

Wombwell Wetlands Extension: Outline design and modelling

Final Report

March 2016

The Garganey Trust

JBA Project Manager

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Revision History

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DRAFT2 October 2015	Added design sections	Jeff Lunn
FINAL November 2015	Additional quote,	Jeff Lunn
FINALv2 March 2016	Additional hydrology and subsequent changes,	Jeff Lunn

Contract

This report describes work commissioned by Jeff Lunn, on behalf of the Garganey Trust, by an email dated 21-1-15. The Garganey Trust’s representative for the contract was Jeff Lunn. David Mould, Mark Tywang, Alex Craven, Laura Thomas and Chris Dale of JBA Consulting carried out this work.

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Purpose

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Acknowledgements

JBA gratefully acknowledge the helpful contributions of Jeff Lunn throughout this project. Thanks also to Ash Hussain (Environment Agency) and Derek Bell (Barnsley Metropolitan Borough Council) for their guidance and the provision of datasets.

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Executive Summary

The Garganey Trust is proposing to create some new wetland habitats on existing agricultural land adjacent to Bulling Dike between Wombwell Ings and Broomhill Flash in the Dearne Valley, South Yorkshire. The Environment Agency may be able to contribute funding towards the project, if the proposed works also provide a flood risk benefit. Therefore, JBA have been appointed by the Trust to undertake a study to progress the proposal. The key project objectives are:

- Review the understanding of existing flood risk in the study area
- Determine how the proposed wetland creation scheme might alter the local flood risk
- Provide an outline design and preliminary costs for the approval and construction of the proposed wetland creation scheme

Initial analysis of the hydraulic model and the hydraulics of the study area showed that the key receptor, which would most likely be influenced by the construction of the proposed wetland scheme is a Caravan Site located to the north of Bulling Dike. The Caravan Site currently floods at the 25-year return period and higher. Hydraulic modelling showed that by redirecting Bulling Dike away from the Caravan Site, combined with the construction of an earth bund, the Caravan Site could be protected from fluvial flood events up to and including the 100-year return period event.

The proposed wetland constructed on the right hand floodplain of Bulling Dike contains both reed bed and wet grassland habitats and would be fed by two sources of water. The wet grassland is fed by overflow from Broomhill Flash (controlled by the Garganey Trust). A water balance analysis showed that the wet grassland area is likely to be in water deficit from May to August in most years. The current management of Broomhill flash involves building up and holding a high water level through the winter, before lowering the water level in the spring. This stored water will therefore, be used to feed the wet grassland area through the summer months.

Any excess water from the wet grassland area will be fed into a reed bed area (via a stop log structure, which can be used to control levels in the wet grassland area). The reed bed can also be fed by water from Bulling Dike, and has an overflow structure to allow water to spill out of the reed bed back into Bulling Dike. Stop log structures will be used to provide a simple, robust method of water level control in both the reed bed and the wet grassland area. The proposed reed bed will have significant variations in water depth (1m to dry), to encourage a diverse and distinctive variety of habitats and associated species.

The proposed scheme has been costed at £237k (costs provided by a contractor for the client).

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Abbreviations

EA	Environment Agency
JBA	Jeremy Benn Associates Consulting Ltd
LIDAR	Light Detection and Ranging
FEH	Flood Estimation Handbook

1 Introduction

1.1 Background and project objectives

The Garganey Trust is proposing to create some new wetland habitats on existing agricultural land adjacent to Bulling Dike between Wombwell Ings and Broomhill Flash in the Dearne Valley, South Yorkshire (Figure 1-1). The Environment Agency may be able to contribute funding towards to project, if the proposed works also provide a flood risk benefit. Therefore, JBA have been appointed by the Trust to undertake a study to progress the proposal.

The key project objectives are:

- Review the understanding of existing flood risk in the study area
- Determine how the proposed wetland creation scheme might alter the local flood risk
- Provide an outline design and preliminary costs for the approval and construction of the proposed wetland creation scheme

Figure 1-1: Site location plan



1.2 Data used

The following data have been used:

- "Do Minimum" baseline model provided by the Environment Agency (last updated by JBA in 2009)
- JBA (with Jacobs) 2009 hydraulic modelling report
- JBA 2011 options testing report
- 1m LIDAR data from EA Geomatics (flown 2nd/3rd December 2014)
- Sketches by Jeff Lunn showing the proposed layout of the scheme.
- National Receptor Dataset (NRD) (obtained from EA Geostore)
- Mapping data, obtained from EA Geostore.
- Envirocheck report.

1.3 Report structure

This report has been split into a number of sections. It is intended as a digestible front-end behind which is a number of technical Appendices sit, which contain full details of the work undertaken.

Chapter 2	Introduces the key flood mechanisms in operation in the vicinity of the proposed wetland, and the key receptors in the area.
Chapter 3	Provides a geo-environmental context for the study site, outlining the constraints and opportunities for the restoration.
Chapter 4	Outlines the proposed designs and gives the rationale behind the design decisions made.
Chapter 5	Summarises the modelling methodology, and the broad assumptions behind the modelling work.
Chapter 6	Shows and discusses the model results, showing the flood risk benefits offered by the scheme.
Chapter 7	Discusses the limitations of the modelling approach used.
Chapter 8	More detail is provided on the proposed planting regime for the proposed wetland, related to proposed water depths and the ongoing maintenance required for the site.
Chapter 9	Provides a summary and recommendations.

2 Flood mechanisms

This section firstly describes the key flooding mechanisms in the area, outlining a description of the key areas at flood risk and how and why they flood.

2.1 Dearne valley

Both Bulling Dike and the River Dove, flow predominantly from West to East before meeting up with the River Dearne. The Dearne has extensive washlands in the valley, including Wombwell Ings, which are located between the River Dove and the Bulling Dike, but water levels in Wombwell Ings have no impact on water levels in the Dove and Bulling Dike, as they are not hydraulically connected.

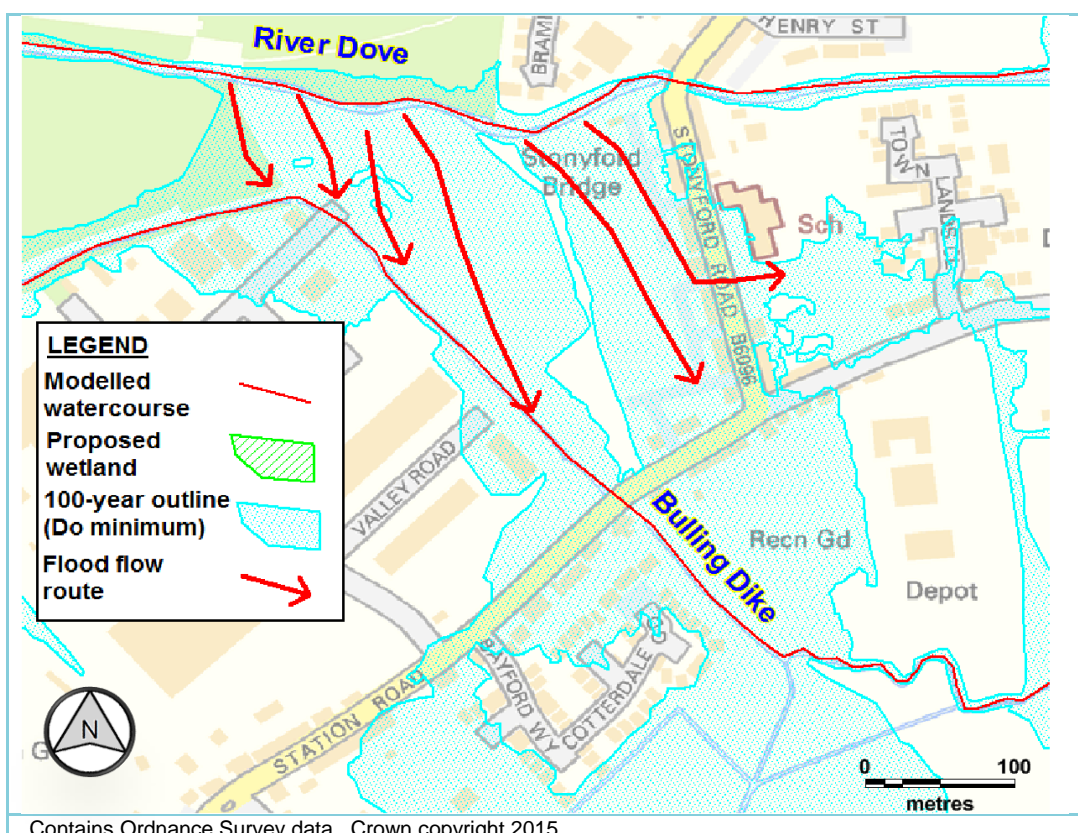
The Dearne will, however, have some influence on water levels on the Dove and Bulling Dike by controlling water levels at the confluence of the rivers. This influence will be localised, and will not impact upon flood mechanisms in the Dove and Bulling Dike.

2.2 Flood mechanisms

There are several key flooding mechanisms that are summarised in the following:

- River Dove - Upstream of the Stonyford Bridge "dogleg". Water overtops the right bank and spills into the Old works/ development site near Valley Road industrial estate (Figure 2-1) and flows south draining into Bulling Dike increasing the water levels, flow and flood risk to properties in the former industrial estate.

Figure 2-1: Old works/ development site and Stonyford Bridge "dogleg" spill points and flow routes to Bulling Dike (2009 flood mapping)



- River Dove - The Stonyford Bridge "dogleg" (see photographs 1 and 2 below). Water overtops the right bank to the rear of the properties on Stonyford Road and then floods the properties from the rear. Once out-of-bank flood waters spread south and east flooding properties on Station Road, the other side of Stonyford Road and along Ings Lane. Finally floodwater flows south from Ings Lane towards the waste water treatment works (WWTW) and into Bulling Dike.

Figure 2-2: Stonyford Bridge photographs

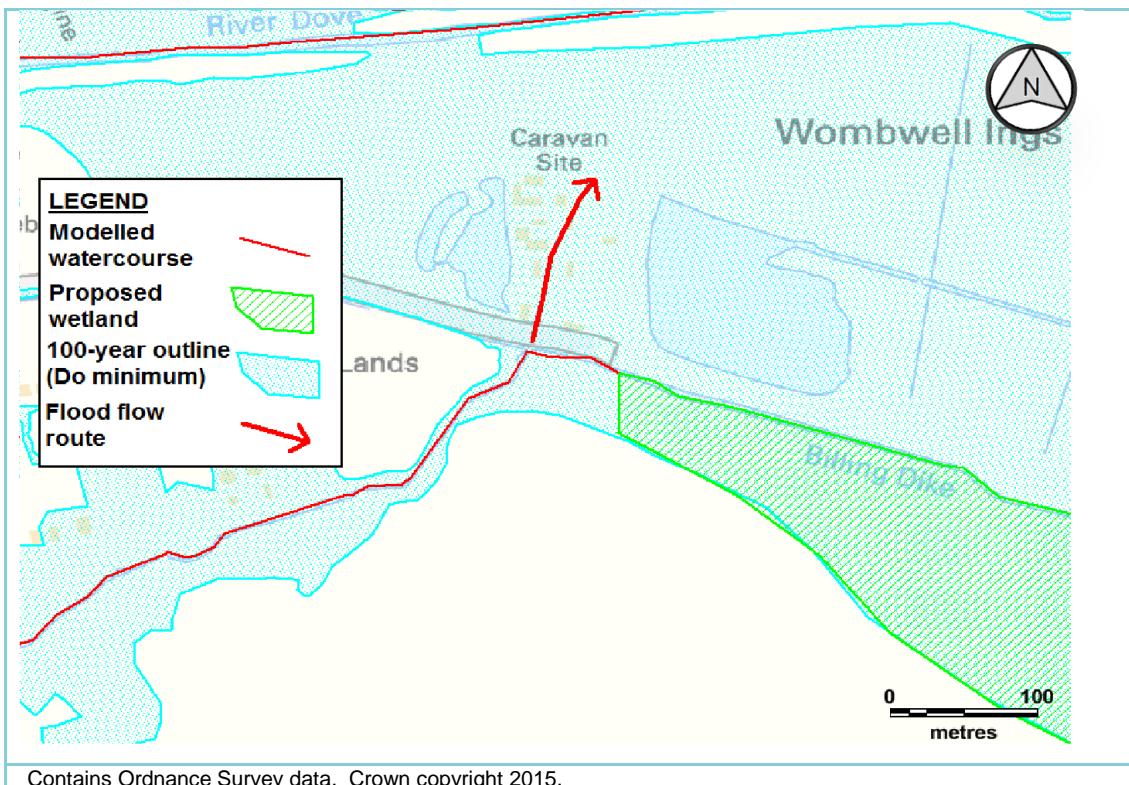


- River Dove - Aldham Bridge. Overtopping of the left bank downstream of Wombwell Lane at Aldham Bridge, industrial units on Wombwell Lane effected.

