Issues/Site Specific Requirements

In addition to the standard requirements of an FRA (described in Appendix F of PPG25), the key issues/requirements identified as necessary to address within this FRA have been identified as:

- A hydrological analysis to establish the peak 1 in 100 year flood flows for the two main watercourses that run through the development area.
- Hydraulic modeling of on site watercourses to determine their peak 1 in 100 year flood levels.
- Assessment of the effect of climate change on the estimated fluvial flood levels, in accordance with the requirements of PPS25, which is to replace PPG 25 in the autumn of 2006.
- Presentation of the proposed stormwater management system for the development.

1.4 Deliverables

The deliverables of the study are:

- A Flood Risk Assessment report in accordance with the requirements of PPG25.
- Design standard (1 in 100 years) flood levels and floodplain envelopes for use in the ongoing planning and design process.
- A brief discussion of the options for dealing with floodwater in relation to the proposed development.

2 SITE AND SURROUNDING AREA

2.1 Site Description

The application site totals 490 hectares in area and is located immediately to the east of the City of Plymouth. The location of the site is shown on Figure 1 included in Appendix A. The majority of the site is located within the administrative area of the South Hams District Council, with a small area in the west of the site within the Plymouth City Council administrative area (see administrative boundaries on Figure 1).

The site is bounded by the A38 to the north, adjacent to the Deep Lane Junction, and by the A379 to the south. It lies four miles by road from the centre of Plymouth. There is a narrow road network throughout the site, enclosed within hedge banks.

The land is a shallow basin enclosed by the surrounding landform and is in turn dissected by a number of shallow valleys, which create a rolling topographic landform of ridges and troughs. With substantial woodland to the south and east of the site, it forms a distinct and visually self-contained area. The gently rolling topography to the west of the site then generally falls away towards the Plympton estuary.

The predominant land use throughout the site is agriculture (pastoral/arable) with some extensive stand of trees along the line of the main valley. Small farmsteads and individual properties are scattered throughout. A number of settlements exist within the vicinity of the site; Plymstock and Elburton to the west, Plympton to the north, and Brixton to the south.

Figure 1 shows the two main watercourses which flow through the site. The first is a tributary of Billacombe Brook and from this point on will be referred to as Bridge Stream. It is situated on the western side of the development area. The head (northern extent) of the catchment contributing to Bridge Stream is the approximate location of the A38(T) Highway, while the actual open channel watercourse initiates approximately 50m north of Vealeholme Farm, or approximately 200m to the south of the A38(T) Highway. The watercourse then extends south-westwards through the site for approximately 1km. Downstream of the development area, Bridge Stream becomes Billacombe Brook which runs westwards, partially in culvert, through an urbanised area to its discharge to the River Plym. This discharge point is located approximately 5km west of the development area. The size of the Bridge Stream channel through the development area is approximately 1.00m wide and 0.25m deep as a result of the small (1.16km^2), relatively steep (1 in 40) catchment.

The second watercourse is a tributary of Cofflete Creek and from this point on will be referred to as Sherford Stream. It is situated on the eastern side of the development area. The head (northern extent) of the catchment contributing to Sherford Stream is the approximate location of the A38(T) Highway, while the actual open channel watercourse initiates approximately 200m west of Butlas Farm, or approximately 200m to the south of the A38(T) Highway. The watercourse then extends south-westwards through the site for approximately 2.7km. Downstream of the development area, Sherford Stream continues southwards through an area of mainly rural land use becoming Cofflete Creek before its confluence with the River Yealm. This confluence is located approximately 3km south of the development area. The size of the Sherford Stream channel through the development area is also approximately 1.00m wide and 0.25m deep as a result of the small (2.49km^2), relatively steep (1 in 70) catchment.

2.1.1 Walkover Survey

A site walkover was undertaken by Stephen Riley of Scott Wilson in June 2005. The purpose of the visit was to ensure that there is a good understanding of the watercourses and the surrounding area, and to identify any key issues that may be of relevance to the hydraulic modelling study and subsequent FRA.

2.2 Topographic Survey

Geometry required for the construction of the hydraulic models was obtained from a Digital Elevation Model (DEM). The DEM was generated in ArcInfo using Nextmap data of the development area. The Nextmap data provides groundlevels to a vertical accuracy of 1m on a 5m grid/resolution. Cross sections were obtained from the DEM by generating a query to automatically extract cross section at 100m intervals along the watercourses. Each cross section is 100m long centred on the valley bottom, elevations were extracted at 10m intervals along each cross section.

While the Nextmap DEM can provide topographical information that is of a resolution and accuracy that allows for the satisfactory representation of the floodplain, details of the channel cannot be obtained from a source of this resolution. This is especially so for watercourses as small as those in question. During the site visit, it was observed that both channels are (on average) fairly uniform in shape with dimensions of approximately 1.00m in width and 0.25m deep. As such, rectangular channels of the aforementioned dimensions were manually inserted into the lowest point of each cross-section to produce an accurate, realistic representation of both watercourses which were then inserted into the HEC-RAS (version 3.2.1) hydraulic modelling software. Note that various spot checks have been undertaken to ensure that the DEM levels are consistent with the available topographical survey (Figure 6)

As previously mentioned, the site includes a number of shallow valleys which create a rolling topographic landform of ridges and troughs. The gently rolling topography generally falls southwards away from the A38(T) at levels of approximately 80 – 90m AOD down to levels of approximately 30 – 40mAOD in the middle of the site, before rising again to levels of up to 70 – 80m AOD along the southern boundary of the site. The west of the development area also generally falls away towards the Plympton estuary to the west.

2.3 Local Hydraulic Structures

A review of OS Mapping and aerial photographs of the area, in conjunction with observations made during the site visit, have resulted in the identification of various structures along the Bridge Stream and Sherford Stream.

On Bridge Stream a farm access road culvert is located at Vealeholme Farm while a culvert of approximately 20m in length conveys the flow of Bridge Stream beneath a section of the Elburton Vineries. Downstream of the site boundary there are various culvert and bridge structures. While these structures may affect the conveyance of flow within the open channel, any effects are expected to be localised and have no effect on flooding at the site. The reason for this is that Bridge Stream is relatively steep (1 in 40 within the site boundary) which will result in water weiring over and/or around these structures with minimal backwatering effects. Culverts under farm access roads also tend to be minor structures and have limited freeboards above the culvert soffit. As a result water levels do not have to rise significantly before water weirs across the access road deck and back into the watercourse downstream of the culvert.

Four farm access road culverts have been identified on Sherford Stream within the site boundary, with the A379 crossing forming the downstream boundary of the site. Farm access culverts on this watercourse are also minor structures that would have minimal backwater effect. As indicated on the Masterplan (Figure 2, Appendix A), the area along the southern edge of the site, adjacent to Sherford Stream has been identified for parkland. Therefore any restriction on flow conveyance that the A379 structure may have, will result in minimal consequences in terms of damage to the proposed properties.

The development of the site will include the removal/replacement of several if not all of these culverts, along with the construction of various new road and foot crossings. The removal of these structures could potentially result in the removal of restrictions to the flow of floodwater which could increase the flow to downstream areas. As previously mentioned however, the topography of the site, in conjunction with the limited size of the in-channel restrictions, means that the effect of these restrictions are limited, thus any increase in downstream flow as a result of their removal would be minor.

In order to construct the hydraulic models, assumptions have been made regarding the size and condition of the structures. It has been assumed that the culverts are pipes of 0.40m in diameter and that their condition is good with Manning's 'n' roughness values of 0.015. It has also been assumed that there are no headwalls and that the pipes have simply been installed into the channel with farm access roads formed over top, approximately 0.3m above the bank levels.

As part of the hydraulic modelling sensitivity analysis (Section 3.4), model runs have been undertaken with increased Mannings 'n' values to represent culverts of poor condition, and decreases in the assumed culvert diameters to represent the effects of blockages.

As will be observed in Section 3.4.2, any under estimation of the assumed capacities of these culverts has only minimal effects on the flood levels within the development site.

2.4 Local Flood Alleviation Measures

There are no formal flood defence measures along the sections of Bridge and Sherford streams either upstream or through the development site. This is likely to attributed to the lack of development in the area and the relatively low sensitivity of the land surrounding the watercourses and/or the lack of historical flooding. A lack of widespread flooding is likely to be the result of the relatively steep, well formed valleys within which the watercourses lie, in conjunction with the fact that the contributing catchments are small (1.16km^2 and 2.49km^2 for Bridge Stream and Sherford Stream respectively) with minimal development (0.013 URBEXT [an index of urban density] and 0.006 URBEXT for Bridge Stream and Sherford Stream respectively).

It is not expected that flood alleviation measures would be included as part of the development proposals over an above those that are required to be incorporated into the design of hydraulic structures. All housing and retail that forms part of the development have to be constructed so that they are not at risk of flooding, consequently the completed development should not place any property or people at risk of flooding. Therefore it is envisaged that a flood warning system will not be required for the development. However, should such a system be required, the Environment Agency operate a national flood warning system, which could be extended to cover the development.

The hydraulic modelling has indicated a slight increase in the 1 in 100 year flood levels as a result of the development (refer to Section 3.3), however this is considered to pose only a negligible increase in flood risk to both the development site and surrounding areas. As a result, it is not viewed as being necessary to provide either flood defences or flood warning measures.

2.5 Proposed Development

The proposed Sherford development will be a new town located near Plymouth in south Devon. The current Masterplan has been included in Appendix A as Figure 2. As indicated, the development would include housing, schools, retail and community facilities, recreational facilities, existing woodland, green corridors as well as two wind turbines for energy conversion. The majority of the development will be located to the central and northern areas of the site with the southern extents being landscaped areas. While the natural topography dictates that the majority of the site is not at risk of flooding, development adjacent to either Bridge Stream and Sherford Stream would include finished floor levels for residential dwellings that result in a minimum 300mm freeboard above the 1 in

100 year flood level (including the effects of climate change). For premises used for commercial purposes a reduced freeboard may be considered appropriate. This will be confirmed in discussions with the EA later in the design process. Roads and footpaths etc would be set at minimum levels equal to the 1 in 100 year flood level to ensure dry ingress/egress routes from areas inundated during the 1 in 100 year flood event.

