

Technical Note

Project:	HTR Havant Thicket Outline Design		
TN Ref. No:	HTR-ATK-XX-ZZ-RP-Z-0001		
Subject:	Technical Note - Wetland Concept and Outline Design		
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Document history

Revision	Status	Purpose description	Origin-ated	Checked	Reviewed	Author-ised	Date
C02	A2	For issue	AB	NL	IM	KIO	29/04/20
C01	A1	First Issue	AB	NL	IM	WI	09/03/20

1. Introduction

Portsmouth Water (PW) is committed to the delivery of both on and off-site mitigation measures to address the likely ecological and visual impacts associated with the construction of the Havant Thicket Reservoir (HTR). Habitat and biodiversity enhancements will be delivered as part of the Project including the provision of wetland habitats along the northern shoreline of the reservoir. The wetland area is one of the key delivery mechanisms for offsetting biodiversity losses and in combination with the overall mitigation package will provide a Project that accords with local and national planning policy and delivers landscape scale biodiversity net gain.

The integration of a wetland area into the HTR provides an opportunity to create habitat of high intrinsic ecological value that can act to maximise natural capital value through the provision of variable design of the wetland habitats and their arrangement within the wetland footprint.

1.1. Purpose of Technical Note

The purpose of this Technical Note is two-fold. Firstly, to chart the decision-making process behind the development of the outline wetland designs from the initial post public consultation concept design (Outline Plan developed by Arup, 2009), through more recent phases of data gathering, water level and depth modelling, design development and stakeholder engagement undertaken by Atkins and PW.

Secondly, to support Portsmouth Water in making a decision, via the project governance process, on the key wetland design concepts and design parameters that are presented in this Technical Note in order to form the basis for future design development to the level of detail required for Planning Submission (as set out in the Planning Strategy), and subsequently sufficient to prepare Works Information.

The wetland design concept shall also support the objective of achieving Biodiversity Net Gain. The key concepts for the wetland are as follows:

- The requirement for wetland retention – supporting achievement of biodiversity net gain, and to ensure the habitat created will thrive and can be managed and maintained so this remains a viable asset for the design life of the reservoir
- Alignment of the wetland retention structure, its form and functionality – to support design freeze for preparation of materials required for planning permission; and
- Size and extent of the wetland area – including the proposal to compartmentalise the retained wetland area and to create wetland habitat adjacent to the retained area to support the planning submission and inform Works Information / robust costing

The structure of this Technical Note is as follows:

- Summary of stakeholder engagement (workshops and field visits with the Wetland Sub-group including written feedback on proposals)
- Outline design process
- Reservoir hydrology and need for wetland retention
 - Conceptual overview of the reservoir hydrology and rationale for wetland retention
- Wetland layout and extent
 - Charts the process of wetland design concept development
 - Flow diagram showing the process undertaken to support outline design development
 - Presents the proposed retention structure typologies, their alignment and resulting wetland layout
 - Modelled outputs of key wetland habitat parameters and material requirements resulting from proposed alignment
 - Outline designs for retention structure
 - Current concept development for islands within the retained wetland area and other wetland habitat features
- Wetland hydrology
 - Presents modelled scenarios depicting changes in water extent and depth provision for the retained wetland areas and areas targeted for wetland habitat creation outside of the retained footprint

- Water level management and water quality
 - Details passive water level control provided by retention approach and options for active water level control
 - Implications of the proposed outline design on water quality
- Landscape considerations
 - Provides details of integrated design development with landscape considerations
- Summary
 - Schedule of wetland outline design elements for which approval is being sort from the Technical Group and a look forward to concepts that are currently being developed for the wetland

1.2. Stakeholder Engagement

Table 1-1 details the stakeholder engagement with the Wetland Sub-group and summary outcomes which have formed the basis of the design objectives and on-going outline design for the wetland along the northern shoreline of the reservoir.

Table 1-1 - Summary of stakeholder engagement

Consultation (date)	Purpose	Outcomes
18 December 2018 Initial consultation between PW and the Wetland Sub-group	Formation of Wetland Sub-group comprising of wetland specialists to develop wetland design objectives	Design objectives that came out of the initial consultation: • Provide resilient habitats • Create a diverse wetland ecosystem • Provide habitat connectivity • Support mitigation and compensation for existing habitats and species present at the site • Future site management • People and education
10 January 2020 Stakeholder workshop and site visit	Presentation to the Wetland Sub-group of options being considered for retention and wetland habitat provision followed by a site visit to look at and ground truth opportunities. Main meeting objective was to determine wetland design parameters including: extent, wetland habitat provision, retaining structure design, water level provision, island concept, nesting birds and water quality. Requirements for water level control, maintenance and recreational assess. Planting requirements, colonisation potential.	General agreement on the concept of a retained wetland with compartmentalisation. Insights from the meeting which have influenced the design going forward include: • Manipulation of existing ground levels to increase habitat complexity • The retention structure to primarily provide an engineering function with berms and shelves to facilitate wetland vegetation establishment • Seasonally inundated islands within the retained wetland area • Provision of ephemeral wetland is an important habitat feature in its own right • Preference is for natural vegetation colonisation although some import of reed may be required as part of a strategic planting strategy
Additional feedback from Wetland Sub-group following workshop (written responses)	To provide additional information on aspects of the wetland that were not covered in detail on the site visit (10/01/20)	Further comments: • Larger islands with a variable surface topography will provide more varied vegetation and be less prone to wave action • Not planting in wetland may lead to establishment of a more natural vegetation community

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Consultation (date)	Purpose	Outcomes
		- Requirement for access along the retention structure should be determined based on maintenance requirements - Visitor centre needs to be at an easily accessible location with maximum amount of engagement nearby but minimum accessibility to high value wildlife areas
20 April 2020 Wetland consultation with specialist stakeholders - including representatives from RSPB and Hampshire Ornithological Society	Presentation of outline design concepts and request for feedback.	Strong support for the need for retention and broader outline design concepts. Feedback from group to inform future project phases includes: - Strong preference for natural plant colonisation approach recognising some imported plant material may be required. Implementation of robust biosecurity protocols in relation to plant procurement process - Consider requirements for more or better placed hides - Adaptive management approach to hide/view-point siting e.g. waiting for the habitat to develop before deciding where to put any extra hides or view-points

1.3. Outline design process

The design of the wetland habitat linked to the Havant Thicket Reservoir scheme has built upon and extended the previous outline concept by Arup (2009) (see Figure 3-1). There are no specific standards and/or specifications for wetland habitat design as each system needs to consider the specifics of the individual location including the baseline topography, hydrology, ecology, water quality and general landscape setting.

To this regard, the wetland design process has moved through different stages of options identification, review and appraisal through a collaborative design process involving wetland design, construction and management specialists from across a dedicated wetland design project team. Figure 3.2 provides a summary of the wetland design process, that ran over a 5-month period between December 2019 and April 2020.

Specific Stop-Go points in the design process were scheduled to stress-test individual design decisions and took the form of targeted contact sessions at key points in the programme. The make-up of the team has been a crucial element for both developing, reviewing and stress-testing different concepts and options to deliver a robust, workable/buildable and locally-relevant design that reflects the full range of environmental, recreational and stakeholder requirements of the scheme.

Specialists involved in the design process included:

- Portsmouth Water staff** who have been involved in the wetland project from the outset, providing essential context and continuity to the design and development of different scheme elements, including the history of option selection and review.
- To ensure integration with the overall scheme and align with the design standards of the reservoir, **Atkins Reservoir and Dam Safety and landscape engineers** were active members of the wetland design team and attended the main review and briefing sessions.
- The overall wetland design coordination and delivery has been provided by the **Atkins Wetland Design Team**, a group of specialists who have worked alongside the reservoir design team on previous award-winning, environmentally lead projects such as the Hampstead Heath Ponds Project (winner of the Institution of Civil Engineers Community Benefit Award and the CIRIA Biodiversity Challenge Award) and London 2012 Olympic Park Wetlands (CEEQUAL winner of Outstanding Achievement Awards, and Peter

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Youngman Award for outstanding contribution to landscape at the Landscape Institute). The team have also brought a detailed local knowledge of wetland creation and restoration in the Solent, the south coast and nationally with a strong focus on hydrological and ecological modelling expertise.

- A **Wetland Sub-group** established by Portsmouth Water has supported the design process from the start and includes representatives from regulatory organisations (Environment Agency, Natural England), planning authorities (Hampshire County Council) and non-governmental organisations that are involved in the creation and/or management of similar wetland systems in and around the Solent and at a national level (e.g. the Hampshire and Isle of Wight Wildlife Trust). The role of the wetland sub-group has been to develop and stress-test ecological objective setting and detailing of the individual wetland features at every step in the process.

This collaborative design approach has ensured that wetland outline design delivers the best local environmental outcomes for the scheme and has undergone appropriate due diligence and challenge regarding the suitability, sustainability and buildability of different design elements. This involvement has also helped to get early buy-in and support for the scheme. Inputs from all the specialists and the details of the agreed scheme that will go into planning and future detailed design development are reflected in the outline design presented in this Technical Note.

2. Reservoir Hydrology and Need for Wetland Retention

Technical constraints relating to the provision of a viable wetland area relate predominately to reservoir hydrology and the influence of water level changes on wetland habitat development, resilience and long-term ecological function. The influence of water level fluctuations within the wetland area, (exacerbated by drought events) in combination with operational drawdown, has been the focus of further investigation and the development of the wetland retention concept design.

The following issues have been identified in relation to the wetland which has driven requirements for water retention through the provision of a wetland retention structure:

- Potential for water level changes to compromise the establishment of wetland habitat as a result of the detrimental effects of shoreline exposure on wetland vegetation and associated species
- Reduction in wetland habitat availability and quality in response to falling levels and the influence on wider habitat connectivity
- Potential for wave action to compromise the establishment of wetland plant communities
- Risk to wetland plants and associated species in marginal wetland areas from reduced water levels e.g. desiccation of plants and potential for increase in predation pressure on birds as wetland become more accessible to foxes, for example
- Potential increase in requirements for wetland habitat maintenance (e.g. management of scrub encroachment) triggered by prolonged periods of exposure and wetland vegetation succession
- Review of the existing topography has shown local topography cannot simply be adapted for use as a water retaining feature

Table 2-1 summarises the advantages and disadvantages of the provision of a wetland retention structure.

Table 2-1 - Advantages and disadvantages of a wetland retention structure

Advantages	Disadvantages
Improved resilience of wetland to reservoir water level fluctuation by holding water within a retained wetland area - some depth variability is provided by the existing topography	Associated design and construction costs - earth movements to create retention structure and any required cut-off to prevent leakage
The structure can be designed to provide additional wetland habitat through the creation of marginal shelves for wetland vegetation establishment – in essence providing appropriate depths for wetland habitat to be created within deeper water areas	Structure will require an engineering solution to manage risk of erosion from wave action – could constrain opportunities for habitat provision on downstream face
The structure will act to protect the wetland area from wave action which has been identified as a constraint to wetland establishment within the reservoir footprint. This includes any islands that may be incorporated into the retained wetland area	Operational costs associated with maintenance and inspection of retention structure
Structure provides a mechanism by which passive water level management can be achieved and facilitates the provision of active water level control if required	Retained wetland water volumes will mean that the structure will need to be considered under the Reservoir Act
Provides opportunity to use the wetland area for surface water management during construction and then adaptively manage to provide wetland retention purpose in operation	Presence of structure provides sites for bird roosts which could adversely affect water quality Structure will provide access points to wetland area which could result in disturbance of wetland species and habitats should unsolicited access result

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2.1. Reservoir Hydrology

The hydrological regime of the reservoir, to the best of our understanding, is shown in the schematic provided as Figure 2-1. In a normal year (in the absence of drought and the requirement for abstraction from the reservoir) the reservoir top water level (TWL) will be maintained at 39.5m OD through pumping from Havant and Bedhampton Springs, typically for the period spanning November through to April.

For the period April through to November the reservoir would not be pump filled, although it may receive limited inflow from the three intermittent streams flowing from the north to the wetland area (see Figure 3-3 for stream locations), during which period the reservoir level will fall to a normal annual minimum of 39.0m OD as a result of evapotranspiration – this is a normal annual reduction through the summer in water level by 500mm.

During a drought event (1 in 5 years, as would result from a very dry summer) the water level is likely to fall below 39.0m OD, after which the reservoir would be topped up in November via pumping from the springs and any inflows from the steams that discharge to the reservoir, until a point that TWL is recovered.

As a conservative estimate, every 1 in 10 years it is anticipated that there will be prolonged drought during which period water would need to be abstracted from the reservoir for potable supply. The concomitant reduction in water level may be significant and span more than one season. This extreme level is shown as 35.0m OD but could theoretically be as low as 27.0m OD based on current engineering design.

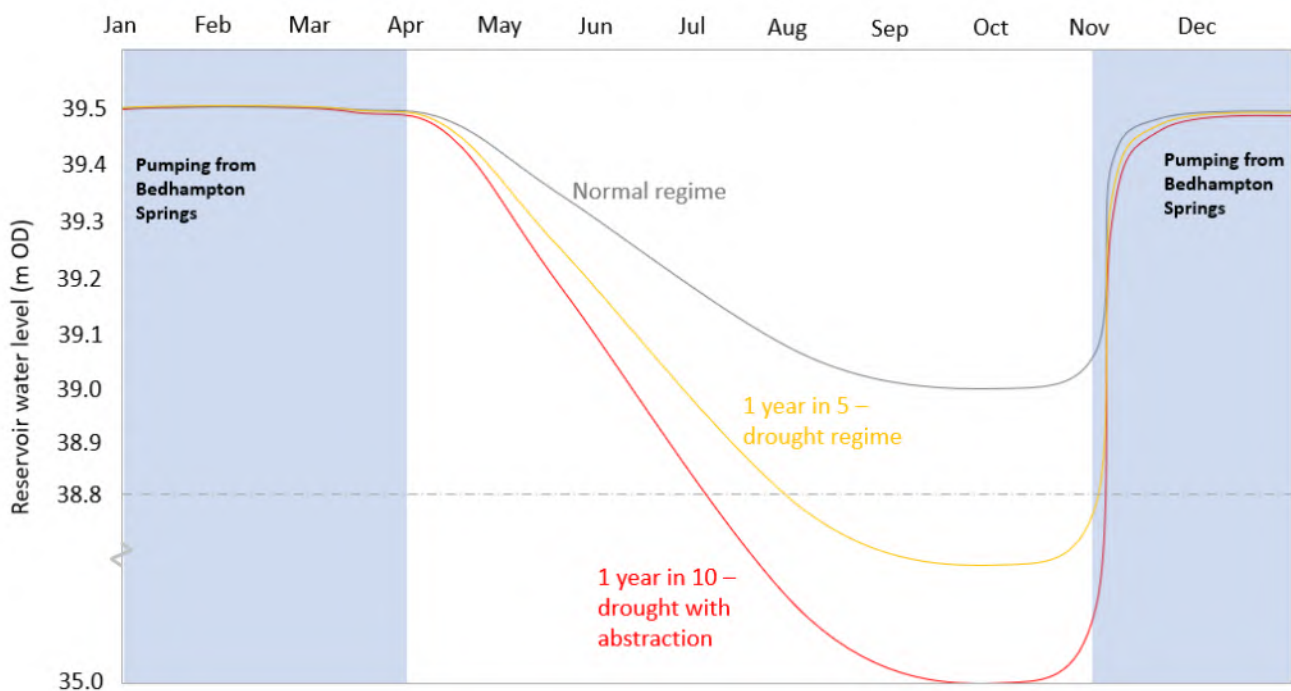


Figure 2-1 - Current conceptual understanding of the hydrological regime of the reservoir

Based on this conceptual understanding, Figure 2-2 has been produced to show the open water condition in the reservoir and the extent of the shoreline that would become exposed at a range of water levels scenarios along three transects (in plan). Since the ground levels are sloping, the actual extent of exposed shoreline will be greater than the plan distances provided.

