MetroWest

Portishead Branch Line (MetroWest Phase 1)

TR040011

Applicant: North Somerset District Council
5.6, Flood Risk Assessment, Part 6 of 17
Appendix N Part 1 of 8, Tidal River Avon hydraulic modelling technical notes, tables of simulated peak flood levels, locations of properties referred to in technical notes
The Infrastructure Planning (Applications: Prescribed Forms and Procedure) Regulations 2009, regulation 5(2)(e)
Planning Act 2008

Author: CH2M
Date: November 2019

Notice

Document history

Project	Portishead Branch Line (MetroWest Phase 1) Development Consent Order Scheme
Planning Inspectorate Scheme Reference	TR040011
Volume and Application Document Reference	5, 5.6
Document title	Flood Risk Assessment, Part 6 of 17 Appendix N Part 1 of 8, Tidal River Avon hydraulic modelling technical notes, tables of simulated peak flood levels, locations of properties referred to in technical notes
Regulation Number	Regulation 5(2)(e)
Applicant	North Somerset District Council
Lead Author	RB at CH2M

Version	Date	Status of Version
Rev: 01	12/11/19	Application Issue

TECHNICAL MEMORANDUM

Metro West Phase 1 FRA – Further development of BCC CAFRA model

Technical Note

PREPARED FOR:	North Somerset Council
COPY TO:	
PREPARED BY:	Kostya Vasilyev
DATE:	September 2019
PROJECT NUMBER:	674946
REVISION NO.:	4
APPROVED BY:	Robert Bird

1.0 Introduction

1.1 The Purpose of this Technical Note

This technical note provides background information and details on hydraulic modelling work carried out as part of the MetroWest Phase 1 Flood Risk Assessment.

1.2 Study Background

CH2M HILL (now Jacobs) was appointed by North Somerset Council to undertake a Flood Risk Assessment (FRA) for the MetroWest Phase 1 Development Consent Order (DCO) application.

As part of this FRA, flood risk to the proposed railway from the River Avon and the impact of the proposed railway development on River Avon flood risk elsewhere was assessed by developing the Bristol City Council (BCC) Central Area Flood Risk Assessment (CAFRA) hydraulic model.

The CAFRA model simulates flooding events from the River Avon, and was used to evaluate flood risk to the railway due to high levels in this river. The model however covers a much larger area and was not built specifically to analyse this problem. Therefore, the CAFRA model detail was reviewed to ensure that the flooding mechanisms that lead to flooding of the railway, and the effects the railway has on flooding elsewhere, were well represented. Results were obtained for both flood risk to the railway and changes to flood risk due to the changes to the railway.

1.3 Study Objectives

The primary study objectives are as follows:

i. Review boundary conditions to the CAFRA model;

ii. Understand flooding mechanisms to the railway. Review their representation in the model and improve where necessary;

iii. Run model and obtain flood risk results for both pre-development and post-development scenarios, for the present day (2015) and future scenarios (2075 and 2115);

iv. Assess flood risk to the proposed railway from the River Avon and impacts on River Avon flood risk elsewhere for the post- development scenario.

2.0 Existing Bristol City Council's CAFRA model overview

The Bristol Central Area Flood Risk Assessment (CAFRA) hydraulic model was developed by Hyder Consulting (UK) Limited (Hyder) following the appointment by Bristol City Council (BCC) in September 2010. The main purpose of the CAFRA model was to provide strategic assessment of flood risk in central Bristol area. The extents of the Bristol CAFRA model are shown in Figure 1.

The CAFRA model is a 1D-2D model. Generally Flood Modeller 4.3 (1D numerical engine 4.3.0.290) was used for the 1D simulation and TUFLOW build 2013-12-AE-iDP-w64 for the 2D simulation. However, for some simulations (mainly with larger flows) it was only possible to get the model to run using one of the following versions of the 1D numerical engine: 6.7.2.117 or 6.5.1.75. For more details see Section 5.5.

The CAFRA model was initially developed with a 2010 baseline (fluvial and tidal boundaries). Throughout this report this is referred to as the CAFRA 2010 model. In 2015 the tidal boundaries were updated to a 2015 baseline. Throughout this report this is referred to as the CAFRA 2015 model.

In 2010 - 2012 Hyder Consulting ran future scenarios for the years 2060 and 2110.

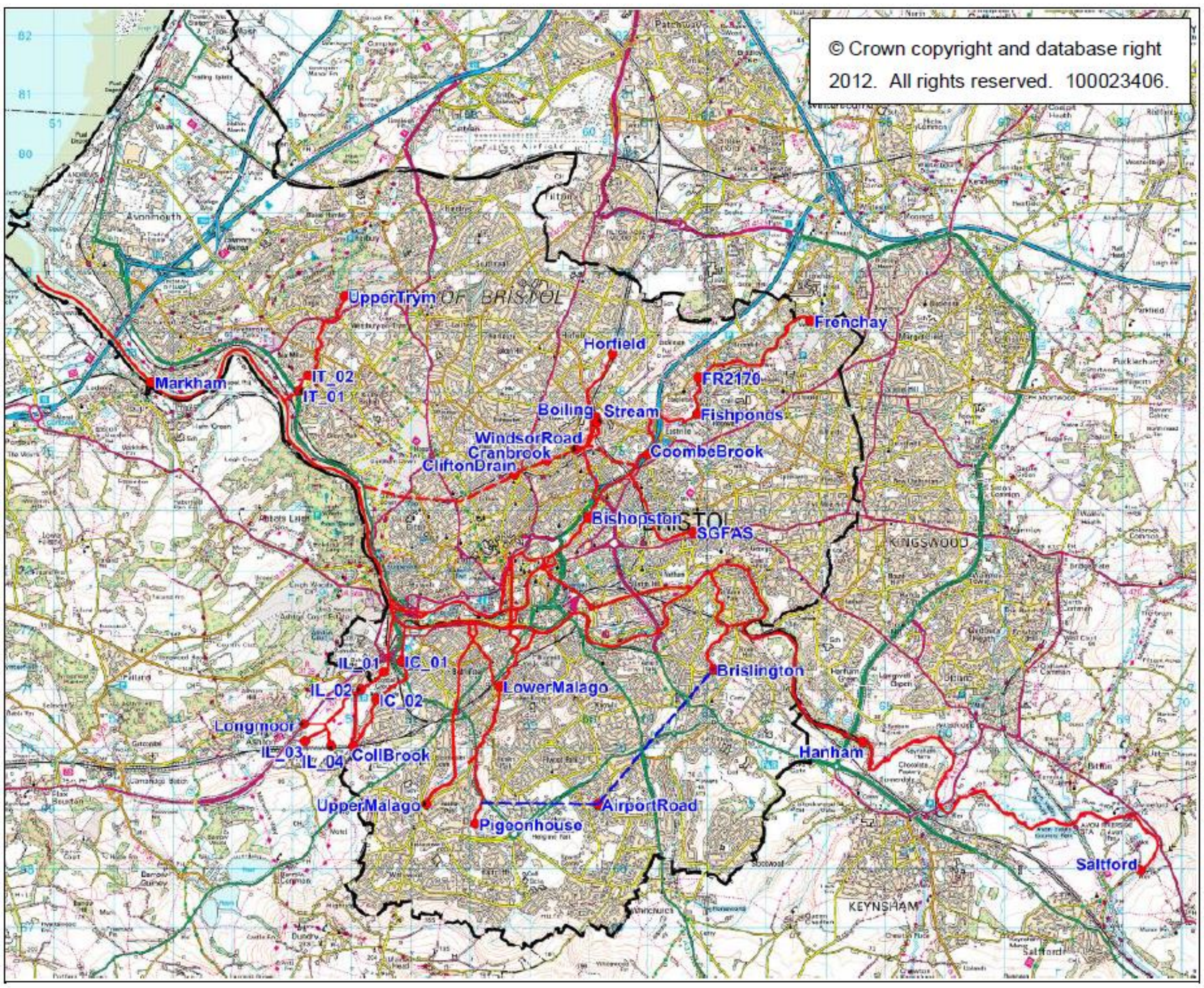


Figure 1. The geographic extents of the Bristol CAFRA model illustrating inflow locations and the extent of the model

3.0 Model Data

3.1 Data List

The existing CAFRA model, which simulates flooding from the River Avon, was used to run the required scenarios. The model however covers a much larger area and was not developed specifically to analyse this problem.

Several data sources were therefore used to improve model detail in the vicinity of the MetroWest Phase 1 DCO scheme.

A summary of this data is provided in Table 1.

Table 1. Summary of data used to update the model

File name	Description	Format	Date	Comments
Network Rail level survey	Survey of the embankments along the railway line.	AutoCAD drawings	November 2015	The survey covers the embankments and the rails along the railway line.
MetroWest Phase 1 project drawings	Information about the proposed design for MetroWest	pdf	December 2015	Proposed design of the railway
2m LiDAR for the area	LiDAR of the study area	ASCII grid	Downloaded in Sept 2015	2m resolution LiDAR for the area used to update the 2d domain, downloaded from Geomatics. Lower resolutions were not available.
Ordnance Survey MasterMap data for the study area	MasterMap tiles used for the 2d domain roughness layer	Shapefile	Downloaded in Sept 2015	Downloaded as 1sq km tiles.
Files such as w1097B-ARP-DRG-ETR-000247.pdf and others	Information about the planned design for MetroWest	PDFs	December 2015	The drawings containing information about the planned design of the railway
Hyder Consulting's Bristol City Council Central Area Flood Risk Assessment Final Report (Workstream 4)	Report provides details on this FRA.	PDF	November 2012	
Hyder Consulting's Bristol City Council Central Area Flood Risk Assessment	The report describes the model prepared for this FRA	PDF	December 2012	

Modelling Report (Workstream 3)				
Hyder Consulting's Joint Probability Technical Note 5006-UA002318-UU41-M-05	This technical note documents the approach taken to derive the joint probability tidal/fluvial boundary conditions for the Bristol CAFRA	PDF	October 2011	
North_Somerset_ Buildings.shp	OS Master map data ('buildings' layer)	.shp file	October 2016	

4.0 Technical method and implementation

4.1 Study Area

Most of the section of the railway that runs along the river is at a relatively high elevation compared to River Avon flood levels. The study therefore only focuses on the area where the railway is at a lower level and is within the simulated flood extents from the river for the events considered here.

Figure 2 shows the elevation of the railway and the zone that was further analysed in this study. The maximum water level obtained in the scenarios considered in this study was 11mAOD.

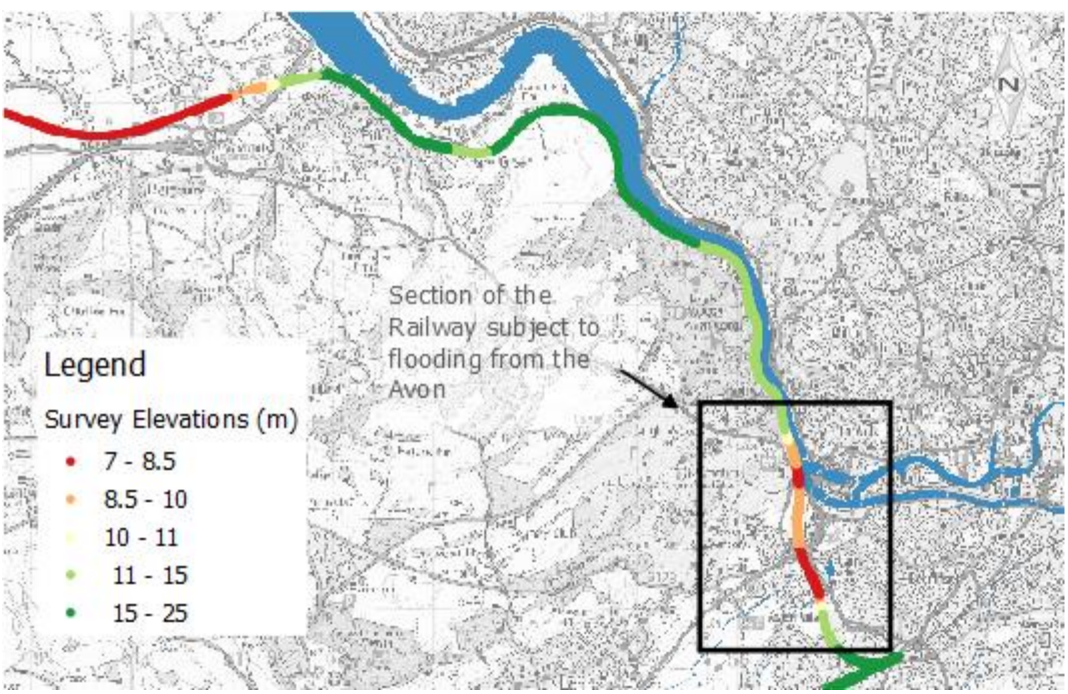


Figure 2. Railway elevations along the River Avon and section of the railway subject to flooding from the River Avon for the events considered in this study.

4.2 Boundary Conditions

There were two sets of simulations carried out as part of this study; tidal dominated events (i.e. tidal River Avon flood events) and fluvial events to assess flood risk from Colliter's Brook and Longmoor/Ashton Brooks.

For the tidal and fluvial simulations undertaken for this study the joint tidal/fluvial event probabilities derived in the CAFRA 2010 report have been applied.

Tidal boundaries

Most of the present day (2015) tidal boundary conditions required for this study were available from the CAFRA 2015 model. Exceptions were the 5 year and 50 year return periods. These were derived from the available CAFRA 2010 model boundaries by adding 20mm sea level rise for the period 2010 to 2015. This increase is slightly higher than the calculated 17.5mm based on National Planning Policy Framework (NPPF) guidance (2013), but the available CAFRA model 2015 tidal boundary conditions are 20mm higher than the 2010 tidal boundaries. Therefore, for consistency, we have applied this value to the 5 year and 50 year return periods (for 2015).

The future 2075 and 2115 tidal event boundaries have been derived by applying 505mm and 1055mm sea level rise respectively to the 2015 boundaries, following NPPF guidance.

Fluvial boundaries

For present day (2015) events, CAFRA model 2010 fluvial inflow boundaries were applied as the 2015 CAFRA model does not update these.

For future 2075 and 2115 events, CAFRA model 2110 fluvial boundaries were applied as the NPPF (2013) guidance specifies the same river flow uplifts for 2075 and 2115 as for 2110.

4.3 Base case scenario – flooding mechanisms and model updates

The model was reviewed and the level of detail was increased in order to represent flood risk relating to the proposed railway development adequately. In order to do this, the CAFRA model and the additional data available were used to identify the flooding mechanisms that lead to flooding of the railway or that could be affected by any changes to it. It was then verified whether these mechanisms were well represented and where necessary the model was adjusted. See Section 4.3.2 for more information on the flooding mechanisms.

The model was also updated to apply the 'stubby buildings' approach to represent buildings in the floodplain, as described further in Section 4.3.1.

4.3.1 'Stubby buildings' representation

'Stubby buildings' is an approach to represent buildings in the TUFLOW model (2D hydrodynamic model). The buildings are represented by (1) an increase in the elevation of the ground grid (typically 0.3 m) to represent the obstruction to flow that the buildings present; (2) specifying high roughness values within the building footprint acknowledging that there may be flood routes through buildings once flood depths exceed the threshold levels of openings in the buildings. Applying the 'stubby buildings' representation has the potential to:

- Reduce available floodplain storage and hence increase modelled flood levels.
- Locally change flow paths and hence change the distribution of flood water in the floodplain

In the CAFRA model the 'stubby buildings' approach was applied as follows:

- Building footprints were based on OS Master Map data
- Model grid levels were raised by 0.3m within building footprints

- Roughness values within building footprints were site to 0.3.

The TUFLOW domains of the original CAFRA model already applied increased roughness values of 0.3 for buildings footprints (the same roughness values as those specified above for the 'stubby buildings' representation). The building extents in the CAFRA model were cross-checked against OS Master Map building footprints and found to be in agreement. Checks indicate there is a perfect match between the areas with Manning's coefficient 0.3 (used for buildings in the TUFLOW domains of the CAFRA model) and the buildings in the OS Master Map for 6 out of 8 TUFLOW domains. There is no match at all in St George's domain and no match for some of the buildings in the Netham domain. However, these domains are the furthest from the MetroWest railway and from the tidal River Avon. It is therefore considered that applying a 'stubby buildings representation' for these areas would have a negligible impact on model results near to the MetroWest railway project (and the MetroWest project would have negligible impact on results at these locations). When applying the 'stubby buildings' representation it was therefore only necessary to increase the model grid elevation by 0.3m within the building footprint.

This CAFRA model grid size is 5m. This is considered appropriate for representing buildings in the FRA model.

4.3.2 Flooding mechanisms

The flooding mechanisms are described below according to the section of the railway they first affect. Figure 3 shows the area where flooding to the railway from the Avon occurs and the locations associated to the different flooding mechanisms. The flood extent given by the updated model for the 200 year event with climate change is shown in the background. Figure 4 shows these locations in a profile view of the same section of the railway. Even though water levels at several locations can be explained by a combination of these flooding mechanisms (especially for events with higher water levels), the mechanisms themselves are distinct.

The checks and adjustments to the model described below concentrated on the zone where flooding to the railway occurs, shown in Figure 3. The CAFRA model covers a much larger area. The full model was used and run for each of the scenarios, and the rest of the model remained largely unchanged. The only modifications to the model besides those in the area analysed below were related to stability issues and involved minor simplifications to the model for running specific scenarios. It was verified that the impact of these changes on water levels closer to the railway were negligible.

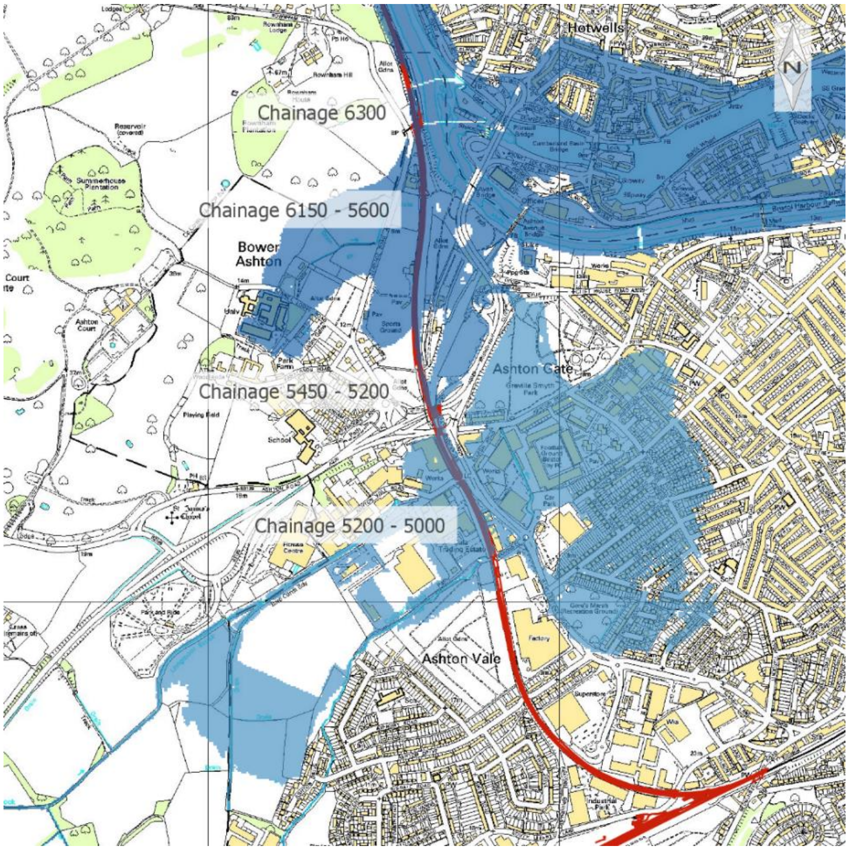


Figure 3. Section of the railway subject to flooding from the River Avon and flood extents for the 200 year with climate change event. Locations on the railway where different flooding mechanisms affect the railway are shown. Note – these results were derived before applying the 'stubby buildings' representation of buildings in the floodplain.

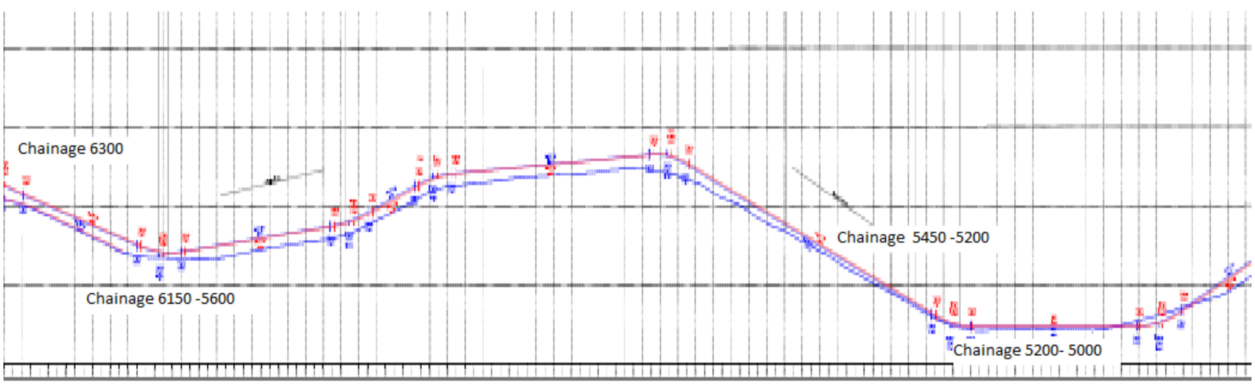


Figure 4. Profile view of section of the railway subject to flooding from the River Avon (Existing rail levels - Red: Up Portbury line; Blue: Down Portbury line). Locations on the railway where different flooding mechanisms affect the railway are shown. Source: The Project.

Chainage 6300

In this area the railway runs parallel to the river, increasing in elevation towards the north. Ground levels between the two are mostly higher than the railway, especially where the railway is at a lower elevation. There is one location however where these levels decrease to levels below the railway level. At this point the railway levels are 8.75mOD. When the River Avon water levels reach this height, water floods the railway and flows south towards Bristol, flooding this section of the railway. Flooding occurs at this location for events with return periods above approximately 10 years for the pre-development situation.

Representation in the model: The 1D-2D boundary for the model crosses this section of the railway a short distance south of this location. The boundary was set at an elevation of 8.75 m to ensure flooding occurs when water exceeds this level.

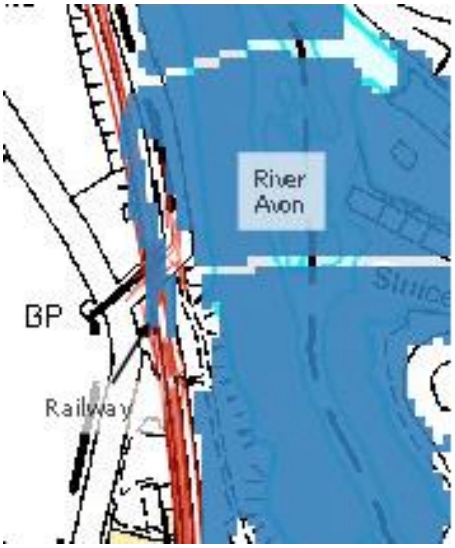


Figure 5. Flooding of the railway at chainage 6300
Note – these results were derived before applying the 'stubby buildings' representation of buildings in the floodplain.

Chainage 6150 -5600

Water reaches this section of the railway after overtopping the River Avon banks. Water reaches the area around the railway for both the pre-development and post-development scenarios on the 10 year return period event, and floods it between the 20 and 50 year return period event.

Representation in the model: Ground levels between the railway and the River Avon are those of the CAFRA model. New survey and project data was used to increase detail in the railway area. At this location the highest points are given either by the railway embankment itself or by higher ground on its side. These higher points were included in a z line representing the railway.

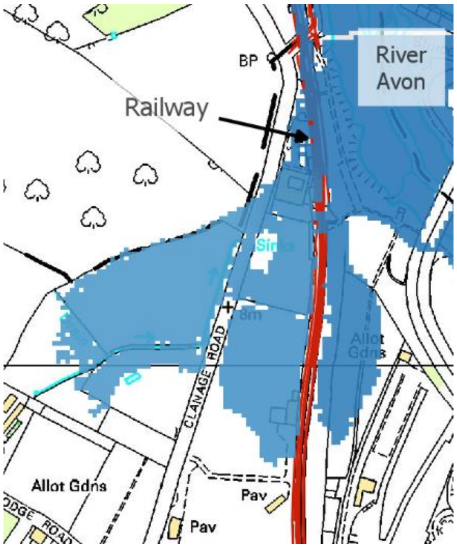


Figure 6. Flooding of the railway at chainage 6150 to 5600
Note – these results were derived before applying the 'stubby buildings' representation of buildings in the floodplain.

Chainage 5450 -5200

Two different flooding mechanisms flood this section of the railway.

From the River Avon:

Water flows towards the railway through the lower ground between Brunel Way and the railway. It reaches the Ashton Gate Underpass where it crosses under Brunel Way, which at this point runs parallel to the railway. Ground levels between the road and the railway are slightly higher than the road at this point. Therefore, water may flood the railway directly or flow southwards on the road through the underpass and flood the railway later depending on the return period of the event (higher return periods with higher water levels will flood the railway directly). Water floods the railway at this location for return periods between 2 and 5 years with climate change and above.

Representation in the model: Same as for flooding at Chainage 6150 -5600

Through the railway itself:

The section of the railway between chainage 6000 (location of flooding mechanism explained above) and chainage 5400 is at a higher level than at chainage 6000 and chainage 5400 (see Figure 4 for locations), but at a lower level than the ground around it. When flood water levels between chainage 6150 and 5600 reach the elevation of the railway, water flows southwards through it. As mentioned above, flooding occurs for return periods from 20 to 50 years for chainage 6150 to 5600, but only reaches the necessary level to flow south through the railway for return periods between 2 and 5 years with climate change and above (No flooding is shown by the model for scenarios without climate change. All events with climate change produce higher water levels than any of those without it in this study).

