Norwich Western Link

Environmental Statement

Chapter 4: Reasonable Alternatives Considered

Appendix 4.5: Design Evolution Report

Author: WSP

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Contents

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1 Introduction

1.1 Purpose of this report

1.1.1 This report sets out the design evolution of the Proposed Scheme from the point at which the route selection was determined. It describes how the design has developed in response to key factors including: policy, stakeholder engagement, and findings from environmental surveys / assessments.

1.1.2 This report supports the Design and Access Statement (document reference: 1.02.00) which presents the design for which planning consent is sought, and the Reasonable Alternatives Considered Chapter of the Environmental Statement (document reference: 3.04.00) by explaining the evolution of the design, alternatives considered, and decision making which has informed the design of the Proposed Scheme put forward as part of the planning application.

2 Design evolution

2.1 Introduction

2.1.1 The Proposed Scheme has maintained a landscape and environmentally led design, to develop a solution that responds to the context and minimises impact. Naturally the design evolves as more information becomes available through surveys and assessments, and where efficiencies have been identified. This document explains the iterations of design, key changes, and continuous factors which have informed the design for the Proposed Scheme.

2.2 Design principles

2.2.1 Norwich Western Link is a scheme committed to conserving and enhancing natural assets and providing community benefits in its delivery of a new link road for Norwich.

2.2.2 The following project wide design principles were developed collaboratively with the 'Local Planning Authority Design Group'. The group comprises officers from various departments in the district and county authorities (such as landscape, ecology, planning, flooding, heritage) to provide their feedback through workshops and ongoing liaison.

2.2.3 The design principles (DP1) are supported by design application (DP1.1) which have informed the design evolution for the Proposed Scheme.

Ref:	Design Principle and Application:
DP1	***Respond to the character and landscape in which the Proposed Scheme is situated, with engineered forms integrated with the landscape to minimise their physical and visual impact and provide wider benefits or features;***
DP1.1	All new planting will be appropriate to the national and local landscape character, in species specification of local provenance, siting and grouping. It should be locally sourced to ensure successful establishment and longevity, resilient to the changing climate.
DP1.2	Landscape design will respond to the National Character Areas and Landscape Character Areas (as described in Chapter 9 of the ES) to realise the opportunities identified for conservation and enhancement of the landscape.
DP1.3	The scheme and particularly structures will be integrated with the landscape using planted earthworks, rather than reinforced walls where practicable.
DP1.4	The viaduct structure will present a sinuous elegant appearance with architectural merit as a large new object in a rural setting, seeking to minimise impact in the floodplain.
DP1.5	Structural designs for green bridge and underpasses will respond directly to the presence and behaviours of target species to ensure effectiveness as mitigation to maintain connectivity for wildlife e.g. Ensuring dark corridors on bat flight paths whilst ensuring suitability for use by other wildlife.
DP2	***Make a positive contribution to the landscape through conserving and enhancing the natural environment and biodiversity net gain;***

Ref:	Design Principle and Application:
DP2.1	The design will seek to minimise impact on the landscape and environment, responding to survey and assessment findings.
DP2.2	The Proposed Scheme will achieve Biodiversity Net Gain (BNG) of at least 10% adhering to the latest guidance and metrics.
DP2.3	Where impacts have been unavoidable, adequate compensation will be provided for protected species, tree loss, and to achieve BNG.
DP2.4	The Proposed Scheme will ensure climate change resilience in its design, choice of materials, and planting.
DP2.5	The Proposed Scheme is generally to remain unlit, with the exception of a minimal number of lighting columns at the southern extent of the Proposed Scheme, leading to the junction with the re-aligned A47. It is also proposed that signage lighting will be required at junctions.
DP2.6	The design will respect and respond to the presence of heritage features.
DP2.7	A robust landscape, ecological maintenance and management plan (LEMP) will be developed to ensure successful delivery, establishment and longevity of planting and mitigation proposed, fulfilling associated ecological objectives and functions such as species mitigation and tree loss compensation.
DP2.8	The Proposed Scheme will maximise opportunities for people to engage with nature and explore the local countryside, enhancing local networks for walking and cycling.
DP3	***Strive to minimise adverse impacts on the landscape and seek sustainability in its use of materials, construction techniques, and maximising multi-functional features wherever possible;***

Ref:	Design Principle and Application:
DP3.1	The Proposed Scheme will minimise loss of existing trees, woodland, and habitats, with suitable protective measures during construction for retained planting.
DP3.2	The Proposed Scheme will minimise greenhouse gases and carbon emissions, striving towards a net zero future in the design, construction methods and equipment.
DP3.3	Maintenance access tracks should multi-functional where possible and safe to do so, to provide dual benefit for the non-motorised user network.
DP3.4	Green bridges will be multi-functional where possible, to provide dual benefit for the non-motorised user network alongside their primary environmental mitigation function. They should have provision to capture rainfall for the planting, to aid successful establishment and longevity.
DP3.5	Construction methodologies will be considerate to the environmental constraints and sensitivity of the setting, ensuring adequate protective buffers from habitat features and root protection areas.
DP3.6	The temporary construction areas and structures will be removed and original conditions reinstated as soon as practicably possible after construction is completed.
DP3.7	Reuse of site-won materials will minimise the use of natural resources and unnecessary import or disposal of materials (e.g. reusing excavated soil for fill requirements)
DP3.8	A competent contractor will be utilised to ensure the most appropriate construction methodology, safe practices, and use of compounds and storage to minimise impacts.

Ref:	Design Principle and Application:
DP3.9	Monitoring and management is required post-construction to ensure successful establishment of planting, mitigation and compensation measures.
DP3.10	Contractors are to consider sustainable resource and waste management measures to use material resources efficiently, reduce waste at source, reduce waste that requires final disposal to landfill and apply the principles of the waste hierarchy.
DP3.11	Contractors will adopt the Considerate Constructors Scheme (or its equivalent) to assist in the reduction of pollution, including Greenhouse gases, from the Proposed Scheme by employing industry best practice measures.

Ref:	Design Principle and Application:
DP3.12	The Contractor will adopt appropriate measures and consider the environment first and foremost in decision making to adopt practices such as: o Implementing a Travel Plan to reduce the use of private car journeys by construction staff and employees o Suitable waste management practices o Avoid the use of diesel or petrol-powered generators in favour of mains electricity or battery powered equipment where practicable o Conducting regular and planned maintenance of the construction plant and machinery to optimise efficiency o Acting as a considerate neighbour.
DP4	***Maintain and enhance the local Rights of Way where possible, for community accessibility, amenity, and to encourage sustainable modes of travel – with consideration of this beyond the scheme's extent;***
DP4.1	The Proposed Scheme will deliver a Sustainable Transport Strategy to enhance the local network and facilities for non-motorised users. This will maintain or divert routes crossed by the Proposed Scheme whilst maintaining connectivity and accessibility.
DP4.2	The Proposed Scheme will consider the experience of non-motorised users in its design and construction.
DP4.3	The Proposed Scheme will introduce way-finding signage and educational boards to provide information about the locality and the environment.

