MetroWest

Portishead Branch Line (MetroWest Phase 1)

Planning Inspectorate Reference: TR040011

Applicant: North Somerset District Council

9.3.3 ExA.SoCG-EA.D3.V2 – Appendix 4 to Statement of Common Ground

Between

(1) North Somerset District Council;
(2) Network Rail Infrastructure Limited; and
(3) Environment Agency

Version: 2
Date: December 2020

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Project Name	**Metro West Flood Risk Assessment – River Avon flood risk: Off-site impacts and mitigation**
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Date	04/08/2020
Project Number	674946CH
Revision No	2

1. Introduction

The Portishead Branch Line (MetroWest Phase 1) Development Consent Order Scheme (the DCO Scheme) design[1] includes a general increase in railway levels, typically by approximately 150mm to 200mm, including in the Bower Ashton / Ashton Gate area. The DCO Scheme Flood Risk Assessment (FRA) hydraulic modelling undertaken for this design indicated that the DCO 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 would 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 DCO 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.

[1] This refers to the original design for the railway as of June 2019. The design was modified as a consequence of the findings of an earlier draft of this Technical Note, resulting in no change to the elevation of the railway through Bower Ashton to avoid increased flood risk to third parties.

- 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.
- Modelling of the selected compensation option with tide and fluvial boundaries in future epochs corrected to latest (December 2019 with minor correction in March 2020) climate change allowances. Reported in Section 7.
- For small catchments (area less than 5 km^2), the current climate change guidance (updated in December 2019 with minor correction in March 2020) states that the allowances specified for rainfall intensity are considered more appropriate than those specified for river flows. As the Longmoor and Colliter's Brooks catchment areas are only slightly larger (Flood Estimation Handbook catchment areas 8.6 km^2 and 5.4 km^2 respectively) the peak rainfall allowances are considered more representative for these watercourses than the peak river flow allowances, which are considered representative of larger catchments. The modelling undertaken in Section 7 therefore applies +40% rainfall allowances for the simulated Longmoor and Colliter's Brooks fluvial events in 2075 and 2115. Further modelling of the selected compensation option was undertaken for the Longmoor and Colliter's Brooks fluvial events in 2075 and 2115, applying +70% climate change peak river flow allowances, as an upper sensitivity test, rather than +40% rainfall allowances applied in Section 7. Reported in Section 8.

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 DCO Scheme[2].

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 Clanage Road compound, by lowering ground levels to 7.4mAOD (relative to the DCO Scheme 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[3]). 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 DCO Scheme 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 DCO Scheme.

[2] Hydraulic modelling technical note in Appendix N of the FRA: *MW_Phase1_CAFRA_Update_TN_Feb_2019.docx*
[3] The scheme design life is 60 years (2075). Models have also been run for the 2115 future year as a sensitivity test.

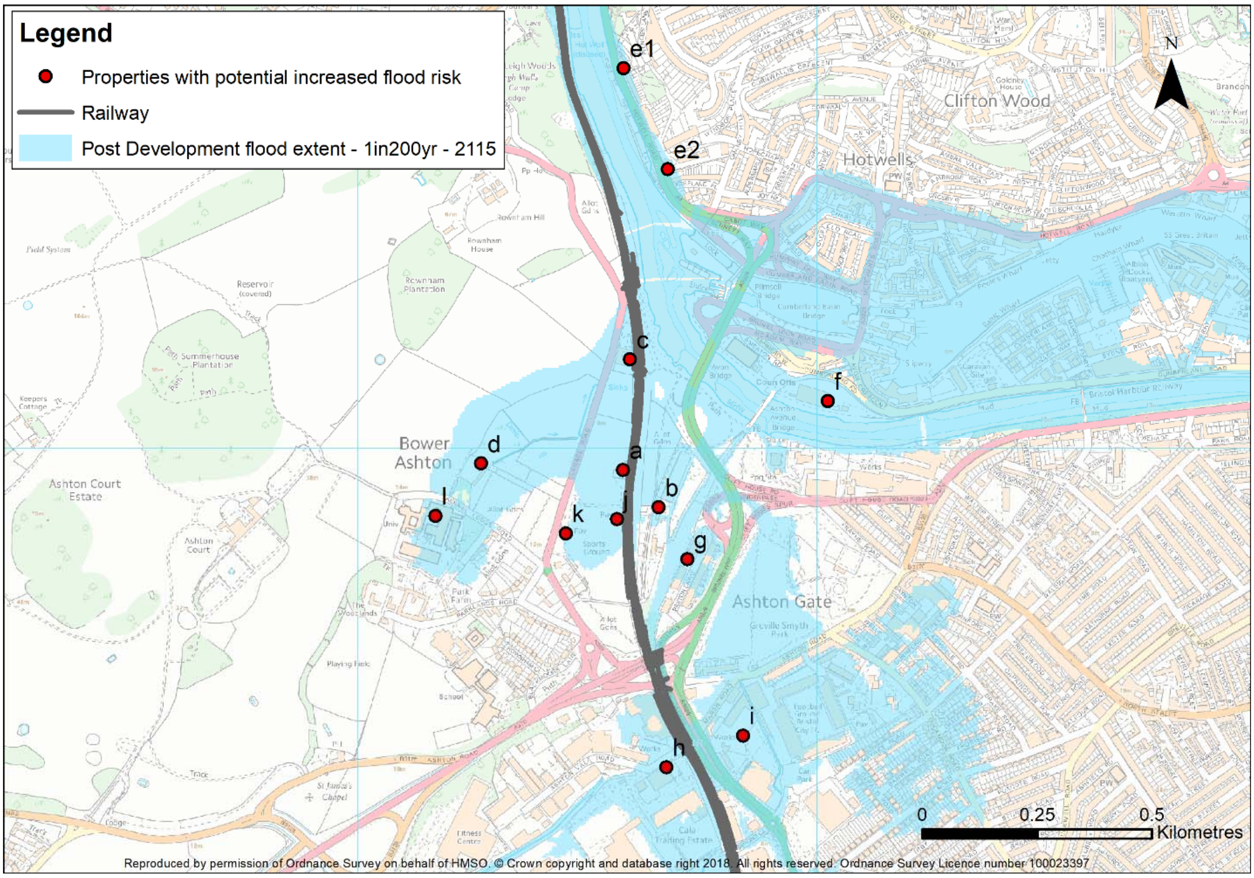


Figure 1-1: Study area and properties potentially at risk

1.2 Floodplain compensation options

North Somerset Council 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 DCO Scheme 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 DCO Scheme and was used to run the required scenarios for the FRA[4].

2.2 Modelling updates

The existing DCO Scheme 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 DCO Scheme 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 DCO 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[5] 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.

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

[5] 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.

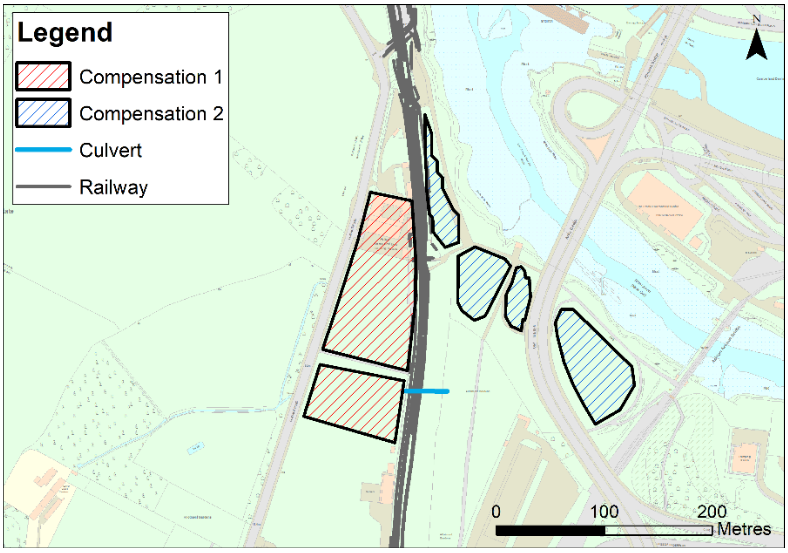


Figure 3-1: Mitigation options

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.

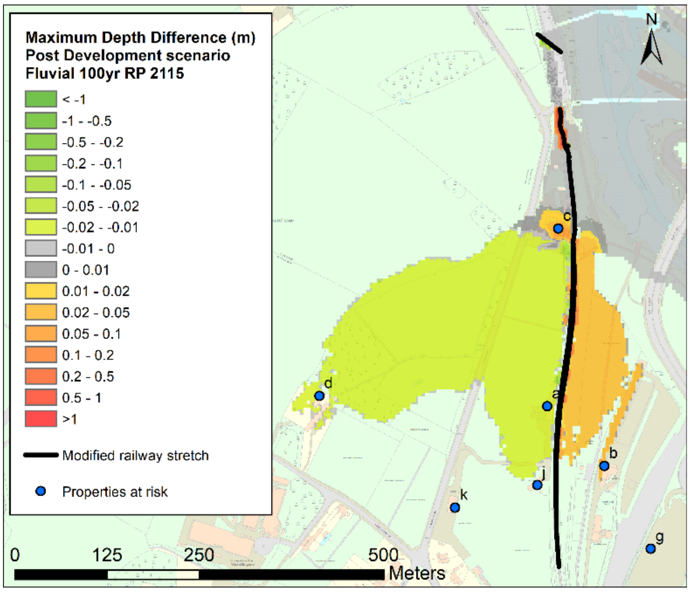


Figure 3-2: Maximum depth difference at Bower Ashton – 100-year fluvial event in 2115 – Post Development scenario

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).

