River Ver Restoration St Albans

River Ver

With and on behalf of the Environment Agency

In partnership with:

Quality information

Document name	Ref	Prepared by	Date	Reviewed by	Approved By
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1. Introduction

1.1 Study Overview

The River Ver is a chalk stream, which is an incredibly rare type of habitat with only around 200 in the world, the majority of which are in England. Sadly, the River Ver, like many of our chalk streams, is in a very poor condition, largely because of historical alterations.

We want to return the river, as it runs through St Albans, to a more natural state that will bring benefits to wildlife and people. The project, referred to as 'Revitalising the River: St Albans' is part of Revitalising Chalk Rivers, a wider programme of work that will improve six chalk streams. Revitalising Chalk Rivers is described further below.

The project area has been split into six sections or 'reaches' which cover the River Ver from Verulamium Park through to Sopwell Mill Farm. An existing, healthier chalk stream section of the Ver is shown in Plate 1.1. A summary of the issues identified throughout the study area is provided in Appendix A.

The Environment Agency, Affinity Water, St Albans City and District Council and Hertfordshire County Council's Countryside Management Service (CMS) are working together to develop proposals that will improve the River Ver, the Verulamium Park lakes and the wider river area through St Albans. AECOM are the consultants on the project and collectively each of the organisations described above have contributed to the project as part of a collective project team.

This report provides a *comprehensive* record of the studies and engagement that have been undertaken to develop the final preferred restoration options for each reach. Great care has been taken to make sure that the preferred options respond to the constraints, issues and opportunities that each reach presents.

At the end of this phase of the project the design of each reach has been developed to an outline level. We have identified what further studies would be needed to further develop the designs so that they could be considered sufficiently detailed and assessed in order for construction to occur.

We are confident that each of these plans will meet the project objectives and bring tremendous benefits for the river, its wildlife, and the people of St. Albans for years to come. This really is a once in a lifetime opportunity to address the historical and current issues and deliver sustainable opportunities on a substantial scale.

Plate 1.1 The River Ver near Sopwell house showing characteristics of a natural chalk stream: crystal clear water flowing over a gleaming gravel bed with beds of water crowfoot and starwort in the channel

1.2 Revitalising Chalk Rivers

‘Revitalising the River: St Albans’ is part of Revitalising Chalk Rivers, a wider programme of projects to protect and restore our rare chalk streams. This partnership is led by Affinity Water and the Environment Agency, working alongside other partners.

As part of this programme, Affinity Water has agreed to cease or reduce the amount of water that they abstract from groundwater sources on six chalk streams – the Rivers Ver, Gade, Misbourne, Upper Lee, Beane, and Mimram.

Affinity Water will continue to meet the demand for water in the area by introducing a number of planned water saving initiatives.

There are four abstraction reductions that affect the River Ver through St Albans. Abstraction was reduced at one pumping station in 1993, abstraction was ceased at another pumping station in 2016 and there will be reductions at two more by 2024.These reductions will mean more water is retained in the environment, which will lead to improved flows and result in a stronger, more resilient and more natural River Ver.

It may also lead to groundwater emerging to more natural levels in some low-lying areas. While we are confident that there will be no increase in flood risk to any properties in St Albans, some areas of the park and wider river area may return to being wetter more often.

We are looking at opportunities resulting from this that will bring benefits for people and wildlife – this may include the creation of wetland habitats, accessible by boardwalks.

As well as abstraction reductions, a number of river restoration projects are currently being planned and delivered by the Environment Agency in collaboration with Affinity Water, Catchment Partnerships, local Councils and others. The aim is to improve the rivers of Hertfordshire and bring them back to their former glory.

1.3 Study Objectives

The overall project consists of three objectives. These are:

i). The River Ver through St Albans achieves Good Ecological Status under the Water Framework Directive

The River Ver has played a very important role in the history of St Albans. Over the last 2000 years the river has been altered for industry, flood risk reduction, amenity and recreation. These alterations, such as changes to the channel location, shape and form, have degraded the natural river habitats and limited the wildlife that it can support.

As a result, the River Ver through St Albans does not currently achieve Good Ecological Status and lacks the habitats, key features and associated wildlife of a healthy chalk stream.

ii). The issues with Verulamium Park lakes are addressed and they are improved for people and wildlife.

The ornamental lakes in Verulamium Park (Plate 1.2) are fed by the River Ver. They suffer from a range of issues including poor water quality, siltation and excessive numbers of wild fowl. As a result, algal blooms and reduced oxygen levels in the water have occurred, which have a negative impact on wildlife and are likely to have contributed to outbreaks of avian botulism.

iii). The areas around the river and lakes are improved

There is an opportunity to improve the wider river areas for people and wildlife. This is particularly important because of planned groundwater abstraction reductions in the coming years. This will mean that groundwater will return to more natural levels in some areas which may be wetter more often as a result. This presents a risk to some existing land uses and an opportunity for wetland habitat creation and associated amenity benefits.

Plate 1.2 The artificial lakes in Verulamium Park

In addition to the above proposed restoration works should be cost effective and sustainable.

1.4 Study Area

The project/ study area covers the River Ver through St Albans, from the top of Bell Meadow in Verulamium Park to just upstream of Sopwell Mill Farm. It also includes the lakes in Verulamium Park and some of the wider areas around the river. We have split the river into six sections or 'reaches', each with its own characteristics, issues and opportunities. The study reaches, and study area are shown in Figure 1.1.

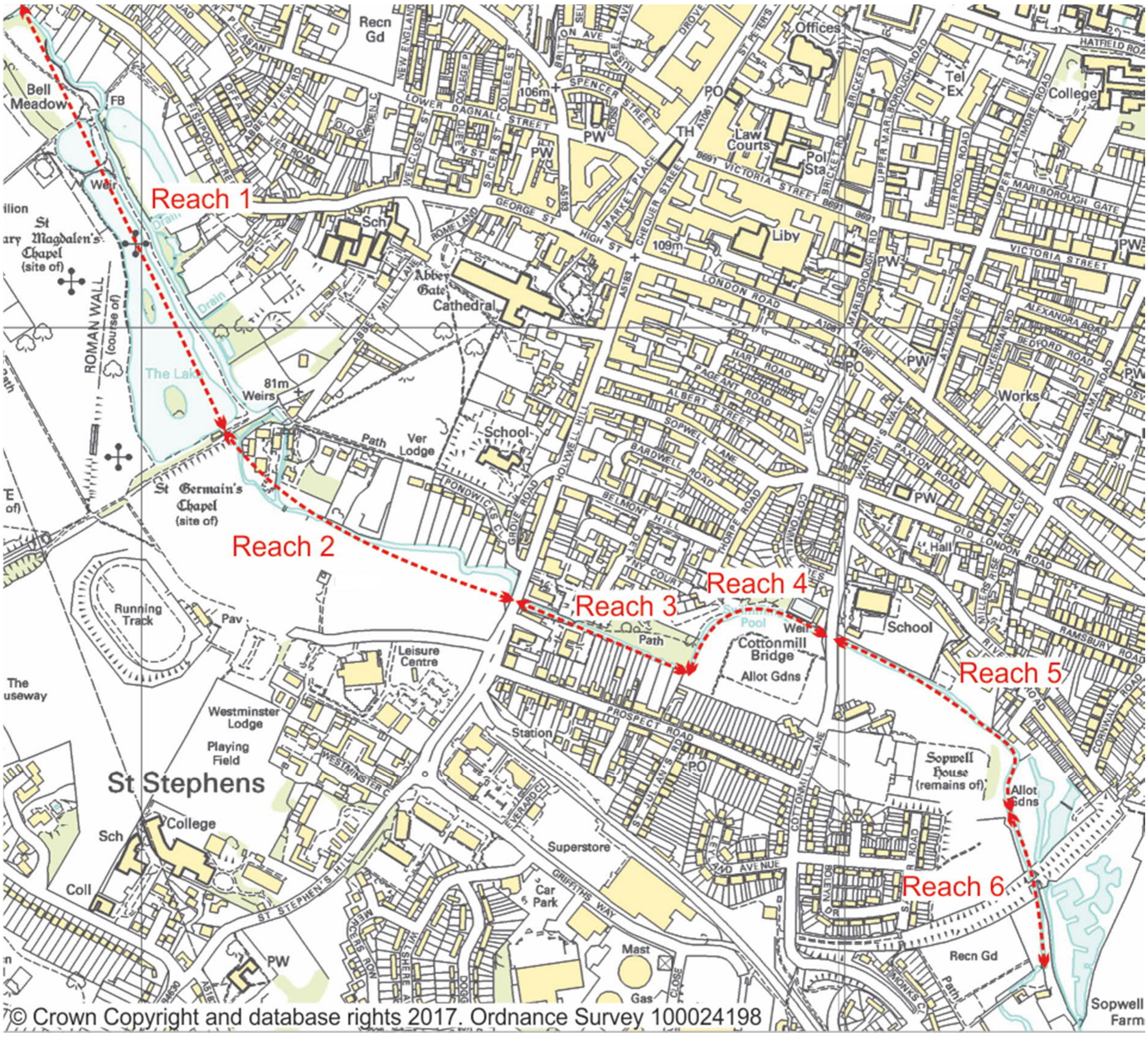

Figure 1.1 River Ver through St Albans study area with outlined reach boundaries

The six reaches are as follows (noting that these have not been considered in isolation but as part of a dynamic and linked river system):

- Reach 1: Upper section of Verulamium Park including the lakes
- Reach 2: Downstream section of Verulamium Park to Holywell Hill
- Reach 3: From Holywell Hill to Cottonmill Lane Allotments
- Reach 4: Cottonmill Lane Allotments to Cottonmill Lane
- Reach 5: From Cottonmill Lane to just upstream of the Watercress Wildlife Site
- Reach 6: From the Watercress Wildlife Site to Sopwell Mill Farm

The Verulamium Lakes (Reach 1) are situated within Verulamium Park to the south west of St Albans. The lake is composed of two areas:

- The small circular upper lake with an area of around 4,300 m^2 and referred to locally as the ‘boating lake’ as it is commonly used for model boating; and
- The lower lake with an area of around 33,600 m^2.

1.5 Ecological Benefits of the Restoration and Wetland Creation

1.5.1 Overview

This section outlines some of the general benefits that the restoration could achieve. This is in addition to the specific issues that the restoration will tackle outlined within the remainder of the report.

1.5.2 River restoration benefits

Environment Agency and Affinity Water have both been working on river restoration projects of chalk streams in the local area. Some case studies, that demonstrate the benefits of river restoration, are provided below.

Bringing Back the Bulbourne, Boxmoor

The Environment Agency, the Box Moor Trust and the Chilterns Chalk Streams Project recently completed improvement works on 1 km of the River Bulbourne in Boxmoor. These are part of a £60,000 project to improve the river and wetland habitat on Bulbourne Moor and Station Moor near Hemel Hempstead. The project was completed with support of local volunteers.

The Bulbourne has been transformed from an over-wide, straight and silty river into a meandering chalk stream with clean gravels and a wide range of habitats to provide home to a rich diversity of wildlife.

The project also reconnected the river with its floodplain and increased the roughness of the channel, to slow the flow of water and help to reduce peak flows.

Volunteers have been monitoring the success of the works and the health of the river and have already detected an improvement in the number and range of riverfly species in the river.

The restoration work has already had a positive impact, both on the river itself and on the wildlife that calls the river home.

The project has won the 2017 Wild Trout Trust Conservation Award and was recognised by The Chartered Institute for Ecology & Environmental Management.

Plate 1.3 Images of the Bulbourne at Boxmoor, before, during and after restoration

Other Planned Projects on the River Ver

Burydell Lane Project

The River Ver has been historically diverted through the mill at Burydell Lane (Plate 1.4). It flows over a substantial weir which impounds flow and obstructs fish passage. To the east of the river are disused watercress beds, which are thought to be in the location of the original course of the river. We are looking at options to allow for fish passage and restore chalk stream characteristics along this section of the river.

Plate 1.4 Ver at Burydell Lane

Hedges Farm

In this location (Plate 1.5) the River Ver flows through fields grazed by cattle, and as a result the banks have been widely poached. This has caused sections of bank de-stabilisation and erosion, which has resulted in siltation in the river. An additional impact of cattle poaching is the destruction of bank and marginal vegetation. Our aim of this project is to create controlled access for cattle accessing the river by installing fencing, crossing points, water gates, and cattle drinking stations. We are also looking to carry out tree work to all more light into the river channel to facilitate the growth of marginal plant species.

Plate 1.5 Ver at Hedges Farm

1.5.3 Ver Wetland/ Wet woodland creation benefits

In several of the reaches increased groundwater emergence is predicted as a result of the upcoming sustainability reductions. Where this occurs, the proposed design intends for these to become wetlands in order that these areas can be used and enjoyed instead of becoming unusable. In addition, the wetland creation would provide important habitat for birds, mammals, butterflies and more.

The nature of each of these would be determined during detailed design, although their ultimate composition would depend strongly on the final ground levels (for example if additional excavation or ground raising is undertaken), the amount of groundwater emergence that is expected (further monitoring would better inform the understanding of this), the summer (minimum) water table groundwater levels, as well as the amount of floodplain connectivity, a design aspect that is included within the restoration design. These would dictate how frequently the areas would be inundated and to what extent and whether the species would survive during summer/ early autumn when groundwater levels would likely be at their lowest. The inclusion of a variety of elevations throughout the wetland would help create a mosaic of habitats.

It is likely that they would vary and could include the following:

- Alluvial meadows
- Wet woodland/ carr woodland
- Neutral grassland communities
- Ponds
- Reedbeds

Such communities can provide important habitat for rare species of wildlife; For example, reedbeds are wetlands with vital importance to many species. These are sites where the water table is at or above ground level for most of the year that incorporate a mosaic of habitats including areas of open water, smaller areas of wet grassland and carr woodland. These habitats are vitally important to many species, with its associated high invertebrate numbers providing feeding sites for many overwintering bird species and many fish species as well as providing refuge to protected species such as the Water Vole. Reedbeds are priority habitats.

Typical flowering species along the Ver include butterbur, yellow Marsh Marigold, pale pink Lady’s Smock and yellow Celery-leaved Buttercup come into bloom. Such plants may find opportunities to grow and thrive in and around the wetlands providing colour and beauty to the landscape.

Examples of the habitat that is anticipated are provided in Plates 1.6 and 1.7 (from nearby sites in Hertford).

Plate 1.6 Panshanger Park Pond/reedbed, Hertford

Plate 1.7 Willowmead, Hertford- small woodland/reedy area located behind a housing estate, connecting to the river

METHODOLOGY

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2. Methodology

2.1 Overview

A summary of the project methodology is provided in Figure 2.1 below. Further information about the different steps is provided in the following sub-sections.

Initial assessment work

- We reviewed relevant previous work, studies and data and their specialists attended a site walkover. Known issues, constraints and opportunities were identified for each reach.
- We carried out initial feasibility work including: an extended Phase 1 Habitat Survey, fluvial audit, heritage desk-based assessment, lake water quality sampling, lake silt sampling, contaminated land preliminary risk assessment and service searches.

Longlisting

- We developed a long list of high level options which could potentially achieve the project objectives.
- We scored the broad pros, cons and feasibility of each of the long listed options. Each option was considered and those which met the project objectives and scored highest were shortlisted for further consideration.

Shortlisting

- We refined the list of options, excluding those that were not feasible or would not adequately meet the project obejctives. This refined list formed the shortlist of options (on average, about 3 options per reach).
- The Cross-Party Working Group of councillors approved the shortlisted options.

Further feasibility work

- We carried out further feasibility work to provide more detail on the shortlisted options, including: additional topographic channel survey, hydraulic modelling, further lake water quality and silt sampling and analysis, lake concrete testing, and additional detail on buried services.

Preferred options

- We reviewed all shortlisted options in light of the additional feasibility work. This enabled a single preferred option to be chosen for each reach that offered the best overall outcome with respect to the project objectives.
- We created outline plan visuals for the preferred option for each reach.
- The preferred options were presented to the Cross-Party Working Group of councillors.

Engagement

- We presented the preferred options outline plans and summary reports to the public and stakeholders to gather views on the restoration.
- We engaged with a range of individuals, groups and organisations through a number of workshops and presentations, to provide further information on the options and listen to the views of others.
- Members of the public were invited to submit their views via an online survey hosted by St Albans City and District Council. These responses were collated and analysed.

Preferred options finalisation

- We updated the preferred options for each reach in response to feedback received during Engagement phase.
- We completed the project reporting that encompassed the steps above through to outline design of the restoration of each reach.

Figure 2.1 River Ver Restoration, St Albans, Outline Design Project Methodology

2.2 Establishing the baseline

To provide a platform to undertake the study, an understanding of the environmental baseline was necessary. As such several studies were undertaken regarding the following disciplines:

- Hydrogeology/ groundwater;
- Hydrology;
- Hydromorphology;
- Water and sediment quality;
- Contaminated Land;
- Terrestrial Ecology;
- Fisheries;
- Heritage; and
- Landscape.

Baselines were established through a combination of desk-top studies (including data interrogation and review of available information such as published literature and mapping) complimented by site visits and meetings with local specialists, such as local officers at St Albans City and District Council.

2.3 Long list appraisal

Potential restoration options were identified through our initial investigations (desk top studies and site walkover) and discussions with the client and other stakeholders. These were collated, becoming the long list of restoration options.

The long list was initially appraised with regard the following questions:

- Does the option help restore or rehabilitate the river for ecological benefit so that it can reach GES under WFD? (yes or no)
- There are no constraints that would make the scheme unfeasible (for example would require a new road bridge which would be prohibitively expensive)? (yes or no)
- Would the option be appropriate from a health and safety perspective? (yes or no)
- The scheme would not result in significant and detrimental changes or loss of important characteristic features of the system? (yes or no)

If the option resulted in a 'no' for any of these questions, then it was considered inappropriate and was screened out and not explored further.

The remaining long list options were then considered and scored regarding the following questions:

- Does the option potentially provide a benefit or disbenefit regarding hydromorphology and naturalisation? (-scored from -2 to 2)
- Does the scheme potentially provide a benefit or disbenefit regarding habitat? (scored from -2 to 2)
- Does the option potentially provide a benefit or disbenefit regarding water quality? (scored from -2 to 2)
- Does the option potentially provide a benefit or disbenefit regarding flood risk? (scored from -2 to 2)
- Does the option potentially provide a benefit or disbenefit from a physical landscape or visual perspective? (scored from -2 to 2)
- Does the option potentially provide a benefit or disbenefit regarding recreation and amenity? (scored from -2 to 2)
- Does the option potentially provide a benefit or disbenefit regarding heritage? (scored from -2 to 2)
- Does the option potentially provide a benefit or disbenefit regarding contaminated land and sediment? (scored from -2 to 2)
- Does the option potentially provide a benefit or disbenefit regarding fish passage? (scored from -2 to 2)

- Does the option potentially provide a benefit or disbenefit regarding sustainability/ ongoing maintenance? (scored from -2 to 2)

More detailed information on the long list appraisal, by parameter, is provided in Appendix B. A score of 2 or -2 is associated with a significant benefit or disbenefit, respectively. A score of 1 or -1 is associated with a minor benefit or disbenefit, respectively. A score of 0 represents a neutral effect.

Options that were short listed following the long listing appraisal were those that fulfilled the necessary criteria (help restore the river, no unmitigable physical or health and safety constraints and no loss of characteristic features of the area) and those which scored at least 5.

In addition, we developed and considered several lake improvement measures as part of the long listing appraisal. Our review acknowledged the issues at the lake and considered the suitability of each option. From this we developed a short list of appropriate lake options that we investigated further.

2.4 Short list appraisal

The shortlisted river options that were derived from the long listing appraisal were considered in further detail as part of the short-listing appraisal. The short-listing appraisal has considered a number of factors including the following:

- Access;
- Flood Risk;
- Hydromorphology;
- Abstractions and other hydrological concerns;
- Groundwater connectivity;
- Environmental Permits / consented discharges;
- Heritage;
- Water Mains and Sewers (foul and surface water);
- Other Utilities;
- Geo-environmental;
- Wildlife Sites;
- Fish passage;
- Tree Protection Orders (TPO);
- Public Rights of Way;
- Lake works;
- Landscape impact;
- Recreation and amenity; and
- Riparian ownership issues.

For each of these, the option was judged in relation to whether it would result in:

- Desired improvements and project objectives achieved. No constraints identified in relation to the category in question (if so it was coloured green for this parameter).
- Desired improvements and project objectives achieved with low or moderate mitigation costs and/ or constraints identified in relation to the category in question (if so it was coloured yellow for this parameter).
- Desired improvements and project objectives achieved. Moderate or high mitigation costs and/ or constraints identified in relation to the category in question (if so it was coloured orange for this parameter).
- Option not considered to result in the project objectives being fulfilled and/ or high mitigation costs and/ or major constraints identified in relation to the category in question. Considered extremely difficult to overcome (if so it was coloured orange for this parameter).

The shortlisting appraisal accounted for more detailed studies, such as additional review of the quality of the sediment within the lake and anticipated groundwater emergence following upcoming Affinity Water sustainability reductions (where groundwater abstractions in St Albans are to be reduced), that had not yet been undertaken at the time of the long listing appraisal.

For each reach, the results of the short-listing appraisal were compared against one another. Through this the preferred option for each reach was identified.

For Reach 1, the lake improvement measures that were shortlisted were considered further by considering the key requirements of the lake restoration, namely that solutions are feasible, sustainable and considered to be value for money.

We undertook the lake short-listing appraisal acknowledging the results of additional studies on the lake that have been recently completed.

