Rother Valley Railway

Approval in Principle: A21 Level Crossing and Mill Stream Flood Relief Culvert

Document Number: 239025-ARP-XX-XX-FM-CS-0001

Issue 2

1	**HIGHWAY DETAILS**
	1.1 Type of Highway Over: A21 (single carriageway) Under: N/A
	1.2 Permitted traffic speed Over: 40mph, increasing to 60mph immediately south Under: N/A
	1.3 Existing restrictions Existing culvert structure in place (A21/72.90 structure key 15-685). Proposed level crossing runs parallel and adjacent to culvert beneath A21. For details of the existing structure refer to Section 3. Proposed works will not alter culvert structure but will place a new reinforced earth embankment alongside headwalls. No existing weight restrictions
2	**SITE DETAILS**
	2.1 Obstacles crossed Current: The A21 crosses perpendicular to the existing Mill Stream Flood Channel Proposed: The level crossing passes over the A21 approximately 4 metres north of the existing Mill Stream Flood Channel

2.2 Existing structure details

Structure Name	Mill Stream Flood Relief Culvert
Structure Number	(A21/72.90)
Structure Key (not Scotland)	15-685
Date Commissioned	1987
Obstacles Crossed	A21 crosses culvert

3 PROPOSED STRUCTURE

3.1 Description of structure and design working life

3.1 Description of structure and design working life. The level crossing will comprise two pre-cast concrete modules made by proprietary manufacturer Edilon Sedra, Holland www.edilonsedra.com inlaid into the highway surface. The modules have grooves into which railway rails are set by removable resin. The level crossing modules are expected to have a design life of 120 years.

The level crossing is to be installed immediately north of and approximately parallel to the line of an Armco culvert at a distance varying from 4.16m at the west channel to 3.96m at the east channel. These distances are measured in plan between the centreline of the proposed railway level crossing and the centreline of the existing culvert.

The existing culvert is a corrugated steel buried structure comprising Armco Hel Cor 100 helical wound galvanised plate 3.5mm thick. The culvert was built in 1987 with a 120-year design working life, thus the remaining design working life would be 87 years (as of year 2020).

As a consequence of the proposed level crossing, railway loading will impose a transient lateral surcharge on the existing culvert.

The purpose of this AIP is to outline the design of the level crossing and to demonstrate that the culvert will not be adversely affected by either railway loading, or construction plant used during the installation of the level crossing. An assessment will be carried out to ascertain the residual strength of the culvert and hence to make a comparison between the design load (HA + 45HB) and proposed railway loading (20 units of RA1).

A reinforced earth retaining wall will avoid adverse effects upon the Armco culvert wing walls, in response to construction and use of the railway embankment leading up to the A21 highway embankment.

3.2 Structural type

The level crossing slabs are 6.0m long x 2.2m wide x 0.4m deep. See details on attached drawings Nos. 2013-1234A and 2017-0722. The two slabs will be butted together at the highway centreline and the outer ends extend part way across the highway verges.

The Armco culvert is 2.20m diameter helically wound corrugated galvanised steel 3.5mm thick with bitumen coating and paved asphalt invert (reference: as-built drawing No. C/T/202/570A/1). This corresponds to Armco Hel-Cor 100.

Structural Form Type	Culvert/Pipe/Subway – Circular corrugated steel		
High Load Route	Yes	**Heavy Load Route**	Yes
Scour Susceptible	Yes (headwall)	**DBFO**	No
Original Design Loading	HA + 45HB		
Number of Spans	1		
Clear opening width	2.20m	**Clear opening height**	2.20m
Structure Length	Culvert: Proposed: Level crossing = 12m	**Skew (deg)**	1
Tensioning	Not Tensioned	**Overall Construction**	Existing Culvert: Galvanised Steel, reinforced concrete headwalls Proposed Level crossing: Reinforced concrete

3.3 Foundation type

Spread footings are proposed for the reinforced earth wall panels, the founding material will need to be reconfirmed following review of the ground investigation data following which the need for mass concrete of reinforced concrete and the size of the foundations will be confirmed.

3.4 Span arrangements

The level crossing slabs will be founded within the road formation layers. Coring data will be obtained to verify the existing road construction. If the coring results are unsatisfactory, the highway design will incorporate the necessary improvements.

Existing information provided by RVR (reference: as-built drawing No. C/T/202/570A/1, included within Appendix B) state the Armco culvert to be circular 2.2m diameter [HE records erroneously state 3.0m].

3.5 Articulation arrangements

The level crossing slabs will be dowelled at the butt joint on the highway centreline to minimise differential movement between slabs. The rails are flexibly mounted within the preformed grooves to permit small movements of the slabs while maintaining rail gauge line and level.

For the Armco culvert: Inherent flexibility in this product enables deformation to occur within the material without any adverse effects.

3.6 Classes and levels

3.6.1 Consequence class

Consequence Class (BS EN 1990, Table B1 and CD 350 Table 7.2): CC2

3.6.2 Reliability class

Reliability Class (BS EN 1990, Table B2 and CD 350 Table 7.2): RC2

(BS EN 1990, Table B3): $K_{FI} = 1.0$

3.6.3 Inspection level

Inspection Level (BS EN 1990, Table B5 and CD 350 Table 7.2): IL2

3.7 Road restraint systems requirements

The level crossing will have anti-trespass panels to deter incursions on to the railway by pedestrians. Critical components of the level crossing such as barrier posts and motor housings may need to have impact protection.

No changes are proposed to the existing pedestrian guardrail around the culvert headwall and wing walls.

3.8 Proposals for water management

Impacts on the existing flood protection infrastructure and flood levels within the catchment due to the proposed works are detailed within the Flood Risk Assessment Report provided in Appendix E. This report has been produced with significant consultation with the Environment Agency.

In summary, the modelling found that the proposed scheme would not increase flood risk to properties during a 1% AEP with climate change design flood event in Northbridge Street and Robertsbridge. Across the wider flood plain the impact varies with reduction in flood levels in some locations and an increase of up to 50mm in others. Immediately adjacent to the proposed railway, there are localised areas where predicted increases in water levels are greater.

The locations of floods relief culverts have been developed to consider flood risk and reduce it where possible.

3.9 Proposed arrangements for future maintenance and inspection of structure. Access arrangements to structure.

3.9.1 Traffic management

The level crossing modules set into the road surface are designed to be as maintenance free as is practicable. The rails are main line standard and heavy duty in relation to the volume of traffic expected on the heritage railway. Nevertheless, during periodic rail replacement at intervals of approximately 60 years, there would need to be a full road closure for a short duration with traffic diverted through Robertsbridge.

No traffic management required for inspection or routine maintenance of culvert structure, railway embankment or reinforced earth retaining wall.

3.9.2 Arrangements for future maintenance and inspection of structure. Access arrangements to structure.

The level crossing would be inspected visually on a regular basis from the verges, primarily focused on ensuring that the flange ways are clear of obstruction. Any clearance work needed would be done using manual tools with the barriers lowered for a short duration to ensure safety of workers. This work would be carried out at off peak times to minimise inconvenience to road users.

No change to access for the existing culvert structure. It is likely to be classified as a Confined Space.

The railway embankment and reinforced earth structure are to be inspected from low level, with appropriate permissions in place.

All new proposed culverts are detailed within the Flood Modelling Report included within Appendix E of this AIP. None of the new culverts pass under the A21, they will be installed and maintainable in accordance with best practice guidance.

3.10 Environment and sustainability

All works will respect best practice to ensure sustainable use and reuse of materials as far as is reasonably practicable. Energy use can be minimised by use of LED lighting at the crossing.

During construction reasonable care shall be taken to remove/mitigate any environmental impact. The contractor will produce an environment management plan which will identify ecological mitigation and pollution strategy.

3.11 Durability. Materials and finishes

For the assessment of the culvert, the following details apply:
Steel plate 3.5mm thick yield strength 227N/mm2

Zinc coating 600g/m^2 of double surface equivalent to 42 µm each face

Bitumen coating, applied in accordance with BD 12/82, although no reliance is placed on the secondary coating for assessment of longevity

Loss of galvanising assumed to be 4 µm per year in non-aggressive environment

Depletion of steel thickness *T* based upon t years (BD 12/01 8.13, CD 375 8.18): $T = 22.5\ t^{0.67}$

Level crossing:

Level crossing modules will use high strength reinforced concrete to the manufacturer’s details. Cover to reinforcement will comply with requirements for exposure class XD3/XF4 appropriate for de-icing salts and freeze/thaw conditions.

3.12 Risks and hazards considered for design, execution, maintenance and demolition. Consultation with and/or agreement from Principal Designer.

The Principal Designer has identified the following risks which will be reviewed in full upon completion of the designer's risk assessment;

- Working adjacent to live traffic
- Working at height. Following earthworks to regrade the embankment; protective fencing along the top of the structure to be reinstated to protect against risk of falls from height.
- Working over/adjacent to water. The watercourse will need to be adequately managed during the works. This is likely to comprise, damming and fluming the watercourse through the culvert and/or scheduling work on the culvert to coincide with low water levels and continually monitoring water levels and forecasts.
- Instability during excavation adjacent to culvert. Works to be controlled to limit out of balance horizontal load effects resulting from uneven ground levels either side of the culvert and headwall. Results from ground investigation will be required to establish maximum ground level differential to avoid sliding failure.
- Instability during backfilling. All works are to be in accordance with CD375 and suppliers' recommendations.
- Environmental risks including but not limited to contaminated water, leptospirosis, contaminated ground, invasive species, protected species. See section 3.9 for further details.
- Buried Services. A water main is present below the east verge of the highway, this will be diverted or lowered in advance of the works. CAT scans will be required to be undertaken before any excavations take place.
- Confined Spaces within culvert. This should be considered during all stages of the works, maintenance and demolition.
- Slope failure of the existing embankment, or temporary slopes, during installation of the proposed culvert extension. Risk to be considered during design and construction.
- Slope failure of the embankment during the structure's design life. Risk to be considered during design stage of the project.
- Risk of adverse environmental impact during construction. To be considered during design and construction.

3.13 Estimated cost of proposed structure together with other structural forms considered (including where appropriate proprietary manufactured structure), and the reasons for their rejection (including comparative whole life costs with dates of estimates)

N/A

3.14 Proposed arrangements for construction

3.14.1 Construction of structure

Construction of structure - The level crossing will be formed of two pre-cast concrete Edilon Sedra units each 6.0m long x 2.2m wide inlaid with resin-set 56E1 (BS 113A) flat bottom rail. Approximate weight 13 tonnes each. The units will be placed on a pre-prepared founding surface inset within the highway formation.

Since the longitudinal gradient of the level crossing (1 in 150) is different to the super-elevated cross fall of the road (1 in 25), the highway vertical alignment will need to be adjusted. The east channel or high side will be retained at the same level, whereas the west channel will be raised 0.314m. This will require transitions within the highway surface in accordance with CD 109 (formerly TD 9/93). A minimum drainage gradient of 0.5% (1 in 200) will be maintained in any direction in accordance with CD 109 clause 5.2.

The excavation adjacent to the culvert headwalls will reduce the capacity of the culvert in resisting vertical and lateral loading. The backfill above the culvert will be removed to enable the excavation for the reinforced earth wall foundations to take place without imposing a significant out of balance lateral earth pressure. The greatest excavation depth required is adjacent to the existing headwalls, in this case the headwall will be checked for a sliding failure in the temporary case following confirmation of ground conditions. If the headwall is susceptible to a sliding failure, the out of balance lateral earth pressure will be reduced by excavating the existing ground on the south side of the headwall.

Surcharge loading above the culvert and headwalls adjacent to the reinforced earth wall should be avoided until the backfill between the reinforced earth wall and the culvert/headwall is reinstated. This is referenced in Section B-B and Section D-D and the Safety, Health and Environment box of drawing 239025-ARP-XX-XX-DR-CB-0001.

3.14.2 Traffic management

It is envisaged that there will be full road closure for one weekend to allow for installation of pre-cast concrete level crossing modules and regrading of the road surface to suit the track gradient where it crosses the highway. Traffic would be diverted through Robertsbridge via The Clappers and Northbridge Street for the duration of the closure.

3.14.3 Service diversions

A water main running below the east verge of the highway will be diverted or lowered as advance works.

3.14.4 Interface with existing structures

The interaction between the new level crossing, railway embankment and existing Mill Stream Flood Relief Culvert and its headwalls is assessed as part of this AIP. The existing headwalls are of reinforced concrete construction with a 3.2m long apron beyond the culvert. Details and dimensions shown on drawing No. C/T/202/570A/1 will be confirmed and used to ensure the stability of the culvert and headwall structures during and after the proposed works.

3.15 Resilience and security

The proposed level crossing is of a standardised and simple construction form that is easily accessible and maintainable. Any damage that would risk either highway or railway traffic, whether deliberate or accidental, is easily visible and rectifiable.

The reinforced earth wall is similarly standardised, the stability of the wall is maintained by buried components that are not accessible and so are secure from deliberate damage.

4 DESIGN CRITERIA

4.1 Actions

4.1.1 Permanent actions:

Densities of material will follow the recommendations of BS EN 1991-1-1:2002 and the UK National Annexe:

- Reinforced concrete 25kN/m^3 (Table A.1)
- Steel 77kN/m^3 (Table A.4)
- Hot rolled asphalt 23kN/m^3 (Table A.6)
- Embankment fill material 20kN/m^3, assumed value pending testing

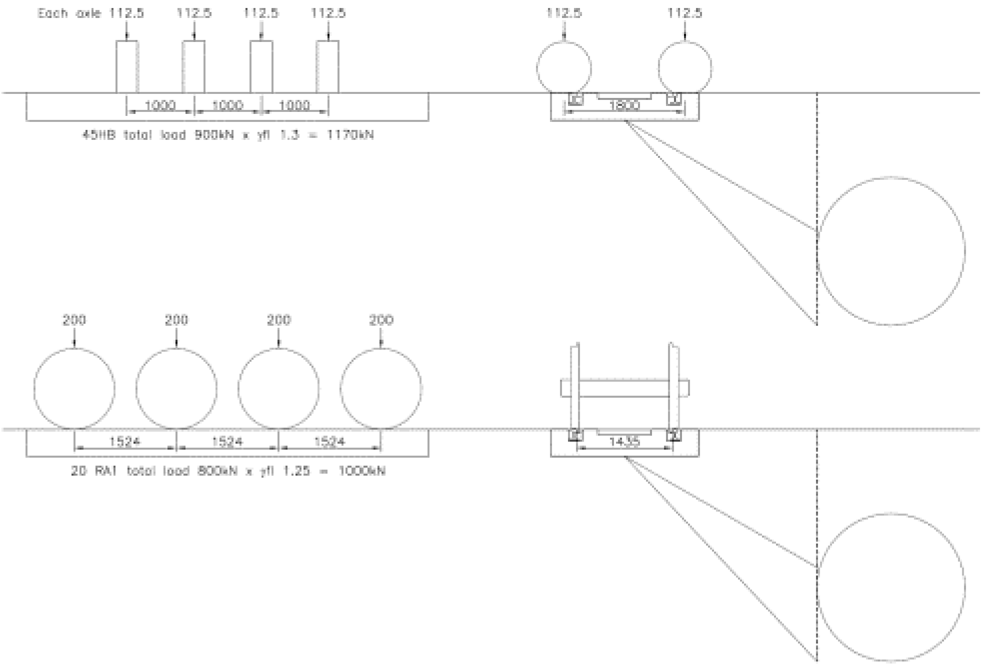
4.1.2 Snow, Wind and Thermal actions

Temperature effects may be ignored (BD 12/01 3.9, no equivalent clause in CD375).

4.1.3 Actions relating to normal traffic under AW regulations and C&U regulations

Reference to the Roads 277 form, a copy of which is attached to WS Atkins Principal Inspection Report November 2001, shows that the bridge was designed to carry HA and 45 units HB loading. This is defined in BS 5400: Part 2: 1978, unchanged in later versions of BD 37/88 and BD 37/01. For the purposes of the design and assessment of corrugated steel buried structures, a single HA wheel load of 100kN and multiple HB wheels of 112.5kN are used, both with contact areas based upon tyre pressures of 1.1N/mm^2. The load factors are 1.5 and 1.3 respectively. Braking and acceleration effects are ignored (CD 375 3.3.3).

The purpose of the current assessment is not to prove adequacy to carry current or future traffic loads, but to demonstrate that the railway loading on the level crossing applied longitudinally to the axis of the culvert will have a no more adverse effect than the passage of a pair of 45HB axles passing transversely. The railway loading is defined in 4.1.9 below. The diagram below shows that railway loading is less than 45HB:



It is not intended to re-assess the structure to current Eurocode loading LM1 or LM2 to BS EN 1991-2: 2003.

4.1.4 Actions relating to General Order traffic under STGO regulations

None mentioned on the Roads 277 record, but 45HB may be taken to represent abnormal loading.

There is no requirement to assess the structure to current Eurocode loading LM3 to UK National Annexe to BS EN 1991-2: 2003.

4.1.5 Footway or footbridge variable actions

Allow for 5kN/m2 on non-trafficked verge areas concurrent with highway loading.

4.1.6 Actions relating to Special Order traffic, provision for exceptional abnormal indivisible loads including location of vehicle track on deck cross-section

N/A

4.1.7 Accidental actions

None

4.1.8 Action during construction

During placement of the pre-cast concrete Edilon Sedra units, consideration will be given to the placement of crane outrigger loads away from the culvert, i.e. on the north side of the level crossing.

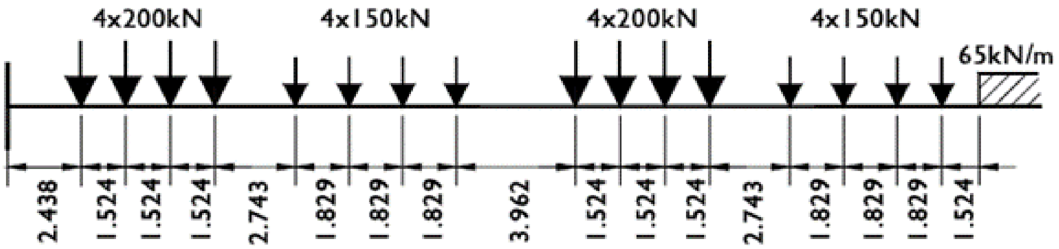
Actions due to other construction activities such as backfilling and compaction will be also be considered, where appropriate. Loading on the section of culvert that is excavated will be limited to an absolute minimum during the construction. This restriction can be reduced after the void between the reinforced earth wall and the culvert is infilled.

Out of balance lateral earth pressures will be considered and, if found necessary after confirmation of the ground conditions, additional limitations on opposing excavation depths will be imposed.

4.1.9 Any special action not covered above

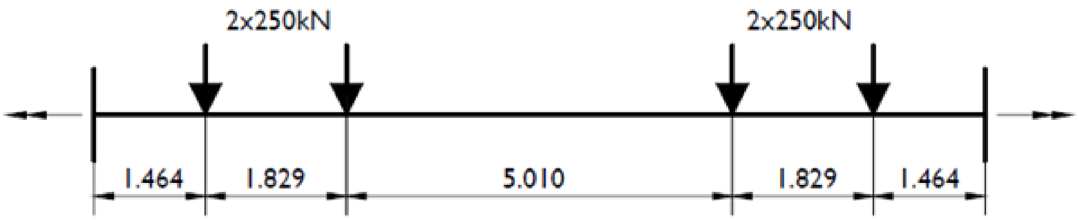
Transient railway loading on the level crossing immediately north of the culvert will impose lateral surcharge loading on the side of the culvert. There is no concurrent highway loading to be considered during the passage of rail vehicle on the level crossing.

The railway load model is 20 units of RA1 as defined by Network Rail Standard NR/GN/CIV/025 Figure 4.1 replicated below:



This load model is deemed to be an appropriate representation of the types of locomotives (steam and diesel) to be found on heritage railways. It is a metric version of BS 153 that was used to design all UK railway bridges prior to 1978. Later standards BS 5400: Part 2:1978, BD 37/88, BD 37/01 and BS EN 1991-2:1991 all make reference to LM 71 load model which is applicable to European main line railways, but not proposed here. The higher axle loads and different spacings associated with LM 71 would result in unnecessary over design for a type of traffic and implied inter-operability that is not required, and for which the rest of the railway is not designed.

The effects of wagon loading will also be considered as per Network Rail Standard NR/GN/CIV/025 Figure 4.2:



Rother Valley Railway is not intended to be a freight railway. However, there is a possibility of construction materials being brought to site from the national rail network via the NR transfer sidings at Robertsbridge Junction, passing eastwards over the level crossing.

Both of the above load diagrams are nominal static which do not allow for SLS/ULS load factors or dynamic factors, the latter being speed related.

Where it is necessary to take account of railway surcharge loading in the assessment of abutments and other soil retaining substructure elements, the values given in Table 11.1 should be adopted, see below. The tabulated values may be deemed to take into account dynamic effects. 20 RA1 units is equivalent to RA 10; the surcharge load is 42kN/m2. This may be compared with 50kN/m2 (BD 37/01 5.8.2.1(c) or 52.1kN/m2 implied by BS EN 1991-2:2003 6.3.6.4 (1) for 250kN axles at 1.6m centres and 3.0m transverse width.

Further justification for adopting the lower figure of 42kN/m2 is provided as the railway will be limited to 10mph (16kph) over the level crossing. Hence dynamic effects are much reduced below those expected for 125mph (200kph) main line railways, although not quantified here.

RA NUMBER	SURCHARGE LOAD (kN/m^2)	RA NUMBER	SURCHARGE LOAD (kN/m^2)
RA0	22	RA8	38
RA1	24	RA9	40
RA2	26	RA10	42
RA3	28	RA11	44
RA4	30	RA12	46
RA5	32	RA13	48
RA6	34	RA14	50
RA7	36	RA15	52

Table 11.1
Nominal Railway Traffic Surcharge Loading

It will be seen that Edilon Sedra slabs are 2.2m wide as opposed to the normal sleeper length of 2.6m. This results in a locally higher surcharge pressure over a narrower zone. By applying four 200kN axles wholly on a 6.0m long module, a surcharge of 60.6kN/m2 results, applied at a depth of 0.4m below road level. The effect of this will also be assessed where it is more adverse to the culvert than the Table 11.1 values tabulated above.

SLS and ULS load factors of 1.10 and 1.25 respectively are proposed. The latter is a reduction from the default BD 37/01 value of 1.4, on the basis of there being reliable control over the trains and their loading that can enter the route as allowed for in NR/GN/CIV/025 Table 2.2 note *4.

Traction and braking effects will be ignored. To minimise impact, there will be no rail joints located within the 12.0m length of the level crossing slabs.

4.2 Heavy or high load route requirements and arrangements being made to preserve the route, including any provision for future heavier loads or future widening

None

4.3 Minimum headroom provided

N/A

4.4 Authorities consulted and any special conditions required

- Office of Road and Rail
- Highways England
- Rother District Council
- Environment Agency – detailed flood modelling has been carried out to inform a Flood Risk Assessment Report as part of the planning application and the TWA Statement of Case annexes. The relevant reports are provided in Annex E for completeness.

4.5 Standards and documents listed in the Technical Approval Schedule

See Appendix A

4.6 Proposed Departures relating to departures from standards given in 4.5

None

4.7 Proposed Departures relating to methods for dealing with aspects not covered by standards in 4.5

None

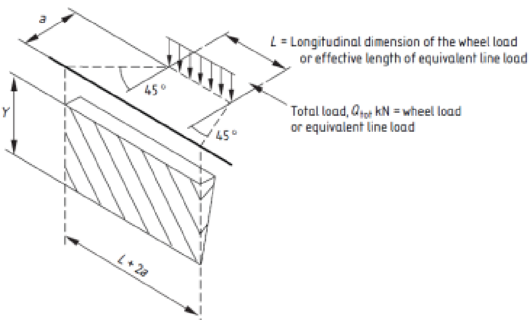
4.8 (Wales only) List of record of options and choices (for Categories 2 and 3 checks)

N/A

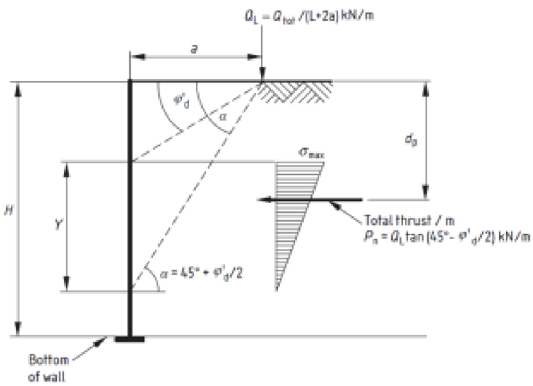
5 STRUCTURAL ANALYSIS

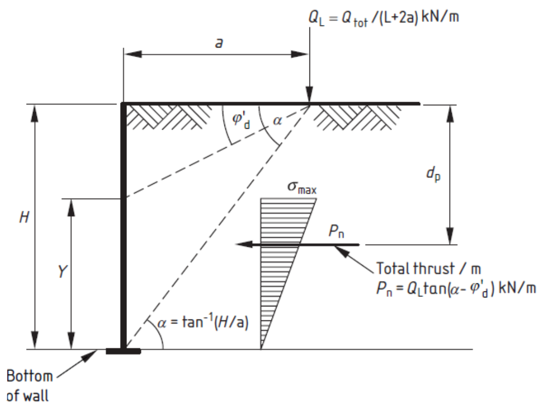
5.1 Methods of analysis proposed for superstructure, substructure and foundations

PD 6694-1:2011 7.6.3 describes a method for determining the horizontal effects of vertical traffic loads. The orientation of the Armco culvert relative to the level crossing is analogous to that of highway loading on a parallel retaining wall as intended by this clause. Patch loads or strip loads of significant width can be simulated by superimposing the effects of a number of parallel line loads. See Figures 3a), 3b) and 3c) below. Since the bottom of the culvert is above the diagonal line described by angle □ = 45° + □'d/2, the lower right diagram 3c) applies. The value ‘a’ is 2.866m to a vertical line coincident with the side of the culvert.



PD 6694-1:2001 Figure 3a). Conservatively, dispersal to L+2a will be ignored.

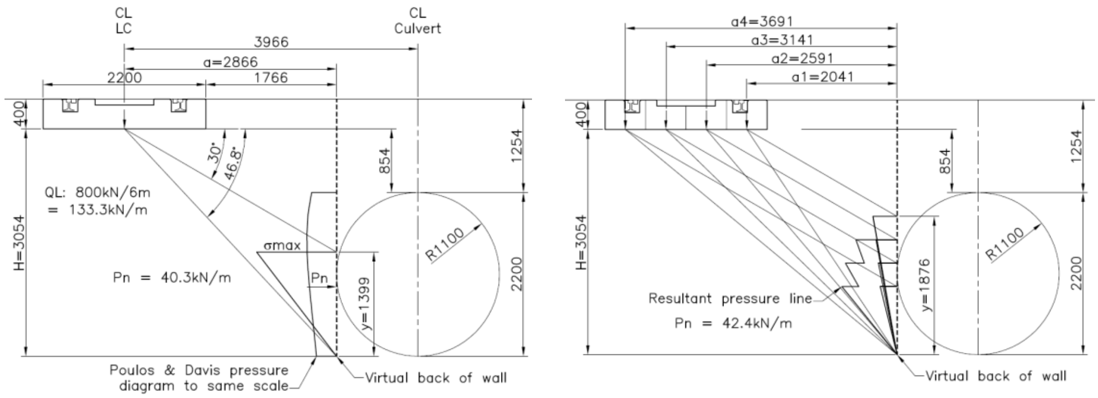




PD 6694-1:2001 Figure 3b)

PD 6694-1:2001 Figure 3c)

ARUP



PD 6694−1: 2011 Figure 3c single line load

PD 6694−1: 2011 Figure 3c four line loads

The arbitrary use of 4 equivalent line loads results in 5.2% increase in lateral load. The Poulos & Davis solution gives a 5.6% reduction compared to the single line load.

5.2 Description and diagram of idealised structure to be used for analysis

As above

5.3 Assumptions intended for calculation of structural element stiffness

The stiffness of the culvert section will be assessed in accordance with CD 375.

5.4 Proposed range of soil parameters to be used in the design of earth retaining elements

No new highway retaining structures are designed as part of this submission. This AiP provides a load comparison between the current arrangement and the proposed arrangement. A Phi of 30° is assumed to carry out this check. Any variation would effect both current and proposed and therefore is likely to have minimal, in any, effect on the outcome.

A GIR will be required and the results will be reviewed in order to validate the existing ground conditions and the impact of any new loads.

6 GEOTECHNICAL CONDITIONS

6.1 Acceptance of recommendations of the Geotechnical Design Report to be used in the design and reasons for any proposed changes

A geotechnical design report has not been provided for this element of works as this looks at the comparative impact of the new infrastructure and does not design any new highway structures. A GIR will be required and the results will be reviewed in order to validate the existing ground conditions and the impact of any new loads.

6.2 Summary of design for highway structure in the Geotechnical Design Report

N/A

6.3 Differential settlement to be allowed for in the design of the structure

Minimal differential settlement expected between the Edilon Sedra slabs, which will be dowelled to restrict relative movement. The highway embankment is expected to be well consolidated by the passage of highway traffic, so any future settlement will be minimal.

6.4 If the Geotechnical Design Report is not yet available, state when the results are expected and list the sources of information used to justify the preliminary choice of foundations

See 6.1 above. Boreholes ref. nos. 11, 12, 13, 14 are included in Appendix C, pertaining to the construction of Robertsbridge bypass in 1987. The underlying strata in the area is predominantly clay and silt to a depth in excess of 20m.

The results of the of the proposed Ground Investigation will be reviewed to confirm that the existing embankment build-up and culvert backfill materials are in agreement with the earthworks information contained in the as-built drawing C/T/202/570A/1. The impacts of any variation from this will be considered during detailed design.

The ground investigation will be undertaken prior to detailed design.

7 CHECK

7.1 Proposed Category and Design Supervision Level

Category 1 check required.

Supervision Level (BS EN 1990 Table B4, CD350 Table 7.2): DSL2

7.2	**If Category 3, name of proposed Independent Checker** N/A
7.3	**Erection proposals or temporary works for which Types S and P Proposals will be required, listing structural parts of the permanent structure affected with reasons** None

8 DRAWINGS AND DOCUMENTS

8.1 List of drawings (including numbers) and documents accompanying the submission

Appendix A – Technical Approval Schedule

Appendix B –Drawings:

Proposed: 239025-ARP-XX-XX-DR-CB-0001 (formerly 239025-A21-G-101)

Historic: C/T/202/570A/1 – as-built drawing of existing culvert, headwalls and embankment

Appendix C – Historic Ground Investigation Borehole Logs

Appendix D – Departures

Appendix E – Relevant correspondence and documents from consultations

Appendix F – Designers Hazard Risk Assessment

9 THE ABOVE IS SUBMITTED FOR ACCEPTANCE

Signed	
Name	Jonathan Portlock
Engineering Qualifications	MEng, CEng, MICE, MIStructE
Name of Organisation	Ove Arup and Partners
Date	11 Dec. 2020

10 THE ABOVE IS REJECTED/AGREED SUBJECT TO THE AMENDMENTS AND CONDITIONS SHOWN BELOW

Signed	______________________
Name	______________________
Position Held	______________________
Engineering Qualifications	______________________
TAA	______________________
Date	______________________

APPENDIX A

Technical Approval Schedule (TAS)

Schedule of Documents Relating to Design of Highway Bridges and Structures

(All documents are taken to include revisions current as of 13 July 2018 – Updated April 2020)

The Designer is responsible for ensuring that the standards and references given in the schedule are correct and up to date.

Eurocodes and associated UK National Annexes

Eurocode part	**Title**	**Amendment / Corrigenda**	
Eurocode 0	**Basis of structural design**		
BS EN 1990:2002 +A1:2005	Eurocode 0: Basis of structural design	+A1:2005 Incorporating corrigenda December 2008 and April 2010	See BD100 Annex A for additional guidance.
NA to BS EN 1990:2002 + A1:2005	UK National Annex to Eurocode 0 Basis of structural design	National Amendment No.1	See BD100 Annex A for additional guidance.
Eurocode 1	**Actions on structures**		
BS EN 1991-1-1:2002	Eurocode 1: Actions on structures. General Actions. Densities, self-weight, imposed load for buildings	Corrigenda December 2004 and March 2009	
NA to BS EN 1991-1-1:2002	UK National Annex to Eurocode 1: Actions on structures. General Actions. Densities, self-weight, imposed load for buildings	-	
BS EN 1991-1-3:2003 +A1:2015	Eurocode 1: Actions on structures. General Actions. Snow loads	+A1:2015 Incorporating corrigenda December 2004 and March 2009	
NA to BS EN 1991-1-3:2003+A1:2015	UK National Annex to Eurocode 1: Actions on structures. General Actions. Snow loads	+A1:2015 Incorporating corrigendum No.1	
~~BS EN 1991-1-4:2005 +A1:2010~~	~~Eurocode 1: Actions on structures. General Actions. Wind actions~~	~~+A1:2010 Corrigenda July 2009 and January 2010~~	
~~NA to BS EN 1991-1-4:2005 + A1:2010~~	~~UK National Annex to Eurocode 1: Actions on structures. General Actions. Wind actions~~	~~National Amendment No.1~~	
~~BS EN 1991-1-5:2003~~	~~Eurocode 1: Actions on structures. General Actions. Thermal actions~~	~~Corrigenda December 2004 and March 2009~~	
~~NA to BS EN 1991-1-5:2003~~	~~UK National Annex to Eurocode 1: Actions on structures. General Actions. Thermal actions~~	~~-~~	
BS EN 1991-1-6:2005	Eurocode 1: Actions on structures. General Actions. Actions during execution	Corrigenda July 2008, November 2012 and February 2013	
NA to BS EN 1991-1-	UK National Annex to Eurocode	-	

6:2005	1: Actions on structures. General Actions. Actions during execution		
BS EN 1991-1-7:2006 +A1:2014	Eurocode 1: Actions on structures. General Actions. Accidental actions	+A1: 2014 Corrigendum February 2010	
NA+A1 to BS EN 1991-1-7:2006+A1:2014	UK National Annex to Eurocode 1: Actions on structures. Part 1-7 : Accidental actions	+A1:2014 Incorporating corrigenda August 2014 and November 2015	See BD100 for additional guidance.
BS EN 1991-2:2003	Eurocode 1: Actions on structures. Traffic loads on bridges	Corrigenda December 2004 and February 2010	See BD100 Annex A for additional guidance.
NA to BS EN 1991-2:2003	UK National Annex to Eurocode 1: Actions on structures. Traffic loads on bridges	Corrigendum No.1	See BD100 Annex A for additional guidance.
Eurocode 2	**Design of concrete structures**		
BS EN 1992-1-1:2004 + A1:2014	Eurocode 2: Design of concrete structures– Part 1-1: General rules and rules for buildings	Incorporating corrigendum January 2008, November 2010 and January 2014	
NA + A2:2014 to BS EN 1992-1-1:2004 + A1:2014	UK National Annex to Eurocode 2: Design of concrete structures – Part 1-1: General rules and rules for buildings		
BS EN 1992-2:2005	Eurocode 2: Design of concrete structures – Part 2: Concrete bridges – Design and detailing rules	Corrigendum July 2008	
NA to BS EN 1992-2:2005	UK National Annex to Eurocode 2: Design of concrete structure – Part 2: Concrete bridges – Design and detailing rules	-	
BS EN 1992-3:2006	Eurocode 2: Design of concrete structures – Part 3: Liquid retaining and containment structures	-	
NA to BS EN 1992-3:2006	UK National Annex to Eurocode 2: Design of concrete structure – Part 3: Liquid retaining and containment structures	-	
Eurocode 3	**Design of steel structures**		
BS EN 1993-1-1:2005 + A1:2014	Eurocode 3: Design of steel structures – Part 1-1 General rules and rules for buildings	Corrigenda February 2006 and April 2009	
NA + A1:2014 to BS EN 1993-1-1:2005 + A1:2014	UK National Annex to Eurocode 3: Design of steel structures – Part 1-1 General rules and rules for buildings	-	
BS EN 1993-1-3:2006	Eurocode 3: Design of steel structures – Part 1-3 General rules – Supplementary rules for cold-formed members and sheeting	Corrigendum November 2009	
NA to BS EN 1993-1-3:2006	UK National Annex to Eurocode 3: Design of steel structures – Part 1-3 Supplementary rules for	-	

	cold-formed members and sheeting		
~~BS EN 1993-1-4:2006~~	~~Eurocode 3: Design of steel structures – Part 1-4 General rules – Supplementary rules for stainless steels~~	-	
~~NA to BS EN 1993-1-4:2006~~	~~UK National Annex to Eurocode 3: Design of steel structures – Part 1-4 Supplementary rules for stainless steels~~	-	
BS EN 1993-1-5:2006+A1:2017	Eurocode 3: Design of steel structures – Part 1-5 Plated structural elements	Corrigendum April 2009, +A1:2017 Amendment No. 1	
NA to BS EN 1993-1-5:2006	UK National Annex to Eurocode 3: Design of steel structures – Part 1-5 Plated structural elements	-	
BS EN 1993-1-6:2007	Eurocode 3: Design of steel structures – Part 1-6 Strength and stability of shell structures	+ A1:2017 Amendment No. 1	
BS EN 1993-1-7:2007	Eurocode 3: Design of steel structures – Part 1-7 Plated structures subject to out of plane loading	Corrigendum April 2009	
BS EN 1993-1-8:2005	Eurocode 3: Design of steel structures – Part 1-8 Design of joints	Corrigenda December 2005, September 2006, July 2009 and August 2010	
NA to BS EN 1993-1-8:2005	UK National Annex to Eurocode 3: Design of steel structures – Part 1-8 Design of joints	-	
BS EN 1993-1-9:2005	Eurocode 3: Design of steel structures – Part 1-9 Fatigue	Corrigenda December 2005, September 2006 and April 2009	
NA to BS EN 1993-1-9:2005	UK National Annex to Eurocode 3: Design of steel structures – Part 1-9 Fatigue	-	
BS EN 1993-1-10:2005	Eurocode 3: Design of steel structures – Part 1-10 Material toughness and through-thickness properties	Corrigenda December 2005, September 2006 and March 2009	
NA to BS EN 1993-1-10:2005	UK National Annex to Eurocode 3: Design of steel structures – Part 1-10 Material toughness and through thickness properties	-	
BS EN 1993-1-11:2006	Eurocode 3: Design of steel structures – Part 1-11 Design of structures with tension components	Corrigendum April 2009	
NA to BS EN 1993-1-11:2006	UK National Annex to Eurocode 3: Design of steel structures – Part 1-11 Design of structures with tension components	-	
~~BS EN 1993-1-12:2007~~	~~Eurocode 3: Design of steel structures – Part 1-12 Additional rules for the extension of EN 1993 up to steel grades S 700~~	~~Corrigendum April 2009~~	

~~NA to BS EN 1993-1-12:2007~~	~~UK National Annex to Eurocode 3: Design of steel structures – Part 1-12 Additional rules for the extension of EN 1993 up to steel grades S 700~~	-	
BS EN 1993-2:2006	Eurocode 3: Design of steel structures – Part 2 Steel bridges	Corrigendum July 2009	
NA + A1:2012 to BS EN 1993-2:2006	UK National Annex to Eurocode 3: Design of steel structures – Part 2 Steel bridges	+ A1:2012	
~~BS EN 1993-5:2007~~	~~Eurocode 3: Design of steel structures – Part 5 Piling~~	~~Corrigendum May 2009~~	
~~NA + A1:2012 to BS EN 1993-5:2007~~	~~UK National Annex to Eurocode 3: Design of steel structures – Part 5 Piling~~	~~+ A1:2012~~	
Eurocode 4	**Design of composite steel and concrete structures**		
BS EN 1994-1-1:2004	Eurocode 4: Design of composite steel and concrete structures – Part 1-1 General rules and rules for buildings	Corrigendum April 2009	
NA to BS EN 1994-1-1:2004	UK National Annex to Eurocode 4: Design of composite steel and concrete structures – Part 1-1 General rules and rules for buildings	-	
BS EN 1994-2:2005	Eurocode 4: Design of composite steel and concrete structures – Part 2 General rules and rules for bridges	Corrigendum July 2008	
NA to BS EN 1994-2:2005	UK National Annex to Eurocode 4: Design of composite steel and concrete structures – Part 2 General rules and rules for bridges	-	
Eurocode 5	**Design of timber structures**		
~~BS EN 1995-1-1:2004 + A2:2014~~	~~Eurocode 5: Design of timber structures – Part 1-1 General – common rules and rules for buildings~~	~~+ A2:2014 Incorporating corrigendum June 2006~~	
~~NA to BS EN 1995-1-1:2004 + A1:2008~~	~~UK National Annex to Eurocode 5: Design of timber structures – Part 1-1 General – common rules and rules for buildings~~	~~+ A1:2008 Incorporating National Amendment No. 2~~	
~~BS EN 1995-2:2004~~	~~Eurocode 5: Design of timber structures – Part 2 Bridges~~	~~-~~	
~~NA to BS EN 1995-2:2004~~	~~UK National Annex to Eurocode 5: Design of timber structures – Part 2 Bridges~~	-	
Eurocode 6	**Design of masonry structures**		
~~BS EN 1996-1-1:2005~~	~~Eurocode 6: Design of masonry structures – Part 1-1 General rules for reinforced and unreinforced masonry structures~~	~~Corrigenda February 2006 and July 2009~~	
~~NA to BS EN 1996-1-1:2005 +A1:2012~~	~~UK National Annex to Eurocode 6: Design of masonry structures – Part 1-1 General rules for reinforced and unreinforced masonry structures~~	~~Corrigendum October 2015~~	
~~BS EN 1996-2:2006~~	~~Eurocode 6: Design of masonry structures – Part 2 Design~~	~~Corrigendum September 2009~~	

	~~considerations, selection of materials and execution of masonry~~		
~~NA to BS EN 1996-2:2006~~	~~UK National Annex to Eurocode 6: Design of masonry structures – Part 2 Design considerations, selection of materials and execution of masonry~~	~~Corrigendum No.1~~	
~~BS EN 1996-3:2006~~	~~Eurocode 6: Design of masonry structures – Part 3 Simplified calculation methods for unreinforced masonry structures~~	~~Corrigendum October 2009~~	
~~NA +A1:2014 to BS EN 1996-3:2006~~	~~UK National Annex to Eurocode 6: Design of masonry structures – Part 3 Simplified calculation methods for unreinforced masonry structures~~	~~+A1:2014~~	
Eurocode 7	**Geotechnical design**		
BS EN 1997-1:2004+A1:2013	Eurocode 7: Geotechnical design – Part 1 General rules	+A1:2013 Corrigendum February 2009	
NA+A1 to BS EN 1997-1:2004+A1:2013	UK National Annex to Eurocode 7: Geotechnical design – Part 1 General rules	+A1:2013 Incorporating Corrigendum No.1	
BS EN 1997-2:2007	Eurocode 7: Geotechnical design – Part 2 Ground investigation and testing	Corrigendum June 2010	
NA to BS EN 1997-2:2007	UK National Annex to Eurocode 7: Geotechnical design – Part 2 Ground investigation and testing	-	
Eurocode 8	**Design of structures for earthquake resistance**		
~~BS EN 1998-1:2004 + A1:2013~~	~~Eurocode 8: Design of structures for earthquake resistance – Part 1 General rules, seismic actions and rules for buildings~~	~~Corrigendum June 2009, January 2011 and March 2013~~	
~~NA to BS EN 1998-1:2004~~	~~UK National Annex to Eurocode 8: Design of structures for earthquake resistance – Part 1 General rules, seismic actions and rules for buildings~~	~~-~~	
~~BS EN 1998-2:2005+A2:2011~~	~~Eurocode 8: Design of structures for earthquake resistance – Part 2 Bridges~~	~~Corrigenda February 2010 and February 2012~~	
~~NA to BS EN 1998-2:2005~~	~~UK National Annex to Eurocode 8: Design of structures for earthquake resistance – Part 2 Bridges~~	~~-~~	
~~BS EN 1998-5:2004~~	~~Eurocode 8: Design of structures for earthquake resistance – Part 5 Foundations, retaining structures and geotechnical aspects~~	-	
~~NA to BS EN 1998-5:2004~~	~~UK National Annex to Eurocode 8: Design of structures for earthquake resistance – Part 5 Foundations, retaining structures and geotechnical aspects~~	-	
Eurocode 9	**Design of aluminium structures**		
~~BS EN 1999-1-1:2007 +~~	~~Eurocode 9: Design of~~	~~+ A2:2013~~	

~~A2:2013~~	~~aluminium structures– Part 1-1 General structural rules~~	~~Incorporating corrigendum March 2014~~	
~~NA to BS EN 1999-1-1:2007 + A1:2009~~	~~UK National Annex to Eurocode 9: Design of aluminium structures – Part 1-1 General structural rules~~	~~National Amendment No.1 Corrigendum No.1~~	
~~BS EN 1999-1-3:2007 + A1:2011~~	~~Eurocode 9: Design of aluminium structures – Part 1-3 Structures susceptible to fatigue~~	~~+ A1:2011~~	
~~NA to BS EN 1999-1-3:2007 + A1:2011~~	~~UK National Annex to Eurocode 9: Design of aluminium structures – Part 1-3 Structures susceptible to fatigue~~	~~+ A1:2011~~	
~~BS EN 1999-1-4:2007 +A1:2011~~	~~Eurocode 9: Design of aluminium structures – Part 1-4 Cold formed structural sheeting~~	~~+ A1:2011 Corrigendum November 2009~~	
~~NA to BS EN 1999-1-4:2007~~	~~UK National Annex to Eurocode 9: Design of aluminium structures – Part 1-4 Cold formed structural sheeting~~	-	
Others			
BS EN 1295-1:2019	Structural design of buried pipelines under various conditions of loading. General requirements		

Bsi Published Documents

For guidance only unless clauses are otherwise specified in BD 100/16 Annex B.

