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ENVIRONMENTAL

Stodmarsh Stream Enhancement Scheme

Technical appendices

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Version history

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V1	Dr Gabriel Connor-Streich	Director and Principal Environmental Scientist	21/03/2025
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Technical Appendices

The following technical appendices provide supporting documentation to the Stodmarsh Stream Enhancement Scheme: Delivery Proposal. This report provides key details describing the proposal for a mitigation scheme using a novel approach to managing drainage ditches and small watercourses that are managed as drainage ditches. In the appendices below, detailed descriptions of the data, processing and analysis used to calculate the mitigation potential of the proposed scheme are provided in Appendix A1. Design details for the scheme are provided in Appendix A3 and the full feasibility assessment is provided in Appendix A4.

Appendix A1

A1. Detailed description of quantifying nutrient mitigation

The following sections provide a detailed description of the processing steps used to quantify the baseline nutrient load input and the mitigation potential of the proposed mitigation scheme. This expands on the steps as described in Tables 1-3 in the main report.

To quantify the nutrient mitigation potential of the proposed drainage ditch management scheme, a three-stage process was completed:

1. Define the nutrient source area for each mitigation option.
2. Quantify the nutrient inputs from this source area.
3. Quantify the nutrient reductions resulting from deployment of the mitigation option.

This approach follows the Enhanced Drainage Ditch Management framework (Connor-Streich, 2024a).

A1.1. Watershed delineation

A desk study to determine the hydrological catchment area draining to the mitigation options used a Geographical Information System (GIS)[1] analysis of freely available topographic data. The analysis and processing workflow is shown in Appendix A4 (which also includes later steps to extract catchment land use and environmental variables). A description of the data sources and processing used in this analysis is provided below.

A1.1.1. Data source

The catchment delineation process used the Environment Agency (EA) Lidar digital elevation model (DEM)[2]. The 1 m resolution DEM data product was used in this analysis. This

[1] GIS analysis was completed in QGIS Desktop 3.34.11

[2] Available for download from: https://environment.data.gov.uk/DefraDataDownload/?Mode=survey, accessed on: 18/03/2025.

is the highest spatial resolution DEM that is freely available for the study area and it represents ground surface elevation in m above ordnance datum (mAOD) for a grid where each 1 m^2 has a corresponding mAOD elevation value. The 1 m DEM was chosen as it enables a more accurate catchment delineation than if using lower resolution DEMs. The DEM used in this analysis was from the most recent Lidar survey for the area, which was conducted between 2018 and 2019. As such, it is assumed that the representation of the topography in the source areas feeding each mitigation option is accurate as large-scale topographic change tends to happen over long time periods.

A1.1.2. Data processing, analysis, assumptions and outputs

The EA Lidar DEMs for the study area are available as 5 km^2 'tiles.' The mitigation options and its upslope catchment area covered by multiple tiles. A contiguous DEM for the area of interest was created using the raster mosaic function. Each raster mosaic was then processed using the *r.fill.dir* algorithm[3] to 'fill' erroneous depressions in a DEM. The DEM filling process is used reduce the risk of routing flow pathways to false topographic low points. It uses a nearest neighbour approach to raise any anomalously low cell heights within a DEM to the height of the lowest neighbouring cell (Jenson and Domingue, 1988). The resulting 'depressionless' DEM lessens the risk of inaccurate catchment delineation.

The next processing step used the *r.watershed* tool to delineate surface water runoff pathways and sub-basins across the area of interest using the commonly applied D8 flow routing algorithm (O'Callaghan and Mark, 1984). This algorithm searches all of the cells in a DEM. For each cell, it finds the lowest of the neighbouring eight cells which it assumes flow is routed to. It also counts the number of upslope cells that have been routed to each cell in the DEM. The *r.watershed* tool uses a minimum basin size parameter that defines the minimum number of raster cells and thus the minimum area for each drainage basin. Larger minimum basin sizes require a larger number of upslope cells to 'contribute' flow to a certain point on the DEM before the algorithm initiates a potential surface water flow pathway. Setting the minimum basin size to a very high number would only delineate flow pathways along larger stream and river channels, whereas selecting a very low minimum basin size can result in the delineation of very dense theoretical surface runoff drainage networks that may not be truly representative of the surface hydrology of the study area. The minimum basin size parameter was iterated to determine the most suitable size for the study site. A minimum basin size of 17,500 m^2 was found to be most effective.

To delineate the catchment that drains to the mitigation options, the *r.water.outlet* tool was used to select a point at the downstream end of the deployment location. This tool delineates the catchment that drains to a selected point, thus defining the source area of surface runoff that accumulates at each location. The boundary of the Water Framework Directive (WFD) waterbody catchment[4] were used as a check against the accuracy of the catchment delineation. None of the delineated catchments crossed the boundary of a WFD waterbody catchment and the delineated catchment boundaries follow the WFD waterbody catchment boundary closely. However, there were some smaller scale inaccuracies in the catchment delineations for the Hinxhill_DD1, Hinxhill_DD2, Wye_DD1, Bliby_wood_DD1 and Bliby_wood_DD2 catchments that were evident as locations where

[3] All processing steps used to model flow pathways and delineate sub-catchments used the Grass Tools hydrology toolbox available in QGIS. See: https://grass.osgeo.org/grass82/manuals/topic_hydrology.html for details, accessed on 18/03/2025.

[4] Made available by the EA from: https://www.data.gov.uk/dataset/298258ee-c4a0-4505-a3b5-0e6585ecfdb2/wfd-river-waterbody-catchments-cycle-2, accessed on: 18/03/2025.

watercourses mapped in Ordnance Survey data crossed the boundaries of a delineated catchment.

To address this issue, a combination of Ordnance Survey base mapping and open-source channel network vector data were used to digitise a contiguous drainage network that could be traced to drain to each mitigation option. This digitised drainage network was then 'burned' into the filled raster DEM, reducing the elevation values where the drainage network overlaps the raster. By reducing the elevation values along the known paths of the drainage network and re-running the *r.watershed* tool, the flow routing algorithm routes flow towards the drainage network and thus results in a more accurate catchment delineation. New mitigation option catchments were generated using the *r.water.outlet tool* and were checked against the mapped drainage network for accuracy. This check found an area to the east of the Bliby_wood_DD1 catchment that was topographically isolated from the rest of the catchment and was thus removed. It should be noted that this area is mapped as within the Stodmarsh NN catchment, which is likely a minor error in the NN catchment mapping.

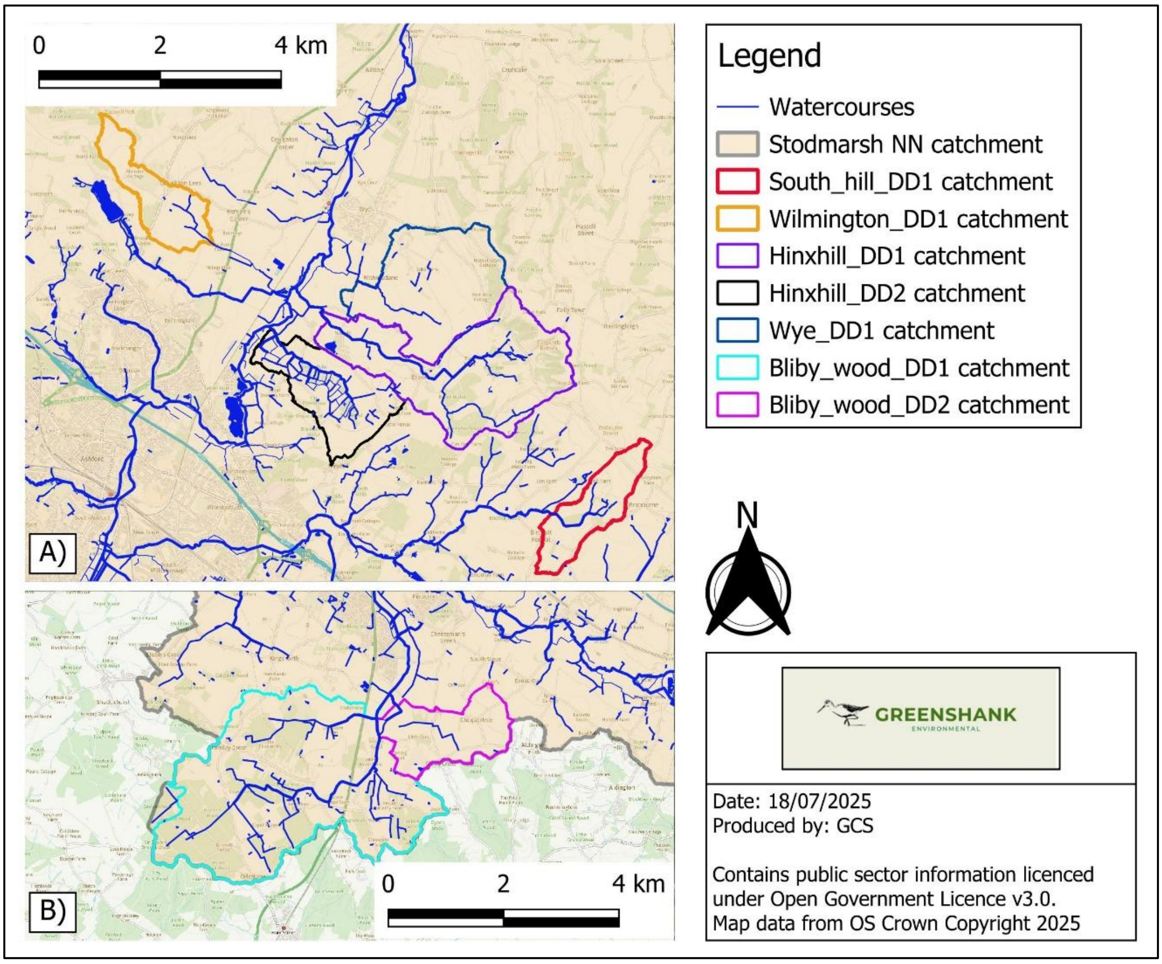

Figure 1: Map showing the delineated catchment boundaries for each of the proposed mitigation options. The map is split to show the catchment boundaries for A) South_hill_DD1, Wimington_DD1, Hinxill_DD1, Hinxhill_DD2 and Wye_DD1; and B) Bliby_wood_DD1 and Bliby_wood_DD2.

A1.2. Land use assessment

Land use in the catchment that drains to the mitigation options is the dominant control on the nutrient input baseline. The data sources, analysis and processing used to determine land uses within the catchment are detailed below.

A1.2.1. Data sources

The land use assessment for the catchment draining to each of the mitigation options used a range of data sources. The key land use dataset was the Crop Map of England (CROME)[5]. This dataset classifies landcovers in England into 20 main crop types, grassland, and non-agricultural land covers. The national dataset comprises ~32 million hexagonal cells, each with an area of 4157 m^2 and a land use code that describes the predicted land use in that cell. The dataset was created using a machine learning-based supervised classification of Sentinel-1 and Sentinel-2 satellite imagery, with validation through field inspections and visual checks that suggest an overall classification accuracy of around 85% (RPA, n.d.). CROME data are available for the years 2016-2021, with an updated land cover classification released following each year (noting that 2022 has not been made available yet).

In the present study, CROME land uses classifications were checked against other land use classification datasets and local knowledge to provide a further level of validation of the land use classifications in each of the mitigation option catchments. The CORINE land cover dataset provides land cover classifications at a European scale (Büttner et al., 2021). The CORINE dataset has a much coarser resolution with less detailed agricultural land use classifications compared with the CROME dataset, however it provides a useful validation of whether the broad typology of land use in CROME data matches the classification provided in CORINE. The extent of urban areas was also checked using the Office for National Statistics (ONS) Built-up Areas (BUA) Boundaries[6] dataset and visual analysis of high-resolution Google satellite imagery available in Google Earth Pro.

A1.2.2. Data processing, analysis, assumptions and outputs

CROME data were clipped to the extent of the each of the mitigation option catchments. The different land use types detailed in the CROME dataset were checked visually against CORINE land cover classifications and the extent of urban areas. This check was conducted against the CORINE dataset using 2018 CROME data, as this was the last year that the CORINE landcover dataset was updated. Comparison against urban extents used the 2017 CROME dataset for comparison with the ONS BUA dataset, as the BUA data was last updated in 2017. Comparison of the 2021 CROME data was also conducted with the most recent (2022) satellite imagery in Google Earth Pro. CROME data did not show any significant disparities with other land cover datasets and thus the CROME data was used as the key dataset for classifying land use within each sub-catchment.

In order to account for changes in agricultural land uses over time due to crop rotations and other land use change, the CROME data for each year were compiled to create a single dataset containing the land use codes for each cell between 2016-2021. Each cell was then

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[5] Produced by the Rural Payments Agency with each year's dataset hosted on a different data.gov.uk webpage. The 2016 dataset can be viewed here for reference: https://www.data.gov.uk/dataset/6f316b8b-ae74-489c-ba3c-c2325a9c16a1/crop-map-of-england-crome-2016-complete, accessed on: 18/03/2025.

[6] Office for National Statistics. 2017. Available from: https://www.data.gov.uk/dataset/15e3be7f-66ed-416c-b0f2-241e87668642/built-up-areas-december-2011-boundaries-v2, accessed on, 18/03/2025.

analysed to determine its modal land use code, which was taken as the dominant agricultural land use in that cell.

The product specification for the CROME dataset, produced by the Rural Payment Agency (RPA, 2022), provides a table of land use codes and their associated land uses, with significant detail on crop types that each cell in the CROME dataset may be classified as. This table is replicated in Appendix A5 and shows that the CROME dataset is sufficiently detailed for the classification of at least cereals and grassland land uses. Areas classified as grassland can be checked against the RPA Less Favoured Area (LFA) dataset to determine whether grassland should be classed as LFA or Lowland Grazing. Where there is ambiguity due to a land use not being classed as Cereals or a grazing farm type, because it is possible to separate grazing from arable farming, it is more accurate to classify the remaining arable areas as the General farm type, which is defined as follows:

> *General cropping*
>
> *Holdings on which arable crops (including field scale vegetables) account for more than two thirds of their total standard output excluding holdings classified as cereals; holdings on which a mixture of arable and horticultural crops account for more than two thirds of their total standard output excluding holdings classified as horticulture and holdings on which arable crops account for more than one third of their total standard output and no other grouping accounts for more than one third.*[7]

Visual verification of CROME land use classifications suggested a low error rate, with limited areas of obviously misclassified land use, matching the suggested ~85% accuracy of the dataset (RPA, n.d.). The dominant land uses in the catchment are mapped in Figure 2. It should be noted that prior to 2016, only CORINE landcover data were available (for the year 2012) and the landcover classification and spatial resolution is coarser in CORINE data compared with CROME land use classifications. There is a general concordance between the CROME land use classifications and the 2012 CORINE data, indicating that land use has been largely consistent within each catchment for more than 10 years. Table 1 provides a breakdown of the land uses and their areas within the catchment of the mitigation options.

Table 1: Land uses and their respective areas within the watersheds that drain to each mitigation options at each site.

Site	Land use	Hectares
Hinxhill_DD1	Cereals	110.62
	General	0.53
	Grazing	208.28
	Greenspace	204.90
Hinxhill_DD2	Cereals	107.22
	General	0.83
	Grazing	68.28
	Greenspace	65.71
Wilmington_DD1	Cereals	103.09
	General	2.93

[7] See https://farmbusinesssurvey.co.uk/DataBuilder/defra-stats-foodfarm-farmmanage-fbs-UK_Farm_Classification.pdf

Site	Land use	Hectares
	Grazing	31.76
	Greenspace	23.35
Wye_DD1	Cereals	282.93
	General	0.30
	Grazing	40.88
	Greenspace	54.88
South_hill_DD1	Cereals	95.07
	General	1.99
	Grazing	33.72
	Greenspace	25.54
Bliby_wood_DD1	Cereals	240.74
	General	14.01
	Grazing	199.83
	Greenspace	587.95
Bliby_wood_DD2	Cereals	92.86
	General	5.13
	Grazing	80.84
	Greenspace	41.12

A1.3. Soil drainage, rainfall and topography

The nutrient export coefficients associated with different land uses vary based on environmental variables. In the NE Nutrient Budget Calculators, soil drainage and rainfall result in varying nutrient export coefficients. Thus, linking areas of different land uses (Table 1) to nutrient export coefficients requires data on soil drainage and rainfall.

A1.3.1. Data sources

Rainfall data for each mitigation option catchment was obtained from the UK Centre for Ecology and Hydrology Gridded Estimated Areal Rainfall (CEH-GEAR) dataset (Tanguy et al., 2021) that provides 1 km^2 gridded estimates of daily and monthly rainfall for the UK. This dataset covers a period from 1890-2019. Monthly average rainfall estimates were acquired from 1989-2019 in order capture data on the previous 30 years of rainfall, based on the standard definition of 30 years of weather observations being required to calculate climate averages (WMO, 2021).

In line with the guidance on selecting soil drainage classes for agricultural areas when calculating nutrient budgets (Ricardo and Natural England, 2022), assessment of soil drainage used soil type data from the Cranfield Soil and Agrifood Institute's Soilscapes[8] soil map. Soilscapes provides a 1:250,000 scale national soil map that shows key soil properties, including a soil drainage classification. Soilscapes data are only available to view in GIS via

[8] Available from https://www.landis.org.uk/soilscapes/index.cfm, accessed on: 21/03/2025

a Web Map Service (WMS) layer, meaning that Soilscapes soil information for the mitigation option catchments needs to be digitised or inferred by visual analysis.