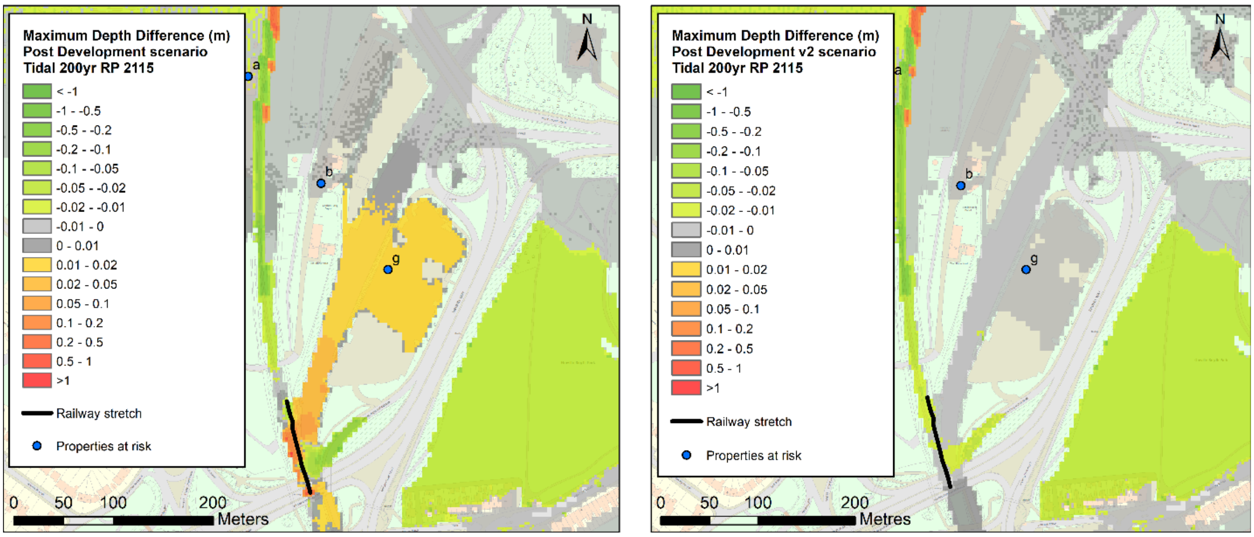


Figure 3-3: Comparison of maximum depth difference at Paxton Drive: Post Development (left) and test option with no change to railway levels in this area (right) – 100-year tidal event in 2115

3.3.4 Impacts of the DCO 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).

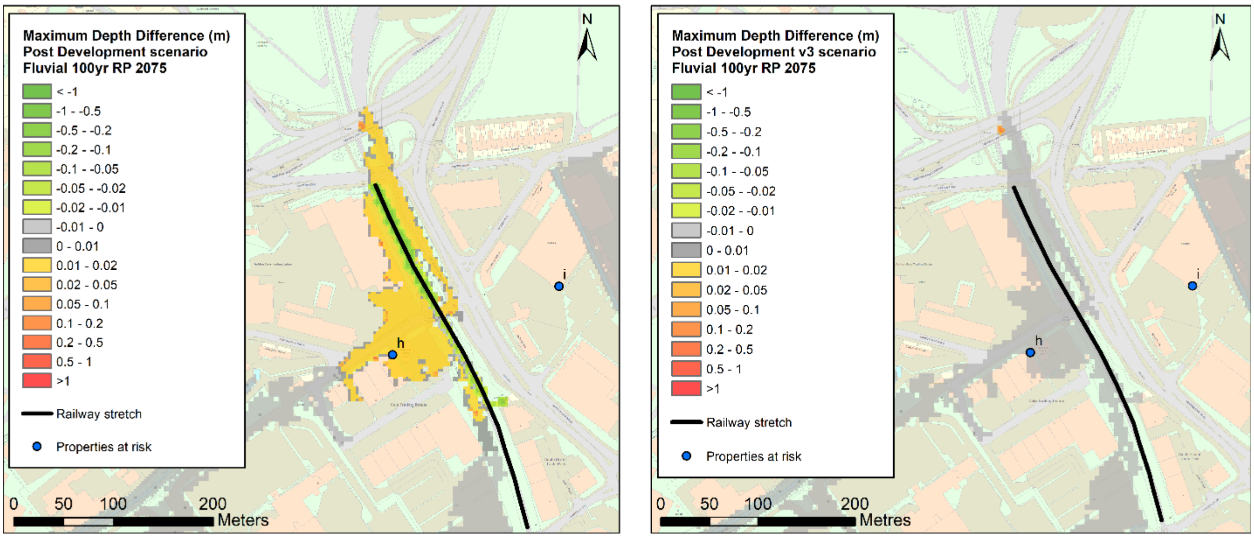


Figure 3-4: Comparison of maximum depth difference at Longmoor and Colliter's Brooks: Post Development (left) and test option with no change to railway levels in this area (right) – 100-year tidal event in 2075

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 the DCO 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.

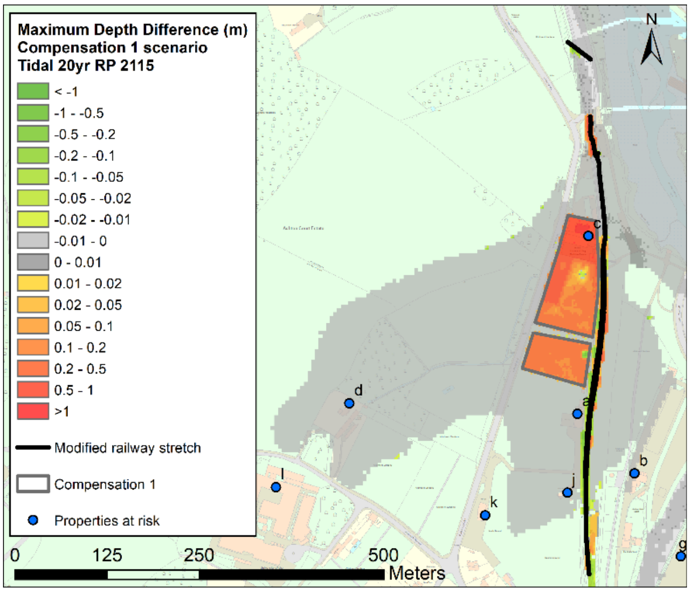


Figure 3-5: Maximum depth difference at Bower Ashton – 20-year tidal event in 2115 – Compensation 1 scenario

3.4.2 Impacts of the DCO 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.

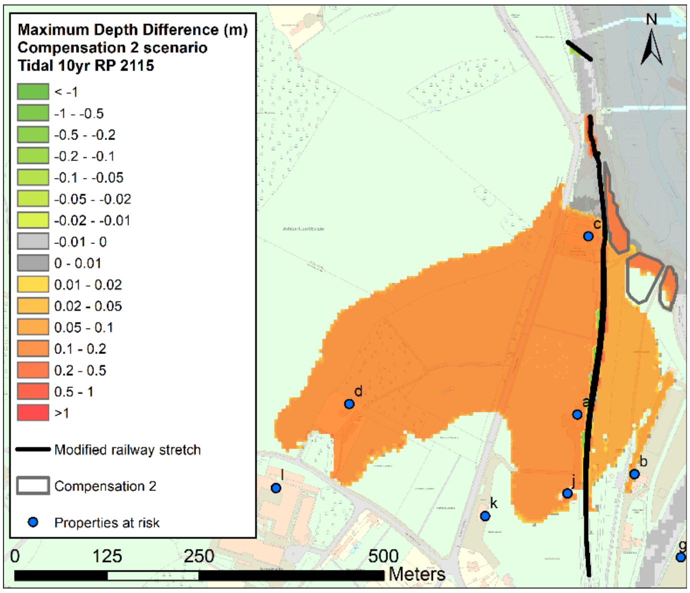


Figure 3-6: Maximum depth difference at Bower Ashton – 10-year tidal event in 2115 – Compensation 2 scenario

3.4.3 Impacts of the DCO 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).

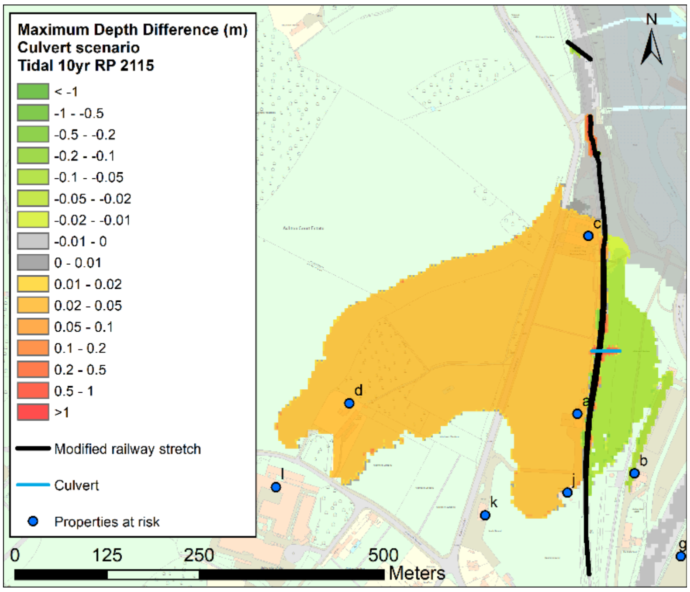


Figure 3-7: Maximum depth difference at Bower Ashton – 10 year tidal event in 2115 – Culvert scenario

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 DCO 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 DCO Scheme 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 DCO 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 DCO 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.