The scenarios presented are as follows:

- TWL (39.5m OD)
- the annual summer minimum (39.0m OD)
- a level representing summer drought conditions (37.5m OD); and
- a level anticipated under a prolonged drought condition with abstraction from the reservoir (indicatively 35.0m OD).

As expected, the extent of exposed shoreline increases as the water level falls, this is particularly evident within the proposed wetland area along the northern shoreline. In plan, water extents fall (as an average across the three transects) from TWL by 17m at the end of a normal summer (39.0m OD), to 129m under the assumed scenario of a prolonged drought during which the reservoir is in operation (35.0m OD).

Under drought condition and operational scenarios, it is apparent that the extent of shoreline exposure will result in a significant constraint on wetland habitat viability as a result of water loss from the marginal area of the northern shoreline. Due to uncertainties surrounding operation of the reservoir it is not possible to confirm the exact spatial and temporal variability of reservoir levels and their recovery, however, water resource modelling has indicated that in a 1 in 100 year drought event with abstraction, the reservoir levels may not recover to TWL for a period of 12 to 18 months.

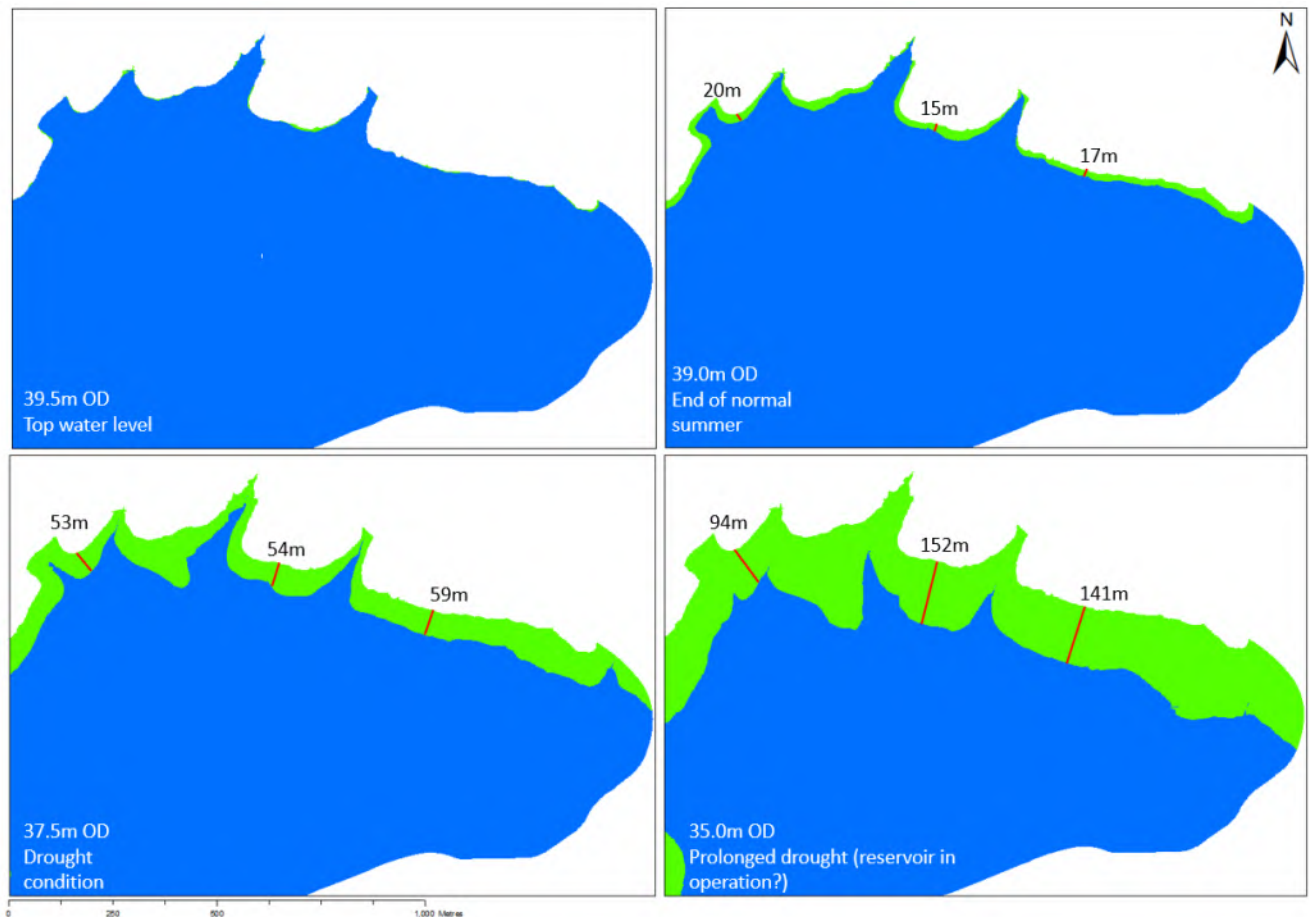


Figure 2-2 - Water and shoreline extents for a range of water levels

Based on our current best understanding of reservoir hydrology and through consultation with the Wetland Sub-group, provision of a wetland retaining structure is seen as the most viable solution to support the requirement for wetland habitat provision and to buffer against anticipated water level fluctuations triggered by drought and periods of water abstraction.

Through the mechanism of water retention within a retained wetland area along the northern shoreline, wetland habitat resilience will be improved and future proofed against the influence and uncertainties surrounding climate change and reservoir operational requirements. Furthermore, provision of a wetland retention structure provides opportunities to control water levels and facilitate wetland habitat management.

3. Wetland Layout and Extent

This section charts the development of concepts for the wetland layout and its extent which have been developed through a process of optioneering, consultation and collaborate design including ground truthing of options at a Wetland Sub-group design site visit. This includes:

- Wetland retention structure alignment
- Compartmentalisation of the retained wetland
- Habitats outside of the retained wetland
- Initial concepts for island creation and ephemeral shallows associated with the wetland area

3.1. Concept development

Initial concept

An initial plan for the wetland area was developed by Arup in 2009 (Figure 3-1). This shows proposed locations for wetland habitat creation within the HTR including areas of marshland and reed bed along the northern reservoir margin. An island chain is shown adjacent to this habitat area which has historically been interpreted as depicting the alignment of a retaining structure, a concept developed to facilitate water retention within the wetland area.

The plan also provides indicative locations for recreational activities such as bird watching view-points as well as other infrastructure elements including a visitor centre and boardwalks.

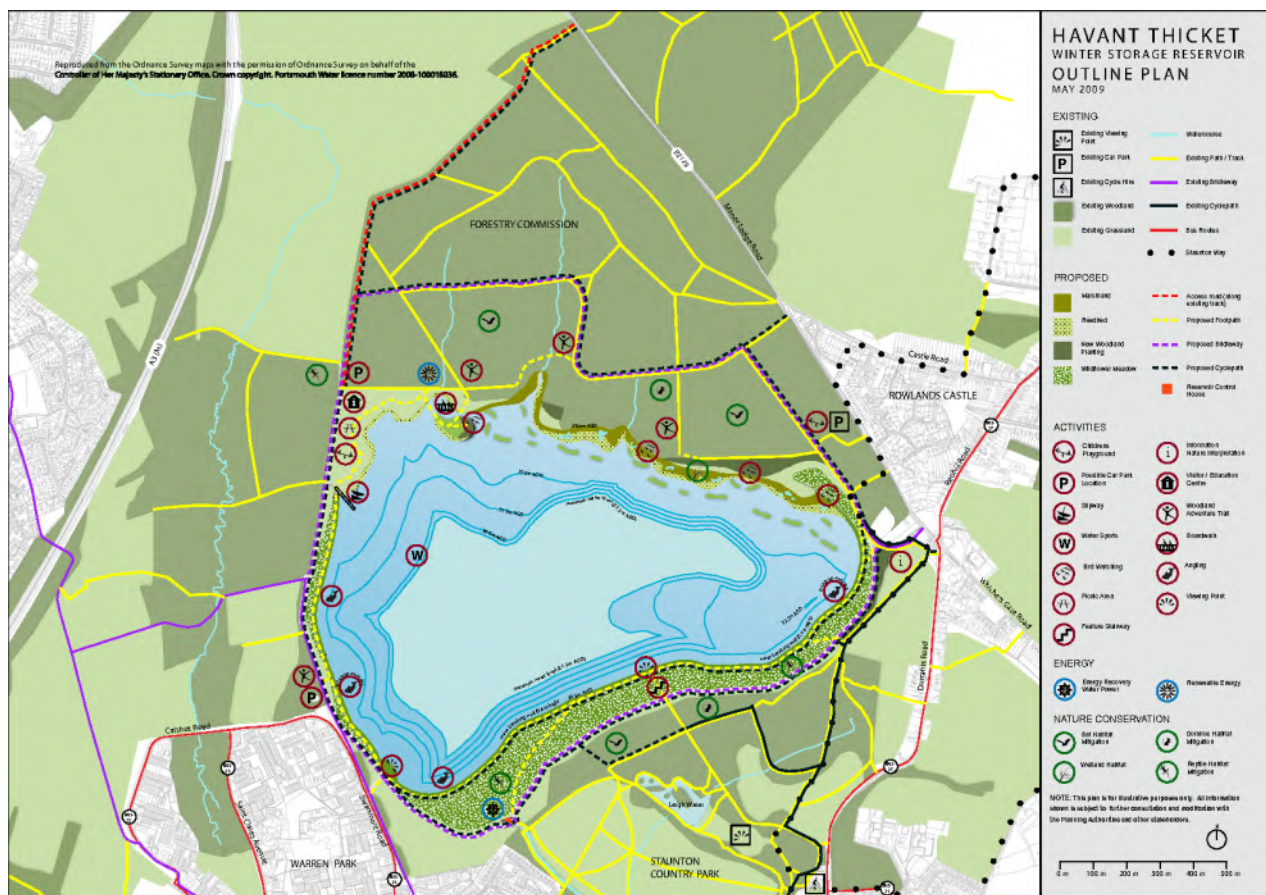


Figure 3-1 – Post public consultation outline plan (Arup, 2009)

Retention structure alignment - step back optioneering

An initial step back was undertaken to look at the implications of not providing any retention along the northern shoreline of the reservoir. This involved the review of topographic data, development of conceptual understanding of fluctuations and initial modelling of the implications of these fluctuations on water extent and depth provision. This concluded that the option of do nothing was not viable in providing a wetland habitat that is resilient to drawdown events and would also not achieve the objectives set out by the Wetland Sub-group.

Building on the concept of retention, first outlined by Arup, several retention options were presented by Atkins in a design workshop on 09/12/19. These are provided in Appendix A.1 and included options for partial retention, extended retention and compartmentalisation of the retained wetland area. During the workshop a collaborative design session between Atkins and PW led to the development of a first alignment of the wetland retention structure, as shown in Appendix A.2. This alignment shows retention along much of the northern shore with four retained compartments. The location at which the retention structure returned to the shoreline at its western extent was informed by initial thoughts on the likely location of a visitor centre with an understanding that the final alignment would need to reflect the outcomes of ongoing consultation regarding the visitor centre location and required public interfaces with the wetland area.

This first design provided the basis of further iterations of the alignments through a process of wetland workshops, stakeholder meetings and receipt of high-resolution topographic data. The workshop development of the distance off shore was subject to ground truthing onsite with the Wetland Sub-group (10/01/19) to ensure there was agreement on its location. The alignment has been designed to fit within the existing topography and utilise the variability in ground level provided by the presence of stream valley formations.

A collaborative and iterative process between Atkins and Portsmouth Water, including cross discipline integration (e.g. landscape and engineering) has resulted in a current agreed alignment that is presented in Section 3 and the process this has followed is presented in Figure 3-2.

The outline wetland design concepts have been subject to further consultation and feedback through engagement with specialist stakeholders representing the RSPB and Hampshire Ornithological Society on 20/04/20.

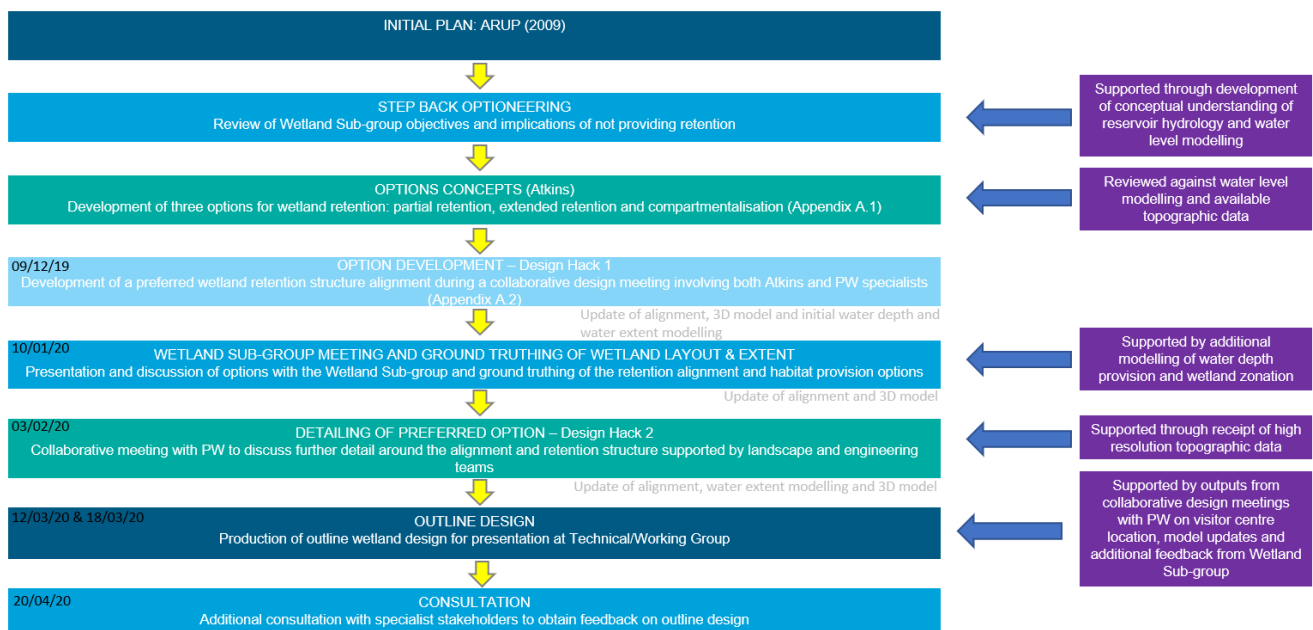


Figure 3-2 - Workflow of collaborative design approach

3.2. Proposed wetland structure alignment

Figure 3-3 shows the proposed retention structure alignment and resulting layout of the retained wetland area.

The retaining structure extends for approximately 1.3km along the northern shoreline to which it returns at strategic locations to facilitate access to the structure for maintenance purposes and to provide the required water retention function. The distance of the retention structure from the shoreline is variable as a result of the influence of existing topography but is typically 60m to 80m under TWL condition (as shown by the 39.5m OD contour), excluding the extremes of the stream valleys. Further wetland parameters e.g. wetland area and volumes, are provided in Table 3-2.