2.5 Further Feasibility

To determine the preferred options for each reach, we carried out further feasibility work to provide more detail on the shortlisted options. This included:

- Additional topographic channel and structure surveys.
- Hydraulic modelling to test the feasibility of restoration options.
- Further lake water quality and silt sampling and analysis.
- Lake concrete testing, and
- Collating additional detail on buried services.

We reviewed this information to determine the preferred options for each reach, acknowledging the project objectives.

2.6 Determination of the Preferred Options

We determined the preferred options of each reach following completion of the further feasibility studies and subsequent review of the short-listed options.

We then produced overview / outline plans of the preferred option for each reach. These indicated the key features of the proposed restoration and outlined several of the potential benefits.

In addition, we produced summary reports of each reach.

The plans and summary reports of each reach's preferred options were presented to and accepted by a St Albans City and District Council Cross-Party Working Group. We then presented them to the public and this process is discussed further below.

2.7 Engagement

The outline plans for all reaches were approved by the Cross-Party Working Group of St Albans City and District Councillors on February 12 2018. The proposals were released to the public for feedback and engagement on 19 March 2018.

Businesses and residents whose properties are adjacent to the project area as well as key stakeholder groups were contacted directly by post on 8 March 2018 and asked to respond to the plans. A follow-up letter was sent on 8 May 2018.

The survey was publicised in the local press and on social media. Posters were put up along the project route.

All councillors were invited to an open event to view plans held on to discuss the project with the project team. Councillors were also all contacted in May 2018 and asked to respond to the survey.

In addition, the project team have:

- Presented plans to St Albans Civic Society;
- Presented plans to the Ver Valley Society;
- Presented plans to the Society of St Michael and Kingsbury;
- Met with the Watercress Wildlife Association;
- Consulted with Herts and Middlesex Wildlife Trust, Historic England and Thames Water;
- Held two information drop-in events for allotment tenants and local residents;
- Presented plans to Verulamium Park Consultative Forum; and
- Appeared at the Community, Environment and Sport Scrutiny Committee.

2.8 Final Options

In response to feedback generated through engagement with stakeholders and the public the plans for each reach have been updated.

ENVIRONMENTAL BASELINE

03

3. Environmental Baseline

3.1 Water Framework Directive Designation

The River Ver (GB106039029920) through St Albans in classified as Main River[1].

The Ver waterbody (WFD Waterbody ID: GB106039029920), which encompasses the 6 reaches of the study area is currently classified as Moderate status (Table 3.1) in the River Basin Management Plan Cycle 2 (2015). The current status of each Ecological quality elements and Chemical are displayed in Table 3.1.

Table 3.1 WFD classification for River Ver (WFD Waterbody ID: GB106039029920)[2]

Parameter	2016 Cycle 2	Future Objectives
Overall Water Body	Moderate	Good by 2027
Ecological elements	Moderate	Good by 2027
Biological quality elements	Moderate	Good by 2027
Fish	Good	Good by 2015
Invertebrates	Good	Good by 2015
Macrophytes and Phytobenthos Combined	Moderate	Good by 2027
Hydromorphological Supporting Elements	Supports good	Supports good by 2015
Morphology	Supports good	Not specified
Hydrological Regime	Does not support good	Supports good by 2027
Physico-chemical quality elements	Moderate	Good by 2015
Ammonia (Phys-Chem)	High	Good by 2015
Dissolved oxygen	Moderate	Good by 2015
pH	High	Good by 2015
Phosphate	High	Good by 2015
Temperature	High	Good by 2015
Specific pollutants	High	High by 2015
Triclosan	High	High by 2015
Chemical	Good	Good by 2015
Other Pollutants	Does not require assessment	Does not require assessment (2015)
Priority hazardous substances	Good	Does not require assessment (2015)
Nonylphenol	Good	Not specified
Priority substances	Does not require assessment	Does not require assessment (2015)

3.2 Catchment Overview

3.2.1 River Ver

The Ver is a lowland chalk stream with winterbourne characteristics in its upper reaches. The Ver's catchment extends from Dunstable to the confluence of the River Colne, 10km south of St Albans. It has an overall length of 28.25km and a catchment area of 146.35km^2. More than half of the catchment is arable (51.4%). Grassland comprises 19.9% of the catchment whilst, urban and woodland area comprise 10.6% and 9.5%.

3.2.2 Verulamium Lake

[1] Environment Agency (2019) Catchment Data Explorer https://environment.data.gov.uk/catchment-planning/WaterBody/GB106039029920 Accessed 22/01/2019

[2] Source: Environment Agency Catchment Data Explorer website (Accessed: January 2017)

Verulamium Lake is comprised of a smaller (lying further upstream) and larger (lying downstream) lake. These are hereon referred to as the upper and lower lakes.

The base and sheer sides of the lake are entirely concrete lined. The present lake was constructed with concrete lining as part of an employment scheme in 1929.

Pedestrian paths surround the lake margin on all sides and grass is present up to the lake edge. The western margin is characterised by grassland while the eastern edge has overhanging deciduous trees, the fallen leaves from which are a significant allochthonous source of organic matter into the lake each autumn. Two small islands in the lower lake are also colonised by deciduous trees.

A previous study[3] in 2012 found water depths of only 0.16-0.40 m in the upper lake and 0.13-0.59 m in the lower lake.

Plate 3.1 Upper lake, looking downstream, and the bridge that separates the upper and lower (Verulamium) lakes

[3] Symbio (2012) Verulamium Lake Survey and Analysis

Plate 3.2 Lower lake looking upstream from its downstream end

3.2.3 Site Topography and River Setting

LiDAR data were interrogated to establish ground levels throughout the study area. Generally, the low points of the landscape were along the present route of the river.

Figure 3.1 provides an indication of the ground levels throughout the study area. This indicates that ground levels close to the river at the top of the study area are around 80m AOD and around 74 -75m AOD at the bottom of the study area. Levels reduce in an east-south-easterly direction with an average slope of less than 0.3% through the study area.

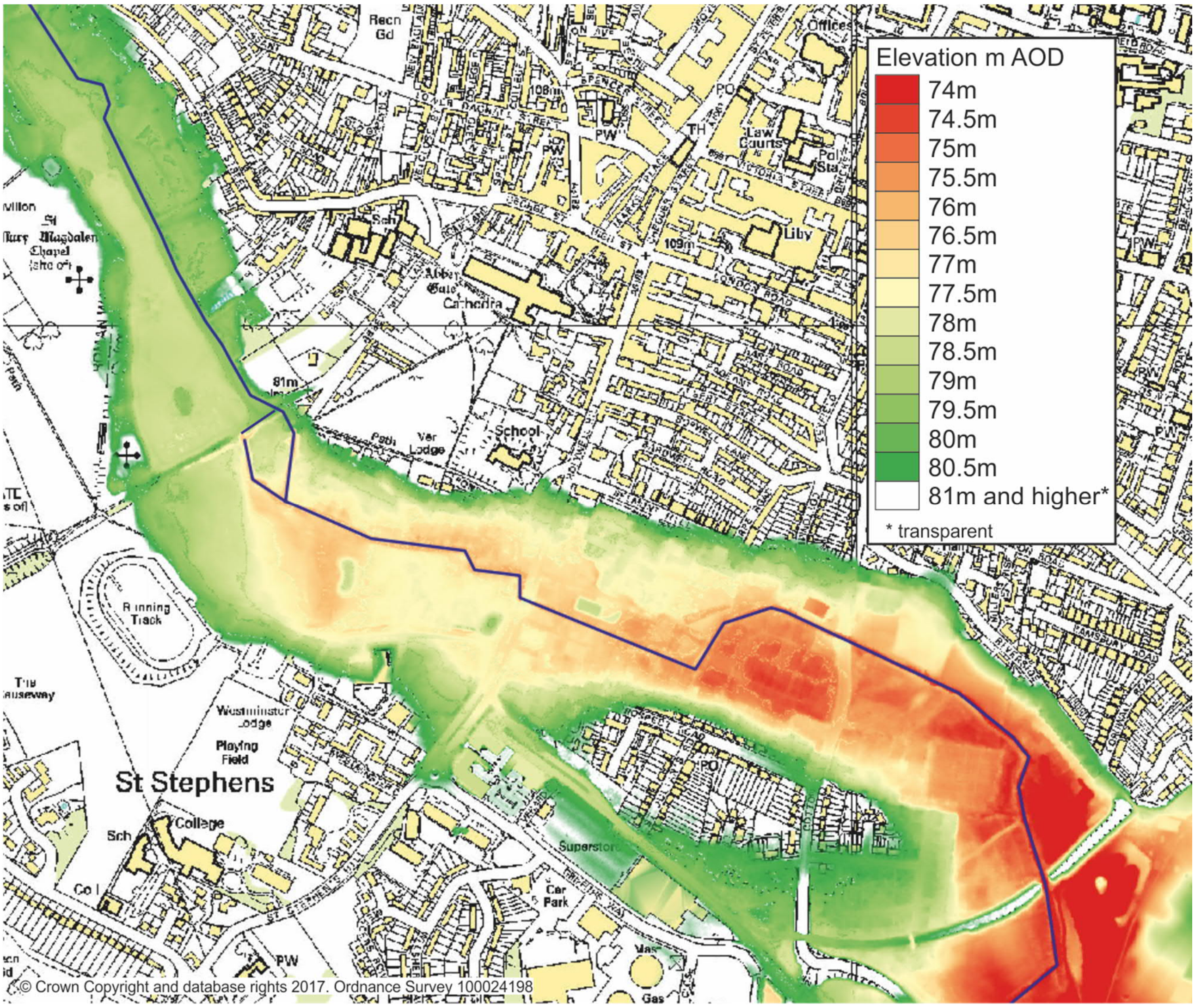


Figure 3.1 Ground levels throughout the study area (Ver indicated by dark blue line)

3.3 Geology and Hydrogeology

3.3.1 Geology

The geology of the area based on geological mapping by the British Geological Survey comprises Lewes Nodular Chalk Formation and Seaford Chalk Formation (undifferentiated) overlain by alluvium comprising clay, silt, sand and gravel.

The superficial geology in the valley bottom across the reaches is predominantly alluvium dating from the Flandrian (12 ka) consisting of clay, silt, sand and gravel. There are also older (up to 2.5 Ma) undifferentiated Quaternary river terrace deposits on either side of the river Ver through these reaches.

Geological logs available along the river valley were reviewed for evidence of made ground. Logs typically showed that the area comprises gravel and clay overlying Chalk. The logs were not detailed enough to identify individual Chalk horizons to judge whether there are high and low permeability horizons locally. However, logs along the valley floor identified gravels overlying chalk and typically 3m of clay overlying this. No evidence of significant earthworks creating low permeability barriers that may affect groundwater flow was found.

3.3.2 Hydrogeology and Groundwater

Hydrogeology

The chalk bedrock is a Principal aquifer of high permeability that provides water storage on a strategic level and is likely to provide baseflow. Superficial geological layers are classified Secondary (A) aquifer throughout the study reach and these are considered to be capable of functioning as localised aquifers and may provide baseflow.

The study area includes Source Protection Zones: Inner zone (Zone 1) – 50-day travel time from any point below water table to source; Outer Zone (Zone 2) – 400-day travel time from any point below water table to source; Total Catchment (Zone 3) – the area around a source within which all groundwater recharge is presumed to be discharged at the source.

Groundwater vulnerability is high across Reaches 1 to 5 and high to intermediate in Reach 6.

Groundwater emergence and flooding

Groundwater flooding is known to have occurred at two locations; the Cottonmill Allotment (Reach 4) and the large grass pitch south of the Verulamium Lake (Reach 2)

A groundwater emergence study was undertaken and is provided as Appendix C. This was undertaken to better understand the potential effects of upcoming Affinity Water sustainability reductions on groundwater emergence. The study explored whether groundwater emergence is likely to result with the permanent reduction in abstraction of 4.42 Ml/d (0.051 m^3/s) from both the abstractions in St Albans in the future (total reduction 8.84 Ml/d (0.10m^3/s)).

The study identified four broad areas within the study area where groundwater emergence is anticipated. These are illustrated on Figure 3.2; from west (upstream) to south east (downstream) these are in and around: Verulamium Park, Cottonmill Allotment, Sopwell Nunnery Green Space and (gardens of) Sopwell Mill Farm. Groundwater emergence is also anticipated in the Ver Valley downstream of Reach 6.

The study found there is a low risk of groundwater emergence in the lake area, and also limited potential for the lake water level to be maintained by groundwater discharge (if it were not sourced from river water).

Further details are provided in Appendix C.

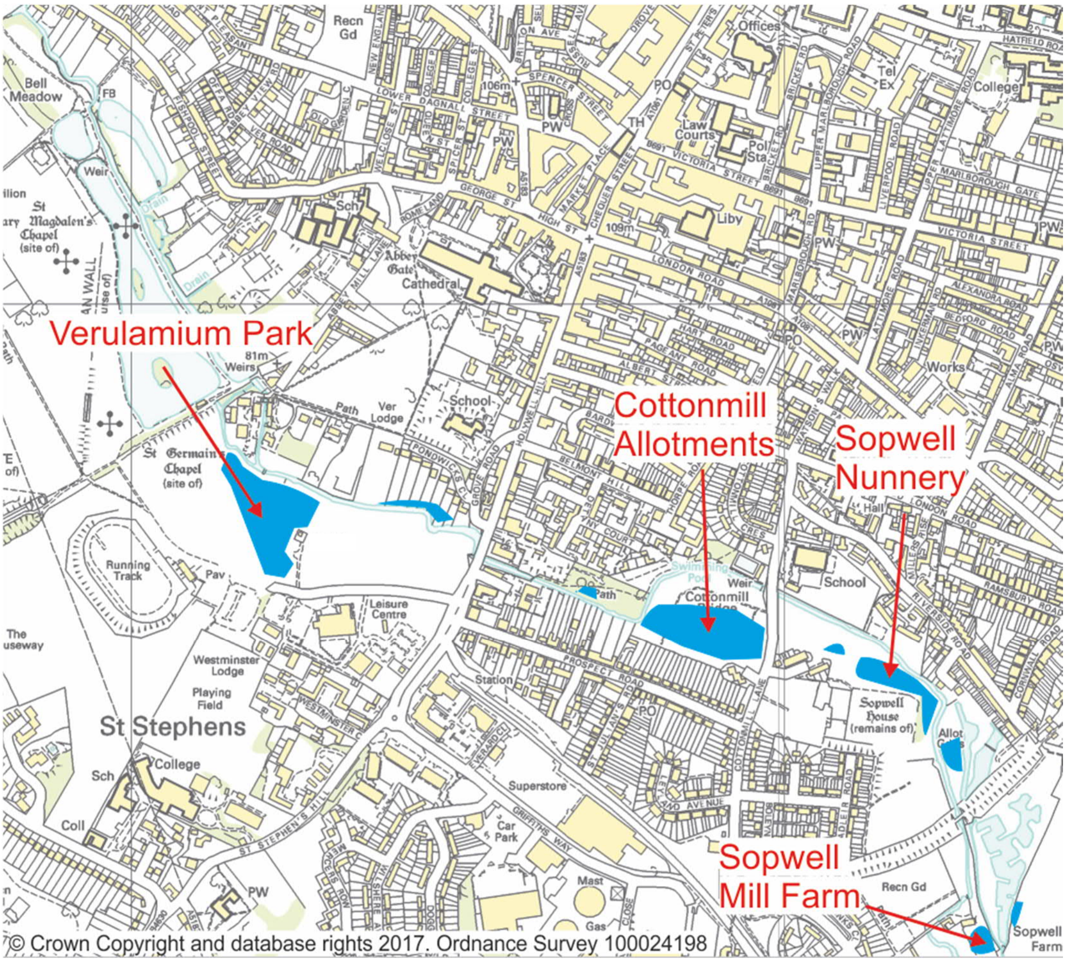


Figure 3.2 Areas Predicted to be at Increased Risk of Groundwater Emergence (Flooding) When Abstraction is Reduced

Groundwater levels

Review of Groundwater levels at Abbey Mill observation borehole (OBH)

Approximately monthly groundwater levels for Abbey Mill observation borehole (OBH) were obtained for the period November 1991 to March 2017. These have been plotted against flow in the Ver (at Hansteads, downstream of St Albans and just upstream of the confluence with the River Colne) in Figure 3.3 below. Groundwater levels are presented regarding ground levels (m below ground level (bgl)), which were found to be 79.85m AOD at the borehole (based on LiDAR data). The location of Abbey Mill OBH is provided on Figure 3.4.

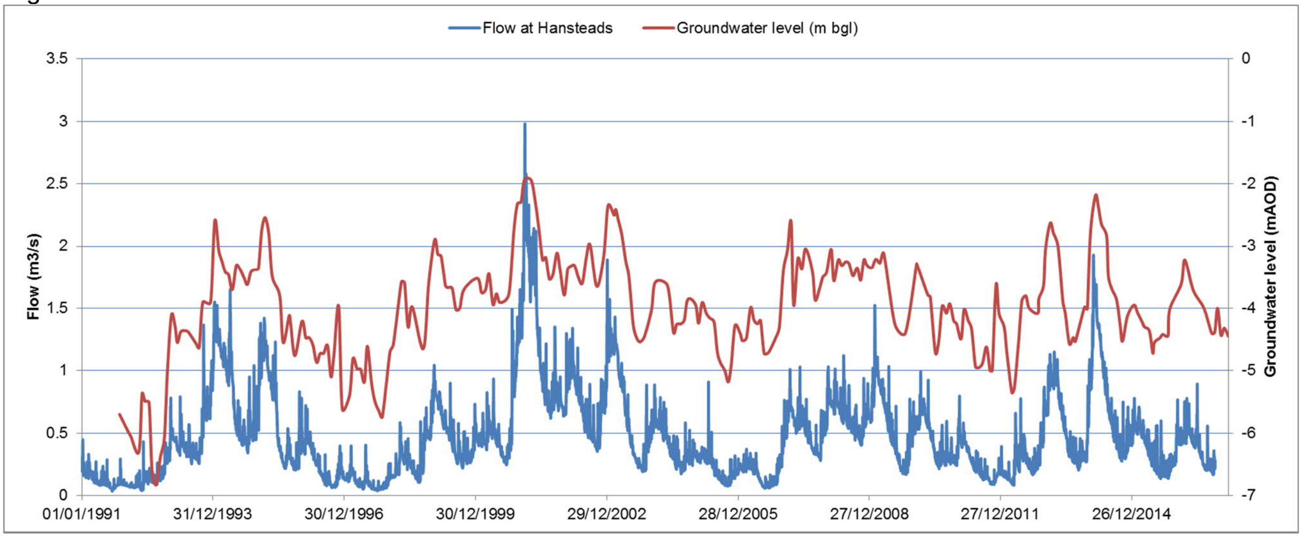


Figure 3.3 Time series of flow in the Ver and groundwater levels at Abbey Mill OBH (with respect to ground level)

Table 3.1 below also indicates groundwater level statistics for the Abbey Mill OBH record.

Table 3.1 Groundwater level statistics (regarding groundwater level)

Statistics	Groundwater level (m below ground level)
Minimum	-6.83
Level exceeded for 95% of the time	-5.47
Level exceeded for 70% of the time	-4.40
Level exceeded for 50% of the time	-3.98
Level exceeded for 20% of the time	-3.30
Level exceeded for 10% of the time	-3.02
Maximum	-1.94

This shows that groundwater levels are typically 4m (~76 m AOD) bgl at the borehole and that they have been observed to fall to almost 7m bgl (~73 m AOD). Regarding high groundwater levels, they have been found to only be less than 3m bgl (~77 m AOD) for 10% of the time and the highest observed level was just under 2m bgl (~78 m AOD).

Potential groundwater levels under Verulamium Lake

Land elevations in and around the Abbey Mill OBH and Verulamium Lake, from LiDAR data, are indicated in Figure 3.4 below. Hard bed elevations in the northern half of the lower lake were found to be around 77.7 m AOD and in the southern half they were around 77.6 m AOD (discussed above in the *Lake Bathymetry and Depth of Sediment* section). Groundwater levels under the lake would be expected to be lower than they are at the borehole, with the borehole being nearer the valley side and the lake being on the valley floor (the lowest point and original discharge point for groundwater), although the magnitude of any difference is not known. The above suggests that groundwater levels would be at least 1m below hard bed levels for at least 90% of the time.

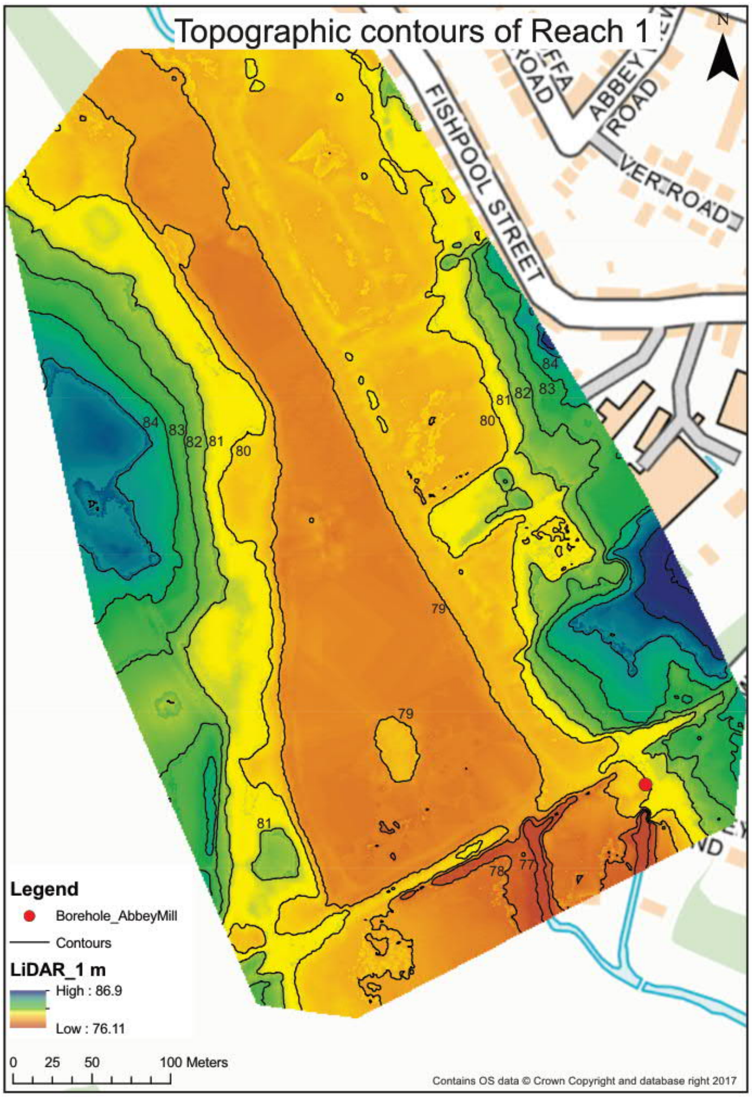


Figure3.4 Ground Elevations in and around Abbey Mill OBH (borehole)

3.4 Fluvial Environment

3.4.1 Overview

A map of the study area and reaches was provided in Figure 1.1 (Section 1.3).

