Network Rail

HELE BRIDGE REPLACEMENT

Flood Risk Assessment

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Flood Risk Assessment

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EXECUTIVE SUMMARY

WSP have been appointed by Network Rail to undertake a Flood Risk Assessment compliant with the NPPF and accompanying PPG, to support planning application for new bridges at Station Road and Devon Valley Mill in Hele, Devon (hereafter referred to as the 'Site'). The reason for the works is to reduce the frequency of flooding to the mainline railway line that connects much of Devon and Cornwall to the rest of the country. The planning application includes:

- Removal and replacement of the existing Station Road with a raised viaduct;
- Demolition of the Mill Access Bridge;
- Construction of a new raised Mill Access Bridge adjacent to the current bridge location; and
- Re-profiling of the flood basin.
- Construction of a flood defence to mitigate against increased risk to properties in Hele Square.

The Site is located in Hele, a village in Devon, lying about three miles SSW of Cullompton and 10 miles NNE of Exeter. The proposed works are part of the Network Rail Western Route Flood Resilience works at Hele and Bradninch.

The Environment Agency Flood Map for Planning shows the entirety of the Site to be in Flood Zone 3. A FRA is therefore required to support the planning application according to National Policy.

The area covered by these proposals is known to flood and causes significant disruption to the road and rail network. The proposed works are required to improve the flood resilience of the railway at Hele and Bradninch.

A Flood Risk Assessment (FRA) was produced in April 2018 to support the original planning application followed by an addendum in July 2018. On the basis of new information, survey data and revisions to the design of the proposed bridge the proposals have been amended and a new assessment of the flood risk has been carried out.

This revised FRA presents the finding of the updated baseline hydraulic modelling, which improves the representation of the modelling.

Existing hydraulic modelling has been adapted and improved to test the impacts of the proposed new bridge structures and re-profiled flood basin. This has shown that the proposed works result in a significant improvement in the flood risk to the railway and other properties in Hele for their lifetime, both in terms of depth and duration of flooding.

There is, however, a small increase in the flood depth that is predicted at three properties and a garage in Hele Square (140mm for 1 in 10 and 100yr Return Periods). Mitigation in the form of a flood defence wall/embankment is proposed at these properties. Discussions between Network Rail and residents as to the final form of the defences are ongoing.

It should be noted that these properties are already at risk and that the mitigation will provide both protection against the current and increased flood risk as a result of the scheme. The proposed defence level for Hele Square will offer protection against the 1 in 100yr RP event including allowances for future increases due to climate change over 100 years, tested against an increase up to 61%, in accordance with current guidance.

The onset of flooding to the railway is predicted to be reduced from less than 1 in 2 years to 1 in 5 years under present conditions. Flood depths are reduced, and the duration of flooding predicted is also significantly reduced. Additional wider benefits include significant reduction in flood risk to the Crossways Tavern and businesses on both sides of the railway, along with reduced flooding to the Devon Valley Mill site and the access bridge. There is also improved conveyance through the constricted area resulting in reduced sedimentation and risk of blockage.

This FRA therefore demonstrates that the proposals, with mitigation at Hele Square, meet the requirements of NPPF and PPG.

1. INTRODUCTION

BACKGROUND

WSP have been appointed by Network Rail to undertake a Flood Risk Assessment compliant with the NPPF[1] and accompanying PPG[2], to support an outline planning application for new bridges at Station Road and Devon Valley Mill in Hele, Devon (hereafter referred to as the 'Site'). The reason for the works is to reduce the frequency of flooding to the mainline railway line that connects much of Devon and Cornwall to the rest of the country.

The planning application includes:

- Removal and replacement of the existing Station Road with a raised viaduct;
- Demolition of the Mill Access Bridge;
- Construction of a new raised Mill Access Bridge adjacent to the current bridge location; and
- Re-profiling of the flood basin.
- Construction of a flood defence to mitigate against increased risk to properties in Hele Square.

A location plan of the Site is included in Appendix A. Details of the proposed new bridges are provided in Appendix B.

THE SITE

The Site is located in Hele, a village in Devon, lying about three miles SSW of Cullompton and 10 miles NNE of Exeter. The proposed works are part of the Network Rail Western Route Flood Resilience works at Hele and Bradninch.

The Environment Agency Flood Map for Planning[3] (Appendix C) shows the entirety of the Site to be in Flood Zone 3. An FRA is therefore required to support the planning application according to National Policy.

SCOPE AND AIMS

This Level 3 FRA (an FRA which incorporates hydraulic modelling) has been undertaken in accordance with the guidelines set out in the NPPF and the associated PPG.

The aim of this FRA is to assess existing flood risk and demonstrate that the Site can be developed safely without exposing the Proposed Scheme to an unacceptable degree of flood risk, or increase the flood risk to third parties (i.e. off-site).

The objectives of this FRA are to:

- Confirm the sources of flooding which may affect the Site;
- Provide an appraisal of the availability and adequacy of existing information;

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[1] Department for Communities and Local Government (2014) - National Planning Policy Framework (NPPF). Accessed online - https://www.gov.uk/government/publications/national-planning-policy-framework--2

[2] Department for Communities and Local Government (2014) - Planning Practice Guidance (PPG). Accessed online - https://www.gov.uk/government/collections/planning-practice-guidance

[3] Environment Agency (2021) Flood Map for Planning. Accessed online via: Link

- Undertake an appraisal of the flood risk posed to the Site, and potential impact of the Proposed Scheme on flood risk elsewhere;
- Provide a conceptual strategy for mitigating flood risks to, or resulting from, the Proposed Scheme; and
- Incorporate latest NPPF guidance on climate change impact.

STUDY METHODOLOGY

To achieve the above aims, the following has been undertaken:

- Engagement with the relevant statutory consultees regarding flooding of the Site, including requesting flood level data, information on historic flooding events and local flood defences;
- Collection and review of existing and publicly available data relevant to flood risk;
- Site visit to identify local flood risk sources, flood mechanisms and pathways;
- Assessment of the risk of flooding to the Proposed Scheme from all sources, including consideration of climate change;
- Update of the existing hydraulic modelling to verify flood extents and to support the design proposals;
- Identify any mitigation measures required to manage the risk of flooding; and
- Report the findings in this technical report, providing sufficient supporting information as required.

LIMITATIONS

WSP has prepared this report in accordance with the instructions of Network Rail and MacLaughlin & Harvey for their sole and specific use relating solely to the above site. Any person who uses any information contained herein does so at their own risk and shall hold WSP harmless in any event.

Whilst this report was prepared using the reasonable skill and care ordinarily exercised by engineers practicing under similar circumstances and reasonable checks have been made on data sources and the accuracy of the data, WSP accepts no liability in relation to the report should any data, information or condition be incorrect or have been concealed, withheld, misrepresented or otherwise not fully disclosed to WSP. In any event, WSP shall not be liable for any loss or damages arising under or in connection to the use of this report

2. PLANNING POLICY AND ENGAGEMENT

2.1. PLANNING POLICY DOCUMENTS AND PREVIOUS STUDIES

The following documents have been reviewed and used to define the scope and technical requirements of this FRA, namely:

- NPPF (June, 2019) and associated PPG (October 2019, online live tool);
- Flood and Water Management Act (April, 2010);
- Mid Devon Level 1 Strategic Flood Risk Assessment (2014);
- Western Route Flood Resilience, Hele and Bradninch GRIP 3 Modelling, April 2016, Mott MacDonald

2.2. ENGAGEMENT

The following organisations were contacted regarding the management of flood risk from the Proposed Scheme at this and earlier stages:

- Environment Agency (as part of the previous stage of the development of the proposals);
- Mid Devon District Council (as part of the previous stage of the development of the proposals); and
- Devon County Council Highways (regarding the form of structure and maintenance).

Copies of relevant correspondence received to date are included in Appendix D and discussed in more detail in relevant sections of this report.

Residents of Hele and local businesses were also consulted during June and July 2018 via meetings and email, and in September 2021 through meetings between Network Rail and individual property owners. Further engagement is planned for November 2021. Engagement between Network Rail, South West Water and the residents of Hele Square regarding mitigation is ongoing.

3. EXISTING SITE

3.1. SITE LOCATION

The Site is located at Station Road in Hele, about one mile SSW of Bradninch and 10 miles NNE of Exeter. The proposed works are to the bridges and floodplain in the immediate vicinity of the existing bridges. These works cover an area of approximately 1 hectare. The area affected is a combination of existing bridges and floodplain. The impacts of the works on flood risk are experienced over a wider area and mitigation measures are proposed to deal with third party flood risk in Hele Square.

An approximate postcode for the site is EX5 4PL. A site location plan has been included in Figure A1 in Appendix A.

3.2. SITE DESCRIPTION

Table 3-1 describes the general Site characteristics.

Table 3-1 - Characteristics of the Site

CHARACTERISTIC		DESCRIPTION
Area		The Site is approximately 1 ha.
Existing Use		The Site includes the existing Station Road Bridge and the existing Mill Access Bridge. The River Culm and its floodplain flows underneath the bridges.
General Topography		The floodplain up and downstream of the bridges is uneven, with some drainage channels, scrub vegetation and standing water at the time of visit (18th January 2018) Ground levels in the floodplain are at approximately 36mODN at the location of the bridges, with the road level varying around approx. 37.4mODN. Over the wider area, levels vary from 39mODN 1km upstream of the site, to 35mODN at the downstream rail crossing.
Boundaries	North	Devon Valley Mill – a paper mill
	South	River Culm floodplain and railway line
	East	Industrial area
	West	A number of residential properties.
Access		Station Road is the main access to the Site.

3.3. EXISTING WATERBODIES

The River Culm and its floodplain flows under Station Road. The aim of the proposed Network Rail works is to improve the flood resilience of the railway and road at Hele from the River Culm.

The River Culm is a Main River, and so falls under the responsibility of the Environment Agency. It rises in the Blackdown Hills at a spring near RAF Culmhead in Somerset, and flows west through Hemyock, then Culmstock (in the Culm Valley) to Uffculme. The river turns south, through Cullompton (and alongside the M5 Motorway), through Hele and then joins the River Exe just south of Stoke Cannon, on the north-western outskirts of Exeter.

The River Culm flows from north east to south west through the Site and has a catchment area of 260 km^2 at the Site. The floodplain varies from approximately 370m upstream to 40m wide at the site location (before flooding onto the road and railway), widening downstream to 160m.

At Devon Valley Mill the River Culm bifurcates, most likely with a Mill Leat coming off to the east. The two channels run parallel under Station Road and then re-join approximately 1 km downstream, between the villages of Beare and Penstone.

There are no other waterbodies within the vicinity of the Site.

The Site is approximately 20km from the Exe Estuary and therefore not tidal at this location.

3.4. EXISTING FLOOD DEFENCE AND DRAINAGE INFRASTRUCTURE

The Environment Agency's Flood Map for Planning[4] shows that the Site is in Flood Zone 3, showing the wide floodplain of the River Culm.

There are flood defences upstream on the River Culm at Cullompton, and downstream at Stoke Cannon, but no Environment Agency owned or designated defences in the vicinity of the Site.

The Devon Valley Mill site is protected by a flood defence wall formed of precast concrete blocks which encloses the north and east sides of the site.

The Site is included in the *River Culm (Lower) from Cullompton to Stoke Cannon, including Hele* Flood Warning. This includes Riverside locations and roads between Cullompton and Stoke Canon, including Woodmill, Hele, Silverton Mills, Rewe, Huxham, the A396 at Stoke Canon, the B3185 at Silverton, and the Exeter to London Paddington Railway Line.

3.5. SOILS, GEOLOGY AND HYDROGEOLOGY

The National Soils Maps show that the soils in the surrounding area of the Site (and the majority of the River Culm catchment) are understood to be freely draining, slightly acid loamy soils. However the Site itself is shown to be loamy and clayey floodplain soils with naturally high groundwater levels.

Information obtained from the British Geological Survey[5] (BGS) indicates that the bedrock at the Site is Cadbury Breccia Formation. These sedimentary rocks are fluvial, lacustrine and marine in origin. The bedrock is then overlaid by Alluvium - clay, silt, sand and gravel.

Site specific GI was obtained to support the design of the bridge. The borehole records agree with the BGS descriptions above. Groundwater was found generally at a depth of approximately 1m.

The Environment Agency's records indicate that the bedrock is classed as a Secondary A Aquifer. This means it has permeable layers capable of supporting water supplies at a local rather than strategic scale, and in some cases forming an important source of base flow to rivers. These are generally aquifers formerly classified as minor aquifers.

The website also shows that the Site is within an area of High Groundwater Vulnerability.

[4] Environment Agency (2021) Flood Map for Planning. Accessed online via: Link

[5] The British Geological Survey online Geology of Britain Viewer. (2020) Accessed online via: Link

3.6. HISTORICAL LAND USES

There is no proposed change to the land use as part of this application. The existing Station Road will be replaced with a new raised viaduct and the current Mill Access Bridge will be removed and replaced with a new bridge. The floodplain will remain as floodplain, although with some re-profiling.

3.7. HISTORICAL FLOODING

The reason for the proposed works are due to the historical flooding at the Site and the resulting disruption to both the railway and road network.

Numerous flood events affecting the bridges and adjacent level crossing have been recorded. As a result of high flows, blockage and constrictions under the bridges, flood water backs up at the Access Bridge, and more significantly at Station Road Causeway. As a result, flooding occurs to the railway, the level crossing and Station Road itself.

Recorded flooding dates include:

- 30th October 2008
- 13th December 2008
- 10th February 2009
- 30th April 2012
- 24th September 2012
- 21st – 25th November 2012
- 24th December 2013
- 6th February 2016
- 21st November 2016
- 15th March 2018
- 21st October 2021

The above listed events have caused disruption to the trains using the railway line and, in many cases, once the flood waters have receded, equipment has had to be replaced and repairs to the track and fencing made before the line can be used safely. In addition to these disruptive events Network Rail have also had to monitor the track on a similar number of additional occasions when there was concern flooding of the line would occur. The railway is therefore out of service for longer than purely the period of the flooding.

Flooding has also occurred to Devon Valley Mill, to businesses in Station Yard and to the older properties in Hele Square.

The 21st October 2021 flood event occurred during the preparation of this report, and a video was produced by a third-party showing drone and ground level video footage of the flooding in this event.[6] This showed the extent of flooding to the railway at the level crossing (resulting in closure of

[6] https://www.youtube.com/watch?v=1he_6ktqSYE

the railway) and into Station Yard, utilisation of the majority of the floodplain up and downstream of Hele, and flooding within the part of the Devon Valley Mill site to the south of the River Culm.

A high-level review of the Woodmill gauge river level data for this event, alongside the Environment Agency rating curve for the gauge has been carried out. This showed a peak flow equivalent to approximately a 1 in 8yr RP event based on the hydrology used for the modelling study which supports this FRA, however the duration and flood volume of the event are shorter than the design events used here. Hence less flooding would be expected than for a similar peak flow in the modelling study.

With this understanding, it is considered that the flood extents, levels and mechanisms which were observed in the 21st October 2021 event were in line with the predictions of the model, showing in particular:

- Flooding within the Devon Valley Mill site
- A higher flood level on the upstream side of the Station Road than downstream, with water weiring over the road
- Flooding to Station Yard and the railway originating from the upstream floodplain.

3.8. EXISTING DRAINAGE

Existing drainage on the roads to be replaced is minimal – a total of 3 gully pots are present on Station Road, all of which are likely to drain directly to the floodplain below.

Existing drainage will be replaced along with the bridges and roads under the new proposals.

4. OUTLINE OF PROPOSED SCHEME

4.1. OVERVIEW

The Proposed Scheme involves:

- Removal and replacement of the existing Station Road causeway with a raised viaduct;
- Construction of a new raised Mill Access Bridge adjacent to the current bridge location;
- Demolition of the current Mill Access Bridge; and
- Re-profiling of the flood basin beneath the bridges.
- Construction of a flood defence to mitigate against increased risk to properties in Hele Square.

The Proposed Scheme is classified as Essential Infrastructure by PPG.

4.2. CONSTRUCTION PROPOSALS

The construction will involve temporary conditions including:

1. Construction of haul roads for Station Road and Mil Access Bridge constructions
2. Construction of new Mill Access Bridge
3. Removal of existing Mill Access Bridge
4. Demolition and construction of Station Road bridges

Through the construction phase a series of environmental management / control measures are proposed to reduce environmental risks. These are as follows: Management of works in accordance with the CIRIA guidance 'C532 - Control of Pollution from Construction Sites' and the implementation of (now removed) EA Pollution Prevention Guidelines.

Further details of the mitigation measures during construction can be provided once the detailed design and approval is obtained.