Lengths of the retaining structure along which vehicular access is required are shown in Figure 3-3 with a solid red line (wetland retention structure), lengths along which no vehicular access is required (wetland retention bund), a dashed red line. Further detail on the outline design of these two retaining structure typologies are provided in Section 3.5. Where the wetland retention structure returns to the shoreline it is shown as aligning to existing access tracks at around the 40.0m OD contour.

Please note that the proposed alignment and form of the wetland retention structure is likely to require minor adjustments to facilitate vehicle access and deter access onto the structure at points of public interface. Current proposals exclude the provision for access to the wetland retention structure from the west to manage the risk of unsolicited public access to the retained wetland area. There is, therefore, a requirement to incorporate vehicle turning heads along the structure by widening its footprint at strategic locations to facilitate vehicular movements.

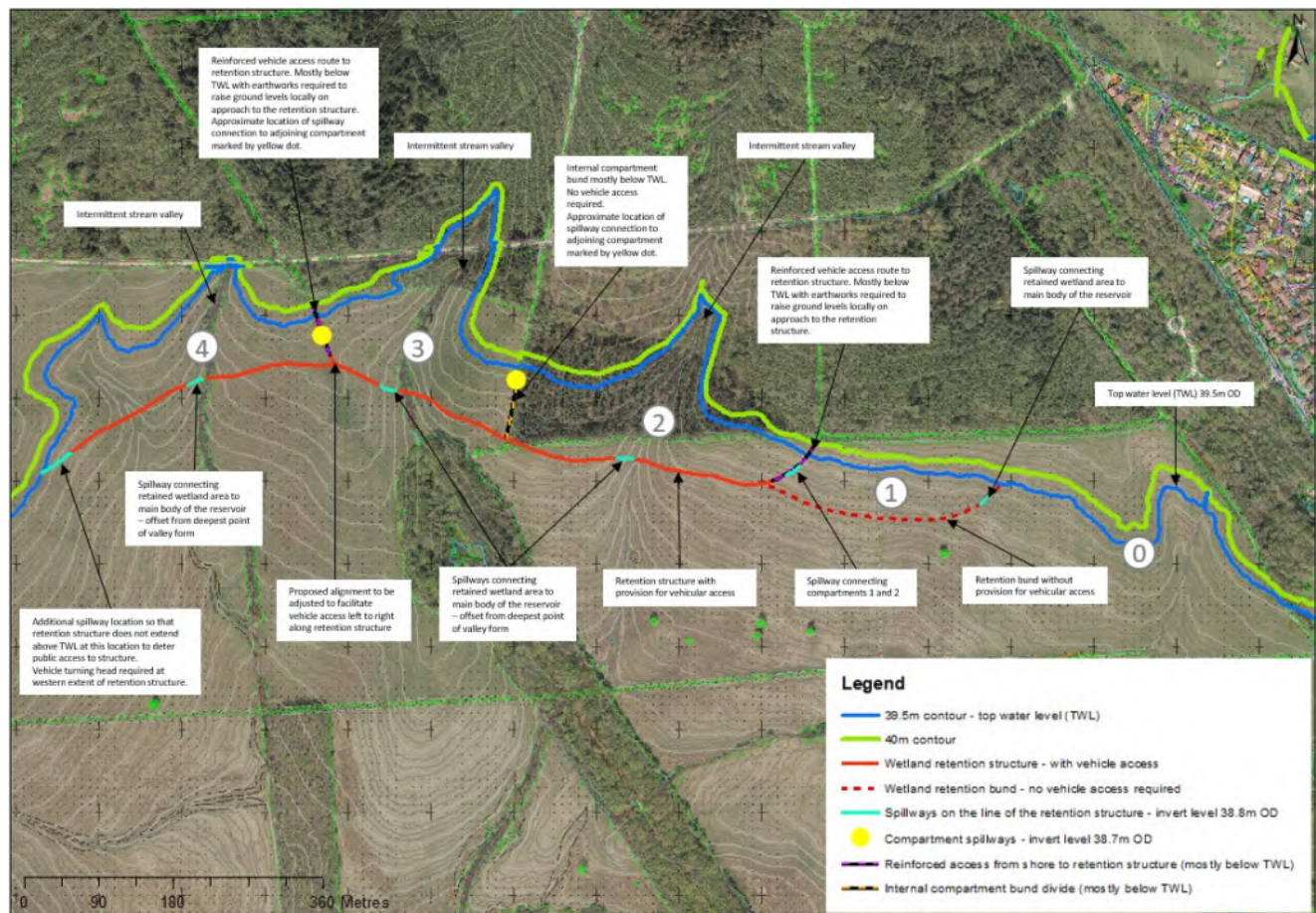


Figure 3-3 - Proposed alignment of the wetland retention structure and key features

3.3. Retained wetland layout

The retained wetland area is shown as being separated into four wetland compartments (compartments 1, 2, 3 and 4) formed by a combination of the retaining structures, natural high points in the topography (incorporating reinforced access tracks), the construction of an internal compartment bund divide between compartments 2 and 3 and a wetland retention bund to form Compartment 1.

The exact alignment and form of the structures and access returns to and from the shoreline will need to be developed through detailed design phases. But in order to manage/reduce potential for unsolicited access and disturbance the access returns are shown at concept as being as being submerged under normal water level condition.

Compartmentalisation of the wetland is being progressed as the preferred option for the following key reasons:

- Facilitates provision of a greater variety of wetland habitat typologies
- Protects the retained wetland area against failure of the retention structure i.e. not all wetland would empty should part of the retention structure fail
- Allows for isolation of wetland areas for maintenance purposes and/or varying water level control
- Increases the edge extent of the wetland area which adds habitat complexity
- Facilitates use of the retention area for surface water management during construction phases
- Wetland compartments can be isolated and drained independently should the requirement arise e.g. to undertake habitat management and/or address future constraints such as invasive species establishment, pollution events or requirement for desilting
- Wetland compartments can be isolated and filled independently through pumping from the main body of the reservoir under extreme drawdown events

Further reasoning for the development of the compartmentalisation approach is provided in Section 5 in relation to water level management and water quality.

Table 3-1 provides a description of each of the retained wetland compartments and details associated hydrological features.

Table 3-1 – Retained wetland compartments

Compartment	Description	Associated hydrological features
1	Retained wetland habitat area formed by a wetland retention bund that does not require vehicular access Proposed as predominantly reed with some sedge habitat with wetland channels and tree e.g. osier willow planting on retaining bund Anticipated that trees will self-seed along the northern shore to provide a more graded wet woodland edge	Hydrological connectivity to main body of the reservoir and to Compartment 2 through passive water level control - spillway/s Plus, active water level control (pipe) to main body of the reservoir
2	Wetland habitat area retained to the east and south by a wetland retention structure requiring vehicular access Bunded to the west by natural topography and an earth internal compartment bund divide Wetland compartment with open water and marginal habitat, including wet woodland – local ground manipulation to improve complexity, including island creation	Seasonal inflows from intermittent stream Hydrological connectivity to main body of the reservoir through passive water level control (spillway) and active water level control (pipe) Plus passive water level control (spillway and compartment spillway) to adjoining compartments 1 and 3

Compartment	Description	Associated hydrological features
3	Wetland habitat area retained to the west and south by a wetland retention structure requiring vehicular access Bunded to the east by natural topography and an earth internal compartment bund divide Wetland compartment with open water and marginal habitat – local ground manipulation to improve complexity, including island creation Wet woodland habitat creation to the north of the existing access route crossing	Seasonal inflows from intermittent stream Hydrological connectivity to main body of the reservoir through passive water level control (spillway) and active water level control (pipe) Plus, passive water level control (compartment spillways) to adjoining compartments 2 and 4
4	Wetland habitat area in front of proposed visitor centre and educational hide location, retained to the east and south by a wetland retention structure requiring vehicular access Wetland compartment with open water and marginal habitat – local ground manipulation to improve complexity, including island creation	Seasonal inflows from intermittent stream Hydrological connectivity to main body of the reservoir through passive water level control (spillways) and active water level control (pipe) Plus, passive water level control (compartment spillway) to adjoining Compartment 3

Wetland Area 0

An additional wetland area (Area 0) is shown located to the east of the retained wetland area (Figure 3-3). The decision was taken not to extend a retaining structure in front of this area through consultation with the Wetland Sub-group. There is limited topographical variation in this location and the slope from the shoreline is typically shallow (1 in 40). Since this area is not retained it will be in full hydrological connectivity with the main body of the reservoir and will, therefore, be subject to the fluctuations therein. Anticipated water level fluctuation across this area facilitates the development of wet grassland habitat which will act to provide a more varied arrangement of wetland habitat typologies and habitat for bird species such as lapwing. Due to the relatively homogenous nature of the ground levels in this area small scale ground manipulation (creation of ephemeral shallows and raised areas above and below TWL) is proposed to increase habitat complexity and build in habitat resilience to water level fluctuations (see Section 3.6). In this area there is potential to link in existing ditch habitats to the north to the proposed wet grassland area to provide additional habitat creation opportunities. These would be progressed at the detailed design phase.

3.4. Key retained wetland parameters

Key parameters for the retained wetland area have been calculated from the 3D model developed for the wetland retention structure (Figure 3-4). The 3D model provides a simplistic interpretation of the wetland retaining structures in so much as it is modelled as having a:

- 4m top width along the lengths of the retention structure requiring vehicular access, with 1 in 4 upstream and downstream slopes back to the existing ground level
- 3m top width of the internal compartment bund in between compartments 2 and 3, with 1 in 3 slopes to existing ground level
- 3m top width of the retention bund around Compartment 1 that does not require vehicular access, with 1 in 4 slopes back to the existing ground level

- A spillway in front of each compartment (4No. spillways in total¹) connecting the wetland to the main reservoir
 - Spillway invert level set at 38.8m OD

Based on these parameters the key wetland statistics are provided in Table 3-2 with a 3D representation of the model provided as Figure 3-4. Please note that the volume and area values provided are based on existing ground levels within the retained wetland area.

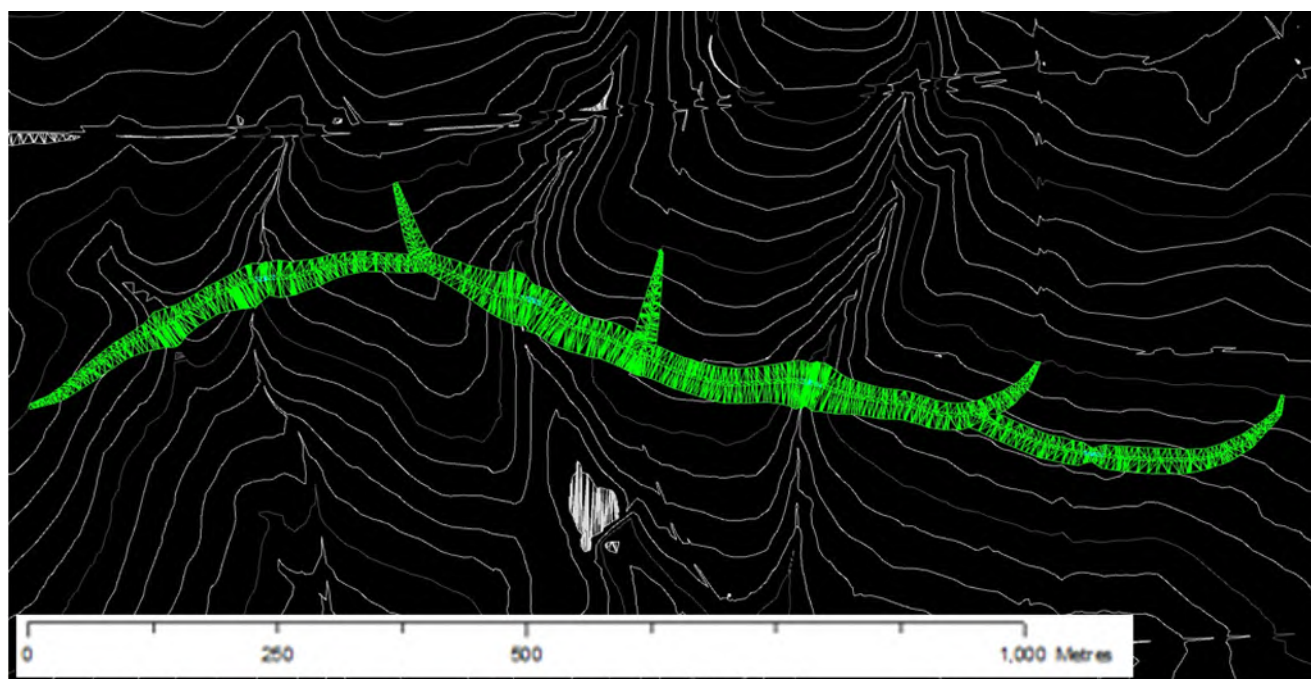


Figure 3-4 - 3D model representation of the wetland retaining structures

Table 3-2 – Retained wetland statistics

Compartment	Volume in m ³ at TWL (39.5m OD)	Area m ² at 39.5m OD	Retained wetland level volume ² in m ³ (38.8m OD)	Area m ² at 38.8m OD	Length of retention structure (m) – outer extent	Typical distance of retention structure from shoreline (m)*
1	9,287	12,172	2,856	6,296	327	60
2	46,591	32,261	27,204	23,158	320	78.5
3	46,066	29,699	28,071	21,883	227	83
4**	29,073	27,984	13,796	16,191	409	68
Totals	131,017	102,116	71,927	67,528	1,283	-

Notes: * distance from shoreline (39.5m OD TWL contour) to centreline of retention structure, excluding extremes of stream valleys;

**structure in front of Compartment 1 is referred to as a wetland retention bund within the text

Based on the 3D model the total volume of the retained wetland area at TWL is **131,017m³**. This reduces to **71,927m³** at the point at which the wetland is currently designed to be retained at 38.8m OD, these volumes

¹ See Section **Error! Reference source not found.** for details of additional spillway locations required at western extent of retention structure and between retained wetland compartments – these are in addition to the 4No. locations represented in the 3D model

² Retained wetland volume represents the volume of water stored in the retained wetland area at a level which equates to the invert level of the spillways that connect the retained wetland area to the main body of the reservoir, 38.8m OD

equate to a wetland habitat open water surface area of **102,116m² (10.2ha)** and **67,528m² (6.75ha)**, respectively.

The exact area of wet grassland habitat creation in Area 0 is still to be confirmed as this will be dependent on the detailed design of local ground manipulations, the concepts for which are provided in Section 3.6. This stated, applying a conservative assumption that wet grassland is most likely to be a viable habitat option where it transitions between the 40.0m and 39.0m OD contour (i.e. 500mm either side of TWL) then an initial estimate of **13,000m² (1.3ha)** is achieved.

It is recognised that the wet grassland habitats will be susceptible to the full influence of reservoir drawdown but this is seen by the Wetland Sub-group and design team as being beneficial in terms of the extra habitat diversity which will be provided in addition to the retained wetland areas.

Implications of retained volume - Reservoirs Act

Based on these statistics there is a requirement for the wetland retention structure to comply with the Reservoirs Act 1975, as the stored volume capacities of 27,204m³ and 28,071m³ in compartments 2 and 3 both exceed the current Reservoirs Act threshold of 25,000m³ (stored above natural ground level) and the reduced volume threshold of 10,000m³ which is expected to be enforced in the near future.

The wetland retaining structure would have to be designed to be compliant with the Reservoirs Act, which would mean that the design and construction of the structure, where it retains compartments 2 – 4, must be supervised by a Construction Engineer appointed to the appropriate panel of engineers, in this case the All Reservoirs Panel.