Ref:	Design Principle and Application:
DP4.4	The application of fencing will consider the visual impact and experience, to prioritise timber post and rail as a suitable solution for the rural character of the landscape.
DP4.5	The Contractor will maintain suitable communications and diversions during construction for any diversions or temporary impacts to locals.
DP5	***Adhere to a design narrative which provides a commonality and theme to unify all components of the scheme;***
DP5.1	The design will adhere to the design philosophy and principles which are informed by environmental constraints, stakeholder engagement and best practice as set out in the DAS.
DP5.2	The Proposed Scheme will deliver good design for all components including the structures and their appearance, as the most visually prominent parts of the design.
DP6	***Respond to the constraints of the scheme, and consider its whole lifespan including capital and maintenance costs.***
DP6.1	The Proposed Scheme will continue to respond to constraints identified through surveys and assessments, or defined by the developer (for example to provide value for money).
DP6.2	The choice of design, materials, and management regime will consider whole life cost and sustainability.
DP6.3	Lower maintenance options should be considered, particularly where they offer additional benefits to the scheme – such as species rich seed mix instead of amenity grass which requires less maintenance and greater benefit to biodiversity and visual amenity.

2.3 Design milestones

2.3.1 The following describes the key design milestones, and evolution of design components comprising the Proposed Scheme. It should be noted that a conservative approach was taken to the design initially until further information was gathered to inform design development from surveys, assessments, ground investigations, and stakeholder engagement.

2.3.2 The following milestones are described:

1. **Route option design**: at the time the route selection was made.
2. **Local Access Consultation design**: to inform the side road strategy, non-motorised user strategy, and design development.
3. **Outline design**: to allow the procurement of a design and build contractor.
4. **Planning application design**: the design for which consent is sought.

2.3.3 For each design milestone the following design components are described: highway design, side roads, structures (including the viaduct, green bridges and underpasses), and environmental design / mitigation measures.

1 - Route option design

2.3.4 Following the route alignment being selected, as described in the Options Selections Report (July 2019) (available to view at: Norfolk County Council website - Norwich Western Link: Timeline and documents), each component of the design was developed to respond to the design principles described in 2.2, the environmental constraints and scheme objectives.

2.3.5 Figure 2.1 illustrates the alignment of the chosen route which was developed for the Proposed Scheme, Figure 2.2 shows the route overview plan with assumed locations for components such as drainage basins, structures, and an indicative scheme boundary.

2.3.6 As further surveys and assessments were undertaken, the design considered how best to respond to findings and avoid impacts.

2.3.7 This included the application of Ordnance survey data, aerial mapping, and subsequently topographical information to ensure accuracy in development of the design where 'Light detection and ranging' (LiDAR) information had been used to date during the route option selection process.

Figure 2-1 The selected route Option C with discounted routes (A,B,D) in grey

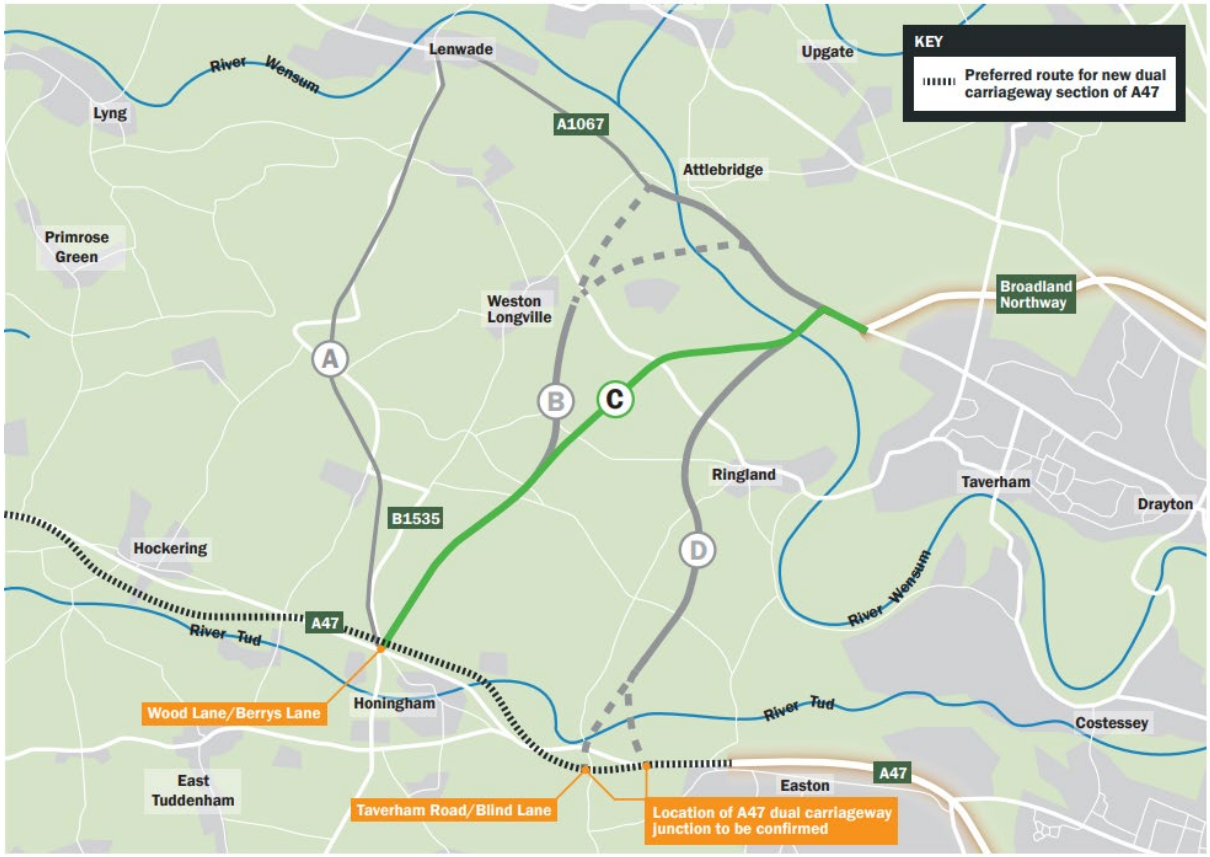
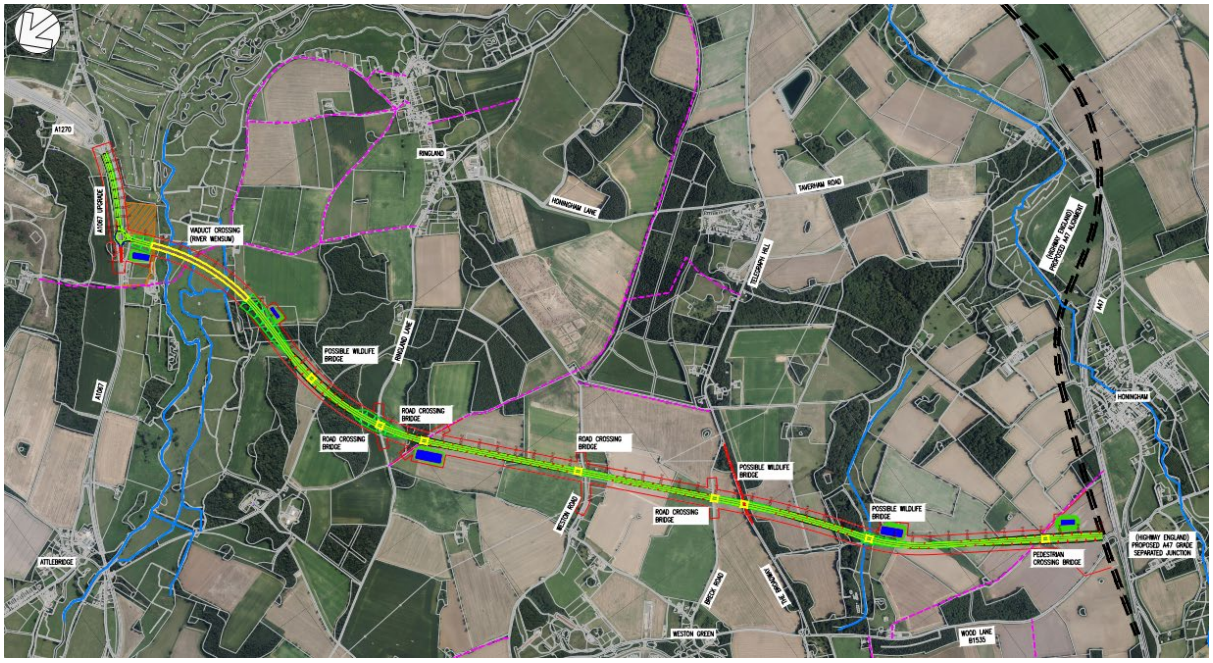