PD 6688-1-1:2011	Recommendations for the design of structures to BS EN 1991-1-1	See BD100 Annex B for additional guidance.
PD 6688-1-4:2015	Background paper to the UK National Annex to BS EN 1991-1-4	See BD100 Annex B for additional guidance.
PD 6688-1-7:2009 +A1:2014	Recommendations for the design of structures to BS EN 1991-1-7	See BD100 clause 2.17 and Annex B for additional guidance.
PD 6688-2:2011	Recommendations for the design of structures to BS EN 1991-2	See BD100 Annex B for additional guidance.
PD 6687-1:2010	Background paper to the UK National Annexes to BS EN 1992-1 and BS EN 1992-3	See BD100 clauses 2.15, 2.16 and Annex B for additional guidance.
PD 6687-2:2008	Recommendations for the design of structures to BS EN 1992-2:2005	See BD100 clause 2.16 and Annex B for additional guidance.
PD 6695-1-9:2008	Recommendations for the design of structures to BS EN 1993-1-9	See BD100 Annex B for additional guidance.
PD 6695-1-10:2009	Recommendations for the design of structures to BS EN 1993-1-10	See BD100 Annex B for additional guidance.
PD 6695-2:2008 + A1:2012 Incorporating Corrigendum No.1	Recommendation for the design of bridges to BS EN 1993	See BD100 Annex B for additional guidance.
PD 6696-2:2007 + A1:2012	Background paper to BS EN 1994-2 and the UK National Annex to BS EN 1994-2	See BD100 Annex B for additional guidance.
PD 6694-1:2011	Recommendations for the design of structures subject to traffic loading to BS EN 1997-1	See BD100 Annex B for additional guidance.

~~PD 6698:2009~~	~~Recommendations for the design of structures for earthquake resistance to BS EN 1998~~	~~See BD100 Annex A for additional guidance.~~
~~PD 6703:2009~~	~~Structural bearings – Guidance on the use of structural bearings~~	
PD 6705-2:2010 + A1:2013	Recommendations for the execution of steel bridges to BS EN 1090-2	Amended 30 April 2013
~~PD 6705-3:2009~~	~~Recommendations on the execution of aluminium structures to BS EN 1090-3~~	
~~PD 6702-1:2009~~	~~Structural use of aluminium. Recommendations for the design of aluminium structures to BS EN 1999~~	

Execution Standards referenced in British Standards or Eurocodes

BS EN 1090-1:2009+A1:2011	Execution of steel structures and aluminium structures – Part 1: Requirements for conformity assessment of structural components	
BS EN 1090-2:2018	Execution of steel structures and aluminium structures. Technical requirements for the execution of steel structures	Supersedes BS EN 1090-2:2008+A1:2011
~~BS EN 1090-3:2008~~	~~Execution of steel structures and aluminium structures – Part 3: Technical requirements for aluminium structures~~	
BS EN 13670:2009 Incorporating corrigenda October 2015 and November 2015	Execution of concrete structures	

Product Standards referenced in British Standards or Eurocodes

BS EN 206:2013	Concrete – Specification, performance, production and conformity	Corrigendum May 2014
BS EN 1317-1:2010	Road Restraint Systems – Part 1 – Terminology and general criteria for test methods	
BS EN 1317-2:2010	Road Restraint Systems – Part 2 – Performance classes, impact test acceptance criteria and test methods for safety barriers.	
BS EN 1317-3:2010	Road Restraint Systems – Part 3 – Performance classes, impact test acceptance criteria and test methods for crash cushions.	
DD ENV 1317-4:2002	Road Restraint Systems – Part 4 – Performance classes, impact test acceptance criteria and test methods for terminals and transitions of safety barriers.	*Draft BS EN 1317-4 for public comment published in June 2012*
BS EN 1317-5:2007+A2:2012	Road Restraint Systems – Part 5 – Product requirements and evaluation of conformity for vehicle restraint systems	Incorporating corrigendum August 2012 *Draft prEN 1317-5 for public comment published in December 2013*
PD CEN/TR 16949:2016	Road Restraint System – Pedestrian restraint system – Pedestrian parapets	*Bsi Published Document / CEN Technical Report*

		published in July 2016 ***(This document should temporarily not be used. The requirements of BS 7818:2015 apply.)***
Draft prEN 1317-7	Road restraint systems – Part 7: Performance classes, impact test acceptance criteria and test methods for terminals of safety barriers	*Draft prEN 1317-7 for public comment published in June 2012*
PD CEN/TS 1317-8:2012	Road restraint systems – Part 8: Motorcycle road restraint systems which reduce the impact severity of motorcyclist collisions with safety barriers	*Bsi Published Document / CEN Technical Specification published in May 2012*
~~BS EN 1337-1:2000~~	~~Structural bearings – Part 1: General Design Rules~~	
~~BS EN 1337-2:2004~~	~~Structural bearings – Part 2: Sliding elements~~	
~~BS EN 1337-3:2005~~	~~Structural bearings – Part 3: Elastomeric bearings~~	
~~BS EN 1337-4:2004~~	~~Structural bearings – Part 4: Roller bearings~~	
~~BS EN 1337-5:2005~~	~~Structural bearings – Part 5: Pot bearings~~	
~~BS EN 1337-6:2004~~	~~Structural bearings – Part 6: Rocker bearings~~	
~~BS EN 1337-7:2004~~	~~Structural bearings – Part 7: Spherical and cylindrical PTFE bearings~~	
~~BS EN 1337-8:2007~~	~~Structural bearings – Part 8: Guide bearings and restraint bearings~~	
~~BS EN 1337-9:1998~~	~~Structural bearings – Part 9: Protection~~	
~~BS EN 1337-10:2003~~	~~Structural bearings – Part 10: Inspection and maintenance~~	
~~BS EN 1337-11:1998~~	~~Structural bearings – Part 11: Transport, Storage and Installation.~~	
~~BS EN 1794-1:2018~~	~~Road traffic noise reducing devices – Non-acoustic performance Part 1: Mechanical performance and requirements~~	~~Supersedes previous version BS EN 1794-1:2011~~
~~BS EN 1794-2:2011~~	~~Road traffic noise reducing devices – Non-acoustic performance Part 2: General safety and environmental requirements~~	
~~BS EN 1916:2002~~	~~Concrete pipes and fittings, unreinforced, steel fibre and reinforced~~	
BS EN 10025-1:2004	Hot rolled products of structural steels Part 1: General technical delivery conditions.	
BS EN 10025-2:2004	Hot rolled products of structural steels Part 2: Technical delivery conditions for non-alloy structural steels.	
BS EN 10025-3:2004	Hot rolled products of structural steels Part 3: Technical delivery conditions for normalized/normalized rolled weldable fine grain structural steels.	
BS EN 10025-4:2004	Hot rolled products of structural steels Part 4: Technical delivery conditions for thermomechanical rolled weldable fine grain structural steels.	
BS EN 10025-5:2004	Hot rolled products of structural steels – Part 5: Technical delivery conditions for structural steels with improved atmospheric corrosion resistance	

BS EN 10025-6:2004+A1:2009	Hot rolled products of structural steels – Part 6: Technical delivery conditions for flat products of high yield strength structural steels in the quenched and tempered condition.	
BS EN 10080:2005	Steel for the reinforcement of concrete – Weldable reinforcing steel – General	
~~BS EN 10210-1:2006~~	~~Hot finished structural hollow sections of non-alloy and fine grain steels – Part 1: Technical delivery conditions~~	
~~BS EN 10210-2:2006~~	~~Hot finished structural hollow sections of non-alloy and fine grain steels – Part 2: Tolerances, dimensions and sectional properties~~	~~*Incorporating corrigendum no.1*~~
~~BS EN 10248-1:1996~~	~~Hot rolled sheet piling of non alloy steels. Technical delivery conditions~~	
~~BS EN 10248-2:1996~~	~~Hot rolled sheet piling of non alloy steels. Tolerances on shape and dimensions~~	
~~BS EN 12063:1999~~	~~Execution of special geotechnical work. Sheet pile walls.~~	
~~BS EN 15050:2007 + A1:2012~~	~~Precast concrete products – Bridge elements~~	~~See BD100 clause 2.18 for additional guidance.~~

British Standards

BS 4449:2005+A3:2016	Steel for the reinforcement of concrete	No longer covers plain round bar. (See BS4482 up to 12mm dia, see BS EN 10025-1 for larger sizes and dowels. See BS EN 13877-3 for dowel bars in concrete pavements.)
~~BS 5896:2012~~	~~Specification for high tensile steel wire and strand for the prestressing of concrete~~	
~~BS 5911-1:2002+A2:2010~~	~~Concrete pipes and ancillary concrete products. Specification for unreinforced and reinforced concrete pipes (including jacking pipes) and fittings with flexible joints (complementary to BS EN 1916:2002)~~	
~~BS 7818:1995~~	~~Specification for pedestrian restraint systems in metal~~	~~Currently the requirements of BS 7818:2015 are to be used instead of PD CEN/TR 16949:2016~~
BS 8002:2015	Code of practice for earth retaining structures	
BS 8004:2015	Code of practice for foundations	
~~BS 8006-1:2010+A1:2016~~	~~Code of practice for strengthened/reinforced soils and other fills~~	
BS 8500-1:2015+A1:2016	Concrete – Complementary British Standard to BS EN 206 : Method of specifying and guidance for the specifier.	Incorporating Corrigendum No.1
BS 8500-2:2015+A1:2016	Concrete – Complementary British Standard to BS EN 206 : Specification for constituent materials and concrete.	

BS 8666:2005	Scheduling, dimensioning, bending and cutting of steel reinforcement for concrete	Incorporating Amendment No.1
BS 9295:2010	Guide to the structural design of buried pipelines	

The Manual Contract Document for Highway Works (MCHW)

MCHW Volume 1: May 2017	Specification for Highway Works	*Specification compliant with the execution standards must be used. A Departure is necessary for the parts where a compliant revision has not been published.*
MCHW Volume 2: May 2017	Notes for guidance on the Specification for Highway Works	*Notes for guidance compliant with the execution standards must be used. A Departure is necessary for the parts where a compliant revision has not been published.*
MCHW Volume 3: February 2017	Highway Construction Details	

The Design Manual for Roads and Bridges (DMRB)

~~BD 2/12~~	~~Technical Approval of Highway Structures~~	**~~Withdrawn & replaced by CG 300~~**
~~BD 7/01~~	~~Weathering steel for highway structures~~	**~~Withdrawn & replaced by CD 361~~**
~~BD 10/97~~	~~Design of highway structures in areas of mining subsidence~~	**~~Withdrawn & replaced by CD 622~~**
~~BD 12/01~~	~~Design of corrugated steel buried structures with spans greater than 0.9 metres and up to 8.0 metres~~	**~~Withdrawn & replaced by CD 375~~**
~~BD 29/17~~	~~Design criteria for footbridges~~	**~~Withdrawn & replaced by CD 353~~**
~~BD 33/94~~	~~Expansion joints for use in highway bridge decks~~	**~~Withdrawn & replaced by CD 357~~**
~~BD 35/14~~	~~Quality assurance scheme for paints and similar protective coatings~~	**~~Withdrawn & replaced by CG 303~~**
~~BD 36/92~~	~~Evaluation of maintenance costs in comparing alternative designs for highway structures~~	**~~Withdrawn & replaced by CD 355~~**
~~BD 43/03~~	~~The impregnation of reinforced and prestressed concrete highway structures using hydrophobic pore-lining impregnants~~	**~~Withdrawn & replaced by CD 373~~**
~~BD 45/93~~	~~Identification markings of highway structures~~	**~~Withdrawn & replaced by CG 305~~**
~~BD 47/99~~	~~Waterproofing and surfacing of concrete bridge decks~~	**~~Withdrawn & replaced by CD 358~~**
~~BD 51/14~~	~~Portal and cantilever signs/signal gantries~~	**~~Withdrawn & replaced by CD 365~~**
~~BD 57/01~~	~~Design for durability~~	**~~Withdrawn & replaced by CD 350~~**
~~BD 62/07~~	~~As built, operational and maintenance records for highway structures~~	**~~Withdrawn & replaced by CG 302~~**
~~BD 65/14~~	~~Design criteria for collision protection beams~~	**~~Withdrawn & replaced by CD 365~~**
~~BD 67/96~~	~~Enclosure of bridges~~	**~~Withdrawn & replaced by CD 362~~**
~~BD 68/97~~	~~Crib retaining walls~~	**~~Withdrawn~~**
~~BD 78/99~~	~~Design of road tunnels~~	**~~Withdrawn & replaced by CD 352~~**
~~BD 82/00~~	~~Design of buried rigid pipes~~	**~~Withdrawn~~**
~~BD 90/05~~	~~Design of FRP bridges and highway structures~~	**~~Withdrawn & replaced by CD 368~~**
~~BD 94/17~~	~~Design of minor structures~~	**~~Withdrawn & replaced by CD 354~~**
~~BD 100/16~~	~~The use of Eurocodes for the design of highway structures~~	**~~Withdrawn & replaced by CD 350~~**
~~BA 26/94~~	~~Expansion joints for use in highway bridge~~	**~~Withdrawn & replaced by CD 357~~**

	~~decks~~	
~~BA 28/92~~	~~Evaluation of maintenance costs in comparing alternative designs for highway structures~~	~~**Withdrawn & replaced by CD 355**~~
~~BA 36/90~~	~~The use of permanent formwork~~	~~**Withdrawn & replaced by CD 359**~~
~~BA 41/98~~	~~The design and appearance of bridges~~	~~**Withdrawn & replaced by CD 351**~~
~~BA 42/96~~	~~The design of integral bridges~~	~~**Withdrawn**~~
~~BA 47/99~~	~~Waterproofing and surfacing of concrete bridge decks~~	~~**Withdrawn & replaced by CD 358**~~
~~BA 57/01~~	~~Design for durability~~	~~**Withdrawn & replaced by CD 350**~~
~~BA 59/94~~	~~Design of highway bridges for hydraulic action.~~	~~**Withdrawn & replaced by CD 356**~~
~~BA 67/96~~	~~Enclosure of bridges~~	~~**Withdrawn & replaced by CD 362**~~
~~BA 68/97~~	~~Crib retaining walls~~	
~~BA 82/00~~	~~Formation of continuity joints in bridge decks~~	~~**Withdrawn & replaced by CD 364**~~
~~BA 85/04~~	~~Coatings for concrete highway structures & ancillary structures~~	~~**Withdrawn & replaced by CD 369**~~
~~BA 92/07~~	~~Use of recycled concrete aggregates in structural concrete~~	~~**Withdrawn & replaced by CD 374**~~
CD 127	Cross-sections and headrooms	Replaced TD 27/05/TD 70/08
CD 350	The design of highway structures	Replaced BD 57/01, BA 57/01, BD100/16, IAN 124/11
CD 351	The design and appearance of highway structures	Replaced BA 41/98
~~CD 352~~	~~Design of road tunnels~~	~~Replaced BD 78/99~~
~~CD 353~~	~~Design criteria for footbridges~~	~~Replaced BD 29/17~~
~~CD 354~~	~~Design of minor structures~~	~~Replaced BD 94/17~~
CD 355	Application of whole-life costs for design and maintenance of highway structures	Replaced BD 36/92 & BA 28/92
CD 356	Design of highway structures for hydraulic action	Replaced BA 59/94
~~CD 357~~	~~Bridge Expansion Joints~~	~~Replaced BD 33/94, BA 26/94, IAN 168/12, IAN 169/12~~
~~CD 358~~	~~Waterproofing and surfacing of concrete bridge decks~~	~~Replaced BD 47/99, BA 47/99 & IAN 96/07~~
~~CD 359~~	~~Design requirements for permanent soffit formwork~~	~~Replaced BD 36/90 & IAN 131/11~~
~~CD 361~~	~~Weathering steel for highway structures~~	~~Replaced BD 07/01~~
~~CD 362~~	~~Enclosure of bridges~~	~~Replaced BD 67/96 & BA 67/96~~
~~CD 364~~	~~Formation of continuity joints in bridge decks~~	~~Replaced BA 82/00~~
~~CD 365~~	~~Portal and cantilever signs/signals gantries~~	~~Replaced BD 51/14, IAN 193/16, BE 7/04~~
~~CD 366~~	~~Design criteria for collision protection beams~~	Replaced BD 65/14
CD 367	Treatment of existing structures on highways widening schemes	Replaced BD 95/07
~~CD 368~~	~~Design of fibre reinforced polymer bridges and highway structures~~	~~Replaced BD 90/05~~
CD 369	Surface protection for concrete highway structures	Replaced BA 85/04
~~CD 370~~	~~Cathodic protection for use in reinforced concrete highway structures~~	~~Replaced BA 83/02~~
~~CD 371~~	~~Strengthening highway structures using fibre-reinforced polymers and externally bonded steel plates~~	~~Replaced BD 85/08, BD 84/02~~
~~CD 372~~	~~Design of post-installed anchors and reinforcing bar connections in concrete~~	~~Replaced IAN 372~~
~~CD 373~~	~~Impregnation of reinforced and prestressed concrete highway structures using hydrophobic pore-lining impregnants~~	~~Replaced BD 43/03~~
~~CD 374~~	~~The use of recycled aggregates in structural~~	~~Replaced BA 92/07~~

	~~concrete~~	
CD 375	Design of corrugated steel buried structures	Replaced BD 12/01
~~CD 376~~	~~Unreinforced masonry arch bridges~~	~~Replaced BD 91/04~~
CD 377	Requirements for road restraint systems	Replaced TD 19/06
CD 529	Design of outfall and culvert details	Replaced HA 107/04
CD 622	Managing geotechnical risk	Replaced HD 22/08, BD 10/97, HA 120/08
CG 300	Technical approval of highway structures	Replaced BD 2/12
CG 302	As-built, operational and maintenance records for highway structures	Replaced BD 62/07
CG 303	Quality assurance scheme for paints and similar protective coatings	Replaced BD 35/14
~~CG 304~~	~~Conservation of highway structures~~	~~Replaced BD 89/03~~
CG 305	Identification marking of highway structures	Replaced BD 45/93
CS 460	Management of corrugated steel buried structures	Replaced BA 87/04
~~TD 19/06~~	~~Requirement for road restraint systems~~	~~**Withdrawn & replaced by CD 377**~~
~~TD 27/05~~	~~Cross-sections and headrooms~~	~~**Withdrawn & replaced by CD 127**~~
~~HD 22/08~~	~~Managing geotechnical risk~~	~~**Withdrawn & replaced by CD 622**~~
~~HA 66/95~~	~~Environmental barriers~~	~~**Withdrawn & replaced by LD 119**~~
~~GD 01/15~~	~~Introduction to the Design Manual for Roads and Bridges~~	~~**Withdrawn & replaced by GG 101**~~
~~GD 02/16~~	~~Quality Management Systems for Highway Design~~	~~**Withdrawn & replaced by GG 102**~~
~~GD 04/12~~	~~Standard for Safety Risk Assessment on the Strategic Road Network~~	~~**Withdrawn & replaced by GG 104**~~
GG 101	Introduction to the Design Manual for Roads and Bridges (DMRB)	Replaced GD 01/15
GG 102	Quality management systems for highway works	Replaced GD 02/16
GG 104	Requirements for safety risk assessment	Replaced GD 04/12
~~LD 119~~	~~Roadside environmental mitigation and enhancement~~	~~Replaced LA 119, HA 65/94, HA 66/95~~

Interim Advice Notes

IAN 69/15	Designing for maintenance
~~IAN 83/06~~	~~Principal and General Inspection of Sign/Signal Gantries, and Gantries with low handrails or open mesh flooring~~
~~IAN 96/07r1~~	~~Guidance on implementing results of research on bridge deck waterproofing. **Withdrawn & replaced by CD 358**~~
~~IAN 97/07~~	~~Assessment and upgrading of existing parapets~~
~~IAN 104/15~~	~~The anchorage of reinforcement and fixings in hardened concrete. **Withdrawn & replaced by CD 372**~~
~~IAN 105/08~~	~~Implementation of construction (design and management) 2007 and the withdrawal of SD 10 and SD 11~~
~~IAN 117/08r2~~	~~Certification of combined kerb and drainage products~~
~~IAN 124/11 Annex C~~	~~Use of Eurocodes for the design of highway structures **Withdrawn & replaced by CD 350**~~
~~IAN 127/10r1~~	~~The use of foamed concrete~~
~~IAN 131/11~~	~~Deflection of Permanent Formwork **Withdrawn & replaced by CD 359**~~
IAN 136/10	Structural safety reporting
~~IAN 149/17~~	~~Existing Motorway Minimum Requirements~~
~~IAN 161/15~~	~~Smart Motorways~~

IAN 177/13	Introduction of the Construction Products Regulation (EU) 305/2011
IAN 184/16	Highways Agency Data & CAD Standard
~~IAN 186/15~~	~~In-situ concrete barriers based on proprietary designs commercialised as products~~
~~IAN 193/16~~	~~Requirements for the provision of access arrangements on gantries~~ **Withdrawn & replaced by ~~CD 365~~**

Miscellaneous

~~CHE Memorandum 227/08~~	~~The Impregnation of Reinforced and Prestressed Concrete Highway Structures using Hydrophobic Pore Lining Impregnants~~	~~CHE memoranda are internal Highways England documents and not available to external organisations. This CHE memorandum is included as a useful reference for the Technical Approval Authority.~~
~~CIRIA C543~~	~~Bridge Detailing Guide~~	
CIRIA C660	Early-age Thermal Crack Control in Concrete	
CIRIA C686	Safe Access for Maintenance and Repair	
~~CIRIA C760~~	~~Guidance on embedded retaining wall design~~	
CIRIA C786	Culvert, screen and outfall manual	

APPENDIX B

General Arrangement Drawing - 239025-ARP-XX-XX-DR-CB-0001

Historic Drawing – C/T/202/570A/1

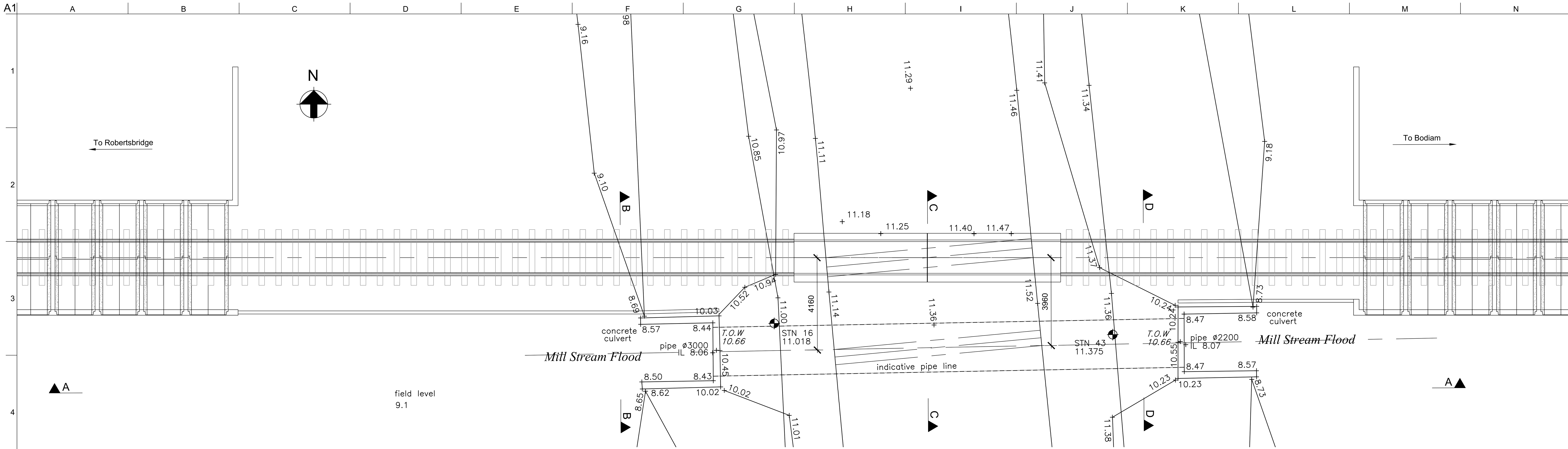
SAFETY, HEALTH & ENVIRONMENT

INFORMATION IN THIS BOX RELATES ONLY TO SIGNIFICANT OR UNUSUAL RISKS.

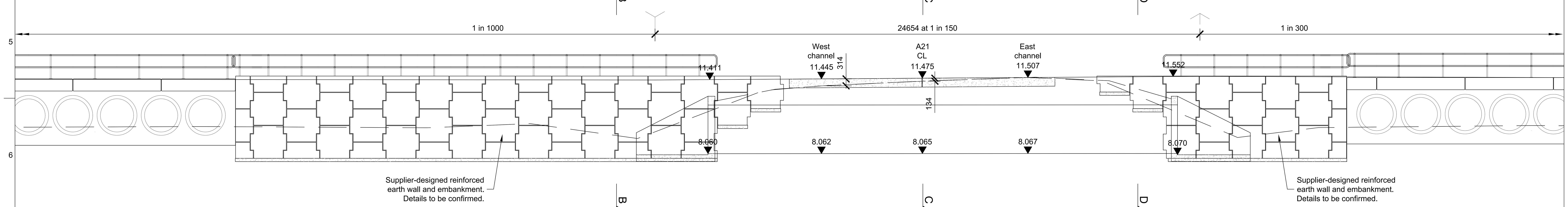
1. No loading should be imposed above culvert or head wall until reinforced earth wall and gravel infill is placed
2. Excavation depth on south side of culvert and headwall to be controlled to minimise out of balance lateral loads on culvert during excavation for reinforced earth wall. Assumed depth shown is to be reviewed following receipt of GIR.

Notes

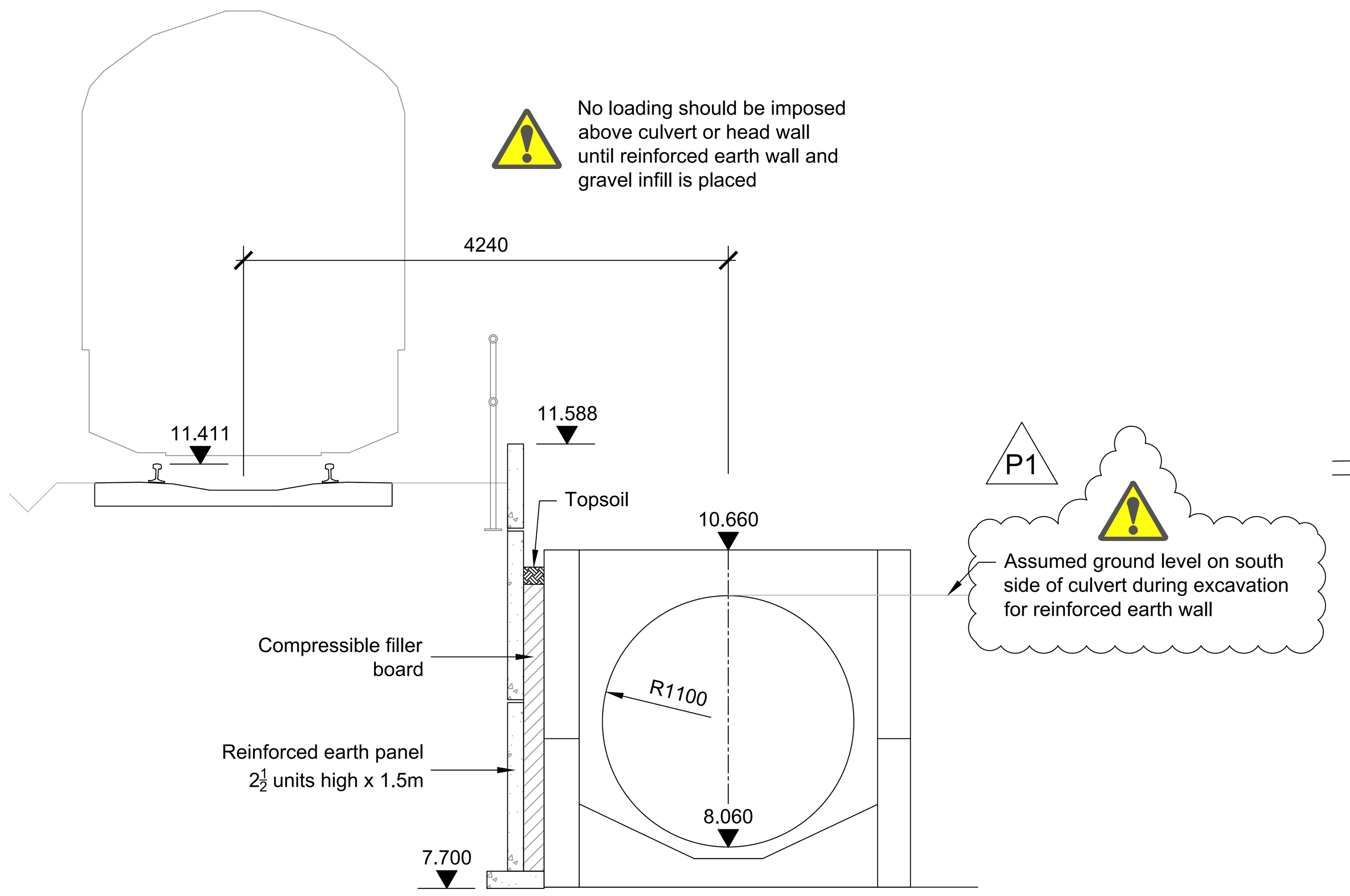
1. Levels are in metres and are based on the topographic survey carried out by J.C.White Geomatics Limited, October 2014.
2. Additional detailed topographic survey is required to confirm levels around existing headwalls.
3. All levels and dimensions are to be confirmed.
4. Details of the reinforced earth embankment are to be confirmed following supplier-design.