Representation in the model: Railway levels through which the flood waters could flow south were checked using the new survey.

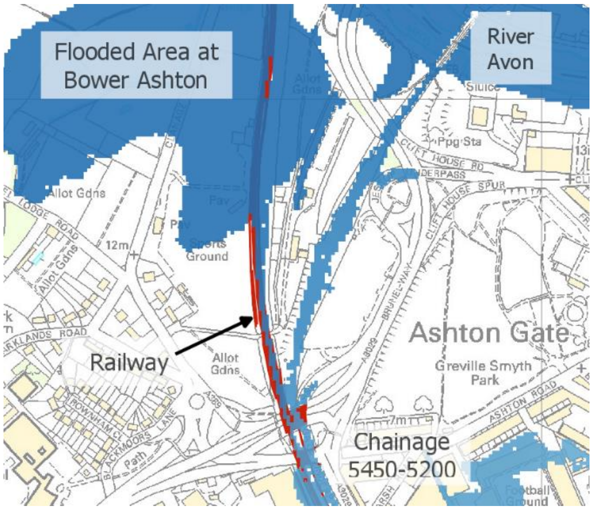


Figure 7. Flooding of the railway at chainage 5450 -5200
Note – these results were derived before applying the 'stubby buildings' representation of buildings in the floodplain.

Chainage 5200- 5000

When the Avon overtops its banks the water reaches the Jessop underpass and flows under Brunel Way towards the East. It then continues to flow southwards on the Eastern side of Brunel Way, crosses Ashton Rd at a low point and later reaches the railway. The model results shows this to happen for the 50 year return period with climate change event and above (No flooding is shown by the model for scenarios without climate change. All events with climate change produce higher water levels than any of those without it in this study).

Representation in the model: Ground levels between the railway and the River Avon are those of the CAFRA model. New survey and project data was used to check the model elevations in the railway area. At this location the highest points are given either by the railway embankment itself or by higher ground on its side.

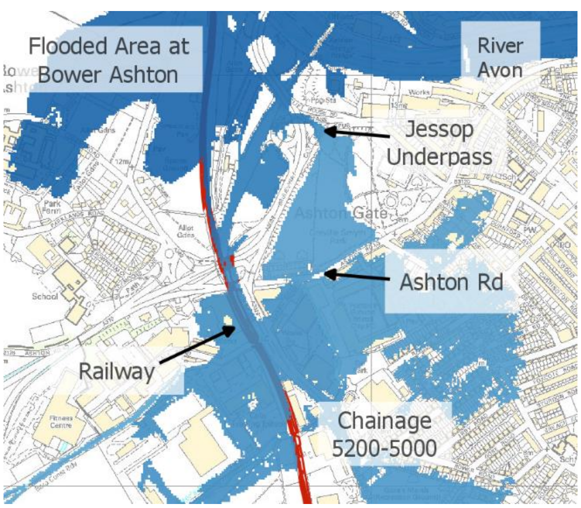


Figure 8. Flooding of the railway at chainage 5200 -5000
Note – these results were derived before applying the 'stubby buildings' representation of buildings in the floodplain.

4.4 Post-Development Scenario

Proposed design changes were included in the model in order to predict flood risk in a post-development situation.

Earlier MetroWest railway designs in the Bower Ashton / Ashton Vale area included a general increase in railway levels and removal of raised bunds adjacent to the railway. However, a consideration of offsite impacts resulted in design modifications such that the proposed works now retain existing railway levels and alignment within the River Avon tidal floodplain and the Longmoor / Colliter's Brooks fluvial floodplain. The representation of the railway is therefore not changed in the post development model (i.e. same as pre development).

The post development design includes a representation of the proposed construction compound adjacent to Clanage Road in Bower Ashton. This includes access ramps within the compound and ground lowering to provide floodplain compensation for the access ramps.

Since the initial (and now superseded) MetroWest CAFRA modelling was undertaken, modelling has been undertaken to consider offsite impacts and floodplain compensation options. This is reported in Appendix A.

5.0 Model Runs

5.1 Tidal design events

River Avon flood levels in the study area are dominated by tidal flood levels. River Avon Tidal events were simulated with return periods "Non flood", 1, 2, 5, 10, 20, 75, 100, 200 and 1000-years, for the pre and post development cases, for the present day (2015) and future (2075 and 2115) scenarios.

The CAFRA study applied the FD2308[1] joint probability calculation spreadsheet to specify joint tidal/fluvial boundary conditions for the simulated design events. The joint events simulated are listed in Table 2.

Table 2. Tidal design events – joint tidal and fluvial combinations

Simulated tidal event return period (yrs)	Tidal design boundary return period (yrs)	Fluvial design boundary return period (yrs)
Non-flood	Base	'mean' (i.e. non-flood)
1	1	'mean' (i.e. non-flood)
2	2	'mean' (i.e. non-flood)
5	5	'mean' (i.e. non-flood)
10	10	'mean' (i.e. non-flood)
20	20	'mean' (i.e. non-flood)
75	75	'mean' (i.e. non-flood)
100	100	'mean' (i.e. non-flood)
200	200	6
1000	1000	12

5.2 Fluvial design events

Fluvial design simulations are required to assess fluvial flood risk in the vicinity of the railway crossing of Colliter's and Longmoor Brooks floodplains. River Avon fluvial events were simulated for the pre and

[1] Defra/EA March 2005: Joint Probability: Dependence Mapping and Best Practice: Technical report on dependence mapping R&D Technical Report FD2308/TR1

post development cases, with return periods 100 and 1000-years for the present day (2015), and 50, 75, 100, 1000 years for the future (2075 and 2115) scenarios.

Joint tidal/fluvial boundary conditions were specified according to the joint probability combinations specified for the CAFRA model, and listed in Table 3 (extended using the FD2308 joint probability calculation spreadsheet for any missing return periods).

The fluvial events were run with additional roughness patches as introduced in the original CAFRA 2010 fluvial runs. These patches were introduced to improve model stability and were located near Malago Stream.

Table 3. Fluvial design events – joint tidal and fluvial combinations

Simulated fluvial event return period (years)	**Fluvial design boundary return period (yrs)**	**Tidal design boundary return period (yrs)**
50	50	Base tide
75	75	2
100	100	2
1000	1000	10

5.3 Other information on simulations

5.3.1 Before May 2019 (earlier MetroWest railway design)

Most of the simulations were run using the following versions of the software:

- Flood Modeller 4.3 (1D numerical engine 4.3.0.290) - for the 1D parts of the CAFRA model
- TUFLOW build 2013-12-AE-iDP-w64 – for the 2D parts of the model.

The following simulations were run using different versions of the 1D software (for 2D it was always TUFLOW build 2013-12-AE-iDP-w64):

- Fluvial pre-development and post development 1000 years present day (2015) simulations -

  1D numerical engine (ISIS) 6.7.2.117
- Fluvial pre-development and post development 1000 years future (2115) simulations -

  1D numerical engine (ISIS) 6.5.1.75
- Tidal pre-development and post development 1000 years future (2115) simulations –

  1D numerical engine (Flood Modeller) 4.1.1.160

A slightly different version of the Flood Modeller 1D network (Avon_ex130_1000_CC.dat) was used in the following simulations (the Preissmann slot on one culvert increased by 1 meter, conduit section MOUTH):

- Tidal post development 1000 years present day (2015) simulation
- Tidal pre and post development 1000 years future (2115) simulations
- Fluvial pre and post development 1000 years present day (2015) simulations

All fluvial simulations have had two 2D stability patches applied (one in Malago North 2D domain and one in Malago South 2D domain).

5.3.2 Post May 2019 simulations (i.e. current pre and post-development models)

Post May 2019 simulations (further assessment of offsite impacts and floodplain compensation options) are reported in Appendix A.

6.0 Model Results and Interpretation

Earlier versions of this technical note discussed model results which have now been superseded by the results in Appendix A.

Appendix A details modelling undertaken to assess options considered to;

- avoid offsite impacts due to the proposed MetroWest works (the final design retains existing railway levels and footprint in the Bower Ashton / Ashton Vale area)
- provide floodplain compensation for the proposed Clanage Road compound access ramps.

The reader is therefore referred to Appendix A for details of the final modelling undertaken and discussion of results.

Appendix N of the MetroWest FRA includes flood maps showing flood depth, velocity and hazard score for the events simulated, as well as tabulated differences in flood levels and mapped differences in flood depths and extents.

The results in Appendix A show that the final design does not increase flood risk to the railway or elsewhere (as pre and post development railway levels are the same, and the raised bunds adjacent to the railway are retained), and proposed floodplain compensation within the Clanage Road compound provides full mitigation for the proposed access ramps within the Clanage Road compound.

6.1 Flood risk to railway at Bower Ashton

The model results show that, for the present day (2015) scenario, the railway is simulated to flood at Bower Ashton for events with a return period between 5 and 10 years for the pre- and post-development scenarios. For the future 2075 and 2115 scenarios simulated flooding occurs with a higher frequency (less than 1-year return period) due to the influence of significant projected sea level rise. Table 4 shows the maximum flood depths simulated along this section of the railway relative to the lowest rail level. Simulated flood risk to the railway during the 1 year return period tidal event in 2075 is discussed further in Section 6.1.3.

Appendix N includes flood maps for the simulated events. These flood maps show the proposed Clanage Road compound to be within the 20-year tidal River Avon flood extent, and outside of the tidal River Avon 10-year flood extent i.e. within simulated Flood Zone 3b.

However, a further consideration of model results in the Bower Ashton area, in the context of available flood history and information relating to CAFRA model uncertainty, indicates the CAFRA model results in the Bower Ashton area are likely to overestimate flood risk, and assigning Flood Zone 3a rather than Flood Zone 3b to the Clanage Road compound is therefore considered appropriate. This is discussed below in Sections 6.1.1 to 6.1.3.

Table 4. Modelled maximum flood depth relative to lowest rail level of the DCO Scheme near Bower Ashton (tidal events)

Maximum flood depth relative to lowest rail level (m)						
	Present day (2015)		Future year (2075)		Future scenario (2115)	
Return period (years)	Pre-development	Post-development	Pre-development	Post-development	Pre-development	Post-development
Base (Tidal): With peak level midway between Mean High Water Spring and Highest Astronomical Tide	No flooding	No flooding	No flooding	No flooding	No flooding	No flooding
1 (Tidal)	Not simulated	Not simulated	0.44	0.44	1.02	1.02
2 (Tidal)	No flooding	No flooding	0.64	0.64	1.09	1.09
5 (Tidal)	No flooding	No flooding	0.80	0.80	1.20	1.20
10 (Tidal)	0.15	0.15	0.90	0.90	1.29	1.29
20 (Tidal)	0.53	0.53	0.98	0.98	1.36	1.36
75 (Tidal)	0.74	0.74	1.11	1.11	1.52	1.52
200 (Tidal)	0.97	0.97	1.33	1.33	1.93	1.93
1000 (Tidal)	1.20	1.20	1.75	1.75	2.27	2.27

6.1.1 Consideration of available flood history information

Whilst the latest MetroWest model results show the compound to be in FZ3b (i.e. within the 20 year flood extent), this does not appear to be consistent with available flood history information.

- Bristol Local Flood Risk Management Strategy identifies significant historic River Avon tidal flood events as 1607 (reported to be a Tsunami), 1896, 1981 and 2014.
- The only events in the EA historic flood maps provided that show the compound area to be flooded are 1703 and 1896
- Internet searches of e.g. “flood Bower Ashton”, “flood police Bower Ashton”, “flood Clanage Road”, “flood Bristol” do not reveal any evidence of historic flooding to the Clanage Road compound site.
- A search of the British Hydrological Society Chronology of British Hydrological Events (http://cbhe.hydrology.org.uk/) does not identify additional flood events

The recording of historic flood records is likely to be most reliable within the last 50 years or so. The above consideration of historic flood information suggests the Clanage Road compound has not flooded due to high tide river Avon tide levels in the last 50 years (and possibly longer). If the compound were within the 20 year flood extent, the most likely number of instances of flooding to the site within the last 50 years would be 2 events with 26% probability, and the probability of no floods in a 20 year period would be only 7.7% (Table 5 below).

Table 5: Probabilities for number of flood events occurring in a 50 year period – assuming flooding occur once every 20 years on average

Number of flood events	Probability (%)
0	7.7
1	20.2
2	26.1
3	22.0
4	13.6
5	6.6

If the compound flooded once every 50 years on average, then the probability of no floods occurring in a 50 year record would be significantly higher at 36% (Table 6).

Table 6: Probabilities for number of flood events occurring in a 50 year period – assuming flooding occur once every 50 years on average

Number of flood events	Probability (%)
0	36.4
1	37.2
2	18.6
3	6.1
4	1.5
5	0.3

This suggests the compound is likely to flood less frequently than once every 20 years on average i.e. the compound is outside of Flood Zone 3b, and a flood frequency of approximately once every 50 years on average is plausible. Estimating a higher return period for flooding of the Clanage Road site is also consistent with understood uncertainty in the MetroWest CAFRA model derived results, as follows in Sections 6.1.2 and 6.1.3.

6.1.2 Uncertainty in CAFRA model results

Updated Coastal Flood Boundary Dataset (2018)

An update to the Defra Coastal Flood Boundary (CFB) dataset has recently been released.

The CFB 2018 Extreme Water Levels (EWLs) at Avonmouth are compared in Table 7 below with those of the CFB 2011 dataset (applied in the CAFRA modelling). This comparison shows the revised CFB2018 EWLs are lower than equivalent CFB2011 EWLs, by 0.09m for the 20 year return period EWL. This indicates that the CAFRA (and hence MetroWest) modelling overstates tidal flood risk. The CFB2018 20 year EWL (8.61mAOD) is similar to the CFB2011 10 year EWL (8.58mAOD), for which the current MetroWest modelling shows no simulated flooding within the Clanage Road compound. This is consistent with the Clanage Road compound being in Flood Zone 3a (no flooding for the 20 year return period event).

Table 7: Comparison of CFB 2018 and CFB 2011 EWLs, for 2017 (the CFB 2018 base year)

Return period (years)	**CFB 2018 EWLs (base year 2017) (mAOD)**	**CFB2011 EWLs adjusted from 2008 base year to 2017 (by +3.5mm/yr) (mAOD)**	**Difference (m)**
1	8.11	8.19	0.08
2	8.22	8.30	0.08
5	8.37	8.46	0.09
10	8.49	8.58	0.09
20	8.61	8.70	0.09
25	8.65	8.75	0.10
50	8.79	8.88	0.09
75	8.86	8.95	0.09
100	8.92	9.01	0.09
200	9.07	9.14	0.07

CAFRA model calibration uncertainty

There is additional uncertain associated with model representation and model calibration. The CAFRA model made use of limited calibration data. The nearest calibration gauge to Bower Ashton is Netham Weir (approximately 6km upstream of the Clanage Road compound). Here, peak levels are generally overpredicted for the calibration events (by +0.098m, +0.231m and +0.024m for the 3 tidal calibration events, and +0.116m for the verification event). This suggest the CAFRA model may have a tendency to overestimate tide levels in the River Avon.

6.1.3 Interpretation of modelling uncertainty and flood history information

Clanage Road compound Flood Zone

In the context of CAFRA model uncertainty, the revised Coastal Flood Boundary dataset 2018 Extreme Water Levels, and available flood history at Bower Ashton, it is considered reasonable to conclude that the Clanage Road compound would not be flooded during the 20 year River Avon tidal flood. Assigning Flood Zone 3a rather than 3b to the Clanage Road compound is therefore considered appropriate, as this is in accord with available flood history information and consistent with understood CAFRA model uncertainty, and recently published CFB2018 EWLs.

Frequency of flooding of railway at Bower Ashton in 2075

Simulations undertaken based on the CAFRA modelling show the railway to be flooded at Bower Ashton during the 1 year return period tidal River Avon flood in 2075. Simulated flooding of the railway begins when River Avon flood levels exceed 8.75mAOD (the threshold at which flood water spills across the railway into the floodplain) adjacent to the railway at Bower Ashton.

Figure 9 shows simulated River Avon levels for the 1 year tidal event in 2075. Figure 1 also shows the 8.75mAOD spill threshold level and lowest rail level (8.35mAOD) in the Bower Ashton area. For this event, simulated River Avon levels exceed the 8.75mAOD spill threshold for approximately 45 minutes, with a peak level of 8.93mAOD. River levels drop below the lowest rail level approximately 1 hour after the spill threshold is first exceeded.

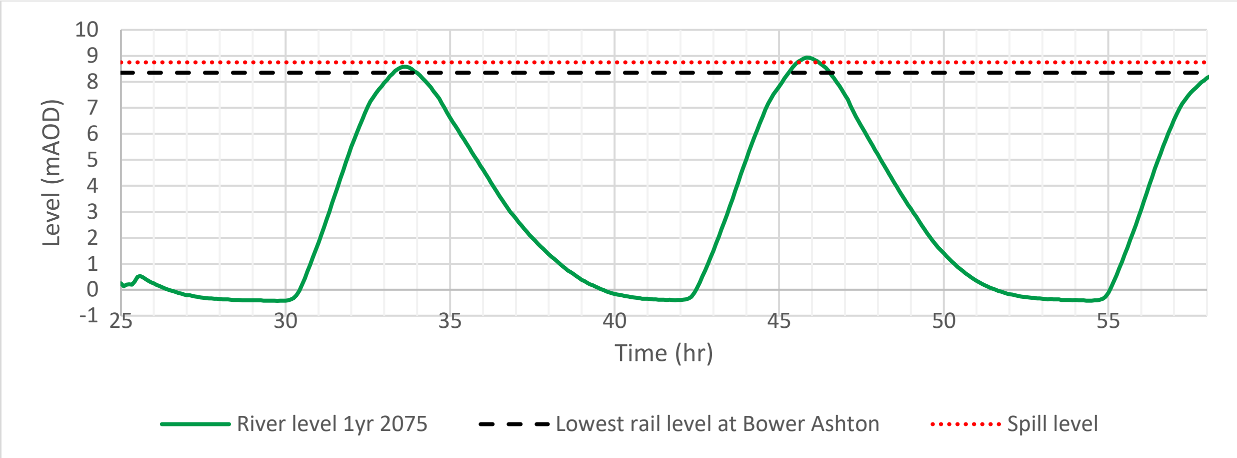


Figure 9: Simulated River Avon levels for the 1 year tidal event in 2075

Table 5 indicates a maximum flood depth along the railway of 0.44m above the lowest rail level at railway chainage 6180m. However, flood water spills from the River Avon onto the railway at chainage 3250m. The modelling assumes flood water flows down the railway towards railway chainage 3180m without drainage through the railway ballast into the railway drainage and into the adjacent floodplain. The simulated maximum depth of 0.44m at chainage 3180m is therefore considered an overestimate. At railway chainage 3250m the maximum simulated flood depth above lowest rail level is 0.26m.

In addition, further contributions to the likely overestimation of the future (2075) 1 year return period peak flood depth and duration of flooding on the railway at Bower Ashton are:

- As described in Sections 6.1.1 and 6.1.2, the CAFRA model is considered likely to overestimate flood levels at Bower Ashton
- The FRA sea level rise allowances are precautionary (rather than central estimates) and so are likely to be an overestimation

In summary, whilst the simulations undertaken show the railway to be flooded at Bower Ashton during the 1yr River Avon tidal event in 2075, the modelling includes a combination of several conservative modelling assumptions, and so the simulation results are likely to be overestimates. The 1 year tidal flood in 2075 is therefore considered likely to have only a relatively minor impact on railway operation (short duration, shallow depth above lowest rail level) and hence only minimal disruption to the railway service.

6.2 Flood risk to railway at crossing of Longmoor and Colliter's Brooks

Table 8 lists maximum River Avon flood depths relative to the lowest rail level at crossing of Longmoor and Colliter's Brooks for simulated fluvial flood events.

The results in Table 8 indicate:

- For the present day (2015) scenario, the railway is simulated to flood near Longmoor and Colliter's Brooks for events with a return period between 100 and 1000 years for the pre- and post-development scenarios. For both the future 2075 and 2115 scenarios simulated flooding occurs for events with a return period between 50 and 75 years for the pre- and post-development scenarios.
- The flooding at Bower Ashton for the present day (2015) and future (2075 and 2115) events during the simulated fluvial events listed in Table 8 is a result of the simulated tidal condition in the joint events specified in Table 3 (e.g. 10 year tidal event for the simulated 1000 year fluvial event in 2015 and 2 year tide condition for the simulated 75 year fluvial event in 2075 and 2115).

Table 8: Modelled maximum River Avon flood depths relative to the lowest rail level at crossing of Longmoor and Colliter's Brooks (fluvial events)

Maximum flood depth relative to lowest rail level (m)						
	Present day (2015)		Future year (2075)		Future scenario (2115)	
Return period (years)	Pre-development	Post-development	Pre-development	Post-development	Pre-development	Post-development
At Longmoor / Colliter's Brooks (fluvial River Avon)						
50 (Fluvial)	No flooding	No flooding	No flooding	No flooding	No flooding	No flooding
75 (Fluvial)	No flooding	No flooding	0.07	0.07	0.39	0.39
100 (Fluvial)	No flooding	No flooding	0.20	0.20	0.49	0.49
1000 (Fluvial)	0.61	0.61	0.81	0.81	0.86	0.86
At Bower Ashton (tidal River Avon)						
50 (Fluvial)	No flooding	No flooding	No flooding	No flooding	No flooding	No flooding
75 (Fluvial)	No flooding	No flooding	0.62	0.62	1.09	1.09
100 (Fluvial)	No flooding	No flooding	0.62	0.62	1.10	1.10
1000 (Fluvial)	0.32	0.32	0.97	0.97	1.52	1.52

7.0 Conclusions

The BCC CAFRA hydraulic modelling has been developed to assess the impacts of the proposed MetroWest Phase 1 development on River Avon tidal flood risk. This note describes the modelling undertaken and key results and flood mechanisms.

An interpretation of model results concludes:

- The proposed works will not increase flood risk elsewhere
- The displacement of floodplain storage by proposed access ramps in the Clanage Road compound will be fully mitigated by providing floodplain storage within the compound
- The Clanage road compound is considered to be within Flood Zone 3a
- The frequency of tidal flooding of the MetroWest railway at Bower Ashton is approximately once every 5 to 10 years for the present day (2015) and approximately once every year for the future (2075) scenario, with relatively minor disruption to the rail service.
- The frequency of fluvial flooding of the MetroWest railway near Longmoor and Colliter's Brooks is approximately once every 100 to 1000 years for the present day (2015) and approximately once every 50 to 75 years for the future (2075 and 2115) scenarios

Further discussion of the results in terms of impact of the proposed development in flood risk on flood are in the project FRA.

Details of the model improvements in the vicinity of the MetroWest Phase 1 project will be provided to BCC for incorporation into future versions of the CAFRA model.

Burderop Park
Swindon, Wiltshire, SN4 0QD
United Kingdom
T +44 1793 812 479
www.jacobs.com

Project Name	**Metro West Flood Risk Assessment – River Avon flood risk: Off-site impacts and mitigation**
Prepared for	North Somerset Council
Prepared by	Francesco lo Iacono
Reviewed by	Robert Bird
Approved by	
Date	23/08/2019
Project Number	674946CH
Revision No	2

1. Introduction

The current MetroWest design (in June 2019) includes a general increase in railway levels, typically by approximately 150mm to 200mm, including in the Bower Ashton / Ashton Gate area. The MetroWest Phase 1 Flood risk Assessment (FRA) hydraulic modelling undertaken to date indicates the MetroWest scheme would result in increased flood depths at some properties, due to the impact of the scheme design on River Avon floodplain hydraulics. In addition, the proposed Clanage Road permanent maintenance compound includes an access ramp from the compound to the railway. This ramp displaces River Avon floodplain storage.

The DCO application will need to demonstrate that options to avoid off-site impacts have been considered and implemented in the design where feasible.

This technical note reports:

- Exploratory hydraulic modelling undertaken to investigate the potential for floodplain compensation options to mitigate off-site impacts of the MetroWest scheme on flood risk elsewhere. The aim of this exploratory modelling is to identify options with potential to mitigate flood risk impacts, that could be developed further in more detail, rather than to develop detailed modelling of options. Reported in Section 3.
- Modelling of realistic floodplain compensation options for the design life (2075 future year), and including representation of the Clanage Road access ramp (assuming the current design with a general increase in railway levels in the Bower Ashton area by approximately 150mm to 200mm), Reported in Section 4.
- Modelling floodplain compensation options to mitigate the impact of the Clanage Road access ramp, with a modified post-development design retaining existing railway levels and footprint in the Bower Ashton area. Reported in Section 5.
- Further modelling of floodplain compensation options to mitigate the impact of the Clanage Road access ramps (access from the compound to the railway and to the road) whilst retaining existing

railway levels and footprint in the post-development design, with all floodplain compensation provided within the Clanage Road compound, by increasing the area of ground lowering within the compound. Reported in Section 6.

The hydraulic model used for this assessment is based on Bristol City Council's Central Area Flood Risk Assessment (CAFRA) model, as developed further for the MetroWest project[1].

Conclusions are drawn from the modelling undertaken regarding whether or not floodplain compensation options considered have potential to mitigate off-site impacts.