Figure 2-2 Overview plan of route Option C design (2019)



Highway design

2.3.8 The highway design at this stage of the design comprised the following:

- Dualling of approximately 400m of the A1067 Fakenham Road from the A1270 Broadland Northway roundabout;
- A proposed three-arm roundabout junction between the A1067 and mainline of NWL;
- Dual carriageway mainline NWL approximately 5.8km long between A1067 and a junction connection with the A47;
- A connection with the proposed grade separated junction near Wood Lane which forms part of the National Highways 'A47 North Tuddenham to Easton Improvements' dualling scheme.
- The highways design was developed in its vertical alignment to respond to the varied topography across the site, managing visual impact by lowering the road in cutting with the need for earthworks balance through reuse of excavated material on site.

Side roads and public rights of way

2.3.9 For the minor rural roads that intercept the proposed scheme alignment, the 'side roads', in most instances, the design at this stage included structures to maintain use of the routes as described below in 2.3.15 including: Ringland Lane, Weston Road, Breck Lane, and The Broadway.

2.3.10 Minor localised realignment was assumed for some side roads to facilitate their crossing of the Proposed Scheme mainline without significant skews.

2.3.11 The Broadway was proposed to be closed to traffic where it crosses the mainline highway with traffic diverted to Weston Road via Breck Road, to enable the route to be maintained for protected species and wildlife by an overbridge structure.

2.3.12 The southern extent of the alignment intercepts Honingham Restricted Byway 1 for which a structure was initially assumed to maintain the route over the Proposed Scheme. This route is also impacted by the A47 National Highways dualling scheme which provides a diversion and underpass for the restricted byway to cross the A47.

Structures (Viaduct, green bridges / underpasses)

2.3.13 Structures are required to carry the scheme over the floodplain, provide environmental mitigation, and maintain existing routes that cross the mainline carriageway. Structures included at this stage of the design listed from north to south are as follows:

- Viaduct crossing of the River Wensum (underbridge).
- Wildlife overpass/bridge (overbridge).
- Ringland Lane bridge (underbridge).
- Unclassified Road / Pedestrian Bridge (overbridge).
- Weston Road bridge (underbridge).
- Breck Lane bridge (overbridge).

- Wildlife bridge at The Broadway (overbridge).
- Wildlife underpass / culvert at a tributary of the River Tud (underpass).
- Pedestrian bridge for the Honingham Restricted Byway 1 (overbridge).

2.3.14 Whilst the design was at an early stage, the viaduct structure carrying the mainline highway over the River Wensum and its floodplain positioned abutments beyond the floodplain extents, whilst the span arrangements and associated placement of piers avoided the watercourses below.

Environmental design and mitigation measures

2.3.15 The design at this stage included provisional locations for wildlife structures (green bridges) where the mainline highway crosses existing woodlands and natural features likely to require continuous connectivity for wildlife.

2.3.16 A series of attenuation basins were included at key locations along the length of the mainline to manage surface water run-off, by discharging to the ground via infiltration or to existing watercourses. This positioning was subject to a review of ground conditions, which were to be further investigated.

2.3.17 Earth embankments of up to 11m high and cuttings of up to 7m deep were included in the design to facilitate the highway whilst responding to the topography.