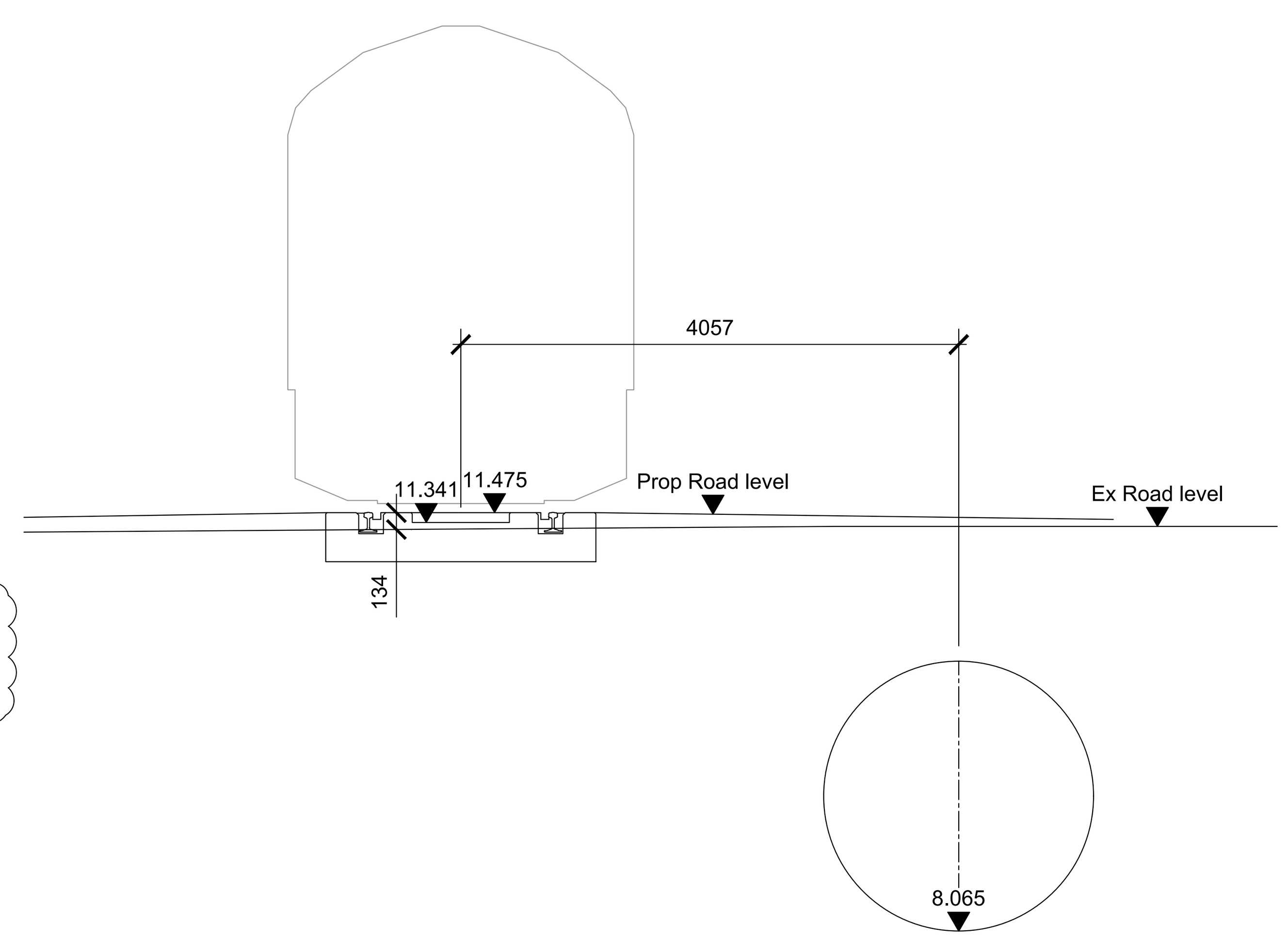
Plan
Scale 1:100



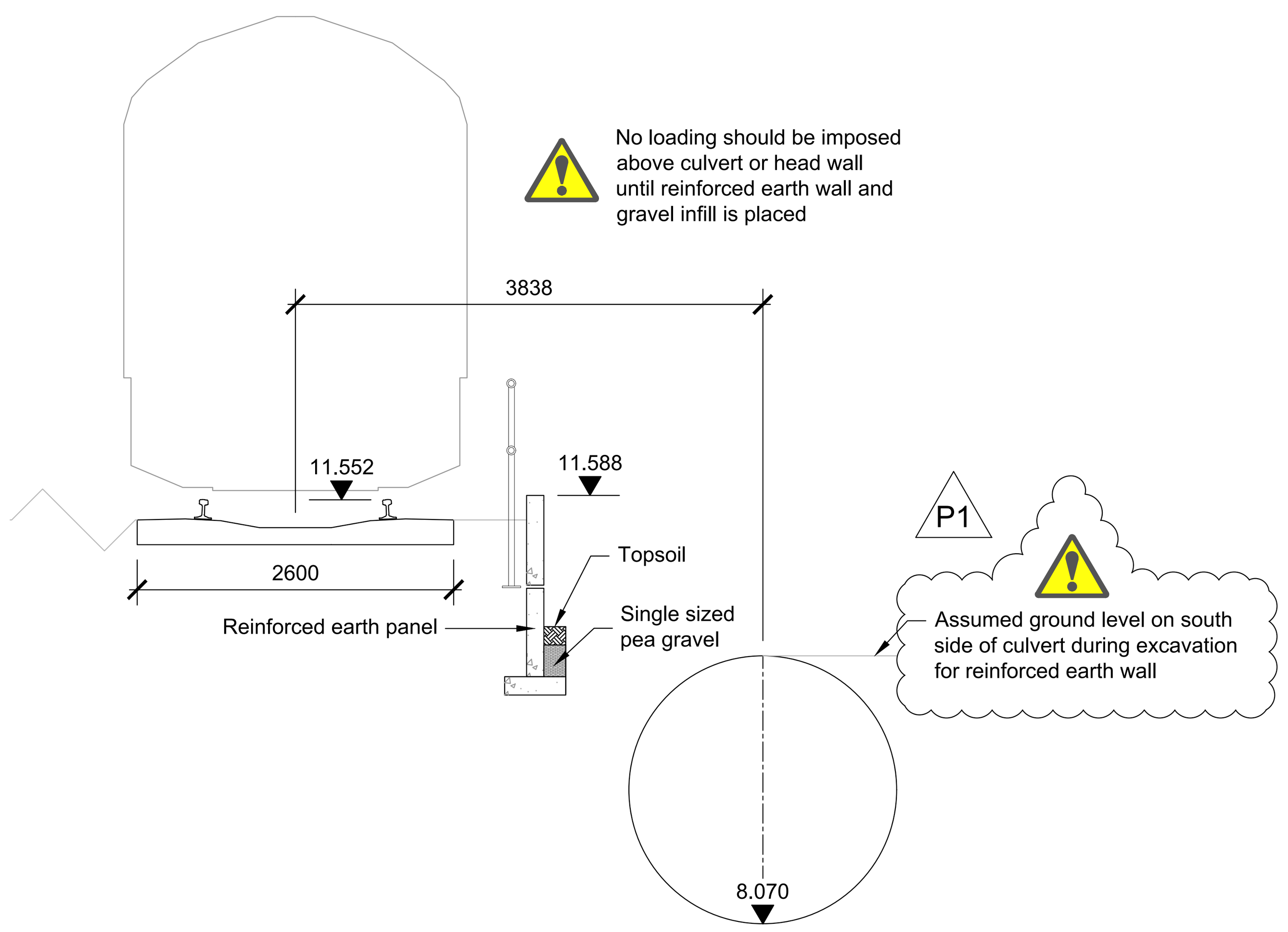
Elevation A-A
Scale 1:100



Section B-B on West headwall (East headwall similar but handed)
Scale 1:50



Section C-C through A21 highway centreline
Scale 1:50



Section D-D through existing culvert and reinforced earth panel
Scale 1:50

Rev	Date	By	Chkd	Appd
P1	11/12/20	ER	CM	JP
	Reissue following AiP comments. Supersedes 239025-A21-G-101			

ARUP

Central Square, Forth Street
Newcastle upon Tyne NE1 3PL
Tel +44 (0)191 261 6080 Fax +44 (0)191 261 7879
www.arup.com

Client: Rother Valley Railway Limited

Project Title: A21 Level Crossing

Drawing Title: Embankment Retaining Wall General Arrangement and Sections

Scale at A1: As Noted

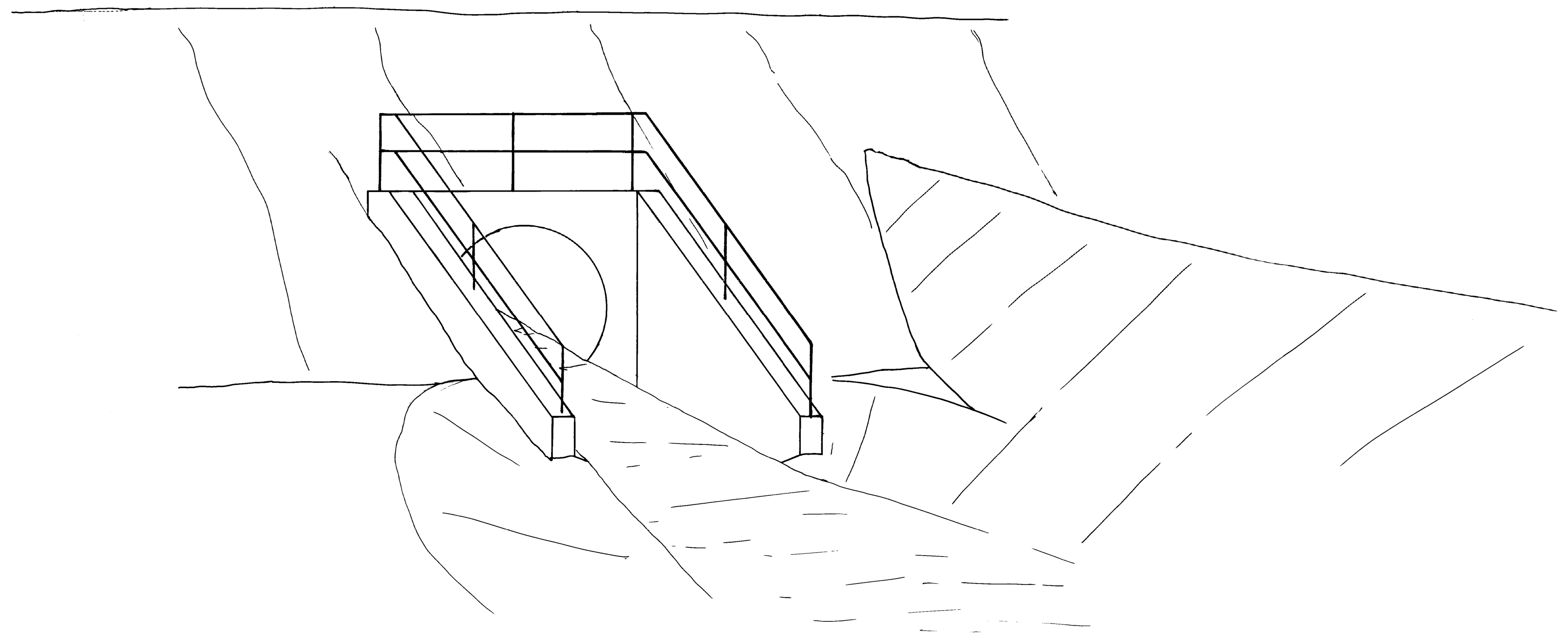
Role: Structures

Suitability: S2 - Suitable for Information

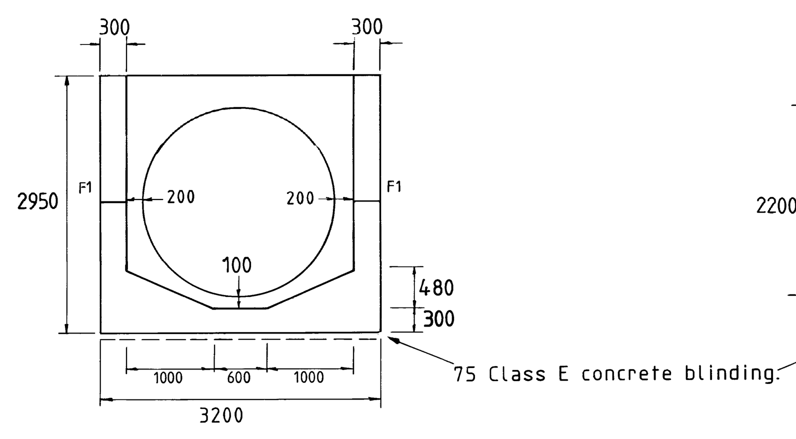
Arup Job No: 239025 | Rev: P1

Name: 239025-ARP-XX-XX-DR-CB-0001

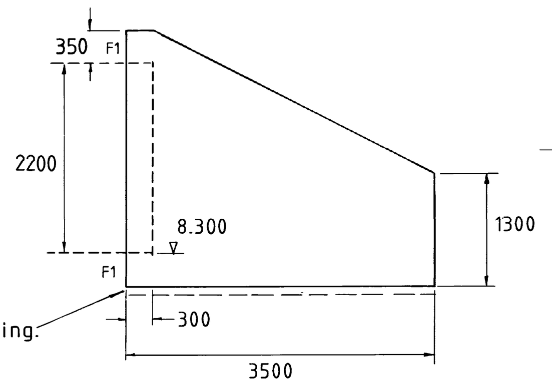
Do not scale



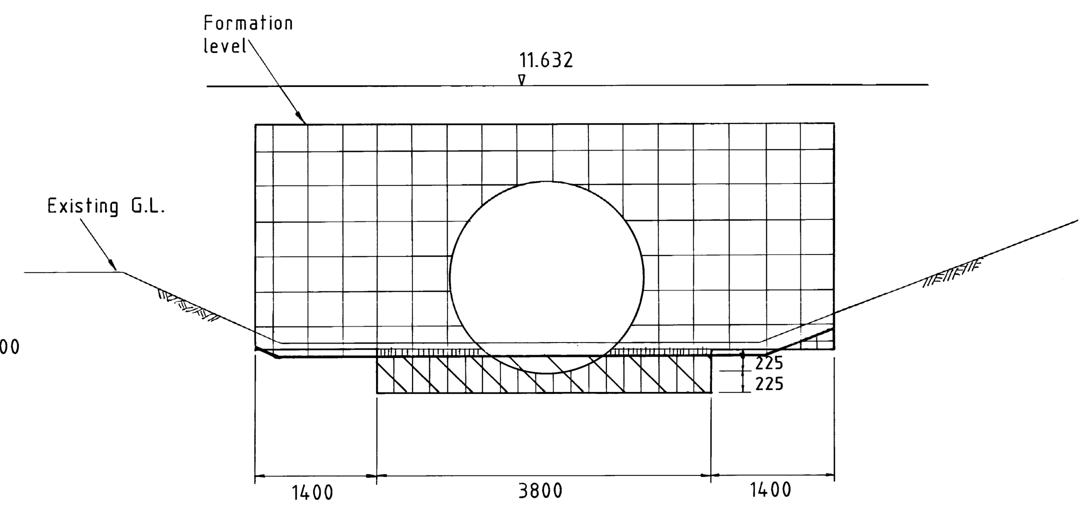
EAST ELEVATION.
Not to scale



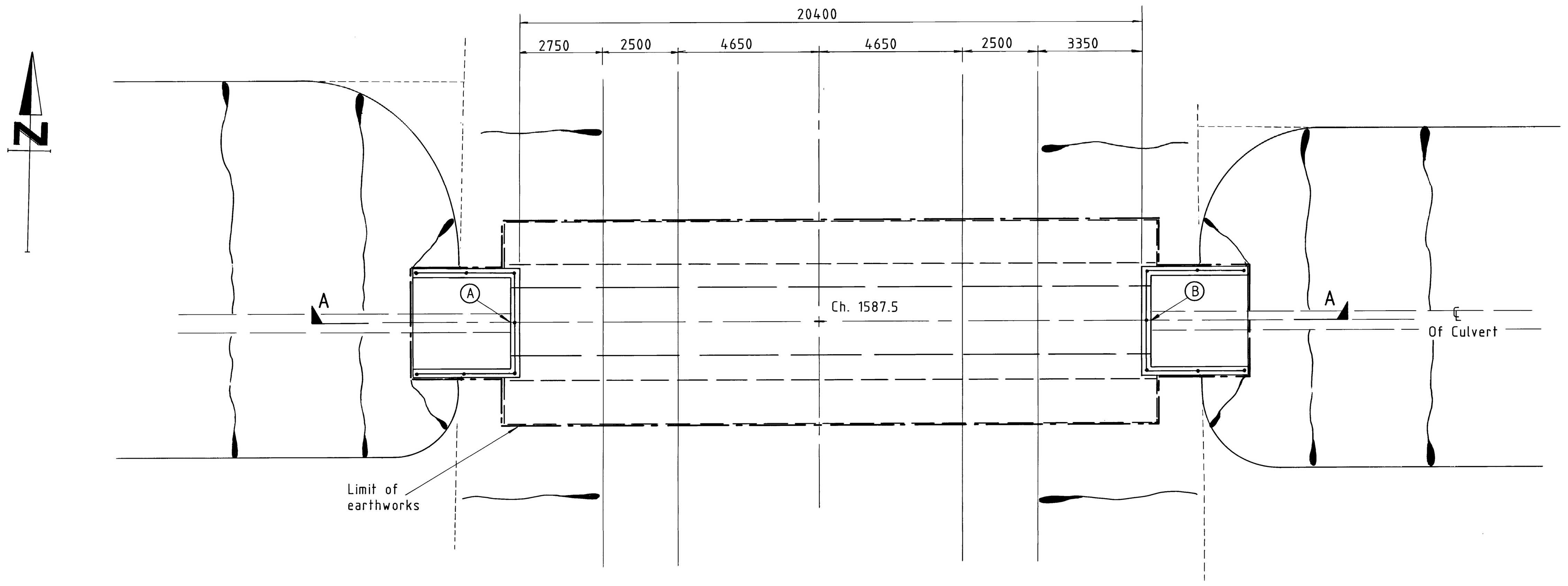
END ELEVATION
Scale 1:50



SIDE ELEVATION
Scale 1:50



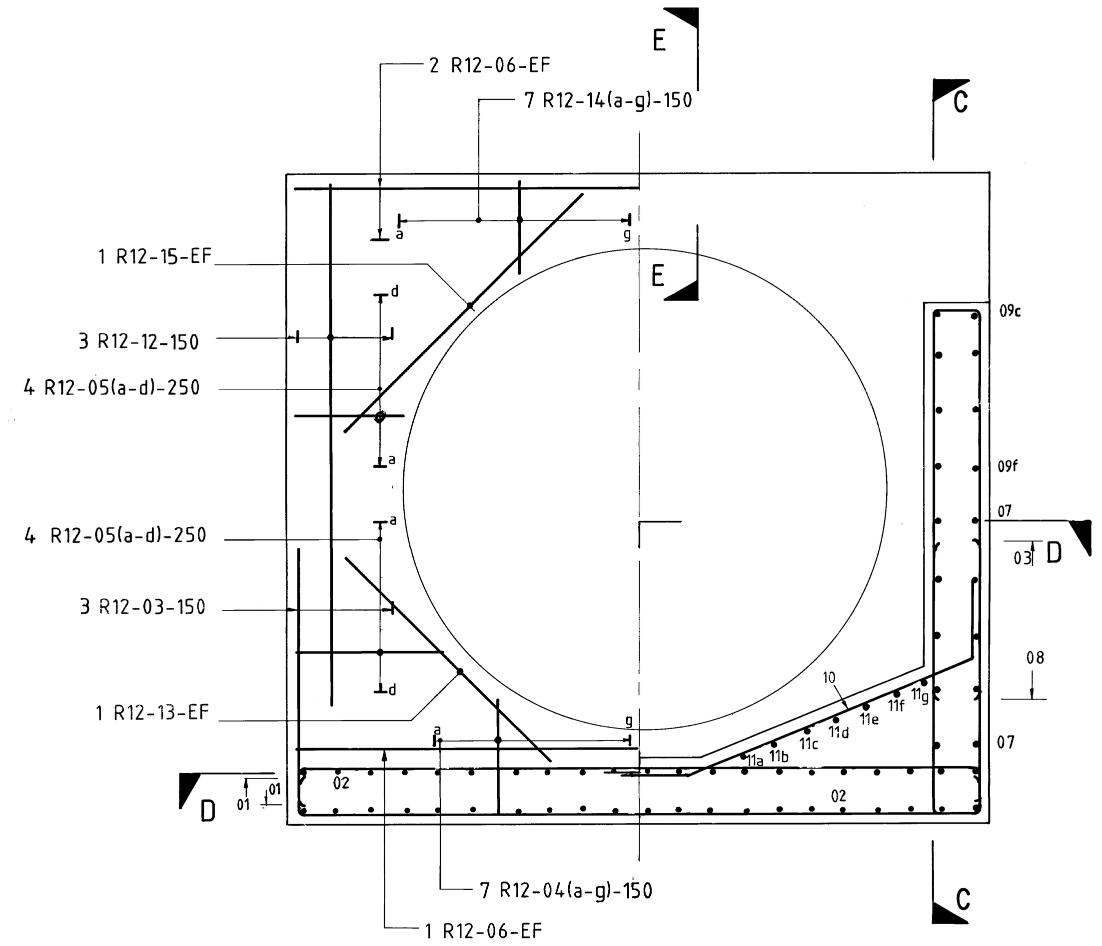
TYPICAL SECTION
Scale 1:50



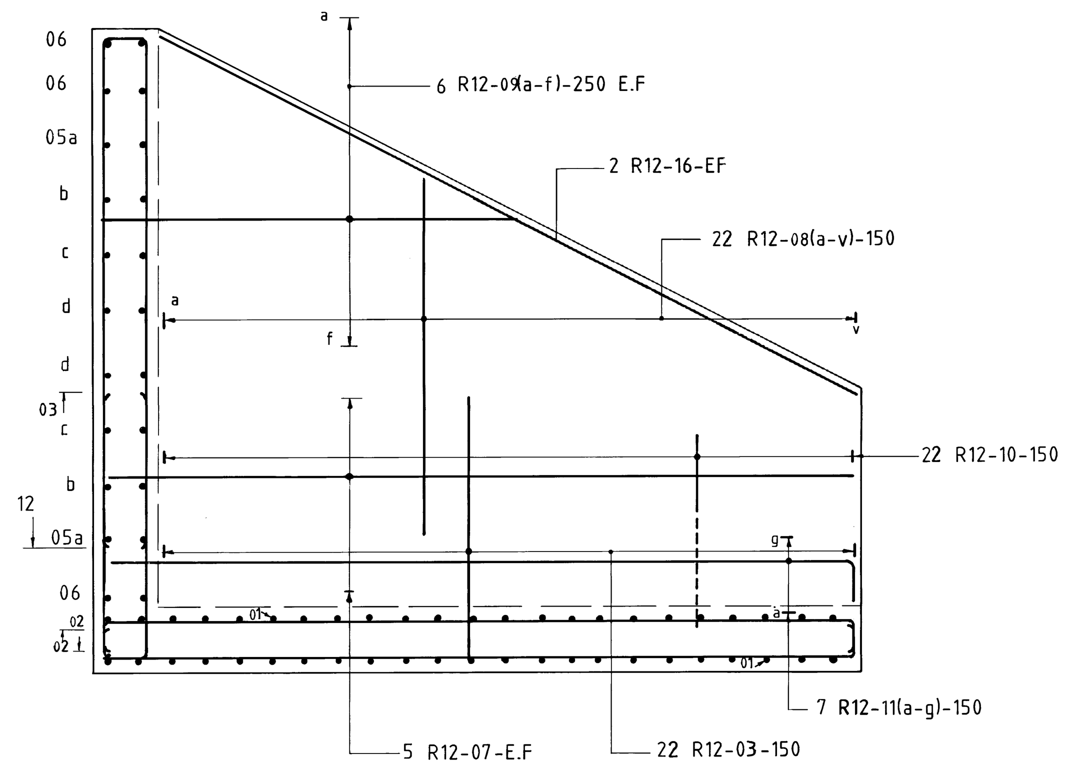
PLAN
Scale 1:100

Point	E	N
A	574107.929	124070.776
B	574128.924	124071.243

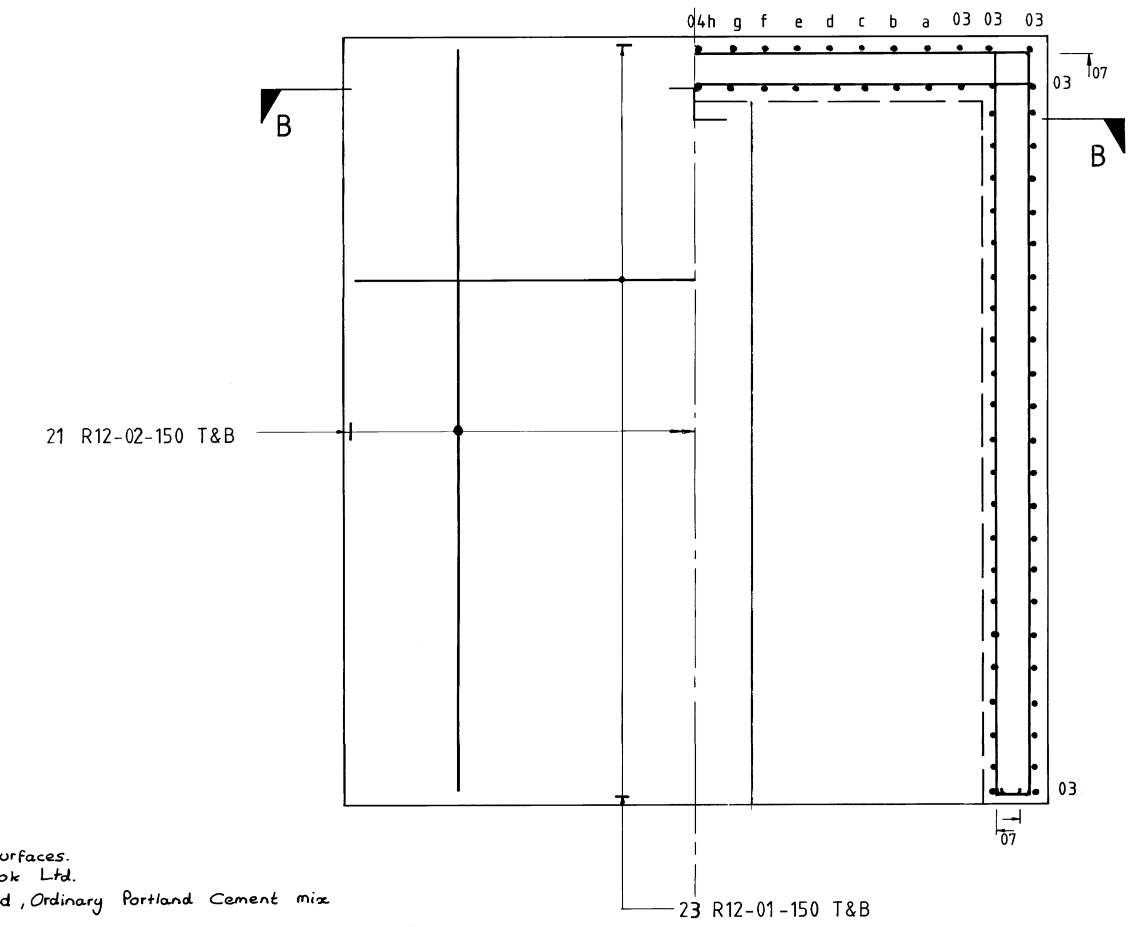
SETTING OUT INFORMATION



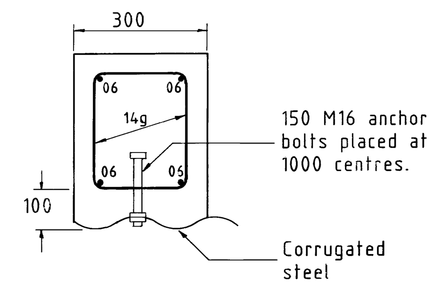
SECTION B-B
Scale 1:20



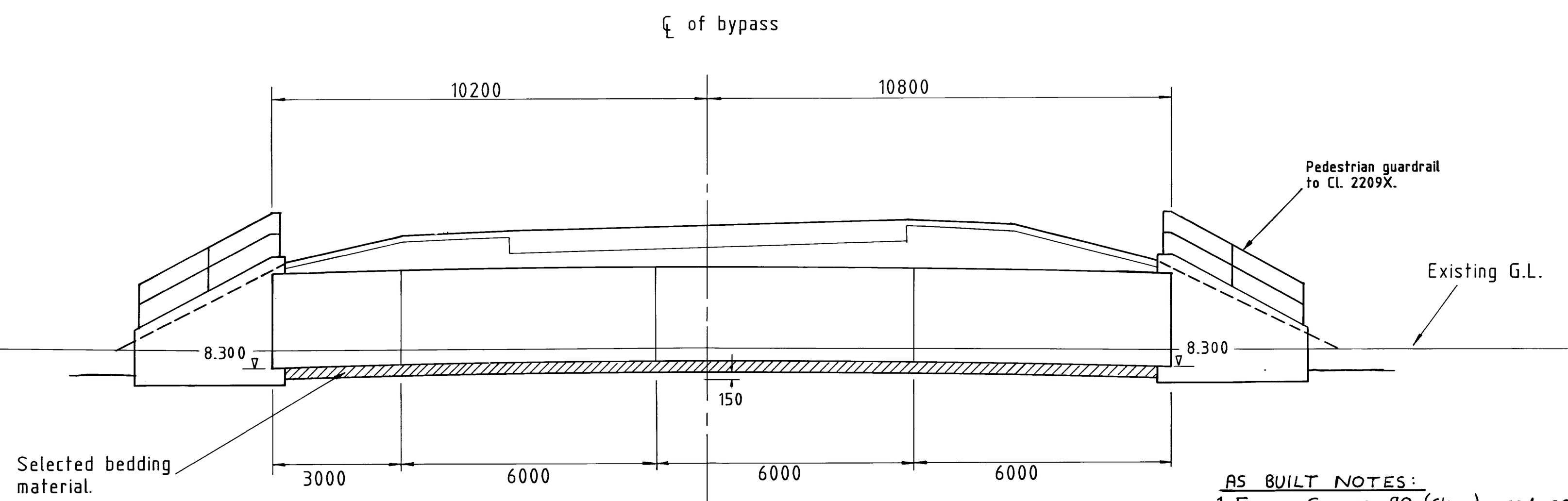
SECTION C-C
Scale 1:20



SECTION D-D
Scale 1:20



SECTION E-E
Scale 1:10



SECTIONAL ELEVATION A-A
Scale 1:100

AS BUILT NOTES:
1. Fosroc Concure 90 (clear) used on all concrete surfaces.
2. Pedestrian Guard Railing Supplied by Franklin and Cook Ltd.
3. Head Walls Bagwashed using 2:1 mix, Silver Sand, Ordinary Portland Cement mix (with part white cement)
4. Concrete finished in accordance with the recommendations in C and CA publication, 'Making Good and Finishing'.

KEY TO EARTHWORKS

- Earthworks outline.
- Excavation of Unsuitable material in structural foundations
- Imported bedding material to Cl.630 deposited around structural foundations.
- Imported bedding material to Cl.630 deposited adjacent to structures excluding around foundations
- Imported sidefill material to Cl.631 deposited around structural foundations.
- Imported sidefill material to Cl.631 deposited adjacent to structures excluding around foundations.

NOTES

1. All dimensions in millimetres, all levels in metres (AOD Newlyn) unless stated otherwise.
2. Culvert to be 2200 diameter helically wound corrugated galvanised steel (3.5 thick) with bitumen coating and paved asphalt invert. Lengths to be mechanically locked together using a purpose made steel band with O-ring rubber gaskets.
3. Bitumen protective coating and paved invert (Clause 1913) to be applied at the factory and any damage to be made good to the satisfaction of the engineer.
4. The culvert is to be constructed with a 150 hog in order to offset the effects of consolidation settlement under the embankment.
5. Selected fill to be as specified in Clause 630 and 631 of the specification.
6. Selected fill for bedding and sidefill to be deposited in layers not exceeding 150 thick and to be deposited and compacted uniformly on both sides of the structure, strictly in accordance with Clause 633 of the specification.
7. Concrete to be Class 40/20. Minimum cement content 325 Kg/m³ maximum Water/Cement ratio 0.55
8. Cover to reinforcement to be 45mm
9. Reinforcement ordered to bar schedule N° 570/01-03
10. Mild steel reinforcement (Ref.R) shall be to B.S.4449
11. Waterproofing - Two coats of bitumen to be applied to outside face of headwalls below proposed ground level.
12. Finishes - Class F3 finish to be provided unless shown otherwise.
13. Minimum lap length to be 450mm.

AS BUILT DRAWING

EAST SUSSEX COUNTY COUNCIL

B C D Kermode BCE, CEng, FICE, FIHT

County Engineer, Lewes.

Director (Transport)
Departments of the Environment and Transport
South East Regional Office
Dorking, Surrey RH4 1SZ

	AMENDMENT	INITIALS	DATE	AMENDMENT	INITIALS	DATE
A.	Detailing amendments	S.M.F.	APRIL 1988			

	INITIALS	DATE
SURVEY		
DESIGN	S.M.B. / D.F.S.	FEB 1987 / MAR 1987
DRAWN	D.F.S.	MAR 1987
CHECKED	R.M.A.G.	JULY 1987

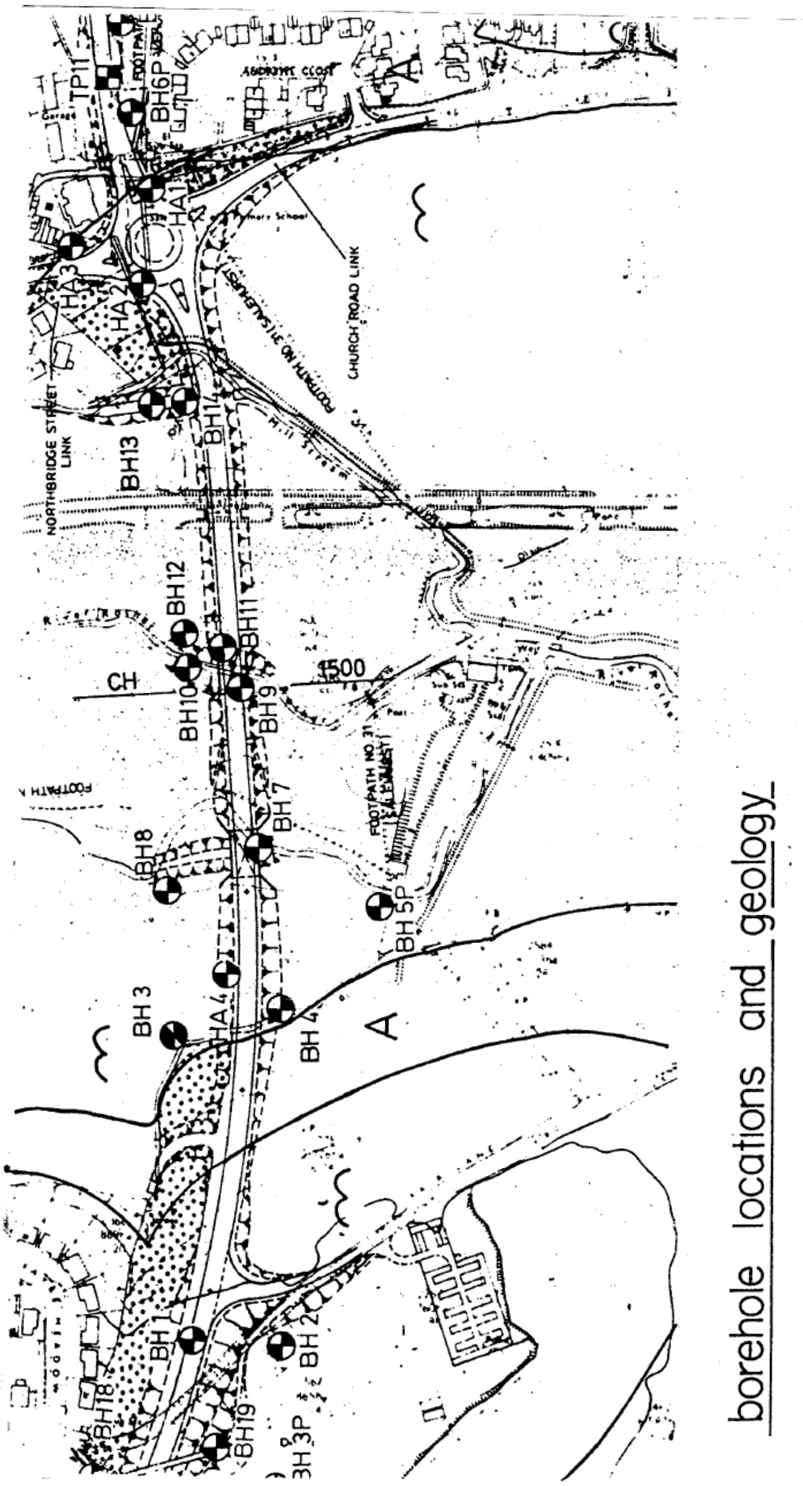
A21 CHEVENING - HASTINGS TRUNK ROAD
ROBERTSBRIDGE BYPASS
CULVERT 2

SCALE 1:10, 1:20, 1:50 and 1:100

DRG. No. C/T/202/570A/1

APPENDIX C

Historic Borehole Logs



BOREHOLE RECORD (PERCUSSION) EAST SUSSEX COUNTY COUNCIL	SCHEME ROBERTSBRIDGE BYPASS A21	BOREHOLE BH11 Grid Ref Sheet 1 of 2

SAMPLING | **STRATA** | **PROPERTIES**

Depth	Type	No	Rec	Depth	Level	Thick-ness	Legend	Description	γ_b Mg/m³	m/c %	N	c kN/m²
0.3	J	1		0.0 0.3	9.6 9.3	0.3		TOPSOIL				
1.5	P	2	900			2.3		Soft olive grey mottled with orange brown ironstained silty CLAY	1.91	33.0		20.0
2.4	J	3						becoming soft and wet, mottled with orangey. brown, very heavily ironstained with black staining				
				2.6	7.0							
3.0	P	4	800						1.89	30.7		15.0
3.9	J	5						Very soft greenish grey silty CLAY (oxidising rapidly to olive brown)				
						5.5						
6.0	P	6	900						1.90	31.7		c'= 0
6.9	J	7										
				8.1	1.5							
8.2– 8.7	B S J	8 9									(15)	
						1.9		Medium dense subangular and rounded siltstone GRAVEL/coarse SAND				
				10.0	–0.4			continues rotary				

DRILLING

Type	From	To	Size	Drill Fluid
Percussion Rotary	0 10.0	10.0 20.5	0.15 H	 water

GROUNDWATER

Struck	Behaviour	Sealed	Date	Time	Depth Hole	Depth Casing	Depth Water
2.5	steady		24.2	am pm	8.7 10.0	8.5 10.0	3.2 –

REMARKS

156

Start date	23/2/83
Finish date	1/3/83
Logged by	RW

BOREHOLE RECORD (ROTARY)	SCHEME	BOREHOLE BH11
EAST SUSSEX COUNTY COUNCIL	ROBERTSBRIDGE BYPASS A21	Grid Ref
		Sheet 2 of 2

STRATA

Depth	Level	Thick-ness	Legend	Description
10.0	-0.4			
		0.7		Stiff yellowish brown CLAY with ironstaining and ironstones
10.7	-1.1			
		2.9		Stiff medium grey CLAY with weakly cemented medium grey SILTSTONE Mottled with brick red.
13.6	-4.0			
		1.8		Very stiff medium grey CLAY with brown ironstaining light grey dark grey and brown
15.7	-6.1			
		0.8		Very weakly cemented dark bluish grey thinly laminated SILTSTONE becoming light grey and clayey SILT
16.5	-6.9			
		4.0		Very stiff light grey thinly laminated silty CLAY with fecal pellets Medium grey many fecal pellets becoming clayey SILT with many fecal pellets weakly cemented SILTSTONE layer brick red mottling dark grey becoming clayey SILT
20.5	10.9		EOB	

PROPERTIES

Depth	W R	TCR %	SCR %	RQD %	AFS mm	N	Is MN/m²
10.0						+	
	90 GREY	20	0	0	–		
11.5							
	90 GREY	0	0	0	–		
13.0						(28)	
	50 GREY	73	93	71	273		
14.5							
	90 GREY	97	83	78	1190		
16.0					very fractured	+	
	90 GREY	89	92	84	220		
17.5							
	90 GREY	95	91	89	286		
19.0						(140)	
	90 GREY	91	89	82	171		
20.5						+	

DRILLING

Type	From	To	Size	Drill Fluid

GROUNDWATER

Struck	Behaviour	Sealed	Date	Time	Depth: Hole	Depth: Casing	Depth: Water

REMARKS + SPT 10.0–10.5 – 70 blows for 75mm total penetration
SPT 16.0–16.5 – 70 blows for 80mm total penetration
SPT 20.5–21.0 – 70 blows for 105mm total penetration

Fecal pellets are coarse sand size particles of mud.

157

Start date	23/2/83
Finish date	1/3/83 –
Logged by	RW

BOREHOLE RECORD (PERCUSSION)

EAST SUSSEX COUNTY COUNCIL

SCHEME ROBERTSBRIDGE BYPASS A 21.