2.6 Regulatory Position

The indicative flood map of the Site (Figure 3, Appendix A), produced by the Environment Agency indicates that the areas of the site along the margins of Bridge Stream and Sherford Stream are within 'Flood Zone 3 - High Risk'.

PPG25 defines Flood Zone 3 as an area that is at high risk from flooding, meaning that flooding of the site would occur during a 1 in 100 year event, from fluvial sources, if flood defences were not present (as is the case for the Sherford site).

PPG25 defines three planning responses for areas within Flood Zone 3, dependent upon the existing land use of the area to be developed. These are:

- Developed Areas: These areas may be suitable for residential, commercial and industrial development provided the appropriate minimum standard of flood defence (including suitable warning and evacuation procedures) can be maintained for the lifetime of the development, with preference being given to those areas already defended to that standard. In allocating or permitting sites for development, authorities should seek to avoid areas that will be needed, or have significant potential, for coastal managed realignment or washland creation as part of the overall flood defence strategy for coastal cells and river catchments.

- Undeveloped & Sparsely developed areas: These areas are generally not suitable for residential, commercial and industrial development unless a particular location is essential, e.g. for navigation and water-based recreation uses, agriculture and essential transport and utilities infrastructure, and an alternative lower-risk location is not available. General-purpose housing or other development comprising residential or institutional accommodation should not normally be permitted. Residential uses should be limited to job-related accommodation (e.g. caretakers and operational staff). Caravan and camping sites should generally not be located in these areas. Where, exceptionally, development is permitted, it should be provided with the appropriate minimum standard of flood defence and should not impede flood flows or result in a net loss of flood-plain storage.

- Functional Floodplains: These areas may be suitable for some recreation, sport, amenity and conservation uses (provided adequate warning and evacuation procedures are in place). Built development should be wholly exceptional and limited to essential transport and utilities infrastructure that has to be there. Such infrastructure should be designed and constructed so as to remain operational even at times of flood, to result in no net loss of flood-plain storage, not to impede water flows and not to increase flood risk elsewhere. There should be a presumption against the provision of camping and caravan sites.

Based on the current Masterplan (Figure 2), the proposed development site is considered to include all three of the above land uses within the areas that are identified as being within Zone 3, albeit confined to the narrow margins along the two watercourses.

In addition to Flood Zone 3, the Environment Agency categorise flood risk into two other flood zones, 2 and 1. Flood Zone 2 indicates the areas at risk from a flood with a 1 in 1000 year return period flood event (for fluvial watercourses, as is the case at Sherford). As indicated by Figure 3 in Appendix A, there is only a small area of the Sherford Stream to the far south west of the site that is located within Flood Zone 2. The remainder (and majority) of the site is located within Flood Zone 1.

This zone indicates areas that are only at risk from a flood event of greater magnitude than a 1 in 1000 year return period event. In other words, these areas have less than a 0.1% probability of flooding in any given year.

As outlined by PPG 25, Flood Zone 1 has *'No constraints due to river, tidal or coastal flooding'* **(**DTLR, 2001). Flood Zone 2 is *'suitable for most development'* (DLTR, 2001) but should be subject to a flood risk assessment that is *'…appropriate to the scale and nature of the development..'* (DTLR, 2001). This FRA meets such requirements of PPG 25.

3 FLOOD SOURCES AND LEVELS

The Environment Agency's flood zone map for the site indicates that some areas of the site are within the flood zone for the 1 in 100 year fluvial floodplain (Figure 3). Consequently at risk areas of the site are classified as 'Flood Zone 3 - High Risk'. For small undeveloped catchments such as the Sherford Valley, the Environment Agency's flood zone maps are often produced using rudimentary methods that can often result in over estimates of the extent of flooding. As a result, a hydraulic modelling study has been undertaken in order to produce updated, more reliable estimates for the 1 in 100 year levels along both Bridge Stream and Sherford Stream. This will allow the 1 in 100 year floodplain envelope to be redefined.

3.1 SHERFORD CATCHMENT DESIGN FLOOD FLOWS

3.1.1 Methodology

Flood flows for Bridge Stream and Sherford Stream for both the existing situation and after the proposed development have been estimated using the statistical procedures of the Flood Estimation Handbook (IoH, 1999).

Neither watercourse has a flow gauge record sufficient for low probability flow statistic generation, therefore flows have been estimated using catchment characteristics to estimate the initial QMED and adjusted using analogue catchments. A pooled analysis has then been undertaken to develop growth factors.

3.1.2 Catchment Characteristics

Catchment characteristics for the Bridge Stream and Sherford Stream catchments have been derived from the Flood Estimation Handbook (FEH) CD ROM. A review of the Lidar derived topographical plan (Appendix B) and OS Mapping (Figure 1, Appendix A) has been undertaken to confirm catchment boundaries and to check for any change in the extent of urbanisation. This revealed no discrepancies between the catchment characteristics and the Lidar/OS information. The catchments are larger than $0.5km^2$, therefore the FEH methodology is appropriate for use.

The median flows ($QMED_{CDs}$) for Bridge Stream and Sherford Stream have been estimated based on a catchment extended to the downstream boundary of each hydraulic model reach (i.e. at Elburton Vineries on Bridge Stream, and the A379 Highway on Sherford Stream). There are no significant tributaries joining either watercourse within the reach identified for hydraulic modelling.

Alternative $QMED_{CDs}$ estimates have also been made using the catchment characteristics for each watercourse, however for comparative purposes the URBEXT values were adjusted to take into account the development proposals.

3.1.3 Pooling Group

The pooling groups for both catchments were derived using data available from the HiFlows-UK programme (Environment Agency, 2005). The effect of the HiFlows-UK programme was to increase the data set by approximately 40% (over the original 1999 FEH-WINFAP dataset), with increased confidence in gauge records and the reliability of the rating curve.

Pooling group stations selected by WINFAP were used to derive the flood growth curve with the exception of stations with descriptors that were deemed to differ too much from the Bridge Stream and Sherford Stream catchments. Where exclusion of these stations resulted in less than the required number of pooled years, further stations were selected to increase the total effective record length to 500 years (in accordance with the ‘5T’ rule). In all cases, the generalised Logistic distribution was identified to give the best fit to the pooling group.

3.1.4 Analogue Catchments

Inspection of the local gauging station network identified no donor catchments were available for either Bridge Stream or Sherford Stream.

Separate pooling groups were obtained for each watercourse using the database derived as part of the Hi-Flows project which includes all stations that are suitable for the calculation of $QMED_{Obs}$ from their observed data record. The top catchments from these pooling groups were reviewed as to their potential to be utilised as analogue catchments for the data transfer. To be suitable for an analogue catchment, the descriptors must be similar to those of the subject catchments. The aim has been to find analogues suitable for use based on the following criteria:

- Should be predominantly rural (URBEXT < 0.025).
- Should not have experienced reservoir development (FARL > 0.95).
- Should have reliable flood flow gauging over a period of at least 15 years.
- Their hydrological characteristics should be similar.

Three gauged sites were judged to be suitable as analogue catchments for Bridge Stream (45817, 45816 and 45818), while six gauged sites were judged to be suitable as analogue catchments for Sherford Stream (45817, 45816, 45818, 52016, 52015, 47007). Following the HiFlows-UK review and the addition of annual maxima data for recent years, each site has a minimum of 11 years of gauged records. Therefore the 95% confidence limits on the estimate of $QMED_{Obs}$ from the annual maximum series is +/- 29%.

3.1.5 Adjustment Factors

Adjustment factors ($QMED_{Obs}/QMED_{CDs}$) for each analogue catchment were derived, and based on their weightings, the geometric means of these factors were calculated and applied to $QMED_{CDs}$ for both the Bridge Stream and Sherford Stream catchments. This was undertaken for the $QMED_{CDs}$ estimates obtained for both the existing and the proposed URBEXT values.

3.1.6 Climate Change

It should also be noted that these estimates are based on historical flow data from the UK and do not allow for any effects of future climate change.

The UKCIP 2002 report (Hulme, M. *et al* 2002) provides the best guidance currently available on the probable effects of climate change and suggests increases up to 20% in rainfall over the next 50 years (up to 2050). Therefore, in line with the recommendations of PPG25, the hydraulic modelling has been undertaken with the 1 in 100 year design flow increased by 20% to allow for the effects of climate change up to the year 2050 (Table 1).

The PPG 25 document is to be superseded with PPS 25 in late 2006. While the recommendation of a 20% flow increase to account for climate change effects by the year 2050 still stands, an additional criteria of a 30% flow increase by the year 2100 is also recommended by PPS 25. As such, the models will also be tested with a 30% increase in the 1 in 100 year design flow.

3.1.7 FEH Calculation Sheets

Calculation sheets for all FEH procedures have been completed and are included in Appendix C.

3.1.8 Final Flow Estimates

Table 1 presents the final flow estimates derived from the flow estimation process. The flows have been derived from the FEH HiFlows-UK dataset.

Suggested error values for the FEH and HiFlows-UK estimates at the 95% confidence interval would be +/- 30% at QMED and +/- 50% at Q100. This however is a subjective assessment based on combination of likely errors (catchment characteristics, then weighting on analogue catchments etc).