The transfer of floodwater from the River Dove into Bulling Dike causes significant overtopping and flooding of properties in several areas along Bulling Dike's reach. The two key pinch points are:

- Bulling Dike - Station Road Bridge. The bridge becomes overwhelmed during large flood events. The structure overtops and floodwater inundates sections of the Cotterdale Gardens housing estate.
- Bulling Dike - "Dogleg" adjacent to Caravan Site. The large flows within Bulling Dike, associated to the upstream transfer of flood waters from the River Dove, results in significant overtopping of the left bank of Bulling Dike, adjacent to the Darfield Caravan Site, located at the eastern end of Ings Lane. This causes significant flooding to properties within the Caravan Site (Figure 2-3).

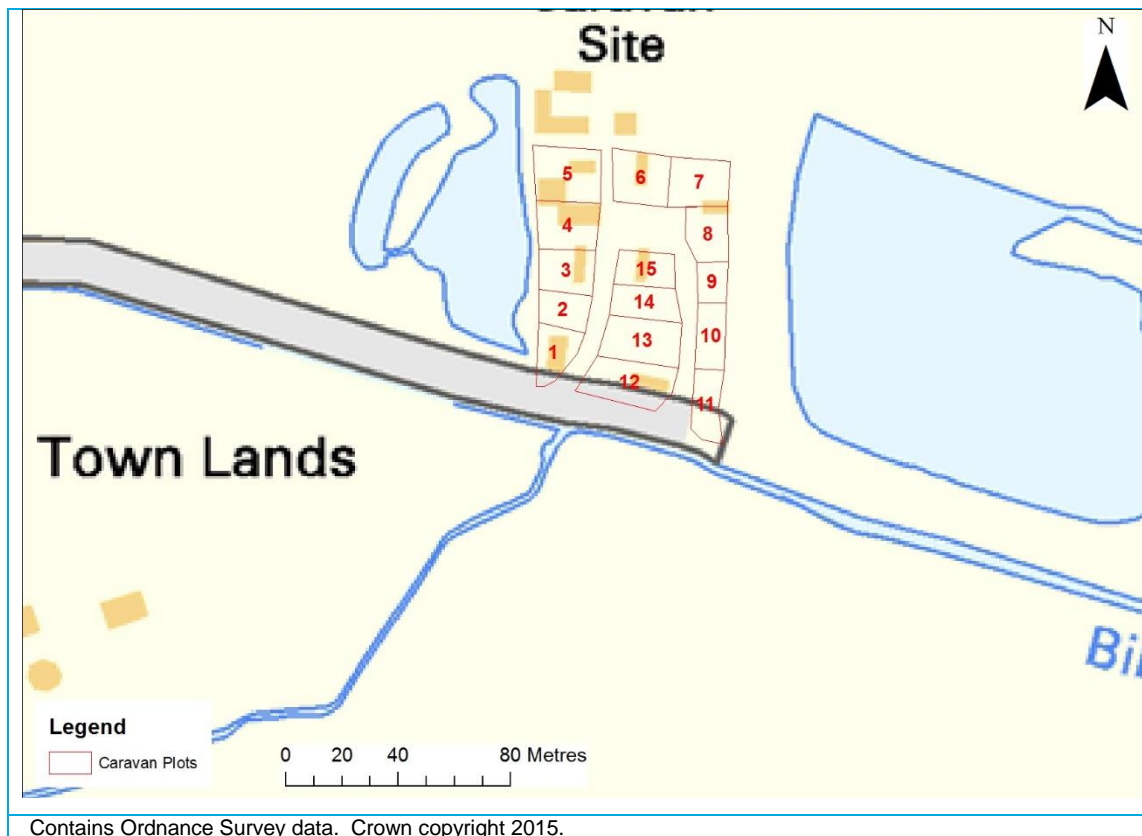
Figure 2-3: Flood routes into Ings Lane Caravan Site (2009 flood mapping)



2.3 Key receptors

The key receptors, which could be impacted upon by the proposed scheme is the Caravan Site located on the left hand bank of Bulling Dike. A property survey undertaken by Pete Wall (Yorkshire Wildlife Trust) on the 13th July 2015, showed that the site had 15 plots often with numerous caravans or buildings on each plot. The details of the survey can be found in Appendix C.

Figure 2-4: Location of caravan plots



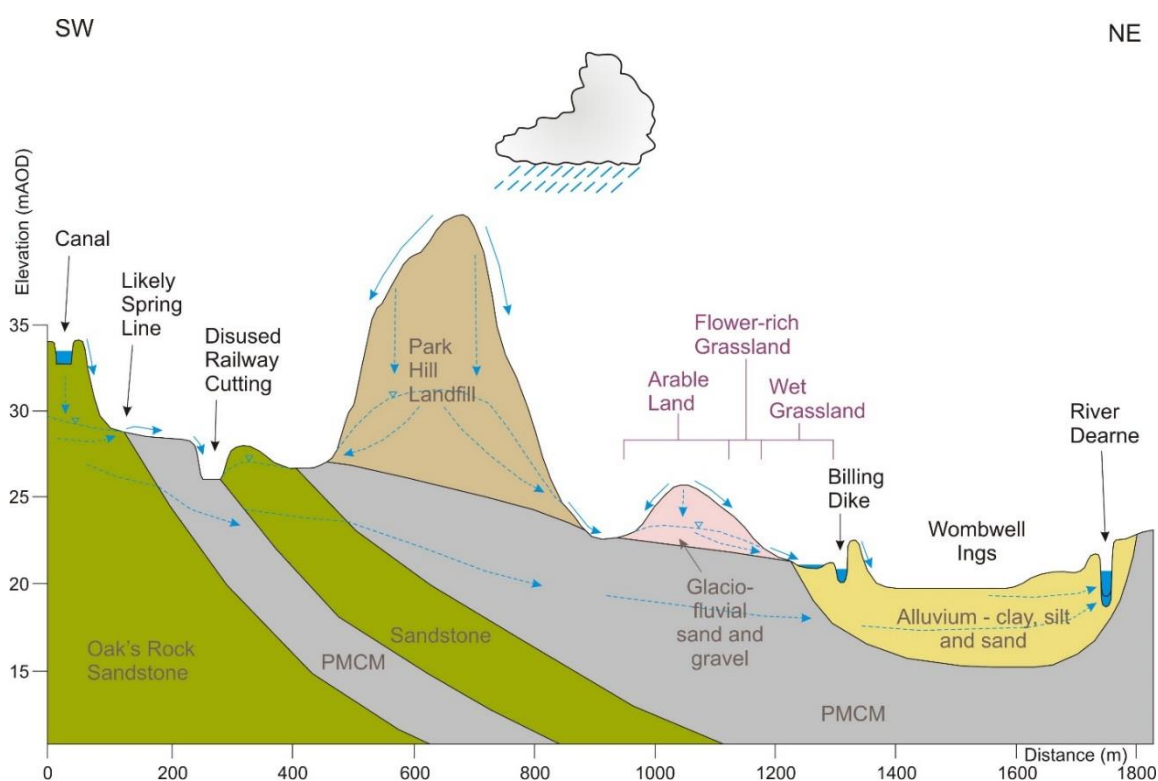
3 Geo-environmental context

This chapter summarises the geological and hydrogeological setting of the site, the environmental (contamination related) risks associated with the proposed development, and the potential water supplies for the site. Further information is available in the full Phase 1 geo-Environmental Desk Study, which is provided as Appendix A.

3.1 Conceptual understanding of the site

A hydrogeological model has been prepared for the site at Wombwell and is presented in Figure 3-1. The conceptual model summarises our understanding of the functioning of the groundwater system, together with its connections to the surface water and river systems.

Figure 3-1: Hydrogeological conceptual model of the site



The main features of the conceptual model are as follows:

- Bulling Dike constitutes the northern boundary of the site, discharging to the River Dearne downstream of the site.
- The bedrock underneath the site belongs to the Pennine Middle Coal Measures Formation (PMCM) which predominantly comprises interbedded mudstone, siltstone, sandstone and commonly coal seams.
- It is proposed to create areas of open water, wet grassland, flower rich grassland, and to retain some of the arable land on site.
- The area in the northern of the site where it is proposed to create areas of open water and flower rich grassland are predominantly underlain by alluvial deposits in which silt and clay dominate.
- The higher arable land on-site is an area of outcropping glaciofluvial deposits predominantly comprising sand and gravel.
- The superficial and bedrock deposits are all regarded as Secondary A aquifers by the Environment Agency:

- The alluvial deposits will typically be lower permeability with groundwater dominating in the more permeable horizons.
- The outcropping glaciofluvial deposits will act as a lower groundwater recharge mound, with their potentially being a seepage face at the base of the deposits where they intersect with the alluvium.
- Groundwater within the PMCM will largely be contained within fractures and fissures
- To the southwest of the site there is a potential spring line where the Oak's Rock Sandstone Member outcrops.
- Park Hill landfill site also lies to the southwest of the site and is an area of groundwater recharge.

3.2 Summary of site constraints

In order to identify any potential constraints to undertaking habitat creation works at Wombwell a series of desk-based assessments were undertaken/ commissioned to collate available data and identify any significant risks to delivery of a project. Areas of consideration included:

- Contaminated land
- Services / Utilities
- Coal Mining
- Geology and hydrogeology
- Obtaining a water supply for the wetland

This section provides a brief summary of the key site constraints that have been identified.

3.2.1 Contaminated Land

Although the general contamination risk to the site is regarded as low, a number of potentially contaminative activities have been identified in close proximity to the site which pose a moderate risk of contamination to the site. In order to fully understand the risks to the site it is recommended that a site investigation incorporating sampling and contamination testing of both soils and water samples be undertaken.

3.2.2 Services / Utilities

A premium utilities search which involved contacting all asset owners was undertaken by Centara in June 2015. The search covered the entire footprint of the proposed Wombwell Wetland, and the utilities identified are indicated in Figure 3-2.

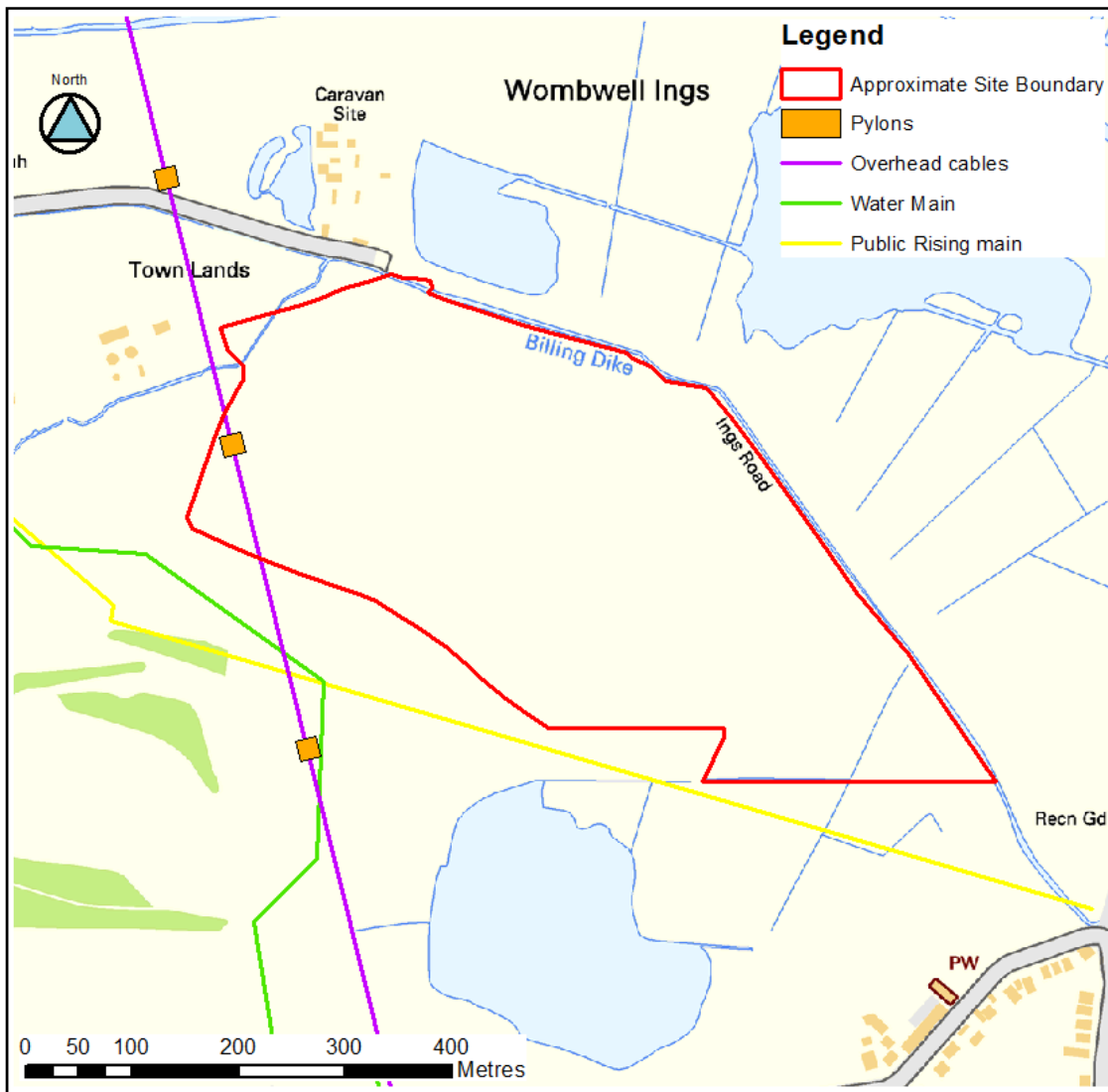
There is one pylon located on site with associated overhead lines running broadly northwest to southeast in the west of the site. Though indicated on services plans and OS mapping, the power lines are not indicated as being live. It is uncertain therefore whether the pylon and associated lines are or are not currently in use, but care should be taken in this area regardless, particularly when undertaken works on site with tall machinery such as a drilling rig. There is a water main and public rising main associated with Wombwell WWTW which pass near to the site but do not cross it.