BOREHOLE BH 12

Grid Ref

Sheet 1 of 3

SAMPLING

Depth	Type	No	Rec
0.9	J	1	
1.9	J	2	
2.0 –2.9	P	3	900
2.9	J	4	
4.5	J	5	
5.0 –5.9	P	6	900
5.9	J	7	
7.5	J	8	
8.0 –8.9	P	9	900
8.9	J	10	
9.1 –9.6	B SJ	11 12	

STRATA / **PROPERTIES**

Depth	Level	Thickness	Description	γ_b Mg/m³	m/c %	N	c kN/m²
0.0	9.7	0.9	Topsoil				
0.9	8.8	1.6	Firm olive grey mottled with orange brown ironstained CLAY becoming soft, silty and yellowish brown with depth.	1.85	32.5		–
2.5	7.2	6.6	Very soft greenish grey clayey SILT (oxidizing rapidly to olive brown)	1.94 1.97	30.1 25.5		c' = 6 17
9.1	0.6	1.1	Loose subangular and rounded siltstone GRAVEL and coarse SAND.			(9)	
10.2	–0.5		continues rotary				

DRILLING

Type	From	To	Size	Drill Fluid
Percussion Rotary	0	10.2	150	–
Rotary	10.2	31.0	H	Water

GROUNDWATER

Struck	Behaviour	Sealed	Date	Time	Depth Hole	Depth Casing	Depth Water
3.0	Steady seepage		3.3	pm	10.2	10.0	–
22.5	Artesian pressure		4.3	am	10.2	10.0	9.8
			7.3	am	17.5	10.0	1.4
			8.3	am	20.5	10.0	1.3
			9.3	am	26.5	10.0	0.0

REMARKS

Artesian head on backfilling hole 2.1 m above G.L. 158

Start date	3.3.83
Finish date	9.3.83
Logged by	RW

BOREHOLE RECORD (ROTARY) EAST SUSSEX COUNTY COUNCIL	SCHEME ROBERTSBRIDGE BYPASS A 21	BOREHOLE BH 12 Grid Ref Sheet 2 of 3

STRATA / PROPERTIES

Depth	Level	Thickness	Legend	Description	Depth	W R	TCR %	SCR %	RQD %	AFS mm	N	Is MN/m²
10.0	-0.3			No lignite	10.0							
10.2	-0.5	0.75		traces; Lignite band; Stiff medium grey mottled with yellowish brown CLAY with lignite traces.		90 Brown Grey	61	100	98	460		
10.95	-1.25	0.75		Stiff medium grey silty CLAY								
11.7	-2.0	0.50		Stiff medium grey CLAY	11.5							
12.2	-2.5	0.60		Very stiff brownish grey CLAY		90 Red Grey	109	100	100	1630		
12.8	-3.1	1.0		With fecal pellets. Very stiff medium grey mottled with brick red CLAY	13.0							
13.8	-4.1	1.4		Dark grey. Very stiff medium grey CLAY	14.5	90 Red Grey	86	100	100	1290		
15.2	-5.5	0.8		Very stiff light grey CLAY with insignificant lenses of yellow fine SAND.		90 Grey	94	100	99	705		
16.0	-6.3	0.2		Very stiff very dark brown CLAY (soil horizon)	16.0							
16.2	-6.5	0.73		brownish grey; medium grey; dark grey. Very stiff CLAY		90 Grey	93	76	59	140		
16.93	-7.23	0.77		well cemented; weakly cemented. Very weakly cemented light grey thinly laminated SILTSTONE								
17.7	-8.0	0.8		Very stiff light grey silty CLAY with fecal pellets	17.5	90 Grey	91	74	70	113		
18.5	-8.8	0.6		Very stiff brownish grey silty CLAY								
19.1	-9.4	1.03		with fecal pellets. Very stiff medium grey CLAY becoming yellowish grey.	19.0	90 Grey	88	83	44	147		
20.13	-10.43	0.62		Very stiff dark grey mottled with light grey CLAY								
20.75	-11.05				20.5							

DRILLING

Type	From	To	Size	Drill Fluid

GROUNDWATER

Struck	Behaviour	Sealed	Date	Time	Depth Hole	Depth Casing	Depth Water

REMARKS Fecal pellets are coarse sand size particles of mud

Start date	3.3.83
Finish date	9.3.83
Logged by	RW

159

BOREHOLE RECORD (ROTARY)	SCHEME	BOREHOLE BH12
EAST SUSSEX COUNTY COUNCIL	ROBERTSBRIDGE BYPASS A 21	Grid Ref
		Sheet 3 of 3

STRATA

Depth	Level	Thickness	Legend	Description
20.5	-10.8			
20.75	-11.05	0.47		Very stiff medium grey silty CLAY
21.22	-11.52	1.38		fecal pellets; Very stiff medium grey clayey SILT; becoming brownish grey
22.6	-12.9	0.8		Medium grey; moderately cemented; Very weakly cemented brownish grey coarse SILTSTONE with lignite traces.
23.4	-13.7	1.05		Very dense brownish grey slightly clayey thinly laminated coarse SILT •
24.45	-14.75	0.5		• • Very stiff brownish grey clayey SILT
24.95	-15.25	2.04		V. weakly cem. coarse SILTSTONE; Weakly cem. light grey fine SANDSTONE; Very stiff clayey SILT; Weakly cem. coarse SILTSTONE; Dense medium grey clayey SILT; Very dense brownish grey thinly laminated slightly clayey coarse SILT
26.99	-17.29	0.37		Moderately cemented light grey fissured fine SANDSTONE
27.36	-17.66	0.89		SAND-STONE; Stiff brownish grey silty CLAY thinly interbedded with light grey fine SAND; Sand becoming predominant
28.25	-18.55	0.51		Very weakly cemented; Very dense brownish grey thinly laminated clayey SILT
28.76	-19.06	0.16		Mod. cem. light grey fine SANDSTONE
28.92	-19.22	0.23		Stiff brownish grey clayey SILT
29.15	-19.45	0.10		Weakly cemented coarse SILTSTONE
29.25	-19.55	0.58		Very dense light grey fine SAND thinly interbedded with brownish grey clayey SILT
29.83	-20.13	1.27		Stiff brownish grey clayey coarse SILT with lignite traces; Moderately cemented light grey fine SANDSTONE (with thin lignite bands)
31.1	-21.4		EOBH	

PROPERTIES

Depth	W R	TCR %	SCR %	RQD %	AFS mm	N	Is MN/m²
20.5							
	90 Grey	97	89	65	183		
22.0					160		
	90 Grey	97	52	30	V.F. / 8.8 / V.F.		
23.5							
	90 Grey	97	64	48	130		
25.0							
	90 Grey	97	61	44	91		
26.5							
	90 Grey	100	33	27	V.F.		
28.0							
	90 Grey	97	25	0	V.F.		
29.5							
	90 Grey	80	0	0	V.F.		
31.0							

DRILLING				
Type	From	To	Size	Drill Fluid

GROUNDWATER							
Struck	Behaviour	Sealed	Date	Time	Depth Hole	Depth Casing	Depth Water

REMARKS • thin lignite bands

Start date	3.3.83
Finish date	9.3.83
Logged by	RW

160

BOREHOLE RECORD (PERCUSSION)	SCHEME	BOREHOLE BH13
EAST SUSSEX COUNTY COUNCIL	ROBERTSBRIDGE BYPASS A21	Grid Ref
		Sheet 1 of 2

SAMPLING

Depth	Type	No	Rec
0.0–0.7	B J	1 2	
0.8–1.3	U	3	400
1.3	J	4	
1.8	VJ	5	
2.3–2.8	U	6	450
2.8	J	7	
3.3	V		
3.8	J	8	
4.3–4.8	U	9	450
4.8	J	10	
5.3	V		
5.8	J	11	
6.3–6.8	U	12	450
6.8	J	13	
7.3	V		
7.8	J	14	
8.3–8.8	U	15	450
8.8	J	16	
9.3	VJ	18	
	W	17	

STRATA

Depth	Level	Thickness	Legend	Description
0.0	9.4	0.7		TOPSOIL
0.7	8.7	1.5		Soft medium grey mottled with yellowish, brown, ironstained slightly silty CLAY.
2.2	7.2	6.0		Very soft bluish grey slightly silty CLAY with occasional sand traces (oxidising to olive brown).
8.2	1.2	2.0		Very soft greenish grey slightly sandy SILT (oxidising to olive brown)
10.2	–0.8			continued..

PROPERTIES

Depth	γ_b Mg/m³	m/c %	N	c kN/m²
0.8–1.3	1.92	32.0	12/450	27
2.3–2.8		41.2	6/450	
3.3				V19
4.3–4.8	1.87	36.4	9/450	6
5.3				V11
6.3–6.8	1.88	33.2	8/450	C'=3
7.3				V23
8.3–8.8		23.5	6/450	
9.3				V12

DRILLING

Type	From	To	Size	Drill Fluid
Percussion	0	17.1	150	–*

GROUNDWATER

Struck	Behaviour	Sealed	Date	Time	Depth Hole	Depth Casing	Depth Water
1.7	Very slight water seepage drilling water obscured measure.		19.1	am	1.8	1.5	1.1
				pm	8.8	7.5	–
			20.1	am	8.8	7.5	8.3
				pm	14.0	12.0	–

REMARKS * Water added to assist boring 2–10m depth.
Heavy hammer used for all U100 samples.

16 i

Start date	18.1.83
Finish date	24.1.83 –
Logged by	RW

BOREHOLE RECORD (PERCUSSION)	SCHEME	BOREHOLE BH13
EAST SUSSEX COUNTY COUNCIL	ROBERTSBRIDGE BYPASS A21.	Grid Ref
		Sheet 2 of 2

SAMPLING				STRATA					PROPERTIES			
Depth	Type	No	Rec	Depth	Level	Thick-ness	Legend	Description	γ_b Mg/m³	m/c %	N	c kN/m²
10.3 –10.8	U	19	450	10.2	−0.8	1.2		Dense subangular and rounded siltstone GRAVEL	2.17		55/450	
10.8	J	20										
10.8 –11.3	SJ & B	21 22									(51)	
11.5 –12.0	U	23	450	11.4	−2.0	3.6		Stiff medium grey mottled with brick red CLAY.		19.4	61/450	
12.0	J	24						Fecal pellet bed				
12.5	J	25										
13.5 –14.0	U	26	450					Dark grey	2.13	20.9	73/450	118
14.0	J	27										
14.5	J	28										
				15.0	−5.6	1.6		Very stiff medium grey very silty CLAY		12.9	112/450	
15.5 –16.0	U	29	400									
16.0	J	30									(76)*	
16.0 –16.5	SJ B	31 32										
16.6 –17.1	SJ B	33 34		16.6	−7.2			Very dense light grey SILT			+	
				17.1	−7.7		EOB					

DRILLING

Type	From	To	Size	Drill Fluid

GROUNDWATER

Struck	Behaviour	Sealed	Date	Time	Depth Hole	Depth Casing	Depth Water
			21.1	am	14.0		13.5
				pm	15.0		–
			24.1	am	15.0	12.0	1.2
				pm	17.1		4.5

REMARKS + SPT at 16.6–17.1 Total penetration at 70 blows 80 mm.
Fecal pellets are coarse sand size particles of mud. 162

Start date	18.1.83
Finish date	24.1.83 –
Logged by	RW

BOREHOLE RECORD (PERCUSSION) EAST SUSSEX COUNTY COUNCIL	SCHEME ROBERTSBRIDGE BYPASS A21	BOREHOLE BH14 Grid Ref Sheet 1 of 4

SAMPLING

Depth	Type	No	Rec
0.6	J	1	
1.6	J	2	
1.7	J	3	
3.0–3.9	P	4	800
3.9	J	4A	
4.5	VJ	5	
6.0–6.9	P	6	
6.9	J	7	
7.5	VJ	8	
9.0–9.9	P	9	
9.9	J	10	

STRATA

Depth	Level	Thickness	Legend	Description
0.0	9.5	0.6		TOPSOIL
0.6	8.9	1.1		Firm to stiff light grey and yellowish brown ironstained clayey SILT with root traces becoming more ironstained and less stiff with depth
1.7	7.8	8.1	∇	Soft bluish grey slightly clayey SILT with occasional sand traces (oxidising to olive brown)
9.7	-0.3	0.5		Soft bluish grey slightly clayey very sandy SILT (oxidising to olive brown)
10.3	-0.8			continues

PROPERTIES

Depth	γ_b Mg/m³	m/c %	N	c kN/m²
3.0–3.9		31·0		
4.5				30V
6.0–6.9	1.89	31.5		10
7.5				23V
9.0–9.9		22.2		

DRILLING

Type	From	To	Size	Drill Fluid
Percussion	0	13.6	150	–
Rotary	13.6	25.6	H	–

GROUNDWATER

Struck	Behaviour	Sealed	Date	Time	Depth Hole	Depth Casing	Depth Water
			28.1	am	7.5	6.0	5.8
				pm	11.7	11.0	–

REMARKS

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Start date	24/1/83
Finish date	10/2/83
Logged by	RW

BOREHOLE RECORD (PERCUSSION) EAST SUSSEX COUNTY COUNCIL	SCHEME ROBERTSBRIDGE BYPASS A21	BOREHOLE BH14 Grid Ref Sheet 2 of 4

SAMPLING				STRATA					PROPERTIES			
Depth	Type	No	Rec	Depth	Level	Thick-ness	Legend	Description	γ_b Mg/m³	m/c %	N	c kN/m²
				10.3	-0.8							
10.4-10.9	SJ B	11 12				0.8		Dense subangular and rounded siltstone GRAVEL			(54)	
				11.1	-1.6							
11.2-11.7	U	13	450						2.14	17.9	64/450	118
11.7	J	14										
						2.5		Stiff dark grey clayey SILT				
12.7-13.2	J B	15 16									(64)	
13.6				13.6	-4.1							
								continues rotary				

DRILLING					GROUNDWATER							
Type	From	To	Size	Drill Fluid	Struck	Behaviour	Sealed	Date	Time	Depth Hole	Depth Casing	Depth Water

REMARKS

164

Start date	24/1/83
Finish date	10/2/83
Logged by	RW

BOREHOLE RECORD (ROTARY)	SCHEME	BOREHOLE BH14
EAST SUSSEX COUNTY COUNCIL	ROBERTSBRIDGE BYPASS A21	Grid Ref
		Sheet 3 of 4

STRATA

Depth	Level	Thickness	Legend	Description
13.6	-4.1			
13.9	-4.4	0.3		Very stiff brownish grey CLAY
14.9	-5.4	1.0		Very stiff medium grey silty CLAY with fecal pellets at depth
15.3	-5.8	0.4		Very stiff dark brownish grey CLAY
16.1	-6.6	0.8		Very stiff light grey slightly silty CLAY
17.1	-7.6	1.0		Very dense light grey thinly laminated slightly clayey SILT
17.7	-8.2	0.6		Very stiff light grey silty CLAY
19.1	-9.6	1.4		Very stiff bluish grey mottled with dark grey CLAY fecal pellets
20.6	-11.1	1.5		Very stiff medium grey silty CLAY
21.0	-11.5	0.4		Very stiff medium grey mottled with brownish grey silty CLAY
22.5	-13.0	1.5		Very stiff greyish brown thinly laminated silty CLAY with occasional fecal pellets and lignite
22.8	-13.3	0.3		Weakly cemented brownish grey thinly laminated SILTSTONE with thin lignite band
23.6	-14.1	0.8		Very weakly cemented brownish grey thinly laminated SILTSTONE with lignite

PROPERTIES

Depth	W R	TCR %	SCR %	RQD %	AFS mm	N	Is MN/m²
13.6							
14.6	90 LIGHT GREY	100	80	80	500		
16.1	90 LIGHT GREY	97	100	100	1500	see remarks	
17.6	90 LIGHT GREY	97	83	62	181		
19.1	90 LIGHT GREY	97	93	86	290	see remarks	
20.6	70 GREY	80	50	27	100		
22.1	90 GREY	96	36	33	160 very fractured	see remarks	
23.6	90 GREY	93	18	9	86 very fractured		

DRILLING

Type	From	To	Size	Drill Fluid

GROUNDWATER

Struck	Behaviour	Sealed	Date	Time	Depth Hole	Depth Casing	Depth Water

REMARKS SPT values; 16.1–16.6 ;– 70 blows, total penetration 150mm
19.1–19.6 ;– 70 blows, total penetration 300mm
22.1–22.6 ;– 70 blows, total penetration 175mm
fecal pellets are coarse sand size particles of mud.

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Start date	24/1/83
Finish date	10/2/83
Logged by	RW/GE

BOREHOLE RECORD (ROTARY)	SCHEME	BOREHOLE BH14
EAST SUSSEX COUNTY COUNCIL	ROBERTSBRIDGE BYPASS A21	Grid Ref
		Sheet 4 of 4

STRATA / **PROPERTIES**

Depth	Level	Thickness	Legend	Description	Depth	W R	TCR %	SCR %	RQD %	AFS mm	N	Is MN/m²
23.6	−14.1				23.6							
		0.5		(weakly cemented SILTSTONE) Very stiff brownish grey clayey SILT		90 GREY	96	24	7	very fractured		
24.1	−14.6											
		0.4		Very dense brownish grey slightly clayey SILT								
24.5	−15.0											
		0.2		Very stiff brownish grey clayey SILT						90		
24.7	−15.2											
		0.9		Very stiff brown mottled with brownish grey silty CLAY	25.1						see remarks	
25.6	−16.1		EOB									

DRILLING

Type	From	To	Size	Drill Fluid

GROUNDWATER

Struck	Behaviour	Sealed	Date	Time	Depth Hole	Depth Casing	Depth Water

REMARKS SPT values: 25.1 - 25.6 : 70 Blows - total penetration 100 mm

Start date	24.1.83
Finish date	10.2.83
Logged by	RW

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APPENDIX D

Departures

None proposed

APPENDIX E

Relevant correspondence and documents from consultations

RVR Flood Risk Assessment - RVR 36 RotherValleyRailway FRA June2016

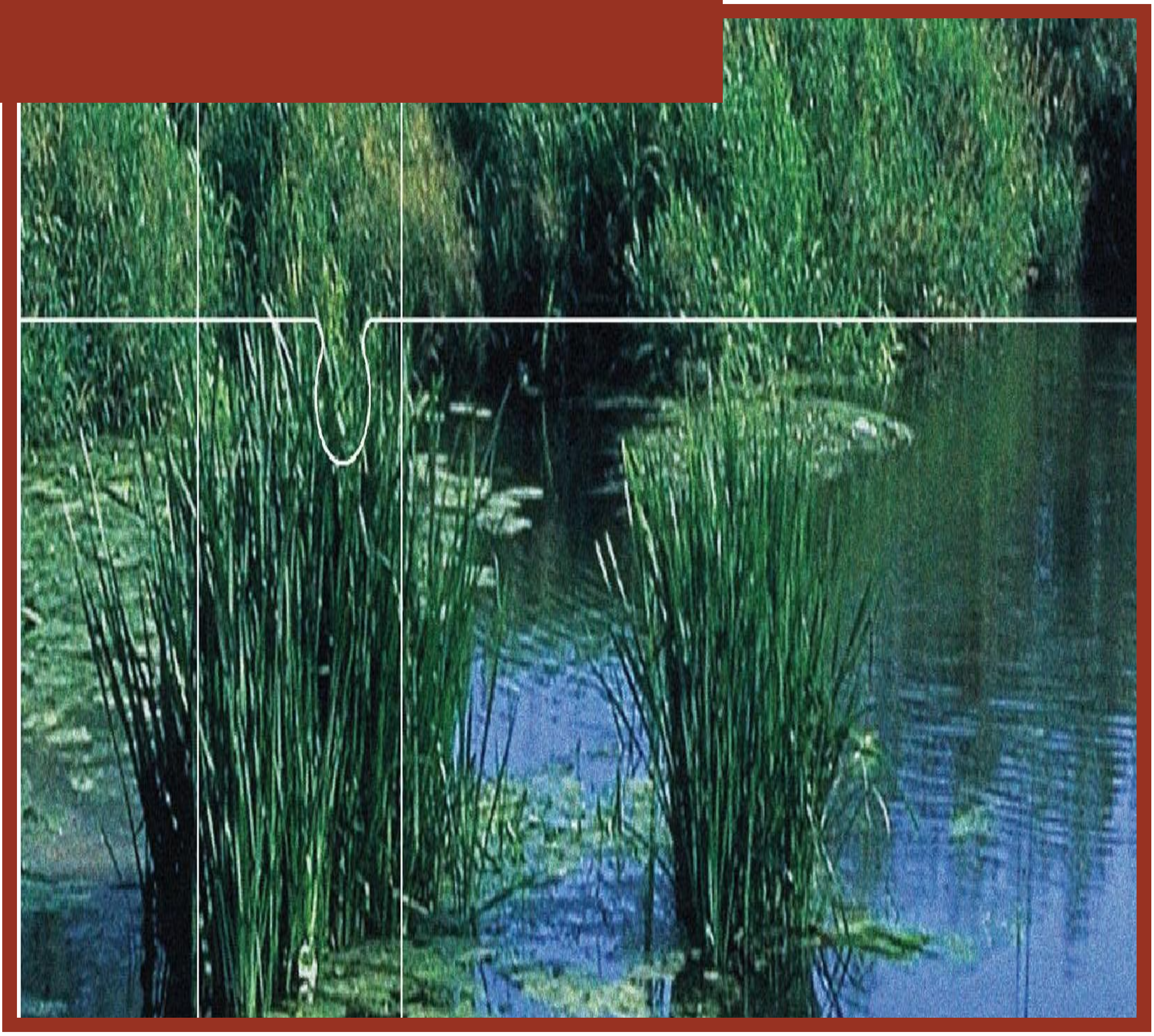
RVR Flood Modelling Report - RVR 37 RotherValleyRailway_FRA_ModellingReport_2016

CAPITA

Rother Valley Railway

Flood Risk Assessment

June 2016



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Executive Summary

1. Capita Property and Infrastructure Ltd (Capita) was commissioned by Rother Valley Railway Limited to undertake a Flood Risk Assessment (FRA) for the proposed reinstatement of the Rother Valley Railway between Robertsbridge and Udiam (Bodiam). The route is approximately 3.5 km and will link the existing railway between Bodiam and Robertsbridge. The proposed scheme includes reinstating the historic railway line with a new embankment and the addition of culverts, bridges and viaducts along its route.

2. The site is located in the Rother catchment. The River Rother flows in an easterly direction for approximately 30 km before flowing into the English Channel, at Rye. The Darwell Stream is a tributary of the Rother that joins the main flow at Robertsbridge. The area has been subjected to quite severe flooding over the last 20 years and a flood defence scheme was put in place for Robertsbridge in 2004.

3. The FRA has been prepared following guidance provided in the National Planning Policy Framework (March 2012) and the 'Planning Practice Guidance' which replaced the 'Technical Guidance to the National Planning Policy Framework' in March 2014. The site has been modelled using Flood Modeller (previously known as ISIS) and TUFLOW which are established software packages used for modelling rivers and floodplains. The modelling covered a number of flooding scenarios and compared the "without railway" baseline (i.e. the existing condition) with the Rother Valley Railway constructed "with railway" scenario.

4. The work was carried out in close liaison with the Environment Agency and the key results are based on a 1% AEP (100 year) with climate change design flood event. The modelling undertaken for this FRA (2016) and by the Environment Agency in 2011 shows that overtopping of the existing flood protection scheme occurs at some locations for a 1% AEP and larger flood events in the baseline (without railway) scenario. The river modelling techniques currently available are more advanced than those available when the flood defence scheme was designed and built.

5. The modelling found that the construction of the railway would not increase flood risk to properties during a 1% AEP with climate change design flood event in Northbridge Street and Robertsbridge. The impact across the floodplain varies with some areas benefiting from reduced flood levels and others experiencing potential increases in flood levels of up to 50mm. There are a few small isolated areas, immediately adjacent to the proposed railway where predicted increases in water levels are greater.

6. Small sections of the defences are overtopped in both the existing (baseline) and 'with railway' scenario in the 1% AEP and 1% AEP with climate change design flood events. The 'with railway' scenario predicts a reduction of up to approximately 400 mm in flood depth behind the defences in Robertsbridge in the 1% AEP with climate change design event. The 'with railway' scenarios predicts a reduction of up to approximately 50mm in flood depth behind the defences in Northbridge Street in the 1% AEP design event

7. Flooding of the existing track downstream of Udiam already occurs and is managed by the operators of the railway line. To manage the consequences of flooding between Robertsbridge and Udiam the train operators will sign up to the Environment Agency's Flood Warnings Direct service and cease any services when there is a risk of flooding.

8. The proposed railway is considered at low risk of groundwater flooding, low to medium risk of flooding from artificial sources and medium risk of flooding from surface water. The approach to managing the residual risk of flooding from artificial sources is discussed in section 5.4.

The table below summarised key aspects of the study:

Site Name	Rother Valley Railway, Robertsbridge
Location	Northbridge Street to Junction Road, Udiam
Client	Rother Valley Railway Ltd
Grid Reference	NGR TQ7380724014 to TQ7718624322
Length of Railway	3.5 km
EA Flood Zone Classification	Flood Zone 3
SFRA	Rother District Council SFRA
Current Site Use	Site of dismantled railway - farm land
Description of proposed development	Reinstate historic railway line in the Rother Valley
Vulnerability Classification	Less vulnerable
History of Flooding	The Robertsbridge area has experienced flood events in 1946, 1960, 1979, 1985, 1993, 1999, 2000, and 2008. The 2000 was severe with approximately 90 properties flooded, some to a depth of 1.5 meters.
Flood Defences	A flood alleviation scheme was constructed at Robertsbridge and Northbridge Street in 2003/4.
Summary of Risks	Fluvial – High Surface Water – Medium Groundwater – Low Artificial Sources - Low to medium

Contents

Tables

Figures

Appendices

1 Introduction

1.1 Scope of Assessment

1.1.1 Capita Property and Infrastructure Ltd (Capita) was commissioned by Rother Valley Railway Limited to undertake a Flood Risk Assessment (FRA) for the proposed reinstatement of the Rother Valley Railway between Robertsbridge and Udiam (NGR TQ 73807 24014 to TQ 77186 24322). The route length is approximately 3.5 km and will link the existing railway between Bodiam and Robertsbridge. The proposed scheme includes reinstating the old line railway line with raised embankments, culverts and bridges along the route. The propose railway scheme also include sections of track lowered close to ground level and a number of viaducts to maintain floodplain flow routes and minimise the impact on flood levels.

1.1.2 A FRA was submitted in January 2014 which is superseded by this report. Amendments to the proposed scheme including changes to the track elevations, number of culverts and viaducts have been made since 2014 and further hydraulic modelling has been undertaken. The potential impact of the railway on flood risk has been managed by these amendments to the scheme and no works are proposed to the existing defences. Further details of the proposed railway scheme and modelling undertaken for the FRA are included in the Rother Valley Railway FRA Modelling Report (June 2016).

1.1.3 The contents of this FRA describe the assessment of the proposed site redevelopment and the implications of the proposed uses on flood risk. The FRA has been prepared following guidance provided in the National Planning Policy Framework (March 2012) and 'Planning Practice Guidance' which replaced the 'Technical Guidance to the National Planning Policy Framework' in March 2014.

1.1.4 A planning application is being submitted and this assessment seeks to provide the level of detail necessary to demonstrate that the potential effects of the proposal with respect to flood risk have been addressed by:

- Identifying the source and probability of flooding to the application site, including effects of climate change;
- Determining the consequences of flooding to and from the proposed development proposal;
- Determining the consequences of flooding to the local area and advising on how this will be managed; and
- Demonstrating the flood risk issues described in this assessment are compliant with the relevant guidance.

1.1.5 An assessment of areas potentially at risk from flooding was undertaken and the proposals were examined in relation to their potential to increase flood risk. The layout of the river crossings, flood relief culverts and viaducts for the railway embankment has been developed considering flood risk at all stages throughout the process. The final development layout reflects the flood risk constraints and the need to manage, and where possible reduce, flood risk.

1.2 Responsibility

1.2.1 Rother Valley Railway Limited is promoting the reinstatement of the historic railway. The layout designers are professional volunteer members who are responsible for the formulation of the design layout and drawings. Capita are responsible for assessing the scheme with respect to its flood risk impact. The assessment is based on the scheme design and site data provided by the designers and developers.

2 Policy and Guidance

2.1 Flood and Water Management Act, 2010

2.1.1 Combined with the Flood Risk Regulations 2009, (which enact the EU Floods Directive in the England and Wales) the Act places significantly greater responsibility on Local Authorities to manage and lead on local flooding issues. The Act and The Regulations together raise the requirements and targets Local Authorities need to meet, including:

- Playing an active role leading Flood Risk Management;
- Development of Surface Water Management Plans (SWMP);
- Implementing requirements of Flood and Water Management legislation;
- Preparation of preliminary flood risk assessments and flood risk management plans;
- Development and implementation of drainage and flooding management strategies; and
- Responsibility for first approval, then adopting, management and maintenance of Sustainable Urban Drainage System (SUDS).

2.1.2 The Flood and Water Management Act also clarifies three key areas that influence development:

1. *Sustainable drainage (SUDs)* - the Act makes provision for a national standard to be prepared on SUDS, and developers will be required to obtain local authority approval for SUDS in accordance with the standards, likely with conditions. Supporting this, the Act requires local authorities to adopt and maintain SUDS, removing any ongoing responsibility for developers to maintain SUDS if they are designed and constructed robustly.
2. *Flood risk management structures* - the Act enables the EA and local authorities to designate structures such as flood defences or embankments owned by third parties for protection if they affect flooding or coastal erosion. A developer or landowner will not be able to alter, remove or replace a designated structure or feature without first obtaining consent.
3. *Permitted flooding of third party land* - The EA and local authorities have the power to carry out work which may cause flooding to third party land where the works are deemed to be in the interest of nature conservation, the preservation of cultural heritage or people’s enjoyment of the environment or of cultural heritage.

2.2 National Planning Policy Framework (NPPF) March 2012

2.2.1 In determining an approach for the assessment of flood risk for the proposal there is a need to review the policy context. Government Guidance requires that consideration be given to flood risk in the planning process. The National Planning Policy Framework was issued in March 2012 and outlines the national policy on development and flood risk assessment. This replaced with immediate effect Planning Policy Statement 25.

2.2.2 The Framework states that the inappropriate development in areas at risk of flooding should be avoided by directing development away from areas at highest risk, but where development is necessary, making it safe without increasing flood risk elsewhere.

2.2.3 The essence of NPPF is that:

- Local Plans should be supported by Strategic Flood Risk Assessment and develop policies to manage flood risk from all sources, taking advice from the Environment Agency and other relevant flood risk management bodies, such as lead local flood authorities and internal drainage boards;
- Polices in development plans should outline the consideration, which will be given to flood issues, recognising the uncertainties that are inherent in the prediction of flooding and that flood risk is expected to increase as a result of climate change;
- Planning authorities should apply the precautionary principle to the issue of flood risk, using a risk based search sequence to avoid such risk where possible and managing it elsewhere;
- The vulnerability of a proposed land use should be considered when assessing flood risk;
- Use opportunities offered by new developments to reduce the causes and impacts of flooding;
- Planning authorities should recognise the importance of functional floodplains, where water flows or is held at times of flood, and avoid inappropriate development on undeveloped and undefended floodplains;
- The concept of Flood Risk Reduction, particularly in circumstances where development has been sanctioned on the basis of the “Exception Test”.

2.3 Planning Practice Guidance (2014)

2.3.1 The Planning Practice Guidance provides additional guidance to enable the effective implementation of the planning policy set out in the National Planning Policy Framework. With respect to Flood Risk and Coastal change it advises on how planning can take account of the risks associated with flooding and coastal change in plan-making and the application process.

2.3.2 The document provides supporting information on a number of items including:

- The application of the sequential approach and Sequential and Exception Tests;
- Reducing the causes and impacts of flooding; and
- Site specific flood risk assessment.

2.4 Rother Local Plan Core Strategy

2.4.1 Rother District Council Core Strategy sets the overall vision and objectives for development in the district up to 2028. The Core Strategy was adopted by Full Council in September 2014. The Core Strategy forms part of the statutory Development Plan for the District and is used in the determination of all planning applications, alongside the saved policies in the Local Plan 2006.

2.4.2 The Objectives for Rural areas set out in the Core Strategy include 'To support sustainable tourism and recreation, including improved access to the countryside' (section 12.6). The Core Strategy also recognises tourism is an important component of the rural economy, including the Kent and East Sussex Railway. It also states there is further scope to develop business and cultural tourism and 'green tourism' particularly in the towns and High Weald. Policy EN7 in the Core Strategy relates to Flood Risk and Development.

2.4.3 The Local Plan (2006) saved policy relevant to the Rother Valley Railway reinstatement is 'EM8 - Bodiam/Robertsbridge railway' and is detailed below.

Policy EM8:
An extension to the Kent and East Sussex Steam Railway from Bodiam to Robertsbridge, along the route identified on the Proposals Map, will be supported, subject to a proposal meeting the following criteria:

1. **it must not compromise the integrity of the floodplain and the flood protection measures at Robertsbridge;**
2. **it has an acceptable impact on the High Weald Area of Outstanding Natural Beauty;**
3. **it incorporates appropriate arrangements for crossing the A21, B2244 at Udiam, Northbridge Street and the River Rother.**

2.4.4 This FRA demonstrates how the proposals meet the criteria 1 - 'it must not compromise the integrity of the floodplain and the flood protection measures at Robertsbridge'.

2.5 Strategic Flood Risk Assessment (SFRA)

2.5.1 A Strategic Flood Risk Assessment SFRA was undertaken in 2008 by Rother District Council. The primary objective of the SFRA is to inform the revision of flooding policies, including the allocation of land for future development, within the emerging Local Development Framework (LDF). The SFRA has a broader purpose however, and in providing a robust depiction of flood risk across the District, it can:

- Inform the development/developer of Council policy that will underpin decision making within the District, particularly within the areas that are affected by (and/or may adversely impact upon) flooding;
- Assist the development control process by providing a more informed response to development proposals affected by flooding, influencing the design of future development within the District;
- Help to identify and implement strategic solutions to flood risk, providing the basis for possible future flood attenuation works;
- Support and inform the Councils emergency planning response to flooding; and
- Identify what further investigations may be required in flood risk assessments for specific development proposals.

2.5.2 A number of conclusions and recommendations were drawn from the SFRA. The following are considered the most relevant to this FRA:

- The SFRA process has highlighted the importance of flood defences throughout Rother District. Future policy should seek to address how these defences are to be maintained to ensure that they are maintained to the current high level of protection.
- Review the condition of existing local defences, the dependence of additional local development on them for flood mitigation and where necessary the Council should seek to maintain and or improve defences if necessary.
- Require all flood risk assessment and sustainable drainage design to consider the impacts of climate change for the lifetime of the development at the site and downstream.

3 Development Site Planning Considerations

3.1 Development Description and Location

3.1.1 The proposed development is the reinstatement of the Rother Valley Railway between Northbridge Street and Udiam (NGR TQ7380724014 to TQ7718624322). The route is approximately 3.5 km and will link the existing railway between Bodiam and Robertsbridge. The proposed scheme includes raised embankment, bridges, culverts, viaducts and setting the track in certain locations to close to ground levels. Figure 1 shows the route of the proposed railway.

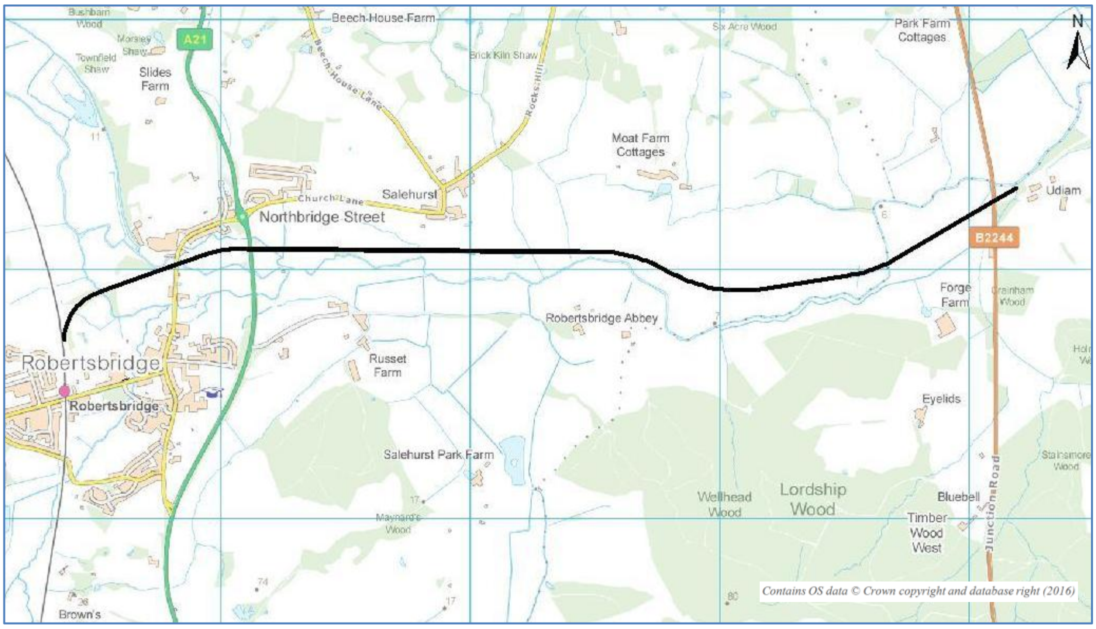


Figure 1 - Proposed Route of Railway

3.2 Vulnerability Classification

3.2.1 The site lies within the Environment Agency's Flood Zone 3, which is described within the Planning Practice Guidance Table 1: Flood Risk as having a 'High Probability' of flooding. Flood Zone 3 comprises of land assessed as having a 1 in 100 or greater annual probability of river flooding (>1%), or a 1 in 200 or greater annual probability of sea flooding from the sea (>0.5%) in any year. The Environment Agency's flood zone map is provided in Figure 2.

3.2.2 The proposed railway is considered to fall under the classification of "Less Vulnerable" land use based on Planning Practice Guidance Table 2: Flood Risk Vulnerability Classification. However it should be noted that there is argument for it to be classified as water compatible as during times of flood the railway will not be operated.

3.2.3 Table 3: Flood Risk Vulnerability and Flood Zone Compatibility in that Planning Practice Guidance, states that less vulnerable land uses are compatible in Flood Zone 3a.

3.2.4 The railway does cross the 5% (1 in 20 year) AEP Flood Extent, which defines the functional floodplain. However the majority of the railway line is above the 5% AEP flood level and the construction of the railway does not increase the extent of flooding. A number of lowered sections of railway, culverts and sections of viaduct are proposed to maintain connectivity across the floodplain, allowing water to flow and be stored within the existing floodplain extents during times of flood. The consequences of flooding to the railway will be managed through the train operator signing up for flood warnings and ceasing services when there is a risk of flooding. Following correspondence with the Environment Agency we understand that given the railway location cannot be changed the Environment Agency has no objections to the railway crossing the functional floodplain.

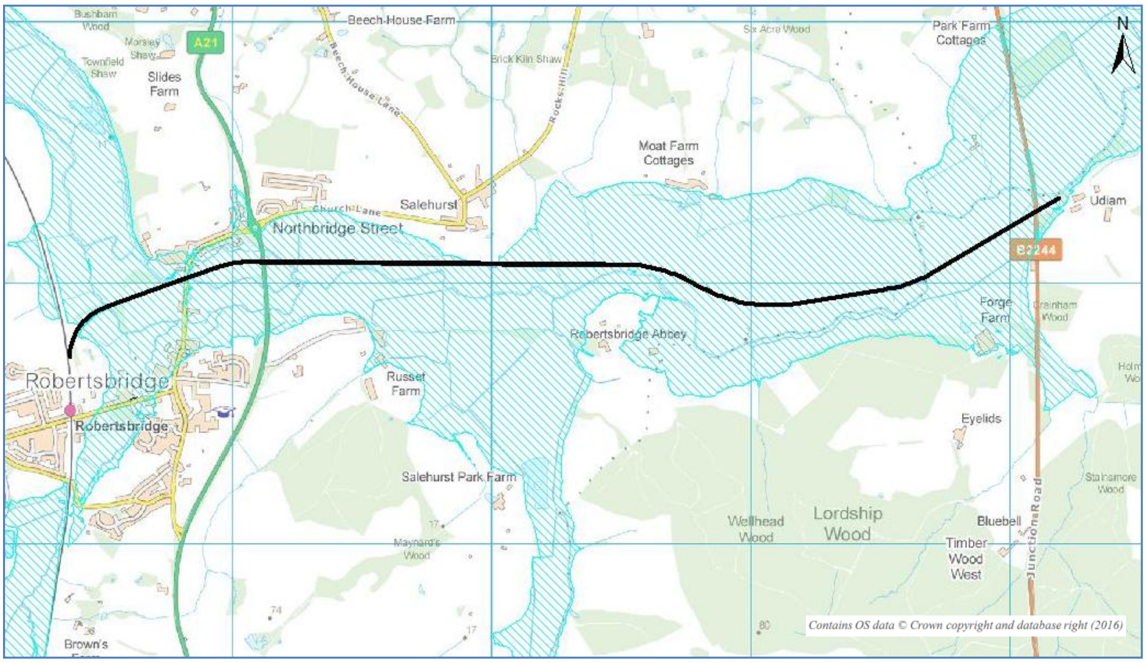


Figure 2 - Environment Agency Flood Zone 3

3.3 Sequential and Exception Test

3.3.1 The aim of the Sequential Test is to demonstrate that there are no reasonably available sites in areas with a lower probability of flooding. Since the proposed route of the railway follows the historic route and is linking two existing sections of railway it is not possible to locate the proposed development elsewhere in a lower risk zone. Accordingly there can be "no reasonably available sites in areas with a lower probability of flooding" and the application site satisfies the Sequential Test.

3.3.2 The development is classified as less vulnerable and is appropriate in Flood Zone 3a. The proposed railway line does cross the functional floodplain as discussed in section 3.2. For completeness the criteria of the Exception Test have been considered. The proposed development will provide wider sustainability benefits to the community as identified in the Rother Local Plan (2006) including tourism and linking to main line services from Hastings to London.

3.3.3 The following chapters of this report discuss the detailed flood study that has been undertaken and the proposal to manage flood risk. This site specific flood risk assessment demonstrates that the development will be safe, and provides a small reduction in flood risk to residential property in Northbridge Street and Robertsbridge during large flood events. It is proposed that the train line is not operational during times of flooding and that the operating company (Kent and East Sussex Railway) subscribes to the Environment Agency's flood warning service.

4 Flood Probability and Hazard

4.1 Catchment Background

4.1.1 In order to assess the risk of flooding to the reinstated railway, and the wider area of Robertsbridge, it is important to understand the existing catchment characteristics and historic flow patterns.