Table 1: Peak Discharges, various return periods, in m^3/sec

	1 in 2 year (Q2/QMED)	1 in 10 year (Q10)	1 in 50 year (Q50)	1 in 100 year (Q100)	1 in 100 year + 20% Climate Change	1 in 100 year + 30% Climate Change
Bridge Stream - Existing	0.37	0.67	1.03	1.24	1.49	1.61
Bridge Stream - Proposed	0.74	1.33	2.06	2.47	2.96	3.21
Sherford Stream - Existing	0.69	1.25	1.91	2.27	2.72	2.95
Sherford Stream - Proposed	0.84	1.51	2.31	2.75	3.30	3.58

3.2 Hydraulic Modelling

3.2.1 Introduction

The objective of this hydraulic modelling study is to estimate peak water levels in both Bridge Stream and Sherford Stream. The peak water levels arising from a flood event with a return period of 100 years will allow the extent of the 1 in 100 year floodplain to be established, and consequently the level of flood risk to both the existing and the proposed site. The flood levels obtained will be used for the FRA to show that both the proposed development, and surrounding areas, would not be exposed to an unacceptable level of flood risk. This hydraulic modelling study has been carried out in four stages:

- Model construction.
- Design runs.
- Sensitivity testing.
- Review of the results.

The model extent and the location of cross-sections used to construct the model are shown on Figure 4 located in Appendix A.

The design flows used in the hydraulic modelling are those produced during the hydrological assessment, discussed in Section 3.1. For conservatism, the flow has been adjusted for climate change. Insufficient information of previous flood events is available to enable a calibration of the model. Therefore instead of calibration, a range of sensitivity tests have been carried out to assess the effect of changes to the assumptions made in the hydraulic modelling.

The hydraulic modelling software selected for the study is Hec-Ras v 3.1.2 from the US Army Corps of Engineers. As there are no surface water bodies included in the model that are likely to provide flood storage and attenuate flood flows, the Hec-Ras model has been run in steady state mode. The computational procedure for the steady state version of Hec-Ras is based on the solution of the 1-D energy equation, while the momentum equation is utilised for situations where the water surface profile is rapidly varied i.e. mixed flow regimes, structures within the channel etc.

With the appropriate simplification of the two watercourses, and the adoption of some assumptions based on good engineering judgement, Hec-Ras is capable of modelling all of the key features required for this assessment.

Note that all levels stated as part of this modelling study, be it ground levels from the topographical survey, or water levels estimated by the modelling, are to Ordnance Datum. Also note that electronic copies of the Hec-Ras model files used in this study are included on the attached CDROM.

3.2.2 Model Construction

The Hec-Ras model layout is illustrated in Figure 4.

The model of Bridge Stream has its upstream boundary located at Vealeholme Farm, approximately 200m to the south of the A38(T) Highway. The modelled reach of this watercourse extends downstream (south-westwards) for approximately 1km to its downstream boundary at Elburton Vineries. The model includes a farm access road culvert at Vealeholme farm near the upstream end of the model, and a 20m length of culvert beneath Elburton Vineries near the models downstream end.

The modelled reach of Sherford Stream has its upstream boundary located at Butlas Farm Road, approximately 200m to the south of the A38(T) Highway. This watercourse extends downstream (south-westwards) for approximately 2.7km to its downstream boundary at the A379 Highway. The Sherford Stream model includes four farm access road culverts as marked on Figure 4.

3.2.3 Cross-sections

The model cross-sections are based on ‘NextMap’ topographic information obtained for the development area with levels taken on a 5m grid with a vertical accuracy of approximately 1m. The data was processed to produce a Digital Terrain Model (DTM) from which cross-sections were abstracted at 100m intervals. This resulted in 14 and 28 cross-sections for Bridge Stream and Sherford Stream respectively. As mentioned in Section 2.2, the survey cannot be used to accurately represent the open channel part of the cross-section and therefore rectangular channels 1.00m wide and 0.25m deep were manually inserted into the lowest point of each cross-section. A review of all cross-sections was undertaken as part of the final model audit to ensure their accuracy.

3.2.4 Structures

Hec-Ras computes energy losses caused by structures in three stages. The first stage consists of losses that occur in the reach immediately downstream of the structure, where the expansion of the flow takes place. The second stage consists of the losses that occur as flow travels through, and out of the structure. The last stage consists of losses that occur in the reach immediately upstream of the structure, where the flow is contracting towards the opening of the structure.

As a result of a site visit, in conjunction with a review of OS Mapping and aerial photographs of the area, various structures have been identified within the modelled reaches of each watercourse. This includes five minor farm access road culverts (assumed lengths of 5m), and a culvert of significant length (20m) which conveys the flow of Bridge Stream beneath part of the Elburton Vineries.

As mentioned in Section 2.3, these structures have not been surveyed and therefore assumptions have been made of their size and condition. It has been assumed that the culverts are pipes of 0.4m in diameter and that their condition is good with Manning's 'n' roughness values of 0.015. These assumptions have been tested as part of the sensitivity analysis (refer to Section 3.4). As will be observed in Section 3.4.2, any under estimation of the assumed capacities of these culverts has only minimal effects on the flood levels within the development site. The reason for this is that they are culverts under farm access roads which have only limited freeboards above the culvert soffit and that water levels do not have to rise significantly before they weir across the road deck and back into the watercourse downstream of the culvert. The watercourses are also relatively steep at 1 in 40 and 1 in 70 for Bridge Stream and Sherford Stream respectively.

3.2.5 Storage

There are no ponds or reservoirs either upstream or within the development site. As such, the model can be run in steady state as storage effects do not need to be considered.

3.2.6 Roughness

The watercourse roughness coefficients used in the hydraulic model are Mannings 'n' roughness values. Values were estimated from visual inspection of the channel and floodplain and with reference to Open Channel Hydraulics (Chow, 1973 Table 5-6).

The channel Manning's 'n' value has been taken as 0.03 based on observations made during a site visit. This represents an earthed, winding, sluggish channel with grass and some weeds.

The Manning's 'n' value for the floodplain component of the cross-sections has been set at 0.050. This value is based upon observations made during a site visit and represents short-high grass with some brush vegetation in places.

The Manning's 'n' value for the culverts has been set at 0.015. This value is based upon the assumption of concrete pipe culverts.

Sensitivity tests have been carried out on channel, floodplain and culvert roughness coefficients (refer to Section 3.4.1).

3.2.7 Boundary Conditions

The upstream inflow boundary conditions consist of the peak flows derived as part of the hydrological assessment. It is generally accepted that climate change will have an effect on river flows in the UK in the future, which are likely to result in higher peak rates of flow for a given return period. In recognition of this, present day peak flow rates used in this flood risk assessment will be increased by both 20% and 30% in line with current EA recommendations to assess the impact on the flood risk.

Normal depth boundaries were used at the downstream ends of each model reach. As part of the sensitivity testing, additional model runs were undertaken where peak water levels at the downstream boundaries were raised by 0.5m to show that the effect of the forced normal depth at the downstream end of the model is negligible (refer to Section 3.4.3).

3.2.8 Calibration and Verification

Insufficient historical flow data was available for full calibration of the models. As a result, a sensitivity study has been undertaken to demonstrate confidence in the model results.

3.3 Simulation Details

The models were run for the 100 year design event simulation as derived from the FEH statistical method. As PPS25 suggests that fluvial flows could increase by up to 20% and 30% by the years 2050 and 2100 respectively as a result of climate change, the 100 year flows were increased to account for these affects. These Q100+30% flows formed the Baseline Case upon which the sensitivity analysis would be evaluated. A summary of the flood depths and floodplain envelope widths are presented in Appendix D while the model files on the attached CD-ROM can be consulted if more details are required.

During the 100 year return period flood, water levels were shown to be out of bank for Bridge Stream however with water depths of approximately 0.4 – 0.6m (average 0.5m, or 0.25m above bank level), the extent of flooding across the floodplain is between 8.4 and 72.9m (average 22.3m). Note that the 72.9m figure is immediately upstream of Elburton Vineries culvert with the floodplain width dropping back to 21.5m 100m upstream at the next cross-section. This is therefore a very localised area of inundation caused by the surcharging of the culvert. Water was shown to weir across the top of the Elburton Vineries culvert, however this would be limited to a depth of 0.02m. The culvert at Vealeholme Farm was also shown to surcharge with water weiring over top of the structure at a depth of 0.13m.

Increasing the peak flow on Bridge Stream by 20% and 30% has the effect of raising flood levels by up to 0.03m and 0.04m respectively. These maximum increases are viewed as being insignificant as are the increases in the width of the floodplain envelope i.e. 0.1– 5.94m (average 1.6m) for the 20% increase, and 0.4– 9.7m (average 2.4m) for the 30% increase.

When the development proposals were represented within the Bridge Stream catchment, the flood depth increased by an average of 0.08m over the undeveloped catchment for all three flow scenarios (Q100, Q100+20%, Q100+30%). This corresponds to the following increases in the width of the floodplain envelope i.e. 1.1 – 32.5m (average 8.7m) for the Q100 flow, 1.6 – 42.2m (average 10.6m) for the Q100+20% flow, and 0.8 – 46.3m (average 11.5m) for the Q100+30% flow.

During the 100 year return period flood, water levels were shown to be out of bank for Sherford Stream however with water depths of approximately 0.3 – 0.9m (average 0.6m, or 0.35m above bank level), the extent of flooding across the floodplain is limited to 2.5 – 31.0m (average 14.1m). All four farm road access culverts on the modelled section of Sherford Stream were shown to surcharge with water weiring over top of the structure at depths of 0.14m to 0.20m.

Increasing the peak flow on Sherford Stream by 20% and 30% has the effect of raising flood levels by up to 0.08m and 0.13m respectively. These maximum increases are viewed as being insignificant as are the increases in the width of the floodplain envelope i.e. 0.2– 1.7m (average 0.8m) for the 20% increase, and 0.3– 2.4m (average 1.2m) for the 30% increase.

When the development proposals were represented within the Sherford Stream catchment, the flood depth increased by an average of 0.04m over the undeveloped catchment for all three flow scenarios (Q100, Q100+20%, Q100+30%). Again this corresponds to minimal increases in the width of the floodplain envelope i.e. 0.2 – 1.8m (average 0.8m) for the Q100 flow, 0.2 – 3.8m (average 1.0m) for the Q100+20% flow, and 0.2 – 10.7m (average 1.2m) for the Q100+30% flow.