4.3. THE PROPOSED SCHEME

PROPOSED LAND USES AND QUANTUM

The scheme consists of two main elements, a new Mill Access bridge, and a new viaduct replacing the existing Station Road causeway and two small culverts.

The new Mill Access bridge is to be offset to the north from the existing location to allow for continuous operation of the Mill during construction. This bridge will be formed of a series of box culverts with the road deck formed above. Details of the proposals can be seen in drawing No. WSP-02-XX-DR-BR-AIP-002 Rev 1 in Appendix B.

The new Station Road viaduct consists of a 5-span integral bridge with 4 sets of piers which support the bridge deck and road above. A concrete apron will be formed under the bridge to reduce the risk of blockage due to siltation and to inhibit vegetation growth.

Scour protection in the form of a downstand to the concrete apron, and a rock armour apron will extend up and downstream of both bridges.

The ground levels upstream, between the bridges and downstream will be profiled to improve conveyance of flood waters through the bridges. The details of this can be seen on WSP-01-XX-DR-DR-HI-001-P04 in Appendix B.

The invert levels of both bridges, and the road levels, have been assessed in relation to predicted baseline and post-development flood levels and have been set accordingly. Restrictions to these levels are present as there is requirement to tie in to existing infrastructure, namely the Station Road bridge over the River Culm, the railway level crossing, Mill yard area and the Station Yard access.

5. FLOOD RISK ASSESSMENT

5.1. INTRODUCTION

WSP have assessed the risk of flooding to the Site from all current and future potential sources of flooding.

Table 5-1 summarises the findings of the assessment. A more detailed explanation of the flood risk issues on the Site and determination of flood risk ratings are presented in the Section below.

Table 5-1 - Degree of risk to the Proposed Scheme from each source of flooding

SOURCE	RISK
Fluvial	**High** for the whole site due to the presence of the River Culm floodplain.
Tidal	**Not at risk** – the River Culm is not tidally affected
Groundwater	**High –** potential impact on foundations. The foundation design will take into account the high water table in the area.
Surface Water	Low – there are limited pathways for surface water to affect properties from the location of the works.
Sewer / Drainage	Not at risk
Artificial Sources:	
Reservoir	Not at risk
Canal	Not at risk

As shown above, the main source of the flood risk is the fluvial risk from the River Culm. To investigate this further WSP have utilised the existing hydraulic model of the area to test the proposals set out in this FRA. Details of the hydraulic modelling undertaken are provided in Appendix E in the form of the modelling report produced by WSP supporting this stage of the modelling. This includes details of improvements and changes to the model, addressing Environment Agency recommendations and reviewing changes to flood risk as a result of the proposed scheme. The Mott McDonald report detailing earlier stages of the modelling is appended to the WSP report.

5.2. FLUVIAL AND SURFACE WATER FLOOD RISK

CLASSIFICATIONS

The River Culm is a Main River that runs through the Site. NPPF categorises flood risk as follows:

- Flood Zone 1 (low probability) is assessed as having less than a 1 in 1,000 annual probability of river or sea flooding (<0.1%);
- Flood Zone 2 (medium probability) is assessed as having between a 1 in 100 and 1 in 1,000 annual probability of river flooding (1% – 0.1%), or between a 1 in 200 and 1 in 1,000 annual probability of sea flooding (0.5% – 0.1%) in any year; and
- Flood Zone 3 (high probability) is assessed as having a 1 in 100 or greater annual probability of river flooding (>1%), or a 1 in 200 or greater annual probability of flooding from the sea (>0.5%) in any year.

The Environment Agency's Flood Map for Planning[7] indicates that the Site lies within Flood Zone 3. The Environment Agency's online Risk of Flooding from Rivers and Sea Map also shows the site to be at High risk from flooding.

The Environment Agency's Risk of Surface Water Flooding Map shows that there is a Medium to Low risk on Station Road itself, as well as the current Mill Access Bridge and the proposed location for the new bridge. The remainder of the Site is considered to be at very low risk of surface water flooding with fluvial flooding being the key mechanism of flooding onto the Site.

A topographical survey (date: 21st December 2017) was provided to WSP to supplement previously collected survey data. These data show that the areas susceptible to surface water flooding correspond to localised topographic low spots across the Site identified during the walkover survey. Additional survey data of ground levels in Hele Square, the Mill site, Station Yard and Station Road were collected in 2018 and 2020 and included within the assessment.

As described in Section 3.7, the site has been subject to a number of historic fluvial flood events which impact the road and level crossing adjacent to the site and properties at Hele Square. The 6th February 2016 event occurred during an outline stage for this bridge replacement and as such wrack levels were measured shortly after the flood event. These wrack marks had previously been used to support the calibration of the modelling. In July 2018 WSP questioned some of the 2016 wrack mark evidence and incorporated some more reliable evidence from the 2012 event. The Environment Agency have agreed this approach and confirmed this in the letter DC/2018/119875/02-L01 ENVPAC/1/DCS/00031, dated 01 August 2018 (this can be found in Appendix D). The information provided by local residents, combined with additional survey, has also been used to help to verify the hydraulic modelling as part of this revised FRA.

WATERCOURSE CONDITION ASSESSMENT

As part of the data review and appreciation of flood risk, an assessment of the watercourse in the area of interest was carried out. This included verification of the existing model parameters for suitability for the assessment of flood risk, both pre and post-development. The assessment took in the area covered by the 2D domain from the model used for this study (described in the following section), with the general channel condition visually.

The in-channel roughness was found to be moderately well represented in the existing models, reflecting a main river with a moderate degree of sinuosity, and vegetation, with some ineffective sections. Out-of-channel roughness required improvement to represent the overall land cover with better definition, with stands of trees included and general land roughness representing light to medium brush. The values used for roughness within the model have been adjusted through the validation and calibration process, within reasonable limits. Details on this are provided in the accompanying Hydraulic modelling report.

HYDRAULIC MODELLING

The model used for the assessment of flood and mitigation risk under the previous optioneering stage was developed from several existing approved models by Mott Macdonald. The report (issued

[7] Environment Agency (2020) Flood Map for Planning. Accessed online via: Link

April 2016) supporting the Mott Macdonald modelling study is included as an appendix to the WSP modelling report in Appendix E.

The previous model utilised a hydrodynamically linked 1D and 2D approach between Kensham Avenue and Killerton Mill. Upstream of Kensham Avenue a 1D only approach was adopted. Following investigation into the discrepancy between the observations and modelled results for the November 2012 event, it was determined that the previous modelling included a misrepresentation of the floodplain upstream of Hele. This meant that the previous modelling was not a true reflection of the current flood risk in Hele.

Revised modelling has therefore been undertaken in support of this FRA. This included utilising the previous model of the local area around Hele, including the recommendations the Environment Agency had suggested, but then extending the 2D domain up to Woodmill gauge and approximately 1km downstream of Killerton Mill. This approach allows for detailed representation of the progression of out of channel flow on the floodplain upstream of Hele and to assess the impacts of the proposed new bridges.

Additional topographic survey (collected in July 2018, June 2020 and July 2021) has been included within the model for Hele Square, Station Road and Station Yard, and for the flood defence wall and entrance area of Devon Valley Mill, as well as additional channel detail.

The upstream extent of the hydraulic model was chosen because the Environment Agency have a gauge located at Woodmill on the River Culm[8]. This gauge is located approximately 5km upstream of Hele. The gauge has a long record and there is high confidence in the rating curve used to calculate the corresponding flow for a given stage recorded. There have also been extensive hydrological assessments to determine the peak flow for extreme events at this gauge. This location was therefore chosen as the upstream extent of the revised model and the input flow boundaries were based on the flow hydrographs extracted from previous calibrated modelling, scaled to match the peak flows at the gauge for a range of return periods. Further details of this are provided in Appendix E.

The original Cowley Bridge and Hele 1D models had already been calibrated to the following three flood events as part of a previous CH2M study in 2014:

- 30th October 2008
- 21st-25th November 2012
- 24th December 2013

During the Mott MacDonald study a flood event occurred on 6th February 2016 and a survey of wrack marks was collected. The Mott MacDonald modelling showed good calibration to some of the surveyed wrack mark levels from the 2016 event but was unable to reproduce levels similar to those seen in the 2012 event by residents and as shown in photographs. The initial modelling by WSP also provided similar calibration results.

The hydrograph for the November 2012 event was produced from the levels recorded at the Woodmill gauge using the rating curve recommended by the Environment Agency in

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[8] https://nrfa.ceh.ac.uk/data/station/info/45003

communications between WSP, and Tim Shipton and Ian Hooper of the Environment Agency in December 2018.

Simulations were carried out using these inflows, and the model results inspected against surveyed levels from the photographic record of the flood event. Extents and depths have been compared against the record where levels were not available.

In order to achieve a closer match to the recorded and observed levels, extents and flow paths, some model parameters were adjusted within acceptable limits. This included adjustments to the bridge parameters for key structures, and in-channel roughness, which were retained in the final model runs.

The amendments to structure parameters were important in representing head loss across those structures appropriately, however additional changes were required to improve the representation of flood levels and flow paths.

As previously mentioned, the in-channel roughness was revised to achieve this improved calibration. This was a key parameter in achieving calibration, in addition to representing the head loss at structures. Water levels both upstream and downstream of Hele were simulated as lower than had been observed using the initial estimates of in-channel roughness, so sensitivity testing was carried out to this parameter through a number of iterations before arriving at the value which has been used throughout the model. This is described further in the hydraulic modelling report located in Appendix E.

The model typically reproduces the surveyed levels within 10mm which is considered to be well within acceptable limits for a study of this kind due to the potential uncertainty in surveyed levels, antecedent conditions, potential presence of blockages and changes to the site.

Additional validation of results has been carried out using photographs from the 2012 event to compare modelling vs observed flood depths, and also using aerial photos from the event in 2008 to further identify that key flow paths are represented in the model.

Residual uncertainty is included within the allowance of freeboard for the flood mitigation that is proposed. The overall trends of the impact of the proposed works on flood levels is consistent throughout the return periods simulated and has remained essentially unchanged throughout all stages of the assessment.

Model simulations have also been carried out including two flood mitigation options for properties in Hele Square.

Details of the results of the modelling are provided in Section 6, along with a discussion of the impacts of the post development modelling.

5.3. CONSIDERATION OF CLIMATE CHANGE

The Environment Agency's guidance 'Flood Risk Assessments: Climate Change Allowances'[9] issued in February 2016 and updated in July 2021 provides up to date information on expected changes in rainfall, river flows and sea level rise as a consequence of climate change. They are based on climate change projections and different scenarios of carbon dioxide (CO2) emissions to

[9] https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances

the atmosphere. There are different allowances for different epochs or periods of time over the next century.

The recommended allowances for fluvial and pluvial climate change for the East Devon management catchment are set out below in Table 5-2 and Table 5-3 respectively.

Table 5-2 - South West river basin district peak river flow allowances

Allowance category	Total potential change anticipated for the '2020s' (2015 to 2039)	Total potential change anticipated for the '2050s' (2040 to 2069)	Total potential change anticipated for the '2080s' (2070 to 2115)
Upper end	34%	55%	96%
Higher Central	22%	33%	61%
Central	16%	24%	46%

Table 5-3 - Peak rainfall intensity allowance

Allowance category	Total potential change anticipated for the '2020s' (2015 to 2039)	Total potential change anticipated for the '2050s' (2040 to 2069)	Total potential change anticipated for the '2080s' (2070 to 2115)
Upper end	10%	20%	40%
Central	5%	10%	20%

The climate change guidance states that Essential Infrastructure in Flood Zone 3 should test against the Higher Central allowance when considering climate change. However, as this is a proposal to replace existing infrastructure with a more resilient alternative, and to reduce current risk of flooding to the roads and rail infrastructure, this has been modelled using an increased inflow of +46% in accordance with the Central allowance. The proposals have however been tested against the Higher Central allowance (i.e. increased inflow by +61%) to identify the sensitivity and any residual flood risk.

6. RESULTS

This section describes the outcomes of the modelling and provides results at key locations in the study area.

Mapping has been created from the model results. Flood depth results for all return periods and scenarios have been mapped. Maps have also been created showing the difference in flood level between the baseline and proposed scenarios, and between baseline and temporary works scenarios. These can be found in Appendix F.

To further support the assessment of localised changes in peak water level, maximum flood levels have been extracted from a number of point locations throughout the model domain. This includes locations that are at key locations of interest within and downstream of Hele. These locations are shown in Figure 6-1.

The locations are:

- Level crossing and railway – focus of study
- Hele Square
- Station Yard
- Lease Cottages
- Crossways Tavern
- Sewage Treatment Plant and Pumping Station
- Devon Valley Mill

For each location localised model results have been provided showing the peak flood depth for the proposed Post-Dev scenario. Difference plots are also provided where pink shows that flooding occurs in the baseline but does not occur in the proposed scenario (i.e. a reduction in flood extent) and green shows where there is flooding only in the proposed scenario (i.e. an increase in flood extent). This is then combined with the colour scale from blue (showing a reduction in depth in the proposed scenario compared to the baseline) to red (showing an increase in depth in the proposed scenario compared to the baseline). White therefore represents no change in flood depth at that location.

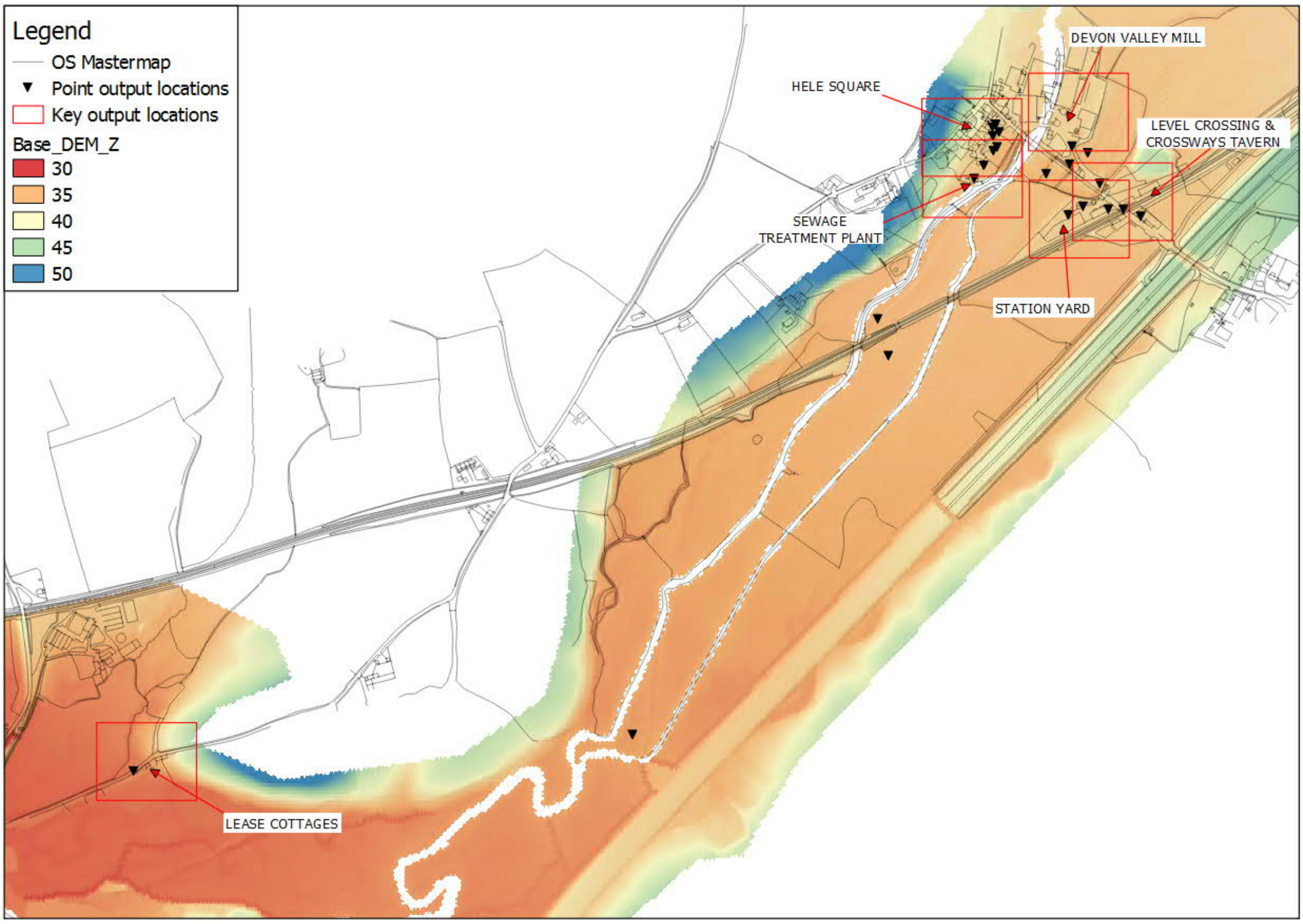

Figure 6-1 - Output locations

The images below present a relevant return period for discussion with the results which varies for the different key locations. The full set of model results can be reviewed in Appendix F and Appendix G.

