KC2

THE OXFORDSHIRE COUNTY COUNCIL (DIDCOT GARDEN TOWN HIGHWAYS INFRASTRUCTURE – A4130 IMPROVEMENT (MILTON GATE TO COLLETT ROUNDABOUT), A4197 DIDCOT TO CULHAM LINK ROAD, AND A415 CLIFTON HAMPDEN BYPASS) COMPULSORY PURCHASE ORDER 2022

THE OXFORDSHIRE COUNTY COUNCIL (DIDCOT TO CULHAM THAMES BRIDGE) SCHEME 2022

THE OXFORDSHIRE COUNTY COUNCIL (DIDCOT GARDEN TOWN HIGHWAYS INFRASTRUCTURE – A4130 IMPROVEMENT (MILTON GATE TO COLLETT ROUNDABOUT), A4197 DIDCOT TO CULHAM LINK ROAD, AND A415 CLIFTON HAMPDEN BYPASS) (SIDE ROADS) ORDER 2022

THE CALLED-IN PLANNING APPLICATION BY OXFORDSHIRE COUNTY COUNCIL FOR THE DUALLING OF THE A4130 CARRIAGEWAY, CONSTRUCTION OF THE DIDCOT SCIENCE BRIDGE, ROAD BRIDGE OVER THE APPLEFORD RAILWAY SIDINGS AND ROAD BRIDGE OVER THE RIVER THAMES, AND ASSOCIATED WORKS BETWEEN THE A34 MILTON INTERCHANGE AND THE B4015 NORTH OF CLIFTON HAMPDEN, OXFORDSHIRE (APPLICATION NO: R3.0138/21

PLANNING INSPECTORATE REFERENCE:

APP/U3100/V/23/3326625 and NATTRAN/SE/HAO/286 (DPI/U3100/23/12)

Appendix to Proof of evidence of

KARL CHAN

(Technical Highways Engineering – Culham River Crossing and Clifton Hampden Bypass)

Appendix KC2.1

Appleford Sidings Road Bridge – Options Study

Idea

Didcot Garden Town HIF 1 – Didcot to Culham River Crossing

Appleford Sidings Road Bridge

Options Study

Oxfordshire County Council

RIV_PD-ACM-SBR-SW_STR_ZZ_ZZ-RP-CB-0003.DOCX P02

Project number: 60606782

August 2022

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Prepared by	Checked by	Verified by	Approved by
SM Engineer	DM Associate Director	PC Lead Verifier	KC Project Manager

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Prepared for:

Oxfordshire County Council
County Hall
New Road
Oxford
OX1 1ND

Prepared by:

AECOM Limited
AECOM House
Saxon House
27 Duke Street
Chelmsford, Essex
CM1 1HT
United Kingdom

T: +44 (1245) 77 1200
aecom.com

Table of Contents

Figures

Tables

Executive Summary

This Report describes the Option Study for the Appleford Sidings Road Bridge included within the scope of the Didcot to Culham River Crossing Scheme. The Scheme comprises two structures: Appleford Sidings Road Bridge and the River Crossing bridge and approach spans. This Options Study focuses on the Appleford Sidings Road Bridge only. A separate Options Study report has been created for the River Crossing and approach spans, document ref. RIV_PD-ACM-SBR-SW_ZZ_ZZ-RP-CB-0004.

A bridge is required to carry the proposed Didcot to Culham River Crossing route over Appleford Sidings which serves as a private railway connection to the Hanson Site and the Landfill Site located to the west of the Appleford Level Crossing. The Scheme alignment crosses Appleford Sidings at a skew of 60°. After consultation with Hanson, the following constraints influencing the structural option were identified;

- the face of the north abutment is to be 1m from the existing drainage ditch running parallel to the rail track;
- the face of the south abutment is to be 4.28m from the proposed southernmost running rail, and;
- minimum vertical clearance from the rail tracks shall be 4.8m to the underside of the structure and is the minimum clearance required to allow for any future electrification of the Appleford Sidings.

OCC have a desire for the bridge to be functional and utilitarian fitting into the industrial setting.

The following span arrangements were considered:

- An “oversized” bridge which spans square to the railway below and with curved abutments set parallel to the boundary constraints providing a clear span of approximately 22m. And;
- A skewed bridge square to the carriageway with straight abutments set outside of the boundary constraints providing a clear span of 48m with a skew of 63°.

To reduce the span lengths, intermediate supports within the Hanson boundary, and two discrete bridges; a road bridge and a footbridge, to take advantage of the curved rail alignment, were considered and discounted due to concerns over access and future proofing.

Deck options explored for the square and skew span lengths included: prestressed concrete beams, steel-concrete composite construction and a half-through girder. The preferred deck construction is precast prestressed concrete beams with a square span as this is the simplest construction form, providing Oxford County Council with the least maintenance requirements, although this option has the largest footprint of the options considered.

An integral bridge is proposed, negating the need for maintenance of bearings and more complex expansion joints. Three integral abutment solutions were explored: a skeletal abutment with columns behind a reinforced soil wall, a skeletal abutment with the columns in front of a reinforced soil wall and a traditional full height cantilevered wall. The preferred abutment is a skeletal abutment with columns behind a reinforced soil wall as it provides a clean, aesthetic face adjacent to the railway and is of a lighter weight leading to smaller foundations compared to the traditional full height cantilever wall. The proposed alignment on the existing topography with the rail tracks leading to the Sidings on a valley means that the reinforced soil structure does not need to extend the full width of the structure. The reinforced soil structure will extend to a length required to retain the approach embankments with the remaining width of the abutments under the redundant triangular deck area sitting

on discrete columns will remain open. As well as being likely to be cheaper than providing soil embankment extending to the full width of the abutment, this would also provide increased light and ventilation under the footprint of the bridge.

Historic boreholes indicate that the first 7m of soil is uncompacted fill from the quarry, and therefore does not have any significant structural capacity, with piled foundations likely. Bored foundations are proposed with piles approximately 25m long from preliminary analysis.

The location of the bridge over a railway requires H4a “Very High” vehicular containment, to prevent vehicle incursion onto the railway tracks below. The H4a parapets shall be 1.8m high with a steeple on top to prevent access and extend 25m beyond the railway boundary. The proposed parapets will be placed parallel to the carriageway. Reinforced concrete and metallic parapets were considered. Reinforced concrete parapets with an option to be in-situ or precast, dependent on Contractor preference are proposed due to the minimal maintenance requirements compared to their metallic counterpart. A departure from standard will be required to design the reinforced concrete parapets to British Standards instead of Eurocodes which require onerous additional crash testing.

The south headwall of an existing 750mm dia. concrete pipe culvert running underneath the existing rail tracks clashes with the proposed south abutment. This culvert drains the surface water from the land north of the Appleford Sidings into the pond on the south. Hence, this culvert is an important structure for proper functioning of the drainage in the area and the rail tracks. AECOM’s Drainage team are developing a drainage strategy within the vicinity of the structure as the approach embankments to the proposed structure severs the existing drainage route. It is envisaged that one of the options to deal with the existing culvert will be to decommission the existing culvert through installation of a new culvert away from the proposed structure as part of the wider drainage strategy and thereby minimising maintenance liability of having the existing culvert and its extension within the structure. However, it is envisaged that the extension of the existing culvert will also be considered as part of the drainage study as it will be more cost effective and less reliant on Hanson to deliver the current scheme by OCC.

It is proposed that inspection and maintenance of the underside of the structure will be carried out in consultation with Hanson under Section 289-291 of the Highways Act. The Hanson boundary fence line is to be agreed at a later design stage. Appropriate fencing will be required to prohibit unauthorised access to the Sidings from the road. Similarly, appropriate fencing will be required to limit unauthorised access to the redundant triangles of the deck behind the H4a parapets including risk of fly-tipping.

Construction of the bridge will entail works over the private Appleford Sidings, requiring closure of the tracks or use inoperative time to install the deck and secure site compounds separating the Sidings operation for the construction of the substructure and foundations. AECOM and Oxford County Council are in discussions with Hanson, FCC and Network Rail (NR) to explore the “windows” available to carry out these works on site. Restrictions on construction are envisaged to be less onerous than over NR infrastructure. The recommended option has been chosen cognisant of the requirement for the construction form to be installed minimising disruption to Appleford Sidings. Continued regular consultation with these Key Stakeholders during the design and construction of the scheme is required to keep them abreast of the development of the structural design, and also ensure their planned expansion of the Appleford Sidings, due to be constructed in Summer 2021, does not clash with this Scheme.

In summary the following proposal is recommended:

Clear Span	22m Square
Articulation	Fully Integral deck
Superstructure	Precast pretensioned concrete beams with an insitu reinforced concrete slab on top

Substructure	Skeletal abutment- Reinforced soil structure to retain the approach embankments with discrete sleeved columns behind
Foundations	Bored reinforced concrete piles with reinforced concrete pile caps
Parapets	Reinforced Concrete (in-situ or precast)
Existing Culvert	Extension or Diversion

Risks and opportunities have been identified to consider or address at the next stage. The risks include:

- working near and at height adjacent and over the live railway,
- unforeseen ground conditions,
- contaminated land,
- impact on ecology and any flora/fauna present.

The opportunities include:

- refining foundation design following ground investigations,
- potential to reduce the redundant triangle area by incorporating a small skew to the beams,
- provision of normal containment parapets instead of high containment parapets through a Departure from Standard and agreement with Hanson,
- improve the visibility splay of the northbound carriageway by increasing the west verge width locally at the south end of the structure.

1. Introduction

1.1.1 The Didcot Garden Town Housing Infrastructure Fund programme (here on in referred to as HIF1) consists of four separate, but interdependent, highways schemes:

- A4130 Widening, which will dual the existing road between Milton Gate and the new Science Bridge, with several new junctions into adjacent proposed developments (Section A in Figure 1-1);
- Science Bridge, a new bridge over the Great Western Railway Mainline and a new road through the former Didcot A Power Station site, re-joining the A4130 Northern Perimeter Road north of the Purchas Road/Hawksworth roundabout (Section B in Figure 1-1);
- Didcot to Culham River Crossing, providing a new road connecting the A4130 at Didcot with the A415 at Culham, including a bridge over the River Thames and another bridge over a private rail line, and connections to Appleford and Sutton Courtney via B4016 (Section C in Figure 1-1);
- Clifton Hampden Bypass, a new relief road north of the village, between the A415 at Culham Science Centre and the B4015 Oxford Road, north of Clifton Hampden (Section D in Figure 1-1).

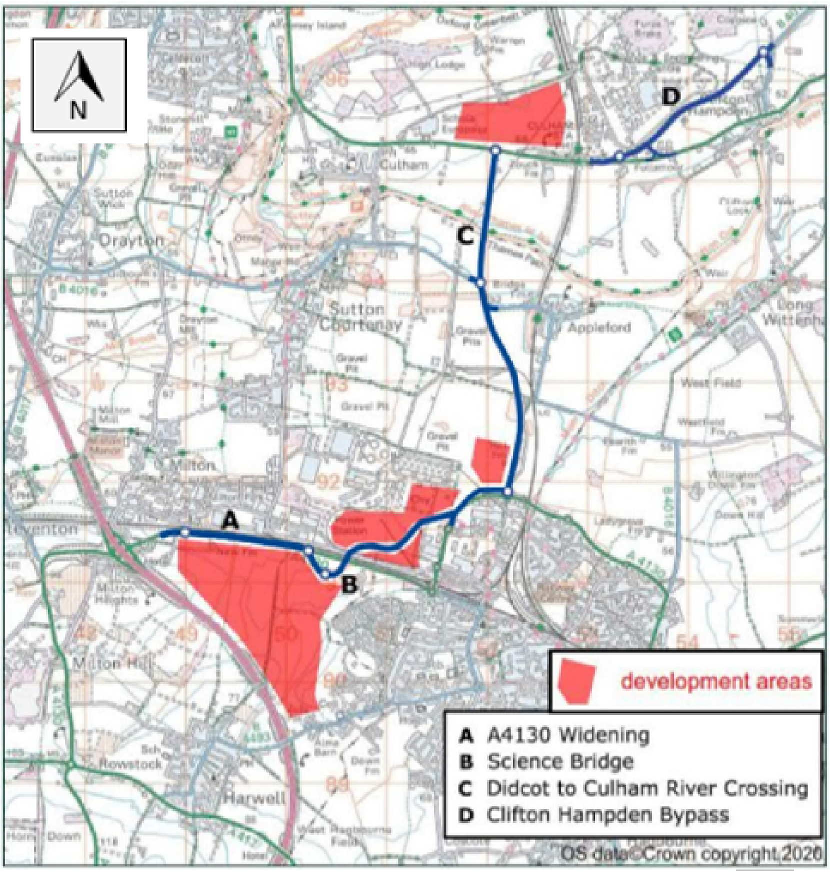


Figure 1-1: HIF1 Schemes Location Plan

1.2 Scheme Overview

1.2.1 This technical note discusses the Options Study for the Appleford Sidings Rail Bridge within the Didcot to Culham River Crossing Scheme, which will be referred to throughout as ‘the Scheme’. The Scheme contains two structures within its scope; Appleford Sidings Rail Bridge and River Crossing Bridge and associated viaducts. For the Options Study of the River Crossing Bridge and approach spans refer to RIV_PD_ACM_SBR-SW_STR_ZZ_ZZ-RP-CB-0004. See Figure 1-2 below.

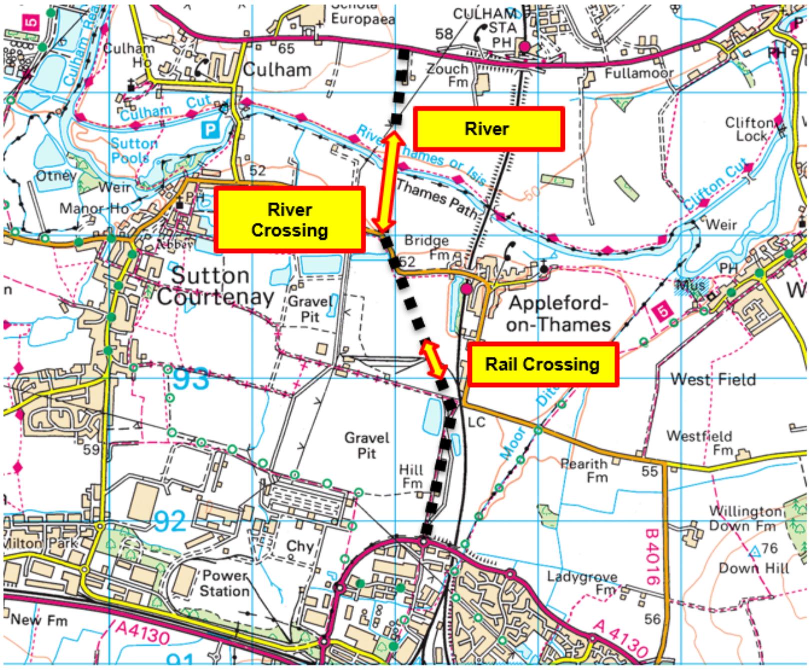


Figure 1-2: Bridge locations on the proposed alignment.

1.2.2 The Scheme consists of a new road approximately 3.65km long, connecting the A4130 to the south and A415 to the north. The south end of the alignment (Ch.0m) ties into the existing north spur of the Collett Road roundabout on the A4130. The alignment follows the existing private Hanson yard access track which is straight until approximately (Ch. 560m), before transitioning to a reverse curve to (Ch. 1320m) to fit between reservoirs to the west and the Didcot to Oxford main line, including Appleford level crossing to the east. The alignment follows a straight north west trajectory north of the Appleford Sidings to (Ch. 2230) where a roundabout connecting the road to the existing B4016 (Main Road) is proposed. The road then travels due north to (Ch. 3650), crossing the River Thames, connecting to A415 (Abingdon Road) with a new roundabout.

1.2.3 The design speed of the road is 85kph (50 mph).

2. Site Description

2.1 Appleford Sidings

2.1.1 The proposed alignment crosses the Appleford Sidings, a private railway connection to the Hanson Site and the Landfill Site located to the west of the Appleford level crossing. There is an existing single standard gauge track with approximately 247m radius. The east side of the scheme is approximately 260m from the Appleford level crossing which provides vehicular access across the mainline rail tracks from the B4016 into the Hanson quarry and a private house. The level crossing is situated approximately 70m south of where the Appleford Sidings joins the mainline.

2.1.2 Hanson have received planning approval (Decision Notice MW.0046.20, October 2020) for the construction of 2no. additional standard gauge tracks to the south of the existing track at the proposed bridge location. This will significantly widen the existing rail corridor. This planning application sets out the proposed extent as a planning red line boundary. The north side of the red line boundary hugs the existing track while the south side is set 8m from the southernmost proposed track. Typical cross-sections of the proposed additional tracks indicate that a small retaining wall is required to achieve the space required for the proposed tracks. For further detail refer to the AECOM produced (Planning team) drawings, shown in Appendix C.

2.1.3 From the topographical survey, the rail track is in a valley. The rail track is set at approximately 51m AOD with surrounding land reaching typically 56m AOD, and with typical slopes of 1 in 6 to the south and 1 in 10 to the north down to the railway. The land is known to be filled with uncompacted pulverised fly ash (PFA) with plantation woodland along the rail tracks on the north and south side.

2.1.4 Evidence of a poorly maintained drainage ditch system perceived to serve as track drainage is found 4m north of the track. It is unclear where the north drainage ditch outfalls, with no connection to the culvert found during site investigations, leading the Drainage team to believe it is acting as soakaway. 2 x 160mm blocked UPVC pipes were found crossing the existing rail track and are believed to serve as a high-level overflow from the north to the south of the rail tracks. Further discussions with Hanson have confirmed that the drainage ditches are to be retained and cleared out as part of their expansion of the Sidings. Refer to Figure 2-1 and Figure 2-2 below for an illustration of the existing drainage provision.

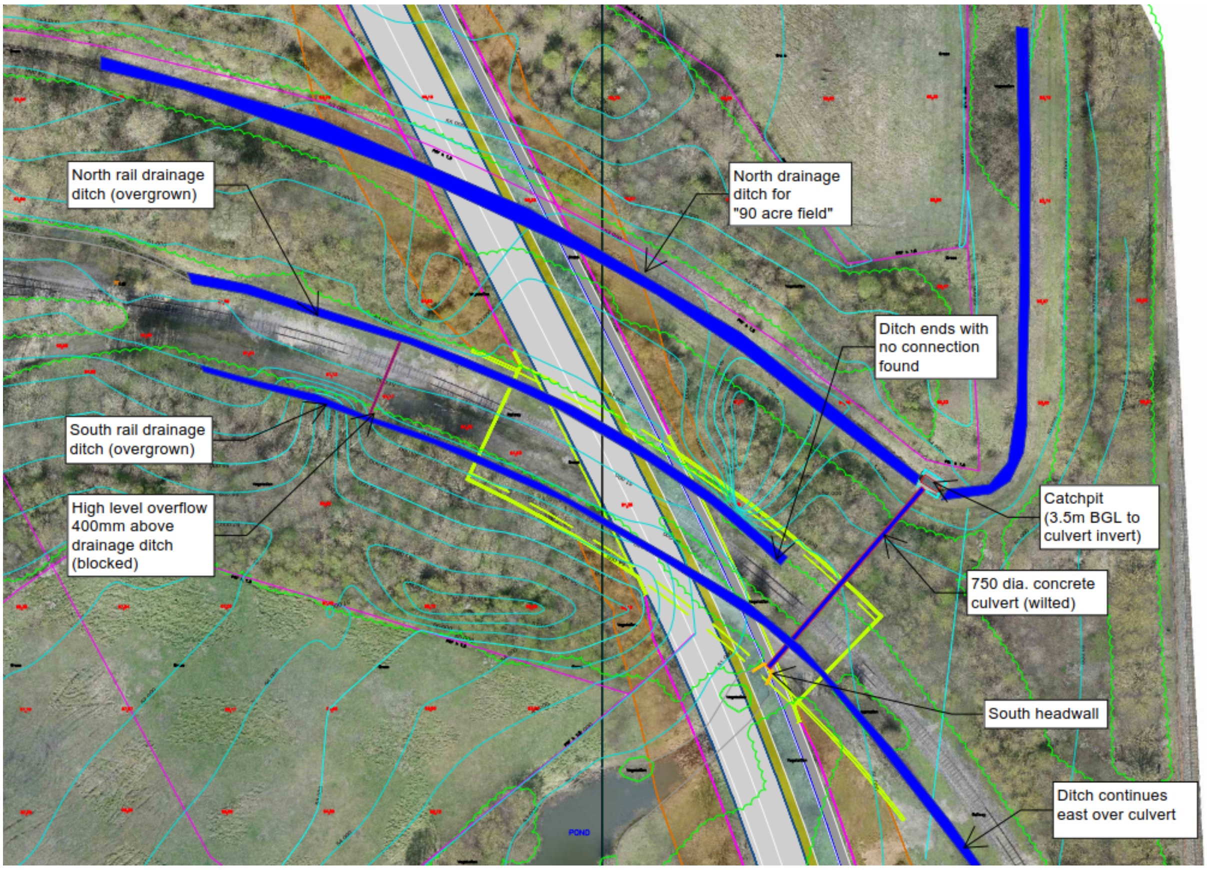


Figure 2-1: Existing drainage infrastructure of the site

Figure 2-2: UPVC pipes serving as a high level overflow

2.2 Culvert

2.2.1 A culvert drains land north of the railway, a parcel of land known as 90-acre landfill site, under the Appleford Sidings to an attenuation pond to the south west of the proposed alignment. The culvert is a 750mm dia. concrete pipe, approximately 46m long. Drainage to the north of the culvert comprises a ditch with a catchpit which cascades down to the culvert invert 3.5m BGL.

2.2.2 The culvert is believed to be owned and maintained by FCC. No record drawings of the structure have been made available. From a Site Inspection undertaken in September 2020, the south end of the culvert was found to be deformed, see Figure 2-3 below.

Figure 2-3: Deformed South headwall

2.2.3 All options for the proposed structure will interface with this culvert in some way, and it is likely that works are required to the culvert possibly in the form of extension, strengthening or diversion. Further discussion on the options for the culvert are included in section 6.8.