3.4 Model Sensitivity

As no historical or gauged information exists with which to calibrate the hydraulic models, it is important to test the sensitivity of the results to the main assumptions in order to give some confidence in the results that have been produced. The following sensitivity tests have been carried out to show the significance of these assumptions:

- Manning's 'n' +20%.
- Structure blockages.
- Increase in water levels at the downstream boundary.

3.4.1 Manning's 'n'

Variation in channel and floodplain resistance reflects the uncertainties in both its estimation, and also the potential seasonal variability, while variation in the culvert resistance reflects the uncertainties in their condition. To test the significance of these estimates and the sensitivity of the water levels to a change in roughness, the Manning's 'n' values for channel, floodplain, and structures were increased by 20% (i.e. from n = 0.03 to n = 0.036 for the channel, from n = 0.050 to n = 0.060 for the floodplain, and from n = 0.015 to n = 0.018 for all the culverts).

A summary of the results is presented in Appendix D while the model files on the attached CD-ROM can be consulted if more details are required. The results indicate that negligible, if any change to the water levels occur as the roughness coefficients are increased by 20%. The maximum increase in water level along Bridge Stream was just 0.05m for both the existing and proposed development scenarios for the Q100+30% flow, while for Sherford Stream the maximum water level increase was just 0.1m.

Note that due to the constraints imposed on this assessment, it was only the Q100+30% flow for which the Mannings 'n' sensitivity testing was undertaken as this flow scenario gives the most conservative flood estimates. While the effect of a Mannings 'n' increase is likely to be greater for lower flow rates, any increase in flood levels are not expected to be significantly larger than the Q100+30% increases.

These results indicate that the models are very insensitive to increases in the roughness parameters. This is because the catchments are quite steep (1 in 40 for Bridge Stream and 1 in 70 for Sherford Stream) and any increase in roughness is likely to involve only a minimal loss in relation to the total energy of the system.

3.4.2 Structure Blockage

The culvert structures within the hydraulic models could potentially become blocked with debris and create backwatering effects as a result of their decrease in conveyance. This effect however is likely to be limited due to the fact that the capacity of all culverts are exceeded for the baseline flows (i.e. Q100, Q100+20% and Q100+30%) causing water to weir over top of these structures.

An assumed diameter for all culverts of 0.4m has been used for the hydraulic modelling. This may in fact be an over estimate and in reality the actual diameters could be less than 0.4. By decreasing the size of these culverts, this structure blockage sensitivity testing will also test for the effects of any potential under estimate of the culvert diameters. All culvert diameters have been reduced to 0.2m (a 75% decrease in area) and the models have been run with the Q100+30% flow for both the existing and the developed catchments. Note however that the results of the model runs which take into account the development proposals may not be of much relevance as it is likely that all these culverts would be removed.

A summary of the results is presented in Appendix D while the model files on the attached CD-ROM can be consulted if more details are required. As expected, the results indicate only negligible increases in flood levels immediately upstream of the culverts occur as a result of their decrease in capacity. It is shown that the majority of the flow weirs over the top of the structures with only a small proportion of the flow (approximately 10% for Bridge Stream and 5% for Sherford Stream for the 0.4m, diameter culvert) is conveyed through the culvert. When the culvert size is reduced to 0.2m in diameter, the proportion of the total flow conveyed through the culverts drops to approximately 1% of the total flow of both watercourses.

3.4.3 Downstream Boundary Raising

The previous model runs have been undertaken using the assumption that the normal depth would occur at the downstream boundary of the modelled reaches. In order to assess the effect that this assumption has on flood levels along the modelled sections of both watercourses, the peak water levels at the downstream boundary cross-sections were raised 0.5m from that which occurred during the Q100+30% model runs.

A summary of the results is presented in Appendix D while the model files on the attached CD-ROM can be consulted if more details are required. These show that the effects of assuming a normal depth at the downstream boundary are limited to less than 100m on Bridge Stream (i.e. there is no change in flood level 100m upstream at the next cross-section) for the Q100+30% flow based on both the existing and the proposed development scenarios. For Sherford Stream the effects extend back 300 upstream for the Q100+30% flow rate based on the existing level of catchment development, however it should be noted that the increase in flood level at the next cross-section 100m upstream from the downstream boundary is just 0.08m. For the Q100+30% flow rate based on the proposed development, the effects extend 500m upstream of the downstream boundary. Again it should also be noted that the increase in flood level at the next cross-section 100m upstream from the downstream boundary is just 0.09m.

These results indicate that the model is relatively insensitive to the assumption of a normal depth for the downstream boundary condition and that any measurable effects extend less than 100m upstream. This can be attributed to the relative steepness of both catchments.

This hydraulic modelling study was undertaken to determine the level of flood risk throughout the proposed development area. This information will now form the basis upon which to base the FRA report for the proposed development. The model was constructed using information obtained from Lidar data, observations and photos taken during a site visit.

The baseline model runs were based on roughness coefficients of 0.03, 0.050 and 0.015 for the channel, floodplain and culverts respectively, normal flow depths at the downstream boundaries, and our estimates of the 1 in 100 year flows with allowances to account for the predicted effects associated with climate change by the years 2050 and 2100. The baseline case model runs indicated that water would spill out of bank and that the existing culvert structures are not capable of conveying the Q100 flows, however both the depth of flooding and the extent of inundation would be limited.

Figure 5 of Appendix A shows the extent of the 1 in 100 year floodplain and thus the flood risk posed to the development area from Bridge Stream and Sherford Stream. Note that these floodplain envelopes have been based on the 1 in 100 year flow with an additional 30% to account for climate change up to the year 2100. This flow rate was also based on the proposed extent of development within both catchments such that a worst-case scenario could be obtained. Note that the scale of Figure 1 is unlikely to highlight any change in the floodplain envelopes between the different climate change scenarios (i.e. Q100, Q100+20% and Q100+30%), and possibly also the existing and proposed levels of development within both catchments.

Increases of the Manning's 'n' roughness values by 20% had insignificant effects to both the flood levels and width of the floodplain envelope along the modelled watercourses. The reason of the models insensitivity to increased Mannings n values can be attributed to the catchments relative steepness and that these increases in roughness are likely to involve only small loss's in relation to the total energy of the system.

The assessment of the potential backwatering effects as a result of either blockages, or alternatively, our under estimation of the size of the various culverts situated on both the watercourses indicated only negligible increases in flood levels immediately upstream of the culverts occur as a result of their decrease in size. It was shown that the majority of the flow weirs over the top of the structures with only a small proportion of the flow being conveyed through each culvert. As such, a reduction in the culvert size causes an increase of the flow weiring across the structures however as this additional flow is spread out over the entire width of the structure, there is little effect on the water levels immediately upstream.

Adopting a normal depth as a downstream boundary condition is the best approach to use when no information of downstream water levels are available. However it is important to test the sensitivity of the flood levels along the modelled reach to this downstream boundary. The downstream boundary of both watercourses was raised by 0.5m which can be considered to be conservative as the normal depths were found to be 0.5m and 1.1m for Bridge Stream and Sherford Stream respectively. The results indicated that the models are relatively insensitive to the assumption of a normal depth for the downstream boundary condition and that any measurable effects extend less than 100m upstream. This can be attributed to the relative steepness of both catchments.

4 ASSESSMENT OF FLOOD RISK

4.1 Probabilities of Extent and Depth of Flooding

The 1 in 100 year fluvial flood levels for the sections of Bridge Stream and Sherford Stream that run through the proposed development area have been estimated as part of a hydraulic modelling study (refer to Section 3). Model runs were undertaken which included the current guidelines on climate change which suggest that an additional 20% and 30% should be added to the 1 in 100 year flow for the effects of climate change by the years 2050 and 2100 respectively.

During the 100 year return period flood, water levels were shown to be out of bank for Bridge Stream with average floodwater depths of 0.5m while the corresponding extent of flooding across the floodplain was 22.3m on average. Increasing the peak flow in Bridge Stream by 20% and 30% has the effect of raising flood levels by up to 0.03m and 0.04m respectively while the increases in the average width of the floodplain envelope were just 1.6m and 2.4m for the 20% and 30% flow additions.

During the 100 year return period flood, water levels were shown to be out of bank for Sherford Stream with average water depths of 0.6m, while the corresponding the extent of flooding across the floodplain was 14.1m on average. Increasing the peak flow in Sherford Stream by 20% and 30% has the effect of raising flood levels by up to 0.08m and 0.13m respectively while the increases in the average width of the floodplain envelope were just 0.8m and 1.2m for the 20% and 30% flow additions.

The development of greenfield land requires the attenuation of surface water runoff to ensure that the discharge to the receiving environment (i.e. Bridge Stream and Sherford Stream is no greater than the present situation). In order to assess the effects that this additional run-off contributing to each watercourse may have, additional model runs were undertaken where the development proposals were represented within the two catchments.

For Bridge Stream the flood depth increased by an average of 0.08m over the undeveloped catchment for all three flow scenarios (Q100, Q100+20%, Q100+30%). This corresponds to the following increases in the width of the floodplain envelope i.e. 1.1 – 32.5m (average 8.7m) for the Q100 flow, 1.6 – 42.2m (average 10.6m) for the Q100+20% flow, and 0.8 – 46.3m (average 11.5m) for the Q100+30% flow.

When the development proposals were represented within the Sherford Stream catchment, the flood depth increased by an average of just 0.04m over the undeveloped catchment for all three flow scenarios (Q100, Q100+20%, Q100+30%). Again this corresponds to minimal increases in the width of the floodplain envelope i.e. 0.2 – 1.8m (average 0.8m) for the Q100 flow, 0.2 – 3.8m (average 1.0m) for the Q100+20% flow, and 0.2 – 10.7m (average 1.2m) for the Q100+30% flow.

Figure 5, included in Appendix A indicates the extent of inundation predicted for the 1 in 100 year flow plus an additional 30% to account for climate change by the year 2100. This flow also includes the development proposals within both catchments. The various model results (Appendix D) can be consulted for flood level information at specific locations along each watercourse.