6.1. LEVEL CROSSING AND RAILWAY

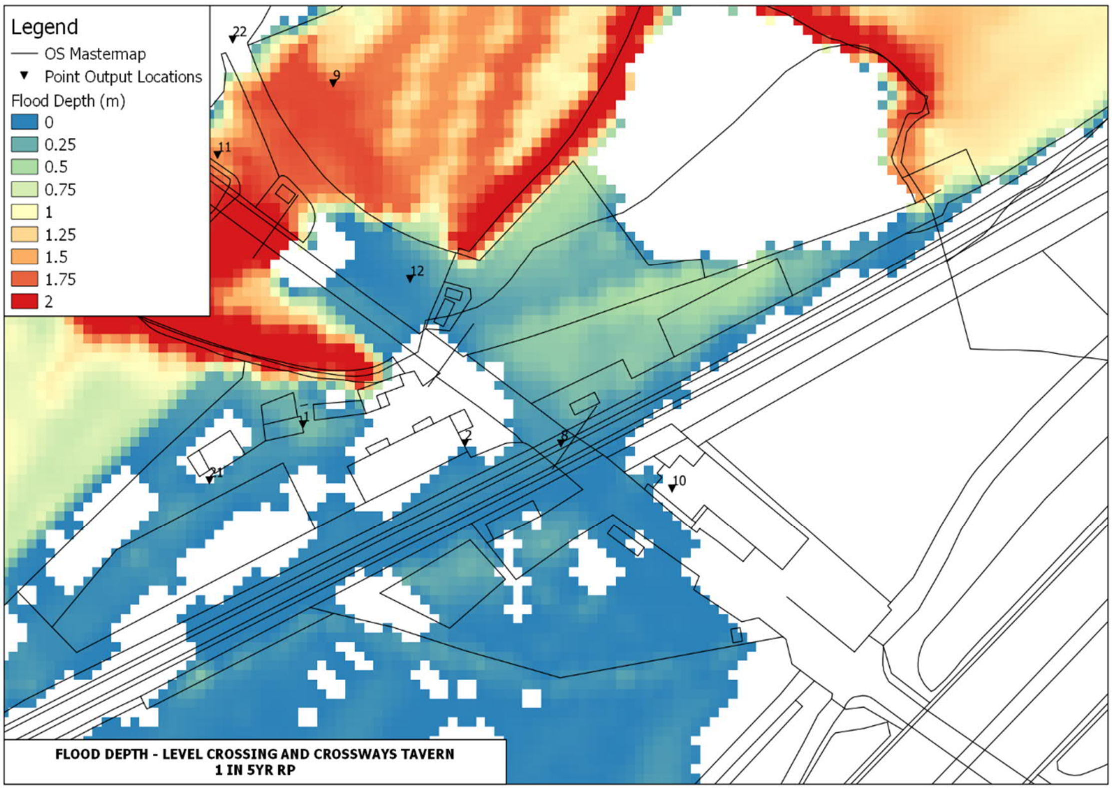

Figure 6-2 – Flood depth for 1 in 5yr RP event at Level Crossing in the Post-Dev scenario

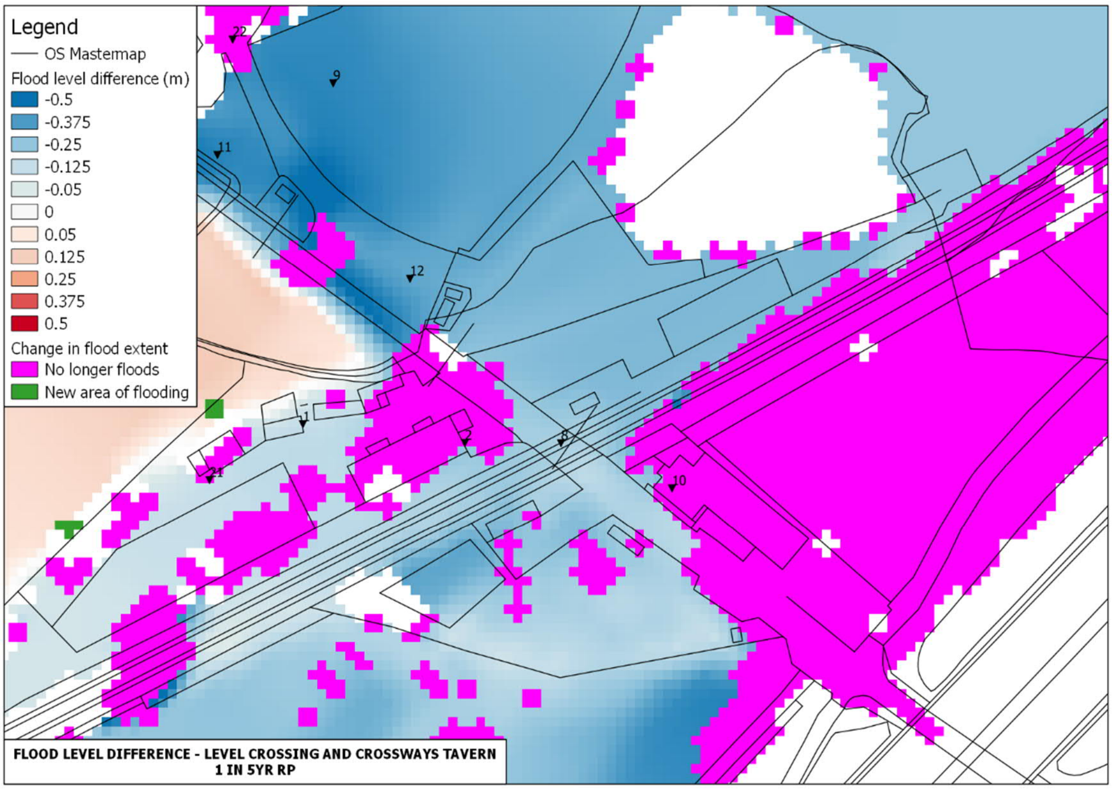

Figure 6-3 – Flood level difference between Baseline and Post-dev for 1 in 5yr RP event at Level Crossing

The main location of interest for this assessment is the level crossing as the overall aim of the proposed improvement works are to reduce the flood risk at this location.

Table 6-1 – Flood level results at level crossing (Point 8)

Return Period (yrs)	Peak WL (mOD)		Difference (m)	Commentary / Implications
	Baseline	Proposed		
2	37.75	-	No longer floods	**Onset** of flooding is improved from less than a 1 in 2 year event in the baseline to a **1 in 5 year event** with the proposed works in place. Depth and duration of flooding is reduced for all return periods. Specifically, at the 1 in 10 year the depth of flooding would be up to ~35mm above the railhead over 9 hours compared to up to ~390mm over 25 hours in the current baseline scenario. This represents a significant improvement at the level crossing.
5	37.81	37.61	-0.19	
10	37.85	37.70	-0.14	
20	37.90	37.77	-0.14	
50	37.96	37.82	-0.14	
100	38.01	37.87	-0.14	
1000	38.19	38.11	-0.08	
100+46%	38.14	38.05	-0.09	
100+61%	38.18	38.10	-0.08	

In addition to a reduction in flood level, significant improvements in duration of flooding are also predicted.

Table 6-2 – Flood duration results at level crossing

Return Period (yrs)	Duration of flooding (hrs)		Difference (hours)
	Baseline	Proposed	
2	12	0	No longer floods
5	20	5.5	-14.5
10	24.75	9	-15.75
20	30	12	-18
50	41.5	17.25	-24.25
100	47.75	21.25	-26.5
1000	54.5	41	-13.5
100+46%	52.75	33.75	-19
100+61%	54.25	40.25	-14

6.2. HELE SQUARE

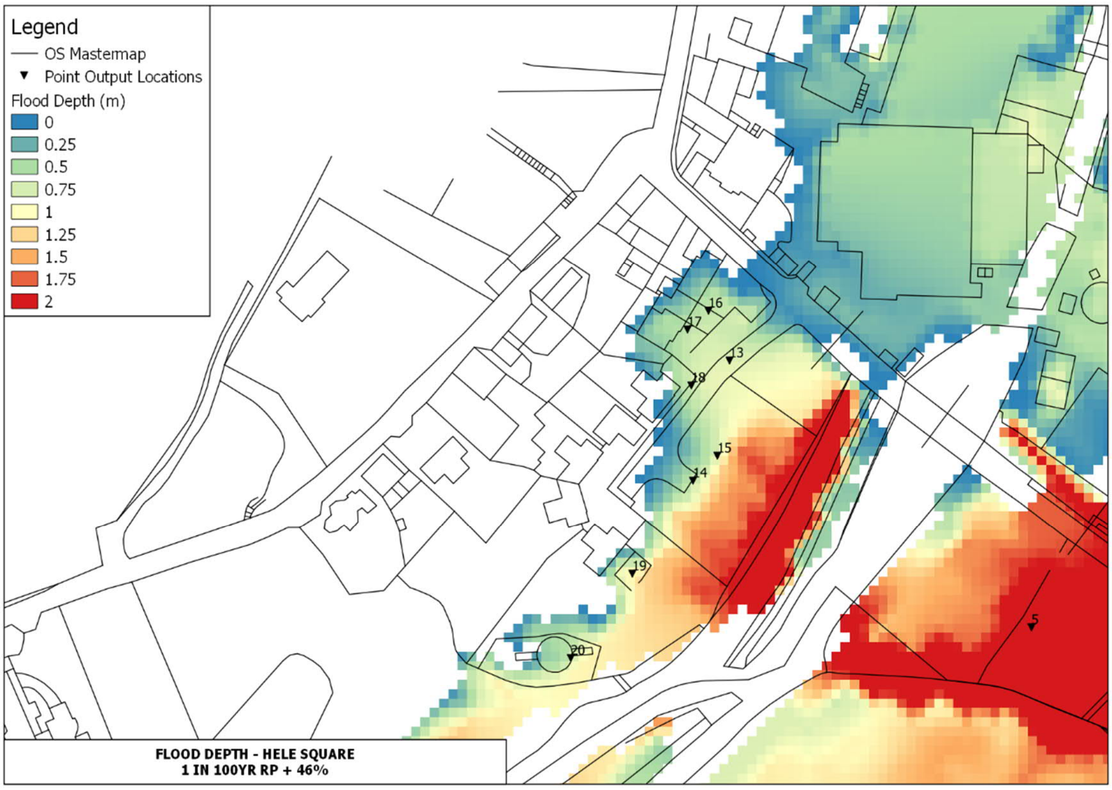

Figure 6-4 – Flood depth for 1 in 100yr RP + 46% event at Hele Square in the Post-dev scenario

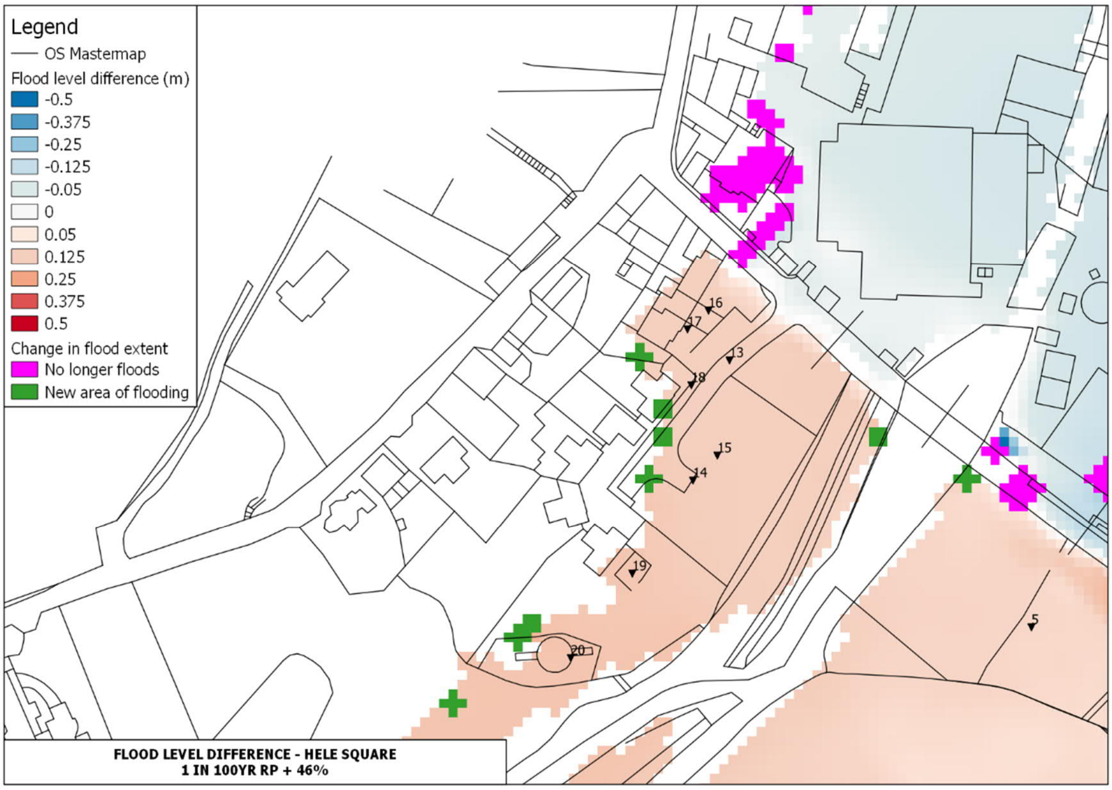

Figure 6-5 – Flood level difference between Baseline and Post-dev for 1 in 100yr RP +46% event at Hele Square

Table 6-3 – Flood level results at Hele Square (Point 13 to 18)

<table>
<tr><th rowspan="2">Return Period (yrs)</th><th colspan="2">Peak WL (mOD)</th><th rowspan="2">Difference (m)</th><th rowspan="2">Commentary / Implications</th></tr>
<tr><th>Baseline</th><th>Proposed</th></tr>
<tr><td>2</td><td>36.57</td><td>36.66</td><td>+0.09</td><td rowspan="18">Flood levels at Hele Square are predicted to increase by up to 140mm in the post-scheme scenario.

For information Threshold Levels (TL) are provided for the properties in Hele Square for comparison against the stated flood levels

Current onset of internal flooding is ~ 1 in 50 – 100 years. Onset of internal flooding would decrease to between approximately 1 in 20 year and 1 in 50 year event if the affected properties were to remain undefended.

No.4 to 8 are not predicted to flood in either the existing or post-scheme scenarios for any of the return periods.</td></tr>
<tr><td>5</td><td>36.75</td><td>36.88</td><td>+0.13</td></tr>
<tr><td>10</td><td>36.85</td><td>36.99</td><td>+0.14</td></tr>
<tr><td>20</td><td>36.97</td><td>37.10</td><td>+0.13</td></tr>
<tr><td>50</td><td>37.08</td><td>37.21</td><td>+0.14</td></tr>
<tr><td>100</td><td>37.16</td><td>37.30</td><td>+0.14</td></tr>
<tr><td>1000</td><td>37.72</td><td>37.79</td><td>+0.07</td></tr>
<tr><td>100+46%</td><td>37.54</td><td>37.66</td><td>+0.12</td></tr>
<tr><td>100+61%</td><td>37.71</td><td>37.78</td><td>+0.08</td></tr>
<tr><th>Property</th><th>TL</th><th>Property</th><th>TL</th></tr>
<tr><td>No.1</td><td>37.13</td><td>No.2</td><td>37.07</td></tr>
<tr><td>No.3</td><td>37.17</td><td>No.4*</td><td>38.04
(37.29)</td></tr>
<tr><td>No.5</td><td>38.02</td><td>No.6</td><td>38.03</td></tr>
<tr><td>No.7</td><td>38.02</td><td>No.8</td><td>38.03</td></tr>
</table>

* Threshold level of Garage of No.4 shown in brackets

Table 6-4 – Flood duration results at Hele Square (Point 15)

Return Period (yrs)	Duration of flooding (hrs)		Difference (hours)
	Baseline	Proposed	
2	1.5	1.5	-
5	2	6.25	+4.25
10	6.25	9.75	+3.5
20	9.25	13.25	+4
50	13.25	18.5	+5.25
100	17	22.5	+5.5
1000	31.5	44.25	+12.75
100+46%	27.5	36.75	+9.25
100+61%	31	43.25	+12.25

Table 6-5 – Flood duration above lowest property threshold level Hele Square

Return Period (yrs)	Duration of flooding (hrs)		Difference (hours)
	Baseline	Proposed	
20	0	2.25	+2.25
50	0.75	6.75	+6
100	4.75	9.25	+4.5
1000	13.75	21	+7.25
100+46%	11.25	18	+6.75
100+61%	13.5	20.5	+7

Flood defences for the affected properties will be required as part of the proposed scheme. The proposed Standard of Protection of the defence would be 1 in 100yr + 46% + freeboard. This would mean they benefit from a higher Standard of Protection than in the current situation. All predicted flood levels are below the proposed defence crest level of 37.98mOD and remain below the threshold level of No. 4 to 8 Hele Square.