Recommendations are made regarding scheme design modifications to avoid offsite flood risk impacts. The recommendations for preferred railway design and floodplain compensation to avoid offsite impacts, reported in Section 6, are as follows:

- Retain existing railway levels and footprint in the Bower Ashton area (within standard railway design and construction tolerances)
- Provide floodplain compensation to mitigate impacts of the Clanage Road maintenance compound access ramps wholly within the Calange Road compound, by lowering ground levels to 7.4mAOD (relative to MetroWest topographic survey datum)

1.1 Site information

Most of the section of the railway that runs along the River Avon is at a relatively high elevation compared to River Avon flood levels. The study therefore only focuses on the area where the railway is at a lower level and is within the simulated tidal River Avon flood extents for the events considered here (up to 200-year return period tidal flood, and 100-year return period fluvial flood, in 2075 and 2115[2]). This study area corresponds to the Ashton area in Bristol, including Bower Ashton, Ashton Gate and Ashton Vale. In this area the railway line runs through the River Avon floodplain, and acts as a hydraulic control between the floodplain east and west of the railway.

Previous MetroWest Phase 1 FRA modelling has shown a potential increase of flood risk for some properties (*a* to *i* in Figure 1-1) within this area as result of the proposed railway development. This study aims to verify the effective impacts on these properties (as well as 3 additional properties identified by the updated modelling presented here to have potential impacts *j, k* and *l*) and the influence of floodplain compensation mitigation options. Figure 1-1 shows the study area and the location of properties potentially exposed to a higher flood risk as a result of the proposed MetroWest scheme.

---

[1] Hydraulic modelling technical note in Appendix N of the FRA: *MW_Phase1_CAFRA_Update_TN_Feb_2019.docx*

[2] The scheme design life is 60 years (2075). Models have also been run for the 2115 future year as a sensitivity test.

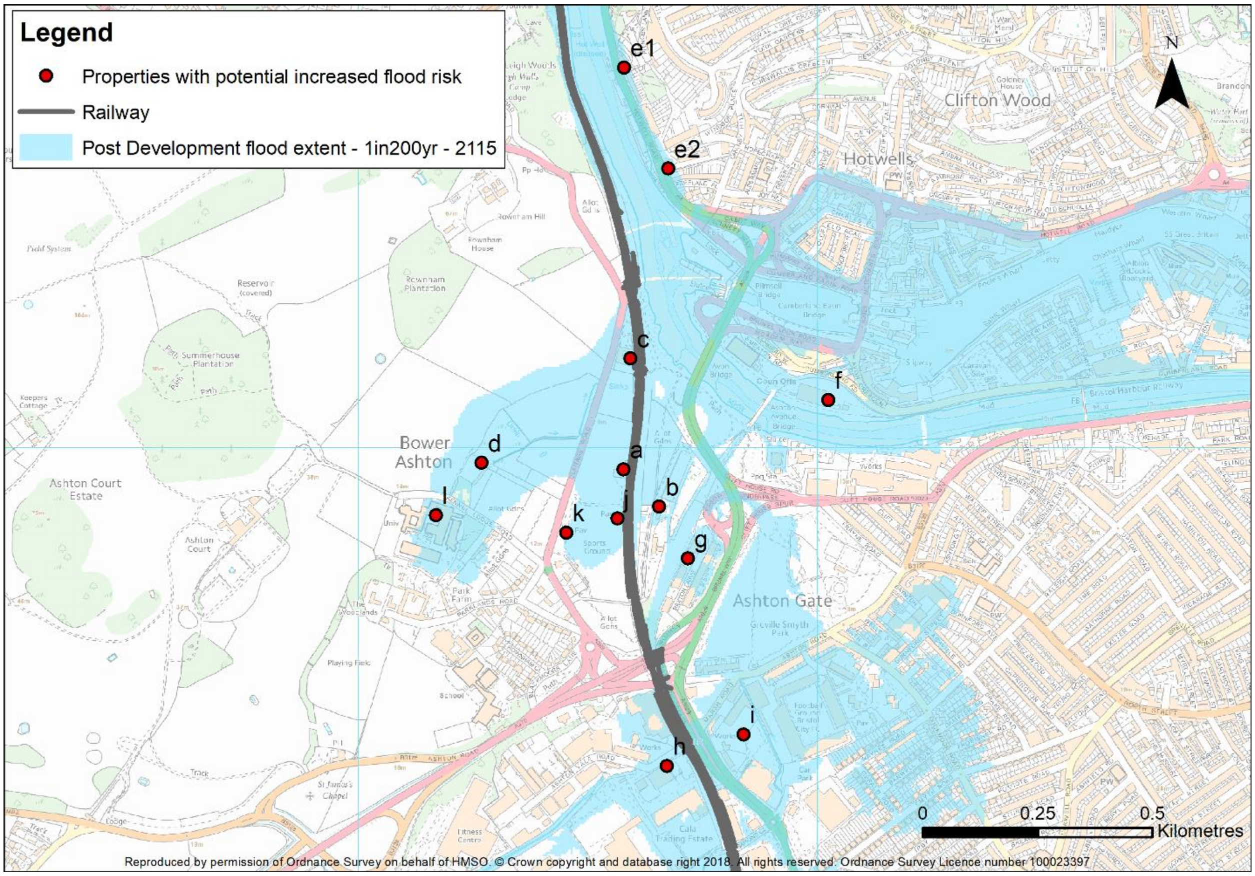


Figure 1-1: Study area and properties potentially at risk

1.2 Floodplain compensation options

North Somerset Council has provided Jacobs with a sketch of possible sites for floodplain compensation areas near the railway (Figure 1-2).

Figure 1-2: Possible sites for floodplain compensation areas

In addition to these compensation areas, the following options have been investigated:

- Adding a culvert under the railway linking the floodplain east and west of the railway
- Retaining the railway level and footprint as existing in the Ashton Gate area
- Floodplain compensation area between Plot 5 and Plot 6
- Floodplain compensation north of Plot 5 (Caravan Club land)
- Retaining the railway level and footprint as existing in the River Avon floodplain (i.e. no change in railway elevation or footprint in the River Avon floodplain)

2. Modelling Approach

2.1 Existing MetroWest FRA CAFRA model

The Bristol Central Area Flood Risk Assessment (CAFRA) hydraulic model was developed by Hyder Consulting (UK) Limited (Hyder) following the appointment by Bristol City Council (BCC) in September 2010. It simulates flooding from the River Avon and was developed to provide strategic assessment of flood risk in central Bristol area. This model is a 1D-2D model. Flood Modeller 4.3 was used for the 1D simulation and TUFLOW build 2013-12-AE-iDP-w64 for the 2D simulation. The model was initially developed with a 2010 baseline (fluvial and tidal boundaries) and in 2015 the tidal boundaries were updated to a 2015 baseline. In 2010 - 2012 Hyder Consulting ran future scenarios for the years 2060 and 2110.

The CAFRA model was developed further for the MetroWest project and was used to run the required scenarios for the FRA[3].

2.2 Modelling updates

The existing MetroWest FRA CAFRA model has been updated applying the most recent Flood Modeller and Tuflow engines (Flood Modeller 4.4 and TUFLOW 2018-03-AC).

During this investigation, it was identified that results from the previous MetroWest FRA simulations were affected by model behaviour issues, with significant model noise in the vicinity of Bower Ashton, due to unstable exchange of large flows between the model 1D domain (River Avon) and 2D domain (floodplain at Bower Ashton and the Cumberland Basin/floodplain in Bristol).

The updated model provides more stable results and shows that some of the impacts from the previous modelling are no longer present (i.e. these simulated impacts were a result of model noise rather than influence of the proposed MetroWest scheme).

As done in the CAFRA modelling, future epochs in 2115 and 2075 have been modelled with a decreased value of the *alpha* run parameter[4] from 0.7 to 0.65. This solution has been applied to improve the stability of the exchange of flows between the model 1D and 2D domains.

2.2.1 Post development model for current post-development design

The post development model includes a representation of proposed changes in the railway elevation within the study area (increase in railway levels by approximately 150mm to 200mm). It also includes the removal of earth bunds east of the railway at Bower Ashton.

[3] Hydraulic modelling technical note in Appendix N of the FRA: *MW_Phase1_CAFRA_Update_TN_Feb_2019.docx*

[4] A lower *alpha* value increases damping in the model numerical algorithms, and hence can improve model stability

3. Exploratory simulation of floodplain compensation mitigation options

The floodplain compensation and culvert mitigation options investigated are listed below, and shown in Figure 3-1:

1) Compensation 1: Two floodplain compensation storage areas at Bower Ashton west of the railway. Both areas have been lowered to plausible constant elevation values, 7.5 mAOD in the northern area and 7.3 mAOD in the southern area.

2) Compensation 2: Four floodplain compensation storage areas at Bower Ashton east of the railway. All these four areas have been lowered uniformly by 0.3m, as the land has significant variation in elevation.

3) Culvert: simplistic representation of 5m width through railway connecting floodplain east and west of railway

This exploratory assessment is considered to represent an upper limit to mitigation that could be achieved by floodplain compensation as the indicative floodplain compensation areas exceed the extent of ground lowering that could realistically be delivered e.g. the compensation area extents include the disused police dog/horse training centre within the northern part of Compensation 1, the proposed access ramp and other constraints within the Clanage Road permanent maintenance compound within the southern part of Compensation 1 are not accounted for.

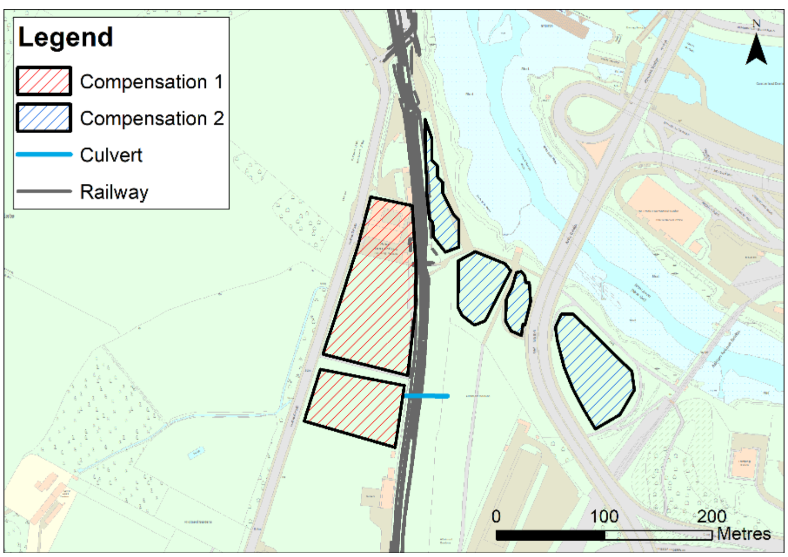


Figure 3-3-1: Mitigation options

3.1 Results of exploratory simulations

3.2 Simulations undertaken

Four tidal events (10-year, 20 year, 75 and 200 year) and one fluvial event (100 year) have been simulated for the exploratory mitigation options listed in Section 2.2.2 for the present day (2015) and future (2115) epochs (i.e. with projected future climate change and sea level rise applied). The post development scenario (without mitigation) has also been simulated for the 2075 future epoch.

3.3 Post development impacts

3.3.1 Impacts at locations adjacent to the River Avon (property locations *e1, e2* and *f*)

As a consequence of running the models using the most recent Flood Modeller and TUFLOW engines, overall simulated impacts are generally less significant than for the previous modelling, as model noise affecting previous results has been addressed. Impacts at locations adjacent to the River Avon (properties *e1* and *e2* near The Portway and *f* near Ashton bridge) are no longer significant (within +/-1mm).

3.3.2 Impacts at Bower Ashton

The proposed railway works and the removal of the bunds at Bower Ashton result in a change in flood mechanisms between the River Avon floodplain east and west of the railway. Since the model topography along the railway is raised at some locations, due to the proposed higher railway levels, and lowered at others, due to the proposed removal of earth bunds, the change in flood mechanisms post development can vary significantly depending on the event considered.

Maximum simulated differences in pre and post development flood depths at properties within this area are 6mm for property j, an increase of 1mm for properties k and l. Maximum simulated increases at properties *a, b* and *c* are 27mm, 19mm and 67mm respectively. The simulated increase in flood depth of +67mm at property *c* for the 100-year fluvial flood event in 2115 is illustrated in Figure 3-2 (at this location the 100-year fluvial event effectively represents a 2-year tidal event, as here flooding is tidally dominated and the 100-year fluvial design event includes a 2-year tide condition).

Floodplain compensation and culvert options at Bower Ashton are discussed in Section 3.4.

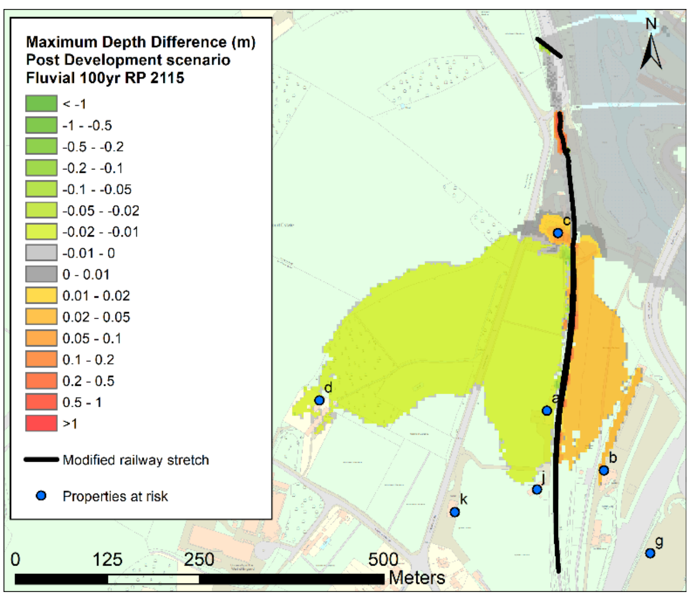


Figure 3-2: Maximum depth difference at Bower Ashton – 100-year fluvial event in 2115 – Post Development scenario

3.3.3 Impacts at Paxton Drive

For the current scheme design, the modelled increase in flood level at Paxton Drive is +12mm for the 200-year tidal flood event in 2115, and no impact for lesser events. The cause of this increase is due to an obstruction effect of the raised railway in the vicinity of Ashton Vale, inhibiting the flow of flood water from the Paxton Drive area southwards. A test option (Post Development v2) has been simulated with no change to railway levels in this stretch (approx. 100m length) and results have confirmed that with this solution results in no increase in flood depth (impact reduced from +12mm to -4mm. See Figure 3-3).

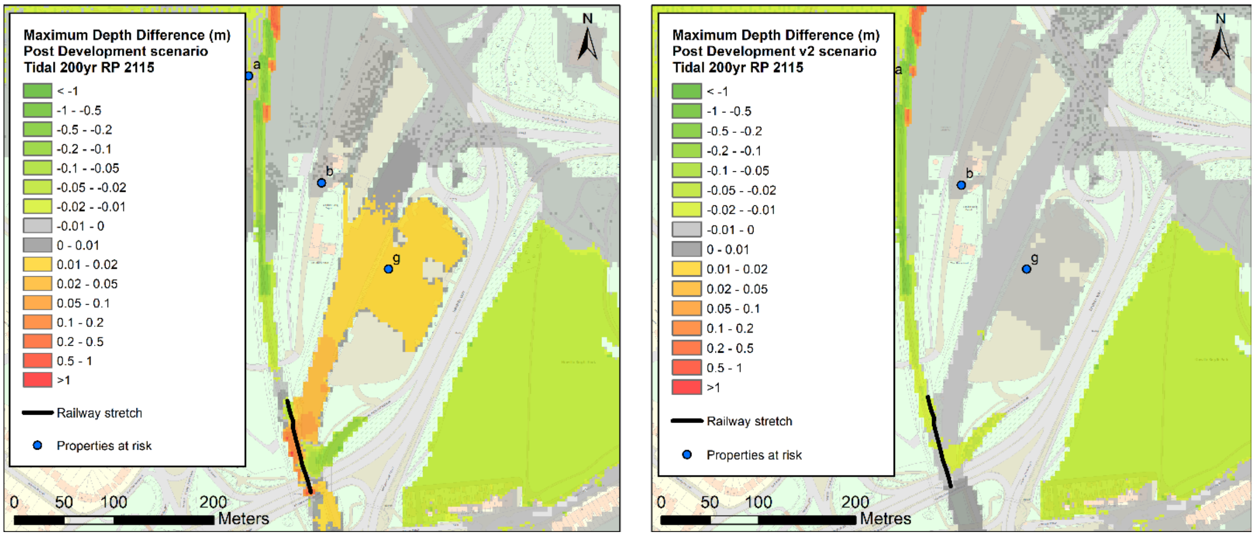


Figure 3-3: Comparison of maximum depth difference at Paxton Drive: Post Development (left) and test option with no change to railway levels in this area (right) – 100-year tidal event in 2115

3.3.4 Impacts of MetroWest Phase 1 scheme at Longmoor and Colliter's Brooks

In the Post Development scenario, the maximum increase in flood depth is +13mm at property *h* for the 100-year fluvial flood event in 2075. Some minor impacts are also observed at properties *h* and *i* for a 100-year fluvial flood event in 2115. These impacts are due to displaced floodplain storage by the raised railway in the vicinity of the crossing of Longmoor and Colliter's Brooks. The effect of this displacement is greater in the 2075 epoch than 2115, as displaced flood water spreads over a lower area than for 2115. A test option retaining existing railway levels for approximately 350m has confirmed that this solution would avoid these impacts (+13mm reduced to +0mm. See Figure 3-4).

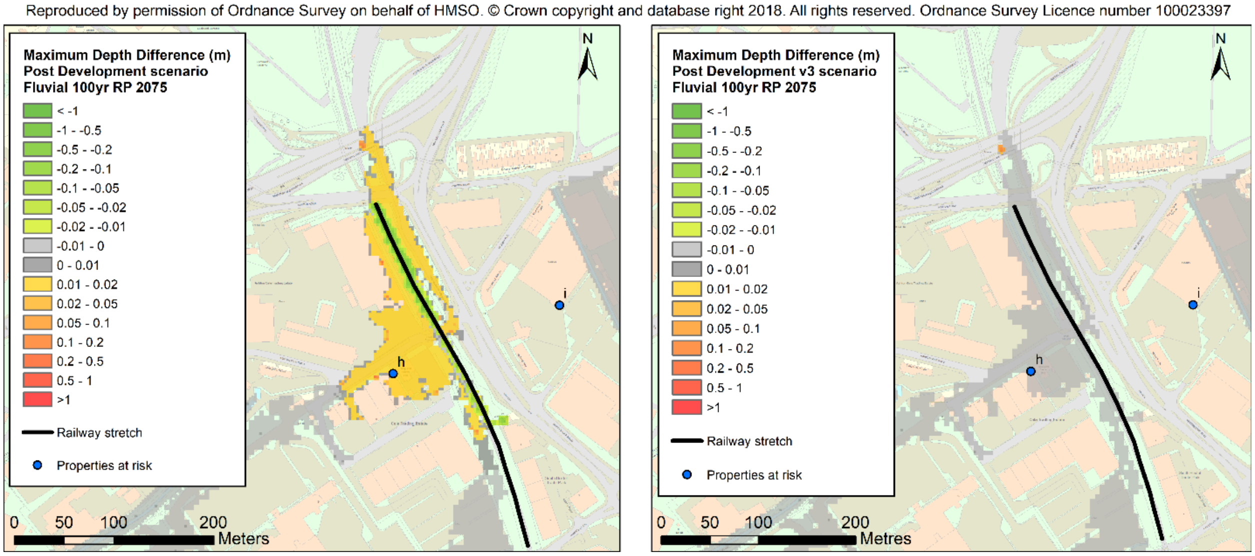


Figure 3-4: Comparison of maximum depth difference at Longmoor and Colliter's Brooks: Post Development (left) and test option with no change to railway levels in this area (right) – 100-year tidal event in 2075

3.4 Floodplain compensation and culvert mitigation options

The effects of the floodplain compensation and culvert mitigation options are generally limited to the Bower Ashton area, while the locations at Paxton Drive, Longmoor and Colliter's Brooks are less affected.

3.4.1 Impacts of MetroWest Phase 1 scheme with Compensation 1 included

Compensation 1 is the option that offers most benefit to reducing impacts in the vicinity of Bower Ashton, (except for property *c*, the former police dog/horse training building which would be within the floodplain compensation area). Property *a*, the nursery north of the sports ground, receives most benefit from this option, with decreased flood levels for all the simulated events. For example, the change in flood level of +7mm observed for the 20-year tidal event in 2115 (Figure 3-5) is reduced to -5mm compared to the existing situation. Flood levels at property *d*, the building north of Kennel Lodge, are also reduced for the 10 year and 20-year tidal events.

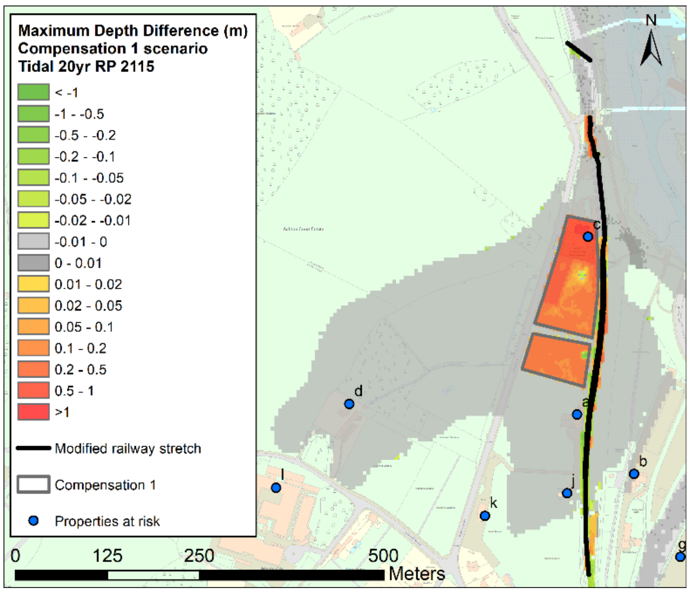


Figure 3-5: Maximum depth difference at Bower Ashton – 20-year tidal event in 2115 – Compensation 1 scenario

3.4.2 Impacts of MetroWest Phase 1 scheme with Compensation 2 included

The inclusion of Compensation 2 does not provide any mitigation for impacts, on the contrary it can promote a flow path from the River Avon into the Bower Ashton area with a corresponding increase in impacts. This mechanism is clearly observed for a 10-year tidal event in 2115 (Figure 3-6), for which flood levels at properties *a*, *c* and *d* are increased from +2/3mm to over +100mm. A reduced footprint for Compensation 2, excluding the most northern compensation area, may avoid this increase, but it is not expected to provide significant benefit.

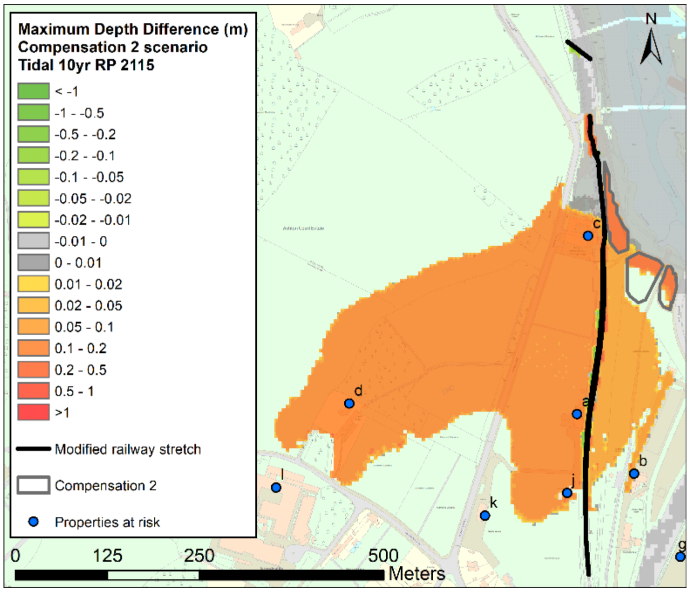


Figure 3-6: Maximum depth difference at Bower Ashton – 10-year tidal event in 2115 – Compensation 2 scenario

3.4.3 Impacts of MetroWest Phase 1 scheme with Culvert included

As Compensation 2, the culvert option also generally leads to increased impacts rather than benefits. For some events the culvert enables more water to flow across the railway alignment from the allotments east of the railway to the Caravan Club land west of the railway. This mechanism results in a benefit for the allotments area but increases flood levels west of railway where properties *a*, *c*, *d, j, k and l* are located. For instance, flood levels at properties *a*, *c* and *d* are increased from about +3mm to about +25mm for the 10 year tidal event in 2115 (Figure 3-7).

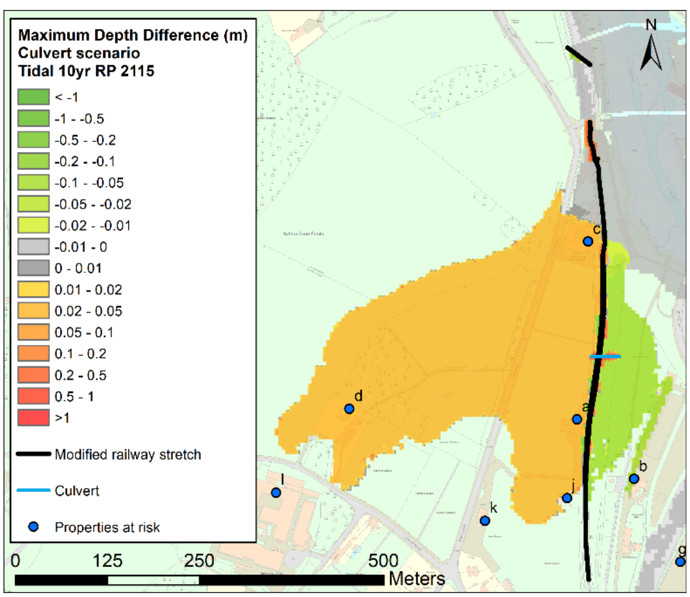


Figure 3-7: Maximum depth difference at Bower Ashton – 10 year tidal event in 2115 – Culvert scenario

Since the culvert would discharge into the Caravan Club Area included in Compensation 1, a combination of Compensation 1 and culvert options might lead to reduced impacts in both the areas east and west of the railway. However, the storage capacity of Compensation 1 might be exceeded causing increased impacts to the nearby properties *a*, *b* and *c*.