4.2 Rate and Duration of Flooding

Because the hydraulic modelling was undertaken in steady state mode, it is not possible to make a detailed assessment of the rate and duration of flooding of the site. Instead it should be noted that both catchments are small and relatively steep in a part of the country that has a relatively high level of rainfall. These factors would tend to suggest that these watercourses may be prone to flash type flooding especially once the catchments have been developed. While water levels in Bridge Stream and Sherford Stream could potentially change (both rise and fall) relatively rapidly, the limited flood risk as associated with the peak 1 in 100 year flood levels means that the consequences with regards to damage, safety concerns etc would be minimal.

4.3 Flood Management Options and Consequences

The hydraulic modelling has indicated that the extent and depth of flooding along both Bridge Stream and Sherford Stream would be relatively minor during the 1 in 100 year flood event. This has been shown for the existing level of development in the catchment, while the additional development that would result from the proposals would give only a minimal increase in the level of flooding. The current Masterplan included in Appendix A as Figure 2 indicates various types of development would take place along the margins of both watercourses.

Due to the narrow margins of inundation, it is envisaged that restricting construction to outside the 1 in 100 year floodplain would be easily achievable while not compromising the scope of the development. Roading and footpaths etc close to the two watercourses would be set at minimum levels of the 1 in 100 year flood level to ensure dry ingress/egress routes to/from areas inundated during the 1 in 100 year flood event. It is therefore considered that with the aforementioned measures, the consequences of flooding to the small areas along the margins of both Bridge Stream and Sherford Stream are minimal. Therefore it is not seen as necessary to provide any formal defences as part of the development nor is it seen necessary to put any formal flood evacuation procedures into place.

As outlined in Section 3.4.2 above, the potential for structure (such as the existing culverted section of the Bridge Stream) blockage is considered to be limited. The development proposals include additional culverting of the Bridge Stream in order to develop the new entrance road. In order for this to minimise the potential for it to cause upstream flooding caused by blockage, the culvert diameter should be large enough to convey floodwaters.

Finished floor levels for residential dwellings would be set such that they result in a minimum 300mm freeboard above the 1 in 100 year flood level while for premises used for commercial purposes, a reduced freeboard may be considered appropriate. It should be noted however, the because of relative steepness of the catchment valleys, it would only be a small number of properties that would be affected by these freeboard requirements.

For the remaining properties finished floor levels would be set such that they are a minimum of 200mm above the surrounding ground levels in order to protect against local surface water flooding. Intense short duration rainfall events may overwhelm the sewer network proposed for the site from time to time. This is particularly so for events with return periods greater than 30 years for which is often adopted for design standard of drainage systems.

4.4 Residual Risks

The sections of Bridge Stream and Sherford Stream that run through the development area are not currently defended due to the small, rural nature of the catchments. As indicated in Section 4.3 above, the main development will be located above the 1 in 100-year return period flood levels. As a result it is not seen as necessary to provide defences as part of the development and therefore there would be no residual risk as a result of any failure.

4.5 Flood Plain Storage Displacement

It is envisaged that due to the limited extent of fluvial flooding within the development area, construction or ground level raising within the floodplain would be minimal. In the event that a loss of floodplain were to occur as a result of the development, the provision of compensatory storage on a level for level basis would be provided at a location that is as close as practically possible to the loss of floodplain.

5 ASSESSMENT OF EXISTING AND PROPOSED DRAINAGE

5.1 Existing Stormwater Runoff Management

The development area is currently rural and drains naturally towards Bridge Stream and Sherford Stream. It is likely that there is a network of drainage ditches to assist in the drainage of the area however the extent of such a network is unknown.

5.2 Proposed Stormwater/Runoff Management

The management and disposal of stormwater is required to consider water quality and flood risk issues.

5.2.1 Water Quality

The quality of water discharged from the development is an important consideration. It is likely that the proposed stormwater management system would utilise a gravity system discharging to Bridge Stream and Sherford Stream. In keeping with the Environment Agency's Pollution Prevention Guideline 3 (PPG3), Class 1 By-pass separators would be installed upstream of all discharge points and be subject to cleaning and maintenance on a regular basis.

5.2.2 Flood Risk

The Sherford area is considered to be greenfield as its land use is predominately agricultural. The area currently drains to Bridge Stream and Sherford Stream and any increase in urbanisation of these catchments would result in an increase of both the rate and volume of surface water run-off discharged into these two watercourses. The Environment Agency generally require that for all new development, surface water run-off is managed within the site boundary for up to the 1 in 100 year storm event to ensure that the rate of discharge to the receiving environment is not increased from the existing situation. This is to ensure that the level of flood risk to downstream areas is not increased due to increased rates of flow for a given return period. In order to attenuate the surface water discharge to at least the existing rate, some form of on-site storage will be required which may or may not utilise the direct infiltration to ground should conditions be suitable.

In order to attenuate discharge from a site the size of Sherford down to greenfield rates would require substantial volumes of on-site storage which is likely to be unviable with regards to both economics, and also trying to fit this storage into the scope of the development. Instead a more pragmatic approach is proposed where approximately half the required storage would be provided. The hydraulic model is used for performance of the drainage system during a high intensity rainfall event is an important consideration if surcharged drains are not to present a flood risk to people and property.

6 CONCLUSIONS

This document describes the Flood Risk Assessment undertaken in support of the outline planning application for the proposed development of Sherford Valley, Plymouth. The Flood Risk Assessment focuses on the key issues and likely implications of flood risk associated with the proposed development and has been undertaken in line with PPG25 and the requirements of the Environment Agency.

This document is supported by the hydrological analysis and hydraulic modelling study undertaken to provide an estimate of the extent of flooding throughout the Sherford area. Following completion of the Flood Risk Assessment, the following can be noted:

6.1 Flood Sources and Levels

- The source of flooding within the Sherford area is fluvial flooding from Bridge Stream and Sherford Stream.
- The design standard flood for the site is the 1 in 100 year fluvial flood which includes an additional 30% to the peak flow to account for predicted climate change effects by the year 2100.
- The estimated average flood depth for the Bridge Stream channel is 0.5m for the 1 in 100 year flood event. The average width of the floodplain envelope for this watercourse is 24.6m. These estimates are based on the Q100+30% flow for the existing level of development within the catchment. When the development proposals are included, the flood levels increase by an average 0.08m while the width of floodplain increases by an average 11.5m.
- The estimated average flood depth for the Sherford Stream channel is 0.6m for the 1 in 100 year flood event. The average width of the floodplain envelope for this watercourse is 15.3m. These estimates are based on the Q100+30% flow for the existing level of development within the catchment. When the development proposals are included, the flood levels increase by an average 0.04m while the width of floodplain increases by an average 1.2m.
- It is proposed that a more detailed hydraulic model be constructed as part of the ongoing planning and design process. This model would include surveyed channel sections and structures, and would extend downstream of the site in order to assess the affects of the increased run-off from the developed catchments. Any proposed changes to the watercourses (i.e. diversions and culverts) could also be included. It would also be advisable that the models are run in unsteady state such that any storage within the system can be utilised.

6.2 Flood Defences

- Neither Bridge Stream nor Sherford Stream is defended. This can be attributed to the lack of historical flooding due to the local topography; in conjunction with the fact that the area is currently used for agriculture and is therefore relatively undeveloped.

6.3 Flood Risk

- The hydraulic modelling has indicated that the extent and depth of flooding along both Bridge Stream and Sherford Stream would be relatively minor during the 1 in 100 year flood event for both the existing catchment and also inclusive of the development proposals.

- The extent of the 1 in 100 year floodplain is indicated on Figure 5 of Appendix A. Note that these floodplain envelopes are based on the Q100+30% flows based on the developed catchments (i.e. the worst case scenario).

6.4 Flood Defence and Flood Mitigation

- The current Masterplan included in Appendix A as Figure 2 indicates various types of development would take place along the margins of both watercourses. However due to the narrow margins of inundation, it is envisaged that restricting construction to outside the 1 in 100 year floodplain would be a feasible means of flood mitigation.

- Finished floor levels for any residential dwellings adjacent to the watercourses would be set such that they result in a minimum 300mm freeboard above the 1 in 100 year flood level, while for premises used for commercial purposes, a reduced freeboard may be considered appropriate.

- If any roads/footpaths etc were to be constructed within the floodplain, they would be set at minimum levels of the 1 in 100 year flood level to ensure dry ingress/egress routes to/from inundated areas.

- It is considered that with the aforementioned measures, the consequences of flooding to the narrow margins of both Bridge Stream and Sherford Stream are minimal. Therefore it is not seen as necessary to provide any formal defences as part of the development nor is it seen necessary to put any formal flood evacuation procedures into place.