0	No Flood	0.001	-0.013	0.01	-0.009	0.011	No Flood	-0.013	No Flood
	No Flood	-0.003		-0.036	-0.012		No Flood	-0.095	
	No Flood	0.001		0.092	-0.008		No Flood	0.183	
	No Flood	0.001		0.158	-0.013		No Flood	0.091	
No Flood	No Flood	0.002	0.019	No Flood	0	0.001	No Flood	0.012	No Flood
	No Flood	0.004		No Flood	0.002		No Flood	0.012	
	No Flood	0.002		No Flood	0.001		No Flood	0.026	
	No Flood	0.003		No Flood	-0.004		No Flood	-0.019	
0.014	-0.009	0.001	0.049	0.012	-0.001	0.005	No Flood	0.067	No Flood
	Inside area	Inside area		Inside area	Inside area		No Flood	Inside area	
	-0.006	0.001		0.054	0		No Flood	0.09	
	-0.009	0.001		0.012	-0.004		No Flood	0.035	
No Flood	No Flood	0	No Flood	No Flood	-0.003	0.005	No Flood	-0.01	No Flood
	No Flood	0.001		No Flood	-0.002		No Flood	-0.078	
	No Flood	0		No Flood	-0.002		No Flood	0.164	
	No Flood	0		No Flood	-0.006		No Flood	0.075	
0	0	0	-0.001	0	0	-0.001	0	0	-0.001
	0	0.001		0	0.001		0	0	
	-0.001	0.001		-0.001	0.002		0	0	
	0	0.001		0	0.001		0	-0.001	
0	0	0	-0.001	0	0	-0.001	0	0	0
	0	0.001		0	0.001		0	0	
	-0.002	0.001		-0.002	0.001		0	0	
	0	0.001		0	0		0	0	
0	-0.001	0	0	-0.001	0	-0.001	No Flood	0	0
	-0.001	-0.001		-0.001	0		No Flood	0	
	-0.002	0.002		-0.002	-0.001		No Flood	0.001	
	-0.001	0		-0.001	0		No Flood	-0.001	
No Flood	No Flood	0.001	No Flood	No Flood	0.012	No Flood	No Flood	No Flood	No Flood
	No Flood	-0.002		No Flood	0.013		No Flood	No Flood	
	No Flood	0.005		No Flood	0.021		No Flood	No Flood	
	No Flood	0.001		No Flood	0.011		No Flood	No Flood	
No Flood	No Flood	-0.047	No Flood	No Flood	-0.003	No Flood	No Flood	0.002	0.013
	No Flood	-0.052		No Flood	-0.004		No Flood	0.003	
	No Flood	-0.015		No Flood	-0.002		No Flood	0.003	
	No Flood	-0.039		No Flood	-0.005		No Flood	0.003	
No Flood	No Flood	-0.082	No Flood	No Flood	-0.007	No Flood	No Flood	0.002	No Flood
	No Flood	-0.096		No Flood	-0.008		No Flood	0.003	
	No Flood	-0.017		No Flood	-0.006		No Flood	0.003	
	No Flood	-0.061		No Flood	-0.009		No Flood	0.003	
No Flood	No Flood	0.001	No Flood	No Flood	0.001	0.006	No Flood	No Flood	No Flood
	No Flood	0.002		No Flood	0.004		No Flood	No Flood	
	No Flood	0.002		No Flood	0.002		No Flood	No Flood	
	No Flood	0.002		No Flood	-0.002		No Flood	No Flood	
No Flood	No Flood	No Flood	No Flood	No Flood	0	No Flood	No Flood	No Flood	No Flood
	No Flood	No Flood		No Flood	0.001		No Flood	No Flood	
	No Flood	No Flood		No Flood	0.001		No Flood	No Flood	
	No Flood	No Flood		No Flood	-0.003		No Flood	No Flood	
No Flood	No Flood	No Flood	No Flood	No Flood	0.001	No Flood	No Flood	No Flood	No Flood
	No Flood	No Flood		No Flood	0.002		No Flood	No Flood	
	No Flood	No Flood		No Flood	0.002		No Flood	No Flood	
	No Flood	No Flood		No Flood	-0.002		No Flood	No Flood	

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:

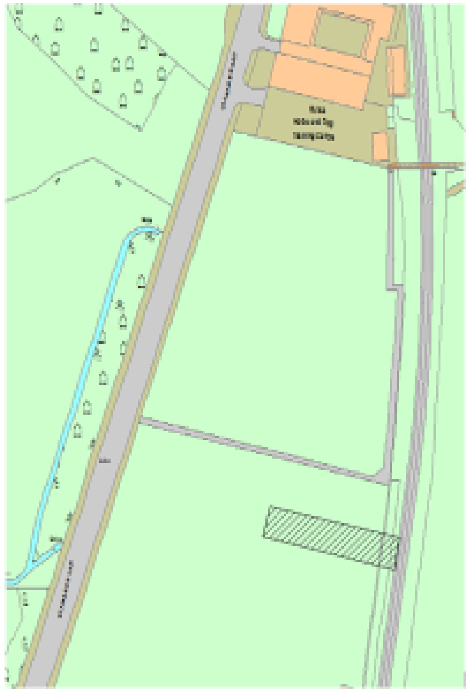
Simulation	Description
Post Development with ramp	Current DCO Scheme railway design with representation of proposed maintenance access ramp within the Clanage Road maintenance compound (shown in Figure 4-1)
Post Development with ramp + Compensation 1 v5	As above with compensation areas as shown in figure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

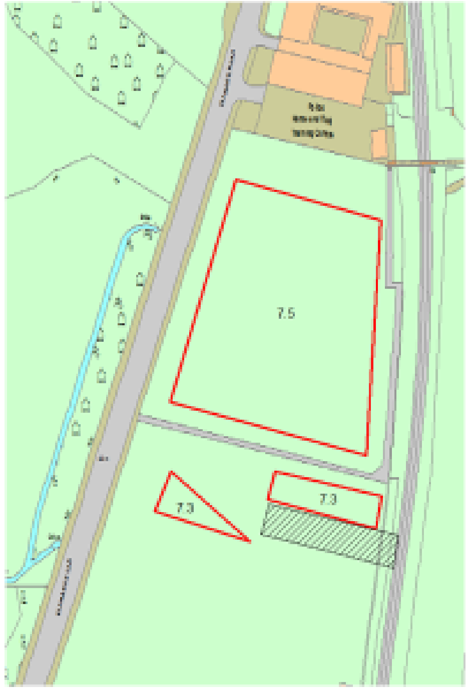


The proposed ramp causes an increase in flood risk at properties a (nursery north of sports ground), b (south east of allotments), c (former police dog/horse centre), d (north of Kennel Lodge road) and j (City Maze)

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 DCO Scheme design, accounting for the proposed ramp (shown as hatched polygon)

Post Development with ramp + Compensation 1 v5

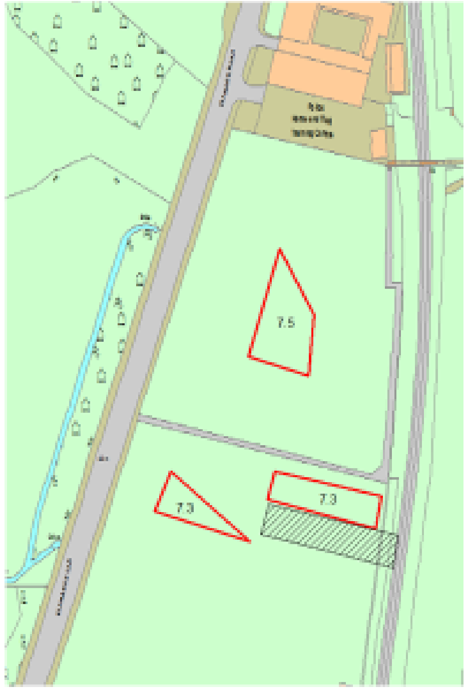


With the addition of Compensation 1 v5, the risk at property a is reduced but still +0.006m for the 200yr event. The risk is reduced also reduced at properties c, d and j for the 200yr event. No change at property b.

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 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 DCO Scheme 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 DCO Scheme 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)

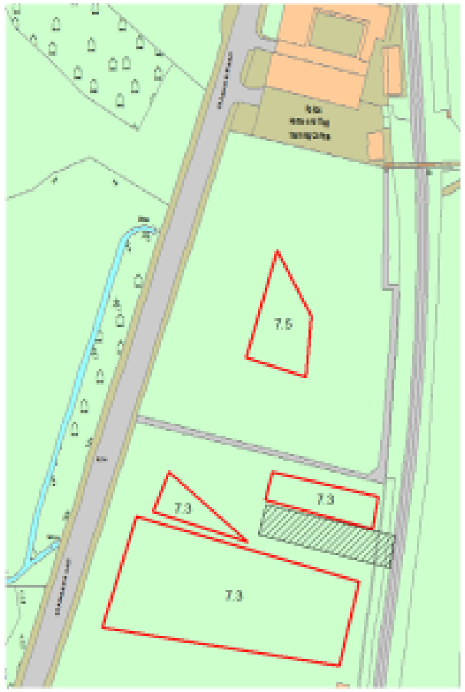
Post Development with ramp + Compensation 1 v7

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

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 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 DCO Scheme 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.