The hydrological, hydromorphological and water quality/ sediment baseline were established through desk top analysis complimented by a field visit undertaken on 14th November 2016. Further water quality and sediment sampling was undertaken in the summer of 2017.

A review of the previous restoration study undertaken on the River Ver at St Albans was carried out. The previous feasibility restoration study[4] assessed options to restore the River Ver through Verulamium Park back into a chalkstream. It also explored options to enhance the visual, recreational and environmental aspects of the river through the park. In addition to this the project explored options to address the frequently occurring problems of blue-green algae and the large numbers of Canada geese in the park lakes.

3.4.2 Hydrology

Rainfall

The nearest meteorological station is at Rothamsted (TL 13873 12548) which is 128.0 m above mean sea level and approximately 2 km from St Albans. Average annual maximum temperature for the period 1981-2010 is 13.7°C and average minimum temperature is 6°C. Monthly average rainfall data and the number of

[4] Halcrow & Countryside Management Services (2004) Ver River Park Project Feasibility Study Final Report April 2004

days per month with rainfall greater or equal to 1 mm for the period 1981-2010 are plotted in Figure 3.5. This indicates that rainfall is consistent throughout the year and slightly greater between October and January than during the rest of the year. Total rainfall, of around 700mm on average, is drier than most of the UK.

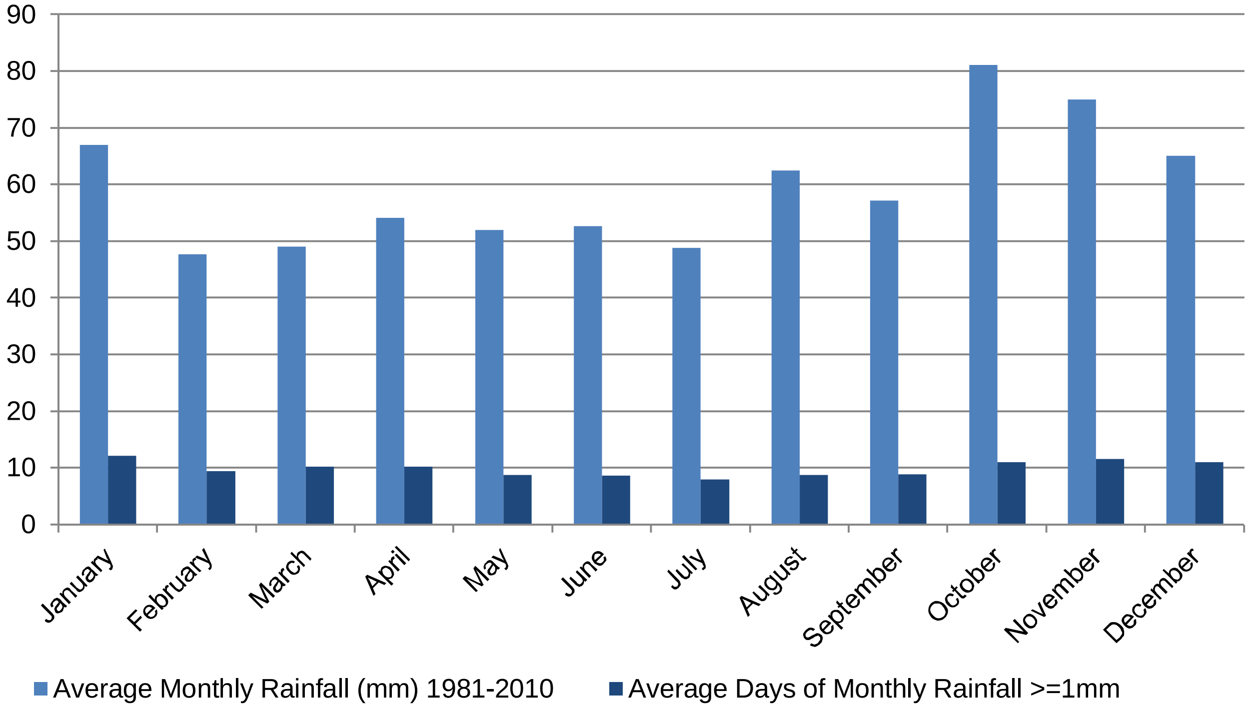


Figure 3.5 Average Monthly Rainfall at Rothamsted No. 2 Meteorological Station 1981-2010

Flow

Flow is measured in the Ver just upstream of its confluence with the River Red, just downstream of Redbourn, and just upstream of its confluence with the River Colne (at Hansteads). Flow is also measured in the River Red just upstream of where it joins the Ver. Flow statistics for these sites were obtained from the National Flow Archive and summarised in Table 3.2 below. In addition flow statistics for the Ver at Hanstead have been derived for the period 2000-2016 and are also presented.

Table 3.2 Flow Statistics for the River Ver and River Red

Location	Ver at Redbourn	Ver at Hanstead	Ver at Hanstead	Red at Redbourn
Period	1993-2016	1956-2016	1981-2010 Reference period	1993-2016
Type of site	Gauge	Gauge	Gauge	Gauge
Catchment size (km^2)	62.6	132	132	18.5
Q_{95} (low flow)	0	0.085	0.081	0.085
Q_{70} (moderate/ low flow)	0.01	0.26	0.241	0.26
Q_{50} (median flow)	0.037	0.369	0.346	0.369
Q_{10} (high flow)	0.24	0.826	0.839	0.826

The flow records indicate that the Ver and Red at Redbourn are both ephemeral and dry up at times of low flows or droughts. The Ver at Hanstead gauge was rebuilt in 1969 which affected the continuity of its record. Results for the period 1956 – 2016 are similar to those of the reference period of 1981 – 2010 for the same gauge.

Comapred to more upland systems the flow regime is not varied (i.e. there is little variation between high and low flows). Due to a low gradient and the system not being hydrologically flashy in nature, flow in the river is also considered to be of low energy.

Flow in the Ver is baseflow dominated, with a baseline flow index (BFI[5]) of 0.88 at the Hanstead gauge. The BFI is 0.92 at the Ver at Redbourn gauge and 0.62 at the Red at Redbourn gauge. This indicates that the Ver is more baseflow dominated than the Red with the former showing characteristics of a typical chalk stream.

Lake Hydrology

Lake level is not recorded. There are two locations where flow in the River Ver can enter the Verulamium Lakes. One of these directs flows into the upper (smaller) lake while the other would direct flow into the lower (larger) lake. However while this second inlet is referenced in the 2015 and 2017 surveys[6], no detailed survey exists of the structure in either these or earlier survey (1997). Additionally the inlet was not observed in the field and as such it is assumed to be blocked.

The inlet into the upper lake consists of two culverts with the connection between the river and lake being managed by a set of gates; a bottom fixed gate and a top moveable gate. Behind the bottom fixed gates is a concrete weir that obscures full vision and access to the bottom fixed gate. Plates 3.3 and 3.4 illustrate an external view of the culverts and an internal view of the weir and gates. Further information on the structure, including invert levels is discussed further within the modelling report (Appendix D). During the modelling we found that under the existing conditions flow into the lake was found to be 0 m^3/s at times of low flow (Q_{95}), 0.008 m^3/s at times of average flow (Q_{50}) and 0.08m^3/s at times of high flow (Q_{10}).

Plate 3.3 External view of the culverts (looking from the River Ver towards the Verulamium Lake)

[5] A BFI of 0 indicates groundwater contributes no baseflow to a watercourse/ while a BFI of 1 indicates flow in a watercourse is entirely from the ground

[6] Environment Agency 2015 and 2017 survey data provided by Maltby Land Surveys Ltd.

Plate 3.4 Internal view of the culvert gates (looking from Verulamium Lake towards the River Ver)

A further weir separates the upper and lower lake. Water flows back to the River Ver through an outlet at the southeast extent of the lower lake.

There is also a culvert that directs some flow from the River Ver/ mill leat under the southeastern corner of the lower lake. This joins the outflow from the lake prior to both joining the River Ver at the top of Reach 2. The combined outflow/ flow into Reach 2 is indicated in Plate 3.5 below.

Plate 3.5 Outflow from (the lower) Verulamium Lake into the River Ver at the top of Reach 2

The areas of the upper and lower lakes are 4,300 m^2 and 33,600 m^2. Approximate average depths of the upper and lower lakes are low and around 0.3 m and 0.45 m, respectively. As such their respective volumes are around 1,290 m^3 and 15,120 m^3 and total Verulamium Lake volume is around 16,410 m^3 (noting this may vary under different climatic conditions).

Flow Splits and Pressures

Abstractions

Five abstractions are reported from the river or from groundwater close to the river. These are described in Table 3.3. The second and third rows relate to the intakes into the lake from the Ver while the fourth and fifth rows relate to Affinity Water's groundwater abstractions where sustainability reductions are proposed.

Table 3.3 Abstraction points with close to the River Ver through St Albans

Type of abstraction	National Grid Reference	Licence Number	Active (Y/N)	Reach	Details
Surface Water	TL1394607314	TH/039/0028/015	Y	1	St Michael's Manor Hotel license for Lake & Pond throughflow (from River Ver)
Surface Water	TL1396807212	TH/039/0028/011	Y	1	St Albans City & District Council license for transfer between sources (from Verulamium Lake). Flow is controlled via a level control structure.
Surface Water	TL1393807288	TH/039/0028/011	Y	1	St Albans City & District Council license for transfer between sources (from Verulamium Lake). Flow is controlled via a level control structure (currently considered to be blocked).
Groundwater	-	28/39/28/0337	Y	2	Affinity Water license for Potable Water Supply (Direct Source Thames Groundwater)
Groundwater	-	28/39/28/0337	Y	3	Affinity Water license for Potable Water Supply (Direct Source Thames Groundwater)

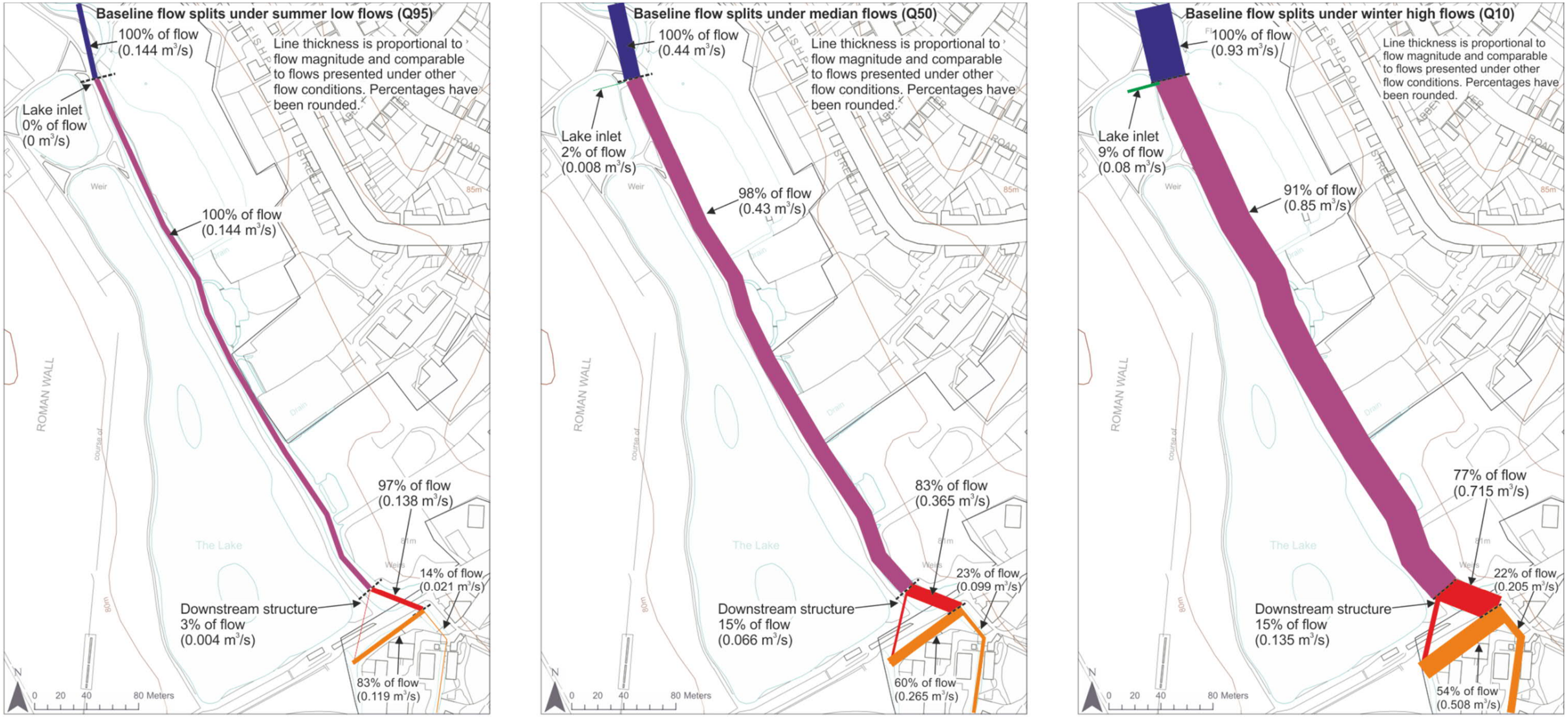
Flow Splits

There is a flow split between mill leat and lakes at the upstream end of Reach 1. At the downstream end the water flows through another offtake and rejoins at the lake outfall. The channel bifurcates into the fish pass channel (considered to be the main channel) and old mill channel. Flow over the fish pass is controlled by an adjustable weir and there is also a weir on the old mill channel. An additional weir is found just upstream of the Causeway bridge and drains into the outlet chamber of the lake with an 18/24 inch concrete pipe running beneath the lake. The old mill channel rejoins the main channel approximately 120m downstream of the start of the reach.

ISIS modelling was undertaken as part of the project. Low (Q_{95}). average (median/ Q_{50}) and high (Q_{10}) flows were simulated through Reach 1 and the results are indicated in Figure 3.6. Information of the structures discussed above under ‘Lake Hydrology’ were included in the modelling. Further details of the modelling work are provided within the Modelling Report (Appendix D). Acknowledging the volumes of the lakes and the inflows (see Figure 3.6), the rate of water travelling through the lakes would be infinite at times of low flow (Q_{95}) as there is no flow into the top lake, 24 days under average flow (Q_{50}) and 8days at times of high flow (Q_{10}).

Flow continues in the main River Ver channel for the remainder of the study area with no formal flow splits. Out of bank flow does occur during higher flows while there is an offtake on the left hand bank to the Local Wildlife Site in Reach 5.

Figure 3.6 Flow splits through Reach 1 under low, median and high flows



3.2.3 Flood Risk

Historic Flooding

An extreme flood occurred through the study area in February 2014. Pictures of the flooding are provided by Plates 3.6 to 3.8 below.

Plate 3.6 Overbanking of the lower lake (at its downstream end) following the February 2014 flood (bottom of Reach 1)

Plate 3.7 Flow from the lake following the February 2014 flood (top of Reach 2)

Plate 3.8 Flooding in Reach 2 following the February 2014 extreme flood (looking downstream)

Flood Modelling

JBA recently produced an 1D-2D ISIS-TuFlow flood risk for the River Ver. The model extends from downstream of Redbournbury Watermill (TL1200310572) to the North Orbital Road (TL15285204769), which encompasses the study area[7]. Prior to this model there was no hydraulic model for the River Ver (flood risk in the area was previously estimated using JFlow, the results of which are still viewable online via the Environment Agency website).

AECOM were given this model by the Environment Agency and it was to be used to inform the outline design of the preferred option for each reach. As part of this the Environment Agency obtained additional topographical (additional cross sectional and structural surveys were undertaken throughout the study area) and bathymetrical surveys (of Lake Verulamium) and these were incorporated into the model. The baseline Ver JBA and updated baseline Ver flood risk extents for the 1 in 100 year flood events (1% chance of flooding each year) are provided in Figures 3.7 to 3.10 below.

Figure 3.7 Extent of the 1 in 100 year flood (original (JBA) and Updated (AECOM) model) through Reach 1

[7] JBA Consulting (2017) 2015s3587 - River Ver Feasibility Study Baseline Check File Final v2.0.docx

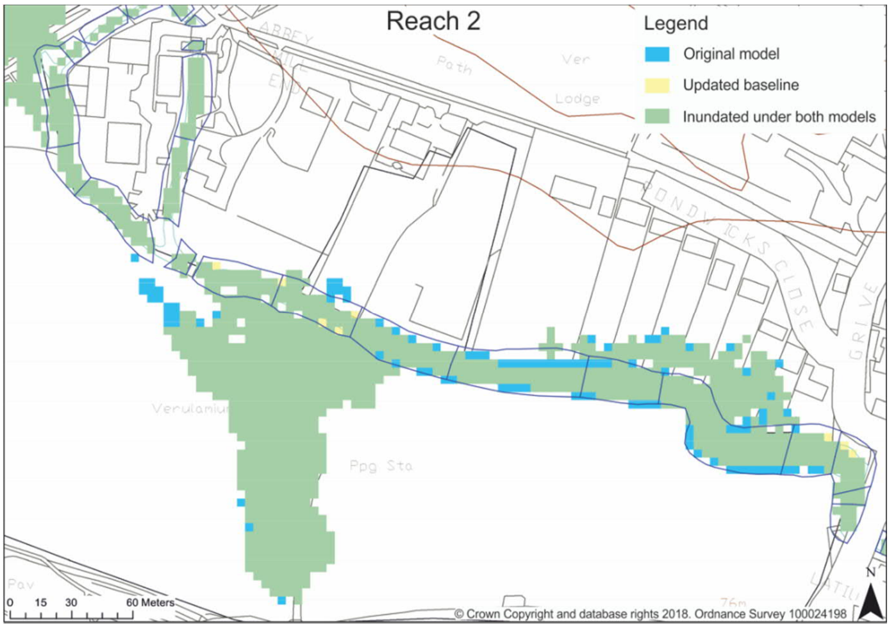


Figure 3.8 Extent of the 1 in 100 year flood (original (JBA) and Updated (AECOM) model) through Reach 2

Figure 3.9 Extent of the 1 in 100 year flood (original (JBA) and Updated (AECOM) model) through Reaches 3 and 4

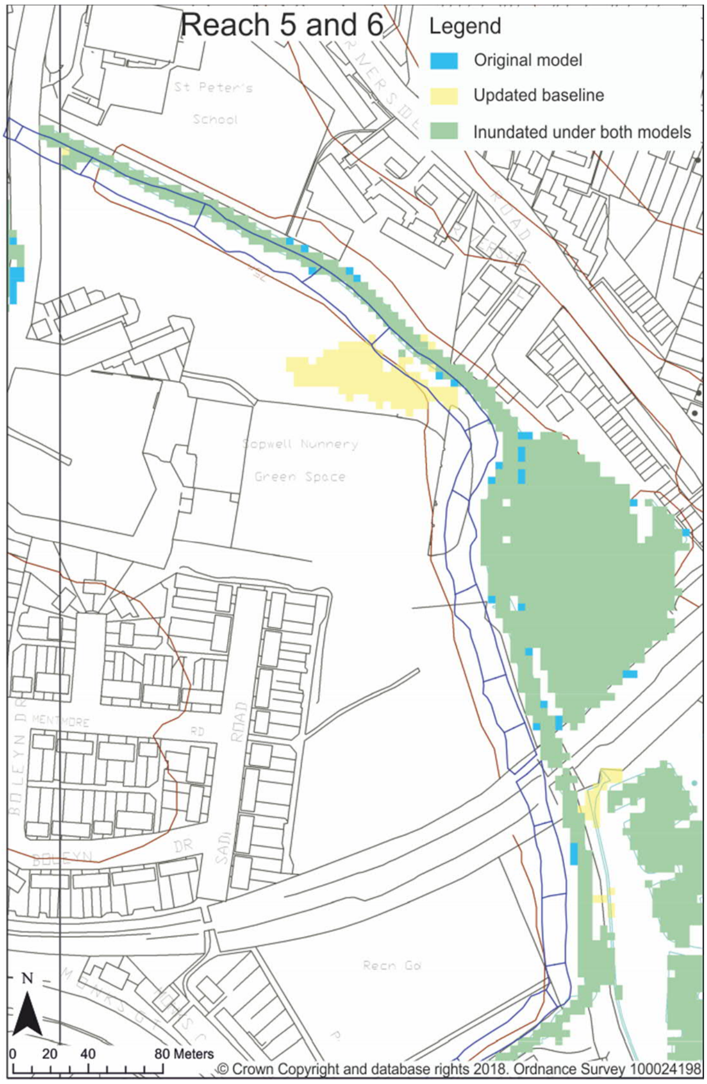


Figure 3.10 Extent of the 1 in 100 year flood (original (JBA) and Updated (AECOM) model) through Reaches 5 and 6

3.2.4 Hydromorphology

Overview

Regarding hydromorphology, the desk based assessment included a review of aerial imagery and historic mapping across the catchment to identify the presence of historic flow routes and the potential to incorporate these into restoration options.