3. Design Parameters & Constraints

3.1.1 The key design requirements and constraints for Appleford Sidings Road Bridge are summarised in Table 3-1 below.

Table 3-1: Summary of Key Design Parameters & Constraints

Constraint or Requirement	Design Parameter		Standard	Commentary
Design Speed	85kph		CD 109 Fig. 2.1	-
Carriageway Cross Section	West Verge	Minimum 0.6m	CD 127 cl. 3.6	Minimum required to comply with setback required in accordance with CD 127. Agreed with OCC TAA on 21st October 2020. Does not encourage undesirable walking route down the west side of the structure, however, will require traffic management to inspect and maintain the inner face of the west parapet.
	Carriageway	7.3m (+1m hard strips) = 9.3m	CD 127 Fig. 2.1.1N1e (S2)	-
	Segregation Strip	2.0m	CD 143 E/3.5.1	Could be reduced to 0.5m and still comply with CD 143 but has been left as 2m to provide continuity from adjoining highways cross section, on OCC's request for future provision and perceived cyclist's riding comfortably adjacent to a 50mph road.
	Cycleway	3.0m	CD 143 E/3.4	Desirable minimum width for segregated shared use routes.
	Footway	2.0m	-	
	East Verge	0.0m	-	No additional width provision required for footway being adjacent to a vertical face.
Horizontal Alignment	Radius= 510m (Desirable Minimum with Superelevation 5%)		CD 109 Table 2.10	The skew of the alignment over the Appleford Sidings is at its most optimal due to the Hanson Site and associated quarry, and reservoirs to the west and the mainline rail track and houses to the east.
Vertical Alignment	K value= 55 (Desirable Minimum crest K Value)		CD 109 Table 2.10	Required to get sufficient clearance over the Appleford Sidings. South-west of the structure there is Appleford Level Crossing and a private property which are sensitive to visual impact of the vertical alignment.
Total Bridge Span between Abutments	22m minimum		-	Minimum achievable span between face of supports if set parallel from the north and south constraints.
	South Boundary Constraint	4.28m from proposed southernmost rail		Agreed with Hanson's Dave Norminton (21st August 2021). This allows for 4m from the end of sleepers, taking the sleeper as 2m and the standard railway gauge 1.435m, i.e. 4m + (2m/2 - 1.435m/2) = 4.28m.
	North Boundary Constraint	1m offset from edge of existing Drainage Ditch		It is believed that Hanson owns and maintains this drainage ditch and it is in a poor condition. The north constraint could be brought further south to 4.28m from the existing northernmost track following the south abutment constraint. However, the drainage ditch, although poorly maintained does provide drainage infrastructure to the Appleford Sidings. A 1m offset from the drainage ditch to the north abutment is therefore proposed to allow working space for construction and the possibility of a future access route and retain/reinstate the drainage ditch as indicated and aspired by Hanson.
Headroom and Clearance	4.8m from existing and proposed tracks		NR/L3/TRK/2049-Module 5	4.78m is the minimum clearance required for OLE. Hanson have stated they may have to consider future electrification of the tracks to the Sidings if the mainline is also to be electrified by NR.
Design Life	Structure	Category 5 120 years	BS EN 1990 :2002 +A1 :2005 Table NA 2.1	-
	Replaceable Components	Category 2 Up to 50 years		
Traffic Loading	SV 80, SV 100		CD 350 Table 7.6.2	Principal Road and as confirmed by OCC TAA (dated 11th November 2020) Hanson and FCC have advised there is no additional SO and STGO loading requirements.
Parapets	1.8m H4a parapets, 25m beyond and after point of no recovery. Pedestrian guardrails at portals.		CD 377 cl. 4.8	Point of no recovery taken as face of north and south abutments. Noise barriers may be required on the east portal subject to a noise assessment.
Fencing	Hanson boundary fence to tie into the abutments. Palisade fencing or similar with an access gate to allow access to the triangles.		-	Fence boundary alignment to be agreed at later design stage. Agreed at Hanson meeting 10th November 2020 and OCCC TAA meeting 11th November 2020 that access to the underside of bridge would be carried out through Hanson land to ensure safe access adjacent and over the Sidings.
Street Lighting	No street lighting provision		-	Street lighting provided on approaches to the roundabouts only and therefore not over the structure.
Existing Utilities	CityFibre- North of existing track		-	C2 Returns October 2019 & GPR Survey
Proposed Utilities	Street Lighting	1no. 125mm I.D	-	No substantial provision for Utilities has been instructed and/or identified. Communication ducts, if required, can be accommodated in the footway/cycleway make-up. None shown in current General Arrangement.
	Empty ducts	None provided at present		
Bridge Deck Topside Drainage	No surface drainage system proposed on structure		-	Due to relative short span and sufficient crossfalls and longfalls, it is anticipated that surface drainage can be accommodated with gullies off the structure.
Planning Red Line Boundary	Fixed		-	Set October 2020 with consultation with OCC.
Technical Approval	OCC- Technical Approval Authority Category 2 Structure		CG 300	-
Design Standards	British and European Standards DMRB LTN 1/20- Cycle Infrastructure Design Oxfordshire Cycling Design Standards		-	-
Key Stakeholders and Consultees	Oxfordshire County Council Hanson Asphalt & FCC Network Rail		-	-

4. Geology

4.1.1 The published 1:50,000 scale geological map of the area produced by the British Geological Survey (Sheet 253, "Abingdon", 1971) indicates the River Crossing scheme in general is underlain by the following geological succession in Table 4-1:

Table 4-1: Geological Succession from Published Mapping

Age	Geological Stratum
Quaternary	Sand and Gravel/Head/Alluvium
Cretaceous	Gault Formation
Cretaceous	Lower Greensand Group
Jurassic	Kimmeridge Clay

4.1.2 There is variation amongst the Superficial (Quaternary) Deposits across the scheme. The Summertown-Radley Sand and Gravel Member is predominantly present in the northern area of the site, in addition to some small areas of Head Deposits and areas of no superficial deposits. Within the central area of the site, the Northmoor Sand and Gravel Member is present, and Alluvium is present around the River Thames. Finally, the Wolvercote Sand and Gravel Member is present in the southern part of the site.

4.1.3 Furthermore, in the vicinity of the Appleford Sidings Road Bridge, areas of landfilling are present, with fill having been placed within former sand and gravel quarries. The shallow soils around the Appleford Sidings Road Bridge are therefore expected to be anthropogenic, rather than natural. A Foundation Risk Assessment report will be prepared if required from the Ground Investigations. The exact boundary of the landfill areas adjacent to the railway is not clearly known. Planned ground investigation works will confirm the shallow ground conditions, however at this stage, it is to be conservatively assumed that bridge foundations will be located on areas of fill on both sides of the bridge.

4.1.4 Previous ground investigations in the landfill area have been provided by the landfill operator and demonstrate clay capping of variable thickness over a variable thickness of predominantly household waste. As such, the following ground model has been tentatively assumed for the bridge structure in Table 4-2 below:

Table 4-2: Preliminary Ground Model- Appleford Sidings Road Bridge

Material	Thickness	Description
Fill	7m	Landfill construction and fill materials – no contribution to pile capacity
Gault Clay	9m	Soft becoming stiff clay with depth
Lower Greensand	2m	Dense clayey sand / Stiff sandy clay
Kimmeridge Clay	>20m	Stiff clay

4.1.5 Groundwater has been assumed as 2m below ground level.

4.1.6 Further detail on the preliminary foundation design can be found in Section 6.6.

5. Environment & Ecology

5.1.1 The Scheme will be consented through the conventional Town and Country Planning Act 1990 procedure with an application for planning permission submitted to Oxfordshire County Council as the local planning authority.

5.1.2 A planning application is likely to be considered a major application due to exceeding the necessary thresholds. Article 2 of the Town and Country Planning (Development Management Procedure) (England) Order 2015 defines applications for 'major development' which includes a threshold for application site area of 1 hectare or more.

5.1.3 The proposed structure will need to be sympathetic with the local environment and shall aim to reduce any adverse impact on local flora and fauna. Oxfordshire County Council requires any new development to achieve a biodiversity net gain of 10%. This will require the preparation of detailed landscaping plans to inform a biodiversity net gain calculation using the DEFRA metric.

5.1.4 Ecology surveys are being undertaken by AECOM's Ecology team as part of the wider scheme. It is currently understood that no evidence for Great Crested Newts have been found in the south west attenuation pond. Additionally, no Badger Setts have been found in the vicinity of the structure footprint, although setts have been found by Hanson further west, nearer to the Hanson site compound.

5.1.5 Since the first revision of this document, an Aesthetics Appraisal Document as recommended by CD 351 will be prepared for this structure and also for the River Crossing and Approach spans to develop the preliminary design.

6. Structure Options Development

6.1.1 This section details how the options have been developed for Appleford Sidings Road Bridge.

6.1.2 Once the site, design parameters and constraints, geology and environment and ecology are established, the first structural design component can be understood; the span.

6.1.3 The span length is one of the primary factors in establishing the superstructure form; allowing for options to be developed suitable for the span length(s). After the feasible superstructure options are settled upon the substructure options can be developed cognisant of the preferred superstructure form and articulation arrangement. From the superstructure and substructure options, preliminary loadings can be calculated to inform foundation options with consideration for the geology. Finally, following these aspects other design considerations such as the parapets and interface with existing structures and infrastructure can be considered.

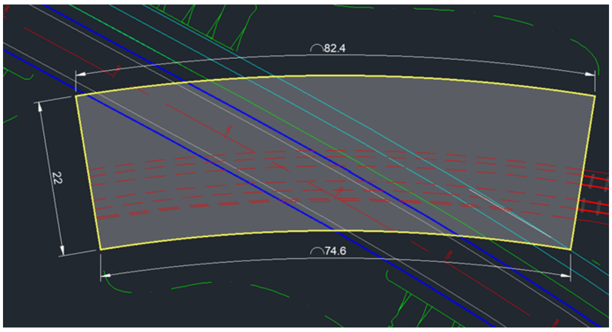
6.1.4 A high-level description of the options for the superstructure, substructure, foundations, parapets and interface with existing structures has been included to introduce the option. How this option relates directly to the structure is then explored with the advantages and disadvantages detailed.

6.2 Span

6.2.1 To determine the structural form of the deck the span lengths need to be established. For the skew of the horizontal alignment relative to the Appleford Sidings of approximately 60°, and the north and south boundary constraints, the following spans between support faces are achieved:

- Square to the north and south constraints with abutments radially set out to constraints- 22m
- Skewed following the road alignment – 48m and a skew of 63°.

6.2.2 Highly skewed bridge decks have numerous issues during design and construction and therefore it is always best to minimise the skew if site constraints allow. Reducing the skew to 45° increases the span to be in the order of 57m. Refer to sketches in Figure 6-1 below for illustration.



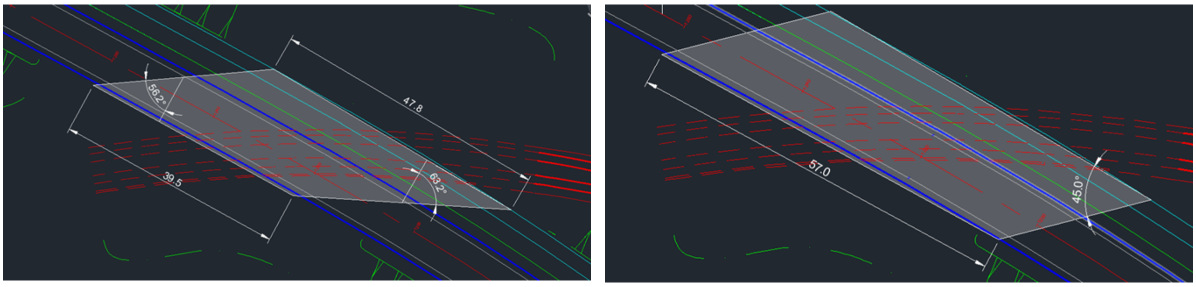


Figure 6-1: Sketch of span options

Intermediate Support

6.2.3 An intermediate support within the Hanson boundary to reduce the span lengths was tabled in initial Stakeholder discussions between Hanson, OCC and AECOM. The spacing between the existing and proposed railway tracks does not allow for an intermediate support to be positioned at a location that would provide a useful span length where the span would be approximately halved. Hanson have stated they need 4.2m either side of the existing and proposed rail tracks for maintenance purposes. Additionally, introducing an intermediate support within the railway boundary could introduce access issues for construction, inspection and maintenance, and potential visibility issues relating to signal sighting. Subsequently, only single span options have been taken forward in this Option study.

Two bridges

6.2.4 The south abutment for both the square and skew options clashes with the south headwall of the existing culvert draining the parcel of land north of the structure.

6.2.5 In initial discussions with OCC, an alternative arrangement to avoid the clash of the bridge abutment with the culvert and minimise the area of the new bridge deck was tabled in a technical note, document reference RIV-PD-ACM-SBR-SW_STR_ZZ_ZZ-RP-CB-0001. This would be achieved by providing two discrete bridge decks on slightly different alignments; one for the carriageway, and one for the footway and cycleway. A sketch of this arrangement is shown in Figure 6-2 below.

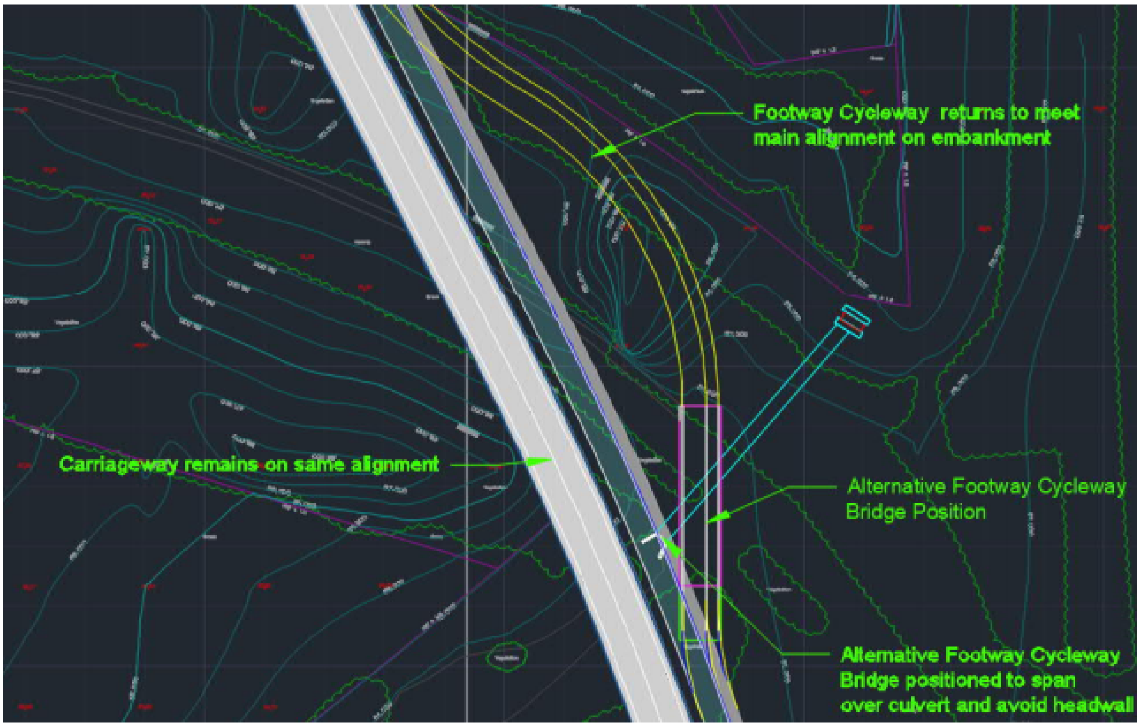


Figure 6-2: Illustrative discrete bridge option

6.2.6 This alternative alignment offers the following possible benefits and opportunities; ·

- Road bridge abutments and foundations can be reduced in size and will avoid a clash with the culvert and its headwall.
- The footway/cycleway bridge may be able to use existing topography to minimise earthworks.
- The footway/cycleway bridge will be a lighter construction type and have a reduced construction depth in comparison to the carriageway bridge, and therefore may be able to benefit from a lowered and improved vertical alignment (i.e. it can offer a 'flatter' alignment than the carriageway).
- The footway/cycleway bridge may be of a lighter construction, reducing costs, and increasing reasonably achievable spans.
- The separate footway/cycleway bridge could be designed to provide an aesthetically pleasing feature of the project.

6.2.7 However, this opportunity was discounted due to the following disadvantages:

- Introducing an additional bridge for OCC to own and maintain.
- The culvert will still need extending or diverting due to the alignment embankments severing route to the attenuation pond.

6.3 Articulation

6.3.1 As noted in CD 350, all bridges with a skew up to 30° or 60m in length shall be designed as integral or require a Departure from Standard. Bridges with a skew angle greater than 30° are permitted to be designed to be non-integral, i.e. with bearings and expansion joints.

6.3.2 Cognisant of the above DMRB clause, an integral articulation will be proposed for the square span arrangement, but it is not deemed appropriate for the high skew option.

6.4 Superstructure Construction

6.4.1 The following possible superstructure options were considered, but were discounted at an early stage as they were not deemed suitable due to their particular drawbacks:

- In situ reinforced concrete deck –The deck would have to be supported by a temporary falsework system during construction, which would impose severe restrictions on rail movements and is therefore unfeasible. The site constraints mean that an insitu deck constructed offline would be difficult to move into place on SPMTs.
- Post-tensioned concrete beam deck – Post-tensioned concrete beams are used for greater spans where segmental construction or long haunch spans necessitate this form of construction. This option is therefore discounted.
- Steel composite ladder type deck – The width of the proposed bridge is such that the transverse members would be of the order of 800-1000mm deep which in turn would result in main girders of a significant depth likely to be 2.4m-2.7m. This would have a significant adverse effect on the vertical alignment, height of embankments etc and as such was discounted.
- Steel through-truss – This form of structure would be less economic than the equivalent steel half-through girder and it would be visually obtrusive in the landscape. The steel half-through girder is explored further below.

6.4.2 Three forms of deck construction were taken forward for further examination:

- Precast pretensioned beams- Square Option
- Steel concrete composite multi-girder – Both Square and Skew Options
- Half-through girder – Skew Option

These options are discussed fully in the subsequent sections of this report.

Precast pretensioned beams

Description of option

6.4.3 This construction form comprises precast pretensioned beams supporting an insitu reinforced concrete slab with permanent Glassfibre Reinforced Concrete (GRC) formwork between the beams. Beams vary in shape and transverse spacing depending on the requirements of the project. An illustrative cross section of the deck is shown in Figure 6-3 below.

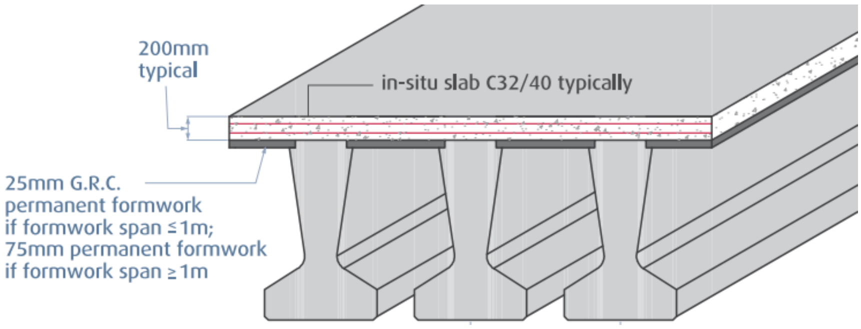


Figure 6-3: Illustrative cross section of a Precast pretensioned beam (Courtesy of Shay Murtagh)

Detail of option

6.4.4 Precast pretensioned beams are a popular construction form for spans less than 42m, although they are generally less than 30m due to road transportation limitations. Generally, this form of construction lends itself to simple square structures with limited skews although some shaped beams such as W-Beams can be suitable for skewed decks which experience high torsional effects. For the span that this structure requires, this option is only suitable for the square option.

6.4.5 Shay Murtagh's Technical Manual indicates that for a clean span of 22m a Y3 Beam, 900mm deep at 1m c/c would be sufficient. A Y3 beam with 1m c/c can span up to 25m, allowing 3m beyond the face of the supports to allow the beams to extend into an end concrete diaphragm with sufficient embedment. Y Beams have been chosen over other shape beams because they provide a smaller depth and lighter section than U and W Beams, T Beams do not reach the spans required and the M Beams soffit prevents the web of the beam being available for inspection and maintenance. 1m centres were chosen as this reduces the depth of the beam the most, however this does increase the total number of beams to 75no. beams. If 2m centres were chosen, the beam depth would need to increase to Y7 beams of 1300mm depth but the number of beams would reduce to 38no. beams.

6.4.6 Beams could be placed parallel to each other with a small skew rather than fanned to minimise the footprint area of the redundant triangles while keeping the span as small as possible. Placing the beams parallel would also mean uniform permanent formwork rather than accommodating a varying width with a fanned arrangement.

6.4.7 Pretensioned beams have been developed over the last 60 years and are a known quantity for Bridge Asset Managers historically having lower maintenance requirements.

6.4.8 Precast pretensioned beams can be made integral with the abutments by providing in-situ reinforced concrete end diaphragms connected to the substructure to act monolithically. The beams could be landed on the partially constructed concrete diaphragm, allowing the beams to rest in their simply supported state. Modest changes in levels can be accommodated with shims/temporary supports.

6.4.9 The simplicity of this construction form is utilised by providing an oversized bridge, to allow the smallest square span to be achieved whilst supporting the road alignment which traverses the bridge at a skew. The abutments can be set parallel to the constraints with the beams fanned to provide a uniform span length and accommodate the radial supports.

6.4.10 However, this “oversized” arrangement will lead to two large redundant triangles adjacent to the carriageway and provides the largest footprint of the Options considered. A plan of this arrangement is shown in Figure 6-4 below.

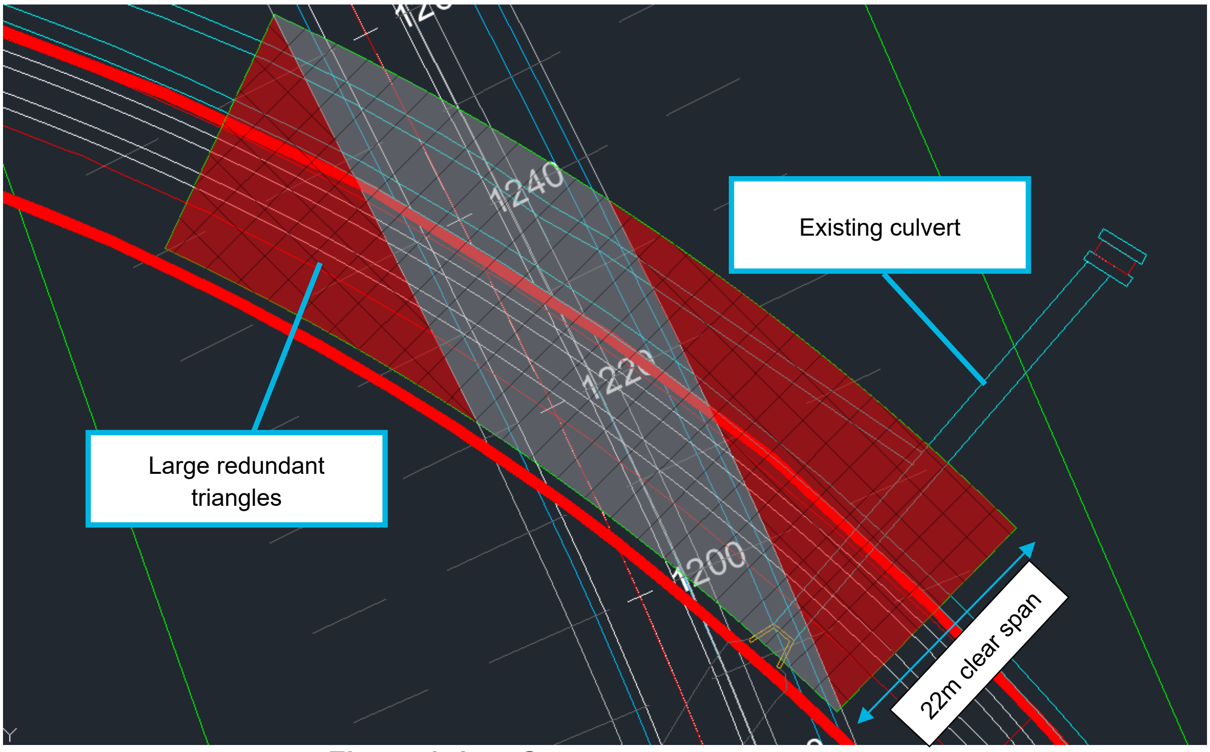


Figure 6-4: Square span arrangement

Redundant triangles

6.4.11 The following opportunities to reduce the size of the redundant triangles were explored:

- Incorporating a small skew to the beams
- In-situ RC deck slab for acute corners cantilevering off main deck.

6.4.12 The size of the redundant triangles could be reduced by incorporating a small skew in the beams and placing the beams parallel to each other. A 10° skew of the beam reduces the west triangle from 406m^2 to 351m^2, however this increases the span length by approximately 400mm. It is proposed to explore the effects of having a small skew in greater detail during the preliminary design, see Opportunities at the end of the report in Section 10.4.

6.4.13 An in-situ reinforced concrete triangular deck slab cantilevering off the main deck was also explored. See Figure 6-5 below. This option includes two reinforced cast-in-situ concrete slabs, triangular in plan, at the acute corners of the deck spanning between abutment and a reinforced cast-in-situ concrete edge beam. The concrete edge beam will in turn be supported on the abutment on one side and the outermost precast prestressed concrete beams on the other side.

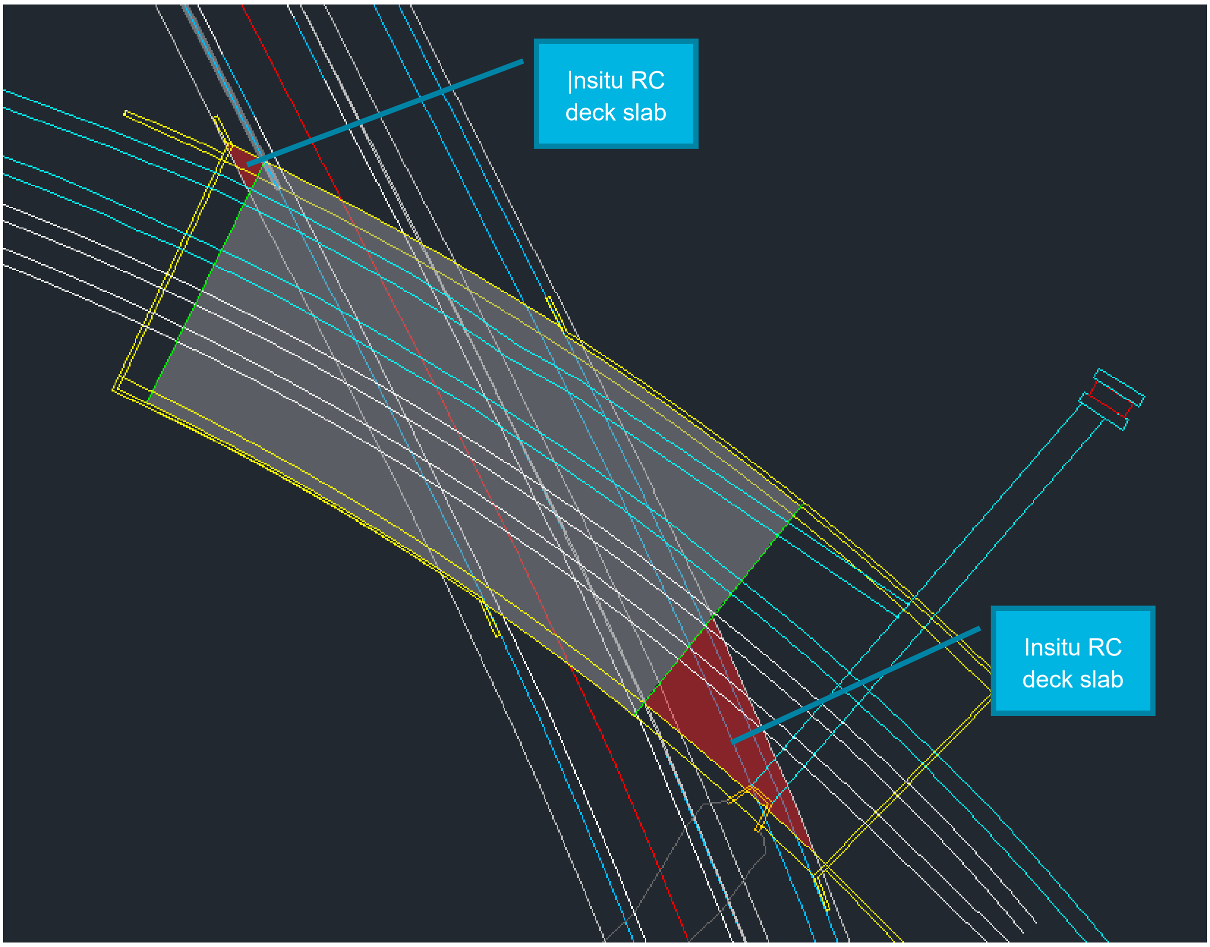


Figure 6-5: Insitu RC deck slabs

6.4.14 This option initially had particular merit on the east side, with the slab only needing to carry pedestrian loading and accidental wheel loads. However, the main advantage of using precast pretensioned beams is its simplicity in construction and minimum future maintenance requirement. The cantilever would be approximately 10m in length, require complex reinforcement detailing into the main deck slab and abutment and require temporary formwork above a live rail track. For these reasons this opportunity was also discounted.