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 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 DCO Scheme 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 DCO Scheme 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:

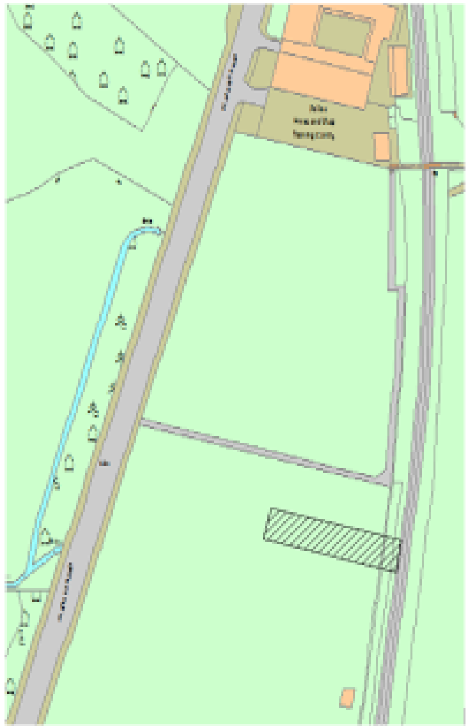
2075 events

- 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

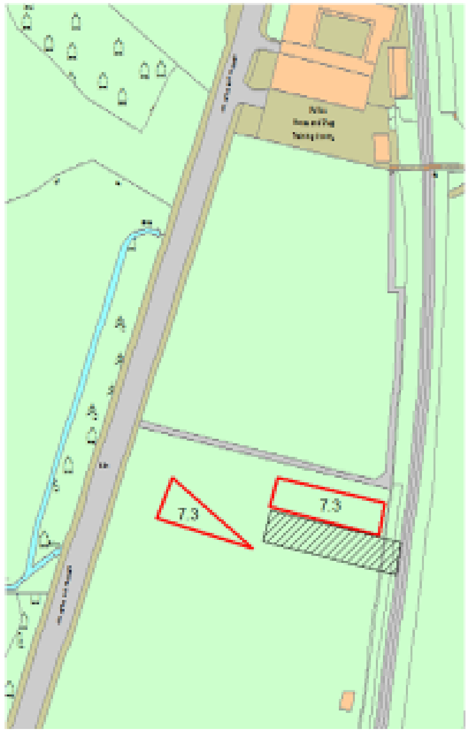


The presence of the new ramp causes an increase of flood levels at property **a** (nursery north of sports ground at Bower Ashton)

		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	
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

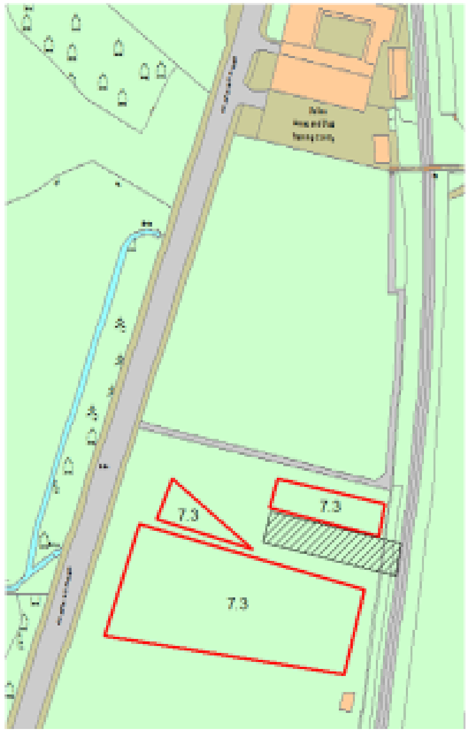


With the inclusion of Compensation v1, the risk at property a is reduced but the change in flood level is still +0.005m in the 20yr event in 2075

		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

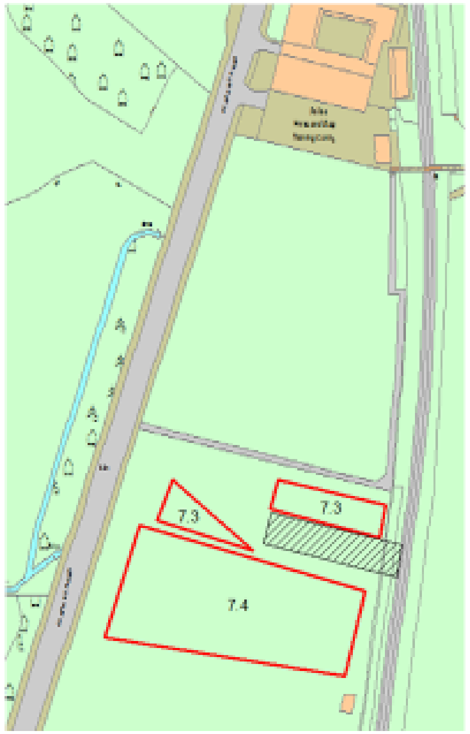


Compensation with an additional storage area south of the ramp reduces the impact at property **a** in all events except for the 200yr tidal event 2115, where the change in peak flood level is +0.009m

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

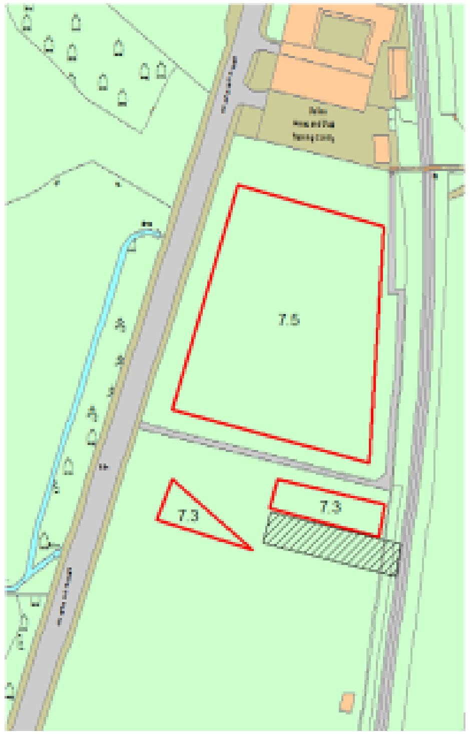


A less deep storage area south of the ramp (ground level lowered to 7.4m AOD instead of 7.3m AOD) still has an increased impact at property **a** in a 200yr Tidal event in 2115

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 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

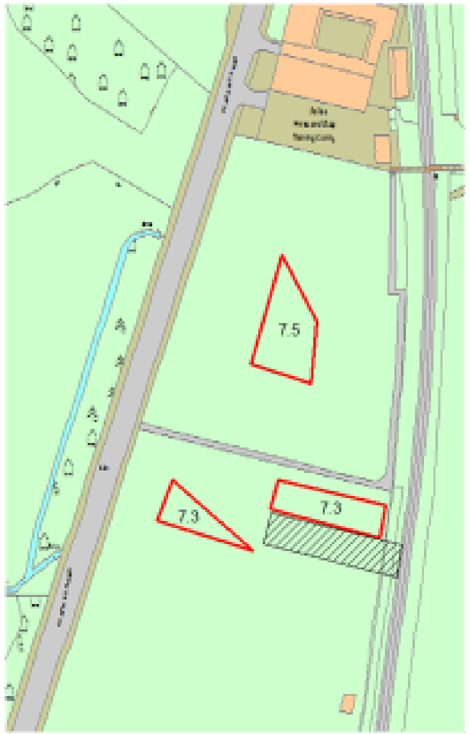


Compensation with an additional large storage area in the future Caravan Club area reduces the impact at property a in all the events

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



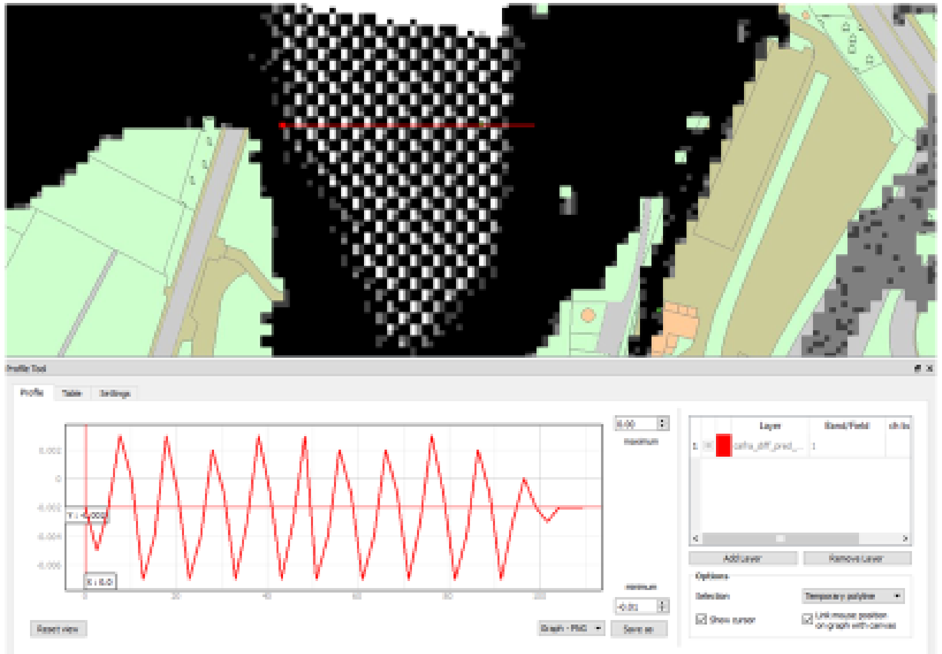
The impact at property a are mitigated also with a limited storage area inside the future Caravan Club area

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	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
		Change in peak flood level (mAOD) for simulated events										
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 modelling 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 DCO Scheme 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 DCO Scheme 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 the 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 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.

