Yeading Brook Restoration

London Wildlife Trust

cbec eco-engineering UK Ltd

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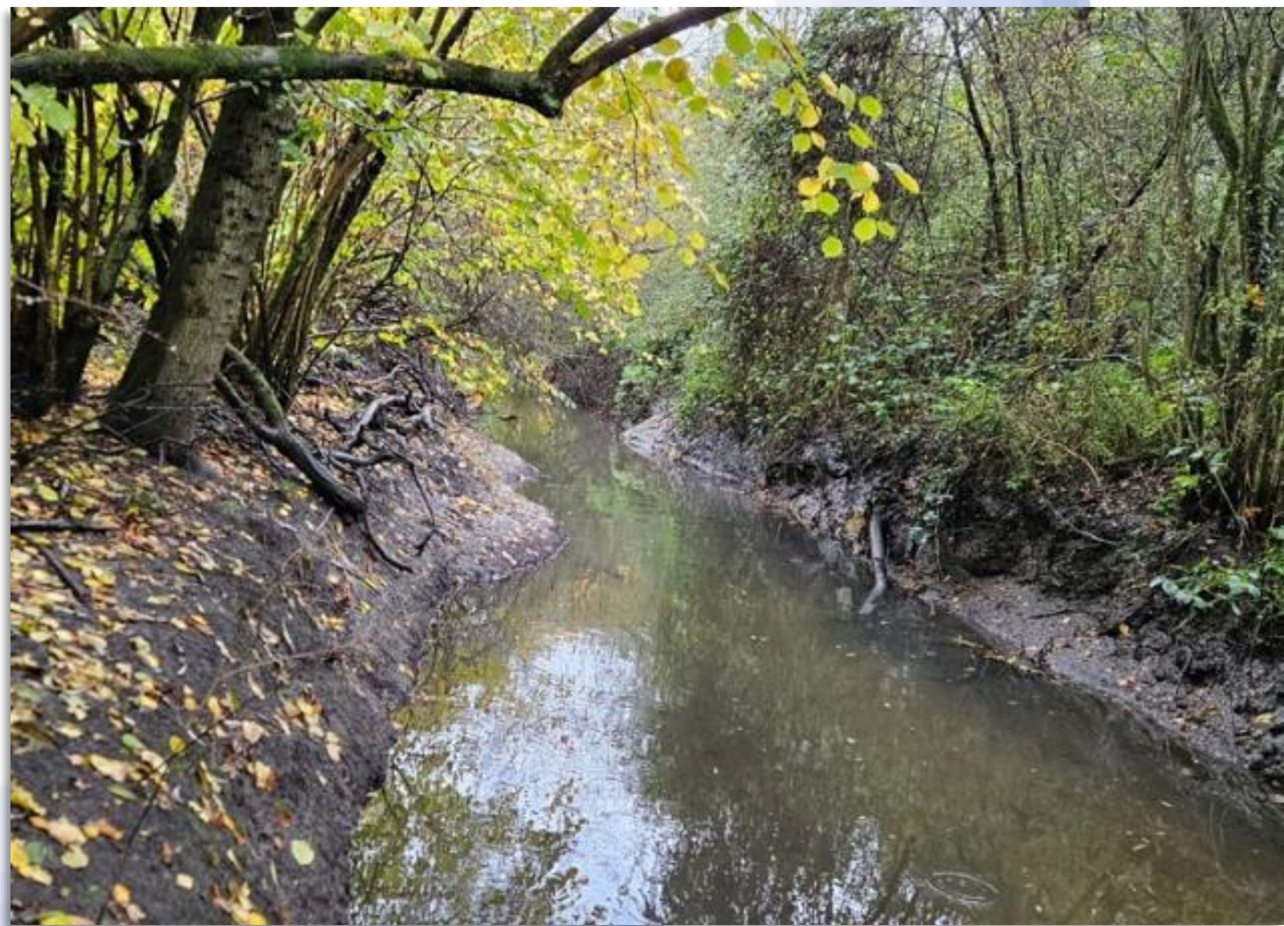

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1. INTRODUCTION

London Wildlife Trust (LWT) is developing a large-scale nature recovery project – *Nature Recovery and Flood Resilience at the Yeading Brook* – for the land within and between their nature reserves above and below the confluence between the Western and Eastern Arms of the Yeading Brook. Historically, the Yeading Brook (Figure 1.1) has been extensively modified to help improve the drainage of its surrounding floodplain for agriculture, industry and urban development. The project land covers an area of ~150 ha and includes Gutteridge Wood, Ten Acre Wood, and the floodplain meadows and pastures between and around these nature reserves (Figure 1.2). The current LWT vision for the site is a less intensively managed area, relying more on natural processes and aiming to: store more water and carbon; reduce the risk of wildfire and provide enhanced and appropriate public access. To realise these aims LWT has contracted cbec eco-engineering Ltd to undertake a Feasibility Study to investigate options to restore the Yeading Brook and its surrounding floodplain. This follows on from a pre-project study that assessed the condition of the channel through Gutteridge Wood (Gurnell & Shuker, 2023). The feasibility study builds upon the results of this previous report and assesses the current condition and options for an expanded area, from Gutteridge Wood and Meadows LNR downstream to Ten Acre Wood LNR, hence forth referred to as 'the project area'.

Large sections of the channel have been straightened and much of the brook is over-deep, overwide and disconnected from its floodplain. Improvements in transport links to London during the 20th century resulted in rapid urbanisation within the upper headwaters of the brook, i.e. Pinner and Harrow. This, and continued urban sprawl within the floodplain since, has significantly disrupted the catchment's natural water cycle and placed strain on the channel. The Yeading Brook suffers from extreme high and low flows, and pollution from urban areas negatively impacts water quality. As a result, morphological and habitat diversity are limited both in-channel and across the wider floodplain.

Despite this, there are opportunities for large scale channel-floodplain restoration within the middle and lower sections of the catchment where the channel is bordered by semi-natural habitat and areas of greenspace. At the confluence between the Western and Eastern Arms of the Yeading Brook the channel flows through areas of ancient woodland, damp meadows and farmland owned by the London Borough of Hillingdon (LBH) and managed by LWT. Two designated sites are present within this area, Yeading Woods Local Nature Reserve (LNR) and Ten Acre Wood LNR. The London Rewilding Taskforce has identified this area and its environs as being a potential site for 'rewilding' (Zone 9 Gutteridge and Ten Acre Wood) and recommended its inclusion as a strategic area in London's Local Nature Recovery Strategy (LNRS) (Greater London Authority, 2023). While being the smallest and most urbanised site considered, re-naturalisation of the Yeading Brook and its adjacent floodplain was recognised as offering significant opportunities for benefiting nature and the community and reducing flood risk. It has been suggested that the introduction of large grazing animals to the site would beneficial, helping to reinstate natural processes and manage habitat (GLA, 2023).

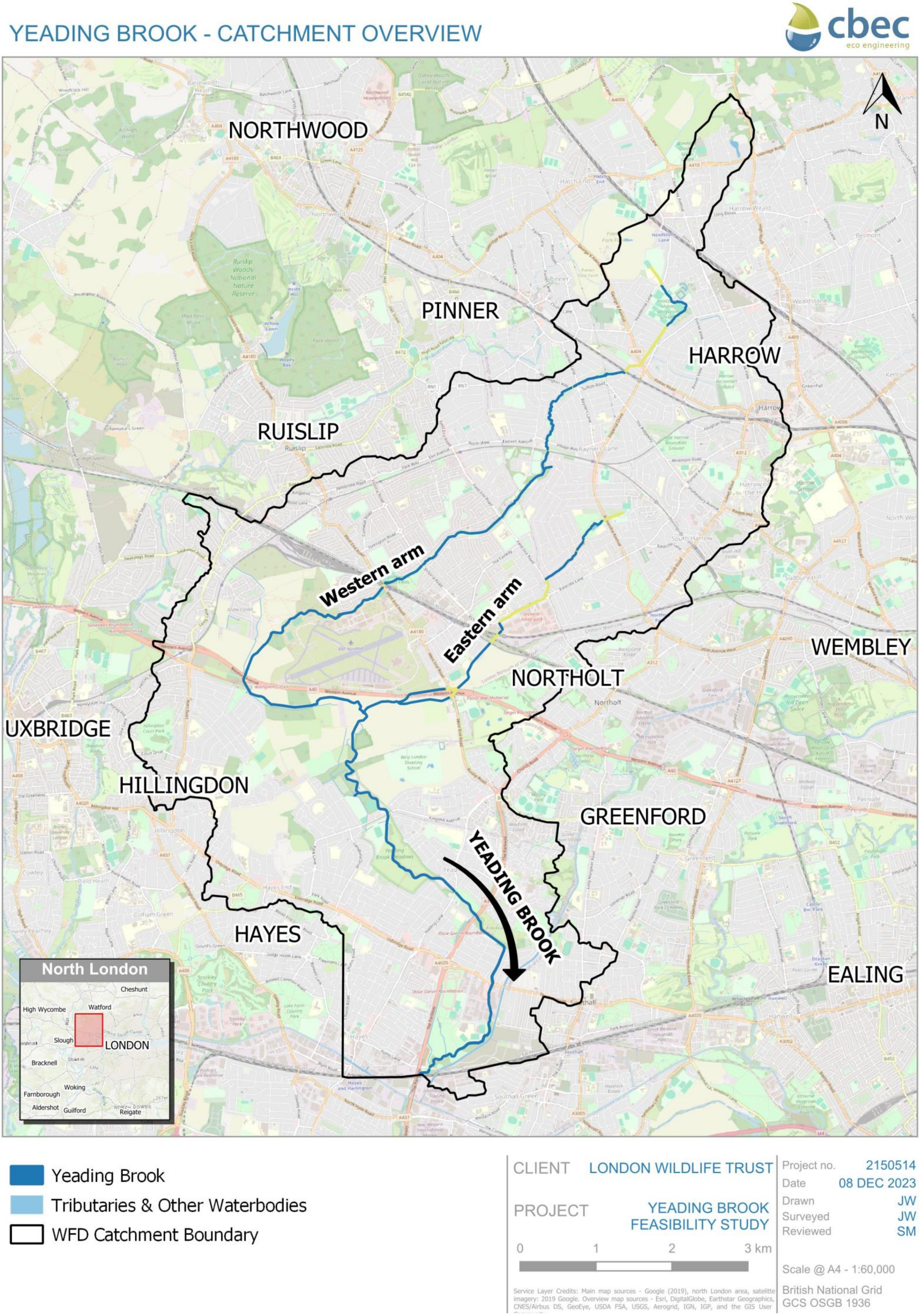


Figure 1.1 Yeading Brook catchment overview.

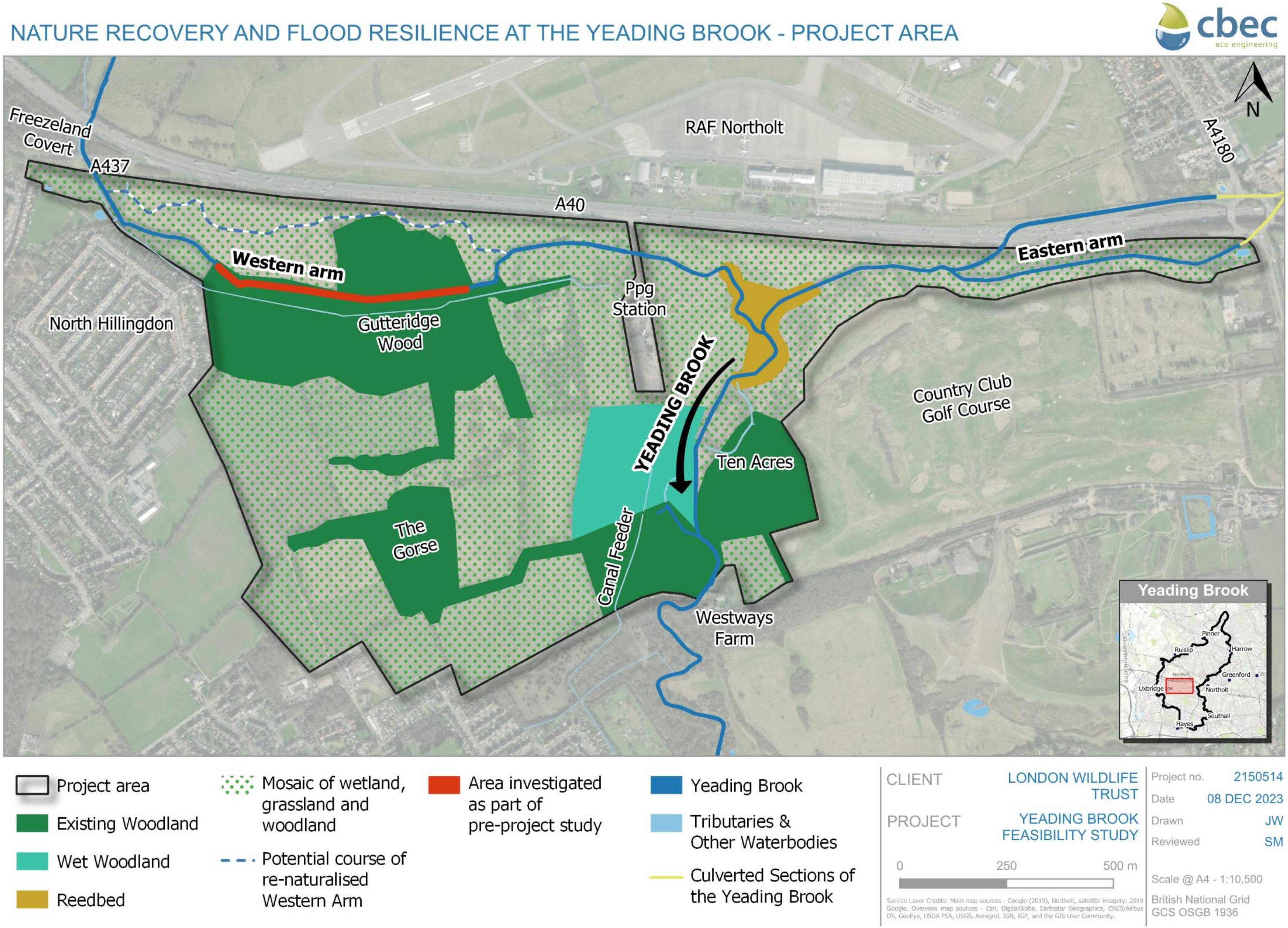


Figure 1.2 Nature Recovery and Flood Resilience at the Yeading Brook project area. Options proposed by LWT to be explored in order to meet the objectives for the.

1.1 PROJECT APPROACH

LWT identified the following options to be explored within this feasibility report:

- Re-naturalising the course of the Yeading Brook's Western Arm. The pre-project report (Gurnell & Shuker, 2023 – summarised in Section 2.2) indicated that the current course of the Western Arm is artificial, and that by realigning the channel to north of Gutteridge Wood (along its former alignment) would help to restore natural river process (see Figure 1.2 for proposed course of re-meandered channel).
- Reintroduction of river meanders and creation of backwaters, thus restoring natural processes and resilience.
- Creation of additional extensive areas of wet woodland, wetland habitat and reedbed to improve water quality and reduce flood risk in the area (see Figure 1.2 for proposed areas).
- Expanding the extent of woodland cover through natural regeneration and appropriate planting (current woodland cover ~26 ha, target cover ~40 ha);
- Creating additional habitat, i.e. areas of exposed riverbank, that will benefit biodiversity;
- Improving the amenity value of the site by providing a safe and inclusive, but respectful, access to the river, wet woodland and meadows.

These options, and any others suggested by cbec, were assessed in light of the following four Smart Water Catchment benefits targeted by LWT project:

1. Reducing pollution/improving water quality;
2. Reducing flood risk;
3. Improving public access and/or site connectivity, and;
4. Improving water flow.

To achieve a sustainable, long-term solution for the site, the project team has adopted a 'process-based' approach, working with the river's natural processes. This allowed the design to be developed within the context of the physical process regime of the wider catchment. A list of high level options were developed based the findings of a desk-based assessment of the catchment and results of field-based surveys (fluvial audit and topographic survey) of the study site. The results of previous studies were also considered during the development of these options. An appraisal of the options was then undertaken to determine the relative merits and constraints of each option. Discussions with LWT and the EA then helped identify preferred options for study site.

1.2 SITE LOCATION

The Yeading Brook is a ~26 km a tributary of the River Crane located in west London (Figure 1.1). Its main source, known as the Western Arm, rises in Harrow and flows in a south westerly direction through Rayners Lane, Ruislip and South Ruislip (skirting the edge of RAF Northolt) before veering to the east and then south east just north of Hillingdon. From here the river flows onwards through Southall, before its confluence with the River Crane at Hayes. A secondary source of the Yeading is the River Roxbourne (referred to as its Eastern Arm, both used interchangeably in this report) which also rises in Harrow but is significantly shorter (~4 km in length) and culverted for much of its length. It converges with the Yeading Brook just north of Hillingdon at Ordnance Survey National Grid Reference (OS NGR) TQ 09951 84198.

The focus of this feasibility study is a ~100 ha area of the Yeading Brook catchment just north of Hillingdon (Figure 1.2). This includes a 2.6 km section of the Yeading Brook from Ordnance Survey National Grid Reference (OS NGR) TQ 08394 84553 to TQ 09796 83732 and a 0.8 km section of the River Roxbourne from OS NGR TQ 10505 84396 to its confluence with the Yeading Brook at TQ 09951 84198.

2. PREVIOUS PROJECTS WITHIN THE YEADING BROOK CATCHMENT

2.1 RESTORATION WORKS ELSEWHERE IN THE CATCHMENT

A series of previous restoration projects have also been completed on the Yeading Brook and its tributaries. A selection of these are presented in Table 2.1.

Table 2.1 Restoration works undertaken on the Yeading Brook and its tributaries.

Name	OS NGR	Measures Implemented	Success of measures	Future aims
Yeading Brook & the Stafford Road Open Space River Improvement Project.	TQ 09688 85506	• London Wildlife Trust undertook various habitat improvement works on the Yeading Brook, with the project completed in 2018. • A historic meander was reinstated, creating a new backwater area. • Planting of native marginal trees and removal of Himalayan balsam.	• The project successfully improved habitat connectivity with downstream reaches. • Public awareness of the Yeading Brook was improved by involving local residents in the planting activities.	• An additional £48.5k in funding was secured from the Thames Restoration Fund for future works.
Yeading Brook at Yeading Meadows	TQ 10267 82852	• The Crane Valley Partnership facilitated removal of dense riverside hedgerows, allowing increase light and improved access to the river • Creation of woody berms to trap fine sediment and encourage plant growth • Planting aquatic vegetation on upstream berms.	• Local ecological conditions were improved by increasing the amount of light reaching the channel, encouraging the growth of macrophytes. • The woody berms were successful in narrowing the channel, increasing local flow diversity.	• No future aims stated.
Headstone Manor Park	TQ 13995 89624	• Thames21 led the project to de-culvert the Yeading Brook close to its headwaters at Headstone Manor Park. • Wetland areas were excavated.	• Flood risk was decreased around the protected Headstone Manor house. • Biodiversity was improved through the planting of wetland areas.	• No future aims stated.

2.2 PRE-PROJECT ASSESSMENT OF THE CHANNEL THROUGH GUTTERIDGE WOOD

In 2023 Cartographer Ltd undertook a pre-project study on behalf of LWT to assess the baseline condition of the Yeading Brook as it flows through Gutteridge Wood and recommend suitable options for restoration (Gurnell & Shuker, 2023) (Figure 1.2). For this the study employed the Modular River Physical (MoRPh) survey method. MoRPh is a field survey used to characterise both the physical habitat and hydromorphological functions within the river or stream at a scale that complements biological surveys. Information on the form, sediments, vegetation structure and human modifications of short river reaches, typically 10 m to 40 m in length, allowing their physical quality to be tracked and the way these change in response to restoration and management actions.

Approximately 600 m of the Yeading Brook flows through Gutteridge Wood, from the footbridge at the western entrance near Lynhurst Crescent to the point at which the river exits the woods in the east. The LNR, which is owned by the LBH and has been managed by LWR since the 1980's is comprised of relatively undisturbed mature woodland. Despite this, the portion of the Yeading Brook that flows through Gutteridge Wood is of poor condition.

The study concluded that the Brook had low geomorphic variability being essentially a straight channel, as well as a homogenous bed material, being comprised predominantly of silt and organic material. This in turn has resulted in low diversity of hydraulic conditions, creating a very uniform river with low habitat complexity, as opposed to a more sinuous, predominantly gravel bed channel with rich hydraulic diversity driven by in-channel large wood. Such a system would have been present in this area, likely prior to significant channel modification in the 1860s (Gurnell et al., 2023). There is also evidence that the Yeading Brook has been significantly embanked and disconnected from its historic floodplain, likely as a result of dredging and repeated removal of fallen trees and wood from the channel (Gurnell et al., 2023).

The Upper Yeading Brook (from around Rayners Lane to North Harrow) is significantly disconnected from its floodplain, particularly through Roxbourne, as the channel is set between high artificial embankments (Gurnell & Shuker, 2023). This results in the Upper Yeading Brook being unable to deposit fine sediment on its floodplain, resulting in elevated delivery of fine sediment downstream to the project reach. The canalisation of the river in this way, paired with its predominantly straight course, will also result in elevated flow velocities, leading to increased erosion of the bed and banks and further delivery of fine sediment downstream.

The Invasive non-native species (INNS) Himalayan balsam has also been identified on the bank faces and bank tops of the Upper Yeading Brook (Gurnell & Shuker, 2023). Given that Himalayan balsam spreads very easily, it is important that any works within the project reach follow correct protocols to prevent spread downstream.

Introduction of LWS and gravels and cobbles, as well as reprofiling of the banks in selected areas has been recommended as viable options for increasing the ecological value of the Yeading Brook (Gurnell & Shuker, 2023; Gurnell et al., 2023). Such works could therefore potentially be considered within the scope of this project.

3. DESK-BASED REVIEW OF CATCHMENT AND STUDY SITE CHARACTERISTICS

3.1 TOPOGRAPHY AND LAND-USE

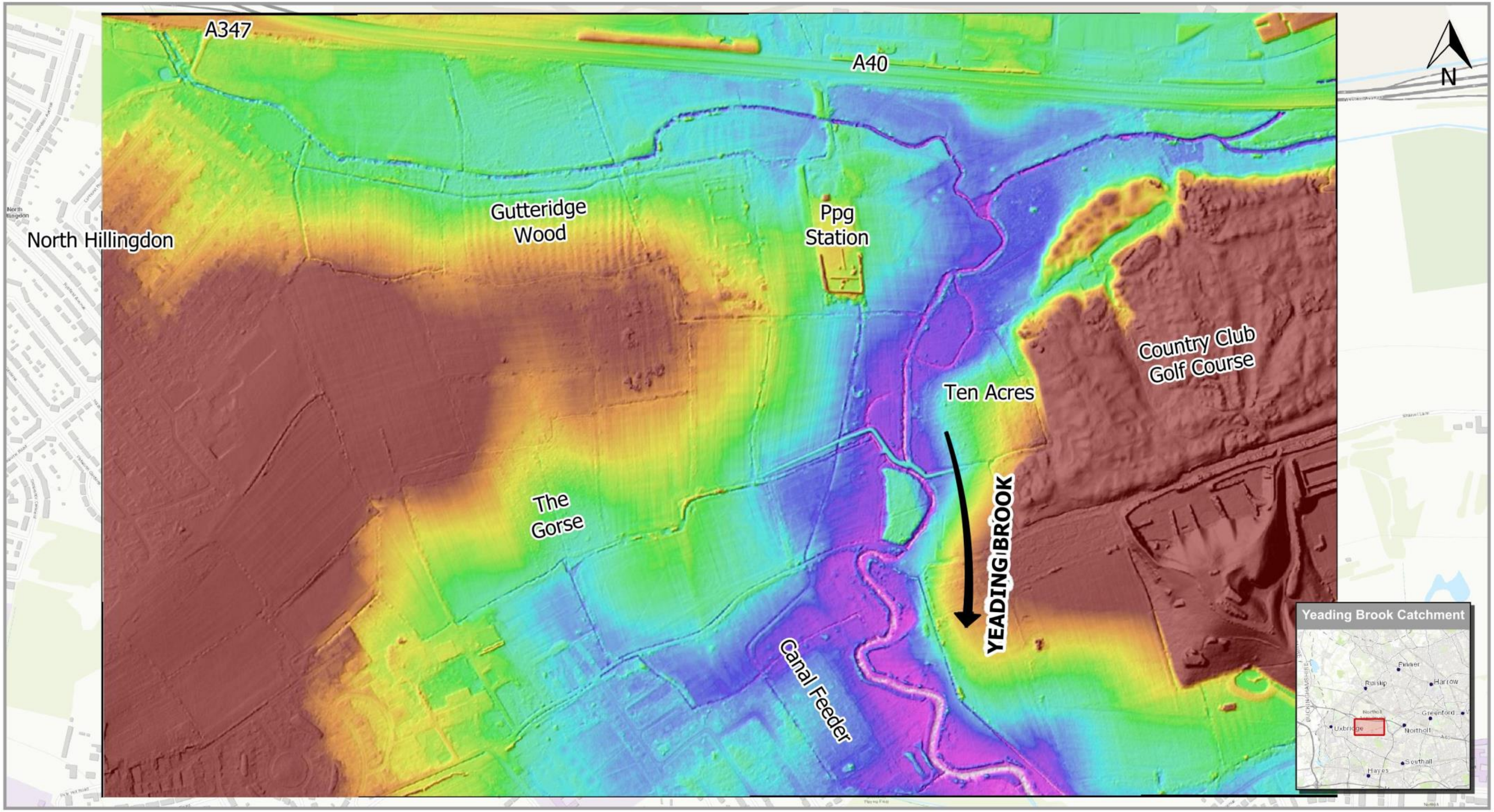
Catchment and valley topography influences how rapidly the system responds to rainfall, affects the energy of the resulting flows, and controls the sediment transport regime within the river system. Land use and land cover patterns within a catchment control the influx of water, sediment, and large wood material to the system. Understanding the Yeading Brook catchment terrain and land use/management upstream of, and within the study site will therefore be essential to developing a restoration design that works with natural river processes.

The land cover across the catchment upstream of the study site is dominated by discontinuous urban fabric (Corine, 2018). The majority of the Western Arm of the Yeading Brook is bordered by a narrow belt of greenspace (public parks) (~20 m either side of the channel), while the River Roxbourne is bordered by private residential gardens along the few sections where it is not culverted. Within the study area, the land cover consists of a mix of agricultural fields (grazed pasture/hay meadows), rough grassland and broadleaf woodland, sections of which are ancient with a semi-natural canopy, i.e. Gutteridge Wood (see Section 3.4). An airfield (RAF Northolt) is immediately north of the study area.

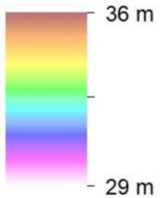
A review of the EA's 1 m resolution LiDAR composite digital terrain model (DTM), showed there is complete coverage across the study site (Figure 3.1). The 2022 1 m resolution LiDAR composite data contain surveys undertaken between June 2000 and September 2020 (DEFRA, 2020). Within the study area the Yeading Brook follows a north to south alignment and is predominantly lowland in nature, with the topography range between ~32 m above ordnance datum (AOD) at the upstream and ~29 m AOD at the downstream extent of the study site. Downstream of the Yeading Brooks confluence with the River Roxbourne the channel is constrained between two areas of high ground ~7 m above the floodplain.