Identifying appropriate low impact (for example flood risk) measures to create a functional integrated river and valley bottom morphology requires an understanding of the character of the system and the controls on form and process. Mapping of morphological types and fluvial processes and system pressures will help identify a desired overall state, in terms of channel and valley bottom form and variability, and highlight where system pressures have altered controlling processes away from natural conditions. The results of the baseline assessment were used to inform the options appraisal process.

Historic River Character

A review of the first epoch Ordnance Survey map (1879-1880) for the River Ver shows that the watercourse planform has remained largely unaltered for the last 138 years through to today. Earlier medieval maps shown (described further under Heritage) also indicate that the general planform of the main watercourse has not changed significantly. Some minor changes are noted in comparison to the current channel and floodplain, including:

- Reach 1 – whilst the main river channel corridor and mill leat channel remain relatively unchanged in terms of their planform, the upper lake and lower lake within Verulamium Park did not exist and had an offtake channel running through it. The small pond was first observed in the 1939 mapping (having been built in 1929). Fish ponds located over the left bank that are now located within private gardens are shown on the medieval maps and therefore changes to the frequency of wetting here associated to restoration option development may present an archaeological constraint.
- Reach 2 – again the main river channel corridor has remained relatively unchanged but in the earliest available map there are a series of channels running across the right hand floodplain that join with the main channel at several points along the reach. These disappear between 1963 and 1973.
- Reach 3 and 4 – there is little change in the main channel planform but in the earliest available maps there is a side channel that runs through the lowest point in the floodplain through the allotments that subsequently disappears between 1924 and 1937.
- Reach 5 and 6 – again there is little change in the current channel planform through these reaches compared to the earliest available map in 1879. Linked to the remains of the Sopwell Tannery, there was a pond and backwater marked on the 1880 map (where the wet woodland is now located) that disappears between 1939 and 1963.

There has undoubtedly been some subtle changes in channel sinuosity that are not shown due to the resolution of the mapping however the modifications to the channel through straightening, dredging, widening and in-channel structures evidently pre-date the earliest available maps and due to the relatively inactive nature of the river, the impacts of the past modifications are still evident today.

Contemporary River Character

The River Ver drains a catchment underlain by chalk comprising arable and pastoral agricultural and urban areas. The natural functioning and character of the chalk system has been extensively degraded with abstraction pressures modifying the flow regime and land use practices introducing unnaturally large volumes of fine sediment to the watercourse as evidenced by extensive berm development, areas of choked river gravels and silt veneers. This in combination with historic artificial modification through dredging, straightening, widening and creation of impounding structure has resulted in highly sedimented channels very different from the original gravel dominated systems they once were.

The River Ver through the all six of the study reaches is no exception to the general degradation, displaying a low energy, generally laterally inactive, sinuous, single thread character typical of many low gradient watercourses in the area. It now has an over-wide occasionally over-deep general cross-section profile with a gravel bed throughout, some of which is buried under accumulations of fine sediment. Transport rates are generally very low due to the naturally subdued flow regime and additional abstraction pressures. The planned reduction in abstraction by Affinity Water will help to reduce the rates of fine sediment deposition (by increasing flows), improving the quality of the gravels for ecology. Reach specific hydromorphological condition and pressures are described below.

Reach 1

The River Ver through Reach 1 has a concrete lined right bank (Plate 3.9) adjacent to the pond and Lake as a result of historic channel straightening but with a natural left bank lined by trees adjacent to private gardens. The gravel bed is highly sedimented as a result of historic overwidening with fine sediment often depositing as lateral berms where the river has attempted to adjust to the overwide conditions by narrowing through lateral fine sediment deposits.

Plate 3.9 Fine sediment deposition, lateral berms and concrete lined right bank

Fine sediment and organic deposition pressures (Plate 3.10) are further exacerbated by the influence of the weir that controls the flow split into the downstream fish pass (Plate 3.11) and through the mill leat channel. This reduces the channel slope and has created a monotonous, low energy, glide flow type along the majority of this reach with very little flow depth or width variation. The low energy and fine sediment pressures mean that there are very few zones of an exposed gravel bed.

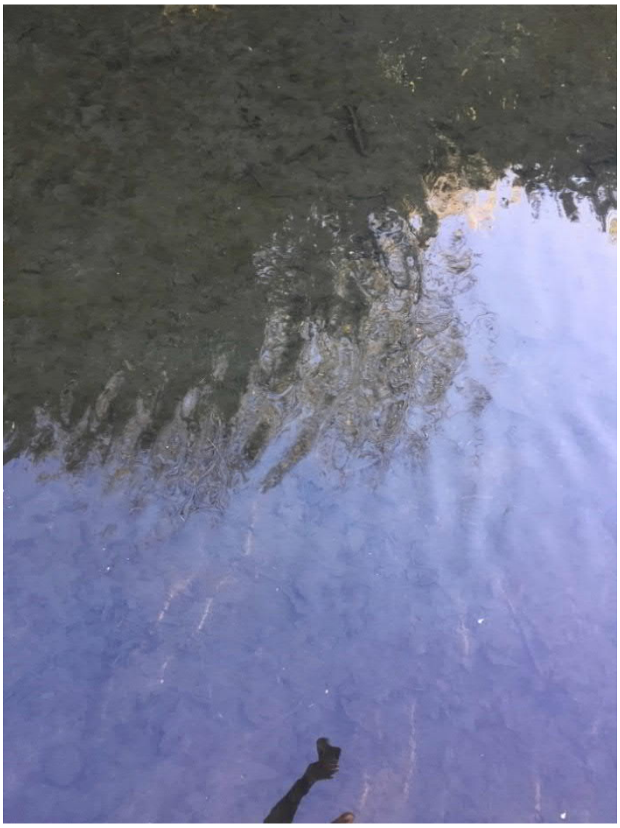


Plate 3.10 Fine sediment deposition on channel bed through Reach 1

Plate 3.11 Impounding influence at downstream end created by weir and fish pass influence

Low flows along the reach are also impacted by the various flow splits between the main channel and the lakes over the right bank (Plate 3.12) and various offtake channels over the left hand bank. These result in less concentrated flow within the main channel, again resulting in lower energy flows creating conditions prone to fine sediment deposition. The various flow splits have been considered as part of the development of restoration options for this reach.

Gradient through the reach is severely limited due to the impounding effect of the historic mill, and its associated structures, downstream.

Plate 3.12 Flow split into lakes from main channel

Reach 2

The fish pass at the upstream end of Reach 2 comprises a series of steps that take out 1.5-2m head of hydraulic gradient upstream. This has an impact on the delivery of sediment to Reach 2 from upstream. However, in this low transfer system, the immediate section downstream of the fish pass is probably the best quality gravel bed of the entire 6 reaches with embryonic riffles generally free from fine sediment (Plate 3.13). This provides significant hydraulic habitat diversity not seen elsewhere within the Ver study reaches.

Gravel exposure is helped by the narrowed channel compared to main Reach 1 channel.

Plate 3.13 Improved gravel bed and riffles just downstream of fish pass

Downstream of this point the fine sediment pressures on the river bed return with historic over widening and deepening providing low energy flow conditions. This severely impacts the quality of the gravel bed and where lateral and mid channel berms (Plate 3.14) have formed, these have often consolidated and become vegetated over time (Plate 3.15). This indicates very infrequent high energy flows energetic enough to mobilise delivered fine sediments.

Plate 3.14 Fine sediment mid-channel berm through Reach 2

Plate 3.15 Vegetated fine sediment lateral berm

Occasional woody features in the channel provide local flow constriction points that provide localised elevated velocities that are able to expose a clean gravel bed.

The river has narrowed itself towards the downstream end of the reach through lateral berm formation that has consolidated and become vegetated providing a flow width that is one third of the size of the channel width further upstream (Plate 3.16). This creates flow conditions energetic enough to expose an improved gravel bed and to keep fine sediment mobilised. This is an important feature that has been used to inform the restoration options for this reach.

Plate 3.16 Channel narrowing exposing an improved gravel bed

The right bank floodplain is partly tree lined in places but is significantly disconnected from the river as a result of past dredging of the channel making it overdeep. Potential restoration options for this reach include improving the connectivity to the local right bank floodplain through a combination of floodplain lowering and water level raising as a result of feature reintroduction. Floodplain lowering was not considered possible over the left bank due to the presence of private gardens. It is possible that the right bank floodplain was once the natural valley bottom for the River Ver here but historic floodplain modification and management makes this difficult to confirm and land raising has occurred towards the downstream end of the right bank floodplain.

Reach 3

Reach 3 is a short straightened section of the River Ver that has a mixture of protected banks that are failing in places (Plate 3.17) and tree lined natural banks. The channel is again over wide as a result of the historic realignment and straightening and this has encouraged deposition of fine sediment as lateral berms and as a variable thickness layer of fine sediment across the gravel bed (Plate 3.18). A glide flow type generally persists throughout the entire reach (Plate 3.17) as a result of the over widening and low energy flow hydraulics. Where woody features have formed in the channel, for example close to the footbridge, the localised constriction created is energetic enough to expose a gravel bed and maintain fine sediment in motion. The flow width at this point is reduced by a minimum of 60% compared to the overall over widened channel through this reach (Plate 3.19).

Plate 3.17 Failing right bank hard protection and low energy glide flow type throughout Reach 3

Plate 3.18 Fine sediment deposition across the gravel bed

Plate 3.19 Local channel narrowing created by woody feature exposing gravel bed

The right bank floodplain is occupied by residential housing but the left bank floodplain downstream of the footbridge is a wooded / scrub area close to the channel that offers an opportunity for channel realignment or improved connectivity to the river. The river is heavily over-shaded and lacks any in-channel or marginal vegetation as a result.

Reach 4

This reach flows adjacent to the allotments (situated on the right bank side of the river). It is known that some sections of floodplain here are lower in elevation than the river bed. This suggests the natural valley bottom runs through the allotments. The left bank is partly tree lined with the footpath close to the banktop. The right bank edge has ad hoc soft bank protection at numerous locations that is often failing and in a state of disrepair, although there is no evidence of significant erosion pressures at these points suggesting that this protection may not be required. Historic realignment of the channel has resulted in an over-wide channel, again resulting in widespread deposition of fine sediment (Plate 3.20) often as lateral berms and as a veneer across the gravel bed. There is very little gradient through this reach and the channel is over-shaded.

Plate 3.20 Fine deposition and lateral berms

There is a small weir crossing the river bed close to the downstream extent of the reach. This impacts sediment transport locally (Plate 3.21). It is possible that this is a service crossing although we have received conflicting service information on this.

Plate 3.21 Small weir at downstream extent of Reach 4

Reach 5 and 6

Reaches 5 and 6 are hydromorphologically similar although natural recovery is most notable through Reach 5 with Reach 6 remaining over-deep in places. A footpath runs close to the right bank top and there is limited tree presence (except for the wooden walkway through the wet woodland area). Over the left hand bank there is a mixture of residential gardens, allotments and ponds and the bank is mostly tree-lined through both these reaches.

The river through both reaches has been historically moved and straightened and it is likely the natural valley bottom would have been over the right hand bank, within the floodplain. As a result of the historic realignment, the river is over wide and over deep, particularly towards the downstream end, creating a disconnected floodplain that is exacerbated by dredged material being dumped on the right bank top throughout both reaches (Plate 3.22). Reach 5 in particular has reacted to the overwide channel form by depositing delivered fine sediment as lateral berms and consolidated point bars that have often become vegetated (Plate 3.23). This has narrowed the channel significantly in places (to around 50% of the previous width) and, combined with a slight increase in hydraulic gradient, has created flow hydraulics energetic enough to expose an improved gravel bed (Plate 3.24). At a couple of locations, flows have become energetic enough to create some localised minor bank erosion (Plate 3.24) providing a rare habitat.

Plate 3.22 Right bank dredged material

Plate 3.23 Channel narrowing created by vegetated lateral berms

Plate 3.24 Sediment shoaling and vegetative colonisation creating conditions for local bank erosion

The flow deflectors seen along both reaches are generally not functioning as intended encouraging only limited scour and deposition (Plate 3.25). However, the degree of channel narrowing created by consolidated fine sediment berms and bars seen elsewhere has been a lot more successful in creating elevated flow velocities under normal flows and these are capable of exposing a gravel channel bed and creating an improved diversity of hydraulic habitat. This narrowing and associated features offer useful analogue information that has been used to inform the restoration optioneering for the project.

Plate 3.25 Ineffective flow deflector

The local right hand bank floodplain offers an opportunity for local lowering to reconnect this margin to the watercourse and create a wetter riparian environment, particularly through Reach 6. The wet woodland zone where the board walk exists also offers an opportunity for improved connectivity to the watercourse through local bank works to encourage more frequent inundation.

3.2.5 Water and Sediment Quality

Verulamium Lake

Overview

Verulamium Lake is home to a large population of waterfowl, most notably Canada Geese (*Branta Canadensis*) and a cyprinid fish population (predominantly carp *Cyprinus carpio*). Faecal wastes from waterfowl (and to a lesser extent fish) combined with food given to them by the public represents a significant nutrient source that may be enriching the lake, which is further exacerbated by the relatively high surface area to volume ratio and low flushing rates.

Strategic removal of sediment has previously been carried out. For instance the upper lake dried out during a drought in 2005 and was cleaned out. In 2008 it was drained and sediment removed and taken to a contaminated waste landfill due to the presence of heavy metals. Further silt removal was undertaken in 2016, notably towards the lake outlet and below the weir into the lower lake[8].

A site survey and analysis of the lake was also undertaken in 1991[9], and the lake was subsequently subject to a bioremediation treatment and biomanipulation programme. This included removal of approximately 8 tonnes of roach *Rutilius rutilus* with the aim of reducing direct pollution inputs, reducing silt disturbance from bioturbation and lowering predatory pressure on invertebrates. Further fish removal was performed in later years. Remedial biological sachets have been used sporadically at the site since 2003. There is considerable public concern about the condition of Verulamium Lake, particularly given a suspected outbreak of avian botulism in 2015[10].

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[8] St Albans City and District Council website (2016) Information about the condition of the Lakes

[9] Symbio (1991) Verulamium Lake Site Survey and Analysis

[10] St Albans City and District Council website (2016) Information about the condition of the Lakes

Water Quality

At the start of the project available water quality and sediment quality data for the upper and lower lakes were reviewed. In addition three water and three sediment samples (for bulk sediment and leachate analysis) were collected on 14th November 2016 for testing. The work was undertaken to inform the restoration options appraisal and development of the outline designs for the River Ver restoration through St Albans. Water quality and sediment samples from the Verulamium Lake (within Reach 1) have been collected and analysed to understand any potential risks to the environment and to human health. Further details on the sampling and interpretation of the results are presented in Appendix E.

The results of the water quality sampling (Appendix E) indicated that the water quality of the shallow upper lake site is poorer and potentially more polluted and nutrient enriched than the lower lake. Recreational activities (model boating) may be a significant local source of some of the contaminants present. Deeper cycling of nutrients and metals within the lower lake or fines and associated contaminants being deposited in the upper lake before water flows into the lower lake may explain water quality being observed as better during the monitoring (noting that the amount of monitoring undertaken was limited).

Following the initial review (Appendix E), further sampling was proposed and this has since been undertaken by the Environment Agency (on two occasions, 14 June 2017 and 3 August 2017). Sampling was undertaken at four locations (including on the River Ver, one location in the upper lake and two locations in the lower lake).

Further details on the Environment Agency sampling and interpretation of the results are presented in Appendix F. The review found that:

- The river does not appear to be contributing significant loads of nutrients or other parameters into the lake.
- Nutrient enrichment (particularly for phosphorus) is an issue within the lakes, and this supports the perceived eutrophic conditions and risk of algal blooms. Such high levels should not ideally be fed back into the river due to the potential to cause detrimental impacts in terms of the WFD requirements.
- Suspended solid concentrations were far higher in the summer 2017 surveys compared to 2016. Suspended solids in the lake are most probably derived from sediment bioturbation by fish and waterfowl and fine organic effluent in the lake from waterfowl excreta. The increase in summer may be a consequence of increased use of the lake by waterfowl in the summer months.
- Metal concentrations are significantly increased in several of the 2017 samples in comparison to 2016 and are particularly noticeable for dissolved copper, dissolved arsenic and total and dissolved lead. These increases include several breaches of Environmental Quality Standards (EQS).
- Similarly, numerous poly-aromatic hydrocarbons (including fluoranthene, benzo(a)pyrene and benzo(g,h,i)perylene) in the lower lake are increased in August 2017 in comparison to November 2016, again with thresholds for EQS being surpassed in some cases. These are commonly sourced from incomplete combustion of organic matter (for example fuel, wood burning, biofuels).

Overall, the review found that lake water quality did not seem to be a matter that would make potential options unfeasible. Nutrient levels in the lake are higher than desired, as expected, which would make those options where the lake did not discharge into the river preferred from a water quality perspective.

Further water quality and sediment sampling were undertaken towards the end of the Outline Design following another spate of bird deaths during the dry summer of 2018. This is also included in Appendix E.

Sediment Quality

The results of the initial sediment quality monitoring (Appendix E) were less varied and suggested that lake sediments are ‘potentially hazardous’, with the upper lake being the most contaminated. This has consequences in terms of sediment re-use, and further sampling to determine the full extent of fuel pollution (potentially relating to model boating) in this area is recommended. However, leachate analysis suggested that lake sediments would be suitable for inert landfill. There were, however, a number of failures of the leachate data with WFD standards, which mainly affected the sample nearest the outflow of the lower lake. Leachate tests typically overestimate the risk in the natural environment and dilution, dispersion and duration factors would need to be considered, but this suggests that significant mobilisation of sediments could potentially have an impact on the lake ecosystem and potentially the River Ver downstream. This risk should be assessed in more detail before any works that affect lake sediments are undertaken. Regardless of the contamination risk, such works would need to be carefully planned and implemented using appropriate techniques and mitigation to minimise this risk. Finally, a pathogen analysis is recommended should lake sediments need to be excavated from the site to determine the viability of *Clostridium botulinum* in the sediment of the Verulamium Lake, and to what extent it poses a risk to the health of waterfowl and humans.

Following the initial review (Appendix E), further sediment sampling was proposed and this has since been undertaken by AECOM (on one occasion, 28 July 2017). Sampling was undertaken at 6 locations (5 in the lower lake and one in the upper lake) on the 28 July 2017.

Further details on the sampling and interpretation of the results are presented in Appendix F. The review found that:

- No individually measured determinant was found to be in excess of human health screening values for those that could be reviewed.
- In general, metal concentrations are higher in concentration in the lower lake (samples VL-17-2 through to VL-17-6, plus VLS 2 and VLS 3) than in the upper boating lake (VL17-1), and so appear to be more prone to accumulate in this area where there is low through flow of water.
- Organic content (as indicated by loss on ignition) varies between 8 and 20% across the two lakes, with the lower values found towards the south of the lower lake.
- Orthophosphate was noticeably elevated in the upper lake and may be related to a greater concentration of faecal inputs in the upper lake from wildfowl. Fluoride and chloride are also elevated in VL-17-1 in comparison to the samples from the lower lake.
- Sediment samples from 2017 have been run through HazWaste Online by AECOM's contaminated land team. The samples have been classified as 'non-hazardous waste' in all cases.
- Leachate testing was undertaken on the sediments to understand hypothetically what the impact of dewatering sediment close to watercourses might be in terms of contaminants leaching from the matrix. When compared to water quality standards, some of the leachate results fail to meet 'good' requirements. As such any dewatering of sediment close to waterbodies could therefore have detrimental impacts downstream if not suitably mitigated for.

River Ver

Water Quality Status

Water quality within the River Ver through the study area was considered to be High in 2015 for those parameters considered under the WFD, including ammonia, dissolved oxygen, pH, phosphate and specific pollutants (see Table 3.1). As discussed above, the river does not appear to be contributing significant loads of nutrients or other parameters into the lake.

Water Quality Pressures

Two active environmental permits (formerly termed discharge consents) are located through the study area and discharge into the River Ver. These are both located in Reach 4.

Pollution Incidents

Pollution incidents recorded by the Environment Agency, between 2010 and 2016, through the study area are outlined in Table 3.4. All pollution incidents in the Table were classified as Category 3 or lower (minor incidents).