3.2.3 Coal Mining

Records held by the Coal Authority do not suggest that the site (and the immediately surrounding area) has been affected by shallow coal mine workings, nor are any historical mine entries indicated on site. However there is much evidence of historical coal workings in the wider locality, and Broomhill Flash, located to the south of the site is believed to have formed as a result of mining related subsidence.

Any historical coal workings underlying the site are unlikely to pose a constraint to the works as the proposed works for wetland creation will involve shallow earth-working. Proposed excavations are not anticipated to extend below the layer of drift deposits. If future phases of development involve the construction of structures or significant earthworks, e.g. creation of deeper voids to retain water) then a site specific investigation should be carried out to evaluate any potential risks posed by former mine workings.

Figure 3-2: Utilities



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3.2.4 Geology and hydrogeology

It is envisaged that it will be possible to create pools of water on site as the overlying alluvial deposits are believed to be of relatively low permeability, and will support perched water sitting within them.

The current wetland design also proposes pools of open water within the glaciofluvial deposits. These deposits are likely to have a higher permeability and it is unlikely that they will support perched water in a similar way to the alluvial deposits. The ability of the glaciofluvial deposits to support pools of open water will largely depend on the groundwater level within the deposits. It is unlikely that pools in contact with the glaciofluvial deposits will be able to support a water level higher than the groundwater level within the surrounding deposits, without a low permeability liner. Should attempts be made to raise the water level within pools higher than the surrounding groundwater level this water would likely be lost to ground.

In order to fully understand the constraints associated with the geological and hydrogeological setting of the site, it is proposed that an intrusive ground investigation be undertaken. This would likely comprise the undertaking of trial pitting and the installation of a number of groundwater monitoring boreholes. The aims of the site investigation would be to confirm:

- The permeability of the alluvial and glaciofluvial deposits,
- The thickness of the alluvial and glaciofluvial deposits,
- The extent of the alluvial and glaciofluvial deposits,

- The groundwater table within the alluvial and glaciofluvial deposits (monitoring over a complete year would be ideal).

This ground investigation should include contamination sampling and testing as discussed earlier.

3.2.5 Water Supply

In order for the proposed wetland to be sustainable a suitable water supply must be secured. There are plans to divert water onto site from Bulling Dike and from the outfall from Broomhill Flash. The quantities of water that will be obtainable from these sources are not fully understood.

Water levels across Broomhill Flash are managed via a sluice situated on Main Drain. Water will only be available for Wombwell Wetland from this source when there is an excess of water once water level targets across the flash have been met. The fact that the inflows to Broomhill Flash are not fully understood, coupled with the fact that it is unclear quite how much water normally leaves the Broomhill Flash system, means it has not been possible to determine quite how much water is available from this source. However, evidence suggests that water will occasionally be available. Installing a new water level management structure on the outfall from Broomhill Flash will maximise the amount of water available for the new wetland. Comparing the volumes of water to be released from the flash during the implementation of the WLMP, to the volumes of water stored within the wet grassland scrapes and reed bed area, it appears that there should be plenty of water available for the filling or topping up of the open water areas.

The natural flows in Bulling Dike generally appear to be low. It will not be possible to divert all of the flow from Bulling Dike towards the new wetland as some flow will need to remain within the watercourse. During the summer months when flows within the watercourse will be lowest it seems likely that there will be little or no water available for input to the wetland.

During periods when there are no external inputs of water to the wetland, that is to say no water is available from either Broomhill Flash or Bulling Dike, and evaporative losses exceed direct recharge and runoff inputs to the wetland, the wetland will to some degree dry out. However, if the pools and scrapes are topped up during the winter months and are relatively full at the onset of the warmer months, they will most likely be able to survive into the summer though the areas of open water will gradually reduce in size. For wading birds it is important that some areas of open water with wetted margins remain until mid-June in most years.

4 Outline design

The design of the scheme and the modelling were undertaken concurrently and information fed into the outline design from the modelling, for the purposes of ease of reading the outline design is presented before the modelling chapters. The design drawings can be found in Appendix B, and proposed planting details are outlined in Chapter 8.

4.1 Description of design

The premise for the design of the proposed wetland was to combine the creation of a large area of new wetland habitat with flood protection for the Caravan Site.

The flood protection to the Caravan Site will be formed by redirecting Bulling Dike to the north-east to cut the corner away from the Caravan Site. The new channel will replicate the existing cross section shape of Bulling Dike in the vicinity. However, due to the volume of flood flows in Bulling Dike during a flood event, the redirection of Bulling Dike alone would not provide sufficient protection to the Caravan Site. Therefore, it is proposed to construct a bund along the left hand bank of the new channel. This bund will tie into high ground near the water treatment works at the upstream end of the diversion and intersect with the existing flood embankment between Bulling Dike and Wombwell Ings at the downstream end of the new channel. The designs and construction of this join between the two bunds will need to be approved by a panel engineer as the Wombwell Wetlands is a statutory reservoir.

The embankment is positioned so that maintenance of the watercourse can be undertaken on a level bank platform with a 9m easement in place. The existing course of Bulling Dike behind the embankment will be filled in. The flood modelling shows that this embankment provides protection for the Caravan Site up to and including the 100-year return period event (Chapter 6). To offset the loss of floodplain storage on the left hand floodplain the right hand floodplain needs to be lowered particularly in the reed bed area, so as to increase storage and not increase flood risk to receptors downstream. A small area of bank lowering is also required on the right hand floodplain upstream of the proposed wetland (adjacent to WWTW) to reduce the water levels adjacent to the WWTW during flood events.

A culvert will be required to connect the Bulling Dike with the existing surface water drainage ditch to the south of the Caravan Site. The invert of this culvert will be set to the bed level of Bulling Dike, and will be flapped on the Bulling Dike side to prevent water from Bulling Dike flooding the Caravan Site during a flood event. A 600mm culvert is proposed. A rainfall analysis showed that in a 100-year rainfall event does not produce enough runoff to cause surface water flooding behind the bund, in the event of the flap being closed by a flood event in Bulling Dike (Appendix E).

As outlined in Chapter 3, the Garganey Trust act to control water levels in Broomhill Flash on a seasonal basis. This is currently undertaken using an existing sluice gate. This sluice gate will be removed and replaced with a tilting weir in a similar location. The tilting weir will provide the Garganey Trust with a simple way of controlling water levels in the Broomhill Flash, as the various control levels could be marked on the structure to simplify the control regime. The height of the adjustable weir will only need to be changed a small number of times over the year to provide the necessary water level regime for Broomhill Flash. This is an improvement on the existing system as adjustments to Broomhill Flash levels using the existing sluice gate are estimates based on the rate of flow through the orifice.

Once water levels reach the crest of the weir, any excess water will spill over the crest and into the wet grassland system. Due to the value of the water to the proposed wetland site, it is proposed to use all of the excess water from Broomhill Flash in the wet grassland system. This will require the remainder of the existing drain to the north of the existing sluice to be filled in, as the water will be required for the wet grassland and the filled in drain will ease riparian access for maintenance and cattle. This current drain is short in length (60m) of low hydromorphic diversity and is disconnected from Bulling Dike and so is considered reasonable to infill in the context of the wider flood risk and biodiversity gains of the project.

The wet grassland features will be constructed using the RSPB's rotary ditcher (or similar). The existing floodplain of the wet grassland area is largely around 21.5mAOD with some variation. Firstly the existing floodplain will need to be smoothed to ensure a constant (very shallow) gradient in the scrapes. The scrapes will typically have a depth of 0.3m and a top width of 5m, and will gradually slope from east to west, leading to shallow water depths of between 0 and 0.3m. The scrapes will converge on a stop log structure set into a shallow bund. The purpose of the shallow

bund is to provide a barrier between the wet grassland and the reed bed and provide appropriate ground levels for the stop log structure to sit within. The stop log structure, with an invert level of 20mAOD, with the ability to add a number of stop logs to simply control water levels within the wet grassland. If high water levels are required in the wet grassland, stop logs can be added to create a backwater, whilst conversely when lower water levels are required in the wet grassland (e.g. to increase the livestock grazing area later in the summer), logs can be removed from the structure.

Any excess water in the wet grassland system will spill over the stop logs at the required level and spill into the reed bed. The reed bed can also be fed directly from the Bulling Dike whenever flows permit. Analysis of Bulling Dike water levels in the proposed restoration showed that water levels would be around 20.3mAOD under flows of Q95 (i.e. flows exceeded 95% of the time), with water levels largely lower than 21mAOD under non-flood flows. The proposed reed bed will have minimum bed levels of 20.0mAOD, however significant variation in bed levels will be encouraged under the design water level (of around 21mAOD) to encourage diversity of plant species in the reed bed. Two structures are proposed to control water levels in the reed bed:

- On the right hand bank on the 'new cut' of Bulling Dike a flapped culvert will allow the reed bed to be topped up in times of high stage on Bulling Dike (when water level in Bulling Dike exceeds that in the reed bed). At times of low stage, the flap valve will act to stop water flowing back into Bulling Dike as water levels in the reed bed will be higher than those in Bulling Dike.
- On the right hand bank of Bulling Dike near the wet grassland. This structure will control the outflow from the reed bed. An invert level of 20mAOD will ensure that the reed bed could be drained for maintenance (if not fully at least to the level of water in Bulling Dike, which is likely to be around 20.3mAOD)

4.2 WFD Benefits of proposed scheme

The reach of Bulling Dike adjacent to the proposed wetland (GB104027057510) is classified as being of poor potential under the Water Framework Directive (WFD), with poor ecological status and classified as Heavily Modified for Hydromorphology. The Water Framework benefits of the proposed scheme are outlined in Table 4-1.

Table 4-1: Water Framework Directive improvements generated by the proposed scheme

OM4 habitat	The scheme will provide 8Ha of water dependent OM4 habitat. This habitat is diverse, providing both a reed bed habitat with a variety of depths and plant species and shallow wet grassland. This scheme would be a significant and complementary addition to biodiversity and in particular Water Framework directive appropriate habitats in the Dearne valley and will support a wide range of aquatic and bird life.
Fish Passage	We propose to add Berry and Escott Eel files to the face of the two stop log structures adjacent to Bulling Dike. This low cost solution should allow juvenile Eels (<i>Anguilla anguilla</i>) to access the reed bed area. The mixture of shallow and deep water and the cover provided by the reeds would provide suitable habitat for the adult Eel to mature, before re-entering Bulling Dike. This additional habitat, distinct and diverse from IDB maintained channels, has the potential to improve Eel populations in the Dearne and so improve the Bulling Dike and the Dearne Water Framework Directive classification.
Water Quality	Although the stretch of Bulling Dike is classified as good, the water quality of any water which enters the reed bed from Bulling Dike at the west of the proposed site has the potential to be improved, as it would be filtered through the slow flowing reed bed area, before re-entering Bulling Dike. This could lead to improvements in the water quality of Bulling Dike.

4.3 Access & maintenance considerations

Figure 4-1 shows the proposed access routes for livestock and maintenance purposes. The east of the site can be accessed by crossing the infilled drain, whilst the western reed bed area can be accessed from the existing field. The culvert which will be used to abstract water from Bulling Dike will allow for vehicle and livestock movement over the top of the culvert to access the area between the reed bed and Bulling Dike. Where possible ditches and existing watercourses will be used as wet fences, but fencing will be used elsewhere to separate the scheme and grazing areas from the nearby, arable areas.