The LiDAR data was further processed to produce a detrended DEM that would enable an assessment of channel-floodplain connectivity. This involved removing the effects of altitude as a trend from the dataset to show only the absolute differences between channel and floodplain elevation. Detrended DEM is useful for visually identifying historic channel features and other low-lying areas of the floodplain. This information is extremely valuable in determining the extents within which channel realignment is possible (i.e. in those less disconnected areas) and those where realignment would not be feasible. The detrended DEM is presented in Figure 3.2. Within the map blue indicates areas of greatest connectivity between channel and floodplain, while orange and red indicate areas of least connectivity. The upstream sections of Yeading Brook and River Roxbourne are shown to be poorly connected with the floodplain, with only small areas of blue through Gutteridge Wood and at their confluence. Downstream there is greater channel-floodplain connectivity as the channel flows Yeading Meadows. However, despite poor existing connectivity much of the floodplain is 1 – 1.5 m above the existing channel bed, meaning realignment is technically feasible.

YEADING BROOK - LiDAR



Surface DEM elevations (m)



CLIENT	LONDON WILDLIFE TRUST
PROJECT	YEADING BROOK OPTIONS APPRAISAL

0 250 500 m

Service Layer Credits: Main map sources - Google (2019), west London area, satelitte imagery: 2019 Google. Overview map sources - Esri, DigitalGlobe, Earthstar Geographics, CNES/Airbus DS, GeoEye, USDA FSA, USGS, Aerogrid, IGN, IGP, and the GIS User Community.

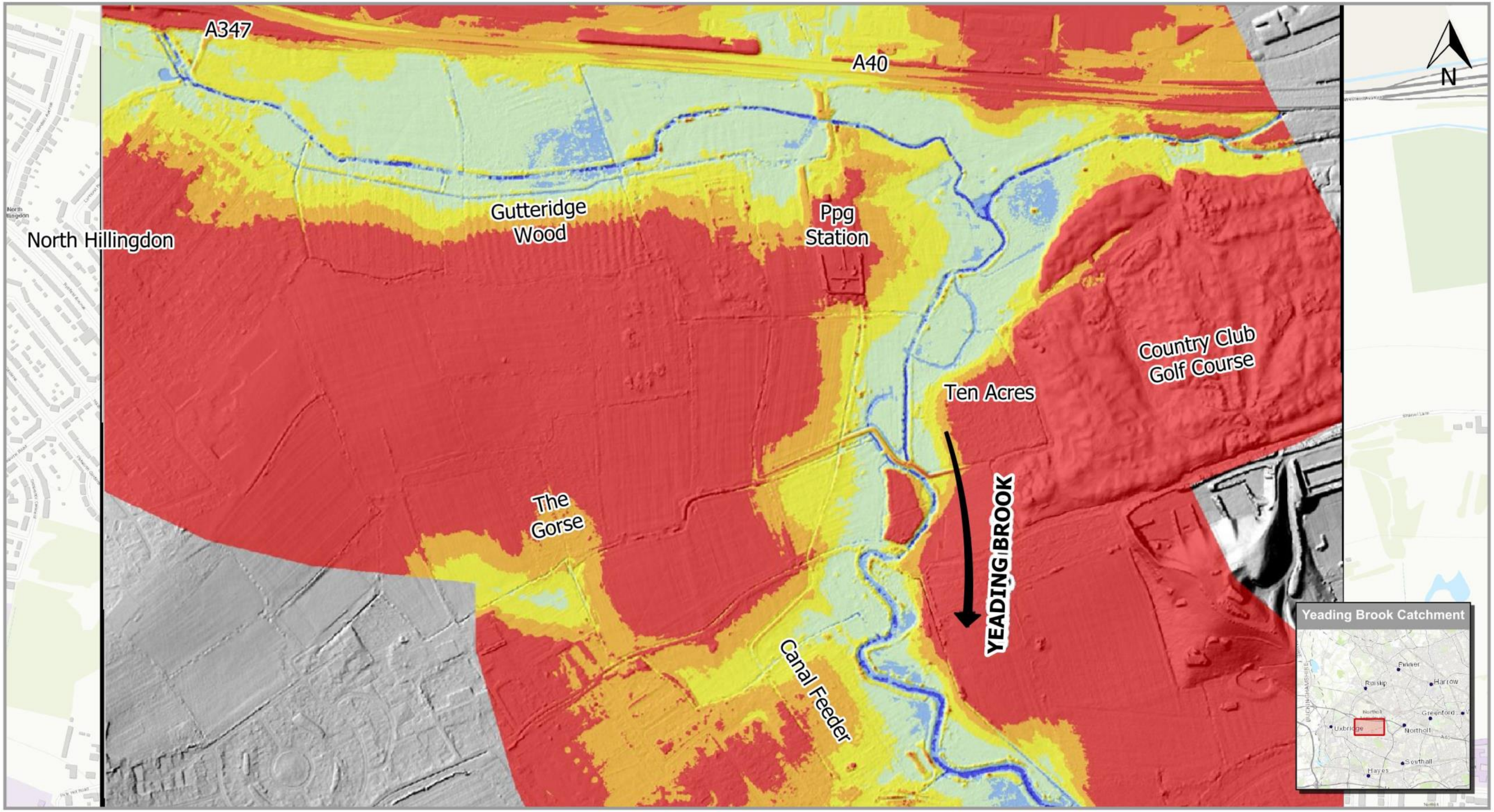
Project no.	2150514
Date	20 NOV 2023
Drawn	JW
Surveyed	JW & SM
Reviewed	SM

Scale @ A4 - 1:10,000

British National Grid
GCS OSGB 1936

Figure 3.1 Topography of Yeading Brook study site.

YEADING BROOK - DETRENDED LiDAR



Elevation difference from bed levels (m)

- <0.5
- 0.5m - 1m
- 1m - 1.5m
- 1.5m - 2m
- 2m - 2.5m
- > 2.5m

CLIENT	LONDON WILDLIFE TRUST
PROJECT	YEADING BROOK OPTIONS APPRAISAL
Project no.	2150514
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0 250 500 m

Scale @ A4 - 1:10,000

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Service Layer Credits: Main map sources - Google (2019), west London area, satellite imagery: 2019 Google. Overview map sources - Esri, DigitalGlobe, Earthstar Geographics, CNES/Airbus DS, GeoEye, USDA FSA, USGS, Aerogrid, IGN, IGP, and the GIS User Community.

Figure 3.2 Detrended DEM showing the elevation of the floodplain relative to the existing channel bed.

3.2 GEOLOGY & SOILS

Geological mapping made available from the British Geological Survey (BGS, 2022), indicates that the majority of the Yeading Brook catchment is underlain by sedimentary bedrock comprised of poorly laminated slightly calcareous silts, clay and sandy clays (blue-grey or grey-brown clays) of the London Clay Formation (Figure 3.4a). These clayey sediments often contain thin films of carbonate concentrations ('cementstone nodules'), as well as the presence of shells, organic material and black rounded flint gravels at the base of the formation. The upstream section of the Yeading Brook is underlain, in part by Lambeth Group, clays, silt and sands, with occasional instances of sand conglomerates. These bedrock formations are associated with fluvial, lagoonal, estuarine and other such marine environments, suggesting that these formations lend themselves well to saturated/wetter environments. In the east of the catchment is a small outcrop of Bagshot Formation bedrock, comprised of fine to coarse grained sands and clays, with sparse gravel seams. Sands within this formation are generally cross bedded with occurrences of fossilised remnants.

In terms of superficial geologies, large parts of the catchment are designated as 'unclassified' by the BGS (Figure 3.4b). This is likely due to one or more of the following:

- i) Areas have not been surveyed,
- ii) Superficial geology in these areas do not exhibit obvious characteristics enabling classification within specific depositional groups or
- iii) No superficial deposits occur in these areas but are instead characterised by outcrops of underlying bedrock.

Within the downstream sections of the Yeading Brook the study area sits within a somewhat relatively narrow section of coarse to fine grained sands and gravels, categorised as the Lynch Hill Gravel Member and are fluvial in origin. These fluvial deposits are boarded by medium to fine grained superficial clays and silts, known as the Langley Silt member. In this case the presence of unconsolidated silts and clays are likely a result of fine sediment deposition from the Yeading Brook and aeolian (wind-blown) deposits. In the southwest of the catchment superficial deposits are comprised of sand and gravels known as the Boyn Hill Gravel Member and Black Park Gravel Members. These are generally older fluvial deposits of the Thames, which range from coarse to fine grained sediments, suggesting that the area surrounding the Yeading Brook which is somewhat disconnected from it's floodplain, has previously been an active floodplain for the Thames.

As the parent material of local soils the underlying geology forms the basis for the character of soil types. Other factors that influence the characteristics of soil type include; climate, topography, vegetation, organisms (i.e. those who promote pedoturbation) and land use (Singer, 2015). Soil type within the area is not fully quantified and there are large areas of the Yeading Brook catchment remain unsurveyed. However, the dominant soil type scattered across the study area is categorised as Plansols (Figure 3.3). Plansols are generally slowly permeably clayey soils, which impede land drainage. There are also distinct areas of Stagnosols which are similar in property, however are slightly acidic

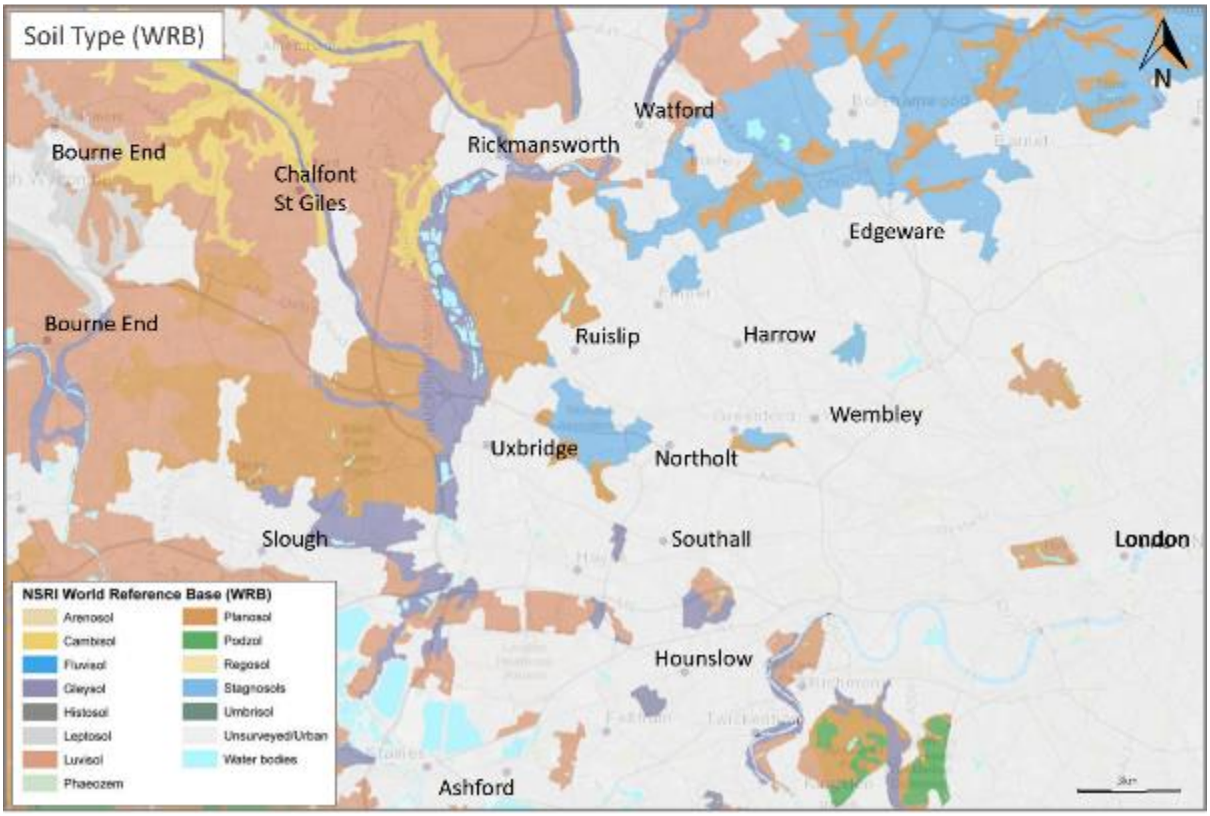


Figure 3.3 Soil types in the north London area.

and base-rich. Such soils are generally associated with grassland and arable land cover with some woodland, seasonally wet pasture and woodland habitat (Encyclopaedia Britannica Inc., 2023).

The study area is also covered by small sections of both Gleysols which generally occur under waterlogged/natural wetland conditions as a result of a combination of rising/high water table and poor drainage, especially where soils are associated with fluvial and marine sediments/parent material. Due to the impermeable nature of these soils land use is often limited to, natural wet/swamp lands or in some cases used for extensive grazing. However, the permeability of Gleysols can be altered if artificially drained, which appears to be the case just south of the study area where some parcels of land have been drained in order to improve the soil permeability for arable and other agricultural crops (Encyclopaedia Britannica Inc., 2023). Thin sections of freely draining, lime-rich loamy, Cambisols are also apparent within the Nort/northwest of the catchment. Such soils generally lend themselves to agricultural landscapes coniferous woodland and arable landcover types.

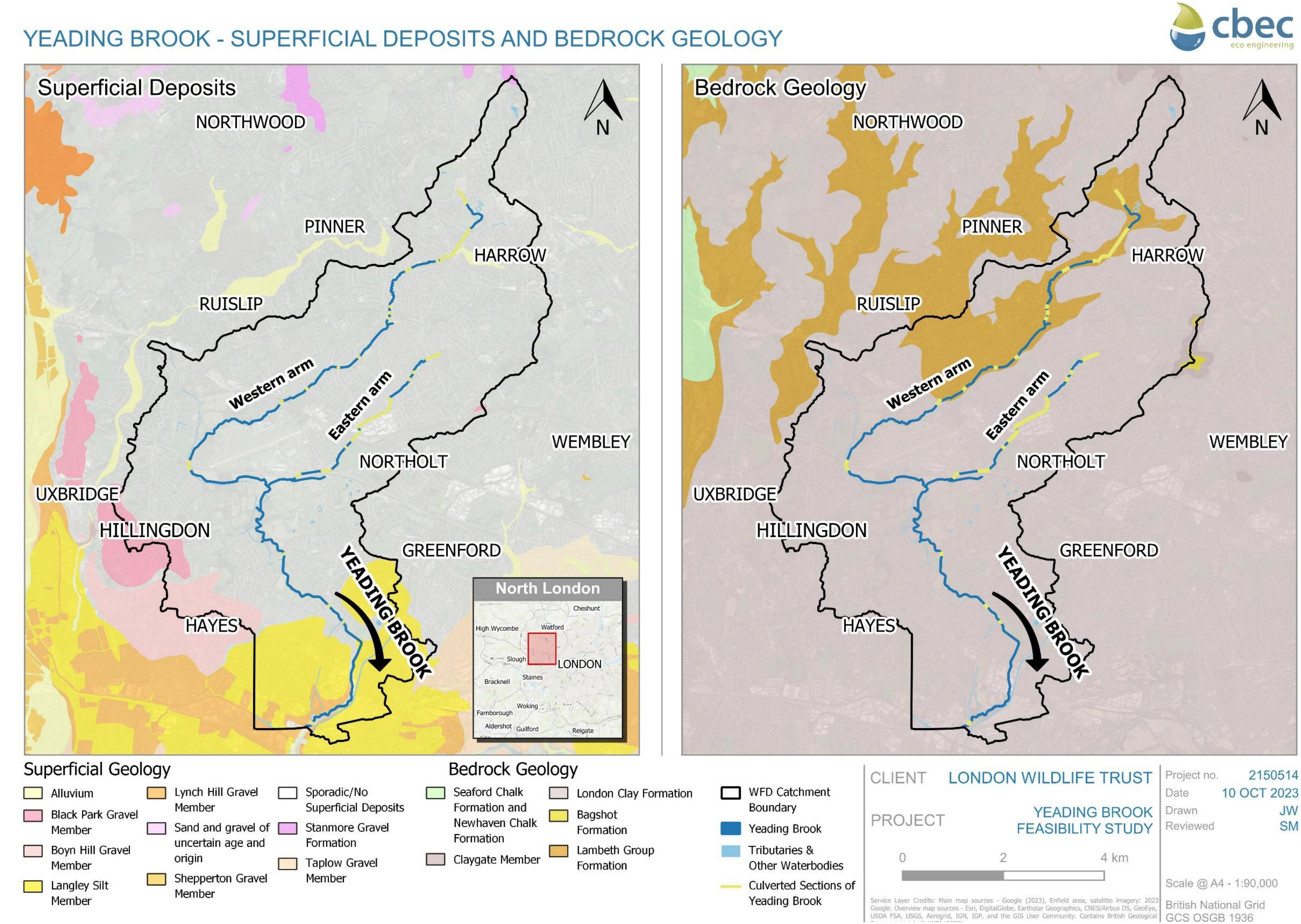


Figure 3.4 Superficial and bedrock geology within the Yeading Brook catchment.

3.3 HISTORIC CHANNEL ADJUSTMENT

Historical channel evolution data for the Yeading Brook were reviewed to determine how the position and planform of the channel may have evolved or been artificially adjusted over time. This offers a useful means of assessing the degree of dynamic behaviour (where channel change has been primarily caused by fluvial process as opposed to human activity) and indicates the degree of channel stability or dynamism. Historical channel change may also be caused by human engineering intervention. In these cases, the degree of adjustment indicates the extent of channel modification. Therefore, historical channel evolution analysis allows for an assessment of the suitability and/or potential risk associated with outline design options.

The historical assessment was undertaken by comparing recent data on channel position with the channel alignment depicted on historic maps held by the National Library of Scotland[1] and aerial imagery from Natural England[2] and Google Earth archive (Google Earth Pro 6.0). LiDAR imagery (previously presented in Section 3.1) was also used to identify (where possible) the position of relict channels shown in historic maps and to identify potential palaeo-channels predating the earliest available maps for the area.

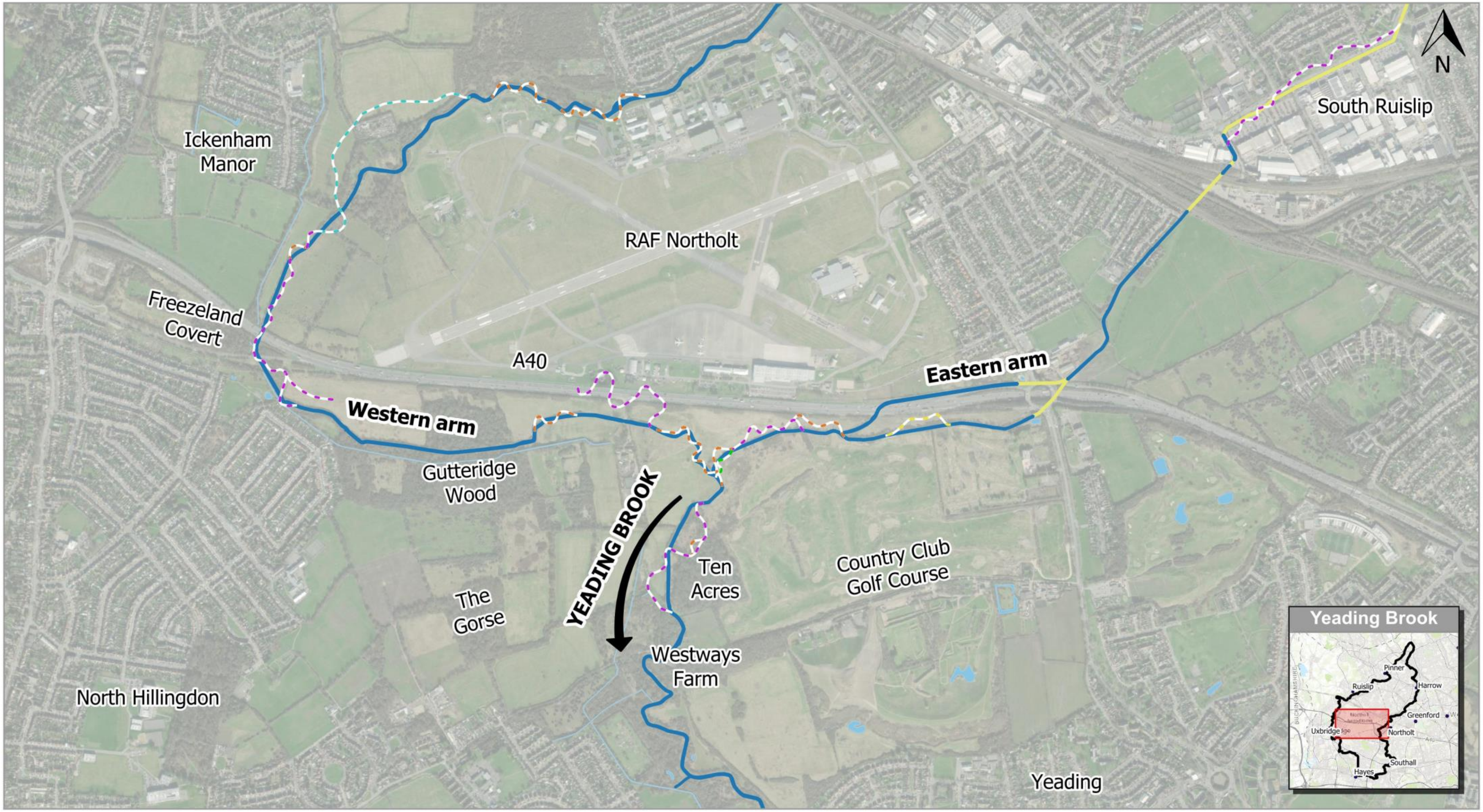
The oldest available map for the area is John Rocque's *Topographical Map of the County of Middlesex* drawn in 1754, an excerpt from which centred on the Yeading Brook is presented in Figure 3.6. A series of Ordnance survey (OS) maps for the area beginning with the 'Old Series' map (surveyed 1804 – 45) to the most recent maps of the area (i.e. National Grid map 1944 – 73) provides a record of channel over time (Figure 3.5).

While LiDAR data helps to confirm the historic course of the channel indicated by historic maps of the area it provides little to no evidence of the channels course prior to the earliest of these maps, i.e. 1754. It is likely that evidence of relict channels has been lost due to human activity within the wider floodplain, i.e. agriculture and urban development.

The cartographic accuracy of 18th century maps varies considerably, with some showing relatively accurate positions when compared against modern features (e.g., field boundaries), while others show more indicative relative position. Within individual maps there may even be variations in quality, with some features being surveyed and plotted with greater consideration and accuracy than others depending on their deemed importance, i.e. key settlements and areas of land ownership may be more accurately represented than natural features such as rivers.

[1] National Library of Scotland historic archive available online at: http://maps.nls.uk/geo/explore. Accessed December 2023.
[2] NE historic aerial photography available online at: https://historicengland.org.uk/images-books/archive/collections/aerial-photos/. Accessed February 2023.

YEADING BROOK - HISTORIC CHANNEL ALIGNMENT



- - - John Roque's Topographical Map of the County of Middlesex 1757
- - - OS One-Inch 'Old Series', surveyed 1804-45
- - - OS Six-Inch 1st Ed., surveyed 1864-75 (Buckinghamshire Sheet LIV)
- - - OS Six-Inch 2nd Ed., surveyed 1894 (Middlesex Sheet XV)
- - - OS National Grid Maps, surveyed 1959-62 (Sheet TQ 18 SW)
- - - OS National Grid Maps, surveyed 1930-59 (Sheet TQ 08 SE)

Yeading Brook

Tributaries & Other Waterbodies

Culverted Sections of the Yeading Brook

CLIENT	LONDON WILDLIFE TRUST	Project no.	2150514
		Date	08 DEC 2023
PROJECT	YEADING BROOK FEASIBILITY STUDY	Drawn	JW
		Reviewed	SM

0 250 500 750 m

Scale @ A4 - 1:18,000

British National Grid GCS OSGB 1936

Figure 3.5 Historic channel alignment of the Yeading Brook.

Figure 3.6 Excerpt from John Rocque's 1754 Map of the County of Middlesex centred on the Yeading Brook. The red box in a) indicates the location of the design area (inset maps b) and c)). The green solid line in c) indicates the likely shape of Gutteridge Wood's western and southern perimeter based on interpretation of field boundaries as well as parish boundary evidence. Confidence in the western boundary geometry is generally high, although there is still some uncertainty as to the precise position of the northwestern corner. The orange line in c) indicates the likely position of the northern and eastern boundaries of Gutteridge Wood. This shape is attested from the Ordnance Survey Old Series although it is a less certain interpretation of John Rocque's 1754 map.

Visual inspection of John Rocque's map of 1754 (Figure 3.6a) shows generally good correspondence with modern maps for features still present in the landscape, e.g., key settlements, roads and fields boundaries. The course of the Yeading Brook upstream and downstream of the study site appears to have been recorded accurately, and largely reflects the historic course of the channel indicated in later maps, i.e. OS 1st Edition (1864 – 75). In some instances, the channel is captured in a level of detail unexpected for a map of this age, with individual meander bends through Yeading Meadows correlating closely with their current course. In the upper catchment the map indicates that both the Yeading and Roxbourne had been modified significantly prior to 1754, with large sections appearing to have been straightened. Downstream of the site the Yeading is shown retaining much of its natural sinuosity (which it still does to its present day through Yeading Meadows) down to its confluence with the River Crane at Hayes. However, within the study area there are several anomalies that are difficult to explain (Figure 3.6a and b). Firstly, the map shows the Yeading to take a more southerly route though land that is topographically outside of the floodplain, i.e. high ground. Additionally, the shape of Gutteridge Wood does not correspond to what would be expected. A parish boundary which matches the OS Old Series (1804 - 45) map helps to constrain with good confidence the western and southern boundaries of the wood (green line in Figure 3.6b) pre- and post- John Rocque. However, the northern and eastern boundaries are more difficult to relate between John Rocque's map and later maps (orange line in Figure 3.6b). This may be due to genuine change in the shape of the wood over the centuries but it seems more likely to have been an error or omission in surveying perhaps due to inaccessibility. What can be reliably interpreted is that the course of the river likely skirted around the edge of Gutteridge Wood, even if the position of that edge as drawn seems unlikely. This interpretation is supported by the modern topography which shows that the course of the river as drawn would have crossed a significant elevation gain of several metres. There is no reason to suppose that large scale earth movement has occurred in this location. Therefore, while the course of the channel upstream and downstream of the study area can be plotted with a relative degree of certainty and is shown in Figure 3.5. the course of the channel through the study area is omitted from our interpretation due to the uncertainties outlined above.