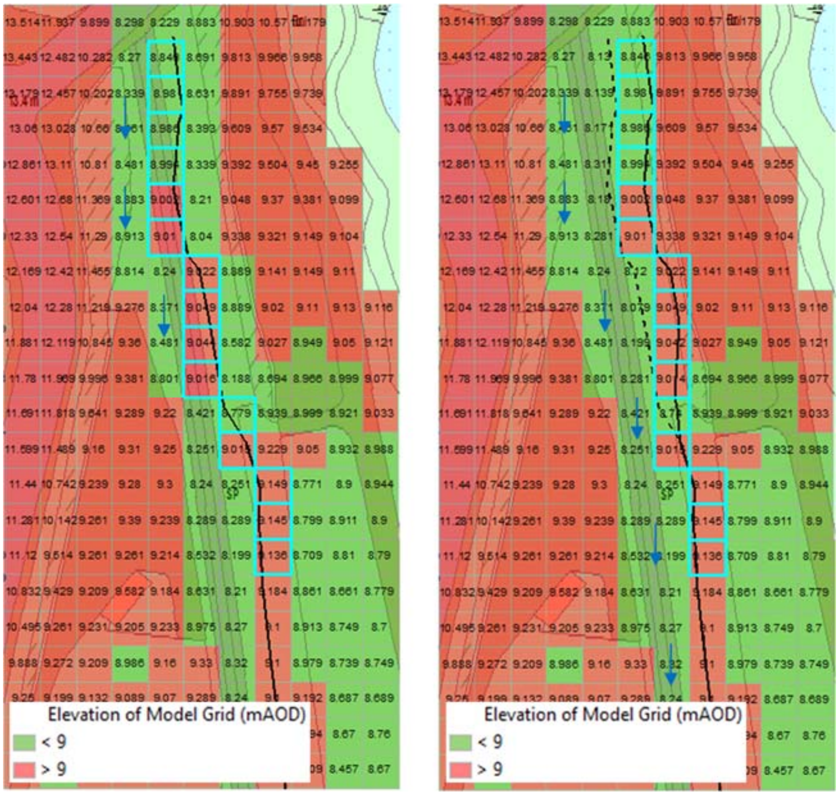


Figure 6-1: Comparison of the elevation model grid between original model and updated model with the first stretch of the zline shifted to east to avoid flow blockages

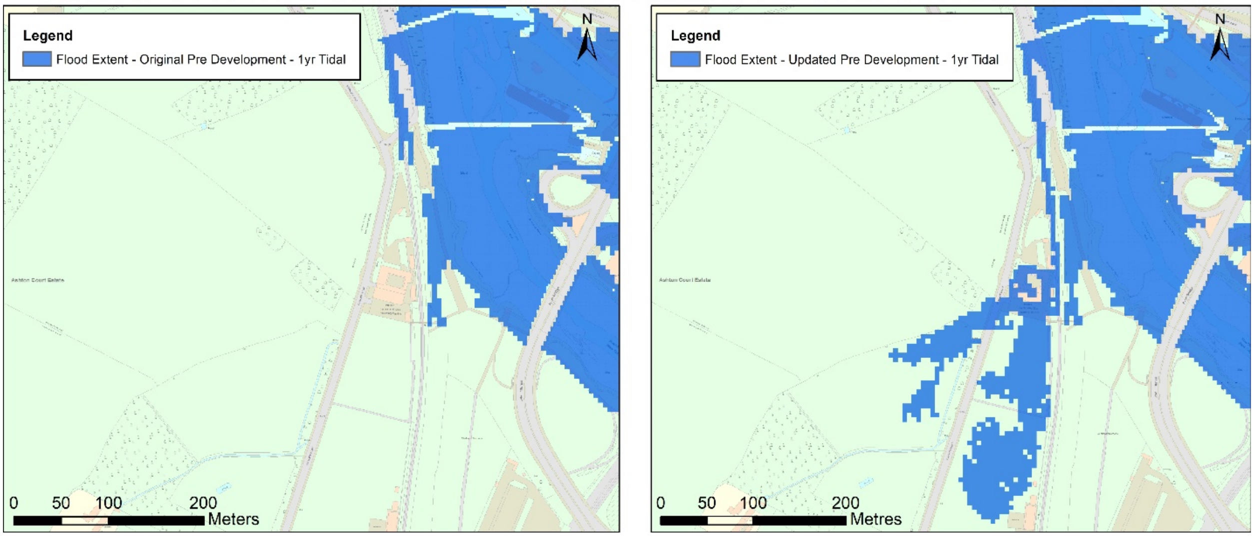


Figure 6-2: Comparison of flood extents between original and updated model – 1yr tidal event in 2075

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. 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.

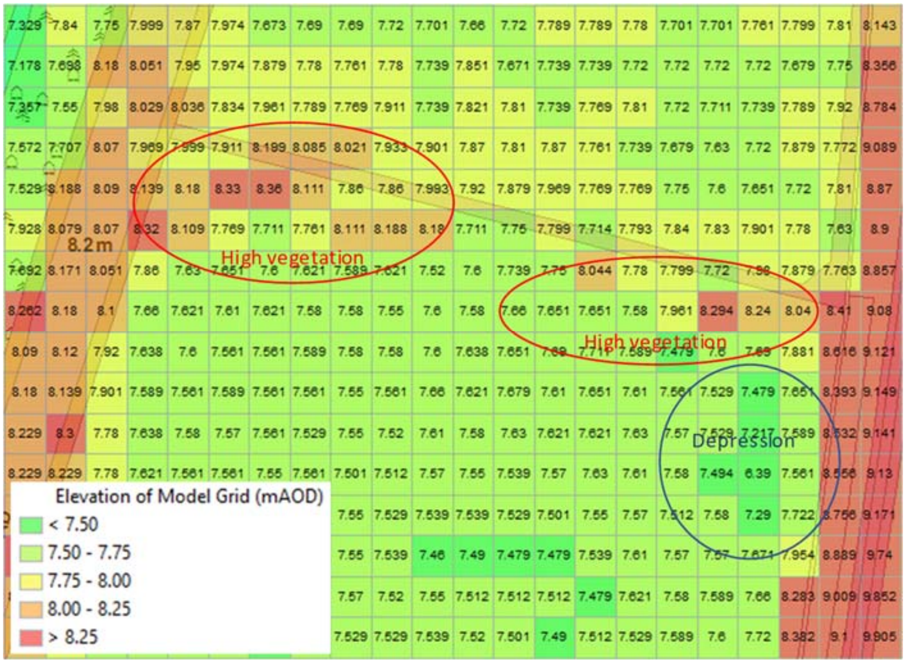


Figure 6-3: Model elevation grid of Clanage Road compound based on LiDAR levels

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), with LiDAR levels higher than survey levels (by approximately 0.1m on average).

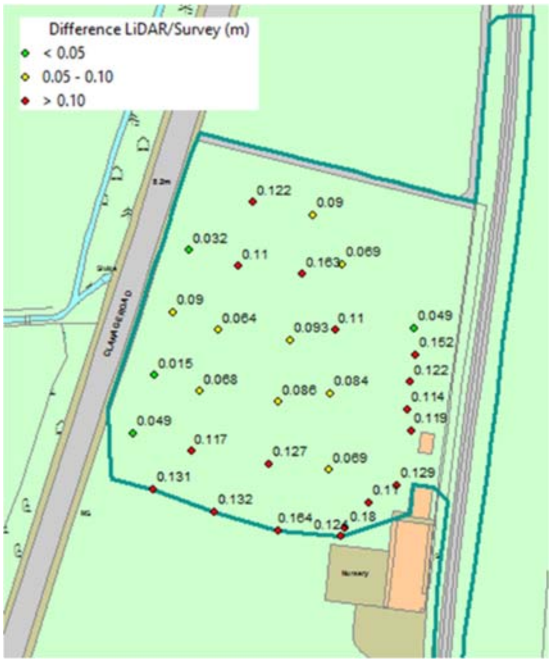


Figure 6-5: Difference between LiDAR level data and topographic survey within the Clanage Road compound

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.