Table 3.4 Pollution incidents recorded by the Environment Agency (2010-2016) through the study area

Observed Date	Event No.	Incident Category	Cause	Type of premises	Pollutant	Location	Grid Reference
03/03/10 11:10	758365	4	Containment and Control Failure	Water Industry	Contaminated Water	Reach 2	-
05/07/10 13:20	798155	3	Containment and Control Failure	Domestic and Residential	Sewage Materials	Reach 5	TL 15102 06500
25/02/11 13:12	861338	3	Cause Not Identified		Oils and Fuel	Reach 6	TL 15234 06330
16/08/11 12:49	913974	3	Containment and Control Failure		Other Pollutant	Reach 2	TL 14499 06643
04/03/13 22:34	1091588	3	Containment and Control Failure	Water Industry	Sewage Materials	Reach 2	-
08/03/13 13:00	1092840	3	Containment and Control Failure		Contaminated Water	Reach 5	TL 15123 06496
21/04/13 11:22	1104767	3	Containment and Control Failure	Water Industry	Sewage Materials	Reach 2	-
24/05/13 15:20	1115877	3	Cause Not Identified		Oils and Fuel	Reach 6	TL 15278 06185
10/11/13 11:03	1175083	3	Other Cause		Other Pollutant	Reach 6	TL 15238 06419
24/05/14 11:20	1238668	3	Unauthorised Activity		Pollutant Not Identified	Reach 4	TL 14999 06550
16/06/14 18:41	1246099	3	Unauthorised Activity		Pollutant Not Identified	Reach 2	TL 14524 06646
13/06/14 10:09	1246277	3	Natural Causes	Natural Source	Other Pollutant	Verulamium Lake	TL 14025 06991
20/06/14 08:45	1247450	4	Other Cause	Water Industry	Other Pollutant	Reach 2	-
07/07/14 10:41	1253264	3	Containment and Control Failure	Water Industry	Contaminated Water	Reach 2	-
01/08/14 18:07	1263995	3	Cause Not Identified		Pollutant Not Identified	Reach 2	TL 14525 06618
09/09/14 18:13	1275937	3	Containment and Control Failure	Water Industry	Sewage Materials	Reach 2	-
15/10/14 11:28	1287008	3	Containment and Control Failure	Other Source	Contaminated Water	Reach 2	TL 14481 06656
25/11/14 12:45	1297206	3	Containment and Control Failure		Contaminated Water	Reach 2	TL 14518 06654
05/12/14 14:15	1299540	3	Containment and Control Failure		Contaminated Water	Reach 5	TL 15001 06557
08/05/15 11:09	1335601	3	Containment and Control Failure	Water Industry	Sewage Materials	Reach 2	-
21/09/15 13:00	1374808	3	Unauthorised Activity		Sewage Materials	Reach 5	TL 15100 06506
13/08/16 09:48	1461746	3	Cause Not Identified		Pollutant Not Identified	Reach 4	TL 14954 06569
16/08/2016 12:38	01462592	4	Cause Not Identified			Reach 1	TL 14024 07014
22/09/2016 13:35	01473513	3	Cause Not Identified			Reach 3	TL 14528 06640
02/12/2016 12:59	01488587	3	Sewer Failure or Overflow	Foul Sewer	Crude Sewage	Reach 5	TL 15233 06326
12/12/2016 08:35	01490378		Cause Not Identified			Reach 5	TL 15261 06273
19/12/2016 11:50	01491665	3	Wrong Connection		Grey Water	Reach 5	TL 15018 06542
16/02/2017 10:05	01502128	3	Not Identified	Surface Water	Grey Water	Reach 6	TL 15243 06258

Observed Date	Event No.	Incident Category	Cause	Type of premises	Pollutant	Location	Grid Reference
				Outfall			
20/02/2017 09:14	0150278 5 (M)	3	Other Inadequate Control or Containment		Crude Sewage	Reach 5	TL 15100 06524
28/02/2017 09:15	0150462 1	3	Not Identified		Not Identified - No evidence of pollutant	Reach 2	TL 14427 06681
17/03/2017 08:55	0150868 9 (M)	3	Wrong Connection	SWO	Grey milky water	Reach 6	TL 15243 06258
29/03/2017 13:51	0151154 7	3	Not Identified		Not Identified	Reach 4	TL 14844 06586
23/04/2017 12:40	0151777 0	3	Unauthorised Discharge or Disposal		Not Identified - suspected misconnection	Reach 5	TL 15173 06455
28/04/2017 10:24	0151906 8 (M)	3	Pipe Failure below ground	Water Distribution System	Clean Water	Reach 3	TL 14529 06586
09/07/2017 21:47	0153806 6	3	Wrong Connection	Surface Water Outfall	Grey Water	Reach 5	TL 15169 06459
16/07/2017 19:07	0154049 3 (M)	3	Pipe Failure below ground	Water Distribution System	Suspended Solids - silt	Reach 6	TL 15240 06299
17/08/2017 11:03	0154863 5	3	Not Identified	Surface Water Outfall	Grey Water	Reach 3	TL 14533 06655
20/08/2017 17:14	0154928 5	3	Pipe Failure below ground	Water Distribution System	Mains water	Reach 2	TL 14271 06658
22/12/2017 16:08	0157497 6	3	Not Identified		Not Identified - no pollution	Reach 5	TL 15019 06549
23/02/2018 16:17	0159154 5	3	Sewer Failure or Overflow	Foul Sewer	Crude Sewage	Reach 3	TL 14585 06586
06/03/2018 13:12	0159398 4 (M)	2	Not Identified		Not Identified	Reach 1	TL 14019 07116
30/04/2018 18:37	0160996 8 (M)	3	Unauthorised Discharge or Disposal	Surface Water Outfall	Grey Water	Reach 1	TL 14009 07133
31/05/2018 15:02	0161826 3	3	Cause Not Identified	Surface Water Outfall	Grey Water - suspected discharge	Reach 5	TL 15125 06490
03/07/2018 18:12	0162873 0	3	Cause Not Identified			Reach 5	TL 15108 06501
12/07/2018 13:32	0163208 2	3	Dry Weather	Other Natural Source	Not Identified	Reach 1	TL 14006 07067
29/07/2018 16:30	0163841 1	3	Cause Not Identified			Reach 1	TL 14000 07100
10/09/2018 17:31	0165027 7	3	Wrong Connection	Surface Water Outfall	Grey Water	Reach 5	TL 15230 06420
20/09/2018 19:36	0165266 2	3	Pipe Failure above ground	Water Distribution System	Other - Clean water	Reach 3	TL 14560 06630
18/10/2018 11:48	0165864 1	3	Cause Not Identified			Reach 6	TL 15337 06147
26/10/2018 11:32	0166032 8 (M)	3	Not Identified		No pollutant found	Reach 4	TL 14929 06584
17/12/2018 10:10	0166953 5	3	Cause Not Identified			Reach 2	TL 14327 06688

3.5 Contaminated Land Preliminary Risk Assessment

A contaminated land preliminary risk assessment (PRA) of the six reaches along the River Ver addressed the following points;

- all previous uses,
- potential contaminants associated with those uses,
- a conceptual model of the site indicating sources, pathways and receptors, and;
- any potentially unacceptable risks arising from contamination at the site.

The PRA also included a collation and review of available environmental records (including 2006 sediment analysis), review of historical and current land uses and geological and hydrogeological information. The full PRA is provided as Appendix G. The results of each reach have been reported in tabular format and that concluded with a conceptual site model and a source – pathway – receptor which enabled potential land quality constraints to the proposed scheme to be identified and mitigation measures considered.

Potential constraints recorded in the contaminated land study are illustrated in the constraints maps provided in Section 3.10.

Key observations from the study included that:

- All reaches fall within an area of adopted green belt.
- All reaches are within a Nitrate Vulnerable Zone
- No current or historic landfill sites are present in the 500 m buffer zone either side of the study reaches
- No sites or installations with hazard substances are reported in the 500 m buffer zone either side of the study reaches
- The floodplain surrounding the Ver through St Albans consists of loamy and clayey floodplain soils with naturally high groundwater, while the surrounding buffer zone consists of freely draining slightly acid but base-rich soils.

3.6 Ecology

3.6.1 Overview

A preliminary ecological appraisal (PEA) was undertaken at the beginning of the project. This is included as Appendix H. Key details from the PEA are indicated below.

3.6.2 Designated Sites

There is one statutory nature conservation designation present within a 1 km radius of the proposed works, as detailed in Table 3.5. There are no Sites of Special Interest (SSSI), Special Areas of Conservation (SAC) or RAMSAR sites close to the study area.

Table 3.5 Sites with Statutory Nature Conservation Designations within 1km of the Study Area

Designation	Reason(s) for Designation	Distance and Direction from the Proposed Works
Watercress Wildlife Site Local Nature Reserve (LNR)/ Sopwell House Watercress Beds	Shallow lake and wetland area that is known to support a range of birds, wildfowl and insects.	Located adjacent to eastern bank of Reach 6 of River Ver.

Several non-statutory nature conservation designations are present within 1 km radius of the proposed works, as detailed in Table 3.6.

Table 3.6 Sites with Non-statutory Nature Conservation Designations within 1km of Study Area

Designation	Reason(s) for Designation	Distance and Direction from the Proposed Works
Verulamium Lake Local Wildlife Site (LWS)	Important for local bird and bat populations: a heronry can be found on one of the lake's islands and numerous bat species use it as a foraging site.	Located adjacent to Reach 1 of River Ver.
Abbey Mill Lane Area LWS	Building and environment important for protected species.	Located approx. 50m east of Reach 1 of River Ver.
Sopwell Meadows LWS	Alluvial meadows formed of semi-improved neutral grassland, unimproved wet marshy grassland, swamp and fen (9.6ha). Water vole has been recorded here. The site is also of importance to inverts and birds.	Located approx. 100m south east of Reach 6 of River Ver.
Ver Valley Meadows LWS	Valuable unimproved grassland habitat (27.9ha). Supports both neutral and acid grassland. Grassland ranges from damp to very vet with marshy/fen areas at low points.	Located approx. 750m south east of Reach 6 of River Ver.

The proposed works are likely to directly affect the Verulamium Lake and ecological considerations should be accounted for within the final Reach 1 restoration option.

Sopwell Meadows and the Ver Valley Meadows are located directly downstream of Reach 6 of the River Ver. It is therefore possible that they will be indirectly affected by the proposed works. However, with the implementation of standard pollution/ siltation control methods, the proposed restoration works should not have any adverse impacts on the either of the non-statutorily designated sites.

3.6.3 Ecological Findings of the PEA

The following key findings were determined during the PEA:

- Verulamium Lake is home to a large population of waterfowl, most notably Canada Geese (Branta canadensis) and a cyprinid fish population (predominantly carp (Cyprinus carpio)).
- The wetted channel along the affected reaches of the River Ver was between 1m and 10m with shallow water typically up to 0.5m deep (on the day of the survey). The channel substrate ranged from silt through to gravel.
- Submerged/ floating vegetation was largely absent from the channel at the time of survey. The extent and depth of silt deposits results in conditions that are sub-optimal for most aquatic plant species, and therefore it is considered that the present habitat conditions are unlikely to allow development of an extensive and diverse aquatic plant community.

3.6.4 Key Ecological Receptors and Further Considerations

The following ecological receptors have been identified as present or potentially present along the affected reaches:

- The Watercress Wildlife Site LNR
- The Verulamium Lake non-statutorily designated site
- Chalk river and wet woodland habitats of principal importance
- River and woodland habitats of local importance
- Invasive non-native plant species
- Water vole
- Otter

- Fish (refer to Fisheries Chapter 3.5 for more detail)
- Roosting bats
- Nesting Birds
- Kingfisher
- Badgers
- Reptiles.

These ecological features may constrain implementation of the restoration scheme and should be considered further when planning and implementing site works. In the case of the identified species these have potential, if present, to be key constraints that will require specific consideration and action to avoid conflicts with, and potential breaches of, relevant nature conservation legislation. Where potential ecological risks are identified, their actual presence/ absence would need to be determined through specialist surveys at the appropriate time of year.

Designated sites are also illustrated in the constraints maps for each reach of the study area in Section 3.10.

Further surveys which are recommended before restoration commences include:

- Water vole/ otter survey along affected reaches to determine the presence/ absence and the need for any mitigation avoidance;
- A preliminary ground level bat roost assessment of all trees and bridges that may be impacted during proposed works, further surveys to determine mitigation requirements are likely to be required if potential roosting features which cannot be avoided are found;
- A breeding bird survey of the river corridor, in particular to identify kingfisher holes / nests between March and August.; and
- A survey of the river channel for aquatic macrophytes and invasive plant species during their growing season (May to September inclusive) as they may not have been detectable at the time of the survey.

3.7 Fisheries

3.7.1 Desk Study

A desk based assessment of the current fishery status recorded in the River Ver utilised available Environment Agency fish survey population data[11] and previous studies undertaken on the River Ver fishery.

Due to the transient nature of fish populations under natural conditions, habitat and fish population data were assessed on both a reach specific and wider Ver catchment basis.

3.7.2 Site Walkover Assessment

A site walkover assessment of each reach of the study area was undertaken on 14th November 2016 by a Fisheries biologist. The suitability of the habitat present within each reach of the study area was assessed in relation to its potential to support the known life-history requirements of the fish species recorded in the Ver desk study, and also those absent which would be expected in the watercourse under natural conditions. Due to the survey being undertaken during the salmonid spawning season (November-January), the presence and location of salmonid spawning sites (redds) were also recorded. The information gained from the survey can be used to determine fish habitat quality at both a reach specific and wider catchment level, and to direct further survey and assessment where necessary.

Previous Studies

A previous feasibility study, including fisheries assessment, was commissioned to assess the potential for river restoration options on the Ver through Verulamium Park[12]. The assessment focused on what were considered 'chalkstream fishery' species only (brown trout, bullhead and brook lamprey), with brown trout used as the indicator for the condition status of the fishery. The study noted the Ver was once a thriving trout

[11] Environment Agency (2016) Freshwater Fish Counts for all Species, all Areas and all Years https://ea.sharefile.com/ds5b6918d01884a129 Accessed 10/11/2016

[12] Halcrow Group Ltd (2004) Countryside Management Services Ver River Park Project Feasibility Study Final Report

stream, with good sized fish throughout the river up to Redbourn, however, it did not refer to the date of this period. The quality of the fishery was deemed to be significantly influenced by in-river habitat quality, with the habitat in the Verulamium Park reach noted as a limiting factor to the breeding or movement of chalkstream species. The study utilised flow conditions as the determinant for the fishery expected in the river. The effectiveness of the fish pass channel located between the mill leat and river downstream of Verulamium Lake was noted as unknown though the Environment Agency believe it to be ineffective. Along with engineering work to the river, the stocking of roach, tench, dace and chub was suggested as a suitable means for increasing the diversity of the fishery. Whilst roach, chub and dace are to be expected in a riverine fishery such as the Ver, tench are a lentic species unlikely to be found in a naturalised chalkstream fishery.

A fish habitat walkover assessment undertaken upstream of the study area at the Redbournbury Fishery in 2002 noted excellent instream habitat[13]. More recent studies undertaken in 2012 noted that whilst the Ver contains brown trout throughout its course, a combination of both historic channel modification (including milling practices) and over-abstraction have resulted in the river possessing a degraded habitat that is most likely limiting the abundance of rheophilic gravel spawning species[14]. There are no records of fish being stocked in the River Ver in the last five years[15].

Fish Population Data Assessment

The restoration reach of the River Ver in St Albans is located in the lower half of the WFD Ver waterbody (Waterbody ID: GB106039029920). The current fishery status is classed as Good [16].

Environment Agency fish population surveys[17] carried out within the last 10 years recorded a total of ten species throughout the River Ver, including brown trout (*Salmo trutta*) (UK Biodiversity Action Plan species), chub (*Leuciscus cephalus*), roach (*Rutilus rutilus*), perch (*Perca fluviatilis*), gudgeon (*Gobio gobio*), pike (*Esox lucius*), bullhead (*Cottus gobio*) (EC Habitats Directive Annex II listed), minnow (*Phoxinus phoxinus*), 3-spined stickleback (*Gasterosteus aculeatus*) and 10-spined stickleback (*Pungitius pungitius*). The species composition is fairly typical of a small stream watercourse, however notably absent species that would be expected in a watercourse like the Ver under reference conditions include dace (*Leuciscus leuciscus*), eel (*Anguilla anguilla*), brook lamprey (*Lampetra planeri*) and stone loach (*Barbatula barbatula*).

There are no records of any fish population surveys within the study area. The closest geographical survey records are located immediately upstream of Reach 1 at Gorehambury Mill (~0.55 km upstream of Reach 1) and immediately downstream of Reach 6 at Verulam Golf Course (~0.35 km downstream of Reach 6).

Survey data from the closest site upstream of Reach 1 (Gorehambury Mill) records the presence of a small wild brown trout population. In addition, a small number of coarse fish including roach, chub and gudgeon are recorded, along with bullhead and minnow. A separate walkover assessment of the fishery at the Gorehambury Estate in 2012 describes a fairly degraded river channel, over-widened, lacking in clearly defined flow regimes and an absence of tree cover[18]. However, the presence of both juvenile and adult brown trout, roach and chub indicate conditions are suitable for supporting a small riverine fishery in this reach of the Ver shortly upstream of the study.

Further fish surveys upstream at Shafford Mill (~2.5km upstream of Reach 1) and Redbourn (~6km upstream of Reach 1) reveal a less diverse species composition. Both sites contained a range of both juvenile and adult brown trout, along with smaller minor species. A relative abundance of a range of different size juvenile and adult roach recorded at Shafford Mill suggests conditions are suitable for the successful recruitment and development of coarse fish in this reach of the river.

Compared to the fishery recorded in the Ver upstream of the study area, survey data shortly downstream of the study area reveals a slightly more diverse fishery, consisting of brown trout and a variety of coarse fish species. Brown trout and roach populations also show signs of recruitment, as indicated by the presence of juvenile fish. Large adult chub are also present, but do not show the same signs of recruitment as upstream of the study area. It is likely that the chub recorded in this reach are recruiting naturally in the wider Ver. Bullhead and minnow are also present, along with perch and 3-spined stickleback (the latter two species are

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[13] Wild Trout Trust (2002) Habitat Advisory Visit, Redbournbury Fishery, River Ver
[14] Wild Trout Trust (2012) River Ver Gorehambury Estate. An Advisory visit by the Wild Trout Trust November 2012
[15] Environment Agency (2017) Fisheries Officer (AD per comms)
[16] Environment Agency (2016) Catchment Data Explorer
http://environment.data.gov.uk/catchmentplanning/WaterBody/GB106039029920 Accessed 06/01/2017
[17] Environment Agency (2016) Freshwater Fish Counts for all Species, all Areas and all Years
https://ea.sharefile.com/ds5b6918d01884a129 Accessed 14/11/2016
[18] Wild Trout Trust (2012) River Ver Gorehambury Estate. An Advisory visit by the Wild Trout Trust November 2012

not recorded upstream of the restoration area). A less balanced fishery is recorded close to the confluence with the River Colne (~ 3km downstream of the study area) at Moor Mill, with brown trout becoming increasingly scarce, with only a single individual recorded. Pike are the most abundant species, followed by a small number of roach, gudgeon and perch. The abundance of pike at the site may be the result of fish escaping and/ or being released by anglers from the adjacent lake complex.

Fish population data is unavailable for Verulamium Lake located in Reach 1. As mentioned in the baseline habitat assessment below, common carp were visually recorded during sediment sampling on 14th November 2016. Previous records also note the removal of fish from the lake including a large biomass of roach[19]. With water quality in the lake highlighted as an issue, the likelihood of a diverse fish population being present is low.

Full fish population survey results are presented in Appendix I.

Baseline Habitat Assessment

The habitat review was informed by a walkover of the study area on the 14th November 2016 and through review of the hydromorphology (described in Section 3.4).

Reach 1

The hydromorphology of the reach was described in Section 3.4 above. The majority of this reach is a mill leat, with water levels held up by weir structures and with a very low gradient. This results in a reach with low hydromorphological diversity (Plate 3.26) and has contributed towards the large amounts of fine sediment deposition throughout the reach. This limits the spawning and recruitment potential for lithophilic riverine species (for example brown trout, chub and dace). Overhead cover is limited to areas of overhanging riparian tree cover and submerged root systems along the left hand bank. The right hand bank bordering the footpath between the lake and the river is made up entirely of concrete for much of the reach, providing very little marginal cover for fish. Around 10-15 chub between 15-35 cm (in length) were observed beneath overhanging tree cover on the left hand bank during the site walkover assessment (Plate 3.27). In the absence of suitable spawning sites for the species within Reach 1, chub are likely to have originated from the spawning population recorded in surveys shortly upstream at Gorehambury Mill.

A pool and traverse fish pass (Plate 3.28) is located at the downstream end of the reach with the aim of providing fish passage between the Abbey Mill and Verulamium Lake obstructions. A formal fish passage assessment of the structure was not undertaken during the site walkover assessment. The fish pass is considered to be ineffective for providing passage for the various life stages of trout and coarse fish associated with the Ver[20].

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[19] Symbio (1991) Verulamium Lake Site Survey and Analysis

[20] Per comms with Environment Agency fisheries officer, 2017

Plate 3.26. Downstream view of the over-wide, impounded River Ver shortly upstream of Abbey Mill

Plate 3.27. Adult chub spotted in Reach 1 of the River Ver. Note the heavily silted channel bed in the foreground (view from the right hand bank facing across stream)

Plate 3.28. Upstream extent of the fish pass structure in Reach 1

Plate 3.29. Downstream view (from Reach 2) of the gravel riffle feature located shortly downstream of the confluence of the Lake discharge and fish pass

Verulamium Lake

A fisheries habitat assessment of Verulamium Lake was undertaken from a boat during the site walkover. The man made nature of the lake provides little in the way of suitable habitat for fish, with the concrete bed and bankside structures limiting the growth of marginal and submerged vegetation, and therefore fish and fish food habitat. Submerged branches and overhanging tree cover on the island features appear to be the only source of cover for fish in the lake. A group of adult common carp (*Cyprinus carpio*) were observed whilst undertaking the assessment from the boat.

Reach 2

Suitable habitat for lithophilic spawning species is very much limited by the fine sediment substrate recorded throughout much of the reach. However, small areas of clean gravel potentially suitable for spawning are present where tree branches have fallen into the river and the concentrated flow of the river has scoured the bed clear of detritus.