6.4.15 The redundant triangles could present a maintenance liability to OCC if not well detailed. OCC TAA were shown a number of examples of oversized bridges over the railway on 3rd December 2020. Some of these examples are shown below in Figure, Figure 6-7, and Figure 6-8 below.

Figure 6-6: Example of an oversized bridge. Inveramsay Bridge A96 over the Aberdeen to Inverness Railway

Figure 6-7: Example of an oversized bridge. M7 over M8 (Ireland)

Figure 6-8: Example of an oversized bridge. A7(M) New Cowdens Railway Bridge near Lockerbee

6.4.16 Figure 6-6 shows an arrangement with a concrete H4a parapet with pedestrian guardrails on the portals. The triangles have a minimal maintenance concrete screed surfacing and access is prohibited to inspection/maintenance staff.

6.4.17 Figure 6-7 shows the possibility to reduce the tunnel-like aesthetic of the oversized bridge by reducing the length of the enclosed section of the structure with a series of discrete columns supporting the triangles, also increasing ventilation and light under the structure.

6.4.18 Figure 6-8 shows how the aesthetics of the triangles could be “softened” by incorporating the triangles into the adjacent embankments continuing the grassed landscaping.

6.4.19 It is understood that OCC wish this structure to be as utilitarian as possible. It is therefore proposed that an arrangement similar to that shown in Figure 6-6 is the most suitable. This option provides the required vehicle containment at the preferred alignment, i.e. parallel to the carriageway, over the railway and provides minimal maintenance requirements as aspired to by OCC. Concerns were raised by the TAA about the areas becoming fly-tipping hotspots, however if a 1.8m high H4a concrete parapets with a coping is provided, these areas will not be readily visible or climbable to the road, pedestrian or cycle user. Additionally, this structure is not in an urban environment but rather 1.2km from the nearest community.

6.4.20 If this issue becomes contentious in future, there is possibility of opening up these areas to provide a more aesthetically pleasing, open area, by providing N2 parapets with a solid infill parapet at the deck portals. However, this proposal introduces an area where road/pedestrian users could congregate and more onerous maintenance requirements.

Advantages

6.4.21 The benefits of this simple construction form should not be underestimated. This includes:

- Minimal maintenance requirements.
- Simple and well-understood construction methodology, not needing specialist temporary works and complex construction sequencing.
- Simple to inspect due to integral nature with no bracing, inspection galleries, bearing plinths, complex joints to inspect.
- Precast beams leading to improved quality control and less construction time on site compared to insitu methods.
- Several manufacturers providing competitive pricing and certainty during construction.
- Smallest span lengths meaning lighter beams that can be lifted using a smaller crane.

Disadvantages

6.4.22 Disadvantages of this construction form include:

- Largest footprint which could lead to a tunnel like effect visually
- Large quantity of beams due to the redundant triangles caused by skew of the road alignment
- Redundant triangles which could become a maintenance liability

Steel Composite Multi-Girder

Description of option

6.4.23 This construction form comprises longitudinal fabricated steel plate girders connected by cross-bracing acting compositely with a cast in-situ reinforced concrete top slab. Refer to Figure 6-9 below.

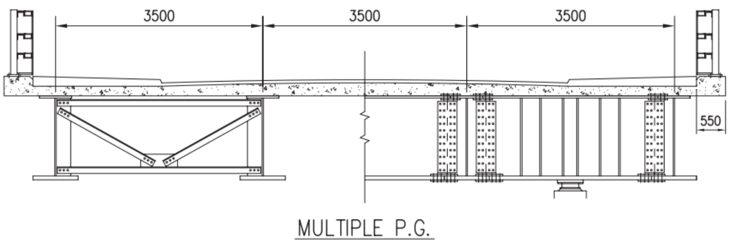


Figure 6-9: Illustrative example of a steel composite bridge arrangement

Detail of option

6.4.24 This form of construction can be used for both the square and skew spans.

6.4.25 For the square arrangement, using rule of thumb, span/20, for outline sizing the construction depth required for a span of 24m (22m + 1m each side) results in a 1200mm deep girder. This value is a robust rule of thumb and it is likely that this depth could be reduced to 1000mm with design refinement.

6.4.26 For the skew arrangement the construction depth increases to 3200mm for the skewed 48m span using a rule of thumb of 1/15 due to the simply supported arrangement and to limit deflections.

6.4.27 A depth of 3200mm for the plate girders is a “showstopper depth” for this structure. The increased construction depth results in the need for the vertical alignment to be increased in height to accommodate the additional depth. The cost of raising the approach embankments to achieve the required 4.8m structure free zone over the Appleford Sidings is likely to be prohibitively expensive and outweigh the benefits of choosing this construction form.

6.4.28 For the square option, with abutment lengths in the order of 80m, using girders spaced at between 3m and 3.5m and having an even pair of girders to assist construction, 24no. girders would be required.

6.4.29 The redundant triangles described for the pretensioned concrete beams would also be present for this square option.

6.4.30 Additionally, similarly to the pretensioned concrete beam option, this option can be designed to be integral with the beams connected to the abutments through cast-in-situ reinforced concrete end diaphragms to act monolithically.

<u>Advantages</u>

6.4.31 The benefit of this construction form includes:

- Light construction form reducing the load onto the substructure and foundations.
- Girders are fabricated off-site benefiting from quality control and less construction time on site.
- Girders can be braced on site and erected in braced pairs to assist lifting operations.
- Significant reduction in heavy lifting requirements on site in comparison to number of lifts required for precast pretensioned beams.
- Several fabricators available providing competitive pricing and certainty during construction.
- Simple to inspect due to integral nature with no bracing, inspection galleries, bearing plinths, complex joints to inspect.

<u>Disadvantages</u>

6.4.32 Disadvantages of this construction form includes:

- Bottom flanges provide nesting areas for birds.
- Large footprint which could lead to a tunnel like effect visually for the square option.
- Large quantity of girders due to the redundant triangles caused by the skew of the road alignment for the square option.
- Increased span of the skew option, leading to increased construction depth, and also likely to require site-splicing of beams.
- Redundant triangles which could become a maintenance liability.

Half-through Girder

Description of option

6.4.33 This construction form comprises a longitudinal steel girder along each edge of the deck with steel cross girders composite with a cast in-situ reinforced concrete deck slab. The girders could either be fabricated plate girders or fabricated box beams. Weathering steel or painted steel could be used. Refer to Figure 6-10 and Figure 6-11 below.

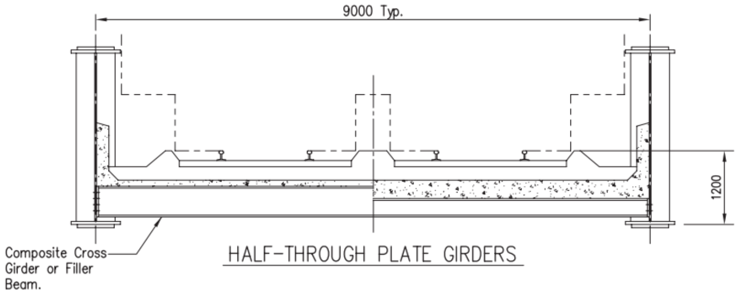


Figure 6-10: Illustrative example of a Half-through plate girder arrangement

Figure 6-11: Example of a through-girder deck being constructed in Thurrock

Detail of option

6.4.34 Half-through bridge configurations are a good solution for small and medium spans where clearance under a bridge is sensitive because the structural capacity comes from the trough "U-shape" and crucially the main structural members transferring load to the supports, the side girders, are above the deck elements. This form of construction is particularly common for railway bridges, where the side girders do not need to be protected in the same manner as road bridges for impact loading. However, for this structure this construction form would require additional width, including working width, to incorporate a H4a barrier adjacent to the running lane to protect the structural beam from any accidental damage from vehicle collision.

6.4.35 The height of the side girders is directly influenced by the cross-member span to provide the required U-frame stiffness to carry the loads. This construction form is therefore more sensitive to the width of the structure compared to the two previous options where the depths of the primary structural members is determined by the span length, rather than just adding more beams.

6.4.36 The width of the carriageway between parapets is 16.9m. Providing H4a barriers to protect the structural side girders and providing a working width would increase the width by another 1.9m (considering a 0.35m H4a concrete beam and a working width of 0.6m), i.e. 18.8m. Using span/20, the cross beams alone would need to be 18.8m/20= 940mm deep.

6.4.37 Two discrete U frames could reduce the size of the trough, by providing longitudinal girders within the central reserve to support the carriageway and the footway/cycleway separately, and reducing the span of the cross-members, separately as shown in Figure 6-12 below.

Figure 6-12: Example of two discrete U-frames (Image courtesy of SCI)

6.4.38 This configuration would result in the lowest practical deck construction depth and hence offer the best option in terms of headroom and vertical alignment. However, it will require a wider central reserve in order to accommodate the two girders and to allow space between them for maintenance purposes. This will also defeat the purpose of providing a wide verge and footway/cycleway to cater for any future provision for automated vehicles for example.

6.4.39 A half-through girder arrangement could accommodate the skewed option leading to the smallest footprint of the three options. However, for the span length and widths available the visual impact of this construction form is of a concern due to the height of the outside girders being several metres in depth and extending well above the road surface. Due to the railway location the girders would warrant being weathering steel. The skewed angle of the road alignment, the height of the girders and the material could be seen to be visually intrusive especially adjacent to the footway/cycleway.

6.4.40 A half-through girder arrangement will need to sit on bearings at the end of the deck rather than be integral due to the magnitudes of longitudinal and transverse movement generated from this construction form and skew to ensure these movements do not induce stress in the superstructure or substructure.

<u>Advantages</u>

6.4.41 The benefits of the half-through girder option configuration are:

- Lowest vertical alignment.
- Girders are fabricated off site benefiting from quality control and less construction time on site.
- Smallest footprint.

Disadvantages

6.4.42 The disadvantages of the half-through girder option configuration are:

- Visual impact is onerous and evident for the bridge users.
- Large crane will be required to lift the primary girders.
- Non-integral.
- Gaps between the H4a barrier and the girders can fill with debris and can be difficult to access for future maintenance.

6.5 Abutments

6.5.1 The abutment options have been developed are suitable for the precast pretensioned beam deck construction and the steel-concrete composite deck construction types.

6.5.2 The abutments are proposed to be curved to minimise the span length and follow the curvature of the rail track. The current proposal, as shown in the General Arrangement in Appendix A sets the abutments with different radii with the same point of origin to minimise the span. At preliminary design stage, it may be found that this arrangement produces large differential load effects on the abutment. If issues arise from thermal movement then options to be explored can include setting the beams parallel to each other rather than fanned and the abutments having the same radius and stiffness.

6.5.3 Various integral abutment construction forms are detailed in PD 6694-1. Integral abutments considered and discounted are described below:

- Embedded Wall- This option was discounted primarily because the ground level would need to be built up prior to constructing the wall comprised of contiguous bored piles. Sheet piles would not offer sufficient bending resistance so would need to be ground anchored. The depth of the soil which is suitable for structural foundations is 7m below existing ground level, meaning these walls would need to retain a significant height of soil and create significant bending moments due to this total height.
- Bank seat abutments- The bank seat could be placed either at the top of a 1v:3h slope or behind a reinforced soil wall as shown in Figure 6-13 below. The historic borehole information combined with an initial loading assessment would suggest that any embankments in the area would be prone to significant settlement and extensive ground improvement is envisaged. As such it is unlikely that the use of a bank seat would provide an economic solution irrespective of where it was placed.

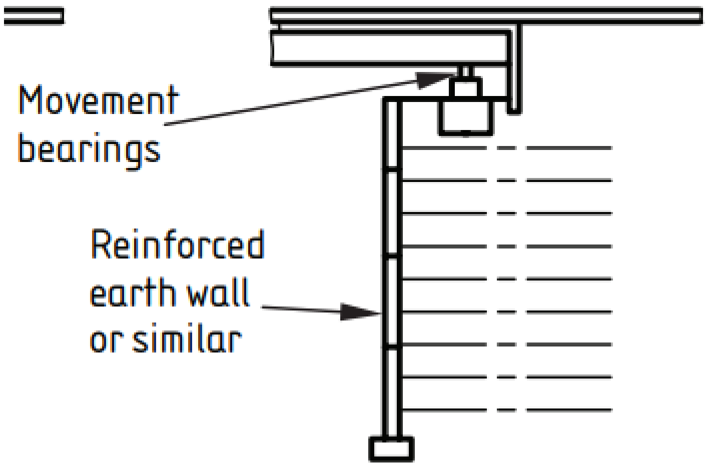


Figure 6-13: Bank seat abutment behind a reinforced soil wall

- Semi-integral end screen abutments-. Unequal earth pressures of the abutments owing to the skewed embankment may result in a twist of the deck which the semi-integral arrangement will not be able to deal with as readily as an integral arrangement.

6.5.4 The three integral construction forms to be explored further are:

- Skeletal Abutment
  - With columns behind a reinforced soil wall
  - With columns in front of a reinforced soil wall
- Full Height conventional cantilevered abutment wall

Skeletal Abutment

Description of option

6.5.5 The superstructure is supported by an end diaphragm which is cast integrally onto a series of columns, which in turn sit on the pile cap. These columns support the deck however they would not provide retention of the embankment; the embankment is retained by a vertical reinforced soil wall erected in front of the columns, providing a vertical face to the abutments.

6.5.6 A reinforced soil wall retains the compacted embankment fill with horizontal tensile reinforcing straps at a series of levels embedded within the fill. Precast reinforced concrete fascia panels are then provided at the face to provide an aesthetically pleasing clean line.

6.5.7 An illustrative example of this abutment configuration is shown in Figure 6-14 below.

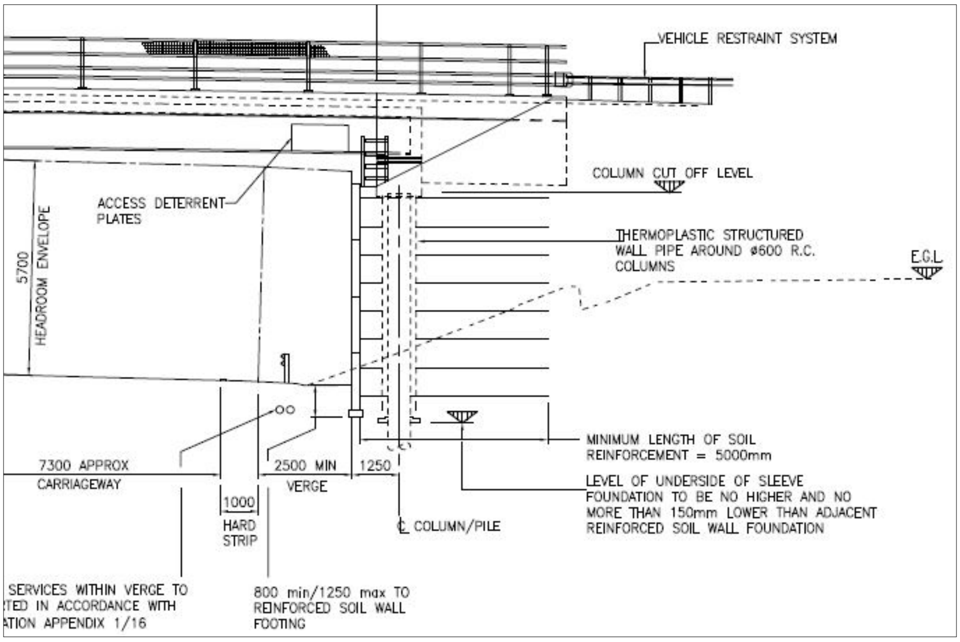


Figure 6-14: Sleeved column arrangement

6.5.8 Preliminary loading of the precast pretensioned beams indicate that 1m diameter columns at 3m spacing are likely to provide sufficient capacity for the moment generated by the portal frame. With the north abutment being 82m wide and the south abutment being 75m wide this equates to 25no. of columns for each abutment.

Detail of option

6.5.9 This abutment arrangement supports the deck on a series of flexible piles or columns within “sleeves” with a reinforced soil wall retaining the approach ramp fill either behind or in front of the columns.

6.5.10 The columns can be designed to act integrally with the deck with a concrete diaphragm spanning between the columns to form a portal frame structure, accommodating thermal movements of the deck through flexure. The sleeves concealing the columns can be constructed from either drainage manhole rings or thermoplastic tubes and act to provide the required movement gap between the substructure and the embankment to allow flexure; thus, preventing build-up of earth pressures on the columns.

6.5.11 Skeletal abutments provide a lightweight solution as the substructure is not required to directly resist earth pressures, and thus smaller foundations are required.

Columns behind the reinforced soil wall

6.5.12 Integral skeletal abutment arrangements traditionally place the columns behind the reinforced soil wall, providing a clean aesthetic line adjacent to the railway. The columns behind the walls means that debris does not build up in the gap between the columns and the wall.

6.5.13 This solution however does present a maintenance difficulty, as the columns would be concealed within the annulus of the sleeves and would therefore not be possible to access directly for inspection and maintenance. It may be possible to make provision for CCTV inspection within the annulus, but access for maintenance would not be easily achieved. This option also carries the risk that the sleeves concealing the columns may move relative to the columns, due to settlement/movement of the embankment; this can be mitigated against during the construction phase by providing inflatable spacers around the columns. However, this is a common problem for all structure foundations and substructures.

Columns in front of the reinforced soil wall

6.5.14 The columns could be placed in front of the reinforced soil wall, allowing access to inspect the columns and reducing the span length, however an unsightly void is then created behind the columns and the reinforced soil wall which can build up with vegetation and debris and may also present a security risk.

Advantages

6.5.15 The benefits of a reinforced soil wall with discrete columns are:

- “Bottom-up” construction so easily controlled.
- Light skeletal option leading to smaller foundations.
- Clean aesthetically pleasing lines adjacent to the railway (If columns behind the wall are chosen.
- Requires proprietary materials such as the straps and fascia panels which can be designed by specialist consultants leading to efficiencies.

Disadvantages

6.5.16 The disadvantages of this option include:

- Cannot readily inspect the columns when buried within the reinforced soil wall (If columns behind the wall are chosen)
- Debris and vegetation can build up behind the columns (If columns in front of the wall are chosen)

6.5.17 The topography of the valley where the Sidings sits means that the reinforced soil wall does not need to extend the full width of the structure but just to retain the approach embankments with the remaining width under the redundant triangles sitting on discrete columns. As well as being likely to be cheaper than providing a wall extending to the full width, this would also provide increased light and ventilation under the footprint of the bridge.

Full Height conventional cantilevered abutment wall

Description of option

6.5.18 A full height conventional cantilevered abutment wall typically of reinforced concrete construction is a more traditional abutment form, supporting the vertical loads from the bridge and acting as retaining wall for the embankment. It is connected structurally to the deck for the transfer of bending moments, shear forces and axial loads and supported on foundations.

Detailed of option

6.5.19 The back of the wall must accommodate earth pressures and thermal movements, requiring a significant mass to stabilise this pressure leading to an ultimately thick, heavy wall onto the foundations.

6.5.20 As described earlier, the soil is likely to have low structural capacity at this location. An initial loading assessment indicates that this form of substructure would be at least double the load of the skeletal abutment which would lead to significantly larger foundations compared to the skeletal abutment.

Advantages

6.5.21 The benefits of a full height cantilevered abutment wall are:

- Monolithic structure so likely to need very little maintenance.
- Economic initial cost outlay as does not need proprietary materials or design.
- Simple to inspect.

Disadvantages

6.5.22 The disadvantages of this option include:

- Option is heavy due to load effects on the back of the wall leading to larger foundations.

6.6 Foundations

6.6.1 Spread footings at this location are unsuitable due to the 7m of uncompacted fill material below existing ground level. Therefore, a pile design has been considered.

6.6.2 The proposal by Hanson as part of the expansion of the tracks shows ground improvement by vibro-stone columns, which will stiffen the ground. These elements are not considered structural. Any localised clashing with proposed bridge piles would not cause an issue. The presence of this ground improvement is beneficial to the scheme as it will reduce the likelihood of induced settlement from the Appleford siding bridge and embankments having an impact on the railway line.

6.6.3 Preliminary pile design has been undertaken in accordance with BS EN 1997-1:2004+A1:2013 and using the associated UK National Annex document.

6.6.4 Curves showing pile design resistance with depth for a range of pile diameters are included on Figure 6-15 and Figure 6-16 below. DA1-1 and DA1-2 represent the Design Approach 1 Combinations 1 and 2 to Eurocode 7.

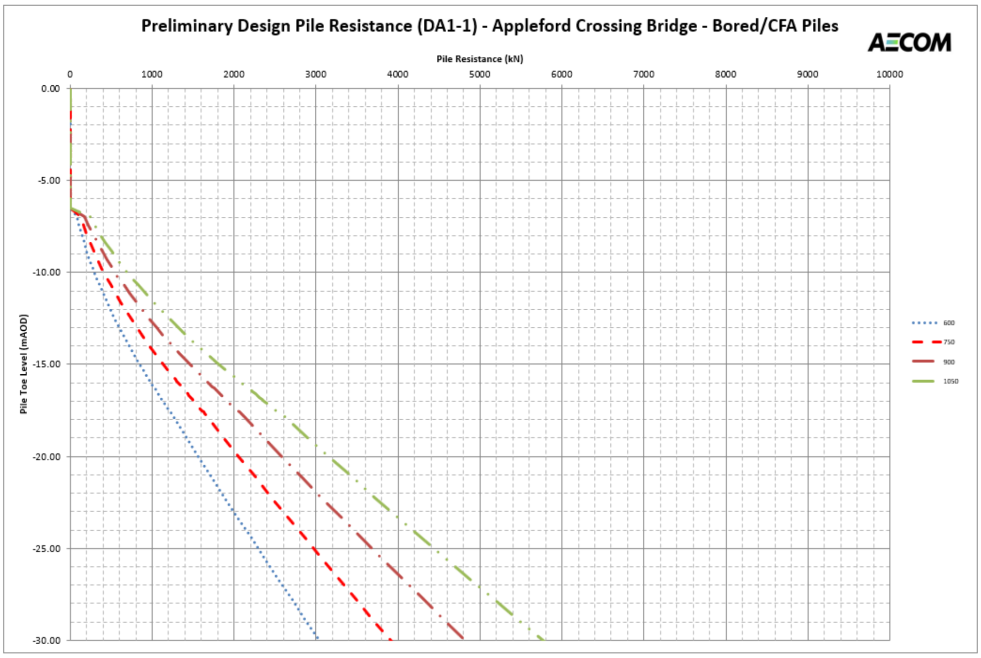


Figure 6-15: DA1-1 Preliminary Pile Resistance

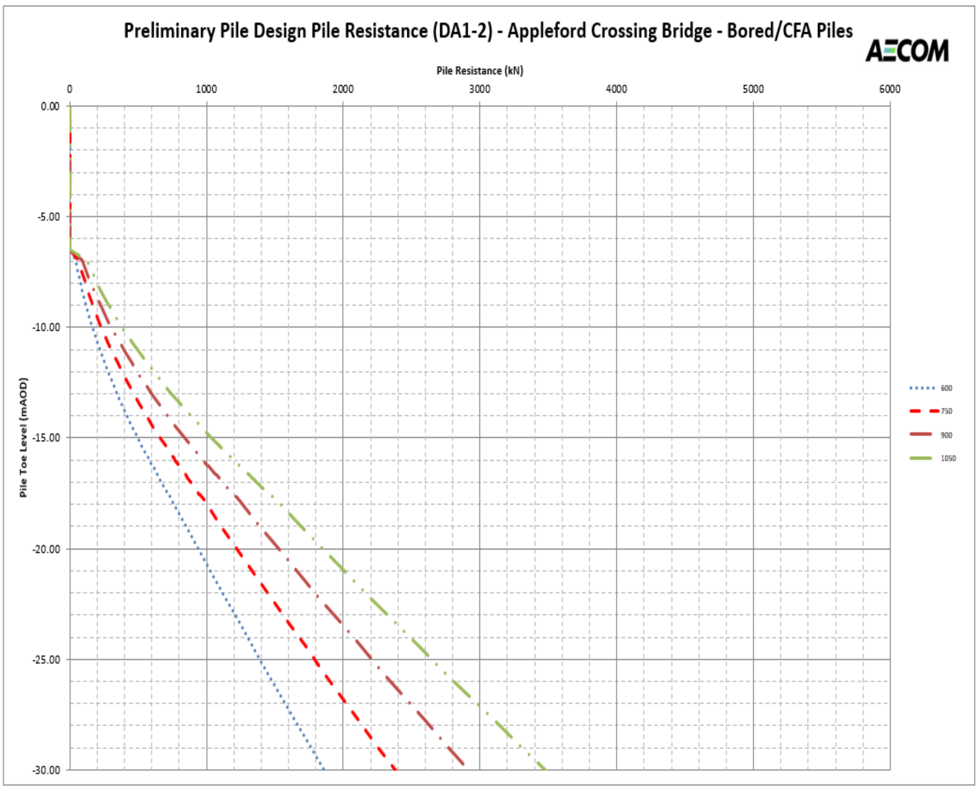


Figure 6-16: DA1-2 Preliminary Pile Resistance

6.6.5 It should be noted that pile group effects have not been considered at this stage.

6.6.6 The effects of settlement of the fill have also not been considered. Long term fill settlement, either as a result of ongoing consolidation, or due to embankment loadings associated with the road construction, could create a “downdrag” effect on the piles. This would have the effect of reducing the effective pile bearing resistance.