Reducing individual retained wetland compartment volumes to below 10,000m³ would significantly impact on the benefits gained from the new wetland design as a result of reduced habitat area. The requirement of the Reservoirs Act would not necessarily be onerous, as in practice the wetland retaining structure will be designed to be stable and impermeable, requiring an engineered (compacted) clay core which is achievable, and the certification of the wetland retaining structure before its potential use as a balancing pond during construction of the main embankment downstream.

Since Compartment 1 would store only 2,856m³ it would not need to comply with the Reservoirs Act, however, the facility to fill or drawdown the retained water in the compartment with a piped control point is seen as being beneficial by the reservoir engineers. It is proposed that the compartment has a spillway to connect it with the main body of the reservoir.

Material requirements

Model outputs currently estimate the volume of material required to construct the retention structure at **64,438m³** (Table 3-3). This volume estimate includes material requirements to return the retention structure and the compartment bund to the shoreline at a level of 40m OD. Since the 3D model development, it should be noted that the extent of earthworks required to facilitate access and compartmentalise the wetland are less than the modelled volume. However, the volume estimate does not include any material requirements for below existing ground level works (e.g. clay core cut-off) or the addition of habitat features such as marginal shelves to the retaining structures to increase habitat complexity within the retained reservoir footprint.

Table 3-3 - Cut and fill balance for the wetland retention structure, extracted from the 3D model

Volume Summary							
Name	Type	Cut Factor	Fill Factor	2d Area (sq.m)	Cut (Cu. M.)	Fill (Cu. M.)	Net (Cu. M.)
VOLUME WRS	full	1.000	1.000	5308402.478	0.875	64438.483	64437.608<Fill>

Wetland 3D model developments will need to include the addition of shelving and slope details associated with retention structure and wetland habitat provision within the retained footprint. Further information on retention structure design and island provision within the retained wetland is provided in Section 3.5.

3.5. Retaining structure outline designs

The wetland retention structure has been designed primarily as an engineered feature with incorporated low points (wetland spillways) along its length. These spillways are required at strategic locations to provide hydrological connectivity between the main reservoir water body and the retained wetland, hydrological connectivity between compartments 1 and 2, to control access to the structure and to facilitate landscape views (see Figure 3-3).

The wetland retention bund around Compartment 1 is designed as a less formal structure along its eastern and southern extent, along which no vehicular access is required, however, it too incorporates a wetland spillway to maintain hydrological connectivity with the main body of the reservoir.

Retaining structures will be designed in such a way as to provide additional wetland habitat such as the provision of shelves for development of marginal vegetation on the upstream face of the retention structure.

The wetland retention structure outline design incorporates provision for vehicular access for maintenance purposes (alignment requiring vehicular access shown as solid red line in (Figure 3-3). Where vehicular access is required a top width of 4m is maintained with a stone surfaced track to accept vehicles. It is proposed that vehicles will access the retention structure from the shoreline at two locations which have been aligned to tie in with appropriate existing access points.

These access locations effectively provide the boundary between wetland compartments 1 & 2 and compartments 3 & 4 as shown in Figure 3-3 (dashed black and purple line). The outline design includes the extension of the existing access route from the north, through the provision of a reinforced 4m wide vehicle access track (stone surfaced) which follows the high point of the natural topography, before gaining elevation on earthworks required to marry the access route with the outer extent of the retention structure. The northern extent of this access track will be below top water level when the reservoir is full.

Outline designs for the retaining structures have been developed in consultation with the reservoir, ground engineering and landscaping teams and the Wetland Sub-group. In their development the following have been considered:

- Formation and slope angles
- Protection requirements against wave action
- Leakage potential associated with the Harwich Formation
- Requirements for passive water level management and/or active water level management
- Access requirements for:
 - maintenance of the retaining structure and compartment bunds e.g. repairs to slips or wave damage to the structure or planting (or removing areas of wetland planting should they not take)
 - operation of pipe control points to allow emergency drawdown of each retained wetland compartment
 - operation of active water level management control points for lifting out valves/penstock gates for replacement or maintenance
- Opportunities to incorporate wetland habitat design into the structure – both on its upstream and downstream face
 - Landscaping elements and required views (see Section 6)

Levels and formations are currently indicative and have been developed based on current best knowledge of reservoir hydrology and operation, wave height, site topography and ground investigation.

Typical section through the wetland retention structure – with vehicular access

An outline section through the retention structure along which vehicular access is required is provided in

Figure 3-5. The key dimensions and engineering features are:

- Retention structure formed of clay – with the core probably extending below existing ground level to form a cut-off to prevent seepage loss from the wetland into reservoir or to the land beyond the eastern and western extent of the wetland (detail to be developed)

- Top level of retention structure is set at 40.0m OD – providing a 500mm freeboard relative to TWL to accommodate wave action – ongoing modelling indicates wave height is a maximum 0.45m for the longest fetch which is to the north east end of the main dam
- 4m top width, with stone surface to provide vehicular access:
 - Access could be formed with turf reinforcement mat, or a combination of stone and turf.
 - The reinforcement may also have the function of wave protection where largest waves may slightly overtop the crest
- 1 in 4 downstream slope into the main body of the reservoir – shown as requiring armour stone to protect against wave action
- Stepped profile within retained wetland area to provide marginal shelves and slopes for wetland vegetation establishment – widths and elevations of marginal shelves vary to provide wetland habitat complexity
 - Slopes and shelves can be planted with wetland species or allowed to colonise naturally. Preference is for natural colonisation as this often results in improved species complexity, although it is recognised that some over-planting using imported nursery stock may be required at key locations

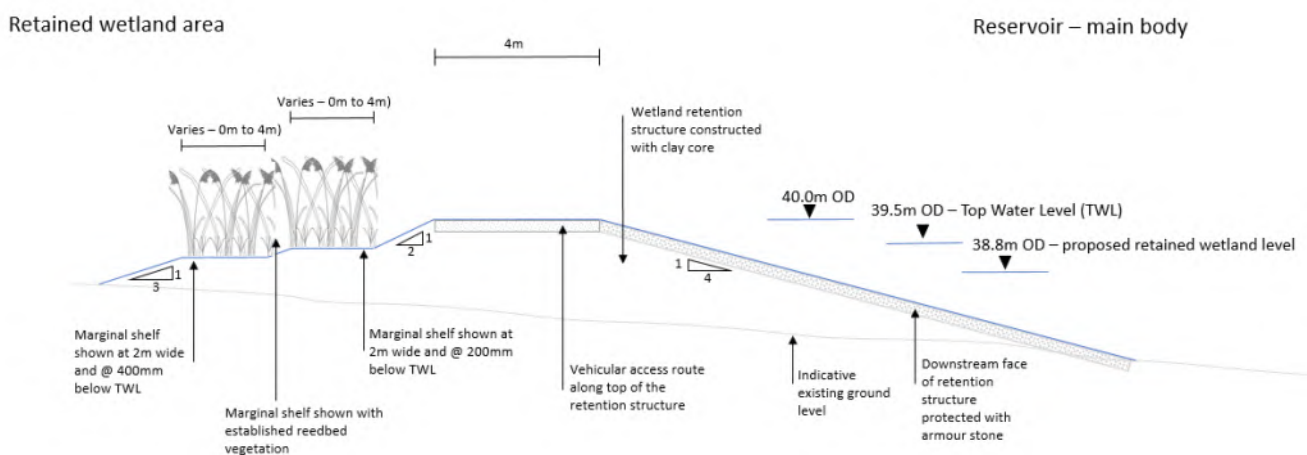


Figure 3-5 – Wetland retention structure section – with vehicular access

Typical section through the wetland retention bund – no vehicular access required

The wetland retention bund associated with Compartment 1 is designed as a less formal structure along its eastern and southern extent, along which vehicular access is not required (alignment shown as dotted red line in Figure 3-3). Since the compartment is not controlled within the Reservoir Act (due to its retained volume) there is potential for more flexibility in its design. As a retaining structure its design life is not seen as being as critical as the lengths of the retention structure requiring vehicular access. In outline it has, therefore, been designed with a function of diversifying the landscape and biodiversity opportunities through tree planting and as a structure that will need to maintain its integrity until the reed bed has established.

An outline section through the retention bund is shown Figure 3-6. The key dimensions and engineering features are:

- Retention structure formed of soil/clay – may be a requirement for a clay core to prevent seepage loss from the compartment into reservoir or to the land beyond the eastern and western extent of the wetland (detail to be developed)
- Top level of retention structure set at 40.0m OD
- 3m top width, without armoured surface, although the associated spillway surface will require armouring
- Shown as planted with trees between to increase habitat complexity e.g. osier willow
- 1 in 4 downstream slope into the main body of the reservoir – not shown as requiring armour stone to protect against wave action, although protection will be required at spillway location

- Stepped profile within retained wetland area to provide marginal shelves and slopes for wetland vegetation establishment – widths and elevations of marginal shelves vary to provide wetland habitat complexity
 - Slopes and shelves can be planted with wetland species or allowed to colonise naturally. Preference is for natural colonisation as this often results in improved species complexity, although it is recognised that some over planting from imported nursery stock may be required at key locations

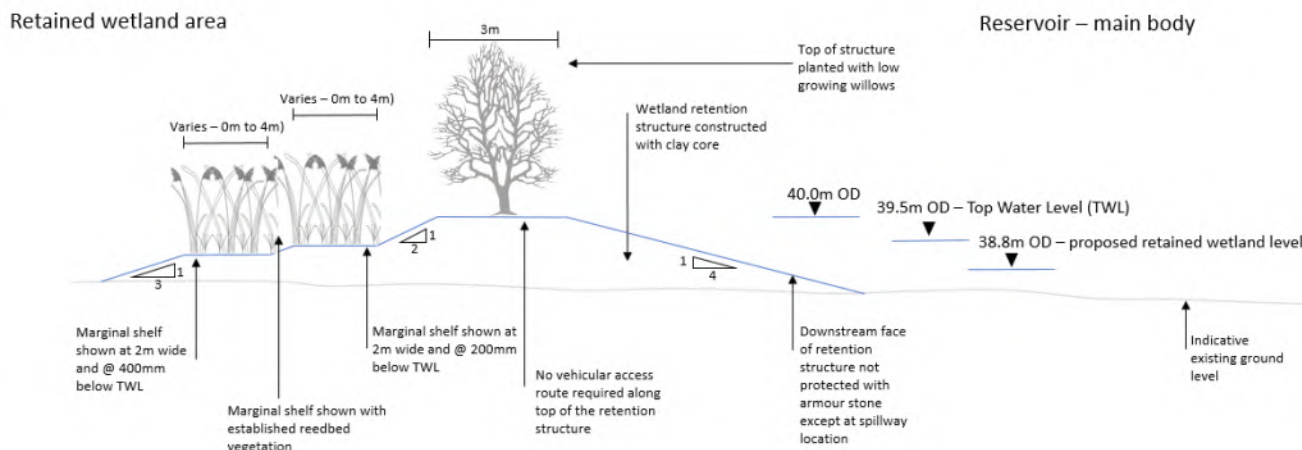


Figure 3-6 – Wetland retention bund section (Compartment 1 only) – no vehicular access required

Typical detail of wetland retention structure spillway

To maintain hydrological connectivity between the retained wetland area and main body of the reservoir during the normal water level regime and connectivity between compartments 1 and 2, it is proposed to provide 6No. wetland spillways (low points) along the retention structure set with an invert level of 38.8m OD - the retained wetland level. These are shown as turquoise lines on Figure 3-3.

Under normal water level conditions (i.e. yearly fluctuation from 39.5m OD to 39.0m OD) the wetland spillways will be submerged providing a connectivity water depth ranging from 700mm to 200mm between the retained wetland area and the main body of the reservoir. Under drought conditions, as the reservoir level falls below 38.8m OD the wetland becomes retained. Water levels within the retained wetland area are then subject to the influence of the intermittent stream inflows and evapotranspiration within the retained footprint.

The implication of spillway provision will be the appearance of the retention structure as a series of longitudinal barrier islands under normal water level conditions. This is a departure from the original Arup concept produced in 2009, that showed a series of large island features along the retention alignment. The outline design includes for provision of island features, but within the retained wetland area where they will be afforded greater protection from wave action.

The exact location and size of spillways along the wetland retention structure is still to be determined and will be developed in conjunction with:

- Wave height modelling outputs
- Requirements for maintenance of historical view-points
- Potential requirements to gain access to operate active water level control structures
- Requirements to deter public access to the structure (see note on Figure 3-3 for requirement to lower retention structure at its western extent for this purpose)
- Requirements to facilitate interchange of water between the wetland and main body of the reservoir

The section and plan provided as Figure 3-7 shows the outline design for a wetland spillway located along the wetland retention structure directly adjacent to low points in the valley form and how, at these locations, they can be integrated with the proposed active piped water level control.

The key dimensions and engineering features of these spillways are as follows:

- Invert level set at 38.8m OD (0.7m below the main reservoir TWL), with 4m base width

- 1 in 10 slopes maintained between highest point of retention structure (40.0m OD) on either side of the wetland spillway, for safe vehicular access – equates to 28m horizontal distance between high points along retention structure
- Wetland spillways slightly offset from existing intermittent stream valley alignment to provide the opportunity to install active water level control structure in valley low point
- Provision of armour stone on the upstream and downstream face to protect against both wave action and flows in or out of the wetland area:
 - Flows out of the retained wetland would occur under a scenario when the wetland is filling from stream inflow and the level within the main body of the reservoir is below the retained wetland level
 - Flows into the retained wetland area would occur under a scenario when the retained level is below the reservoir level and the wetland is not filling from piped controls while the main reservoir level rises from pumped inflows to be stored.

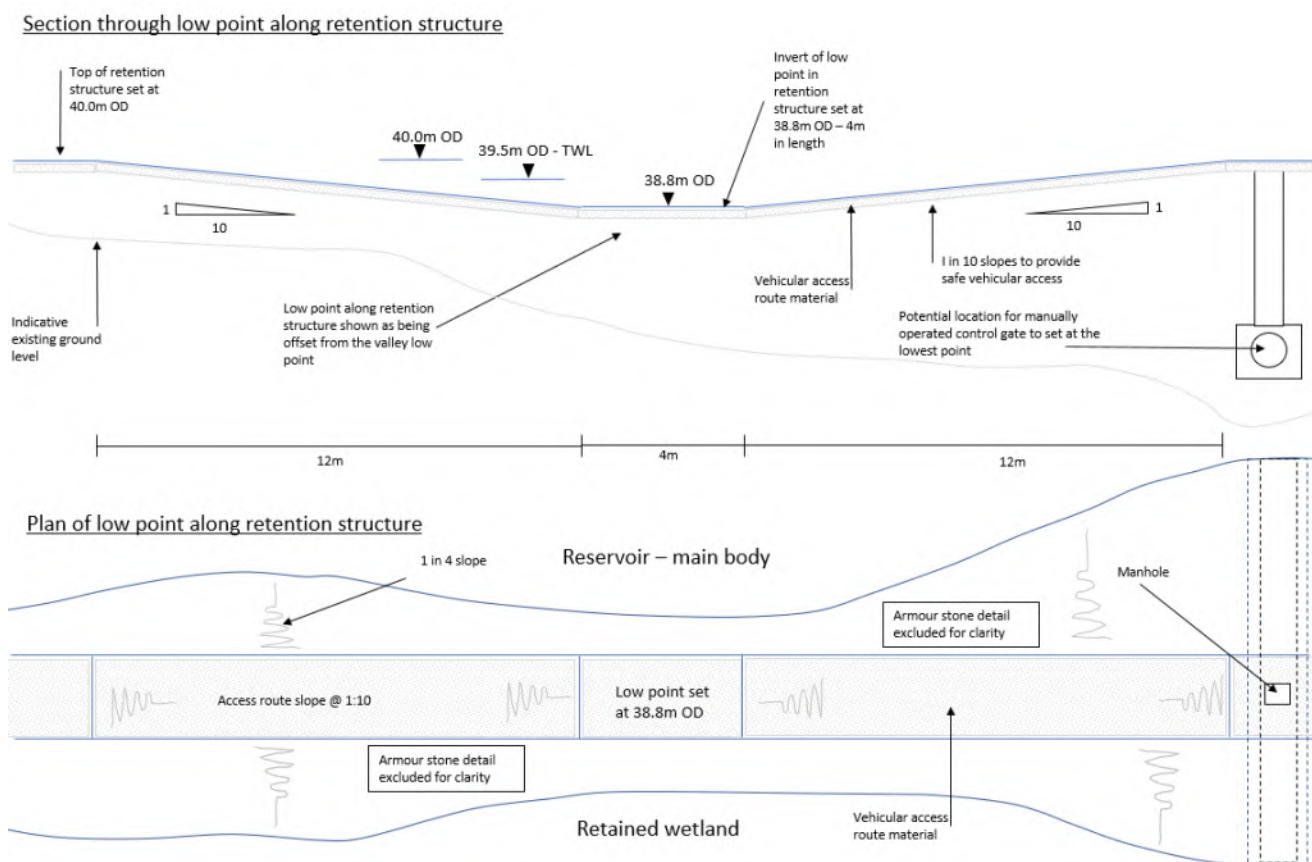


Figure 3-7 – Wetland spillway section and plan

Indicative sections and plans for the other spillways on the line of the retention structure are not provided, but in concept they will need to be designed with reinforced surfaces so that they are protected against erosion, and their invert levels will need to be set at 38.8m OD. In relation to the spillway connecting compartment 2 and 1 this will need to be incorporated into the alignment of the required reinforced vehicular access route which follows the high point of the natural topography.