A1.3.2. Data processing, analysis and assumptions

CEH-GEAR data were compiled using the *ncdf4* package (Pierce, 2023) in R Statistics (R Core Team, 2022). Monthly rainfall totals for each year from 1989-2019 were first summed to obtain a raster map where each grid cell for a given year held the estimated total annual rainfall for that 1 km^2. The mean rainfall for each grid cell for the 30-period was then calculated from the annual totals to obtain a single raster map where each cell contained an estimated annual average rainfall (AAR) value for further analysis. The QGIS *zonal statistics* algorithm was used with the mitigation option catchment polygons to calculate the average annual rainfall for each sub-catchment. The average annual rainfall for the five catchments ranged from 755 mm/year to 827 mm/year and thus each catchment fell into the 700 mm/year to 900 mm/year rainfall band within Farmscoper export coefficients.

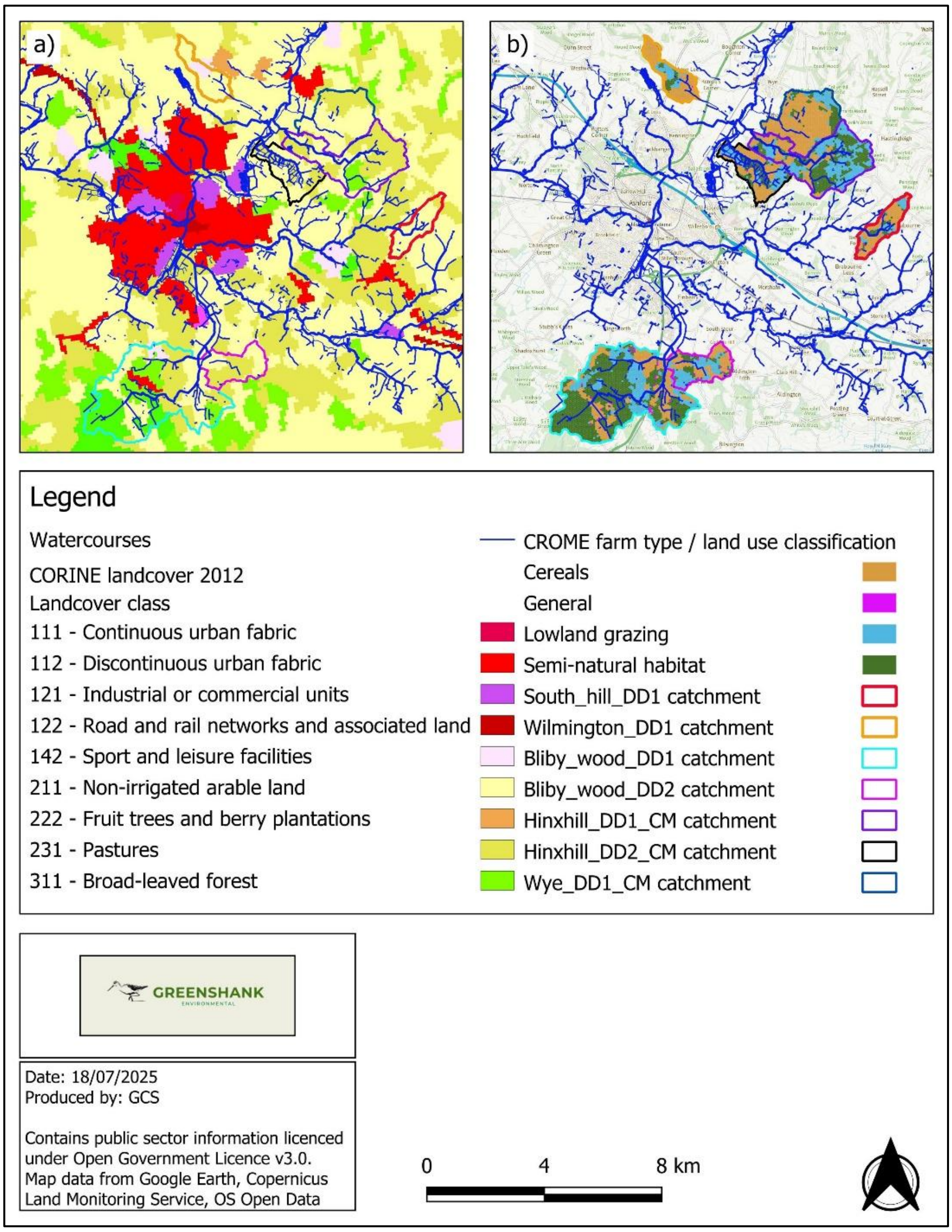


Figure 2: Landcover maps showing land uses within the mitigation site catchment: a) the CORINE landcover classification from 2012; b) the dominant land uses in Crop Map of England (CROME) data covering the period 2016-2022.

To determine the soil drainage characteristics for the mitigation option catchments, the catchment boundary polygon was overlain on the Soilscapes mapping dataset (**Error! Reference source not found.**). There are multiple soil drainage classes within the mitigation option catchments and thus the areas of each drainage class were digitised in order to provide a more accurate assessment of the soil drainage that is likely to be associated with the different types of agriculture within the mitigation option catchments. A map of soil drainage types is provided in the main report. The areas associated with each soil drainage type are detailed in **Error! Reference source not found.**.

Table 2: Area of each mitigation option catchment associated with Farmscoper soil drainage classes based on digitising the areas of each catchment with different soil types in the Soilscapes soil map.

Site	Soil type	Hectares
Hinxhill_DD1	Freely draining	178.18
	Impeded drainage	288.64
	Semi-impeded drainage	25.91
Hinxhill_DD2	Freely draining	58.40
	Impeded drainage	184.81
Wilmington_DD1	Freely draining	161.14
Wye_DD1	Freely draining	276.75
	Impeded drainage	115.46
	Semi-impeded drainage	17.22
South_hill_DD1	Freely draining	51.70
	Impeded drainage	101.12
	Semi-impeded drainage	3.49
Bliby_wood_DD1	Impeded drainage	1042.53
Bliby_wood_DD2	Impeded drainage	219.95

The topography of the mitigation option catchments is somewhat variable across the seven ditches. Wye_DD1 and Hinxhill_DD1 are characterised by band of very steep slopes where the catchments transition into chalk downland (Figure 4a). There is a fairly rapid decrease in gradient over a distance of around 1 km from the foot of the escarpment to location of the deployment locations which are set in low relief areas of floodplain. The upper areas of the Hinxhill_DD2 catchment have a similar profile, though without the area of very steep downland slopes characterising the upper areas of the catchment (Figure 4a). The more extensive area of low relief floodplain at the valley bottom shows an extensive network of drainage ditches that feed the Hinxhill_DD2 sites. These ditches were likely cut to alleviate drainage issues in a flat area with heavy soils receiving runoff from steeper surrounding hillslopes.

The Bliby_wood_DD1 catchment is characterised by smaller and more isolated hills and hillocks which provide localised topographic features around which an extensive ditch and stream network flows through a low relief valley bottom (Figure 4b). The dominance of low permeability, loamy and clayey soils will also contribute the historic establishment of a field drainage network. At Bliby_wood_DD2, the ditch is fed by a catchment that drops relatively steeply from a small hill to a very flat valley bottom area where a ditch has been established to channel runoff to the deployment location.

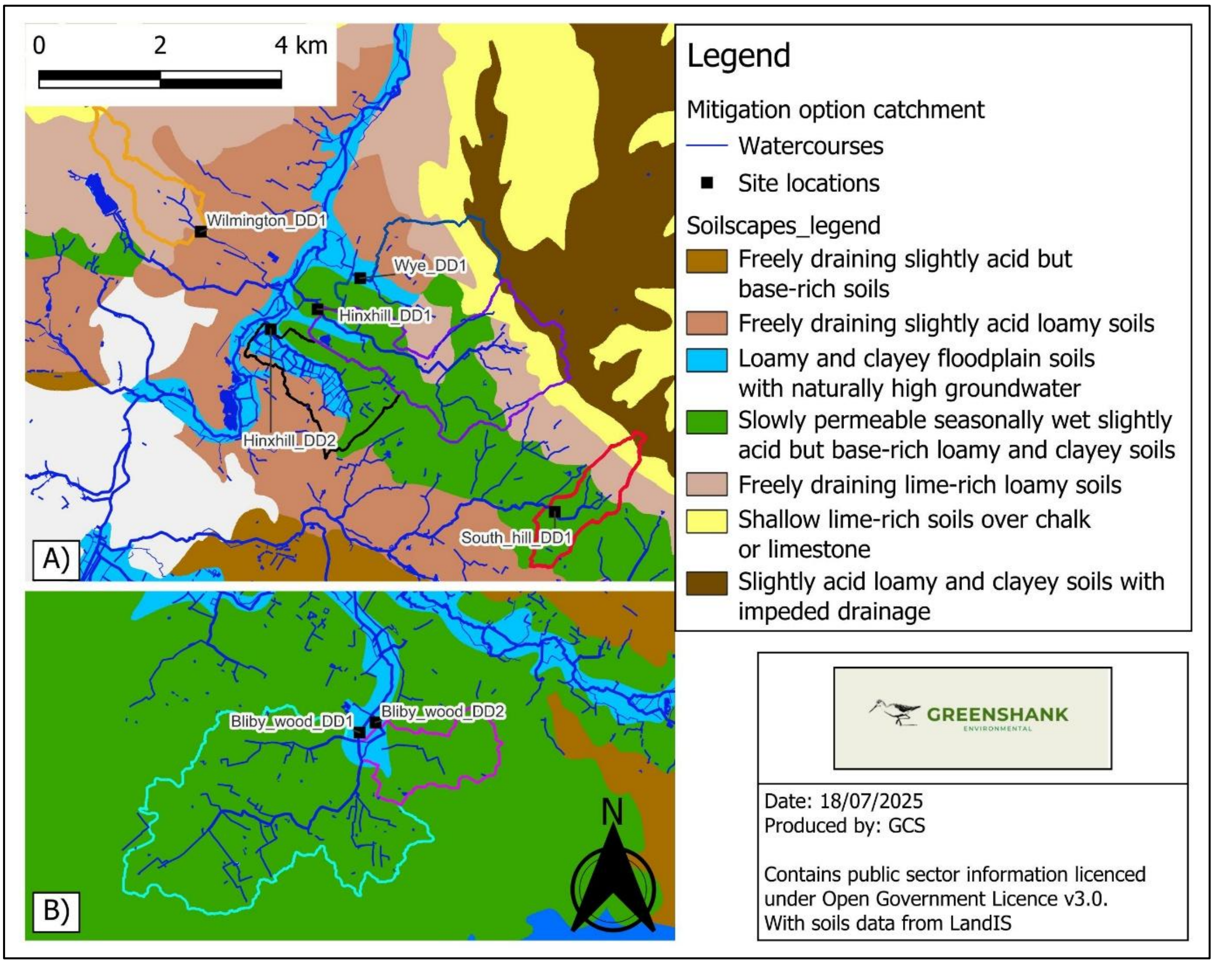


Figure 3: The mitigation option catchments overlain on Soilscapes soil type mapping. The map is split to show the catchment boundaries for A) South_hill_DD1, Wimington_DD1, Hinxill_DD1, Hinxhill_DD2 and Wye_DD1; and B) Bliby_wood_DD1 and Bliby_wood_DD2.

Wilmington_DD1 is located on a ditch draining a relatively narrow valley that slopes steeply from an area of chalk downland in the upper area of the catchment and maintains a relatively high relief profile in the prevailing flow direction of the drainage channel (Figure 4c). Approaching the deployment reach, the valley slope is progressively towards the drainage ditch. Although this catchment is located in an area of freely draining soils, fairly steep slopes seen throughout the catchment are likely to promote surface water runoff generation. The South_hill_DD1 channel is also located in a relatively steeply sloping valley which, to the northeast, drains part of the same chalk downland that forms the upper areas of the Hinxhill_DD1 and Wye_DD1 catchments (Figure 4d and Figure 4a). A fairly steep hillslope to the south of the deployment location also routes runoff from an area of impeded drainage soils towards the stream channel.

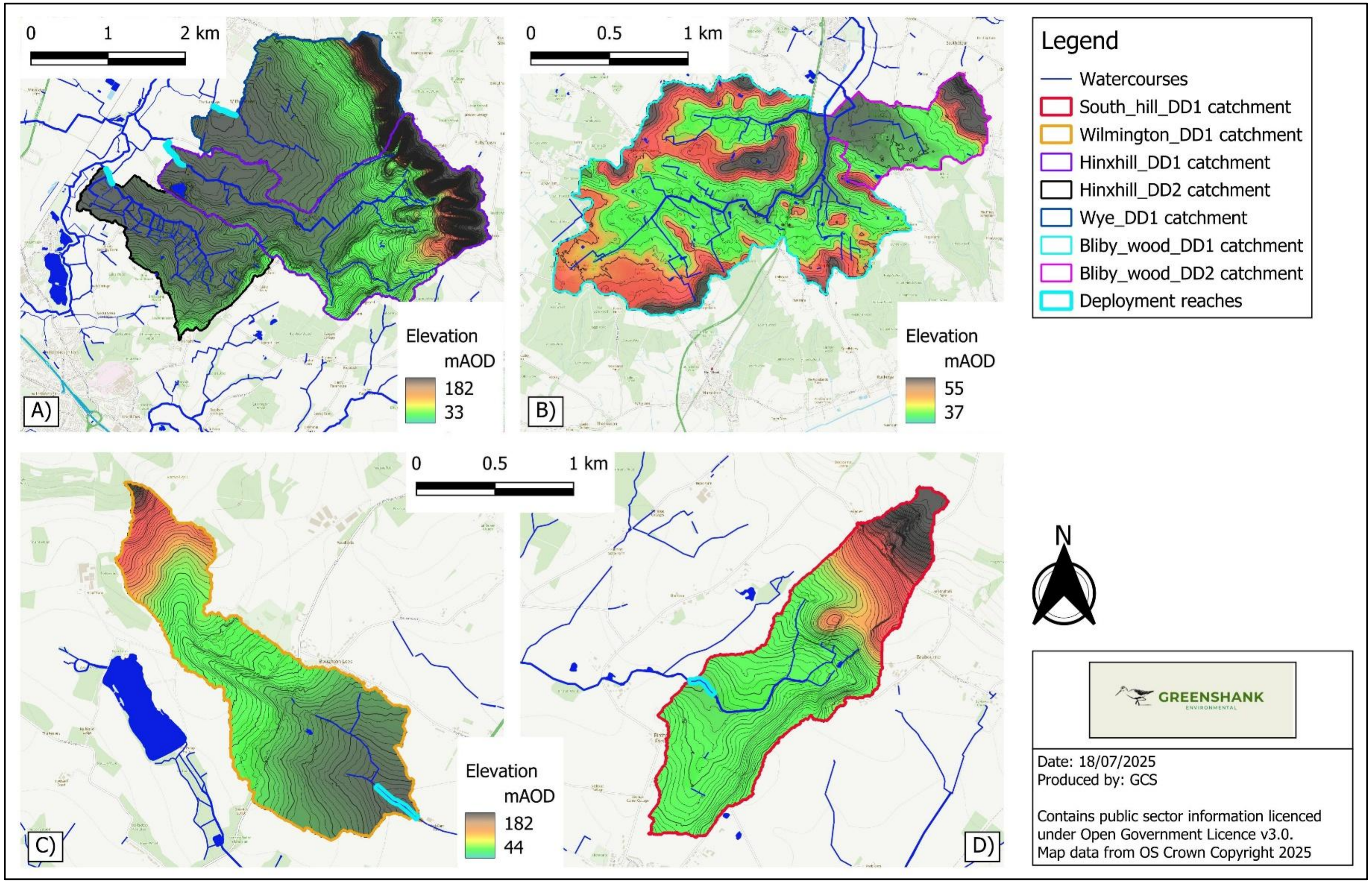


Figure 4: Topographic maps for A) the Wye_DD1, Hinxhill_DD1 and Hinxhill_DD2 catchments; B) the Bliby_wood_DD1 and Bliby_wood_DD2 catchments; C) the Wilmington_DD1 catchment; and D) the South_hill_DD1 catchment. Contours are at 1 m intervals. C) and D) share a scale and elevation shading colour map.

A1.4. Correcting nutrient export coefficients to account for nutrient losses to groundwater

Calculation of nutrient inputs to each mitigation option required determination of export coefficients for the various land uses within each watershed that drains to a mitigation option. Nutrient export coefficients describing the nutrient export from land uses in each catchment have previously been generated for the NE Stodmarsh Nutrient Budget Calculator and were derived from a Farmscoper modelling exercise. The use of these export coefficients has become standard practice in assessments of mitigation scheme potential. However, these export coefficients include the loss of N and P via a combination of surface runoff, preferential flow (i.e., in field drains and soil macropores) and leaching to groundwater. As the proposed mitigation scheme will only intercept surface runoff and preferential flow pathways, there is a need to remove N and P lost along leaching pathways from the export coefficients used to calculate the nutrient input baseline.

A1.4.1. Data sources

The data required to remove the leaching pathway from the nutrient export coefficients is held in a set of Farmscoper Evaluate files that can be output when running the Farmscoper Upscale module that is used to generate data for conversion to export coefficients. The pathway-specific nutrient loss data held in the Farmscoper Evaluate files for each combination of farm type, rainfall, soil drainage and NVZ class were analysed to determine corrected nutrient export coefficients by removing N and P loss to groundwater.