4.1.2 The site is located in the Rother catchment. The River Rother flows in an easterly direction for approximately 30 km before flowing into the English Channel, at Rye (NGR TQ 95700 17400). The Darwell Stream is a tributary of the Rother that flows through Robertsbridge.

Local Geology

4.1.3 Robertsbridge lies on a succession of sandstones, siltstones and mudstones (commonly clays) of the Hastings Beds. The solid geology around Robertsbridge is Ashdown Sandstone Formation and the drift geology includes alluvium and river terrace deposits[1].

4.1.4 The Environment Agency "Aquifer Maps – Superficial Deposits designations map" classifies the deposits as a Secondary (undifferentiated). The Aquifer Maps - bedrock designation is Secondary A. The Environment Agency groundwater vulnerability map classifies the site as Minor Aquifer High.

Flood History

4.1.5 Table 4.1 provides information on historic local flood events in the catchment based on information provided in the Rother Strategic Flood Risk Assessment (SFRA). In the SFRA the Highway Authority's Divisional Engineer has provided a schedule of the locations most prone to highway flooding in Rother District these include the Robertsbridge area.

Table 4.1 Historic flood events at Robertsbridge

Date	Description and Source
1946. 1960, 1979, 1985, 1999, 2001	Fluvial - Insufficient storage capacity. Very intense rainfall on an already wet soil leading to rapid runoff. Recent development in the floodplains, debris in the river channel.
1993	Fluvial - Intense rainfall, properties flooded by sewage contaminated water
12th October 2000 (greater than 1% event) 31st October 2000 5th November 2000	Fluvial - Very intense rainfall on an already wet soil leading to rapid runoff. Recent development in the floodplains, debris in the river channel, backing up from road drains and surcharging of combined sewerage system (indirect source), backing up behind culverts and bridges, overtopping of low flood embankment, back up of floodwater from the floodplains, reduced storage capacity due to repeat events

4.1.6 The East Sussex County Council Preliminary Flood Risk Assessment (PFRA) indicates groundwater flooding has occurred historically in the Robertsbridge area. The PFRA also indicates sewer flooding occurred in Northbridge Street and Station Road in Robertsbridge in 2002, 2008, and 2010. In 2010 blocked culverts and drains resulted in isolated surface water flooding.

[1] Harris, R.B., 2009, Robertsbridge Historic Character Assessment Report, Sussex Extensive Urban Survey.

4.1.7 There is an existing hydraulic model of the River Rother which has been used to assess flood risk and the impact of the proposed reinstatement of the railway. The model was developed by Hyder for the Environment Agency in 2011. While reviewing the model for use in this flood risk assessment a number of opportunities for improvements were noted. The improvements made to the model are detailed in the Rother Valley Railway FRA Modelling Report (June 2016) and have been discussed with the Environment Agency.

4.2 Site Topography

4.2.1 Existing ground levels along the route of the proposed railway vary from 11.7 m AOD to 4.4 m AOD generally falling from the west towards the east.

4.2.2 The ground levels for the proposed railway will be altered along the route gradually falling from 11.53 m AOD near Northbridge Street to 5.865 m AOD to meet the existing Kent and East Sussex railway. The elevation of the railway varies along the route to maintain existing floodplain flow paths and floodplain connectivity.

4.3 Flood Zone

4.3.1 Flood Zones describe the extent of flooding that would occur on the basis that no flood defences were in existence. The definition of Flood Zones is provided in Table 1 of the Flood Risk and Coastal Change section of the Planning Practise Guidance.

4.3.2 A review of the Flood Zone Mapping undertaken by the Environment Agency has identified that the site is located within Flood Zone 3a 'Land assessed as having a 1 in 100 or greater annual probability of river flooding (>1%) or a 1 in 200 or greater annual probability of flooding from the sea (>0.5%) in any year.' The site is assessed as being at high probability of flooding.

4.4 Existing Flood Risk Management Infrastructure

4.4.1 Robertsbridge and Northbridge Street both benefit from defences on the River Rother and Darwell Stream.

4.4.2 After the autumn 2000 floods, a major flood defence scheme was implemented in Robertsbridge, consisting of raised permanent flood walls/bunds along the river, and a number of movable gates that can be used to create temporary flood walls. This scheme was completed in 2004 (Atkins, 2007). Pumps were also added to the scheme to deal with runoff resulting from incident rainfall within the defended area which was no longer able to connect directly back into the river due to the flood defences blocking flow. These pumps facilitate removal of water from within the defended area back into the river. Pumps on the Mill Stream also convey high flows over the defences and back into the Rother.[2]

4.4.3 The modelling undertaken for this FRA (2016) and by the Environment Agency in 2011 shows that overtopping of the existing flood protection scheme occurs at some locations for a 1% AEP and larger flood events. The river modelling techniques currently available are more advanced than those available when the flood defence scheme was designed and built.

4.4.4 The topographical survey shows the crest level of the defences are between 12.4 m AOD (upstream) and 11.2 m AOD (downstream) at Northbridge Street, and between 12.7 m AOD and 11.5 m AOD at Robertsbridge.

[2] Environment Agency, 2011, River Rother Final Hydraulic Modelling, ABD, and Hazard Mapping Report, Hyder.

4.5 Sources of Flooding – Actual Flood Risk

4.5.1 The NPPF describes potential sources of flooding. It is necessary to consider the risk of flooding from all sources within a FRA. This section provides a review of flooding from land, sewers, groundwater and artificial sources, in addition to rivers.

Fluvial Flood Risk

4.5.2 Fluvial flooding occurs when the amount of water exceeds the flow capacity of the river channel. Most rivers have a natural floodplain into which the water spills in times of flood. The historic route of the railway is through the Rother floodplain and therefore the proposed reinstated route is also through the floodplain.

4.5.3 The improved Environment Agency model was edited to create a version of the model with the proposed railway embankment, bridge crossings, viaducts and flood relief culverts through the embankment. This model is referred to hereafter as 'with railway' scenario. It was identified that the defences at Northbridge Street are predicted to overtop in the 1% AEP design event for both the baseline and 'with railway' scenario. The defences at Robertsbridge are predicted to overtop in the 1% AEP with climate change design event for both the baseline and 'with railway' scenario (see Figure 3).

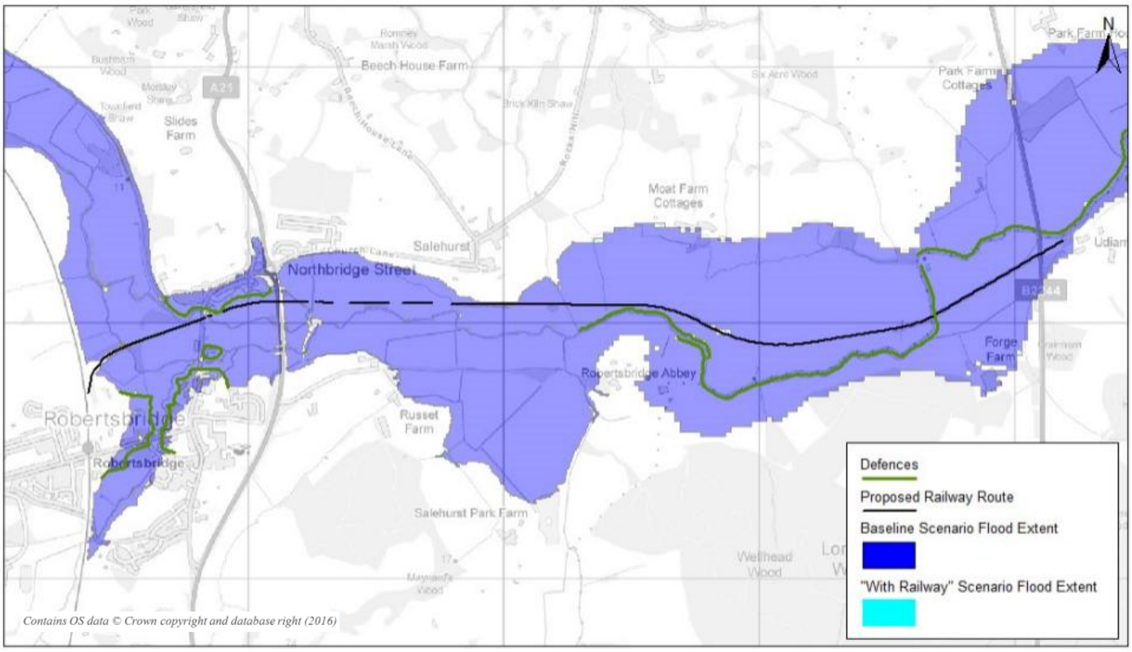


Figure 3 - 1% AEP with climate change flood extent for the 'baseline' and 'with railway' scenario.
(Note the 'with railway' scenario flood extent is drawn below the baseline flood extent shown and therefore it is only visible on the map where its extent is greater than the baseline flood extent).

4.5.4 The section of the railway between Salehurst and Robertsbridge Abbey and near Udiam between Austins Bridge and the B2244 are at risk in all the flood events modelled. The proposed railway elevations between Salehurst and Robertsbridge Abby have been lowered to maintain floodplain flow paths and connectivity. Table 4.2 provides water levels and depths of flooding along the proposed reinstated railway for the modelled flood events. The locations referred to in the table are shown in Figure 4. The management of flood risk along the proposed railway is discussed in section 5.2.

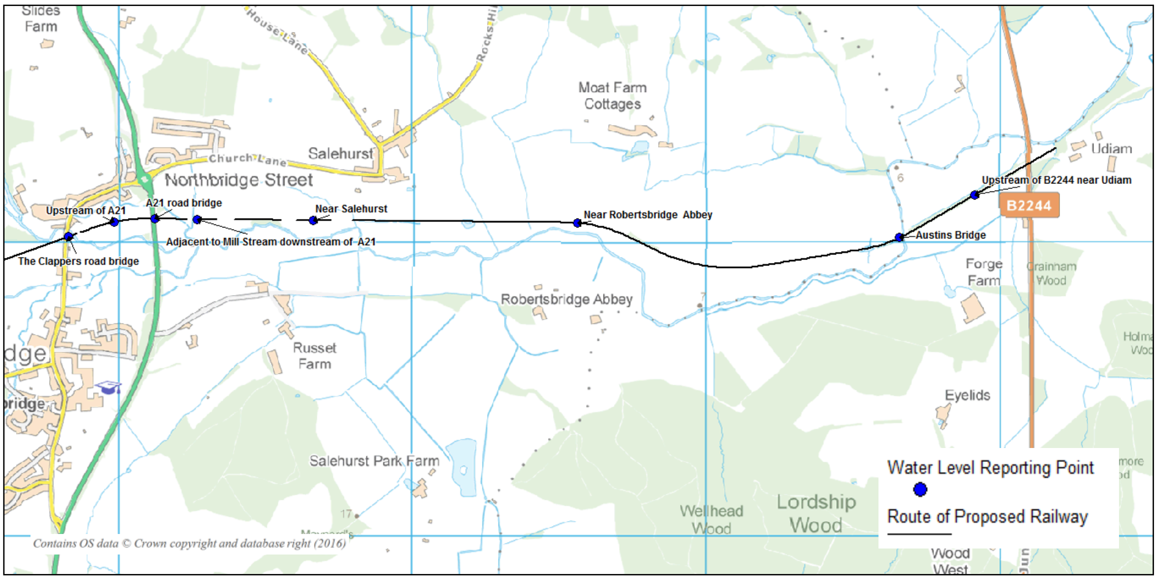


Figure 4 - The locations referred to in Table 4.2

Table 4.2 Flood Levels along the proposed reinstated railway

Location Description	NGR	Design Flood Event	Railway level (m AOD)	With Railway Flood Level (m AOD)*	Approximate depth of water on railway (m)
		5% AEP		NA	NA
		2% AEP		11.64	0.11
		1.33% AEP		11.80	0.27
		1% AEP		11.88	0.35
The Clappers road bridge	TQ7382024019	1% +CC AEP	11.53	11.99	0.46
		5% AEP		NA	NA
		2% AEP		NA	NA
		1.33% AEP		NA	NA
		1% AEP		NA	NA
Upstream of A21	TQ7397724069	1% +CC AEP	11.523	NA	NA
		5% AEP		NA	NA
		2% AEP		NA	NA
		1.33% AEP		NA	NA
		1% AEP		NA	NA
A21 road bridge	TQ7411524079	1% +CC AEP	11.387	NA	NA
		5% AEP		NA	NA
		2% AEP		NA	NA
		1.33% AEP		NA	NA
		1% AEP		NA	NA
Adjacent to Mill Stream downstream of A21	TQ7426124078	1% +CC AEP	11.115	NA	NA
		5% AEP		9.07	0.29
Near Salehurst	TQ7465424075	2% AEP	8.78	9.20	0.42

Location Description	NGR	Design Flood Event	Railway level (m AOD)	With Railway Flood Level (m AOD)*	Approximate depth of water on railway (m)
		1.33% AEP		9.27	0.49
		1% AEP		9.32	0.54
		1% +CC AEP		9.45	0.67
Near Robertsbridge Abbey	TQ7555724065	5% AEP	7.79	7.80	0.01
		2% AEP		7.89	0.10
		1.33% AEP		7.93	0.14
		1% AEP		7.96	0.17
		1% +CC AEP		8.03	0.24
Austins Bridge	TQ7665324017	5% AEP	6.55	NA	NA
		2% AEP		NA	NA
		1.33% AEP		6.57	0.02
		1% AEP		6.62	0.07
		1% +CC AEP		6.73	0.18
Upstream of B2244 near Udiam	TQ7690924161	5% AEP	5.4	6.04	0.64
		2% AEP		6.24	0.84
		1.33% AEP		6.32	0.92
		1% AEP		6.39	0.99
		1% +CC AEP		6.53	1.13

Note: 5% AEP (Annual Exceedance Probability) = 20 year Flood Event; 2% AEP = 50 year Flood Event; 1.33% AEP = 75 year Flood Event; 1% AEP = 100year Flood Event; and 1% +CC AEP = 100 year with climate change Flood Event)

4.5.5 The changes in flood risk between the 'with railway' and baseline scenarios, at key locations are listed in Table 4.3. The locations referred to in the table are shown in Figure 5. The table demonstrates that flood risk is not increased behind the defences in the Northbridge Street and Robertsbridge area in the 'with railway' scenario.

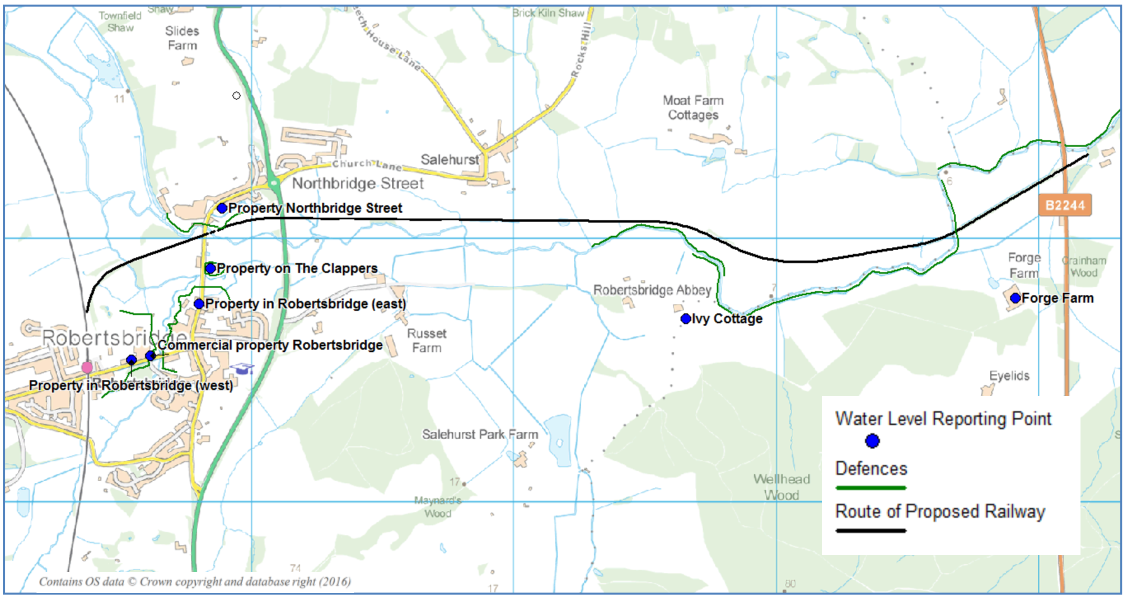


Figure 5 - The locations referred to in Table 4.3

Table 4.3 Change in Flood Risk

Location	Flood Event	Change in Flood Risk between 'with railway' and baseline scenario (mm)
Commercial property, Station Road, Robertsbridge	5%	No Change
	2% AEP	No Change
	1.33% AEP	No Change
	1% AEP	No Change
	1% AEP + CC	No Change*
Property in Robertsbridge (west)	5%	Not Flooded
	2% AEP	Not Flooded
	1.33% AEP	Not Flooded
	1% AEP	Not Flooded
	1% AEP + CC	Reduced Flood Risk - Approx. 50mm reduction in flood depths in 'with railway' scenario
Property in Robertsbridge (east)	5%	Not Flooded
	2% AEP	Not Flooded
	1.33% AEP	Not Flooded
	1% AEP	Not Flooded
	1% AEP + CC	Reduced Flood Risk - Approx. 40mm reduction in flood depths in 'with railway' scenario
Property on The Clappers (Bridge Bungalow/Museum)	5%	Not Flooded
	2% AEP	Not Flooded
	1.33% AEP	Not Flooded
	1% AEP	Not Flooded
	1% AEP + CC	No Change*
Property in Northbridge Street	5%	Not Flooded
	2% AEP	Not Flooded
	1.33% AEP	Not Flooded
	1% AEP	Reduced Flood Risk - Approx. 80mm reduction in flood depths in 'with railway' scenario
	1% AEP + CC	Reduced Flood Risk - Approx. 10mm reduction in flood depths in 'with railway' scenario
Ivy Cottage, near Robertsbridge Abbey	5%	Not Flooded
	2% AEP	Not Flooded
	1.33% AEP	Reduced Flood Risk - Approx. 40mm reduction in flood depths in 'with railway' scenario

	1% AEP	Reduced Flood Risk - Approx. 50mm reduction in flood depths in 'with railway' scenario
	1% AEP + CC	Reduced Flood Risk - Approx. 40mm reduction in flood depths in 'with railway' scenario
Forge Farm, B2244, near Udiam (Note finished floor levels in FRA)	5%	Not Flooded
	2% AEP	Not Flooded
	1.33% AEP	Not Flooded
	1% AEP	Flood depth 2mm in 'with railway' scenario**
	1% AEP + CC	No change in flood risk - Approx. 2mm change in 'with railway' scenario*** Predicted water level is 6.558 mAOD in baseline and 6.560 mAOD in 'with railway' scenario

* Where the reduction in flood depth in the 'with railway' scenario is less than 5mm, no change has been stated in the table due to the accuracies of the modelling.

** Given the accuracy and stability tolerances of the model this is not considered significant. The area shown as hatched in Figure A4, Appendix A.

*** 2mm is considered as no change in flood risk due to the accuracies of flood modelling.

4.5.6 The differences in flood levels at Forge Farm are very small and are within the stability tolerances of the model. Given the accuracy of the model flood risk is considered to be unchanged at Forge Farm. It should be noted that this area is not the focus of this FRA and a more detailed model may be required by the Environment Agency for any future development at the Forge Farm site.

4.5.7 It should be noted that a FRA was undertaken in 2008 for the Forge Farm site. This was prior to the Environment Agency Modelling and no modelling appears to have been undertaken for the FRA. The FRA reports 1% AEP and 1% AEP with climate change levels lower than those predicted by the baseline model. The FRA recommends floor slabs are set to a minimum of 6.41mOD. The Environment Agency comments on the development included a recommendation that the occupants register with the Floodline Warnings Direct service.

4.5.8 Flood extent figures for all design flood events are provided in Appendix A. The difference in predicted water depth between the 'with railway' and baseline scenarios are also in Appendix A (Figures B1 to C5). The figures illustrate the proposed railway has a negligible impact on flood levels across the majority of the floodplain.

4.5.9 The extent of flooding is very similar in all design flood events for the baseline and 'with railway' scenarios. The slight increase in flood extent at the Forge Farm site for the 1% AEP design event is due to the 2 mm depth of water above the floor levels recommend in the 2008 FRA. The area is shown as hatched in Figure A4, Appendix A. As discussed above, 2 mm is not considered significant given the accuracy and tolerances of the model.

4.5.10 The difference in flood levels across the floodplain between the baseline and 'with railway' scenario are generally less than 50 mm. There are some areas of the floodplain where the water levels are lower in the 'with railway' scenario than the baseline. There are also some small areas generally adjacent to the railway where the water levels in the 'with railway' scenario are more the 50mm above the baseline flood levels. There are no properties at these locations. This is shown in the Figure 6 below.

4.5.11 The model has demonstrated that the railway does not increase the frequency or extent of flooding. It has also demonstrated that the proposed reinstatement of the railway does not impact floodplain water levels upstream or downstream of the proposed development.

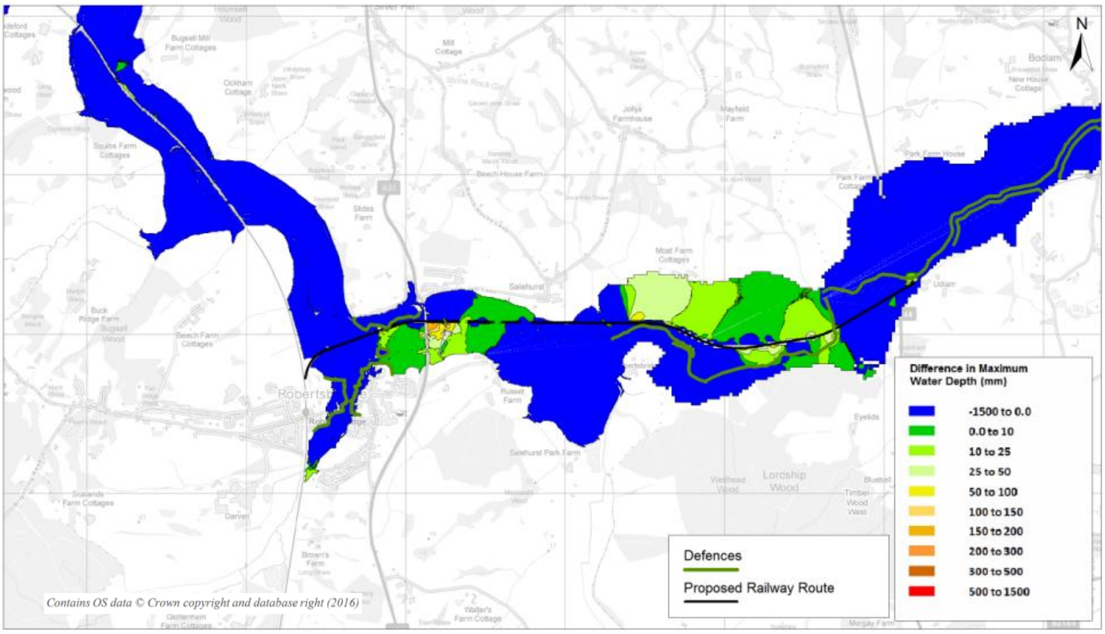


Figure 6 – Difference in water depths between ‘with railway’ and baseline scenarios for the 1% AEP with climate change design event

Tidal Flood Risk

4.5.12 There is no risk of tidal flooding at the site.

Flood Risk from Land, Surface Water and Sewers

4.5.13 Flooding from land can be caused by rainfall being unable to infiltrate into the natural ground or entering the drainage systems due to blockage, or flows being above design capacity. This can then result in (temporary) localised ponding and flooding. The natural topography and location of buildings/structures can influence the direction and depth of water flowing off impermeable and permeable surfaces.

4.5.14 The proposed railway is considered at low to medium risk of surface water/sewer flooding. The track for the majority if it length is higher than the surrounding ground. Where the track elevation is close to ground level to facilitate floodplain flows there is a greater risk of surface water ponding. The risk of surface water flooding to the track will be managed by the train operators and services will be stopped. The remaining sections of the railway line are unlikely to have ponding on the tracks in significant volumes. The railway line will be built on a permeable base with no significant change in surface water runoff.

4.5.15 The culverts and sections of viaduct included in the proposals to maintain connectivity across the floodplain will also act as flow paths for surface water. The areas immediately upstream of the proposed railway embankment are farmland/open spaces where local ponding of surface water adjacent to the railway embankment will not increase the risk of flooding to property.

Groundwater Flood Risk

4.5.16 Groundwater flooding occurs when water levels in the ground rise above surface elevations. It is most likely to occur in low-lying areas underlain by permeable rocks.

4.5.17 The proposed railway is considered at low risk of groundwater flooding. The proposed route is generally higher than the surrounding ground. The risk of groundwater flooding to the track will be managed by the train operators and services will be stopped.

Flood Risk from Artificial Sources

4.5.18 Artificial sources of flooding include reservoirs, canals, lakes and mining abstraction.

4.5.19 The Darwell Reservoir is the closest artificial water features to the site. Wadhurst Park lake is the second closest large artificial water feature. The Environment Agency risk of flooding from reservoirs map indicates that both these reservoirs could affect the Robertsbridge area if they were to fail and release the water they hold. The maps show the largest area that might be flooded in the worst case scenario and it is unlikely that any actual flood would be this large. The Darwell Reservoir is approximately 4 km from the proposed railway. There is no information within the SFRA to indicate that flooding from artificial water bodies is considered a significant flood risk to the site.

4.5.20 Reservoir flooding is extremely unlikely to happen. There has been no loss of life in the UK from reservoir flooding since 1925. All large reservoirs must be inspected and supervised by reservoir panel engineers. As the enforcement authority for the Reservoirs Act 1975 in England, the Environment Agency ensures that reservoirs are inspected regularly and essential safety work is carried out.

4.5.21 The risk from artificial sources is considered low to medium.

5 Flood Risk Management

5.1 Principles of Flood Risk Management

5.1.1 NPPF requires a precautionary approach to be undertaken when making land use planning decisions regarding flood risk. This is partly due to the considerable uncertainty surrounding flooding mechanisms and how flooding may respond to climate change. It is also due to the potentially devastating consequences of flooding to the people and property affected.

5.1.2 Flood risk is a combination of the probability of flooding and the consequences of flooding. Hence 'managing flood risk' involves managing either, the probability of flooding or the consequences of flooding, or both.

5.1.3 NPPF requires flooding from tidal, fluvial, land, surface water & sewerage and from groundwater to be considered. The flood risk management measures discussed in this section are based on the sources of flooding identified in Section 4 that are considered to pose an unacceptable risk to the development proposals.

5.2 Flood Risk Management along the Rother Valley Railway

5.2.1 Section 4 identified the following sources of flooding that require management to reduce risk to an acceptable level in compliance with NPPF:

- Fluvial sources along the route of the railway; and
- Residual risk of flooding from reservoirs.

5.3 Management of Fluvial Flood Risk along the Railway

5.3.1 The flood risk to the railway will be managed through restricting operation of the railway during times of severe flood. If there is a risk of flooding to the railway line it is proposed that services along the railway between Bodiam and Robertsbridge are cancelled.

5.3.2 The proposed railway elevations, culverts, bridges and viaduct crossings maintain connectivity across the current floodplain and minimise the impact of the railway on floodplain water levels and flow paths.

5.3.3 The existing operational railway line already experiences frequent flooding along certain sections of the track. Procedures are already in place to deal with the flooding if this occurs and so these procedures will be applied to the new reinstated line. The risk of flooding to the track will be managed by the train operators and services will be stopped.

5.4 Management of Residual Risk of flooding from reservoirs

5.4.1 To manage residual risk of flooding from reservoirs it is recommended that the train operator contact East Sussex County Council and the reservoirs owners to review the procedures in the emergency plan and the processes proposed within the off-site reservoir management plan. From this review the train operator should understand what they can do in the event of flooding and/or have their name added to a contact list so that they are warned of an impending breach of the reservoir.

5.5 The Environment Flood Warning and Evacuation plan

5.5.1 The Environment Agency operates a Flood Warnings Direct service; the Robertsbridge Flood Warning area covers part of the route of the railway between Robertsbridge and Udiam and therefore if deemed appropriate, it is recommended the train operator (Kent and East Sussex Railway) subscribe to this service. It is proposed that train operator (Kent and East Sussex Railway) cancel services between Bodiam and Robertsbridge in the event of a Flood Warning or Severe Flood Warning. A Flood Alert should be the trigger for reviewing services and consulting with the Environment Agency on the expected flood levels.

6 Conclusion

6.1.1 Capita were commissioned by Rother Valley Railway Limited to undertake a Flood Risk Assessment (FRA) for the proposed reinstatement of the Rother Valley Railway between Robertsbridge and Udiam (NGR TQ 73807 24014 to TQ 77186 24322). The route is approximately 3.5 km and will link the existing railway between Bodiam and Robertsbridge. The route is located within Flood Zone 3 on the Environment Agency Flood Zone Map and is identified by Rother District Council as being an acceptable development if flood risk is managed. The proposed scheme includes reinstating the historic railway line and incorporates a number of flood relief culverts, viaducts and bridges connecting the surrounding floodplains.

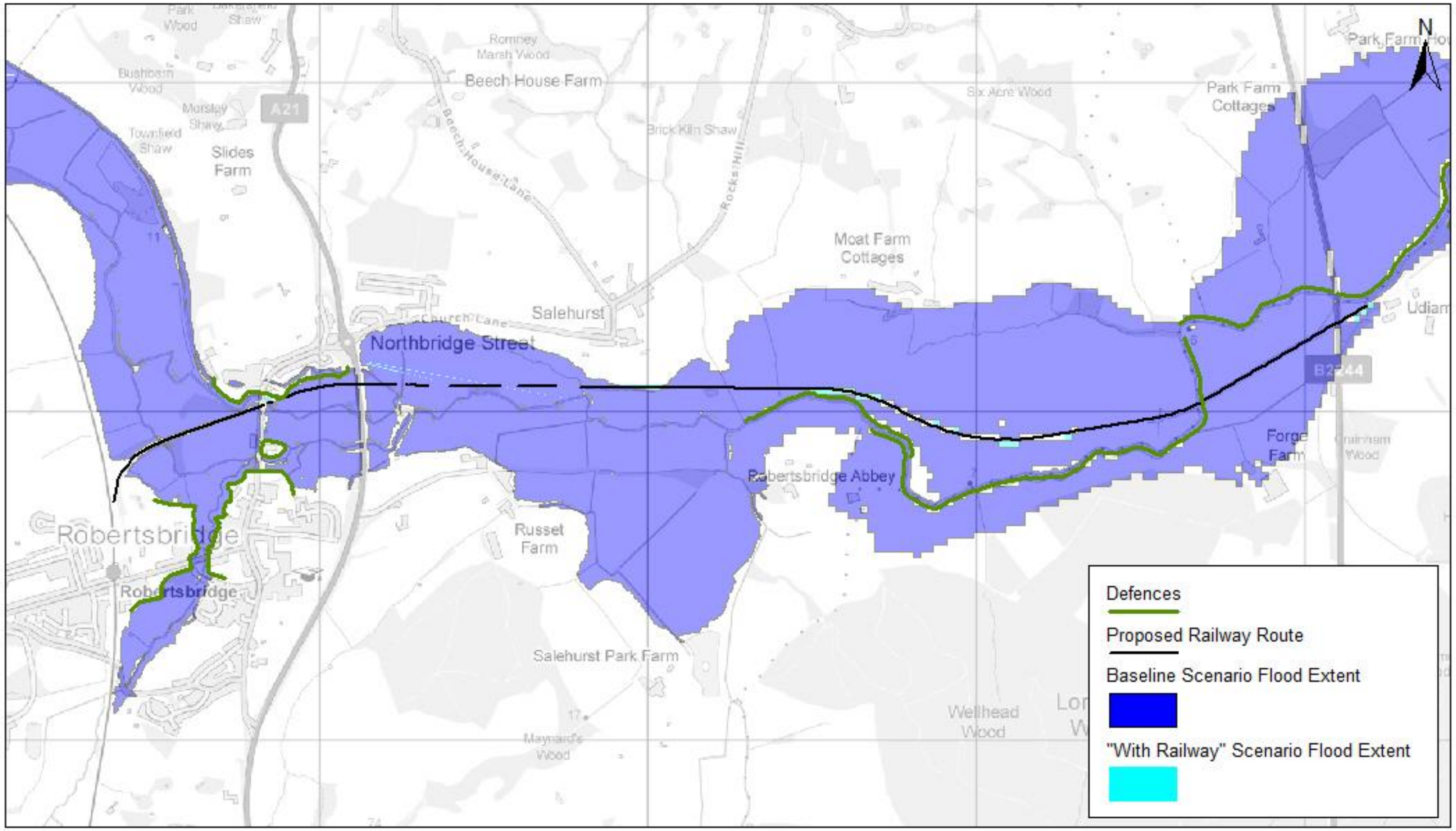
6.1.2 The modelling results have shown the flood extents between the baseline scenario and the proposed 'with railway' scenario have not changed significantly. The modelling indicates that there is a reduction in flood depths behind the Robertsbridge and Northbridge Street defences in the 1% AEP with climate change design flood events. The 'with railway' scenarios indicates some areas where water levels increase by up to 50mm, however there are also areas where the flood levels are lower in the 'with railway' scenario. The small areas where a larger increase in flood levels is predicted in the 'with railway' scenario are adjacent to the proposed railway, where no property is located.

6.1.3 In locations where the reinstated railway line ties into existing ground levels flooding is likely to inundate the track and impact on its operation. The risk from flooding to the public associated with the operation of the railway will be managed through restricting operation during times of severe flooding. If there is a risk of flooding to the railway line it is proposed that services along the railway between Bodiam and Robertsbridge are cancelled.

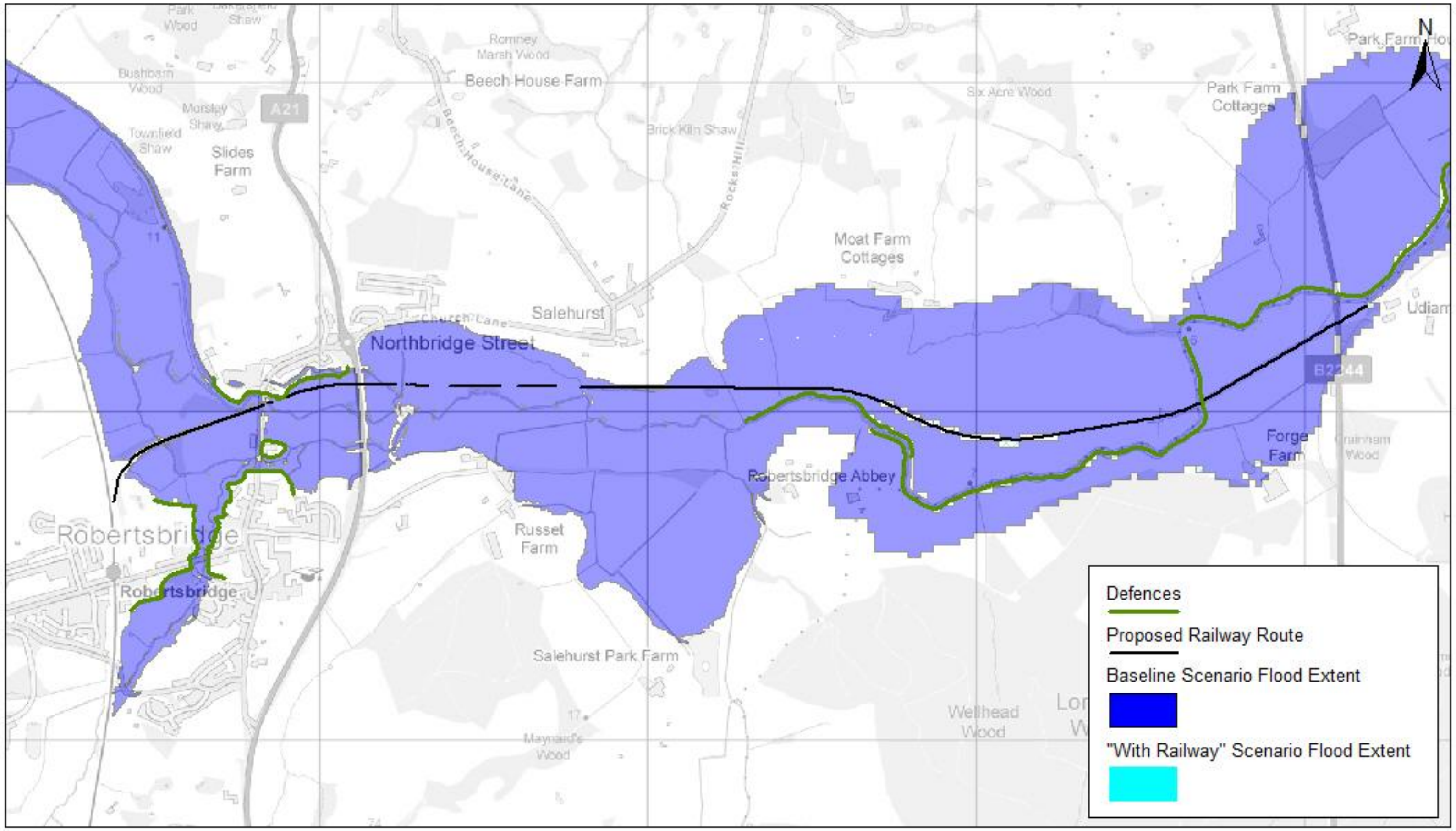
6.1.4 It is recommended the train operator Kent and East Sussex Railway register to the Environment Agency's Flood Warnings Direct service to receive early warnings and updates of any potential risk of flooding. The use of this service will help them to effectively plan and utilise their flood risk management procedures currently in place.

6.1.5 The development proposal has considered flood risk at all stages throughout the development of the final layout and reflects the flood risk constraints and the need to manage, and where possible reduce, flood risk in compliance with the guidance in the NPPF. This FRA demonstrates that the flood risk related to the proposed reinstatement of the railway can be adequately managed.