Compartment spillway design concepts

The outline design provides for a further 2 No. spillways allowing flow over the bunds dividing compartments 2 and 3 and compartments 3 and 4. The indicative location of these compartment spillways are shown on Figure 3-3 as solid yellow circles. The inverts of the two compartment spillways are set in outline design at 38.7m OD, 100mm below the retained wetland level, to provide hydrological connectivity between compartments 2, 3 and 4 when the wetland is in its retained state and to provide passive water level control (see Section 5.1).

Outline design drawings for these spillways are not provided, however, the concept is that the existing topography provides the compartmentalisation to the point at which the ground level falls to 38.7m OD. At this level the compartment spillway is formed, extending horizontally for nominally 4m. Earthworks are then required to raise existing ground levels towards the wetland retention structure which is set at 40.0m OD.

For the retaining structure between compartments 3 and 4, a slope of no steeper than 1 in 10 needs to be maintained for vehicular access, which is integrated into the alignment of the spillway through a continuation of the reinforced access route surfacing. At the compartment spillway location, a grid or mesh may be required underneath at the low point of the spillway which extends along the lower part of the slope either side of the 4m flat section.

A similar concept is applied to the compartment spillway between compartments 2 and 3, noting that vehicle access may be required for inspection of the spillway (shown in Figure 3-3 as a dashed black and yellow line). From the spillway location, the bund rises to meet with the wetland retention structure from which access could be facilitated. Due to the relatively shallow slope along the alignment of the internal bund it is possible to undulate the bund to provide increased habitat complexity and depth provision.

Summary of spillway locations and types

The exact location, size and armouring detail of the spillways will need to be developed through detailed design. The outline design provides for a minimum of 8No. spillways set along the line of the wetland retaining structure as shown on Figure 3-3. These are as follows:

- Set at 38.8m OD:
 - 1No. connecting Compartment 1 to the main body of the reservoir – on retention bund
 - 1No. between compartments 1 and 2 – on wetland retention structure reinforced access alignment
 - 1No. connecting Compartment 2 to the main body of the reservoir – on wetland retention structure
 - 1No. connecting Compartment 3 to the main body of the reservoir – on wetland retention structure
 - 2No. connecting Compartment 4 to the main body of the reservoir, the most westerly of which is to prevent unsolicited access to the structure from the visitor centre area – on wetland retention structure
- Compartment spillways set at 38.7m OD:
 - 1No. connecting compartments 3 and 4 – on wetland retention structure reinforced access alignment
 - 1No. connecting compartments 2 and 3 – on internal compartment bund divide

Benefits arising from this provision of wetland spillways in relation to water level management and water quality are covered in Section 5.

Options for wetland habitat provision on downstream face of the wetland retention structure

Bioengineering options to provide opportunities to vegetate the sections of armoured 1 in 4 downstream slope of the wetland retention structure are being investigated to maximise potential for wetland habitat creation.

Noting that any approach will need to integrate with the requirements to protect against wave action and address constraints associated with the potential for greater fluctuation in water level in the main body of the reservoir.

The following section and plan provide an outline bioengineering approach to facilitate vegetation establishment (Figure 3-8). The key dimensions and engineering features are as follows:

- Rock mattresses placed directly on the 1 in 4 slope at same surface level as armour stone:
 - Rock mattresses typically supplied as 2m x 1m, 250mm deep
 - Stone held in place by 3mm polyethylene braided net, which is filled with granite or frost resistant limestone or other hard local stone – stone 40 – 80mm in size
 - Mattress secured to the retention structure using anchor plates or rebar
- Treatment is shown as extending over a vertical height of 1.5m which equates to a water level range 39.8m OD to 38.3m OD – maximises potential for vegetation establishment in light of anticipated water level fluctuations
- Mattress stone blinded with top soil and plug planted with wetland species, or left to colonise naturally

ATKINS BASELINE - LOW RISK

- Section of bioengineered solution on downstream slope of retention structure



Designs are currently being developed for the following wetland features which are considered necessary to improve wetland habitat complexity, improve resource provision for wetland birds and to provide habitat resilience:

- Islands are a key wetland habitat feature as they will provide valuable nesting habitat within the wetland area for a range of wetland bird species. The wetland retention structure provides the primary function of holding water within the retained wetland area providing barrier island which will protect the habitats therein from wave action (noting that waves will propagate through the spillway locations). The outline design includes provision of island habitats within the retained wetland area. Figure 3-9 shows an indicative design for two island forms of nominally 30m x 16m in their maximum dimension, showing surface levels ranging from 39.5m OD to 39.0m OD.

- Islands created through the local manipulation of ground levels within the retained wetland area – this will act to further increase wetland habitat provision and yield material for island creation
- Islands can be constructed within the retained wetland area through two mechanisms which should be developed with a target of achieving a neutral cut and fill balance:
 - Excavation of existing ground to form required island design levels; and/or

- The placement of material to raise ground to appropriate island design levels and form
- Island location and sizing should be developed with a target of achieving a neutral cut and fill balance within the retained wetland area
 - This is based on the current assumption that material excavated from the retained wetland area is suitable for the formation of stable island features
- Island surface levels set to ensure that the island becomes progressively exposed during the normal annual hydrograph to produce seasonally inundated nesting habitat
 - This will act to reduce the potential for vegetation growth on the surface of the island as this would be partially controlled by the influence of winter flooding
- Islands should be aligned to the south-west to reduce the potential for erosion from wave action and the surface composed of a material suitable for nesting bird requirements and erosion protection
- Islands should be aligned to viewing points e.g. educational hide, with the lower and narrower point of the island directed to the viewing point to improve views across the island

Further work is required to determine the number, size and exact location of islands within the retained wetland area. This requires further review of existing ground levels, habitat provision in the retained wetland (as informed through depth variability), spillway location and landscaping considerations e.g. required views from the visitor centre, education hide and bird viewing areas.

However, the island design concepts could be met through the creation of islands within the indicatively shown island zone areas in Figure 3-10 which equates to existing ground levels of 39.5 m and 38.5m OD. These zones have been located based on current understanding of view-points from visitor centre, education hides and other view-points.

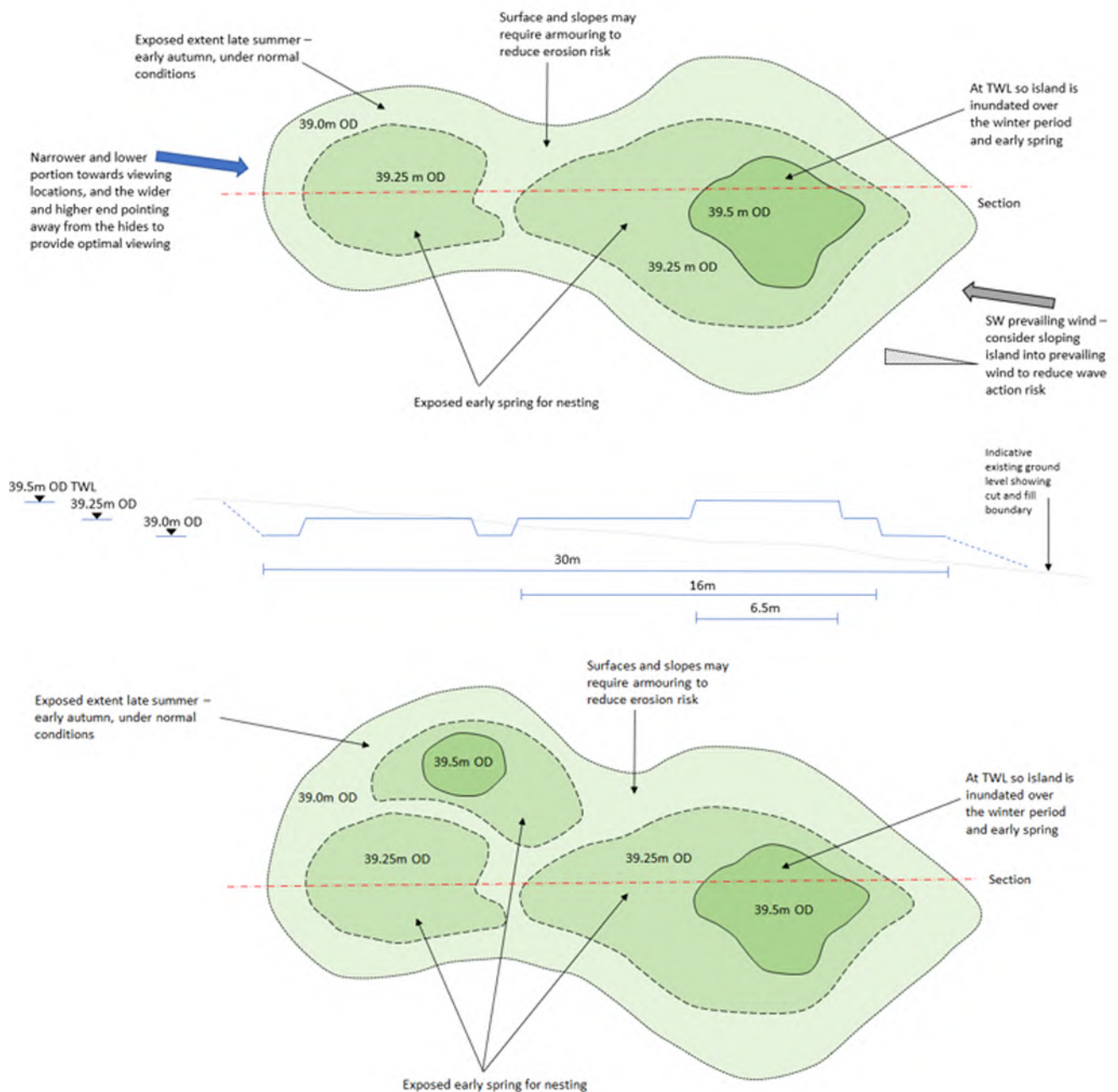


Figure 3-9 – Indicative plans and section of island formations proposed for inclusion within the retained wetland compartments

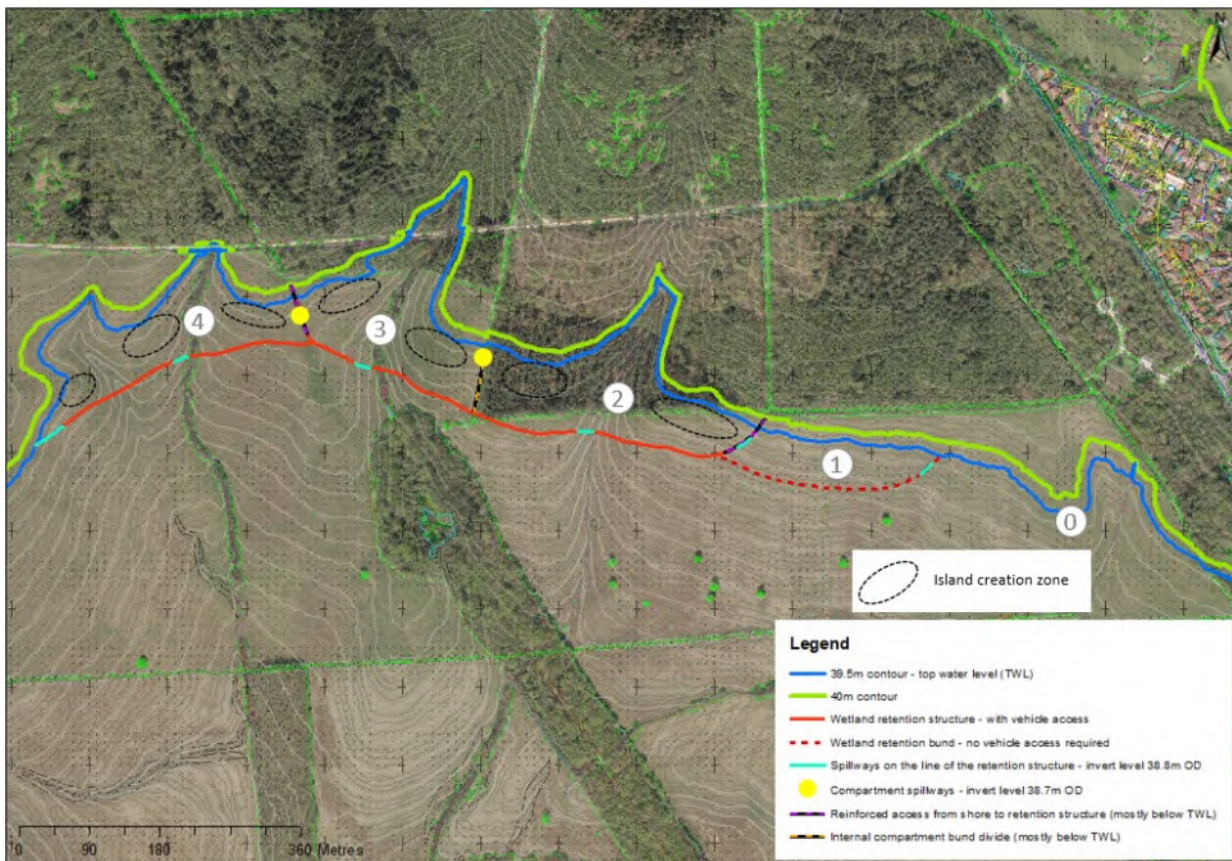


Figure 3-10 – Indicative island creation zone locations

Wet grassland - ephemeral shallows

In order to improve habitat complexity in the proposed wet grassland area and provide resilience to water level fluctuation it is proposed that local ground manipulation is undertaken in Area 0 and that options are explored to link in the ditch drainage system to the north, to keep the habitats wetter for longer.