Figure 4-1: Access routes

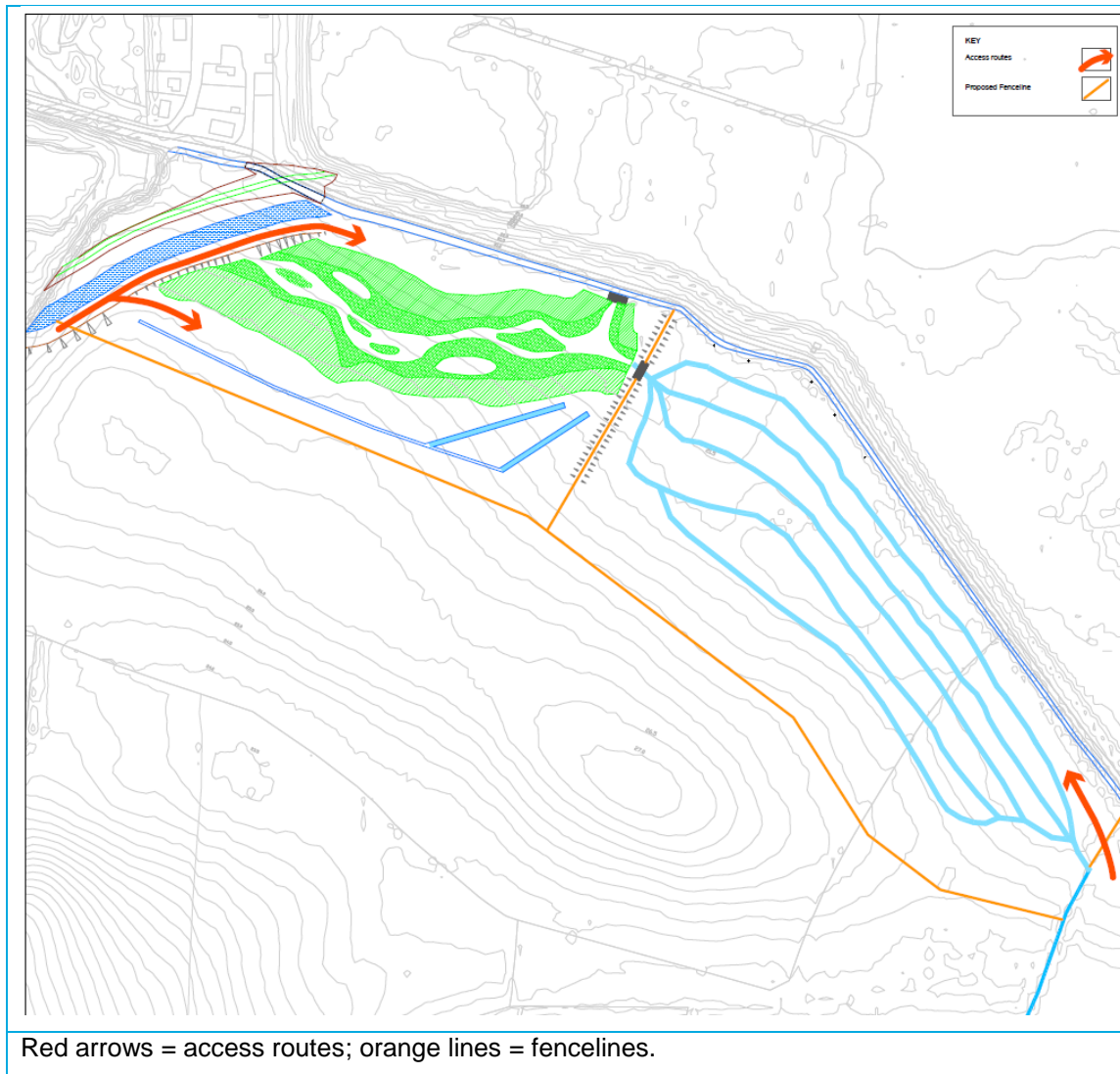


Table 4-2 outlines the maintenance responsibilities for key aspects of the proposed scheme.

Table 4-2: Maintenance responsibilities

Flood Bund	It is assumed that the flood bund will be adopted by the EA as the proposed bund links in with the existing flood bund between Bulling Dike and Wombwell Ings.
New reach	Adopted by the Danvm IDB.
Other infrastructure	All other infrastructure associated with the proposed wetland will be maintained by the Garganey Trust.

4.4 Outline costs

A quote was sourced by the client (Garganey Trust) from a contractor with extensive experience of constructing wet grassland habitat. The cost of the works were estimated at, £237,194, broken down as in Table 4-3. Our client has stipulated that no contingency should be included in this cost.

An alternative quote was provided by a different contractor and can be found in Appendix G.

Excavation volume were calculated by comparing the existing levels of the site (as per LIDAR data), with the bed levels proposed by the scheme. Net removal of 25,320m³ is required for the wet grassland area, net removal of 62,205m³ is required to create the reed bed area with the shallow margins, and net removal of 5,900m³ is required on the right hand floodplain adjacent to the WWTW.

Table 4-3: Cost breakdown

Item Description	Cost
Top soil strip and replacement	£15,000
Excavations	£115,412
Flood bank creation	£6,250
Structures	£20,000
Fencing	£8,000
Estimated Cost of Works	£164,662
Access permission over private land	£12,000
General items (signage, planting, planning fees etc)	£21,000
TOTAL	£197,662
TOTAL +VAT	£237,194

5 Modelling methodology

5.1 Modelling aim

The primary aim of the modelling is to determine whether the proposed changes to the floodplain of Bulling Dike can help reduce flood risk to nearby receptors. The modelling will also be used, where possible, to help to optimise the design of the new wetland system to maximise available habitat.

5.2 Key assumptions

The modelling undertaken for the study has been based on JBA's 2009 "Do Minimum" 1D ISIS hydraulic model of the River Dove/Bulling Dike system. It is assumed that it is not within the scope of this project to update the entire model, but rather to update the model at key locations so it can be used to provide a relative assessment of the potential impact of the restoration project.

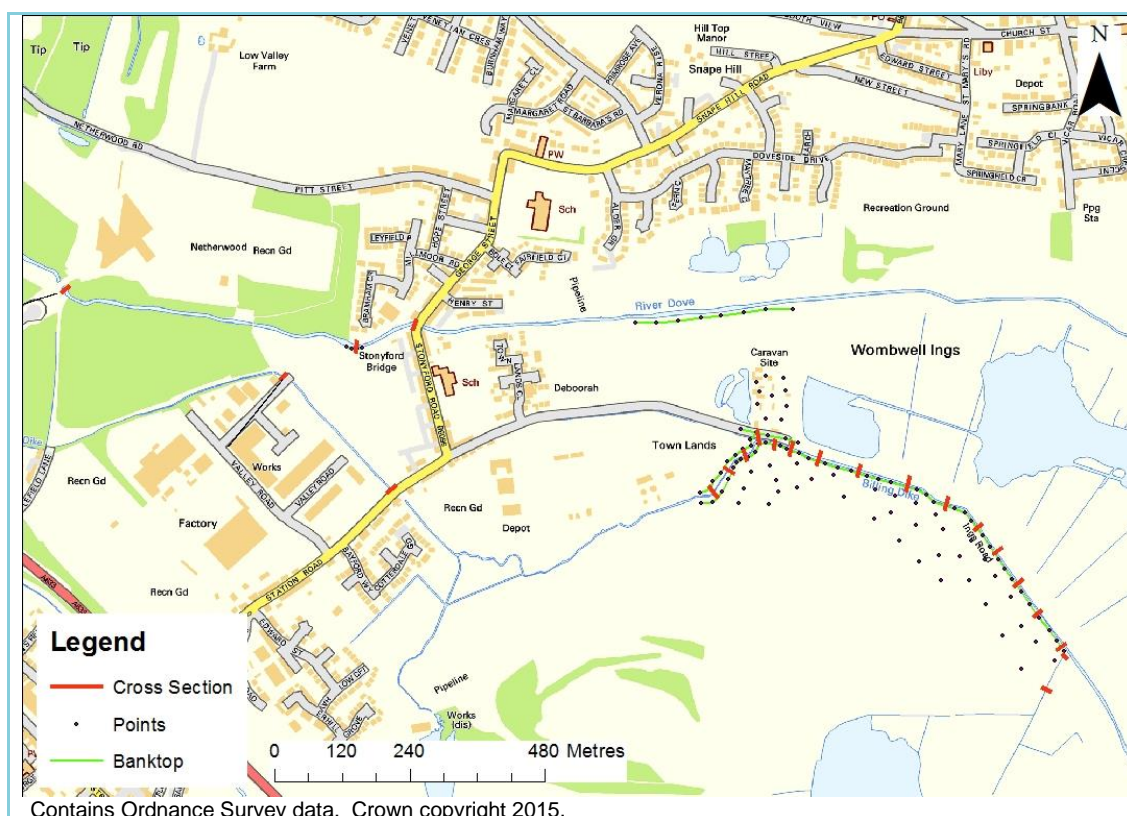
5.3 Topographic survey

In light of the model review and initial modelling (Appendix F), further survey was undertaken on the river system and adjacent land. The nature of the new survey is described below:

1. Spot levels were acquired at various locations and used to serve as check survey points to verify the reliability of the previously surveyed levels within the existing ISIS model at key structures.
2. Key structures and features were surveyed where levels may have changed since the previous modelling (e.g. the Pit Bridge and the right hand bank upstream of Stoneyard bridge where gabions have been introduced).
3. A topographical survey was carried out in the vicinity of the proposed wetland site in order to provide further detail. The survey at this location covered both bank top crest levels and general ground levels within the site.

Figure 5-1 shows the location of the new survey collated for this study.

Figure 5-1: New survey



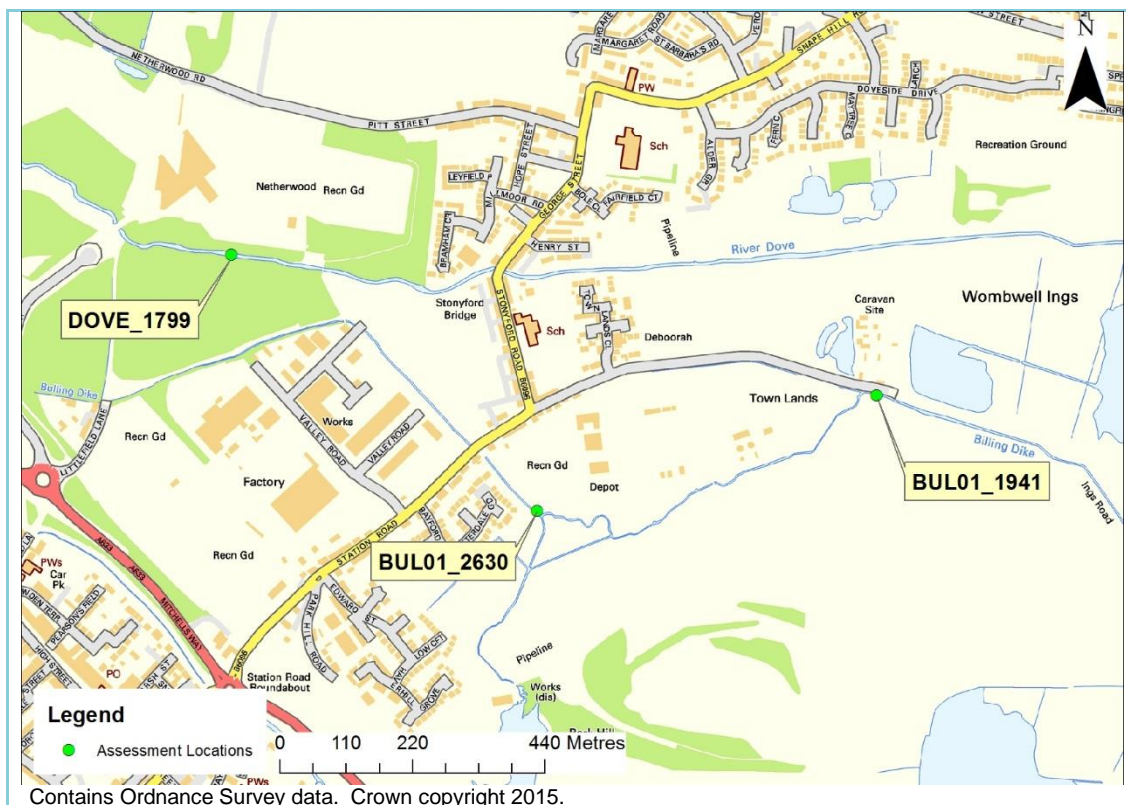
5.4 Flood hydrology

Design flood estimates have been calculated using two techniques. Due to the timings associated with the two techniques they have each been presented using a separate FEH calculation record in Appendix D.