7 REFERENCES

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APPENDIX A: FIGURES

APPENDIX B: HYDROLOGICAL ANALYSIS CALCULATIONS

Calculations

Project	Sherford FRA - Developed Catchment Flood Flow Estimation

D108531		Date 03 April 2006	Page 1 of 2

Originator	Checked	Rev	Suffix	Orig						
ASM	SR		Date	Check						

Input		Output
	QMED calculation for the Sherford Stream using the Catchment Descriptors	

AREA	2.49	km2
FARL	1	
BFIHOST	0.657	
SAAR	1129	mm
SPRHOST	24	
URBEXT	0.128	

Calculation of rural QMED

RESHOST = -0.018
QMED rural = 0.657 m3/s

Calculation of urban adjusted QMED Applicable if catchment is urban (URBEXT > 0.025). Therefore adjustment is required

QMED =UAF x QMED rural
where UAF = PRUAF$(1+URBEXT)^{0.83}$
and PRUAF = 1 + 0.615URBEXT((70/SPRHOST)-1)

PRUAF = 1.15088
UAF = 1.271881
QMED = 0.836 m3/s

Data Transfer
QMED x 1.055 = 0.836x1.055
=0.840m3/s

Return Period	Growth Curve Factor	Flow
Q2 (QMED)	1	0.84
Q10	1.80	1.51
Q50	2.75	2.31
Q100	3.27	2.75

Calculations

Project	Sherford FRA - Developed Catchment Flood Flow Estimation									
D108531			Date	03 April 2006		Page	2 of 2			
Originator	Checked	Rev	Suffix	Orig						
ASM	SR		Date	Check						

Input		Output

QMED calculation for the Bridge Stream using the Catchment Descriptors

AREA	1.16	km2
FARL	1	
BFIHOST	0.68	
SAAR	1099	mm
SPRHOST	21.4	
URBEXT	0.38	

Calculation of rural QMED

RESHOST = -0.029
QMED rural = 0.272 m3/s

Calculation of urban adjusted QMED Applicable if catchment is urban (URBEXT > 0.025). Therefore adjustment is required

QMED =UAF x QMED rural
where UAF = PRUAF$(1+\text{URBEXT})^{0.83}$
and PRUAF = 1 + 0.615URBEXT((70/SPRHOST)-1)

PRUAF = 1.530739
UAF = 1.999866
QMED = 0.544 m3/s

Data Transfer
QMED x 1.055 = 0.544x1.361
=0.740m3/s

Return Period	Growth Curve Factor	Flow
Q2 (QMED)	1	0.74
Q10	1.80	1.33
Q50	2.79	2.06
Q100	3.34	2.47

APPENDIX C: HYDRAULIC MODEL RESULTS

Table E1: Bridge Stream - Hec-Ras Modelling Results

Scenario	Q100 Existing Catchment		Q100+20% Existing Catchment				Q100+30% Existing Catchment				Q100 Developed Catchment				Q100+20% Developed Catchment				Q100+30% Developed Catchment			
Plan File	14		15				16				17				18				19			
Geometry File	2		2				2				2				2				2			
Steady Flow File	8		9				10				11				12				13			
Section Chainage	W.S. Elev	Floodplain Width	W.S. Elev	Change[A]	Floodplain Width	Change[A]	W.S. Elev	Change[A]	Floodplain Width	Change[A]	W.S. Elev	Change[A]	Floodplain Width	Change	W.S. Elev	Change[B]	Floodplain Width	Change[B]	W.S. Elev	Change[C]	Floodplain Width	Change[C]
105.25	62.70	9.07	62.73	0.03	9.99	0.92	62.74	0.04	10.41	1.34	62.81	0.11	12.75	3.68	62.84	0.11	13.72	3.73	62.86	0.12	14.35	3.94
1000	60.35	16.51	60.36	0.01	16.84	0.33	60.36	0.01	16.93	0.42	60.39	0.04	17.58	1.07	60.41	0.05	18.43	1.59	60.39	0.03	17.77	0.84
995	59.98	10.58	60.00	0.02	11.51	0.93	60.01	0.03	11.95	1.37	60.08	0.10	14.78	4.20	60.10	0.10	15.76	4.25	60.12	0.11	16.40	4.45
900	55.62	8.42	55.65	0.03	9.30	0.88	55.66	0.04	9.66	1.24	55.73	0.11	11.96	3.54	55.76	0.11	12.82	3.52	55.78	0.12	13.30	3.64
800	51.23	12.81	51.26	0.03	14.62	1.81	51.27	0.04	15.58	2.77	51.34	0.11	45.29	32.48	51.37	0.11	56.79	42.17	51.38	0.11	61.83	46.25
700	46.35	20.00	46.37	0.02	22.11	2.11	46.38	0.03	23.04	3.04	46.43	0.08	26.87	6.87	46.46	0.09	29.21	7.10	46.47	0.09	30.31	7.27
600	45.24	17.24	45.25	0.01	18.08	0.84	45.26	0.02	18.63	1.39	45.30	0.06	20.89	3.65	45.32	0.07	21.73	3.65	45.32	0.06	22.13	3.50
500	42.85	33.28	42.86	0.01	36.47	3.19	42.87	0.02	37.35	4.07	42.90	0.05	41.05	7.77	42.91	0.05	41.80	5.33	42.91	0.04	42.23	4.88
400	38.93	17.68	38.95	0.02	18.59	0.91	38.95	0.02	18.82	1.14	39.00	0.07	21.62	3.94	39.01	0.06	22.61	4.02	39.02	0.07	22.93	4.11
300	37.02	32.15	37.02	0.00	32.24	0.09	37.02	0.00	32.61	0.46	37.06	0.04	44.97	12.82	37.08	0.06	46.83	14.59	37.08	0.06	47.07	14.46
200	35.58	13.90	35.61	0.03	15.88	1.98	35.62	0.04	16.36	2.46	35.69	0.11	21.26	7.36	35.73	0.12	23.86	7.98	35.72	0.10	23.45	7.09
100	34.64	21.49	34.65	0.01	22.46	0.97	34.66	0.02	23.39	1.90	34.69	0.05	26.35	4.86	34.70	0.05	27.86	5.40	34.73	0.07	36.97	13.58
0	33.82	72.88	33.83	0.01	73.64	0.76	33.84	0.02	74.10	1.22	33.87	0.05	76.65	3.77	33.88	0.05	77.06	3.42	33.89	0.05	77.34	3.24
-20	33.43	25.53	33.45	0.02	31.47	5.94	33.46	0.03	35.19	9.66	33.49	0.06	43.50	17.97	33.51	0.06	63.35	31.88	33.53	0.07	69.36	34.17
-160	31.73	22.84	31.75	0.02	24.23	1.39	31.75	0.02	25.02	2.18	31.80	0.07	34.92	12.08	31.82	0.07	37.42	13.19	31.83	0.08	38.39	13.37

Scenario	Sensitivity Test Run Mannings n+20%, Q100+30%, Existing Catchment				Sensitivity Test Run Mannings n+20%, Q100+30%, Developed Catchment				Sensitivity Test 75% Culvert size Reduction, Q100+30%, Existing Catchment				Sensitivity Test 75% Culvert Size Reduction, Q100+30%, Developed Catchment				Sensitivity Test DS Boundary +0.5m, Q100+30%, Existing Catchment			
Plan File	21				20				5				6				23			
Geometry File	4				4				7				7				2			
Steady Flow File	10				13				10				13				16			
Section Chainage	W.S. Elev	Change[C]	Floodplain Width	Change[C]	W.S. Elev	Change[D]	Floodplain Width	Change[D]	W.S. Elev	Change[C]	Floodplain Width	Change[C]	W.S. Elev	Change[D]	Floodplain Width	Change[D]	W.S. Elev	Change[C]	Floodplain Width	Change[C]
105.25	62.74	0.00	10.41	0.00	62.86	0.00	14.35	0.00	62.74	0.00	10.41	0.00	62.86	0.00	14.35	0.00	62.74	0.00	10.41	0.00
1000	60.37	0.01	16.97	0.04	60.39	0.00	17.75	-0.02	60.38	0.02	17.30	0.37	60.40	0.01	18.15	0.38	60.36	0.00	16.93	0.00
995	60.01	0.00	11.95	0.00	60.12	0.00	16.40	0.00	60.01	0.00	11.95	0.00	60.12	0.00	16.40	0.00	60.01	0.00	11.95	0.00
900	55.66	0.00	9.66	0.00	55.78	0.00	13.30	0.00	55.66	0.00	9.66	0.00	55.78	0.00	13.30	0.00	55.66	0.00	9.66	0.00
800	51.27	0.00	15.58	0.00	51.38	0.00	61.83	0.00	51.27	0.00	15.58	0.00	51.38	0.00	61.83	0.00	51.27	0.00	15.58	0.00
700	46.41	0.03	25.22	2.18	46.51	0.04	33.27	2.96	46.38	0.00	23.04	0.00	46.47	0.00	30.31	0.00	46.38	0.00	23.04	0.00
600	45.26	0.00	18.63	0.00	45.32	0.00	22.13	0.00	45.26	0.00	18.63	0.00	45.32	0.00	22.13	0.00	45.26	0.00	18.63	0.00
500	42.87	0.00	37.35	0.00	42.91	0.00	42.23	0.00	42.87	0.00	37.35	0.00	42.91	0.00	42.23	0.00	42.87	0.00	37.35	0.00
400	38.95	0.00	18.82	0.00	39.02	0.00	23.04	0.11	38.95	0.00	18.82	0.00	39.02	0.00	22.93	0.00	38.95	0.00	18.82	0.00
300	37.02	0.00	32.61	0.00	37.08	0.00	47.07	0.00	37.02	0.00	32.61	0.00	37.08	0.00	47.07	0.00	37.02	0.00	32.61	0.00
200	35.66	0.04	19.24	2.88	35.77	0.05	26.52	3.07	35.62	0.00	16.36	0.00	35.72	0.00	23.45	0.00	35.62	0.00	16.36	0.00
100	34.66	0.00	23.39	0.00	34.73	0.00	36.97	0.00	34.66	0.00	23.39	0.00	34.73	0.00	36.97	0.00	34.66	0.00	23.39	0.00
0	33.84	0.00	74.18	0.08	33.89	0.00	77.44	0.10	33.84	0.00	74.50	0.40	33.89	0.00	77.64	0.30	33.84	0.00	74.10	0.00
-20	33.46	0.00	35.19	0.00	33.53	0.00	69.48	0.12	33.46	0.00	35.19	0.00	33.53	0.00	69.36	0.00	33.46	0.00	35.19	0.00
-160	31.77	0.02	26.98	1.96	31.85	0.02	40.70	2.31	31.75	0.00	25.02	0.00	31.83	0.00	38.39	0.00	32.25	0.50	92.02	67.00

See next page for notes.