Appendix A - Flood Risk Maps



Rother Valley Railway							
Figure A-1: Comparison of baseline scenario and 'with railway' scenario 5% AEP flood extents						CAPITA	
DRAWN BY	CHECKED BY	PASSED BY	DATE	SCALES @ A3	ISSUING OFFICE	DRAWING NUMBER	REV
TL	SC	AC	24/05/16	1:16000	E.Grinstead	Figure A-1	1



Rother Valley Railway							
Figure A-2: Comparison of baseline scenario and 'with railway' scenario 2% AEP flood extents						CAPITA	
DRAWN BY	CHECKED BY	PASSED BY	DATE	SCALES @ A3	ISSUING OFFICE	DRAWING NUMBER	REV
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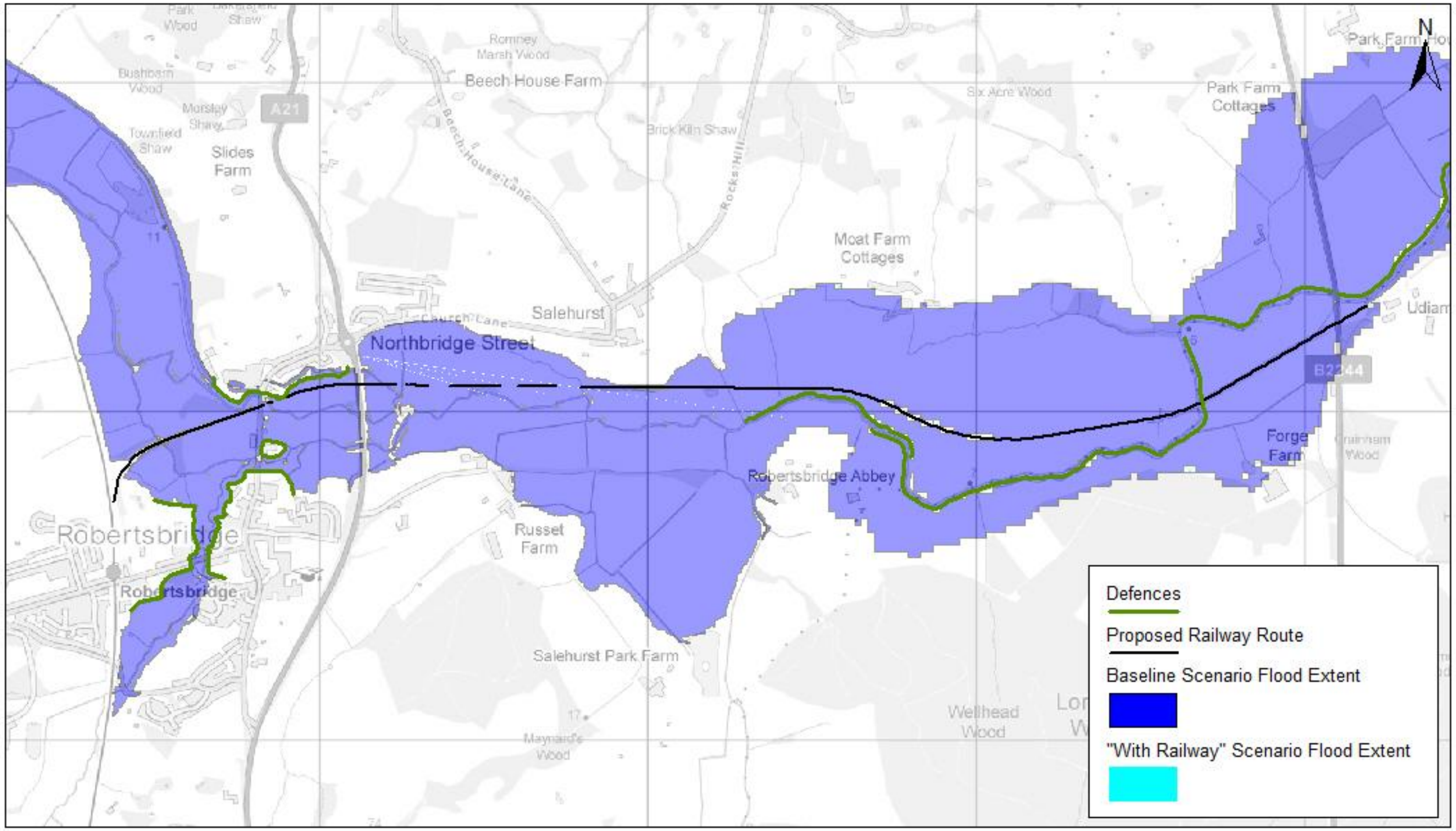

Rother Valley Railway							
Figure A-3: Comparison of baseline scenario and 'with railway' scenario 1.33% AEP flood extents						CAPITA	
DRAWN BY	CHECKED BY	PASSED BY	DATE	SCALES @ A3	ISSUING OFFICE	DRAWING NUMBER	REV
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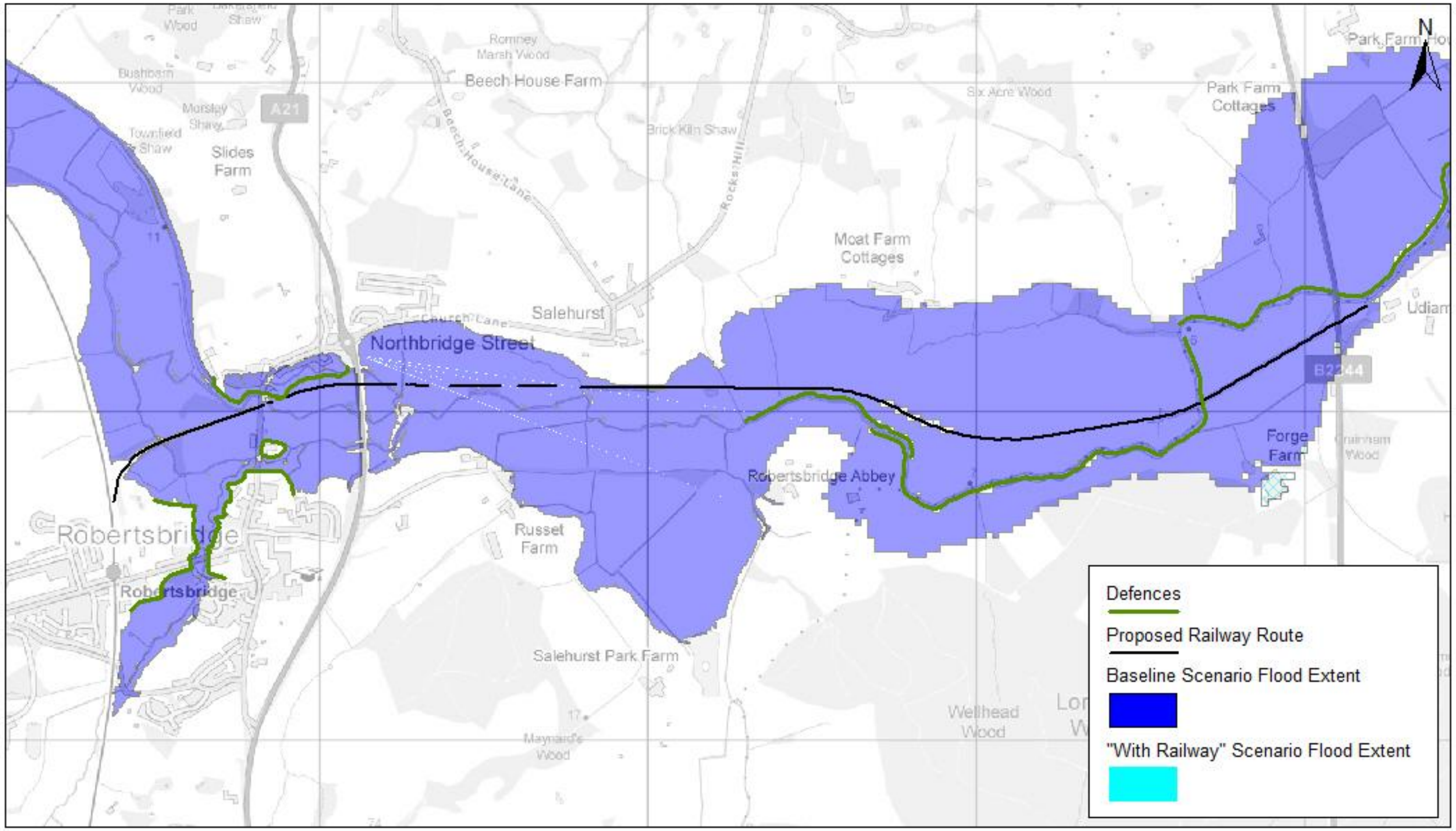

Rother Valley Railway							
Figure A-4: Comparison of baseline scenario and 'with railway' scenario 1% AEP flood extents						CAPITA	
DRAWN BY	CHECKED BY	PASSED BY	DATE	SCALES @ A3	ISSUING OFFICE	DRAWING NUMBER	REV
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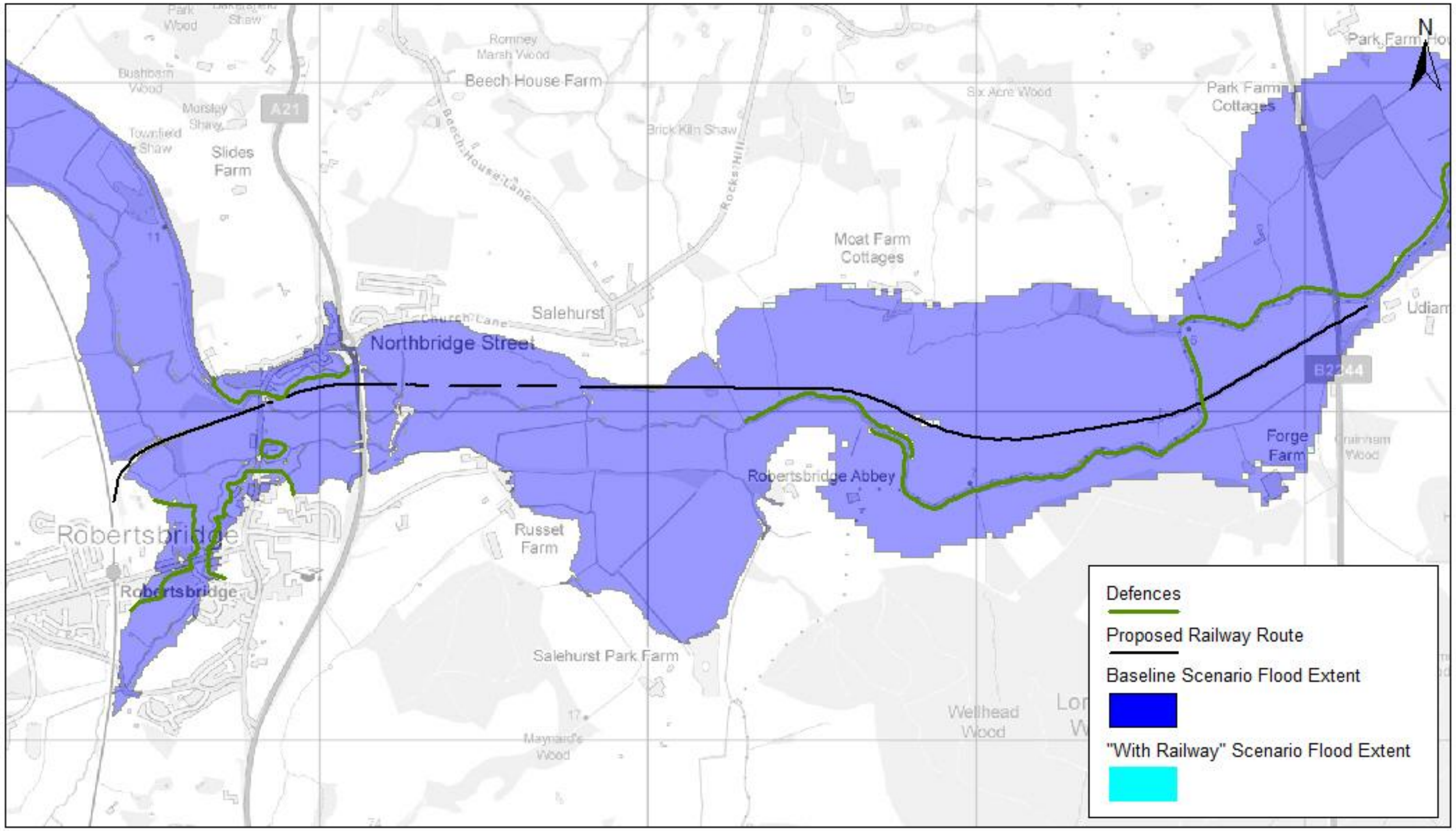

Rother Valley Railway							
Figure A-5: Comparison of baseline scenario and 'with railway' scenario 1%+CC AEP flood extents						CAPITA	
DRAWN BY	CHECKED BY	PASSED BY	DATE	SCALES @ A3	ISSUING OFFICE	DRAWING NUMBER	REV
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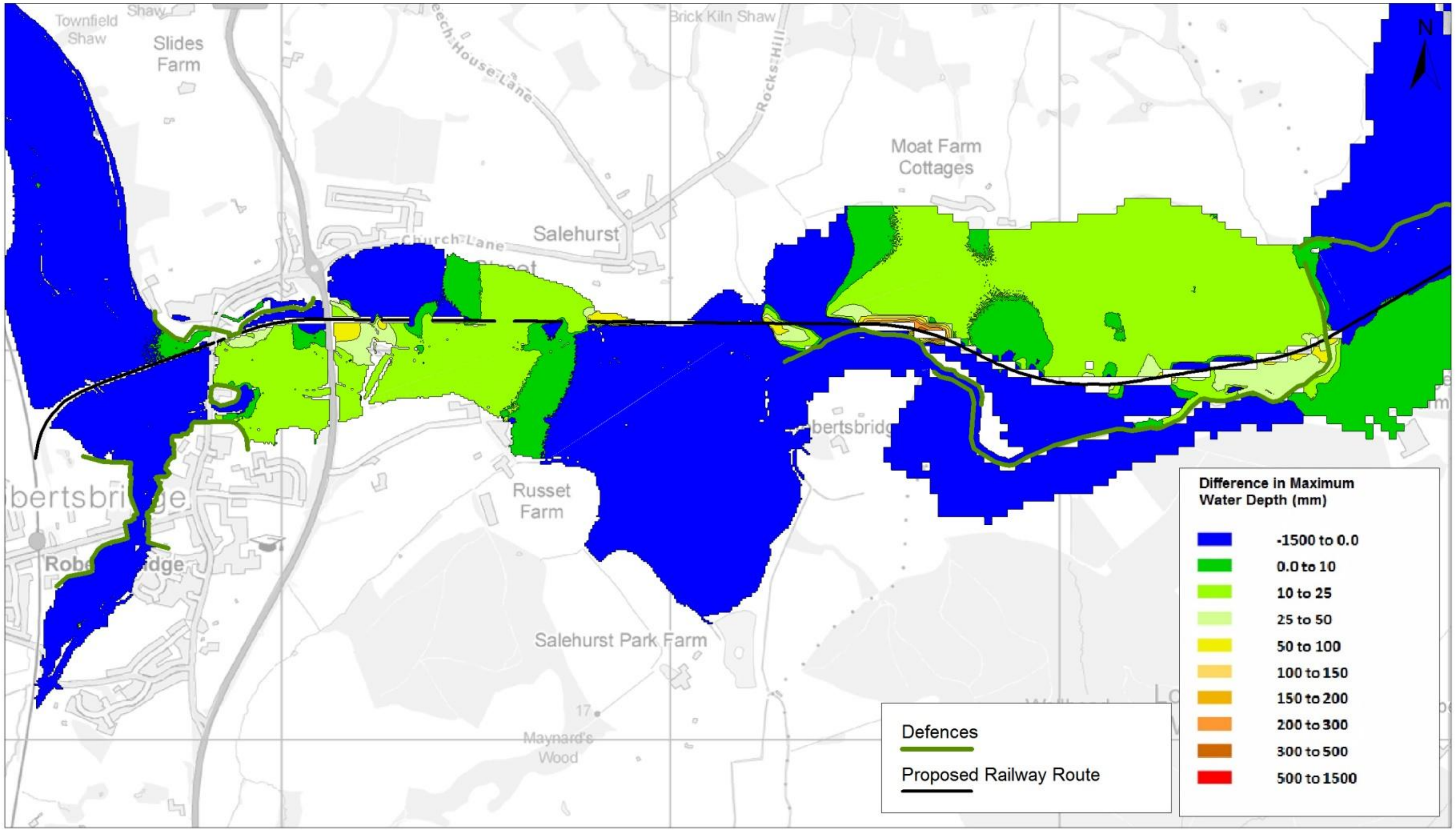

Rother Valley Railway							
Figure B-1: Difference in maximum depth between 'with railway' scenario and baseline scenarios for the 5% AEP flood event						CAPITA	
DRAWN BY	CHECKED BY	PASSED BY	DATE	SCALES @ A3	ISSUING OFFICE	DRAWING NUMBER	REV
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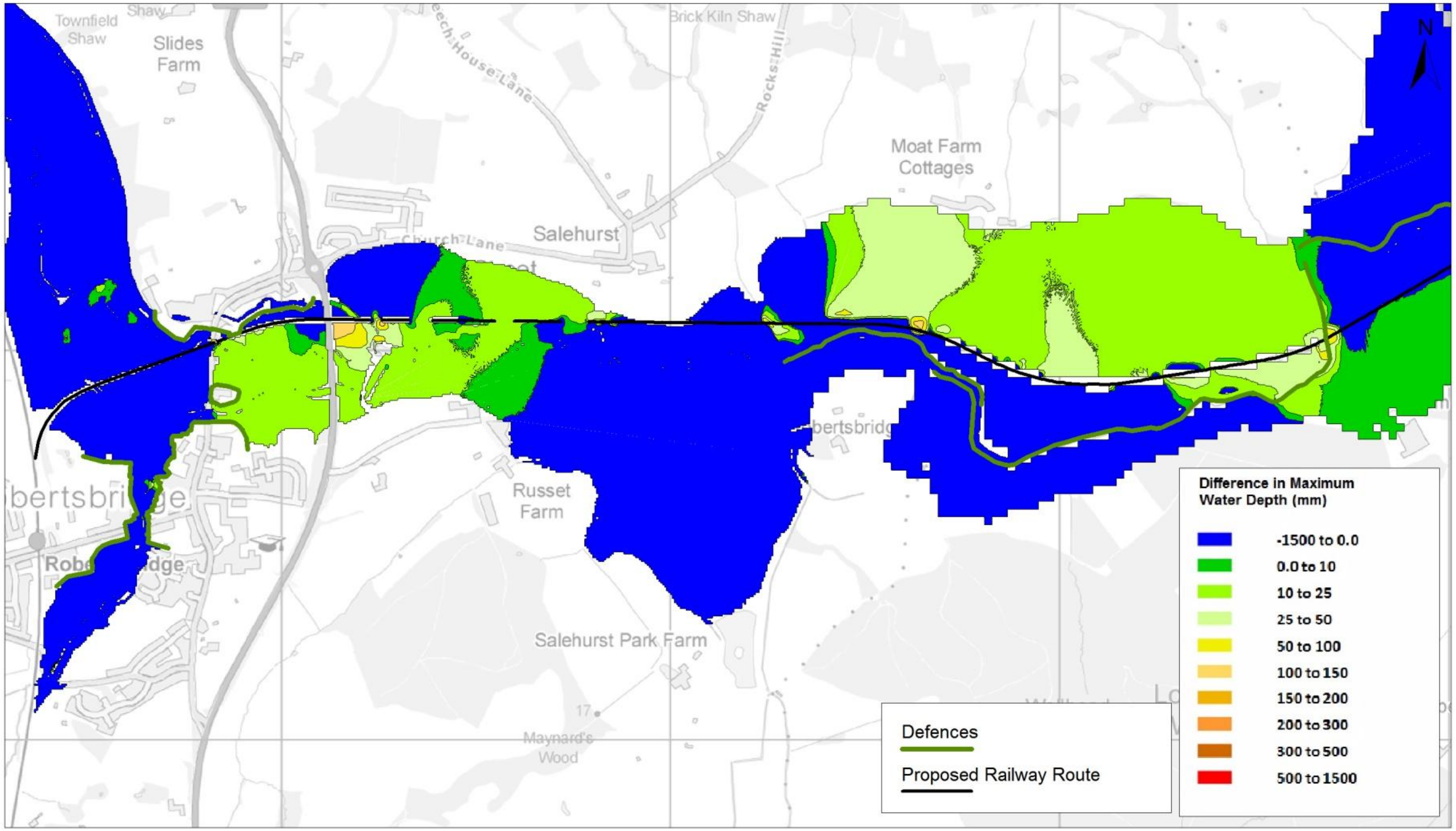

Rother Valley Railway

Figure B-2: Difference in maximum depth between 'with railway' scenario and baseline scenarios for the 2% AEP flood event

CAPITA

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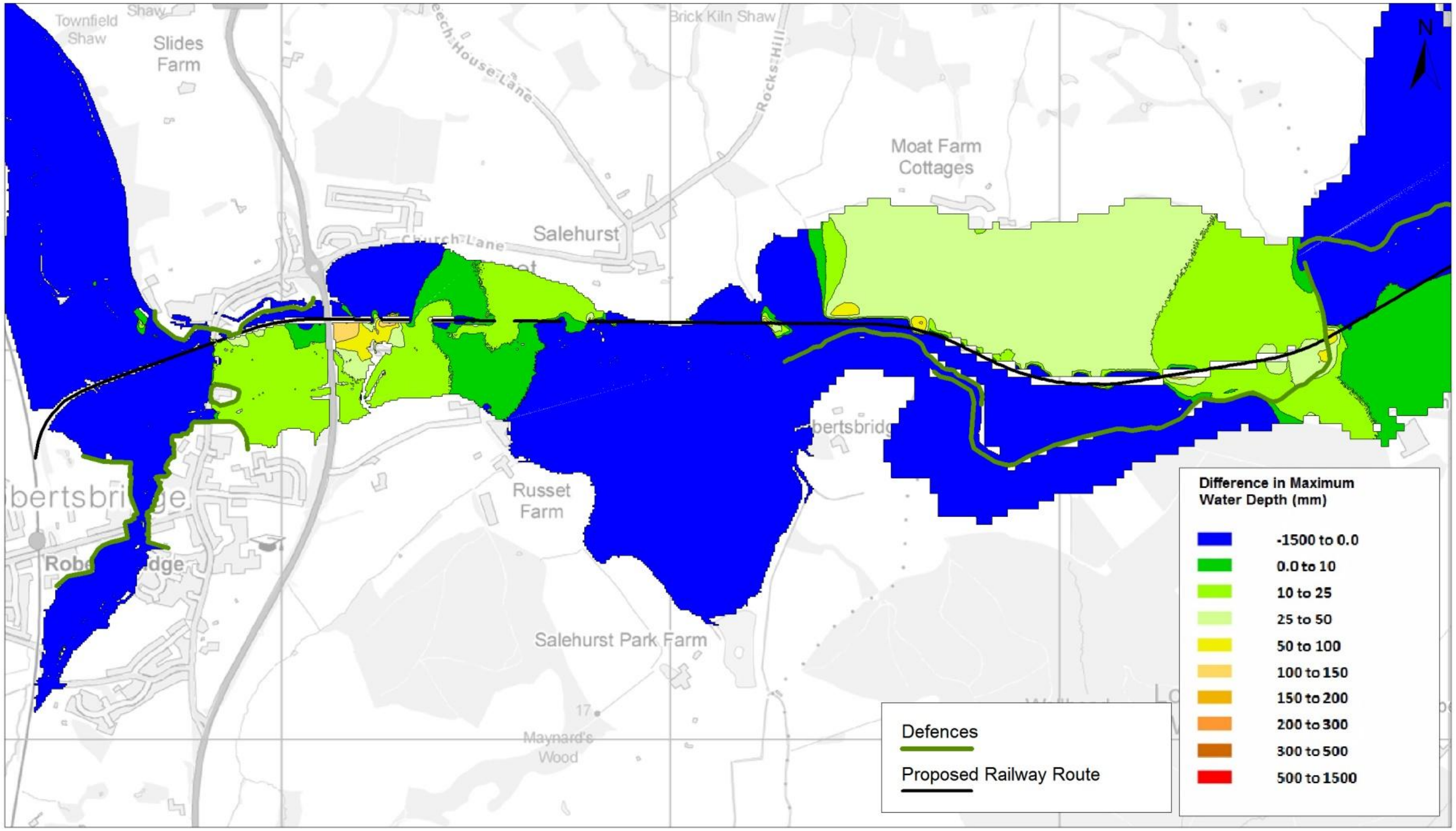

Rother Valley Railway

Figure B-3: Difference in maximum depth between 'with railway' scenario and baseline scenarios for the 1.33% AEP flood event

CAPITA

DRAWN BY	CHECKED BY	PASSED BY	DATE	SCALES @ A3	ISSUING OFFICE	DRAWING NUMBER	REV
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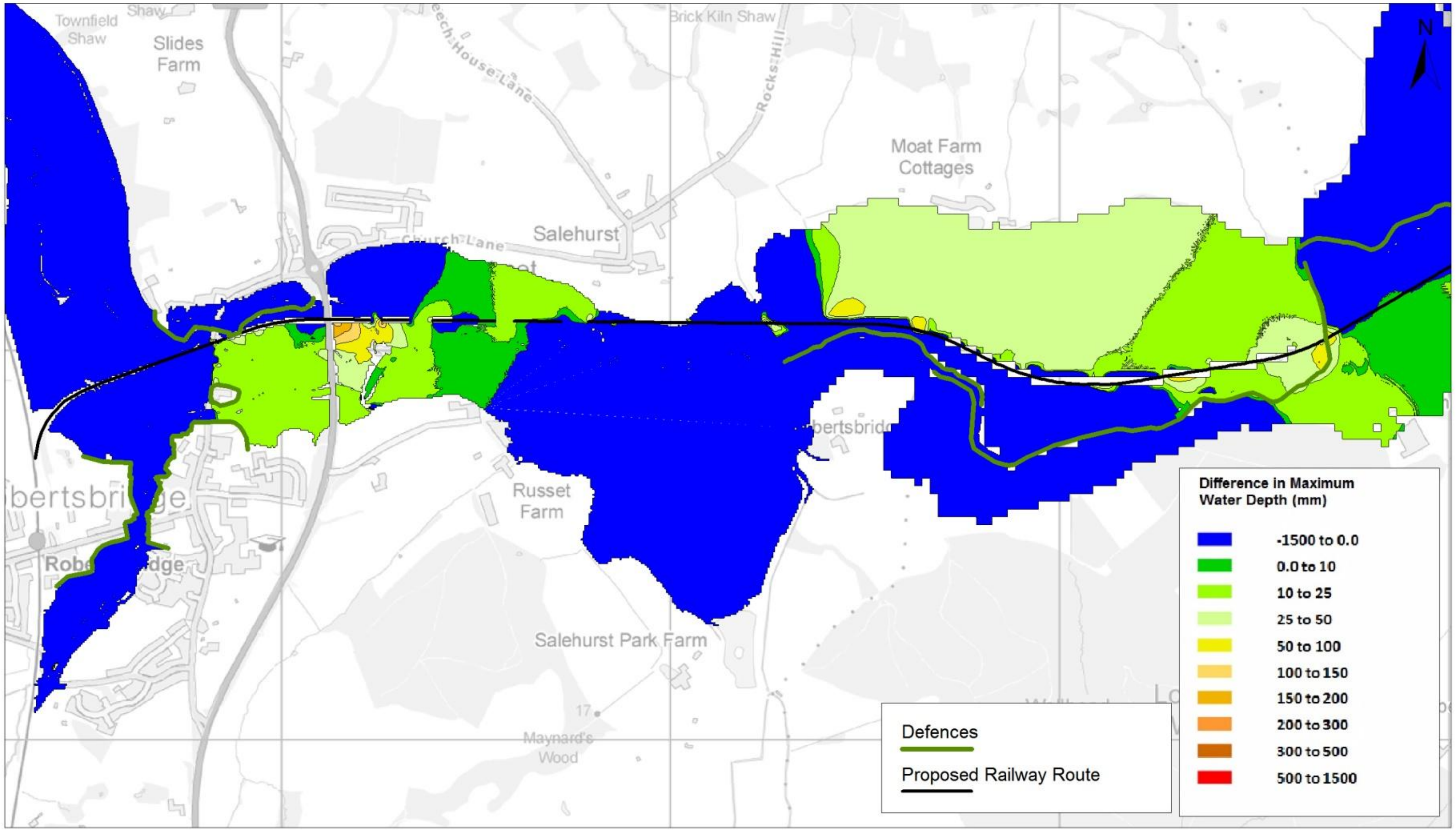

Rother Valley Railway

Figure B-4: Difference in maximum depth between 'with railway' scenario and baseline scenarios for the 1% AEP flood event

CAPITA

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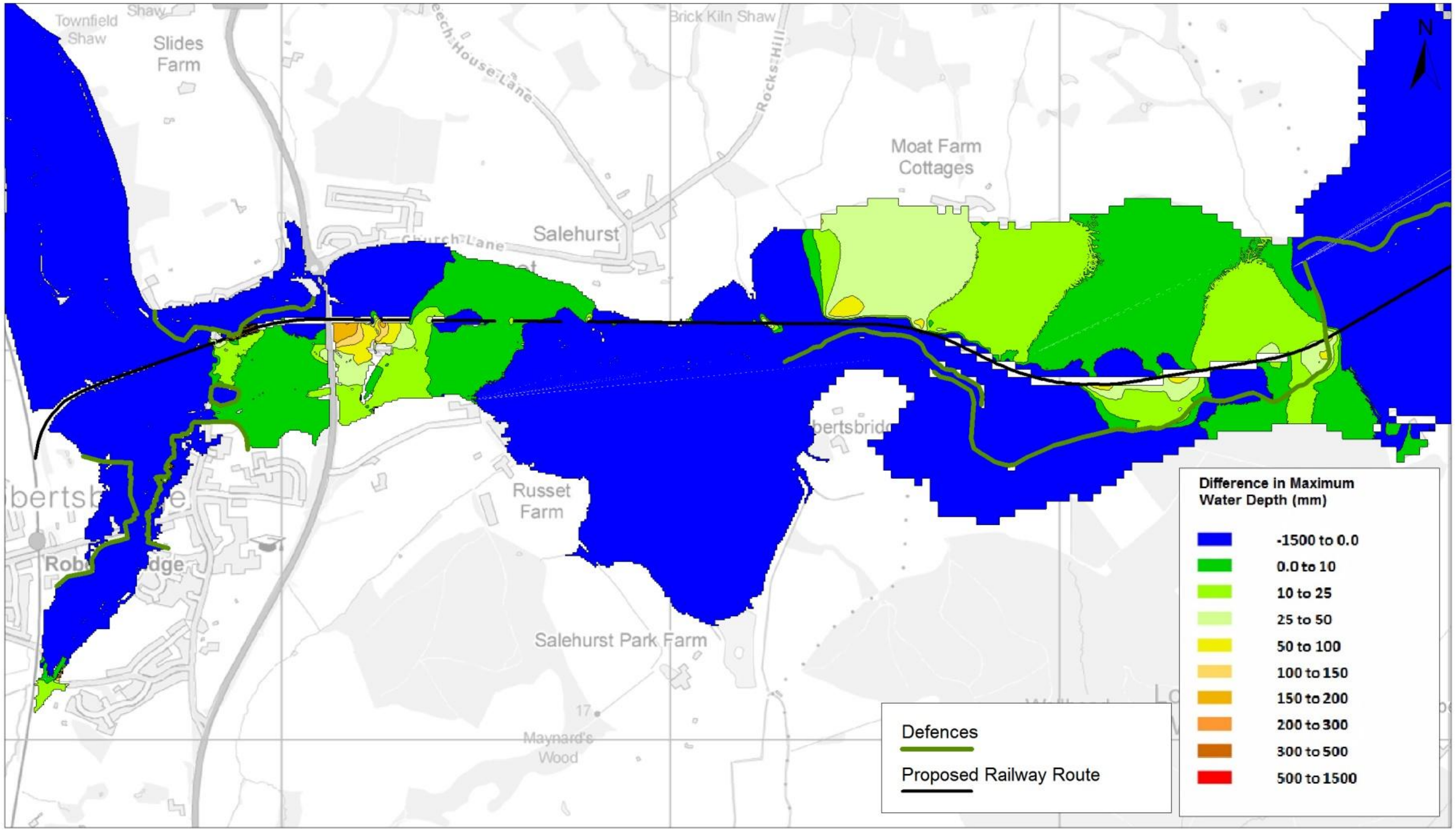

Rother Valley Railway

Figure B-5: Difference in maximum depth between 'with railway' scenario and baseline scenarios for the 1% AEP with climate change flood event

CAPITA

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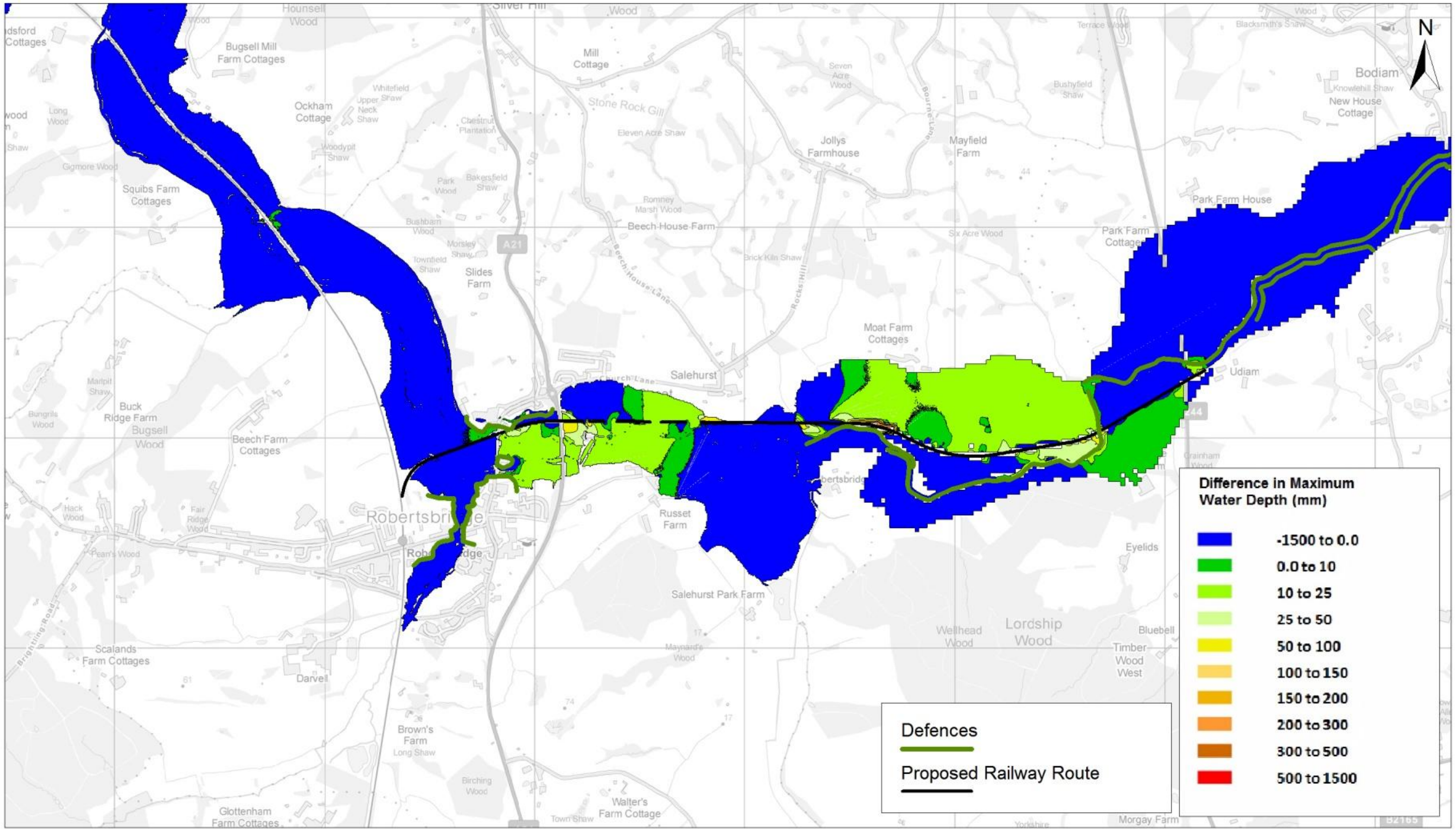

Rother Valley Railway								
Figure C-1: Difference in maximum depth between 'with railway' scenario and baseline scenarios for the 5% AEP flood event						CAPITA		
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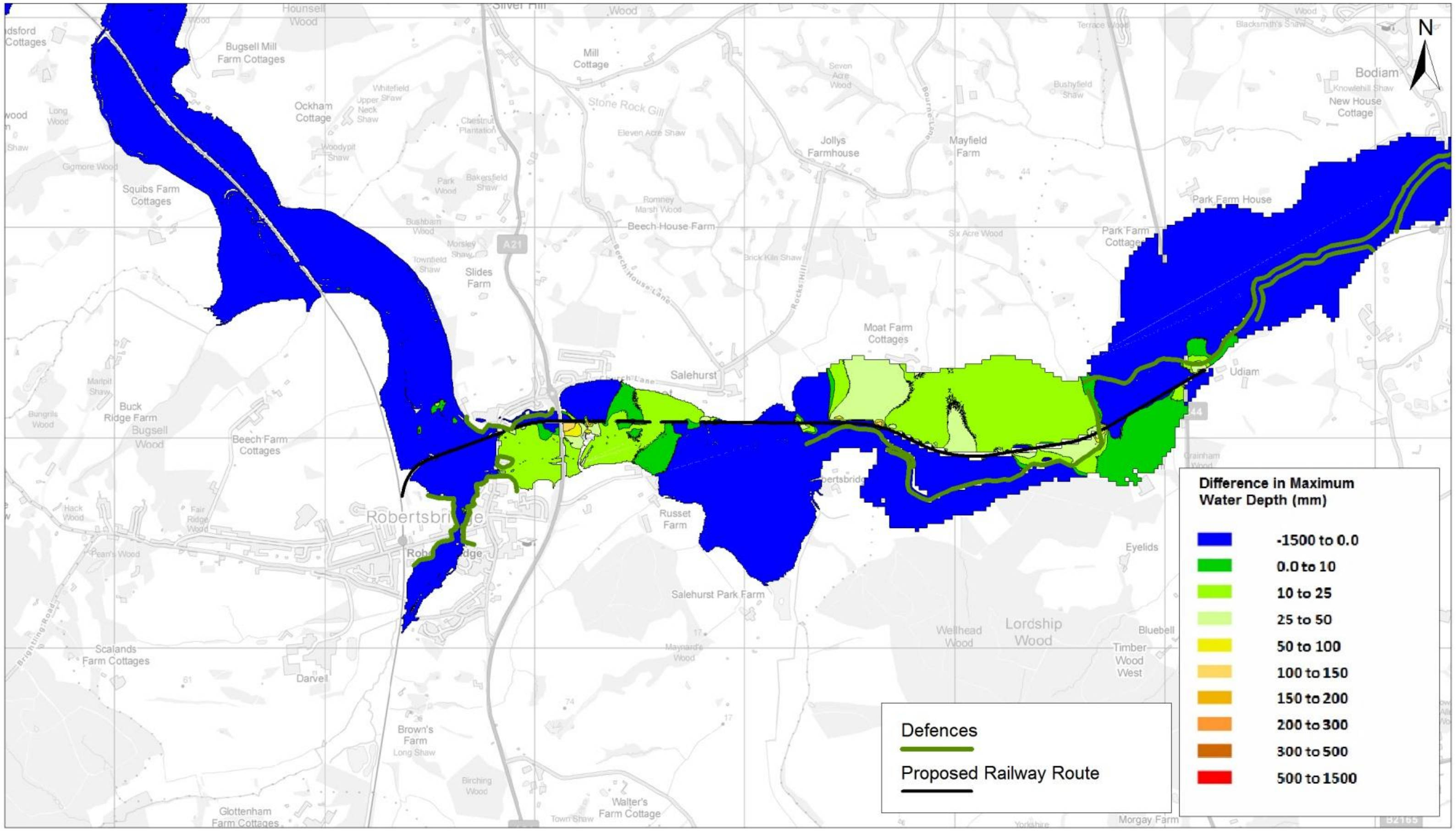