<p>Statistical Method</p>	<p>The design flood estimates used in the 2009 flood mapping study were updated with six years extra data gathered since the 2009 study.</p>
<p>Urban ReFH</p>	<p>This method allows urbanisation within the catchment to be accounted for in detail. The study catchments were split into drainage units and flow estimates derived for each of these. Rural areas were assumed to drain towards the drainage unit outlet whilst in urban areas the Yorkshire Water sewer network maps were consulted to determine which parts drain towards and away from the study watercourses. This process allowed each drainage unit to be split into three categories of area with differing characteristics; undeveloped land, paved areas draining to the watercourse and paved areas draining away from the watercourse. Flow estimates are calculated as a sum of these component parts. As part of the calculations assumptions are made regarding the response to rainfall of each type of area and parameters are set accordingly.</p>

One advantage of the Urban ReFH approach over the statistical method is that the Urban ReFH approach is likely to provide more appropriate estimates of flood volume than the statistical method, which is more appropriate for the estimation of peak flows. A critical storm duration analysis was performed using the Urban ReFH boundary units in the model using the pre-change model and the 100-year event. The aim of this was to determine the duration at which the highest water levels occurred so as to gain a conservative estimate of flood volumes in particular at the area of interest. Three key locations of interest are shown in Figure 5-2.

Figure 5-2: Critical duration assessment locations



The model was run for a number of storm durations ranging from two to thirty hours and compared against the maximum modelled flows and levels using the statistical method as inflows to the model. The same duration was used for both watercourses to model realistic flood mechanisms between the two watercourses. Table 5-1 shows that as the storm duration increases, the modelled flows and levels also keep increasing even up to the thirty hour storm duration. The key area of interest is BUL01_1941 which is located at the bend in Bulling Dike near the Caravan site. Analysis of the storm durations suggests a levelling out of the maximum modelled levels at around the 15 to 18 hour storm duration. Table 5-1 also shows that with a storm duration of 18 hours, the model predicts higher maximum stage and flow levels at each of the three key locations compared to those predicted when the statistical flows were used as inflows to the model.

Table 5-1: Critical duration analysis (100-year return period)

	Dove1799 – upstream of RHB overtopping on Dove		BUL01_2630 – Bulling Dike upstream where TUFLOW starts		BUL01_1941 – node adjacent to caravan park
	Stage (mAOD)	Flow (m ³ /s)	Stage (mAOD)	Flow (m ³ /s)	Stage (mAOD)
Statistical flows	27.57	25.98	24.45	9.19	22.60
SD = 2hours	27.29	19.17	23.80	4.18	21.85
SD = 9 hours	27.52	24.8	24.39	8.51	22.71
SD = 12 hours	27.59	26.6	24.53	9.997	22.87
SD = 15 hours	27.65	27.9	24.63	11.27	22.97
SD = 18 hours	27.68	28.81	24.69	12.06	22.99
SD = 24 hours	27.71	29.71	24.75	12.95	23.01
SD=30 hours	27.73	30.37	24.79	13.5	23.01

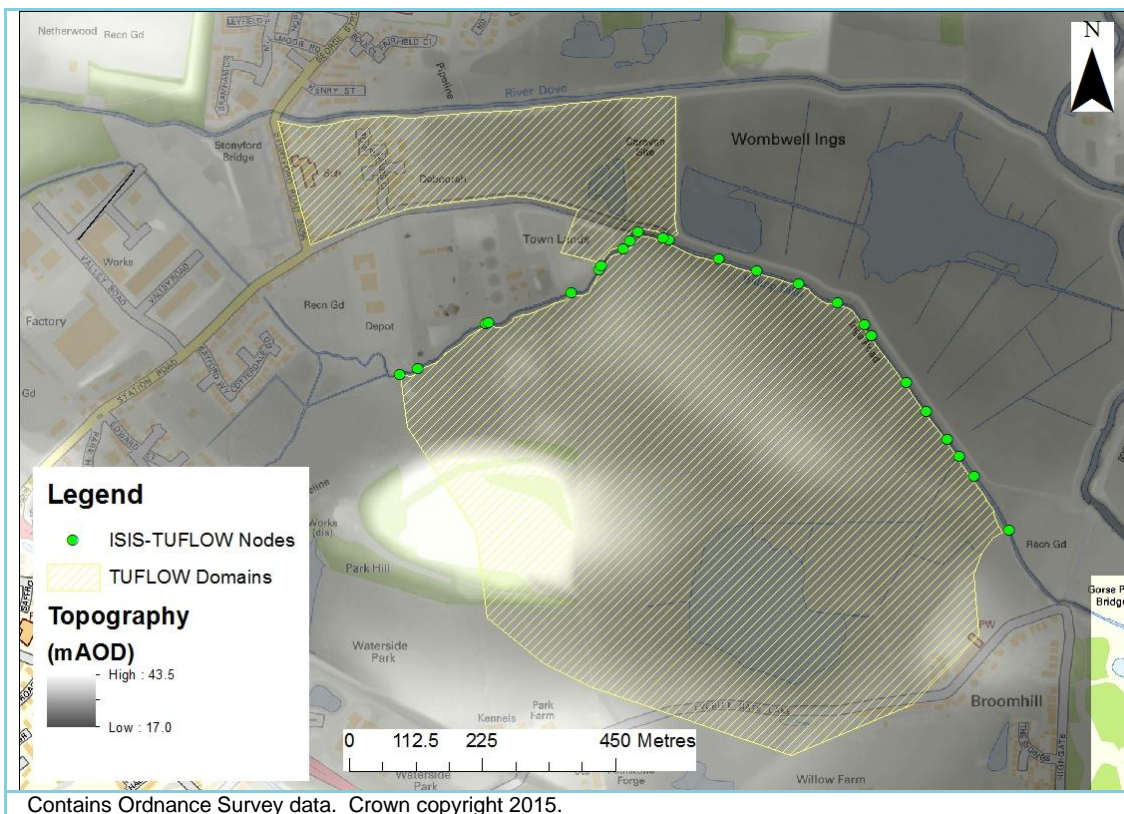
The above analysis shows that there is considerable variation in maximum modelled flows and levels depending on the flood estimation method employed and the storm duration chosen for the Urban ReFH method. However, there is a lack of hydrometric data or flood history data for this catchment at the moment, and so it is not possible to choose an approach or storm duration using such data.

Therefore the choice of approach (and storm duration if necessary) is more subjective. In this case, the Urban ReFH approach was preferred as it was likely to better estimate flood volumes in the catchment, which will be critical when the storage of the proposed wetland is to be considered. A storm duration curve of 18 hours was chosen for both Bulling Dike and River Dove because 18 hours is around the point of the levelling out of peak modelled levels in Bulling Dike adjacent to the Caravan site and would provide the best balance between under and over-estimation of modelled flows and levels, without any hydrometric or anecdotal information which could be used to further manipulate the estimates.

5.5 Model schematisation

Two key floodplain areas in the model were converted to ISIS-TUFLOW, the floodplain where the proposed wetland will be located and the area where the Caravan Site is situated (Figure 5-3). Care was taken locate the boundaries of the 2D domains at locations where the water was in-channel and so ensure a reasonable transition between the 1D and 2D domains. The remainder of the model was modelled using 1D extended sections and storage areas.

Figure 5-3: TUFLOW model schematisation

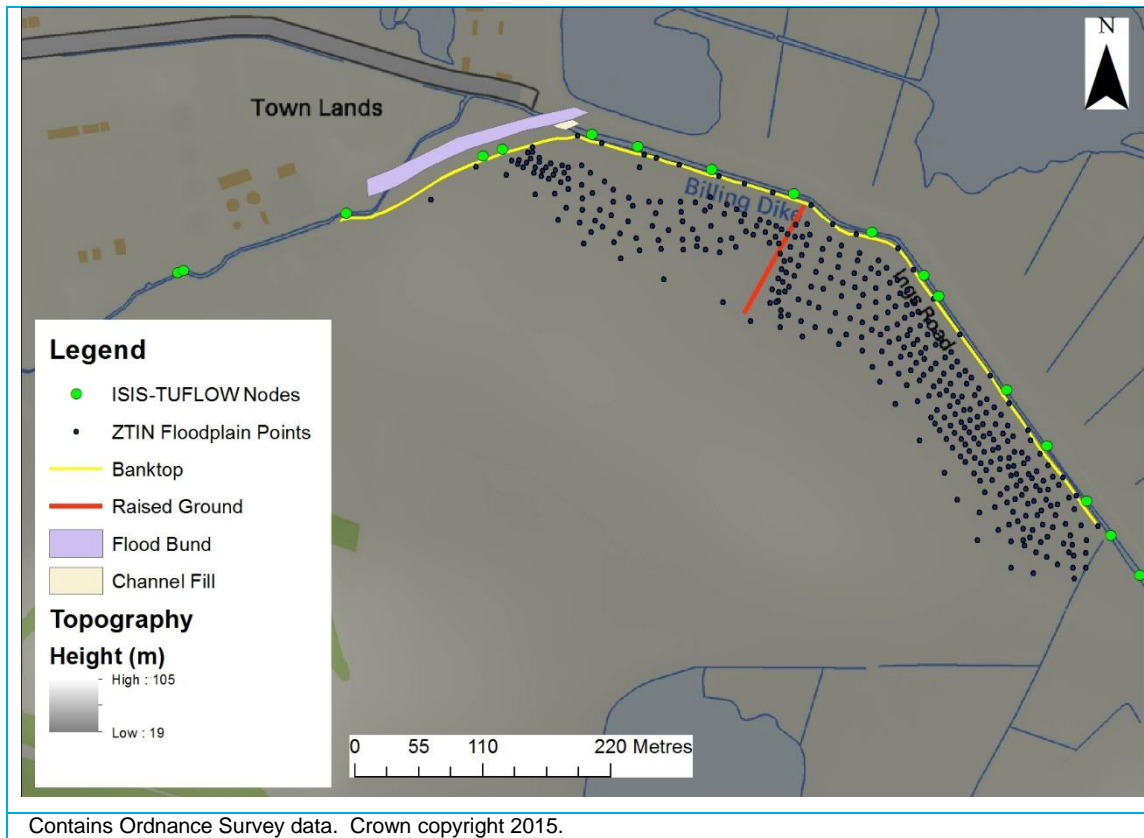


5.6 Proposed restoration

From a flood risk perspective, the key mechanism which inundates the Caravan Site is the overtopping of Bulling Dike near the dogleg, which forces water onto the Caravan Site and surrounding land. By filling in the existing course of Bulling Dike and redirecting the Dike away from the Caravan site, it is hoped to mitigate against that flood risk mechanism. Lowering floodplain levels to create the reed bed and wet grassland, will increase storage on the floodplain, but is thought to be a secondary mechanism.

All model schematisation from the existing situation model were retained apart from the redirection of the channel and topographic modifications to represent the flood bund and proposed reed bed and shallow grassland (Figure 5-4). Further details of the post-change model schematisation can be found in Appendix F.

Figure 5-4: Post-change model schematisation



5.7 Model proving

The robustness of the model was tested using sensitivity tests to test key model parameters and verified against the small amount of available flood history information. Please see the Model User Report in Appendix F for details on model stability and performance.

25 - year RP



50 - year RP



75 - year RP



100 - year RP



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No flooding occurs at the Caravan Site at return periods lower than 10-years. Table 6-1 shows the modelled flood depths at each of the Caravan Site plots (Figure 2-4) for return periods of 10-years and higher. Eight of the plots are inundated during the 10-year event, with all plots inundated at the 25-year return period.