6.6.7 The landfill materials pose an environmental hazard if piling through landfill. The creation of contaminant pathways to aquifers will not be acceptable. While the Gault Clay and Kimmeridge Clay are not aquifers, the Lower Greensand is defined as an aquifer. Piles extending to this strata (i.e. deeper than 15m) would need to be constructed in such a way to prevent the formation of contaminant pathways. The use of CFA piling may be sufficient to prevent the formation of such pathways, but may cause other technical issues such as slumping of concrete from the pile bore into the fill material leading to oversupply of concrete and bulging of the pile. Therefore, the use of bored piles with temporary or permanent casing through the fill section may be necessary.

6.6.8 An initial loading assessment using precast pretensioned beam and skeletal abutment indicate that 1m diameter bored piles spaced at 3m spacing are required. An optimisation of the pile diameter and spacing has not been carried out at this stage. Piles spaced at these dimensions with 1m diameter, and using Figure 6-16 with a loading estimated in the order of approximately 2500kN per pile indicates that pile lengths in the order 25m deep are required.

6.7 Parapets

6.7.1 CD 377 states that for new bridges over rail, an H4a containment level vehicle parapet shall be provided. This parapet should be 1800mm high. The length of need on two-way carriageways should extend beyond the rail boundary for 25m in advance of the point of no recovery in both directions. The point of no recovery has been taken as the face of the abutments in accordance with Network Rail Standard NR/L3/CIV/020 Issue 1.

6.7.2 The structure crosses over a private Sidings rather than a Network Rail track. It is therefore in OCC's gift to provide a lesser parapet containment (N2 containment) subject to a Departure from Standard from CD 377 and agreement with Hanson. A risk assessment to CS 461 has been prepared, refer to Appendix E, as if the structure was an existing structure to establish the Incursion Rating. The Risk Incursion scored 29 if providing a H4a parapet and 30 if providing an N2 parapet which are both lower than 100; the value required to retrofit a H4a parapet to an existing structure. This could be used to support a Departure from Standard application. Advantages of providing an N2 parapet could include opening up the redundant triangles as the parapets can be less high and intrusive. However, an N2 parapet is not to Standards, does not future proof the structure and could present a design liability to OCC due to the on-going monitoring of the sub-standard provision.

6.7.3 A H4a parapet has been considered in the section below due to the current stage of the project. Provision for an N2 parapet is shown in the Opportunities section at the end of this report.

6.7.4 The material options considered are:

- Option 1: Metallic parapet (proprietary system)
- Option 2: Reinforced concrete parapets
    - Precast
    - In-situ

Option 1: Metallic Parapet

6.7.5 Steel parapets present a lightweight, easy to install solution, although they require the installation of a relatively wide edge beam to provide the necessary connection with the deck. The parapet would be assembled on site and lifted into place on the deck, with relatively little need for working at height on the bridge deck. In the event of a collision, the forces transferred to the bridge deck are significantly less than in the case of concrete parapets. This is because the connection of the metal parapets to the deck is not as stiff and is designed to deform, absorbing part of the impact energy. This means in the event of a significant impact collision affected panels can be relatively readily replaced compared to their reinforced concrete counterparts.

6.7.6 The disadvantages of steel fabricated parapets are they have a high initial cost and a reduced design life compared to the concrete option due to general deterioration of the protective coatings and the metal, and it is more prone to frequent minor damage caused by minor impacts or vandalism.

Option 2: Reinforced concrete parapet

6.7.7 The significant advantage of a reinforced concrete parapet is the minimal maintenance requirements. In most cases the parapet will last as long as the design life of the bridge. Concrete parapets are also less susceptible to minor damage and graffiti.

6.7.8 Cast in-situ concrete parapets are likely to have a lower material cost than a precast alternative, however programme, quality and healthy and safety implications may outweigh these benefits.

6.7.9 CD 377 cl. 4.78, states that reinforced concrete parapets shall be CE marked in accordance with BS EN 1317-5. This involves the parapets being compliant with Test Acceptance Criteria of EN 1317, with all proposed systems subjected to collision tests to demonstrate that they satisfy the acceptance criteria. This however is impractical for concrete parapets as the testing would be prohibitively expensive. This requirement is difficult to achieve for in-situ concrete parapets so parapets can be designed in accordance with BS 6779-2 with a Departure from Standard from the Overseeing Organisation. This process of applying for a Departure from Standards for in-situ parapets is recognised in the standards as an acceptable method of providing parapets.

6.7.10 The main disadvantage of reinforced concrete parapets is the replacement of the section of damaged parapet in the event of significant impact damage is much more onerous. Replacement/reconstruction or repair of the damaged concrete parapet element after an impact would be less practical than that of a metal parapet. If the concrete parapets were cast in-situ, the replacement would be complex due to the reinforcement being anchored substantially into the deck and introduce increased health and safety risk with works undertaken over the railway line.

6.7.11 Alternatively, if precast concrete panels were used, replacement of the damaged panel would need to be procured and manufactured and involve lifting and positioning over the railway line. Precast units may also require local breakout or hydro-demolition to expose fixings.

6.8 Interface with existing structures/infrastructure

6.8.1 The embankment of the road will sever the existing drainage route. It is intended to provide a culvert north of the bridge to continue the flow along the existing peripheral drainage ditch in the north 90-acre landfill site adjacent to the railway, and to the south of the bridge to discharge to the attenuation pond to the south west.

6.8.2 These culverts are not the subject of this Options study and are being developed separately by the drainage team. An appropriate solution for the culvert will be included into the preliminary design of the bridge structure.

Existing Culvert

6.8.3 The existing culvert described in Section 2.2 clashes with the proposed abutments. There are two options for the culvert are shown in Figure 6-17 below and are:

- Option 1: Retain and extend the existing culvert
- Option 2: Divert the culvert

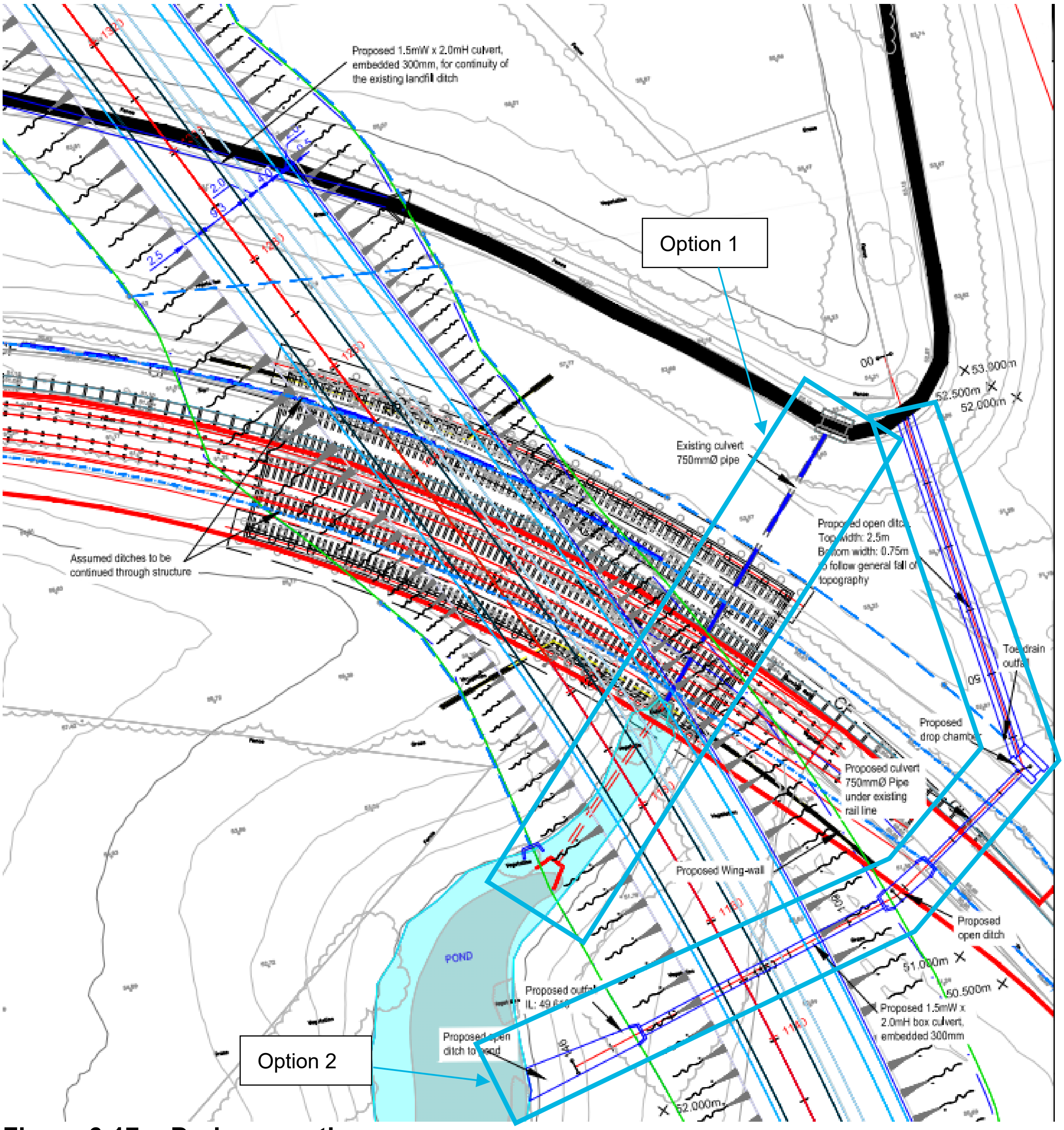


Figure 6-17: Drainage options

6.8.4 These options are discussed below and under further consideration in a separate study carried out by the drainage design team. It should be noted the following appraisal has only been considered from a Structural perspective.

<u>Option 1: Retain and extend the extend culvert</u>

6.8.5 Retaining the existing culvert would initially indicate less work as the route underneath the rail track has already been achieved. However, retaining this drainage route has two aspects which need to be overcome; short term- establishing the culvert condition and integrity and long-term, the on-going liability of having a separate structure passing through or under the bridge.

6.8.6 In the short-term to determine if the culvert can be retained, extensive intrusive site investigations would be required to confirm the structural integrity and condition of the culvert, for which no record drawings have been forthcoming. It was also noted from a Site inspection that the south end has visibly deformed indicating repair and possible strengthening works are likely to be required.

6.8.7 Long-term, the disadvantages include issues with differential settlement between the piled bridge and the culvert which could lead to the culvert leaking possibly contaminated water onto the adjacent bridge elements and undermining the bridge foundations. This solution also builds in a drainage route that is near impossible to inspect and maintain. Additionally, ownership and crucially maintenance of the culvert is less clear cut. To facilitate this, a drop chamber needs to be provided in front of the south abutment to demarcate the end of the existing culvert and start of the new culvert. This will also require the north abutment and its foundation to be designed to avoid the clash and facilitate any future strengthening or reconstruction of the culvert by Hanson.

Option 2: Diversion of culvert

6.8.8 Although likely to have a larger initial cost outlay, the advantages of providing a diverted drainage route away from the structure is likely to be more cost-effective in the long term.

6.8.9 The most significant benefit is OCC not having the liability of inheriting a poorly maintained culvert and the associated risks that this introduces from placing a heavy new structure on it. The drainage culvert can be designed to appropriate standards with clearly defined culvert ownership and maintenance agreements agreed between Hanson and OCC.

6.8.10 A re-routed drainage system is likely to require directional drilling or cut and cover under the railway to provide this diversion. The alignment can be designed to provide the smallest lengths possible while crossing perpendicular to the railway and under the embankment to the south. This will also require construction of a long open ditch on the east side including new drop chamber. Discussions about whether the section under the railway could be constructed at the same time as the Hanson expansion of the Sidings are being initiated by OCC. Hence, this option is reliant on Hanson agreeing to construct the section under the railway tracks prior to constructing the additional tracks. If this strategy fails, it will be a significant challenge for OCC to construct this section under three operational railway tracks at a later date.

7. Options Appraisal

7.1.1 In Section 6, the options for the various components of the structure were identified with the advantages and disadvantages explored. This section will appraise these options. High level comments adjacent to key considerations are tabulated, with a colour code to clearly identify the preferred option for each structural component shown. The key considerations comprise:

- Whether the option achieves the project requirements and constraints
- Programme Implications
- Safety Risks
- Commercial Risks
- Aesthetics
- Environment
- Future Maintenance
- Ease & Design of Construction

7.1.2 A brief discussion follows to support the preferred option and why the other options have been discounted.

7.2 Deck construction

7.2.1 A summary of the deck construction options benefits and disadvantages are summarised in Table 7-1 below. Key comments are included for the different options, with a broad green being positive, orange being neutral and red being negative.

Table 7-1: Summary of deck construction options

	Precast pretensioned beams	Steel composite multi-girder	Half-through girder
Achieves Requirements and Constraints	Square Arrangement	Square Arrangement	Skew Arrangement
Programme Implications	Simple design	Simple design	Big visual impact makes planning approval more contentious
Safety Risks	Minimal inspection and maintenance of the beams and soffit over the railway.	Minimal inspection and maintenance of the beams and soffit over the railway if weathering steel used.	Working at height to inspect side girders
Commercial Risks	Procurement security- Lots of manufactures available	Procurement security- Lots of fabricators available.	Limited number of fabricators
Environment	Recycled aggregates. Efficient design and innovation.	Recycle girders at end of design life.	Recycle girders at end of design life.
Aesthetics	Large Footprint	Large Footprint	Visual Impact obtrusive to road users and nearby properties

	Precast pretensioned beams		Steel composite multi-girder		Half-through girder	
Future Maintenance		Simple to inspect and maintain. Integral.		Simple to inspect and maintain. Integral.		Non-integral; More complex expansion joints and bearings
Ease of Design & Construction		Simple construction		Simple construction		Large Crane required

Preferred Superstructure solution

7.2.2 The preferred deck construction option is **precast pretensioned concrete beams.** Although this square span arrangement has the largest footprint it is the simplest design which should transfer to the most cost-effective solution for design and construction. From a planning perspective it is aesthetically not controversial providing a utilitarian aesthetic which is in keeping with the surrounding industrial environment. The simple design is also well understood meaning that there is less risk for programme overrun caused by design complications, supplier and plant issues. From a bridge maintenance perspective, the integral nature means there is no bearings to inspect, maintain or replace. The nature of precast pretensioned concrete beams is that they are durable with minimal maintenance requirements and are visually easy to inspect with clean lines.

7.2.3 The steel composite multi-girder arrangement in the square arrangement is the second preferred option and compares favourably with the precast pretensioned beam construction form on several aspects. This option would provide a lighter construction than the pretensioned concrete alternative leading to potentially smaller substructure and foundations, particularly pertinent given the poor ground conditions. However, the economic costs are likely to be higher for the steel-concrete composite deck, see Section 9.1 for further detail.

7.2.4 The half-through girder, although initially thought to be able to provide a reduction in vertical alignment and potential savings on approach ramp heights, does not lend itself to the structure location due to the road alignment skew over the railway. This construction form is visually obtrusive due to the size of the girders and is likely to be controversial during the planning process. A large crane will be required to lift the girders into place and bearings and more complex expansion joints will be required. For these reasons this option was discounted.

7.3 Abutment

7.3.1 A summary of the abutment options benefits and disadvantages are summarised in Table 7-2 below. The abutment has been developed considered the precast pretensioned concrete beams or the steel-composite deck. Key comments are included for the different options, with a broad green being positive, orange being neutral and red being negative.

Table 7-2: Summary of abutment options

	RERW with columns behind the wall		RERW with columns in front of the wall		Full height cantilevered wall	
Achieves Requirements and Constraints		Integral		Integral		Integral

	RERW with columns behind the wall	RERW with columns in front of the wall	Full height cantilevered wall
Programme Implications	Smaller piles required	Smaller piles required	Large piles required which adds risk to programme
Safety Risks	No bearings to maintain	No bearings to maintain	No bearings to maintain
Commercial Risks	Proprietary materials- straps and fascia panels	Proprietary materials- straps and fascia panels	Conventional design and construction
Aesthetics	Clean lines adjacent to railway- assisting planning	Discrete Columns adjacent to railway	Clean lines adjacent to railway- assisting planning
Environment	Skeletal design is efficient with material	Skeletal design is efficient with material	Large quantities t of material and larger piles
Future Maintenance	Columns buried in RERW	Debris fills behind columns	Monolithic design with minimal maintenance requirements
Ease of Design & Construction	Well understood design & construction	Well understood design & construction	Well understood design & construction

7.3.2 The preferred abutment configuration solution is a **skeletal abutment with discrete columns behind a reinforced soil wall**. Although having the columns behind the reinforced soil wall introduces a maintenance concern, the columns will be designed with a 120-year design life, and appropriate cover for the buried exposure conditions. Additionally, this allows for clean lines to be adjacent to the railway.

7.3.3 The proposed alignment on the existing topography with the rail tracks leading to the Sidings on a valley means that the reinforced soil structure does not need to extend the full width of the structure. The reinforced soil structure will extend to a length required to retain the approach embankments with the remaining width of the abutments under the redundant triangular deck area sitting on discrete columns will remain open. As well as being likely to be cheaper than providing soil embankment extending to the full width of the abutment, this would also provide increased light and ventilation under the footprint of the bridge.

7.3.4 Impact loading is not required if the columns are placed greater than 4.5m from the cess in accordance with NA to EC 1 cl. NA2.30.

7.3.5 A skeletal arrangement provides a lightweight solution reducing the foundation sizes to as low as reasonably practical for an integral solution.

7.3.6 The skeletal abutment with discrete columns in front of the reinforced soil wall has the benefit of having the columns accessible for maintenance. However, it has been discounted due to it having discrete columns providing a gap between the columns and the wall which can introduce a maintenance and security concern.

7.3.7 A traditional full height cantilevered wall would provide a monolithic, durable solution, however for the soil conditions, this option would result in more expensive, larger foundations which is likely to not outweigh the initial potentially cheaper construction of the abutment compared to the skeletal arrangement.

7.4 Parapet

7.4.1 A summary of the parapet options benefits and disadvantages are summarised in Table 7-3 below. Key comments are included for the different options, with a broad green being positive, orange being neutral and red being negative. Only H4a (very high containment) have been considered.

Table 7-3: Summary of parapet options

	Reinforced Concrete Parapets (In-situ)	Reinforced Concrete Parapets (Pre-cast)	Metallic Parapets
Achieves Requirements and Constraints	H4a parapet	H4a parapet	H4a parapet
Programme Implications	Departure from Standard required	Departure from Standard required	Quick to install
Safety Risks	Able to install during deck construction	Requires lifting heavy precast parapets at height	Able to install during deck construction
Commercial Risks	Within contractors' control	Within contractors' control	Proprietary system with limited manufacturer options
Aesthetics	Clean aesthetic lines	Clean aesthetic lines	Susceptible to vandalism
Environment	Readily recycled	Readily recycled	Readily recycled
Future Maintenance	Minimal maintenance	Minimal maintenance	Requires maintenance
Ease of Design & Construction	Well understood construction methodology	Well understood construction methodology	Quick to install

7.4.2 The preferred parapet material is **reinforced concrete parapet**. Reinforced concrete parapets by their nature are significantly heavier than their metallic counterparts. Metallic parapets offer a practical solution when the deck is cantilevered, however this structure does not have a cantilever with the parapet sitting directly on the main longitudinal members. The initial cost and minimal maintenance requirement of reinforced concrete parapets make this option cost-effective over the whole life of the structure, compared to the metallic option. Although, the metallic parapet makes replacement of a section easier following significant impact, it is unlikely that this impact will occur on this relatively short stretch of road for the design life of the structure.

7.4.3 It is not unusual to provide a parapet design that can be altered to become precast relatively easily should the Contractor prefer this route for programme, cost and health and safety issues. It is therefore recommended that the parapets are reinforced concrete, with a view to develop an adaptable design that can accommodate the Contractor's preference. This supports the opportunity for off-site manufacture.

7.5 Existing Culvert

7.5.1 A summary of the existing culvert options benefits and disadvantages are summarised in Table 7-4 below. Key comments are included for the different options, with a broad green being positive, orange being neutral and red being negative.

Table 7-4: Existing culvert option

	Extending culvert		Diverting culvert	
Achieves Requirements and Constraints		Provides adequate drainage		Provides adequate drainage
Programme Implications		No need to rely on Hanson for the culvert under the railway tracks. Only new culvert extension to be constructed by OCC.		Fewer unknowns but reliant on agreement of Hanson to include its construction as part of their construction to add in additional tracks
Safety Risks		Differential settlement concerns including structural interface with the proposed structure		New culvert designed to standard with minimal interface with the proposed structure.
Commercial Risks		Construction is not reliant on Hanson and pose less commercial risk on the current scheme construction.		If Hanson cannot accommodate the construction as part of their rail track addition, OCC will have to bear more cost to do it later with all the tracks functional.
Aesthetics		N/A as underground		N/A as underground
Environment		OCC will not have any control over the maintenance of the existing culvert and may affect the functioning of the extended stretch.		New culvert designed to standard
Future Maintenance		Difficult access.		Easily maintained with clear structure ownership
Ease of Design & Construction		Connections between existing and old can be difficult.		Requires agreement with Hanson to construct new culvert under the railway tracks

7.5.2 Although there will be additional expense and work for construction of the diverted culvert underneath the railway tracks, the new culvert can be designed to current standards and reduces the future maintenance risk for both Oxford County Council and Hanson.

7.5.3 Options will be developed by the Drainage team and in cognisant with Hanson requirements as a key stakeholder.

8. Inspection & Maintenance

8.1.1 Inspection and maintenance are important components of an Options Appraisal. The following section discusses fencing arrangements, access and maintenance and durability considerations of the proposed option.

Parapets and fencing

8.1.2 The H4a parapets are placed parallel to the road as this is the more traditional alignment for parapets, with the Eurocodes loading developed with this intent. This arrangement leads to the two redundant triangles being cut off from access from the road on the structure and for a distance off the structure.

8.1.3 It is proposed that palisade fencing or similar is placed at the ends of the H4a parapets with a gate allowing access to the redundant triangles for maintenance and inspection personnel while preventing unauthorised access. Pedestrian guardrails with mesh infill will be required on the edges of the structure to prevent falls and debris dropping onto the track and provide an upstand for the surfacing or fill used to surface these areas.

Access

8.1.4 Topside, the areas between the parapets will be readily available for access from the carriageway and footway/cycleway. Touching distance access to the inside face of the west parapet will require a lane closure of the northbound carriageway. If reinforced concrete parapets are agreed, minimal maintenance will be required.

8.1.5 As described above, it is proposed that the redundant triangles behind the parapets will be accessed from the topside via access gates in the palisade fencing beyond the parapets.

8.1.6 After discussion with Hanson and the OCC TAA they have both expressed a preference that inspections and maintenance should be done with consultation with Hanson to ensure safety of the staff and also ensure there is no unwarranted access from members of the public. It is therefore proposed that the Hanson fence line will connect to the abutments with no access provision from the road. OCC will use their Statutory Powers under the Highways Act to gain access and it is understood that this access provision will be included in future legal agreements with Hanson.