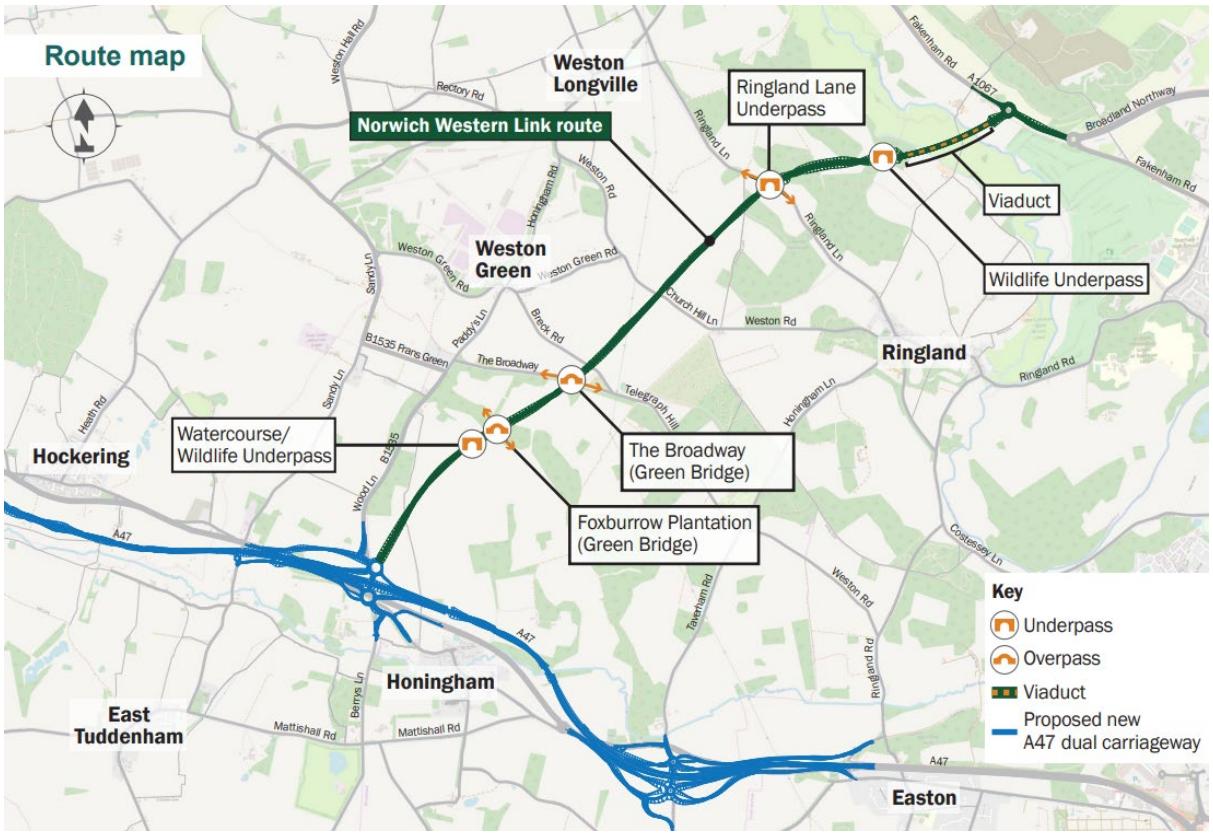
2 - Local Access Consultation design

2.3.18 The Local Access Consultation in July-September 2020 sought feedback focussed on local access in the vicinity of the Proposed Scheme, as shown in Figure 2.3. This consultation demonstrated support for the closure of side roads, and therefore removal of their proposed structures from the design development at a subsequent stage.

2.3.19 A number of factors influenced the design development at this stage including feedback from local parish councils, current usage of the side roads and potential impacts on journeys across the wider transport network, local

topography, environmental considerations, environmental mitigation requirements, and value for money.

Figure 2-3 Route map presented in the Local Access Consultation



Highway design

2.3.20 The highway design remained largely unchanged at this stage of the design, with a focus on other design elements through consultation and ongoing surveys.

Side roads and public rights of way

2.3.21 As a result of the consultation undertaken, along with The Broadway being closed to traffic where it crosses the mainline highway, Breck Lane and Weston Road were also proposed to be stopped up as part of the design development. This allowed the removal of the associated structure from the design in its subsequent stages of development.

2.3.22 Turning heads were included in the design for general traffic where side roads had been stopped up in the design.

2.3.23 A shared footway/cycleway was developed north of the A1067 Fakenham Road between the A1270 roundabout and the Attlebridge Footpath 1 existing Public Right of Way.

2.3.24 Two options were presented for Ringland Lane as part of the consultation:

- to keep the road open to all through traffic; or
- for it to be restricted to walkers, cyclists and horse riders only.

2.3.25 Both options would see Ringland Lane cross under the mainline carriageway through a structure. It was concluded that this route should be kept open for all traffic to maintain east to west movement, but that monitoring may inform any restrictions imposed in the future. Due to the presence of a bat flight path along Ringland Lane, a structure of some form would always be required in this location.

2.3.26 Diversion of the Honingham Restricted Byway 1 north of the A47 where intersected by the mainline highway removed the need for a structure to be provided here. This was determined through liaison with National Highways to ensure that the proposed design aligned with their proposals.

Outline design

2.3.27 The outline design was developed further in response to survey / assessment outcomes, and stakeholder engagement. The design was used to facilitate the procurement of a design and build contractor in 2021, to develop and construct the Proposed Scheme.

2.3.28 The factors influencing the design included policy requirements, environmental constraints, and the above design principles, which were presented to ensure continuity in the approach to good design by the contractor moving forward.

2.3.29 Conservative assumptions were made at this stage about components of the Proposed Scheme such as compound areas, storage areas and haul routes that may be required during construction. As these temporary use areas ultimately need to be included in the Scheme Boundary and assessments,

these assumptions made allowed the survey areas and buffers to be defined. This is shown in Figure 2.4.

2.3.30 The design also retained flexibility for the appointed Contractor to develop the design in accordance with the factors already described, with efficiency and innovation sought.

Figure 2-4 Overview plan of the Outline Design

Highway design

2.3.31 The removal of structures at Weston Road and Breck Lane offered opportunities for further refinement to the overall highway vertical and horizontal alignments. This included consideration of what the most appropriate solution is for retained side road crossings, including whether structures should cross over or under the mainline carriageway.

2.3.32 The Broadway continued to be maintained for non-motorised user and wildlife connectivity, though this was possible by means of an underpass or overbridge (green bridge) options. Both designs were drafted and appraised by specialists before concluding that the green bridge offered the most effective solution by minimising the associated footprint of the design and therefore loss of existing trees.

2.3.33 Consideration was given to construction compounds, storage, and haul routes that may be used during construction.

Side roads and public rights of way

2.3.34 The non-motorised user provision was further refined at this stage of the design to maintain and improve connectivity in the area. This included the design of maintenance access tracks as dual purpose, for use by non-motorised users.

2.3.35 The proposed diversion of Honingham Restricted Byway 1 from the A47 to The Broadway was rerouted across the Tud Tributary beneath the Foxburrow and The Broadway green bridges to minimise impact on adjacent landowners and privacy concerns – between mainline and earth bund. This also offered the most efficient route, with user-friendly gradients alongside the mainline rather than needing to negotiate or reprofile steep topography in this area of the landscape to accommodate the route.

Structures (Viaduct, green bridges / underpasses)

2.3.36 The viaduct design development at this stage involved exploration of structural options and span arrangements that responded to the environmental constraints and key factors acting upon the Proposed Scheme. It also sought to retain flexibility in design and construction methodology for the subsequent stage of design development whilst providing sufficient detail for preliminary assessments and surveys to be undertaken.