Although not captured in either John Rocque's map or the OS Old Series Map, the OS 1st Edition map of 1863 – 76 shows two small watercourses that may indicate the river's historical course pre-1754 north of Gutteridge Wood. Close to where the A40 currently crosses the Yeading Brook a short distributary is shown draining from the left bank of the Brook into a wetland area while just upstream

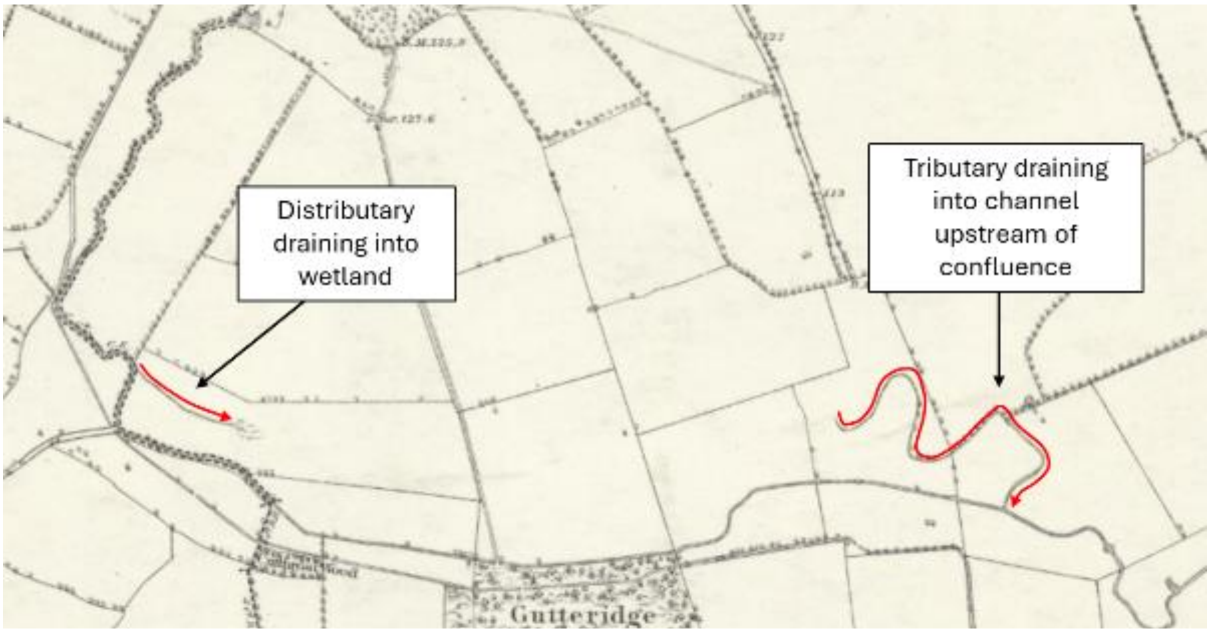


Figure 3.7 OS 1st Edition map of 1863 – 76 showing the distributary and tributary (highlighted in red) that possibly indicate the Western Arm of the Yeading Brooks historical course.

of the confluence between the Western and Eastern Arms of the Yeading a small tributary feeds into the channel from the true left bank (TLB). The lower section of the latter of these is still visible within the landscape (see Section 4) and is now occupied by a stream that drains from RAF Northolt. Both these hint at an earlier course of the river, however, there are no obvious landform features within the LiDAR that would indicate the course of this former channel. It is possible that earthworks undertake to construct RAF Northolt in 1915 and/or the A40 between 1964 - 70 may have removed any evidence of this former channel.

John Rocque's map indicates much of the Yeading Brook catchment was dominated by agricultural activity by 1754, with sporadic hamlets and villages linked by an emerging road network. Agriculture at this time would have been low intensity, a mix of arable land and grazed pasture with floodplain meadows along the channel margin in areas more susceptible to inundated during autumn/winter flooding. Evidence for older agricultural activity can be seen along the Western Arm of the Yeading where distinctive broad reverse s-shaped undulations created by ox drawn plough, known as 'ridge-and-furrow' is evident within the LiDAR. These are located in the fields along the TLB and the true right bank (TRB), which is currently occupied by Gutteridge Wood. This would indicate that Gutteridge Wood was at one point under plough.

Between 1804 - 75 many of the remaining meanders along the Yeading Brook upstream of Westway Farm were bypassed and the channel straightened, with the large meander bends located at the southern limit of the study remaining until the turn of the 19th century. A sewage treatment works was built along the TRB of the Western Arm of the Yeading between 1890 – 1930 but this structure was decommissioned by 1950. By 1900 urban areas within wider Yeading Brook catchment were expanding with urban sprawl increasing dramatically between 1910 – 1930. By 1912 agricultural fields to the north of study area had been repurposed as an airfield, although runways do not appear to not have been constructed until the ~1915. Figure 3.8 shows a series of aerial images of the study area that shows changes in land use from 1945 up to the present day. As can be seen, large areas of land adjacent to the Yeading had been prepared (roads laid and lots allocated) for housing construction by 1945, which corresponds to the housing boom around this part of London during the 1930's. Between 1945 and 1999 Yeading town expanded significantly (indicated by red square in Figure 3.8 - 1999) with remaining greenspace in North Hillingdon being infilled. The most recent change has occurred in ~2020 with fields along the TLB of the River Roxbourne being developed as a golf course (County Club Golf Course).

Figure 3.8 Sequence of aerial images from 1945 – 2022 documenting land change (particularly urban sprawl) around the study area.

3.4 ECOLOGY

The Yeading Brook Catchment and the wider London/Thames region are home to several ecologically important and sensitive areas, which have been given specific conservation designations in order to protect their unique and diverse habitats and/or to promote local access to and education on areas of semi-natural habitat. The study area falls within multiple Higher Level Environmental Stewardship scheme areas, including areas shown in Figure 3.9, managed by both LWT and the LBH to promote effective land management across environmentally sensitive landscapes. According to the EA, Natural England (NE), Centre for Ecology and Hydrology (CEH) and other local organisations, the most ecologically important areas both within and surrounding the study area include:

Ancient Woodlands;

- Gutteridge Wood, Ancient and Semi-Natural Woodland

Local Nature Reserves;

- Yeading Woods (including Gutteridge Wood and Meadow and Ten Acre Wood)
- Yeading Brook Meadows
- Yeading Meadows
- Islip Manor

Country Parks;

- Minet Country Park

Sites of Important Nature Conservation

- M51 Yeading Brook Meadows (including Gutteridge Woods & Ten Acre Wood)
- BI12 Home Covert, Lowdham Field and Pole Hill Open Space
- BI13 Ickenham Marsh, Austin's Lane Pastures & Freezeland Covert
- L03 Yeading Brook between Roxbourne Park & Ruislip Gardens

Aside from the designations mentioned above and included within Figure 3.9, observations of protected and notable species including Skylark, Slow worm, Grass snake and narrow-leaved water-dropwort suggest that the Yeading Brook and surrounding habitats support populations of these significant species.

YEADING BROOK - ECOLOGICAL DESIGNATIONS/PROTECTION

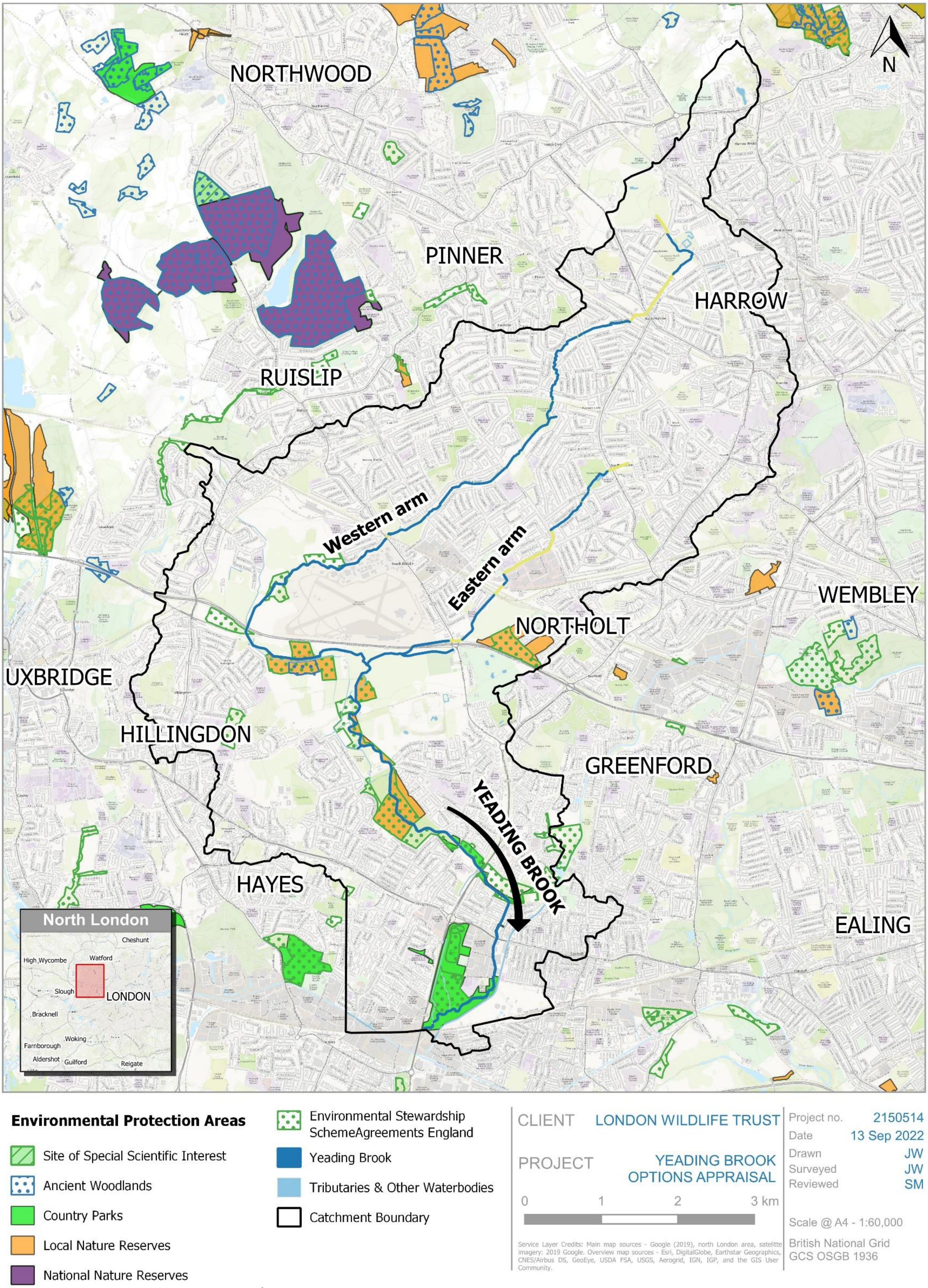


Figure 3.9 Ecological designations/protected areas within the Yeading Brook catchment and wider north London area.

3.5 ARCHAEOLOGY AND HERITAGE DESIGNATIONS

A desk-based search of data available online at Historic England (HE) was conducted to identify cultural heritage sites and buildings of historical interest (listed buildings) within and in close proximity to, the study site (HE, 2023).

There are no heritage designated areas or structures within the project area. However, upstream of the study area there are several sites of historical importance within 500 m of the channel (Figure 3.10). Four sites with heritage designations are located upstream of the site on the Western Arm:

- Ickenham Village (Conservation Area) (Western Arm)
- Garden Walls To East Of Manor Farmhouse (Grade II)
- Ickenham Manor (Grade I)
- Ickenham Manor Farm (Scheduled Monument)

A single site with a heritage designation is located upstream of the site on the Eastern Arm:

- Polish Air Force Memorial (Grade II)

Further spatial details of archaeology and heritage assets, including Listed Buildings, Scheduled Monuments, Heritage Conservation Areas and 'at risk' heritage sites are shown within Figure 3.10. These are not likely to constrain restoration option development, due to the relative distance from the study area and channel. However, constraints imposed by these areas should be considered as part of the options development and any design development and construction phase of works.

3.5.1. Other Planning Designations

All of the project area falls within the Metropolitan Green Belt as shown in the Hillingdon Local Plan (LBH, 2012).

YEADING BROOK - ARCHEOLOGY & HERITAGE

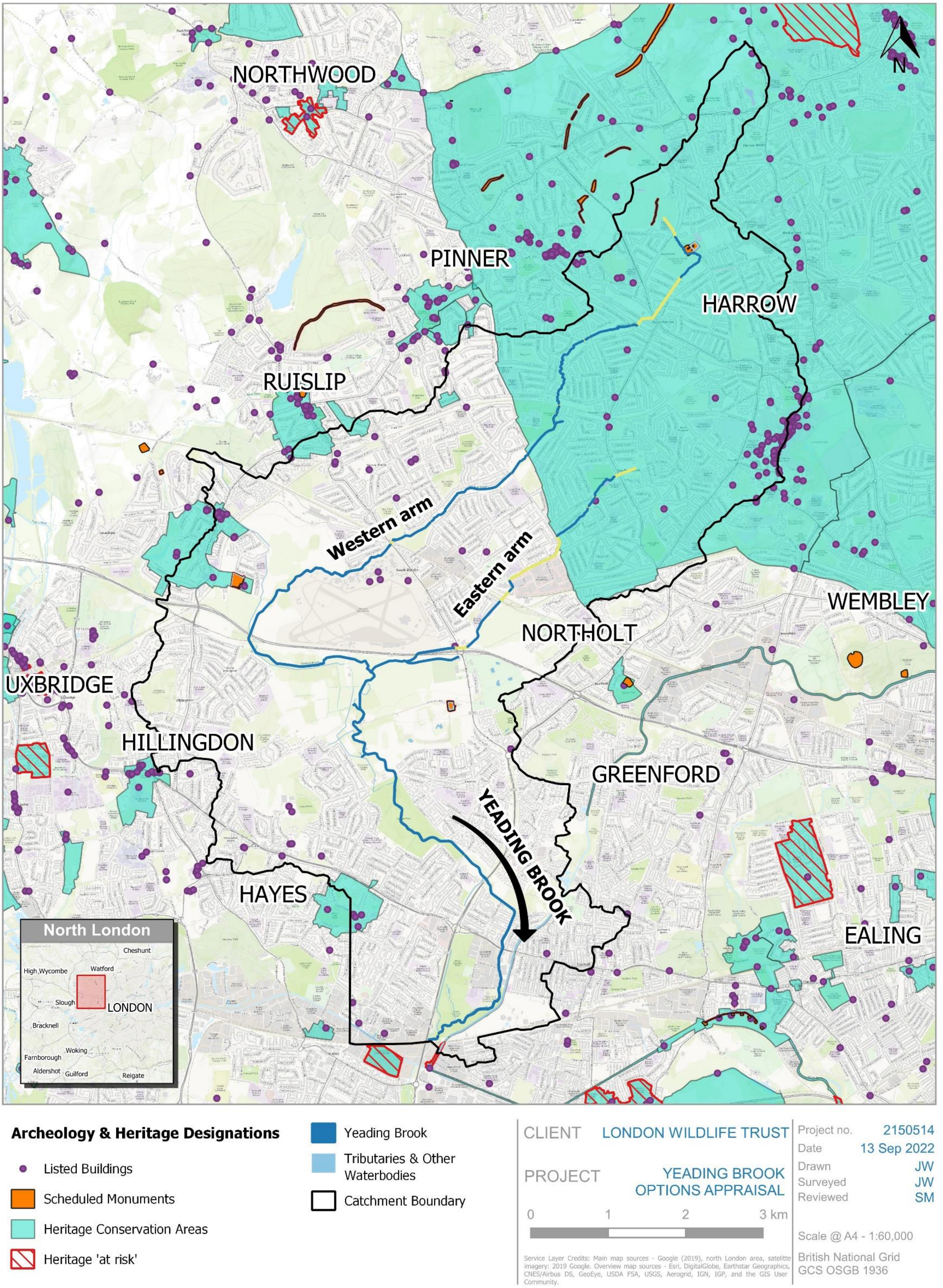


Figure 3.10 Spatial distribution of archaeological and heritage designations identified within the Yeading Brook catchment.

3.6 WATER FRAMEWORK DIRECTIVE

The Yeading Brook catchment (GB106039023051) is made up of a single water body as designated by the Environment Agency (EA) under the Water Framework Directive (WFD) classification system. The catchment consist of two branches of the Brook (the Western Arm and Eastern Arm) that meet at a confluence just south of the A40 (OS NGR TQ 09958 84198) before flowing south. Table 3.1 details the WFD classification for the Yeading Brook channel.

As a result of physical alterations by human activity the channel is designated as a heavily modified water body (HMWB).

Several factors have resulted in the Yeading Brook being assigned poor status for various elements. However, the underlying cause is the urban setting of the channel, which has promoted physical changes to the channel to be instigated (i.e. channelisation, dredging, etc.) and diffuse pollution from surrounding urban areas, with phosphate and dissolved oxygen (DO) from water industry and domestic outfalls being noted as particular problem

Table 3.1 WFD classification of the Yeading Brook.

Element	2022 Status	Predicted Status by 2027 and Confidence in Achievement	Reason for Not Achieving Objectives/Predicted Status
Ecological	**MODERATE**		
Biological Quality Elements	**Poor**		
Invertebrates	Poor	Moderate (Low Confidence)	Disproportionately expensive: Disproportionate burdens; Good status prevented by A/HMWB designated use: Action to get biological element to good would have significant adverse impact on use
Macrophytes and Phytobenthos Combined	Good	Good (2015)	-
Macrophytes Sub Element	Poor	-	-
Phytobenthos Sub Element	Poor	-	-
Physico-Chemical Quality Elements	**Moderate**		
Ammonia (Phys-Chem)	Poor	Good (Low Confidence)	Disproportionately expensive: Disproportionate burdens
Biochemical Oxygen Demand (BOD)	Poor	-	-
Dissolved oxygen (DO)	Bad	Good (Low Confidence)	Disproportionately expensive: Disproportionate burdens

Element	2022 Status	Predicted Status by 2027 and Confidence in Achievement	Reason for Not Achieving Objectives/Predicted Status
Phosphate	Poor	Good (Low Confidence)	Disproportionately expensive: Disproportionate burdens
Temperature	High	Good (2015)	-
pH	High	Good (2015)	-
Hydromorphological Supporting Elements	**Supports Good**		
Hydrological Regime	Supports Good	-	-
Supporting Elements (Surface Water)	**Moderate**		
Mitigation Measures Assessment	Moderate or Less	Good (Low Confidence)	Disproportionately expensive: Disproportionate burdens
Supporting Elements (Surface Water)	**High**		
Triclosan	High	High (2015)	
Chemical	**FAIL**		
Priority Hazardous Substances	**Fail**		
Polybrominated diphenyl ethers (PBDE)	Fail	Good (2063)	Natural conditions: Chemical status recovery time

4. FLUVIAL AUDIT

4.1 METHODOLOGY

A fluvial audit (geomorphic walkover) was undertaken on 10th November 2023. The walkover covered the defined study area, as well as ~700 m upstream and ~800 m downstream of the site. The extent of the survey is noted below:

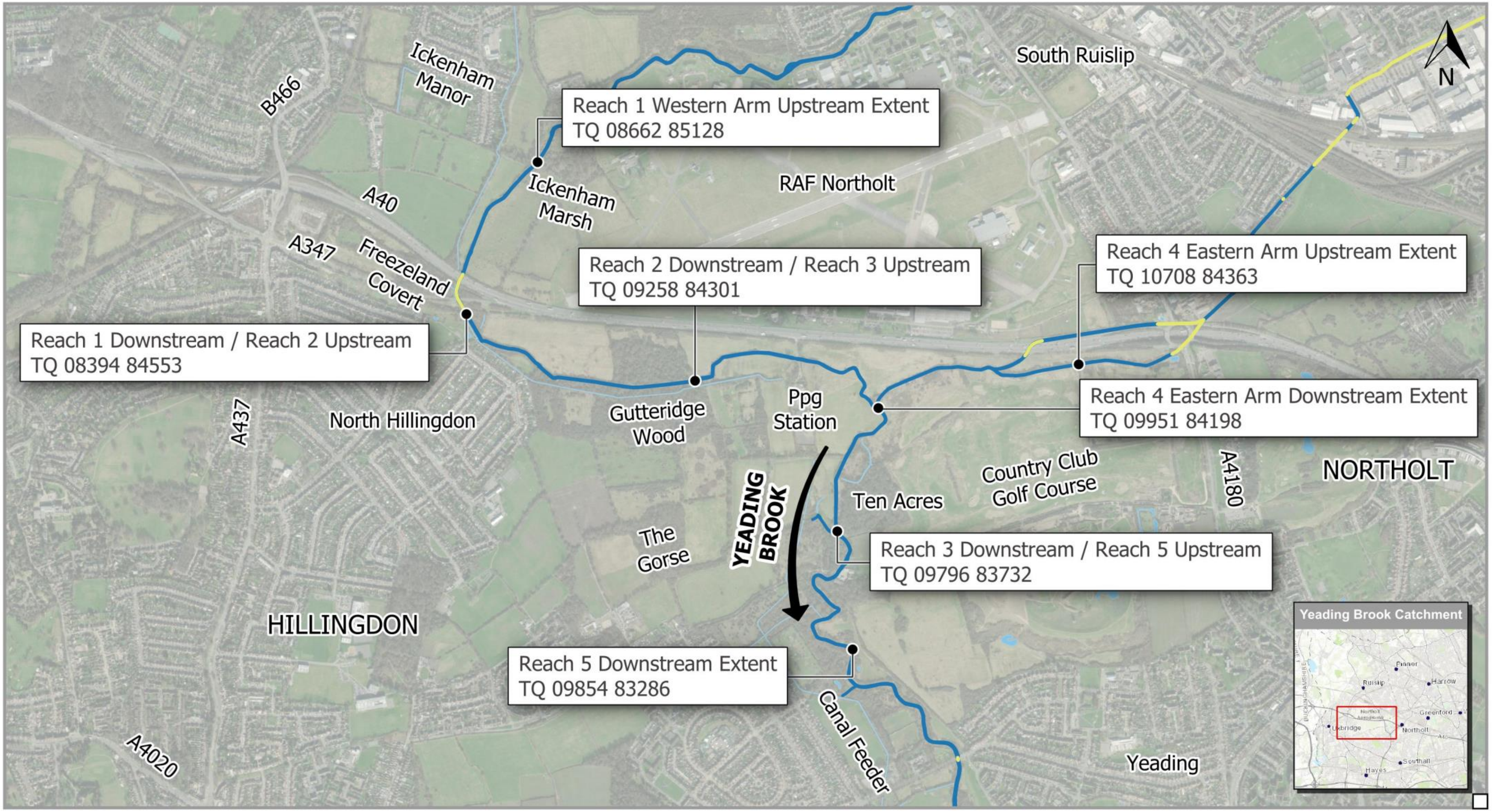
- Western Arm upstream extent: TQ 08662 85128.
- Eastern Arm upstream extent: TQ 1050 84396.
- Downstream extent: TQ 09854 83286.
- Total surveyed length: ~5 km.

This field-based assessment allowed for the collection of channel/riparian morphology data and associated fluvial processes both within the restoration reaches and at a larger spatial scale (i.e. providing some wider physical context to conditions within the study reach).

Locations and characteristics of physical features were recorded on tablets using a mobile GIS platform (Qfield) with integral GPS capability. High-resolution georeferenced photos were also taken throughout the survey reach to capture significant features/structures and illustrate the general character of specific reaches. This process allows accurate determination of the position and extent of key features (e.g., length of bank erosion, engineering pressures). Recording the data digitally in this way allowed outputs (shapefiles) to be viewed immediately following the conclusion of the survey in GIS. The types of features recorded are listed below:

- **Reach scale channel morphology** (using a classification scheme that draws on aspects of other recognised procedures – Montgomery & Buffington 1997, Brierley & Fryirs, 2000).
- **Morphological units (i.e. pools, riffles, runs).** These are the specific 'meso-scale' features that, together, define reach scale morphology.
- **Indicators of the sediment transport regime** (e.g., the form, texture and vegetation cover of bedforms and bar features).
- **Sediment sources/storage** (e.g., tributaries, bank erosion, within-channel storage in bar forms), noting dominant sediment sizes.
- **River engineering pressures** (e.g., culverts, bank protection, canalisation/realignment, embankments, hydraulic structures, bridge crossings, livestock poaching etc.).
- **Floodplain morphology and land use** (i.e. drainage channels/ditches, relict natural secondary channels, wetland areas, swales, ox-bow lakes, etc.).
- **Vegetation** – both in-channel vegetation (e.g. 'large wood structures' (LWS), macrophytes) and riparian/bankside cover, as well as invasive alien species.
- **Water management** (e.g., locations of abstraction, flow diversion/augmentation, etc.).
- **Infrastructure and utilises** such as pipeline crossings, power lines, etc.
- **Other land use pressures** within the surveyed extents (e.g., infrastructural-related constraints and associated impacts such as minimal riparian zones, etc.).

YEADING BROOK - REACHES OVERVIEW



- Reaches
- Culverted Sections of Yeading Brook
- Yeading Brook
- Tributaries & Other Waterbodies

CLIENT	LONDON WILDLIFE TRUST	Project no.	2150514
		Date	20 NOV 2023
PROJECT	YEADING BROOK OPTIONS APPRAISAL	Drawn	JW
		Surveyed	JW & SM
		Reviewed	SM

0 0.5 1 km

Scale @ A4 - 1:20,000

British National Grid GCS OSGB 1936

Service Layer Credits: Main map sources - Google (2019), west London area, satellite imagery: 2019 Google. Overview map sources - Esri, DigitalGlobe, Earthstar Geographics, CNES/Airbus DS, GeoEye, USDA FSA, USGS, Aerogrid, IGN, IGP, and the GIS User Community.

Figure 4.1 Yeading Brook reaches overview.

4.2 PHYSICAL CHARACTERISTICS AND MORPHOLOGICAL PRESSURES

4.2.1. Reach 1

Table 4.1 provides a summary for the fluvial audit while Figure 4.2 and Figure 4.3 show the locations and characteristics of physical features observed along Reach 1. Selected photographs are presented in Table 4.2 to illustrate site characteristics, in addition to drone imagery to show the landscape context.

Table 4.1 Reach 1 fluvial audit summary.

Reach 1: Ickenham Marsh to Freezeland Covert (Western Arm)	**LENGTH (km)**	0.7
	OS NGR	Upstream: TQ 08662 85128 Downstream: TQ 08394 84553
Setting:	• The channel is laterally unconfined, situated within a wide valley (valley sides not visible) dominated by open grassland (TRB – use unknown) and agricultural land (TLB – grazed pasture).	
Flow Conditions	• The survey was conducted during a high flow period following heavy rain; although the channel was not at bankfull, the bed of the channel was not visible in places.	
MORPHOLOGICAL CHARACTERISATION		
Channel Dimensions	• 5 – 6 m.	
Planform Type	• Single thread channel with low sinuosity. • Much of the channel exhibits evidence of modification; the channel has been realigned (straightened) and is over-deepened and disconnected from the floodplain.	
Bed Material	• Fine sediments (silts). • At the lower limit of the reach the bed of the channel is lined with concrete where the river flows beneath the A40 and A437.	
Bed Morphology Units	• None observed; the channel was devoid of natural bedforms.	
Bankface Materials	• Alluvium (silts and sand). • Both banks of are reinforced with concrete towards the downstream limit of the reach where the channel flows beneath two main roads (A40 and A437) (see Infrastructure & Engineering below).	