Simulations have been carried out including a representation of a flood wall/embankment to identify the impacts (if any) of these defences on flood levels. The results showed that having these measures in place have negligible impact on the flood levels for the surrounding areas for any return period.

Figure 6-6 shows the flood depth difference map for the simulations with a flood wall/embankment.

The increase in flood depth and extent at Hele Square also corresponds to an increase in the duration of flooding as shown in Table 6-4.

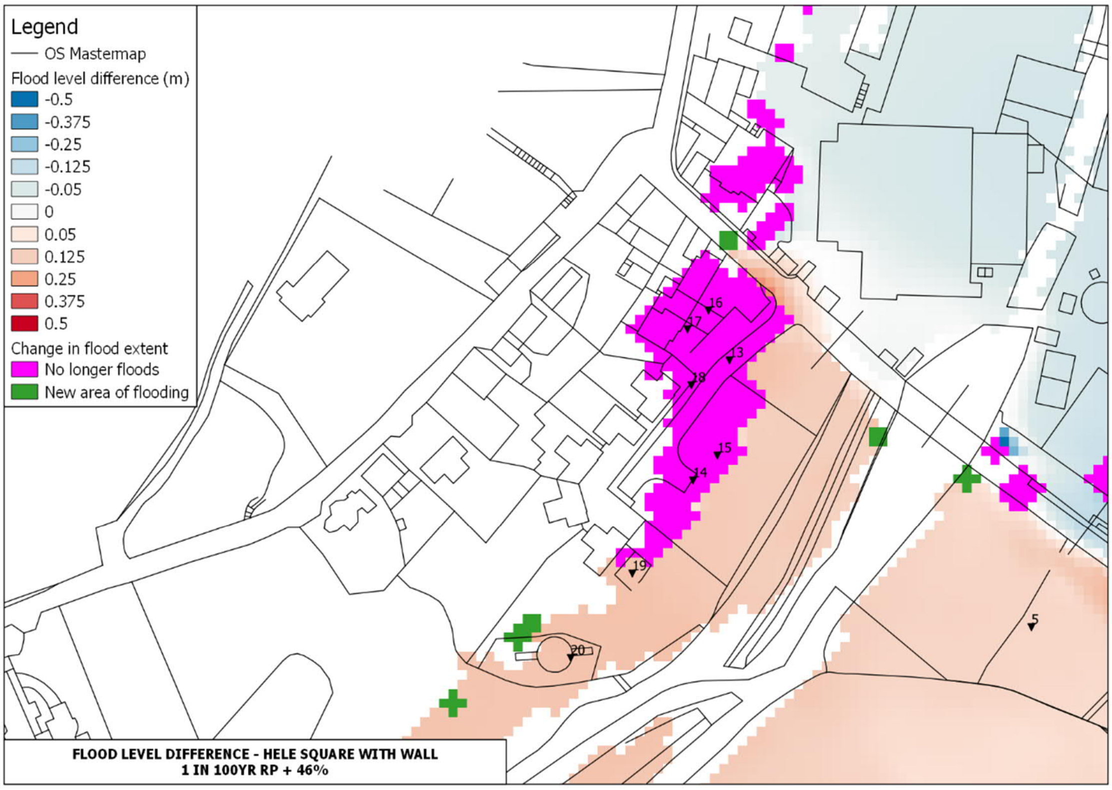

Figure 6-6 – Flood level difference between existing and proposed for 1 in 100yr RP +46% event at Hele Square with wall

6.3. STATION YARD

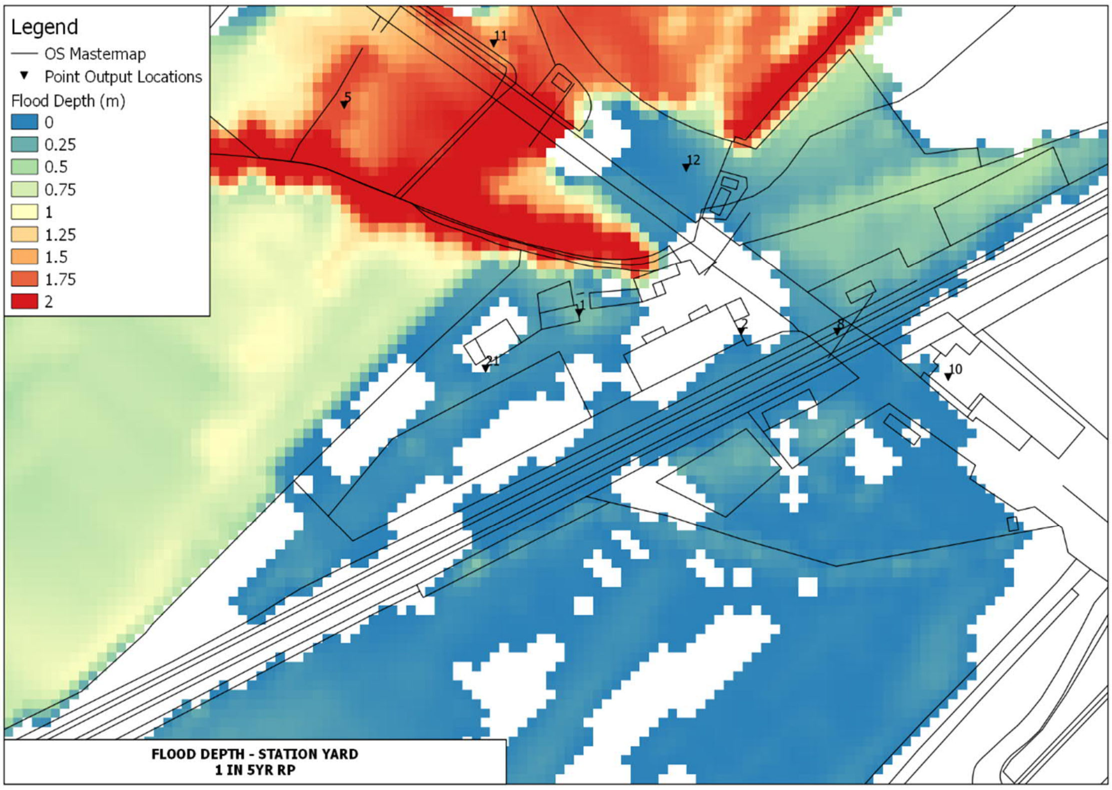

Figure 6-7 – Flood depth for 1 in 5yr RP event at Station Yard in the proposed scenario

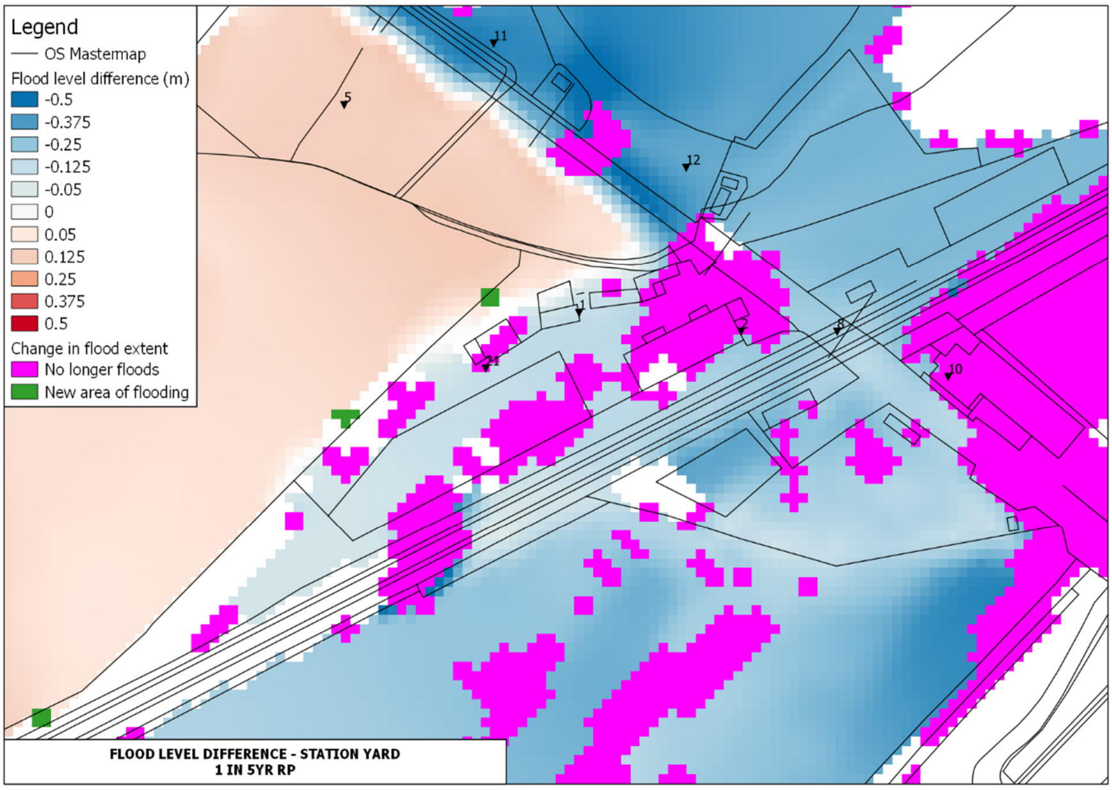

Figure 6-8 – Flood level difference between existing and proposed for 1 in 5yr RP event at Station Yard

Table 6-6 – Flood level results at workshop in Station Yard (Point 1)

Return Period (yrs)	Peak WL (mOD)		Difference (m)	Commentary / Implications
	Baseline	Proposed		
2	37.45	37.20	-0.25	These are sampled at the main entrance to the workshop on the north side of Station Yard (adjacent to Point 1). Ground levels may be lower in parts of the workshop interior and hence subject to flooding at lower return periods. **Onset** of flooding is unchanged however the depth and duration of flooding is reduced for all return periods, including climate change up to 1 in 100 year + 61% event, with the exception of the 1 in 100yr event, which shows a small increase in depth. This is an increase of 20mm in addition to a baseline flood depth of approximately 0.6m. Taking into account the reductions in flood depths at most return periods suggests that the scheme provides a benefit overall to Station Yard.
5	37.51	37.38	-0.12	
10	37.54	37.47	-0.07	
20	37.59	37.56	-0.03	
50	37.64	37.64	0.00	
100	37.68	37.70	0.02	
1000	38.01	38.01	0.00	
100+46%	37.94	37.93	-0.01	
100+61%	38.00	38.00	0.00	

In addition to reducing flood levels for the majority of return periods the duration of flooding is reduced for all return periods.

Table 6-7 – Flood duration results at Station Yard (Point 1)

Return Period (yrs)	Duration of flooding (hrs)		Difference (hours)
	Baseline	Proposed	
2	8.5	4.25	-4.25
5	15.5	10.5	-5
10	20.25	14.75	-5.5
20	24.5	18.5	-6
50	30.75	24.25	-6.5
100	39.75	28.25	-11.5
1000	52	49	-3
100+46%	50.75	47.25	-3.5
100+61%	52	49	-3

Table 6-8 – Flood level results at Station Yard (Point 2)

Return Period (yrs)	Peak WL (mOD)		Difference (m)	Commentary / Implications
	Baseline	Proposed		
2	37.71	-	No longer floods	**Onset** of flooding is improved with the proposed works in place. Depth of flooding is reduced by up to 160mm for return periods 1 in 10 years and above. Duration of flooding is also reduced. This represents a significant improvement in flood risk for this property.
5	37.79	-	No longer floods	
10	37.82	37.67	-0.16	
20	37.88	37.73	-0.15	
50	37.94	37.80	-0.14	
100	37.99	37.85	-0.14	
1000	38.20	38.13	-0.07	
100+46%	38.14	38.06	-0.08	
100+61%	38.19	38.12	-0.07	

Table 6-9 – Flood level results at west end of Station Yard (Point 21)

Return Period (yrs)	Peak WL (mOD)		Difference (m)	Commentary / Implications
	Baseline	Proposed		
2	-	-	No flooding	**Onset** of flooding is improved from less than a 1 in 5 year event in the baseline to a **1 in 20 year event** with the proposed works in place. This is dependent on the location selected within the west end of Station Yard, but changes in flood level are essentially negligible at all return periods. A small increase (approx. 7mm) is observed in this area at the 1 in 1000 year event. This is an increase of 7mm on a flood depth of 0.57m. Taking into account the reductions in flood depths at most return periods suggests that the scheme provides a benefit overall to Station Yard.
5	37.47	-	No longer floods	
10	37.50	-	No longer floods	
20	37.54	37.49	-0.05	
50	37.59	37.56	-0.03	
100	37.63	37.61	-0.02	
1000	37.86	37.87	+0.01	
100+46%	37.80	37.80	0.00	
100+61%	37.85	37.86	0.00	

It should be noted that in the baseline model, flooding to Station Yard first occurs from the east, with water flooding from upstream of Station Road into the yard and past the buildings. This corresponds with photographs of flooding which show a higher level upstream of Station Road than in the floodplain downstream.

Anecdotal descriptions from the occupants suggest that flooding may occur initially from low points to the north of Station Yard and from the west end, backing up from the downstream rail structure.

From a review of the model results this would only be likely to happen in the baseline scenario if the capacity of the downstream structures was significantly less than is currently calculated in the modelling. The structure has been reviewed and we are confident that the model is representing it appropriately.

If flooding has occurred in this way in the past then this may be as a result of blockage to this structure, or a misinterpretation of the mechanisms of flooding e.g. surface water flooding also occurring.

Survey does highlight a low spot to the north of Station Yard adjacent to the workshop at Point 1. This low spot floods earlier than other areas of the Yard in the post-development scenario due to reduced flooding over Station Road and increased flow in the channel downstream. Flooding also occurs to the west end of Station Yard, backing up from downstream. It should be noted that while depths of flooding may increase in some of these areas for the larger return period and climate change runs, overall the frequency and duration of flooding, and therefore the impacts are predicted to significantly reduce across the yard.

The additional survey data has provided greater certainty of the levels in Station Yard, and particularly along the northern edge and hence how flooding impacts these areas.