Table E1 continued: Bridge Stream - Hec-Ras Modelling Results

Scenario	**Sensitivity Test Run Mannings n+20%, Q100+30%, Proposed Catchment**			
Plan File	21			
Geometry File	4			
Steady Flow File	10			
Section Chainage	**W.S. Elev**	**Change[D]**	**Floodplain Width**	**Change[D]**
105.25	62.86	0.00	14.35	0.00
1000	60.39	0.00	17.77	0.00
995	60.12	0.00	16.40	0.00
900	55.78	0.00	13.30	0.00
800	51.38	0.00	61.83	0.00
700	46.47	0.00	30.31	0.00
600	45.32	0.00	22.13	0.00
500	42.91	0.00	42.23	0.00
400	39.02	0.00	22.93	0.00
300	37.08	0.00	47.07	0.00
200	35.72	0.00	23.45	0.00
100	34.73	0.00	36.97	0.00
0	33.89	0.00	77.34	0.00
-20	33.53	0.00	69.36	0.00
-160	32.33	0.50	102.45	64.06

Notes: Levels are to Ordnance Datum
Levels and floodplain widths are measured in metres
[A] Levels and floodplain widths are related to the Q100, Existing Catchment model run to obtain the change in level/width
[B] Levels and floodplain widths are related to the Q100+20%, Existing Catchment model run to obtain the change in level/width
[C] Levels and floodplain widths are related to the Q100+30%, Existing Catchment model run to obtain the change in level/width
[D] Levels and floodplain widths are related to the Q100+30%, Proposed Catchment model run to obtain the change in level/width

Table E2: Sherford Stream - Hec-Ras Modelling Results

Scenario	**Q100 Existing Catchment**		**Q100+20% Existing Catchment**				**Q100+30% Existing Catchment**				**Q100 Developed Catchment**				**Q100+20% Developed Catchment**				**Q100+30% Developed Catchment**			
Plan File	8		9				10				11				12				13			
Geometry File	3		3				3				3				3				3			
Steady Flow File	2		3				4				7				6				5			
Section Chainage	**W.S. Elev**	**Floodplain Width**	**W.S. Elev**	**Change[A]**	**Floodplain Width**	**Change[A]**	**W.S. Elev**	**Change[A]**	**Floodplain Width**	**Change[A]**	**W.S. Elev**	**Change[A]**	**Floodplain Width**	**Change**	**W.S. Elev**	**Change[B]**	**Floodplain Width**	**Change[B]**	**W.S. Elev**	**Change[C]**	**Floodplain Width**	**Change[C]**
2697.2	58.25	16.92	58.28	0.03	17.71	0.79	58.29	0.04	18.01	1.09	58.28	0.03	17.79	0.87	58.30	0.02	18.59	0.88	58.31	0.02	20.25	2.24
2600	54.82	15.28	54.84	0.02	15.76	0.48	54.84	0.02	15.92	0.64	54.84	0.02	15.79	0.51	54.86	0.02	16.35	0.59	54.87	0.03	16.54	0.62
2500	51.80	5.33	51.85	0.05	5.83	0.50	51.88	0.08	6.06	0.73	51.85	0.05	5.86	0.53	51.91	0.06	6.39	0.56	51.94	0.06	6.67	0.61
2400	49.55	7.85	49.59	0.04	8.55	0.70	49.61	0.06	8.92	1.07	49.60	0.05	8.67	0.82	49.64	0.05	9.35	0.80	49.66	0.05	9.68	0.76
2300	47.67	10.93	47.70	0.03	11.80	0.87	47.71	0.04	12.11	1.18	47.70	0.03	11.85	0.92	47.73	0.03	12.75	0.95	47.75	0.04	13.15	1.04
2200	45.51	16.88	45.53	0.02	18.12	1.24	45.54	0.03	18.61	1.73	45.53	0.02	17.97	1.09	45.56	0.03	19.67	1.55	45.57	0.03	20.40	1.79
2100	43.33	23.46	43.34	0.01	23.69	0.23	43.35	0.02	23.95	0.49	43.35	0.02	23.89	0.43	43.37	0.03	24.29	0.60	43.38	0.03	24.59	0.64
2095	43.08	19.69	43.11	0.03	20.59	0.90	43.12	0.04	20.87	1.18	43.11	0.03	20.63	0.94	43.14	0.03	21.34	0.75	43.16	0.04	21.64	0.77
2000	42.08	7.18	42.13	0.05	7.82	0.64	42.15	0.07	8.16	0.98	42.13	0.05	7.86	0.68	42.17	0.04	8.55	0.73	42.20	0.05	8.93	0.77
1900	39.79	13.08	39.82	0.03	13.98	0.90	39.83	0.04	14.32	1.24	39.82	0.03	14.03	0.95	39.85	0.03	14.92	0.94	39.86	0.03	15.29	0.97
1800	37.98	19.15	38.01	0.03	20.10	0.95	38.02	0.04	20.54	1.39	38.01	0.03	20.17	1.02	38.04	0.03	23.86	3.76	38.07	0.05	31.19	10.65
1700	36.60	15.55	36.62	0.02	16.58	1.03	36.63	0.03	17.08	1.53	36.62	0.02	16.64	1.09	36.65	0.03	17.76	1.18	36.65	0.02	18.09	1.01
1600	35.19	12.29	35.23	0.04	13.51	1.22	35.24	0.05	13.90	1.61	35.23	0.04	13.57	1.28	35.26	0.03	14.44	0.93	35.27	0.03	15.02	1.12
1500	33.63	14.20	33.65	0.02	15.15	0.95	33.66	0.03	15.71	1.51	33.65	0.02	15.23	1.03	33.69	0.04	16.59	1.44	33.70	0.04	17.01	1.30
1405	33.04	31.04	33.06	0.02	31.72	0.68	33.08	0.04	32.78	1.74	33.06	0.02	31.88	0.84	33.08	0.02	32.59	0.87	33.08	0.00	32.99	0.21
1400	32.86	25.39	32.87	0.01	26.17	0.78	32.88	0.02	26.50	1.11	32.87	0.01	26.22	0.83	32.89	0.02	26.99	0.82	32.90	0.02	27.34	0.84
1300	31.10	18.06	31.13	0.03	19.77	1.71	31.14	0.04	20.46	2.40	31.13	0.03	19.87	1.81	31.15	0.02	21.45	1.68	31.16	0.02	21.92	1.46
1200	29.52	12.83	29.54	0.02	13.53	0.70	29.55	0.03	14.21	1.38	29.54	0.02	13.65	0.82	29.58	0.04	15.30	1.77	29.58	0.03	15.45	1.24
1100	29.16	18.51	29.18	0.02	18.94	0.43	29.19	0.03	19.18	0.67	29.18	0.02	19.00	0.49	29.21	0.03	19.49	0.55	29.22	0.03	19.73	0.55
1095	28.93	14.99	28.96	0.03	15.56	0.57	28.98	0.05	15.87	0.88	28.96	0.03	15.60	0.61	28.99	0.03	16.16	0.60	29.01	0.03	16.50	0.63
1000	27.93	19.32	27.95	0.02	20.58	1.26	27.96	0.03	20.98	1.66	27.95	0.02	20.65	1.33	27.98	0.03	21.94	1.36	27.99	0.03	22.32	1.34
900	27.23	21.86	27.24	0.01	22.34	0.48	27.26	0.03	22.67	0.81	27.25	0.02	22.41	0.55	27.27	0.03	23.08	0.74	27.27	0.01	23.12	0.45
895	27.04	17.84	27.08	0.04	18.83	0.99	27.09	0.05	19.29	1.45	27.08	0.04	18.88	1.04	27.12	0.04	19.95	1.12	27.14	0.05	20.46	1.17
800	26.39	8.02	26.44	0.05	8.79	0.77	26.46	0.07	9.12	1.10	26.44	0.05	8.84	0.82	26.49	0.05	9.66	0.87	26.52	0.06	10.06	0.94
700	25.38	8.02	25.42	0.04	8.73	0.71	25.44	0.06	9.09	1.07	25.42	0.04	8.78	0.76	25.46	0.04	9.53	0.80	25.48	0.04	9.87	0.78
600	23.88	11.54	23.90	0.02	11.79	0.25	23.91	0.03	11.91	0.37	23.90	0.02	11.81	0.27	23.93	0.03	12.04	0.25	23.94	0.03	12.20	0.29
500	22.39	11.77	22.42	0.03	12.68	0.91	22.45	0.06	13.28	1.51	22.43	0.04	12.75	0.98	22.48	0.06	13.86	1.18	22.49	0.04	14.24	0.96
400	21.64	10.23	21.68	0.04	11.31	1.08	21.69	0.05	11.51	1.28	21.69	0.05	11.36	1.13	21.72	0.04	12.29	0.98	21.75	0.06	12.93	1.42
300	20.66	5.73	20.71	0.05	6.24	0.51	20.73	0.07	6.45	0.72	20.71	0.05	6.26	0.53	20.77	0.06	6.75	0.51	20.79	0.06	6.98	0.53
200	19.90	9.00	19.94	0.04	9.76	0.76	19.96	0.06	10.14	1.14	19.94	0.04	9.81	0.81	19.99	0.05	10.70	0.94	20.01	0.05	11.14	1.00
100	19.38	7.46	19.46	0.08	8.32	0.86	19.50	0.12	8.74	1.28	19.47	0.09	8.38	0.92	19.56	0.10	9.35	1.03	19.60	0.10	9.81	1.07
0	18.75	2.51	18.83	0.08	2.71	0.20	18.88	0.13	2.80	0.29	18.84	0.09	2.72	0.21	18.94	0.11	2.93	0.22	18.98	0.10	3.03	0.23

Notes: Levels are to Ordnance Datum
Levels and floodplain widths are measured in metres
[A] Levels and floodplain widths are related to the Q100, Existing Catchment model run to obtain the change in level/width
[B] Levels and floodplain widths are related to the Q100+20%, Existing Catchment model run to obtain the change in level/width
[C] Levels and floodplain widths are related to the Q100+30%, Existing Catchment model run to obtain the change in level/width