Bank Profile & Stability	• The channel show characteristic signs of resectioning. These include:
	  • Steep, uniformly angled (~45°) banks.
	  • Trees/vegetation all of a similar age.
	• At the downstream limit of the reach the banks of the channel are reinforced with concrete and vertical (90°).	

Flow Type & Diversity	• The channel exhibited limited flow variability and the predominant unit morphology was that of glide.	
Instream Vegetation	• Winter surveys are not optimal for surveying in-channel vegetation. • No in-channel vegetation recorded. • However, given the heavily shaded condition of the channel it is likely that the lack of vegetation reflects the true state of the channel.	

RIVER CORRIDOR PRESSURES	
Landcover/Use	**Both Banks** • The dominant land use type along the left bank was open grassland. While the TLB appeared to be agricultural land (grazed pasture) it is unknown whether the TRB is also grazed. • A public footpath (Hillingdon Trail) runs along the TRB.
Riparian Conditions	**Both Banks** • The riparian vegetation along both banks was dominated by mature trees with a limited understorey of thorny shrub and rank vegetation. • In places where the tree canopy was thick and the ground heavily shaded the banks were bare of vegetation. • Along the left bank, riparian vegetation was largely confined to the immediate banktop and bank face, with agricultural fields extending up to the bank top. • A narrow strip of unmanaged land extended along the right bank, dominated by species poor ground flora.
Prior management	• The channel shows signs of historic management, and has been straightened, resectioned and dredged. • Well-established riparian vegetation indicates recent management to be minimal.
Tributaries & Drainage	• A tributary flows into the Brook from the right bank at the lower limit of the reach immediately upstream of the A40.
Infrastructure & Engineering	• Two major road bridges (A40 and A437) are located towards the lower limit of Reach 1. The beds and banks of the channel are reinforced with concrete. • A step weir marks the lower limit of Reach 1.
Invasive non-native species	• None observed at time of survey (winter months not suitable for INNS observation).

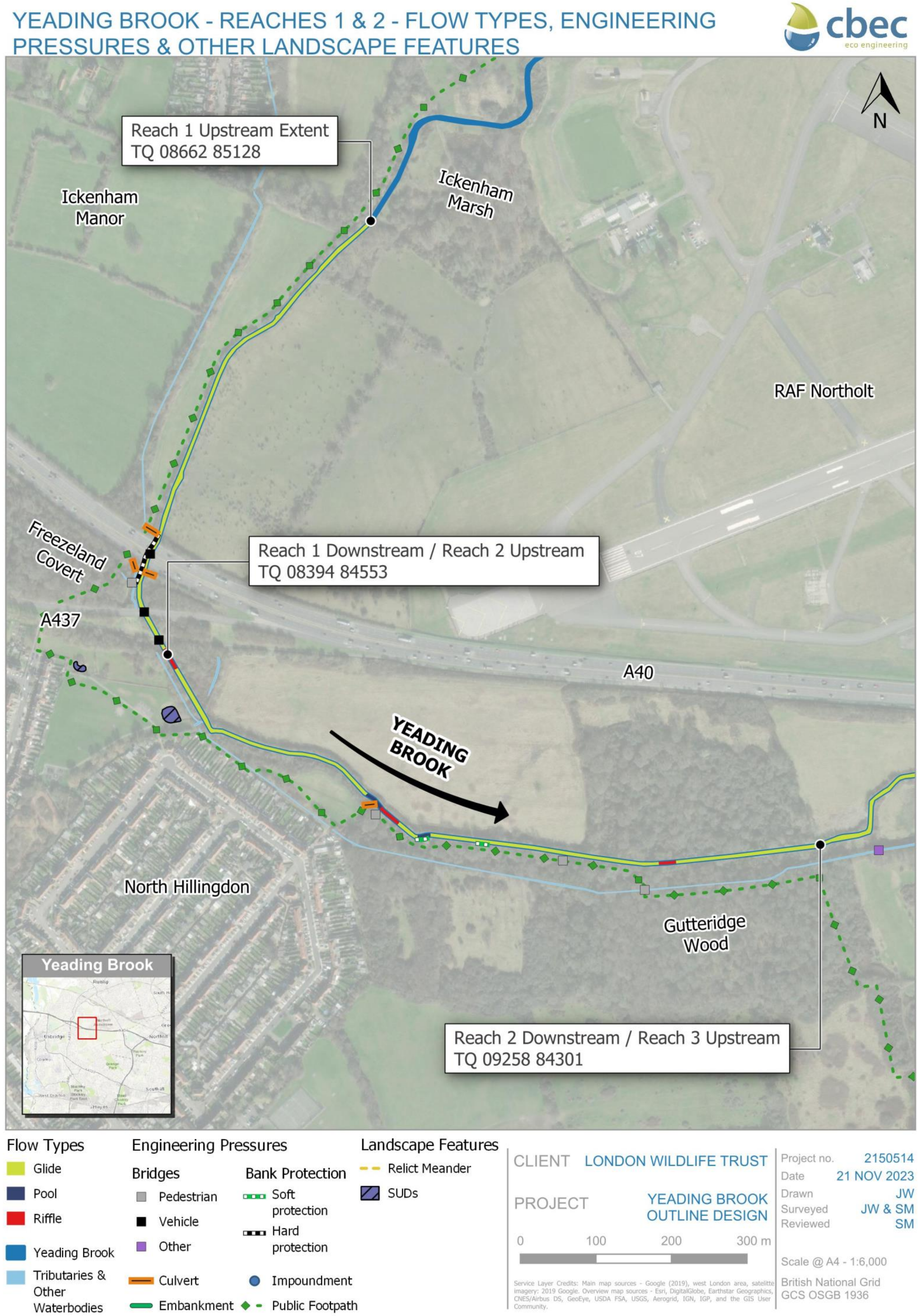


Figure 4.2 Flow types, engineering pressures and landscape features along Reaches 1 and 2.

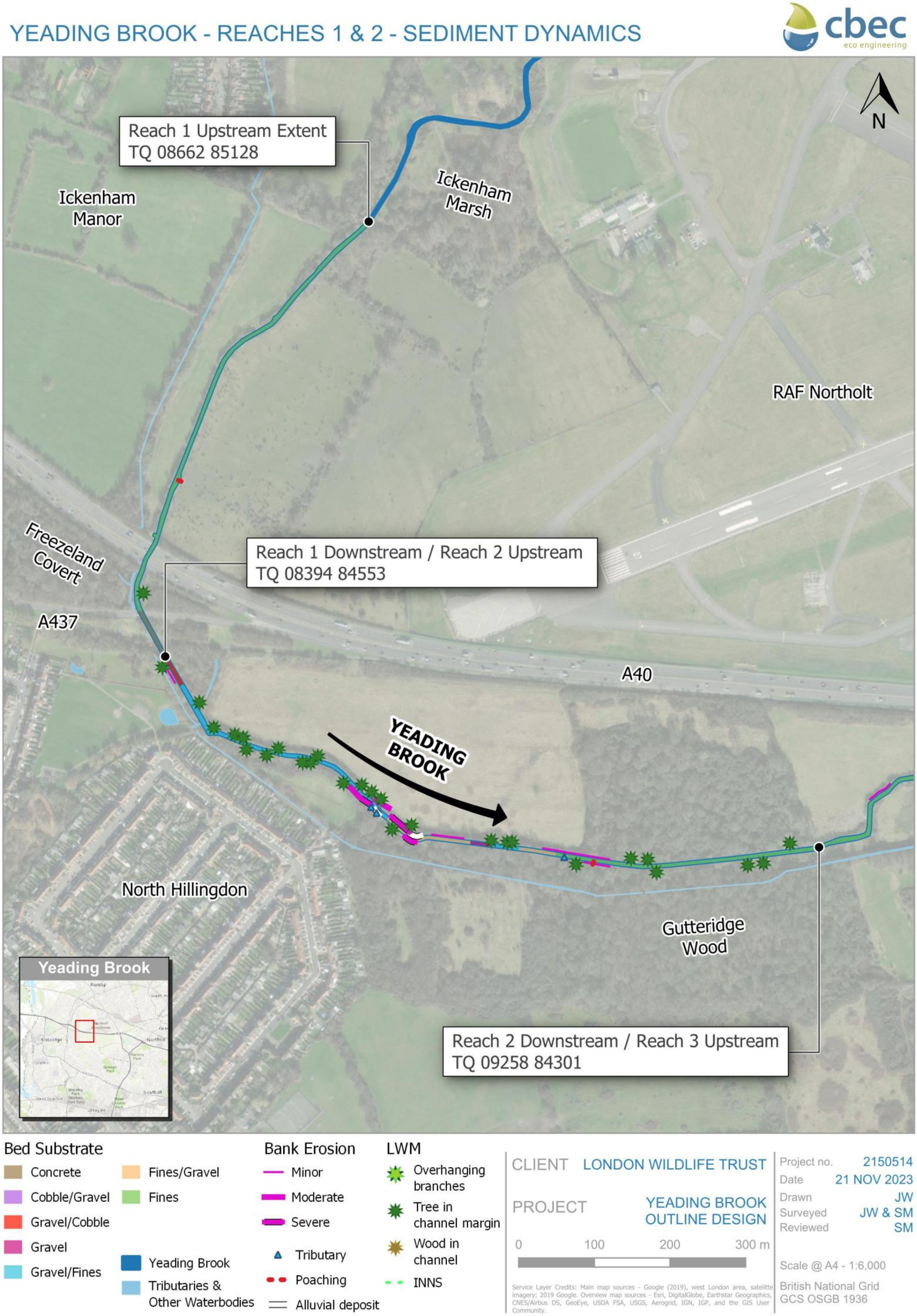


Figure 4.3 Sediment dynamics and vegetation characteristics along Reaches 1 and 2.

Table 4.2 Selected Site Photographs – Reach 1.

Figure 4.4 ↑ Upstream extent of Reach 1. The channel has been extensively modified; it has been straightened, resectioned, and is now disconnected from its floodplain. Marginal and in-channel vegetation is largely absent or poorly developed.

Figure 4.6 → Looking downstream along the channel. The channel is bordered by grazed pasture. The riparian vegetation is characterised by mature trees and an understorey of thorny scrub.

Figure 4.5 → Parts of the channel are heavily shaded by marginal trees and vegetation.

Figure 4.7 Trees form a dense hedge along the channel. Note the limited understorey and bare earth of the banks. Erosion (toe scour) is also evident.

Figure 4.8 A culverted tributary flowing into the channel immediately upstream of the A40 road bridge. Note the trash guard.

Figure 4.9 Looking downstream along the channel at the A40 road bridge. The beds and bank of the channel are reinforced with concrete.

Figure 4.10 Surface water outfall (SWO) located in Freezeland Covet.

Figure 4.11 Channel as it flows through Freezeland Covert. The channel is slow flowing and lacks geomorphic features

Figure 4.12 Step weir at the lower limit of Reach 1. The bed and banks of the Brook are reinforced with concrete as it flows beneath the A437.

4.2.2. Reach 2

Table 4.3 provides a summary for the fluvial audit while Figure 4.2 and Figure 4.3 show the locations and characteristics of physical features observed along Reach 2. Selected photographs are presented in Table 4.4 to illustrate site characteristics, in addition to drone imagery to show the landscape context.

Table 4.3 Reach 2 fluvial audit summary.

<table>
<tr><th rowspan="3">Reach 2: Freezeland Covert to Gutteridge Wood (W. Arm)</th><th>LENGTH (km)</th><th colspan="2">1.0</th></tr>
<tr><th rowspan="2">OS NGR</th><th>Upstream:</th><th>TQ 08394 84553</th></tr>
<tr><th>Downstream:</th><th>TQ 09258 84301</th></tr>
<tr><td>Setting:</td><td colspan="3">• The channel is laterally unconfined, situated within a wide valley (valley sides not visible) with areas of deciduous woodland and open grassland broken by urban development.</td></tr>
<tr><td>Flow Conditions</td><td colspan="3">• The survey was conducted during a high flow period following heavy rain; although the channel was not at bankfull, the bed of the channel was not visible in places.</td></tr>
<tr><td colspan="4">MORPHOLOGICAL CHARACTERISATION</td></tr>
<tr><td>Channel Dimensions</td><td colspan="3">• 5 – 7 m.</td></tr>
<tr><td>Planform Type</td><td colspan="3">• Single thread channel with low sinuosity.
• Much of the channel exhibits evidence of modification; the channel has been realigned (straightened) and is over-deepened and disconnected from the floodplain.</td></tr>
<tr><td>Bed Material</td><td colspan="3">• At the very upstream extent of the reach the bed consists of gravel to cobble sized material. The cobble sized material unnatural mainly man-made bricks/rubble.
• In the middle of the reach the bed material consists primarily of fines (sand) and gravel. Short sections of gravel were observed in association with localised riffles.
• The bed material along the downstream section of the reach was comprised of fine sediment, primarily silt but with isolated sections of sand.</td></tr>
<tr><td>Bed Morphology Units</td><td colspan="3">• The channel exhibited few natural geomorphic features.
• A confluence bar was noted in the vicinity of the outfall of the culverted tributary at TQ 08666 84355.
• A vegetated point bar was observed in the middle of the reach.</td></tr>
<tr><td>Bankface Materials</td><td colspan="3">• Alluvium (silts and sand).</td></tr>
<tr><td>Bank Profile & Stability</td><td colspan="3">• The channel show characteristic signs of resectioning. These include:
  • Steep, uniformly angled (~45°) banks.
  • Trees/vegetation all of a similar age.
• Areas of erosion were observed in the middle of the reach primarily of toe scour but also shear face erosion.
• While erosion was mainly minor to moderate in severity sections of severe erosion (shear face) were observed downstream of the outfall at TQ 08666 84355.</td></tr>
</table>

	• Bank protection (wooden logs and brash) has been placed along sections TRB were erosion is impacting the pedestrian footpath through Gutteridge Wood.
Flow Type & Diversity	• The channel exhibited limited flow variability and the predominant unit morphology was that of glide. • However, two short riffles were observed, at the immediate upstream limit of the reach and downstream of the outfall at TQ 08666 84355.
Instream Vegetation	• The time of year (winter) is not optimal for survey in-channel vegetation. • However, given the conditions it is likely the heavily shaded conditions channel is devoid of instream vegetation.
RIVER CORRIDOR PRESSURES	
Landcover/Use	**Left Bank** • The primary landcover type along the left bank is agricultural fields (grazed pasture/hay meadow). • The channel is bordered by deciduous woodland along the lower section of the reach.
	Right Bank • At the upstream extent the channel is bordered by recreational green space and urban development (residential properties and gardens). This is separated from the Brook by a narrow belt of trees. • The middle and downstream sections of the reach is bordered by Gutteridge Wood as part of Yeading Woods LNR.
Riparian Conditions	**Both Banks** • The riparian zone is characterised by mature trees with an understorey of scrub/shrub and brambles. • In places where the channel is heavily shaded the banks are bare.
Prior management	• The channel shows signs of historic management, and has been straightened, resectioned and dredged. • More recently attempts restoration attempts have been made with the construction of raised berms. These are usually used as a means of narrowing the channel, reintroducing flow heterogeneity and habitat diversity. All these berms have failed and only the wooden stakes used to secure brushwood remain, the backfill having also been washed away. • Towards the downstream limit is a series of deflectors along a short section of the channel (~20 m length). These appear to have been created by keying logs into the bank. While some flow variability is noted in the vicinity of these their overall affect appears to be limited. • The TLB has been reinforced in two locations with logs/brash to mitigate against erosion (shear face).
Tributaries & Drainage	• A culverted tributary feeds into the channel at TQ 08666 84355. • A shallow ditch runs parallel to Brook along the entire length of the Reach. This is set back from TRB at a distance of ~30 – 40 m.
Infrastructure & Engineering	• A road bridge (A437) marks the upstream extent of the reach. • A series of guidance lights associated with RAF Northolt are situated within the TLB floodplain in the upper reach. • A pedestrian footpath runs along the TRB.
Invasive non-native species	• None observed at time of survey (winter months not suitable for INNS observation).

Table 4.4 Selected Site Photographs – Reach 2

Figure 4.13 Looking downstream along Reach 2. The channel is overwide and slow flowing, with limited natural geomorphic features.

Figure 4.14 A small retention pond/SuD at the upstream limit of Reach 2 set back from the right bank.

Figure 4.15 The dominant landcover type along the left in the upper reach is rough grassland. It is unknown if this is grazed. There are approach lights associated with RAF Northolt within the western portion of these fields.

Figure 4.16 Evidence of former restoration attempts; berms built along the channel have failed leaving wooden stakes used to secure brushwood fascines.

Figure 4.17 A culverted tributary flows into the channel in the upper reach. This likely conveys runoff from roads and residential properties south of the Brook.

Figure 4.18 The channel exhibits toe scour (minor to moderate in severity). Short sections of erosion protection measures consisting of logs/brash have been installed.

Figure 4.19 Several trees in the channel margin were noted to have fallen over.

Figure 4.20 Looking downstream along the channel. Note the channel is largely devoid of natural alluvial bedforms and exhibits limited hydrological diversity.

Figure 4.21 A derelict structure is located in the TRB floodplain set back ~40 m from the channel. Conversations with LWT would suggest this is a former pumping station.

Figure 4.22 Looking upstream along the channel. Note that the channel is heavily shaded and that the banks are bare of vegetation.

Figure 4.23 Although not clearly visible it appears that deflectors have been key into the bank along a short section of the channel ~ 20 m. The effectiveness of these appears to be limited.

Figure 4.24 Drainage ditch running parallel to the channel through the TRB floodplain. This is set back ~30 – 40 m from the bank top.

4.2.3. Reach 3

Table 4.5 provides a summary for the fluvial audit while Figure 4.25 and Figure 4.26 show the locations and characteristics of physical features observed along Reach 3. Selected photographs are presented in Table 4.6 to illustrate site characteristics, in addition to drone imagery to show the landscape context.

Table 4.5 Reach 3 fluvial audit summary.

Reach 3: Gutteridge Wood to Ten Acre (W. Arm)	LENGTH (km)	2.5
	OS NGR	Upstream: TQ 09258 84301 Downstream: TQ 09796 83732
Setting:	• The channel is laterally unconfined, situated within a wide valley (valley sides not visible) dominated deciduous woodland and open grassland (agricultural land)	
Flow Conditions	• The survey was conducted during a high flow period following heavy rain; although the channel was not at bankfull, the bed of the channel was not visible in places.	
MORPHOLOGICAL CHARACTERISATION		
Channel Dimensions	• 6 – 8 m.	
Planform Type	• Single thread channel with low sinuosity. • Much of the channel exhibits evidence of modification; the channel has been realigned (straightened) and is over-deepened and disconnected from the floodplain.	
Bed Material	• The bed material was comprised primarily of fine sediment (mainly silt but also short sections of sandy deposits). • Two areas were noted were coarser sediments occurred. In the middle of the reach immediately downstream of a tributary inflow the bed was noted to consist of fines/gravels, while at the downstream limit of the reach a short section was observed comprised of cobbles/gravels. The cobble sized material is unnatural, man-made bricks.	
Bed Morphology Units	• The upstream and middle sections of the reach was largely devoid of natural geomorphic features. • Towards the downstream limit lateral berms were observed. These consisted of fine sediments, were vegetated and thus in-active. • Berms are 'natural recovery' features which form following the initial establishment of vegetation (i.e., reeds) along the margins of an over-widened channel resulting in sediment deposition and the development of a step-like feature.	
Bankface Materials	• Alluvium (silts and sand). • In two locations the channel is bricked lined, at TQ 09645 84386 at TQ 09796 83732 where the Brook flows through flow control structures (gauging station and Charville Lane Flood Control Structure (FSA) respectively) (see Infrastructure & Engineering below).	
Bank Profile & Stability	• The channel show characteristic signs of resectioning with the banks of the channel being uniformly angled (~45°) and lined by trees all of a similar age.	

	• Long sections (ranging from 20 – 40 m in length) of minor to moderate erosion (mainly toe scour) were noted along much of the reach. • Several areas of severe toe scour were also observed.
Flow Type & Diversity	• The dominant flow type was that of glide, however, several deeper pools were observed and three short riffles.
Instream Vegetation	• The time of year (winter) is not optimal for surveying in-channel vegetation. • Small sections of the channel were noted to have in-channel vegetation, primarily linear, fine leaved. It is likely these are more extensive during summer months.
RIVER CORRIDOR PRESSURES	
Landcover/Use	**Left Bank** • The primary land cover type in the upper and middle reach is open grassland (agricultural land). • In the upper reach a main road (A40) is set back from the TLB ~70 m from the channel, with RAF Northolt immediately to the North. • Towards the downstream limit the primary landcover type is deciduous woodland (Ten Acre Wood).
	Right Bank • The primary land cover type in the upper and middle reach is open grassland (hay meadow and grazed pasture).
Riparian Conditions	**Left Bank** • Primarily scrub/shrub and brambles. • Towards the downstream limit of the reach a pedestrian footpath runs along the TRB top. • The channel is bordered by mature trees (Ten Acre Wood) within the middle of the reach.
	Right Banks • Primarily scrub/shrub and brambles. • Towards the lower limit of the reach the channel is bordered by mature trees.
Prior management	• The channel shows signs of historic management, and has been straightened, resectioned and dredged. • Willow spiling has been installed along a short (<5 m) section of channel in the vicinity of the pedestrian footbridge at TQ 09829 84012. • A wildlife pond has been constructed at TQ 09816 83863 set back from the TLB top.
Tributaries & Drainage	• The Eastern Arm of the Yeading Brook merges with the main Western Arm at TQ 09951 84201. This has a medium flow input and a high (fine) sediment input. • Two small tributaries/drainage ditches feed into the main channel at TQ 09654 84384, TQ09793 83932. The latter of these tributaries occupy sections of relict meanders bypassed following straightening of the channel.
Infrastructure & Engineering	• Two EA gauging stations are located within Reach 3, one in the middle of the Reach at TQ 09645 84386 (Yeading Brook FSA – 36YB0202/SR01) the other at TQ 09796 83732 (Charville Lane FSA – 36YB0102/SR02/VB01) marking the downstream extent of the reach.

	• A vehicle bridge is located at TQ 09648 84384 providing access to properties and the pumping station from the A40. • A farm access (vehicle) bridge constructed from concrete is located at TQ 09879 84317. This appears to be in a poor state of repair. • Two pedestrian footbridges span the channel in Reach 3, the first at TQ 09829 84012, the second at TQ 09796 83732 over the Charville Lane gauging station. • A public footpath runs along the TRBtop downstream of the pedestrian footbridge for 0.3 km from TQ 09829 84012 to TQ 09803 83733 (downstream extent of Reach 3). • A man hole cover was identified within the TLB floodplain at TQ 09850 84237. This is likely associated with one of two foul sewer drains: *1200 Harrow Branch Relief Sewer* or *1372 Harrow Branch Sewer* both managed by Thames Water (see Section 5.4.1).
Invasive non-native species	• Evidence of Himalayan balsam identified along the downstream section of Reach 3 where the channel flows through Ten Acre wood. • Himalayan balsam also identified along relict meander. • Sporadic but coverage likely to be more extensive given site was surveyed during winter months when the identification of INNS is suboptimal.

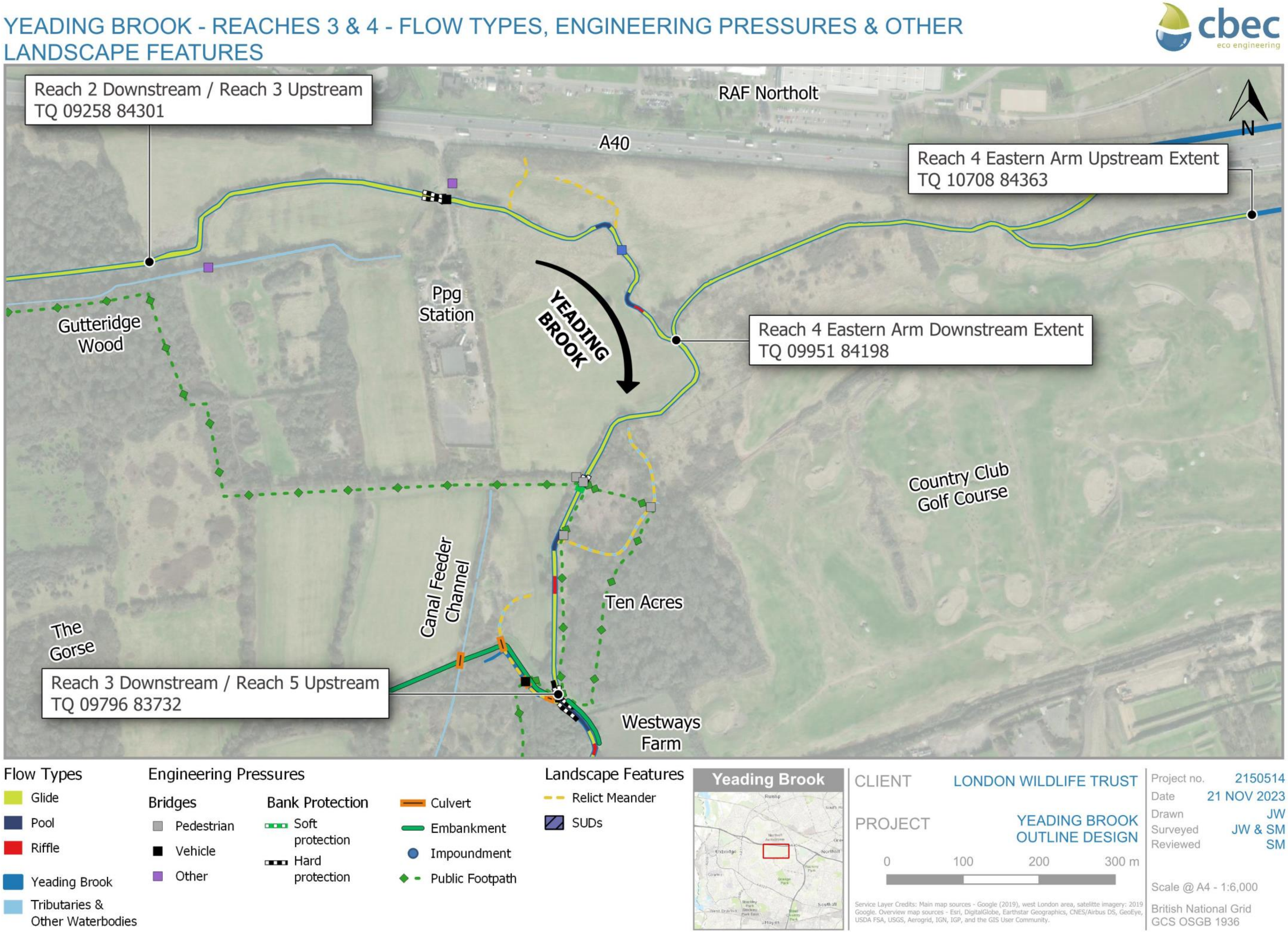


Figure 4.25 Flow types, engineering pressures and landscape features along Reach 3.