A1.4.2. Data processing, analysis and assumptions

To derive a set of nutrient export coefficients corrected for groundwater loss, the nutrient export was isolated for each loss pathway associated with each combination of farm type, rainfall, soil drainage and NVZ class. This was achieved by analysing the individual Farmscoper Evaluate files that are output for each combination of farm type and environmental characteristics when Farmscoper is run using the Upscale module. Within the individual evaluation files, the ‘Loss Data’ worksheet contains data on the losses of nutrients attributable to each component of a modelled farm, including the pathway for nutrient losses (Figure 5). The ‘Leaching’ pathway describes the estimated nutrient losses to groundwater. Thus, by removing all nutrient losses attributed to the leaching pathway and summing the remaining nutrient losses associated with the surface runoff and preferential flow pathways, it was possible to obtain an estimate of the total export of nutrients that will be intercepted by the proposed mitigation scheme. Following the methodology used to calculate the nutrient export coefficients provided in the NE Nutrient Budget Calculators, the total nutrient export along non-groundwater pathways was divided by the average farm area for each farm type within the mitigation option sub-catchment to derive a groundwater-corrected per ha nutrient export coefficient.

Item	Pollutant	Source	Area	Pathway	Type	Timescale	Form	Baseline Value	Prior Value	New Value
Component	Nitrate	Beef	Arable	Preferential	FYM	Short	Dissolved	0.07	0.05	0.05
Component	Nitrate	Beef	Arable	Runoff	FYM	Short	Dissolved	0.09	0.05	0.05
Component	Nitrate	Beef	Arable	Preferential	Slurry	Short	Dissolved	0.02	0.01	0.01
Component	Nitrate	Beef	Arable	Runoff	Slurry	Short	Dissolved	0.02	0.01	0.01
Component	Nitrate	Beef	Arable	Preferential	FYM	Medium	Dissolved	1.79	1.60	1.57
Component	Nitrate	Beef	Arable	Runoff	FYM	Medium	Dissolved	0.10	0.08	0.07
Component	Nitrate	Beef	Arable	Leaching	FYM	Medium	Dissolved	1.18	1.14	1.11
Component	Nitrate	Beef	Arable	Preferential	Slurry	Medium	Dissolved	0.64	0.58	0.57

Figure 5: An extract from the Loss Data worksheet within a Farmscoper Evaluate file. One of the rows is highlighted to show the quantum of nitrate losses due to leaching to groundwater associated with this component of the modelled farm. The losses (in kg/year) for different mitigation scenarios are shown in the final three columns.

The nutrient export coefficients in the NE Nutrient Budget Calculators also accounted for the impact of compliance with agricultural regulations through the implementation of two different mitigation scenarios. These scenarios applied different rates of on-farm mitigation methods to reflect farm management that is mandatory for regulatory compliance and farm management that may be ‘reasonably’ required to comply with Farming Rules for Water (reasonable) regulations. To align with the approach taken in the generation of the NE Nutrient Budget Calculator nutrient export coefficients, final groundwater-corrected nutrient export coefficients were calculated using the following steps:

- Calculate 15% of the difference between the export coefficients from the mandatory regulatory compliance scenario and the Farming Rules for Water (reasonable) scenario.
- Subtract the 15% difference from the export coefficients for the mandatory regulatory compliance scenario.

The final output from this data analysis procedure is a single set of nutrient export coefficients that account for both regulatory compliance and losses of nutrients to groundwater and are thus appropriate for calculating the nutrient input baseline to interceptor mitigation options.

A1.5. Baseline nutrient load input calculation

The baseline nutrient load input was calculated using groundwater-corrected nutrient export coefficients for the various land uses within each mitigation option catchment. The sections below detail how data on land use, soil drainage and rainfall were combined to estimate the nutrient input baseline.

A1.5.1. Data sources

Data on land use, rainfall and soil drainage in each watershed (as described above) were used to select relevant nutrient export coefficients. For agricultural land uses, the estimated rainfall and soil drainage information were used to select export coefficients associated with that combination of land use, rainfall and soil drainage class. For non-agricultural land uses, i.e., semi-natural habitats, the default nutrient export coefficient for greenspace was used.

There are likely to be a number of properties, both commercial and residential, within the mitigation option catchments that are not served by mains drainage. These properties are likely to be served by onsite private sewage treatment systems that may contribute nutrients to the mitigation options in each catchment. Brook wastewater treatment works

(WwTW), a municipal WwTW operated by Southern Water, discharges to the channel that feeds the Hinxhill_DD1 deployment location. Following the approach detailed in Connor-Streich (2024a), an Environmental Information Regulations request was made to Southern Water to obtain the population served by Nat's Brook WwTW. As the Nat's Brook WwTW does not have a TN or TP permit, default concentrations 24 mg TN/l and 5 mg TP/l were used to describe quality of the treated effluent discharge.

A1.5.2. Baseline nutrient load inputs from diffuse sources

Table 1 shows the area of each land use within that drains to the mitigation options proposed for this mitigation scheme. The land use in this watershed was classified as predominantly agricultural with some areas of woodland / semi-natural habitats.

Soil drainage is variable across the mitigation option catchments, with some catchments having only one soil drainage class while other catchments have areas of all three of the soil drainage classes available in Farmscoper (**Error! Reference source not found.**). Using the rainfall estimates for the watershed, the relevant N and P export coefficients were selected and the areas of each land use across different soil drainage classes was used to calculate the N and P input to each mitigation option (Table 3). Note that all of the mitigation option catchments are within an NVZ, with the relevant export coefficients chosen to reflect this.

Table 3 provides totals of catchment area and associated export of N and P from these catchment areas to each mitigation option. The seven sites that comprise the proposed mitigation scheme have a total catchment area of 2729.48 ha. This catchment area is predicted to deliver total N and P inputs from diffuse agricultural sources to the mitigation options of:

- 22706.67 kg N/year
- 1029.04 kg P/year

A1.5.3. Correcting for the impact of online ponds within the drainage network

As can be seen in Figure 1, there are a number of ponds mapped within each of the mitigation option catchments. Ponds have the potential to provide some N and P mitigation benefits through a similar set of processes of nutrient cycling processes that an Enhanced Drainage Ditch Management scheme aims to promote. Most of these ponds are offline, i.e., they are not fed by influent water from a drainage network, nor do they have an outflow that transfers water through the pond to the downstream drainage network. These ponds are unlikely to be a significant source of water to the drainage network in each mitigation option catchment and therefore they are unlikely to markedly impact the baseline nutrient load input. However, there are a limited number of online ponds within the drainage networks which may already be providing some mitigation benefit that needs to be accounted for. An example of where such an online pond has been identified is shown in Figure 6, which also shows examples of offline ponds.

To account the impact of online ponds, the drainage network was searched visually in each catchment to locate relevant ponds. Where online ponds were found, the catchment for each pond was delineated and land uses and associated nutrient export were identified using the same processes detailed above. This resulted in a baseline nutrient load input to each pond. There is no established nutrient reduction efficiency associated with ponds that have not been designed and maintained for nutrient mitigation. Indeed, some studies have found that small ponds are not effective for nutrient capture and cycling (Barber and Quinn, 2012). Due to the potential for limited efficacy, a nominal nutrient reduction of 10% of the baseline nutrient load input to each online pond was used.

Online ponds were found in three catchments: Hinxhill_DD1, South_hill_DD1 and Bliby_wood_DD1. These ponds were all in the upper parts of each catchment, with the total area draining to online ponds calculated as 45 ha, 10 ha and 45 ha in the three catchments respectively. Applying a 10% reduction to the baseline nutrient input load resulted in the following suggested existing mitigation benefit from the online ponds in each catchment:

- Hinxhill_DD1: 29.28 kg N/year and 1.09 kg P/year
- South_hill_DD1: 5.82 kg N/year and 0.38 kg P/year
- Bliby_wood_DD1: 34.39 kg N/year and 1.13 kg P/year

This estimated existing mitigation benefit was accounted for in the final mitigation potential calculation detailed in Section A1.6, below.

A1.5.4. Baseline nutrient load inputs from point sources

Although there are likely to be a number of private sewerage systems within the mitigation option catchments, the locations of these systems and other characteristics, such as whether they have drainage fields, were not available. As such, it was not possible to account for the impact of these nutrient sources on the baseline nutrient load input to the mitigation options. This adds some additional precaution to the estimate of the baseline nutrient load input calculations.

Data were available for the Brook WwTW within the Hinxhill_DD1 catchment, and this point source nutrient input was quantified as follows:

- The population served by the WwTW was confirmed as 266 people.
- It was assumed that water use is 120 l/person/day (Connor-Streich, 2024a).
- The daily flow to the WwTW was estimated as 120 l/person/day x 266 people =31,920 l/day
- Using the default TN and TP effluent concentrations (see Section A1.5.1), the annual nutrient load output from the WwTW was calculated as:
    - (31,920 l/day x 27 mg TN/l)/10^6 x 365.25 days) = 314.79 kg TN/year
    - (31,920 l/day x 5 mg TP/l)/10^6 x 365.25 days) = 58.29 kg TP/year

This N and P source was accounted for in the final mitigation potential calculation detailed in Section A1.6, below.

Table 3: N and P input to each mitigation option proposed as part of this scheme.

Site	Land use	Rainfall (mm/year)	Soil drainage class	Catchment area (ha)	N export coefficient (kg N/ha/year)	N input to mitigation option (kg N/year)	P export coefficient (kg P/ha/year)	P input to mitigation option (kg P/year)
Hinxhill_DD1	Cereals	789	Freely draining	16.84	1.96	33.01	0.13	2.12
	Grazing	789	Freely draining	89.30	1.37	122.47	0.09	7.73
	Greenspace	NA	Freely draining	87.98	3	263.93	0.02	1.76
	Cereals	789	Impeded drainage	93.64	22.23	2081.68	0.94	87.63
	General	789	Impeded drainage	0.53	15.20	8.11	0.73	0.39
	Grazing	789	Impeded drainage	96.97	8.02	777.80	0.67	65.01
	Greenspace	NA	Impeded drainage	106.61	3	319.82	0.02	2.13
	Cereals	789	Semi-impeded drainage	0.14	15.89	2.24	0.67	0.09
	Grazing	789	Semi-impeded drainage	22.02	2.52	55.55	0.17	3.73
	Greenspace	NA	Semi-impeded drainage	10.31	3	30.94	0.02	0.21
Hinxhill_DD1			**Total catchment size**	**524.34**	**Total N input**	**3695.65**	**Total P input**	**170.80**

Site	Land use	Rainfall (mm/year)	Soil drainage class	Catchment area (ha)	N export coefficient (kg N/ha/year)	N input to mitigation option (kg N/year)	P export coefficient (kg P/ha/year)	P input to mitigation option (kg P/year)
Hinxhill_DD2	Cereals	770	Freely draining	41.19	1.96	80.72	0.13	5.18
	General	770	Freely draining	0.80	1.43	1.15	0.10	0.08
	Grazing	770	Freely draining	2.85	1.37	3.91	0.09	0.25
	Greenspace	NA	Freely draining	13.29	3	39.87	0.02	0.27
	Cereals	770	Impeded drainage	66.03	22.23	1467.99	0.94	61.80
	General	770	Impeded drainage	0.03	15.20	0.47	0.73	0.02
	Grazing	770	Impeded drainage	65.43	8.02	524.82	0.67	43.87
	Greenspace	NA	Impeded drainage	52.41	3	157.24	0.02	1.05
Hinxhill_DD2			**Total catchment size**	**242.04**	**Total N input**	**2276.17**	**Total P input**	**112.50**
Wilmington_DD1	Cereals	755	Freely draining	103.09	1.96	202.05	0.13	12.96
	General	755	Freely draining	2.93	1.43	4.20	0.10	0.28
	Grazing	755	Freely draining	31.76	1.37	43.56	0.09	2.75
	Greenspace	NA	Freely draining	23.35	3	70.06	0.02	0.47

Site	Land use	Rainfall (mm/year)	Soil drainage class	Catchment area (ha)	N export coefficient (kg N/ha/year)	N input to mitigation option (kg N/year)	P export coefficient (kg P/ha/year)	P input to mitigation option (kg P/year)
Wilmington_DD1			**Total catchment size**	**161.14**	**Total N input**	**319.87**	**Total P input**	**16.46**
Wye_DD1	Cereals	776	Freely draining	179.38	351.56	351.79	0.13	22.55
	Grazing	776	Freely draining	32.73	44.89	58.47	0.09	2.83
	Greenspace	NA	Freely draining	48.63	145.90	163.84	0.02	0.97
	Cereals	776	Impeded drainage	100.82	2241.33	2240.79	0.94	94.35
	General	776	Impeded drainage	0.30	4.53	4.53	0.73	0.22
	Grazing	776	Impeded drainage	2.41	19.30	69.14	0.67	1.61
	Greenspace	NA	Impeded drainage	4.39	13.17	17.23	0.02	0.09
	Cereals	776	Semi-impeded drainage	2.73	43.34	44.51	0.67	1.84
	Grazing	776	Semi-impeded drainage	5.75	14.50	29.88	0.17	0.97
	Greenspace	NA	Semi-impeded drainage	1.86	5.58	7.73	0.02	0.04

Site	Land use	Rainfall (mm/year)	Soil drainage class	Catchment area (ha)	N export coefficient (kg N/ha/year)	N input to mitigation option (kg N/year)	P export coefficient (kg P/ha/year)	P input to mitigation option (kg P/year)
Wye_DD1			**Total catchment size**	**378.99**	**Total N input**	**2884.09**	**Total P input**	**125.47**
South_hill_DD1	Cereals	828	Freely draining	33.99	1.96	66.61	0.13	4.27
	General	828	Freely draining	0.33	1.43	0.47	0.10	0.03
South_hill_DD1	Grazing	828	Freely draining	13.54	1.37	18.57	0.09	1.17
	Greenspace	NA	Freely draining	3.85	3.00	11.54	0.02	0.08
	Cereals	828	Impeded drainage	57.85	22.23	1286.07	0.94	54.14
	General	828	Impeded drainage	1.66	15.20	25.21	0.73	1.21
	Grazing	828	Impeded drainage	19.92	8.02	159.79	0.67	13.36
	Greenspace	NA	Impeded drainage	21.69	3.00	65.07	0.02	0.43
	Cereals	828	Semi-impeded drainage	3.23	15.89	51.36	0.67	2.18
	Grazing	828	Semi-impeded drainage	0.26	2.52	0.66	0.17	0.04

Site	Land use	Rainfall (mm/year)	Soil drainage class	Catchment area (ha)	N export coefficient (kg N/ha/year)	N input to mitigation option (kg N/year)	P export coefficient (kg P/ha/year)	P input to mitigation option (kg P/year)
South_hill_DD1			**Total catchment size**	**471.90**	**Total N input**	**1685.35**	**Total P input**	**76.91**
Bliby_wood_DD1	Cereals	732	Impeded drainage	240.74	22.23	5351.81	0.94	225.29
	General	732	Impeded drainage	14.01	15.20	212.95	0.73	10.21
	Grazing	732	Impeded drainage	199.83	8.02	1602.88	0.67	133.98
	Greenspace	732	Impeded drainage	587.95	3.00	1763.86	0.02	11.76
Bliby_wood_DD1			**Total catchment size**	**1046.71**	**Total N input**	**8790.58**	**Total P input**	**370.23**
Bliby_wood_DD2	Cereals	739	Impeded drainage	92.86	22.23	2064.27	0.94	86.90
	General	739	Impeded drainage	5.13	15.20	78.02	0.73	3.74
	Grazing	739	Impeded drainage	80.84	8.02	648.48	0.67	54.20
	Greenspace	739	Impeded drainage	41.12	3.00	123.36	0.02	0.82
Bliby_wood_DD2			**Total catchment size**	**219.95**	**Total N input**	**2914.12**	**Total P input**	**145.66**

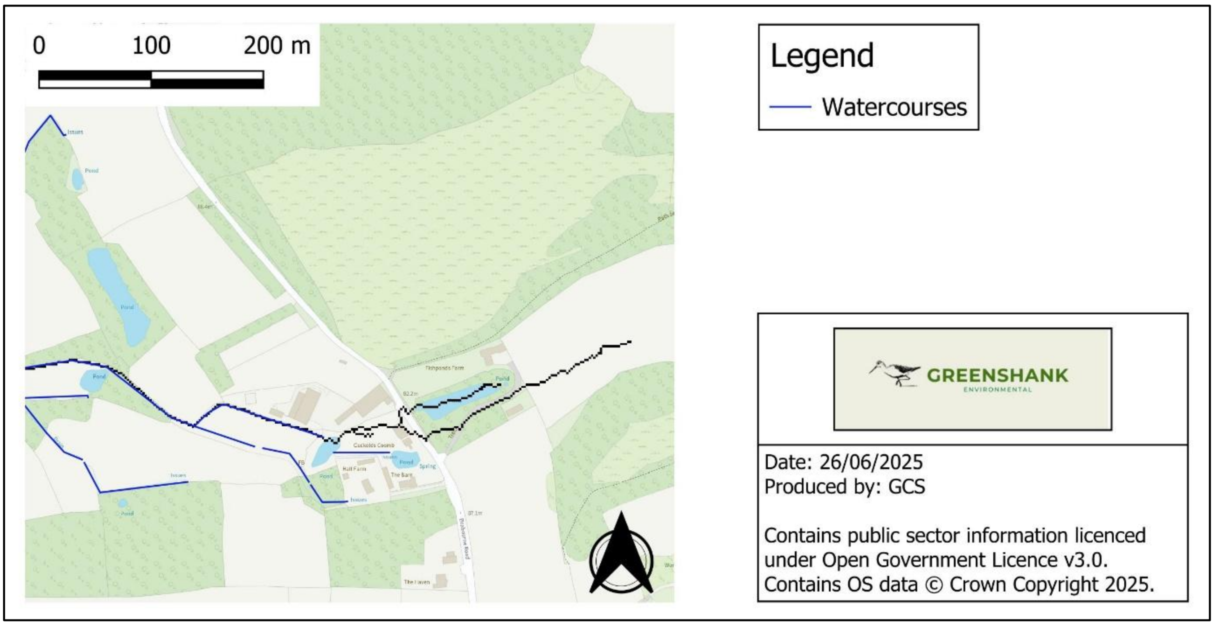


Figure 6: Map showing an example of online ponds and offline ponds within the Hinxhill_DD1 catchment. The black pixellated line shows the flow pathways delineated from a 1 m DEM for the catchment.