3.5 Summary of exploratory results

The changes in peak flood depths at the properties identified to have a simulated increased in flood risk as a result of the proposed MetroWest scheme, based on the previous hydraulic modelling (properties a to i), and additional properties (j, k and l) in the Bower Ashton area with minor impacts added as a result of the updated modelling are listed in Table 3-1 for the exploratory simulated mitigation options and events.

3.6 Conclusions of exploratory results

1. The updated MetroWest CAFRA hydraulic modelling presented here has addressed the model behaviour issue (unstable exchange of flow between the River Avon and floodplain at Bower Ashton / Bristol).

2. Simulated impacts of the current proposed MetroWest scheme on flood risk elsewhere for the revised modelling are generally lower than for the previous modelling.

3. Simulated impacts for locations *e1* and *e2* (River Avon downstream of Bower Ashton, and *f* (River Avon floodplain in Bristol, opposite Bower Ashton) are insignificant (within +/- 1mm and so within model convergence tolerance).

4. Impacts of the proposed scheme on flood risk at location *g* (Paxton Drive) is due to the proposed increased railway levels in the Ashton Gate area. Retaining existing railway levels and footprint locally for approximately 100m would remove these impacts.

5. Impacts of the proposed scheme on flood risk at locations *h* and *i* (upstream and downstream of the railway crossing of Longmoor and Colliter's Brooks) are due to local displacement of floodplain storage by the proposed higher railway levels. Retaining existing railway levels and footprint locally for approximately 350m (in addition to the 100m in item 4 above) would remove these impacts.

6. The impact of the current MetroWest scheme on flood risk at Bower Ashton (property locations *a* to *d* and *j* to *l*) is influenced by complex hydraulics (increased railway level, removal of earth bunds, dynamic tidal process with flow into and out of floodplain.

Further simulations have been undertaken to represent realistic compensation options for the design life (future year 2075). These are presented in Sections 4 and 5.

Project location	Description	Option	10 year tidal 2015	10 year tidal 2115	10 year tidal 2075	20 year tidal 2015	20 year tidal 2115	20 year tidal 2075	75 year tidal 2015	75 year tidal 2115	75 year tidal 2075	200 year tidal 2015	200 year tidal 2115	200 year tidal 2075	100 year fluvial 2015	100 year fluvial 2115	100 year fluvial 2075
			Change in peak flood level (mAOD) for simulated events														
a	Building north of sports ground at Bower Ashton (nursery / pre-school centre)	Post Development	No Flood	0.003	0.027	No Flood	0.007	0	No Flood	0.001	-0.013	0.01	-0.009	0.011	No Flood	-0.013	No Flood
		Compensation 1	No Flood	-0.038		No Flood	-0.005		No Flood	-0.003		-0.036	-0.012		No Flood	-0.095	
		Compensation 2	No Flood	0.106		No Flood	0.052		No Flood	0.001		0.092	-0.008		No Flood	0.183	
		Culvert	No Flood	0.025		No Flood	0.015		No Flood	0.001		0.158	-0.013		No Flood	0.091	
b	Building south east of allotments at Bower Ashton (employment/industrial)	Post Development	No Flood	0.011	No Flood	No Flood	-0.001	No Flood	No Flood	0.002	0.019	No Flood	0	0.001	No Flood	0.012	No Flood
		Compensation 1	No Flood	0.011		No Flood	-0.007		No Flood	0.004		No Flood	0.002		No Flood	0.012	
		Compensation 2	No Flood	0.019		No Flood	0.043		No Flood	0.002		No Flood	0.001		No Flood	0.026	
		Culvert	No Flood	-0.022		No Flood	0.009		No Flood	0.003		No Flood	-0.004		No Flood	-0.019	
c	Building between northern Clanage Road and railway (former police dog / horse training centre)	Post Development	No Flood	0.002	0.007	No Flood	0.002	0.014	-0.009	0.001	0.049	0.012	-0.001	0.005	No Flood	0.067	No Flood
		Compensation 1	No Flood	Inside area		No Flood	Inside area		Inside area	Inside area		Inside area	Inside area		No Flood	Inside area	
		Compensation 2	No Flood	0.103		No Flood	0.043		-0.006	0.001		0.054	0		No Flood	0.09	
		Culvert	No Flood	0.025		No Flood	0.009		-0.009	0.001		0.012	-0.004		No Flood	0.035	
d	Building north of Kennel Lodge Road at Bower Ashton (Lower Court Gardens, residential)	Post Development	No Flood	0.003	No Flood	No Flood	0.002	No Flood	No Flood	0	No Flood	No Flood	-0.003	0.005	No Flood	-0.01	No Flood
		Compensation 1	No Flood	-0.034		No Flood	-0.005		No Flood	0.001		No Flood	-0.002		No Flood	-0.078	
		Compensation 2	No Flood	0.107		No Flood	0.048		No Flood	0		No Flood	-0.002		No Flood	0.164	
		Culvert	No Flood	0.024		No Flood	0.011		No Flood	0		No Flood	-0.006		No Flood	0.075	
e1	Buildings in the tidal River Avon floodplain between the Clifton suspension bridge and Freeland Place (residential)	Post Development	0.001	0	-0.001	0.001	0	0	0	0	-0.001	0	0	-0.001	0	0	-0.001
		Compensation 1	0.001	0		0.001	0.001		0	0.001		0	0.001		0	0	
		Compensation 2	0.001	-0.002		0	-0.001		-0.001	0.001		-0.001	0.002		0	0	
		Culvert	0.001	-0.001		0.001	0		0	0.001		0	0.001		0	-0.001	
e2	Buildings in the tidal River Avon floodplain between the Clifton suspension bridge and Freeland Place (residential)	Post Development	0	0	-0.001	0.001	0	0	0	0	-0.001	0	0	-0.001	0	0	0
		Compensation 1	0	0		0.001	0		0	0.001		0	0.001		0	0	
		Compensation 2	0	-0.002		0	-0.002		-0.002	0.001		-0.002	0.001		0	0	
		Culvert	0	-0.001		0.001	-0.001		0	0.001		0	0		0	0	
f	Buildings in the tidal River Avon northern floodplain, adjacent to the River Avon and directly upstream of Brunel Way (A3029) – (employment/leisure)	Post Development	No Flood	-0.001	0	0	0	0	-0.001	0	0	-0.001	0	-0.001	No Flood	0	0
		Compensation 1	No Flood	-0.001		0	0		-0.001	-0.001		-0.001	0		No Flood	0	
		Compensation 2	No Flood	-0.001		0	0.006		-0.002	0.002		-0.002	-0.001		No Flood	0.001	
		Culvert	No Flood	-0.001		0	0		-0.001	0		-0.001	0		No Flood	-0.001	
g	Buildings at Paxton Drive (residential)	Post Development	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	0.001	No Flood	No Flood	0.012	No Flood	No Flood	No Flood	No Flood
		Compensation 1	No Flood	No Flood		No Flood	No Flood		No Flood	-0.002		No Flood	0.013		No Flood	No Flood	
		Compensation 2	No Flood	No Flood		No Flood	No Flood		No Flood	0.005		No Flood	0.021		No Flood	No Flood	
		Culvert	No Flood	No Flood		No Flood	No Flood		No Flood	0.001		No Flood	0.011		No Flood	No Flood	
h	Buildings directly upstream of the railway crossing of Longmoor and Colliter's Brooks (trading estate).	Post Development	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	-0.047	No Flood	No Flood	-0.003	No Flood	No Flood	0.002	0.013
		Compensation 1	No Flood	No Flood		No Flood	No Flood		No Flood	-0.052		No Flood	-0.004		No Flood	0.003	
		Compensation 2	No Flood	No Flood		No Flood	No Flood		No Flood	-0.015		No Flood	-0.002		No Flood	0.003	
		Culvert	No Flood	No Flood		No Flood	No Flood		No Flood	-0.039		No Flood	-0.005		No Flood	0.003	
i	Buildings directly downstream of the railway crossing of Longmoor and Colliter's Brooks (employment and retail).	Post Development	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	-0.082	No Flood	No Flood	-0.007	No Flood	No Flood	0.002	No Flood
		Compensation 1	No Flood	No Flood		No Flood	No Flood		No Flood	-0.096		No Flood	-0.008		No Flood	0.003	
		Compensation 2	No Flood	No Flood		No Flood	No Flood		No Flood	-0.017		No Flood	-0.006		No Flood	0.003	
		Culvert	No Flood	No Flood		No Flood	No Flood		No Flood	-0.061		No Flood	-0.009		No Flood	0.003	
j	Building in the north-east corner of sports ground at Bower Ashton (leisure)	Post Development	No Flood	No Flood	No Flood	No Flood	0.002	No Flood	No Flood	0.001	No Flood	No Flood	0.001	0.006	No Flood	No Flood	No Flood
		Compensation 1	No Flood	No Flood		No Flood	-0.005		No Flood	0.002		No Flood	0.004		No Flood	No Flood	
		Compensation 2	No Flood	0.124		No Flood	0.047		No Flood	0.002		No Flood	0.002		No Flood	No Flood	
		Culvert	No Flood	No Flood		No Flood	0.011		No Flood	0.002		No Flood	-0.002		No Flood	No Flood	
k	Building east of sports ground at Bower Ashton (cricket club building)	Post Development	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	0	No Flood	No Flood	No Flood	No Flood
		Compensation 1	No Flood	No Flood		No Flood	No Flood		No Flood	No Flood		No Flood	0.001		No Flood	No Flood	
		Compensation 2	No Flood	No Flood		No Flood	No Flood		No Flood	No Flood		No Flood	0.001		No Flood	No Flood	
		Culvert	No Flood	No Flood		No Flood	No Flood		No Flood	No Flood		No Flood	-0.003		No Flood	No Flood	
l	Buildings south of Kennel Lodge Road at Bower Ashton (university, residential)	Post Development	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	0.001	No Flood	No Flood	No Flood	No Flood
		Compensation 1	No Flood	No Flood		No Flood	No Flood		No Flood	No Flood		No Flood	0.002		No Flood	No Flood	
		Compensation 2	No Flood	No Flood		No Flood	No Flood		No Flood	No Flood		No Flood	0.002		No Flood	No Flood	
		Culvert	No Flood	No Flood		No Flood	No Flood		No Flood	No Flood		No Flood	-0.002		No Flood	No Flood	

Table 3-1: Changes in peak flood levels at the properties at risk for the exploratory simulated scenarios and events

4. More realistic representation of mitigation options

Further modelling has been undertaken to assess potential for mitigation of scheme impacts, for the 60-year (future year 2075) design life, with more realistic representations of available floodplain compensation areas as follows:

- Accounting for the proposed maintenance access ramp and other constraints limiting the amount of floodplain compensation area available for ground lowering within the Clanage Road maintenance compound
- Exclusion of the disused police dog/horse training centre building
- Representation of the Caravan Club's preference to limit ground lowering within its land to an area within the middle of its land

The following options have been simulated:

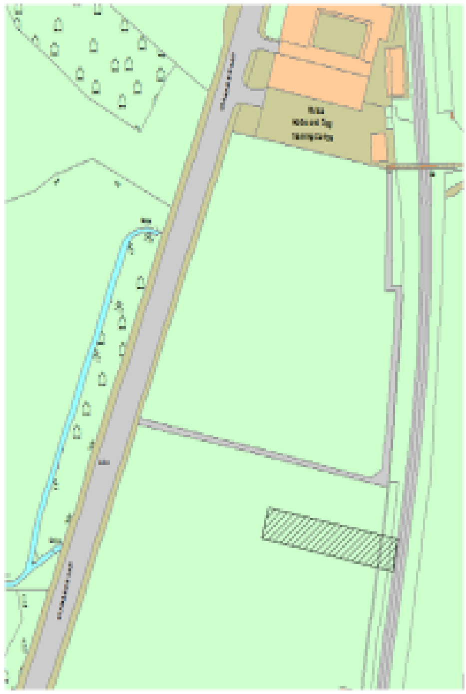
Simulation	Description
Post Development with ramp	Current MetroWest railway design with representation of proposed maintenance access ramp within the Clanage Road maintenance compound (shown in Figure 4-1)
Post Development with ramp + Compensation 1 v5	As above with compensation areas as shown in figure 4-2
Post Development with ramp + Compensation 1 v6	As above with compensation areas as shown in figure 4-3
Post Development with ramp + Compensation 1 v7	As above with compensation areas as shown in figure 4-4
Post Development with ramp + Compensation 1 v8	As above with compensation areas as shown in figure 4-5

These options are illustrated in Figures 4-1 to 4-5 together with a summary of the modelled impacts of the access ramp and benefits of compensation options. These model results indicate:

- The presence of the Clanage Road maintenance access ramp results in an increase in flood risk at properties a, b, c, d and j
- None of the options with compensation areas west of the railway fully mitigates the impacts at property b (east of the railway)
- The option with a larger compensation area within the Caravan Club land (Compensation option 1 v5) provides some benefit at properties a, c, d and j. However, the impact at property a is still +6mm or the 200 year event
- A larger compensation area within the Caravan Club land combined with a larger compensation area south of the Clanage Road maintenance compound (Compensation option 1 v7) reduces the impact at property a from +6mm to +3mm and at property j from +2mm to -1mm in the 200 year event
- A larger compensation area within the Caravan Club land is more beneficial than a larger compensation area south of the Clanage Road maintenance compound

As none of the realistically available compensation options fully mitigates flood risk impacts at properties, further simulations were undertaken to assess the potential for floodplain compensation to mitigate impacts of the Clanage Road maintenance access ramp, whilst retaining existing railway levels and footprint (i.e. no change in floodplain storage by the proposed railway works). These are detailed in Sections 5 and 6.

Post Development with ramp

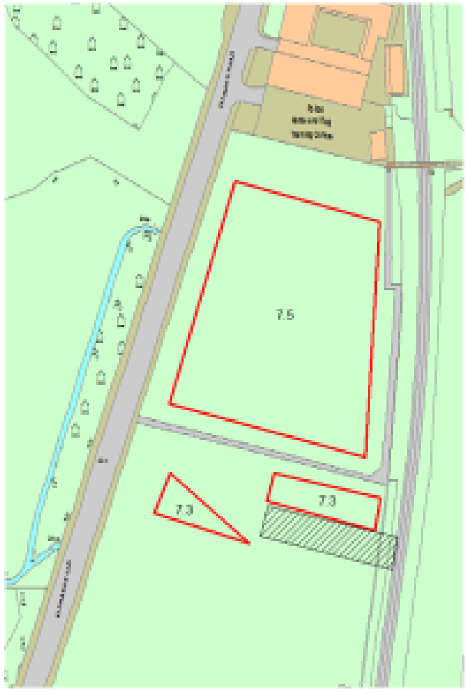


The proposed ramp causes an increase in flood risk at properties a (nursery north of sports ground), b (south east of allotments), c (former police dog/horse centre), d (north of Kennel Lodge road) and j (City Maze)

Proper	Option	10yr Tidal 2075	20yr Tidal 2075	75yr Tidal 2075	200yr Tidal 2075
a	Post Development	0.027	0.000	-0.013	0.011
a	Post Development Ramp	0.036	0.009	-0.008	0.012
b	Post Development	No Flood	No Flood	0.019	0.001
b	Post Development Ramp	No Flood	No Flood	0.019	0.002
c	Post Development	0.007	0.014	0.049	0.005
c	Post Development Ramp	0.007	0.014	0.049	0.006
d	Post Development	No Flood	No Flood	No Flood	0.005
d	Post Development Ramp	No Flood	No Flood	No Flood	0.006
e1	Post Development	0.000	0.000	-0.001	0.000
e1	Post Development Ramp	0.000	0.000	-0.001	0.000
e2	Post Development	0.000	0.001	0.000	-0.001
e2	Post Development Ramp	0.000	0.001	0.000	-0.001
f	Post Development	0.000	0.000	0.000	-0.001
f	Post Development Ramp	0.000	0.000	0.000	-0.001
g	Post Development	No Flood	No Flood	No Flood	No Flood
g	Post Development Ramp	No Flood	No Flood	No Flood	No Flood
h	Post Development	No Flood	No Flood	No Flood	No Flood
h	Post Development Ramp	No Flood	No Flood	No Flood	No Flood
i	Post Development	No Flood	No Flood	No Flood	No Flood
i	Post Development Ramp	No Flood	No Flood	No Flood	No Flood
j	Post Development	No Flood	No Flood	No Flood	0.006
j	Post Development Ramp	No Flood	No Flood	No Flood	0.008
k	Post Development	No Flood	No Flood	No Flood	No Flood
k	Post Development Ramp	No Flood	No Flood	No Flood	No Flood
l	Post Development	No Flood	No Flood	No Flood	No Flood
l	Post Development Ramp	No Flood	No Flood	No Flood	No Flood

Figure 4-1: Simulated changes in flood depths (m) as a result of the current MetroWest Phase 1 design, accounting for the proposed ramp (shown as hatched polygon)

Post Development with ramp + Compensation 1 v5

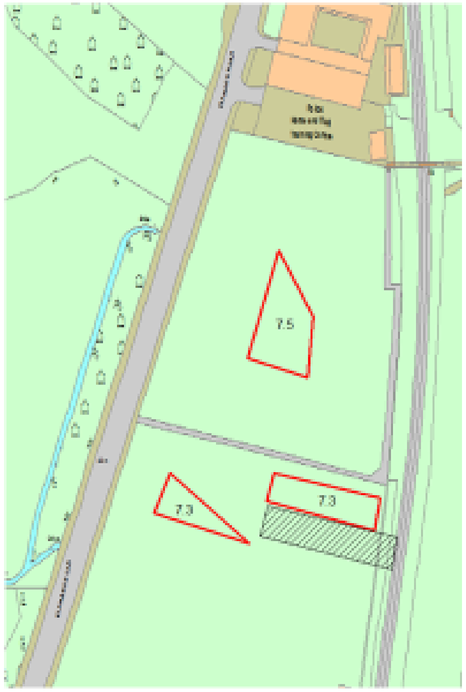


With the addition of Compensation 1 v5, the risk at property a is reduced but still +0.006m for the 200yr event. The risk is reduced also reduced at properties c, d and j for the 200yr event. No change at property b.

Propert	Option	10yr Tidal 2075	20yr Tidal 2075	75yr Tidal 2075	200yr Tidal 2075
a	Post Development	0.027	0.000	-0.013	0.011
a	Compensation 1 v5	0.007	-0.020	-0.033	0.006
b	Post Development	No Flood	No Flood	0.019	0.001
b	Compensation 1 v5	No Flood	No Flood	0.019	0.000
c	Post Development	0.007	0.014	0.049	0.005
c	Compensation 1 v5	0.007	0.015	0.049	0.000
d	Post Development	No Flood	No Flood	No Flood	0.005
d	Compensation 1 v5	No Flood	No Flood	No Flood	0.000
e1	Post Development	0.000	0.000	-0.001	0.000
e1	Compensation 1 v5	0.000	0.000	-0.001	-0.001
e2	Post Development	0.000	0.001	0.000	-0.001
e2	Compensation 1 v5	0.000	0.001	0.000	-0.001
f	Post Development	0.000	0.000	0.000	-0.001
f	Compensation 1 v5	0.000	0.000	0.000	-0.001
g	Post Development	No Flood	No Flood	No Flood	No Flood
g	Compensation 1 v5	No Flood	No Flood	No Flood	No Flood
h	Post Development	No Flood	No Flood	No Flood	No Flood
h	Compensation 1 v5	No Flood	No Flood	No Flood	No Flood
i	Post Development	No Flood	No Flood	No Flood	No Flood
i	Compensation 1 v5	No Flood	No Flood	No Flood	No Flood
j	Post Development	No Flood	No Flood	No Flood	0.006
j	Compensation 1 v5	No Flood	No Flood	No Flood	0.002
k	Post Development	No Flood	No Flood	No Flood	No Flood
k	Compensation 1 v5	No Flood	No Flood	No Flood	No Flood
l	Post Development	No Flood	No Flood	No Flood	No Flood
l	Compensation 1 v5	No Flood	No Flood	No Flood	No Flood

Figure 4-2: Simulated changes in flood depths (m) as a result of the current MetroWest Phase 1 design, accounting for the proposed ramp (shown as hatched polygon), and Compensation option 1 v5 (shown as red polygons, with lowered ground levels within polygons stated in mAOD)

Post Development with ramp + Compensation 1 v6

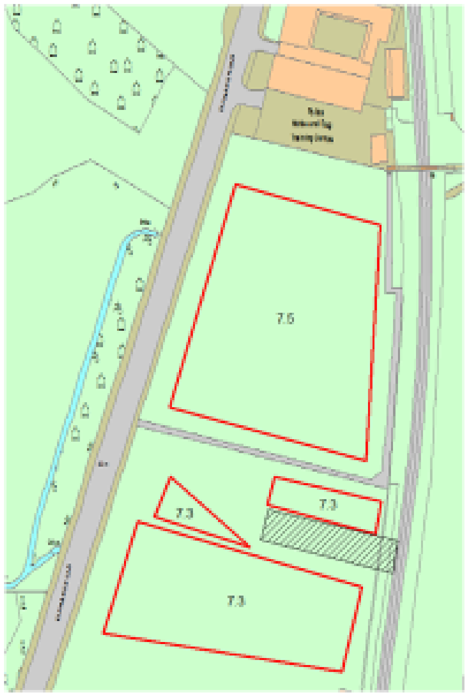


Compensation 1 v6 (smaller compensation area within the proposed Caravan Club land) does not provide any significant benefit to the properties at risk

Proper	Option	10yr Tidal 2075	20yr Tidal 2075	75yr Tidal 2075	200yr Tidal 2075
a	Post Development	0.027	0.000	-0.013	0.011
a	Compensation 1 v6	0.021	0.000	-0.013	0.010
b	Post Development	No Flood	No Flood	0.019	0.001
b	Compensation 1 v6	No Flood	No Flood	0.019	0.001
c	Post Development	0.007	0.014	0.049	0.005
c	Compensation 1 v6	0.007	0.014	0.049	0.005
d	Post Development	No Flood	No Flood	No Flood	0.005
d	Compensation 1 v6	No Flood	No Flood	No Flood	0.005
e1	Post Development	0.000	0.000	-0.001	0.000
e1	Compensation 1 v6	0.000	0.000	-0.001	-0.001
e2	Post Development	0.000	0.001	0.000	-0.001
e2	Compensation 1 v6	0.000	0.001	0.000	-0.001
f	Post Development	0.000	0.000	0.000	-0.001
f	Compensation 1 v6	0.000	0.000	0.000	-0.001
g	Post Development	No Flood	No Flood	No Flood	No Flood
g	Compensation 1 v6	No Flood	No Flood	No Flood	No Flood
h	Post Development	No Flood	No Flood	No Flood	No Flood
h	Compensation 1 v6	No Flood	No Flood	No Flood	No Flood
i	Post Development	No Flood	No Flood	No Flood	No Flood
i	Compensation 1 v6	No Flood	No Flood	No Flood	No Flood
j	Post Development	No Flood	No Flood	No Flood	0.006
j	Compensation 1 v6	No Flood	No Flood	No Flood	0.006
k	Post Development	No Flood	No Flood	No Flood	No Flood
k	Compensation 1 v6	No Flood	No Flood	No Flood	No Flood
l	Post Development	No Flood	No Flood	No Flood	No Flood
l	Compensation 1 v6	No Flood	No Flood	No Flood	No Flood

Figure 4-3: Simulated changes in flood depths (m) as a result of the current MetroWest Phase 1 design, accounting for the proposed ramp (shown as hatched polygon), and Compensation option 1 v6 (shown as red polygons, with lowered ground levels within polygons stated in mAOD)

Post Development with ramp + Compensation 1 v7

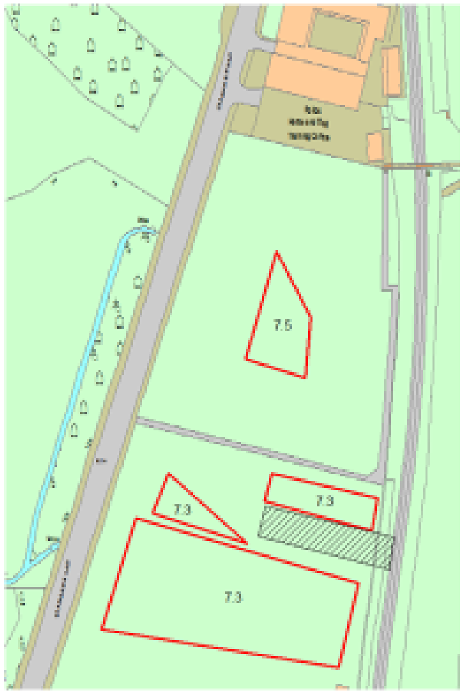


Compensation 1 v7, with additional compensation area south of the ramp, provides some additional benefits compared to Compensation 1 v5 at a (from +0.006 to +0.003) and j (from +0.002 to -0.001) for the 200yr event

Propert	Option	10yr Tidal 2075	20yr Tidal 2075	75yr Tidal 2075	200yr Tidal 2075
a	Post Development	0.027	0.000	-0.013	0.011
a	Compensation 1 v7	-0.023	-0.044	-0.041	0.003
b	Post Development	No Flood	No Flood	0.019	0.001
b	Compensation 1 v7	No Flood	No Flood	0.019	0.000
c	Post Development	0.007	0.014	0.049	0.005
c	Compensation 1 v7	0.005	0.015	0.050	-0.002
d	Post Development	No Flood	No Flood	No Flood	0.005
d	Compensation 1 v7	No Flood	No Flood	No Flood	-0.002
e1	Post Development	0.000	0.000	-0.001	0.000
e1	Compensation 1 v7	-0.001	0.000	0.000	-0.001
e2	Post Development	0.000	0.001	0.000	-0.001
e2	Compensation 1 v7	-0.003	0.001	0.000	-0.001
f	Post Development	0.000	0.000	0.000	-0.001
f	Compensation 1 v7	-0.003	0.000	0.000	-0.001
g	Post Development	No Flood	No Flood	No Flood	No Flood
g	Compensation 1 v7	No Flood	No Flood	No Flood	No Flood
h	Post Development	No Flood	No Flood	No Flood	No Flood
h	Compensation 1 v7	No Flood	No Flood	No Flood	No Flood
i	Post Development	No Flood	No Flood	No Flood	No Flood
i	Compensation 1 v7	No Flood	No Flood	No Flood	No Flood
j	Post Development	No Flood	No Flood	No Flood	0.006
j	Compensation 1 v7	No Flood	No Flood	No Flood	-0.001
k	Post Development	No Flood	No Flood	No Flood	No Flood
k	Compensation 1 v7	No Flood	No Flood	No Flood	No Flood
l	Post Development	No Flood	No Flood	No Flood	No Flood
l	Compensation 1 v7	No Flood	No Flood	No Flood	No Flood

Figure 4-4: Simulated changes in flood depths (m) as a result of the current MetroWest Phase 1 design, accounting for the proposed ramp (shown as hatched polygon), and Compensation option 1 v7 (shown as red polygons, with lowered ground levels within polygons stated in mAOD)

Post Development with ramp + Compensation 1 v8



Compensation 1 v8 is as 1v7 but with less compensation at the Caravan Club. Property impacts are higher than for Compensation 1 v5, suggesting the Caravan Club land is more beneficial than the most southern area considered.