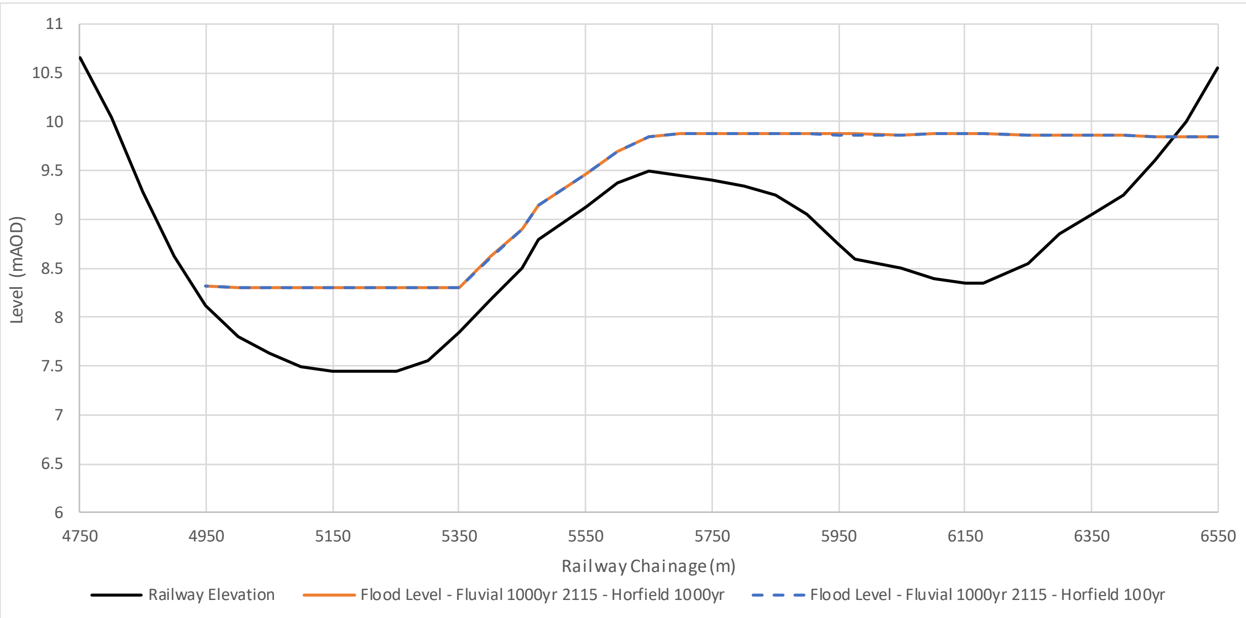


Figure 6-6: Maximum flood levels along the railway using Horfield inflows 1000yr and 100yr

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

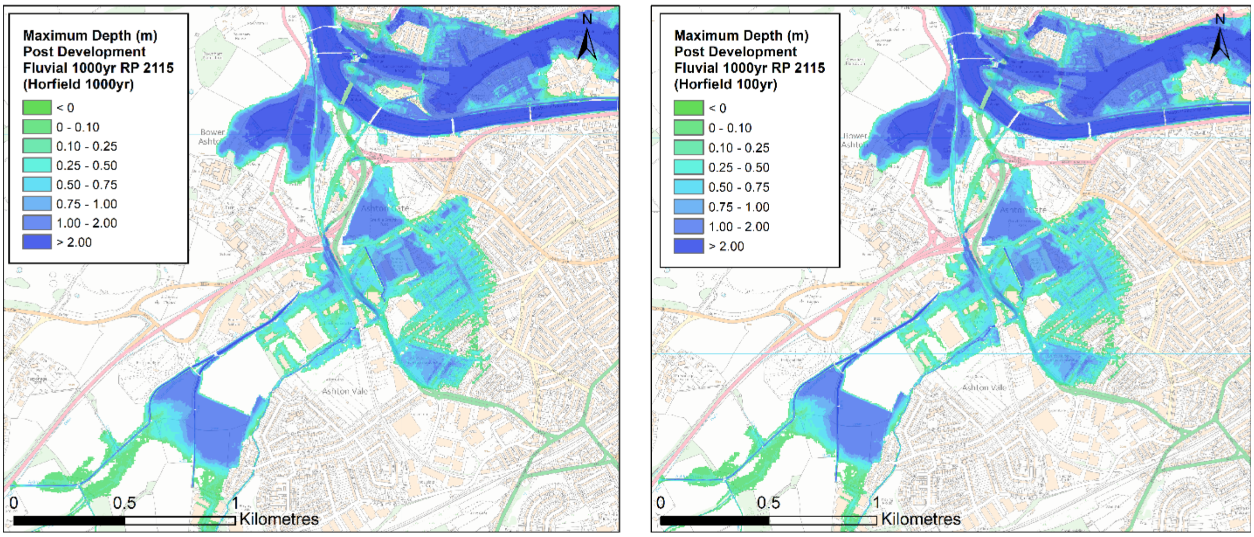


Figure 6-7: Maximum flood depth in the study area using Horfield inflows 1000yr and 100yr

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

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.

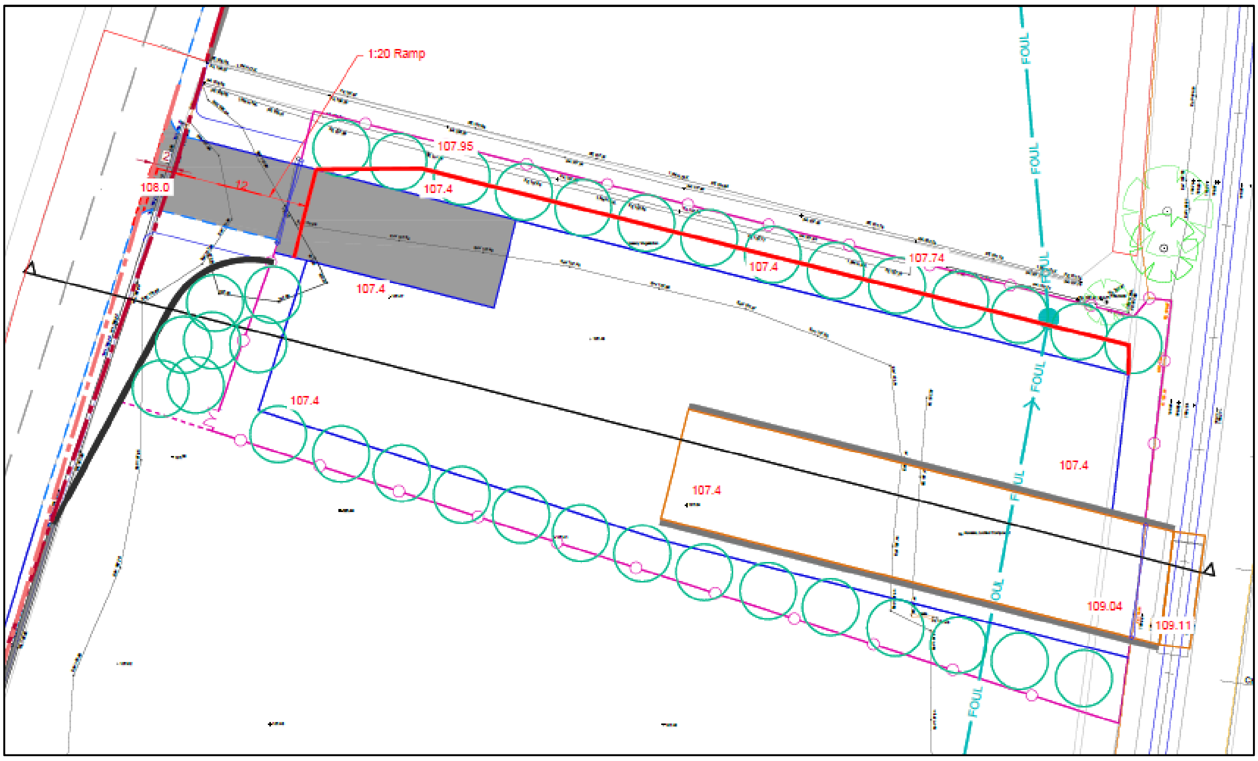


Figure 6-8: Design of the Clanage Road compound including two access ramps

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 DCO Scheme 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).

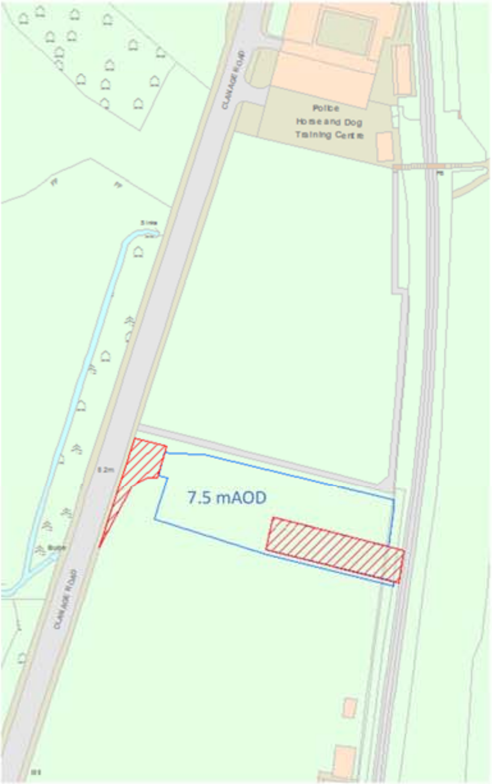
Based on these results, the option with compound ground levels lowered to 7.4mAOD (Ramps version 2) is preferred for the following reasons.