A1.6. Quantifying nutrient mitigation

A drainage ditch management mitigation scheme is proposed across seven sites within the River Stour catchment that drains to the Stodmarsh Lakes Habitats Sites. These mitigation options will receive nutrient inputs from upstream land uses in catchments used predominantly for intensive agriculture. Where possible, larger point source nutrient inputs were accounted for, and the impact of existing features that may provide a mitigation benefit were factored into the baseline N and P input to each mitigation option. As described in Connor-Streich (2024b), the drainage ditch management approach described herein can reduce nutrients in watercourses through the same processes that are active in wetlands. The output from the literature review that supports the Enhanced Drainage Ditch Management approach suggests it can achieve TN and TP removal efficiency of at least 28%. Using this removal efficiency and the baseline nutrient load inputs detailed in Sections A1.5.2 to A1.5.4, the mitigation potential for the enhanced drainage ditch management options was quantified as shown in Table 4.

Table 4: N and P mitigation potential for the seven proposed mitigation options.

Site	Baseline N input (kg N/year)	N mitigation (kg N/year)	Baseline P input (kg P/year)	P mitigation (kg P/year)
Hinxhill_DD1	3981.07	1114.70	228.01	63.84
Hinxhill_DD2	2276.17	637.33	112.50	31.50
Wilmington_DD1	319.87	89.56	16.46	4.61
Wye_DD1	2884.09	807.54	125.47	35.13
South_hill_DD1	1679.53	470.27	76.53	21.43
Bliby_wood_DD1	8897.12	2491.19	380.11	106.43
Bliby_wood_DD2	2914.12	815.95	145.66	40.79
Total	**22951.97**	**6426.55**	**1084.74**	**303.73**

Appendix A2

A2. Feasibility assessment

The following sections describe the feasibility assessment used to determine any constraints to deploying the scheme at the deployment locations, and any mitigations that may be required to ensure the deployment location is suitable. A constraints and options assessment summarising the feasibility assessment is detailed in the main report accompanying these appendices.

A2.1. Topography and levels

The channel slope for each mitigation option was estimated using the 1 m resolution EA lidar DEM for the deployment locations. Slopes ranged from a 1.26% at the Willmington_DD1 site to 0.19% at the Bliby_wood_DD2 site. This is reflective of the lowland, low gradient catchments within which the mitigation options are located. Channel slopes at all deployment locations are below the 3% threshold for potential adverse impacts on channel bed morphology and thus does not need further consideration in respect of scheme design to mitigate the impact of bed scour.

A2.2. Geology and hydrogeology

With the exception of the Hinxhill DD1 site, there are no sources of non-agricultural pollution within the drainage ditch catchments, which reduces the risk of groundwater contamination for these four sites. The Southern Water Services operated Brook WwTW discharges to Spider Castle Dyke upstream of the Hinxhill DD1 site. Treated sewage effluent can contain additional pollutants that may contaminate groundwater. However, local superficial geology, bedrock geology and hydrogeology is shown (Figure 7) shows that the Hinxhill DD1 site is in area of superficial alluvium deposits overlying an area bedrock geology that is a mix of mudstone, sandstone and limestone. Alluvial deposits can vary in their hydraulic conductivity but are unlikely to be very conductive of water to deeper rock layers. The presence of mudstone and hydrogeology that is characterised as rocks that do not hold groundwater also indicates a lack of any significant risk of increased localised infiltration resulting in pollution leaching to groundwater.

The other six deployment sites are located on the same of very similar bedrock geology formations as the Hinxhill DD1 site and are either on alluvial or brickearth superficial deposits, barring South Hill DD1 which does not have superficial geology. The Wilmington DD1 site is located at a transition between chalk- and mudstone-dominated bedrock geologies, which is also reflected in the transition from a highly productive aquifer to non-water holding rocks. As the Wilmington DD1 site is located in areas of silt-dominated superficial geology, it is highly unlikely that the proposed scheme will increase groundwater connectivity at this location, with minimal risk to groundwater pollution at this site. Figure 7 also shows that the deployment sites do not intersect with a Source Protection Zone.

A2.3. Soil and sediment

Soils at the deployment locations are shown in Figure 3 in the main report and are summarised as follows:

- Hinxhill_DD1 and South_hill_DD1: Seasonally wet loamy and clayey soils are heavy with high cohesiveness that will increase when wet.
- Wye_DD1, Hinxhill_DD2, Bliby_wood_DD1 and Bliby_wood_DD2: Loamy and clayey floodplain soils with naturally high groundwater are likely to be cohesive and less prone to erosion.
- Wilmington_DD1: Freely draining loamy soils are likely to be more friable, especially when dry, but as loams contain a roughly proportional mix of silt, sand and clay, they will be less prone to erosion when wet.

The deployment locations are all perennially flowing channels and there is a risk of downstream sediment mobilisation. This risk will increase during periods of wet weather when flows in each channel will increase. However, barring the Wilmington_DD1, the soils at each of the deployment locations are cohesive and more resistant to erosion than more friable soil types. To limit the risks associated with sediment mobilisation during earthworks, scheme deployment will be carried out during a period of dry weather when rainfall is not forecast. Exposed sediment will be damped down to increase cohesion and if required, plastic sheeting, geotextile or natural erosion protection, e.g., coir matting will be installed to reduce sediment mobilisation risks. Silt fences, silt wattles and/or silt mats will be deployed at the downstream end of the deployment location to trap mobilised sediment.

A2.4. Flood risk

Flood risk mapping for the deployment locations is shown in Figure 8. The Wilmington_DD1 and South_hill_DD1 sites are located in Flood Zone 1, which is an area of low flood risk. Wye_DD1, Hinxhill_DD1, Hinxhill_DD2, Bliby_wood_DD1 and Bliby_wood_DD2 are all located in areas of high flood risk (Flood Zone 3). These locations are therefore more likely to be frequently inundated and experience higher flows. The design of the proposed mitigation scheme is intended to convey flows up to the 1-in-100 year (+climate change) runoff event for the catchment. This should mean that a higher return period flood flow events, which are generally the flows that transport the majority of nutrient pollution from diffuse sources, the increased hydraulic residence time in the redesigned channels will be beneficial for nutrient reduction processes. It is likely that, regardless of design, nutrient reduction potential will decrease for low return period flow events, but these should be sufficiently rare as to have little impact on the average nutrient reduction potential of three deployment locations that are within Flood Zone 3.

The deployment locations in Flood Zone 3 are at a higher risk of damage during high flow events and this is recognised in the monitoring and maintenance plan provide in the main report. Detailed design for these sites will include flood risks assessment which will be used to inform the likelihood of high flows causing damage to the scheme in these locations. The mitigation scheme is designed to attenuate surface water runoff, which should provide a reduction to downstream flood risk.

A2.5. Protected sites and species, Invasive Non-Native Species (INNS)

The deployment locations have been checked against the locations of protected sites and shown to be outside of the following site designations (Figure 9):

- Special Areas of Conservation
- Special Protection Areas
- Ramsar Sites
- Sites of Special Scientific Interest
- Local Nature Reserves
- Local Wildlife Sites
- National Parks
- Areas of Outstanding Natural Beauty (AONB) – with the exception of Wye_DD1
- National Nature Reserves
- Priority Habitats - with the exception of Hinxhill_DD2

There are no protected sites linked to any of the deployment locations via a hydrological pathway within 5 km. A Preliminary Ecological Appraisal (PEA) of the Hinxhill_DD1, Hinxhill_DD2, Wye_DD1, Wilmington_DD1 and South_hill_DD1 deployment locations has confirmed that the only potential impact on a protected site would be through pollution mobilisation during the construction phase of the project and onward transport to the Stodmarsh Habitats Sites. The PEA notes that this risk is very minor and can be mitigated via good practice construction techniques. The Bliby_wood_DD1 & DD2 sites are scheduled for a PEA and given the lack of any hydrological connection with a protected site within 5 km, it is expected that only very minor construction-related risks may arise.

The Wye_DD1 site is within the Kent Downs AONB and the Kent Downs AONB is within 5 km of all the proposed deployment locations. The design of the mitigation scheme at each location will increase the landscape quality through the restoration of areas of more natural and biodiverse river corridors. As such, the proposed scheme is aligned to the objectives of the Kent Downs AONB.

The Hinxhill_DD2 site is located adjacent to an area of priority habitat, some of which is classed as 'no main habitat but additional habitats present' with small areas of deciduous woodland. The PEA classed the areas proposed for the scheme as predominantly agricultural grassland and arable field margins, with a small line of trees. The proposed scheme will reinstate denser riparian woodland mosaic planting of locally relevant tree species that will provide a link to nearby deciduous woodland. Hinxhill_DD1 and Bliby_wood_DD1 & DD2 also have some proximal areas of deciduous woodland priority habitat that will be benefited by the deployment of the scheme.

The PEA also noted no obvious issues with INNS and an INNS survey will be completed at the time of scheme deployment to reduce the risk of spreading INNS.

A2.6. Land use

The deployment locations are managed for buffer strips under Countryside Stewardship agreement, however the landowners are ending these agreements in order to use the deployment location for a nutrient neutrality mitigation scheme.

A2.7. Ownership

The mitigation option deployment locations are being leased for a period of 80 years by the Oliver Davis Group Limited and thus there are no barriers to deployment related to ownership. The maintenance plan for the scheme specifies the requirements for Oliver Davis Group Limited to manage the scheme for the perpetuity period, Funds from the sale of mitigation credits will be used to pay for monitoring and maintenance activities. Ownership and maintenance considerations will be secured through legal agreements that will be required to ensure delivery of the scheme.

A2.8. Rights of way and public access

There are no public rights of way that will be impacted by the proposed scheme. There is a public right of way that crosses a footbridge at the South_hill_DD1 site, however this footbridge is not being altered as part of the scheme and an exclusion zone will be placed around the footpath so that works do not impact the public right of way.

A2.9. Bird strike risk

Figure 10 shows the location of the nearest airfields to each site. Bliby_wood_DD1 & DD2 are 1 km from the Hamilton Farm Airfield, which is a small airfield used by hobby pilots in single propeller aircraft. The owners of the airfield have been contacted to discuss the proposals. As the proposed mitigation option is unlikely to result in a large increase in local bird populations, there is likely to be a negligible risk to aviation that may result from deployment of the scheme.

A2.10. Nature recovery

Figure 11 shows Habitat Network and priority river habitat mapping in the area around the deployment locations. There are no sections of river mapped as priority river habitat in within the catchments of any of the deployment locations. Only the Wilmington_DD1 location is within a Habitat Network Expansion Zone, which is linked to an area of wood pasture and parkland. The site is towards the edge of the Network Expansion Zone and seeing as the proposed scheme will increase tree planting it is likely to contribute to any plans to expand the proximal area of wood pasture and parkland habitat. This indicates that the deployment locations are only likely to positively intersect with future nature recovery projects and that the scheme will provide an improvement to the current watercourse management approach.

The areas upstream and downstream of all deployment locations are of similar character to the reaches proposed for the scheme. These are heavily managed watercourses lacking in natural processes and with artificial morphologies. As such, there is limited risk of the proposed scheme resulting in changes that would impact the ability to restore larger sections of each watercourse, and the scheme is more likely to result in an improvement to habitat in the upper reaches of each catchment.

All deployment locations were checked against the emerging Local Nature Recovery Strategy mapping for the Kent and Medway area[9]. All sites are located within 'Areas that Coul become of Importance for Biodiversity', while no sites are within areas of 'Particular Importance'. The proposed scheme was also referenced against the specific measures for freshwater environments and was found to deliver against a number of these measures which are seeking to manage historic physical modifications, slow flow within drainage networks and manage diffuse pollution risks.

A2.11. Unexploded ordinance

The landowners have been consulted and there is a low risk of discovering unexploded ordinance during project deployment. Appropriate steps will be taken to dispose of any unexploded ordinance should it be discovered during earthworks.

A2.12. Services and infrastructure

There are no overhead services at the deployment location and thus there is no risk of disruption to services and infrastructure.

A2.13. Regulatory considerations

The consents and assessments listed below will be required to support delivery of the scheme. These will be produced and applied for as detailed design of the scheme progresses.

- Water Framework Directive (WFD) Assessment:
    - Required at Hinxhill_DD1 as this is a WFD waterbody.
- Habitats Regulations Assessment
    - Required at all sites
- Planning permission
    - It is assumed that the works have Permitted Development rights – this is to be confirmed via pre-application advice with Ashford Borough Council.
- Flood Risk Activity Permit
    - Required at Hinxhill_DD1 as this watercourse is a Main River.
    - Environment Agency have been engaged for pre-application advice.
- Internal Drainage Board (IDB) consent
    - Required at Hinxhill_DD2, Wye_DD1, Bliby_wood_DD1 & DD2.
    - Positive initial engagement conducted with the River Stour IDB.
- Ordinary Watercourse Consent

[9] Available from: https://webapps.kwtg.uk/public/app/lnrs_measures_webmap/, accessed on 30/06/2025.

- Required for South_hill_DD1 and Wilmington_DD1.
- Will be applied for with Kent Lead Local Flood Authority following detailed design.

A2.14. Feasibility assessment summary – constraints and options assessment

A summary of the feasibility assessment outcomes is provided in the Delivery Proposal report. This highlights the scheme has not been found to have any significant constraints, but that that some assessment criteria will require further assessment as the detailed design as the scheme progresses. The only major consideration with respect to constraints is due to impacts from soil and sediment mobilisation during construction. As part of the detailed construction plans for the scheme, options will be assessed to ensure a suitable pollution control methodology is used to mitigate these risks. It is not considered at present that any of the issues highlighted as part of the feasibility assessment cannot be mitigated.

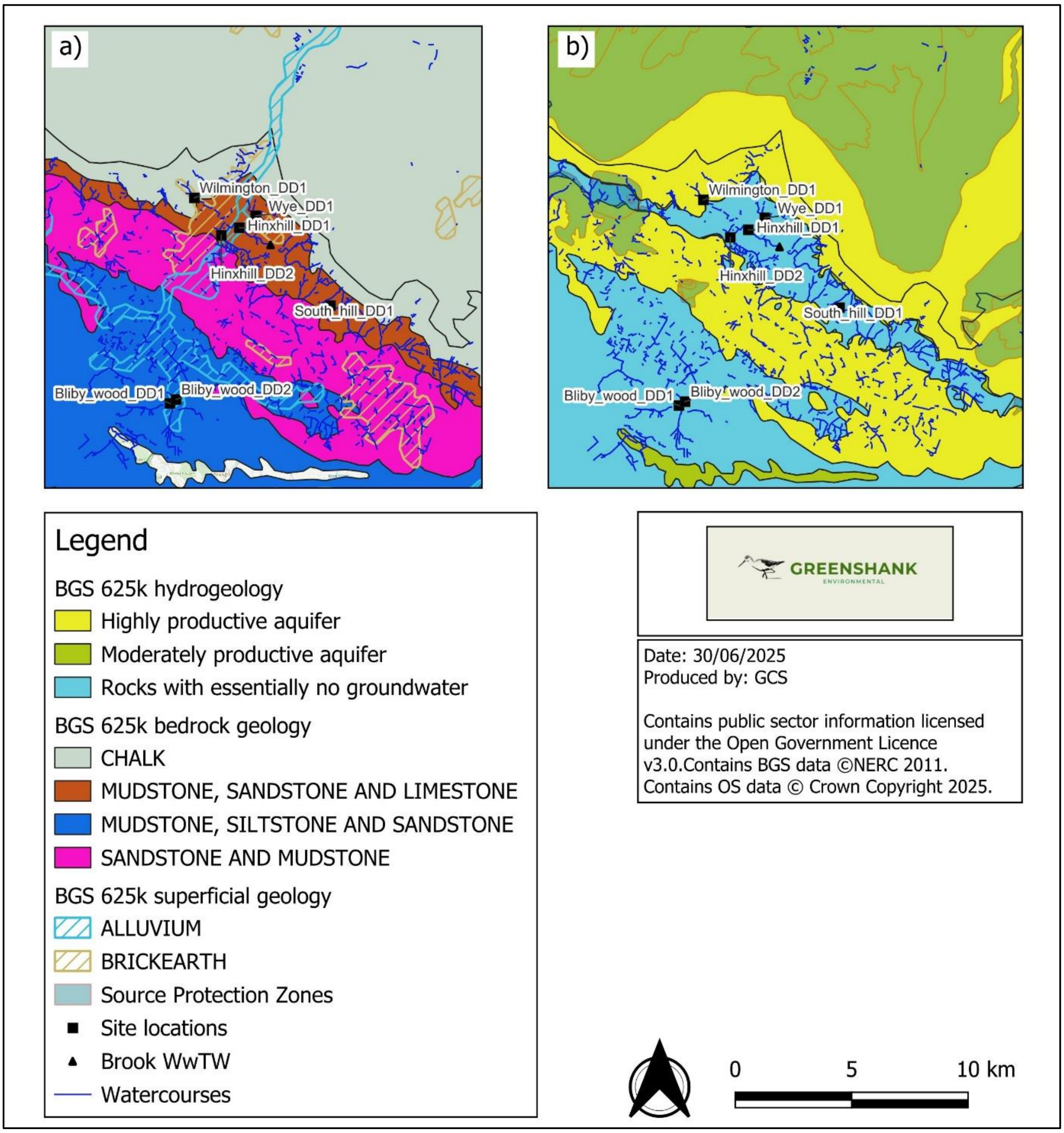


Figure 7: Map of a) bedrock and superficial geology and b) hydrogeology and Source Protection Zones at the deployment locations and surrounding catchment areas.