2.3.37 The viaduct design at this stage comprised:

- A thirteen-span twin-deck weathering steel trapezoidal box girder bridge with a reinforced concrete deck slab. The 2.5m gap between the structures maintained light through to the River Wensum to minimise impacts of shading. This structure type was used to provide:
    - A constant depth which aids the appearance of the viaduct as a sinuous line through the landscape, and long spans to minimise the number of piers and piles required in the floodplain – with 4 sets of columns per pier location;
    - A constant radius curve so as not to constrain the contractor should they wish to construct the viaduct by incremental launching – a construction method suited to environmentally sensitive areas by minimising construction area in the floodplain;
    - Weathering steel for the four steel box girders to eliminate the need for painting, future repainting, and associated maintenance liabilities, thus minimising the risk of polluting watercourses beneath. The brownish patina that weathering steel develops after a couple of years can be fitting in a rural setting;
    - Retain flexibility for an experienced contractor to further develop the design;
- Further consideration was given to the structures required for environmental mitigation, such as minimum dimensions and associated planting to support functionality.
- Crossing structures were introduced to the design in the floodplain, to accommodate maintenance access tracks to the viaduct over minor watercourses.

Environmental design and mitigation measures

2.3.38 A drainage strategy and design were developed through engagement with the Lead Local Flood Authority at this stage, this resulted in eight basins of varying shapes and sizes proposed in various locations along the length of the mainline carriageway. Consideration was also given to the capacity of the A1270 basin at the north-eastern extent of the Proposed Scheme and feasibility for it to support the drainage design.

2.3.39 Earth bunds were designed on either side of the carriageway to support visual screening of the Proposed Scheme from local residents and to enable the reuse of site won materials. The earth bunds accommodate planting of trees and shrubs to contribute to the integration of the design in the landscape.

2.3.40 Refinement of the design generally enabled important tree groups to be retained and protected with suitable root protection areas designated as part of the proposals. This was reviewed again during the Planning Application design development described overleaf.

2.3.41 Provisional areas for environmental mitigation were identified, for habitat creation and flood compensation which were subject to refinement as assessment outcomes emerged.

2.3.42 A landscape design was developed including native tree planting, scrub planting, and hedgerow to integrate the scheme with its surrounding context and maintain connectivity for wildlife with existing habitats. The planting areas proposed enabled early biodiversity net gain calculations to be made and ensure the Proposed Scheme was able to meet its targets within the design that was developed.

2.3.43 Through ongoing engagement with landowners regarding their land use, access, and operations, it was possible to relocate design features such as drainage basins to minimise impacts where practicable.

2.3.44 As environmental assessments were ongoing to inform the design, a conservative approach was taken by including an environmental barrier at the outer edges of the viaduct structure to mitigate potential effects of wind, noise and tyre splash on the surrounding environment. It was intended that this design component would be developed at the next stage in response to the outcome of surveys and assessment.

4 – Planning application design

2.3.45 The design for which planning consent is sought, has been developed by the Contractor, appointed to design and construct the Proposed Scheme. Development of the design has maintained continuity in the response to the key factors acting upon the Proposed Scheme as described in 2.2 and outcomes of surveys and assessments.

Highways design

2.3.46 The highways design development at this stage of the design includes:

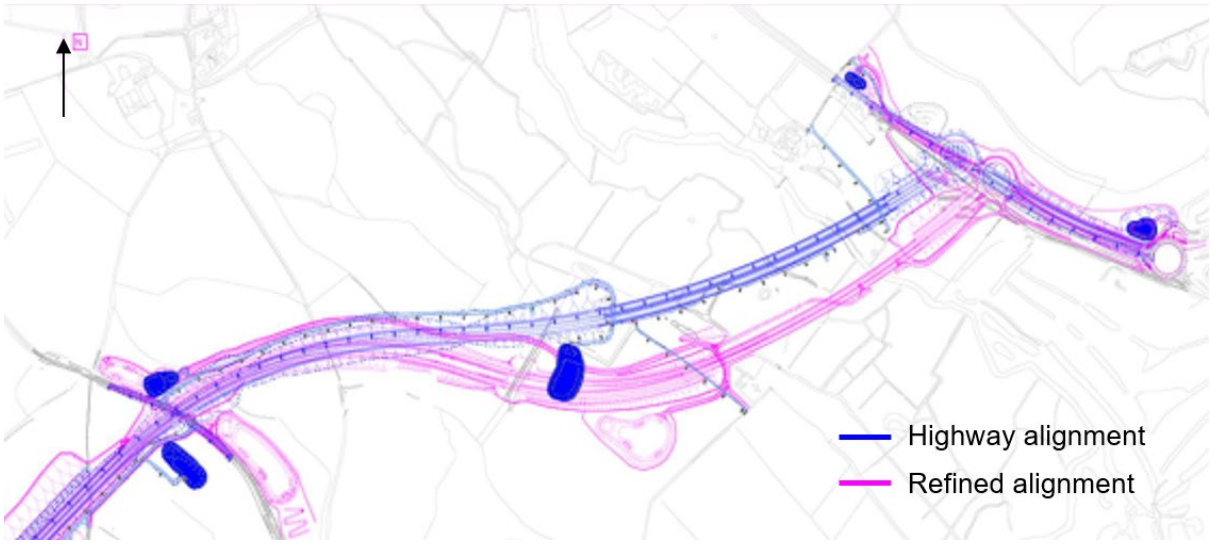
- Alterations to the proposed A1067 roundabout configuration to provide private access to utility chambers and the northern abutment with a minor realignment to the east. The siting of the roundabout junction had previously been constrained by an adjacent site for which consent was granted for construction of a reservoir associated with the neighbouring golf course. This consent lapsed in November 2021 and was no longer a constraint upon the Proposed Scheme at this stage of the design.
- Alterations to the A47 tie in, as a result of engagement with National Highways on their adjoining 'A47 North Tuddenham to Easton improvements' (dualling) scheme;
- Refinement of the highway alignment to avoid a bat roost (described further below);
- Optimisation of cut slope gradients;
- Reduction of access and maintenance track widths;

- Optimisation of drainage ponds;
- Optimisation of earth bunds;
- Drainage provision introduced for access tracks; and
- Emergency crossing points in the vehicle restraint system to allow contraflow diversions across central reserve.

2.3.47 Refinement of the highway alignment was required following the identification of a bat roost during surveys in an area of woodland south of the floodplain, options were considered for how to avoid and protect this habitat feature.

2.3.48 A number of alternative highway alignments were considered and appraised by the design team, with a solution chosen and adopted by the design for the Proposed Scheme. Further detail is presented in the Review of OSR conclusions in light of 2022 Alignment Refinement Report (document reference: 3.04.03). The highway design and its alignment refinement can be seen in Figure 2.5.

Figure 2-5 Overview plan of the alignment refinement to avoid protected species habitats in nearby woodland



Side roads and public rights of way

2.3.49 Design development was undertaken in light of the proposed closure of Churchill Lane (known as Weston Road) and Breck Lane with necessary turning head provision provided.

2.3.50 Refinements were made to the PRoW network across the design, utilising structures (including green bridges) to maximise connectivity as presented in the Sustainable Transport Strategy (document reference 4.02.00). Consideration was also given to access/security for landowners through provisional placement of gates and fencing.