6.4. LEASE COTTAGES

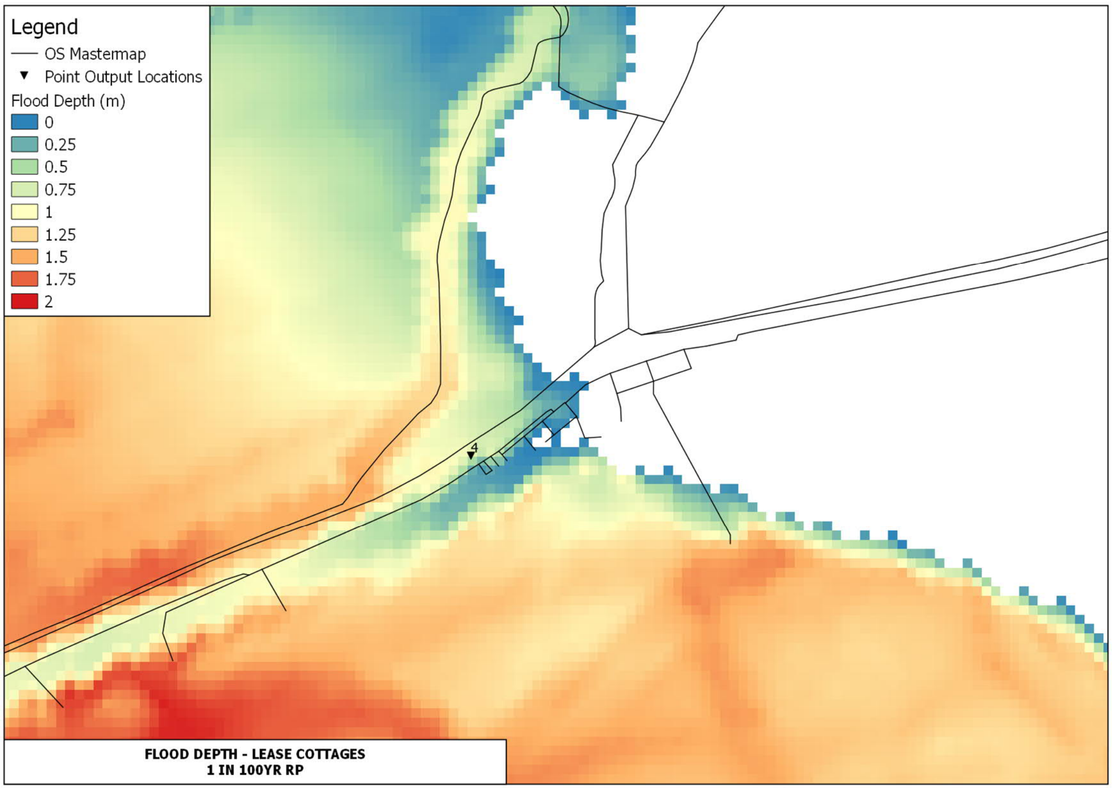

Figure 6-9 – Flood depth for 1 in 100yr RP event at Lease Cottages in proposed scenario

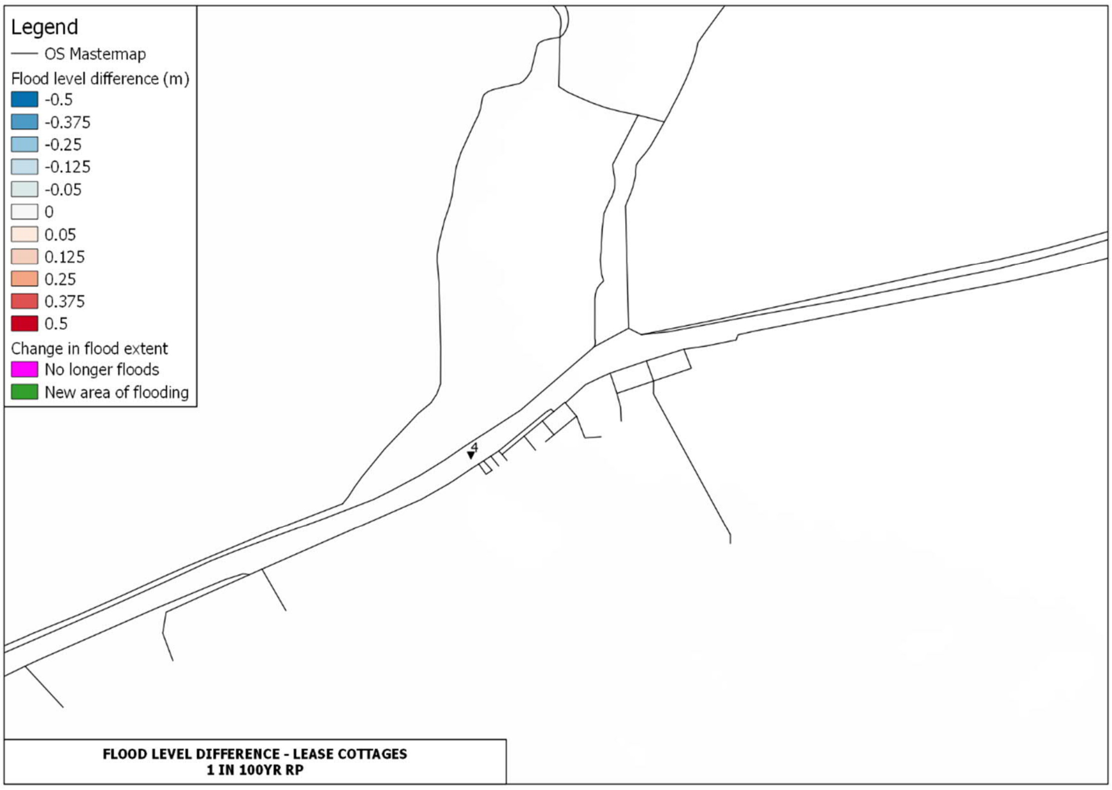

Figure 6-10 – Flood level difference between existing and proposed for 1 in 100yr RP event at Lease Cottages

Table 6-10 – Flood level results adjacent to Lease Cottages (Point 4)

Return Period (yrs)	Peak WL (mOD)		Difference (m)	Commentary / Implications
	Baseline	Proposed		
2	33.27	33.27	0.00	The model predicts no change in flood depths at Lease Cottages.
5	33.40	33.40	0.00	
10	33.47	33.47	0.00	
20	33.57	33.57	0.00	
50	33.69	33.69	0.00	
100	33.82	33.82	0.00	
1000	34.22	34.22	0.00	
100+46%	34.13	34.13	0.00	
100+61%	34.21	34.21	0.00	

6.5. CROSSWAYS TAVERN

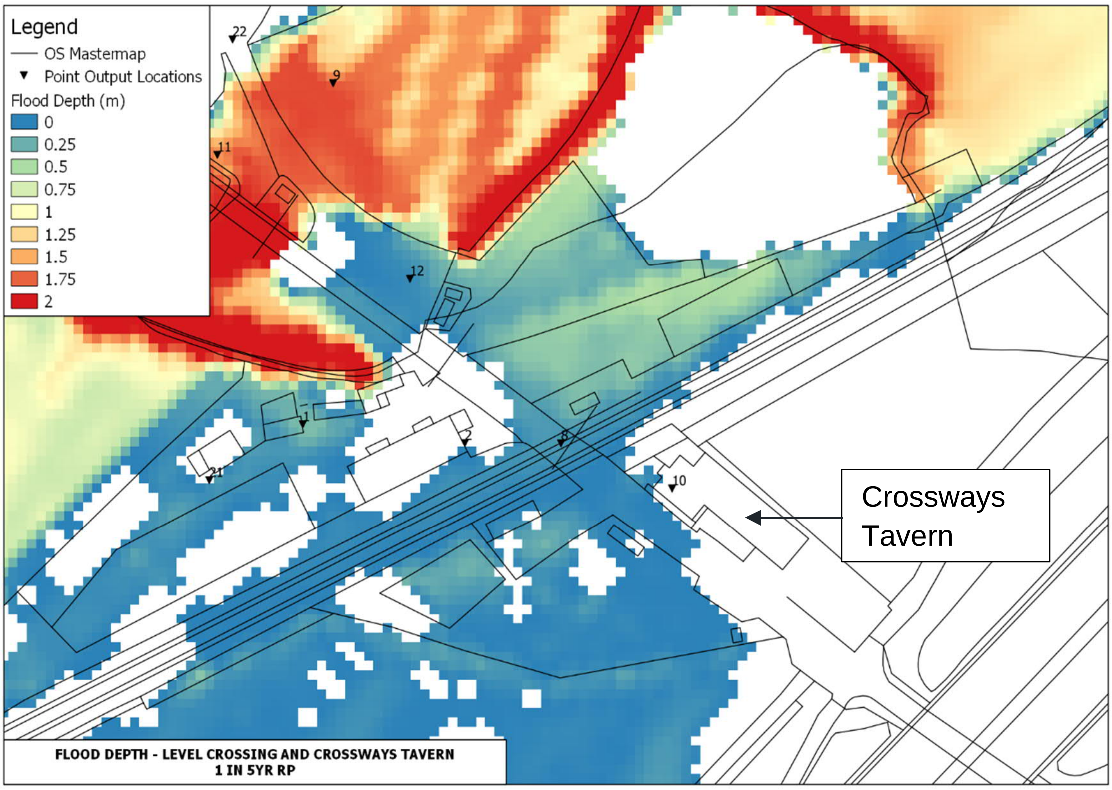

Figure 6-11 – Flood depth for 1 in 5yr RP event at Crossways Tavern in proposed scenario

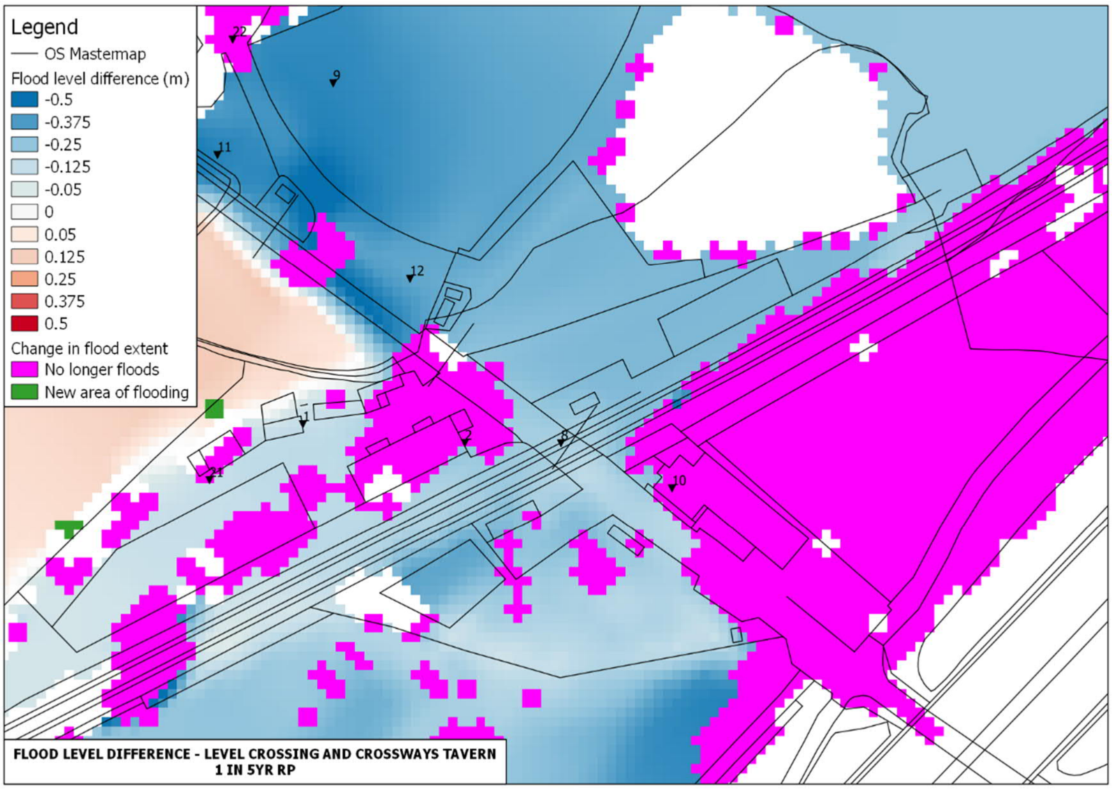

Figure 6-12 – Flood level difference between existing and proposed for 1 in 5yr RP event at Crossways Tavern

Table 6-11 – Flood level results at Crossways Tavern (Point 10)

Return Period (yrs)	Peak WL (mOD)		Difference (m)	Commentary / Implications
	Baseline	Proposed		
2	37.65	-	No longer floods	**Onset** of flooding is improved from less than a 1 in 2 year event in the baseline to a **1 in 10 year event** with the proposed works in place. Depth of flooding is reduced by up to 180mm for return periods 1 in 10 and above. Duration of flooding is also significantly reduced by approximately 16 hours in this event and 21 hours in a 1 in 100 event. This represents a significant improvement in flood risk for the Tavern.
5	37.72	-	No longer floods	
10	37.75	37.57	-0.18	
20	37.81	37.70	-0.11	
50	37.86	37.75	-0.11	
100	37.90	37.79	-0.11	
1000	38.08	38.02	-0.06	
100+46%	38.03	37.96	-0.07	
100+61%	38.08	38.01	-0.06	

Table 6-12 – Flood duration results at Crossways Tavern

Return Period (yrs)	Duration of flooding (hrs)		Difference (hours)
	Baseline	Proposed	
2	15.25	0	No longer floods
5	22	0	No longer floods
10	26.75	11.25	-15.5
20	30.75	14.75	-16
50	37	18.5	-18.5
100	43.25	22	-21.25
1000	52.25	34.75	-17.5
100+46%	51	31.75	-19.25
100+61%	52	34.25	-17.75

6.6. SEWAGE TREATMENT PLANT AND PUMPING STATION

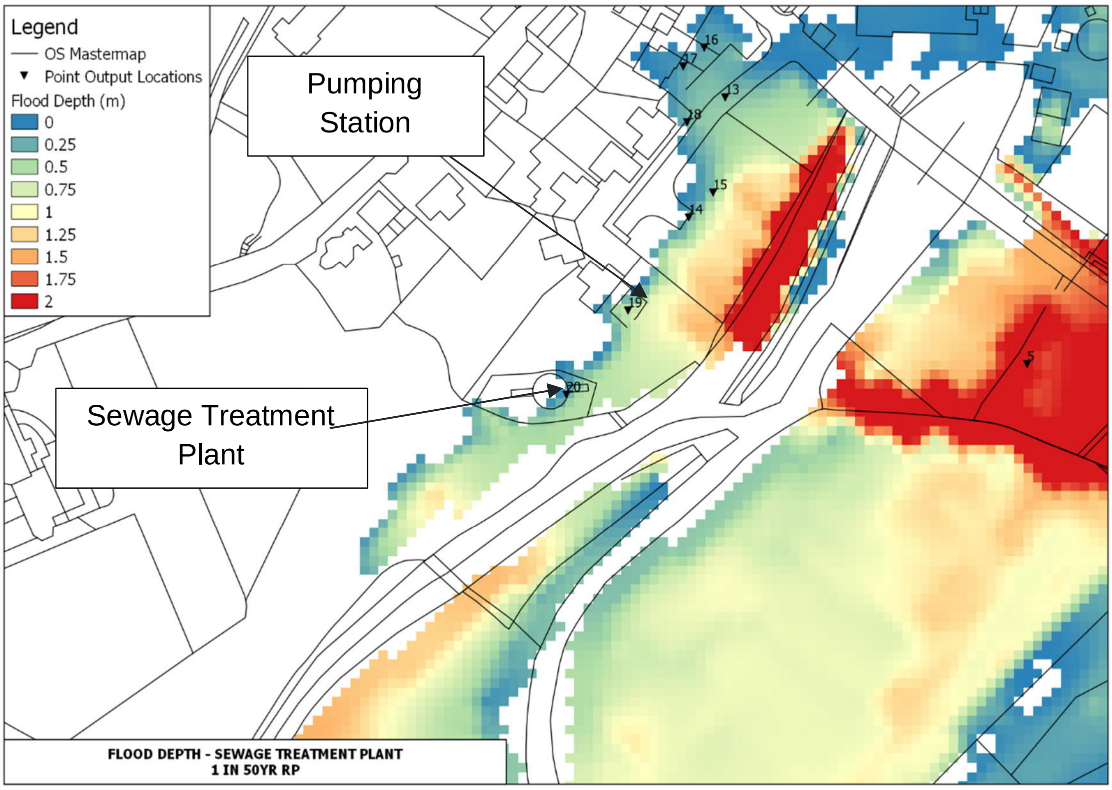

Figure 6-13 – Flood depth for 1 in 50yr RP event at STP in proposed scenario

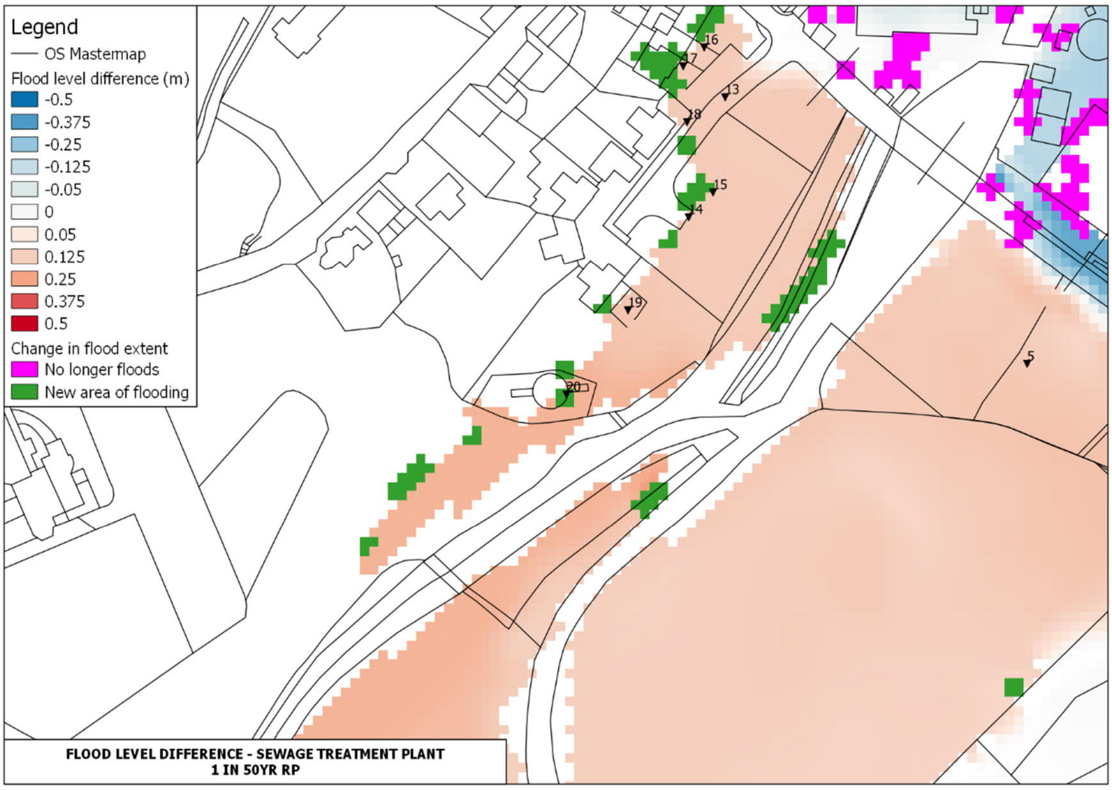

Figure 6-14 – Flood level difference between existing and proposed for 1 in 50yr RP event at STP

Table 6-13 – Flood level results at Sewage Treatment Plant (Point 20)

Return Period (yrs)	Peak WL (mOD)		Difference (m)	Commentary / Implications
	Baseline	Proposed		
2	-	-	No flooding	Flood levels are increased by up to 190mm as a result of the proposed works, however the onset of flooding (based on level described below) does not change. The duration of flooding is increased by approximately 2-3 hours for the climate change events.
5	-	-	No flooding	
10	-	-	No flooding	
20	-	-	No flooding	
50	-	37.07	Now floods	
100	36.98	37.17	+0.19	
1000	37.61	37.69	+0.07	
100+46%	37.41	37.57	+0.15	
100+61%	37.60	37.67	+0.07	

The onset of flooding will depend on which part of the sewage treatment plant needs to be overtopped for it to be considered flooded. Figure 6-15 shows the concrete surround of an outlet pipe, surveyed at 37.232 mODN. For the purpose of this assessment, this is the level used for comparison with the results above. The model predicts that the flood level for the 1 in 100 year event in the post-development scenario increases to 37.17mOD, which does not exceed this level.