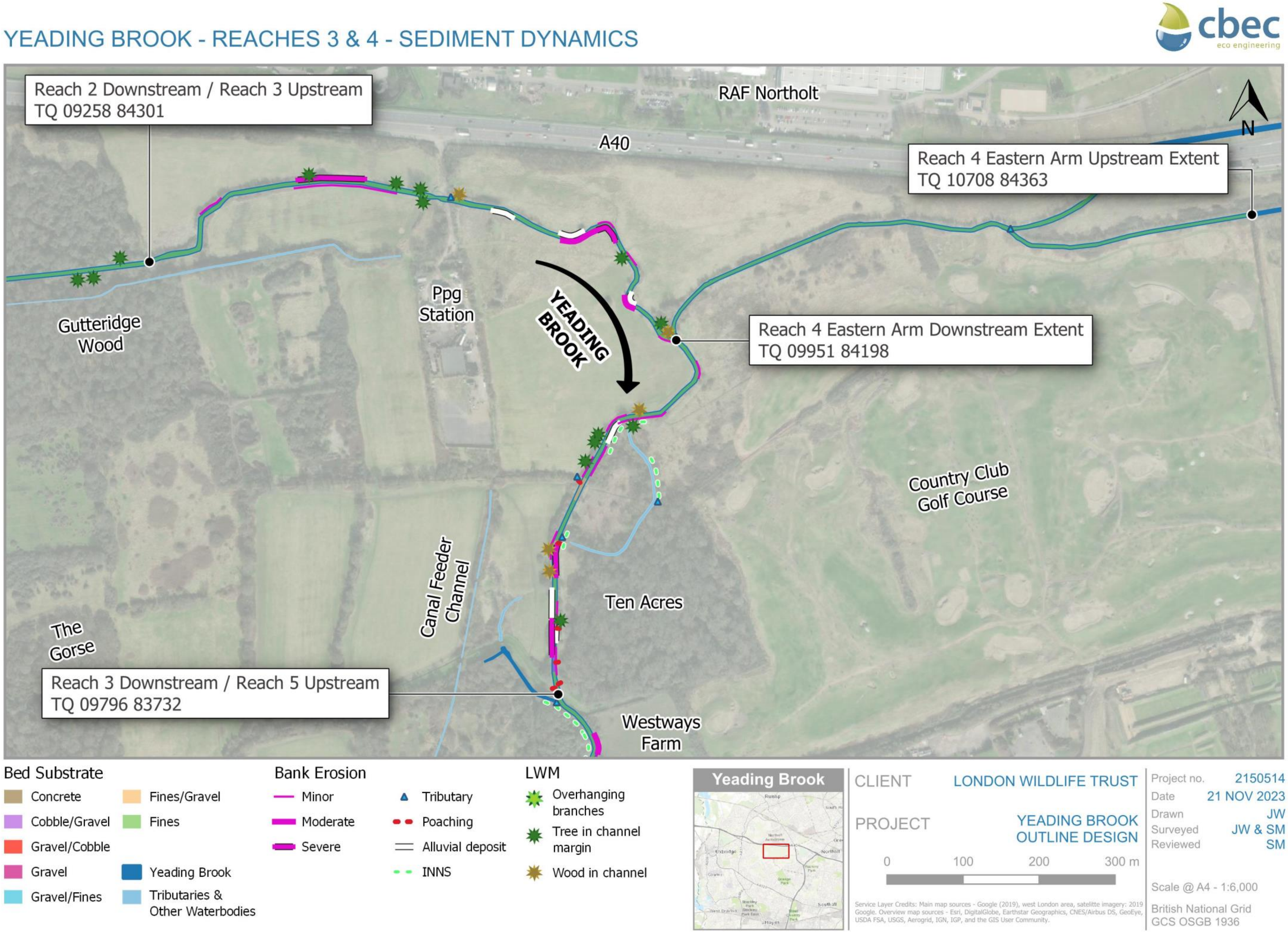


Figure 4.26 Sediment dynamics and vegetation characteristics along Reach 3.

Table 4.6 Selected Site Photographs – Reach 3.

Figure 4.27 The channel is straight with little to no geomorphic variability and limited in-channel habitat.

Figure 4.28 Riparian vegetation is confined to the immediate banktop and bankface, and is characterised by shrub and rank vegetation.

Figure 4.29 EA gauging station (Yeading Brook FSA – 36YB0202/SR01). Conversations with the EA confirm that this gauging station has been decommissioned.

Figure 4.30 Raised pipe just downstream of the gauging station. This is a mains distribution pipe owned by Affinity Water.

Figure 4.31 TLB floodplain; the dominant land use type is grazed pasture. Low-lying areas of the floodplain are wetter and characterised by tussocky grasses and sedges. These are likely palaeo channels.

Figure 4.32 Vehicle bridge located at TQ 09879 84317.

Figure 4.33 Man hole cover for foul sewer drain located at TQ 09850 84237. This is an asset of Thames Water.

Figure 4.34 Sections of the channel exhibit erosion (either toe-scour or shear face)

Figure 4.35 Looking downstream from the confluence between the Eastern (left) and Western (right) arms of the Yeading Brook.

Figure 4.36 Look upstream from the pedestrian footbridge at TQ 09829 84012. Here, the channel is bordered by a line of mature trees and is shaded. Himalayan balsam was noted along the TLB and is also likely present along the TRB.

Figure 4.37 Poaching immediately downstream of pedestrian footbridge at TQ 09829 84012. Several sections of poaching were observed along the pedestrian footpath (TLB), likely caused by dogs entering the channel.

Figure 4.38 Live willow fencing along the TRL in the vicinity of the pedestrian footbridge at TQ 09829 84012.

Figure 4.39 A relict meander is located in the TLB floodplain which was bypassed when the channel was straightened c. 1940. Himalayan balsam was observed in several locations along the relict meander.

Figure 4.40 Pedestrian footbridge spanning the relict meander at TQ 09917 83979.

Figure 4.41 Relict meander bend located in TLB floodplain. A small tributary feeds into the relict meander immediately upstream of the pedestrian footbridge at TQ 09917 83979.

Figure 4.42 A small tributary occupies the relict meander located in the TLB floodplain.

Figure 4.43 A wildlife pond has been excavated on the edge of Ten Acre Wood at TQ 09816 83863 set back from the TLB top.

Figure 4.44 Looking downstream; vegetated lateral berms were observed along the lower section of the reach.

Figure 4.45 TRB floodplain; the primary land cover type here appears to be semi-improved grassland likely used for grazing or silage.

Figure 4.46 Area of poaching along the TRB, likely caused by dogs and other animals entering the channel/

Figure 4.47 Flood embankment delineating Charville Lane FSA. Note the tributary in the foreground; this occupies a relict meander of the channel.

Figure 4.48 Looking upstream from Charville Lane gauging station (TQ 09796 83732). This structure marks the lower limit of the reach.

4.2.4. Reach 4

Table 4.5 provides a summary for the fluvial audit while Figure 4.25 and Figure 4.26 show the locations and characteristics of physical features observed along Reach 3. Selected photographs are presented in Table 4.6 to illustrate site characteristics, in addition to drone imagery to show the landscape context.

Table 4.7 Reach 4 fluvial audit summary.

Reach 4: A40 culvert to confluence (River Roxbourne – Eastern Arm)	**LENGTH (km)**	0.8
	OS NGR	Upstream: TQ 10505 84396 Downstream: TQ 09951 84198
Setting:	• The channel is laterally unconfined, situated within a wide valley (valley sides not visible) dominated by urban infrastructure and agricultural land.	
Flow Conditions	• The survey was conducted during a high flow period following heavy rain; although the channel was not at bankfull, the bed of the channel was not visible in places.	
MORPHOLOGICAL CHARACTERISATION		
Channel Dimensions	• 6 – 8 m	
Planform Type	• Single thread straight channel with no sinuosity. • Much of the channel exhibits evidence of modification; the channel has been realigned (straightened) and is over-deepened and disconnected from the floodplain.	
Bed Material	• Predominately fines (silts).	
Bed Morphology Units	• None observed; the channel was devoid of natural bedforms.	
Bankface Materials	• Alluvium (silts and sand).	

Bank Profile & Stability	• The channel show characteristic signs of resectioning. These include:
	  • Steep, uniformly angled (~45°) banks.
	  • Trees/vegetation all of a similar age	

Flow Type & Diversity	• The dominant flow type was that of glide, and there was little perceptible flow.	
Instream Vegetation	• The time of year (winter) is not optimal for survey in-channel vegetation. • However, given the conditions it is likely the heavily shaded conditions channel is devoid of instream vegetation.	
RIVER CORRIDOR PRESSURES		
Landcover/Use	**Left Bank** • The dominant land cover type along both banks is open, scrubby grassland. • A main road (A40) is set back from the TLB ~40 – 70 m from the channel, with RAF Northolt immediately to the North.	
	Left Bank • The dominant land cover type along both banks is open, scrubby grassland. • A golf course is located immediately to the south, a distance of ~100 m from the channel.	

Riparian Conditions	**Both Banks** • The riparian zone is characterised by mature, dense hedgerow. • The understorey is limited and both the banks and channel are heavily shaded. Large parts of the banks are bare of vegetation.
Prior management	• The channel shows signs of historic management, and has been straightened, resectioned and dredged. • Well-established riparian vegetation indicates recent management to be minimal.
Tributaries & Drainage	• A tributary flows into the main channel at TQ 10389 84344. This drains the airport to the north (RAF Northolt).
Infrastructure & Engineering	• None observed.
Invasive non-native species	• None observed at time of survey (winter months not suitable for INNS observation).

Table 4.8 Selected Site Photographs – Reach 4.

Figure 4.49 Looking downstream along the River Roxbourne (Eastern Arm). The channel is slow flowing and exhibits limited hydromorphological diversity. In places the bank and channel are heavily shaded.

Figure 4.50 Looking upstream. Note the channel is overwide and disconnected from the floodplain.

Figure 4.51 Outfall entering the channel from the TRB, likely delivering road runoff from the A40.

Figure 4.52 The channel was slow flowing with the primary flow type being glide.

Figure 4.53 More open section of channel.

Figure 4.54 Just upstream of the confluence with the Yeading Brook there are several areas where debris (wood and urban rubbish) has collected.

4.2.5. Reach 5

Table 4.9 provides a summary for the fluvial audit while Figure 4.55 and Figure 4.56 show the locations and characteristics of physical features observed along Reach 4. Selected photographs are presented in Table 4.10 to illustrate site characteristics, in addition to drone imagery to show the landscape context.

Table 4.9 Reach 5 fluvial audit summary.

Reach 5: Ten Acre south to Westway Farm	**LENGTH (km)**	0.5
	OS NGR TQ 09734 83564	Upstream: TQ 09796 83732 Downstream: TQ 09854 83286
Setting:	• The channel is laterally unconfined, situated within a wide valley (valley sides not visible) dominated by deciduous woodland.	
Flow Conditions	• The survey was conducted during a high flow period following heavy rain; although the channel was not at bankfull, the bed of the channel was not visible in places.	
MORPHOLOGICAL CHARACTERISATION		
Channel Dimensions	• 9 – 10 m.	
Planform Type	• Single thread, passive meandering channel. • Much of the channel exhibits evidence of dredging; the channel is over-deepened and disconnected from the floodplain.	
Bed Material	• Predominately fine sediments (silts with short sections of sandy deposits).	
Bed Morphology Units	• The reach was largely absent of alluvial bedforms, those that were observed were short (< 2 m) unvegetated and likely active. These consisted of fine sediments (silts).	
Bankface Materials	• Alluvium (silts and sand).	
Bank Profile & Stability	• The channel is entrenched, likely due to dredging, with moderately steep banks 30 – 45°. • Shorts sections of the channel exhibited minor to moderate toe scour.	
Flow Type & Diversity	• The channel exhibited limited flow variability and the predominant unit morphology was that of glide.	
Instream Vegetation	• No in-channel vegetation was observed, however, the time of year (winter) was not optimal for survey in-channel vegetation.	
RIVER CORRIDOR PRESSURES		
Landcover/Use	**Left Bank** • At the upstream extent the channel is bordered by fields (agricultural) and urban development (residential property and garden) associated with Westway Farm. This is separated from the Brook by a narrow belt of trees. • Downstream of Westway Farm the primary land cover type is deciduous woodland.	
	Right Bank • The primary land cover type along the TRB is deciduous woodland.	
Riparian Conditions	**Both Banks**	

	• The riparian zone is characterised by mature trees with an understorey of scrub/shrub and brambles. • In places where the channel is heavily shaded the banks are bare of vegetation.
Prior management	• The channel shows signs of historic management, and has been straightened, resectioned and dredged. • Wooden stakes indicate prior management but
Tributaries & Drainage	• A tributary feeds into the channel at the upstream limit of Reach 5 at TQ 09799 83720. This tributary occupies a relict meander. • A culvert feeds into the channel at TQ 09768 83552, likely drainage from Westways Farm. • The 'Channel Feeder' channel merges with the Yeading Brook at TQ 09739 83400.
Infrastructure & Engineering	• Charville Lane Flood Storage Area (FSA - 36YB0102/SR02/VB01) and associated flood defences (earth embankments) delineate the upper limit of reach 5 (TQ 09796 83732). • A pedestrian footbridge is located in the vicinity of Charville Lane FSA and a footpath runs along the top of the embankment (bordering the TLB top between TQ 09796 83732 and TQ 09832 83713 (~ 0.3 km). • Rock filled gabions line both banks immediately downstream of the Charville Lane FSA. • A vehicle bridge is located at TQ 09794 83570 providing access to Westways Farm. • The banks of the channel are reinforced with wooden planks in the vicinity of the road bridge. • Two pedestrian footbridges span the channel at TQ 09734 83563 (Golden Bridge) and TQ 09809 83302. • A pedestrian footpath runs along the TLB downstream of Golden Bridge.
Invasive non-native species	• Himalayan balsam identified along the entire length of Reach 4.

YEADING BROOK - REACH 5 - FLOW TYPES, ENGINEERING PRESSURES & OTHER LANDSCAPE FEATURES

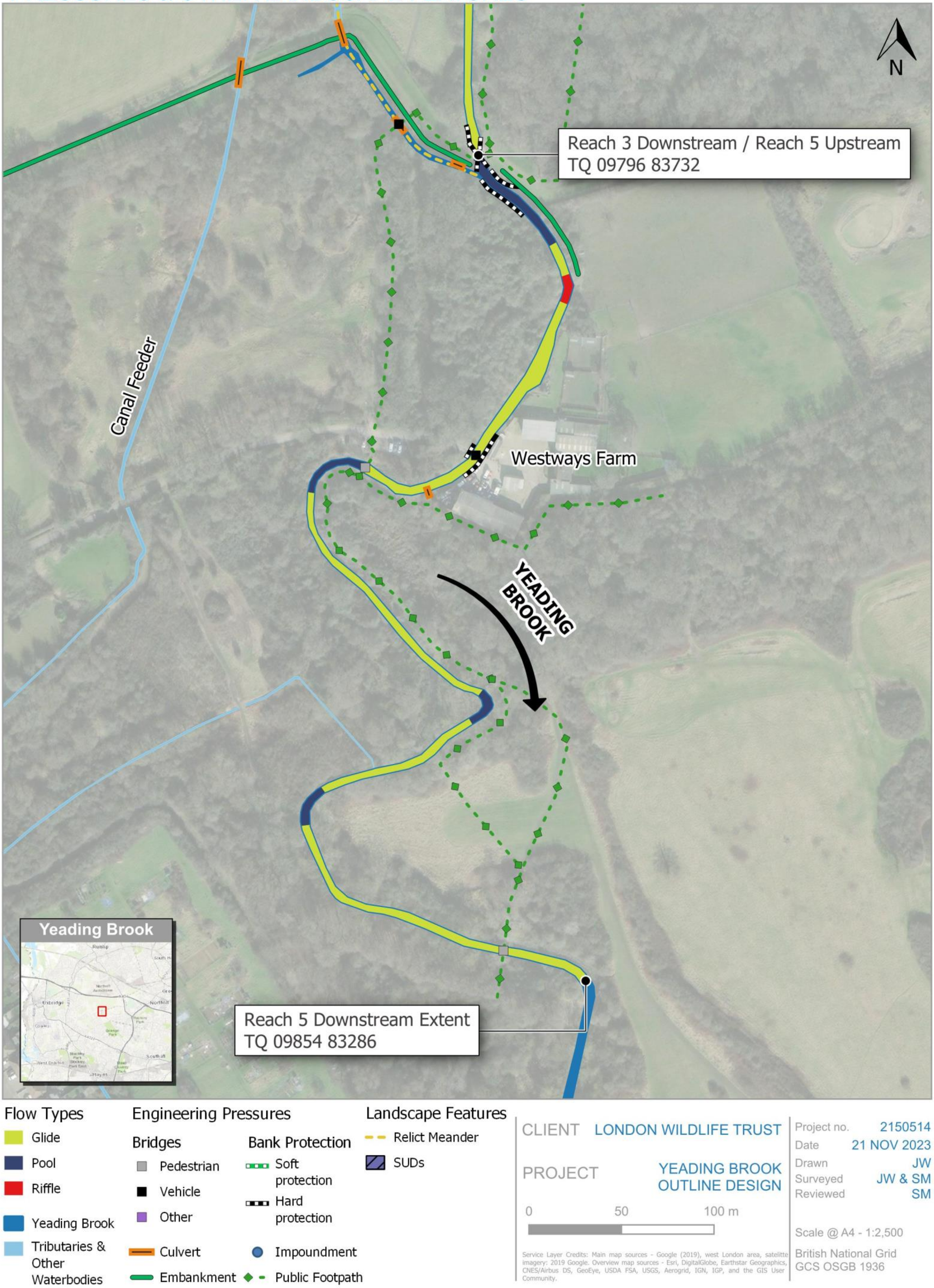


Figure 4.55 Flow types, engineering pressures and landscape features along Reach 5.

YEADING BROOK - REACH 5 - SEDIMENT DYNAMICS

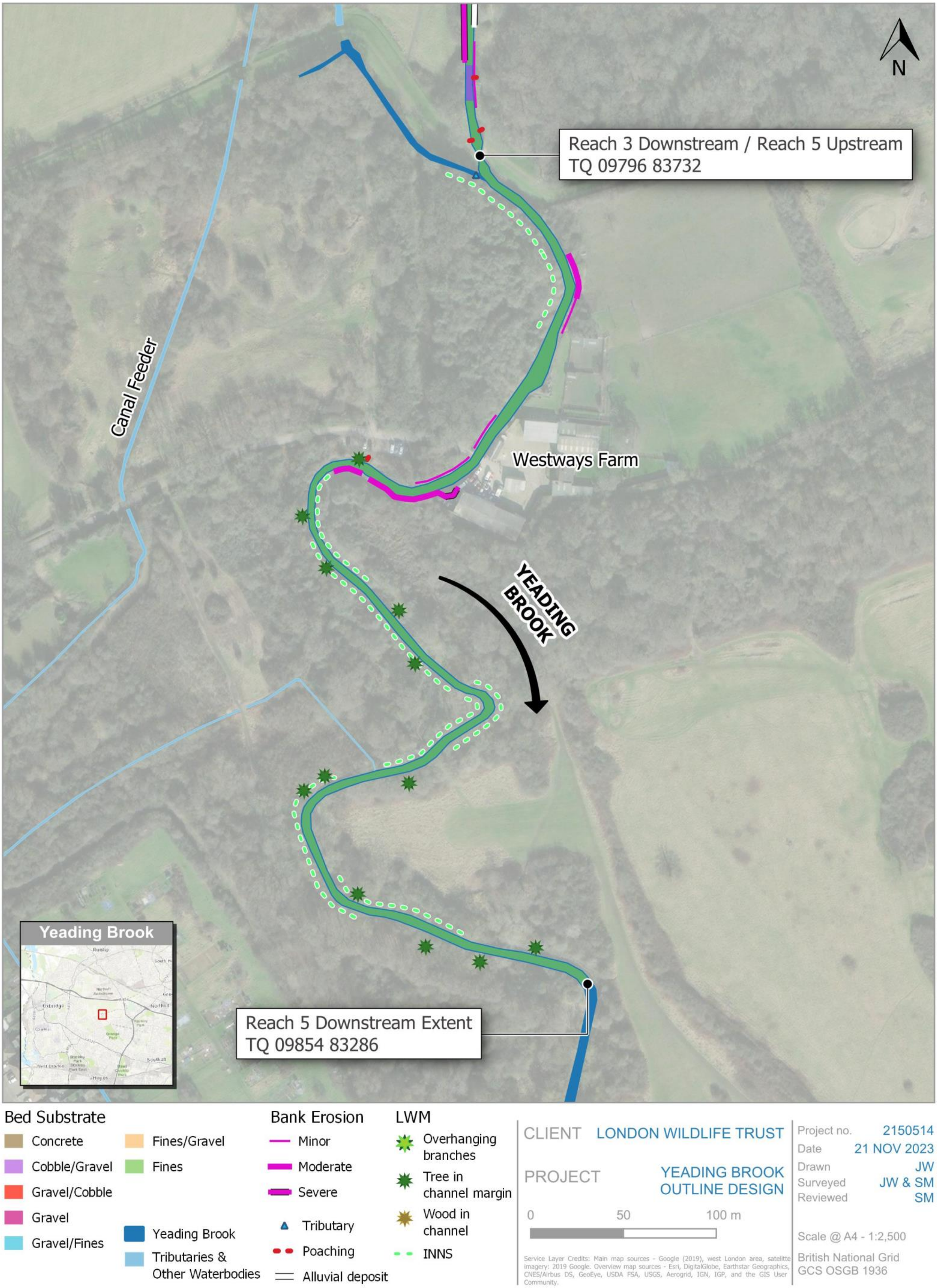


Figure 4.56 Sediment dynamics and vegetation characteristics along Reach 5.

Table 4.10 Selected Site Photographs – Reach 5.

Figure 4.57 Charville Lane FSA marks the immediate upstream extent of Reach 5.

Figure 4.58 Rock filled gabions line both banks of the channel immediately downstream of Charville Lane FSA.

Figure 4.59 Flood embankment bordering the TLB of the channel downstream of Charville Lane FSA.

Figure 4.60 Looking upstream along the channel towards the vehicle bridge located at TQ 09794 83570. This provides access to Westway Farm. The banks in the vicinity of the bridge have been reinforced with wooden panels/fencing.

Figure 4.61 Moderate erosion (shear face) was observed along the right bank just downstream of Westways Farm

Figure 4.62 Looking downstream along the channel towards Golden Bridge. Note the riparian vegetation primarily consists of thorny brush and semi-mature trees.

Figure 4.63 The channel is overwide and straight, exhibiting limited geomorphic variability and little in-channel habitat.

Figure 4.64 The channel was turbid indicating a high fine sediment load. The riparian vegetation was limited to scrub and thorny scrubs (brambles).

Figure 4.65 Pedestrian footbridge towards the downstream end of the reach and survey site (location TQ 09809 83302). Note the bare banks of the channel.

5. DESIGN DEVELOPMENT

5.1 DESIGN APPROACH

The design philosophy underpinning the development of the restoration measures of the Yeading Brook is to restore natural fluvial process, as much as is practical, within the constraints imposed by the site. These processes are key to improving the WFD status (Section 3.6), encouraging more natural flow heterogeneity within the channel and, in turn, generating increased ecological diversity. This approach aims to promote a self-sustaining river system that requires minimal long-term management. This concept of 'process' or 'nature-based' restoration seeks to tackle the cause of a specific problem rather than the site-specific symptom, i.e. historic straightening and re-sectioning. Therefore, the design attempts to recreate natural and self-sustaining process and/or form interactions wherever feasible and at a maximum possible extent, to optimise the benefits of applying this approach to the Yeading Brook site.

As noted in Section 4, the area surveyed extended ~700 m upstream and ~800 m downstream of the proposed restoration area to gain a wider context of the river network and avoid misinterpretation of conditions at the edge of the study site (Figure 4.1). The additional length of channel surveyed upstream and downstream were classified as Reaches 1 and 5 respectively. Restoration options for these two reaches are not included in this report since they fall outside of the defined restoration area (Figure 1.2).

The development of the design has been guided by an assessment of the overall catchment characteristics (Section 3) and field surveys including a fluvial audit (Section 4) and topographic survey (Appendix B) to ensure that the proposed design is appropriate. Section 5.2 provides an appraisal of the proposed options for each reach and identifies a preferred restoration option. This followed by a summary of the constrains which may impact the feasibility and/or delivery of the design in Section 5.3.

5.2 OPTIONS APPRAISAL

The options outlined here have been developed based on the assessment of the physical form and process of the Yeading Brook, as described above. The design approach has taken into consideration the brief from LWT, which was to explore all options for restoration. This section describes the options proposed for Reach 2, 3 and 4 in turn, including associated benefits, disadvantages, potential risks and mitigation measures, alongside a consideration of any further assessments required to progress the preferred option to Outline Design, Detailed Design and finally construction. Options for Reaches 1 and 5 are not provided since these fall outside the design area defined by LWT. An options matrix has also been produced for each reach to allow a visual comparison of the relative merits and constraints of each option.

The potential restoration options for each reach were developed and assessed against a range of criteria. This assessment is intended to provide an objective and comprehensive data set to allow LWT and other stakeholders and landowners to assess option feasibility and select a preferred option for each reach. The criteria considered included the following.

- *Benefit to fluvial process and habitat (within and adjacent to the river).* Given that the restoration reach has been straightened significantly and has generally limited morphological diversity and a lack of dynamic fluvial process, most restoration options are likely to offer improvements. However, restoration options that can move the river closer to its reference condition can be considered to offer greater benefits.

- *Flood risk.* The proposed options have the potential to both increase and decrease flood risk, both locally and downstream;
- *Impact on landscape and amenity value.* This criterion is somewhat subjective, as stakeholders and landowners are likely to have differing views as to what constitutes 'value' in this context. Accordingly, both positive and negative influences were considered. Consultation with landowners, stakeholders and local residents is recommended to gauge opinions on the various options; and
- *Degree of disruption/disturbance required for construction.* Although construction is likely to create only short-term disruption, many of the proposed options will require some level of disruption to infrastructure and agricultural land.
- *Complexity of construction and 'buildability'.* Although this criterion is reflected broadly in the overall cost, its consideration here highlights any specific issues with the proposed options that may increase the complexity of the construction.
- *Cost.* Cost estimates should be considered approximate at this stage. Accordingly, they should be considered a guide only and are presented here to allow comparison of options via a qualitative cost benefit assessment.

The general philosophy underpinning the development of options for the Yeading Brook is the restoration, as far as is practicable, of natural fluvial form and process. This approach aims to promote a self-sustaining river system that requires minimal long-term management. This concept of 'process restoration' seeks to tackle the cause of a specific problem (e.g., historic straightening) rather than tackling the site-specific symptom (e.g., lack of morphological diversity).

5.2.1. Reach 2

Reach 2 marks the upstream extent of the design area where the channel flows through Gutteridge Wood. The channel through Reach 2 has been historically modified and is straightened, over-widened, entrenched and disconnected from the floodplain. The channel is heavily shaded by trees in the channel margin with limited in-channel vegetation.