Propert	Option	10yr Tidal 2075	20yr Tidal 2075	75yr Tidal 2075	200yr Tidal 2075
a	Post Development	0.027	0.000	-0.013	0.011
a	Compensation 1 v8	-0.009	-0.023	-0.023	0.008
b	Post Development	No Flood	No Flood	0.019	0.001
b	Compensation 1 v8	No Flood	No Flood	0.019	0.001
c	Post Development	0.007	0.014	0.049	0.005
c	Compensation 1 v8	0.007	0.014	0.049	0.003
d	Post Development	No Flood	No Flood	No Flood	0.005
d	Compensation 1 v8	No Flood	No Flood	No Flood	0.003
e1	Post Development	0.000	0.000	-0.001	0.000
e1	Compensation 1 v8	0.000	0.000	-0.001	-0.001
e2	Post Development	0.000	0.001	0.000	-0.001
e2	Compensation 1 v8	0.000	0.000	0.000	-0.001
f	Post Development	0.000	0.000	0.000	-0.001
f	Compensation 1 v8	0.000	0.001	0.000	-0.001
g	Post Development	No Flood	No Flood	No Flood	No Flood
g	Compensation 1 v8	No Flood	No Flood	No Flood	No Flood
h	Post Development	No Flood	No Flood	No Flood	No Flood
h	Compensation 1 v8	No Flood	No Flood	No Flood	No Flood
i	Post Development	No Flood	No Flood	No Flood	No Flood
i	Compensation 1 v8	No Flood	No Flood	No Flood	No Flood
j	Post Development	No Flood	No Flood	No Flood	0.006
j	Compensation 1 v8	No Flood	No Flood	No Flood	0.004
k	Post Development	No Flood	No Flood	No Flood	No Flood
k	Compensation 1 v8	No Flood	No Flood	No Flood	No Flood
l	Post Development	No Flood	No Flood	No Flood	No Flood
l	Compensation 1 v8	No Flood	No Flood	No Flood	No Flood

Figure 4-5: Simulated changes in flood depths (m) as a result of the current MetroWest Phase 1 design, accounting for the proposed ramp (shown as hatched polygon), and Compensation option 1 v8 (shown as red polygons, with lowered ground levels within polygons stated in mAOD)

5. Retaining existing railway levels and mitigating for access ramp

As realistic compensation options do not fully mitigate impacts of the current MetroWest Phase 1 design on flood risk to properties (Section 4), additional simulations have been undertaken to explore the potential for compensation options to mitigate the impacts of the Clanage Road maintenance compound access ramp, whilst retaining the existing railway levels and footprint in the Bower Ashton / Ashton Vale area for approximately 1.65km between chainages 4900 to 6550 (i.e. there is no displacement of floodplain storage by the proposed railway works, only by the compound access ramp).

This would be achieved in the railway design as follows.

- The proposed railway will be replaced at the same level as the existing railway, within standard railway design and construction tolerances (approximately +/-25mm).There will be no net increase in displaced floodplain storage by the railway (there may minor adjustments to existing alignment to meet railway design standards, but there will be no net increase in displaced floodplain by the railway).
- The existing earth bunds adjacent to the railway will be retained as these bunds act as a hydraulic control during flooding

Usually compensation would be provided on a level-for-level matched volume basis i.e. creating new floodplain storage volumes within level ranges equal to the volumes displaced within the same level ranges, with the floodplain compensation hydraulically linked to the displaced floodplain storage. However, the realistically available floodplain compensation areas do not provide level-for-level compensation, as the ramp rises to a level higher than the potential compensation areas. The mitigation for displaced floodplain storage by the ramp provided by the realistic compensation options has therefore been assessed by hydraulic modelling, with the ramp and compensation options represented in the model as level changes in the model digital terrain grid.

The options tabulated below have been simulated for the 60-year design life (future year 2075) 10, 20, 50 and 200 year River Avon tidal events, and the present day (2015) 75 and 200 year tidal events. In addition, the same options have also been simulated for the future 2115 year as a sensitivity test, for the same events as well as the 100 year fluvial event. This event has been added for the 2115 simulations as there are potential impacts at properties for the 2115 100 year fluvial event (and this is not the case for the 2075 simulations).

Simulation	Description
Pre Development with ramp	Existing railway levels and footprint with representation of proposed maintenance access ramp within the Clanage Road maintenance compound (shown in Figure 5-1)
Pre Development with ramp + Compensation v1	As above with compensation areas as shown in figure 5-2 (within Clanage Road permanent maintenance compound only)
Pre Development with ramp + Compensation v2	As above with compensation areas as shown in figure 5-3 (Compensation 1 with an additional storage area south of the ramp)
Pre Development with ramp + Compensation v3	As above with compensation areas as shown in figure 5-4 (same as v2 but with higher finished ground levels than v2 south of the ramp)
Pre Development with ramp + Compensation v4	As above with compensation areas as shown in figure 5-5 (Compensation 1 with an additional storage area in the Caravan Club land)
Pre Development with ramp + Compensation v5	As above with compensation areas as shown in figure 5-6 (Compensation v4 but with reduced compensation area within the Caravan Club land)

These options are illustrated in Figures 5-1 to 5-6 together with a summary of the modelled impacts of the access ramp and benefits of compensation options. These model results indicate:

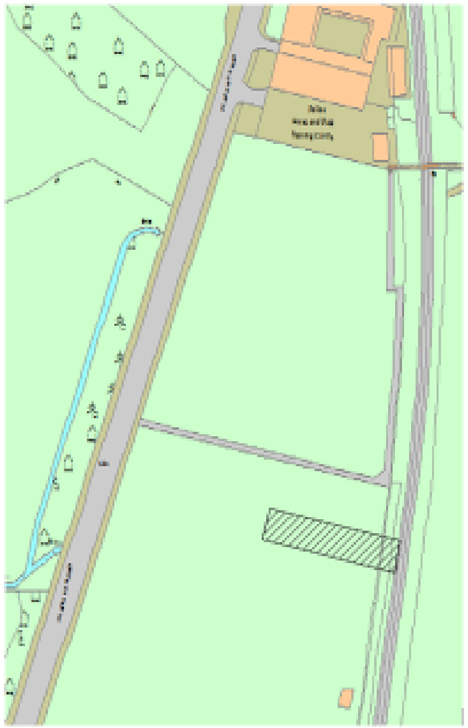
2075 events

- The presence of the access ramp results in an increase in flood levels at property a (nursery north of sports ground at Bower Ashton) by up to 10mm, for the 20 year tidal event in 2075.
- With the inclusion of Compensation v1, the risk at property a is reduced but the increase in flood level is still +5mm for the 20 year event in 2075
- Compensation v2 to v5 all provide full mitigation for the ramp

2115 events

- The presence of the access ramp results in an increase in flood levels at properties a, c and d (nursery north of sports ground at Bower Ashton) by up to 3mm, for the 10 year tidal event in 2075.
- The presence of the access ramp results in other small increases (+1mm). These increases are considered insignificant and within model accuracy.
- Options 2 and 3, both with lowered ground levels south of the ramp, result in an increase in flood depth at property a, by 9mm and 8mm respectively, due to a more efficient flow path southwards towards property a
- The maximum impact at properties for Options 4 and 5 is +1mm. This is considered insignificant and within model accuracy.

Pre Development with ramp

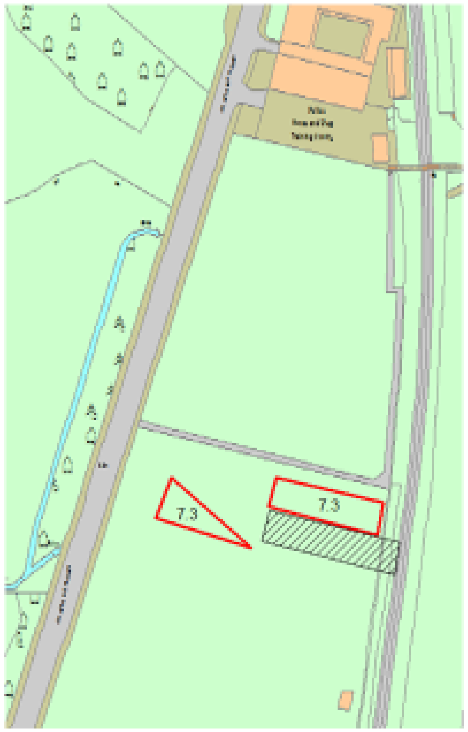


The presence of the new ramp causes an increase of flood levels at property **a** (nursery north of sports ground at Bower Ashton)

Property	Option	Change in peak flood level (mAOD) for simulated events										
		10yr Tidal 2075	10yr Tidal 2115	20yr Tidal 2075	20yr Tidal 2115	75yr Tidal 2015	75yr Tidal 2075	75yr Tidal 2115	200yr Tidal 2015	200yr Tidal 2075	200yr Tidal 2115	100yr Fluvial 2115
a	Ramp	0.008	0.002	0.010	0.000	No Flood	0.004	0.000	0.009	0.001	-0.004	
b	Ramp	No Flood	0.000	No Flood	0.000	No Flood	No Flood	0.000	No Flood	0.000	-0.004	
c	Ramp	0.000	0.003	0.000	0.000	0.000	0.000	0.000	-0.001	0.001	-0.002	
d	Ramp	No Flood	0.002	No Flood	0.000	No Flood	No Flood	0.000	No Flood	0.001	-0.003	
e1	Ramp	0.000	0.000	0.000	0.000	No Flood	0.000	0.000	-0.001	0.000	0.001	
e2	Ramp	0.000	0.000	0.000	-0.001	0.000	0.000	0.000	-0.001	0.000	0.000	
f	Ramp	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	
g	Ramp	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	0.001	No Flood	No Flood	-0.001	
h	Ramp	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	0.001	No Flood	No Flood	-0.001	
i	Ramp	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	0.001	No Flood	No Flood	0.000	
j	Ramp	No Flood	No Flood	No Flood	0.001	No Flood	No Flood	0.000	No Flood	0.001	-0.002	
k	Ramp	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	-0.003	
l	Ramp	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	-0.003	

Figure 5-1: Simulated changes in flood depths (m) assuming existing railway levels, accounting for the proposed ramp (shown as hatched polygon)

Pre Development with ramp + Compensation v1

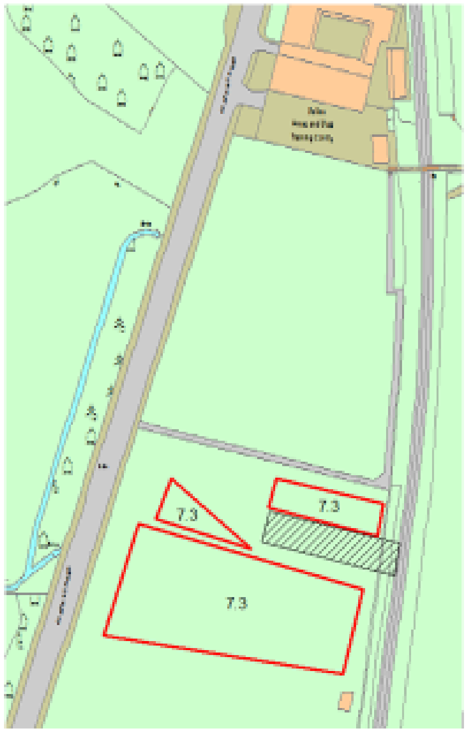


With the inclusion of Compensation v1, the risk at property a is reduced but the change in flood level is still +0.005m in the 20yr event in 2075

		Change in peak flood level (mAOD) for simulated events										
Property	Option	10yr Tidal 2075	10yr Tidal 2115	20yr Tidal 2075	20yr Tidal 2115	75yr Tidal 2015	75yr Tidal 2075	75yr Tidal 2115	200yr Tidal 2015	200yr Tidal 2075	200yr Tidal 2115	100yr Fluvial 2115
a	Ramp	0.008	0.002	0.010	0.000	No Flood	0.004	0.000	0.009	0.001	-0.004	
a	Ramp + Comp v1	-0.001	0.001	0.005	0.000	No Flood	0.001	0.000	0.002	0.000	-0.003	0.001
b	Ramp	No Flood	0.000	No Flood	0.000	No Flood	No Flood	0.000	No Flood	0.000	-0.004	
b	Ramp + Comp v1	No Flood	0.000	No Flood	0.000	No Flood	No Flood	0.000	No Flood	0.000	-0.003	0.000
c	Ramp	0.000	0.003	0.000	0.000	0.000	0.000	0.000	-0.001	0.001	-0.002	
c	Ramp + Comp v1	0.000	0.001	0.000	0.000	0.000	0.000	0.000	-0.001	0.000	-0.002	0.000
d	Ramp	No Flood	0.002	No Flood	0.000	No Flood	No Flood	0.000	No Flood	0.001	-0.003	
d	Ramp + Comp v1	No Flood	0.001	No Flood	0.000	No Flood	No Flood	0.000	No Flood	0.000	-0.003	0.001
e1	Ramp	0.000	0.000	0.000	0.000	No Flood	0.000	0.000	-0.001	0.000	0.001	
e1	Ramp + Comp v1	0.000	0.000	0.000	0.000	No Flood	0.000	0.000	-0.001	0.000	0.001	0.000
e2	Ramp	0.000	0.000	0.000	-0.001	0.000	0.000	0.000	-0.001	0.000	0.000	
e2	Ramp + Comp v1	0.000	0.000	0.000	-0.001	0.000	0.000	0.000	-0.001	-0.001	0.000	0.000
f	Ramp	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	
f	Ramp + Comp v1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	-0.001
g	Ramp	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	0.001	No Flood	No Flood	-0.001	
g	Ramp + Comp v1	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	0.000	No Flood	No Flood	-0.001	No Flood
h	Ramp	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	0.001	No Flood	No Flood	-0.001	
h	Ramp + Comp v1	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	0.000	No Flood	No Flood	-0.001	-0.001
i	Ramp	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	0.001	No Flood	No Flood	0.000	
i	Ramp + Comp v1	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	0.000	No Flood	No Flood	0.000	0.000
j	Ramp	No Flood	No Flood	No Flood	0.001	No Flood	No Flood	0.000	No Flood	0.001	-0.002	
j	Ramp + Comp v1	No Flood	No Flood	No Flood	0.000	No Flood	No Flood	0.000	No Flood	0.000	-0.003	No Flood
k	Ramp	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	-0.003	
k	Ramp + Comp v1	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	-0.003	No Flood
l	Ramp	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	-0.003	
l	Ramp + Comp v1	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	-0.003	No Flood

Figure 5-2: Simulated changes in flood depths (m) assuming existing railway levels, accounting for the proposed ramp (shown as hatched polygon), and Compensation v1 (shown as red polygons, with lowered ground levels within polygons stated in mAOD)

Pre Development with ramp + Compensation v2

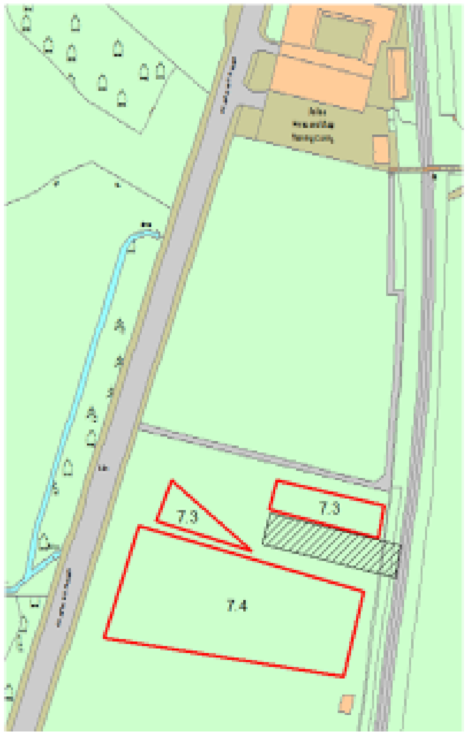


Compensation with an additional storage area south of the ramp reduces the impact at property **a** in all events except for the 200yr tidal event 2115, where the change in peak flood level is +0.009m

Property	Option	Change in peak flood level (mAOD) for simulated events										
		10yr Tidal 2075	10yr Tidal 2115	20yr Tidal 2075	20yr Tidal 2115	75yr Tidal 2015	75yr Tidal 2075	75yr Tidal 2115	200yr Tidal 2015	200yr Tidal 2075	200yr Tidal 2115	100yr Fluvial 2115
a	Ramp	0.008	0.002	0.010	0.000	No Flood	0.004	0.000	0.009	0.001	-0.004	
a	Ramp + Comp v2	-0.018	-0.003	-0.025	-0.001	No Flood	-0.009	-0.001	-0.024	-0.003	0.009	-0.007
b	Ramp	No Flood	0.000	No Flood	0.000	No Flood	No Flood	0.000	No Flood	0.000	-0.004	
b	Ramp + Comp v2	No Flood	0.000	No Flood	-0.001	No Flood	No Flood	0.001	No Flood	0.000	-0.003	0.000
c	Ramp	0.000	0.003	0.000	0.000	0.000	0.000	0.000	-0.001	0.001	-0.002	
c	Ramp + Comp v2	-0.004	-0.002	0.000	-0.001	0.000	0.000	0.000	0.000	-0.002	-0.002	0.000
d	Ramp	No Flood	0.002	No Flood	0.000	No Flood	No Flood	0.000	No Flood	0.001	-0.003	
d	Ramp + Comp v2	No Flood	-0.003	No Flood	-0.001	No Flood	No Flood	0.000	No Flood	-0.002	-0.002	-0.006
e1	Ramp	0.000	0.000	0.000	0.000	No Flood	0.000	0.000	-0.001	0.000	0.001	
e1	Ramp + Comp v2	-0.001	0.000	0.000	0.000	No Flood	0.000	-0.001	0.000	0.000	0.001	0.000
e2	Ramp	0.000	0.000	0.000	-0.001	0.000	0.000	0.000	-0.001	0.000	0.000	
e2	Ramp + Comp v2	-0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000
f	Ramp	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	
f	Ramp + Comp v2	-0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.001
g	Ramp	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	0.001	No Flood	No Flood	-0.001	
g	Ramp + Comp v2	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	0.000	No Flood	No Flood	-0.001	No Flood
h	Ramp	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	0.001	No Flood	No Flood	-0.001	
h	Ramp + Comp v2	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	0.000	No Flood	No Flood	-0.001	0.000
i	Ramp	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	0.001	No Flood	No Flood	0.000	
i	Ramp + Comp v2	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	-0.001	No Flood	No Flood	0.000	0.000
j	Ramp	No Flood	No Flood	No Flood	0.001	No Flood	No Flood	0.000	No Flood	0.001	-0.002	
j	Ramp + Comp v2	No Flood	No Flood	No Flood	-0.001	No Flood	No Flood	0.000	No Flood	-0.002	-0.003	No Flood
k	Ramp	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	-0.003	
k	Ramp + Comp v2	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	-0.002	No Flood
l	Ramp	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	-0.003	
l	Ramp + Comp v2	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	-0.003	No Flood

Figure 5-3: Simulated changes in flood depths (m) assuming existing railway levels, accounting for the proposed ramp (shown as hatched polygon), and Compensation v2 (shown as red polygons, with lowered ground levels within polygons stated in mAOD)

Pre Development with ramp + Compensation v3

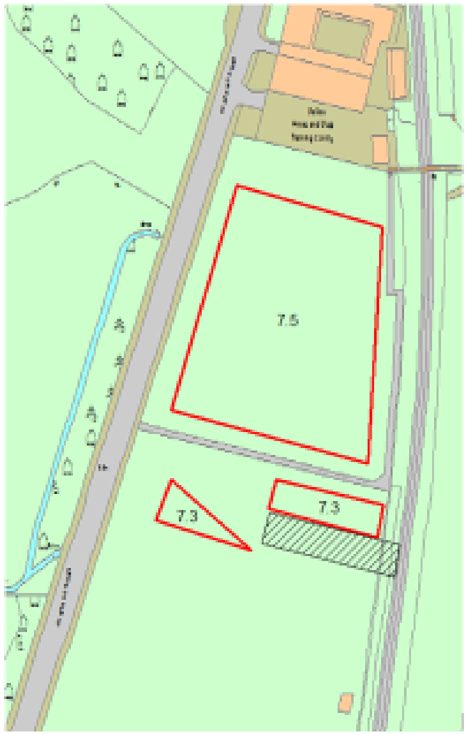


A less deep storage area south of the ramp (ground level lowered to 7.4m AOD instead of 7.3m AOD) still has an increased impact at property a in a 200yr Tidal event in 2115

		Change in peak flood level (mAOD) for simulated events										
Property	Option	10yr Tidal 2075	10yr Tidal 2115	20yr Tidal 2075	20yr Tidal 2115	75yr Tidal 2015	75yr Tidal 2075	75yr Tidal 2115	200yr Tidal 2015	200yr Tidal 2075	200yr Tidal 2115	100yr Fluvial 2115
a	Ramp	0.008	0.002	0.010	0.000	No Flood	0.004	0.000	0.009	0.001	-0.004	
a	Ramp + Comp v3	-0.009	-0.001	-0.010	-0.001	No Flood	-0.004	-0.001	-0.013	-0.002	0.008	-0.004
b	Ramp	No Flood	0.000	No Flood	0.000	No Flood	No Flood	0.000	No Flood	0.000	-0.004	
b	Ramp + Comp v3	No Flood	0.000	No Flood	-0.001	No Flood	No Flood	0.000	No Flood	0.000	-0.003	0.000
c	Ramp	0.000	0.003	0.000	0.000	0.000	0.000	0.000	-0.001	0.001	-0.002	
c	Ramp + Comp v3	-0.004	-0.001	0.000	-0.001	0.000	0.000	0.000	0.000	-0.002	-0.002	0.000
d	Ramp	No Flood	0.002	No Flood	0.000	No Flood	No Flood	0.000	No Flood	0.001	-0.003	
d	Ramp + Comp v3	No Flood	-0.001	No Flood	-0.001	No Flood	No Flood	0.000	No Flood	-0.001	-0.003	-0.003
e1	Ramp	0.000	0.000	0.000	0.000	No Flood	0.000	0.000	-0.001	0.000	0.001	
e1	Ramp + Comp v3	-0.001	0.000	-0.001	0.000	No Flood	0.000	0.000	0.000	0.000	0.001	0.000
e2	Ramp	0.000	0.000	0.000	-0.001	0.000	0.000	0.000	-0.001	0.000	0.000	
e2	Ramp + Comp v3	-0.003	0.000	0.000	-0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
f	Ramp	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	
f	Ramp + Comp v3	-0.003	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000
g	Ramp	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	0.001	No Flood	No Flood	-0.001	
g	Ramp + Comp v3	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	0.000	No Flood	No Flood	-0.001	No Flood
h	Ramp	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	0.001	No Flood	No Flood	-0.001	
h	Ramp + Comp v3	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	0.000	No Flood	No Flood	0.000	-0.001
i	Ramp	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	0.001	No Flood	No Flood	0.000	
i	Ramp + Comp v3	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	0.000	No Flood	No Flood	0.000	0.000
j	Ramp	No Flood	No Flood	No Flood	0.001	No Flood	No Flood	0.000	No Flood	0.001	-0.002	
j	Ramp + Comp v3	No Flood	No Flood	No Flood	0.000	No Flood	No Flood	0.000	No Flood	-0.001	-0.002	No Flood
k	Ramp	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	-0.003	
k	Ramp + Comp v3	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	-0.002	No Flood
l	Ramp	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	-0.003	
l	Ramp + Comp v3	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	-0.003	No Flood

Figure 5-4: Simulated changes in flood depths (m) assuming existing railway levels, accounting for the proposed ramp (shown as hatched polygon), and Compensation v3 (shown as red polygons, with lowered ground levels within polygons stated in mAOD)