Figure 6-15 – Top of concrete to sewage treatment plant outlet pipe surround

Table 6-14 – Flood level results at Pumping Station (Point 19)

Return Period (yrs)	Peak WL (mOD)		Difference (m)	Commentary / Implications
	Baseline	Proposed		
2	36.56	36.64	+0.08	Onset of flooding is unchanged, with water levels exceeding the threshold in 1 in 2 year event for both scenarios (as described below). Predicted depths increase for all return periods simulated, with the largest increase of 150mm occurring for a 1 in 50 year event. The duration of flooding is increased by approximately 3 hours for the 1 in 100 year event.
5	36.72	36.85	+0.12	
10	36.81	36.95	+0.14	
20	36.93	37.07	+0.14	
50	37.04	37.19	+0.15	
100	37.13	37.27	+0.14	
1000	37.65	37.72	+0.08	
100+46%	37.48	37.63	+0.15	
100+61%	37.64	37.70	+0.07	

Figure 6-16 shows the threshold of the concrete base to the pumping station. This was surveyed at 36.465mODN. South West Water will be consulted with regard to how these changes in flood level will impact on the equipment/plant within the pumping station building and whether any protection works will be required.

Figure 6-16 – Pumping Station threshold

The duration of flooding is also increased in the area of the pumping station and sewage treatment plant. This is shown in Table 6-15.

Table 6-15 – Flood duration results at Pumping Station (Point 19)

Return Period (yrs)	Duration of flooding (hrs)		Difference (hours)
	Baseline	Proposed	
2	2.75	5	2.25
5	9.25	11.25	2
10	13.25	15.25	2
20	17.25	19.25	2
50	22.5	24.75	2.25
100	26.5	29.25	2.75
1000	48	49.5	1.75
100+46%	45.75	48	2.25
100+61%	47.75	49.5	1.75

6.7. DEVON VALLEY MILL

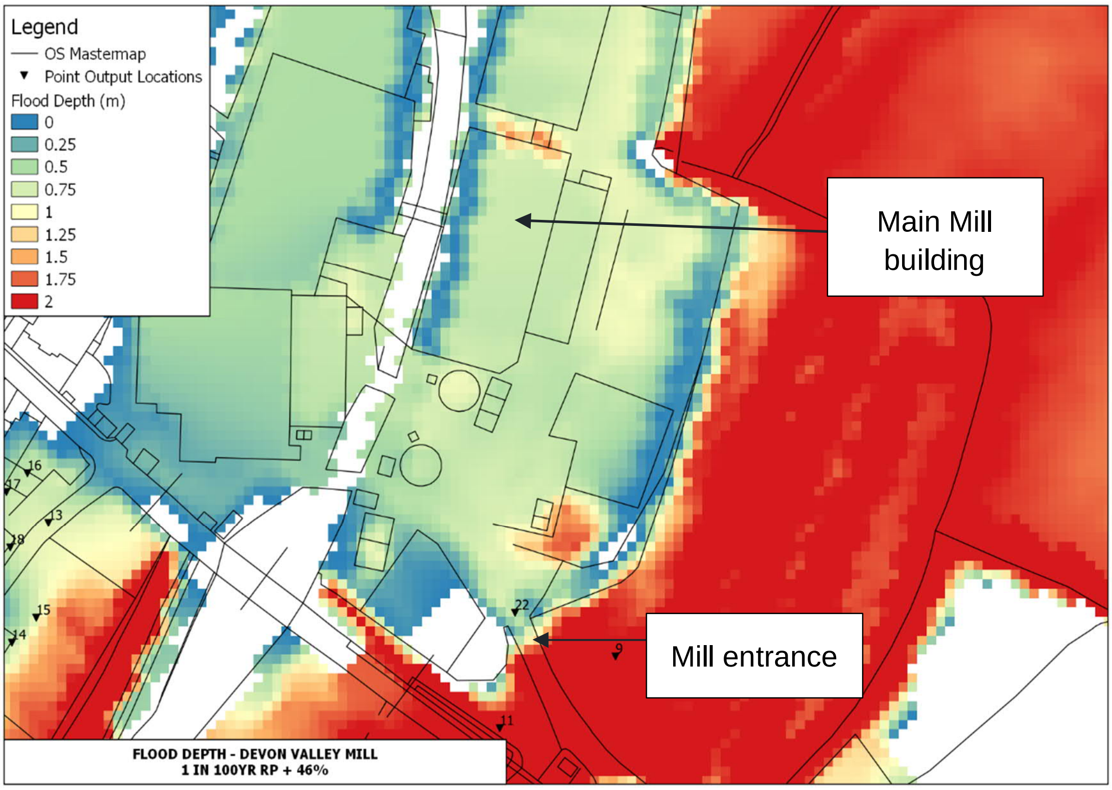

Figure 6-17 – Flood depth for 1 in 100yr+46% RP event at Devon Valley Mill in proposed scenario

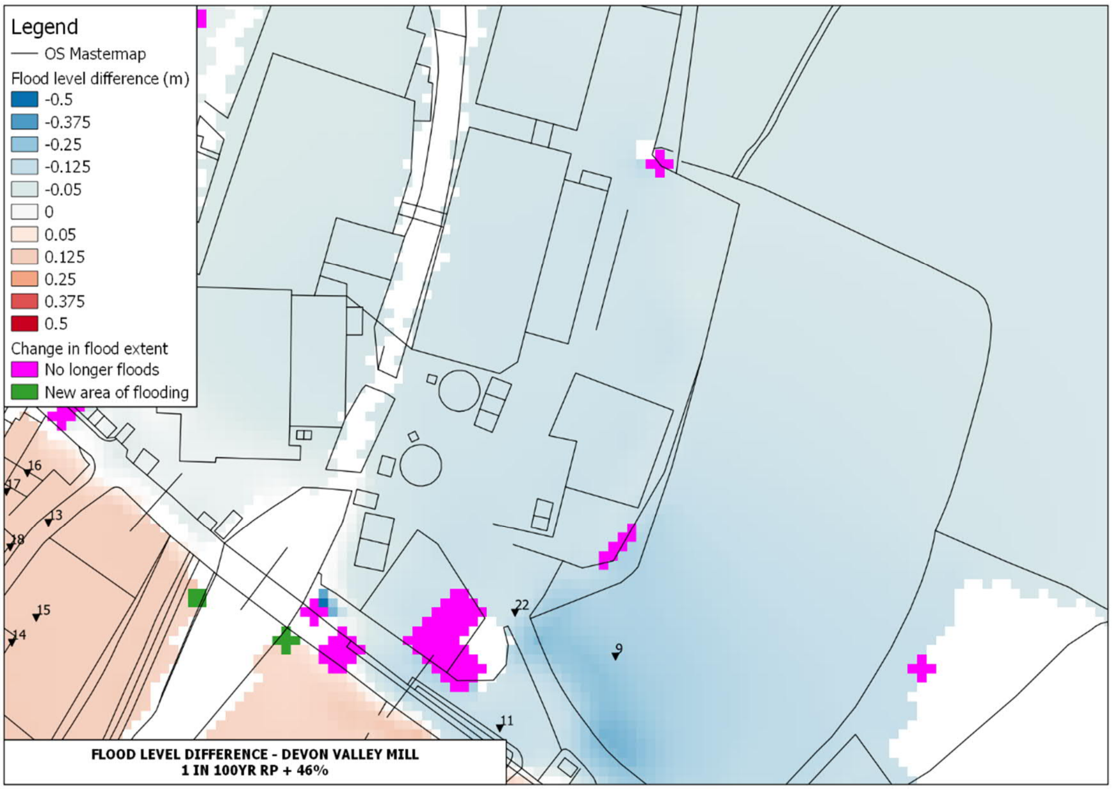

Figure 6-18 – Flood level difference between existing and proposed for 1 in 100yr+46% RP event at Devon Valley Mill

Table 6-16 – Results at Devon Valley Mill (Point 22)

Return Period (yrs)	Peak WL (mOD)		Difference (m)	Commentary / Implications
	Baseline	Proposed		
2	37.80	-	No longer floods	Water levels are sampled at the entrance to the Mill grounds, adjacent to the access bridge. Onset of flooding is unchanged. Predicted depths decrease for all return periods simulated, with the largest decrease of 240mm occurring for a 1 in 20 year event. The duration of flooding is also predicted to reduce by approximately 37 hours for the 1 in 50 year event. Note however that Station Road itself still floods in a 1 in 5 year RP, although for a significantly reduced duration. This means the Mill itself will not be flooded but access may be affected during a 1 in 5 year flood event or greater.
5	37.92	-	No longer floods	
10	37.98	-	No longer floods	
20	38.07	37.83	-0.24	
50	38.16	37.95	-0.21	
100	38.23	38.06	-0.17	
1000	38.54	38.46	-0.08	
100+46%	38.46	38.37	-0.09	
100+61%	38.53	38.46	-0.07	

Table 6-17 shows that in addition to improvements to the onset of flooding and reductions in flood level, there is a considerable reduction in the duration of flooding for those events which still affect the Mill.

Table 6-17 – Flood duration results at Devon Valley Mill (Point 22)

Return Period (yrs)	Duration of flooding (hrs)		Difference (hours)
	Baseline	Proposed	
2	20.75	0	No longer floods
5	27.5	0	No longer floods
10	32	0	No longer floods
20	34.5	23.5	-11
50	36.5	27.5	-9
100	39.75	30.5	-9.25
1000	51.25	35	-16.25
100+46%	50	33.75	-16.25
100+61%	51.25	34.75	-16.5

6.8. TEMPORARY WORKS SCENARIO

A conservative temporary works scenario has been modelled, representing the proposed haul road in place, in addition to the existing Station Road causeway, and both the existing and proposed Mill Access bridges. Results have been extracted at each output location for comparison with the baseline water levels at each return period. The difference between baseline and temporary works scenario peak water level are shown in Table 6-18.

Climate change scenarios have been not been simulated as the works will be temporary.

Table 6-18 – Point depth difference during the temporary works scenario

Point	Location	Depth Difference (m)					
		Return Period (yrs)					
		2	5	10	20	50	100
1	Station yard workshop	0.003	0.007	0.015	0.012	0.028	0.039
2	RC Motors	0.006	0.006	0.006	0.002	-0.001	-0.011
3	DS crossing - floodplain	-0.002	0.001	-0.002	-0.001	0.003	0.004
4	Just west of Lease cottages	0.002	0.000	-0.001	0.001	-0.001	0.000
5	DS of Station Road - in floodplain	-0.013	-0.024	-0.024	-0.007	-0.026	-0.027
8	Level crossing	0.005	0.007	0.006	0.001	-0.001	-0.017
9	US of Mill Access	-0.006	-0.009	-0.014	-0.026	-0.036	-0.050
10	Crossways tavern	0.005	0.006	0.003	0.001	-0.001	-0.011
11	US of station road causeway	0.017	0.019	0.017	0.003	-0.046	-0.071
12	Mill hardstanding (east of bridge)	0.004	0.009	0.007	-0.003	-0.006	-0.045
13	Hele Square	-	-	-	-0.005	0.004	0.008
19	Pumping station	-0.005	-0.009	-0.013	-0.006	0.003	0.007
20	Sewage Treatment Plant	-	-	-	-	-	0.013
21	West end of station yard	-	0.005	0.013	0.007	0.007	0.009
22	Mill entrance	0.007	0.004	0.001	-0.015	-0.028	-0.042

With the exception of some small and very localised increases in water level, this conservative approach to the temporary works shows that the presence of the haul roads will have a very small impact on flooding. Any small increases could be offset through the provision of culverts beneath the haul road which are not modelled here.

This conservative scenario includes both haul roads and the most constrictions to the floodplain, in the form of the existing Station Road viaduct and both the existing and proposed Mill Access bridges. Throughout the works the constrictions will reduce as the existing Mill Access bridge is removed and the Station Road viaduct is replaced with the proposed bridge.

It is recommended that the works at Hele Square are undertaken early in the construction programme to minimise the adverse impacts of the proposed permanent works.

6.9. SUMMARY OF IMPACTS

In summary, the results of the modelling indicate that:

- By carrying out the bridge works alone without additional mitigation onset of flooding is increased to a 1 in 5 year event.
- Flooding is reduced in onset, level and duration at the railway and upstream of Station Road, including at Devon Valley Mill and the Crossways Tavern.
- The onset of flooding at Station Road is predicted to reduce slightly to 1 in 5 years. This means there is a small improvement for the access to Devon Valley Mill but there will still be disruption during flood events above this onset level.
- Flooding is predicted to generally reduce in onset, level and duration for properties in Station Yard, with some very small increases in flood level under extreme events where significant flooding is already occurring. RC Motors is predicted to experience considerable betterment from the scheme.
- Flooding is predicted to increase at Hele Square in line with the previous modelling – however the maximum water level is below the proposed defence level of 37.98mOD and below the floor levels of other properties within Hele Square. This is described further in Section 7. Works are proposed to these properties to mitigate both this increase and their current flood risk. Discussions are being held between stakeholders and details of the proposed mitigation measures will be provided in an addendum to this FRA.
- Flood depths are predicted to increase at the Sewage Treatment Plant and Pumping Station, – the implications of this increased flood depth are to be discussed with South West Water. Consideration of the pumping station is also underway as part of the mitigation options for Hele Square.
- There is no increase in flood level at Lease Cottages.

7. MANAGEMENT OF FLOOD RISK

7.1. PROPOSED MITIGATION

The previous section of this FRA identifies the current and future fluvial flood risk to the site and the surrounding receptors, and how this would change as a result of the proposed works. As detailed in Section 3 all other sources of flood risk are low and not affected by the proposed works.

The works themselves are being implemented to improve the flood risk to the roads and rail infrastructure, and to reduce maintenance requirements and blockage risk at the Mill Access and Station Road structures. The supporting hydraulic modelling demonstrates that the proposed designs will be effective in achieving these aims.

In line with NPPF, mitigation proposals are required for any properties that could be adversely affected in terms of flood risk by the proposed bridge works. This relates to three properties and a garage in Hele Square, the pumping station and sewage treatment plant. Therefore, the mitigation proposals discussed below focus on only these properties. Other properties in Hele Square are shown to not be at risk of flooding and are not impacted by the proposed bridge works.