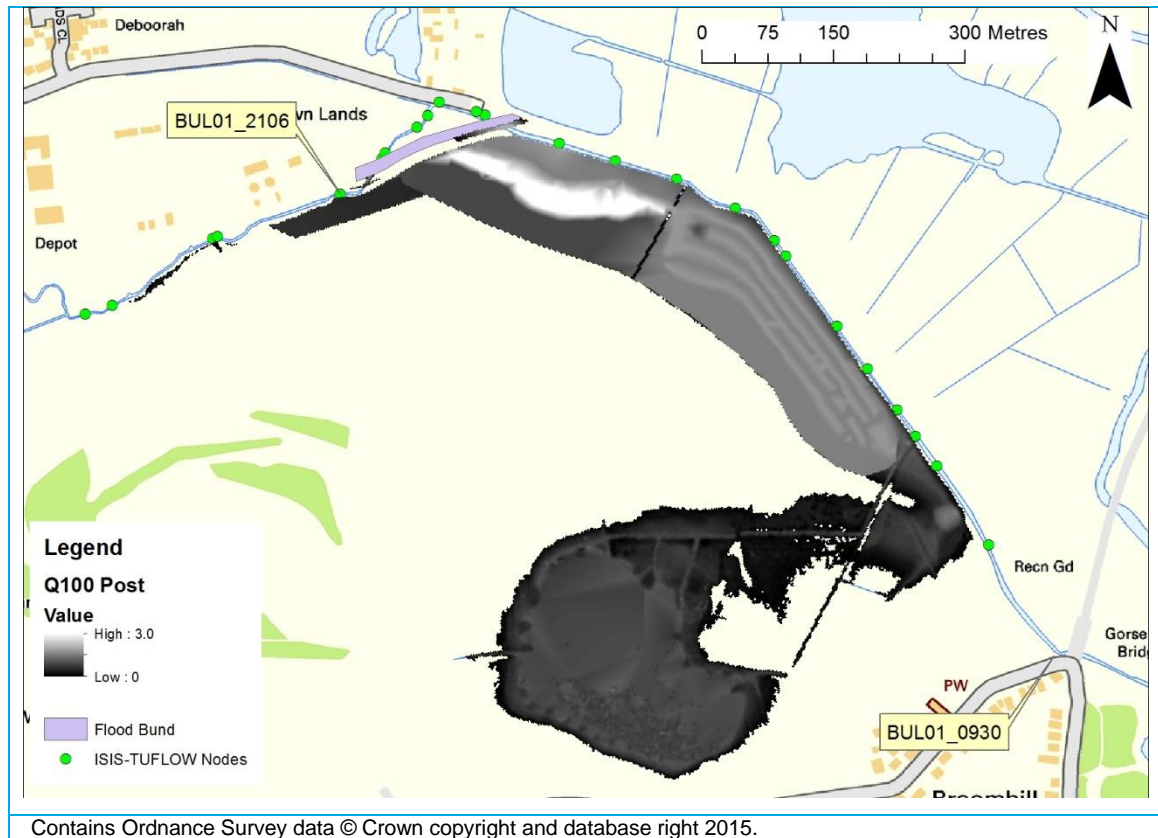
Table 6-1: Flood depths at each plot

Plot	Depth of flood water (m)					Standard of Protection
	Q10	Q25	Q50	Q75	Q100	
1	0.18	0.71	1.11	1.30	1.35	Q10
2	0.28	0.81	1.22	1.41	1.46	Q10
3	0	0.50	0.90	1.09	1.14	Q25
4	0	0.56	0.97	1.15	1.21	Q25
5	0	0.61	1.01	1.20	1.25	Q25
6	0	0.38	0.78	0.97	1.02	Q25
7	0	0.59	0.99	1.18	1.23	Q25
8	0	0.49	0.90	1.08	1.14	Q25
9	0.04	0.57	0.98	1.17	1.22	Q10
10	0.15	0.68	1.08	1.27	1.32	Q10
11	0.27	0.80	1.20	1.39	1.44	Q10
12	0.19	0.72	1.21	1.31	1.36	Q10
13	0.27	0.80	1.20	1.39	1.44	Q10
14	0.12	0.65	1.06	1.24	1.30	Q10
15	0	0.49	0.90	1.08	1.13	Q25

6.2 Proposed situation

The key elements from a flood risk perspective, namely redirecting the river channel and raising the bund along the left hand bank of the channel. Figure 6-2 shows that by redirecting Bulling Dike, the addition of the flood bund, and changes made to the floodplain, the Caravan Site is no longer at risk even in the 100-year return period event.

Figure 6-2: Post-change 100-year flood outline and flood depths



The maximum modelled stage downstream of the site remains unchanged in the 100-year event. Maximum modelled flows at BUL_930 are also unchanged (not plotted) (Figure 6-3). Extraction of water levels immediately upstream of the site (Figure 6-3) shows that at BUL_2106 there is a decrease in maximum modelled water levels of 0.40m.

Comparison downstream of the site shows that at BUL01_930, there is a very small (<0.01m) increase in maximum modelled water level following installation of the scheme. There are no receptors between the end of the scheme reach and the confluence in the Dearne, as the properties at Broomhill are well above river level (24.7mAOD compared to Q100 maximum modelled level of 22.85mAOD). There is no increase in maximum modelled water levels at the confluence of Bulling Dike and the River Dearne.

Figure 6-3: Comparison of water levels for the 100-year event

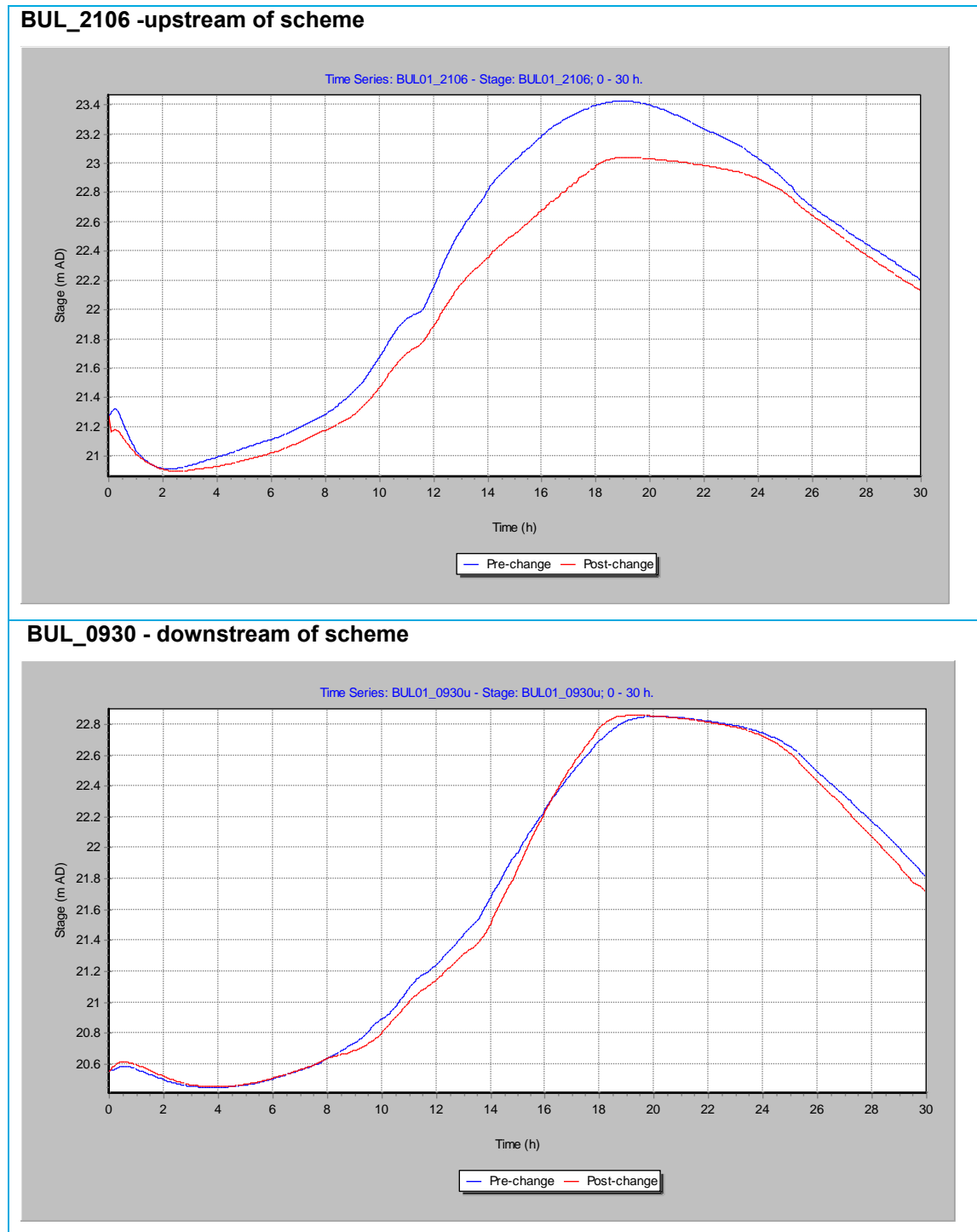
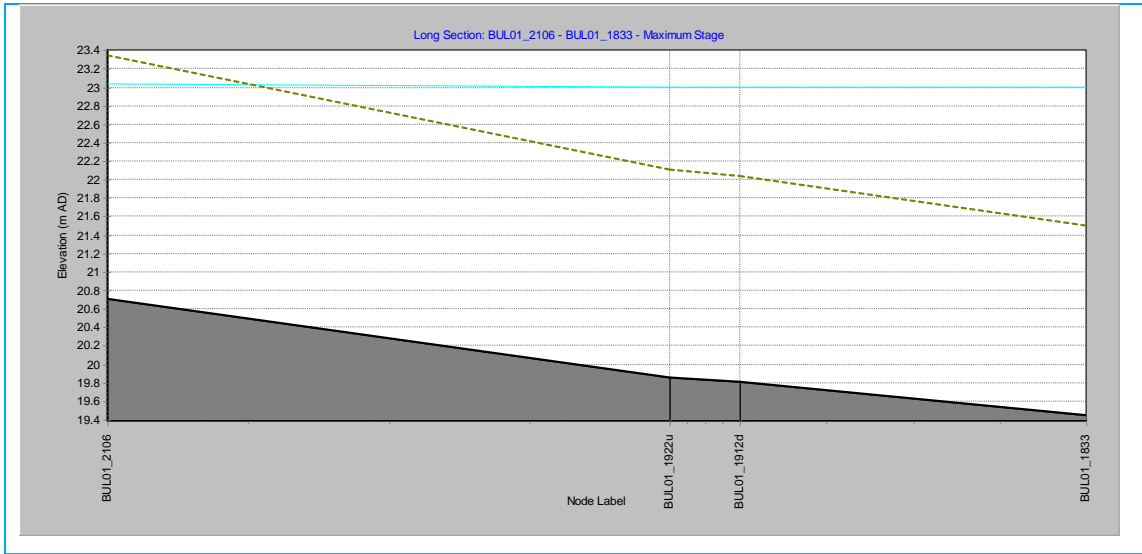


Figure 6-4 shows the maximum modelled water level for the 100-year return period post change scenario in the reach where the new left hand bank will be formed by the new bund (BUL01_2106 to BUL01_1833). Maximum water levels immediately upstream of the diversion and bund are 23.04m AOD, whilst water levels at the downstream end of the bund reach a peak of 22.99m AOD.

A level bund with a crest level of 23.30m AOD, will provide protection for the 100-year event, with 0.26m freeboard at the upstream end and 0.30m at the downstream end. A bund of 23.30m AOD is 0.30m higher than the existing bund between Bulling Dike and Wombwell Ings and so is highly unlikely to overtop.

Figure 6-4: Long section adjacent to the proposed flood bund.



7 Limitations of modelling approach

7.1 Introduction

This chapter identifies key model assumptions and limitations of the method and data of the hydraulic modelling.

7.2 Model assumptions

The results of the ISIS-TUFLOW model are subject to the following key limitations:

Fluvial flooding only	The modelling undertaken only accounts for fluvial flooding resulting from the River Dove and Bulling Dike and makes no allowance for surface water flooding which may be a contributory factor to flooding. However as the key flood mechanism for the Caravan Site is fluvial flooding, this is a reasonable assumption.
Bank top accuracy	ISIS-TUFLOW predictions are critically dependent on the modelled volume of overtopping. The volume of water overtopping the banks is highly dependent on the banktop levels defined on the model. Banktop survey has been used along the critical reaches, however in small areas the LIDAR data is used to define the bank top levels, which may have a slightly lower level of accuracy.
Roughness representation	The approach of using spatially variant roughness maps to distinguish between the different role of buildings and roads (in obstructing or enhancing flow routes) is obviously a simplification of the real world situation. It is not possible to model the 2D domain in sufficient detail to capture the full range of complex hydraulics that would be likely to occur in any real event. However, this is the accepted approach and follows good practice guidelines specified by the EA and achieves a good representation.
LIDAR quality DTM	<p>The flood outlines that result from areas of shallow floodplain flow will often be critically dependent on the quality of the DTM. Small fluctuations in the DTM can have an important influence on the modelled flow routes. For example, a small perturbation in the DTM on a road within an urban area could cause shallow flow to be diverted elsewhere (along another road).</p> <p>LIDAR data was compared against spot level data taken at various locations in the study site and have found close agreement (max $\pm 0.03\text{m}$ difference). This increases confidence in the quality of the LIDAR data which underpins the hydraulic analysis.</p>

7.3 Data limitations

7.3.1 Calibration data

No calibration data were available for this study. The best available data to check the validity of the model results were anecdotal reports of flooding and, as such, the model could only be 'sensitivity' checked using this information rather than quantitatively validated (see Appendix F). Should recorded data become available in the future they could be used to carry out model calibration and provide greater confidence in the accuracy of the model.

8 Water and habitat management plan

8.1 Introduction

As part of the proposed scheme, the preferred option involves creation of a reed bed area in the upstream, western part of the site. At the lowest, wettest parts of the site it is intended that this will be Common Reed *Phragmites australis* dominated, but moving away from the core reed bed area it is hoped that the communities will transition into species-rich swamp and fen habitat, such as sedge *Carex sp.* beds and wet grasslands.