Rother Valley Railway							
Figure C-2: Difference in maximum depth between 'with railway' scenario and baseline scenarios for the 2% AEP flood event						CAPITA	
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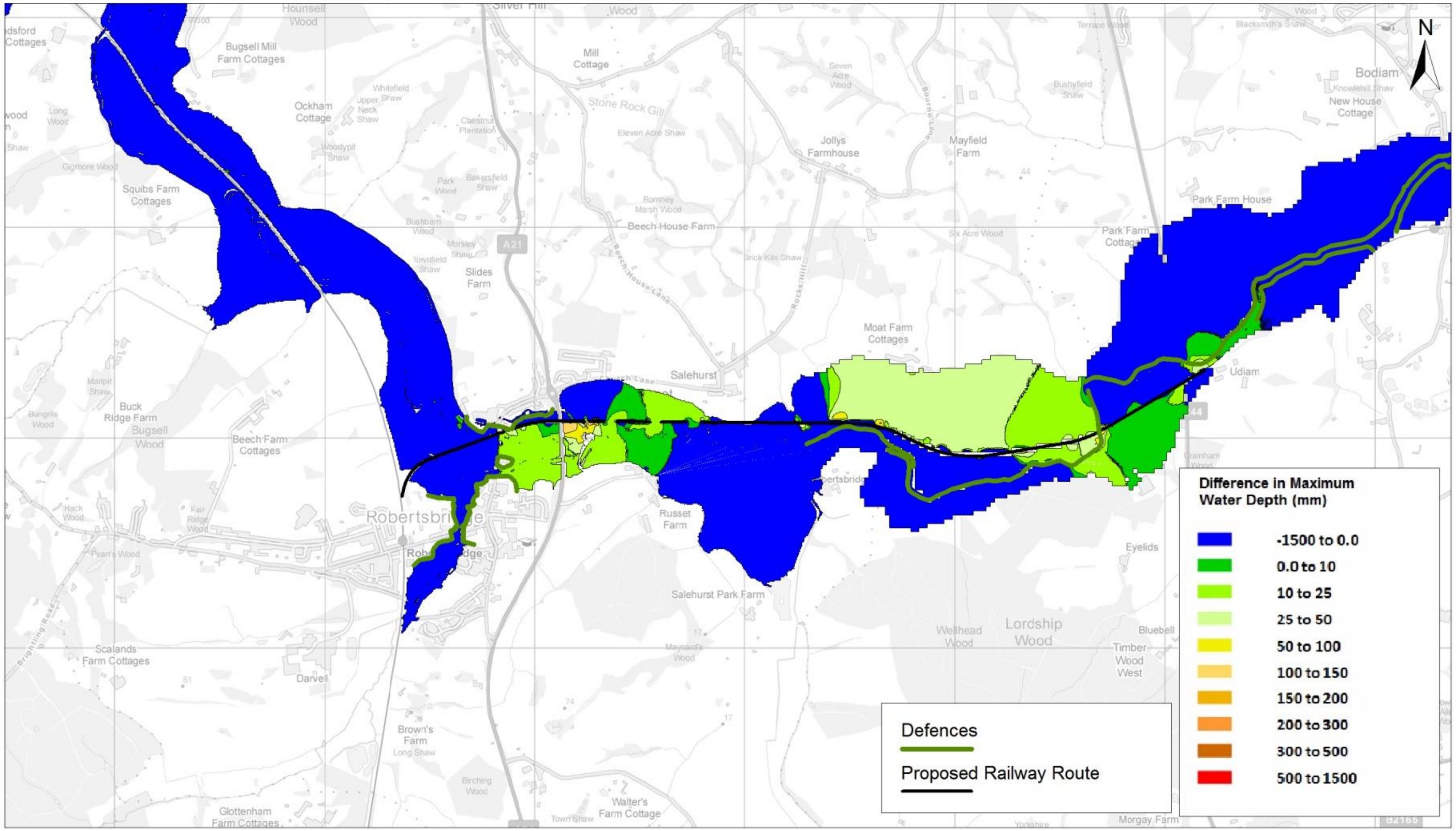

Rother Valley Railway						
Figure C-3: Difference in maximum depth between 'with railway' scenario and baseline scenarios for the 1.33% AEP flood event						CAPITA
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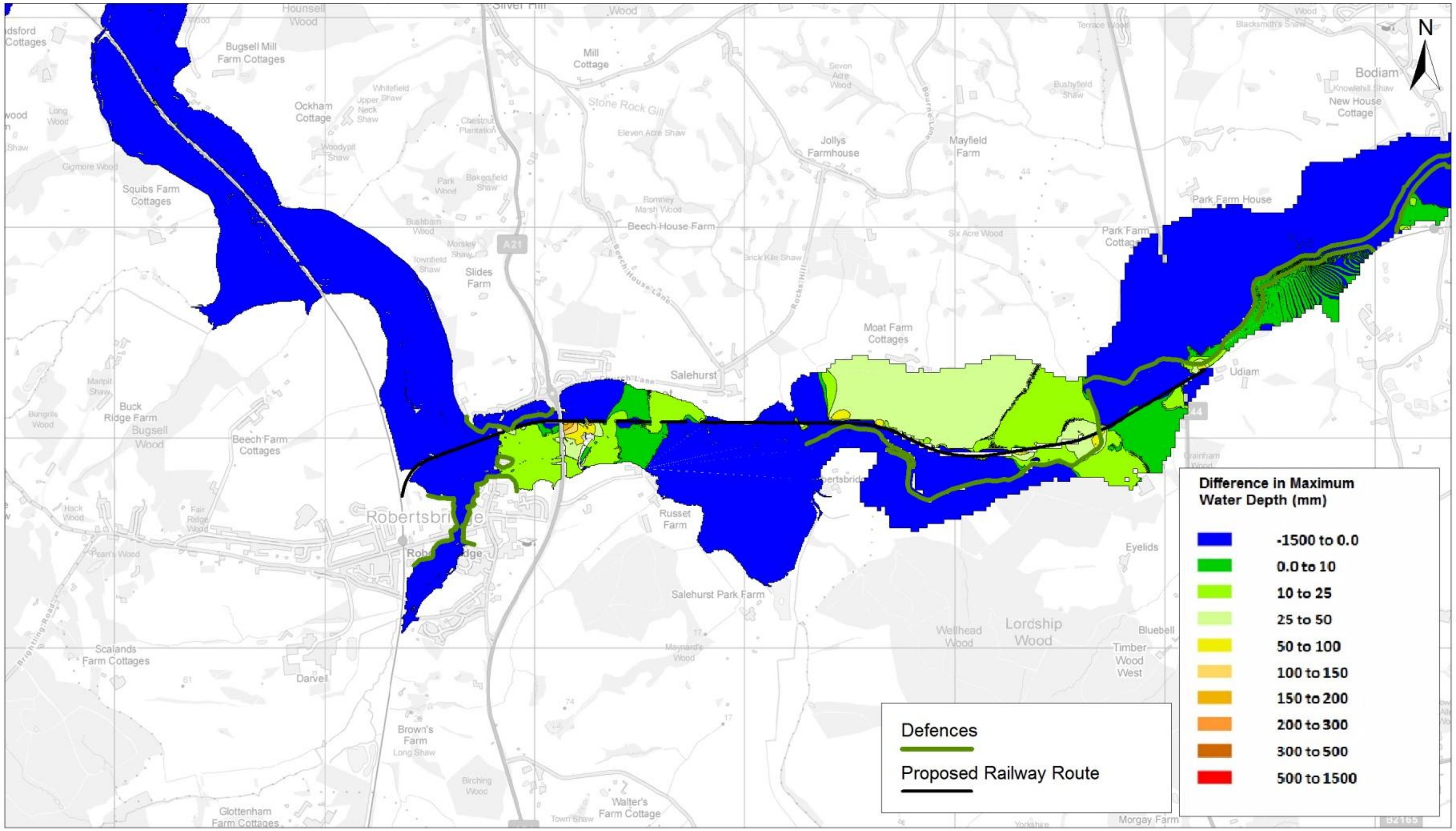

Rother Valley Railway						
Figure C-4: Difference in maximum depth between 'with railway' scenario and baseline scenarios for the 1% AEP flood event						CAPITA
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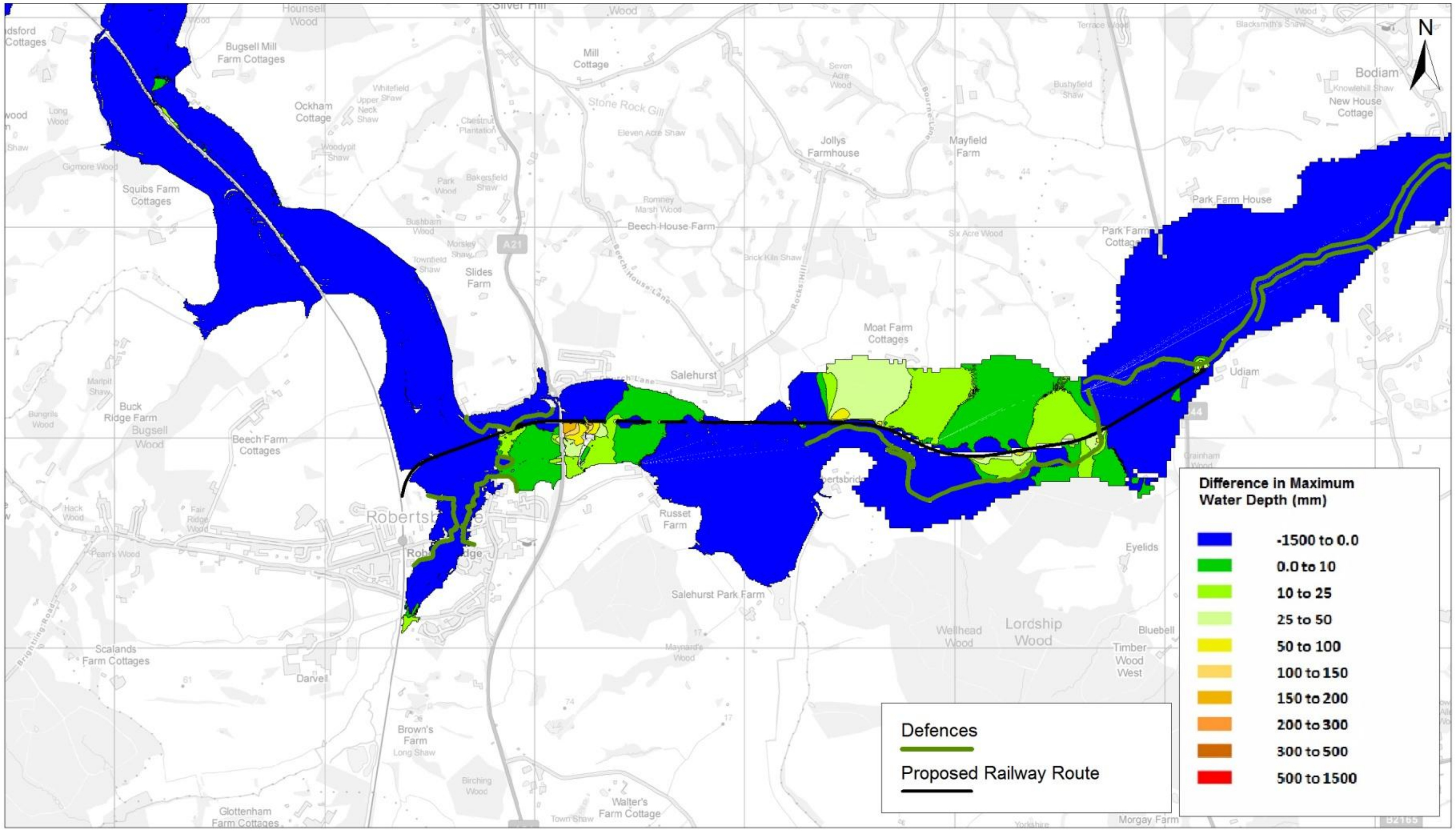

Rother Valley Railway

Figure C-5: Difference in maximum depth between 'with railway' scenario and baseline scenarios for the 1% AEP with climate change flood event

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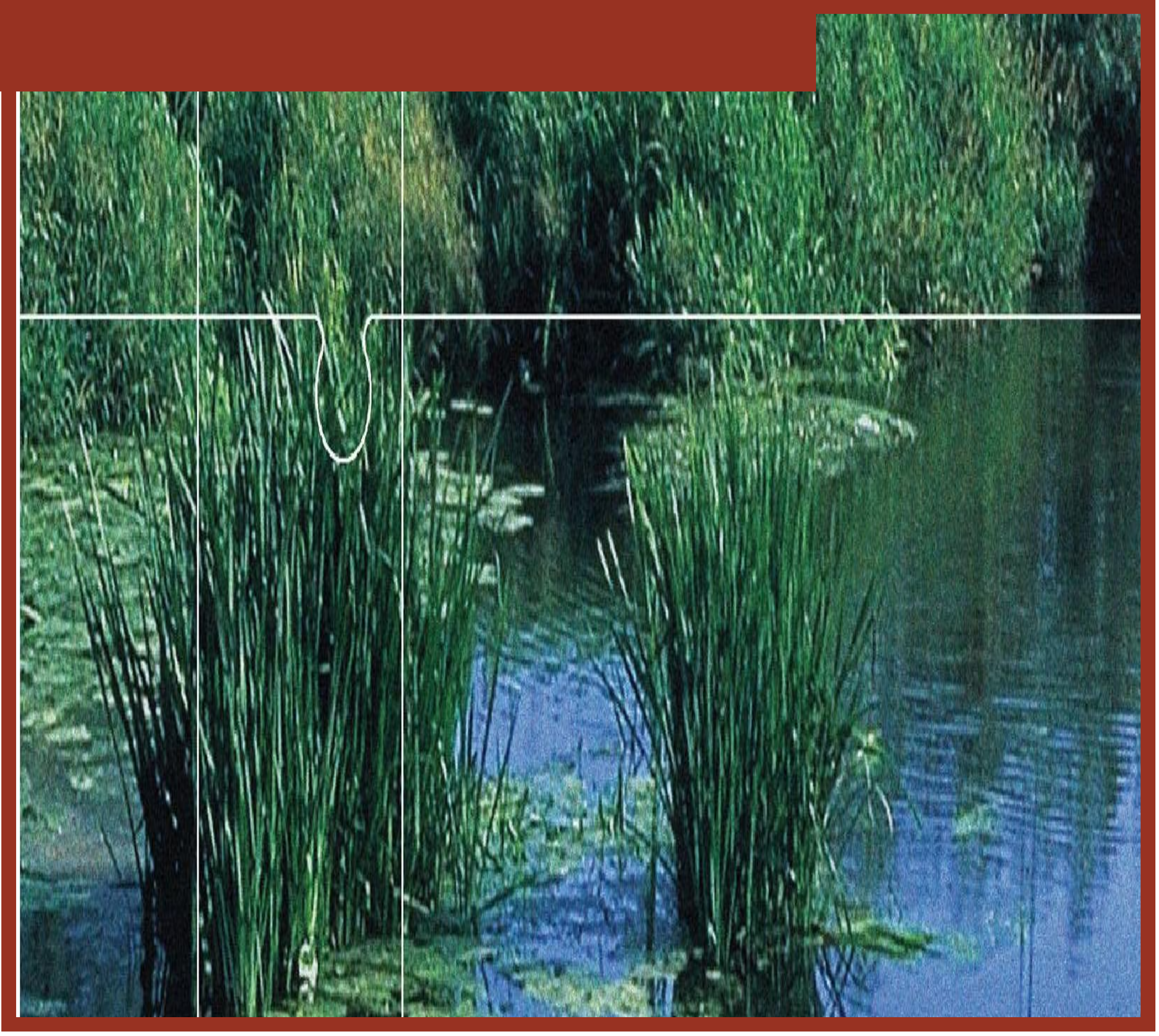
Rother Valley Railway

Modelling Report

June 2016



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Executive Summary

1. Capita Property and Infrastructure Ltd (Capita) has been commissioned by Rother Valley Railway Limited to undertake a Flood Risk Assessment (FRA) for the proposed reinstatement of the Rother Valley Railway between Robertsbridge and Udiam (Bodiam). The route is approximately 3.5 km and will link the existing railway between Bodiam and Robertsbridge. The proposed scheme includes reinstating the historic railway line with a new embankment and the addition of culverts, bridges and viaducts along its route.

2. The FRA is detailed in a separate report. This report provides additional detail about the modelling that was undertaken as part of the FRA. There is an existing Environment Agency hydraulic model of the River Rother. This report focuses on the amendments made to the hydraulic model as part of the FRA. These include a number of improvements to the existing model and the development of a new version of the model which includes the proposed railway.

3. The site is located in the Rother catchment. The River Rother flows in an easterly direction for approximately 30 km before flowing into the English Channel, at Rye. The Darwell Stream is a tributary of the Rother that joins the main channel at Robertsbridge. The area has been subjected to quite severe flooding over the last 20 years and a flood defence scheme was put in place for Robertsbridge in 2004.

4. The site has been modelled using Flood Modeller (previously known as ISIS) and TUFLOW which are established software packages used for modelling rivers and floodplains. The modelling covered a number of flooding scenarios and compared the “without railway” baseline (i.e. the existing condition) with the Rother Valley Railway constructed, ‘with railway’ scenario.

5. The work was carried out in close liaison with the Environment Agency and the key results are based on a 1% AEP (100 year) with climate change design flood event. The modelling undertaken for this FRA (2016) and by the Environment Agency in 2011 shows that overtopping of the existing flood protection scheme occurs at some locations for a 1% AEP and larger flood events. The river modelling techniques currently available are more advanced than those available when the flood defence scheme was designed and built.

6. The modelling found that the construction of the railway would not increase flood risk to properties during a 1% AEP with climate change design flood event in Northbridge Street and Robertsbridge. The impact across the floodplain varies with some areas benefiting from reduced flood levels and others experiencing potential increases in flood levels of up to 50mm. There are a few small isolated areas, immediately adjacent to the proposed railway where predicted increases in water levels are greater.

7. To investigate future flood risk, modelling was undertaken for the 1% AEP with climate change flood event (this includes a 20% increase in the 1% AEP flood event flows). The majority of the FRA work and consultation with the Environment Agency was undertaken prior to the latest climate change allowances being published (February 2016) and therefore the Environment Agency has agreed to base its advice on the previous allowances.

8. To manage the consequences of flooding to the railway the train operators will sign up to the Environment Agency’s Flood Warnings Direct service and cease any services when there is a risk of flooding.

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1 Introduction

1.1 Study Background

1.1.1 Capita Property and Infrastructure Ltd (Capita) has been commissioned by Rother Valley Railway Limited to undertake a Flood Risk Assessment (FRA) for the proposed reinstatement of the Rother Valley Railway between Robertsbridge and Udiam (near Bodiam). The route is approximately 3.5 km and will link the existing railway between Bodiam and Robertsbridge (**Figure 1**). The proposed scheme includes reinstating the old railway line with raised embankments, culverts and bridges along the route. The propose railway scheme also includes sections of track lowered close to ground level and a number of viaducts to maintain floodplain flow routes and minimise the impact on flood levels.

1.1.2 The FRA forms a separate report. This modelling report provides additional detail about the modelling that was undertaken as part of the FRA. There is an existing Environment Agency hydraulic model of the River Rother and details of this are given below. This report focuses on the amendments made to the hydraulic model as part of the FRA. The Environment Agency Final Modelling Report[1] should be referenced for further details about the original model.

1.1.3 It should be noted at the outset that the historic route of the railway is through the Rother floodplain. Therefore the proposed reinstated route, which links two existing sections of railway, is also through the floodplain.

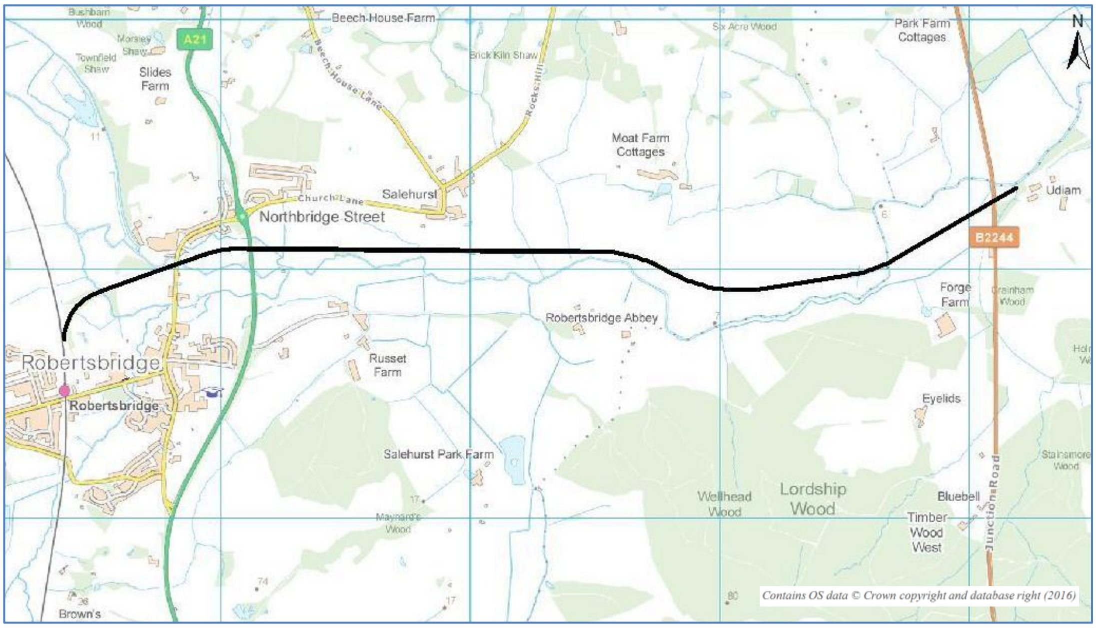

Figure 1 - Proposed Route of Railway

[1] Environment Agency, 2011, River Rother Final Hydraulic Modelling, ABD, and Hazard Mapping Report, Hyder.

1.2 Catchment and Flooding Background

1.2.1 In order to assess the risk of flooding to the reinstated railway, and the wider area of Robertsbridge, it is important to understand the existing catchment characteristics, flow patterns and flooding history.

1.2.2 The site is located in the Rother catchment. The River Rother flows in an easterly direction for approximately 30 km before flowing into the English Channel, at Rye (NGR TQ 95700 17400). The Darwell Stream is a tributary of the Rother that flows through Robertsbridge.

1.2.3 Table 1-1 provides information on historic fluvial flood events in the Robertsbridge area based on information provided in the Rother SFRA. Historic flooding from other sources is detailed in the FRA report.

Table 1-1 Historic flood events at Robertsbridge

Date	Description and Source
1946. 1960, 1979, 1985, 1999, 2001	Fluvial - Insufficient storage capacity. Very intense rainfall on an already wet soil leading to rapid runoff. Recent development in the floodplains, debris in the river channel.
1993	Fluvial - Intense rainfall, properties flooded by sewage contaminated water
12th October 2000 (greater than 1% event) 31st October 2000 5th November 2000	Fluvial - Very intense rainfall on an already wet soil leading to rapid runoff. Recent development in the floodplains, debris in the river channel, backing up from road drains and surcharging of combined sewerage system (indirect source), backing up behind culverts and bridges, overtopping of low flood embankment, back up of floodwater from the floodplains, reduced storage capacity due to repeat events

1.3 Existing Flood Risk Management Infrastructure

1.3.1 After the autumn 2000 floods, a major flood defence scheme was implemented in Robertsbridge, consisting of raised permanent flood walls/bunds along the river, and a number of movable gates that can be used to create temporary flood walls. This scheme was completed in 2004 (Atkins, 2007). Pumps were also added to the scheme to deal with runoff resulting from incident rainfall within the defended area which was no longer able to connect directly back into the river due to the flood defences blocking flow. These pumps facilitate removal of water from within the defended area back into the river. Pumps on the Mill Stream also convey high flows over the defences and back into the Rother[1].

1.3.2 Robertsbridge and Northbridge Street both benefit from defences on the River Rother and Darwell Stream.

1.3.3 The modelling undertaken for this FRA (2016) and by the Environment Agency in 2011 shows that overtopping of the existing flood protection scheme occurs at some locations for a 1% AEP and larger flood events. The river modelling techniques currently available are more advanced than those available when the flood defence scheme was designed and built.

1.3.4 The topographical survey shows the crest level of the defences are between 12.4 m AOD (upstream) and 11.2 m AOD (downstream) at Northbridge Street, and between 12.7 m AOD and 11.5 m AOD at Robertsbridge.

1.4 Existing Flood Model

1.4.1 There is an existing hydraulic model of the River Rother which has been used to assess flood risk and the impact of the proposed reinstatement of the railway. The model was developed by Hyder for the Environment Agency in 2011. The model includes the River Rother and its tributaries between Turk's Bridge at Bivelham Farm and a point 0.4 km downstream of Kent Ditch's confluence with the Rother.

1.4.2 The aim of the 2011 hydrological and hydrodynamic modelling was to quantify predicted flooding of the Rother and its tributaries for flood events ranging from the 20% AEP (1 in 5 year) to 0.1% AEP (1 in 1000 year). The study defined flood extents, areas benefiting from defences and produced flood hazard mapping.

1.4.3 Three models had been constructed of the Rother and its tributaries prior to the 2011 study; the details of these are provided in the 2011 report[1]. However, these models were considered unsuitable for the purposes of the 2011 study.

1.4.4 The 2011 River Rother model was constructed as a linked 1D-2D hydraulic model using ISIS and TUFLOW software. The versions of modelling software used in the 2011 study were ISIS 3.1.1.38 and TUFLOW version 2008-08-DB-iSP. The model was based on survey undertaken in 2001 and 2009. A channel Manning's *n* value of 0.045 was applied in the model based on the channel being typically natural, with a pebbled bed including a small amount of debris and some aquatic vegetation. The 2D model domains were based on 1m filtered LiDAR. The model included multiple domains to manage runs times. A 5m grid was applied in the key areas of interest (around Robertsbridge), and a 20m grid was used in more rural areas. OS MasterMap data was used to define Manning's *n* values across the floodplain. The raised defences around Northbridge Street and Robertsbridge are included in the model. The 2011 report[1] also states that the pump in the Mill Stream which pumps water over the defence bund has been included in the model. The pair of Penstock Sluice Gates (grid ref. 573676, 124095) on the Mill race in Northbridge Street are designed to close during a flood event. This was represented in the model by disconnecting the 1D channel between the main Rother and the Mill Stream, although flow is still transmitted to the Mill Stream via overland routes.

1.4.5 The 2011 report[1] details the model calibration, which was based on three events, 12th October 2000, 30th October 2000 and 6th November 2000. The report states that the outputs of the study agree very well with the historic flood outline from the flood events in October 2000 as well as hydrometric data at Udiam and photographic evidence at Robertsbridge. In addition to the calibration the original study also included a sensitivity analysis. The maximum change in stage was reported for changes to model inflows. Changes in Manning's *n* resulted in changes in stage of up to 0.2m. The sensitivity analysis also indicated that the flood extents in Robertsbridge are sensitive to changes in Manning's *n* and inflow.

1.4.6 The 2011 model (defended version) is considered suitable for assessing flood risk in the Robertsbridge area. The 2011 report recommends the model is reviewed prior to its use in Flood Risk Assessments. Capita reviewed the model to assess its suitability for use in the FRA. The model was considered a suitable baseline model for use in the Rother Valley Railway FRA subject to the changes detailed in this report.

1.4.7 While reviewing the model for use in this flood risk assessment a number of opportunities for improvements were noted. The improvements made to the model included the following and further details are given in Chapter 2:

- improvements to the 2d_2d boundary between the middle and lower domains, where an unrealistic water surface profile was observed in the 1% AEP design event;
- changes to the Darwell Stream and downstream of the A21 to improve model stability including changes to weir coefficients and modular limits in the spill units, changes to spill widths, removal of a minor footbridge, improvements to floodplain Manning's *n* values, and changing some SX boundaries between Flood Modeller (previously ISIS) and TUFLOW to HX connections;
- amendments to the defences layer in the model which included removing a defence along The Clappers which doesn't exist, raising the defence to the north of the Museum/Bridge bungalow which was set 100mm to low, and raising the defence to the east of The Clappers Flood Gate which was too low for approximately 10m;
- the application of HX loss coefficients (relatively new feature), which improves the representation of energy losses as water flows out of bank and model stability; and
- the addition of zshapes to enforce road elevations at key locations and enforce the existing historic railway embankment, which is picked up in the LiDAR, but due to the model grid resolution is not fully represented in the model grid.

1.4.8 Chapter 2 of this report describes the amendments made to the original Environment Agency model to develop the FRA baseline model. The FRA baseline model was used to assess the current flood risk in the study area.

1.4.9 Chapter 3 of this report describes the amendments made to the FRA baseline model to develop a scenario model that represent the proposed reinstated railway.

2 Improvements to the 2011 model

2.1 Introduction

2.1.1 A description of the Environment Agency's 2011 model has been provided in section 1.4 of this report. This chapter describes the amendments made to the original Environment Agency model to develop a baseline 'current' scenario for the FRA. The baseline FRA model was used to assess the current flood risk in the study area.

2.1.2 The FRA model was run using Flood Modeller version 4.1 (previously known as ISIS) and TUFLOW version 2013-12-AD-isp. The 1% AEP results from the 2011 model and FRA 2016 baseline model were compared to make sure that the results were similar and that significant differences could be explained (section 2.7).

2.2 2d_2d boundary

2.2.1 The review of the existing Environment Agency 2011 model identified that there was a significant head loss at some points along the 2d_2d boundary near Robertsbridge Abbey (TQ 73500 23970), giving an unrealistic water surface profile. The 2d_2d boundary "stitches" two 2D domains together by a series of water level control points. Momentum across the link is preserved provided the Zpt elevations along the selected cells in both 2D domains are the same or similar[2]. In order to improve the water surface profile across the boundary the zline along the boundary was edited to improve the smoothing of the Zpt elevations along the boundary.

2.2.2 Based on previous research we have undertaken on 2d_2d boundaries to determine suitable 'a' and 'd' attributes we also adjusted these attributes in the 2d_2d boundary line. The "a" attribute default value is 2. Increasing this value from the default of 2 may improve stability, but may unacceptably attenuate results. The "d" attribute is the minimum distance between 2d_2d water level control points between vertices along the 2D line. If set to zero, only the vertices along the 2D polyline are used. This value should not be less than the larger of the two 2D domains' cell sizes[2]. The 'a' and 'd' attributes were amended from 0 to 2, and from 20 to 30 respectively.

2.2.3 The graph in **Figure 2** illustrates the difference in water surface profile between the set up of the 2d_2d boundary as included in the Environment Agency 2011 model and the FRA baseline model (with amended Zpts and attributes at the 2d_2d boundary). It should be noted that although the transition across the boundary was improved, there remains a relatively large head loss across some sections of the boundary in the amended model. However given that the FRA baseline and proposed scenario models include identical 2d_2d boundary configurations, the comparison of results remains valid (i.e. consistency across the versions of the model, like for like comparison).

[2] BMT WBM, 2010, TUFLOW Manual.2010-10-AB,.

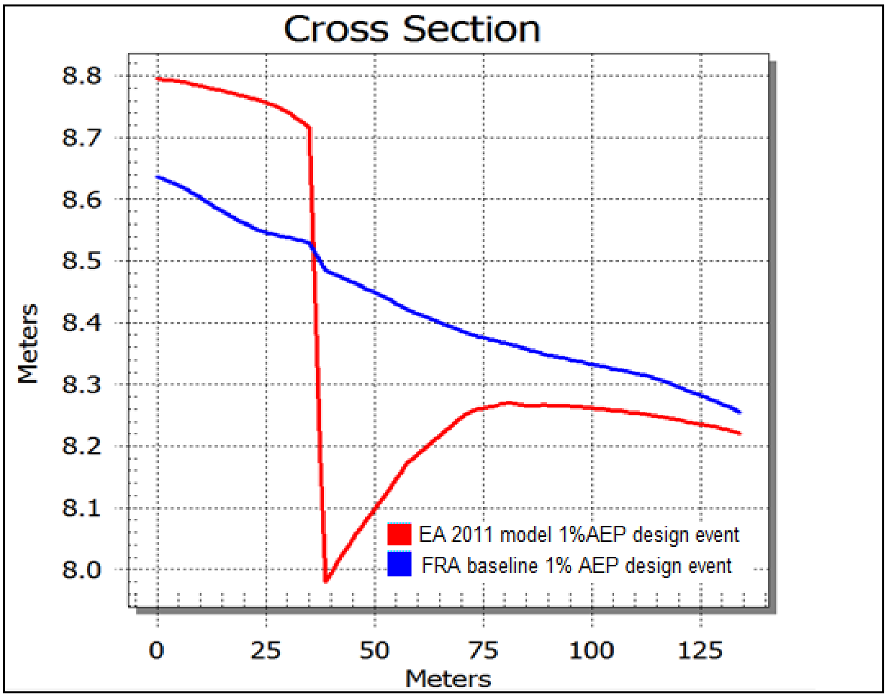

Figure 2 - Impact of amendments to 2d_2d boundary

2.3 1D-2D links

2.3.1 **Darwell Stream** - A review of model results identified that some sections of defences were predicted to overtop around Robertsbridge. At some locations in channel flood levels were marginally lower than the defence crest heights suggesting they should not be overtopping. The cause of this was identified as the method of 1D-2D linking between the Flood Modeller and TUFLOW domains; SX boundaries had been used. When SX connections are used the flow interaction of the Flood Modeller and TUFLOW domains are controlled by Flood Modeller spill units rather than via the TUFLOW domain via HX connections. Relatively small oscillations caused by model instabilities in the Flood Modeller were resulting in flow into the 2D domain. The right bank 1D-2D links between node DA4995 and DA4780 were changed from SX to HX connections and this rectified the issue.

2.3.2 The inline spill widths and coefficients were reviewed along the Darwell Stream. The widths of spills over structures were compared to the null area in TUFLOW i.e. the width of the watercourse that should be represented in Flood Modeller. The width of spill unit sp5226u was reduced from 28.766m to approximately 15m and the width of sp5181u was reduced from 151.049m to approximately 15m. The flow over the bridges at these locations is represented in Flood Modeller, however either side of the structures overland flow is represented in TUFLOW. The spill coefficient was set very low (0.3) at sp5046u, this was increased to 0.7 which is more appropriate for flow over a track.

2.3.3 Just downstream of the confluence between the Darwell Stream and the main channel, spill unit PS4728h was reduced in width from 30.699m to approximately 20m wide to match the null area width in TUFLOW. The spill coefficient was also adjusted from 1.7 to 1.2, which was considered more appropriate for the flow over the road at this location. To the south of this structure a row of TUFLOW cells were amended to set the Manning's *n* value to 0.05 (consistent with the Manning's *n* specified at adjacent cells downstream of the road). This was to address a model instability which was resulting in an over estimate of flooding behind defences in the baseline 1% AEP with climate change scenario.

2.3.4 To improve the representation of floodplain flow paths at the Darwell Stream confluence, changes were made to the HX line configuration between the Darwell Stream (right bank) and The Clappers (Figure 5). An interpolate was also added, 'PS4737i', between PS4737 and PS4737a to improve the water surface profile and stability. To reflect the HX line location change the width of sections NDA4809n and DA4780 were amended.

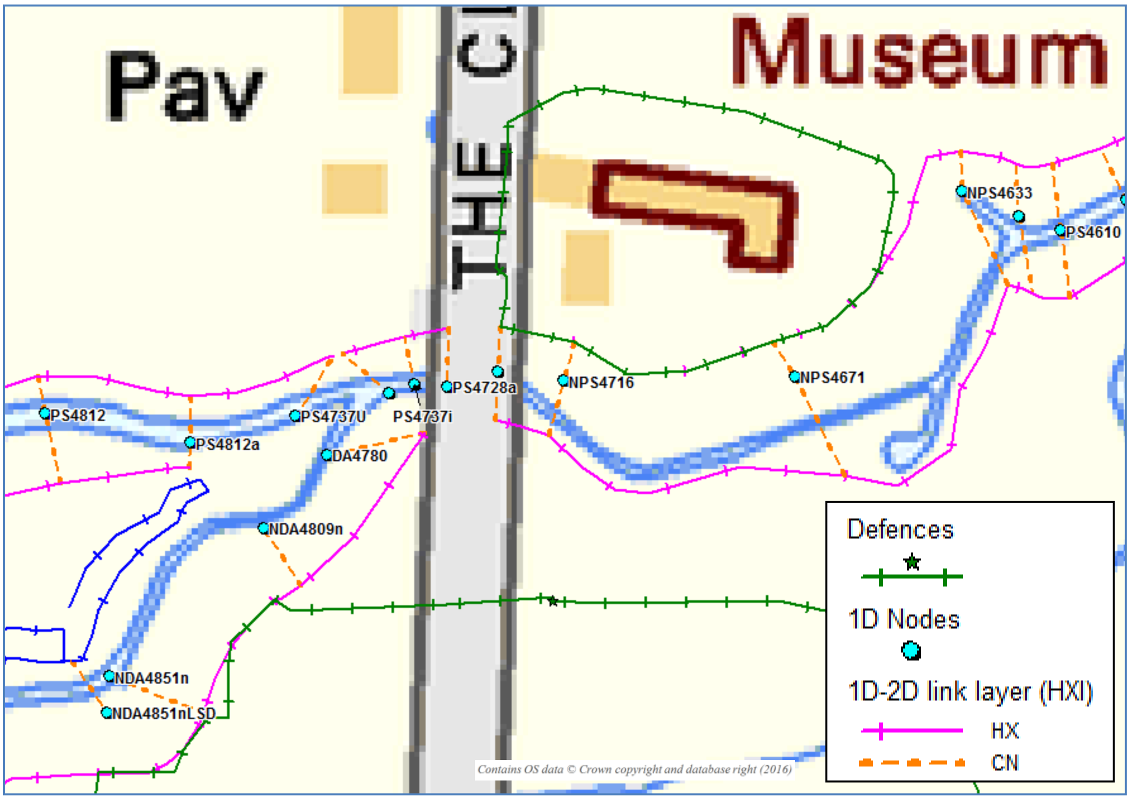

Figure 3 – Improved 1D-2D link and representation of flow paths at the Darwell Stream confluence.

2.3.5 Manning's *n* was refined behind the left bank defences in Robertsbridge. This was to improve the representation of the vegetation and fences/walls in the area. The modelled flood extent in this area was shown to be quite sensitive to Manning's *n* in the original 2011 study.

2.3.6 **Downstream of A21** – In the 2011 model SX connections were used downstream of the A21 to link the Flood Modeller and TUFLOW domains. An area of instability was identified between Flood Modeller node PS4381 and PS4234arbd. In addition to this the difference in floodplain water levels either side of the river channel was not realistic and the SX connections were replaced by HX connections between the A21 and model node RO3825.

2.3.7 The river channel represented in 1D from RO4187 to RO4341u was not connected to the 2D domain. The hxi layer was updated to include new HX lines and CN connections at this location.

2.3.8 **Downstream of The Clappers -** An interpolate was added between model nodes RO4673 and RO4649 to increase stability and improve the water surface profile.

2.3.9 The width of spill unit sp4649u was amended from 61m to 13.2m wide, to match the width of the watercourse modelled in 1D.

2.3.10 **Upstream of the B2244 at Udiam** - Interpolates and associated links to the 2D were added to improve stability and the water surface profile between ROT1746 and RO0425.

2.3.11 **Other -** A loss coefficient of between 0.1 and 0.5 was applied to the HX line along the study reach. This was to improve the representation of energy losses as water flows out of bank and improve model stability.

2.4 Defences

2.4.1 The review of the existing Environment Agency 2011 model included comparing the drawings of the defences around Northbridge Street and Robertsbridge with those represented in the model. A number of inconsistencies were identified between the drawings and the representation of defences in the model. These were initially investigated using Google Street View and a site visit was deemed necessary. Based on site visit observations, which confirmed the drawings were correct, the following amendments were made to the zlines representing the defences in the model.

2.4.2 The zline in the model representing the defence to the east and adjacent to the demountable defence north of Robertsbridge (TQ 73819 23818) was raised to a level of 12.1 m downstream of the road for approximately 10 m.

2.4.3 The defence zline in the model along the High Street between the demountable defence north of Robertsbridge and the Fireplace shop/museum (TQ 73813 23836) was removed.

2.4.4 The Bridge Bungalow/Museum (TQ 73820 23900) defence zline was amended to raise a section of low model cells which had been set to 12 m AOD rather than 12.1 m AOD.

2.4.5 The model grid upstream of the Mill area (TQ 73673 24080) in Northbridge Street was amended to remove a low grid cell and to tie in the defence and ground levels.

2.5 Topography

2.5.1 The following zshapes were added or amended to make sure that the correct elevations were represented in the 2D model grid.

2.5.2 A zshape was added (2d_zsh_road_274.TAB) to enforce the road elevations along Northbridge Street.

2.5.3 The zshape enforcing elevations along a section of The Clappers wasn't applying correctly. This was rectified (2d_zsh_road_v39.3_297.TAB).

2.5.4 Sections of the dismantled railway embankment still exist downstream of Salehurst and are shown in the LiDAR. However particularly within the 20m model domain, the top of the embankment is not picked up by the grid, due to the resolution. Therefore a zshape has been added to the model to make sure the crest of the embankment is represented by the model grid. (2d_zsh_ExistingRailEmbankment_276.TAB).