At the most downstream end of the reach the Ver appears to have benefitted from a lack of artificial straightening and modification, possessing a relatively diverse channel form; marginal macrophytes help narrow the channel to a more naturalised width whilst also providing cover for fish and fish food organisms. The increased flow velocity associated with the narrow channel width exposes the natural gravel bed of the river, with survey team members visually noting the presence of fish. This short section of the river provides an example of the natural channel width of the Ver during the current flow conditions.

Reach 3

Once more smothering of the natural gravel bed, as a result of channel modification and fine sediment over-supply has occurred, limiting lithophilic fish spawning potential. The heavily modified channel recorded throughout Reach 3 provides very little in the way of suitable riverine fish habitat.

Reach 4

Small patches of exposed gravels are present where instream debris has accumulated, scouring the natural gravel bed free of sediment and providing fisheries habitat. Channel is over wide and heavily shaded so lacks maginal and in channel vegetation.

A small weir is located immediately upstream of the Cottonmill Lane road crossing at the downstream end of the reach. The head difference across the structure is around 0.1 m, resulting in a small downstream pool and upstream silt accumulation behind the weir structure. A full passability assessment was not undertaken, however the diminutive nature of the structure is unlikely to pose a threat to stronger swimming riverine species (for example brown trout, dace and chub), but could limit certain life stages of the less stronger swimming (for example roach, perch, bullhead and minnow). Suitable riverine fish habitat is very much limited throughout Reach 4.

Plate 3.30 Upstream view of the heavily shaded, over-wide nature of the River Ver throughout much Reach 2

Plate 3.31 Upstream view of the heavily shaded, artificial bank structure and heavily silted river bed typical of the Ver throughout Reach 3

Plate 3.32 Downstream view of the River Ver through Reach 4 illustrating the heavy accumulation of leaf litter in and around the margins of the watercourse

Plate 3.33 Upstream view of an area of the River Ver through Reach 5 possessing a suitable channel width, vegetated instream and margins, and a gravel substrate

Reach 5

Reach 5 possesses a straightened, dredged channel course as it passes between residential gardens on the left hand bank and the Sopwell Nunnery green space on the right hand bank, resulting in the lateral disconnection with the floodplain. However, unlike the study area upstream, the channel shows signs of natural morphological processes such as erosion and deposition. Clean gravel riffles, pools and berm features have formed, with the width of the river channel narrowing itself to a more natural width. The right hand bank is largely clear of mature trees, allowing light to reach the channel bed and instream macrophyte growth to flourish (water crowfoot noted) amongst the shallow riffles. As a result, these sections of the Ver in Reach 5 provide rheophilic fish species with a suitable and potentially valuable source of habitat (Plate 3.33). In contrast to the more open areas of the channel, where the banksides are heavily shaded by riparian vegetative cover, macrophytes are largely absent.

Reach 6

The effects of historic dredging practices and channel re-alignment continue into Reach 6, however as a result of increased riparian vegetative cover along the course of the left hand bank (Plate 3.34), channel shading increases and instream macrophyte growth is limited to very small areas. Consequently, the channel takes on a much more homogenous morphology, with habitat for fish scarce throughout. Much of the right hand bank riparian zone consists of heavily overgrown scrub vegetation. Substrate shifts from the clean gravel bed recorded in Reach 5, to a largely fine sand/ silt based composition in Reach 6. At the downstream extent of the reach, a large gravel riffle area is present beneath the old railway bridge, however the gravel appears heavily compacted and unsuitable for lithophilic spawning species.

Plate 3.34 Upstream view of the River Ver through Reach 6 illustrating the heavily incised, overgrown channel course

Fisheries Conclusions

Whilst the River Ver currently supports a Good WFD fishery status, this outcome is based on fish population survey data collected outside of the study area. Due to the contrasting conditions observed between the WFD classification fish population survey sites (sub-urban/agricultural) and the study area (urban), it cannot be assumed that the river through St Albans is of the same quality.

In order for a healthy, self-sustaining riverine fishery to thrive, a range of factors are required, including diverse habitat and good water quality. A diverse habitat is maintained by the dynamic riverine processes of erosion and deposition which, in turn, depend on the hydraulic and sedimentation regimes of the watercourse[21]. Many of the historic alterations made to the study area have resulted in a reduction in habitat diversity, a uniform flow regime and lack of longitudinal and latitudinal connectivity. The direct effects these issues are having on the fishery are likely to include the following:

- Limited spawning/ recruitment potential for lithophilic riverine species
- A lack of habitat for both juvenile and adult fish (for example an absence of instream and marginal macrophyte growth and riffle/ pool/glide flow regime)
- Barrier to the free movement of fish (for example longitudinal connectivity impacted by obstructions such as Abbey Mill/ Verulamium Lake in Reach 1)

However, the small pockets of suitable chalkstream-like habitat highlight the potential for effective riverine restoration practices to be implemented throughout the study area. The potential for the Ver to support a more diverse riverine fishery is supported by the findings of fish population surveys undertaken throughout the wider Ver catchment both upstream and downstream of the study.

River restoration efforts should aim to increase species diversity and abundance and enable free movement of the River Ver fish population throughout the study area and wider catchment. By addressing the issues impacting upon the natural functioning of the watercourse, the limiting factors to the fishery can be alleviated.

3.8 Heritage

A heritage desk top study including a meeting with St Albans City and District Council heritage officer were undertaken. The heritage and archaeological study provides an overview of the archaeological and historical background of the study area to better understand its historical context and the significance of any heritage assets within it. The full Heritage baseline is described in detail in Appendix J.

The study found the following:

- There are no World Heritage Sites, registered parks and gardens or registered battlefields within the study area.
- There are three scheduled monuments within the study area. These are Verulamium Roman settlement (Reach 1), St Albans Abbey (Reach 2) and the ruins of Sopwell Nunnery (Reach 5).
- All Reaches of the river covered in the assessment lie within the St Albans Conservation Area. The Conservation Area was defined and extended to encompass the Roman town, the medieval centre of the town and the 19th century residential area. The size of the area, the complexity of its history and the range of building styles and uses contributes to the character and significance of the of the Conservation Area.
- A number of historic buildings lie within the study area. Of these, 82 are statutorily designated and include six grade II* listed buildings. A single grade II* listed building belongs to the medieval period. This is Kingsbury Barn (B64), a monastic barn built in the 1390s and associated with St Albans Abbey. The remaining five are examples of housing developed outside of the historic core of St Albans during the post-medieval period. These comprise Darrowfield House (B9), Manor Garden House (B13), 13 Fishpool Street (B25), St Michaels Manor (B59) belonging to the late 16th to early 18th centuries, and Abbey Gate House constructed in the early 19th century.
- Seventy-six grade II listed buildings lie within the study area. These primarily comprise post-medieval domestic buildings, with a total of 55 houses and associated structures attesting to the gradual growth of St Albans during the period. Amenities accompanying such development include nine public houses (B2, B5, B6, B26, B44, B55, B62), and these largely focus around Fishpool Street north of the River Ver, and Michael Street, which runs approximately north-south and crosses the River Ver at St Michael's Bridge (B47). Four mills (B4, B29, B30, B53) and a forge (B73) are demonstrative of limited small scale industrial activity which took place near the River Ver during the post-medieval period, and the survival of a barn (B54) from this period attests to a continuity in the open rural character during the period (Runcie, 1977). The Ruins of Sopwell Nunnery, which date to the 17th century, supports this.

[21] Brookes A. (1988) Channelized Rivers: Perspectives for Environmental Management

Heritage assets located close to the study area, which may be considered as potential constraints to restoration, are indicated in the Constraints maps (see Section 3.10).

3.9 Landscape

Overview

A Landscape architect visited each reach of the study area on 14th November 2016. Their findings are presented below. Further to this the views of St Albans City and District Council's Landscape Architect were sought and these are also presented.

Site Visit

The following general observations were made during the site visit:

- Common tree species found along Reaches 1-6: oak, lime, willow, alder, elder, sycamore. Occasional specimens of horse chestnut, hawthorn, elm, with beech and hornbeam particularly in reaches 4-6. Wet woodland comprised where the board walk was located: willow, alder, poplar, hazel and sycamore.
- The river is typically constrained along its eastern boundary by the boundaries of adjacent properties. Generally these boundaries are weak, varying between various types of fence, or completely open to residential gardens.

Strengths and weaknesses as well as opportunities and constraints for each Reach are presented in Table 3.7 below. Key landscape views and landscape observation are illustrated in Figure 3.11.

Landscape Constraints, including Tree Preservation Orders, are indicated within the Constraints mapping of each reach and presented in Section 3.10.

Landscape Consultation

During our landscape assessment we consulted with St Albans City and District Council's landscape team, who advised the following:

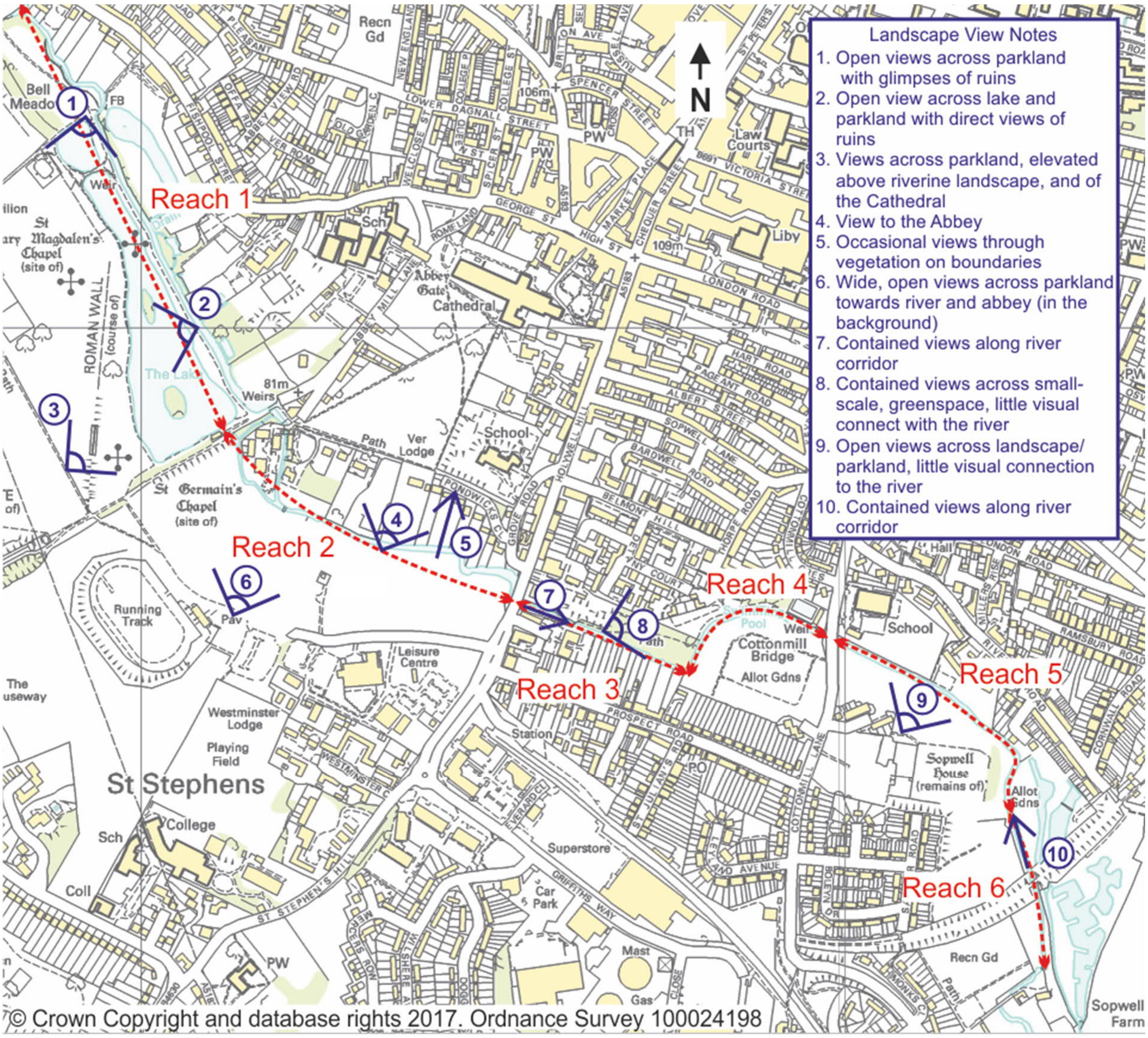
- The loss of existing mature trees is likely to be a sensitive issue. New tree planting in the Scheduled Monument area is difficult to achieve due to archaeological constraints.
- Solutions must support the continuation of the Ver/Colne walk, existing access routes and links to the wider access network.
- Regular public events are held in Verulamium Park and Westminster Lodge. Any impact on/adaptation required in the events programme needs to be considered.
- The Landscape and Trees team wholeheartedly support the restoration of the Ver chalk stream through the city. The issues surrounding the river and lakes, including construction method/detail, age, wildfowl population, pollution, flow of water/lack of, accumulated silt, visitor and resident expectations, constraints etc. may require some major changes to the local environment and could be very unpopular with the public.
- Verulamium Park draws visitors from within and outside St Albans and is extremely popular all the year round with all ages, particularly as it links the Cathedral grounds, the Roman town, Verulamium Museum, St Michaels village and Westminster Lodge. The needs and aspirations of the community must be taken into account as their support will be vital for the project to be a success.
- The paths around the lakes are important for the functioning and visitor enjoyment of the whole park as this is the main circular surfaced route. The path between the river channel and the lake is elevated which enhances views and the perception of the landscape the visitor is travelling through. The path to the west of the lake could function better as part of a circular route with improvements.
- The lakes are a popular visitor attraction and a major landscape feature not found elsewhere in the area. It is considered that a reduction in open water over 30% would diminish the lakes as a landscape feature and adversely affect the local landscape character, the setting of the Cathedral and Scheduled Ancient Monument. A 20-30% reduction in open water might be made to work without detrimental effects if accompanied by other beneficial treatments.
- There is likely to be objection from the public if the small lake is removed, but improvements here are considered to be desperately needed.

Table 3.7 Landscape Strengths, Weaknesses, Opportunities and Constraints for each Reach

Reach	Strengths	Weaknesses	Opportunities	Constraints
1	• Both standing and running water is a key feature of the park, the Site of the Roman city of Verulamium, a Scheduled Monument • Lake is key characteristic of open parkland with mature scattered trees • Verulamium Lake is a historic feature, originally a man-made fish pond dating back to Saxon times, which has been substantially altered over time, and now forms a substantial feature within the park at the valley bottom • Footpath between the lake and river provides unique recreational experience through the park • Trees and vegetation on the narrow eastern bank of the river provide visual screening between the park and adjacent residential properties • Open views of roman wall remains and across open parkland	• Degraded and failed hard edges to both the lake and river are unattractive and limit habitat and recreation potential and overall amenity value • Trees and vegetation along the eastern bank of the river forming the park boundary is limited and there is very little space to improve vegetation structure • Trees and vegetation along the eastern bank of the river are likely to contribute to fish habitat and structure of river bank	• Remove river channel retaining walls and grade out to naturalise and soften existing edges and create planting areas to increase habitat diversity and visual interest • Remove lake retaining walls to naturalise and soften existing edges (these would need to be suitably managed with access restricted to prevent damage). Create wetland and marginal planting areas in locations that are waterlogged along the lake edge to increase habitat diversity and visual interest. • Realign existing footpath between lake and river to provide different experience and journey through the naturalised water edges. Path widths would need to match the existing to accommodate the same level of usage. • Measures to restrict damage to marginal vegetation by controlling wildfowl. • Increase area of land along eastern boundary of existing	• Trees and vegetation along the eastern bank of the river forming the park boundary may limit options proposals, very thin strip of vegetation is sensitive and there is evidence that tree roots are vital habitat for fish • Large mature trees located between the river and the lake are a key characteristic along the eastern side of the park. These provide benefits along the river corridor and this would need to be balanced with any restoration. • Effects on setting of and views from Scheduled Monuments
2	• Large-scale open parkland • Views from park towards the Cathedral through vegetation in gardens of houses on Pondwick Close • Habitat variety and structure added to park in scrub, shrub and rough grass margins and wood piles • Open views across open parkland with groups of trees and shrubs creating visual interest	• Established vegetation and trees are lacking maintenance reducing visual connectivity to the river from rest of park to west • Majority of this part of the park is amenity grassland therefore providing limited habitat and recreation opportunities • Footpath along river is unmade reducing access and recreation opportunities • Area of shrubs and scrub along southern boundary of river are large limiting access to and visual connectivity with river from the rest of the park • Open views to car park and large-scale leisure centre on Mud Lane, development is intrusive to park	• Realignment of the river to its historic route would allow for the creation of substantial areas wetland habitat and increase recreation opportunities • Footpath along river corridor could be surfaced to improve access if the channel remains in existing position • Visual connection to the river could be re-established through coppicing of large shrubs and maintenance of scrubs areas along with the creation of informal paths to improve access • Increased habitat, amenity and visual characteristics of the grass areas by introducing species rich areas of grassland suitable for chalk soils • Reduce dominance of leisure centre and car park through tree planting (this could encourage buy-in from local residents for the proposed scheme)	• Trees and vegetation along the northern bank of the river forming the park boundary may limit options proposals, very thin strip of vegetation is sensitive and there is evidence that tree roots are vital habitat for fish • Direct private access into park from residential gardens over river • Effects on setting of and views from Scheduled Monuments
3	• Small-scale park area east of footbridge has variety of large, mature parkland trees and shrubs • Well connected to river • Views across park to river from adjacent residential properties (Detany Court and Prospect Road) result in park being enclosed but overlooked (passive surveillance)	• Entrance from Holywell Hill is narrow and uninviting • Narrow, enclosed footpath adjacent to river from Hollywell Hill to footbridge • Footpath appears to be unmade • Level of tree cover creates dark area beside river and increases sense of enclosure • Hard concrete edge to river channel • Boundaries of the park adjacent to residential properties are poor quality • Large shrubs are encroaching on the footpath west of the footbridge • Footbridge has stepped access and is very utilitarian in appearance • Fencing on eastern side of footbridge is ad-hoc and unattractive • Woodland and shrubs appear to be largely unmaintained and are dominated by ivy	• Improve, soften and naturalise river edge • Increase light levels by thinning/ pruning trees and large shrubs on river bank to make path more inviting and increase safety • Increase openness and accessibility adjacent to footpaths by coppicing/ pruning large shrubs • Improve footpath and accessibility by widening and surfacing • Improve accessibility by regrading footpath and providing new bridge to all for access for all • Improve maintenance of vegetation to remove ivy and coppice large shrubs and increase visual connectivity to river	• Large mature trees located along the reach and are a key characteristic. These provide benefits along the river corridor and this would need to be balanced with any restoration. • Views across park to river from adjacent residential properties (Detany Court and Prospect Road) may result in resident opposition to any changes • Footbridge has stepped access

Reach	Strengths	Weaknesses	Opportunities	Constraints
4	• Large mature trees line the footpath adjacent the river and create a unique character • Open grassy area adjacent to the residential gardens and large mature trees allows views from houses and connection to river • Boundary with residential gardens is formed of a hedgerow, allowing views towards park and river. The area to the south of the former swimming baths was planted and opened as a pocket park	• Head wall and fencing is unattractive and forms barrier between park, footpath and river • Fencing surrounding the side of the swimming pool is dominating and unattractive • River bank vegetation is limited and bank steep • Boundaries to properties on Cottonmill Crescent and rear of swimming pool are unattractive with barbed wire fence attached to wall • Vegetation to rear of swimming pool appears largely unmaintained • Steep riverbank adjacent to headwall and swimming pool, combined with scrub and shrubs along the bank limit visual connectivity to the river and reduce visual amenity • Substation to side of swimming pool surrounded by fencing adjacent to the footpath is unattractive • Stepped access to footpath from Cottonmill Lane currently obscured	• Improve appearance of head wall and associated fencing • Improve river bank and provide areas of planting • Manage scrub and coppice where possible to improve connectivity with river • Improve allotment boundary • Mark gateway/ improve entrance to river trail/ footpath from Cottonmill Lane	• Allotment provision is likely to be set out in the local plan and may therefore need to be relocated elsewhere if proposal to re-route through allotment site is taken forward • Any changes to the boundary with the allotments could be opposed • Large mature trees located along the reach and are a key characteristic. These provide benefits along the river corridor and this would need to be balanced with any restoration. • Substation to side of swimming pool surrounded by fencing constrains footpath width and access
5	• Attractive open parkland with individual parkland trees and groups of trees and shrubs • Direct views from houses over parkland provide passive surveillance of park • Boardwalk provides diverse walking experience and connectivity to nature and different habitat	• Residents may oppose changes to established green space where they have direct views over the park • Large part of both sides of the river are obscured and shaded by shrubs, trees and scrub limiting visual connectivity to the river • Steep river bank limiting influence and connectivity with water • Vegetation along river bank would be suitable for coppicing and would improve access, visual connectivity and amenity • Vegetation alongside boardwalk appears largely unmanaged	• Vegetation alongside boardwalk would benefit from maintenance (coppice/pollard/ remove ivy) and improve views out across wet woodland	• Effects of proposals on views from and setting of Sopwell Nunnery Scheduled Monument • Large mature trees located along the reach and are a key characteristic. These provide benefits along the river corridor and this would need to be balanced with any restoration.
6	• Area of mixed habitat/ vegetation across green space with large-scale open grassland provides for a variety of uses and experiences • Close proximity and connection to river • Well vegetated river banks with trees, scrub and rough grassland provide visual interest and habitat diversity	• Very steep river bank in close proximity to footpath • Varying quality boundary to allotments • Ad-hoc fencing panels to prevent dog access is unattractive and poor quality • Well vegetated river banks with trees and scrub in some places are dense and limit visual and physical connectivity with the river	• Improve boundary to allotments • Remove chestnut pale fencing between footpath and river • Improve vegetation structure along river banks, coppice where required	• Large mature trees located along the reach and are a key characteristic. These provide benefits along the river corridor and this would need to be balanced with any restoration.