The design concepts for the wet grassland area include:

- Provision of ephemeral shallows and raised areas between 40m OD and 39.0m OD - i.e. 500mm above and below TWL (39.5m OD):
 - An indicative design is provided as Figure 3-11 showing ground manipulation in the form of the creation of two ephemeral shallows with a raised area between
 - It is anticipated that due to the fetch in this location, provision of ephemeral shallows above TWL (39.5 m OD) will provide opportunity for inundation of shallows from inland wave propagation
 - Creation of shallows below TWL will add value when water levels recede as standing water will be temporarily held within the shallows
- A neutral cut and fill balance should be achieved through reuse of material generated from shallow creation to be used to provided raised areas - based on the current assumption that material excavated from the wet grassland area is suitable for the formation of raised area
- Alternatives such as the creation of ridge and furrow features designed to retain water as levels in the reservoir fall are being considered
- There is a requirement to protect the existing grassland habitat as part of the construction activities to facilitate establishment of wet grassland

Further work is required to determine the arrangement of such features within the wet grassland area and how the ditch habitats can be integrated into the wet grassland design to take advantage of existing low points. This requires further review of existing ground levels and the influence of drawdown events on habitat provision.

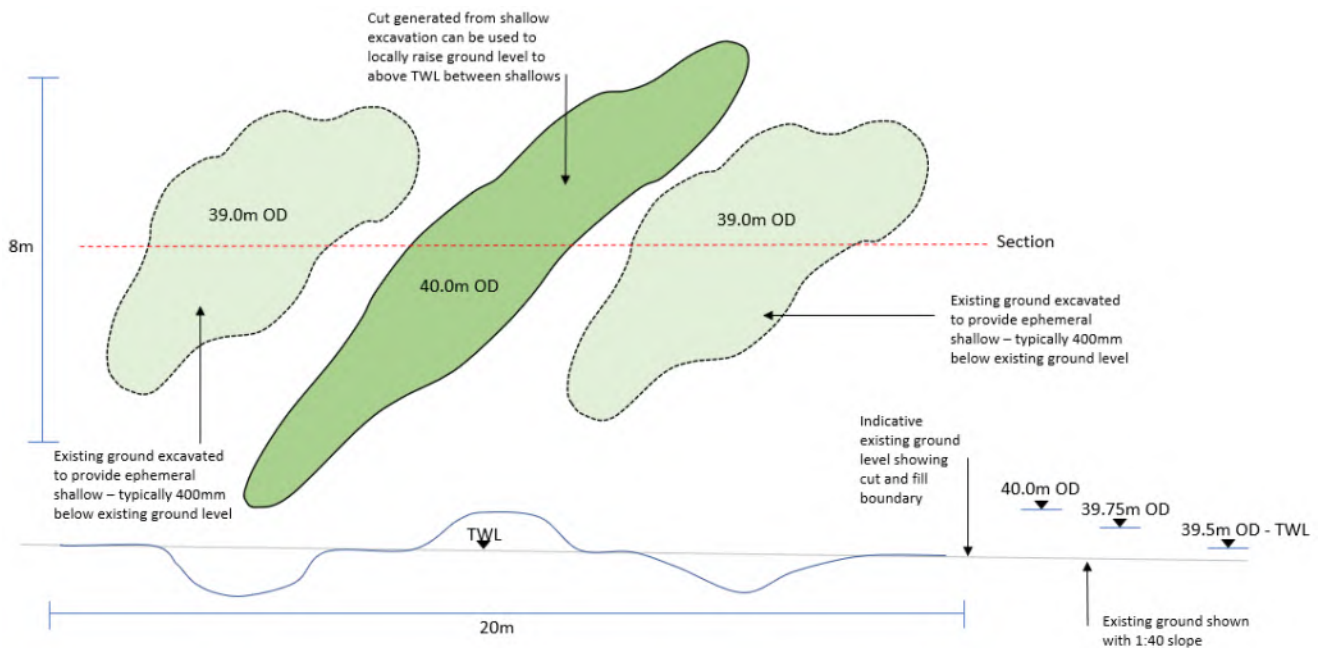


Figure 3-11 – Indicative plan and section of ephemeral shallows and raised ground in wet grassland area (Area 0)

Retained wetland Compartment 1

Compartment 1 is being progressed as an area predominantly for reed bed habitat creation with some sedge that grades to scrub/wet woodland to the north. It is proposed that the existing topography within the compartment is locally manipulated to improve habitat complexity. The design concepts for Compartment 1 include:

- Variation in water depth within compartment to be achieved by creating a peripheral ditch system with shallower interconnecting channels.
 - Peripheral ditch system to be designed to deter access to the area by both the public and predators such as foxes.
- Compartment area will benefit from some localised planting of *Phragmites australis* common reed stock (or seeding), which would then spread rapidly through the compartment. This is in preference to natural colonisation, which is the preferred option for the other compartments in the retained wetland area.
- Increased habitat diversity to be achieved by planting some appropriate native sedge species
- Some interconnecting channels to provide wider scraped/scalloped edges to the channels to increase habitat complexity as the reed bed develops.

Increased habitat value to be achieved through the planting of tree species on the retaining structure, including species such as osier willow.

4. Wetland Hydrology

4.1. Wetland hydrology

Wetland hydrology will be governed by water balances associated with the exchange of water with the main body of the reservoir, evaporation, transpiration, precipitation, inflow from the three intermittent streams, compensation release from the reservoir to the Riders Lane Stream (which discharges to the Hermitage Stream) and the influences of reservoir operation on water availability (Figure 4-1). The compensation release from the reservoir is currently anticipated to mimic the natural flows from the upstream catchment.

The monthly median stream inflow totals to the wetland area presented in this section have been modelled from historical data for the period of 1961 to 2015 using Catchmod rainfall run-off model calibrated to flow data collected by PW in 2008 to 2010.

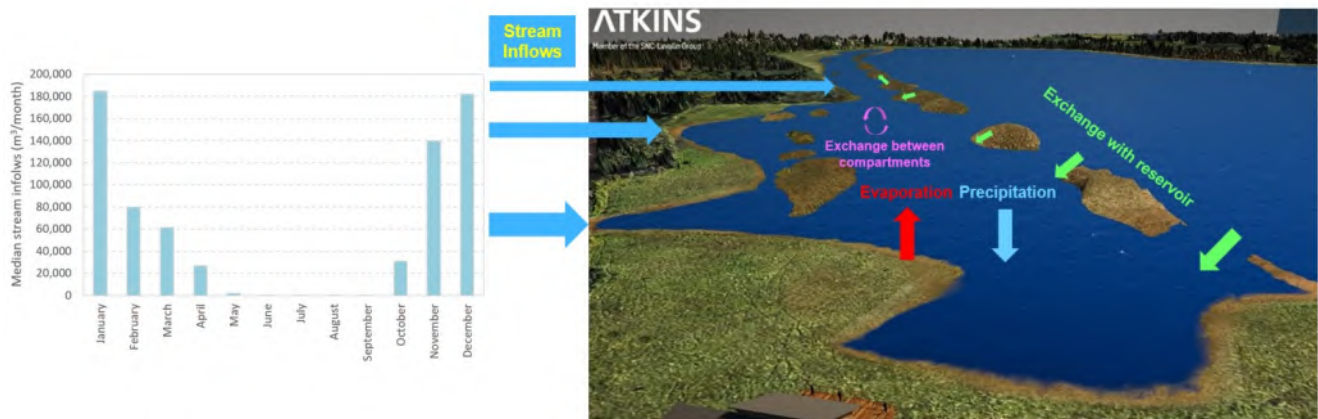


Figure 4-1 – Conceptual wetland hydrology and modelled seasonality of surface water inflows (1961-2015)

In a normal year (fluctuations in level between 39.5m OD and 39.0m OD) and with the wetland retention structure spillway invert levels set at 38.8m OD, the wetland will be in full hydrological connectivity with the main body of the reservoir, facilitating exchange of waters between it and the wetland. It is only when the water level in the reservoir falls below 38.8m OD, as will occur during drought events, that the retention structure will begin to retain water within the retained wetland area.

The resulting hydrological condition of the retained wetland area is presented in Table 4-1.

Table 4-1 – Retained wetland hydrological condition

Scenario	Description	Implications	Retained wetland connectivity with main body of the reservoir
Typical regime – normal yearly change in level	Typical annual change in water level 39.5m OD (TWL) to 39.0m OD (end of normal summer level)	Fall in wetland levels by 500mm resulting in exposure of marginal areas until levels recover in the winter – acceptable level of fluctuation which will act to maintain habitat diversity	Maintained by 200mm – 700mm water depth through the spillways along the retaining structures
Dry summer	Reservoir levels fall to 38.8m OD	Wetland becomes retained at a point where level falls to invert of spillway. This equates to a further reduction in level of 200mm compared to the typical regime scenario – further exposure of marginal area will result	Connectivity lost to the reservoir and wetland becomes retained
Prolonged drought	Reservoir levels continue to fall below 38.8m OD	Water levels within the retained wetland become subject to net water balances resulting from any inflow from the intermitted streams and evapotranspiration within the retained wetland area – levels anticipated to continue to fall within retained area	No connectivity – wetland retained

The wetland will periodically receive surface water input from the intermittent streams (under the proposed wetland layout flows from the three stream valleys will be to compartments 2, 3 and 4, see Figure 3-3). Figure 4-1 provides modelled values for monthly stream inflows based on historical records (1961-2015). Inflow to the retained wetland area during the months of November to January are typically high and may exceed the full capacity of the wetland i.e. full turnover of the retained wetland area would theoretically occur. Limited or no input from these streams is expected during the summer months; which equates to the period during which the wetland is most likely to be in its retained state considering drought/operational scenarios.

Open water extent in wetland areas

Figure 4-2 shows the open water extent under TWL (39.5m OD) conditions, the normal summer minimum level (39.0 m OD), retained wetland level (38.8m OD), and a retained condition where the water levels have fallen in the retained wetland area by an additional 600mm (to a level of 38.2m OD) due to continued evapotranspiration. The latter is combined with an indicative scenario where water level in the reservoir is at 35.0m OD when it is in operation. These are shown for the compartments within the retained wetland area (compartments 1 – 4) and for the wetland area outside of the retained footprint to the east (Area 0).

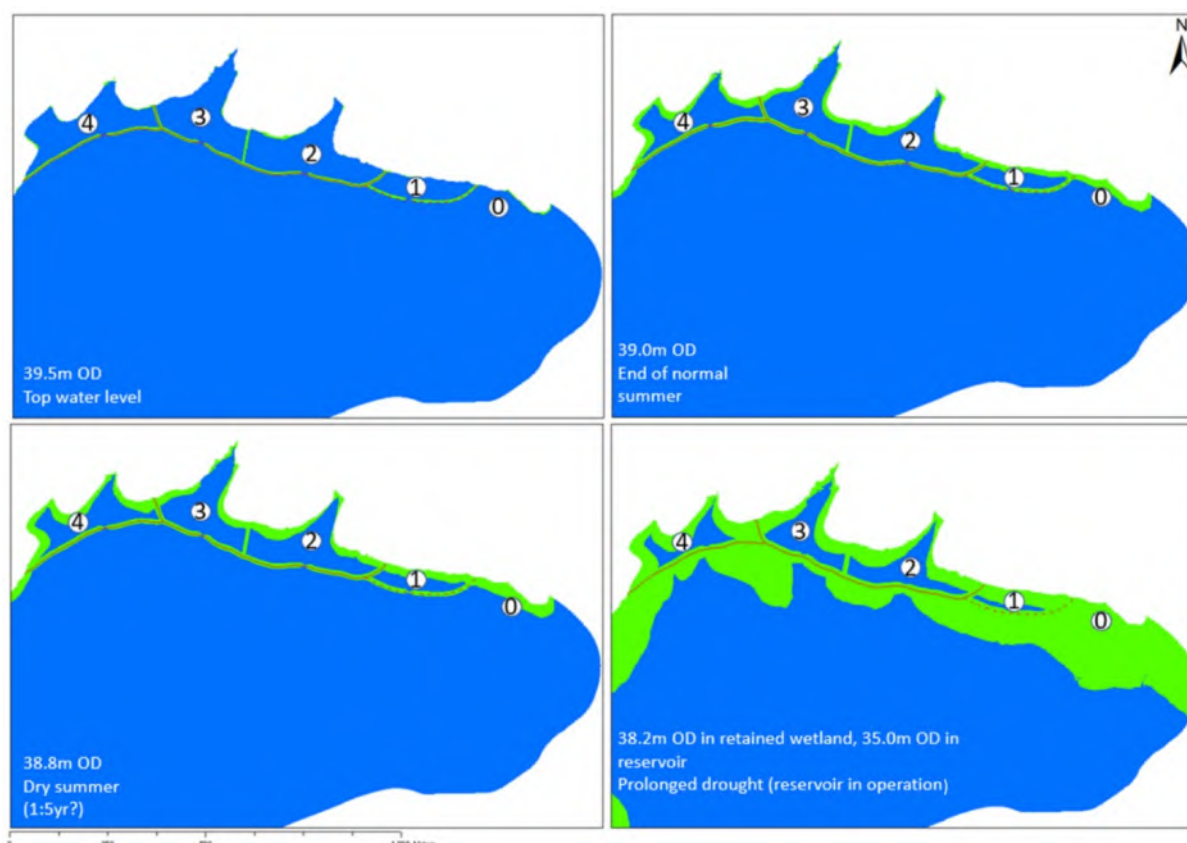


Figure 4-2 - Water extents in the wetland under a variety of water levels

Although the existing topography created by the valley formations provide a reasonable degree of depth variability within wetland compartments 2, 3 and 4, initial modelling of water depths within the compartments show that this variability is quickly lost under the water level reduction scenarios (Figure 4-3).

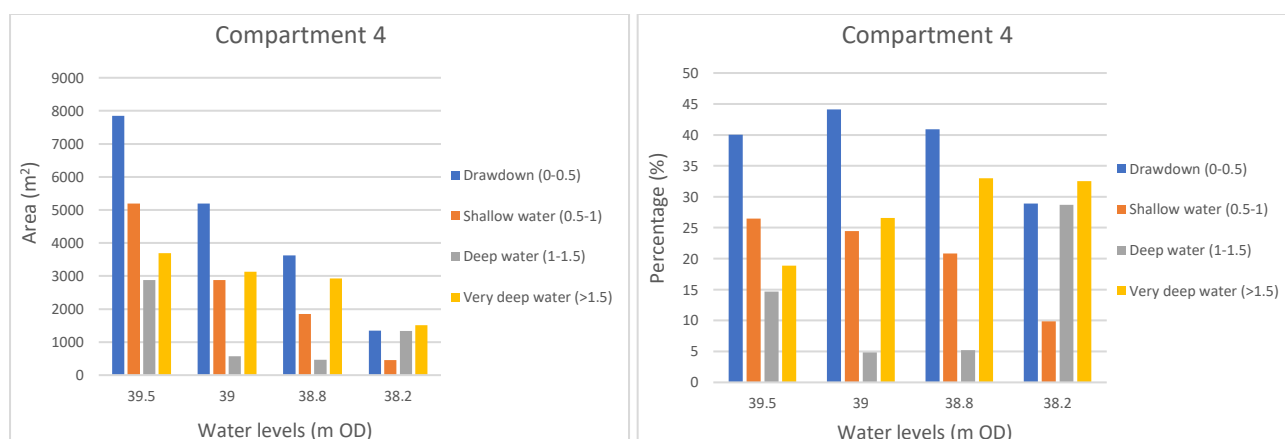


Figure 4-3 - Example of the changes in water depth under water depth reduction scenarios

Figure 4-3 provides an example of the modelling outputs for the change in area, and percentage, in water depth zones for Compartment 4 under a range of water level scenarios. The area of shallow water, which is 0.5-1m deep, declines rapidly as water levels reduce, as does the drawdown zone (0-0.5m). Due to the steepening topography towards the valley floor, these are replaced with either deep water or marginal habitats. As a result, we propose the need for manipulation of existing ground levels to maximise depth provision and increase habitat complexity. As previously mentioned, this can be achieved alongside the creation of seasonally inundated islands to provide nesting bird habitat and improve resilience of wetland communities to drought events, the design concepts for which are provided in Section 3.6.