2.5.5 **Forge Farm -** A zshape was added (2d_zsh_embankment_327.TAB) to represent the raised land (intermittent embankment) north of Forge Farm and the elevation of the building footprints at Forge Farm (design floor levels should be above 6.41 mAOD based on the recommendations in the FRA[3]).

[3] Rother District Council Planning Portal references RR/2013/343/P and RR/2013/342/P

2.5.6 A zshape (2d_zsh_ditch_327.TAB) was added to make sure the model grid represented the flow path north of Forge Farm to the B2244 and from downstream of the B2244 to the railway at Udiam. Structures under the road were added (see section 2.6).

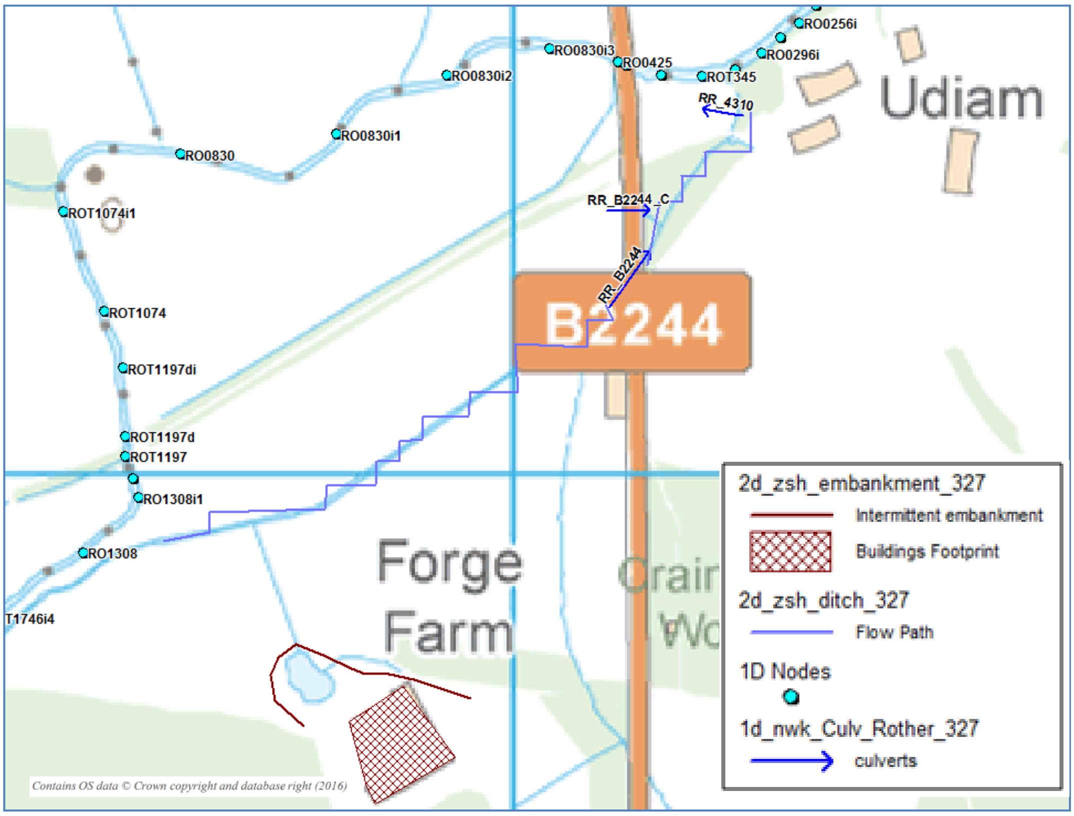

Figure 4 – Amendments to the model in the Forge Farm area, near Udiam

2.6 Structures

2.6.1 **Forge Farm –** There are two flow paths under the B2244 and one under the existing reinstated railway that were not included in the 2011 model. These have been added using ESTRY 1D elements linked to the 2D model domain. The location of the culverts (RR_4310, RR_B2244, and RR_B2244_C) is shown in Figure 4. The dimensions of the culverts are provided in Table 2-1.

Table 2-1 - Culvert Dimensions

Reference	Description	Dimensions	Invert
RR_4310	Circular Culvert	1.4 m diameter	2.1 mAOD
RR_B2244_C	Circular Culvert	0.9 m diameter	3.1 mAOD
RR_B2244	Bridge (modelled using rectangular culvert)	Cross sectional area 11 m^2 (Width 3.14 m, Height 3.5 m)	1.1 mAOD (estimated), Bridge soffit 4.6 mAOD

2.6.2 **Downstream of A21** – The head loss at structures and water surface profiles were reviewed to identify areas where they were unrealistic. One location identified for further consideration was immediately downstream of the A21. The following model nodes were removed: Footbridge ROT4257 is clear spanning, with open handrails and is not a significant structure; River section RO4262 has a short chainage length and inconsistent channel shape.

2.7 Comparison of Results

2.7.1 Comparisons of the model results and flood extents were made between the Environment Agency 2011 model and the amended FRA 2016 baseline model.

2.7.2 The long section in Figure 5, extracted from Flood Modeller, illustrates there are no significant differences in water level along the majority of the reach between Robertsbridge and Udiam. The greatest difference in water level, shown by the long section, is located between The Clappers and 400m downstream of the A21. The difference between the two models results at this location can be explain by the amendments to the 1D-2D linking method and the connection of a short reach of 1D not previously connected to the 2D domain. For the majority of the stretch of river between Robertsbridge and Udiam the difference in water levels is less than 100 mm.

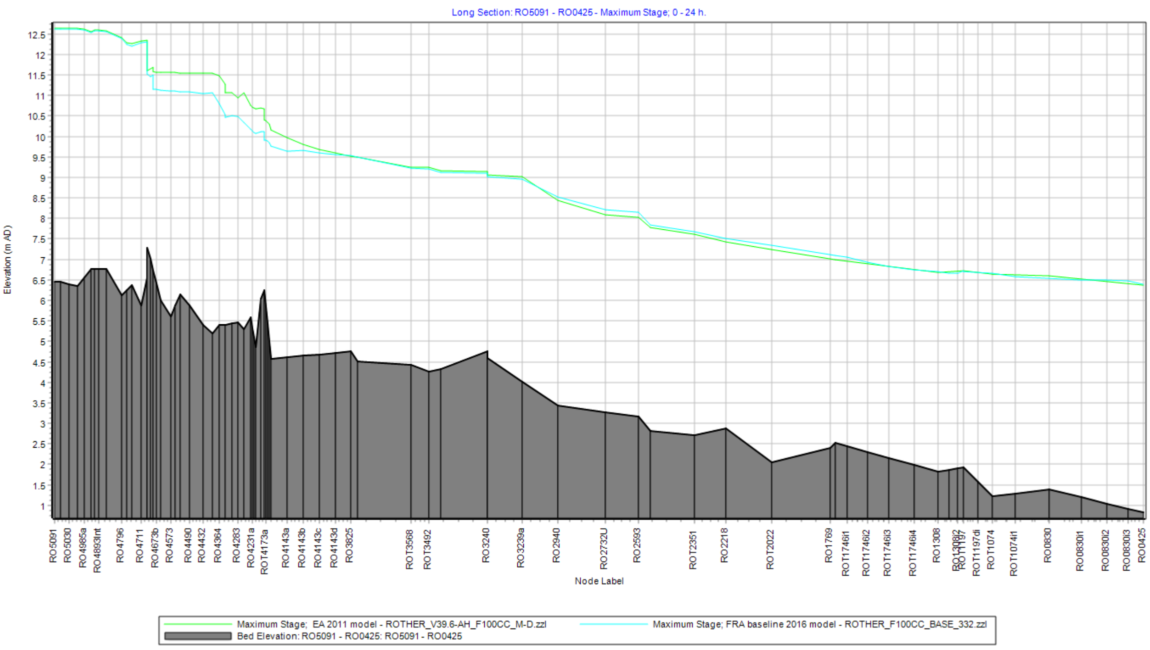

Figure 5 - Comparison of 1% AEP with climate change modelled water levels

2.7.3 The 1% AEP with climate change flood extents were compared for the Environment Agency 2011 model and the amended FRA 2016 baseline model (**Figure 6**). Overall the flood extents are similar, although there are some differences in the predicted flood extent at Robertsbridge and near Robertsbridge Abbey.

2.7.4 The amendments to the defences and 1D-2D linking along the Darwell Stream had the greatest impact on flood extent. The Environment Agency 2011 1% AEP with climate change flood extent is larger behind the defences in Robertsbridge, with the exception of one small area on the right bank upstream of Station Road, where the FRA 2016 modelled flood extent is larger.

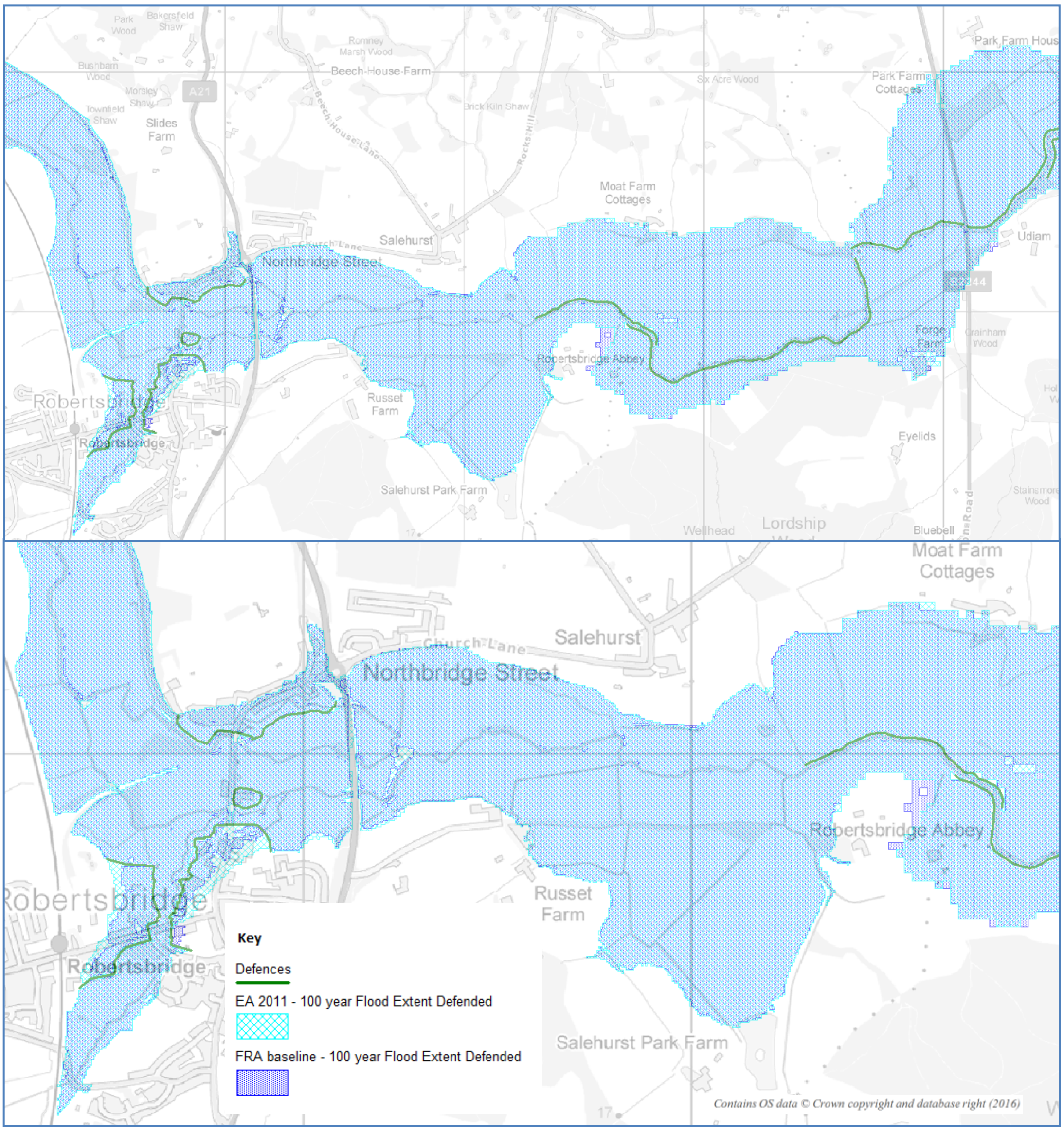

Figure 6 - Comparison of 1% AEP with climate change flood extents

2.7.5 The FRA baseline model was used to provide the ‘current’ baseline scenario for comparison with the proposed railway scenario.

3 Proposed scenario modelling

3.1 Summary of design

3.1.1 The representation of the reinstated railway has been based on drawings RVR-G-001 to RVR-G-006. Subsequent amendments were made to the railway elevations, flood relief culverts and viaducts in consultation with Rother Valley Railway to minimise the impact of the proposed railway on flood risk. These changes to the model are detailed below.

3.1.2 Existing ground levels along the route of the proposed railway vary from 11.7 m AOD to 4.4 m AOD generally falling from the west towards the east. The embankment levels for the proposed railway vary along its length to accommodate floodplain flow paths (Figure 7). The railway embankment elevation is 11.53 m AOD near Northbridge Street and 5.86 m AOD where it meets the existing Kent and East Sussex railway.

3.2 Methodology for modelling

3.2.1 The updated baseline model (as described in Chapter 2) was used as the basis for the ‘with railway’ model which includes the proposed reinstated railway. The initial modelling of the proposed reinstated railway included a number of iterations to optimise the railway elevations, number of viaducts, and proposed culverts through the railway embankment. The aim was to retaining connectivity across the existing floodplain and minimise the impact on flood risk. Once this initial modelling was completed and the revised scheme agreed with Rother Valley Railway the ‘with railway’ model was taken forward for assessment in the FRA.

3.2.2 Further details of the amendments made to the baseline model in developing the ‘with railway’ scenario are given in section 3.3.

3.2.3 The model was run for a range of design flood events including the 5%, 2%, 1.33%, 1% and 1% with climate change AEP design flood events. The results are summarised in chapter 4, and further discussion of the results is presented in the FRA report.

3.3 Amendments to model

3.3.1 **Reinstated Railway Line –** Zlines have been used to represent the reinstated railway line within the 2D domain (TUFLOW). A series of specified elevation points have been placed along the line to ensure the grid cells are either raised or lowered to the required levels. The railway elevations are required to tie in to the existing road crossings and the existing railway at Robertsbridge and Udiam. The elevation of the railway therefore varies along its length to meet these requirements, utilise existing sections of embankment and to allow floodplain connectively (Figure 7).

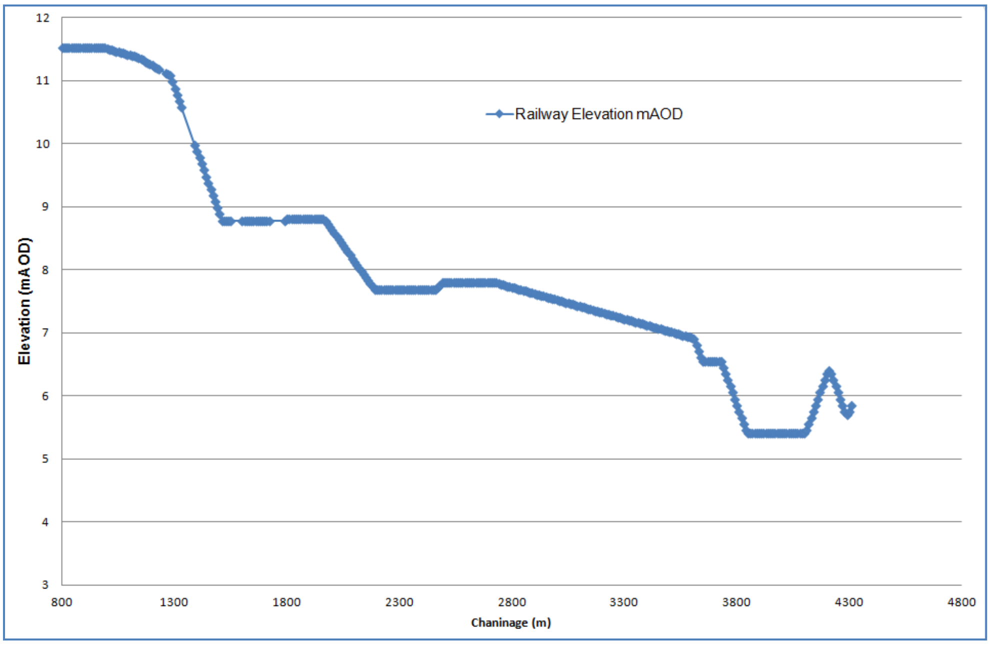

Figure 7 - Plot of the proposed railway elevations

3.3.2 The modelled scenario includes breaks in the zline to represent viaducts (Figure 8, green). Minimal headloss has been assumed through the viaducts. The viaducts and sections of railway where proposed elevations are close to ground levels aim to maintain floodplain flow paths and allow water to transfer across the floodplain.

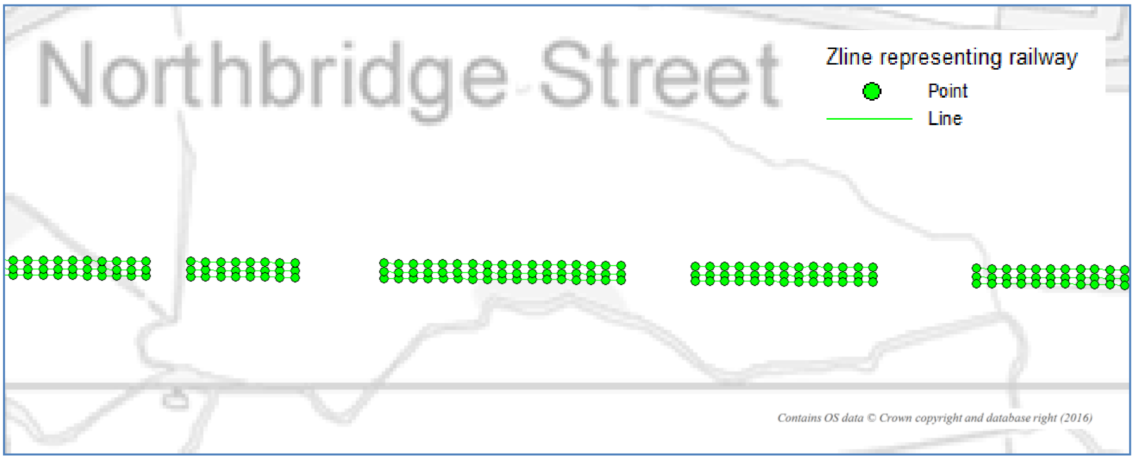

Figure 8 - Image of the 2d Zline used to represent the reinstated railway line

3.3.3 **Flood Relief Culverts –** A combination of rectangular and circular culverts were included in the model to represent the flood relief structures through the embankment. The culverts allow flood waters to transfer across the floodplain under the railway.

3.3.4 The culverts have been modelled using ESTRY as 1D network features and are connected to the 2D domain via 2d_bc SX connections.

3.3.5 The model includes 45 circular culverts and 4 rectangular box culverts under the reinstated railway. Default loss coefficients were applied to the culverts based on square/sharp edged openings and Manning's *n* values of 0.015 were applied along the length of the culverts.

3.3.6 **Other Structures –** In addition to the flood relief culverts a number of structures were edited or added in Flood Modeller to represent the bridges crossing the watercourse. These included:

3.3.7 Bridge at chainage 840 – Model node RO4649u was amended initially based on drawing RVR-G-001 in the 'with railway' model. It was then updated again to incorporate the latest design information in June 2013 (including soffit level 10.863 mAOD, width of opening at soffit 10.573m).

3.3.8 Bridge at chainage 1200 – Model node MS4311 was included in Flood Modeller as an orifice unit.

3.3.9 A list of structures included in the model along the propose railway is provided in Appendix A.

4 Model Results

4.1 Flood Extents

4.1.1 The model results are discussed in detail in the main FRA report. In summary the model results illustrate that the proposed railway has a relatively small impact on water levels in the study area and in some locations reduces the level of flooding compared to the baseline.

4.1.2 The flood extents are very similar for all the flood events up to and including the 1% AEP with climate change (Figure 9).

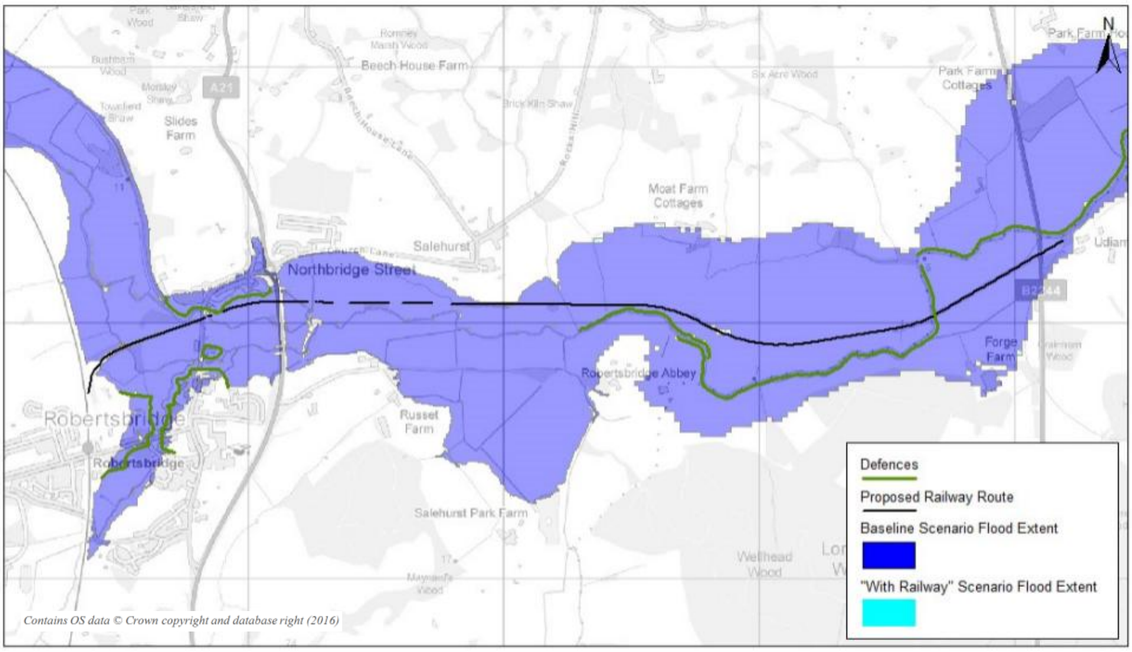

Figure 9 - 1% AEP with climate change flood extent for the 'baseline' and 'with railway' scenario.
(Note the 'with railway' scenario flood extent is drawn below the baseline flood extent shown and therefore it is only visible on the map where its extent is greater than the baseline flood extent).

4.1.3 The section of the railway between Salehurst and Robertsbridge Abbey and near Udiam between Austins Bridge and the B2244 are at risk in all the flood events modelled. The proposed railway elevations between Salehurst and Robertsbridge Abby have been lowered to maintain floodplain flow paths and connectivity.

4.1.4 The flood extents for the baseline and the 'with railway' scenario are provided in Appendix A (Figures A-1 to A-5) of the Rother Valley Railway FRA report (2016). The difference in predicted water depth between the 'with railway' and baseline scenarios are also in Appendix A (Figures B1 to C5) of the Rother Valley Railway FRA report (2016). The figures illustrate the proposed railway has a negligible impact on flood levels across the majority of the floodplain.

5 Model Accuracy and Limitations

5.1.1 Model accuracy and limitations can be understood through considering the underlying hydraulic equations used by the model, the accuracy of the input data, through model calibration and sensitivity analysis. The original 2011 study included sensitivity analysis and therefore further sensitivity testing was not undertaken as part of the FRA. The sensitivity analysis undertaken in 2011 indicated that the largest changes in modelled water levels were caused by changes in flow and Manning's *n*.

5.1.2 The 2011 modelling report[1] explains model accuracy in terms of the calibration results and accuracy of the input data, specifically the LiDAR, which has a vertical accuracy of 150 mm. The modelled peak stage for the 12th October 2000 event was within 60 mm of the recorded.

5.1.3 The 2011 modelling report[1] states the following assumptions:

- That there will be no blockages at the structures which might impede flow and elevate flood levels.
- That flood water levels may exceed structure capacity and hence the model allows flow bypassing/overflowing units at all structure locations.
- That the structural survey, channel survey and digital terrain model represent the correct data and terrain levels for each of the calibration events and the current conditions. Furthermore that there have been no major earthworks or construction in the channel or floodplain subsequent to measuring of any ground data used.

5.1.4 The 2011 modelling report[1] details the limitations associated with the study and are summarised as:

- The model provides a representation of the river and floodplain and a balance was required between the representation of certain structures and model stability.
- The size of the study area required the floodplain to be represented at a 5m and 20m grid cells in the model. (It should be noted that the FRA falls primarily within the more detailed 5m grid).
- It is recognised that studies on smaller reaches may be able to improve the estimates produced by the 2011 study.

5.1.5 The following assumptions should also be noted with respect to the FRA modelling:

- It was assumed that the hydrological inflows developed for the 2011 model were suitable for use in this study and provide the best estimate of design flows.
- Following a review of the 2011 modelling report and model, it was assumed that the 2011 study provided a good baseline from which to develop the FRA model.
- The drawings of the railway embankment that the model is based on are current at time of modelling and the proposed locations of flood relief culverts and viaducts (based on the modelling) will be included in the final plans.
- Minimal head loss is assumed in the method used to represent viaducts in the model.
- A roughness value of 0.5 has been selected for Buildings which allows for some storage of water and flow through the buildings and is appropriate at the grid resolution of the model.

5.1.6 Three _MB.csv files are output by TUFLOW reporting on the various inflows and outflows, volume, predicted volume error and the mass and cumulative mass errors as a percentage a. These give an indication of the health of the model. The graphs in Figure 10 and Figure 11 are based on the _MB.csv file, which is for the overall model (all 1D and 2D domains).

5.1.7 The Cumulative Mass Balance (%) reported for the 1% AEP with climate change model runs are shown in Figure 10. The values are within +/- 1% and indicate the model is healthy.

5.1.8 The dVol reported for the 1% AEP with climate change model runs are shown in Figure 10. The initial spike in dVol is related to the initial water levels in the 1D model upstream of Etchingham. This is outside the FRA study area and does not impact on the FRA results.

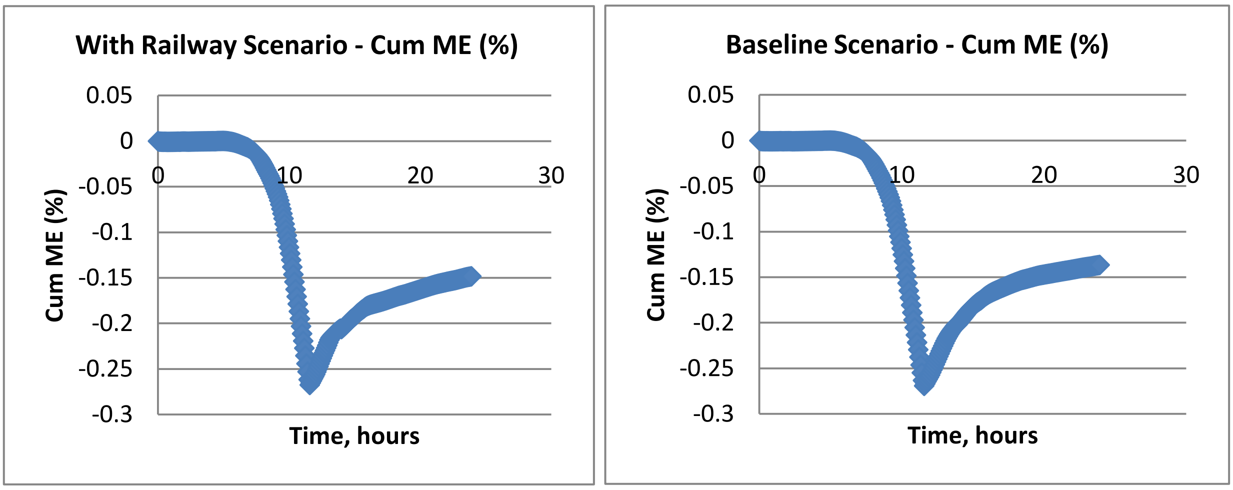

Figure 10 - Cumulative Mass Balance (%) for 1% AEP with climate change scenarios

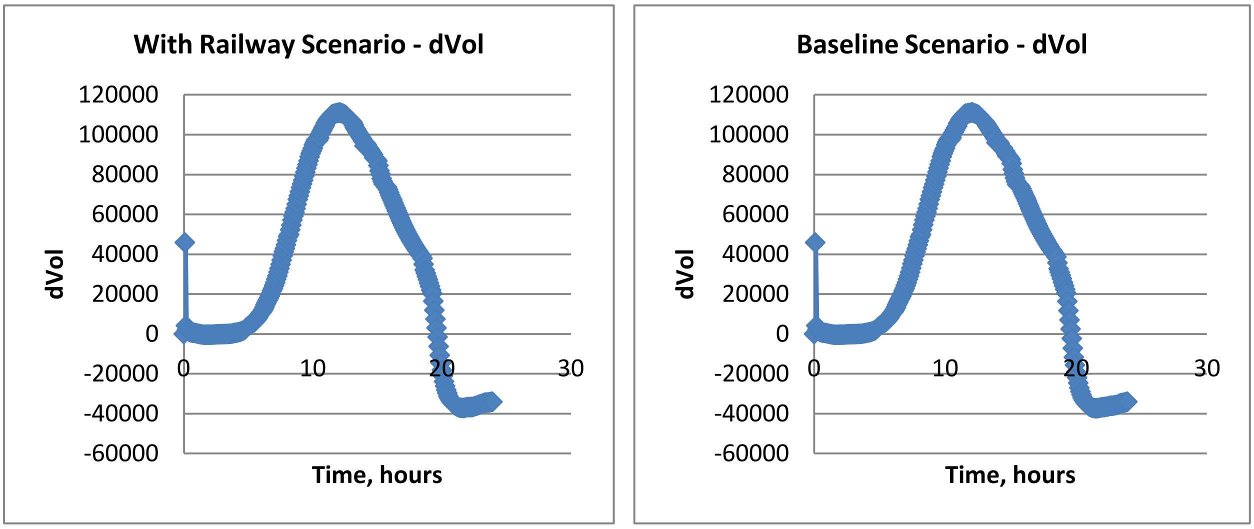

Figure 11 - dVol for 1% AEP with climate change scenarios

5.1.9 The check and warning messages reported by the model are documented in Appendix B.

6 Conclusion

6.1.1 Capita have been commissioned by Rother Valley Railway Limited to undertake a Flood Risk Assessment (FRA) for the proposed reinstatement of the Rother Valley Railway between Robertsbridge and Udiam (NGR TQ 73807 24014 to TQ 77186 24322). The route is approximately 3.5 km and will link the existing railway between Bodiam and Robertsbridge.

6.1.2 This report has detailed the amendments made to the Environment Agency 2011 model to produce an improved FRA baseline model. The amendments made to the FRA baseline model to create the 'with railway' scenario model have also been described. This report has provided a summary of the model results. Further analysis of the results is presented in the FRA report (2016).

6.1.3 The modelling results have shown the flood extents between the baseline scenario and the proposed 'with railway' scenario have not changed significantly. The modelling indicates that there is a reduction in flood depths behind the Robertsbridge and Northbridge Street defences in the 1% AEP with climate change design flood events. The 'with railway' scenarios indicates some areas where water levels increase by up to 50mm, however there are also areas where the flood levels are lower in the 'with railway' scenario. The small areas where a larger increase in flood levels is predicted in the 'with railway' scenario are adjacent to the proposed railway, where no property is located.

6.1.4 In low lying areas where the reinstated railway line is close to existing ground levels flooding is likely to inundate the track and impact on its operation. The risk from flooding to the public associated with the operation of the railway will be managed through restricting operation during times of severe flooding. If there is a risk of flooding to the railway line it is proposed that services along the railway between Bodiam and Robertsbridge are cancelled.

Appendix A - Structures

The proposed railway embankment includes a series of viaducts, bridges and culverts to allow water to flow across the surrounding floodplain. The table below provides details of these structures:

Model ID	Approx. chainage along railway	Type	Number of culverts	US Invert, mAOD	DS Invert, mAOD	Width or Diameter of culverts, m	Height of rectangular culverts only, m	Soffit, mAOD
	820 to 830	Viaduct/ bridge	-	-	-	-	-	-
br4649u	840	Bridge downstream of The Clappers	-	6.996	6.996	-	-	10.863
	850 to 860	Viaduct/ bridge	-	-	-	-	-	-
RR_C0920	920	Circular culvert	6	9.43	9.43	1.5	-	-
RR_C1070	1070	Circular culvert	6	9.198	9.198	1.5	-	-
RR_C1085	1085	Circular culvert	6	9.198	9.198	1.5	-	-
RR_C1150	1150	Circular culvert	8	9	9.2	1.5	-	-
MS4311u	1200	Bridge downstream of A21	-	6.5	6.5	-	-	10.563
	1230 to 1260	Viaduct	-	-	-	-	-	-
RR_C1280	1280	Circular culvert	8	8.8	8.8	1.5	-	-
	1330 to 1390	Viaduct	-	-	-	-	-	-
	1550 to 1600	Viaduct	-	-	-	-	-	-
	1720 to 1790	Viaduct	-	-	-	-	-	-
RR_C1800	1800	Rectangular culvert	1	6.977	6.977	6	1	-
RR_C1845	1845	Circular culvert	3	7.5	7.5	0.75	-	-
RR_C2245	2245	Circular culvert	3	6.8	6.8	0.4	-	-
RR_C2400	2400	Circular culvert	2	6	6	0.75	-	-
RR_C3045	3045	Circular culvert	1	5.8	5.8	0.75		
RR_C3585	3585	Rectangular culvert	1	5.164	5.164	13.397	1.051	
RR_C3675	3675	Rectangular culvert	2	5.1	5	3	1	
ROT1197bru				1.927	1.927			5.79

The manning’s ‘n’ coefficient has been set to 0.015 for all of the above structures which is reasonable value for a standard culvert structure.

Appendix B - Check/ Warning Messages

BASE 100CC – Check/ Warning Messages		
Check/ Warning ID	**Message**	**Comment**
Check 2099	Ignored repeat application of boundary to 2D cell. BC Type = HX or SX	This message indicates a repeat application of a boundary to a 2D cell. This can occur when multiple SX or HX lines select a model grid cell. Spot checks indicate no changes are required.
Check 2108	2D HX link applied more than once at cell.	Occurs at 2D-2D boundary and indicates a repeat application of a boundary to a 2D cell (not within FRA study extents). No amendment required.
Check 2109	Raised HX ZC Zpt by 0.09m to 1D bed level.	No amendment required.
Warning 2117	Inactive 2D cell made active by 2D SX link.	This warning occurs where the inactive cells along the channel have been activated by an SX connection along the river banks. Spot checks of the 2D SX lines indicate no changes are required.
Check/ Warning 2118	Lowered SX ZC Zpt by XXm to 1D node bed level.	Lowered SX ZC Zpt to 1D node bed level. The use of a "Z" flag for the SX connector adjusts the elevation at each grid cell on the 2D SX object. This message indicates the cells have been lowered as the original grid cell elevations were higher. The elevations at the 1D node and 2D cells were spot checked to identify any inconsistencies. The elevations were appropriate.
Warning 2444	ZU of -9999.000 outside Zpt Range Check	All warnings are located outside of flood extent and will not impact results.
Warning 2991	Negative U depth at [0726;0454]	A 2D negative depth has occurred at the cell which indicates the solution failed to converge at this point in the 2D domain. The messages layer was imported and the duration of the negative depths were checked. The negative depths at this location will not impact on the FRA results. The location of this warning is outside of the FRA study area.

RAIL 100CC – Check/ Warning Messages		
Check/ Warning ID	**Message**	**Comment**
Check 2099	Ignored repeat application of boundary to 2D cell. BC Type = HX or SX	This message indicates a repeat application of a boundary to a 2D cell. This can occur when multiple SX or HX lines select a model grid cell. Spot checks indicate no changes are required.
Check 2108	2D HX link applied more than once at cell.	Occurs at 2D-2D boundary and indicates a repeat application of a boundary to a 2D cell (not within FRA study extents). No amendment required.
Check 2109	Raised HX ZC Zpt by 0.09m to 1D bed level.	No amendment required.
Warning 2117	Inactive 2D cell made active by 2D SX link.	This warning occurs where the inactive cells along the channel have been activated by an SX connection along the river banks. Spot checks of the 2D SX lines indicate no changes are required.
Check/ Warning 2118	Lowered SX ZC Zpt by XXm to 1D node bed level.	Lowered SX ZC Zpt to 1D node bed level. The use of a "Z" flag for the SX connector adjusts the elevation at each grid cell on the 2D SX object. This message indicates the cells have been lowered as the original grid cell elevations were higher. The elevations at the 1D node and 2D cells were spot checked to identify any inconsistencies. The elevations were appropriate.
Warning 2444	ZU of -9999.000 outside Zpt Range Check	All warnings are located outside of flood extent and will not impact results.
Warning 2991	Negative U depth at [0726;0454]	A 2D negative depth has occurred at the cell which indicates the solution failed to converge at this point in the 2D domain. The messages layer was imported and the duration of the negative depths were checked. The negative depths at this location will not impact on the FRA results. The location of this warning is outside of the FRA study area.

Warning 2991	WARNING 2991 - Negative V depth at [0429;0700].	A 2D negative depth has occurred at the cell which indicates the solution failed to converge at this point in the 2D domain. The messages layer was imported and the locations of the negative depths were checked. This warning occurs once as floodplain cells wet. The negative depths at this location will not impact on the FRA results. From a healthy model perspective, the occasional negative depth is not necessarily a concern, but repeat occurrences at the same location are an indication of poor topography or a difficult location in the model to solve.
Warning 2991	WARNING 2991 - Negative U depth at [0716;0491].	A 2D negative depth has occurred at the cell which indicates the solution failed to converge at this point in the 2D domain. The messages layer was imported and the locations of the negative depths were checked. This warning occurs once. The negative depths at this location will not impact on the FRA results. From a healthy model perspective, the occasional negative depth is not necessarily a concern, but repeat occurrences at the same location are an indication of poor topography or a difficult location in the model to solve.
Warning 2991	WARNING 2991 - Negative V depth at [0279;1102].	A 2D negative depth has occurred at the cell which indicates the solution failed to converge at this point in the 2D domain. The messages layer was imported and the locations of the negative depths were checked. This warning occurs twice as floodplain cells wet. This is the only negative depth warning within the FRA study area, however the negative depths at this location will not impact on the FRA results. From a healthy model perspective, the occasional negative depth is not necessarily a concern, but repeat occurrences at the same location are an indication of poor topography or a difficult location in the model to solve.

Appendix C – Model Log Summary

Baseline Model

Design Event	ief files	dat	tcf/ecf	Results File Name
5% AEP	Rother_F020_BASE_332	Rother_F0000_BASE_332	Rother_~e1~_BASE_332	Rother_F0020_BASE_332
2% AEP	Rother_F050_BASE_332			Rother_F0050_BASE_332
1.33% AEP	Rother_F075_BASE_332			Rother_F0075_BASE_332
1% AEP	Rother_F100_BASE_332			Rother_F100_BASE_332
1% AEP + CC	Rother_F100CC_BASE_332			Rother_F100CC_BASE_332

'With Railway' Model

Design Event	ief files	dat	tcf/ecf	Results File Name
5% AEP	Rother_F020_RAIL_333	Rother_F0000_RAIL_333	Rother_~e1~_RAIL_333	Rother_F0020_RAIL_333
2% AEP	Rother_F050_RAIL_333			Rother_F0050_RAIL_333
1.33% AEP	Rother_F075_RAIL_333			Rother_F0075_RAIL_333
1% AEP	Rother_F100_RAIL_333			Rother_F100_RAIL_333
1% AEP + CC	Rother_F100CC_RAIL_333			Rother_F100CC_RAIL_333

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APPENDIX F

Designers Hazard Risk Assessment

To follow