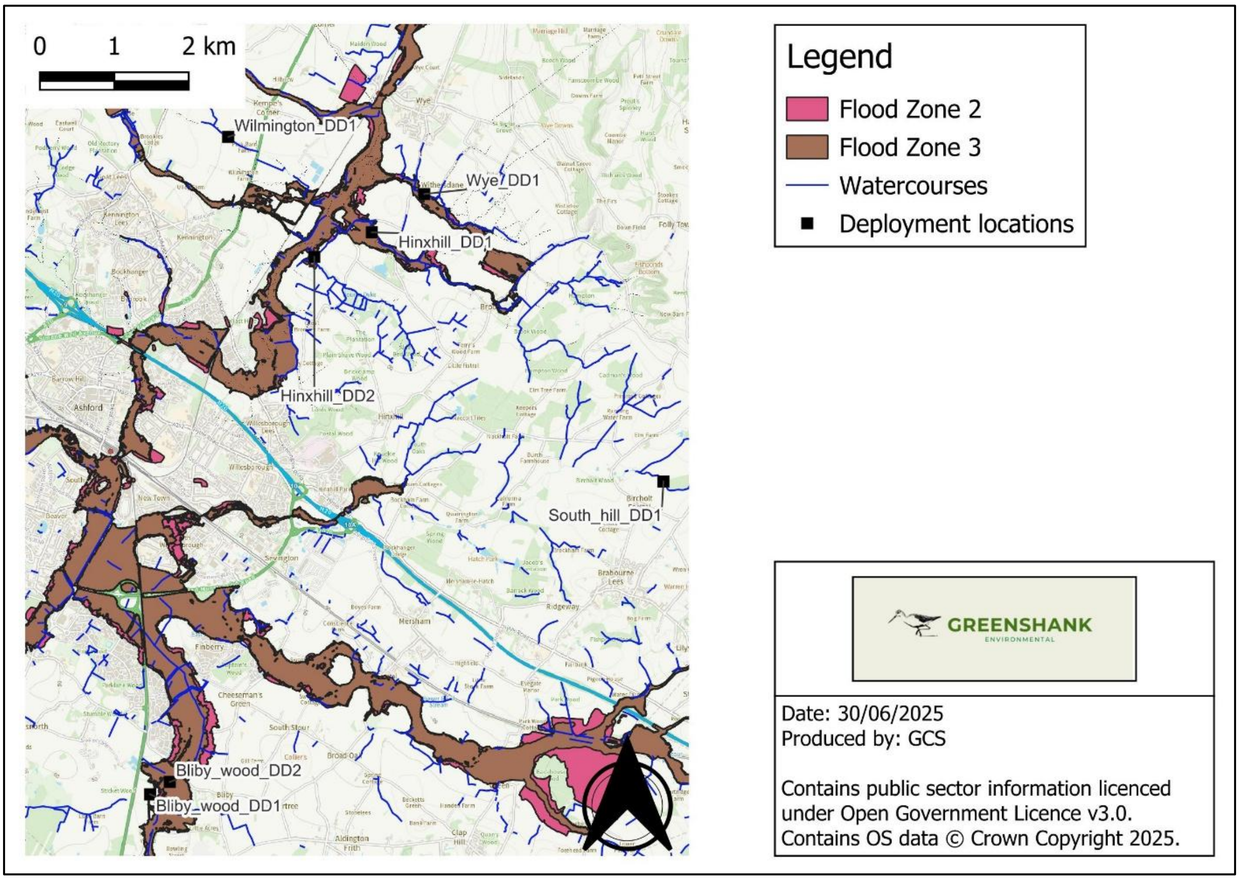


Figure 8: Flood risk feasibility assessment ma

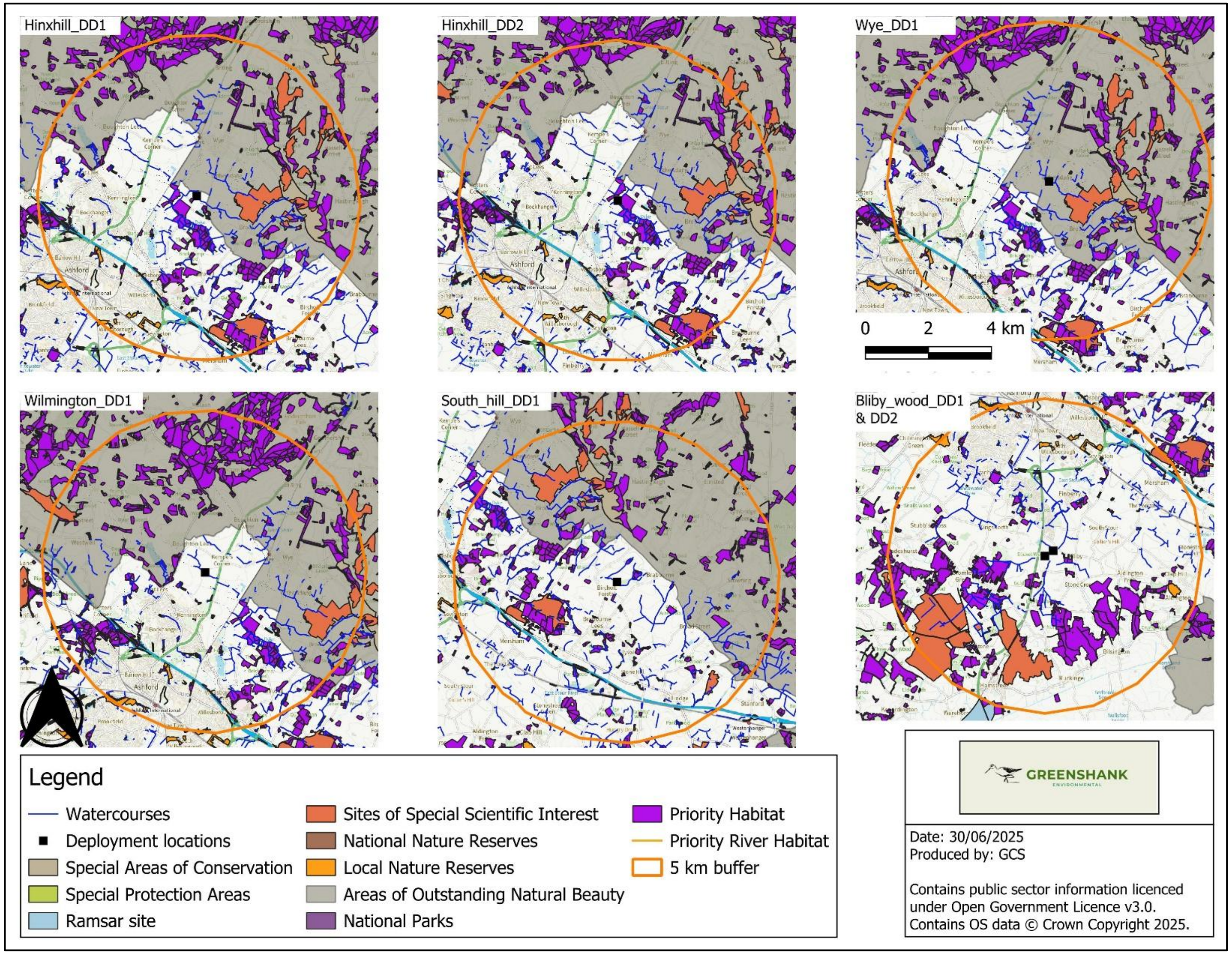


Figure 9: Protected sites feasibility assessment map showing sites with

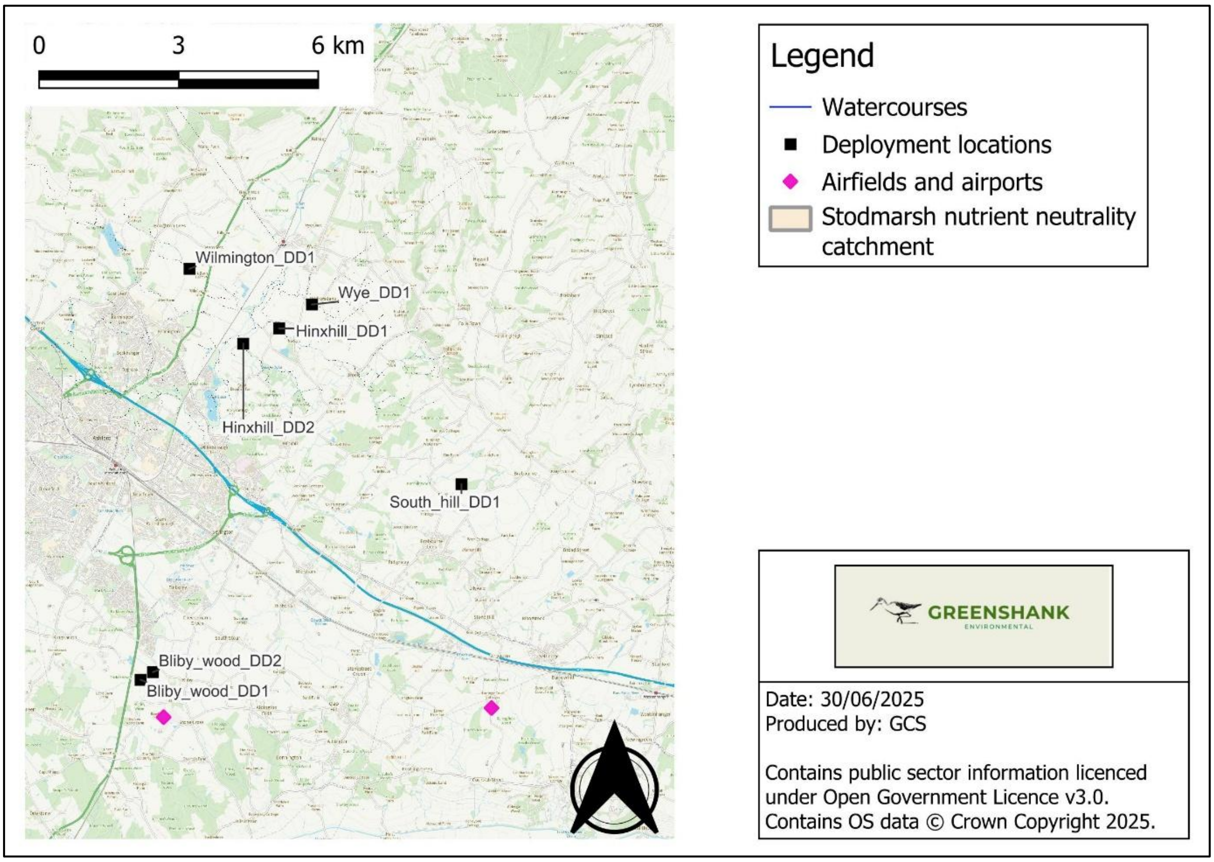


Figure 10: Map showing the locations of the nearest airfields and airports to the proposed deployment location.

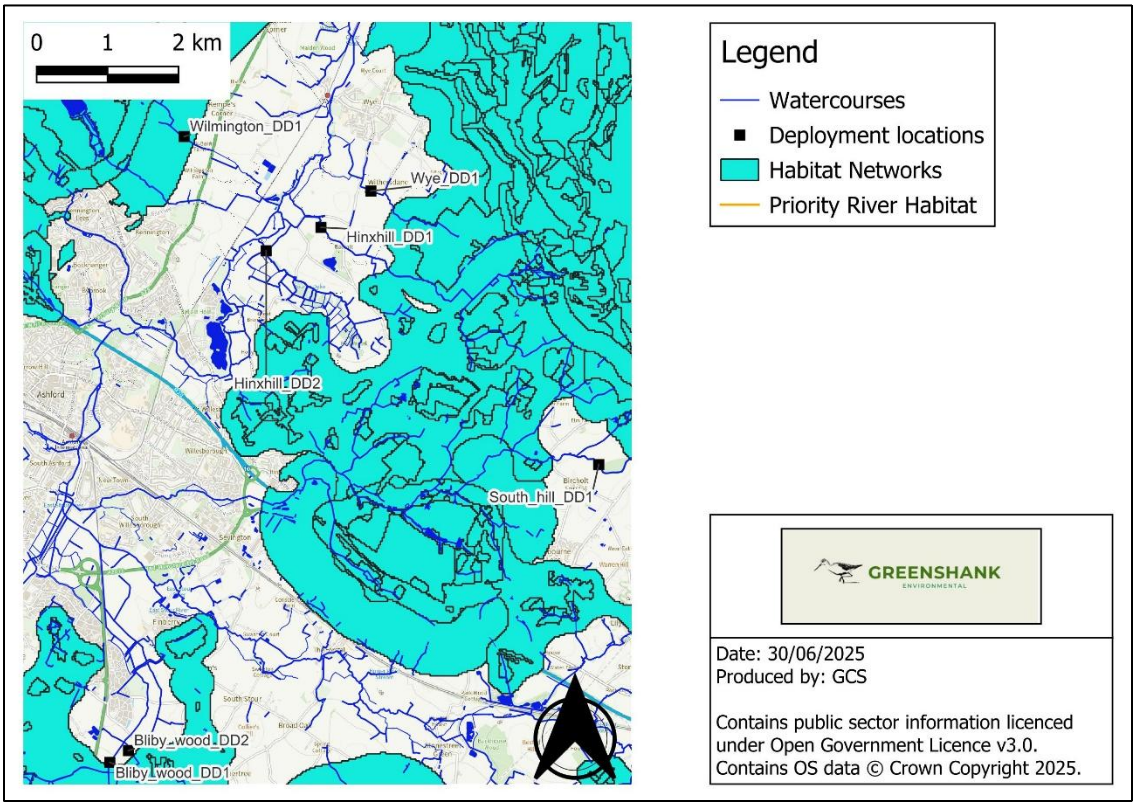


Figure 11: Habitat network and priority river habitat feasibility assessment map.

Appendix A3

A3. Mitigation option design

Figure 12 shows the conceptual design of a two-stage ditch. The steps for specifying two-stage ditch dimensions in small, trapezoidal UK agricultural drainage ditches are described below, based on guidance detailed in Connor-Streich (2024a), USDA (2007) and Powell et al. (2007). For ease of reference, these steps will refer to different parts of the two-stage ditch design by the names shown in Figure 12. The underlying technical rationale for these steps is detailed in Connor-Streich (2024b).

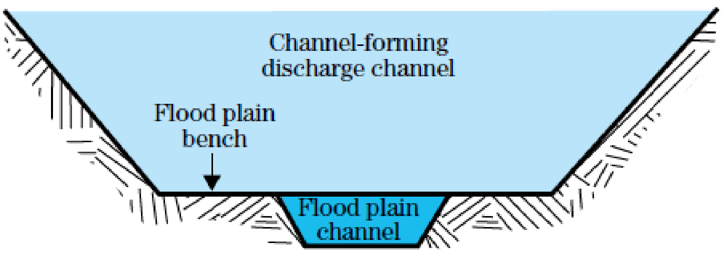


Figure 12: Conceptual design of a two-stage channel. Source: USDA (2007).

Steps for specifying two-stage ditch dimensions:

1. Measure the existing dimensions of the trapezoidal channel that is proposed for reengineering.
    a. Ditch dimensions were measured from cross-sections extracted from at 20 m intervals along each ditch. Cross-sectional elevation profiles were extracted from the EA 1 m lidar DEM and analysed to extract the existing dimensions of each ditch.
    b. The existing dimensions were used as a starting point for the two-stage ditch dimensions.
    c. The two-stage channel aims to incorporate these dimensions in the floodplain channel width and depth, the floodplain bench widths and the channel-forming discharge channel width and depth.
    d. For the proposed two-stage ditches, the current trapezoidal channels have the dimensions shown in Table 5.
    e. The average dimensions shown in Table 5 have been used to inform the outline design of the mitigation option at each site and will be refined through a detailed design process.

Table 5: Existing average (mean) dimensions of trapezoidal watercourse cross-sections extracted from a 1 m resolution lidar DEM.