The channel suffers pressures from surrounding land use. A surface water outfall (SWO) is located in the upper reach which delivers fine sediments and nutrients in to the channel from surrounding residential areas (North Hillingdon). An airfield (RAF Northolt) is located to the north of the channel and within the TLB floodplain several structures are noted (landing lights).

- **Option 1: Natural Recovery – Do Nothing**; Cease all regular management activities within the restoration site and do not undertake any additional in-channel habitat improvement works.
- **Option 2: Assisted Natural Recovery – Minimal Intervention**; Retain flow through existing channel but introduce LWS at carefully targeted locations to further improve habitat diversity in main channel, with placement guided by detailed physical assessments.
- **Option 3: Active Restoration – Full-Scale**; Realign/re-meander the channel through the TLB floodplain to create more natural, sinuous planform. Due to the entrenched nature of the existing channel surface lowering within the floodplain may be required to improve channel-floodplain connectivity. Alternatively, a two stage channel system could be created along the river corridor. The former of these two options for improved channel-floodplain connectivity

is shown in Figure 5.1. As with Option 2 LWS will be installed along the channel. Improve the riparian and floodplain habitat through seeding and/or tree planting.

***RECOMMENDATION*:**	***Option 3***	***Full-Scale Intervention***

Table 5.1 shows the options matrix for Reach 2, while a full breakdown of the long list of options in is shown in Table 5.1. This includes a description of individual interventions, their advantages and disadvantages, and potential risks and mitigation measures.

Table 5.1 Options matrix for Reach 2. Coloured cells indicate: Significantly Positive; Slightly Positive; Neutral; Slightly Negative; Significantly Negative.

	Option 1 (Do Nothing)	Option 2 (Partial Intervention)	Option 3 (Full-Scale Intervention)
Benefit to geomorphic process			
Impact to in-stream habitat (longer term)			
Impact on wider biodiversity			
Impact on landscape/amenity value			
Impact on flood risk (to upstream and downstream areas)			
Ease of construction (short term)			
Cost of design/construction (short term)			
Cost of maintenance (longer term)			

Table 5.2 Summary of Options for the Reach 3.

	Description	Benefits	Disadvantages	Risk Appraisal and Mitigation Measures	Additional work required	Approximate design and build costs
Option 1: Natural Recovery	**Do Nothing**					
	• **Cease all regular channel management** activities and do not undertake any additional in-channel habitat improvement works.	• No short-term costs associated with construction. • No short-term disruption to current site use (agriculture and public rights of way) • No disturbance to existing in-stream and riparian habitats.	• No improved resilience to low flows. • No benefits for channel/floodplain connectivity. • No benefits to in-channel habitat and wider environment.	Not applicable	Not applicable	£0
Option 2: Assisted Natural Recovery	**Minimal Intervention**					
	• **Retain** flow through **existing channel**. • **Introduce LWS** at carefully targeted locations to further improve habitat diversity in main channel, with placement guided by detailed physical assessments.	• Benefit to geomorphic process through increased in-channel morphological diversity. • Improvement to ecological condition/habitat through the introduction of LWS. • Relatively inexpensive intervention option. • In-channel works only means existing infrastructure, i.e. fences, bridges and footpaths, can be retained.	• Some disruption to agriculture (upstream fields)) and public access (downstream at Ten Acre Wood) during construction, although much of existing in-stream and floodplain habitats can be retained. • Risk of continued incision and further channel deepening and canalisation. • Further natural recovery towards reference state unlikely given low-energy, incised river.	• Risk of LWS mobilising during high flows: Can be minimised through careful design that assesses the maximal forces likely to act on the structures, allowing for measures that optimise their stability, potentially employing stabilising measures in extreme cases.	• Physical assessment to guide LWS placement. • Regulatory requirements.	£50k – £80k
Option 3: Active Restoration	**Full-Scale Intervention**					
	• Where possible **realign/re-meander the channel** to create more natural, sinuous planform. • Ensure channel/floodplain connectivity throughout entire reach by **surface lowering**. • Where surface lowering is undertaken, promote the **development of wetland habitat** via seeding. • **Introduce LWS** at carefully targeted locations in realigned channel to further improve habitat diversity. Additionally, where the existing channel is to be retained consider placement of log jams to improve in-channel habitat and promote natural deposition and thus bed raising (placement to be guided by detailed physical assessments). • Utilise existing channel to include **backwater features** and infill channel elsewhere. • Maintain natural riparian woodland vegetation where already present and **plant native trees** along realigned channel to improve floodplain habitat and roughness.	• Significant improvement to **geomorphic process** through design of more sinuous channel, introduction of LWS and enhanced floodplain connectivity. • Improvement to ecological condition/habitat through the introduction of LWS. • Benefits to wider biodiversity through improvements to riparian zone and floodplain. • Potential improvements to downstream flood risk by flow attenuation within reconnected floodplain. • Significant positive impact on landscape through creation of more natural habitat and river corridor environment.	• Short-term disruption to agricultural land and public acces during construction, although much of existing in-stream and floodplain habitats can be retained. • Increased local flood risk due to retention of flood waters on floodplain. • Increased cost associated with more extensive restoration measures. • Greater complexity of construction relative to other options. • Land take required to achieve realigned channel. • Significant cut likely required to balance differences in floodplain and bed levels.	• Risk of LWS mobilising during high flows: Can be minimised through careful design that assesses the maximal forces likely to act on the structures, allowing for measures that optimise their stability, potentially employing stabilising measures in extreme cases. • Risk of encountering contaminated land or impacting utilities: Considered to be low but can be better constrained during design phase. • Risk of local increase in flood risk: Can be mitigated as part of design phase. • Complexity associated with floodplain levels relative to bed levels: Can be mitigated by careful design. • Risk of avulsion and head cut: Can be mitigated by infilling upstream end of existing channel and careful design of tie-in points.	• Outline/detailed design. • Regulatory requirements. • Ground investigation. • Landowner consultation. • Ecological assessment.	£200k – £500k

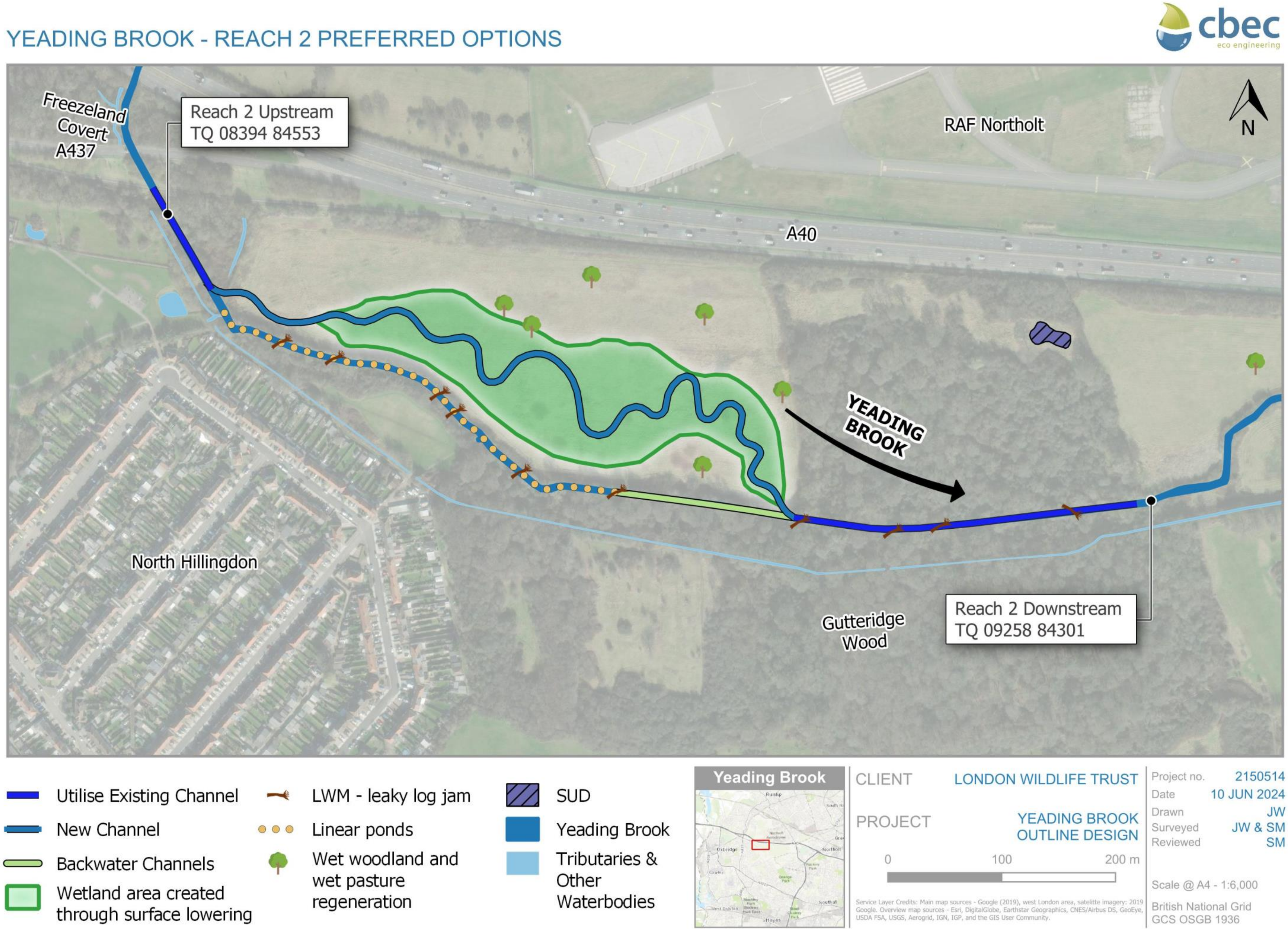


Figure 5.1 Preferred option for Reach 2.

5.2.2. Reach 3

The channel through Reach 3 has been historically modified; it has been straightened and re-sectioned (banks reprofiled), and dredging has resulting in the channel becoming entrenched and disconnected from the floodplain. Upstream of the confluence between the Yeading Brook and River Roxbourne an EA gauging station (confirmed to have been decommissioned in 2015/16, Ainslie *pers. comm.* 2024) impacts longitudinal connectivity (i.e. flow and the transfer of sediments downstream and the movement of aquatic organisms).

The channel suffers pressures from surrounding land use. Several outfalls from the A40 feed into the channel which provide a source for the input of fine sediments and nutrients in to the channel.

The riparian zone along both banks of the channel is heavily managed, and there is only a limited buffer zone between the banktop and surrounding agricultural land. Riparian vegetation is largely confined to the immediate bank top and bank face, and is characterised by scrub/shrub and brambles and a limited variety of ground flora. In the upper reach there are isolated mature trees while along the middle and lower reach the channel flows along the border of Ten Acre Wood.

Four potential options are described here, with varying degrees of potential improvement to the existing channel, which include:

- **Option 1: Natural Recovery – Do Nothing**; Cease all regular management activities within the restoration site and do not undertake any additional in-channel habitat improvement works.
- **Option 2: Assisted Natural Recovery – Minimal Intervention**; Retain flow through existing channel but introduce LWS at carefully targeted locations to further improve habitat diversity in main channel, with placement guided by detailed physical assessments.
- **Option 3: Active Restoration – Partial Intervention**; Same as Option 2 but undertake bank reprofiling where possible to improve channel/floodplain connectivity. Maintain natural riparian woodland vegetation where already present (i.e. Ten Acre Wood) and enhance vegetation along reprofiled banks for additional stability.
- **Option 4: Active Restoration – Full-Scale Intervention**; Realign/re-meander the channel through the floodplain to create more natural, sinuous planform. As with Option 2 LWS will be installed along the channel to improve channel habitat/kick start natural geomorphic processes. Improve the riparian and floodplain habitat through seeding and/or tree planting.

***RECOMMENDATION*:**	***Option 3***	***Full-Scale Intervention***

Table 5.3 shows the options matrix for Reach 4, while a full breakdown of the long list of options in is shown in Table 5.4. This includes a description of individual interventions, their advantages and disadvantages, and potential risks and mitigation measures.

Table 5.3 Options matrix for Reach 3. Coloured cells indicate: Significantly Positive; Slightly Positive; Neutral; Slightly Negative; Significantly Negative.

	Option 1 (Do Nothing)	Option 2 (Minimal Intervention)	Option 3 (Patial Intervention)	(Full-Scale Intervention)
Benefit to geomorphic process				
Impact to in-stream habitat (longer term)				
Impact on wider biodiversity				
Impact on landscape/amenity value				
Impact on flood risk (to upstream and downstream areas)				
Ease of construction (short term)				
Cost of design/construction (short term)				
Cost of maintenance (longer term)				

Table 5.4 Summary of Options for the Reach 3.

	Description	Benefits	Disadvantages	Risk Appraisal and Mitigation Measures	Additional work required	Approximate design and build costs
Option 1: Natural Recovery	**Do Nothing**					
	• **Cease all regular channel management** activities and do not undertake any additional in-channel habitat improvement works.	• No short-term costs associated with construction. • No short-term disruption to current site use (agriculture and public rights of way) • No disturbance to existing in-stream and riparian habitats.	• No improved resilience to low flows. • No benefits for channel/floodplain connectivity. • No benefits to in-channel habitat and wider environment.	Not applicable	Not applicable	£0
Option 2: Assisted Natural Recovery	**Minimal Intervention**					
	• **Retain** flow through **existing channel**. • **Introduce LWS** at carefully targeted locations to further improve habitat diversity in main channel, with placement guided by detailed physical assessments.	• Benefit to geomorphic process through increased in-channel morphological diversity. • Improvement to ecological condition/habitat through the introduction of LWS. • Relatively inexpensive intervention option. • In-channel works only means existing infrastructure, i.e. fences, bridges and footpaths, can be retained.	• Some disruption to agriculture (upstream fields) and public access (downstream at Ten Acre Wood) during construction, although much of existing in-stream and floodplain habitats can be retained. • Risk of continued incision and further channel deepening and canalisation. • Further natural recovery towards reference state unlikely given low-energy, incised river.	• Risk of LWS mobilising during high flows: Can be minimised through careful design that assesses the maximal forces likely to act on the structures, allowing for measures that optimise their stability, potentially employing stabilising measures in extreme cases.	• Physical assessment to guide LWS placement. • Regulatory requirements.	£50k – £80k
Option 3: Active Restoration	**Partial Intervention**					
	• **Retain** flow through **existing channel**. • **Introduce LWS** at carefully targeted locations to further improve habitat diversity in main channel, with placement guided by detailed physical assessments. • **Reprofile banks** to improve channel/floodplain connectivity (**potentially incorporating bed-raising** and/or creation **of two-stage channel**). • Maintain natural riparian woodland vegetation where already present (i.e. Ten Acre Wood) and **enhance vegetation along reprofiled banks** for additional stability.	• Benefit to geomorphic process through increased in-channel morphological diversity. • Improvement to ecological condition/habitat through the introduction of LWS. • Benefits to wider biodiversity through improvements to riparian zone and floodplain. • Potential improvements to flood risk by enhancing/formalising floodplain storage. • Positive impact on landscape through creation of more natural habitat and river corridor environment.	• Some disruption to agricultural land (upstream) aduring construction, although much of existing in-stream and floodplain habitats can be retained. • Works will impact public access downstream at Ten Acre Wood (short-term). • Increased cost associated with more extensive restoration measures. • Risk of continued incision and further channel deepening and canalisation. • Further natural recovery towards reference state unlikely given low-energy, incised river. • Existing structures, i.e. fencing, likely to be affected by bank reprofiling. • Some land take required to achieve more stable bank configuration. • Considerable cut may be generated by bank regrading which will require disposable either on-site or off-site.	• Risk of LWS mobilising during high flows: Can be minimised through careful design that assesses the maximal forces likely to act on the structures, allowing for measures that optimise their stability, potentially employing stabilising measures in extreme cases. • Risk of encountering contaminated land or impacting utilities: Considered to be low but can be better constrained during design phase.	• Physical assessment to guide LWS placement. • Regulatory requirements.	£200k – £1M

Option 4: Active Restoration	**Full-Scale Intervention**					
	• Where possible **realign/re-meander the channel** to create more natural, sinuous planform. • Ensure channel/floodplain connectivity throughout entire reach by **surface lowering**. • Where surface lowering is undertaken, promote the **development of wetland habitat** via seeding. • **Introduce LWS** at carefully targeted locations in realigned channel to further improve habitat diversity. Additionally, where the existing channel is to be retained consider placement of log jams to improve in-channel habitat and promote natural deposition and thus bed raising (placement to be guided by detailed physical assessments). • Utilise existing channel to include **backwater features** and infill channel elsewhere. • Maintain natural riparian woodland vegetation where already present and **plant native trees** along realigned channel to improve floodplain habitat and roughness.	• Significant improvement to **geomorphic process** through design of more sinuous channel, introduction of LWS and enhanced floodplain connectivity. • Improvement to ecological condition/habitat through the introduction of LWS. • Benefits to wider biodiversity through improvements to riparian zone and floodplain. • Potential improvements to downstream flood risk by flow attenuation within reconnected floodplain. • Significant positive impact on landscape through creation of more natural habitat and river corridor environment.	• Short-term disruption to agricultural land during construction, and public access although much of existing in-stream and floodplain habitats can be retained. • Increased local flood risk due to retention of flood waters on floodplain. • Increased cost associated with more extensive restoration measures. • Greater complexity of construction relative to other options. • Land take required to achieve realigned channel. • Significant cut likely required to balance differences in floodplain and bed levels.	• Risk of LWS mobilising during high flows: Can be minimised through careful design that assesses the maximal forces likely to act on the structures, allowing for measures that optimise their stability, potentially employing stabilising measures in extreme cases. • Risk of encountering contaminated land or impacting utilities: Considered to be low but can be better constrained during design phase. • Risk of local increase in flood risk: Can be mitigated as part of design phase. • Complexity associated with floodplain levels relative to bed levels: Can be mitigated by careful design. • Risk of avulsion and head cut: Can be mitigated by infilling upstream end of existing channel and careful design of tie-in points. • Risk of increased bird population and thus bird hit rates to RAF Northolt: can be mitigated by ensuring standing water depth is minimised so as not to encourage waterfowl.	• Outline/detailed design. • Regulatory requirements. • Ground investigation. • Landowner consultation. • Ecological assessment.	£500k – £1M

Figure 5.2 Preferred restoration options for Reach 3.

5.2.3. Reach 4

Reach 4 encompasses the lower section of the Eastern Arm of the Yeading Brook down to its confluence with the Western Arm just upstream of Ten Acre Wood. The entire reach has been heavily modified (straightened, deepened and over-steepened), is low-energy (primarily glide and pool units) and devoid of natural geomorphic features. Cessation of maintenance activities in recent years has allowed the development of riparian vegetation and the channel is currently lined by dense hedgerow, which acts to shade the channel limiting the growth of in-channel vegetation. In places an understorey of grasses and thorny scrub persists, but for the most part the banks are characterised by bare earth. The Eastern Arm is identified as one of the main conveyance paths for fine sediments and pollutants entering the main channel and in places thick deposits of silt were noted. The need to tackle fine sediment input from Reach 4 was highlighted by LWT during early discussions relating to the design, with the steer being to consider options such as the construction of online swales that would remove fine sediments from the system.

Three potential options are described here, with varying degrees of potential improvement to the existing channel. Construction within the existing channel is likely to be problematic, due to the potential ecological importance of the hedge(row) lining the channel. Therefore, options involving the construction of large features to assist natural recovery, i.e. in-channel benches used to increase sinuosity and diversity in-situ, are therefore not considered. The options identified for Reach 4 are as follows:

- **Option 1: Natural Recovery – Do Nothing**; Cease all regular management activities within the restoration site and do not undertake any additional in-channel habitat improvement works.
- **Option 2: Assisted Natural Recovery – Minimal Intervention**; Retain flow through existing channel. Introduce LWS (log jams) at carefully targeted locations to further improve habitat diversity and promote deposition and retention of fine sediments. Overtime this will also act to help elevate the channel with its floodplain improving channel-floodplain connectivity.
- **Option 3: Active Restoration – Full-Scale**; At the upstream extent introduce LWS (log jams) at carefully targeted locations to further improve habitat diversity and promote deposition and retention of fine sediments. Downstream divert the channel out onto the TRB floodplain. Develop a anastomosing (multi-channel) system with undersized channels to encourage overtopping during flood events. This area will be slow-flowing, developing as a wetland habitat that will encourage the deposition and retention of fine sediments. Improve the riparian and floodplain habitat through seeding and/or tree planting.

***RECOMMENDATION*:**	***Option 3***	***Full-Scale Intervention***

Table 5.5 shows the options matrix for Reach 4. A fact sheet describing each option is presented shown in Table 5.6. This includes a description of individual interventions, their advantages and disadvantages, and potential risks and mitigation measures.

Table 5.5 Options matrix for Reach 4. Coloured cells indicate: Significantly Positive; Slightly Positive; Neutral; Slightly Negative; Significantly Negative.

	Option 1 (Do Nothing)	Option 2 (Minimal Intervention)	Option 3 (Full-Scale Intervention)
Benefit to geomorphic process			
Impact to in-stream habitat (longer term)			
Impact on wider biodiversity			
Impact on landscape/amenity value			
Impact on flood risk (to upstream and downstream areas)			
Ease of construction (short term)			
Cost of design/construction (short term)			
Cost of maintenance (longer term)			

Table 5.6 Summary of Options for the Reach 3.

	Description	Benefits	Disadvantages	Risk Appraisal and Mitigation Measures	Additional work required	Approximate design and build costs
Option 1: Natural Recovery	**Do Nothing**					
	• **Cease all regular channel management** activities and do not undertake any additional in-channel habitat improvement works.	• No short-term costs associated with construction. • No short-term disruption to current site use (agriculture and public rights of way) • No disturbance to existing in-stream and riparian habitats.	• No improved resilience to low flows. • No benefits for channel/floodplain connectivity. • No benefits to in-channel habitat and wider environment.	Not applicable	Not applicable	£0
Option 2: Assisted Natural Recovery	**Minimal Intervention**					
	• **Retain** flow through **existing channel**. • **Introduce LWS** (log jams) at carefully targeted locations along the entire reach to further improve habitat diversity in main channel, with placement guided by detailed physical assessments.	• Benefit to geomorphic process through increased in-channel morphological diversity. • Improvement to ecological condition/habitat through the introduction of LWS. • Relatively inexpensive intervention option. • In-channel works only means existing infrastructure, i.e. fences, bridges and footpaths, can be retained.	• Some disruption to agriculture (upstream fields)) and public access (downstream at Ten Acre Wood) during construction, although much of existing in-stream and floodplain habitats can be retained. • Risk of continued incision and further channel deepening and canalisation. • Further natural recovery towards reference state unlikely given low-energy, incised river.	• Risk of LWS mobilising during high flows: Can be minimised through careful design that assesses the maximal forces likely to act on the structures, allowing for measures that optimise their stability, potentially employing stabilising measures in extreme cases.	• Physical assessment to guide LWS placement. • Regulatory requirements.	£50k - £80k
Option 4: Active Restoration	**Full-Scale Intervention**					
	• Within the lower section of the reach **realign/re-meander the channel** through the TRB floodplain creating a series of undersized channels that will develop as an anastomosing (multi-braided) system. • Consider planting this area with **natural wetland vegetation** to encourage the establishment of reedbed. • **Introduce LWS** (log jams) at carefully targeted locations along upper reach to further improve habitat diversity in main channel, with placement guided by detailed physical assessments. • Utilise existing channel to include **backwater features** and infill channel elsewhere. • Maintain natural riparian woodland vegetation where already present and **plant native trees** along realigned channel to improve floodplain habitat and roughness.	• Significant improvement to **geomorphic process** through design of more sinuous channel. • Floodplain reconnection and the slow-flowing nature of the anastomosing system will encourage the deposition and retention of fine sediments and sediment-bound pollutants. • Benefits to wider biodiversity through improvements to riparian zone and floodplain. • Potential improvements to downstream flood risk by flow attenuation within reconnected floodplain. • Significant positive impact on landscape through creation of more natural habitat and river corridor environment.	• Short-term disruption to agricultural land during construction, although much of existing in-stream and floodplain habitats can be retained. • Increased local flood risk due to retention of flood waters on floodplain. • Increased cost associated with more extensive restoration measures. • Greater complexity of construction relative to other options. • Land take required to achieve realigned channel. • Significant cut likely required to balance differences in floodplain and bed levels.	• Risk of LWS mobilising during high flows: Can be minimised through careful design that assesses the maximal forces likely to act on the structures, allowing for measures that optimise their stability, potentially employing stabilising measures in extreme cases. • Risk of encountering contaminated land or impacting utilities: Considered to be low but can be better constrained during design phase. • Risk of local increase in flood risk: Can be mitigated as part of design phase. • Complexity associated with floodplain levels relative to bed levels: Can be mitigated by careful design. • Risk of avulsion and head cut: Can be mitigated by infilling upstream end of existing channel and careful design of tie-in points. • Risk of increased bird population and thus bird hit rates to RAF Northolt: can be mitigated by ensuring standing water depth is minimised so as not to encourage waterfowl.	• Outline/detailed design. • Regulatory requirements. • Ground investigation. • Landowner consultation. • Ecological assessment.	£100k - £500k

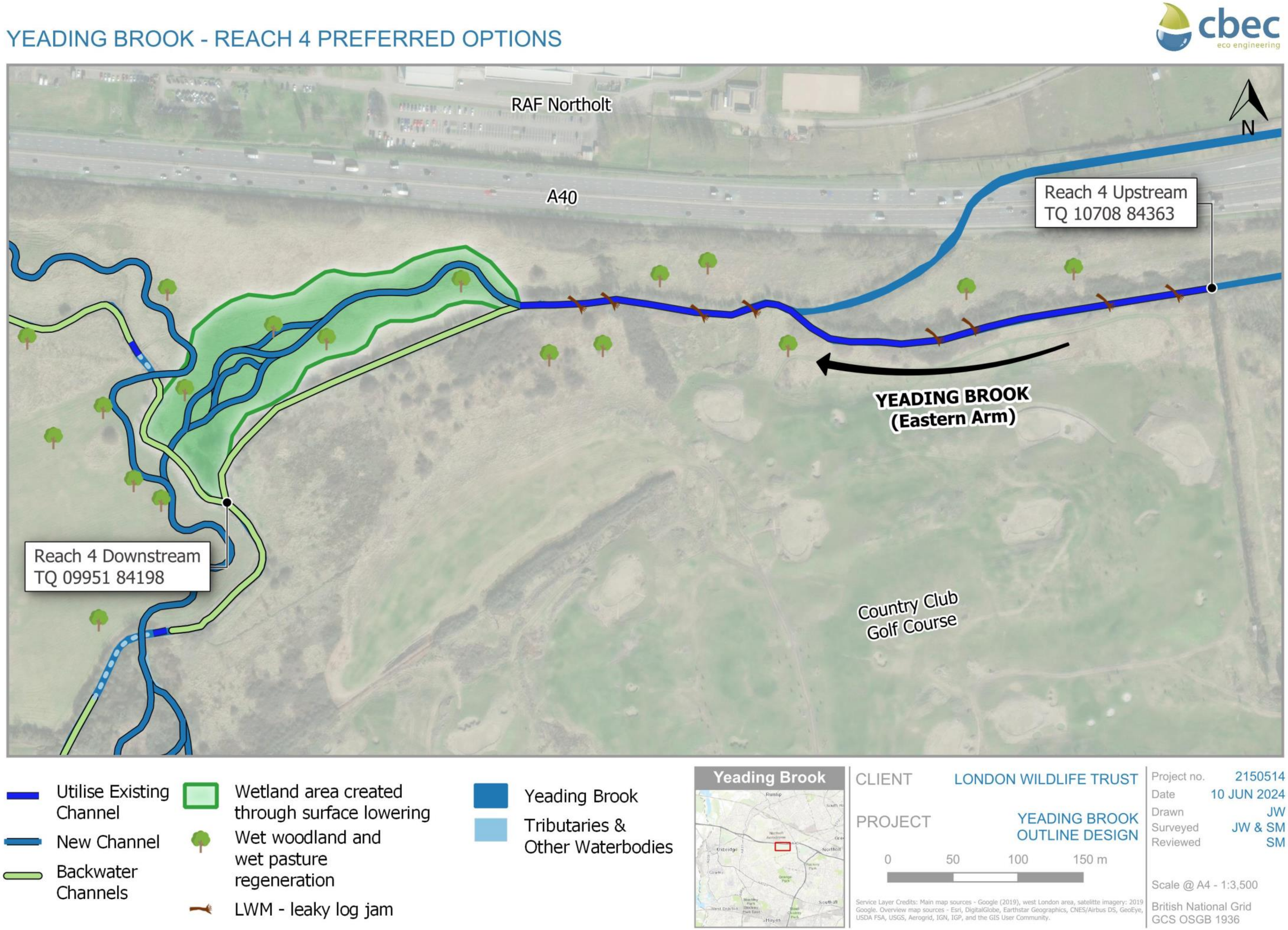


Figure 5.3 Preferred option for Reach 4. Note the grid reference for the downstream extent of the reach is for the channel in its current state.