Pre Development with ramp + Compensation v4

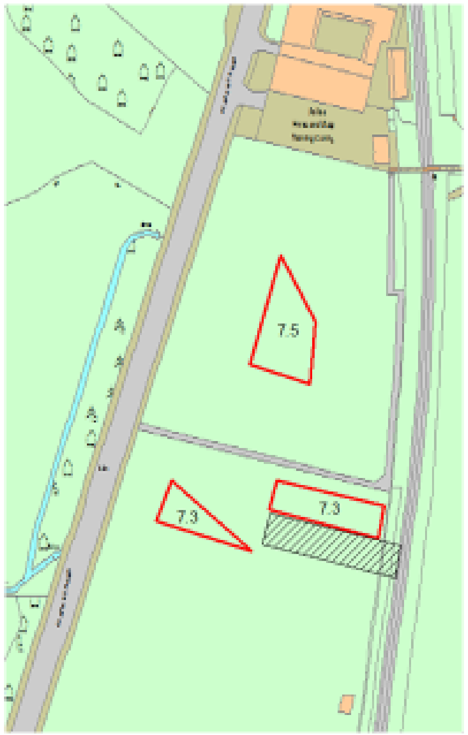


Compensation with an additional large storage area in the future Caravan Club area reduces the impact at property **a** in all the events

Property	Option	Change in peak flood level (mAOD) for simulated events										
		10yr Tidal 2075	10yr Tidal 2115	20yr Tidal 2075	20yr Tidal 2115	75yr Tidal 2015	75yr Tidal 2075	75yr Tidal 2115	200yr Tidal 2015	200yr Tidal 2075	200yr Tidal 2115	100yr Fluvial 2115
a	Ramp	0.008	0.002	0.010	0.000	No Flood	0.004	0.000	0.009	0.001	-0.004	
a	Ramp + Comp v4	-0.023	-0.007	-0.030	-0.002	No Flood	-0.018	-0.001	-0.027	-0.004	-0.006	-0.017
b	Ramp	No Flood	0.000	No Flood	0.000	No Flood	No Flood	0.000	No Flood	0.000	-0.004	
b	Ramp + Comp v4	No Flood	0.000	No Flood	-0.002	No Flood	No Flood	0.001	No Flood	-0.001	-0.005	0.000
c	Ramp	0.000	0.003	0.000	0.000	0.000	0.000	0.000	-0.001	0.001	-0.002	
c	Ramp + Comp v4	0.000	-0.006	0.000	-0.003	0.000	0.000	0.000	0.000	-0.004	-0.004	0.001
d	Ramp	No Flood	0.002	No Flood	0.000	No Flood	No Flood	0.000	No Flood	0.001	-0.003	
d	Ramp + Comp v4	No Flood	-0.007	No Flood	-0.002	No Flood	No Flood	0.001	No Flood	-0.003	-0.006	-0.014
e1	Ramp	0.000	0.000	0.000	0.000	No Flood	0.000	0.000	-0.001	0.000	0.001	
e1	Ramp + Comp v4	0.000	0.000	0.000	0.000	No Flood	0.000	-0.001	0.000	0.000	0.000	0.000
e2	Ramp	0.000	0.000	0.000	-0.001	0.000	0.000	0.000	-0.001	0.000	0.000	
e2	Ramp + Comp v4	0.000	0.000	0.000	-0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
f	Ramp	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	
f	Ramp + Comp v4	0.000	0.000	0.000	0.000	0.000	0.000	-0.001	0.000	0.000	0.000	0.000
g	Ramp	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	0.001	No Flood	No Flood	-0.001	
g	Ramp + Comp v4	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	0.000	No Flood	No Flood	-0.002	No Flood
h	Ramp	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	0.001	No Flood	No Flood	-0.001	
h	Ramp + Comp v4	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	-0.001	No Flood	No Flood	-0.001	0.000
i	Ramp	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	0.001	No Flood	No Flood	0.000	
i	Ramp + Comp v4	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	-0.001	No Flood	No Flood	0.000	0.000
j	Ramp	No Flood	No Flood	No Flood	0.001	No Flood	No Flood	0.000	No Flood	0.001	-0.002	
j	Ramp + Comp v4	No Flood	No Flood	No Flood	-0.002	No Flood	No Flood	-0.001	No Flood	-0.004	-0.004	No Flood
k	Ramp	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	-0.003	
k	Ramp + Comp v4	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	-0.004	No Flood
l	Ramp	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	-0.003	
l	Ramp + Comp v4	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	-0.003	No Flood

Figure 5-5: Simulated changes in flood depths (m) assuming existing railway levels, accounting for the proposed ramp (shown as hatched polygon), and Compensation v4 (shown as red polygons, with lowered ground levels within polygons stated in mAOD)

Pre Development with ramp + Compensation v5



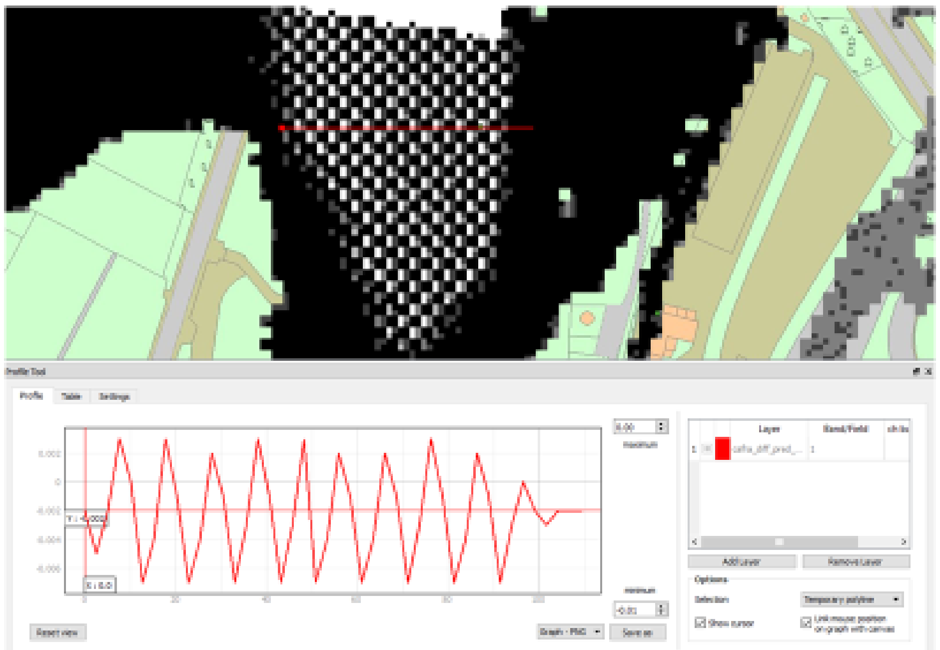
The impact at property a are mitigated also with a limited storage area inside the future Caravan Club area

Property	Option	Change in peak flood level (mAOD) for simulated events										
		10yr Tidal 2075	10yr Tidal 2115	20yr Tidal 2075	20yr Tidal 2115	75yr Tidal 2015	75yr Tidal 2075	75yr Tidal 2115	200yr Tidal 2015	200yr Tidal 2075	200yr Tidal 2115	100yr Fluvial 2115
a	Ramp	0.008	0.002	0.010	0.000	No Flood	0.004	0.000	0.009	0.001	-0.004	
a	Ramp + Comp v5	-0.004	0.001	0.000	0.000	No Flood	0.000	-0.001	-0.001	0.000	-0.003	0.000
b	Ramp	No Flood	0.000	No Flood	0.000	No Flood	No Flood	0.000	No Flood	0.000	-0.004	
b	Ramp + Comp v5	No Flood	0.000	No Flood	0.000	No Flood	No Flood	0.000	No Flood	0.000	-0.001	0.000
c	Ramp	0.000	0.003	0.000	0.000	0.000	0.000	0.000	-0.001	0.001	-0.002	
c	Ramp + Comp v5	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.002	0.001
d	Ramp	No Flood	0.002	No Flood	0.000	No Flood	No Flood	0.000	No Flood	0.001	-0.003	
d	Ramp + Comp v5	No Flood	0.001	No Flood	0.000	No Flood	No Flood	0.000	No Flood	0.000	-0.002	0.000
e1	Ramp	0.000	0.000	0.000	0.000	No Flood	0.000	0.000	-0.001	0.000	0.001	
e1	Ramp + Comp v5	0.000	0.000	0.000	0.000	No Flood	0.000	0.000	0.000	0.000	0.000	0.000
e2	Ramp	0.000	0.000	0.000	-0.001	0.000	0.000	0.000	-0.001	0.000	0.000	
e2	Ramp + Comp v5	0.000	0.000	0.000	-0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
f	Ramp	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	
f	Ramp + Comp v5	0.000	0.000	0.000	0.000	0.000	0.000	-0.001	0.000	0.000	0.000	0.000
g	Ramp	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	0.001	No Flood	No Flood	-0.001	
g	Ramp + Comp v5	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	0.000	No Flood	No Flood	0.000	No Flood
h	Ramp	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	0.001	No Flood	No Flood	-0.001	
h	Ramp + Comp v5	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	0.000	No Flood	No Flood	0.000	0.000
i	Ramp	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	0.001	No Flood	No Flood	0.000	
i	Ramp + Comp v5	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	0.000	No Flood	No Flood	0.000	0.000
j	Ramp	No Flood	No Flood	No Flood	0.001	No Flood	No Flood	0.000	No Flood	0.001	-0.002	
j	Ramp + Comp v5	No Flood	No Flood	No Flood	0.000	No Flood	No Flood	0.000	No Flood	0.000	-0.001	No Flood
k	Ramp	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	-0.003	
k	Ramp + Comp v5	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	-0.001	No Flood
l	Ramp	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	-0.003	
l	Ramp + Comp v5	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	0.000	No Flood

Figure 5-6: Simulated changes in flood depths (m) assuming existing railway levels, accounting for the proposed ramp (shown as hatched polygon), and Compensation v5 (shown as red polygons, with lowered ground levels within polygons stated in mAOD)

Summary impacts at property a

Property	Option	Change in peak flood level (mAOD) for simulated events 10yr Tidal 2075	10yr Tidal 2115	20yr Tidal 2075	20yr Tidal 2115	75yr Tidal 2015	75yr Tidal 2075	75yr Tidal 2115	200yr Tidal 2015	200yr Tidal 2075	200yr Tidal 2115	100yr Fluvial 2115
a	Ramp	0.008	0.002	0.010	0.000	No Flood	0.004	0.000	0.009	0.001	-0.004	
a	Ramp + Comp v1	-0.001	0.001	0.005	0.000	No Flood	0.001	0.000	0.002	0.000	-0.003	0.001
a	Ramp + Comp v2	-0.018	-0.003	-0.025	-0.001	No Flood	-0.009	-0.001	-0.024	-0.003	0.009	-0.007
a	Ramp + Comp v3	-0.009	-0.001	-0.010	-0.001	No Flood	-0.004	-0.001	-0.013	-0.002	0.008	-0.004
a	Ramp + Comp v4	-0.023	-0.007	-0.030	-0.002	No Flood	-0.018	-0.001	-0.027	-0.004	-0.006	-0.017
a	Ramp + Comp v5	-0.004	0.001	0.000	0.000	No Flood	0.000	-0.001	-0.001	0.000	-0.003	0.000



Please note that 2D results in the area surrounding property **a** are affected by model noise in some of the simulated events. E.g. the change in peak flow for Option Ramp + Comp v2 in 20yr tidal event – 2075 can vary from +0.002m to – 0.006m. In these cases, the values reported in the tables are average values.

Figure 5-7: Summary of simulated changes in flood depths (m) at property a - assuming existing railway levels, accounting for the proposed ramp (shown as hatched polygon), and Compensation v1 to v5

6. Retaining existing railway levels and providing floodplain mitigating for access ramps wholly within the Clanage Road compound

6.1 Introduction

This section reports further modeling undertaken to explore options to provide floodplain compensation for the proposed Clanage Road access ramps wholly within the Clanage Road compound (i.e. no requirement for third party land for floodplain compensation to mitigate impacts of the proposed Clanage Road compound ramps).

For this modelling:

- Detail in the Clanage Road area has been improved based on available MetroWest project topographic survey data.
- Model representation of conveyance of flood flows by the railway has been improved.
- As well as the access ramp from the compound to the railway, the access ramp into the compound from the main road has also been represented in the modelling
- Further to discussions with the Clanage Road compound design team, floodplain compensation options include lowering a larger area within the Clanage Road compound

6.2 Updates to the MetroWest pre-development model

6.2.1 Flow path along the railway at Bower Ashton

The original CAFRA model has a shortcoming in the representation of the railway near the River Avon at Bower Ashton. The model makes use of a TUFLOW zline to represent both the railway and the adjacent earth bunds by taking the highest railway or bund levels to determine the hydraulic control. This representation is appropriate where the railway is acting as barrier in the floodplain. However, there are some locations where bunds adjacent to the railway act as a hydraulic control whilst the adjacent railway acts as a conduit for flow. Due to the grid resolution of the model, the zline applied resulted in a modelled blockage of flows southwards along the railway. This is illustrated in Figure 6-1, showing the ground level of the original model with raised levels acting as flow blockages along the railway and the ground level of the updated model, with the zline slightly shifted to east, allowing the railway to act as a flow conduit.

Whilst results do not change significantly for the larger simulated events, as flood levels are significantly higher than the blockage levels, there are more significant changes for 1yr and 2yr tidal events in 2075. Figure 6-2 6-2 shows the difference in flood extents of the original and updated models for a 1yr tidal event in 2075. In the updated model the railway is able to convey flood water southwards, and this spreads to the floodplain west of the railway.

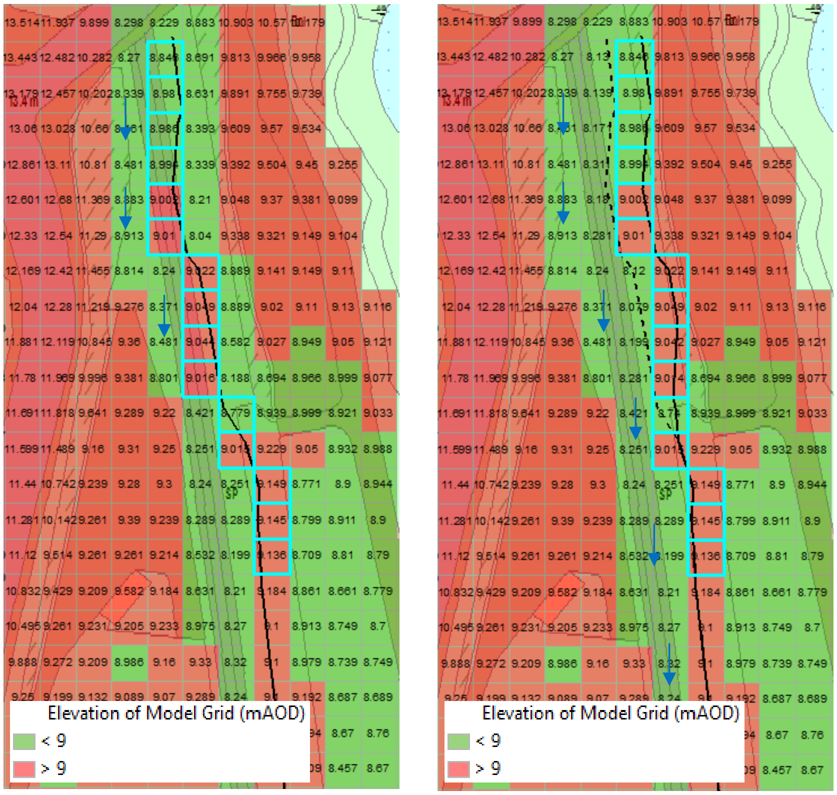


Figure 6-6-1: Comparison of the elevation model grid between original model and updated model with the first stretch of the zline shifted to east to avoid flow blockages

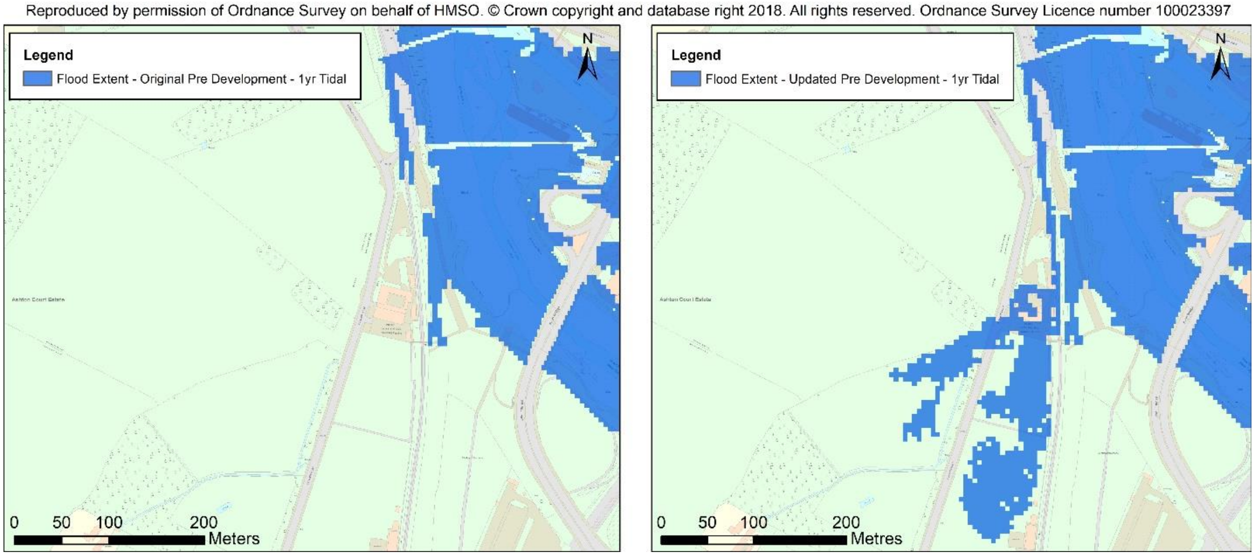


Figure 6-2: Comparison of flood extents between original and updated model – 1yr tidal event in 2075

6.2.2 Updated ground levels within the Clanage Road compound

The original CAFRA hydraulic model uses LiDAR level data to represent ground levels within the Clanage Road compound. MetroWest topographic survey of this area and LiDAR levels have been compared. This check has shown that the LiDAR data picks wrong elevation values south of the footpath located north of the Clanage Road compound, representing the vegetation cover rather than existing ground levels. Moreover, the LiDAR has a depressed area east of the compound that is not reported in the topographic survey. These features in the LiDAR data are shown in Figure 6-3.

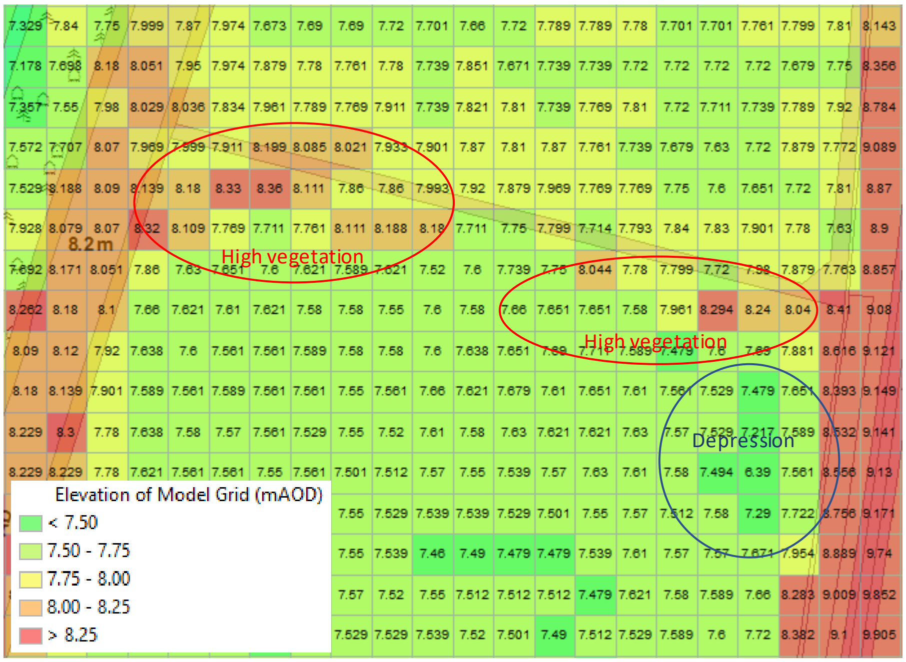


Figure 6-3: Model elevation grid of Clanage Road compound based on LiDAR levels

As shown in Figure 6-4, the model has been updated with new elevation levels south of the footpath to comply with the topographic survey, making use of a TUFLOW zshape to correct the levels affected by high vegetation and the depression observed in the LiDAR. A zline representing the footpath has also been added, with levels obtained from the topographic survey.

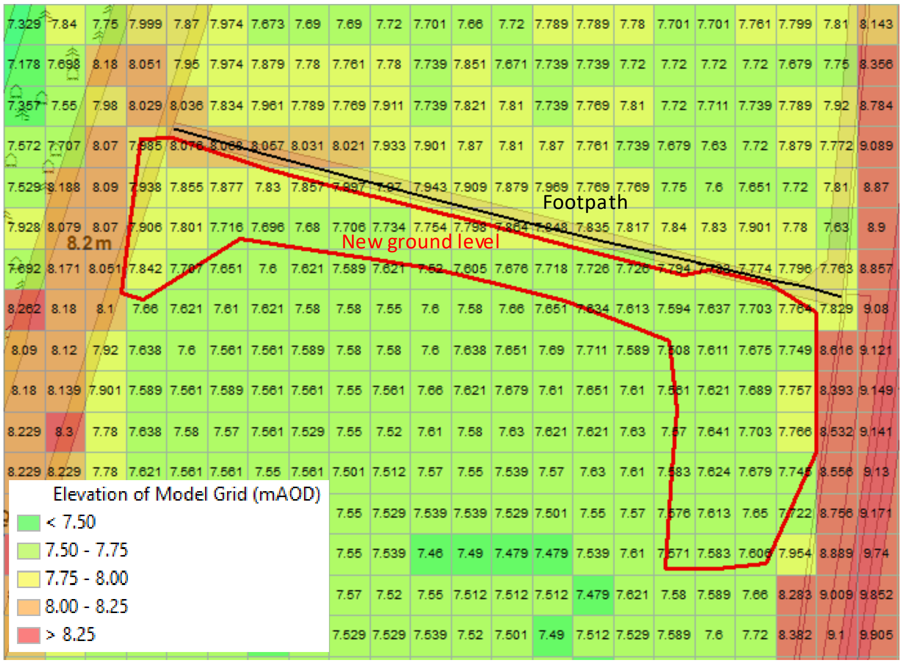


Figure 6-4: Updated model elevation grid Clanage Road compound without vegetation and depression (red polygon) and with new footpath representation (black line)

The check between LiDAR levels and levels from the topographic survey has revealed a level datum difference between the two datasets within the compound (Figure 6-5 6-5), with LiDAR levels higher than survey levels (by approximately 0.1m on average).

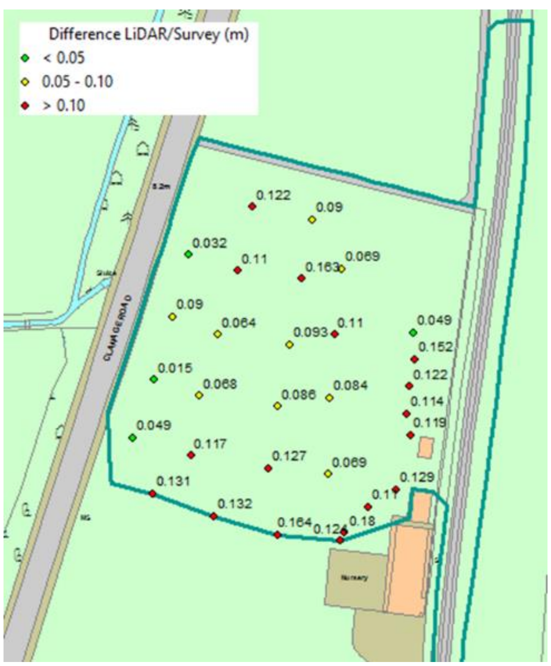


Figure 6-5: Difference between LiDAR level data and topographic survey within the Clanage Road compound

The topographic survey is available for a limited area only, and the model ground levels outside of the surveyed area are based on LiDAR data. As a consequence, modification of model ground levels within the compound using levels based on the available topographic survey would create an unrealistic step at the edge of the surveyed area. Therefore, it has been decided to retain model elevations within the compound based on LiDAR data, whilst noting that any design solution proposed within the compound (and with design levels based on the topographic survey) will be represented in the model applying an elevation adjustment of +0.1m, taking into account the difference in LiDAR and topographic survey level datums.

6.2.3 1000yr simulations

The results of the 1000yr tidal and fluvial events are required for the Flood Risk Assessment appendices. In order to avoid model convergence issues, the following amendments have been applied:

1) All the 1000yr tidal events in present day (2015) and future (2075 and 2115) epochs have been modelled using halved 1D and 2D timesteps (0.5s for the 1D and 0.5s/1s for the 2D domains)

2) The 2075 and 2115 fluvial events have been modelled using:

- A different version of the 1D software (Flood Modeller 4.5)
- An increased Preisemann slot on the following conduit sections: WOUT, WMH6D, 0.1.007_A, 01.007_B
- The 100yr fluvial inflow at Horfield (instead of the 1000yr)

Replacing the 1000yr fluvial inflow at Horfield with the 100yr inflow does not significantly affect flood levels in the study area. Figure 6-6 shows that the difference in maximum flood levels (Post Development, 1000yr event) along the railway using Horfield 1000yr and Horfield 100yr is negligible, with a maximum difference of 3mm.