Reed bed habitats are typically species-poor with Common Reed dominating, however, it is hoped that as part of this project creation of a more species-rich wetland type could be trialled.

8.2 Possible vegetation communities

8.2.1 Reed bed

In order to identify suitable species mixes and appropriate communities to try and develop at the proposed site, a review of available literature, primarily the National Vegetation Classification (NVC) handbook for aquatic communities, swamps and tall-herb fens (Rodwell *et al.*, 1995) was undertaken.

The typically created reed bed community in UK wetland habitat creation schemes is a monoculture of almost pure Common Reed. This equates to the S4 *Phragmites australis* swamp and reed bed community as described in Rodwell *et al.* (1995)¹. However, there are a number of S4 sub-communities which have slightly differing species compositions that may help inform future species-mixes at the site, as described in the table below. There are also a number of other reed bed communities described in Rodwell *et al.* (1995) that could help inform species composition in the reed bed, as also detailed and discussed in Table 8-1.

Table 8-1: Description of Common Reed dominated NVC communities (From: Rodwell *et al.*, 1995)

Community/Sub-community	Community Summary	Habitat Requirements/ Distribution	Appropriateness
S4 <i>Phragmites australis</i> swamp and reed beds – <i>Phragmites australis</i> sub-community	This sub-community includes pure and very species-poor stands where Common Reed is the sole constant. Other species can be locally prominent.	Occurs in permanently wet or periodically waterlogged habitats of different trophic status. Common in open water transitions around lakes and ponds, floodplain mires, estuaries and along ditches. Performs best in eutrophic situations. Can occur in areas with a wide variety of water regimes, but best performance is typically at water depths of +50cm to	Considered a suitable community to create at Wombwell, however, it is not particularly species-rich.

¹ Rodwell, J.S., Pigott, C.D., Ratcliffe, D.A., Malloch, A.J.C., Birks, H.J.B., Proctor, M.C.F., Shimwell, D.W., Huntley, J.P., Radford, E., Wigginton, M.J. and Wilkins, P. (1995) British Plant Communities - Volume 4: Aquatic communities, swamps and tall-herb fens. Cambridge University Press, Cambridge.

Community/Sub-community	Community Summary	Habitat Requirements/ Distribution	Appropriateness
		-20cm, with flooding for several months.	
S4 <i>Phragmites australis</i> swamp and reed beds – <i>Galium palustre</i> sub-community	Reed cover tends to be a little more open and vegetation richer with Marsh Bedstraw <i>Galium palustre</i> , Water Mint <i>Mentha aquatica</i> , Purple Loosestrife <i>Lythrum salicaria</i> , Yellow Iris <i>Iris pseudacorus</i> and Great Willowherb <i>Epilobium hirsutum</i> , although none are particularly abundant.	Occurs in shallower waters where flooding is rare and/or brief and where litter can begin to accumulate. Often occurs on floating rafts of peat vegetation over loose silts or on firm organic or mineral soil in open-water transitions, floodplain mires and along watercourses where water table is below the surface for up to 8 months of the year.	Considered a suitable community to create at Wombwell in areas where inundation is less and water does not stand above ground level for significant periods.
S4 <i>Phragmites australis</i> swamp and reed beds – <i>Menyanthes trifoliata</i> sub-community	A community of open reed cover with an understory of generally small amounts of Bogbean <i>Menyanthes trifoliata</i> , Water Horsetail <i>Equisetum fluviatile</i> , Bottle Sedge <i>Carex rostrata</i> and Marsh Cinquefoil <i>Potentilla palustris</i> .	Found in more oligotrophic waters over acid peats or nutrient-poor silts. Distinctive of lake margins in the north and west.	Not appropriate at Wombwell as conditions are unlikely to be oligotrophic given nature of the catchment and soils. Furthermore, being in the east of the UK it is not within the typical distribution of this sub-community and soils will have elevated nutrient levels due to agricultural usage.
S4 <i>Phragmites australis</i> swamp and reed beds – <i>Atriplex prostrata</i> sub-community	Stands of sometimes open cover and often short Common Reed, frequently associated with Spear-leaved Orache <i>Atriplex prostrata</i> although it can be unevenly distributed. Other halophytes may also be present.	Occurs in saline waters where salt decreases or prevents bud formation of the reed, allowing greater light penetration. Requires tidal inundation and accumulation of leaf litter.	As a coastal community it is not appropriate at Wombwell Washlands.
S24 <i>Phragmites australis</i> – <i>peucedanum</i>	A herbaceous fen community with a varied species composition. Common Reed, Great Fen-sedge <i>Cladium</i>	Found in fen peats with moderate to high summer water levels and some winter flooding, with	As a typical Broadland community it would be inappropriate to create an

Community/Sub-community	Community Summary	Habitat Requirements/ Distribution	Appropriateness
palustre tall-herb fen	<i>mariscus</i> and Purple Small-reed <i>Calamagrostis canescens</i> are typically dominant. A range of other species are also associated.	base-rich calcareous and often oligotrophic waters. Almost entirely confined to Broadland areas.	analogous community at Wombwell Washlands.
S25 Phragmites australis – Eupatorium cannabinum tall-herb fen	A rather variable vegetation community with a prominence of tall herbaceous dicotyledons, including Hemp Agrimony <i>Eupatorium cannabinum</i> , Angelica <i>Angelica sylvestris</i> , Purple Loosestrife, Marsh Thistle <i>Cirsium palustre</i> , Common Valerian <i>Valeriana officinalis</i> , Yellow Iris, Meadowsweet <i>Filipendula ulmaria</i> and Great Willowherb. Common Reed is constant throughout and is often abundant.	Characteristic of moderately eutrophic situations where mineral or organic soils are irrigated and frequently waterlogged by usually calcareous and base-rich waters. Typically found in valley mires alongside small lowland rivers in catchments with calcareous bedrock.	Given the soils present, and underlying bedrock, conditions are unlikely to be calcareous enough to support this community. However, some of the associated species, which have relatively broad habitat tolerances, and may be appropriate for Wombwell Washlands.
S26 Phragmites australis – Urtica dioica tall-herb fen	A very variable community with Common Reed and Common Nettle <i>Urtica dioica</i> constant and Marsh Bedstraw. A variety of other tall dicotyledons or monocotyledons can also be frequent. The canopy is often dense and tangled by climbers and sprawlers.	Characteristic of eutrophic, circumneutral to basic water margins and mires where organic or mineral substrates are kept fairly moist throughout the year, and in some cases, winter flooding. Distribution is likely to be related to eutrophication and occurs throughout lowland Britain.	Considered a suitable community to create at Wombwell Washlands.

From the above review, it is apparent that the following communities could be appropriate to inform development of the reed bed:

- S4 *Phragmites australis* swamp and reed beds – *Phragmites australis* sub-community
- S4 *Phragmites australis* swamp and reed beds – *Galium palustre* sub-community – key species associated with this community that are considered appropriate for introduction in the reed bed, include Marsh Bedstraw *Galium palustre*, Water Mint *Mentha aquatica*, Yellow Iris *Iris pseudacorus* and Purple Loosestrife *Lythrum salicaria*.
- S26 *Phragmites australis* – *Urtica dioica* tall-herb fen – key species associated with this community that are considered appropriate for introduction in the reed bed include Meadowsweet *Filipendula ulmaria*, Hemp Agrimony *Eupatorium cannabinum*, Hemlock Water-dropwort *Oenanthe crocata*, Marsh Woundwort *Stachys palustris*, Water Forget-me-not *Myosotis scorpioides*, Water Mint *Mentha aquatica*, Angelica *Angelica sylvestris*,

Purple Loosestrife *Lythrum salicaria*, Marsh Bedstraw *Galium palustre*, Yellow Iris *Iris pseudacorus*, Common Valerian *Valeriana officinalis* and Gypsywort *Lycopus europaeus*.

The species typically found within these communities can be used to inform the proposed species-mix of the wetland communities at Wombwell Washlands. However, these communities have differing habitat requirements, and it is likely a mix of each will develop at the site, depending on the ground conditions, hydrological regime and water levels created as part of the scheme. As the land in the western part of the site will be cut and earthworks undertaken, there is opportunity to create the conditions required for a variety of reed bed, swamp and wetland communities to develop.

8.2.2 Wet grassland

Given that the site will be created with a series of landforms and earthworks to develop areas of different water depths and hydrological regimes, other communities will also likely be able to be created in the transitional areas around the reed bed. The species for inclusion in these transitional areas could be informed by the communities discussed in Table 8-2.

Table 8-2: Other tall-herb fen and wet grassland community descriptions

Community/Sub-community	Community Summary	Habitat Requirements/ Distribution	Key Species for Possible Inclusion
S6 <i>Carex riparia</i> swamp	A generally dense sward of Greater Pond-sedge <i>Carex riparia</i> , which can be species-poor, but typically contains a patchy abundant other swamp emergent and/or tall herbs.	Characteristic of wet or waterlogged, mesotrophic to eutrophic circumneutral mineral soils alongside standing or slow-moving waters.	Slender Tufted-sedge <i>Carex acuta</i> , Water Horsetail <i>Equisetum fluviatile</i> , Meadowsweet <i>Filipendula ulmaria</i> , Marsh Bedstraw <i>Galium palustre</i> , Gypsywort <i>Lycopus europaeus</i> , Water Mint <i>Mentha aquatica</i> , Hemlock Water-dropwort <i>Oenanthe crocata</i>
S7 <i>Carex acutiformis</i> swamp	Lesser Pond-sedge <i>Carex acutiformis</i> dominates, with some scattered tall herbs present.	Similar to S6 community above, although potentially more associated with calcareous habitats.	Angelica <i>Angelica sylvestris</i> , Marsh Bedstraw <i>Galium palustre</i> , Soft Rush <i>Juncus effusus</i> , Water Mint <i>Mentha aquatica</i> , Common Valerian <i>Valeriana officinalis</i>
MG8 <i>Cynosurus cristatus-Caltha palustris</i> grassland	A species-rich and varied grassland with no single species consistently dominant. Grasses account for most of the cover, with some smaller sedges and well represented dicotyledon components.	Characteristic of periodically inundated areas managed in a traditional manner. Soils are naturally enriched by inputs from deposited silt or moving water and not artificial sources.	Marsh Marigold <i>Caltha palustris</i> , Meadowsweet, Great Burnet <i>Sanguisorba officinalis</i> , Jointed Rush <i>Juncus articulatus</i> , Ragged Robin <i>Lychnis flos-cuculi</i> , Marsh Bedstraw, Angelica, Soft Rush, Water Forget-me-not <i>Myosotis scorpioides</i> , Water Mint

8.3 Recommended species mixes

Given the above review, there are a range of herb species that would potentially be appropriate for introduction as part of the scheme, however, each has different habitat and, more specifically, water level requirements. It is therefore recommended that the landform is designed in such a way to create deeper areas, which result in differing periods of inundation so that different communities with different species can develop. The table below details those species recommended for planting/introduction in different parts of the site. In-combination with these herbs, for the seasonally and rarely inundated areas, a number of grass species tolerant of wetter/slightly damp conditions are also likely to colonise, such as Creeping Bent *Agrostis stolonifera*, Marsh Foxtail *Alopecurus geniculatus*, Meadow Foxtail *Alopecurus pratensis*, Yorkshire Fog *Holcus lanatus* and Tufted Hair-grass *Deschampsia cespitosa*, most likely with other grass species more typical of drier areas where conditions allow (Table 8-3).