Table E2 continued: Sherford Stream - Hec-Ras Modelling Results

Scenario	**Sensitivity Test Run Mannings n+20%, Q100+30%, Existing Catchment**				**Sensitivity Test Run Mannings n+20%, Q100+30%, Developed Catchment**				**Sensitivity Test 75% Culvert size Reduction, Q100+30%, Existing Catchment**				**Sensitivity Test 75% Culvert Size Reduction, Q100+30%, Developed Catchment**				**Sensitivity Test DS Boundary +0.5m, Q100+30%, Existing Catchment**			
Plan File	1				2				4				3				7			
Geometry File	5				5				6				6				3			
Steady Flow File	4				5				4				5				14			
Section Chainage	**W.S. Elev**	**Change[C]**	**Floodplain Width**	**Change[C]**	**W.S. Elev**	**Change[D]**	**Floodplain Width**	**Change[D]**	**W.S. Elev**	**Change[C]**	**Floodplain Width**	**Change[C]**	**W.S. Elev**	**Change[D]**	**Floodplain Width**	**Change[D]**	**W.S. Elev**	**Change[C]**	**Floodplain Width**	**Change[C]**
2697.2	58.29	0.00	18.01	0.00	58.31	0.00	20.25	0.00	58.29	0.00	18.01	0.00	58.31	0.00	20.25	0.00	58.29	0.00	18.01	0.00
2600	54.84	0.00	15.92	0.00	54.87	0.00	16.54	0.00	54.84	0.00	15.92	0.00	54.87	0.00	16.54	0.00	54.84	0.00	15.92	0.00
2500	51.88	0.00	6.06	0.00	51.94	0.00	6.67	0.00	51.88	0.00	6.06	0.00	51.94	0.00	6.67	0.00	51.88	0.00	6.06	0.00
2400	49.61	0.00	8.92	0.00	49.66	0.00	9.68	0.00	49.61	0.00	8.92	0.00	49.66	0.00	9.68	0.00	49.61	0.00	8.92	0.00
2300	47.71	0.00	12.11	0.00	47.75	0.00	13.15	0.00	47.71	0.00	12.11	0.00	47.75	0.00	13.15	0.00	47.71	0.00	12.11	0.00
2200	45.54	0.00	18.61	0.00	45.57	0.00	20.40	0.00	45.54	0.00	18.61	0.00	45.57	0.00	20.40	0.00	45.54	0.00	18.61	0.00
2100	43.36	0.01	24.08	0.13	43.38	0.00	24.52	-0.07	43.36	0.01	24.21	0.26	43.39	0.01	24.76	0.17	43.35	0.00	23.95	0.00
2095	43.17	0.05	21.88	1.01	43.21	0.05	22.73	1.09	43.12	0.00	20.87	0.00	43.16	0.00	21.64	0.00	43.12	0.00	20.87	0.00
2000	42.15	0.00	8.16	0.00	42.20	0.00	8.93	0.00	42.15	0.00	8.16	0.00	42.20	0.00	8.93	0.00	42.15	0.00	8.16	0.00
1900	39.83	0.00	14.32	0.00	39.86	0.00	15.29	0.00	39.83	0.00	14.32	0.00	39.86	0.00	15.29	0.00	39.83	0.00	14.32	0.00
1800	38.06	0.04	29.70	9.16	38.09	0.02	31.67	0.48	38.02	0.00	20.54	0.00	38.07	0.00	31.19	0.00	38.02	0.00	20.54	0.00
1700	36.65	0.02	18.05	0.97	36.69	0.04	19.43	1.34	36.63	0.00	17.08	0.00	36.65	0.00	18.09	0.00	36.63	0.00	17.08	0.00
1600	35.25	0.01	14.21	0.31	35.29	0.02	15.68	0.66	35.24	0.00	13.90	0.00	35.27	0.00	15.02	0.00	35.24	0.00	13.90	0.00
1500	33.66	0.00	15.71	0.00	33.70	0.00	17.01	0.00	33.66	0.00	15.71	0.00	33.70	0.00	17.01	0.00	33.66	0.00	15.71	0.00
1405	33.06	-0.02	32.07	-0.71	33.08	0.00	32.98	-0.01	33.07	-0.01	32.37	-0.41	33.09	0.01	33.32	0.33	33.08	0.00	32.78	0.00
1400	32.86	-0.02	25.62	-0.88	32.89	-0.01	27.06	-0.28	32.88	0.00	26.50	0.00	32.90	0.00	27.34	0.00	32.88	0.00	26.50	0.00
1300	31.14	0.00	20.47	0.01	31.16	0.00	21.92	0.00	31.14	0.00	20.46	0.00	31.16	0.00	22.16	0.24	31.14	0.00	20.46	0.00
1200	29.61	0.06	16.74	2.53	29.68	0.10	19.65	4.20	29.55	0.00	14.21	0.00	29.59	0.01	15.83	0.38	29.55	0.00	14.21	0.00
1100	29.19	0.00	19.19	0.01	29.21	-0.01	19.52	-0.21	29.20	0.01	19.35	0.17	29.23	0.01	19.86	0.13	29.19	0.00	19.18	0.00
1095	29.03	0.05	16.92	1.05	29.07	0.06	17.65	1.15	28.98	0.00	15.87	0.00	29.01	0.00	16.50	0.00	28.98	0.00	15.87	0.00
1000	27.96	0.00	20.98	0.00	27.99	0.00	22.32	0.00	27.96	0.00	20.98	0.00	27.99	0.00	22.32	0.00	27.96	0.00	20.98	0.00
900	27.26	0.00	22.73	0.06	27.29	0.02	23.61	0.49	27.26	0.00	22.86	0.19	27.29	0.02	23.56	0.44	27.26	0.00	22.67	0.00
895	27.12	0.03	20.03	0.74	27.17	0.03	21.37	0.91	27.09	0.00	19.29	0.00	27.14	0.00	20.46	0.00	27.09	0.00	19.29	0.00
800	26.53	0.07	10.30	1.18	26.58	0.06	11.12	1.06	26.46	0.00	9.12	0.00	26.52	0.00	10.06	0.00	26.46	0.00	9.12	0.00
700	25.45	0.01	9.33	0.24	25.51	0.03	10.39	0.52	25.44	0.00	9.09	0.00	25.48	0.00	9.87	0.00	25.44	0.00	9.09	0.00
600	23.91	0.00	11.91	0.00	23.94	0.00	12.20	0.00	23.91	0.00	11.91	0.00	23.94	0.00	12.20	0.00	23.91	0.00	11.91	0.00
500	22.48	0.03	14.07	0.79	22.53	0.04	15.00	0.76	22.45	0.00	13.28	0.00	22.49	0.00	14.24	0.00	22.45	0.00	13.29	0.01
400	21.74	0.05	12.86	1.35	21.80	0.05	14.06	1.13	21.69	0.00	11.51	0.00	21.75	0.00	12.93	0.00	21.69	0.00	11.51	0.00
300	20.78	0.05	6.88	0.43	20.84	0.05	7.41	0.43	20.73	0.00	6.45	0.00	20.79	0.00	6.98	0.00	20.76	0.03	6.71	0.26
200	20.02	0.06	11.34	1.20	20.08	0.07	12.47	1.33	19.96	0.00	10.14	0.00	20.01	0.00	11.14	0.00	19.92	-0.04	9.53	-0.61
100	19.57	0.07	9.44	0.70	19.67	0.07	10.55	0.74	19.50	0.00	8.74	0.00	19.60	0.00	9.81	0.00	19.58	0.08	9.55	0.81
0	18.98	0.10	3.02	0.22	19.09	0.11	3.27	0.24	18.88	0.00	2.80	0.00	18.98	0.00	3.03	0.00	19.38	0.50	3.91	1.11

Notes: Levels are to Ordnance Datum
Levels and floodplain widths are measured in metres
[C] Levels and floodplain widths are related to the Q100+30%, Existing Catchment model run to obtain the change in level/width
[D] Levels and floodplain widths are related to the Q100+30%, Proposed Catchment model run to obtain the change in level/width

Table E2 continued: Sherford Stream - Hec-Ras Modelling Results

Scenario	**Sensitivity Test Run Mannings n+20%, Q100+30%, Proposed Catchment**			
Plan File	22			
Geometry File	3			
Steady Flow File	15			
Section Chainage	**W.S. Elev**	**Change[D]**	**Floodplain Width**	**Change[D]**
2697.2	58.31	0.00	20.25	0.00
2600	54.87	0.00	16.54	0.00
2500	51.94	0.00	6.67	0.00
2400	49.66	0.00	9.68	0.00
2300	47.75	0.00	13.15	0.00
2200	45.57	0.00	20.40	0.00
2100	43.38	0.00	24.59	0.00
2095	43.16	0.00	21.64	0.00
2000	42.20	0.00	8.93	0.00
1900	39.86	0.00	15.29	0.00
1800	38.07	0.00	31.19	0.00
1700	36.65	0.00	18.09	0.00
1600	35.27	0.00	15.02	0.00
1500	33.70	0.00	17.01	0.00
1405	33.08	0.00	32.99	0.00
1400	32.90	0.00	27.34	0.00
1300	31.16	0.00	21.92	0.00
1200	29.58	0.00	15.45	0.00
1100	29.22	0.00	19.73	0.00
1095	29.01	0.00	16.50	0.00
1000	27.99	0.00	22.32	0.00
900	27.27	0.00	23.12	0.00
895	27.14	0.00	20.46	0.00
800	26.52	0.00	10.06	0.00
700	25.48	0.00	9.87	0.00
600	23.94	0.00	12.20	0.00
500	22.50	0.01	14.46	0.22
400	21.73	-0.02	12.56	-0.37
300	20.81	0.02	7.18	0.20
200	19.98	-0.03	10.64	-0.50
100	19.69	0.09	10.79	0.98
0	19.48	0.50	4.12	1.09

Notes: Levels are to Ordnance Datum
Levels and floodplain widths are measured in metres
[D] Levels and floodplain widths are related to the Q100+30%, Proposed Catchment model run to obtain the change in level/width