Site	Bankfull average width (m)	Bankfull depth (m)	Channel width at 33% bankfull depth (m)	Channel bed width
Wilmington_DD1	2.40	0.17	1.20	1.00
Wye_DD1	5.00	0.86	1.30	1.00
Hinxhill_DD1	5.60	0.45	2.00	1.00
Hinxhill_DD2	4.80	0.34	1.60	1.00
South_hill_DD1	4.40	0.32	1.40	1.00
Bliby_wood_DD1	7.00	1.06	3.20	2.00
Bliby_wood_DD2	5.40	0.40	2.00	1.00

2. Determine a regional curve (see Connor-Streich, 2024b) for the River Stour catchment in which the two-stage channels are being deployed:
    a. A regional curve was developed by measuring channel widths in satellite imagery (Figure 13).
    b. A point at the downstream end of each WFD waterbody catchment within the Upper and Lower Stour Operational Catchments was found where the channel was visible in satellite imagery and an approximate bankfull channel width was measured. The drainage area was then taken from the WFD catchment polygon.

c. Additional measurements were taken on small tributaries within WFD catchments that comprise the Upper and Lower Stour Operational Catchments, with drainage areas determined using a 1 m lidar DEM.

d. Linear regression showed that the relationship between channel width and drainage area is significant ($R^2 = 0.89$, $p < 0.01$, $df = 10$).

e. By substituting the drainage area for each two-stage channel location into the equation shown in Figure 13, it is possible to estimate an approximate bankfull width for the two-stage channel.

f. The bankfull widths estimated from the regional curve are shown for each deployment location in Table 6.

g. It is recognised that measurements of channel width taken from satellite imagery will be prone to error and the outputs from a regional curve generated in this way should be used as a guide to sizing two-stage channel dimensions.

h. It was also noted that the estimated bankfull widths from the regional curves are notably smaller than those measured using average cross-sectional dimensions measured from a DEM. This is likely due to the heavily managed nature of the channels at the deployment locations which have been set in overwide and overdeep trenches to reduce the risk of flooding surrounding farmland and to encourage field drainage.

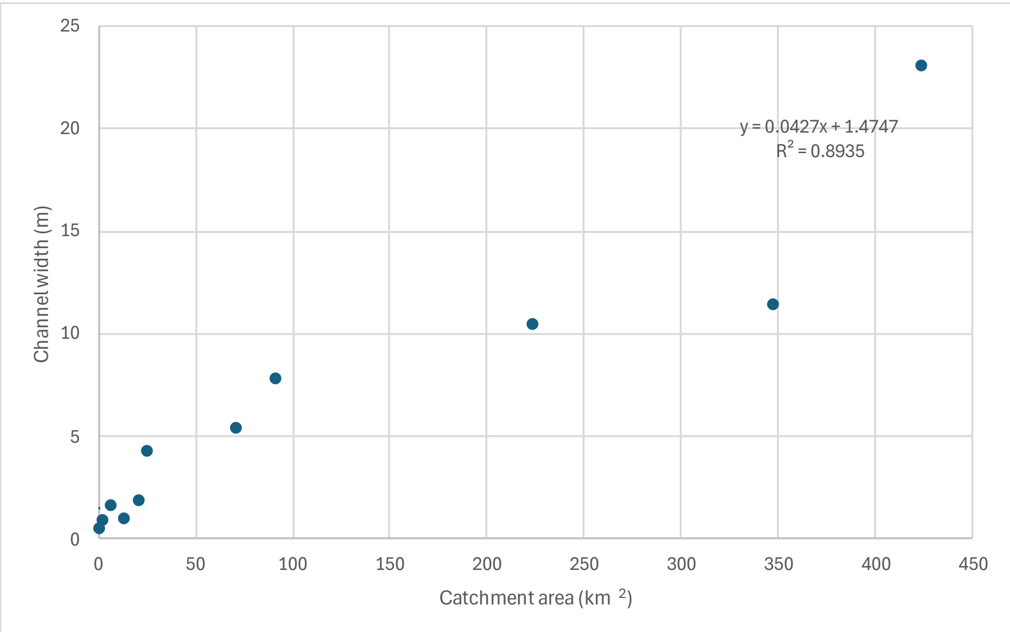


Figure 13: Regional curve for the River Stour catchment showing the relationship between channel width measured from satellite imagery and drainage area at the point of width measurement.

Table 6: Estimated bankfull widths of channels at the proposed two-stage channel deployment locations, based on a regional curve for the River Stour catchment.

Site	Catchment area (km²)	Predicted bankfull width (m)
Wye_DD1	4.09	1.65
South_hill_DD1	1.56	1.54
Hinxhill_DD1	4.93	1.69
Hinxhill_DD2	2.43	1.58
Wilmington_DD1	1.61	1.54
Bliby_wood_DD1	2.2	1.57
Bliby_wood_DD2	13.94	2.07

3. Estimate the channel slope from topographic data.
    a. Using a 1 m lidar DEM, the slope of the channel slope was measured and ranged from between 1.26% (Wilmington_DD1) to 0.19% (Bliby_wood_DD2).
    b. The slope of all channels at the deployment locations is < 3% and therefore low-grade weir height and spacing does not need to be set to manage channel slope.
4. Determine a conceptual channel geometry.
    a. The initial channel dimensions detailed in Step 1 were used as a starting point for determining the conceptual channel geometries.
    b. The dimensions of the floodplain channel were set as shown in Table 7:
        i. The bankfull floodplain channel width was informed by the existing channel width at 33% of existing bankfull depth. Due to the overdeep and overwide nature of all of the channels, the width of the floodplain channels was set lower than predicted from the channel cross-section, which will aid connectivity with the floodplain benches.
        ii. The bankfull floodplain channel depth was set at 33% of existing bankfull channel depth for each deployment location.
    c. The dimensions of the floodplain benches were set as follows:
        i. Total floodplain bench width = bankfull floodplain channel width x 4.5. This should allow for some meandering of the floodplain channel to develop, improving habitat.
    d. The dimensions of the channel-forming discharge channel were set as follows:
        i. Channel-forming discharge channel width = total floodplain bench width + floodplain channel width.
        ii. The channel-forming discharge channels are considerably m wider than the bankfull channel widths estimated from the regional curve (Table 6), which should allow for conveyance of runoff at low return

period runoff rates and should promote significant connectivity between the floodplain benches and the floodplain channel.

iii. For each deployment location, the channel-forming discharge channel depth = existing bankfull depth.

e. It should be noted that this report details the outline design for each deployment location and the geometries detailed in Table 7 will be subject to change through the detailed design process. However, the detailed design will maintain a geometry that promotes significant connectivity between the floodplain channel and the floodplain benches, in order to promote nutrient cycling processes.

Table 7: Conceptual channel geometries for each proposed mitigation option deployment location.

Site	Floodplain channel width (m)	Floodplain channel depth (m)	Total floodplain bench width (m)	Channel-forming discharge channel width (m)	Channel-forming discharge channel depth (m)
Wilmington_DD1	1.20	0.06	4.80	6.00	0.17
Wye_DD1	1.30	0.20	5.85	7.15	0.86
Hinxhill_DD1	2.00	0.15	9.00	11.00	0.45
Hinxhill_DD2	1.60	0.11	7.20	8.80	0.34
South_hill_DD1	1.40	0.11	6.30	7.70	0.32
Bliby_wood_DD1	3.20	0.35	14.40	17.60	1.06
Bliby_wood_DD2	2.00	0.13	9.00	11.00	0.40

5. Estimate flow conveyance capacity of the two-stage ditch.

a. Manning's equation for open-channel flow was used to estimate the flow conveyance capacity of the two-stage ditches.

b. The equation was used to estimate flow in the floodplain channel at bankfull discharge and in channel-forming discharge channel at bankfull discharge. The equation has the form:

$$V = \frac{1}{n} R_h^{2/3} S^{1/2}$$

where *V* is the cross-sectional velocity (m/s), *n* is the Manning coefficient, R_h is the hydraulic radius (m), *S* is the stream slope (m/m). Calculation of *V* allows for an estimate of discharge using the velocity-area method:

$$Q = AV$$

where *Q* is discharge (l/s) and *A* is the cross-sectional area of the channel (m^2).

c. Manning's *n* was set to 0.05 to reflect the plan for tall grasses on floodplain benches and the low-grade weirs in the floodplain channel.

d. The two-stage ditch geometries detailed in Table 7 result in the estimated flow conveyances at bankfull discharge detailed in Table 8.

Table 8: Flow conveyance capacities for each of the proposed mitigation options following reprofiling of the channels to the two-stage cross-section detailed above.

Site	Flow conveyance capacity (l/s)
Wilmington_ DD1	295.78
Wye_DD1	5976.72
Hinxhill_DD1	2487.38
Hinxhill_DD2	1308.57
South_hill_DD1	1050.84
Bliby_wood_DD1	17501.84
Bliby_wood_DD2	2180.74

6. Estimate the discharge in the channel for a range of return periods up to the 1-in-100-year runoff event plus climate change.

    a. The discharge conveyed by each ditch was estimated using a greenfield runoff rate estimation tool[10].

    b. The Wilmington_DD1, Bliby_wood_DD1 and Bliby_wood_DD2 catchments have a single soil type, whereas there are variable soil types within the other mitigation option catchments. For catchments with variable soil types, runoff rates from multiple locations within the catchment were checked to develop a range of runoff rates from which an average was calculated (Table 9).

    c. The greenfield runoff rates were adjusted up by 40% for up to the 1 in 30 year return period and 45% for the 1 in 100 year return period to account for the potential impact of climate change (CC), using the Environment Agency Climate Change Allowances dataset[11].

    d. Comparing the greenfield runoff rates (Table 9) to the estimated flow conveyance capacity of the ditches (Table 8), the proposed two-stage ditch design at Wilmington_DD1 and Wye_DD1 should be able to convey all flows up to the 1 in 100 year runoff rate + CC. At the other sites, each redesigned channel should be able to convey flows up to the 1 in 30 year return period flow without allowing for climate change. It should be noted that at all locations, the estimated flow conveyance capacity of the proposed two-stage channel geometry is greater than the flow conveyance capacity of the existing trapezoidal cross-section. Therefore, the proposed scheme is

[10] The HR Wallingford greenfield runoff rate estimation tool – IH124 method was used in this case. Available from: https://www.uksuds.com/tools/greenfield-runoff-rate-estimation, accessed on: 21/03/2025.
[11] Available from: https://environment.data.gov.uk/hydrology/climate-change-allowances/rainfall?mgtmcatid=3017, Accessed on: 21/03/2025.

likely to confer some improvement to localised flood risk but will not be able to convey all flows at very low return periods.

Table 9: Greenfield runoff rate estimates for the catchment of the proposed two-stage channels.

Site	Return period	Average greenfield runoff (l/s)
Wilmington_DD1	Qbar	24.8 (+CC = 34.72)
	1 in 1 year	21.1 (+CC = 29.54)
	1 in 30 years	57.1 (+CC = 79.94)
	1 in 100 years	79.2 (+CC = 114.84)
Wye_DD1	Qbar	883.3 (+CC = 1236.62)
	1 in 1 year	750.85 (+CC = 1051.19)
	1 in 30 years	2031.65 (+CC = 2844.31)
	1 in 100 years	2817.8 (+CC = 4085.81)
Hinxhill_DD1	Qbar	1041.6 (+CC = 1458.24)
	1 in 1 year	885.35 (+CC = 1239.49)
	1 in 30 years	2395.65 (+CC = 3353.91)
	1 in 100 years	3322.7 (+CC = 4817.92)
Hinxhill_DD2	Qbar	547.95 (+CC = 767.13)
	1 in 1 year	465.8 (+CC = 652.12)
	1 in 30 years	1260.35 (+CC = 1764.49)
	1 in 100 years	1748.05 (+CC = 2534.67)
South_hill_DD1	Qbar	382.5 (+CC = 535.5)
	1 in 1 year	325.15 (+CC = 455.21)
	1 in 30 years	879.8 (+CC = 1231.72)
	1 in 100 years	1220.3 (+CC = 1769.44)
Bliby_wood_DD1	Qbar	4784.2 (+CC = 6697.88)
	1 in 1 year	4066.6 (+CC = 5693.24)
	1 in 30 years	11003.6 (+CC = 15405.04)
	1 in 100 years	15261.6 (+CC = 22129.32)
Bliby_wood_DD2	Qbar	925.1 (+CC = 1295.14)
	1 in 1 year	786.3 (+CC = 1100.82)
	1 in 30 years	2127.6 (+CC = 2978.64)
	1 in 100 years	2950.9 (+CC = 4278.81)

7. Low-grade weir heights and spacing:

a. In order to improve the habitat creates through this scheme, low-grade weirs will mimic large woody debris within the channel using a 'kerplunk' design. As the features will be mimicking natural wood recruitment to each channel, they will not be designed to achieve a specific crest height, but it will be ensured that parts of the structures are at set to at least 20% of the depth of the floodplain channel with the intention of promoting more sediment deposition and greater floodplain bench connectivity.

b. Kerplunks will be spaced at ~70 m intervals along each channel. As kerplunks can have considerable impact on slowing flow as flow increases within a channel, this spacing is intended to facilitate floodplain bench connectivity while not creating significant backwater risks that would reduce flow conveyance capacity. This spacing may be refined through detailed design.

Figure 14: An example of a 'kerplunk' woody debris installation[12].

8. Plan how to establish vegetation rapidly on floodplain benches and a buffer strip.

   a. Grasses will be established rapidly on the floodplain benches and the banks of the channel-forming discharge channel.

   b. Grasses are recommended over woody vegetation as larger plants can shade the floodplain benches, resulting in areas of bare soil that are more prone to erosion.

   c. A 10 m vegetated margin will be established along the banks of the channel. This will provide additional nutrient retention for nutrients being transported by overland flow and throughflow that would enter the ditch laterally, as well as providing visual evidence of the scheme is retained in perpetuity.

[12] Image from: https://www.gov.uk/government/news/natural-flood-management-work-underway-in-northumberland-village, accessed on: 21/03/2025

A3.1. Vegetated margin design and cross-section profiles

Following design recommendations by Cole et al. (2020), Feld et al. (2018), Connor-Streich (2024) and Woodland Trust (2016), the vegetated margins will be planted in a mosaic of riparian woodland and open areas of grass and herbaceous planting with occasional trees. Figure 15 shows a schematic planform representation of how the buffer strips will be planted. This planting plan is aimed at reducing the risk of dense woodland developing along the whole riparian corridor, which could have adverse impacts on water temperatures due to excess shading and may also result in excess recruitment of large wood into the channel.

The riparian wooded areas will be planted in zones, with a grass zone extend from the upslope edge of the buffer followed by clumps of trees planted intermittently along the edge of each channel. This design is shown Figure 16 and differs slightly from that shown in Figure 15 where riparian tree planting is shown to the upslope edge of the buffer strip and is aimed at increasing particulate nutrient deposition as runoff enters the vegetated margin, with trees providing bank stabilisation closer to the channel, as well as deeper rooting to increase nutrient retention on throughflow pathways. The vegetation planted within the buffer will be specified through consultation with the project ecologist during the detailed design phase and will include suitable native species.

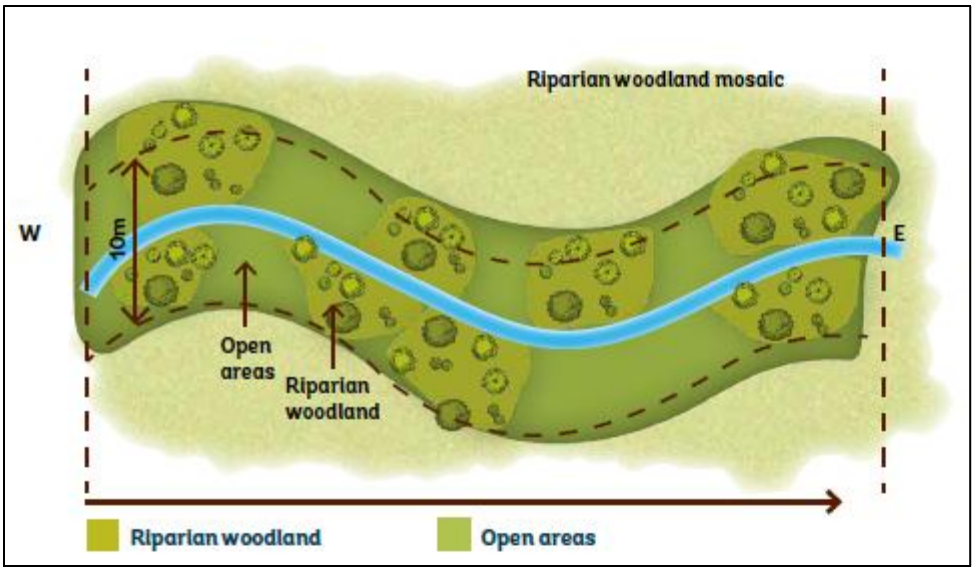


Figure 15: Schematic representation of the planting plan for buffer strips adjacent to the proposed two-stage ditch deployment locations. Source: Woodland Trust (2016)

Figure 16 shows a schematic representation of the cross-sectional profile of the proposed scheme design at each deployment location. This provides a visual representation of how each channel will be reprofiled. The specific dimensions of the cross-section at each site will be set using the approach detailed above, with the dimensions detailed in Table 7 refined through the detailed design process.