5.3 HYDRAULIC MODELLING OF THE PREFERRED DESIGN OPTIONS

Hydraulic modelling was undertaken for the preferred design options, full details of which are presented in Appendix D. This was supported by an assessment of the hydrology of the Yeading Brook which is summarised in Appendix C. The following section provides an overview of the modelling results, focusing primarily on how the design impacts local flood risk.

Design development was informed by an iterative modelling approach with particular focus given to design options that reconnect the channel with its floodplain through re-meandering and reprofiling of banks, the creation of wetland and backwater habitats, and improvement of habitat diversity with LWS placement. The design iteration modelling was undertaken using a fully 2D approach using HEC-RAS v6: 2D modelling with sub-grid sampling, as is possible with HEC-RAS, gives a more accurate representation of channel-floodplain interaction than 1D-2D modelling approaches common in flood modelling. This design model could be run relatively quickly to investigate various design options and iterations to achieve the desired low flow performance. As agreed with the project group, the modelling runs undertaken were flood flows for the 1 in 2-, 5-, 10-, 20-, 50- and 100-year return periods plus the 100-year return period with an uplift of 17% for climate change (100-year+CC), to give a view of how flood extents change over a range of flows, from the typical bank full event (i.e. 2-year return period) to extreme flood events.

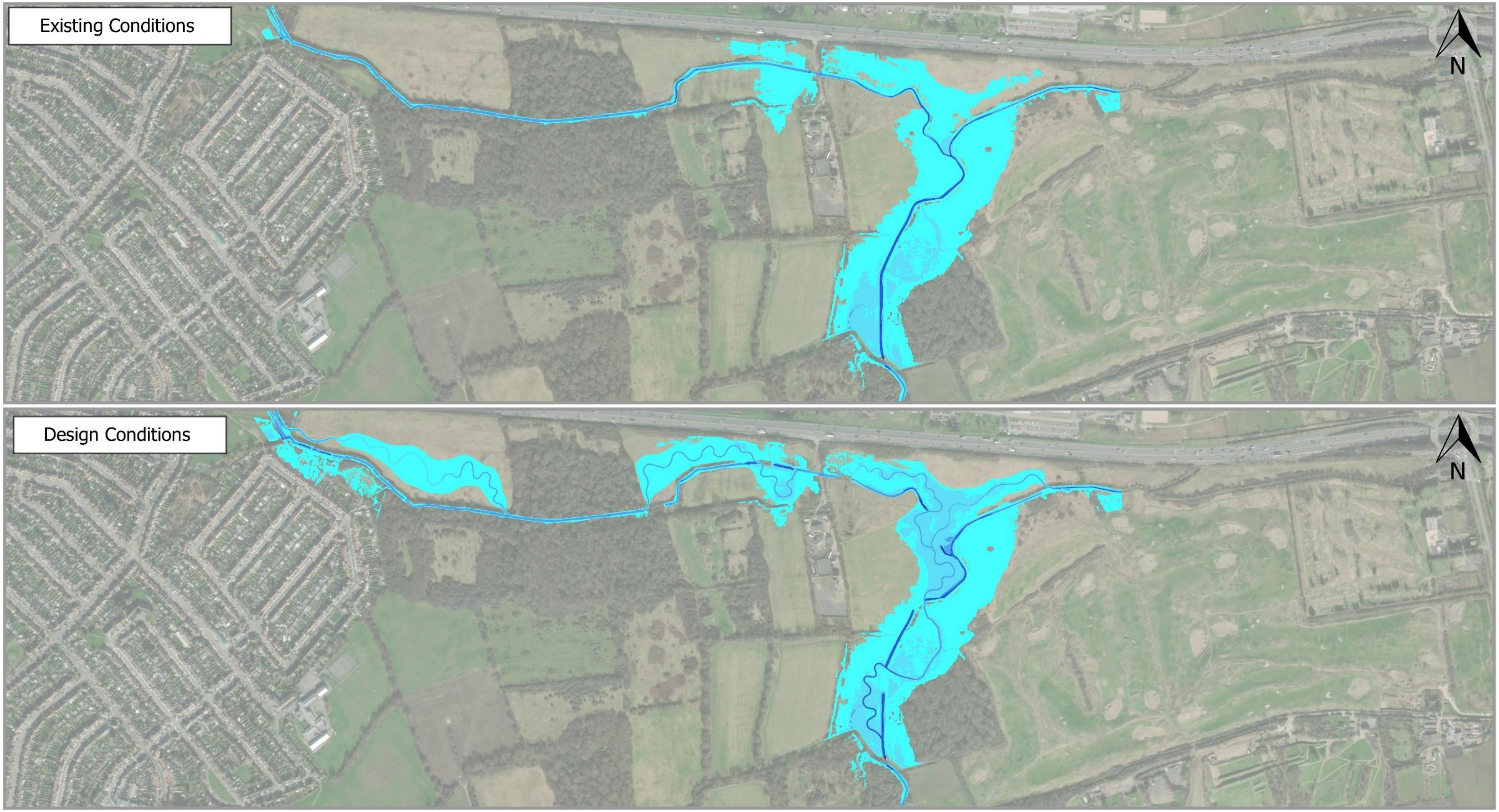
Figure 5.4 to Figure 5.6 show a comparison of the existing and design water depths for the 1 in 2-, 10- and 100-year return period peak flows respectively. These output maps demonstrate how the proposed design significantly alters the extent of flooding within the study area, particularly along the Western Arm of the Yeading Brook (Reaches 2 and 3) where extensive re-meandering of the channel and surface lowering of the floodplain is proposed. The design promotes a much larger inundated area, with improved channel-floodplain connectivity for typical bankfull events (i.e. 1 in 2-year floods) in the fields to the north and east of Gutteridge Wood. In comparison, existing conditions inundation is mainly at the downstream extent of the design area, in the vicinity of Ten Acres Wood, with inundation through Gutteridge Wood only occurring under extreme flood events (1 in 100-year return period).

The modelling results demonstrate that the design serves to reduce flood risk to the A40, with proposed surface lowering helping to formalise floodwater storage within the floodplain. Inundation of the A40 under existing conditions is shown to occur during 1 in 50-year and greater return periods. In comparison, while the design results in an increased area of inundation in the fields south of the A40 floodwaters do not overtop onto the road even under the most extreme events (i.e. 1 in 100-year floods). Additionally, pass-forward hydrographs for the 1 in 2-year and 100-year+CC return periods (shown in Figure 5.7) show increased duration of flood water storage within the site resulting in delayed flood peaks of several hours downstream of the design area.

The design conditions show an increase in flood risk to residential properties south of Gutteridge Wood (i.e. Lynhurst Crescent, North Hillingdon) for the 1 in 2-, 5- and 10-year return periods, and a slight increase seen in flood extents for more extreme events (i.e. 1 in 20-year return period and greater). However, given the limitations of the model (detailed in full in Appendix D) the increase in flood risk caused by the design may be exaggerated. Refinement of the model is recommended to better represent the site specific conditions (e.g., the inflows from the SWO draining residential properties to the south and the hydrological connectivity of ditches, etc.) and specific design elements (e.g., leaky logjams) in order to determine the true flood risk.

2150514 - HYDRAULIC MODELLING RESULTS - 2Y RETURN PERIOD

cbec
eco engineering



Depth - Maximum (m)			
<= 0.57		2.30 - 2.88	
0.57 - 1.15		2.88 - 3.45	
1.15 - 1.72		3.45 - 4.02	
1.72 - 2.30		> 4.02	

NORTH LONDON

CLIENT: LONDON WILDLIFE TRUST

PROJECT: YEADING BROOK RESTORATION

0 250 500 m

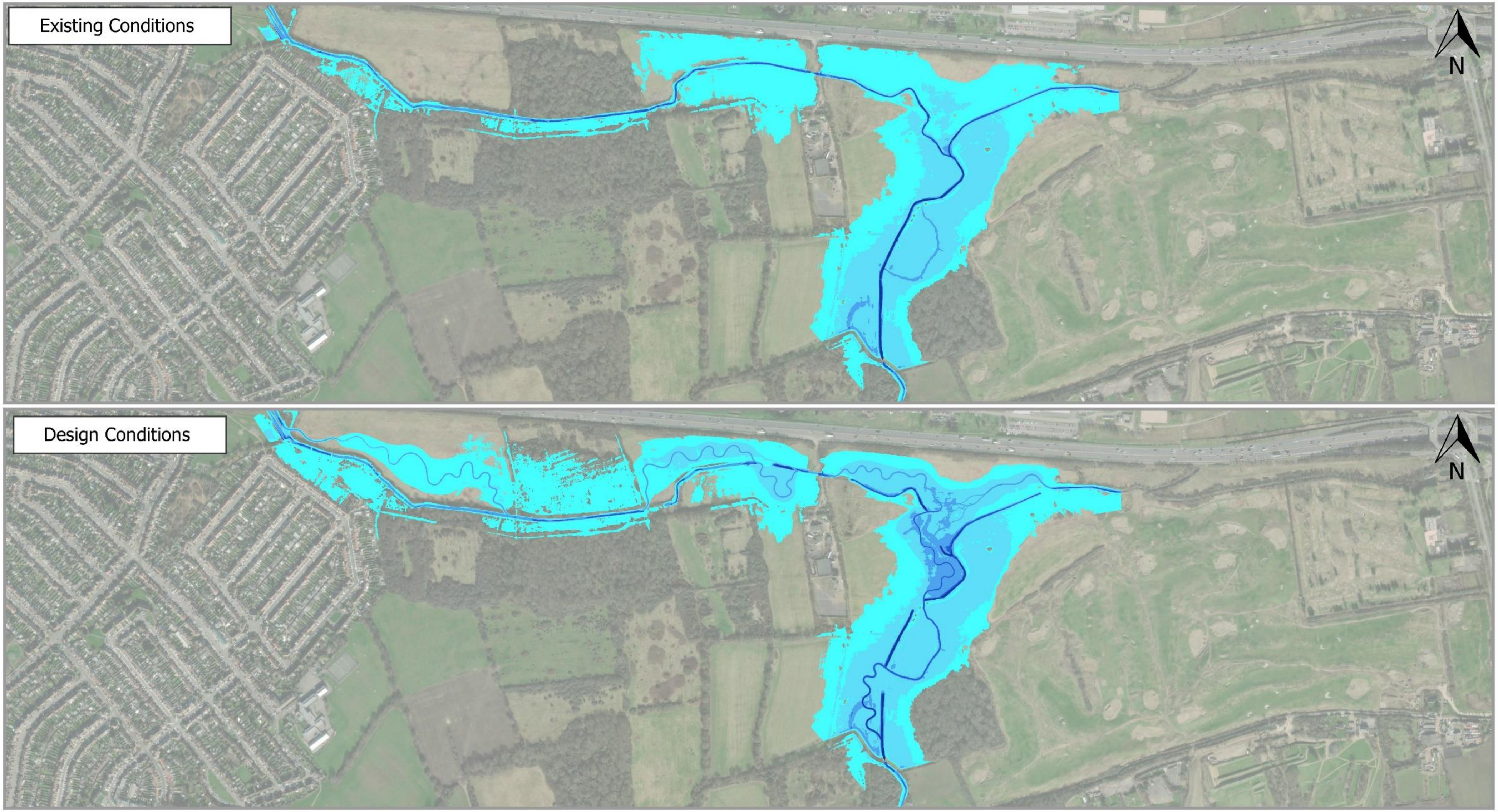
Service Layer Credits: Main map sources - Google (2019), North London area, satellite imagery: 2019 Google. Overview map sources - Esri, DigitalGlobe, Earthstar Geographics, CNES/Airbus DS, GeoEye, USDA FSA, USGS, Aerogrid, IGN, IGP, and the GIS User Community.

Project no. 2150514
Date 18 JUL 2024
Drawn ED
Modelled ED
Reviewed DP

Scale @ A4 - 1:12,000
British National Grid
GCS OSGB 1936

Figure 5.4 Comparison of the existing condition and design water depths for the 1 in 2-year return period.

2150514 - HYDRAULIC MODELLING RESULTS - 10Y RETURN PERIOD



Depth - Maximum (m)	
<= 0.57	2.30 - 2.88
0.57 - 1.15	2.88 - 3.45
1.15 - 1.72	3.45 - 4.02
1.72 - 2.30	> 4.02

NORTH LONDON

CLIENT	LONDON WILDLIFE TRUST
PROJECT	YEADING BROOK RESTORATION

0 250 500 m

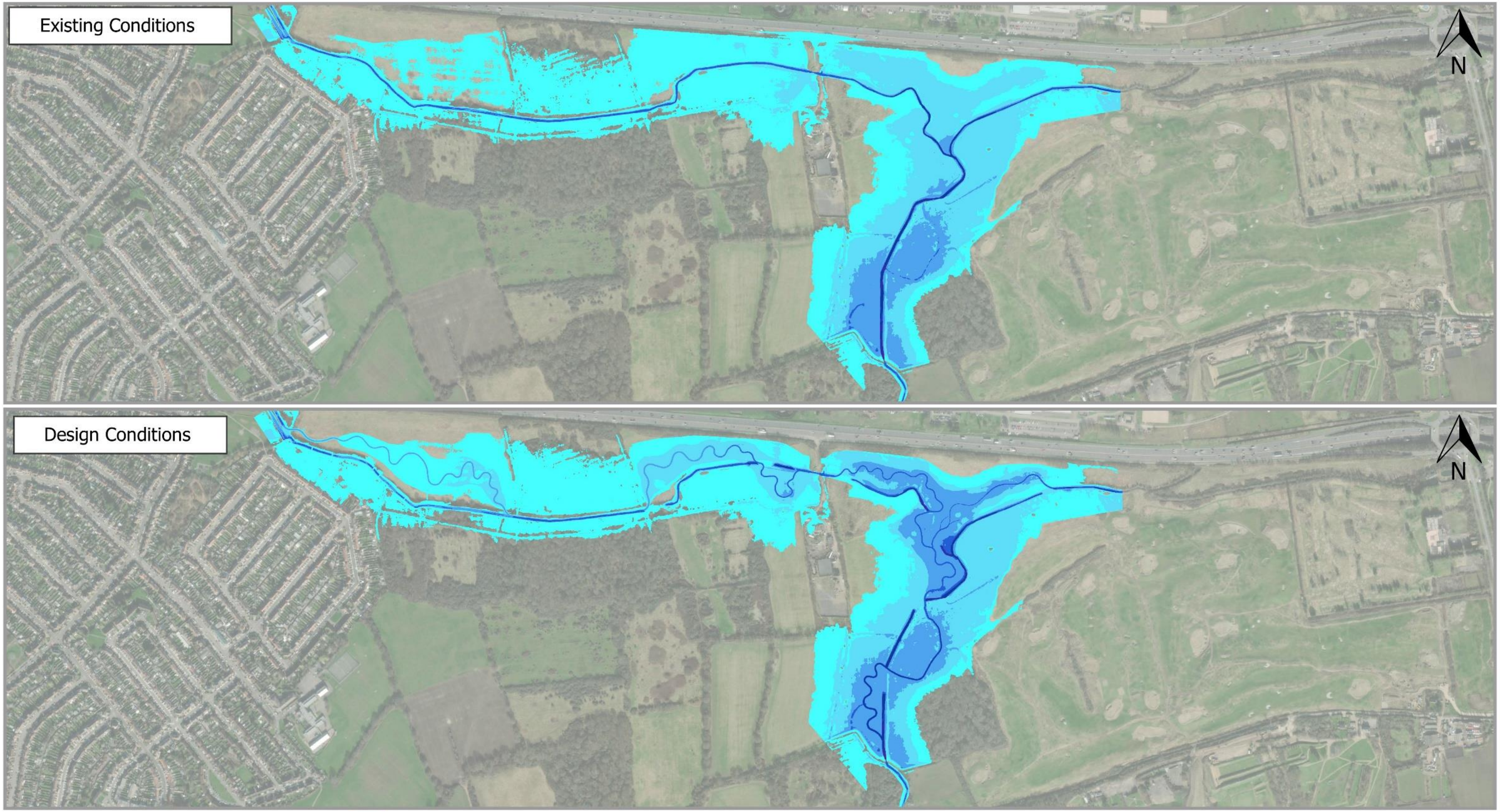
Service Layer Credits: Main map sources - Google (2019), North London area, satelitte imagery: 2019 Google. Overview map sources - Esri, DigitalGlobe, Earthstar Geographics, CNES/Airbus DS, GeoEye, USDA FSA, USGS, Aerogrid, IGN, IGP, and the GIS User Community.

Project no.	2150514
Date	18 JUL 2024
Drawn	ED
Modelled	ED
Reviewed	DP

Scale @ A4 - 1:12,000
British National Grid
GCS OSGB 1936

Figure 5.5 Comparison of the existing condition and design water depths for the 1 in 10-year return period.

2150514 - HYDRAULIC MODELLING RESULTS - 100Y RETURN PERIOD



Depth - Maximum (m)

<= 0.57	2.30 - 2.88
0.57 - 1.15	2.88 - 3.45
1.15 - 1.72	3.45 - 4.02
1.72 - 2.30	> 4.02

CLIENT LONDON WILDLIFE TRUST

PROJECT YEADING BROOK RESTORATION

0 250 500 m

Service Layer Credits: Main map sources - Google (2019), North London area, satellite imagery: 2019 Google. Overview map sources - Esri, DigitalGlobe, Earthstar Geographics, CNES/Airbus DS, GeoEye, USDA FSA, USGS, Aerogrid, IGN, IGP, and the GIS User Community.

Project no.	2150514
Date	18 JUL 2024
Drawn	ED
Modelled	ED
Reviewed	DP

Scale @ A4 - 1:12,000
British National Grid
GCS OSGB 1936

Figure 5.6 Comparison of the existing condition and design water depths for the 1 in 100-year return period.

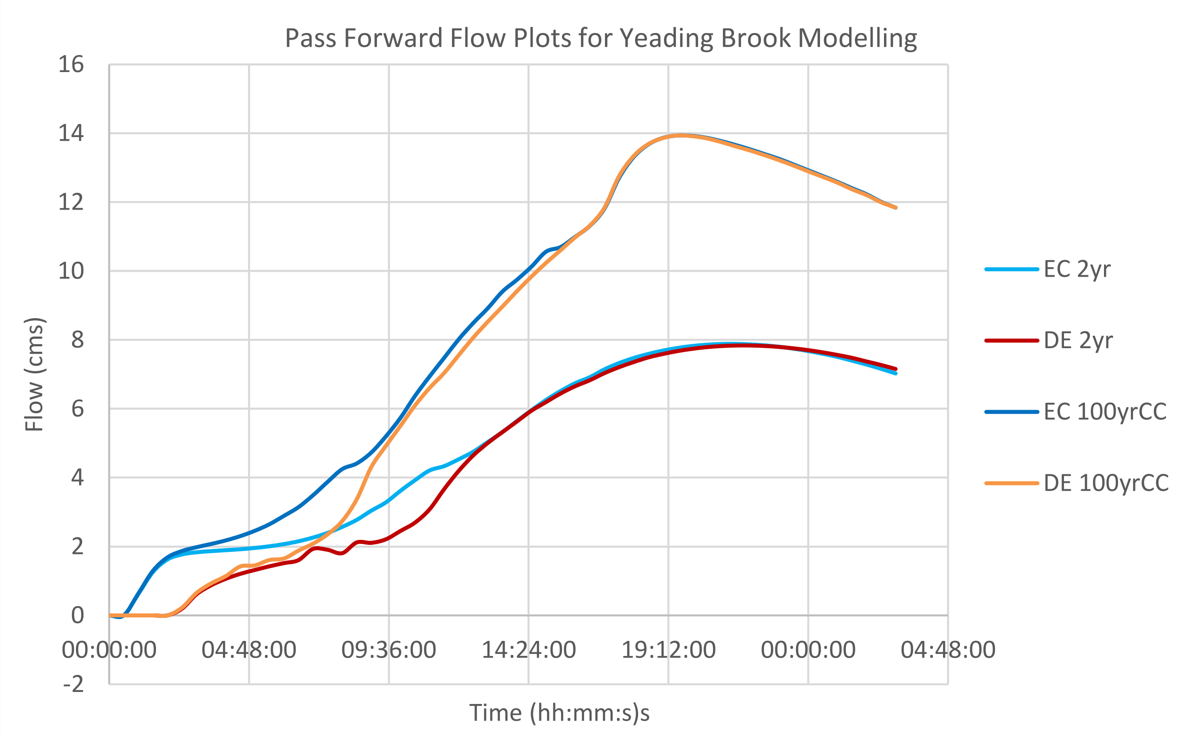


Figure 5.7. Comparison of the existing and design pass-forward hydrographs for the 1 in 2-year and 1 in 100-year+CC return periods.

3.2 RECOMMENDATIONS

Recommendations for further hydraulic modelling would be to ensure more information is available regarding the inflow on the Yeading Brook West and to ensure flow is accurately represented in the model. Furthermore, details of the diameter of the log jams and the percentage flow intended through these features should be available, to ensure accuracy of further modelling.

5.4 CONSTRAINTS AND OTHER RESTORATION OBJECTIVES

The Yeading Brook sits within a urbanised setting, and there are significant constraints that need to be accommodated by the scheme. These include foul sewer drains, underground and overhead electrical cables that cross the design area in several locations (see Figure 5.8).

5.4.1. Utilities

Full details of the utilities search results are provided in Appendix A. The following section discusses the main assets believed by the design team to represent the main constraints to restoration objectives. However, it should be noted that this does not represent the full list of utilities considered to be affected by the proposed design. For a full list of affected utilities the reader is referred to the Appendix A.

Low Voltage (LV) Underground Cable

A low voltage underground cable runs along the entire length of the Western Arm of the Yeading Brook (TRB) and along the upstream and middle sections of the River Roxbourne (TLB). Through Reach 2 it is proposed that the channel is realigned through the TRB, and thus if the locations of the cable are correct the designs will not risk disturbing this asset in this location. However, in Reach 3 and 4 the realigned channel will cross the LV underground cable in several locations.

UK Power Networks, the owner of these assets, will need to be consulted to determine what (if any) negative impact proposed realignment of channel and thus excavation may have on any buried cables. UK Power Networks will need to provide final approval for works being undertaken in these areas. If approval is granted, careful consideration will need to be given to the construction methodology to prevent any potential damage caused any excavations.

Foul Sewer

There are four foul sewer drains that cross the design area (Figure 5.8). The 1600 Ruislip Branch approaches from west and crosses the western arm of the Brook at TQ 0936 8438, while from the east the *1200 Harrow Branch Relief Sewer* and *1372 Harrow Branch Sewer* both run parallel to eastern arm of the Brook (right bank) crossing the western arm at TQ 0988 8425 and TQ 0988 8424. These three pipes converge to form the *1981 Crane Valley Sewer (Main Line)* which drains southwards running parallel with the Yeading Brook (right bank). Manhole invert levels provided in the utilities search (Appendix A) suggest these are buried at a depth of ~4 – 6 m below the floodplain.

The current outline design seeks to minimise works (channel realignment and floodplain lowering) within areas where pipe crossing points are believed to be, primarily in Reaches 2, 3 and 4. However, the exact locations and burial depths of these sewers will need to be confirmed to inform the final detailed designs. Bed raising may be required in the vicinity of the crossing points to maintain bed gradients between sections of realigned channel and existing channel, resulting in an increase in the burial depth of pipes. Thames Water, the owner of these assets, will need to be consulted to determine what (if any) negative impact proposed bed raising may have on the sewers, and to provide final approval for works being undertaken in these areas. If approval is granted, careful consideration will need to be given to the construction methodology to prevent any potential damage caused by the movement of large machinery crossing the buried pipes.

Surface Water Outfalls (North Hillingdon)

There are three SWOs that drain into the Western Arm of the Yeading Brook from the TRB in Reach 2. These convey runoff from residential areas south of the Brook (i.e. North Hillingdon). Due to limitations in the available data flows from these SWOs have not been included within the current hydraulic model. To ensure accuracy of future modelling it is recommended that an extended utilities search be undertaken to characterise the surface water drainage network in Hillingdon to characterise the catchment of these SWOs.