Structures

2.3.51 The structures included in the design at this stage including the reference used on the relevant drawings (document reference 2.06.01 to 2.06.08) are as follows:

- BR1 - River Wensum Viaduct.
- MA1 - Maintenance access culvert.
- GB5 - Nursery Woodland Green bridge.
- BR2 - Ringland Lane Bridge.
- *GB3 - Reference not in use.*
- GB4 - Morton Green bridge.
- GB1 - Broadway Green bridge.
- GB2 - Foxburrow Green bridge.
- CU1 - Tud Tributary underpass (culvert).

Viaduct design

2.3.52 The viaduct structure does not span a large obstacle in the form of a major sized waterbody, road or other physical feature, but rather traverses open land and can touch down at regular intervals. There is no reason nor justification to engage an over-deck structure such as trusses, arches, suspended and cable-stayed structures. Such structures would be considered to achieve the required spans for large obstacles and would be a structurally inappropriate contrivance as well as unrealistic in cost.

2.3.53 The specific circumstances of the Wensum valley dictate a multi-span beam viaduct structure as an appropriate structural type for this situation. The alternative structural options may be aesthetically interesting, but not necessary of the engineering design. This maintains the integrity of 'good' bridges where no more is proposed for the form, than is necessary to provide simplistic and honest design without decorative additions.

2.3.54 Opportunities were identified to find efficiencies in the design without creating further adverse impact on the environment.

2.3.55 The design was able to eliminate the 2.5m air gap and reduce overall carriageway and verge widths, reduce the number of columns for each pier location. This reduced materials, improving cost and reduced the potential for shading to the SSSI and SAC in the Wensum valley beneath. The superstructure type was changed from 4 box girders to 3 steel girders and cross-beams to form a ladder beam deck with composite action with a concrete deck. The number of columns was reduced from 4 to 3 at each pier location, saving 12 column/piles and 14 bearings. The total material saving was some 12,600 tonnes of steelwork, concrete and rebar leading to a 10,367 CO2e (carbon dioxide equivalent) saving and a significant cost saving. The alignment refinement in 2022 also resulted in a shorter viaduct as the floodplain was narrower at the location of the refinement compared to the original alignment.

2.3.56 A viaduct structure was brought forward on the basis of a craned construction methodology concluding this the most appropriate approach.

2.3.57 The design development to this stage has been informed by:

- Health and safety: During design development health and safety was considered for the whole life cycle of the asset. The principles given in DMRB GD304 - Designing Health and Safety into Maintenance during the process were considered;
- Construction duration: Opportunities were taken to minimise the construction period, reducing exposure of construction workers to site hazards. These included refining viaduct design and reducing earthworks cut to fill volumes;
- Environment: Reducing Embedded carbon by pursuing a lean design to reduce material quantities; and
- Cost: The design opportunities identified resulted in a construction cost lower than the earlier outline design.

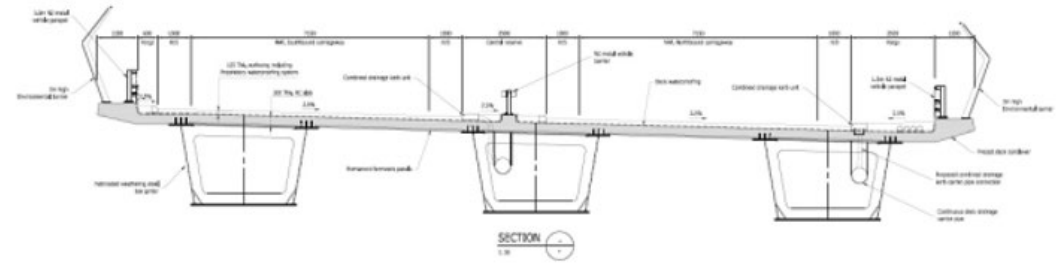
2.3.58 Viaduct structures investigated during design development include:

(A) Three cell box girder in weathering steel;

(B) Precast prestressed deck with in situ connections; and

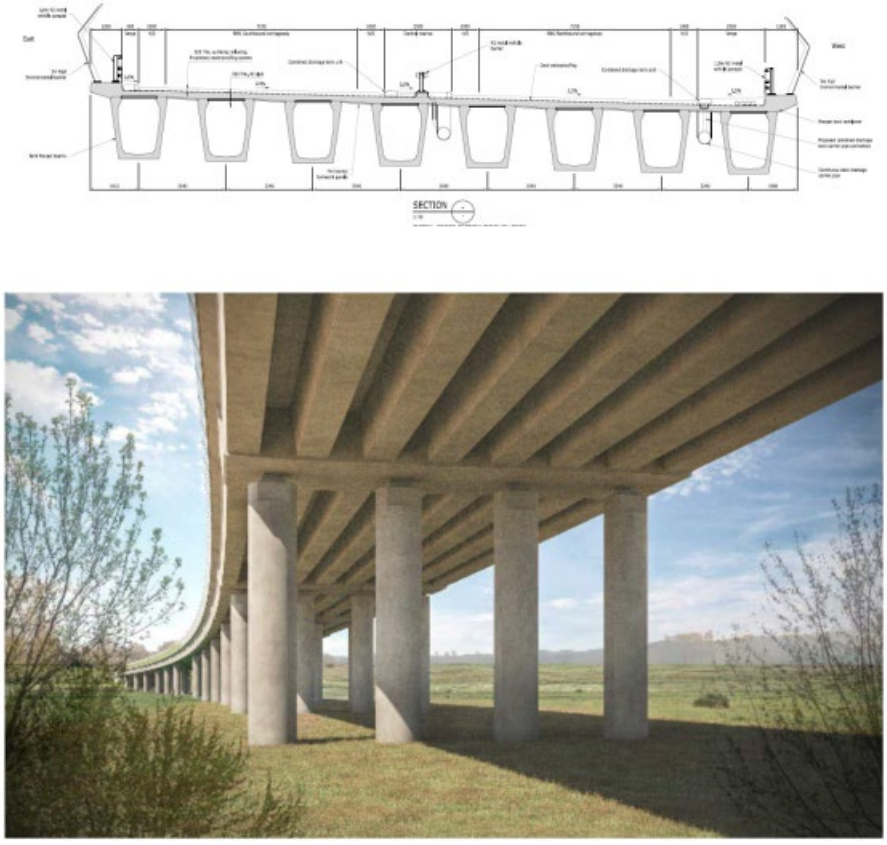
(C) Three girder ladder beam deck in weathering steel.

Figure 2-6 Viaduct Option A – Three Cell Box Girder in Weathering Steel, 10 Piers, 3 Columns per Pier



2.3.59 This option benefitted from the smooth appearance of the trapezoidal boxes, facilitated launching due to its inherent torsional stiffness, whilst being deep enough for ease of internal inspection. The deck arrangement was also developed for a 10 Pier arrangement, which gave a further reduction in works in the floodplain and reduced visual clutter. However, the costs of fabrication and launch erection proved very high, and whilst an elegant solution it was found to be too costly. The option was discounted on the fundamental basis of affordability.