- 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)



		Change in peak flood level (mAOD) for simulated events			
Property	Option	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

		Change in peak flood level (mAOD) for simulated events			
Property	Option	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. Tide and fluvial boundaries in future epochs corrected to latest Climate Change allowances

The climate change allowances applied in the DCO Scheme FRA modelling tidal and fluvial boundaries (i.e. applied in the earlier sections of this technical note) have been superseded by current climate change guidance, which was updated in December 2019[6]. In addition, the Environment Agency's Coastal Flood Boundary dataset was updated in 2018 (denoted CFB2018).

Further modelling has therefore been undertaken, applying revised tidal and fluvial boundaries, to demonstrate that the preferred compensation option (Ramps version 2) still provides mitigation for the impacts of the access ramps when the current climate change allowances and CFB2018 Extreme Water Levels (EWLs) are applied.

The current climate change guidance states that:

- Upper end peak river flow allowances should be used for essential infrastructure in flood zones 2 or 3a (i.e. +70% in both 2075 and 2115 for the DCO Scheme FRA).

- Central and upper end peak rainfall allowances should be used in flood risk assessments to understand the range of impact (i.e. +20% and +40% for central and upper end respectively in both 2075 and 2115 for the DCO Scheme FRA.)

Revised simulations have been undertaken as follows.

- 200 year River Avon tidal flood event in 2075 and 2115 applying revised sea level rise allowances and river flow allowances (upper end +70%). For the Longmoor and Colliter's Brooks catchments (small catchments) rainfall allowances (upper end +40%) are applied rather than river flow allowances, as the guidance specifies that rainfall allowances should be applied for catchments less than 5 km^2. As the Longmoor and Colliter's Brooks catchments are only slightly larger (catchment areas 8.6 km^2 and 5.4 km^2 respectively) the rainfall allowances are considered more representative than the river flow allowances.

- 25, 50 and 75 year fluvial events in Longmoor and Colliter's Brooks in 2075 and 2115 applying revised rainfall uplifts in the Longmoor and Colliter's Brooks catchment (upper end +40% allowance applied). The revised river flow allowances were not applied in the other rivers contributing to River Avon flow, as these design runs are already conservative with respect to design flows in the other rivers. The design runs assume the same design return period event in all rivers, which is a significantly rarer event than the design event occurring in the Longmoor and Colliter's brooks catchments only.

The simulations undertaken with updated tidal and fluvial boundaries are summarised in Table 7-1. These simulations have been re-run for both the Pre-Development (PreD_v6) and the Post-Development (Ramps_v2) scenarios.

In order to increase the model stability of these additional runs, all the simulations reported in Table 7-1 have been run using the latest Tuflow build (version 2018-03-AE) and Flood Modeller build (version 4.6) and the 1D and 2D timesteps have been halved (0.5s for the 1D and 0.5s/1s for the 2D domains).

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

Event description	Model tag*	Tidal boundary	Fluvial boundary
Tidal – 200 year return period in 2075	new_BD_v2	200 year return period corrected to latest SLR allowances (+0.05m adjustment)	Same fluvial return period as before (6 year), but revised climate change allowances: + 40% for Longmoor and Colliter's Brooks inflows +70% all other fluvial inflows
Tidal – 200 year return period in 2115		200 year return period corrected to latest SLR allowances (+0.19m adjustment)	
Fluvial – 25 year return period in 2075	new_BD_v1	Same tidal condition as previously simulated (base tide) – adjusted according to current sea level rise allowances (+0.137m adjustment)	Apply +40% climate change allowance for Longmoor and Colliter's Brooks inflows, and no change for other inflows (+25%)
Fluvial – 25 year return period in 2115		Same tidal condition as previously simulated (base tide) – adjusted according to current sea level rise allowances (+0.275m adjustment)	
Fluvial – 50 year return period in 2075		Same tidal condition as previously simulated (base tide) – adjusted according to current sea level rise allowances (+0.137m adjustment)	
Fluvial – 50 year return period in 2115		Same tidal condition as previously simulated (base tide) – adjusted according to current sea level rise allowances (+0.275m adjustment)	
Fluvial – 75 year return period in 2075		Same tidal return period as previously simulated (2 year) – adjusted according to CFB2018 EWLs and current sea level rise allowances (+0.040m adjustment)	
Fluvial – 75 year return period in 2115		Same tidal return period as previously simulated (2 year) – adjusted according to CFB2018 EWLs and current sea level rise allowances (+0.180m adjustment)	

* included for ease of reference with the model log i.e. as referred to in the model log

Table 7-1: Simulations with updated tide and fluvial boundaries applying latest Climate Change allowances

Table 7-2 compares EWLs applied in DCO Scheme FRA tidal River Avon modelling with up to date EWLs, applying the current CFB2018 dataset and current climate change guidance. The differences between the two set of EWLs have been used to adjust the boundaries, as a constant level shift, when undertaking revised simulations.

	CFB 2018 EWLs adjusted for future year (mAOD)					EWLs applied in DCO Scheme tidal River Avon modelling (mAOD)			Differences: EWLs applied in DCO Scheme modelling minus CFB2018 EWLs adjusted with UKCP18 climate change allowances (m)			
Return period (years)	Bas e year 2017	adjusted to 2075 UKCP18 Higher central	adjusted to 2075 UKCP18 Upper end	adjusted to 2115 UKCP18 Higher central	adjusted to 2115 UKCP18 Upper end	2015	2075	2115	2075: DCO Scheme EWLs – CFB2018 EWLs with Higher central adjustment	2075: DOC Scheme EWLs – CFB2018 EWLs with Upper end adjustment	2115: DCO Scheme EWLs – CFB2018 EWLs with Higher central adjustment	2115: DCO Scheme EWLs – CFB2018 EWLs with Upper end adjustment
2	8.22	8.71	8.85	9.20	9.54	8.30	8.81	9.36	0.10	-0.04	0.15	-0.18
5	8.37	8.86	9.00	9.35	9.69	8.46	8.97	9.52	0.11	-0.03	0.16	-0.17
10	8.49	8.98	9.12	9.47	9.81	8.58	9.09	9.64	0.11	-0.03	0.16	-0.17
20	8.61	9.10	9.24	9.59	9.93	8.70	9.21	9.76	0.11	-0.03	0.16	-0.17
50	8.79	9.28	9.42	9.77	10.11	8.88	9.39	9.94	0.11	-0.03	0.16	-0.17
200	9.07	9.56	9.70	10.05	10.39	9.14	9.65	10.20	0.09	-0.05	0.14	-0.19
1000	9.43	9.92	10.06	10.41	10.75	9.46	9.97	10.52	0.05	-0.09	0.10	-0.23

Table 7-2: Comparison of EWLs applied in DCO Scheme tidal River Avon modelling with EWLs applying the current CFB2018 dataset and current climate change guidance (https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances)

Table 7-3 lists the differences in pre and post development peak flood levels for the simulated 200 year return period tidal events in 2075 and 2115 applying the current climate change allowances. The differences listed in Table 7-3, and the flood depth difference maps included in Appendix E, show that the proposed floodplain compensation within the Clanage Road compound site fully mitigates for the proposed access ramps with no offsite impacts.

The fluvial simulations undertaken with current climate change allowances (i.e. flood risk to the railway from Longmoor and Colliter's Brooks) indicate that the frequency of flooding in 2075 and 2115 will be approximately once every 50 to 75 years on average (see Appendix E).

	Differences in simulated pre and post development peak flood levels applying latest climate change allowances (m) (Post development minus pre development level)	
Location	**200yr Tidal event 2075**	**200yr Tidal event 2115**
a	0.001	0.000
b	0.001	0.000
c	0.001	0.000
d	0.001	0.000
e1	0.000	0.000
e2	-0.001	0.000
f	0.000	0.000
g	0.000	0.000
h	0.000	0.000
i	No Flood	0.000
j	0.000	0.000
k	No Flood	0.000
l	No Flood	0.000

Table 7-3: Differences in simulated pre and post development peak flood levels applying latest climate change allowances

8. Applying peak river flow Climate Change allowances rather than rainfall Climate Change allowances in Longmoor and Colliter's Brooks fluvial boundaries

8.1 Introduction

For small catchments (area less than 5 km^2), the current climate change guidance (updated in December 2019 with minor correction in March 2020) states that the allowances specified for rainfall intensity are considered more appropriate than those specified for river flows. As the Longmoor and Colliter's Brooks catchment areas are only slightly larger (Flood Estimation Handbook catchment areas 8.6 km^2 and 5.4 km^2 respectively) the peak rainfall allowances are considered more representative for these watercourses than the peak river flow allowances, which are considered representative of larger catchments.

Further to the simulations detailed in Section 7 applying current CFB2018 EWLs and current rainfall allowances in Longmoor and Colliter's Brooks, simulations were also undertaken applying the current Upper end peak river flow allowances (+70% in both 2075 and 2115) rather than peak rainfall allowances (+40% in both 2075 and 2115) in Longmoor and Colliter's Brooks.

These simulations have been undertaken as "upper limit" sensitivity tests to derive an upper limit on the frequency of future flooding of the proposed railway due to flooding in the Longmoor and Colliter's Brooks catchment, and to assess whether there are simulated offsite impacts with the higher river flow allowances applied.

8.2 Simulations undertaken

Longmoor and Colliter's Brooks fluvial event simulations have been undertaken as follows.