Figure 3.11 Key Views and Landscape Observations through the Study Area



3.10 Constraints

3.10.1 Overview

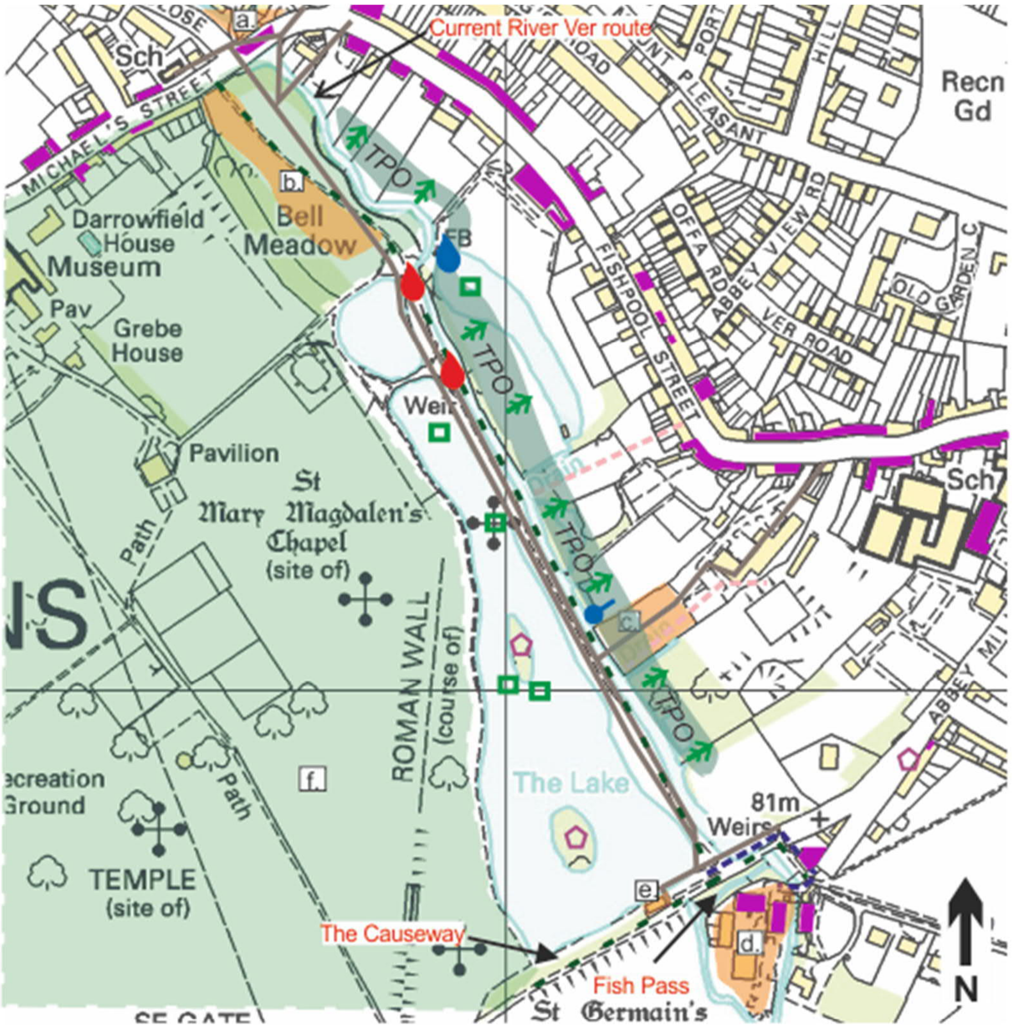
Constraints for each of the disciplines described above have been compiled and mapped. These are presented in this section. The constraints that have been mapped include:

- Environmental designations, including sites of national (for example Site of Special Scientific Interest) and local significance (for example Local Wildlife Sites)
- public rights of way
- archaeological heritage including recorded features and Scheduled Monuments
- former and present land uses with the potential to act as a constraint on the option/s
- orders relating to planning, including Tree Preservation Orders, Conservation Areas and Listed Buildings
- environmental permits, including water abstractions and discharges
- pollution events logged on the Environment Agency's National Incident Reporting System

In addition service information was provided by the Environment Agency and through liaison with service providers, such as Affinity Water, Thames Water, UK Power Networks, BT Openreach and National Grid. This information is also presented within the constraints maps.

3.10.2 Constraints Maps

The constraints maps are presented through Figures 3.12 (Reach 1) to Figures 3.17 (Reach 6).



Legend

- Water Mains Pipeline (BG) - Affinity Water
- Foul Sewer Pipeline (BG) - Thames Water
- Surface Sewer Pipeline (BG) - Thames Water
- Hertfordshire Rights of Way
- Archaeological/ Heritage - Feature
- Archaeological/ Heritage - Notable extent of Scheduled Monument
- Local Wildlife Site - Non-Statutory
- Land Use - Past & present extent of notable land use (See code a-f)
- Abstraction - St Michael's Manor Hotel
- Abstraction Transfer - Between Sources
- Consented Discharge - 'The Maltings'
- Tree Preservation Order (TPO) - Area of TPO's
- Listed Building

Geoenvironmental Risk

Land Use Description

a. Former mill
b. Former allotments
c. Former timber yard
d. Former mill & elec. sub-station
e. Present site of public lavatory
f. Present site of rec land and former agriculture

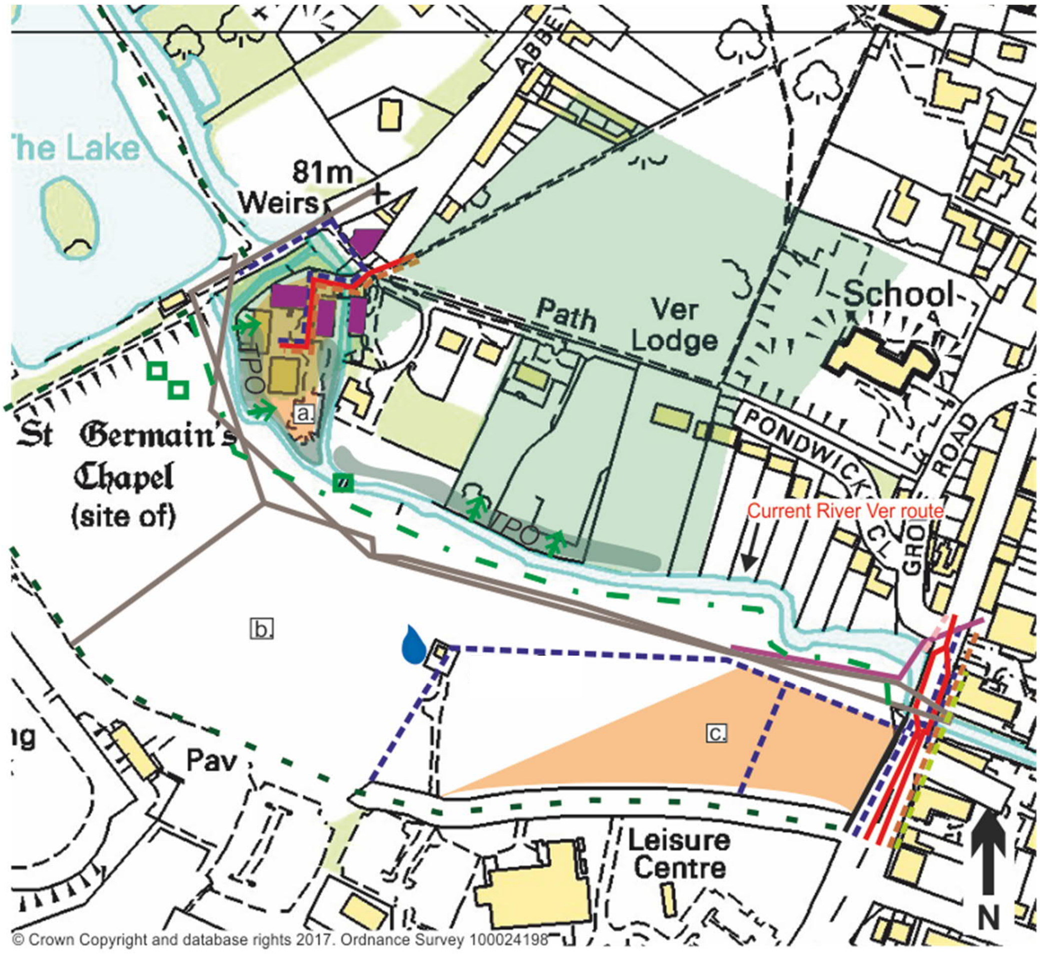
Pollution Incidents

Two pollution incidents (category 3 and uncategorised) recorded in the reach.

(BG) - Below Ground

Note: The entire of Reach 1 falls within Conservation Area No 11 (St Albans)

Figure 3.12 Reach 1 Constraints Map



Legend

- Water Mains Pipeline (BG) - Affinity Water
- Foul Sewer Pipeline (BG) - Thames Water
- Surface Sewer Pipeline (BG) - Thames Water
- Electricity (BG) - Private Cable of Unknown Status
- Gas Mains Pipeline (LP) - National Grid
- Telecom Line (BG) - BT Openreach
- Telecom Line (BG) - Virgin Media
- Hertfordshire Rights of Way
- Ver Valley Trail
- Abstraction - Mud Lane Pumping Station - Affinity Water
- Archaeological/ Heritage - Feature
- Archaeological/ Heritage - Notable extent of Scheduled Monument
- Local Wildlife Site - Non-Statutory
- Land Use - Past & present extent of notable land use (See codes a-c)
- Tree Preservation Order (TPO) - Area of TPO's
- Listed Building

(BG) - Below Ground

(LP) - Low Pressure

(LV) - Low Voltage

Geoenvironmental Risk

Land Use Description

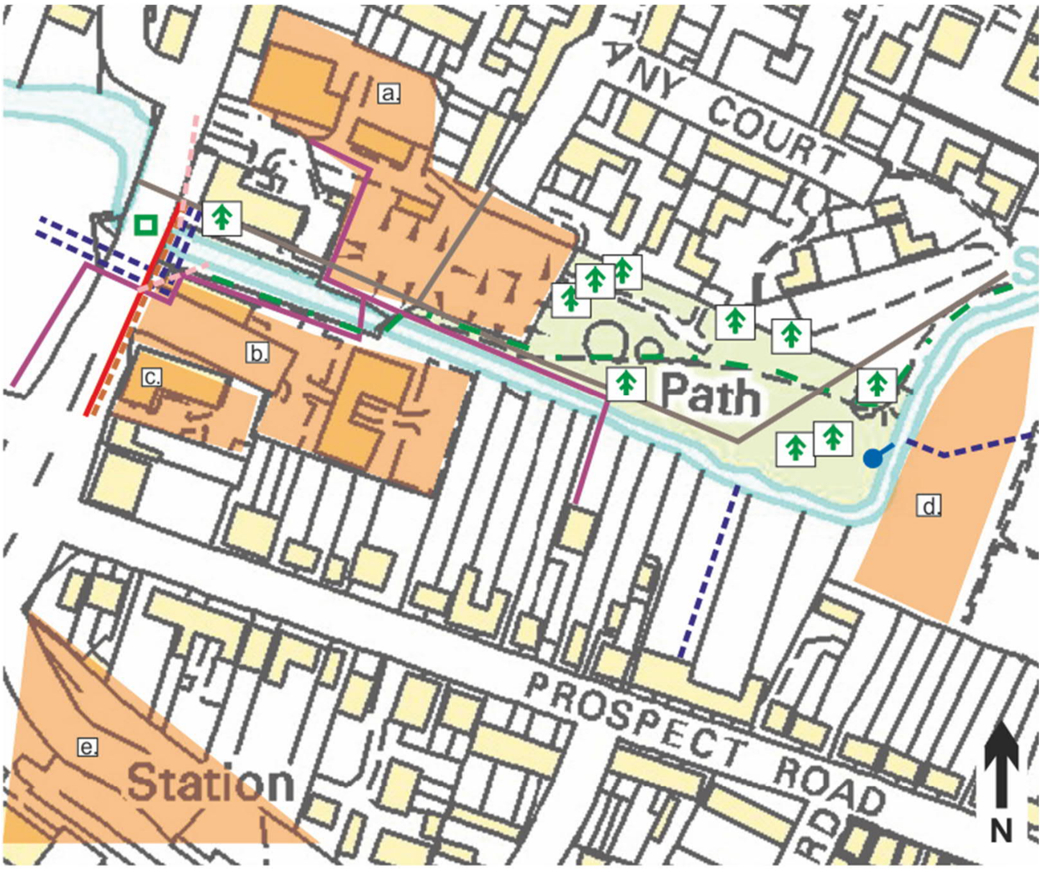
a. Former mill & elec. sub-station
b. Former agriculture
c. Former allotments

Pollution Incidents

Nineteen pollution incidents (category 3/4 - minor/ no reported impact) recorded in the reach, with the majority recorded immediately upstream of Holywell Hill road crossing

Note: The entire of Reach 2 falls within Conservation Area No 11 (St Albans)

Figure 3.13 Reach 2 Constraints Map



Legend

- Water Mains Pipeline (BG) - Affinity Water
- Foul Sewer Pipeline (BG) - Thames Water
- Surface Sewer Pipeline (BG) - Thames Water
- Electricity - Secondary Distrib. Cable (LV) (BG) - UK Power Networks
- Gas Mains Pipeline (LP) - National Grid
- Telecom Line (BG) - BT Openreach
- Archaeological/ Heritage - Feature
- Land Use - Past & present extent of notable land use (See code a-e)
- Ver Valley Trail
- Discharge - Holywell & Mud Lane Pumping Station - Affinity Water
- Tree Preservation Order Listed Tree
- Consented Discharge
- Listed Building

Geoenvironmental Risk

Land Use Description

a. Former water works
b. Former unspecified works
c. Former petrol station
d. Former allotments
e. St Albans Abbey Railway Station

Pollution Incidents

Three pollution incidents (uncategorised) recorded in the reach

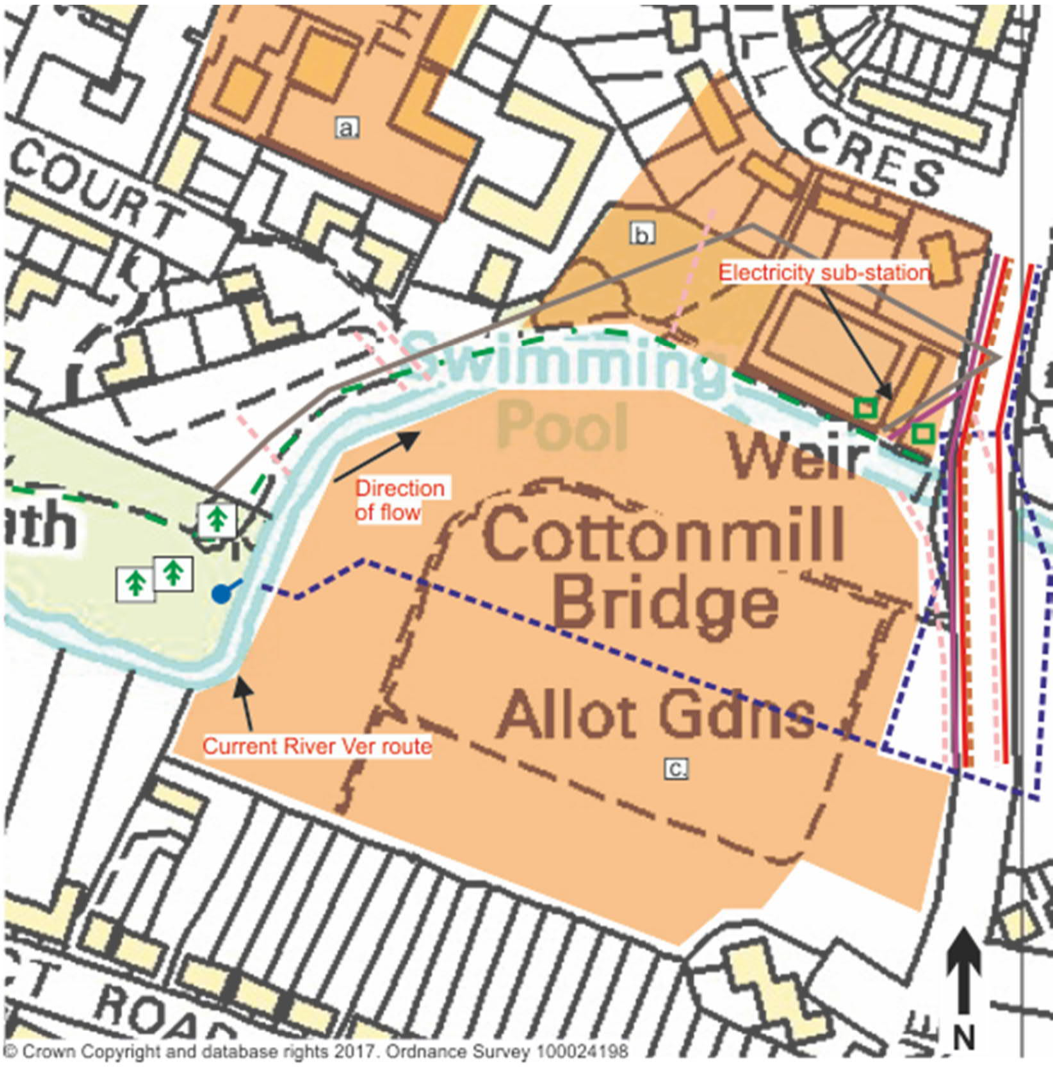
(BG) - Below Ground

(LP) - Low Pressure

(LV) - Low Voltage

Note: The entire of Reach 3 falls within Conservation Area No 11 (St Albans)

Figure 3.14 Reach 3 Constraints Map



Legend

- Water Mains Pipeline (BG) - Affinity Water
- Foul Sewer Pipeline (BG) - Thames Water
- Surface Sewer Pipeline (BG) - Thames Water
- Electricity (BG) (LV & HV) - UK Power Networks
- Gas Mains Pipeline (LP) - National Grid
- Telecom Line (BG) - BT Openreach
- Archaeological/ Heritage - Feature
- Land Use - Past & present extent of notable land use (See codes a-c)
- Ver Valley Trail
- Tree Preservation Order Listed Tree
- Consented Discharge

Geoenvironmental Risk

Land Use Description

a. Former unspecified works
b. Former allotments
c. Present allotments site

Pollution Incidents

One pollution incident recorded in the reach (uncategorised).

(BG) - Below Ground
(LP) - Low Pressure
(LV) - Low Voltage
(HV) - High Voltage

Note: The entire of Reach 4 falls within Conservation Area No 11 (St Albans). There are no listed buildings in this reach.