Figure 2-7 Viaduct Option B – Precast Prestressed Deck with insitu connections – 16 Piers, four Columns per Pier



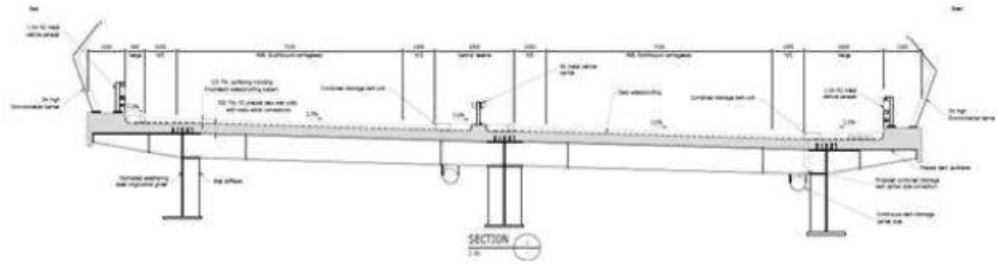
2.3.60 In an endeavour to reduce cost, a precast prestressed deck option with in situ concrete diaphragm connections and in situ slab was considered. The design for this option was driven by the size of the largest available precast beams which resulted in a 16 Pier, 17 span arrangement. In addition, to balance the load effects across the pier diaphragms four columns per pier were required.

2.3.61 This option increased the number of piers in the floodplain, required more in situ concrete to be placed and was considered to be poorer from an environmental and visual aspect. When studied further, it became apparent that there were significant temporary works required to connect the spans together and support thousands of tons of wet concrete above the SAC and floodplain areas.

2.3.62 The additional temporary works required under this option would increase the duration of the works in the floodplain which was considered to present risks in terms of the effects on third parties and programme risk due to a greater exposure to seasonal flooding.

2.3.63 The initial consideration of an optimum cost solution was outweighed by the factors discussed above and this option was not progressed.

Figure 2-8 Viaduct Option C – Three girder ladder beam deck in weathering steel, 10 or 12 Piers, three columns per pier



2.3.64 In an effort to balance cost with the design and landscape strategy objectives the steel composite design was reconsidered using more efficient to fabricate 'I' Girders in a ladder beam configuration. The approach to construction would be crane erected to reduce cost and also potentially shorten the construction programme. This options also avoided the complications that were considered to be present with the settlement issues of the north abutment for a launched solution.

2.3.65 Two different span arrangements were considered, one with 10 Piers identical in spans to Option A , the three cell box, and one with 12 Piers following the same span arrangement as the reference design. The optimum arrangement was considered to be the 12 pier, 13 span design which saved approximately 10 % more structural steel than the 10 pier, 11 span design, outweighing the additional cost of substructures. The pier diameter of Option C is more slender than that of Option A.

2.3.66 This option makes maximum use of precast concrete having full depth slabs and cantilever edges, and so minimising insitu concrete works over the SAC and floodplain.

2.3.67 Design opportunities were implemented during the design development, these comprised:

- Span optimisation and a single deck proposed for the viaduct, to benefit the sunlight hours and shading impact on the floodplain below; and
- Optimisation of carriageway vertical profile without introducing extra departures from standard.

2.3.68 Further design development involved a conglomeration of the twin deck into a single structure, and efficiencies to the functional width that result in a significant reduction of 8.7m overall, from 35m to 26.3m wide.

2.3.69 A narrower deck allowed a reduction to three lines of longitudinal structures and the consequent removal of one pier column in every group, from four to three. Additionally, a slight adjustment to the span configuration was proposed reducing the number of spans from 13 to 11. This resulted in a combined reduction in the number of pier columns by 18 to 30, with clear architectural and environmental benefits;

2.3.70 The flared cylinder pier design was also considered relatively complex to construct and the geometry was reconfigured to improve architectural sophistication whilst expediting constructability and maintenance characteristics; and

2.3.71 The outline design conservative environmental barrier doubled the height of the composition adding a further 3m to the 3m deep superstructure and deck. It was considered that a largely opaque barrier resulted in a significantly 'heavy' aesthetic. The design team worked with acousticians to understand the parameters and propose a lower height fully transparent barrier, with evident benefits to user experience and aesthetics.

2.3.72 The conclusion was that a reduced height barrier could be acceptable in environmental terms. Ultimately, a 1.2m high barrier incorporating the vehicle restraint system (VRS) was proposed.

2.3.73 The viaduct design retains the use of weathering steel assumed at Outline Design stage, rather than painted steel to avoid the need for maintenance activities to re-paint the structure.

Other structures

2.3.74 An additional green bridge (GB4 Morton Green bridge) was introduced north of Weston Road in response to ecological survey data, to maintain connectivity for bats on observed flightlines.

2.3.75 Alterations were made to the green bridge designs (such as the skew) and approaches to refine the planting proposed and to accommodate agricultural vehicle use by adjacent landowner, where required.

2.3.76 Nursery Woodland Green bridge (GB5) was developed following the refinement to the highway alignment and is described further in 2.3.80 to 2.3.86.

Environmental design and mitigation measures (incl. barrier, drainage, planting)

2.3.77 Design development for environmental design and mitigation measures at this stage included:

- Additional planting (particularly of trees) to ensure BNG is achieved;
- Development of the planting species schedule;
- Amendments to the design following ecology surveys in response to bat roosts and flight paths;
- Alteration of the environmental barrier on the outer edge of the viaduct structure to provide a combined solution with the vehicle restraint system and lowered height following the outcomes of surveys and assessments;
- Development of the flood compensation area in Wensum Valley;
- Refinement of balancing pond designs and areas of infiltration;
- Additional earth bunds and softening of slopes;
- Alterations to the design where it crosses proposed utility corridors associated with Orsted-Hornsea Three and Equinor projects where planting proposals were restricted;
- Changes to the design in response to the Airport Safeguarding assessment requirements;
- Development of the drainage strategy and design in response to Lead Local Flood Authority (LLFA) engagement and ground investigation findings; and

- Inclusion of sensitively sited additional temporary use areas for construction compounds and storage.

2.3.78 The design has been continuously reviewed to ensure that it continues to avoid impacts and protect habitats and environmental features wherever possible. This includes:

- Root protection areas, and also Ancient and Veteran trees I, as presented in the Ancient and Veteran Trees Avoidance Alignment Optioneering Report (document reference: 3.04.04);
- Consideration of the management of peaty soils in the floodplain presented in the **Outline Soil Management Plan** (document reference: 3.03.01a); and
- Development of the 'Essential Environmental Mitigation Areas' described further in 2.3.86 to 2.3.90.