Table 8-3: Recommended species and water level requirements (From: Newbold and Mountford, 1997²)

Indicative Water Depth/ Hydrological Regime	Recommended Species	Preferred Water Depth Range (cm)		
		Dry	Preferred	Wet
Permanent deeper areas of water (>50cm)	Common Reed <i>Phragmites australis</i>	-100	-20-0	+50
	Water Horsetail <i>Equisetum fluviatile</i>	-30-10	+60	+100
Seasonal areas of shallow water inundation (0-20cm)	Marsh Marigold <i>Caltha palustris</i>	-35	Not given	+15
	Slender Tufted-sedge <i>Carex acuta</i>	-100	-40+10	+10
	Lesser Pond-sedge <i>Carex acutiformis</i>	-40	0	+50
	Greater Pond-sedge <i>Carex riparia</i>	-60	-40-20	+30
	Marsh Bedstraw <i>Galium palustre</i>	-40	-20-0	+20
	Yellow Iris <i>Iris pseudacorus</i>	-60	-10+10	+60
	Soft Rush <i>Juncus effusus</i>	-55	Not given	+30
	Gypsywort <i>Lycopus europaeus</i>	-90	-30+5	+10
	Purple Loosestrife <i>Lythrum salicaria</i>	-40	-10+10	+10
	Water Mint <i>Mentha aquatica</i>	-60	-10+10	+60
	Water Forget-me-not <i>Myosotis scorpioides</i>	-20	Not given	+20
Rarely inundated damp areas	Angelica <i>Angelica sylvestris</i>	-100	Not given	+5
	Hemp Agrimony <i>Eupatorium cannabinum</i>	-100	-50-10	+5
	Meadowsweet <i>Filipendula ulmaria</i>	-60	-20-0	+5
	Jointed Rush <i>Juncus articulatus</i>	-60	-30-0	+10
	Ragged Robin <i>Lychnis flos-cuculi</i>	-40	-20+5	Not given
	Hemlock Water-dropwort <i>Oenanthe crocata</i>	-60	-20-0	+10
	Great Burnet <i>Sanguisorba officinalis</i>	-60?	-30-20	Not given
	Marsh Woundwort <i>Stachys palustris</i>	-100	-30-0	+15

² Newbold, C. and Mountford, O. (1997) Water Level Requirements of Wetland plants and animals. English Nature, Peterborough

Indicative Water Depth/ Hydrological Regime	Recommended Species			Preferred Water Depth Range (cm)		
				Dry	Preferred	Wet
	Common <i>officinalis</i>	Valerian	<i>Valeriana</i>	Not given	-5	Not given

As each of the above areas require different depths of water, they will also consequently require inundation for different durations. Suggested durations of inundation for each are given below:

- **Permanent deeper areas of water (>50cm)** – Deeper water in winter (up to 1m), dropping to a lower summer level (5-30cm).
- **Seasonal areas of shallow water inundation (0-20cm)** – December-March maintain shallow surface water (0-20cm); April to August allow water on fields to decrease (Benstead *et al.*, 1997³).
- **Rarely inundated damp areas** – Only infrequent periods of inundation. Watertable is typically below ground surface.

8.4 Vegetation establishment

8.4.1 Reed bed

The RSPB (2004)⁴ recommend that when creating a reed bed the following are recommended:

- 25-30% open pools – approximately 1m deep in spring, with potentially a few areas deeper than this
- 40-50% wet reed areas
- 15-25% drier reed areas
- 5% scrub – this will likely develop overtime at Wombwell Washlands as the site develops.

Several techniques are available for establishing reed, including sowing seed, planting seedlings, planting cuttings, spreading rhizomes and turf transplants. RSPB (2004) provides useful information on all of these approaches, however, it will not be necessary to plant the whole site. Planting of reed should be in a small area with good water level control to create a source of reed that can then spread out into other areas of the site. Ideally, the reed material should be locally sourced.

The first growing season is then the most critical for establishing the reed bed. If necessary the new reeds may need to be protected from grazing (i.e. from livestock and wildlife) with fencing.

8.4.2 Wet grassland

In order to get these species-rich communities to develop, a nearby species-rich wetland/grassland community could be used as a source of the seeds. This could be done through the collection and then sowing of seed, or potentially through the spreading of green hay collected from the donor site. Green hay is herbage cut at, or just before, the hay stage, which is then collected without prior wilting or turning and spread immediately on the receptor site.

When sowing seed to create a species-rich wetland/grassland habitat, ground preparation is vital. Much of the area will have been subject to earthworks to create the desired landform, and in other areas, so long as previous fertilisation has not occurred, sowing can occur directly onto the existing sward. Prior to sowing in areas unaffected by earthworks, the existing sward should be cut hard in the autumn, with the aim of keeping the grass short (30-50mm) and reducing the vigour of any coarser grasses. Any perennial weeds present should be spot-treated with an appropriate herbicide, applied by an approved person in accordance with the on-label instructions. Gaps should be created within the existing sward either mechanically by harrowing or raking, which

³ Benstead, P., Drake, M., José, P., Mountford, O., Newbold, C. and Treweek, J. (1997) The Wet Grassland Guide: Managing floodplain and coastal wet grasslands for wildlife. RSPB, Bedfordshire.

⁴ RSPB (2004) Information and Advice Note: Reed bed design and establishment. RSPB.

should aim to expose up to 50% bare soil; this will not be necessary on areas disturbed by the earthworks. The mechanical disturbance needs to be severe to work as grass can recover and grow back very quickly; it is therefore advised that disturbance and seeding is undertaken at a time when growth is declining (i.e. in the Autumn).

Once the ground preparation has been completed, seed can be sown by surface broadcasting. It is advised that sowing is undertaken in autumn (August-September), or alternatively in spring (March-April). Rolling is also not usually needed for autumn applications as the weather will settle the seed to the soil.

If spreading of green hay is selected, it requires careful management and preparation, including:

1. Treatment of pernicious weeds, if necessary.
2. Disturbance of the sward as spreading onto undisturbed ground is unlikely to succeed. The sward should therefore be cut short (either by cutting or grazing) and 50% of the area disturbed to allow seeds to come into contact with the soil (again by machine or livestock).

The hay should then be spread thinly on the day it is cut and left for one week in dry weather and three weeks in wet weather for the seeds to drop. After this period stock (ideally cattle) should be allowed to graze the site to bed in the seeds, alternatively the area could be rolled lightly (Natural England, 2010⁵).

8.5 Recommended management

8.5.1 Reed bed

Once established, it will be important that the reed bed areas are managed to prevent them succeeding into drier habitats and scrub. Cutting to maintain reed dominance of the species-poor Common Reed dominated areas should be undertaken during the non-growing season. There are a variety of techniques available to do this, as detailed in RSPB (2009)⁶, often dependent on ground conditions and wetness.

Traditionally, cutting of a reed bed for conservation purposes is done on rotation every 7-15 years (RSPB, 2009), on a small-scale to create structural variation and so the whole area is not affected at once.

8.5.2 Wet grassland

To maintain the species-richness of the flora, and to ensure it remains suitable for target fauna such as waders and wildfowl, management will be required. Grazing, especially by cattle given the likely wet ground conditions, will be the most effective way of managing the vegetation within wet grasslands, however, it needs to be carefully managed.

Ideally, the vegetation should be cut in late summer (August), with cattle introduced to aftermath graze. Grazing during the breeding season should be avoided to prevent the trampling of nests. Cattle should be excluded from the site between the end of February and the end of June.

The cattle should be kept on site until late autumn (October/November) when ground conditions become softer and poaching occurs (a small amount of poaching is however, beneficial).

⁵ Natural England (2010). Sward enhancement: diversifying grassland by spreading species-rich green hay. [online] Available at: <http://adlib.everysite.co.uk/resources/000/102/926/TIN063.pdf> [date accessed 27th October 2015].

⁶ RSPB (2009) Information and Advice Note: The future of reed bed management [online] Available at: https://www.rspb.org.uk/Images/Reed_bed_management_tcm9-255077.pdf [date accessed 27th October 2015].

9 Summary & recommendations

9.1 Summary

A wetland complex has been designed which provides both biodiversity and flood risk benefits to the Low Valley area. The scheme has been designed to make best available use of two water sources; a) excess water from Broomhill Flash and b) inputs from Bulling Dike. The scheme provides 8ha of Water Framework Directive OM4 wetland habitat and protects 15 plots at the Caravan Site from flooding up to and including the 100-year return period.

9.2 Required consents

The purpose of this section is to introduce the consents which will be required before construction of the proposed wetland can take place, any costs associated with the wetland and the potential timescales for the consents to be secured.

9.2.1 Planning Permission

The proposed wetland is greater than 0.5ha and so may be classed as a major development. This may have a 16 week decision time following submission of the application. However, as Barnsley Metropolitan Borough Council is a partner in this study, it is assumed that the decision time could be reduced.

9.2.2 Land Drainage Consent

Land Drainage Consent will be required for the proposed works. This will need to be obtained from Danvm Internal Drainage Board. Consent will be determined by the Internal Drainage Board (IDB) under Section 23 of the Land Drainage Act 1991 (as amended) [LDA] and the Drainage Byelaws created under Section 66 of the LDA.

Section 23 LDA prohibits obstructions, etc. in watercourses and states "no person shall erect any mill dam, weir or other like obstruction [or] erect any culvert that would be likely to affect the flow of any watercourse ... without the consent in writing of the drainage board concerned.". The IDB will charge a non-refundable Application fee (£50 per application or as prescribed) for Section 23 LDA Consents.

Section 66 LDA provides the power to make byelaws which state that "no person shall ... introduce any water into any watercourse in the District so as to directly or indirectly increase the flow or volume of water ... without the previous consent of the Board [and] no person ... shall erect any building or structure whether temporary or permanent, or plant any tree, shrub, willow ... without the previous consent of the Board, amongst other byelaws specific to each IDB.". The IDB will not charge Application fee for byelaw consents under Section 66 LDA.

Applications for consent will be required for both temporary and permanent works and the IDB have a statutory 2 month determination period from the day on which the application is made or when the application fee (£50 per application or as prescribed) is discharged, whichever is later.

At least seven days' notice of the start of works will be required to the IDB as a condition of any consent. Please note that conditions may be imposed with the consent and those conditions must be discharged in writing (with evidence where necessary) to the IDB before the start of works. Upon receiving a request to discharge conditions of consent we will endeavour to respond, or determine the condition, within ten working days depending on complexity of the condition.

The IDB will also need to be consulted about the adoption of the new reach of Bulling Dike.

9.2.3 Abstraction licence

An abstraction licence will not be required as long as the abstraction from Bulling Dike is kept to less than 20m³/s per day.

9.3 Recommendations

The following recommendations can be made for further work:

Detailed design	Further work will be required on the design before submission to FCERM GiA and submission for competitive tenders. Budget estimate (£10,000 + VAT).
Archaeology/ Heritage	Only a desk based assessment of any archaeological/heritage assets was undertaken for this study. As part of the detailed design, liaison with South Yorkshire Archaeology Services (SYAS) is recommended, and a further more detailed desk based assessment may be required to address any concerns from SYAS. Estimated costs £1,500 (+VAT).
Ground Investigation (incorporating contamination testing)	Required to determine the following: <ul style="list-style-type: none"> - Whether there is sufficient clay on site to form the core of the bund. - Whether the soils on the wider floodplain are sufficient to retain the open water of the reed bed and wet grassland. - The groundwater levels in the glaciofluvial deposits in the proposed location of the reed bed (this would be achieved through the installation of a number of shallow groundwater monitoring boreholes). - The risks of contamination to the site (this would be achieved through sampling and testing of soils). It is envisaged that a ground investigation satisfying these aims could be achieved with a budget of around £6,000 (+ VAT).
Ecology	Before any construction takes place a preliminary ecological appraisal should be undertaken to understand whether there are any ecological constraints which will need to be taken into account during detailed design and construction. Baseline assessment budget price of £1,500 (+VAT).
Water Supply from Broomhill Flash	In order to better determine the amount of water that may be available from Broomhill Flash to support the wetland, it is recommended that additional monitoring be undertaken on-site. An automatic water level monitoring device could be installed on Broomhill Flash, and detailed records of the opening/closing regime of the orifice of the sluice gate be maintained. It is envisaged that the necessary equipment could be purchased and installed for around £1,200 (+ VAT), though additional costs are likely to be encountered gathering and manipulating the data. N.B. Gathering the water level data will be of limited use if accurate and clear records of sluice opening periods are not maintained.
Reservoir Engineer	As it is proposed to link the flood bund with the existing bund of the Wombwell flood storage reservoir (left hand bank of Bulling Dike), the designs will need to be signed off by a panel engineer to ensure that the existing bund is not compromised by the addition of the new bund. A reservoir construction engineer may also need to be on site for that aspect of the construction to supervise works.

Appendices

A Phase 1 Geoenvironmental Report

B Design Drawings

C Caravan site survey

D FEH Calculation Record

E Rainfall volumes

F Model User Report

G Alternative construction quote

The table below outlines an alternative costs for the proposed scheme, provided by a different contractor to the estimate provided in Section 4.4. This cost does not make an allowance for seeding and planting.

Cost breakdown

Item Description	Unit	Quantity	Rate	Cost
Topsoil Strip & Store on Site	cu.m	12,000	£2.00	£24,000.00
Excavation	cu.m	92,330	£2.00	£184,660.00
Transport & Place	cu.m	92,330	£2.00	£184,660.00
Replace Topsoil	cu.m	12,000	£3.00	£36,000.00
Place material in Flood Bank	cu.m	5,000	£4.00	£20,000.00
Installation of culverts and headwalls	no.	2	£15,000.00	£30,000.00
Supply and installation of Stop Log	no.	2	£2,500.00	£5,000.00
Supply and installation of Tilting Weir	no.	1	£20,000.00	£20,000.00
Fencing	m	1,000	£10.00	£10,000.00
Temporary Works	sum	1	£10,000.00	£10,000.00
General Items	sum	1	£20,000.00	£20,000.00
			Estimated Cost of Works	£544,320.00
			Contingency @ 10%	£54,432.00
			Total Budget	£598,752.00

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