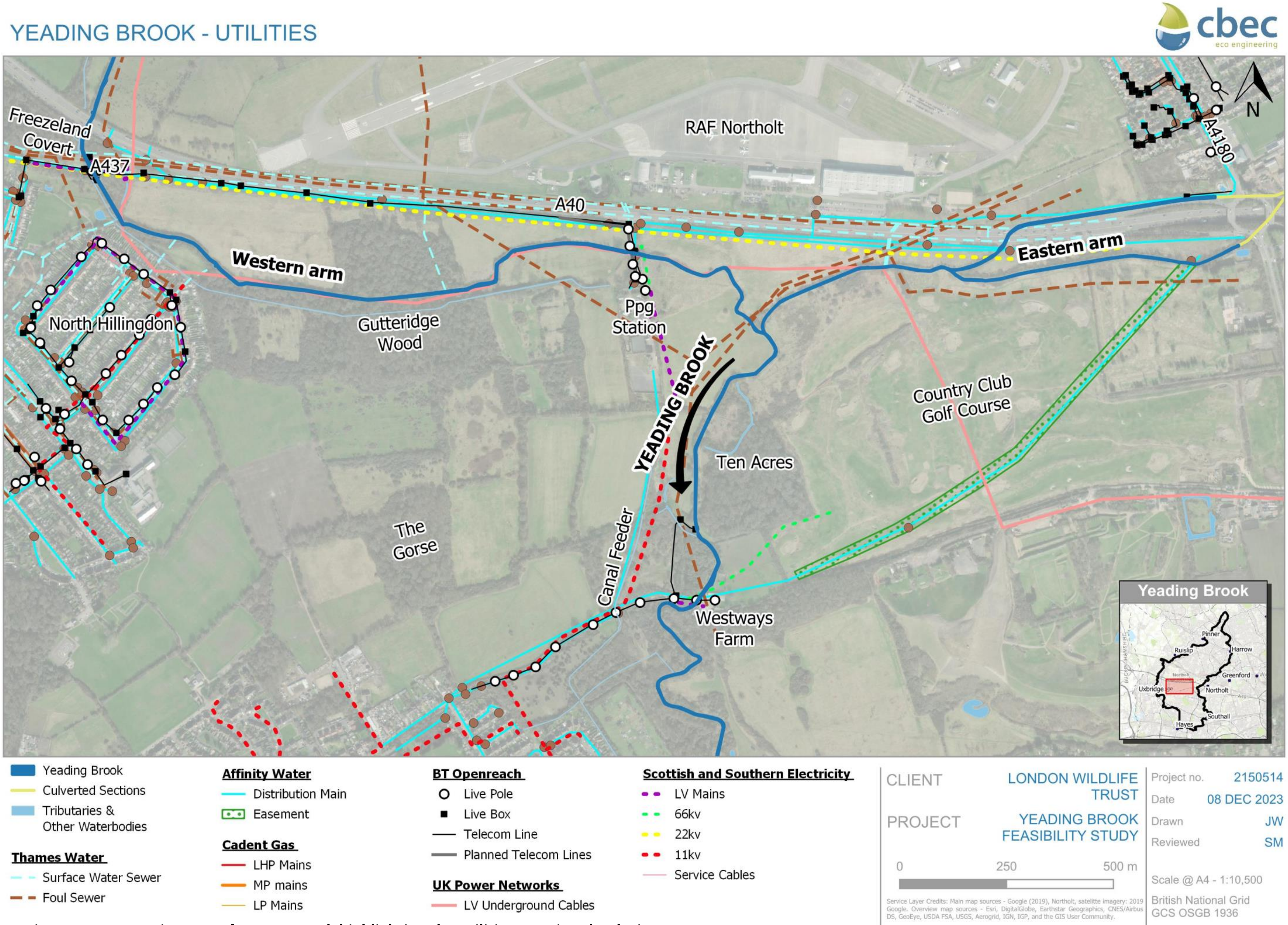


Figure 5.8 Constraints map for Arnos Park highlighting the utilities crossing the design area.

5.4.2. RAF Northolt

RAF Northolt is located to the north of the site and there are several structures (landing lights) associated with the airport located within the TRB floodplain. As part of the preferred design it is proposed that the channel is realigned through the TRB north of Gutteridge Wood in the vicinity of the landing light structures. Careful consideration will be needed to ensure these are not impacted by any potential changes to local flood risk in their immediate vicinity and/or by increased dynamism of the channel following restoration.

By increasing the overall area of open water and wet grassland it is likely that local/migratory populations of wildfowl will be encouraged to the site. Therefore, there is a risk that the design may increase the risk of bird strikes for planes landing and taking off from RAF Northolt. While it is proposed that certain design features be excluded to reduce open standing water, i.e. scrapes, improved floodplain connectivity will mean that during the autumn/winter months large areas of the site may experience flooding. Further engagement with the Civil Aviation Authority and RAF Northolt is advised at the next stage of the project to ascertain what constraint this will put on the proposed scheme. Depending on RAF Northolt's response it may be necessary to have input from a wildfowl specialist to the design process. This would be beyond the current scope but cbec can recommend suitable experts.

5.4.3. Bridges and Access

The realignment of Yeading Brook will create issues for public use of the existing footpath network within this area. As part of the design it is proposed that the channel be reconnected with a relict meander in the vicinity Ten Acre Wood. A small footbridge located at OS NGR TQ 09918 83979 currently allows access across this relict meander, but this will need replacing following realignment with a suitable free-span bridge or culvert. Additionally, crossing structures of some description may also be needed elsewhere on site to improve access to areas not currently accessible by the public. Installation of culverts potentially presents a cost effective solution, however, installing a structure that in essence creates a manmade bed for the channel goes against the overriding restoration strategy which is driving the project. Therefore, a more geomorphically sensitive solution would be the installation of clear span bridges (not a bridge over a box culvert) which retain a natural channel bed.

Figure 5.9 Example of a hardwood bridge being installed over a realigned channel. Source: cbec eco-engineering UK Ltd.

The exact requirements for bridge sizing will not become evident until the detailed design phase, when the channel sizing has been finalised. Figure 5.9 illustrates an example of suitable style of bridge.

A farm access (vehicle) bridge is located at TQ 09879 84317 which while in a poor state of repair may be required for access. The current design bypass this bridge, and therefore a replacement structure would be required if access is to maintained across the channel. As noted above, culverts would be a cost effective option but will negatively impact the channel. Therefore, it is recommended that a free-span bridge suitable for use by vehicles should be installed to enable continued access. The exact requirements for bridge sizing will not become evident until the detailed design phase, when the channel sizing has been finalised. Figure 11.3 shows an example of a suitable style vehicle bridge.

Figure 5.10 Example of a steel and timber bridge suitable for vehicles that could be installed (Photo courtesy CTS Bridges).

5.5 UNEXPLODED ORDNANCES

A high level review for the risk of unexploded ordnances (UXO) at the study site has highlighted a low risk of unexploded bombs being present as a result of World War Two bombing. Although the risk is low, the presence of a Luftwaffe target being present to the north at RAF Northolt and the recorded discovery of two UXO in its vicinity mean that consideration is required as the design process progresses.

Generally, a moderate or high risk of UXO require a detailed UXO desk study and risk assessment to be undertaken, but as the risk is low, this will not be required at this point in the project.

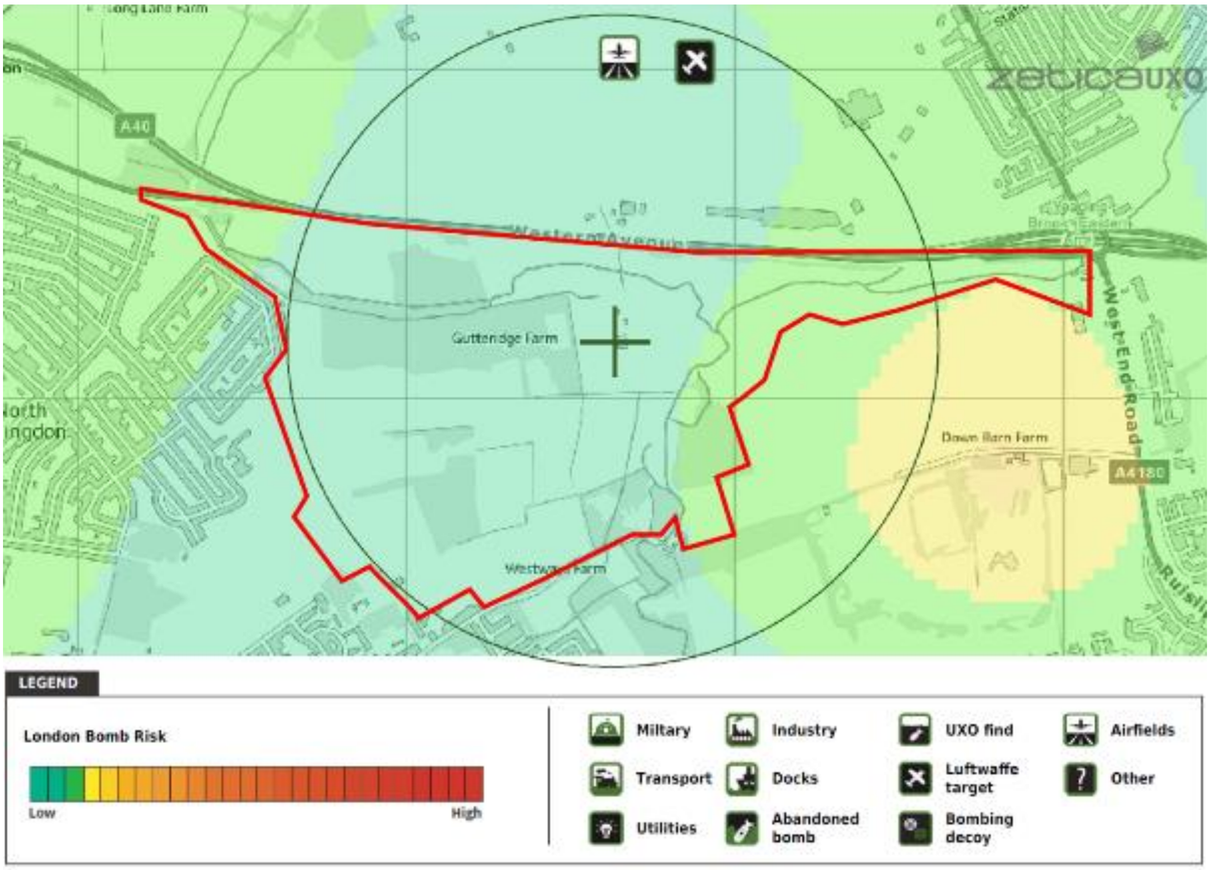


Figure 5.11 Overview of unexploded ordnance risk for Arnos Park (Red rectangle). Source: www.zeticauxo.com.

6. NEXT STEPS

Upon review of this report by LWT, the restoration strategy proposed for Yeading Brook should continue into outline/detailed design. Engagement with all relevant stakeholders, such as the Civil Aviation Authority (RAF Northolt), utilities companies, the primary landowner (LBH) and other local landowners will be integral to continue project momentum. Therefore, the starting point for the next project phase needs to be a workshop where the conceptual design is discussed and any unidentified constraints flagged prior to the commencement of the subsequent design phase.

cbec wish to emphasise the importance of gathering all design inputs prior to further modelling and as the intervention of stakeholders may necessitate changes to design and repeat model runs. This has the potential to increase the number of model runs beyond scope. In particular we strongly recommend early engagement with utilities companies and the RAF.

6.1 ACTION PLAN

To inform the design process, an action plan needs to be finalised to outline any further investigations which need to be undertaken to inform the design development. A list of known constraints/gaps in knowledge are identified below, which should be considered during the next phase of works.

To inform the design development, the stratum type and depths will need to be investigated. Although trial pits may be fit for purpose, undertaking borehole will allow a clearer illustration of ground conditions, whilst also making the process of any subsequent soil testing more streamlined, as samples can be differentiated and stored more easily.

6.1.1. Contaminated Land

In the event that any made ground or contaminants are identified within the boreholes, subsequent testing to determine which contaminants are present may be required. A Phase 1 desk-based assessment could be undertaken as an intermediary step, however, as classification of the stratum type is also required for the design, proceeding immediately to ground investigations may streamline the process.

6.1.2. Asset Management for Infrastructure

Discussions with the relevant utilities (e.g., Thames Water, Affinity Water, UK Power Networks, etc.) to determine appropriate approaches to protect affected utilities will require consultation.

6.1.3. Public Access

Improved public access for the site and/or connectivity is one of the Smart Water Catchment objectives LWT wishes to meet for the site. Public access has not been considered in this report and it is suggested that further conversation between the designer, LWT and LBH, including council personnel who are currently not involved in the project. Determination of proposed footpath locations crossing points, amenities, etc., will all need to be covered within the next phase of works.

6.1.4. Floodplain Habitat Creation

The primary focus of this concept design has been the feasibility and alignment for the restoration channel through the study site. As outlined in Section 5, the realignment will create possibilities for the creation of floodplain habitat. Consultation with community stakeholders will form key step in the development phase for determining the most appropriate solution within the floodplain. Ecological consideration of target species and any associated amenity value will be prudent.

6.1.5. Wider Landscape Habitat Creation

While restoration of the channel and floodplain forms an integral part of Nature Recovery and Flood Resilience of the Yeading Brook project, consideration of wider habitat enhancement objectives is required as part of the restoration design. LWT have outlined several aspirations for habitat creation within the wider landscape, e.g., increasing the extent of woodland (including wet woodland) cover from ~26 ha to ~40 ha, and specific habitat types to be created as part of the river restoration component of the project, e.g., areas of exposed river bank soils to benefit biodiversity. A detailed ecological assessment of the entire project site should be undertaken as part of the design phase to generate holistic understanding of the site and ensure the river and terrestrial components complement and enhance each other.

6.1.6. Management Plan (river and terrestrial habitat)

Consideration should be given to the ongoing management of the site. Certain habitats and features may require maintenance, e.g. coppicing and pollarding of wet woodland, erection and maintenance of cattle exclusion fencing and designated drinking areas (if livestock grazing is envisaged), etc. A management plan may also include aspirations for ongoing survey and monitoring, e.g., invertebrate assemblages or macrophytes, etc.

6.2 OUTLINED/DETAILED DESIGN

If, following consultation with the key stakeholders, there is clear instruction to proceed with the outline/detailed design phases of this restoration project, the following tasks should be included within the design scope:

- Undertaking of the tasks identified within the action plan as the basis for extending conceptual design ideas into detailed plans;
- Re-running of the existing hydraulic model with the updated design surface to assess hydraulic performance and inform a flood risk assessment. The updated hydraulic model will form an integral task to inform on variables such as design channel sizing, sediment transport potential and floodplain connectivity/flow attenuation;
- A Level 2 Flood Risk Assessment (fully quantitative) to accurately assess the potential benefits of the scheme for minimising downstream flood risk;
- Production of design drawings to inform the construction phase;
- A bill of quantities for all design features including cut and fill and large wood;
- Investigation on the impact of the detailed design on surrounding land users.

Further to the above listed items, as is required under CDM (2015), the principal designer will also need to prepare the relevant documents (Pre-Construction Information (PCI), Health & Safety File, Design Risk Register and Design Method Statement) to enable the construction contract to be tendered.

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APPENDIX A

Utilities Report

A desk-based utilities search was undertaken by Atkins, in order to identify all potential utility infrastructure and the relevant providers within the area study area. A summary of the utility responses provided by the local utilities companies is provided by Table A.1 and the locations of utilities shown in Figure A.1. The main affected responses are; Thames Water, Affinity Water and Scottish and Southern Electricity providers and UK Power Networks, along with other utilities, highlighted 'Affected'. Most telecom and network providers with the exception of BT Telecoms and other utilities such as Network Rail are unaffected by the project.

Table A.1 Summary of utilities responses.

Utility Provider	Status	Summary
	WATER & SEWER	
Affinity Water	Affected	Distribution Mains Following a tributary of the Yeading Brook from the 'Gutteridge Works' to TQ 09641 83566 where it intersects the waterbody before joining another mains distribution pipe. The other distribution mains pipe within the search area of the Yeading Brook crosses the channel at TQ 09796 83570 before continuing in an Eat/ Northeasterly direction, towards Western Avenue, crossing Yeading Brook once more at TQ 10842 84385. The secondary distribution mains pipe noted is surrounded by an easement area which is in situ between ~ TQ 10037 83657 and TQ 10842 84385.
Thames Water	Affected	Thames Water Assets within the search area include both surface water and foul sewer pipes. Surface water sewers join the Yeading Brook at four locations along the searched section all of which run perpendicular away from the channel. Foul Sewer pipes cross the channel on 6 occasions within the searched area forming a 'Y' shape over the Yeading Brook, such intersections must be considered in all restoration options, in order to reduce the potential for contamination of freshwater.
	ELECTRICITY	

UK Power Networks	Affected	Low Voltage Underground electrical Cables are present within the search area of Yeading Brook, these generally follow the course of the Brook, from TQ 08483 84563, where the cables first intersect a tributary of the Yeading Brook and TQ 08444 84468, where LV mains intersect the Brook, before changing direction to follow the channel line to TQ 09865 84347, near the confluence, where the LP mains continue until it intersects the channel again at TQ 10176 84354. From this intersection, LV mins change direction, perpendicular to the original direction and are in place down to Charvill Lane, before changing direction again, away from Yeading Brook.
Scottish and Southern Electricity	Affected	Both overhead and buried electrical cables run parallel to the main road (Western Avenue), which generally do not affect potential restoration of the Yeading Brook. However, 66kv powerlines cross the channel at TQ 09657 84386, before meeting a Low Voltage Mains cable which covers the 'Gutteridge Works', before connecting to a 11Kv line that crosses a tributary of the Yeading Brook at TQ 09756 83753, and continuing towards Charvill Lane. Service Cables are also in the vicinity of the study area boundary, connecting main powerlines to residential property.
Utility Assets	Affected	Not confirmed as no official statement has been received regarding specific assets. However, Utility Assets states that if no response is received, it likely means there are no assets within the study area.
Eclipse Power	Not Affected	-
GAS		
Cadent Gas	Affected	Locally High Pressure (LHP) Cadent Gas Mains intersect the search area and cross the channel and or associated tributaries at the following locations; TQ 08424 84500, TQ 08463 84505 and TQ 09298 84318 before leaving the Searched area. LHP mains also cross the Yeading Brook outside of the searched area at, TQ 09706 83386. Other Affected Cadent Gas Pipelines run parallel to the search area along the main road; Western Avenue. These include LHP, Medium Pressure (MP) and Low Pressure (LP) mains.
TELECOMS		

BT (Openreach)*	Affected	BT telecoms overhead cables and the relevant posts are present in three key places within the Yeading brook search area these are: 1. Parallel to the study area running along the main road 2. Directly crossing the Brook at (TQ 09649 84387), running perpendicular to the main road (Western Avenue) to the northernmost point of the Gutteridge works (Figure A.1); this includes both established and planned Telecom Infrastructure. 3. Intersecting the southern section of the search area, where Telecom infrastructure runs parallel to Charvill Lane, before crossing Yeading Brook at TQ 09796 83571. Telecom lines also cross Yeading Brook and its associated tributaries, at TQ 09767 83727 and TQ 09795 83748. These Telecom lines are connected via live power boxes, which are also in close proximity to Yeading Brook.
C.A. Telecom UK (Colt)	Not Affected	-
GTC	Not Affected	-
Leap Utilities	Not Affected	-
OCU Group	Not Affected	-
SKY Telecoms Services	Not Affected	-
Vodafone	Not Affected	-
Verizon	Not Affected	-
Virgin Media	Not Affected	-
City Fibre	Not Affected	-
OTHER		
Environment Agency	Affected	Request for any proposals of works to be submitted to the EA, for consideration for an environmental permit to undergo work; in, under, over or near to a main river.
Network Rail	Not Affected	-
Transport for London	Not Affected	-
London Borough of Hillingdon	Not Affected	-
London Underground	Not Affected	-
LinesearchbeforeUdig	Affected	Underground and overhead gas pipelines and both high/low voltage cables identified within the surveyed area.

Whilst none of the proposed options presented in Section 5 involve construction which will disturb these assets, where designs are in close proximity to these assets, or may impact flood risk, this should be considered carefully during design development so that any potential risks are understood and mitigated against and, where required, asset owners consulted. Since these data provide indicative locations only, the location of buried utilities should be verified prior to construction.

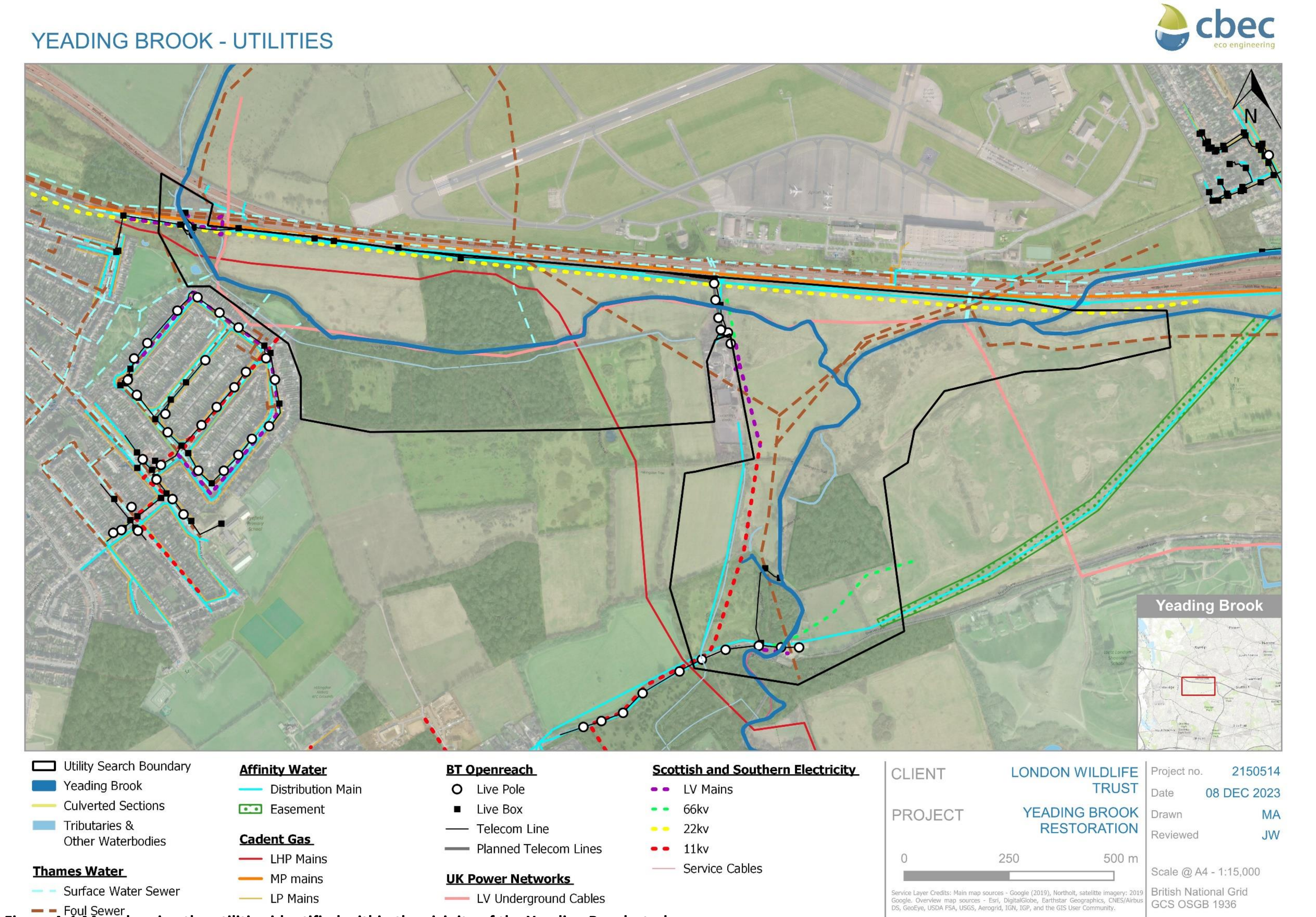

Figure A.1 Map showing the utilities identified within the vicinity of the Yeading Brook study area.

APPENDIX B

Hydrology & Flood Risk

A review of the EA flood risk inundation map Figure B.1, reveals that the river corridor lies within a flood risk zone 3 band (high probability of flooding) throughout its entirety, particularly in the immediate floodplain of the Yeading Brook and into the wider floodplain the Yeading Brook / Yeading Brook eastern Arm confluence. With distance from the channel this flood risk is reduced to a Flood Risk Zone 2 (medium probability of flooding)

In the Yeading Brook catchment there is a large area of water storage in the vicinity of Ten Acre Wood, Hayes; which allows for the creation of a natural buffer due to increased water capacity for and mitigation of some effects of flooding for towns at the site and further downstream.

The Yeading Brook is constrained by flood defences, in two locations, one being along a short section of the A40, Western Avenue; and to the southern extent of the water storage area. Both sections of flood defences are in place to reduce and where possible prevent riverine flooding, particularly where key infrastructure is at risk.

Therefore, undertaking a higher resolution flood risk model would be the most appropriate methodology to establish if these results are valid for the site conditions and for the validation of design proposals.

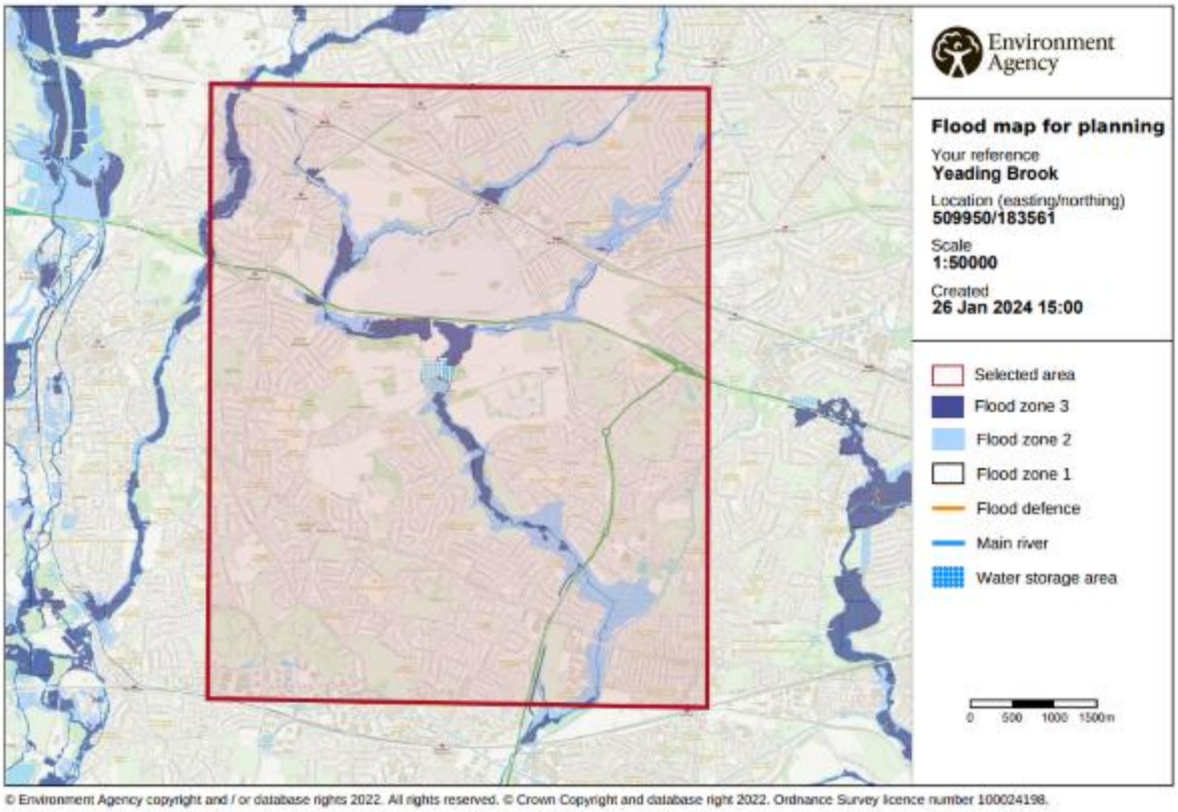

Figure B.1. EA flood risk map.

APPENDIX C

Hydrology Report

APPENDIX D

Hydraulic Modelling Report

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