Nursery Woodland Green bridge

2.3.79 As a result of the highway alignment refinement, the underpass previously included to maintain connectivity between parcels of woodland either side of the highway was no longer appropriate. This was due to the vertical alignment of the highway being in cutting alongside the woodland, and need for a solution with a greater width to maintain connectivity where bat flightlines were not as direct as other locations for a structure to respond to. Alternative solutions were considered to maintain connectivity for wildlife (particularly bats) in this location. This concluded with the inclusion of GB5 Nursery Woodland Green bridge.

2.3.80 Engineers and ecologists worked together to consider the option of a 'hop-over' using earthworks and planting to encourage bats up and over the road between woodland blocks. They also considered a green bridge solution spanning over the road based on the green bridge design used in other locations for the Proposed Scheme. Throughout the development of these

design proposals, stakeholders such as Natural England were engaged to provide feedback.

2.3.81 The hop-over required retention of the cutting earthworks with the use of soil nails, sheet piling and retaining wall solutions considered to maximise the retention of woodland either side of the road. It involved the separation of the northbound and southbound carriageways to retain an area of existing woodland in the centre as shown in Figure 2.6.

2.3.82 It was later concluded that the tree species in this area were not suitable for this purpose, being predominantly Scot's Pine, which are liable to falling over, particularly when exposed to wind. This would have posed too greater safety risk for the carriageway below and not provided the connectivity required if those trees were lost.

Figure 2-9 Hop-over option considered as part of the highway alignment refinement

2.3.83 A green bridge (GB5 – Nursery Woodland Green bridge) was chosen for this location as the most appropriate solution to provide continuous wildlife connectivity and safety for road users below. For this particular location the green bridge is wider than the other green bridges proposed, and no central track provided to ensure this is a wildlife only structure as shown in Figure 2.10 and Figure 2.11.

2.3.84 A retaining wall is maintained with the green bridge option, to minimise the footprint of the design near the Ancient Woodland and ensure the protective buffer can be maintained.

2.3.85 The separation of the carriageway has also been retained for visibility safety purposes for road users, they return to the standard cross section design with standard central reservation south of Ringland Lane.

Figure 2-10 Green bridge 5, the chosen solution to maintain wildlife connectivity between woodlands

Figure 2-11 Plan View render of Nursery Woodland Green bridge 5

Essential Environmental Mitigation Areas

2.3.86 Mitigation areas have been developed to provide new planting for protected species mitigation, tree loss compensation, and to contribute to Biodiversity Net Gain (BNG). This has been developed through an iterative process in which ecologists, landscape architects and the developer have identified a long list of opportunity areas for habitat creation and planting.

2.3.87 To ensure attractiveness and functionality of the planting for target species such as bats, barn owls, water voles – areas have been carefully selected with consideration to observed movements or presence of the species and connectivity to existing habitats.

2.3.88 The relevant landowners have been engaged to understand their interest in providing land for environmental mitigation, allowing the areas and placement of planting to be refined whilst maintaining their ecological objectives to provide habitat and/or foraging areas.

2.3.89 The mitigation requirements are described in the Biodiversity Chapter of the ES (document reference: 3.10.00) which have dictated the minimum areas required for delivery as part of the Proposed Scheme.

2.3.90 The Essential Environmental Mitigation Areas Plan (document reference: 2.11.00) presents the location of the following habitat types:

- Grassland creation and enhancement,
- Woodland and scrub creation,
- Woodland enhancement,
- Installation of bird and bat boxes,
- hedgerow creation and enhancement, and
- Watercourse and floodplain enhancements, including water framework directive (WFD) mitigation.

3 Conclusion

3.1.1 Throughout the design development for the Proposed Scheme, it has responded to the design principles and new information as it has emerged during the process to deliver a considered solution that is fit for purpose and achievable. Design principles have provided a consistent reference point for what the design must deliver, the following table summarises how these have been applied.

Ref:	Design Principle:	How the principle has been applied
DP1	***Respond to the character and landscape in which the Proposed Scheme is situated, with engineered forms integrated with the landscape to minimise their physical and visual impact and provide wider benefits or features;***	The design has integrated the highway and structures with the landscape through the use of earthworks and native planting species of local provenance to soften the appearance and respond to the surrounding context in which it is situated. Structures such as the Ringland Lane bridge provide functions beyond maintaining the current road route, allowing a bat flightline to be maintained with a dark corridor provided by a solid infill parapet.

Ref:	Design Principle:	How the principle has been applied
DP2	***Make a positive contribution to the landscape through conserving and enhancing the natural environment and biodiversity net gain;***	The landscape design (Document reference: 2.07.00) and essential environmental mitigation (Document reference: 2.11.00) provide connections to existing woodland and habitats nearby, and respond to the species surveys, including bat flight lines observed, to maintain their routes. Green bridges also facilitate connectivity across the landscape, whilst providing non-motorised user routes (including Morton and Broadway green bridges). The design has been developed to ensure net gain is provided for biodiversity.
DP3	***Strive to minimise adverse impacts on the landscape and seek sustainability in its use of materials, construction techniques, and maximising multi-functional features wherever possible;***	The design has sought to provide multi-purpose features to reduce the footprint of the scheme and maximise the benefits realised, through features such as the use of maintenance access tracks and green bridges by non-motorised users. Construction methodologies consider the environment in their approach, to minimise impacts.

Ref:	Design Principle:	How the principle has been applied
DP4	***Maintain and enhance the local Rights of Way where possible, for community accessibility, amenity, and to encourage sustainable modes of travel – with consideration of this beyond the scheme's extent;***	A sustainable transport strategy (Document reference: 4.02.00) has been developed to promote walking and cycling, maintain existing routes, and provide diverted routes over the Proposed Scheme where appropriate. This includes improvements in the local vicinity such as a crossing and cycle facility at Marl Hill Road.
DP5	***Adhere to a design narrative which provides a commonality and theme to unify all components of the scheme;***	The design philosophy and principles described in this report and the Design and Access Statement (Document reference: 1.02.00) have been applied to the design to deliver good design for all components of the Proposed Scheme.
DP6	***Respond to the constraints of the scheme, and consider its whole lifespan including capital and maintenance costs.***	The design has been informed by the constraints identified through surveys and assessments, and for mitigation of impacts. The choice of materials, structure types, and planting has considered the whole life cost including maintenance, for example species rich seed mixes applied instead of amenity grass as this required less maintenance, with greater benefits for biodiversity.

3.1.2 The environmental constraints presented by the Environmental Statement (document reference 3.01.00) and stakeholder engagement (described in the Statement of Community Involvement (document reference: 1.03.00)) have remained at the forefront of design decision making, shaping the design at its various stages.

3.1.3 Whilst design evolution is inevitable as a scheme develops and more information becomes available through surveys and assessments, the design principles have remained at the core of what is delivered for the Proposed Scheme.