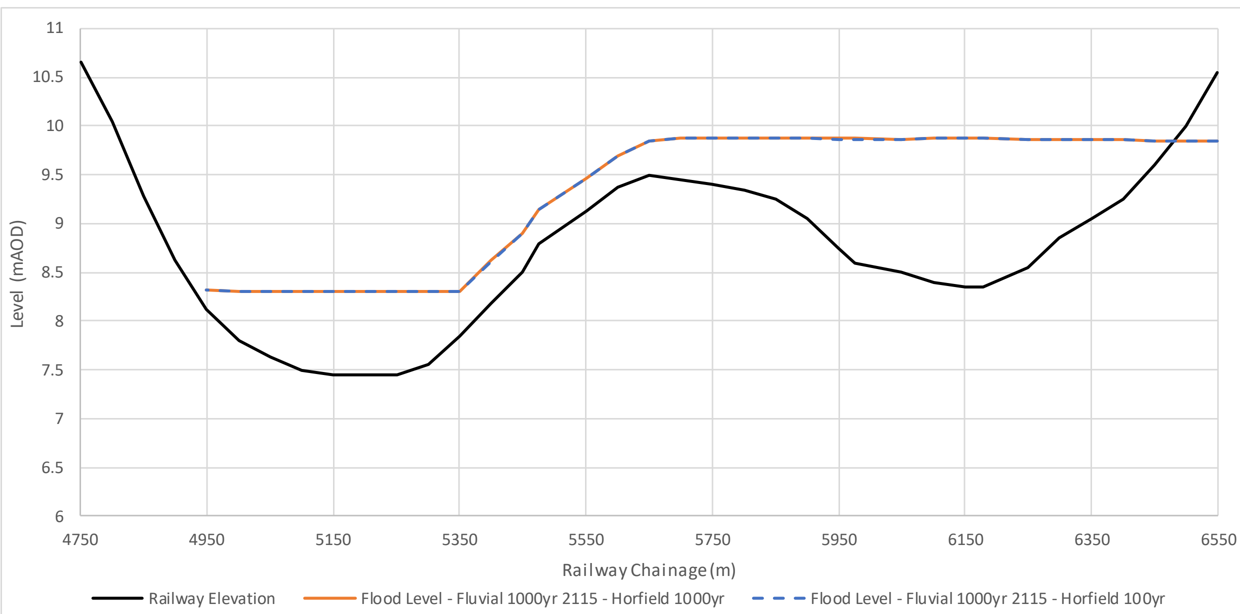


Figure 6-6: Maximum flood levels along the railway using Horfield inflows 1000yr and 100yr

As illustrated in Figure 6-7, differences in flood extents and in flood depths in the study area are also the negligible:

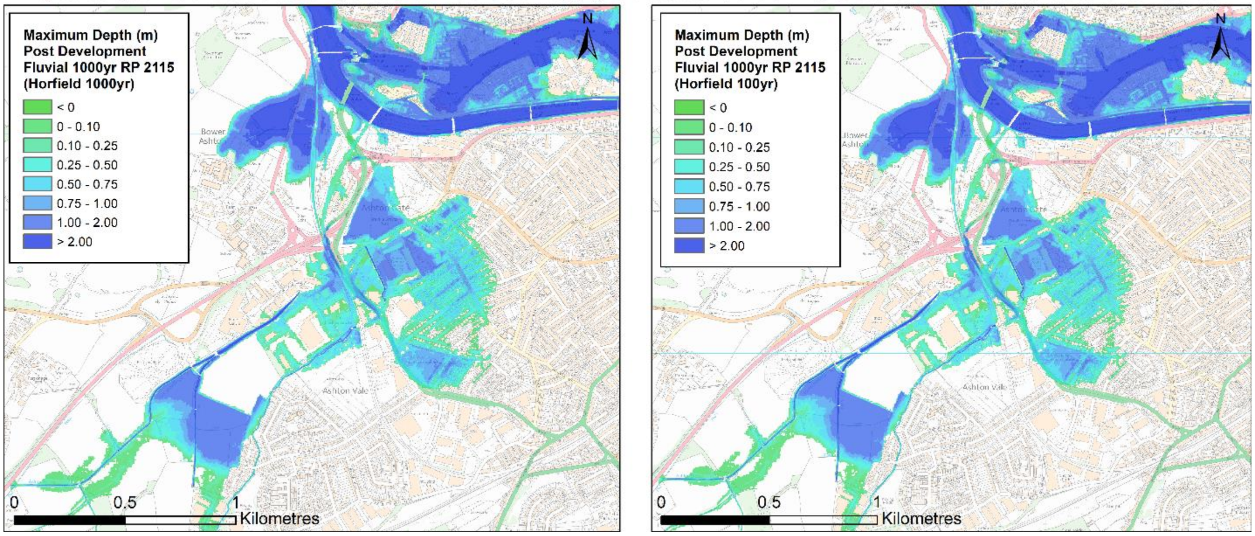


Figure 6-7: Maximum flood depth in the study area using Horfield inflows 1000yr and 100yr

6.3 Representation of ramps and lowered ground levels within Clanage road compound

The updated pre-development model was developed further to represent post-development scenarios, including the proposed Clanage Road maintenance compound access ramps and options with lowered ground levels within the maintenance compound to explore the potential for mitigating the impacts of the proposed ramps.

The Clanage Road compound access ramps, shown in Figure 6-8, are proposed as follows:

- Access ramp from the compound to the railway, 45m long, 10m wide, top elevation of 9.11 mAOD
- Access ramp from Clanage Road to the compound, 12m long, 8m wide, top elevation of 8 mAOD

The ground level within the compound is set to a constant elevation. Figure 6-8 shows this to be 7.4mAOD (note the Network rail survey topographic levels are 100m higher than mAOD). Compound ground level options tested to mitigate the impacts of the ramps include 7.5, 7.4 and 7.3 mAOD.

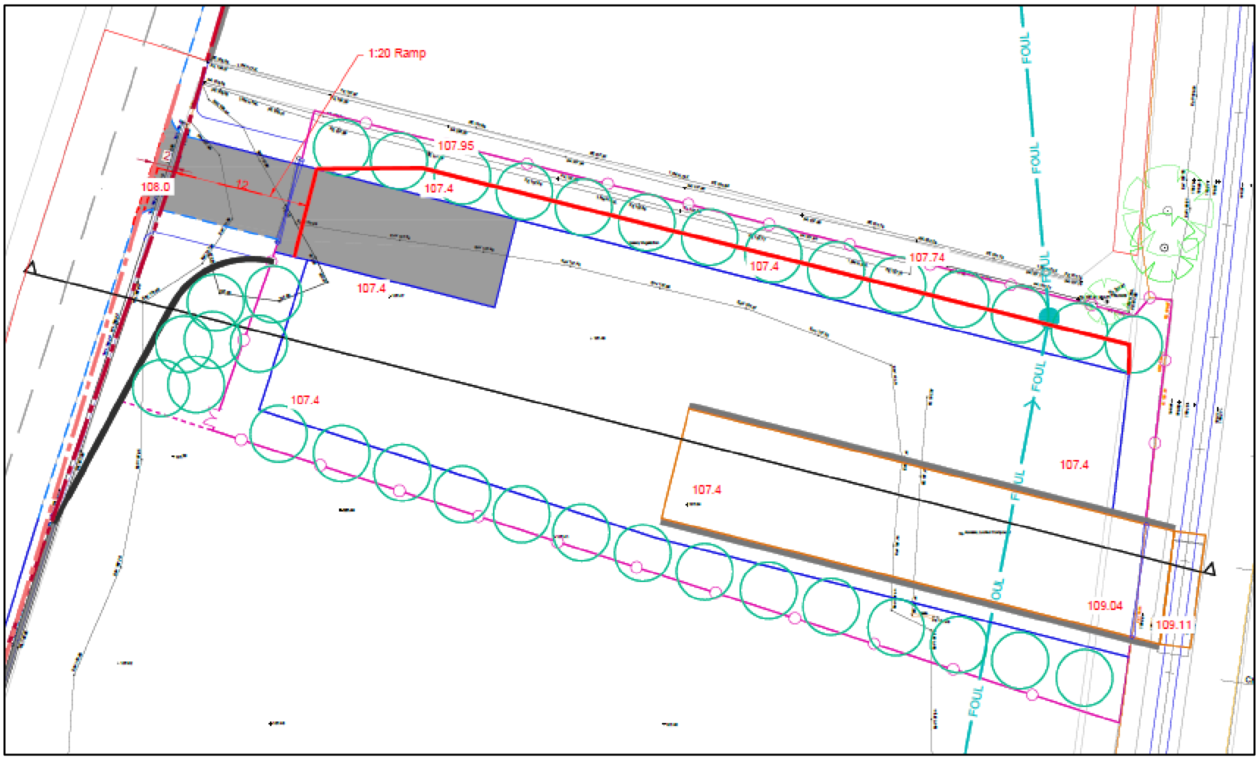


Figure 6-8: Design of the Clanage Road compound including two access ramps

6.4 Compensation options simulated and results

6.4.1 Options simulated

The following options have been simulated for the 60-year design life (future year 2075), for the 2, 10, 75 and 200 year River Avon tidal events:

Simulation	Description
Ramps version 1	Current MetroWest railway design with representation of proposed access ramps and compound levels set to 7.5 mAOD (topographic survey datum) (shown in Figure 6-7)
Ramps version 2	As above with compound levels set to 7.4 mAOD (topographic survey datum) (shown in Figure 6-8)
Ramps version 3	As above with compound levels set to 7.3 mAOD (topographic survey datum) (shown in Figure 6-9)

The levels of the proposed access ramps and compound ground levels are represented in the model applying an increase in elevation of 0.1m (compared to the topographic survey applied in the design), to account for difference in LiDAR and topographic survey level datums (e.g. the compound level of Ramps version 1 is modelled with an elevation of 7.6mAOD, relative to the LiDAR datum).

These options are illustrated in Figures 6-9 to 6-12 together with a summary of the modelled impacts.

6.4.2 Results

Model results indicate:

- With ramps and a compound ground level set to 7.5mAOD, property a has slightly increased flood levels (maximum change +3mm for the 10 year flood in 2075)
- With a compound level lowered to 7.4mAOD the offsite impacts are negligible (maximum change +1mm for the 200 year flood in 2075, and changes are otherwise zero or negative)
- With a compound level lowered to 7.3mAOD there are no offsite impacts (changes are all zero or negative).

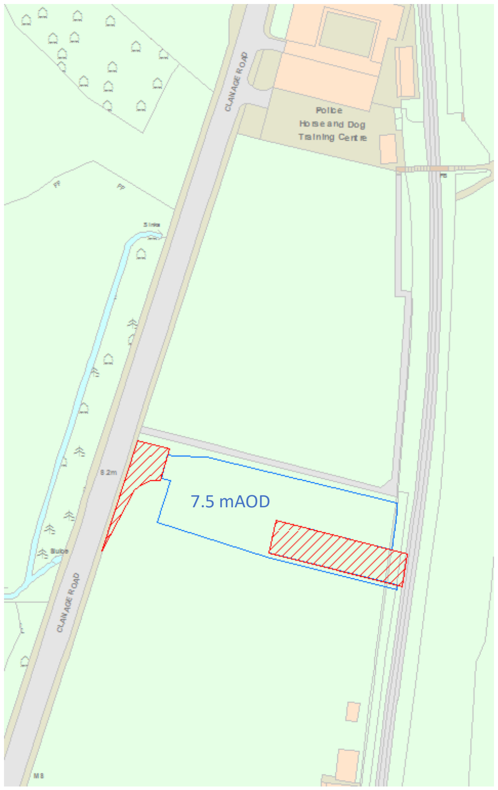
Based on these results, the option with compound ground levels lowered to 7.4mAOD (Ramps version 2) is preferred since:

- Simulated offsite impacts are negligible and so the impacts of the access ramps on offsite flood risk are considered to be mitigated by lowering the compound levels to 7.4mOAD (relative to topographic survey datum).
- Lowered ground levels of 7.4mAOD are only approximately 0.1m below typical existing ground levels within the compound. Lowering ground levels further within the site may increase the risk/frequency of damp site conditions within the compound.
- There is no requirement for third party land for floodplain compensation to mitigate impacts of the proposed Clanage Road compound ramps.

Additional simulations of this option have been run for the present-day (2015) and to test the sensitivity to a longer climate change epoch (2115). The summary results presented in Figure 6-12 confirm simulated offsite impacts are negligible (maximum change +1mm).

Ramps version 1: existing design with compound levels set to 7.5 mAOD

The presence of the ramps results in a slight increase of flood levels, especially at property **a** (nursery north of sports ground at Bower Ashton)

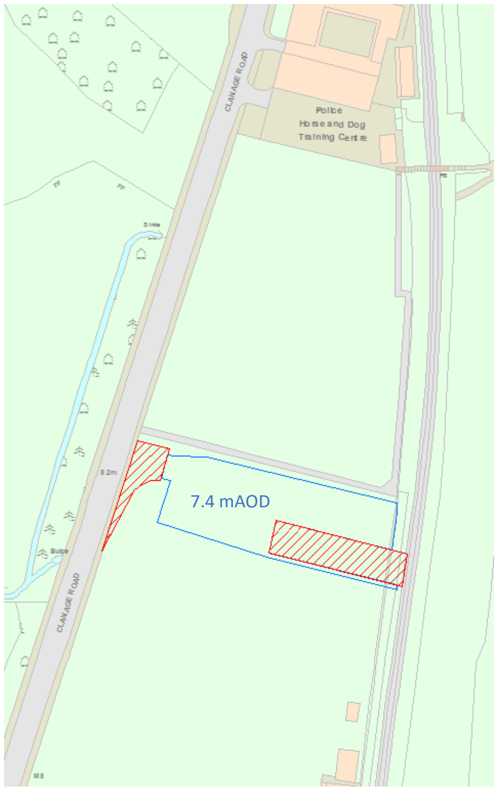


Property	Option	Change in peak flood level (mAOD) for simulated events			
		2yr Tidal 2075	10yr Tidal 2075	75yr Tidal 2075	200yr Tidal 2075
a	Ramps v1	0.000	0.003	0.002	0.001
b	Ramps v1	No Flood	No Flood	No Flood	0.000
c	Ramps v1	0.000	0.000	0.000	0.001
d	Ramps v1	No Flood	No Flood	0.002	0.001
e1	Ramps v1	No Flood	0.000	0.000	0.000
e2	Ramps v1	0.000	0.000	0.000	-0.001
f	Ramps v1	0.000	0.000	0.000	0.000
g	Ramps v1	No Flood	No Flood	No Flood	No Flood
h	Ramps v1	No Flood	No Flood	No Flood	No Flood
i	Ramps v1	No Flood	No Flood	No Flood	No Flood
j	Ramps v1	No Flood	No Flood	No Flood	0.001
k	Ramps v1	No Flood	No Flood	No Flood	No Flood
l	Ramps v1	No Flood	No Flood	No Flood	No Flood

Figure 6-9: Simulated changes in flood depths (m) assuming existing railway levels, accounting for the proposed ramps (shown as hatched red polygons) and for a constant compound level set to 7.5 mAOD (shown as blue polygon)

Ramps version 2: modified design with compound levels set to 7.4 mAOD

A lower ground level within the compound (7.4 mAOD) reduces the offsite impacts of the ramps – max impact +1mm

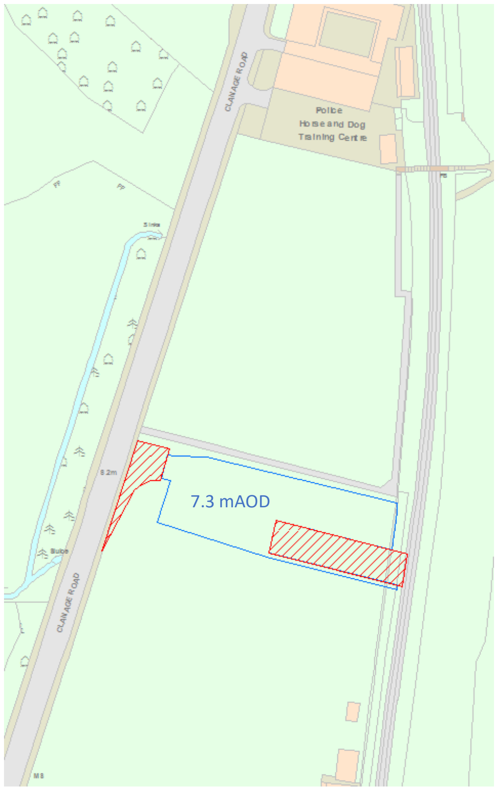


Property	Option	Change in peak flood level (mAOD) for simulated events 2yr Tidal 2075	10yr Tidal 2075	75yr Tidal 2075	200yr Tidal 2075
a	Ramps v1	0.000	0.003	0.002	0.001
a	Ramps v2	-0.014	-0.004	0.000	0.001
b	Ramps v1	No Flood	No Flood	No Flood	0.000
b	Ramps v2	No Flood	No Flood	No Flood	0.000
c	Ramps v1	0.000	0.000	0.000	0.001
c	Ramps v2	0.000	0.000	0.000	0.000
d	Ramps v1	No Flood	No Flood	0.002	0.001
d	Ramps v2	No Flood	No Flood	0.000	0.001
e1	Ramps v1	No Flood	0.000	0.000	0.000
e1	Ramps v2	No Flood	0.000	0.000	0.000
e2	Ramps v1	0.000	0.000	0.000	-0.001
e2	Ramps v2	0.000	0.000	0.000	0.000
f	Ramps v1	0.000	0.000	0.000	0.000
f	Ramps v2	0.000	0.000	0.000	0.000
g	Ramps v1	No Flood	No Flood	No Flood	No Flood
g	Ramps v2	No Flood	No Flood	No Flood	No Flood
h	Ramps v1	No Flood	No Flood	No Flood	No Flood
h	Ramps v2	No Flood	No Flood	No Flood	No Flood
i	Ramps v1	No Flood	No Flood	No Flood	No Flood
i	Ramps v2	No Flood	No Flood	No Flood	No Flood
j	Ramps v1	No Flood	No Flood	No Flood	0.001
j	Ramps v2	No Flood	No Flood	No Flood	0.001
k	Ramps v1	No Flood	No Flood	No Flood	No Flood
k	Ramps v2	No Flood	No Flood	No Flood	No Flood
l	Ramps v1	No Flood	No Flood	No Flood	No Flood
l	Ramps v2	No Flood	No Flood	No Flood	No Flood

Figure 6-10: Simulated changes in flood depths (m) assuming existing railway levels, accounting for the proposed ramps (shown as hatched red polygons) and for a constant compound level set to 7.4 mAOD (shown as blue polygon)

Ramps version 3: modified design with compound levels set to 7.3 mAOD

There are no offsite impacts with the compound ground level lowered to 7.3 mAOD



Property	Option	Change in peak flood level (mAOD) for simulated events			
		2yr Tidal 2075	10yr Tidal 2075	75yr Tidal 2075	200yr Tidal 2075
a	Ramps v1	0.000	0.003	0.002	0.001
a	Ramps v3	-0.027	-0.010	-0.003	0.000
b	Ramps v1	No Flood	No Flood	No Flood	0.000
b	Ramps v3	No Flood	No Flood	No Flood	0.000
c	Ramps v1	0.000	0.000	0.000	0.001
c	Ramps v3	0.000	0.000	0.000	0.000
d	Ramps v1	No Flood	No Flood	0.002	0.001
d	Ramps v3	No Flood	No Flood	-0.002	0.000
e1	Ramps v1	No Flood	0.000	0.000	0.000
e1	Ramps v3	No Flood	0.000	0.000	0.000
e2	Ramps v1	0.000	0.000	0.000	-0.001
e2	Ramps v3	0.000	0.000	0.000	0.000
f	Ramps v1	0.000	0.000	0.000	0.000
f	Ramps v3	0.000	0.000	0.000	0.000
g	Ramps v1	No Flood	No Flood	No Flood	No Flood
g	Ramps v3	No Flood	No Flood	No Flood	No Flood
h	Ramps v1	No Flood	No Flood	No Flood	No Flood
h	Ramps v3	No Flood	No Flood	No Flood	No Flood
i	Ramps v1	No Flood	No Flood	No Flood	No Flood
i	Ramps v3	No Flood	No Flood	No Flood	No Flood
j	Ramps v1	No Flood	No Flood	No Flood	0.001
j	Ramps v3	No Flood	No Flood	No Flood	0.000
k	Ramps v1	No Flood	No Flood	No Flood	No Flood
k	Ramps v3	No Flood	No Flood	No Flood	No Flood
l	Ramps v1	No Flood	No Flood	No Flood	No Flood
l	Ramps v3	No Flood	No Flood	No Flood	No Flood

Figure 6-11: Simulated changes in flood depths (m) assuming existing railway levels, accounting for the proposed ramps (shown as hatched red polygons) and for a constant compound level set to 7.3 mAOD (shown as blue polygon)

Ramps version 2 – All results

Based on these results, the option with the compound levels at 7.4 mAOD (Ramps version 2) can be considered the best solution, as offsite impacts are insignificant (+1mm) and lowering the compound levels to 7.3 mAOD would increase the likelihood of wet ground conditions within the compound.

Additional runs of this option for the present day situation (2015 epoch) and sensitivity tests for a longer design life (2115 epoch) have also confirmed that the offsite impacts are still negligible (+1mm).

		Change in peak flood level (mAOD) for simulated events														
Property	Option	10yr Tidal 2015	10yr Tidal 2075	10yr Tidal 2115	20yr Tidal 2015	20yr Tidal 2075	20yr Tidal 2115	75yr Tidal 2015	75yr Tidal 2075	75yr Tidal 2115	200yr Tidal 2015	200yr Tidal 2075	200yr Tidal 2115	100yr Fluvial 2015	100yr Fluvial 2075	100yr Fluvial 2115
a	Ramps v2	No Flood	-0.004	0.001	No Flood	-0.001	0.000	-0.008	0.000	0.000	-0.001	0.001	0.000	No Flood	-0.014	0.001
b	Ramps v2	No Flood	No Flood	0.000	No Flood	No Flood	0.000	No Flood	No Flood	0.000	No Flood	0.000	0.000	No Flood	No Flood	0.000
c	Ramps v2	No Flood	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	No Flood	0.000	0.000
d	Ramps v2	No Flood	No Flood	0.000	No Flood	No Flood	0.000	No Flood	0.000	0.000	No Flood	0.001	0.000	No Flood	No Flood	0.001
e1	Ramps v2	No Flood	0.000	0.000	No Flood	0.000	0.000	No Flood	0.000	0.000	0.000	0.000	0.000	No Flood	No Flood	0.000
e2	Ramps v2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	No Flood	0.000	0.000
f	Ramps v2	No Flood	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	No Flood	0.000	0.000
g	Ramps v2	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	0.000	No Flood	No Flood	0.000	No Flood	No Flood	No Flood
h	Ramps v2	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	0.000	No Flood	No Flood	0.000	No Flood	0.001	0.000
i	Ramps v2	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	0.000	No Flood	No Flood	0.000	No Flood	No Flood	0.000
j	Ramps v2	No Flood	No Flood	No Flood	No Flood	No Flood	0.000	No Flood	No Flood	0.000	No Flood	0.001	0.000	No Flood	No Flood	No Flood
k	Ramps v2	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	0.000	No Flood	No Flood	No Flood
l	Ramps v2	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	0.000	No Flood	No Flood	No Flood

Figure 6-12: Additional simulated changes in flood depths (m) for Ramp version 2, accounting for the proposed ramps and for a constant compound level set to 7.4 mAOD

7. Conclusions and implications for MetroWest Phase 1 design

7.1 Conclusions

1. The updated MetroWest CAFRA hydraulic modelling presented here has addressed the model behaviour issue (unstable exchange of flow between the River Avon and floodplain at Bower Ashton / Bristol).

2. Simulated impacts of the current proposed MetroWest scheme on flood risk elsewhere for the revised modelling are generally lower than for the previous modelling.

3. Simulated impacts for locations *e1* and *e2* (River Avon downstream of Bower Ashton, and *f* (River Avon floodplain in Bristol, opposite Bower Ashton) are insignificant (within +/- 1mm and so within model convergence tolerance).

4. Impacts of the proposed scheme on flood risk at location *g* (Paxton Drive) is due to the proposed increased railway levels in the Ashton Gate area. Retaining existing railway levels and footprint locally for approximately 100m would remove these impacts.

5. Impacts of the proposed scheme on flood risk at locations *h* and *i* (upstream and downstream of the railway crossing of Longmoor and Colliter's Brooks) are due to local displacement of floodplain storage by the proposed higher railway levels. Retaining existing railway levels and footprint locally for approximately 350m (in addition to the 100m in item 4 above) would remove these impacts.

6. The impact of the current MetroWest scheme on flood risk at Bower Ashton (property locations *a* to *d* and *j* to *l*) is influenced by complex hydraulics (increased railway level, removal of earth bunds, dynamic tidal process with flow into and out of floodplain.

7. The current MetroWest Phase 1 scheme design (i.e. with a proposed increase in railway levels at Bower Ashton by typically 150mm to 200mm) results in impacts on flood risk to properties that cannot be fully mitigated by realistic floodplain compensation options.

8. The modelling presented here demonstrates that the impact on flood risk of the proposed access ramps within the permanent Clanage Road maintenance compound can be fully mitigated by providing local floodplain compensation, wholly within the compound (Section 6). Whilst it is not possible to provide floodplain compensation on a level-to-level basis within realistically available compensation areas, mitigation is provided by realistically available options.

7.2 MetroWest Phase 1 design changes

9. To prevent impacts of the MetroWest Phase 1 scheme on flood risk elsewhere (including to properties), the current design will be modified to retain the existing railway elevations and footprint in the River Avon floodplain in the Bower Ashton/Ashton Gate area, including retaining the existing bunds adjacent to the railway. No floodplain compensation will therefore be required to mitigate the proposed MetroWest Phase 1 railway works within the River Avon floodplain, as there is no associated change in floodplain storage.