Maintenance & Durability

8.1.7 One of the overarching aspects governing the recommended option is providing OCC with a structure that is easy and inexpensive to maintain. This structure is intended to be utilitarian in nature; in keeping with its industrial setting.

9. Illustrative Costs

9.1 Capital Costs

9.1.1 This Capital Cost section has been prepared to inform discussions on the weighting of options for comparative purposes only. Costs included are taken from Spon's Price Book for Civil Engineering Works 2020.

9.1.2 This exercise is not intended to inform the true cost of construction and must not be used for project budgeting purposes. These rates have not included for risk, Optimism Bias and design fees have not been included.

9.1.3 This high-level approach does not include for proprietary systems such as the reinforced soil wall or more uncertain engineering tasks such as piling which is heavily dependent on ground investigations. Additionally, cost of the culvert diversion or extension has not been included as all options require a culvert diversion or extension and it is difficult to sensibly quantify at this stage.

Capital costs for span arrangements

9.1.4 Prior to this option study, to establish the north and south support constraints and span arrangement 4 options were considered as part of a technical note (document reference: RIV_PD-ACM-SBR-SW_STR_ZZ-ZZ-RP-CB-0002 P02). The 4 options considered were:

- Option 1: Square Combined Bridge outside Hanson Redline boundary
- Option 1a: Square Road Bridge with separate NMU Bridge outside Hanson Redline boundary
- Option 2: Square Combined Bridge within Hanson Redline boundary
- Option 2a: Square Road Bridge with separate NMU Bridge within Hanson Redline boundary
- Option 3: Skewed Combined Bridge outside Hanson Redline boundary
- Option 3a: Skewed Road Bridge with separate NMU Bridge outside Hanson Redline Boundary.

9.1.5 Option 2 was found to be the cheapest option with the skewed bridge, Option 3, approximately £2.9 million more expensive. A copy of the costs can be found in Appendix G.

Capital costs for superstructure options

9.1.6 The options considered for the high-level costing are the deck construction options:

- Option 1: Pretensioned Concrete Beams with Skeletal Abutment
- Option 2: Steel-Concrete Composite with Skeletal Abutment

9.1.7 The skewed half-through girder deck option has not been considered as by inspection this bridge is going to be significantly more expensive than the Options listed above. Additionally, the structure will require bearings, complex expansion joints and will be visually intrusive.

9.1.8 A detailed cost analysis will be completed on approval of the proposed option as a baseline cost reference.

Table 9-1: High Level, top down estimate

Options	Option 1	Option 2	Commentary on Assumptions and Costs
Type of deck	Prestressed concrete deck	Steel-concrete composite	All references to pages are references to Spon 2020.
Type of abutment	Skeletal (RSW and columns)	Skeletal (RSW and columns)	Proprietary system so not included in cost allowance.
Type of foundation	Bored piles	Bored piles	Heavily dependent on GI so not included in cost allowance.
Geometry			
Span length (m)	24.65	24.65	
Width (m)	82.45	82.45	
Total area (m2)	2032	2032	Bridge deck areas have been taken from our CAD models for ease, due to the curvature of the deck.
Estimated costs from Spon 2020: Approximate Estimating Rates	*(Text taken from SPONS) "These costs are taken per m² of deck area between abutments. The rates include all items associated with the bridge and abutments including excavation, reinforcement, formwork, concrete, bearings, expansion joints, waterproofing, finishes, and simple parapet, but exclude any approach works and foundations."*		
Cost of prestressed beams (£/m2)	2600		Assuming Span 22m, pg 153 of SPONs 2020 gives a rate of £2600 to £4450. Noting that if this option is to be selected it is a large but not complex structure so we can take some economy of scale, hence the lower end of the scale has been taken.
Cost of steel-concrete composite (£/m2)		3400	Assuming Span, 20m, pg. 153 of SPONs 2020 gives a rate of £3400 to £5900. Noting that if this option is to be selected it is a large but not complex structure so we can take some economy of scale, hence the lower end of the scale has been taken.
Cost (£)	£5,284,221	£6,910,135	
Difference from baseline option	£0	£1,625,914	

9.1.9 This high-level costing exercise indicates that the precast prestressed concrete beams are likely to be cheaper than the steel-composite deck arrangement.

9.2 Whole Life Costs

9.2.1 A whole life costing exercise has been completed for the two superstructure options: prestressed concrete beams and steel-concrete composite and is included in Appendix F. These costs have been calculated for comparative purposes and do not reflect absolute maintenance costs and do not include the cost of new construction.

9.2.2 A Life Cycle planning approach was used to derive the Whole Life Cost (WLC) and determine the total cost of ownership of the elements of the proposed structure covered under the current project scope. The life cycle planner was used as a tool to provide the spread of the cost of managing the asset and a measurement of the depreciation of the asset.

9.2.3 Individual elements of the bridge have considerably different life cycles e.g. shorter life of parapets compared to longer life for waterproofing. Hence, the structure was broken down into its component levels for the purpose of the life cycle planning. The elements considered under the scope of this project were assigned with the current condition score as new (1A) and used to predict the functional life for these elements.

9.2.4 The following assumptions have been used for the Whole life costing:

- Capital costs include for Contractors and Designers costs and allowance for traffic management.
- General and Principal Inspection costs are excluded.
- Costs are based on current rates on similar projects without any allowance for inflation and are not to be treated as actual work costs.
- No allowance included for risk or contingency.
- Traffic delay costs, third party costs, service diversion costs, socio-economic impacts, and any other monetised risk and/or benefits are not included.

9.2.5 It should be noted that the whole life costing does not provide a particularly useful comparison or method for choosing between the two superstructure options as the structural components of the bridge have a design life of 120 years which is greater than the 60 years considered for the Whole Life Costing. Additionally, the components that contribute to the Whole Life costs, the parapets, waterproofing, surfacing area are the same for both options.

9.2.6 The whole life costing over 60 years has a maintenance activity cost of £955,446, with an additional uplift for preliminaries such as traffic management and night working increasing this value to £1,959,481.

9.3 Environmental Costs

9.3.1 Sustainability and how best to achieve it, is now an important aspect for the entire construction industry. Running in conjunction with the overall issue of sustainability is the desire to limit carbon footprints, not just for entire companies but also for projects, large and small. This applies to the construction of bridges, but until recently there has not been a definitive way of calculating the carbon footprint of these structures.

9.3.2 Tata Steel and the BCSA in conjunction with Atkins developed a spreadsheet tool for estimating the carbon footprint of a typical steel- concrete composite bridge. This tool has been modified to allow for a comparison between the pretensioned concrete beam and the steel-concrete composite bridge option.

9.3.3 The spreadsheet allows the total carbon emissions to be calculated for a structure. The tool determines the $C0_2$ associated with site set-up and close down, materials, transportation of materials and plant used during construction and maintenance and the traffic delay during bridge construction and maintenance.

9.3.4 Using preliminary quantities for the superstructure, substructure and foundations the spreadsheet then calculates the embodied carbon. It should be noted that the substructure and foundations are considered the same in the calculations.

9.3.5 The pretensioned concrete beam option had a total embodied CO_2 of 6950t CO_2 compared to an embodied CO2 of 7339 tCO2 for the steel-concrete composite deck. Refer to Appendix D for the spreadsheets.

9.3.6 This indicates that the embodied carbon of the steel-concrete composite deck is 5% higher than the pretensioned concrete beam which is negligible.

10. Recommended Option

10.1.1 The recommended option is summarised below in Table 10-1 below.

Table 10-1: Summary of recommended Option

Clear Span	22m Square
Articulation	Fully Integral deck
Superstructure	Precast pretensioned concrete beams with an insitu reinforced concrete slab on top
Substructure	Skeletal abutment- Reinforced soil structure to retain the approach embankments with discrete sleeved columns behind
Foundations	Bored reinforced concrete piles with reinforced concrete pile caps
Parapets	Reinforced Concrete (in-situ or precast)
Existing Culvert	Extension or Diversion

10.2 Departures from Standard

10.2.1 As noted in the Parapet section, section 6.7, a departure from standard from CD 377 will be required to design the reinforced concrete parapets to BS 6779-2 instead of Eurocodes.

10.2.2 Also noted in the Parapet section, section 6.7, a departure from standard from CD 377 for providing an N2 parapet instead of H4a parapets could be considered.

10.2.3 It is not anticipated that any other Structure departures are required at this stage.

10.3 Construction Methodology

10.3.1 It is anticipated at this stage that the construction methodology will follow a “bottom up” approach, i.e. foundations, abutments, deck, parapets, surfacing.

10.3.2 A high-level sequence of events has been developed to indicate initial proposals of how the structure could be constructed. It should be noted that this construction methodology only considers this structure and the immediate approach embankments. It does not consider the phasing of the wider scheme.

Welfare and Site Compound

10.3.3 The site is relatively cut-off from publicly available access routes due to the mainline railway and Appleford Level Crossing to the east and Hanson Quarry, Sidings and balancing ponds to the west. Possible site compounds are shown in Figure 10-1 below.

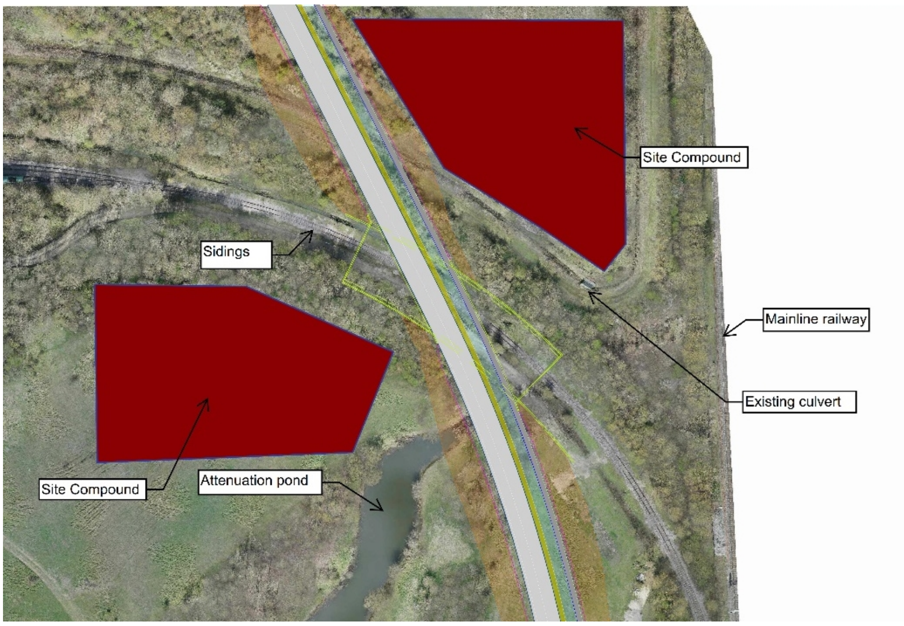


Figure 10-1: Welfare and Site Compound

10.3.4 It is proposed that there are two site compounds; one to the north east and to the south west quadrants of the site. The reasoning behind two site compounds is due to the Appleford Sidings severing the site and difficulties in transferring material over live tracks. Access to the north site compound can be achieved by building an access track down the side of the field from the B4016, 600m to the north. Access to the south site compound will come from the private Hanson road accessed either over Appleford Level Crossing or to the south from Collets roundabout. This access will need to be agreed with the landowners.

<u>Construction sequence</u>

10.3.5 With a “bottom up” approach it is intended that the foundations are built first. The high-level construction sequencing is as follows:

- Set up site compound
- Decommission existing culvert and lay new culverts or extension of the existing culvert.
- Construct foundations.
- Construct substructure and wing walls.
- Lift precast pretensioned beams onto substructure.
- Cast deck and parapets.
- Waterproof deck.
- Install statutory undertaker ducts and subsurface drainage.
- Lay surfacing install pedestrian guardrails and kerbs.
- Install fencing and access gates.
- Decommission site compounds.

10.4 Risks and Opportunities

Risks

10.4.1 Principal Health, Safety & Environment risks considered at this stage are as follows:

- Working adjacent to and over live railway.
- Unforeseen ground conditions, including the potential for loose fill/restoration works.
- Potential for disturbing contaminated ground.
- Impact on ecology and any flora/fauna present.

Opportunities

10.4.2 The extent of the uncompacted fill is only estimated at this stage from historic boreholes. The uncompacted fill has been assumed to have no structural capacity. If, following a detailed ground investigation, it is found to be more extensive than currently estimated, the design of the foundations as assumed in the preliminary design and associated costing is subject to change.

10.4.3 The precast beams could have a small skew and be placed parallel to each other to reduce the redundant triangle footprint areas.

10.4.4 The number of precast beams could potentially be reduced from 75no. Y3 beams at 1m c/c to 38No. deeper Y7 beams at 2m c/c. Y7 beams are 400mm deeper and 30% heavier than Y3 beams so may not be able to be accommodated by the proposed vertical alignment without considerable expense of raising the approach ramps. Additionally, the crane required to lift the Y7 beams at the required radius may make this prohibitive.

10.4.5 As part of the diversion of the existing culvert, the section of the culvert underneath the Sidings could be constructed as part of Hanson’s expansion of the Sidings to limit disruption to the railway during this structure’s construction programme.

10.4.6 The H4a parapets could be explored to be precast if the Contractor has a predisposition to having as much of the structure precast as possible.

10.4.7 N2 parapet provision instead of H4a parapet subject to a Departure from Standard approval and agreement with Hanson.

10.4.8 Localised widening of the west verge to improve the northbound visibility splay.

10.4.9 The current arrangement is for the reinforced soil walls to continue the whole length of the abutments. This is not necessarily required as the reinforced soil wall is only required to retain the approach embankments. The length of the reinforced soil walls could be reduced by returning the walls at 90° at the edges of the road embankments with the precast pretensioned beams supporting the redundant triangles sitting on the concrete diaphragm and discrete columns. The advantage of this opportunity is the reduction in embankment fill; however, this option may not be preferred visually. Refer to Figure 10-2 below. This option has since been agreed since the P01 revision and is now shown in Appendix A General Arrangement.

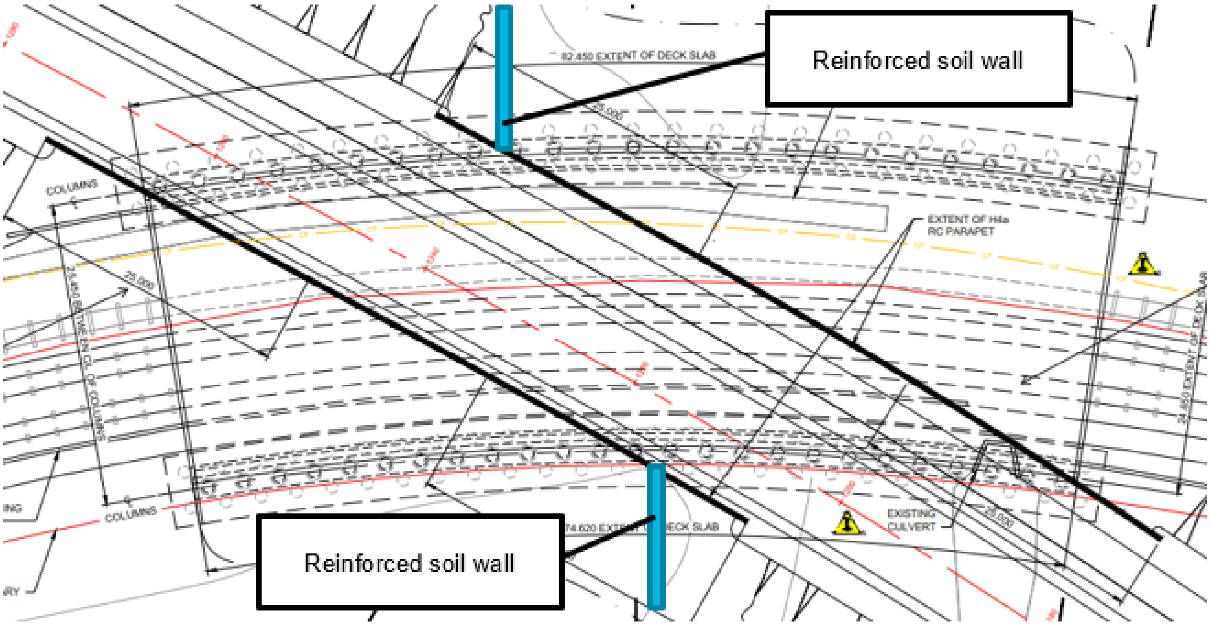
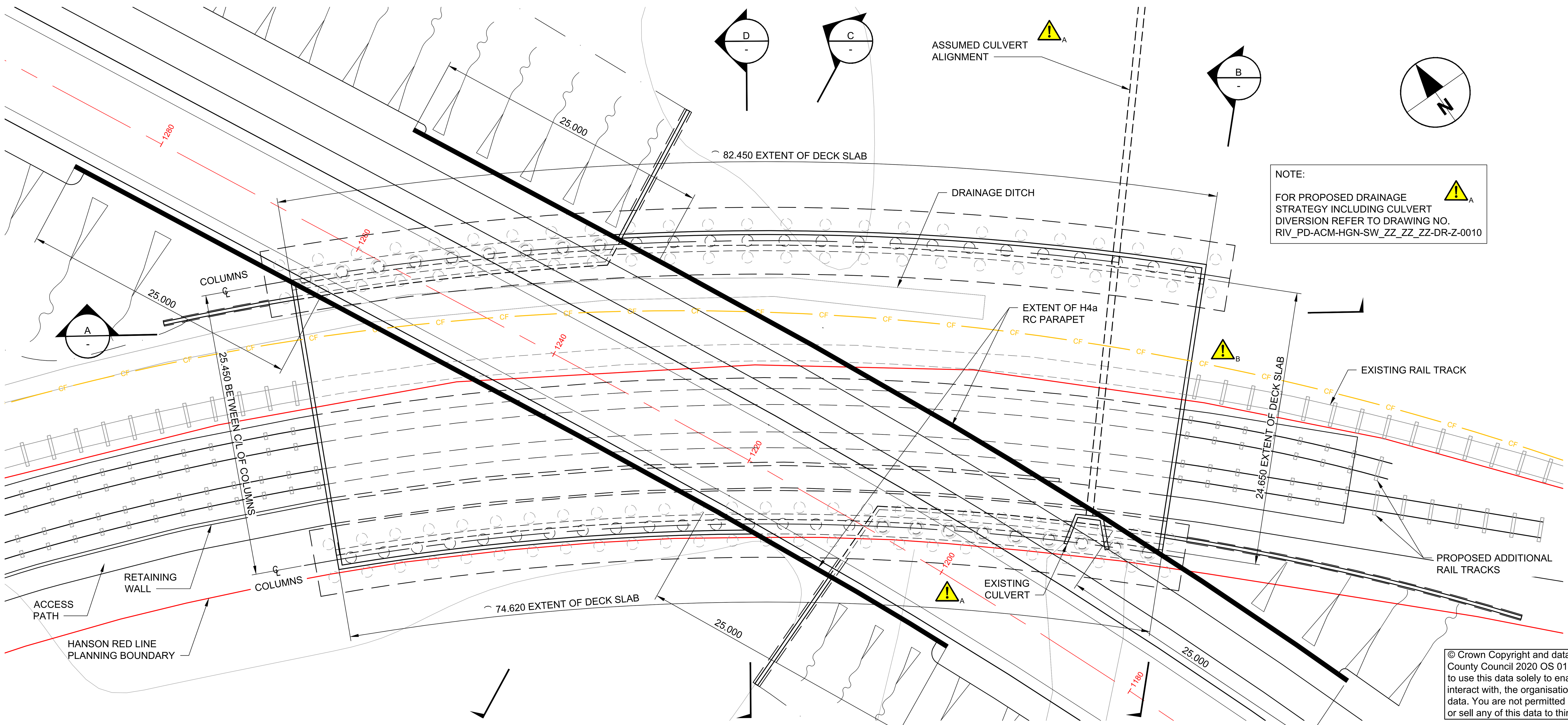
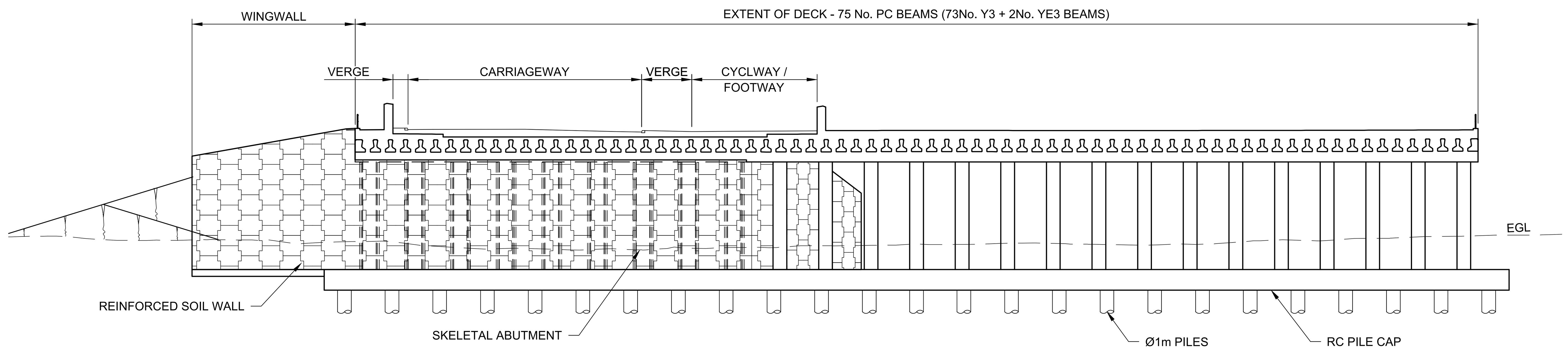