Figure 17 to Figure 23 show topographic maps of the deployment location and surrounding area, along with photos of each channel at the deployment locations. As can be seen from these figures, the sites sit within low relief areas. At the Wilmington_DD1 and South_hill_DD1 sites the valley slopes slightly more towards the channels, although the valley gradient is still very shallow. At the other sites, there is limited change in relief in the floodplain areas adjacent to the channels. The low gradient nature of the deployment areas should facilitate the development of meandering floodplain channels within the constraint of the floodplain benches and the channel-forming discharge channels. As can be seen in the photos of each location, the channels suffer from historic management, having been straightened and deepened. The proposed design shown in Figure 16 should therefore support a re-naturalisation of the channels at the deployment locations, resulting in improvements for habitats while delivering nutrient mitigation.

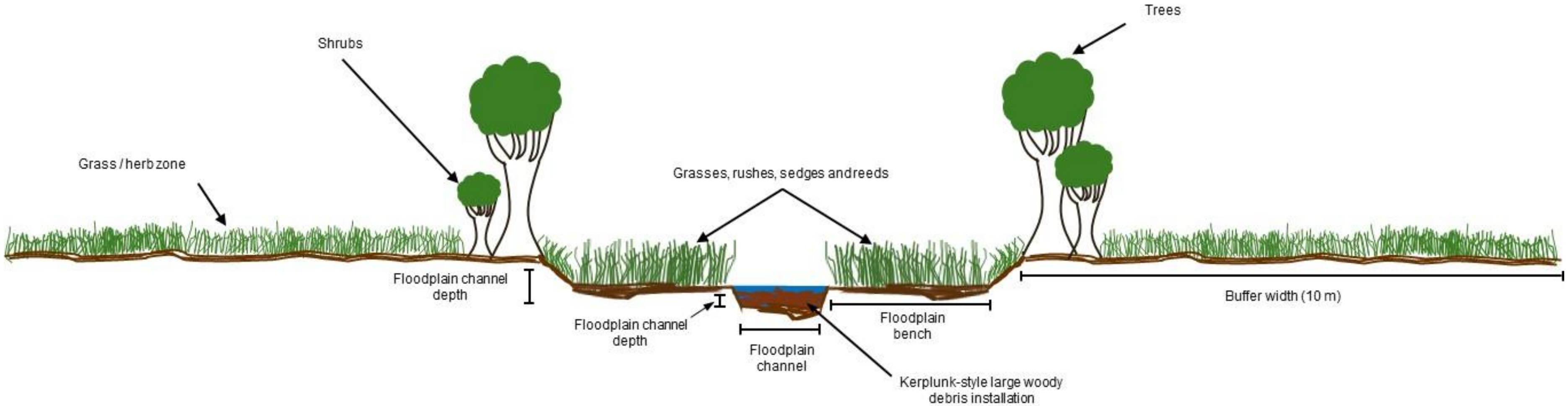


Figure 16: A schematic design of the proposed two-stage cross-section and buffer strips at each of the five deployment locations. Drawing not to scale.

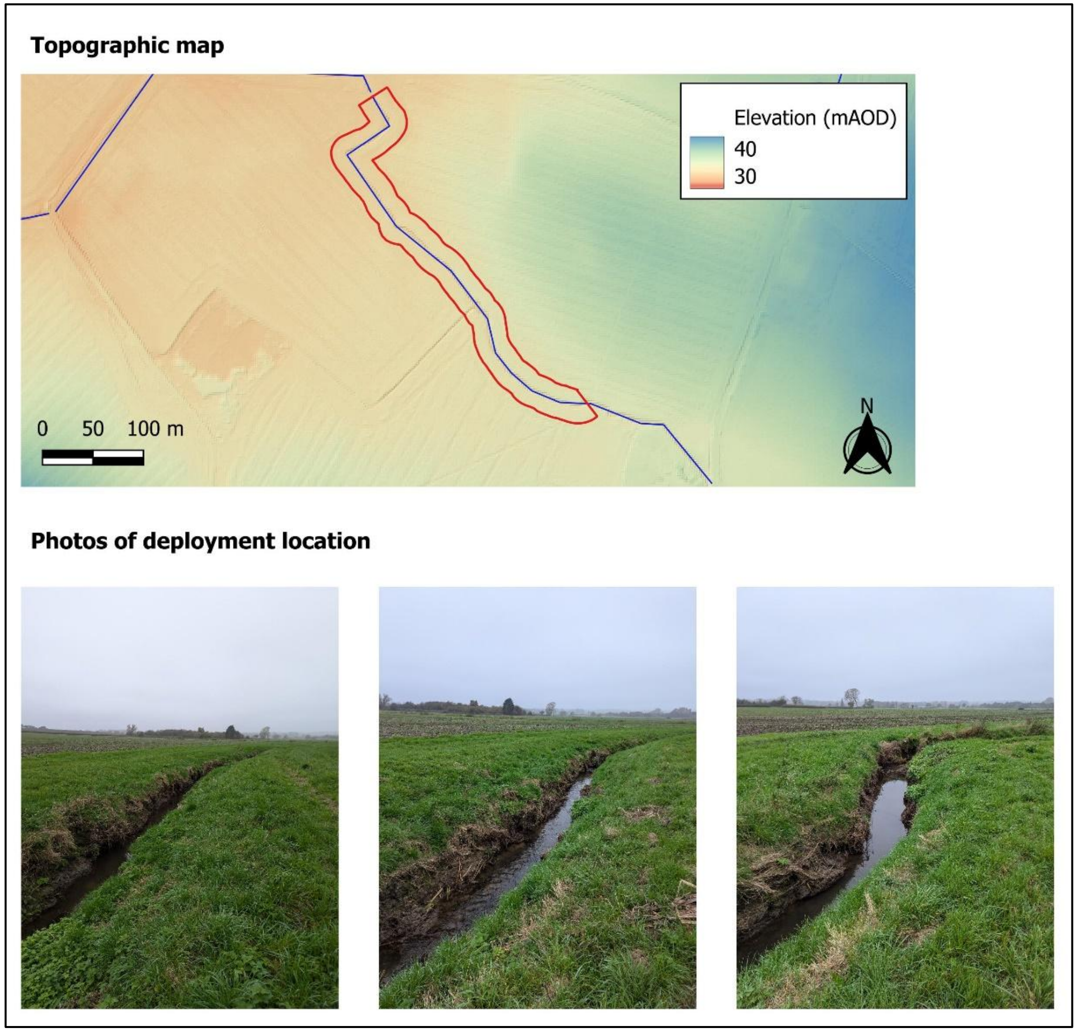


Figure 17: Showing a topographic map and photos showing the character of the channel at the Hinxhill_DD1 deployment location. The redline area shows the outline for where the scheme will be deployed.

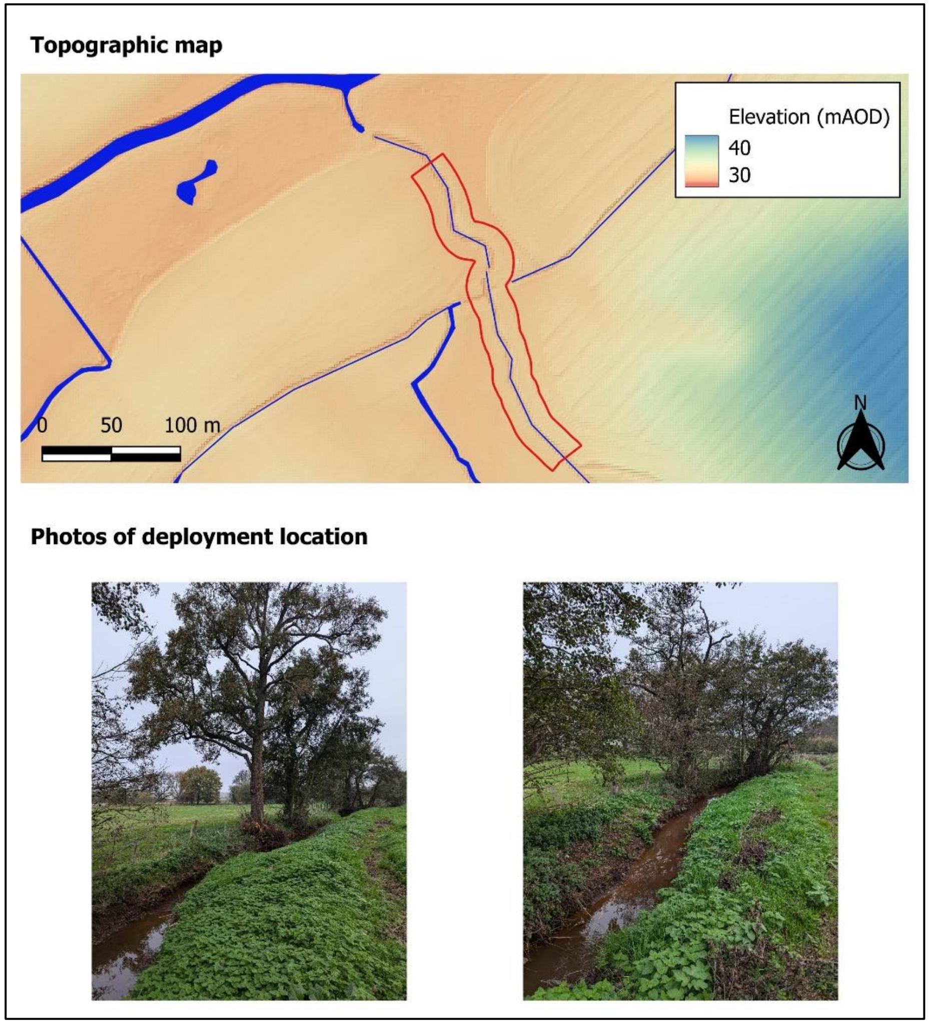


Figure 18: Showing a topographic map and photos showing the character of the channel at the Hinxhill_DD2 deployment location. The redline area shows the outline for where the scheme will be deployed.

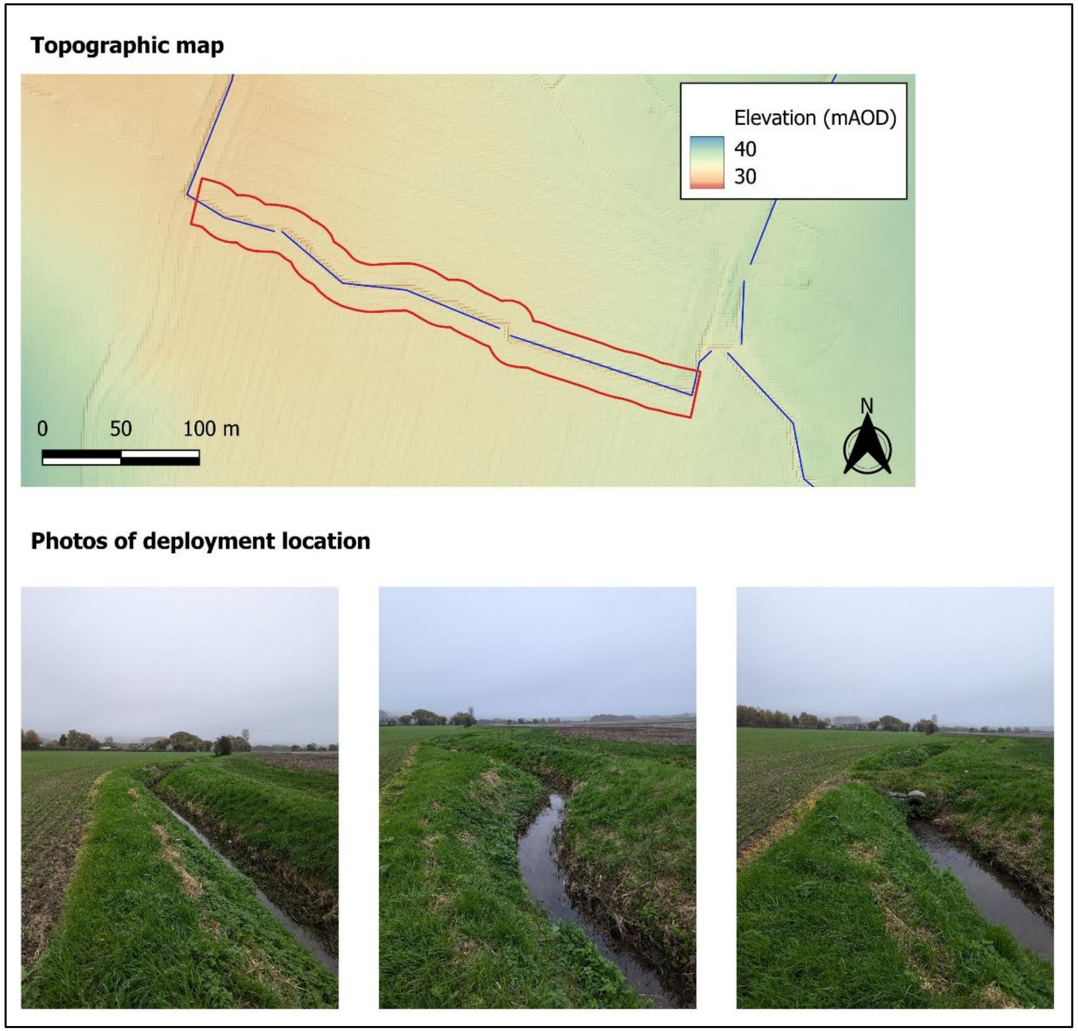


Figure 19: Showing a topographic map and photos showing the character of the channel at the Wye_DD1 deployment location. The redline area shows the outline for where the scheme will be deployed.

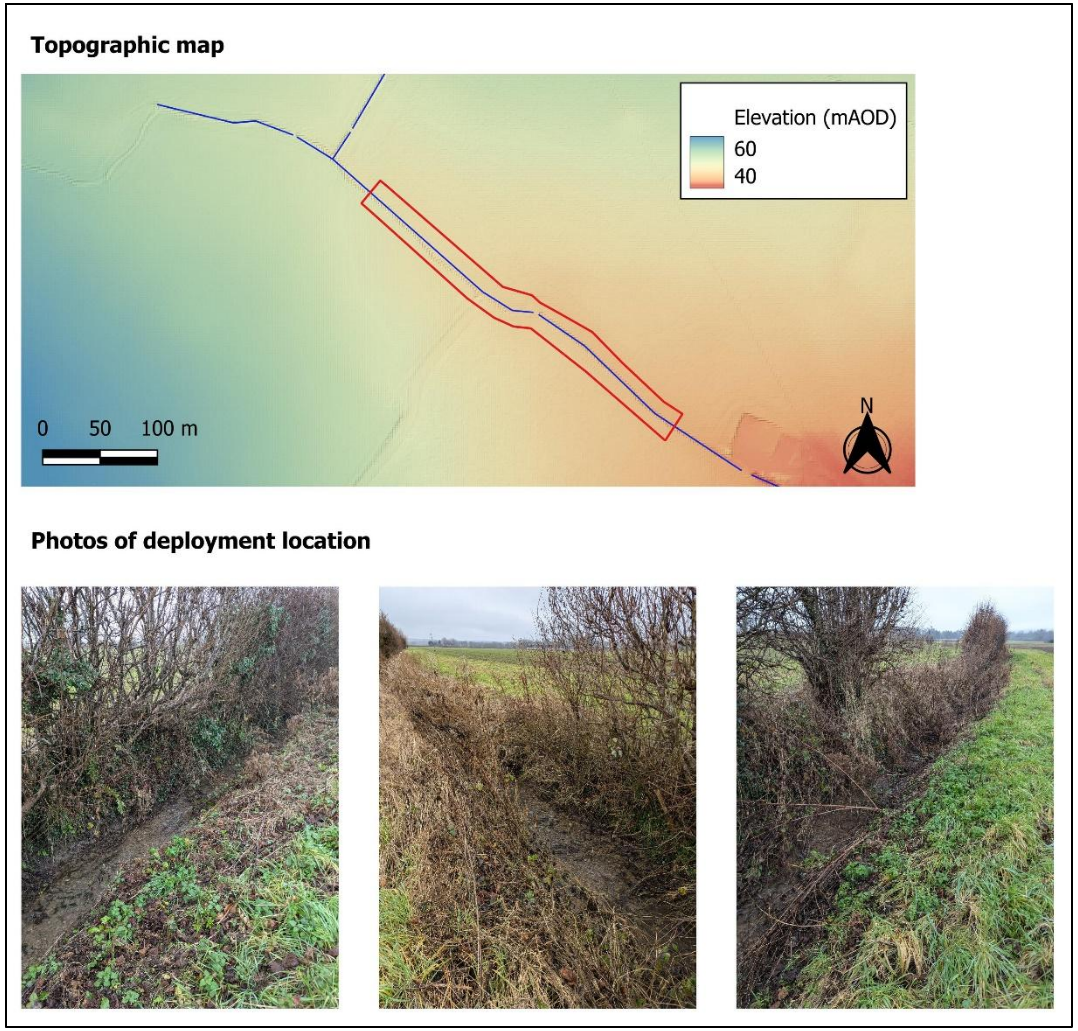


Figure 20: Showing a topographic map and photos showing the character of the channel at the Wilmington_DD1 deployment location. The redline area shows the outline for where the scheme will be deployed.