5. Water Level Management and Water Quality

The provision of a wetland retention structure facilitates implementation of approaches for water level management within the retained wetland area and its associated compartments. Water level management approaches for the wetland are divided into two approaches:

- Passive water level management – reliance on water level changes (including stream inputs) and spillway design levels to control water retention within the retained wetland area
- Active water level management:
 - the installation and active management of structures e.g. pipes with gate valves to control and manipulate water levels, and/or
 - the deployment of pumps to lift water from the main body of the reservoir to the retained wetland area

5.1. Water level management - passive control

The outline design of the retained wetland, its structures and its associated spillways, provide a means of passive water level management in the retained wetland area, in so much as:

- When the reservoir level is greater than the retained wetland level (>38.8m OD) the main body of the reservoir is in full hydrological connectivity with the retained wetland via the spillways (see Figure 3-3 for spillway locations connecting main body of the reservoir to the retained wetland area)
- When the reservoir falls below the retained wetland level (<38.8m OD) the wetland becomes retained
- Under a scenario where reservoir levels begin to recover (through pumping from Bedhampton Springs, for example), and assuming the wetland levels have fallen below 38.8m OD, water will spill from the reservoir into the retained wetland area when the spillway level is exceeded
 - conversely, under a scenario where watercourse inflows to the retained wetland area exceed losses from the wetland, then the retained wetland area will fill to a level that water will then discharge over the downstream face of the spillways of the structure to the main body of the reservoir (i.e. when wetland levels are at 38.8m) – this scenario could occur should operational demands on the reservoir result in significant drawdown and the levels have not recovered to TWL over the winter period

The outline design of the retained wetland area also provides for passive control between the wetland compartments. This is achieved through the provision of compartment spillways shown indicatively as solid yellow circles in Figure 3-3.

- The invert levels of these spillways are set at 37.7m OD, slightly below those of the spillways connecting the retained wetland to the main body of the reservoir, , thus in its retained state there would be a depth of 100mm of water over the compartment spillway
- Under a scenario where reservoir levels are lower than the retained wetland level and water is flowing into the retained wetland area from the intermittent streams then:
 - the compartment spillways ensure that water is shared across the larger wetland compartments (2, 3 and 4) to a level of 38.8m OD, before water spills to the main body of the reservoir; so that
 - water is not lost from the retained wetland area before the retained level of 38.8m OD is achieved
- At this point water would also spill from wetland Compartment 2 into Compartment 1 providing inflow to the reed bed area

5.2. Water level management - active control

There is a requirement for pipes through the retention structure (and retention bund around Compartment 1) connecting the wetland compartments at their base to the main body of the reservoir. An indicative pipe arrangement is shown in Figure 5-1 which places a pipe in the lowest point of the watercourse valley formations. This arrangement would need to be implemented at each of the valleys associated with compartments 2, 3 and 4 as shown by solid blue circles. The pipe shown for Compartment 1 has been located on advice from the reservoir engineers away from the interface with Compartment 2. The following advantages and disadvantages are identified. The pipes would be controlled by gate valves within buried chambers and would normally be closed to allow the wetland to be retained during droughts.

Table 5-1 - Advantages and disadvantages of an active water level control provided by pipes with gate valves connecting retained wetland and main body of the reservoir

Advantages	Disadvantages
Provision of pipes would facilitate more rapid filling of the retained wetland during periods of reservoir level recovery – bottom-up filling, avoiding the need for pumping to the wetland. This is likely to be an infrequent operation under conditions where the retained wetland levels are below that of the recovering reservoir level.	Associated design and pipe installation costs
Provides improved opportunities for wetland habitat management and maintenance as would allow individual compartments to be drained down – pipes could only be active during periods when water levels in the main body of the reservoir are below the pipe invert level	Pipe installation would generate the requirement for long-term maintenance and operation
If the retained wetland area is to be progressed as the location for surface water management during construction any pipes installed for this purpose could be integrated with the wetland in operation	During manual operation of the structures, disturbance to birds and other species using wetland would occur. Although it is not envisaged that manual operation would be required on a regular basis.
When the retained wetland area and the reservoir are in hydrological connectivity open pipes at the base of the compartments would facilitate mixing at greater water depth – could be beneficial for water quality	

In addition to providing active water level control between the retained wetland area and the main body of the reservoir via piped connection, consideration has also been given to the provision of active controls e.g. pipes with gate valves, between the wetland compartments. Review of ground levels and water depth scenarios adjacent to the compartment divides indicate that meaningful piped water level control cannot be achieved without the requirement for extensive pipe lengths and/or ground excavation.

Combined, active and passive water level management approaches would facilitate preferential filling of wetland compartments, the ability to drawdown a compartment/s, if necessary, without impacting the rest of the wetland (e.g. for maintenance) and to transfer water between compartments if one is drier than the other. For example, Compartment 1 does not have a stream inflow so during drawdown, if there is a summer flood, Compartment 1 could be filled up from Compartment 2 if a surplus of water results from stream inflow.

It is noted, that to increase water levels in the retained wetland area during periods of prolonged and or supra-seasonal drought there may be a requirement to actively lift water from the main body of the reservoir to the wetland area using temporary or permanent pumping equipment. The compartmentalisation of the retained wetland area would facilitate more rapid and preferential filling of areas suffering from reduced levels, such as may be required to maintain water adjacent to the visitor centre location and/or to provide improved water levels for habitat maintenance in the wider retained wetland area.

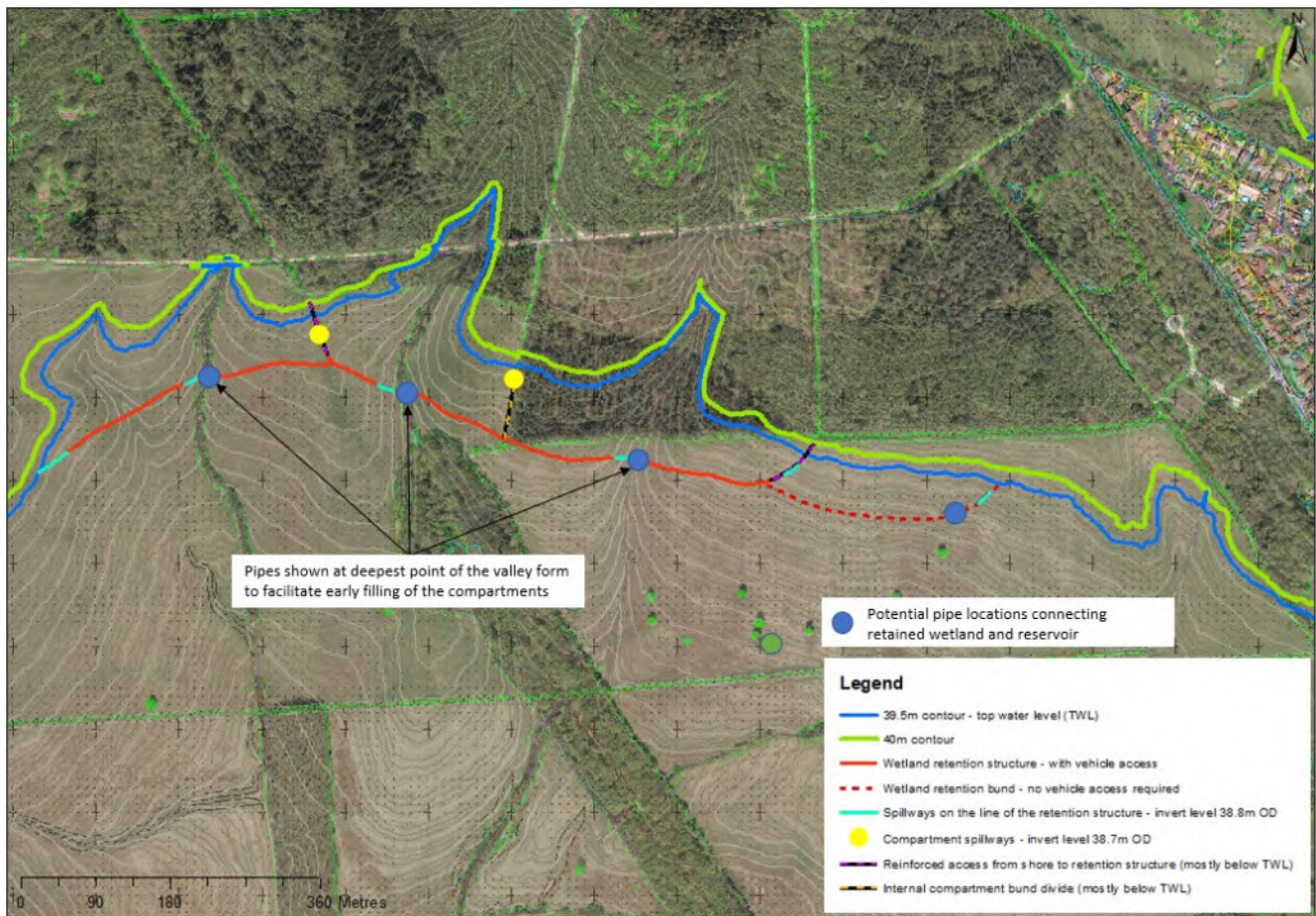


Figure 5-1 – Locations for active water level management control structure

5.3. Water quality

Water quality within the reservoir has been assessed to have a low to moderate risk from algal development and it is expected that the intermittent stream inflows, which are high in iron, will be buffered by the spring water in the reservoir. The largest nutrient input is estimated to be phosphorus from bird populations using the reservoir, however, there is uncertainty around the number of birds that may roost within the reservoir and wetland area. If large numbers of gulls and/or geese do roost at the reservoir, the risk of algal blooms, as a result of phosphorus input, will be increased (Atkins, 2020).

In a normal year, when it is anticipated that reservoir levels will fluctuate between 39.5m OD and 39.0m OD, the retained wetland will be in hydrological connectivity with the main body of the reservoir due to the spillway inverts being set at 38.8m OD. This will result in exchange and mixing of water between the retained wetland and the reservoir which is likely to be beneficial in terms of water quality i.e. will reduce stagnation and potential for increases in nutrient concentration. Improved mixing may be facilitated through the provision of pipes along the retention structure aligning with the stream valley low points – if pipes are left open then exchange of water from the deeper points within the retained wetland may occur.

Inflows from the intermittent stream systems have been modelled as exceeding the volume of water within the retained wetland area when at TWL (volume of wetland approximately 131,000m³) for the months of November through to January (see Figure 4-1). However, the retained wetland area is at greatest risk of water quality deterioration in its retained state i.e. when not in hydrological connectivity with the reservoir (when reservoir levels are at/or below 38.8m OD) and stream inflows are not occurring (typically May through to September).

Monthly inflows to the retained wetland area will on average only exceed the retained volume of approximately 72,000m³ during the months of November to February (noting that the March inflow of 60,000m³ is within 80% of the retained volume).

It should be noted that features such as the wetland retaining structures and any islands that may be incorporated within the footprint of the retained wetland may attract gulls and geese, which are likely to

increase phosphorus input to the wetland and reservoir, the effects of which will be more pronounced during periods in which the wetland is in its retained state.

A sensitivity analysis has already been completed to review the impact of larger bird roosts using the reservoir, such as gulls and geese. Further modelling of water quality implications of the wetland design should be considered to ascertain levels of risk and potential management requirements in operation at the detailed design stage.

6. Landscape Considerations

There are several landscape elements associated with the wetland and the retention structures that require further consideration, these include:

- Provision of view-points and the maintenance of historical views
- Screening of the retention structure
- Integration of wetland features with the visitor centre

6.1. View-points

A requirement to provide long-range views from the site of the proposed visitor centre, educational hide and view-points has been identified by the landscaping team. There is consideration being given for a Heritage Feature to be located on the reservoir embankment at the location of the current wooded avenue. This is still subject to ongoing discussions within the landscape team. Figure 6-1 shows the location of this Heritage Feature and the direction of the long-range views.

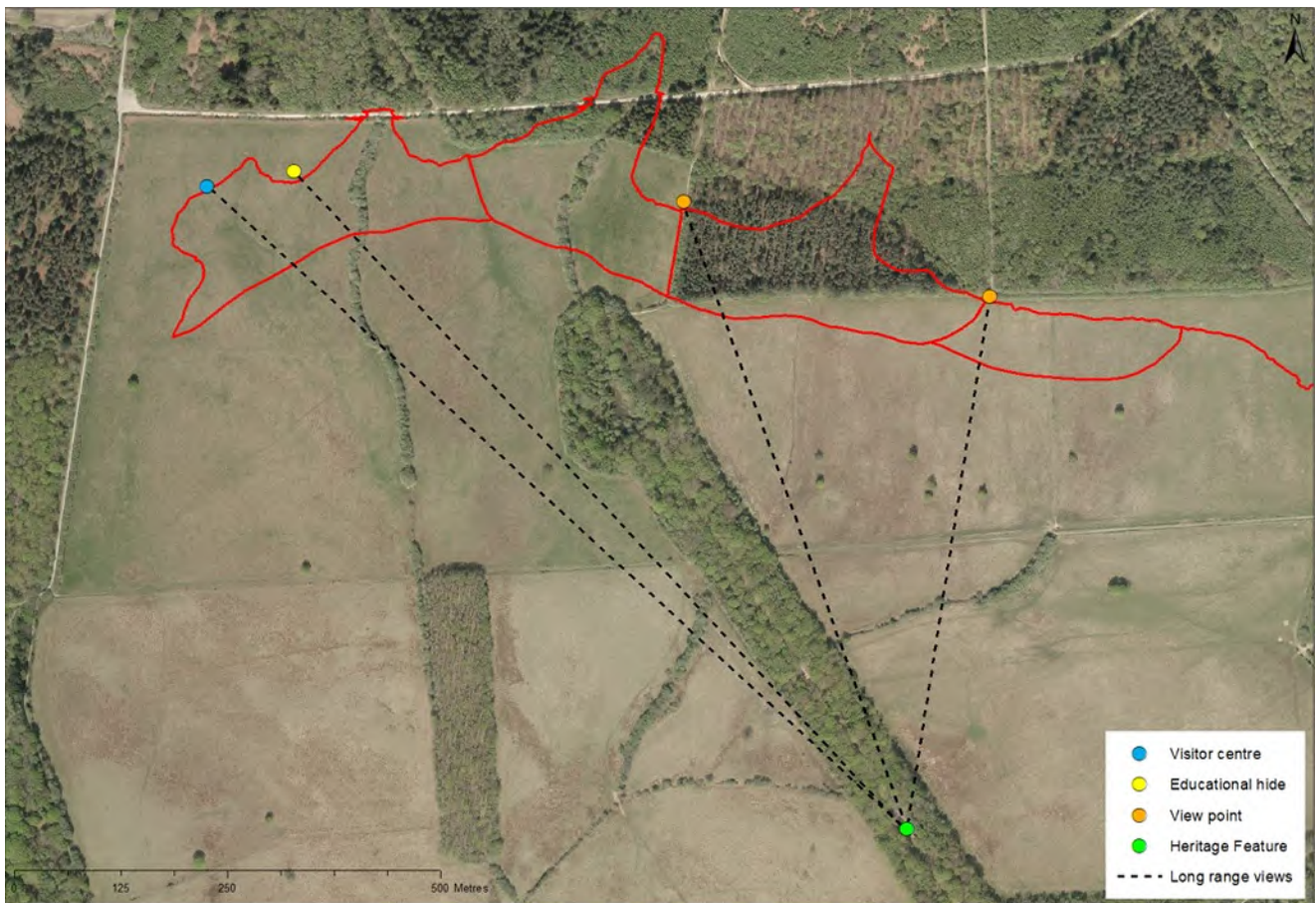


Figure 6-1 – Views from wetland area

In order to provide these long-range views, consideration is being given to aligning some of the spillways along the retention structure accordingly to maintain the views along lines of open water.