Figure 10-2: Opportunity to reduce embankment fill

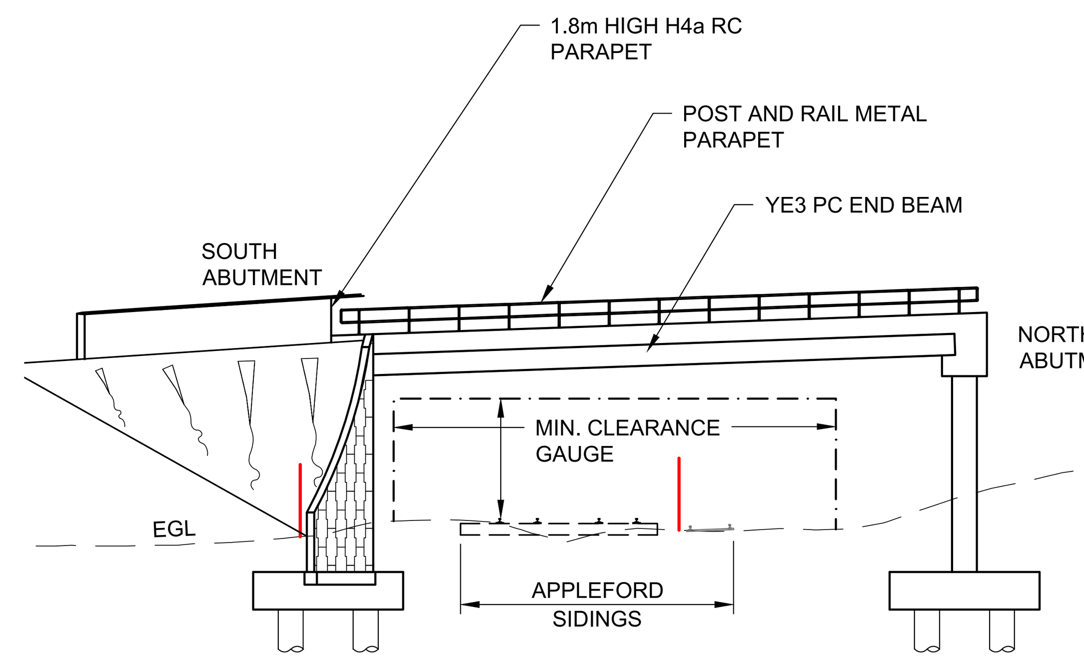
Appendix A Drawings



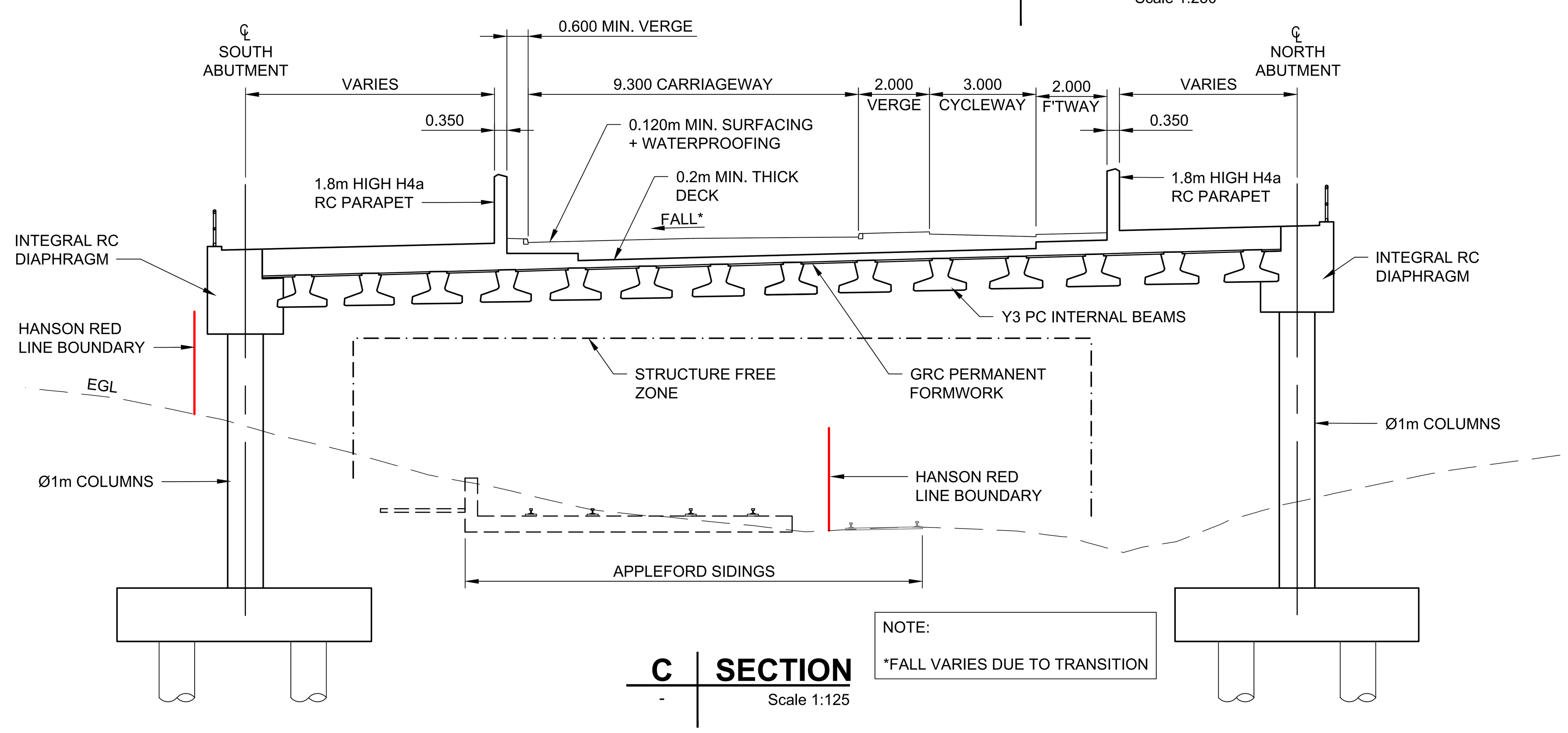
PLAN
Scale 1:250



A - ELEVATION
Scale 1:250

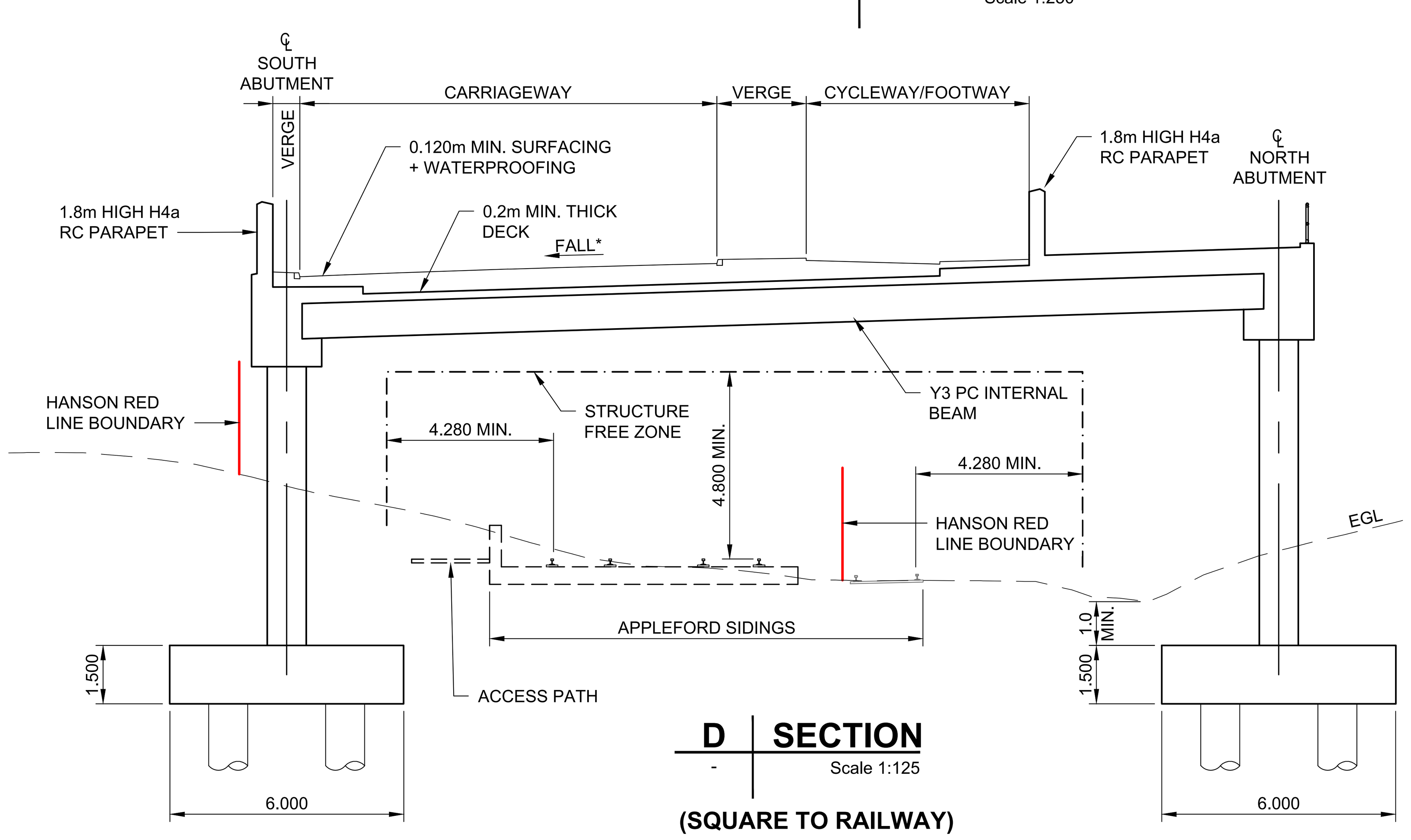


B - ELEVATION
Scale 1:250



C - SECTION
Scale 1:125

(SQUARE TO CARRIAGEWAY)



D - SECTION
Scale 1:125

(SQUARE TO RAILWAY)

IT IS ASSUMED THAT ALL WORKS ON THIS DRAWING WILL BE CARRIED OUT BY A COMPETENT CONTRACTOR WORKING, WHERE APPROPRIATE, TO AN APPROPRIATE METHOD STATEMENT.

THIS DRAWING IS TO BE USED ONLY FOR THE PURPOSE OF ISSUE THAT IT WAS ISSUED FOR AND IS SUBJECT TO AMENDMENT.

NOTES:

1. ALL DIMENSIONS ARE IN METRES UNLESS OTHERWISE STATED.
2. DO NOT SCALE FROM THIS DRAWING.

SAFETY, HEALTH AND ENVIRONMENTAL INFORMATION

THE FOLLOWING NOTES HIGHLIGHT SIGNIFICANT RESIDUAL HAZARDS IDENTIFIED BY THE DESIGNER. TYPICAL HAZARDS THAT SHOULD BE IDENTIFIED BY A COMPETENT CONTRACTOR ARE NOT INCLUDED. THE CONTRACTOR SHALL CARRY OUT THE WORKS USING AN APPROVED SAFE SYSTEM OF WORK.
FURTHER INFORMATION ON RESIDUAL HAZARDS CAN BE FOUND ON THE SiD WORKBOOK RESIDUAL HAZARD LOG.

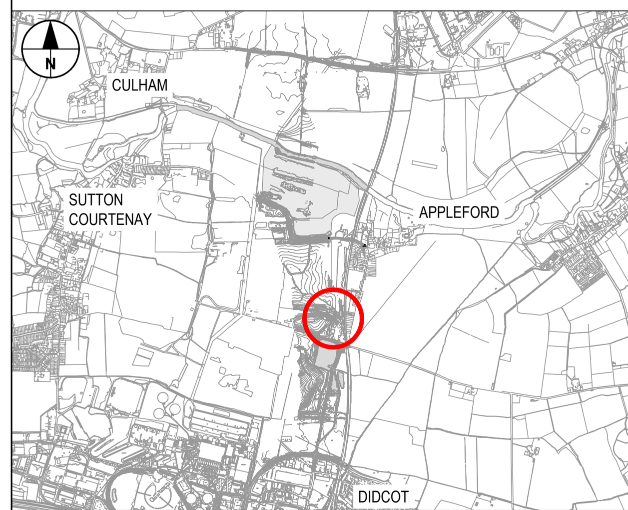
USE OF WARNING TRIANGLES ON DRAWINGS

REF	HAZARD
A	South abutment clashes with culvert. Diversion or extension required.
B	Buried utilities in vicinity of works.

SIGNIFICANT HAZARDS PRESENT THROUGHOUT THE EXTENT OF THE WORKS WHICH ARE DEEMED BY THE DESIGNER TO BE UNAVOIDABLE AND CANNOT BE ELIMINATED OR REDUCED ARE LISTED IN THE TABLE ABOVE. WHERE PRACTICAL THE LOCATION OF INDIVIDUAL HAZARDS ARE INDICATED ON THE DRAWING. FOR FURTHER DETAILS, SEE RESIDUAL DESIGN HAZARD REGISTER IN PRE-CONSTRUCTION INFORMATION.

LEGEND:

CF — CityFibre



REVISION DETAILS	By / Check	Date	Suffix
Issued for Comment	IR / KC	30/10/20	P01
Issued for Approval	IR / KC	11/12/20	P02

Purpose of issue
SUITABLE FOR APPROVAL

Client
OXFORDSHIRE COUNTY COUNCIL

Project Title
DIDCOT GARDEN TOWN
HIF 1 SCHEMES
PRELIMINARY DESIGN

Drawing Title
APPLEFORD SIDINGS
ROAD BRIDGE
OPTION STUDY
GENERAL ARRANGEMENT

Designed	Drawn	Checked	Approved	Date
SM	IR	SM	KC	11/12/20

Internal Project No. 60632497 | Suitability S4
Scale @ A1 AS SHOWN | Discipline Civil - Bridge and Structures

AECOM
Sunley House
4 Bedford Park
Croydon
CR0 2AP
Tel: +44 (0)20 8639 3500
www.aecom.com

AECOM Infrastructure & Environment UK Limited
Registered in England Registered number: 880328
Registered office: Midpoint, Alencon Link, Basingstoke, Hampshire RG21 7PP

Drawing Number
Work Package ID | Originator | Volume
RIV_PD - ACM - SBR -
DGT_STR_ZZ_ZZ - DR - CB - 0010
Location | Type | Role | Number
Rev P02

Plot Date : 11 December 2020 15:43:38
File Name C:\PWWORKING\AECOM_DS02_UK-CLYIAN.ROBINSON@AECOM.COM\D0130893\RIV_PD-ACM-SBR-DGT_STR_ZZ_ZZ-DR-CB-0010

Appendix B Designers Risk Register

Menu | SiD Procedure | Instructions | Safety Review Check List | Safety Symbols | Residual Hazard & Risk Log | SiD DOCS | Example Sheet | Revision

AECOM

Preliminary Design - SiD Assessment

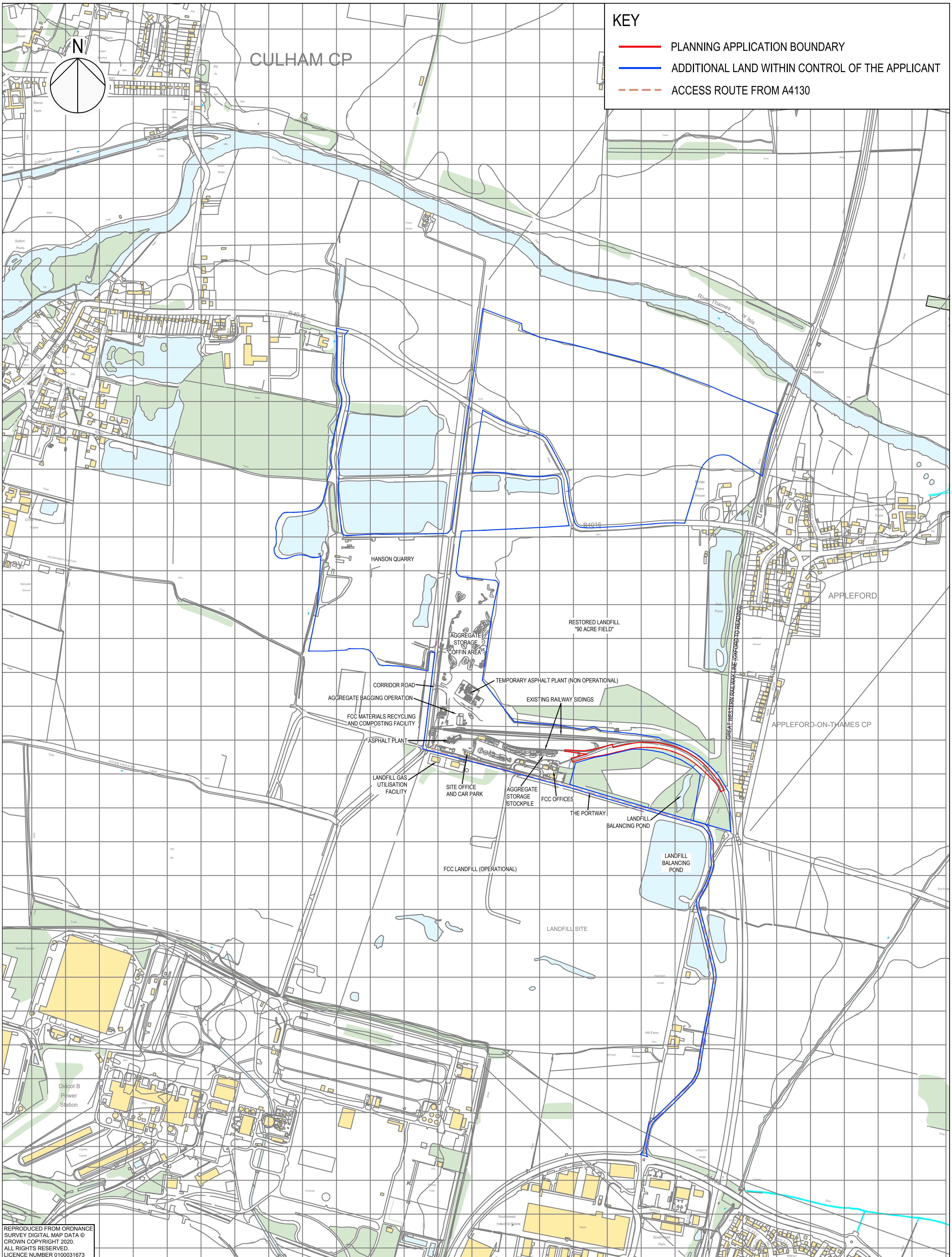
AECOM Project Name:	Didcot Gardent Town HIF 1 Schemes River Crossing
AECOM Project No:	6060782

Risk Rating (Probability x Severity)
1 to 4 (Low)
5 to 9 (Medium)
10 to 25 (High)

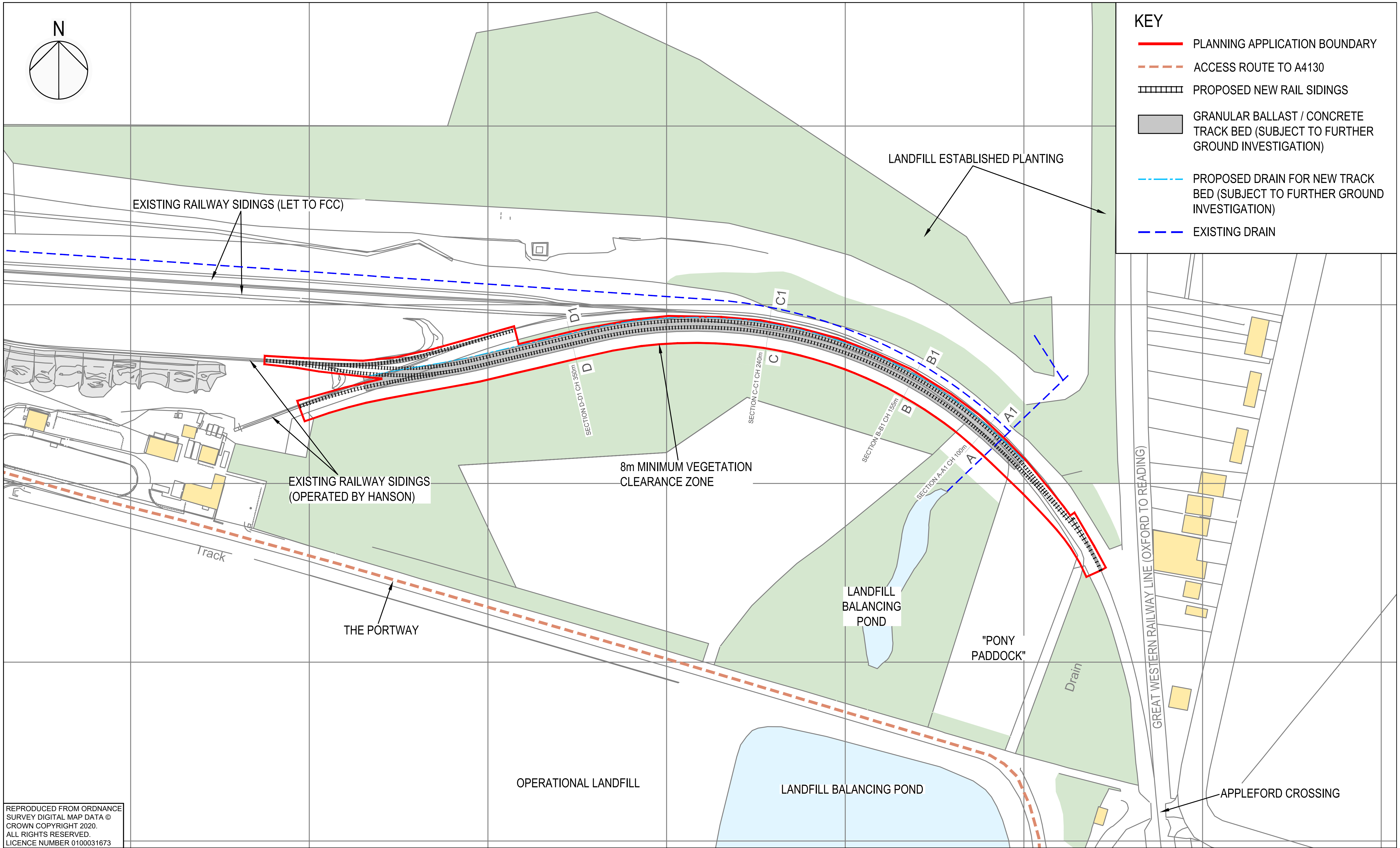
	Severity				
Probability	5 - Catastrophic	4 – Critical	3 – Major	2 – Moderate	1 - Minor
5 – Frequent	25	20	15	10	5
4 – Probable	20	16	12	8	4
3 – Occasional	15	12	9	6	3
2 – Remote	10	8	6	4	2
1 - Improbable	5	4	3	2	1

Hazard and Risk Identification						Pre-mitigation assessment			Mitigation	Post-mitigation assessment				Output				
Item No.	Feature, element, structures, process or activity considered	Client's or other H&S Information used	Significant Design Hazards Identified	Design Risks Identified	Environment/Persons at Risk?	Severity	Probability	Risk Factor	Design input Control to Eliminate or Reduce Hazard and/or Reduce Risk	Has Selected Control created a new Hazard? (Y/N)*	Severity	Probability	Risk Factor	Output Residual Hazard to Residual Hazard Log	Output Residual Risk to Residual Hazard Log	Ownership	Output Residual Design Hazard Feedback Location	Closeout date for Output
RS 1	Rail Sidings Bridge Existing Culvert	Topographical Survey	Culvert severed by proposed bridge abutment.	Flooding of railway Washout of abutment foundations	Local area Construction staff & plant	5	4	20	Establish culvert owner and maintainer. Obtain archive information. Liaise with drainage team when deciding upon Bridge option GAs. Explore if culvert requires extending or diverting.	NO	5	3	15	Culvert severed by bridge abutment	Flooding of railway Washout of abutment foundations	AECOM	Rail Sidings Bridge	
RS 2	Rail Sidings Bridge Existing Culvert	Topographical Survey	Culvert collapses from increased loading on structure Disturbance of supporting soil from nearby piling activity	Flooding of railway Washout of abutment foundations Settlement of railway line	Local area Construction staff & plant Railway users	5	4	20	Establish culvert owner and maintainer. Obtain archive information. Consider if assessment is required to confirm structural adequacy of the culvert.	NO	5	3	15	Culvert collapses from increased loading or construction activity	Flooding of railway Washout of abutment foundations Settlement of railway line	AECOM	Rail Sidings Bridge	
RS 3	Rail Sidings Bridge Ground Information	Historic boreholes	Bridge substructure and foundations not suitable for ground conditions	Bridge foundations unsuitable leading to construction issues or structure instability.	Local area Construction staff & plant Railway users	5	4	20	Structures team to liaise with Geotechnics team when specifying the GI to ensure enough quality data is obtained. GI to be undertaken in a timely manner to feed into Structures options report.	NO	5	2	10	Bridge substructure and foundations not suitable for ground conditions	Bridge foundations unsuitable leading to construction issues or structure instability.	AECOM	Rail Sidings Bridge	
RS 4	Rail Sidings Bridge Horizontal alignment	Highways Alignment DMRB standards Topographical Survey	Bridge carriageway and ped width provision too narrow.	Road Traffic Accident/ NMU accident	Public	5	4	20	Structure team to liase with Highways team to understand cross section of alignment including required sight lines for design speed of road. Alignment to be compliant with CD 127. Highways Team to have design freeze to allow Structures team to progress.	NO	5	1	5	Cross section to narrow	Road Traffic Accident/ NMU accident	AECOM	Rail Sidings Bridge	
RS 5	Rail Sidings Bridge Vertical Alignment	Highways Alignment DMRB standards Topographical Survey	Freight clash with structure	Impact damage to structure Impact damage to Freight	Public Railway users	5	4	20	Structures team to liaise with Rail users (Hanson and FCC) to understand Structure Free Zone (SFZ) requirement and ensure is compliant with NR standards. Make sure Highways Team are aware of dimension and the footprint when they develop vertical alignment. Dimension to include additional tolerances for deflection from live loading, construction tolerances. Additional risk: High embankments/retaining walls.	YES	5	1	5	Vertical alignment to shallow over Railway line	Impact damage to structure Impact damage to Freight	AECOM	Rail Sidings Bridge	
RS 5A	Rail Sidings Bridge High embankments/Retaining Walls	Highways Alignment DMRB standards Topographical Survey	Fall from height.	Road Traffic Accident/ NMU accident Construction accident	Public Railway users Construction staff & plant	5	4	20	H4a parapets to be specified over the railway and extended sufficent length beyond/after structure in accordance with CD 377. RRRAP assessment or risk assessment (LARA) to be produced by Highways Team to assess risk and specify fencing where required. Construction methodology to be developed with working at height risks included.	NO	5	1	5	Fall from height.	Road Traffic Accident/ NMU accident Construction accident	AECOM	Rail Sidings Bridge	
RS 6	Rail Sidings Bridge Piling adjacent to railway		Disturbance to railway line from vibration Disturbance to culvert from vibration	Freight derailment	Railway users	5	3	15	GI to be carried out to inform Structure foundation choice with consideration of vibration impact on the tracks.	NO	5	1	5	Disturbance to railway line from vibration	Freight derailment	AECOM	Rail Sidings Bridge	
RS 7	Rail Sidings Bridge Proposed Hanson Construction works	Hanson Planning drawings	Clash due to change from Hanson planning drawings.	Numerous design risks; leading to rework of AECOM design	Railway Users Public Construction staff	5	4	20	Understood that Hanson Construction work is likely to be complete prior to River Crossing being on site. Regular communication with Hanson team to understand their project requirements. Early agreement of constraints to be agreed in simple drawing before AECOM design progresses. Degree of conservativity in assumptions to allow for changes.	NO	5	3	15	Clash due to change from Hanson planning drawings.	Numerous design risks; leading to rework of AECOM design	OCC	Rail Sidings Bridge	
RS 8	Rail Sidings Bridge Working/ Lifting Beams over Railway	Topographical Survey	Beams/material falling from height onto railway	Damage to track Injury/death to Construction staff	Railway Users Construction staff	5	4	20	Design to consider construction methodology to ensure it is feasbile for construction of the bridge. Possession of railway for lifting of the beams.	NO	5	2	10	Beams/material falling from height onto railway	Damage to track Injury/death to Construction staff	AECOM/ OCC	Rail Sidings Bridge	
RS 9	Rail Sidings Bridge Constructing adjacent to railway	Topographical Survey Hanson Planning drawings	Construction material falling onto railway	Freight derailment Injury/death to Construction Staff and Rail Users	Railway Users Construction staff	5	4	20	Abutments to be set out at a sufficient distance from the rail track to allow construction of the abutment. Temporary works to be designed by Contractor.	NO	5	2	10	Construction material falling onto railway	Freight derailment Injury/death to Construction Staff and Rail Users	AECOM/OCC	Rail Sidings Bridge	
RS 10	Rail Sidings Bridge Isolated Site	Topographical Survey Hanson Planning drawings	Construction material/plant can't get to site	Local environment Injury/death to Construction staff	Construction staff & plant	5	3	15	Access road from the B4016 Appleford Road to be explored. Issues with traffic conflict using Hanson private access road.	NO	5	1	5	Isolated site leading to construction material/plant having difficulties getting to site.	Local environment Injury/death to Construction staff	OCC	Rail Sidings Bridge	
RS 11	Rail Sidings Bridge Inspection/maintenance of bridge	Topographical Survey Hanson Planning drawings	Inspector/Freight accident	Injury/death to inspection/maintenance staff and rail users	Railway Users Inspection/Maintenance Staff	5	3	15	Access from topside to the bridge to be considered to allow bridge inspection/mainenance of the substructure without entering the railway environment unless necessary for inspecting the underside of the bridge.	No	5	1	5	Inspector/Freight accident caused by lack of access provision.	Injury/death to inspection/maintenance staff and rail users	AECOM/OCC	Rail Sidings Bridge	