It is important to note that there will still be properties at risk of flooding in Hele that do not have mitigation works funded by this scheme. This is because the bridge works do not increase the risk of flooding to them. In most areas the onset of flooding and duration of flooding is reduced with the scheme in place.

HELE SQUARE

In light of evidence of flood levels and modelling results, the proposed mitigation measures include a robust freeboard. This means that should there be a greater flood than recently experienced or predicted, the residents of the properties in Hele Square will remain protected. The mitigation measures proposed also mean they will be less at risk of flooding than they currently are.

There are a number of constraints which have influenced the selection of the option and the details, including:

- Providing improved standard of defence to properties
- Minimising disruption
- Minimising requirement for active intervention in advance of a flood event
- Land ownership
- Buried services and drainage
- Visual and amenity impact

Network Rail are currently engaging with residents to establish a suitable option.

The defence crest level is to be set to a minimum of 37.98mAOD based on the modelled results. This gives a freeboard of 680mm for the 100yr event, 320mm for the 100yr event + 46% for the Central allowance of climate change, and is in excess of the flood level for the 100yr event + 61% used as a sensitivity test for the Higher Central estimate of climate change over 100 years, as well as the flood level for the 1000yr event. These freeboard allowances are appropriate for the assessment as described in *Accounting for Residual Uncertainty – Updating the Freeboard Guide*, Environment Agency, 2017. The defence level proposed here represents an increased standard of defence over that previously discussed.

The defence height for the mitigation measures, set in the context of known and predicted levels, is indicated in Table 7-1. There has been a lot of anecdotal information provided to the team and this, combined with the revised modelling, is being used to create a robust design for the mitigation measures. As shown in Table 7-1 the defence height is therefore set well above the flood levels discussed with residents.

Table 7-1 - Defence height in relation to known & predicted flood levels

	Level / depth of flooding	Freeboard @ defence height of 37.98mAOD
1 in 100 year predicted flood	37.30mAOD	0.68m
1 in 1000 year predicted flood	37.79mAOD	0.19m
1 in 100 year + 46% (to represent increase in flows over 100yrs)	37.66mAOD	0.32m
1 in 100 year + 61% (to represent increase in flows over 100yrs)	37.78mAOD	0.20m
Observed flood level	37.16mAOD	0.82m

The options which have been assessed and are being consulted on include a combination of flood walls, gates and embankments to the minimum proposed crest height of 37.98mAOD. In some locations existing walls will be repointed or reinforced as necessary to form part of the defence, at which locations the defence crest may be higher. Defence heights may also be higher in some locations for practical reasons. This is to be discussed during detailed design.

Gates will be provided in the defences as appropriate to provide access outside flood events, and to maintain the defence line where required if a flood warning is received.

There are a number of options for the gates. These options will be discussed with the residents so that the most appropriate measures can be determined. The finish of the wall will also be discussed with the residents as part of the detailed design process. Non-return valves and sealed manhole covers may also be needed to prevent the ingress of flood water or sewerage underneath the wall through services.

Exact wall/embankment alignments will need to be confirmed, including tie-in locations to higher ground.

Two options have been assessed within the hydraulic modelling in support of this FRA. These are as follows:

Option 2 – A flood defence wall around the perimeter of the affected three properties within Hele Square following the existing fence/wall line and tying into high ground. Flood gates for pedestrian and car access would be included as required. A flood gate/barrier to protect the affected garage would also be included.

Option 3 - A combined flood wall and embankment between Hele Square and the floodplain. Gates will be provided in the defence as appropriate to provide access outside flood events, and to maintain the defence line where required if a flood warning is received.

Note that Option 1 was for Property Flood Resilience which has been rejected.

Engagement on these measures is being carried out between Network Rail, the designers, and the property owners, with variations on these options being considered. Discussions are also underway with the residents and the Mill regarding the position of gates to prevent flooding to Hele Square from the Mill site, via Station Road.

Figure 7-1 and Figure 7-2 show the proposed location of the defence with indications of heights, and form of construction for Option 2 and Option 3 respectively.

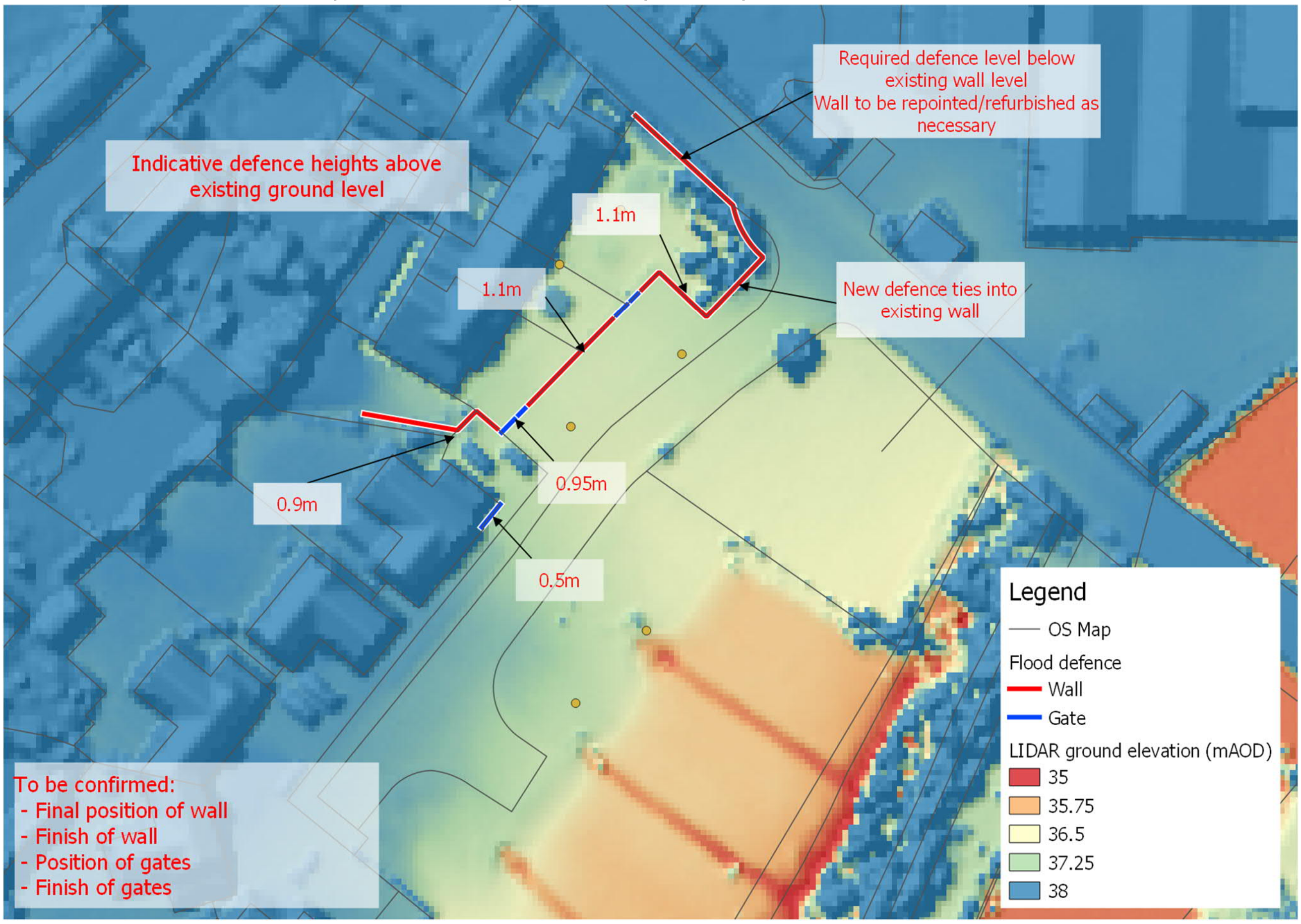

Figure 7-1 – Proposed Hele Square mitigation – Option 2

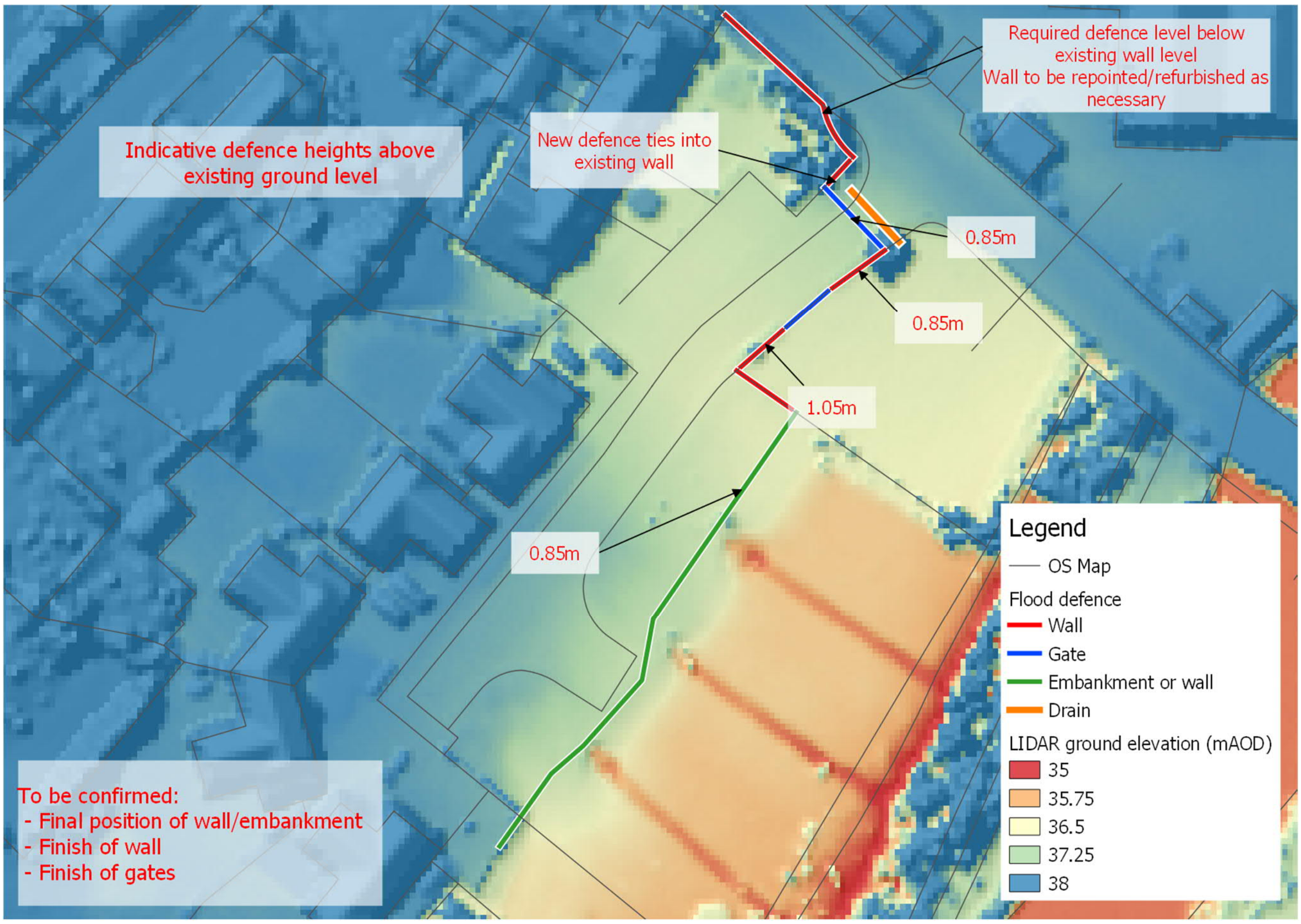

Figure 7-2 – Proposed Hele Square mitigation – Option 3

Flood modelling of these options has been carried out to identify if there are any impacts to surrounding properties as a result of the defences. This found that impact on flood levels with the defences in place would be negligible.

Option 4 - A further option is being explored following engagement with residents, which is a development of Option 3. This can be seen in Figure 7-3. This option has the benefit of providing protection from flooding to the South West Water pumping station located adjacent to No. 8 Hele Square, as well as providing additional reassurance to residents. While a greater length of wall is required, there is only minimal impact on floodplain with the wall largely following the edge of higher ground and hence not reducing storage. Option 4 includes a flood gate across the Mill entrance opposite Hele Square, and the pedestrian access points in the Mill wall, and the Hele Square defence will tie into higher levels along the south side of Station Road. Drains are likely to be required to intercept any surface water in this area and are shown indicatively in Figure 7-3. This option has not been modelled at this stage however the impact is expected to be similar to the original Option 3.

Residents will also be encouraged to sign up to the flood warning service, if they are not already, to ensure any gates are closed prior to a flood event. Where possible the gates will be closed at all times and only opened for access.

There is already a flood warning system in place for this area.

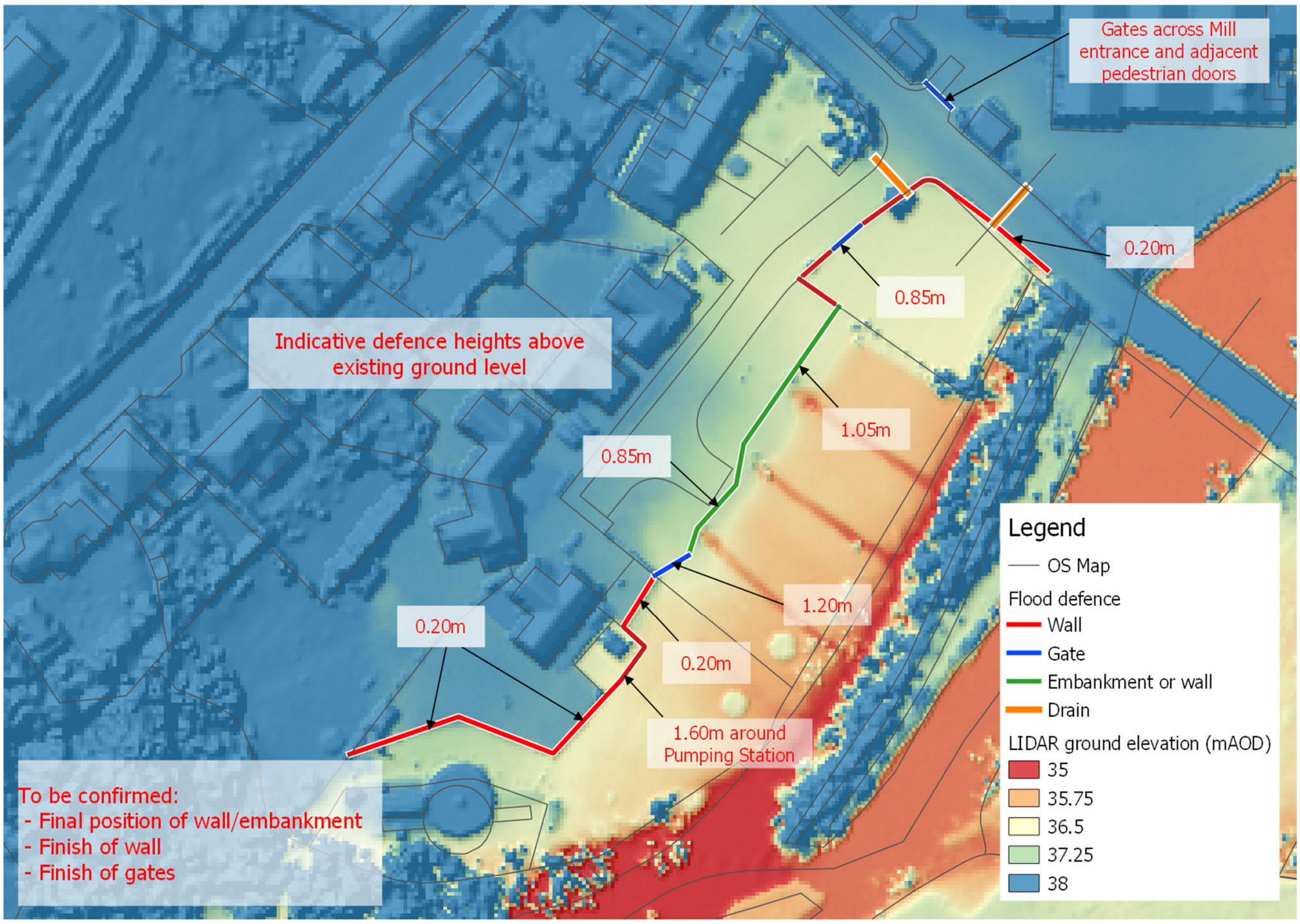

Figure 7-3 – Proposed Hele Square mitigation – Option 4

SOUTH WEST WATER ASSETS

Network Rail are currently in discussions with South West Water regarding the increase in flood risk to their infrastructure.