6.2. Screening

During periods of low reservoir level, the downstream face of the retention structure will be exposed and clearly visible from the reservoir embankment location. The form and material used to armour the downstream face to protect against wave action therefore requires careful consideration to uphold the aesthetic value of the reservoir. The designs for bioengineering on the reservoir face of the retention structure presented in Figure 3-8 should facilitate the establishment of vegetation and therefore, as well as providing additional habitat, will improve the aesthetic look of the structure.

Within the retained wetland area, the provision of shelves and shallow slopes along the upstream face of the retention structure will support the development of wetland plant communities to provide screening of the structure from the northern shoreline as well as screening of the wetland from disturbance associated with access roads and hide location.

6.3. Visitor centre

The HTR visitor centre has been confirmed as being at the western end of the wetland area. The wetland retention structure extends in front of this location so that water is 'held' within the visitor centre compartment (Compartment 4) providing the required mechanism to facilitate the development of this waterside setting. There is a recognised need to develop an integrated wetland habitat design for this location that manages the potential for conflict between the requirement to provide wetland habitat and the public interfaces created through the siting of the visitor centre and associated infrastructure.

Alternative concepts were developed and considered by the wetland design team for the western end of the wetland area, including a reduction in the size of Compartment 4 (separated into 4a and 4b) by returning the retention structure to the shoreline just west of the stream valley. This was combined with an option to 'draw' water into the shoreline location through the excavation of a borrow pit. These alternatives are presented in Appendix A.3 to highlight the development of the retention structure alignment in this location.

The engineers will consider the potential opportunity to extend the borrow pit closer to the visitor centre as they review the borrow pit design and site investigation information. This has the advantage of:

- There being less initial visual impact on the view from the visitor centre during reservoir drawn down
- Providing a close-by source of material for construction of the retaining structure, reducing the distance for vehicle movements

7. Summary

This Technical Note presents the outline design for the HTR wetland covering the requirements for wetland retention, retention structure alignment and form and the resulting wetland layout and habitat area provision. It should be noted that the requirement for wetland retention is based on a conceptual understanding of reservoir hydrology developed from modelled data where available.

This stated, the need for retention has been identified based on a clear understanding that water level changes, under drought and operational scenarios, will be of a magnitude that would prevent the establishment of a viable wetland within HTR. If the proposed wetland area were to be in full hydrological connectivity with the reservoir i.e. no retention, then drawdown outside of the normal condition, would almost certainly compromise wetland habitat viability and remove the opportunity to create a wetland of high intrinsic ecological value, as is required to offset biodiversity losses associated with the reservoir's construction.

Recognising that the final location of the retaining structures cannot be determined until the exact location of the borrow pit/s are known (which will not be confirmed until post planning when further site investigation has been completed), approval is being sought for the outline wetland design concepts presented in this Technical Note to support:

- Design freeze for the preparation of materials required for planning permission
- Information flow to the required Works Information packages
- Provision of robust costing estimates

Approval of the outline wetland extent and layout will allow the design team to progress current wetland area calculations towards confirmation of the provision of wetland habitat to feed into biodiversity offsetting calculations required for planning and for the Project to fulfil its obligations under the planning system's mitigation hierarchy.

Wetland approvals are required for the following key outline design elements.

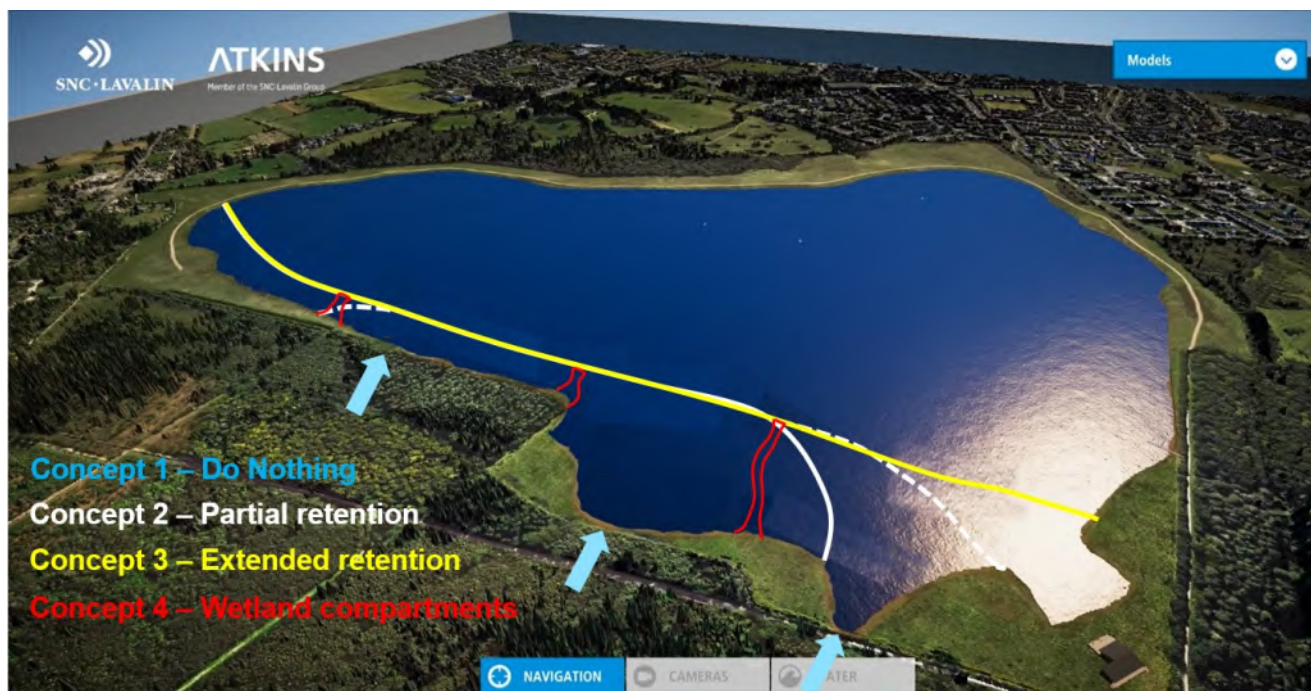
- Retention structure:
 - the need for retention
 - the proposed outline retention structure and compartment alignment (as shown in 0)
 - requirements for vehicular access and access routes to retention structure
 - provision of spillways for passive water management control

The following aspects be supported and included in the outline design concepts for further development at the detailed design stage:

- provision of piped controls to facilitate active water level management between the retained wetland area and reservoir – this would need to be infrequent operation in order to balance appropriately with the biodiversity objectives
- outline design approaches to add wetland habitat value to both the upstream and downstream face of the retention structure and to protect from erosion risk from wave action, subject to ongoing development
- provision of seasonally inundated bird nesting islands and associated ground manipulation within the retained wetland compartments to provide greater depth and habitat variability (compartments 2, 3 and 4)
- measures to improve habitat complexity in Compartment 1 for reed bed development
- development of wet grassland habitat outside of the retained wetland area and required ground manipulation to create ephemeral shallows and raised
- exact spillway location and alignment relative to landscaping and access control requirements
- provision of piped controls to facilitate active water level management between wetland compartments which balance the advantages presented in terms of water level management provision and potential for disturbance to the wetland area
- use of retained wetland area for surface water management during construction

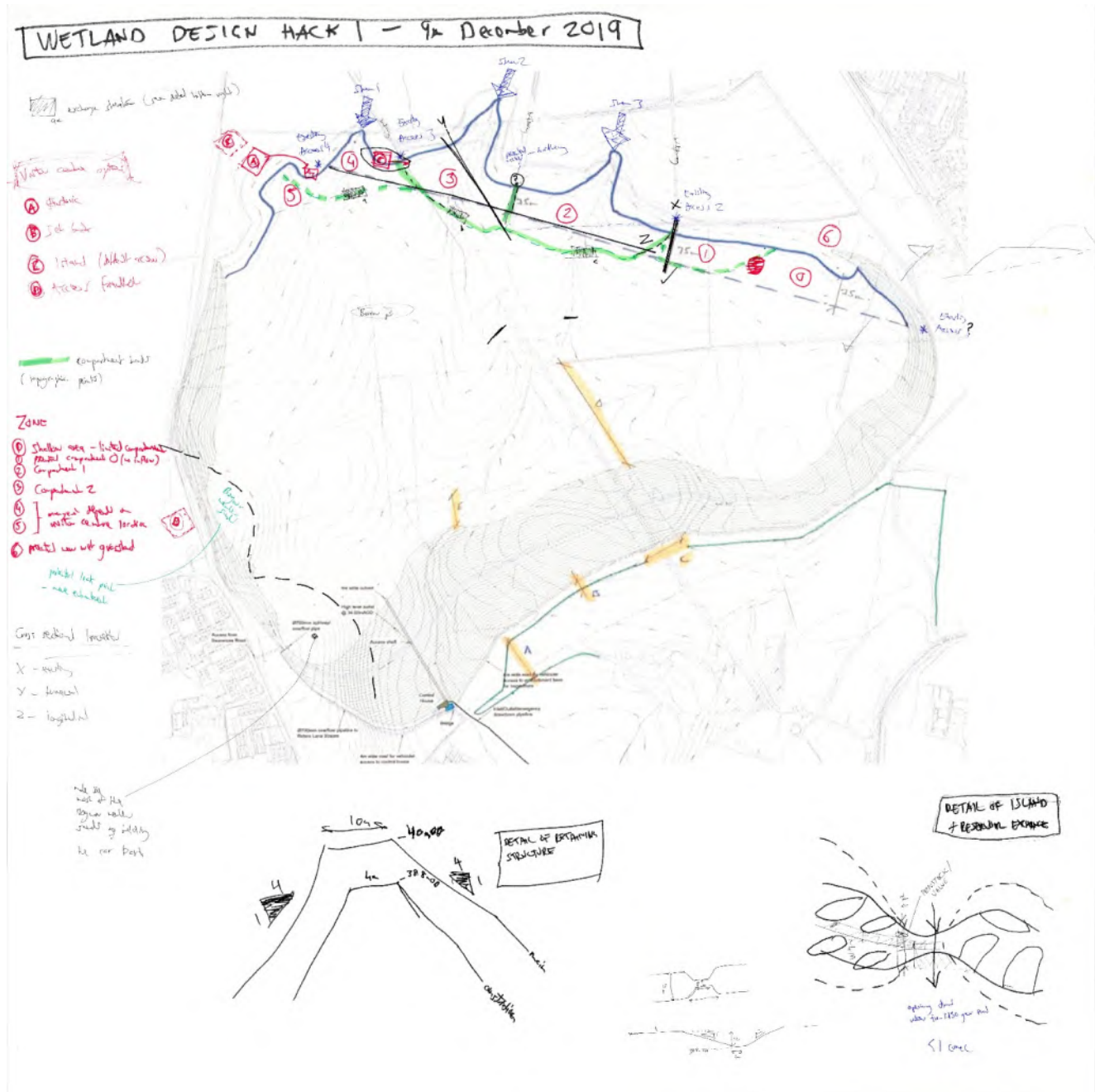
Appendix A.

A.1. Optioneering



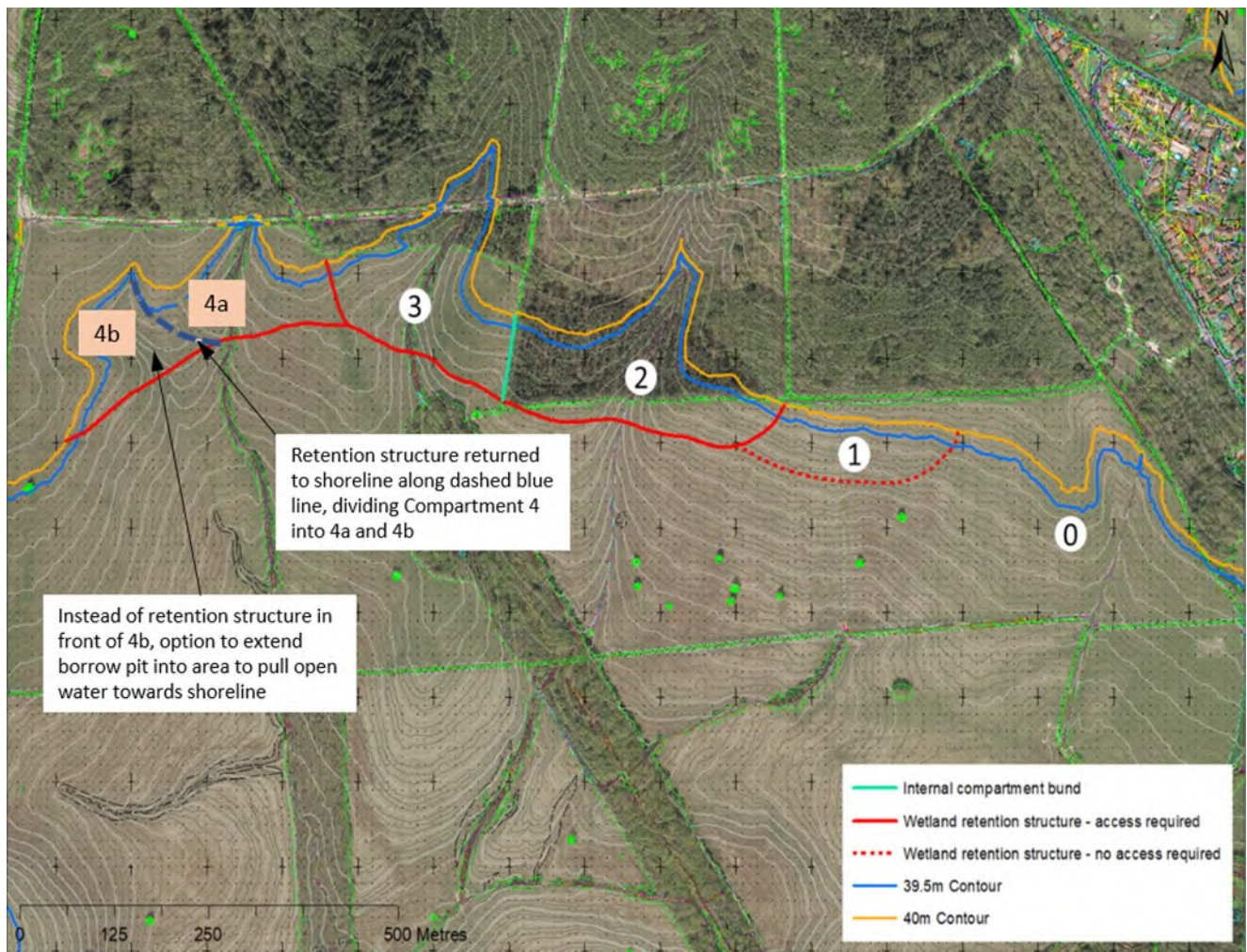
ATKINS BASELINE - LOW RISK

A.2. Output from wetland design meeting 1 – 09/12/19



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A.3. Alternative option for returning the retention structure on the west shore



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