Appendix C Hanson Planning Drawings



Project Title	Figure Title	Purpose of issue	
APPLEFORD RAIL SIDINGS	PLANNING APPLICATION BOUNDARY AND LAND OWNERSHIP	Designed: - / Drawn: AAO / Checked: HW / Approved: HW / Date: 03/20	AECOM Royal Court, Basil Close Chesterfield Derbyshire. S41 7SL Telephone. (01246) 209221 Fax. (01246) 209229 www.aecom.com
Client: Hanson HEIDELBERGCEMENT Group		AECOM Internal Project No. 60596044	Figure Number 60596044.APP.RAIL.002
		Scale @ A3 1:10,000	Rev -



Project Title APPLEFORD RAIL SIDINGS	Drawing Title PROPOSED SITE LAYOUT	Purpose of issue				
		Designed -	Drawn AAO	Checked HW	Approved HW	Date 04/20
Client Hanson HEIDELBERGCEMENTGroup		AECOM Internal Project No. 60596044		Suitability -		
		Scale @ A3 1:2,000		Zone / Mileage -		

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Royal Court, Basil Close
Chesterfield
Derbyshire. S41 7SL
Telephone. (01246) 209221
Fax. (01246) 209229
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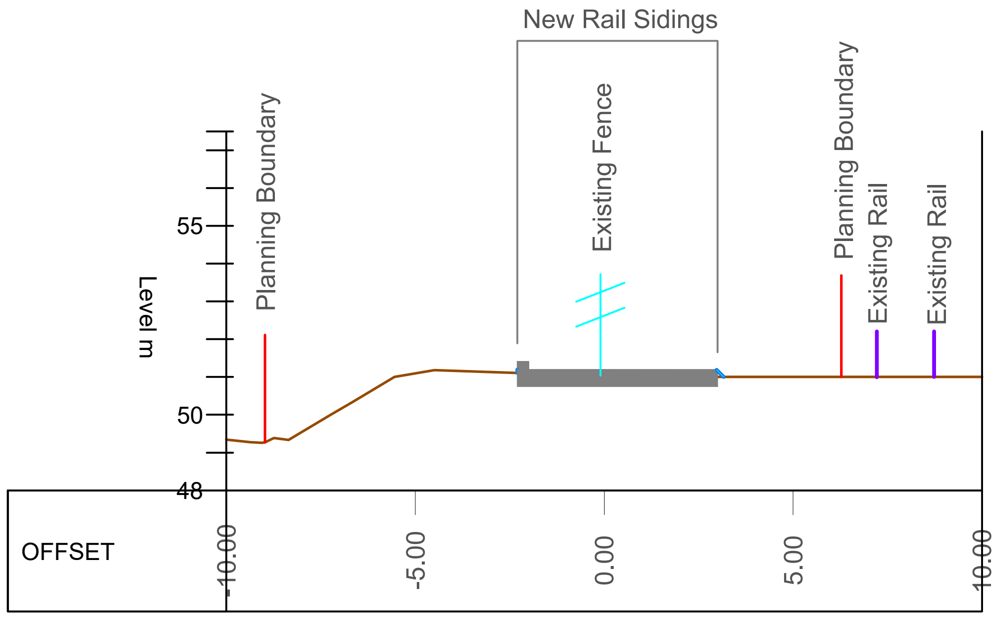
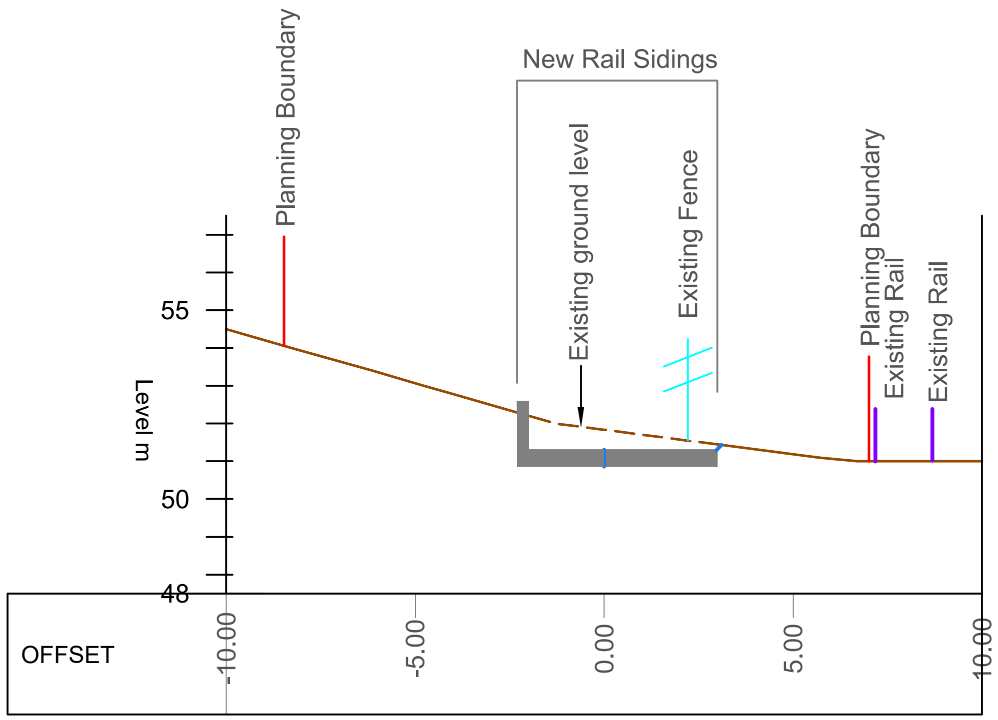
Drawing Number	Rev
60596044.APP.RAIL.005	-

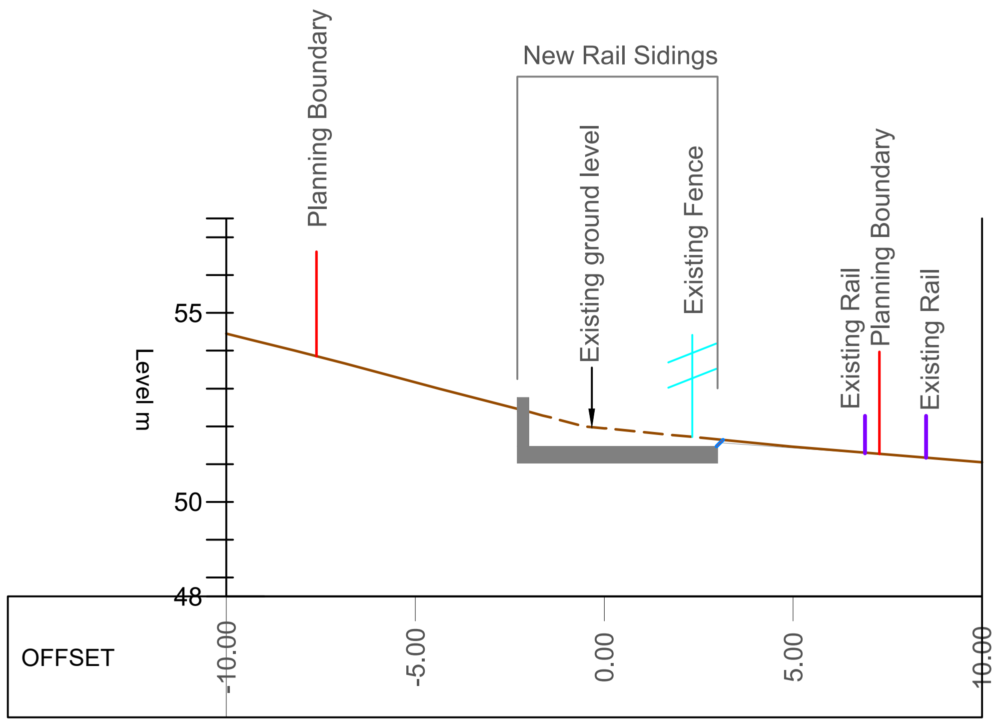


SECTION A-A1 CHAINAGE 100m

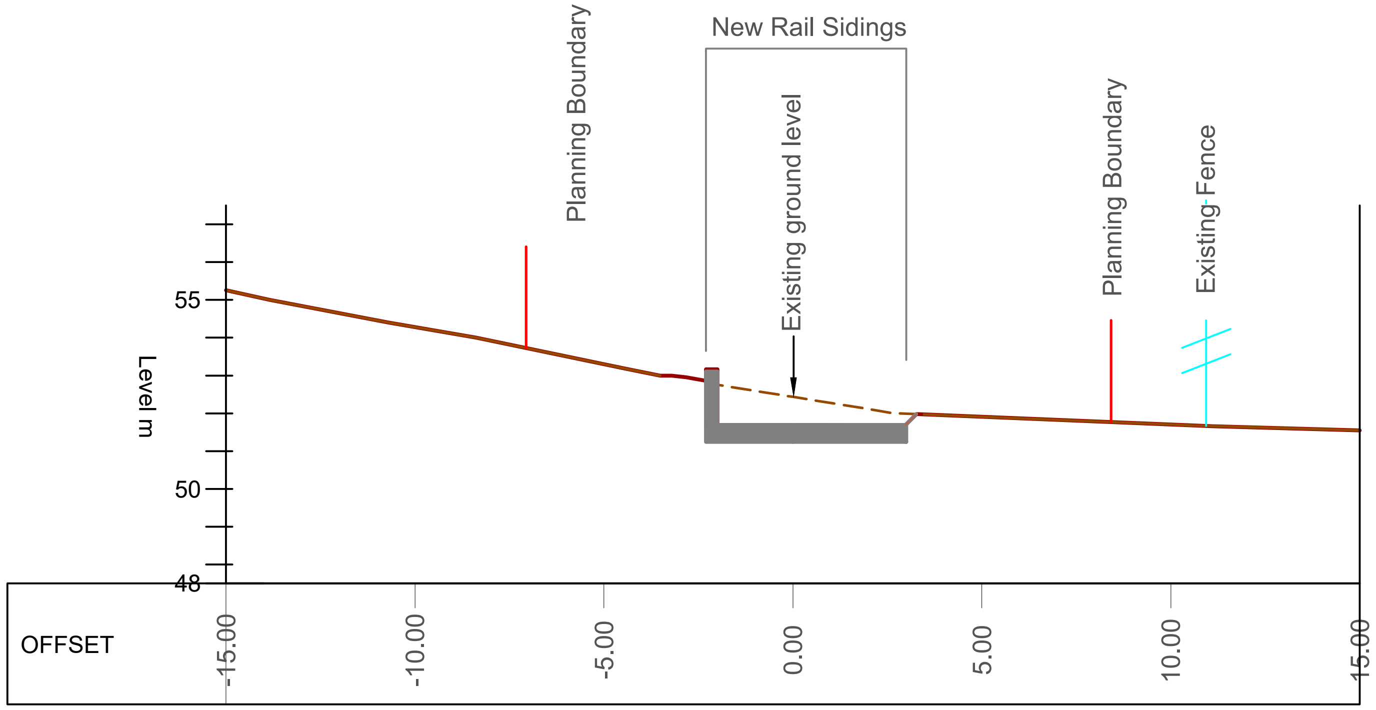


SECTION B-B1 CHAINAGE 155m

Note:
This drawing is for planning purposes only and will be subject to change during detailed design. Under no circumstances must this drawing be used for scaling or measuring for construction purposes.



SECTION C-C1 CHAINAGE 240m



SECTION D-D1 CHAINAGE 350m

NOTE
for locations of cross sections see 60596044.APP.RAIL.005 proposed site layout

Project Title: APPLEFORD RAIL SIDINGS	Drawing Title: INDICATIVE CROSS SECTIONS	Purpose of issue			
		Designed: -	Drawn: AAO	Checked: HW	Approved: HW
		Date: 04/20			
Client: Hanson HEIDELBERGCEMENTGroup		AECOM Internal Project No.: 60596044	Suitability: -		
		Scale @ A3: 1:200	Zone / Mileage: -		

AECOM
Royal Court, Basil Close
Chesterfield
Derbyshire. S41 7SL
Telephone. (01246) 209221
Fax. (01246) 209229
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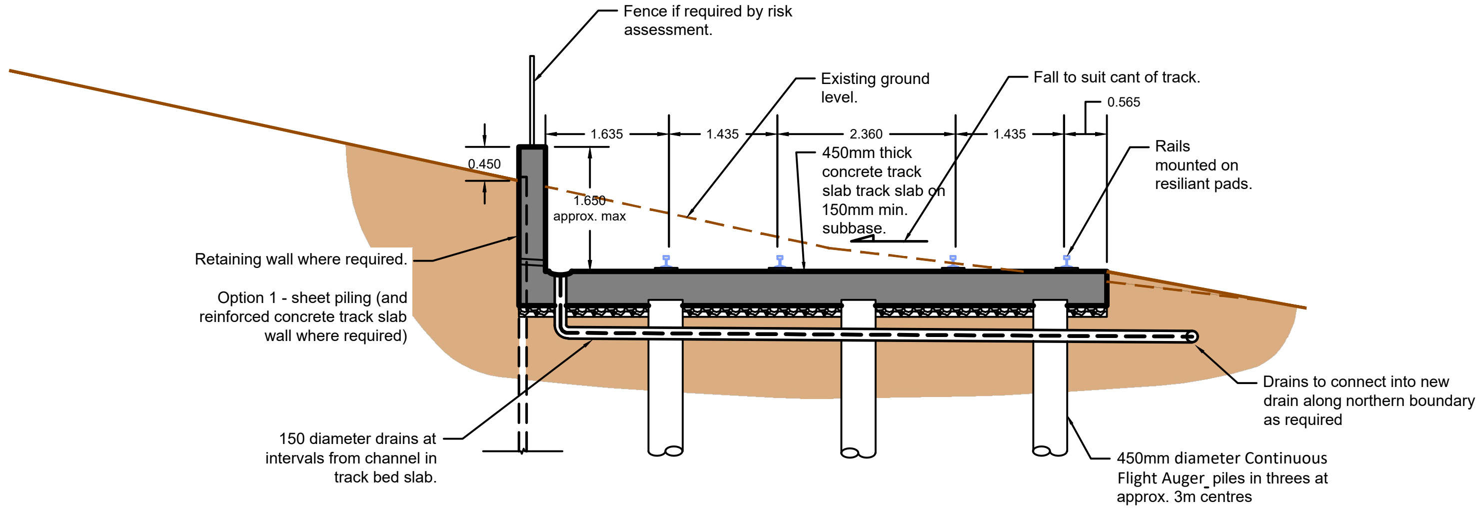
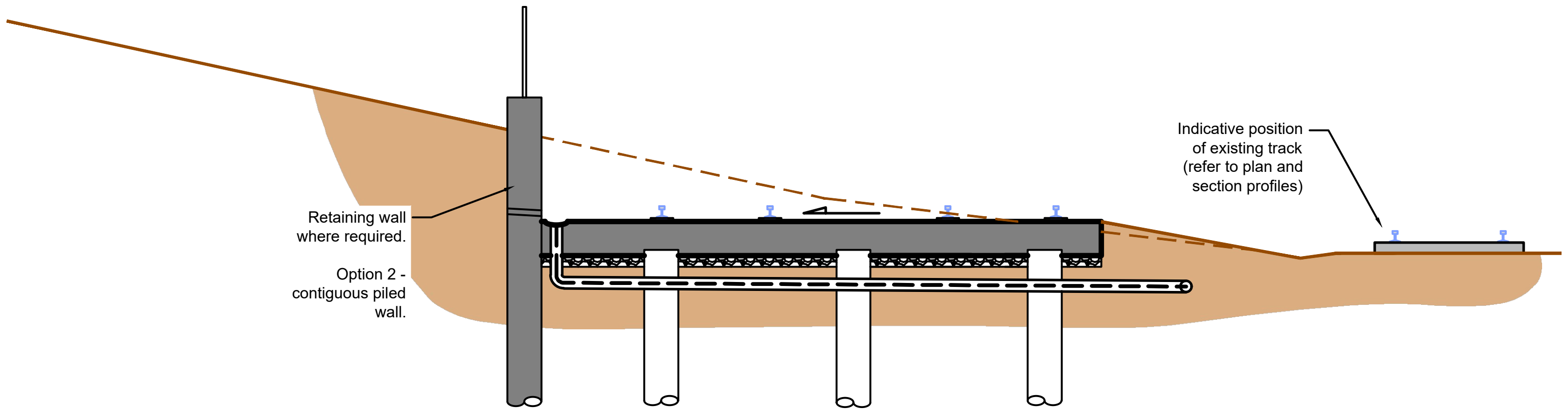
Drawing Number: 60596044.APP.RAIL.008
Rev: -



PROPOSED SECTION ON TRACK SLAB AT RETAINING WALL
Option 1 - Sheet-piled Retaining Wall
(1:100)

Note:
This drawing is for planning purposes only and will be subject to change during detailed design. Under no circumstances must this drawing be used for scaling or measuring for construction purposes.



PROPOSED SECTION ON TRACK SLAB AT RETAINING WALL
Option 2 - Contiguous Piled Wall.
(1:100)

Project Title: APPLEFORD RAIL SIDINGS	Drawing Title: INDICATIVE CROSS SECTION DETAIL	Purpose of issue				
		Designed: -	Drawn: AAO	Checked: HW	Approved: HW	Date: 04/20
Client: Hanson HEIDELBERGCEMENTGroup		AECOM Internal Project No.: 60596044		Suitability: -		
		Scale @ A3: 1:100		Zone / Mileage: -		

AECOM
Royal Court, Basil Close
Chesterfield
Derbyshire. S41 7SL
Telephone. (01246) 209221
Fax. (01246) 209229
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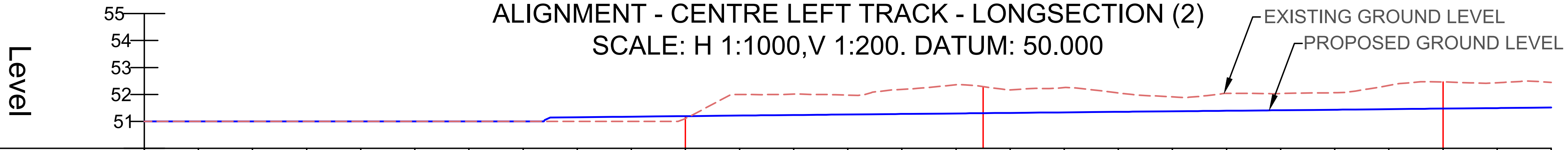
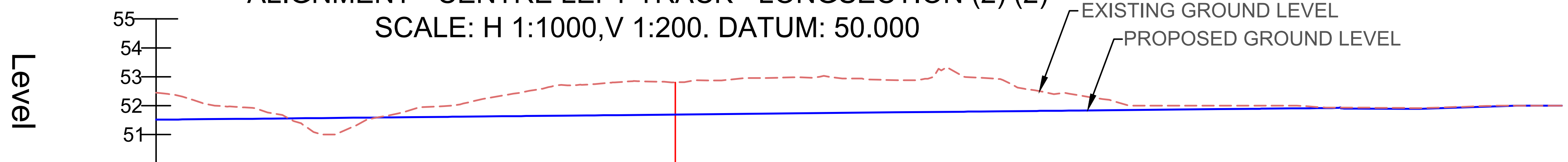
Drawing Number: 60596044.APP.RAIL.009
Rev: -

ALIGNMENT - CENTRE LEFT TRACK - LONGSECTION (2)
SCALE: H 1:1000,V 1:200. DATUM: 50.000



CHAINAGE	00.00	10.00	20.00	30.00	40.00	50.00	60.00	70.00	80.00	90.00	100.00	110.00	120.00	130.00	140.00	150.00	160.00	170.00	180.00	190.00	200.00	210.00	220.00	230.00	240.00	250.00	260.00
EXISTING LEVELS	51.00	51.00	51.00	51.00	51.00	51.00	51.00	51.00	51.00	51.00	51.11	52.00	52.01	51.98	52.18	52.36	52.16	52.26	52.05	51.91	52.04	52.04	52.06	52.33	52.46	52.43	52.44
PROPOSED LEVELS	51.00	51.00	51.00	51.00	51.00	51.00	51.00	51.00	51.16	51.18	51.20	51.22	51.24	51.26	51.27	51.29	51.31	51.33	51.35	51.37	51.39	51.41	51.43	51.45	51.47	51.49	51.51
LEVEL DIFFERENCE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.18	0.09	-0.78	-0.78	-0.72	-0.91	-1.07	-0.85	-0.92	-0.70	-0.53	-0.64	-0.62	-0.63	-0.88	-0.99	-0.94	-0.93

ALIGNMENT - CENTRE LEFT TRACK - LONGSECTION (2) (2)
SCALE: H 1:1000,V 1:200. DATUM: 50.000



CHAINAGE	260.00	270.00	280.00	290.00	300.00	310.00	320.00	330.00	340.00	350.00	360.00	370.00	380.00	390.00	400.00	410.00	420.00	430.00	440.00	450.00	460.00	470.00	480.00	490.00	500.00	503.68
EXISTING LEVELS	52.44	52.01	51.74	51.00	51.65	51.98	52.35	52.71	52.81	52.81	52.91	52.98	52.94	52.88	53.00	52.60	52.36	52.00	52.00	52.00	51.97	51.93	51.92	51.98	52.00	
PROPOSED LEVELS	51.51	51.53	51.55	51.57	51.59	51.61	51.63	51.65	51.67	51.69	51.71	51.73	51.75	51.77	51.79	51.81	51.83	51.85	51.87	51.89	51.91	51.90	51.89	51.96	52.00	
LEVEL DIFFERENCE	-0.93	-0.47	-0.19	0.57	-0.06	-0.37	-0.72	-1.06	-1.14	-1.11	-1.20	-1.24	-1.19	-1.11	-1.21	-0.79	-0.53	-0.15	-0.13	-0.11	-0.06	-0.03	-0.03	-0.03	0.00	

Project Title	APPLEFORD RAIL SIDINGS
Client	Hanson HEIDELBERGCEMENTGroup
Drawing Title	INDICATIVE LONG SECTIONS
Purpose of issue	
Designed	-
Drawn	AAO
Checked	HW
Approved	HW
Date	04/20
AECOM Internal Project No.	60596044
Suitability	-
Scale @ A3	1:2,000
Zone / Mileage	-
Drawing Number	60596044.APP.RAIL.010
Rev	-

AECOM
Royal Court, Basil Close
Chesterfield
Derbyshire. S41 7SL
Telephone. (01246) 209221
Fax. (01246) 209229
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Appendix D Embodied Carbon spreadsheets

TATA STEEL / BCSA / ATKINS Carbon Footprint for Steel / Concrete Composite Bridges

Bridge Details

Project Title	Prestressed concrete beams
Job number	60606782
Bridge Type	Road over
Specify road classification	Rural_A
Obstacles crossed	Rail under
Specify road classification	Not applicable
Construction duration (weeks)	52
Bridge length (m)	24
Bridge width (m)	84

(green)	Drop down menu
(blue)	Text entry

Site set up/close down

Site set up/close		Total tCO_2eq Default values	Total tCO_2eq User values
	Transportation of accomodation units	1.123	1.123