7.2. FLOODPLAIN COMPENSATION AND REPROFILING

Due to the proposal to replace the Station Road causeway with a bridge structure supported on piers, the amount of floodplain available in this area is increased by approximately 900m^2. The ground reprofiling provides additional floodplain volume at lower levels as well as improving conveyance through this area. Figure A2 in Appendix A shows the difference in ground levels between LIDAR and reprofiled ground level.

During engagement with the Environment Agency throughout the project, they expressed that they believed that reprofiling works in the floodplain downstream of Hele could have a beneficial impact on flooding by improving conveyance through the floodplain and into the structures under the railway downstream on the River Culm.

The impact of these has been tested within the modelling and is included in the post-development scenario runs.

Testing of the impacts of this reprofiling at earlier stages in the modelling showed negligible impacts of these measures on flood levels, particularly at more extreme return periods.

Figure 7-4 shows the representation of the floodplain reprofiling within the 2D domain of the model overlaid on the baseline flood depth results. Note that the areas modified correspond to areas of shallow depth in the results, and hence areas of higher land (prior to reprofiling).

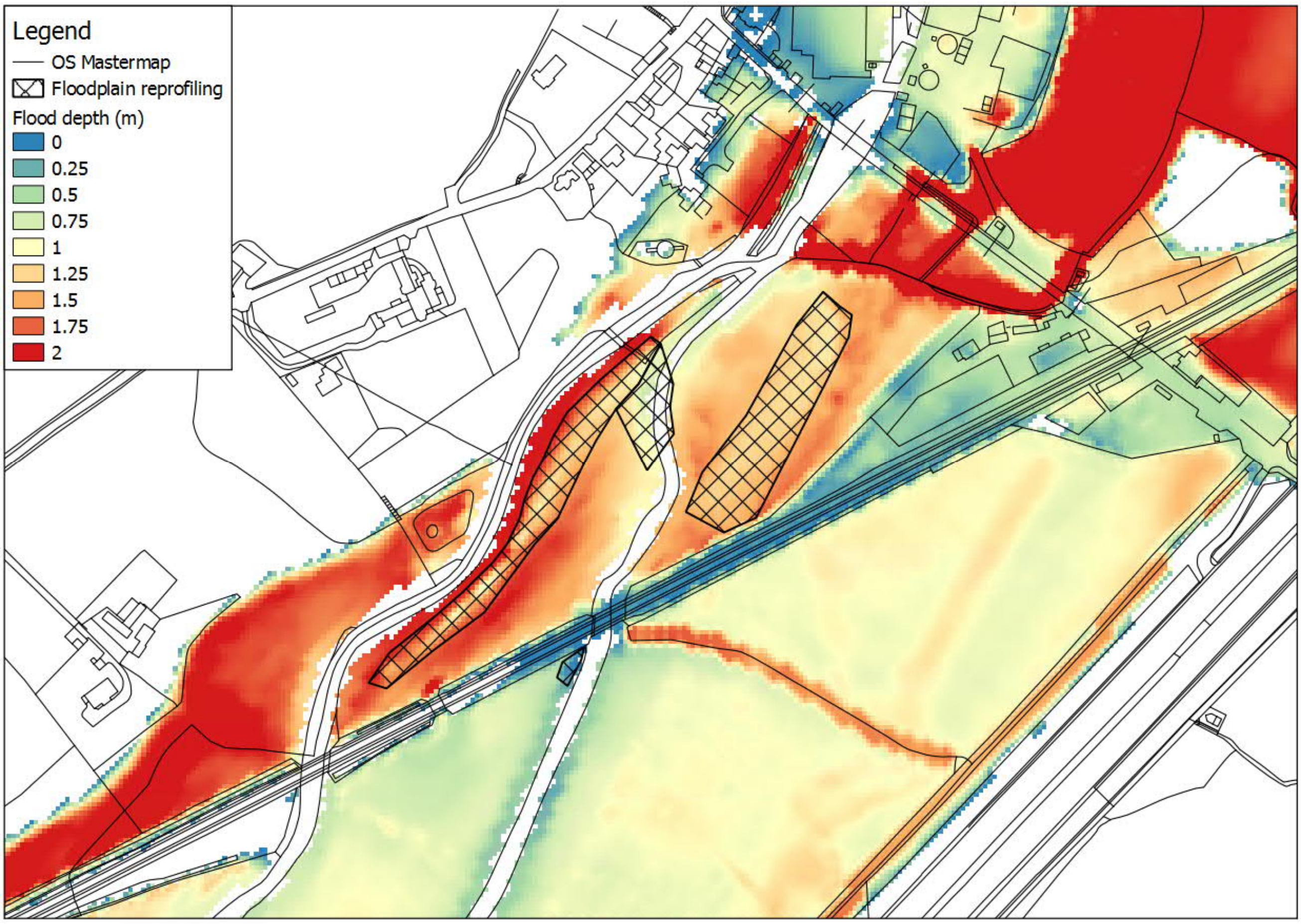

Figure 7-4 - Downstream floodplain reprofiling as modelled in 2D

The mitigation for the scheme does not depend upon these reprofiling works to provide a reduction in levels for properties.

8. POLICY COMPLIANCE

8.1. NATIONAL PLANNING POLICY FRAMEWORK

VULNERABILITY CLASSIFICATION

The NPPF was published in March 2012 and revised most recently in June 2019. It sets out the Government's national policies for flood risk management in a land use planning context within England.

The NPPF states that developers and local authorities should try to situate new development and relocate existing development to land in zones with the lowest probability of flooding.

A sequential risk-based approach to determining the suitability of land for development in flood risk areas is central to the policy statement and should be applied at all levels in the planning process. This includes the intent to steer the most vulnerable parts of a development to the areas that experience the least, or an acceptable, degree of flood risk.

In accordance with Table 2 and Table 3 of the PPG associated with the NPPF (Department for Communities & Local Government, 2014), the proposed structures and associated temporary access tracks and site compounds which are required to facilitate the development are classed as 'Essential Infrastructure' and as such, appropriate in Flood Zones 2, 3a and 3b. The Sequential and Exception test however need to be applied.

SEQUENTIAL TEST

The aim of the Sequential Test is to steer development towards areas with a lower probability of flooding in accordance with Paragraph 101 of the National Planning Policy Framework. The test would apply if there are reasonably available alternative sites with a lower probability of flooding.

Given the nature of the asset, namely the culverts and causeway under Station Road and the access road serving Devon Valley Mill, there is no reasonable alternative site within Flood Zone 1 or 2. The temporary haul roads and site compounds are pertinent to the development and are required to enable development of the permanent works and as such, no alternative sites are available within Flood Zone 1 or 2.

Based on the above assessment, the requirements of the Sequential Test have been met for the proposed development.

EXCEPTION TEST

The Proposed Scheme needs to pass the Exception Test. There are two aspects of the Exception Test that need to be passed to demonstrate that these land use types can be located within Flood Zone 3, these are outlined below and addressed in turn:

- it must be demonstrated that the development provides wider sustainability benefits to the community that outweigh flood risk, informed by a Strategic Flood Risk Assessment where one has been prepared; and
- a site-specific flood risk assessment must demonstrate that the development will be safe for its lifetime taking account of the vulnerability of its users, without increasing flood risk elsewhere, and, where possible, will reduce flood risk overall.

THE DEVELOPMENT PROVIDES WIDER SUSTAINABILITY BENEFITS TO THE COMMUNITY THAT OUTWEIGH FLOOD RISK

Flooding causes disruption to the road and rail infrastructure at Hele. Line closures on the rail network at this location have significant impact on this major transport link disrupting trains on the main line. Locally, flooding to Station Road and the level crossing prevents the use of the most direct access to and from the village of Hele. In addition, flooding of the Mill Access would cause significant disruption to Devon Valley Mill which operates at all times of day and night.

In addition to the reduction in flood depth and duration at the railway, flooding is also predicted to be significantly reduced to the Mill itself, at the Crossways Tavern, and to businesses in Station Yard.

The proposed works will improve the resilience of the infrastructure to flood risk and therefore benefit the local economy and ensure transport links are maintained during a flood, both locally and on a wider basis.

THE DEVELOPMENT IS SAFE FOR ITS LIFETIME TAKING ACCOUNT OF THE VULNERABILITY OF ITS USERS, WITHOUT INCREASING FLOOD RISK ELSEWHERE, AND, WHERE POSSIBLE, WILL REDUCE FLOOD RISK OVERALL

Hydraulic modelling has been undertaken to support the design process and determine the potential impacts on the flood risk elsewhere. The development itself is Essential Infrastructure that has been designed to remain operational, and therefore safe, during a flood. The results of the hydraulic modelling demonstrate that the proposed designs will be successful in their aim to maintain operation of the road and railway up to a 1 in 5 year event, an improvement over the current situation where the railway floods more frequently than a 1 in 2 year event. The duration of flooding will also be reduced for all return periods. The general flood risk for the area is therefore reduced and Station Road bridge is not predicted to overtop, although Station Road itself will flood.

The modelling has shown that generally there is a reduction in flood risk to third parties as a result of the proposed works. The only area where there is an adverse impact is the water level in Hele Square is shown to increase by 140mm for the 10 year and 100 year events. Three properties in Hele Square are already at risk and are known to have flooded internally in the past. The existing and increased flood risk will be managed through the provision of a flood defence, to be detailed in discussions with Network Rail, the Environment Agency, property owners and designers. As a result of the mitigation measures the properties will have an increased protection against flooding compared to their current standard of protection.

The Exception Test is therefore deemed to be passed.

9. SUMMARY

This FRA supports ana planning application for the replacement of two road bridges and re-profiling of the floodplain. This includes an assessment of flood risk from all potential sources and sets out proposed mitigation and strategies to address the risks identified.

The main source of flood risk to the Site is the fluvial risk from the River Culm, with the whole of the Site lying within Flood Zone 3. The area has flooded on numerous occasions in the past, resulting in significant disruption to the road and rail network. The aim of the proposals are to improve the flood resilience of the area, therefore minimising the disruption during a flood event.

There is no risk of flooding from reservoirs, the risk of flooding from groundwater is high but manageable through the design of the new bridges. There are currently localised areas within the Site at risk of surface water flooding, however this generally corresponds to the low-lying areas of the road that will be replaced. The surface water flood risk will be factored into the bridge design and drainage infrastructure designed accordingly.

Hydraulic modelling was undertaken to test the inclusion of the new bridges and re-profiled flood basin. This modelling has shown that the proposals will improve the onset of flooding at the level crossing from less than 1 in 2 years to 1 in 5 years. The modelling showed that there is a minor increase in flood risk for three properties and a garage in Hele Square as a result of the proposed works, however this does not impact on the onset of flooding at the properties.

Options for the mitigation measures in Hele Square to prevent the increase in flood risk are being developed. Network Rail is undertaking engagement with residents and landowners at the time of production of this FRA. This will be progressed in discussions with the Environment Agency, property owners and designers.

The details of options will be discussed and agreed with the residents as part of the detailed design process. The detail of the mitigation will be provided in an addendum to this FRA once the option has been selected.

Summary of Scheme Benefits

The proposed design provides greater capacity compared with the baseline, allowing for reduced flood levels upstream and a number of benefits resulting from this:

- The probability of flooding and disruption to rail services are likely to be significantly reduced from less than 1 in 2 years (50% AEP) to 1 in 5 years (20% AEP) with the new bridges in place. A significant reduction in the duration of flooding is also predicted (from approx. 55 hours to 21 hours for the 1 in 100 year event).
- Flood risk to the Devon Valley Mill is reduced, and in particular uninterrupted access to the Mill will be possible under during more frequent flood events as flooding to the access road will be reduced.
- The proposed design provides increased climate change resilience – increased capacity results in reduced onset of flooding when future climate change is included.
- Flood risk to the Crossways Tavern located to the south west of the railway is predicted to reduce significantly, with the onset return period of flooding greatly reduced in probability. Similarly, flooding to the businesses on either side of the railway to the west side of Station

Road, adjacent to the level crossing will also experience a significant reduction in the probability and in particular the duration of flooding.

- By reducing constrictions due to the bridges, including widening of the floodplain in this area, and reprofiling of the ground, risk of blockage of the structures will be reduced, hence reducing the risk of increased flood levels as a result of blockage. Creating a more free-flowing connection between up and downstream, sedimentation in this area is also likely to be reduced.

This FRA has presented the findings of the hydraulic modelling and shown that the proposed works, including the mitigation at Hele Square, will provide a flood risk reduction to the village of Hele and more specifically the railway line without adversely impacting on flood risk elsewhere. These proposals therefore satisfy NPPF and the associated PPG.

Appendix A

FIGURES

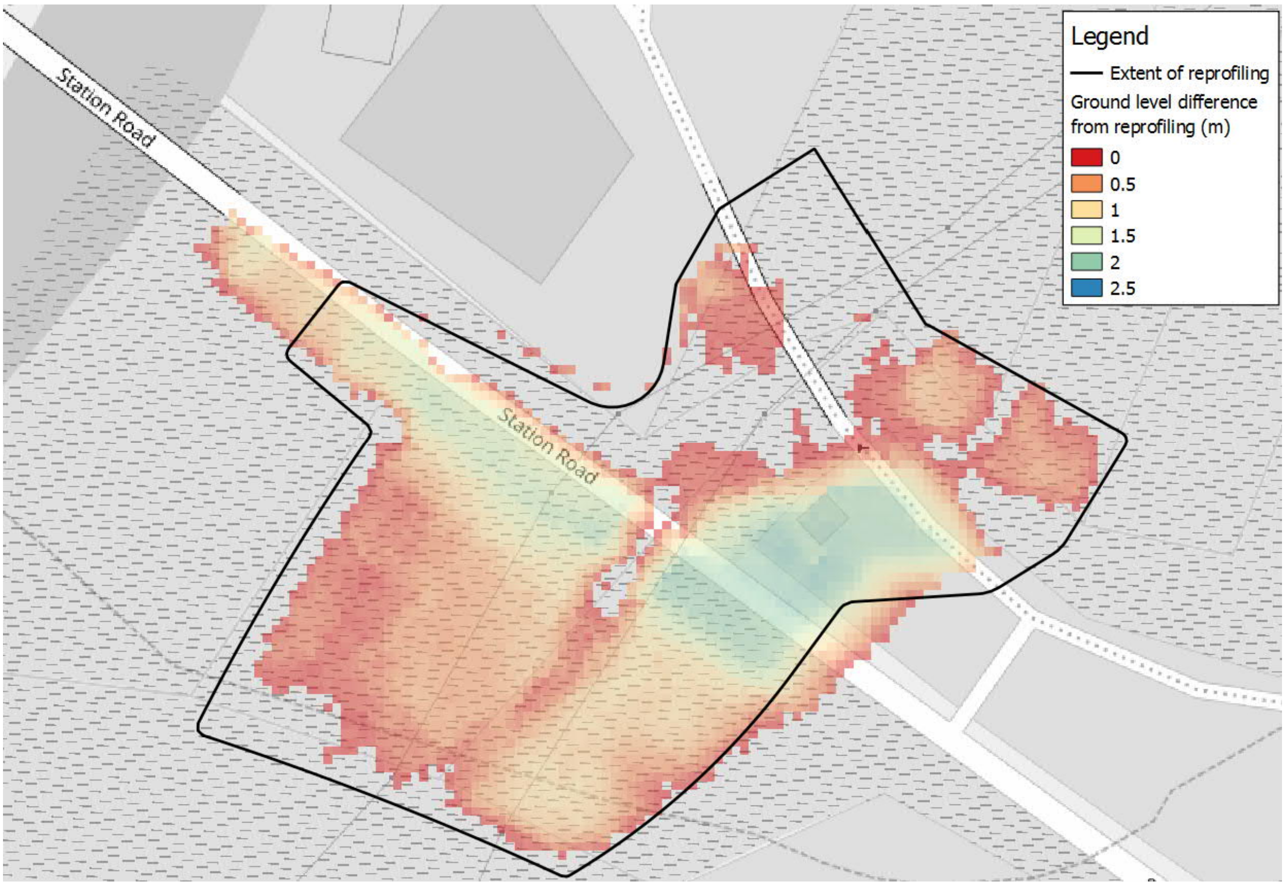

Figure A2 – Reduction in ground level from proposed reprofiling

Appendix B

DEVELOPMENT DRAWINGS / PLANS

Appendix C

STRATEGIC MAPPING

Appendix D

CORRESPONDENCE

Appendix E

HYDRAULIC MODELLING

Appendix F

FLOOD DEPTH MAPPING

Appendix G

FLOOD LEVEL DIFFERENCE MAPPING

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