10. This would be achieved in the railway design as follows.

- The proposed railway will be replaced at the same level as the existing railway, within standard railway design and construction tolerances (approximately +/-25mm). There will be no net increase in displaced floodplain storage by the railway (there may minor adjustments to existing alignment to meet railway design standards, but there will be no net increase in displaced floodplain by the railway).

- The existing earth bunds adjacent to the railway will be retained as these bunds act as a hydraulic control during flooding

11. Floodplain compensation will be provided to mitigate the impact of the Clanage Road maintenance compound access ramps on flood risk to properties. The preferred compensation option (Ramps version 2 in Figure 6-8) comprises lowering of ground levels only within the permanent Clanage Road maintenance compound, to 7.4mAOD relative to MetroWest the topographic survey datum. This option is considered to fully mitigate the impact of the ramps on flood risk elsewhere.

APPENDIX A: Flood depth difference maps - Exploratory simulations of floodplain compensation mitigation options

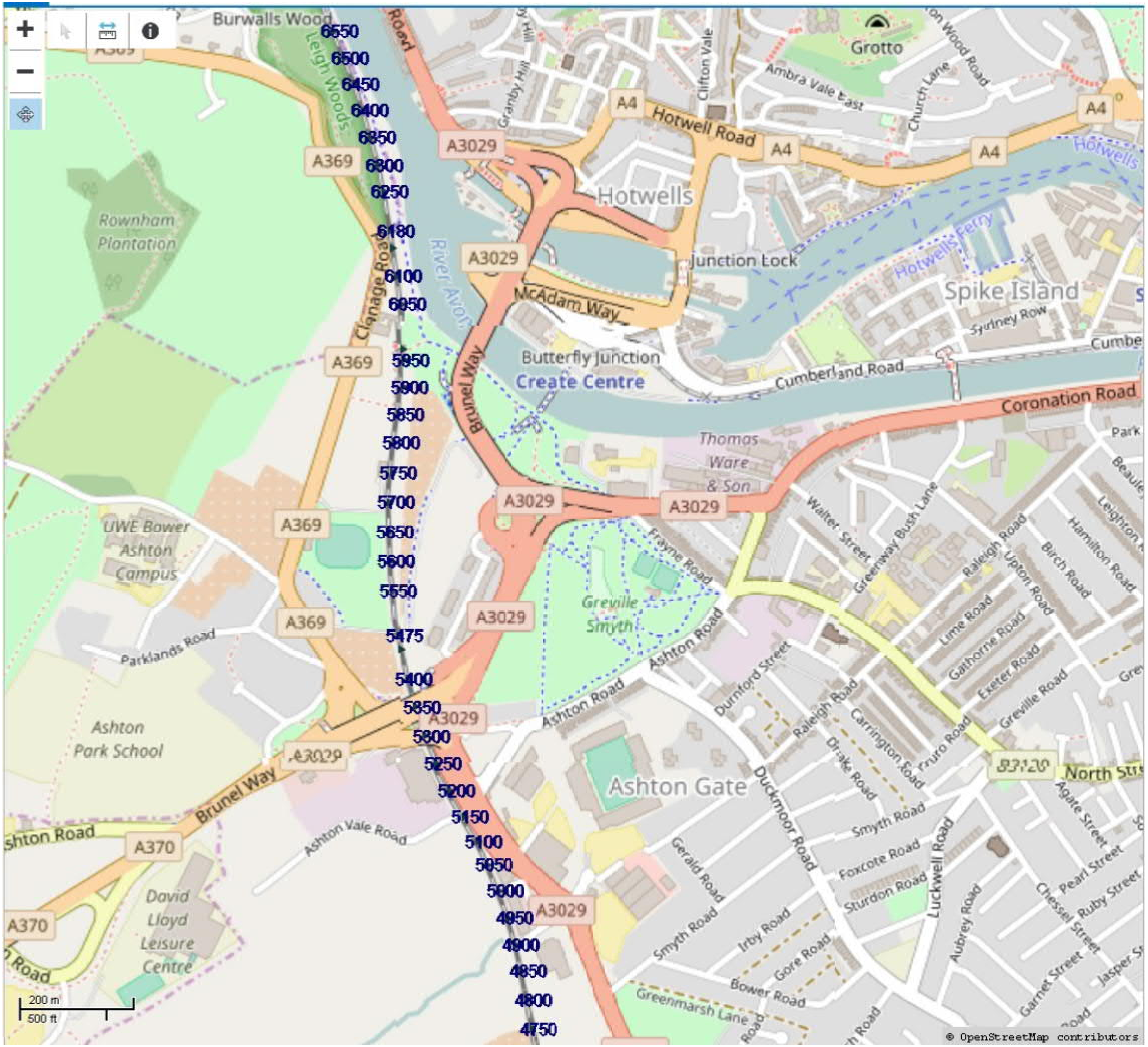
APPENDIX B: Flood depth difference maps - More realistic representation of mitigation options

APPENDIX C: Flood depth difference maps - Retaining existing railway levels and mitigating for access ramp

APPENDIX D: Flood depth difference maps - Retaining existing railway levels and mitigating for access ramps wholly within the Clanage Road compound

Note – only the final flood maps (App D above) are included in the FRA Appendix N (located in the fluvial events and tidal events flood map directories), as the interim results in App A, App B and App C above do not represent the DCO proposed works.

Approximate locations of railway chainages



Modelled peak flood levels for Tidal River Avon design flood events

		LEVEL	LEVEL	LEVEL	LEVEL	LEVEL	LEVEL	LEVEL	LEVEL	LEVEL	LEVEL	LEVEL	LEVEL
Chainage	Railway elevation	Base_BL_2015	Base_PD_2015	2yr_BL_2015	2yr_PD_2015	5yr_BL_2015	5yr_PD_2015	10yr_BL_2015	10yr_PD_2015	20yr_BL_2015	20yr_PD_2015	75yr_BL_2015	75yr_PD_2015
6550	10.550	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6500	10.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6450	9.600	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6400	9.250	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6350	9.050	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	9.098	9.098
6300	8.850	0.000	0.000	0.000	0.000	0.000	0.000	8.851	8.851	8.951	8.951	9.101	9.101
6250	8.550	0.000	0.000	0.000	0.000	0.000	0.000	8.562	8.562	8.893	8.893	9.103	9.103
6180	8.350	0.000	0.000	0.000	0.000	0.000	0.000	8.497	8.497	8.883	8.884	9.094	9.094
6150	8.350	0.000	0.000	0.000	0.000	0.000	0.000	8.497	8.497	8.878	8.878	9.090	9.090
6100	8.400	0.000	0.000	0.000	0.000	0.000	0.000	8.502	8.502	8.861	8.861	9.024	9.024
6050	8.500	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	8.810	8.810	9.003	9.003
5975	8.600	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	8.893	8.893
5950	8.750	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5900	9.050	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5850	9.250	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5800	9.350	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5750	9.400	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5700	9.450	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5650	9.500	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5600	9.380	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5550	9.130	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5475	8.800	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5450	8.500	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5400	8.180	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5350	7.850	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5300	7.550	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5250	7.450	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5200	7.450	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5150	7.450	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5100	7.500	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5050	7.625	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5000	7.800	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4950	8.125	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4900	8.625	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4850	9.280	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4800	10.050	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4750	10.650	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

LEVEL	LEVEL	LEVEL	LEVEL	LEVEL	LEVEL	LEVEL	LEVEL	LEVEL	LEVEL	LEVEL	LEVEL	LEVEL	LEVEL
200yr_BL_2015	200yr_PD_2015	1000yr_BL_2015	1000yr_PD_2015	Base_BL_2075	Base_PD_2075	1yr_BL_2075	1yr_PD_2075	2yr_BL_2075	2yr_PD_2075	5yr_BL_2075	5yr_PD_2075	10yr_BL_2075	10yr_PD_2075
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
9.316	9.316	9.543	9.543	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
9.315	9.315	9.544	9.544	0.000	0.000	0.000	0.000	0.000	0.000	9.145	9.145	9.238	9.238
9.315	9.315	9.546	9.546	0.000	0.000	8.930	8.930	9.011	9.011	9.147	9.147	9.241	9.241
9.317	9.317	9.550	9.550	0.000	0.000	8.805	8.805	9.008	9.008	9.152	9.152	9.245	9.245
9.319	9.319	9.551	9.551	0.000	0.000	8.785	8.785	8.988	8.988	9.152	9.152	9.246	9.246
9.319	9.319	9.551	9.551	0.000	0.000	8.782	8.782	8.980	8.980	9.150	9.150	9.246	9.246
9.317	9.317	9.550	9.550	0.000	0.000	8.772	8.772	8.942	8.942	9.112	9.112	9.238	9.238
9.288	9.288	9.525	9.525	0.000	0.000	8.728	8.728	8.869	8.869	9.056	9.056	9.178	9.178
9.018	9.018	9.267	9.267	0.000	0.000	0.000	0.000	0.000	0.000	8.919	8.919	8.966	8.966
9.096	9.096	9.380	9.380	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

LEVEL	LEVEL	LEVEL	LEVEL	LEVEL	LEVEL	LEVEL	LEVEL	LEVEL	LEVEL	LEVEL	LEVEL	LEVEL	LEVEL
20yr_BL_2075	20yr_PD_2075	75yr_BL_2075	75yr_PD_2075	200yr_BL_2075	200yr_PD_2075	1000yr_BL_2075	1000yr_PD_2075	Base_BL_2115	Base_PD_2115	1yr_BL_2115	1yr_PD_2115	2yr_BL_2115	2yr_PD_2115
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	10.080	10.080	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	9.672	9.672	10.081	10.081	0.000	0.000	0.000	0.000	0.000	0.000
9.321	9.321	9.451	9.451	9.672	9.672	10.083	10.083	0.000	0.000	9.357	9.357	9.428	9.428
9.321	9.321	9.450	9.450	9.673	9.673	10.084	10.084	0.000	0.000	9.357	9.357	9.427	9.427
9.323	9.323	9.453	9.453	9.676	9.675	10.087	10.087	0.000	0.000	9.360	9.360	9.430	9.430
9.327	9.327	9.457	9.457	9.678	9.678	10.089	10.089	0.000	0.000	9.364	9.364	9.435	9.435
9.329	9.329	9.458	9.458	9.681	9.680	10.092	10.092	0.000	0.000	9.365	9.365	9.435	9.435
9.329	9.329	9.458	9.458	9.681	9.681	10.095	10.095	0.000	0.000	9.365	9.365	9.435	9.435
9.325	9.325	9.456	9.456	9.680	9.680	10.095	10.095	0.000	0.000	9.364	9.364	9.434	9.434
9.298	9.298	9.435	9.434	9.654	9.653	10.094	10.094	0.000	0.000	9.339	9.339	9.414	9.414
9.024	9.024	9.188	9.188	9.597	9.598	10.094	10.094	0.000	0.000	9.058	9.058	9.178	9.178
9.103	9.103	9.287	9.287	9.599	9.599	10.094	10.094	0.000	0.000	9.138	9.138	9.275	9.275
0.000	0.000	0.000	0.000	9.603	9.604	10.094	10.094	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	9.605	9.605	10.095	10.095	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	9.606	9.607	10.095	10.095	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	9.607	9.607	10.096	10.096	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	9.608	9.608	10.096	10.096	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	9.595	9.596	10.072	10.072	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	9.424	9.424	9.957	9.957	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	9.185	9.185	9.812	9.812	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	9.487	9.487	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	9.362	9.362	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	8.219	8.219	8.993	8.993	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	8.447	8.447	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	8.122	8.123	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	8.117	8.117	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	8.101	8.101	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	8.093	8.093	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	8.087	8.087	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	8.077	8.077	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	8.063	8.063	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

LEVEL	LEVEL	LEVEL	LEVEL	LEVEL	LEVEL	LEVEL	LEVEL	LEVEL	LEVEL	LEVEL	LEVEL
5yr_BL_2115	5yr_PD_2115	10yr_BL_2115	10yr_PD_2115	20yr_BL_2115	20yr_PD_2115	75yr_BL_2115	75yr_PD_2115	200yr_BL_2115	200yr_PD_2115	1000yr_BL_2115	1000yr_PD_2115
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	10.580	10.580
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	10.266	10.266	10.581	10.581
0.000	0.000	9.627	9.627	9.700	9.700	9.860	9.860	10.265	10.265	10.581	10.581
9.542	9.542	9.625	9.625	9.697	9.697	9.857	9.857	10.265	10.265	10.581	10.581
9.541	9.541	9.624	9.624	9.695	9.695	9.856	9.856	10.265	10.265	10.582	10.581
9.544	9.544	9.628	9.628	9.699	9.699	9.859	9.859	10.267	10.267	10.583	10.583
9.548	9.548	9.634	9.634	9.707	9.707	9.867	9.867	10.271	10.271	10.588	10.588
9.549	9.549	9.636	9.636	9.708	9.708	9.870	9.870	10.275	10.275	10.595	10.595
9.549	9.549	9.636	9.636	9.709	9.709	9.874	9.873	10.280	10.280	10.615	10.615
9.547	9.547	9.633	9.633	9.706	9.706	9.872	9.872	10.278	10.278	10.597	10.597
9.520	9.520	9.602	9.602	9.673	9.673	9.866	9.866	10.275	10.275	10.594	10.594
9.273	9.273	9.374	9.374	9.637	9.638	9.863	9.863	10.275	10.275	10.591	10.591
9.384	9.384	9.441	9.441	9.638	9.638	9.862	9.862	10.272	10.272	10.591	10.591
0.000	0.000	9.360	9.361	9.641	9.641	9.862	9.862	10.271	10.272	10.591	10.591
0.000	0.000	9.361	9.362	9.641	9.642	9.863	9.863	10.270	10.273	10.592	10.592
0.000	0.000	9.362	9.362	9.643	9.643	9.864	9.864	10.272	10.271	10.592	10.592
0.000	0.000	9.411	9.411	9.643	9.643	9.864	9.864	10.271	10.272	10.592	10.592
0.000	0.000	0.000	0.000	9.643	9.644	9.864	9.864	10.271	10.272	10.592	10.592
0.000	0.000	0.000	0.000	9.632	9.632	9.828	9.828	10.260	10.260	10.585	10.585
0.000	0.000	0.000	0.000	9.446	9.446	9.679	9.679	10.166	10.166	10.484	10.484
0.000	0.000	0.000	0.000	9.212	9.212	9.449	9.449	10.070	10.070	10.393	10.393
0.000	0.000	0.000	0.000	0.000	0.000	9.096	9.096	9.794	9.794	9.958	9.958
0.000	0.000	0.000	0.000	8.517	8.517	8.860	8.860	9.474	9.474	9.599	9.599
0.000	0.000	0.000	0.000	8.249	8.249	8.571	8.571	9.044	9.044	9.491	9.491
0.000	0.000	0.000	0.000	7.892	7.892	8.185	8.185	8.534	8.534	8.836	8.836
0.000	0.000	0.000	0.000	0.000	0.000	7.867	7.867	8.301	8.302	8.597	8.597
0.000	0.000	0.000	0.000	0.000	0.000	7.867	7.867	8.294	8.294	8.611	8.610
0.000	0.000	0.000	0.000	0.000	0.000	7.867	7.867	8.270	8.270	8.553	8.552
0.000	0.000	0.000	0.000	0.000	0.000	7.867	7.867	8.262	8.262	8.546	8.546
0.000	0.000	0.000	0.000	0.000	0.000	7.867	7.867	8.259	8.260	8.548	8.548
0.000	0.000	0.000	0.000	0.000	0.000	7.866	7.866	8.255	8.255	8.548	8.548
0.000	0.000	0.000	0.000	0.000	0.000	7.866	7.866	8.254	8.254	8.547	8.547
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	8.252	8.252	8.545	8.545
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Modelled peak flood levels for Fluvial River Avon design flood events

		Simulated peak flood levels (BL = pre development; PD = post development; Epoch 2015, 2075, 2115)										
		LEVEL	LEVEL	LEVEL	LEVEL	LEVEL	LEVEL	LEVEL	LEVEL	LEVEL	LEVEL	LEVEL
Chainage	Railway elevation	50yr_BL_2015	50yr_PD_2015	75yr_BL_2015	75yr_PD_2015	100yr_BL_2015	100yr_PD_2015	1000yr_BL_2015	1000yr_PD_2015	50yr_BL_2075	50yr_PD_2075	75yr_BL_2075
6550	10.550	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6500	10.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6450	9.600	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6400	9.250	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6350	9.050	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6300	8.850	0.000	0.000	0.000	0.000	0.000	0.000	8.880	8.880	0.000	0.000	8.991
6250	8.550	0.000	0.000	0.000	0.000	0.000	0.000	8.674	8.674	0.000	0.000	8.986
6180	8.350	0.000	0.000	0.000	0.000	0.000	0.000	8.667	8.667	0.000	0.000	8.968
6150	8.350	0.000	0.000	0.000	0.000	0.000	0.000	8.666	8.666	0.000	0.000	8.962
6100	8.400	0.000	0.000	0.000	0.000	0.000	0.000	8.662	8.662	0.000	0.000	8.927
6050	8.500	0.000	0.000	0.000	0.000	0.000	0.000	8.630	8.630	0.000	0.000	8.856
5975	8.600	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5950	8.750	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5900	9.050	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5850	9.250	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5800	9.350	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5750	9.400	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5700	9.450	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5650	9.500	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5600	9.380	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5550	9.130	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5475	8.800	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5450	8.500	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5400	8.180	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5350	7.850	0.000	0.000	0.000	0.000	0.000	0.000	8.063	8.063	0.000	0.000	0.000
5300	7.550	0.000	0.000	0.000	0.000	0.000	0.000	8.063	8.063	0.000	0.000	0.000
5250	7.450	0.000	0.000	0.000	0.000	0.000	0.000	8.063	8.063	0.000	0.000	0.000
5200	7.450	0.000	0.000	0.000	0.000	0.000	0.000	8.063	8.063	0.000	0.000	0.000
5150	7.450	0.000	0.000	0.000	0.000	0.000	0.000	8.063	8.063	0.000	0.000	7.517
5100	7.500	0.000	0.000	0.000	0.000	0.000	0.000	8.063	8.063	0.000	0.000	0.000
5050	7.625	0.000	0.000	0.000	0.000	0.000	0.000	8.063	8.063	0.000	0.000	0.000
5000	7.800	0.000	0.000	0.000	0.000	0.000	0.000	8.063	8.063	0.000	0.000	0.000
4950	8.125	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4900	8.625	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4850	9.280	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4800	10.050	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4750	10.650	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

LEVEL	LEVEL	LEVEL	LEVEL	LEVEL	LEVEL	LEVEL	LEVEL	LEVEL	LEVEL	LEVEL	LEVEL	LEVEL
75yr_PD_2075	100yr_BL_2075	100yr_PD_2075	1000yr_BL_2075	1000yr_PD_2075	50yr_BL_2115	50yr_PD_2115	75yr_BL_2115	75yr_PD_2115	100yr_BL_2115	100yr_PD_2115	1000yr_BL_2115	1000yr_PD_2115
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	9.854	9.854
0.000	0.000	0.000	9.303	9.303	0.000	0.000	9.435	9.435	9.443	9.443	9.857	9.857
0.000	0.000	0.000	9.305	9.305	0.000	0.000	9.435	9.435	9.444	9.444	9.860	9.860
8.991	8.990	8.990	9.309	9.309	0.000	0.000	9.436	9.436	9.445	9.445	9.864	9.864
8.986	8.984	8.984	9.315	9.315	0.000	0.000	9.437	9.437	9.446	9.446	9.868	9.867
8.968	8.967	8.967	9.317	9.317	0.000	0.000	9.439	9.439	9.449	9.448	9.871	9.870
8.962	8.961	8.961	9.317	9.317	0.000	0.000	9.439	9.439	9.448	9.448	9.873	9.872
8.927	8.926	8.926	9.314	9.314	0.000	0.000	9.438	9.438	9.447	9.447	9.871	9.870
8.856	8.856	8.856	9.283	9.284	0.000	0.000	9.419	9.419	9.427	9.427	9.866	9.866
0.000	0.000	0.000	9.014	9.014	0.000	0.000	9.203	9.203	9.213	9.213	9.869	9.870
0.000	0.000	0.000	9.091	9.091	0.000	0.000	9.304	9.304	9.315	9.315	9.870	9.871
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	9.870	9.871
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	9.872	9.874
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	9.876	9.877
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	9.876	9.878
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	9.878	9.879
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	9.840	9.841
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	9.697	9.699
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	9.466	9.467
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	9.139	9.142
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	8.898	8.896
0.000	0.000	0.000	8.262	8.262	0.000	0.000	0.000	0.000	0.000	0.000	8.614	8.622
0.000	0.000	0.000	8.262	8.262	0.000	0.000	0.000	0.000	7.939	7.939	8.311	8.311
0.000	7.645	7.646	8.262	8.262	0.000	0.000	7.840	7.840	7.939	7.939	8.311	8.311
0.000	7.645	7.646	8.262	8.262	0.000	0.000	7.840	7.840	7.939	7.939	8.311	8.311
0.000	7.645	7.646	8.262	8.262	0.000	0.000	7.840	7.840	7.938	7.939	8.311	8.311
7.517	7.645	7.646	8.261	8.262	0.000	0.000	7.840	7.840	7.938	7.938	8.310	8.310
0.000	7.645	7.646	8.260	8.261	0.000	0.000	7.840	7.840	7.937	7.937	8.309	8.310
0.000	0.000	0.000	8.260	8.260	0.000	0.000	7.839	7.840	7.934	7.934	8.308	8.309
0.000	0.000	0.000	8.262	8.263	0.000	0.000	7.840	7.840	7.934	7.934	8.312	8.312
0.000	0.000	0.000	8.266	8.267	0.000	0.000	0.000	0.000	0.000	0.000	8.316	8.316
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

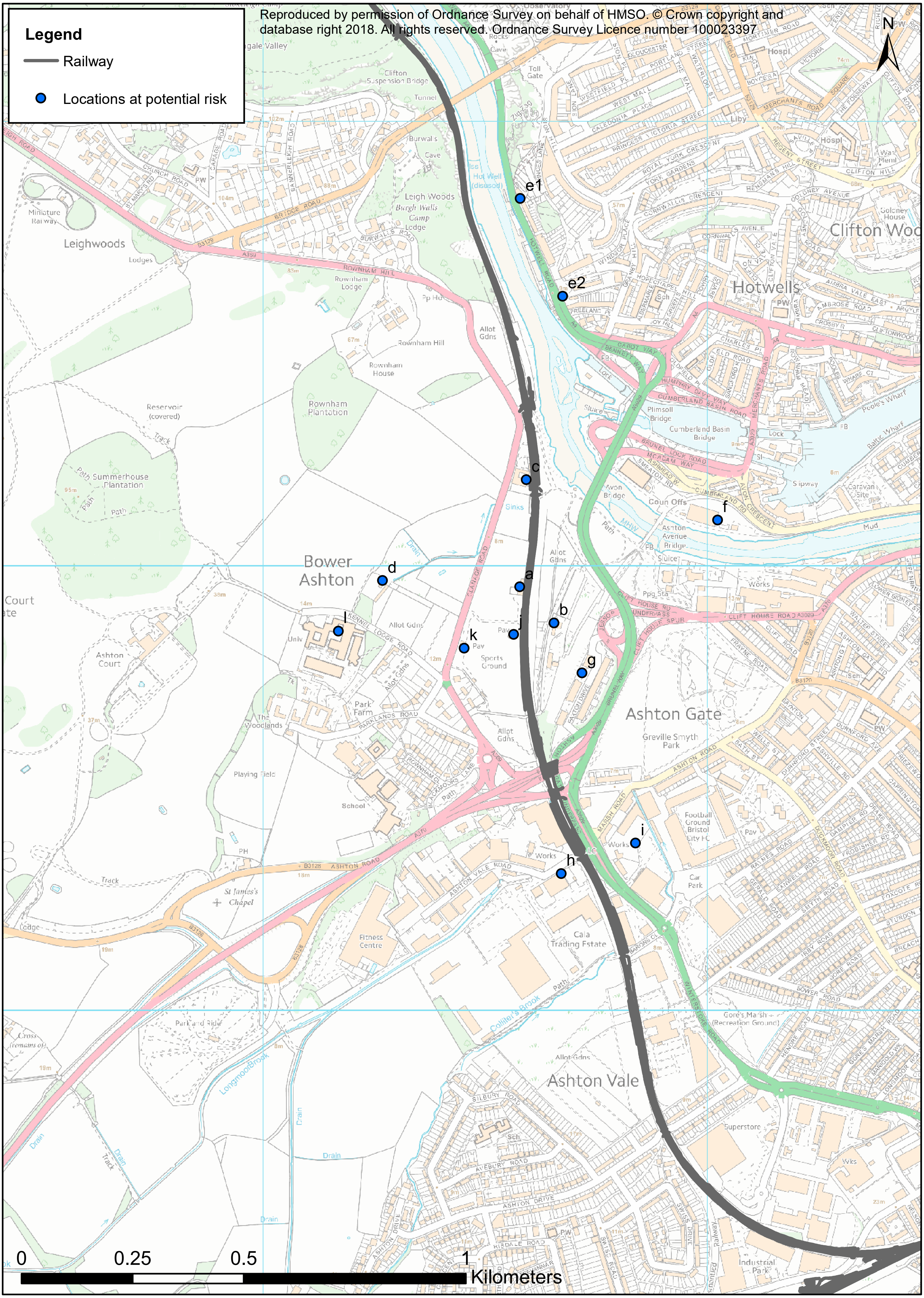


Figure 201: Locations of properties at potential risk