Design/Construction

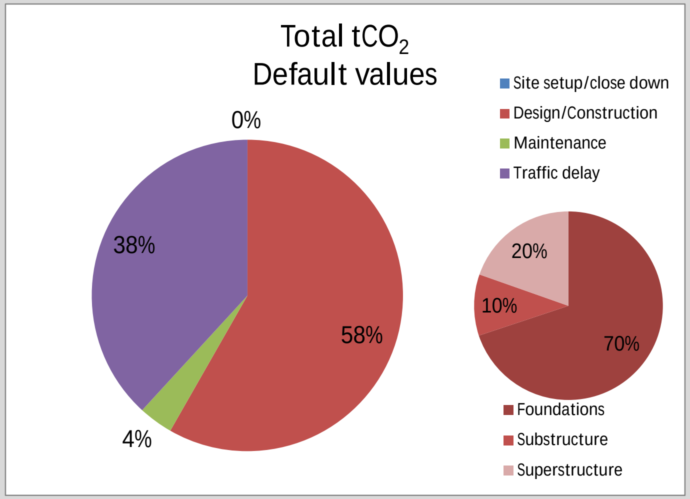
Bridge Element	Type	Material	Volume (m^3) / Tonnage (t) / Quantity (No.)	Total tCO_2 Default values	Total tCO_2 User values
Foundations			Volume (m^3)		
	Foundations	Reinforced Concrete	3554.035225	1941.102	1941.102
		Structural Steel	710.807045	887.968	887.968
Sub-structure			Volume (m^3)		
	Sub-structure	Reinforced Concrete	518.519449	423.575	423.575
Super-structure			Quantity (No.)		
	Articulation	Bearings	0		
			Tonnage		
	Deck	Painted Structural Steel	0		
		Weathering Structural Steel	0		
			Volume (m^3)		
		Reinforced Concrete	1076.4	729.918	729.918
		Miscellaneous		65.232	65.232

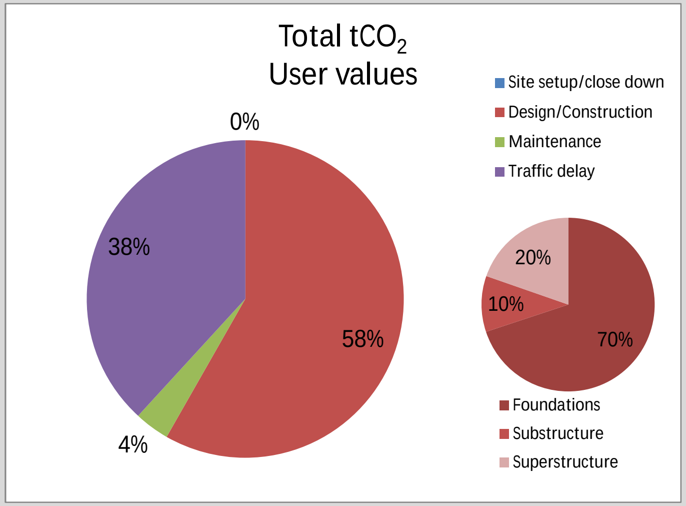
Maintenance

Maintenance Activity	Activity	Number	Total tCO_2 Default values	Total tCO_2 User values
Inspection of Structure	Principal inspections	19	5.531	5.531
	Interim inspections	41	11.911	11.911
Routine Maintenance	Maintenance	10	230.782	230.782

Traffic Delay

Effects of traffic delay	Total tCO_2 emitted traffic management / road closure	Total tCO_2eq Default values	Total tCO_2eq User values
Full duration for construction and maintenance	2653.315853	2653.316	2653.316
Total CO_2		**6950.457**	**6950.457**





TATA STEEL / BCSA / ATKINS Carbon Footprint for Steel / Concrete Composite Bridges

Bridge Details

Project Title	Steel-concrete composite
Job number	60606782
Bridge Type	Road over
Specify road classification	Rural_A
Obstacles crossed	Rail under
Specify road classification	Not applicable
Construction duration (weeks)	52
Bridge length (m)	24
Bridge width (m)	84

(green)	Drop down menu
(blue)	Text entry

Site set up/close down

	Total tCO_2eq Default values	Total tCO_2eq User values
Transportation of accomodation units	1.123	1.123

Design/Construction

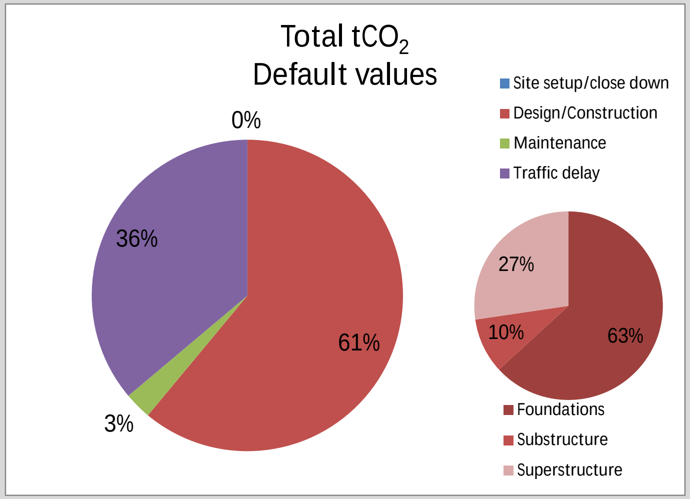
Bridge Element	Type	Material	Volume (m^3) / Tonnage (t) / Quantity (No.)	Total tCO_2 Default values	Total tCO_2 User values
Foundations			Volume (m^3)		
	Foundations	Reinforced Concrete	3554.035225	1941.102	1941.102
		Structural Steel	710.807045	887.968	887.968
Sub-structure			Volume (m^3)		
	Sub-structure	Reinforced Concrete	518.519449	423.575	423.575
Super-structure			Quantity (No.)		
	Articulation	Bearings	0		
			Tonnage		
	Deck	Painted Structural Steel	0		
		Weathering Structural Steel	678.24	835.247	835.247
			Volume (m^3)		
		Reinforced Concrete	403.2	324.257	324.257
		Miscelleanous		65.232	65.232

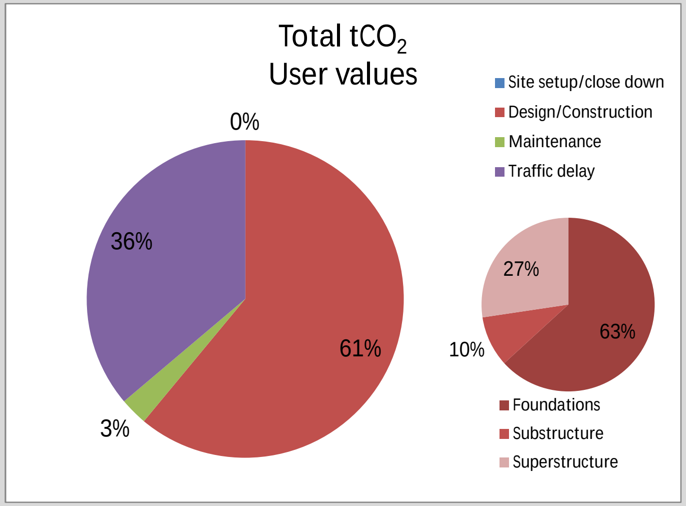
Maintenance

Maintenance Activity	Activity	Number	Total tCO_2 Default values	Total tCO_2 User values
Inspection of Structure	Principal inspections	19	5.531	5.531
	Interim inspections	41	11.911	11.911
Routine Maintenance	Maintenance	10	190.216	190.216

Traffic Delay

Effects of traffic delay	Total tCO_2 emitted traffic management / road closure	Total tCO_2eq Default values	Total tCO_2eq User values
Full duration for construction and maintenance	2653.315853	2653.316	2653.316
Total CO_2		**7339.477**	**7339.477**





Appendix E CS 461: Parapet risk assessment

CS 461 Assessment and upgrading of in-service parapets.

	Factor	Score	Justification
f1	Road Approach Containment	1	Approaches to have adequate containment to CD 377 and RRRAP
f2	Road alignment (horizontal)	3	Curved alignment at least 7.3m wide carriageway
f3	Road alignment (vertical)	1	Constant grade
f4	Actual speed of approaching road traffic	5	Speed < 50mph
f5	Site topography	1	Vehicle/debris very unlikely to foul track due to “redundant triangles”
f6	Site specific hazards increasing likelihood of road traffic accident	1	No obvious hazards. No junctions, lay-bys, shops, bus-stops etc.
f7	Site specific hazards increasing consequences of event	3	Single- site specific hazard. Private railway siding beneath the bridge.
f8	Vehicle parapet resilience on upper road	1	Very High Containment (H4a) parapet
		2	Normal Containment (N2) parapet
f9	Road verges and footpaths	2	At least 1m both sides
f10	Road signage/carriageway markings	1	Signage/markings to be designed to be fit for purpose and clearly visible
f11	Volume of road traffic	4	Assumed Strategic road <1000 HGVs per day
f12	Permissible Line Speed and Track Alignment	4	Curved track up to 45mph
f13	Type of Rail Traffic	1	Non-Dangerous Goods Freight
f14	Combined volume of road traffic on both carriageways of lower road	1	<500 trains per year
R_{INC}	Sum of 14 factors	**29**	If provide a H4a parapet
R_{INC}	Sum of 14 factors	**30**	If provide a N2 parapet

R_{CONT} expressed as a proportion of the required containment resistance C_{REQ}= 1.00N2

Table 3.6 Required containment resistance

Bridge/structure over or adjacent to:	Speed limit (mph)				
	70	60	50	40	30[2]
Railway	1.00N2 at all speed limits				
Road or Other[1]	1.00N2	0.73N2	0.50N2	0.33N2	0.20N2

Notes:

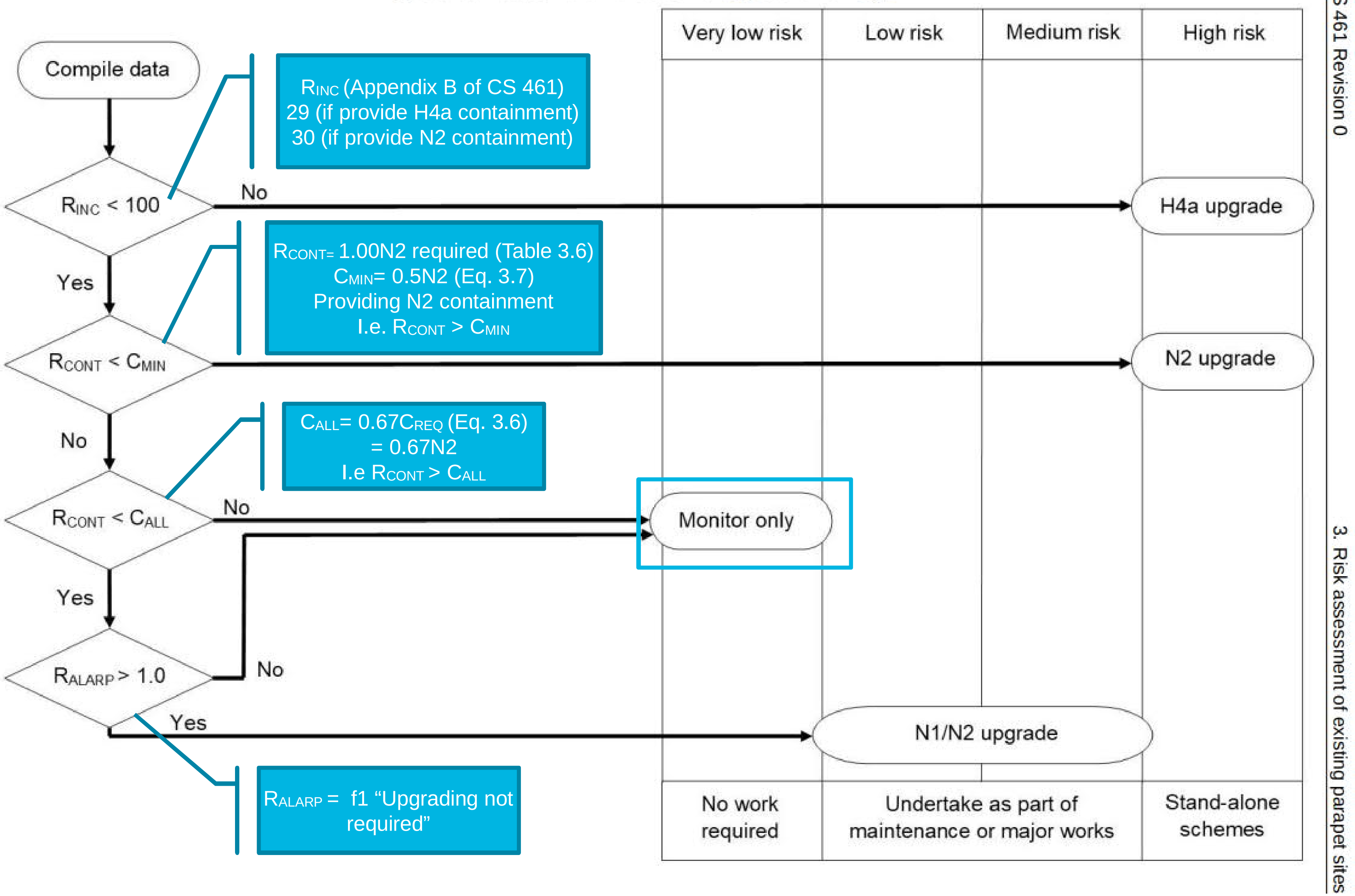
1) Other refers to river, canal, WCH/agricultural access routes, open land, etc.
2) Speed limit restrictions apply for accommodation bridges and roundabouts in accordance with clauses 3.6.1 and 3.6.2.

3.7 For railway bridges/structures, the minimum resistance of the parapet, C_{MIN} shall be determined in accordance with Equation 3.7.

Equation 3.7 Minimum parapet resistance for railway bridges/structures

$$C_{MIN} = 0.5\text{N2}$$

Figure 3.8b Assessment flowchart - bridges over railways



Appendix F Whole Life Costing

Intervention Schedule

Appleford Sidings Road Bridge

ID	CSS Element Description	CSS Element Importance	Type	Material	Influencing Criterion	Exposure Environment
1	Primary deck element	Very High	Precast Prestressed Concrete or Steel Girders	Precast Concrete or Steel Girders	Environment	Mild
3	Secondary deck	Very High	Insitu RC deck slab	Insitu RC	Environment	Mild
6	Parapet beam or	Very High	Insitu reinforced concrete	Insitu RC	Environment	Severe
8	Foundations	High	Deep Foundation: Piles	Insitu RC	Environment	Mild
9	Abutments (incl. arch	High	Insitu Reinforced concrete	Insitu RC	Environment	Mild
12	Cross-head/capping	Very High	Insitu reinforced concrete	Insitu RC	Environment	Mild
17	Waterproofing	Medium	Spray Systems	Spray systems	N/A	N/A
23	Handrail/parapets/safety fences	High	Solid H4a High Containment Steel Parapet (RC)	Steel	Environment	Severe
			Pedestrian guardrail	Insitu RC		Severe
24	Carriageway surfacing	Medium	Carriageway surfacing relaid with asphalt surfacing.	Asphalt	Annual Average	Moderate
25	Footway/verge/footbrid	Low	Footway surfacing	Asphalt	Environment	Severe
31	Wing walls	High	Reinforced soil wall	Precast Concrete	Environment	Mild

Works Cost for Intervention, T years After Construction

T =	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	Total Works Cost for Component
1																																																														£0
3																																																														£0
6																																									#																					£3,700
8																																																														£0
9																																																														£0
12																																																														£0
17																																									#																					£624,000
23																									#																									#												£126,096
																									#																									#												£106,400
24																																									#																					£33,450
25																															#																														#	£61,800
31																																																														£0

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	
ACTIVITY COST																																																														
Total Works Cost in Time Step (including Eng. Difficulty)	£0	£0	£0	£0	£0	£0	£0	£0	£0	£0	£0	£0	£0	£0	£0	£0	£0	£0	£0	£0	£0	£0	£0	£0	£116,248	£0	£0	£0	£0	£0	£30,900	£0	£0	£0	£0	£0	£0	£0	£0	£0	£661,150	£0	£0	£0	£0	£0	£0	£0	£0	£116,248	£0	£0	£0	£0	£0	£0	£0	£0	£0	£0	£30,900	£955,446
SCHEME COST																																																														
Additional Uplift Cost of Preliminaries																									£221,228						£64,803										£1,120,598									£221,228											£64,803	
Other Costs																																																														
Design Costs																									£44,246						£12,961										£134,472									£44,246											£30,900	
FINAL SCHEME COST																									£265,473						£77,763										£1,255,069									£265,473											£95,703	£1,959,481

Extent	Severity				
	1	2	3	4	5
A	1A				
B	1B	2B	3B	4B	5B
C	1C	2C	3C	4C	5C
D	1D	2D	3D	4D	5D
E	1E	2E	3E	4E	5E

Intervention

Component Cost

Appleford Sidings Road Bridge

T years after construction	Element	Intervention	Unit	Extent	Base Rate	Works Cost	Eng. Difficulty Uplift Factor		Total Works Cost	Comments/Assumptions
							Railway - Non-Electrified	Working at height between 5 and 8m		
							2.0	1.3		
24	23	Parapet: Replacement	m	148	£426	£63,048			£63,048	Replacement of pedestrian guardrail. (2no. 24m+2no. 50m)= 148m
		Concrete repairs (moderate)	m^2	53	£1,004	£53,200			£53,200	10% of concrete surface requiring repair. (24m +25m+25m *1.8m high * 2sides * 2parapets) = 532*0.1= 53.2
30	25	Resurfacing of footway/verge/footbridge	m^2	206	£150	£30,900			£30,900	Resurfacing of footway ((24m * (0.6m+2m+4m+2m)= 206m^2)
40	6	Concrete repairs (moderate)	m^2	4	£1,000	£3,700			£3,700	10% of concrete repair surface (24m + 25 +25m length * 0.5m high) =37*0.1= 3.7m^2
40	17	Waterproofing: Replacement	m^2	1920	£325	£624,000			£624,000	Re-waterproofing of deck (24m*80m= 1920m^2)
40	24	Resurfacing of carriageway	m^2	223	£150	£33,450			£33,450	Resurfacing of carriageway (24m length * 9.3m wide= 223m)
49	23	Parapet: Replacement	m	148	£426	£63,048			£63,048	Replacement of pedestrian guardrail. (2no. 24m+2no. 50m)= 148m
		Concrete repairs (moderate)	m^2	53	£1,004	£53,200			£53,200	10% of concrete surface requiring repair. (24m +25m+25m *1.8m high * 2sides * 2parapets) = 532*0.1= 53.2
60	25	Resurfacing of footway/verge/footbridge	m^2	206	£150	£30,900			£30,900	Resurfacing of footway ((24m * (0.6m+2m+4m+2m)= 206m^2)

Total 60-Year Works Cost	£955,446

* Base rates taken from LoBEG Good Practice Guide. Lifecycle Planning for Highway Structures, Version 5.3. August 2011.
* No engineering difficulty has been included as all work is topside.

Scheme Cost

Appleford Sidings Road Bridge

T years after construction	Element ID	Interventions	Total Works Cost in Time Step	Preliminaries *: Work Pattern: Work Pattern	Work Pattern: Uplift Factor	Work Pattern: Works Cost (including Work Pattern)	Scheme Duration: Days	Traffic Management (TM): Lane closure (one lane) /day £1,800	Traffic Management (TM): Pedestrian Traffic Management /day £500	Traffic Management (TM): TM Cost	Eng. Difficulty of Scheme: Scheme Eng. Difficulty	Eng. Difficulty of Scheme: Uplift Factor	Preliminaries Costs (Works Cost + TM Cost +: Preliminaries Cost	Preliminaries Costs (Works Cost + TM Cost +: Additional Uplift Cost of Preliminaries	Other Costs	Design Costs	FINAL SCHEME COST (Preliminaries Cost + Other Costs + Design Costs)	Discount Rate (%)	
24	23	Parapet: Replacement																	
		Concrete repairs (moderate)	£116,248	Nightime	1.5	£174,372	10	X		£18,000	None	1.0	£192,372	£221,228		£44,246	£265,473	3.50	£116,266
30	25	Resurfacing of footway/verge/footbridge	£30,900	Nightime	1.5	£46,350	20		X	£10,000	None	1.0	£56,350	£64,803		£12,961	£77,763	3.00	£32,037
40	6	Concrete repairs (moderate)																	
40	17	Waterproofing: Replacement																	
40	24	Resurfacing of carriageway	£661,150	Nightime	1.5	£991,725	30	X		£27,000	None	1.0	£1,018,725	£1,120,598		£134,472	£1,255,069	3.00	£384,750
49	23	Parapet: Replacement																	
		Concrete repairs (moderate)	£116,248	Nightime	1.5	£174,372	10	X		£18,000	None	1.0	£192,372	£221,228		£44,246	£265,473	3.00	£62,373
60	25	Resurfacing of footway/verge/footbridge	£30,900	Nightime	1.5	£46,350	20		X	£10,000	None	1.0	£56,350	£64,803		£12,961	£77,763	3.00	£13,199

Total 60-Year Works Cost	£924,546		
Total 60-Year Scheme Cost	£1,941,542		£608,625

* All costs and uplift factors taken from LoBEG Good Practice Guide. Lifecycle Planning for Highway Structures, Version 5.3 August 2011.

Appendix G : Illustrative costs for various span arrangements

Didcot to Culham River Crossing

Comparison of Budget Estimates for the Rail Bridge from SPONS 2020

RIV_PD-ACM-SBR-SW_STR_ZZ_ZZ-BQ-CB-0001-P01 Rev 00 13/08/2020

Purpose of Document and Key Points to Note:

This costing exercise has been prepared to inform discussions on the weighting of options for comparative purposes only.
Costs included are generally taken as a guide from Spon's Price Book for Civil Engineering Works 2020. Some costs have been taken from other recent experience where noted.
Costs which are assumed similar across all options have been excluded as they will not influence comparison.
This excercise is not intended to inform the true cost of construction and must not be used for project budgetting purposes.
These rates have not included for risk or Optimism Bias.
It should be noted that design fee is not included.
Costs of culvert diversion are not included. Consideration should be given for this cost, which may be significant but is very difficult to sensibly quantify at this stage, for options 1, 2 and 3.

High Level, Top Down Estimate

This estimate is a very simple estimate of cost based on per metre square of deck area as provided by Spon. It is intended as a control and comparator for the bottom up estimate.

		Option 1	Option 1a	Option 2	Option 2a	Option 3	Option 3a	Commentary on Assumptions and Costs
1.0	Options							
1.1	Description	Square Combined Bridge Outside Redline Boundary	Square Road Bridge with separate NMU Bridge Outside Redline boundary	Square Combined Bridge Within Redline Boundary	Square Road Bridge with separate NMU bridge Within Redline boundary	Skewed Combined Bridge Outside Redline Boundary	Skewed Road Bridge with separate NMU bridge Outside Redline boundary	All references to pages are references to Spon 2020.
1.2	Type of deck	Prestressed concrete deck	Prestressed concrete deck	Prestressed concrete deck	Prestressed concrete deck	Composite deck	Composite deck	
2.0	Geometry							
2.1	Max. span length (m) Combined or road bridge	26	26	20.5	19.5	67	56.5	
2.2	Max. width (m) Combined or road bridge	90	67	78.5	56	28	16.5	
2.3	Total area (m^2) Combined or road bridge	2231	1611	1581	1058	1301	655	Bridge deck areas have been taken from our CAD models for ease, due to the curvature of the deck.
2.4	Max. span length (m) NMU bridge		40		33		40	
2.5	Max. width (m) NMU bridge		7		7		7	
2.6	Total area (m^2) NMU bridge		280		231		280	
3.0	Estimated costs from Spon 2020: Approximate Estimating Rates							These costs are taken per m² of deck area between abutments. The rates include all items associated with the bridge and abutments including excavation, reinforcement, formwork, concrete, bearings, expansion joints, waterproofing, finishes, and simple parapet, but exclude any approach works
3.1	Cost of prestressed beams (£/m^2) Combined or road bridge	2600	2600	2600	2600			Assuming Span 22m, pg 153 of Spons 2020 gives a rate of £2600 to £4450. Noting that if this option is to be selected it is a large but not complex structure so we can take some economy of scale, hence the lower end of the scale has been taken.
3.2	Cost of steel (£/m^2) Combined or road bridge					5400	5400	Spon 2020, pg 153 does not go >40m span, however at 40m it gives a rate of £3100 to £5400. Noting we will be way in excess of this span and due to the very heavy skew this bridge will be complex with a lit of bracing and stiffeners, so we have selected the high end of this scale.
3.3	Cost of steel (£/m^2) NMU bridge		3350		3350		3350	Spon 2020, pg 154, if a proprietary steel footbridge were to be used, a rate at 20m span is provided at £2600 to £4100. This is a relatively simple bridge but is unusually wide, so we will select the mid point in this range.
4.0	Cost (£)	£5,800,600	£5,126,600	£4,110,600	£3,524,650	£7,025,400	£4,475,000	
4.1	Difference from baseline option	£1,690,000	£1,016,000	£0	-£585,950	£2,914,800	£364,400	