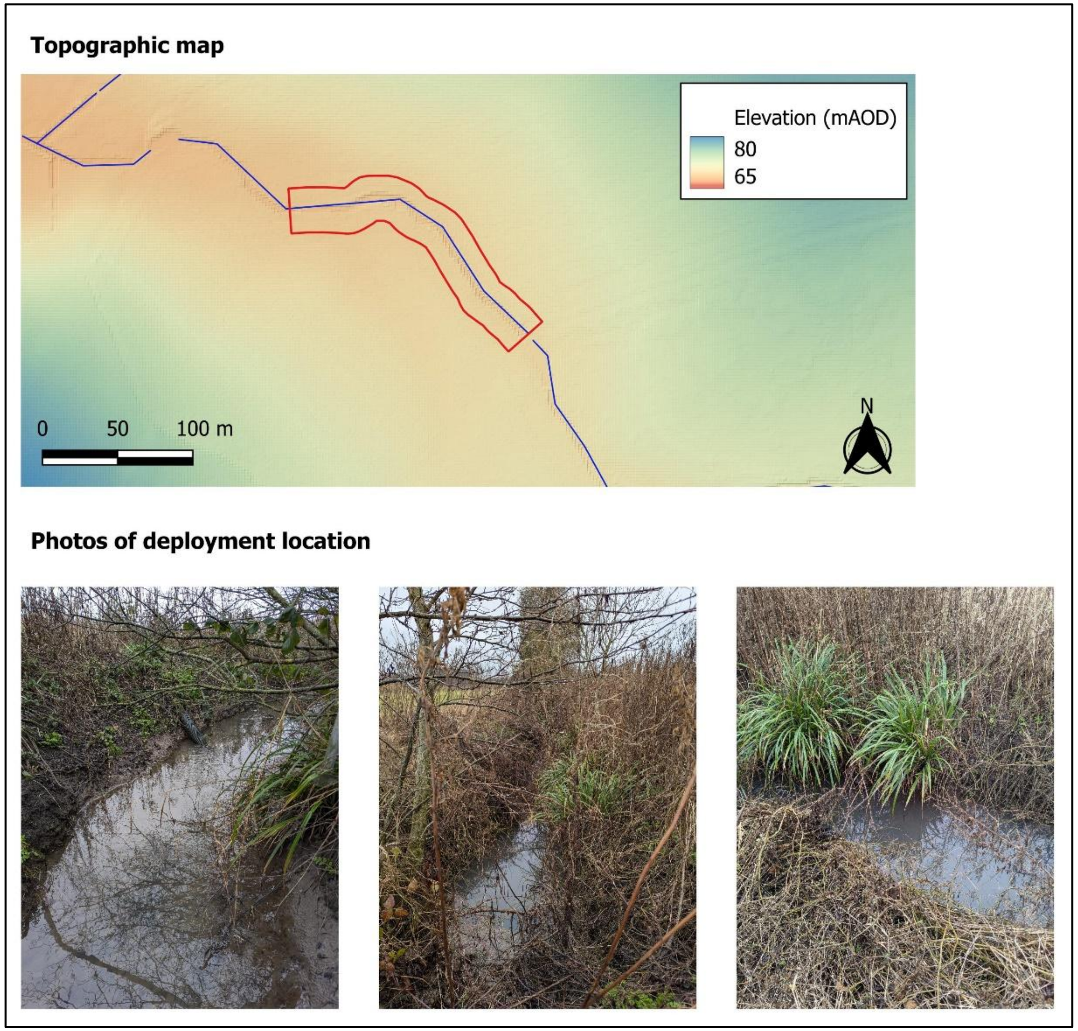


Figure 21: Showing a topographic map and photos showing the character of the channel at the South_hill_DD1 deployment location. The redline area shows the outline for where the scheme will be deployed.

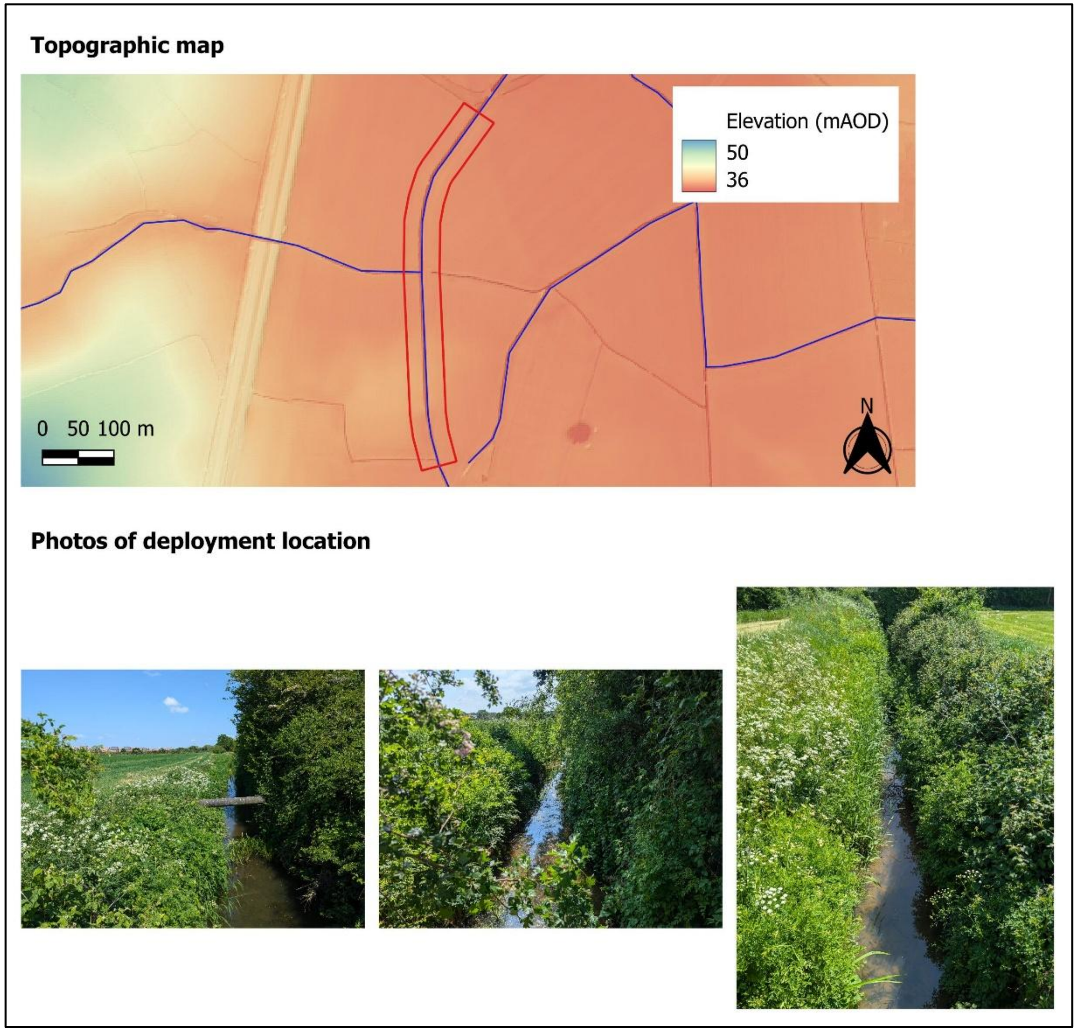


Figure 22: Showing a topographic map and photos showing the character of the channel at the Bliby_wood_DD1 deployment location. The redline area shows the outline for where the scheme will be deployed.

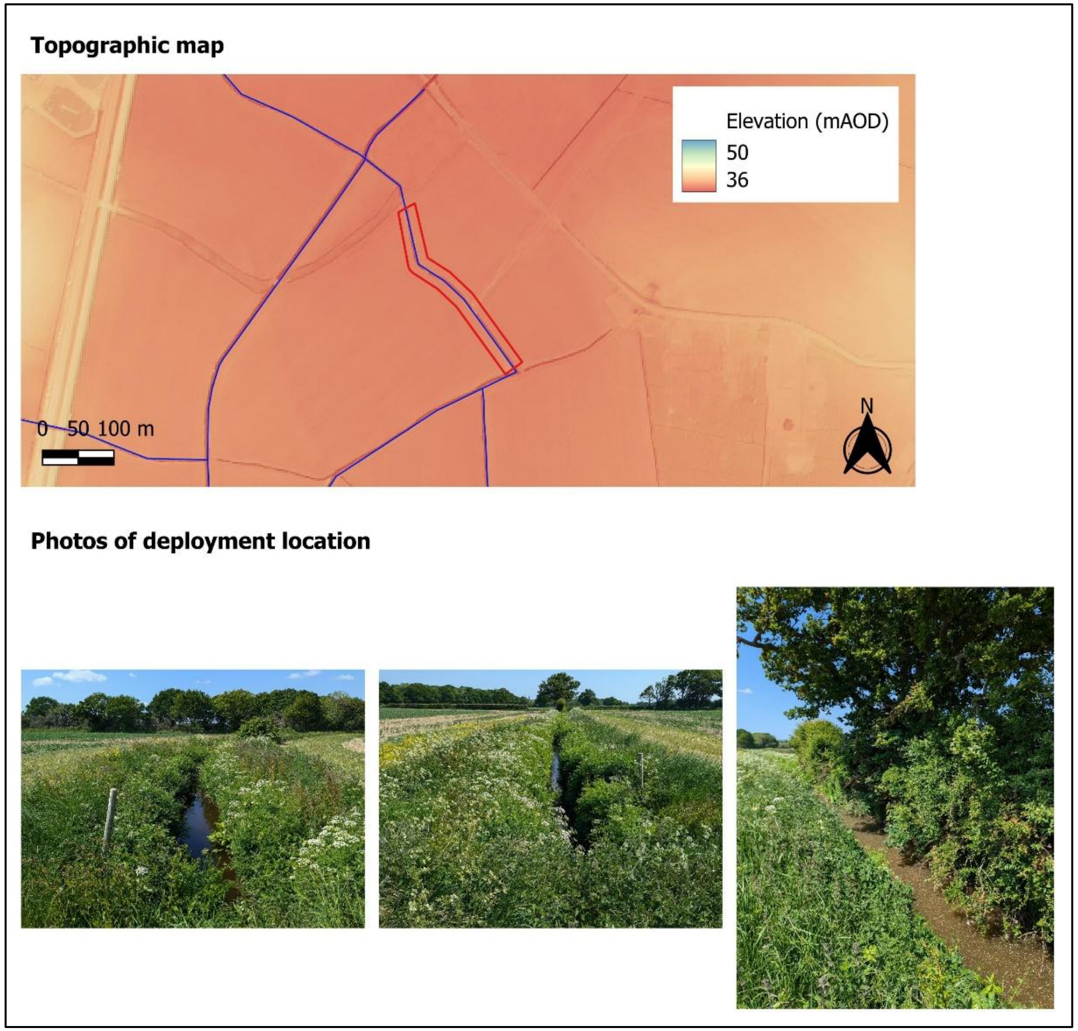
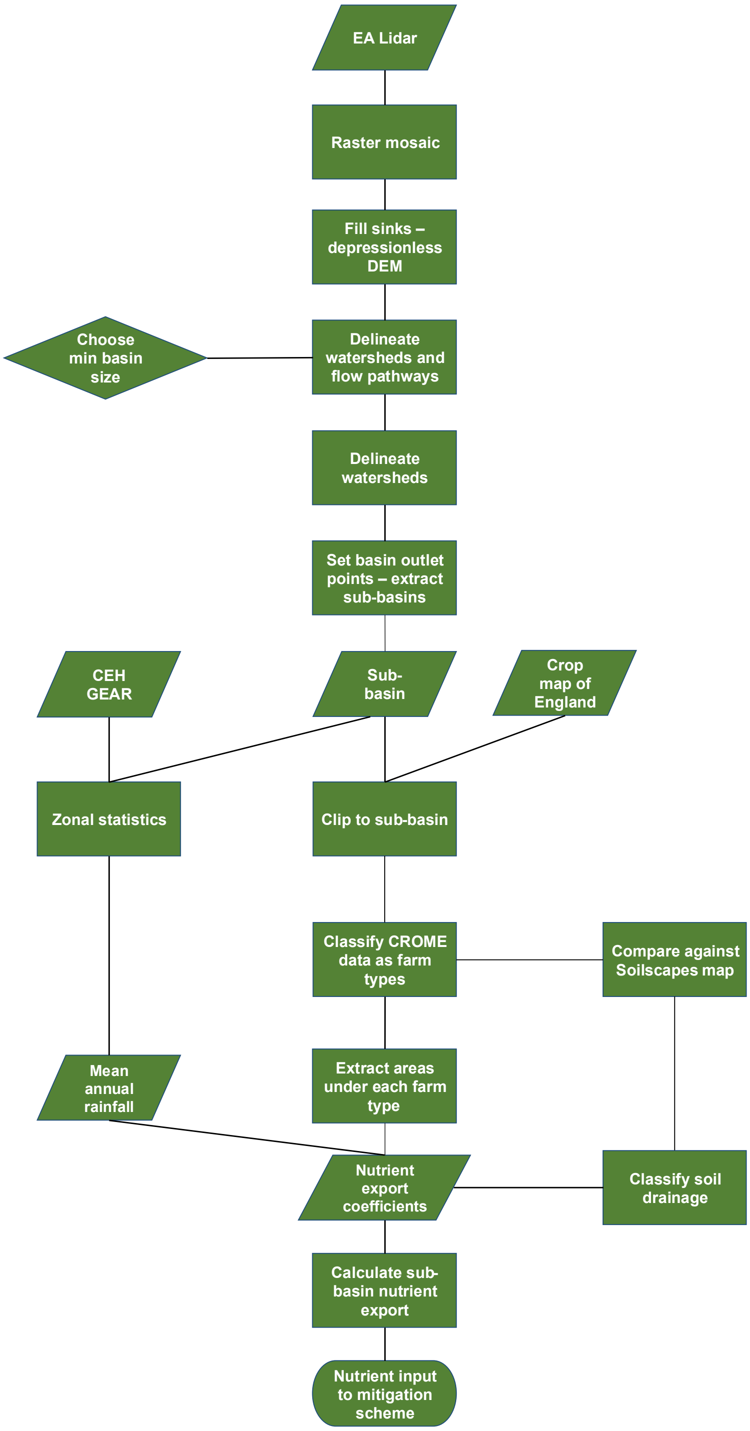


Figure 23: Showing a topographic map and photos showing the character of the channel at the Bliby_wood_DD2 deployment location. The redline area shows the outline for where the scheme will be deployed.

Appendix A4

Flow diagram showing the data inputs and processing steps used to determine nutrient inputs each mitigation option.



Appendix A5

RPA CROME land use codes and descriptions.

Land Cover Description	LUCODE	Land Use Description
Cereal Crops	AC01	Spring Barley
	AC03	Beet
	AC04	Borage
	AC05	Buckwheat
	AC06	Canary Seed
	AC07	Carrot
	AC09	Chicory
	AC10	Daffodil
	AC14	Hemp
	AC15	Lettuce
	AC16	Spring Linseed
	AC17	Maize
	AC18	Millet
	AC19	Spring Oats
	AC20	Onions
	AC22	Parsley
	AC23	Parsnips
	AC24	Spring Rye
	AC26	Spinach
	AC27	Strawberry
	AC30	Spring Triticale
	AC32	Spring Wheat
	AC34	Spring Cabbage
	AC35	Turnip
	AC36	Spring Oilseed
	AC37	Brown Mustard
	AC38	Mustard
	AC41	Radish
	AC44	Potato
	AC45	Tomato
	AC50	Squash

Land Cover Description	**LUCODE**	**Land Use Description**
	AC52	Siam Pumpkin
	AC58	Mixed Crop-Group 1
	AC59	Mixed Crop-Group 2
	AC60	Mixed Crop-Group 3
	AC61	Mixed Crop-Group 4
	AC62	Mixed Crop-Group 5
	AC63	Winter Barley
	AC64	Winter Linseed
	AC65	Winter Oats
	AC66	Winter Wheat
	AC67	Winter Oilseed
	AC68	Winter Rye
	AC69	Winter Triticale
	AC70	Winter Cabbage
	AC71	Coriander
	AC72	Corn gromwell
	AC74	Phacelia
	AC81	Poppy
	AC88	Sunflower
	AC90	Gladioli
	AC92	Sorghum
	AC94	Sweet William
	AC100	Italian Ryegrass
	CA02	Cover Crop
Leguminous Crops	LG01	Chickpea
	LG02	Fenugreek
	LG03	Spring Field beans
	LG04	Green Beans
	LG06	Lupins
	LG07	Spring Peas
	LG09	Cowpea
	LG08	Soya
	LG11	Lucerne
	LG13	Sainfoin

Land Cover Description	LUCODE	Land Use Description
	LG14	Clover
	LG15	Mixed Crops–Group 1 Leguminous
	LG16	Mixed Crops–Group 2 Leguminous
	LG20	Winter Field beans
	LG21	Winter Peas
Energy Crop	SR01	Short Rotation Coppice
Grassland	FA01	Fallow Land
	HE02	Heathland and Bracken
	PG01	Grass
Non–Agricultural Land	NA01	Non-vegetated or sparsely vegetated Land
Water	WA00	Water
Trees	TC01	Perennial Crops and Isolated Trees
	NU01	Nursery Crops
	WO12	Trees and Scrubs, short Woody plants, hedgerows
Unknown Vegetation Or Mixed Vegetation	AC00	Unknown or Mixed Vegetation

Appendix A6

A6. References

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