- 50, 75 and 100-year return period fluvial events in Longmoor and Colliter's Brooks in 2075 and 25, 50, 75 and 100-year return period fluvial events in 2115 applying current peak river flow allowances in the Longmoor and Colliter's Brooks catchment (upper end +70% allowance applied). The +70% river flow allowances were not applied in the other rivers contributing to River Avon flow (for the other rivers the CAFRA model +25% allowances were retained), as these design runs are already conservative with respect to design flows in the other rivers. The design runs assume the same design return period event in all rivers, which is a significantly rarer event than the design event occurring only in the Longmoor and Colliter's brooks catchments.

The simulations undertaken, and the tidal and fluvial boundaries applied, are summarised in Table 8-1, which also includes a model tag for ease of reference with the model log i.e. as referred to in the model log. These simulations have been re-run for both the Pre-Development (PreD_v6) and the Post-Development (Ramps_v2) scenarios.

The simulations have been run using TUFLOW version 2018-03-AE and Flood Modeller version 4.6 and the 1D and 2D timesteps were:

- 1 in 25 years - 0.5 s for 1D domain and 0.5 or 1 s for 2D domains
- 1 in 50 years - 0.5 s for 1D domain and 0.5 or 1 s for 2D domains
- 1 in 75 years - 0.5 s for 1D domain and 0.5 or 1 s for 2D domains
- 1 in 100 years - 1 s for 1D domain and 1 or 2 s for 2D domains

<table>
<tr><th>Event description</th><th>Model tag*</th><th>Tidal boundary</th><th>Fluvial boundary</th></tr>
<tr><td>Fluvial – 25 year return period in 2115</td><td>new_BD_v2</td><td>Same tidal condition as simulated in Section 7 (new_BD_v1)</td><td rowspan="9">Apply +70% climate change allowance for Longmoor and Colliter's Brooks inflows, and no change for other inflows (+25%)</td></tr>
<tr><td>Fluvial – 50 year return period in 2075</td><td rowspan="2">new_BD_v2</td><td>Same tidal condition as simulated in Section 7 (new_BD_v1)</td></tr>
<tr><td>Fluvial – 50 year return period in 2115</td><td>Same tidal condition as simulated in Section 7 (new_BD_v1)</td></tr>
<tr><td>Fluvial – 75 year return period in 2075</td><td rowspan="2">new_BD_v2</td><td>Same tidal condition as simulated in Section 7 (new_BD_v1)</td></tr>
<tr><td>Fluvial – 75 year return period in 2115</td><td>Same tidal condition as simulated in Section 7 (new_BD_v1)</td></tr>
<tr><td>Fluvial – 100 year return period in 2075</td><td rowspan="2">nBD_v3</td><td>Same tidal return period as previously simulated (2 year) in Sections 3 to 5 – adjusted according to CFB2018 EWLs and current sea level rise allowances (Section 6 tidal boundary adjusted by +0.040m)</td></tr>
<tr><td>Fluvial – 100 year return period in 2115</td><td>Same tidal return period as previously simulated (2 year) in Sections 3 to 5 – adjusted according to CFB2018 EWLs and current sea level rise allowances (Section 6 tidal boundary adjusted by +0.180m)</td></tr>
</table>

* included for ease of reference with the model log i.e. as referred to in the model log

Table 8-1: Simulations with +70% peak river flow allowances applied in Longmoor and Colliter's Brooks

8.3 Results

8.3.1 Frequency of flooding

The fluvial simulations undertaken in Section 8.2 provide an upper estimate of the frequency of flooding of the DCO Scheme at the crossing of Longmoor and Colliter's Brooks of approximately once every 50 to 75 years on average in 2075 and once every 25 to 50 years on average in 2115 (see flood maps in Appendix F), applying the +70% peak river flow allowance in 2075 and 2115. This compares to approximately once every 50 to 75 years on average in both 2075 and 2115 applying +40% rainfall allowances in Longmoor and Colliter's Brooks (Section 7).

8.3.2 Offsite impacts

Table 8-2 lists the differences in pre and post development peak flood levels for the simulated Longmoor and Colliter's Brooks fluvial events in 2075 and 2115 applying the current peak river flow allowances. The differences listed in Table 8-2, and the flood depth difference maps included in Appendix F, show that for these "upper limit" sensitivity test fluvial simulations, the proposed floodplain compensation within the Clanage Road compound site fully mitigates for the proposed access ramps with no offsite impacts.

8.4 Conclusions

Applying +70% river flow allowances as an upper limit, rather than +40% rainfall allowances, does not qualitatively change the assessed future frequency of flooding of the DCO Scheme at the crossing of Longmoor and Colliter's Brooks (the +70% results show a slight increase in simulated frequency of flooding in 2115 compared to the +40% simulations), and does not change the conclusion that the Clanage Road compound site fully mitigates for the proposed access ramps with no offsite impacts. The results in Section 7, applying +40% river flow allowances, are considered more representative of the Longmoor and Colliter's Brooks catchments due to their small catchment sizes (Section 8.1).

Differences in simulated pre and post development peak flood levels applying latest climate change allowances (m) (Post development minus pre development level)							
Location	50yr Fluvial event 2075	75yr Fluvial event 2075	100yr Fluvial event 2075	25yr Fluvial event 2115	50yr Fluvial event 2115	75yr Fluvial event 2115	100yr Fluvial event 2115
a	No Flood	-0.010	-0.010	No Flood	No Flood	0.000	0.001
b	No Flood	No Flood	No Flood	No Flood	No Flood	0.001	0.000
c	No Flood	0.000	0.000	No Flood	No Flood	0.000	0.001
d	No Flood	No Flood	No Flood	No Flood	No Flood	0.000	0.001
e1	No Flood	No Flood	No Flood	No Flood	No Flood	0.000	0.000
e2	No Flood	0.000	0.000	No Flood	No Flood	0.000	0.000
f	No Flood	0.000	0.000	No Flood	No Flood	0.000	0.001
g	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood
h	No Flood	0.000	-0.001	No Flood	0.000	0.000	-0.001
i	No Flood	0.000	0.000	No Flood	No Flood	0.000	-0.001
j	No Flood	No Flood	No Flood	No Flood	No Flood	0.000	0.001
k	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood
l	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood	No Flood

Table 8-2: Differences in simulated pre and post development peak flood levels applying +70% peak river flow allowances in Longmoor and Colliter's Brooks

9. Conclusions and implications for the DCO Scheme design

Note – points 1 to 7 below refer to the earlier DCO Scheme design, which has been revised for the DCO application to eliminate offsite impacts, as described in points 8 and 9 below. Points 10 and 11 are with respect to the revised design (as in the DCO application).

9.1 Conclusions – before the design was modified to retain the existing railway elevations and footprint in the River Avon floodplain in the Bower Ashton/Ashton Gate area

1. The updated DCO Scheme 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 DCO 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) are 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 DCO 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 (in June 2019 DCO Scheme design[7] results in impacts on flood risk to properties that cannot be fully mitigated by realistic floodplain compensation options.

9.2 DCO Scheme design changes to retain the existing railway elevations and footprint in the River Avon floodplain in the Bower Ashton/Ashton Gate area

8. To prevent impacts of the DCO Scheme on flood risk elsewhere (including to properties), the design was 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 DCO Scheme railway works within the River Avon floodplain, as there is no associated change in floodplain storage.

9. 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 be minor adjustments to existing alignment to meet railway design standards, but there will be no net increase in displaced floodplain by the railway).

[7] i.e. with a proposed increase in railway levels at Bower Ashton by typically 150mm to 200mm – this design has since been updated to retain existing railway elevations and footprint in the River Avon floodplain in the Bower Ashton/Ashton Gate area

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

9.3 Conclusions – after the design was modified to retain the existing railway elevations and footprint in the River Avon floodplain in the Bower Ashton/Ashton Gate area

10. 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 the DCO Scheme topographic survey datum. This option is considered to fully mitigate the impact of the ramps on flood risk elsewhere (Section 7 and Section 8).

11. For small catchments (area less than 5 km^2), the current climate change guidance (updated in December 2019 with minor correction in March 2020) states that the allowances specified for rainfall intensity are considered more appropriate than those specified for river flows. As the Longmoor and Colliter's Brooks catchment areas are only slightly larger (Flood Estimation Handbook catchment areas 8.6 km^2 and 5.4 km^2 respectively) the peak rainfall allowances are considered more representative for these watercourses than the peak river flow allowances, which are considered representative of larger catchments. The simulated frequency of flooding of the DCO Scheme at its crossing of Longmoor and Colliter's Brooks is once every 50 to 75 years on average in both 2075 and 2115 applying +40% rainfall allowances in Longmoor and Colliter's Brooks (Section 7). Applying the +70% peak river flow allowance in 2075 and 2115 provides an upper estimate of the frequency of flooding of the DCO Scheme railway at the crossing of Longmoor and Colliter's Brooks of approximately once every 50 to 75 years on average in 2075 and once every 25 to 50 years on average in 2115 (Section 8).

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

APPENDIX E: Flood depth difference maps - Tide and fluvial boundaries in future epochs updated with latest (published in December 2019) Climate Change allowances

APPENDIX F: Flood depth difference maps - Longmoor and Colliter's Brooks fluvial events applying +70% peak river flow allowances in Longmoor and Colliter's Brooks (instead of +40% rainfall allowances)

Note – only the final flood maps (App D above) are included in the DCO Application 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, and Appendices E and F were completed after the DCO application.