Figure 3.15 Reach 4 Constraints Map

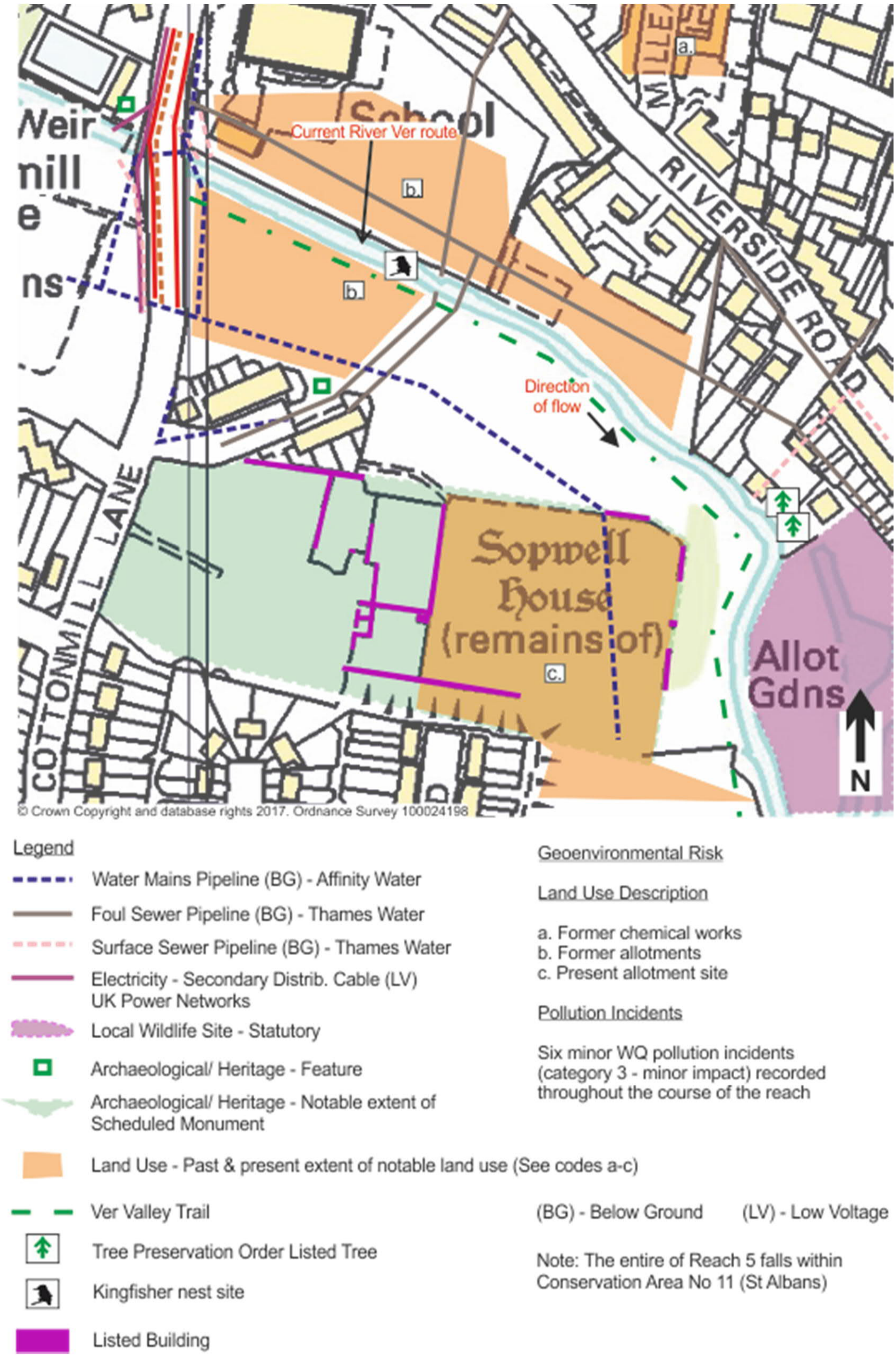


Figure 3.16 Reach 5 Constraints Map

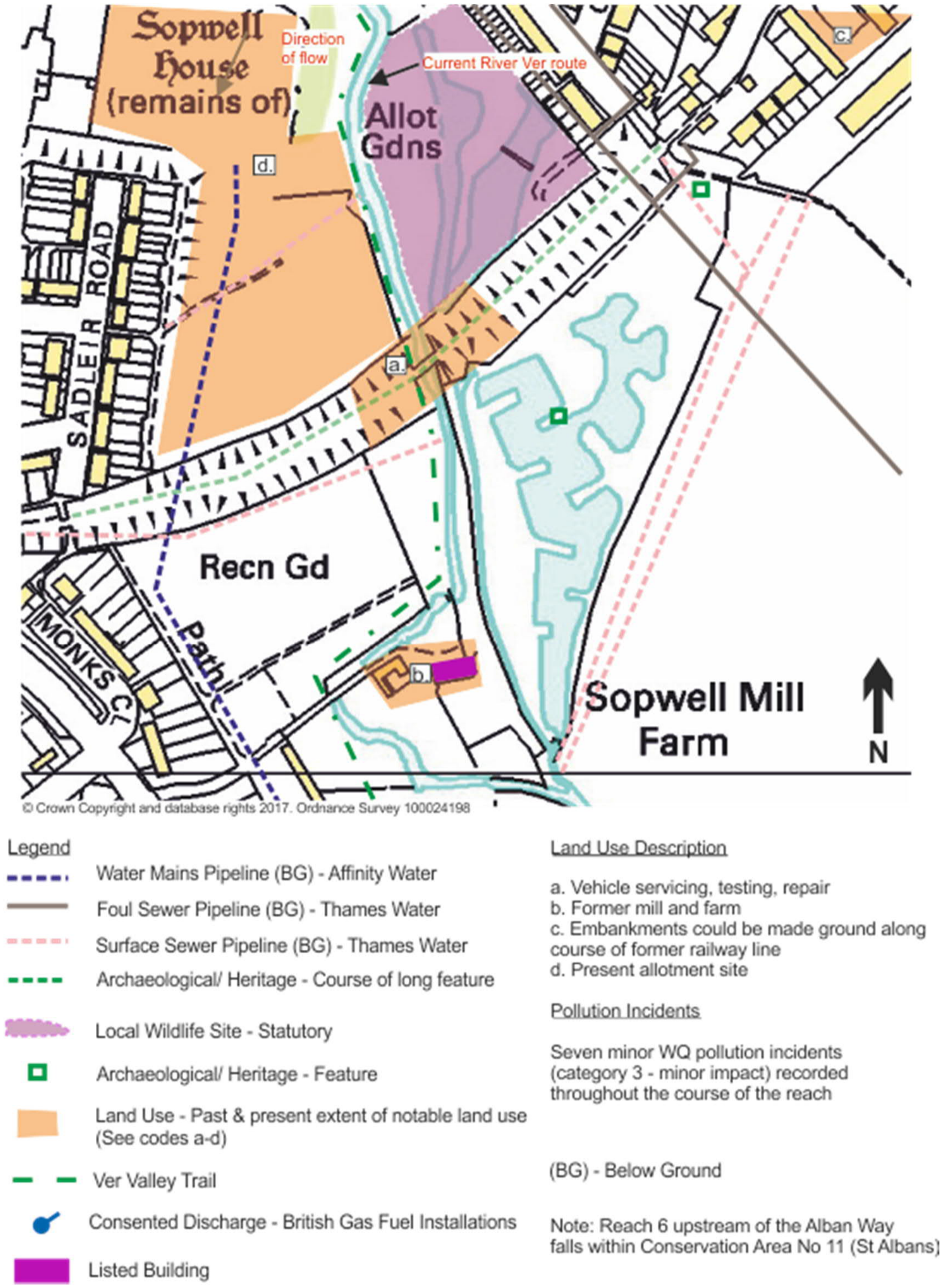


Figure 3.17 Reach 6 Constraints Map

THE PREFERRED OPTION FOR REACH 1

04

4. The Preferred Option for Reach 1

4.1 Overview

Reach 1 covers the River Ver from St Michael's Street through the upper section of Verulamium Park down to the Causeway and also includes the ornamental lakes (see Figure 4.1).

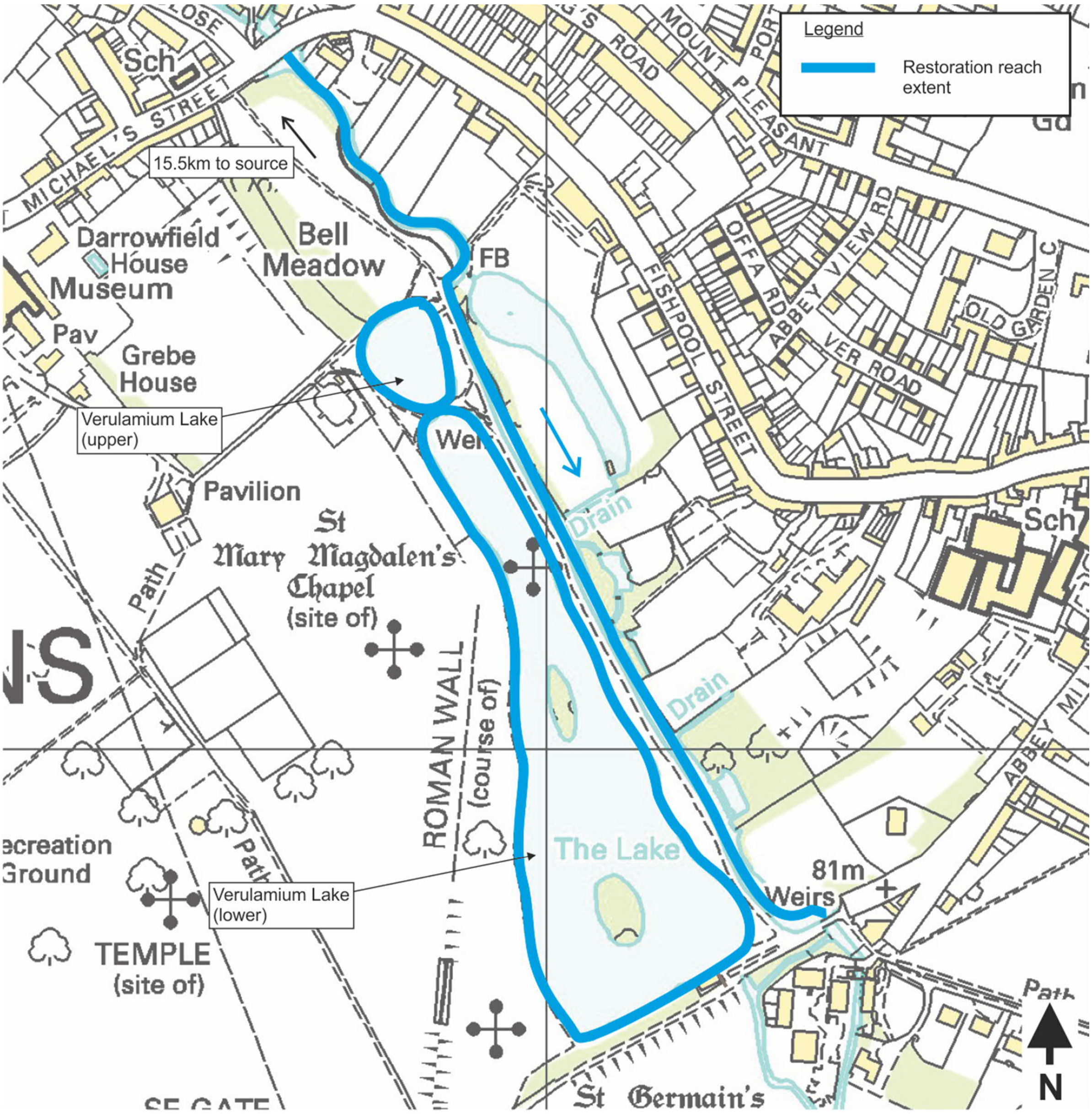


Figure 4.1 Reach 1 of the study area (Upper section of Verulamium Park including the lakes)

Verulamium Park is hugely popular with residents and visitors. However, the artificial lakes that are a central feature of the park have suffered badly in recent years from high profile water quality issues. The River Ver, which flows through the park, has played an important role in the history of St Albans, but has been significantly changed from the natural chalk stream it once was. As a result, the river no longer has many of the iconic chalk stream features and the varied and abundant wildlife it should support.

Our proposed plans offer a solution to the issues in Reach 1 and include a range of features to improve the river, lake and park for both people and wildlife.

4.2 Issues in Reach 1

4.2.1 Issues with the River Ver

The River Ver through Reach 1 is in a particularly bad condition. It has lost all its chalk stream characteristics through historic alterations. The issues which affect the river in Reach 1 are:

- Perched channel – the river was moved northward out of the valley bottom to a higher elevation to form the mill leat and provide the head drop required to power the mill.
- Weirs – the mill weir still exists, severely reducing the natural bed gradient and impounding flow throughout this reach, as well as preventing fish passage.
- Over-wide and straight – again, as a result of the milling industry, the river was widened and straightened slowing flows and removing natural channel variation.
- Low flows – due to abstraction pressure and many different flow splits (for example to the main lakes, other online lakes to the north, to feed the ineffective fish pass, and to flow over the mill weir) the flow in the river is often very low.
- Silty – because of the above factors, in particular slow flows, the natural gravel river bed is smothered in silt.
- Heavy shading – the overhanging trees block light to the river, which restricts plant growth.
- Disconnected from the floodplain – the natural valley bottom is to the south of the river where the lakes are.
- Concrete banks – the south bank of the river is concrete which prevents marginal plant growth.

Restoration in this design should account for each of these issues and result in the project objectives being achieved. Further information on the river issues is provided in Appendix A.

4.2.2 Issues with the lakes

The lakes in Verulamium Park were constructed between 1929 and 1932 partly to give much needed work to unemployed people during the depression. The lakes were lined with hand poured concrete and are no more than around one metre deep.

Plate 4.1 – shows the concrete base of the lake under construction

The lakes are a completely artificial feature and as a result they suffer from a variety of issues and require substantial maintenance. However, they are a much-loved feature of the park with huge potential to be improved both for people and wildlife.

The problems with the lake arise from several factors which we explain in Table 4.1 below. Some of these are illustrated in Plates 4.1 to 4.4.

Table 4.1 Description of Issues with the existing lakes

Issue	Description	Why is this a problem?
Low through-flow of water	The lakes are fed by the River Ver via a sluice gate into the northern boating lake. The volume of the lakes is very large in comparison to the amount of flow they receive from the River Ver. The river itself suffers from low flows and often doesn't have water to spare for the lakes. When the river level is too low, no water enters the lake.	Low inflow from the River Ver means it takes a long time for water to be flushed through the lake. This exacerbates water quality issues as there is often little freshening of the lake water.
Large and shallow	The lakes are large, but very shallow with an even depth. This means that they have a high surface area to volume ratio making them more susceptible to progressive warming throughout the summer and dramatic water temperature changes.	This can create conditions which contribute to algal blooms and oxygen crashes (as planktonic biomass is decomposed). These are bad for wildlife and water quality.
Excessive nutrients - eutrophication	The lake water is nutrient enriched. Causes include wildfowl waste, uneaten rotting food fed to the birds, leaf litter input, decaying algal matter (especially following algal blooms), waste and stirring up of sediments by bottom feeding fish, and the release of nutrients stored in sediments under certain conditions.	Nutrient enriched conditions cause poor water quality which can lead to algal blooms and low oxygen levels. These are bad for wildlife and algal blooms can also be unsightly.

Issue	Description	Why is this a problem?
Algal blooms	An algal bloom is a rapid growth of algae in the water which often results in a surface scum or murky water conditions. The size and shallow nature of the lake causes the water temperature to rise dramatically in hot weather. Combined with the nutrient-rich water and lack of flow throughput this creates conditions for blooms to occur, especially in the summer when weather conditions are calm and water levels often at their lowest.	The decay of algal matter uses up the oxygen in the water, which can impact wildlife. The decaying matter also exacerbates the eutrophication issue and contributes to the sediment in the lakes when the algal bloom dies back.
Wild fowl	People like to feed the birds on the lakes, but this encourages an excessively high population of wild fowl – particularly Canada geese. These wildfowl contribute a high organic load to the lake through their waste, but the uneaten food also rots in the water adding to the high nutrient load in the lakes.	As organic matter is decomposed it uses up the oxygen in the lake which can impact other aquatic life.
Avian botulism	Avian botulism outbreaks are caused by toxins released during the growth of the C. botulinum bacterium. This bacterium is naturally occurring but may multiply under certain conditions. This includes warm temperatures, an anaerobic (no oxygen) environment (such as in lake sediments), and in the presence of a protein source.	This is a serious bacterial disease that kills birds. There have been several suspected cases in recent years in the lakes.
Lack of plants in the lake and around the lake margins	The lack of plants is due to several factors: • Plants can't root into the concrete bed • Sheer concrete banks don't allow natural marginal plants to grow • Any young plants that do manage to grow are eaten by grazing wildfowl and fish so it's difficult for them to establish • High suspended sediment and low oxygen conditions restrict aquatic plant growth • Enriched nutrient conditions encourage a phytoplankton dominated ecosystem	Aquatic and marginal plants help to manage nutrients in lake water and sediment. Plants also help regulate water temperature, water clarity, and submerged plants are important for generating oxygen during the day by photosynthesis. A lack of plants also means that there is very little habitat to support diverse lake wildlife.
Concrete lining and banks	The concrete lining and banks of the lakes restrict the establishment of plants that would help to balance the levels of nutrients in the water.	Plants cannot establish and the benefits of having a plant rich lake are not available.
Silt / sediment	More organic material enters the lakes than can be processed naturally. This builds up as silt on the lake bed. It is nutrient rich and adds to the issue of eutrophication (excessive nutrients) The organic matter that forms silt comes from amongst others, wildfowl and fish waste, rotting uneaten food, leaf litter and decaying algal matter. Some sediment also comes from the Ver inflow.	When the water level is low sediment protrudes above the surface. This represents a hazard to wildlife, people and dogs that walk onto it. The silt itself is not hazardous, but it is unsightly and can be very smelly in warm weather. The build-up of silt creates even shallower conditions in an already shallow lake environment. This reduces water quality and makes the lakes warm up faster in hot weather.
Bottom-feeding fish	The fish in the lake are predominantly non-native species such as carp. These are bottom-feeding fish which stir up sediments at the bottom of the lake creating cloudy water conditions as they cause the silt to be re-suspended in the lake water.	Turbid, or cloudy, water restricts light penetration which means that aquatic plants struggle to grow. Re-suspension of silt and its associated nutrients contributes to the eutrophication issues mentioned earlier.

Plate 4.1 (top left) Concrete lake bed at the margins of the upper lake; Plate 4.2 (top right) Exposed sediment downstream of the weir between the upper and lower lake; Plate 4.3 (bottom left) Exposed sediment at the southwestern corner of the lower lake; Plate 4.4 (bottom right) Algal accumulations on the surface of the lower lake

Figure 4.2 presents a visual summary of the issues within Reach 1.

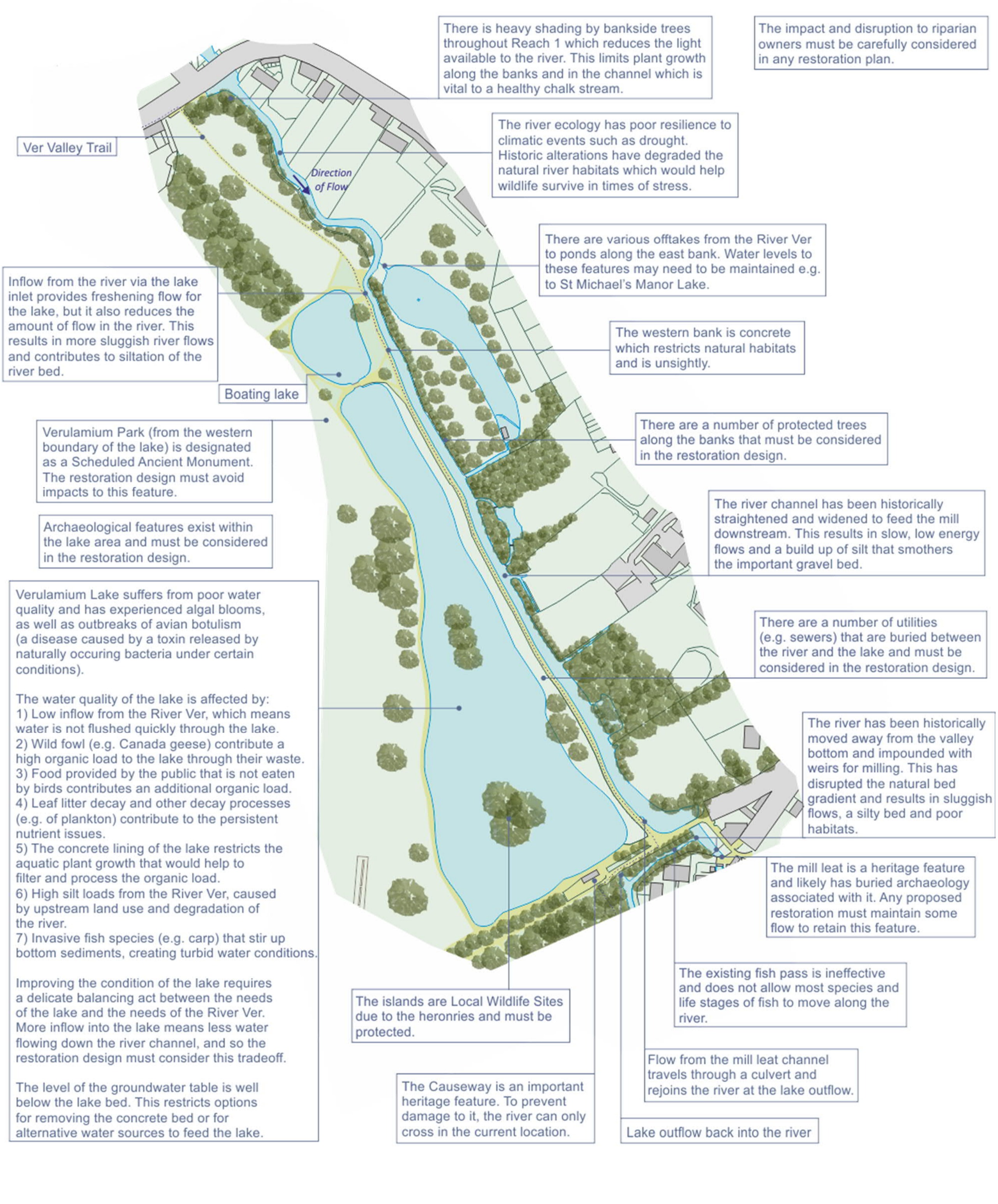


Figure 4.2 Reach 1 Issues and Constraints Overview

4.3 Derivation of the Preferred Option for Reach 1

4.3.1 Long Listing and Short-listing Appraisal

Full results of the long listing and short-listing appraisal of Reach 1 options is included within Appendix K. The appraisals considered the issues indicated in Section 4.2 and constraints identified in Section 3.10.

For this reach there was an initial 'long list' of 14 different options to improve the river. In addition, a long list of 16 lake improvement options were considered. These long lists of options were carefully considered and a short list of four river options and seven lake options were taken forward.

River Options

Following the long list appraisal of the initial 16 river options, four were shortlisted. These were:

- Option 5 Small re-alignment of the River Ver at the downstream end of the reach, through an infilled section of the lower end of the large lake. Upstream bed regrading and in-channel enhancements.
- Option 7 Full re-alignment of the channel through the west of the lakes with a new connection to Reach 2 further west through the Causeway.
- Option 8 Full re-alignment of the channel in between the lakes and the current channel.
- Option 14 Maintain current channels, re-design fish pass and lower weir.

Each of these was examined as part of the detailed shortlist appraisal.

The decision we reached was to take forward aspects of options 7 and 8 to form a proposed 'hybrid 'option. The hybrid option offers the greatest environmental outcome for the river, and resolves some of the potential issues presented by each of the separate options.

Lake Options

In addition, at the start of the project we developed 16 potential lake improvement options. Following consideration of each of these we decided to take forward the following combination of measures:

- Removal/ dredging of all sediments within the lake and reusing the material (likely after drying) in the creation of marginal planting areas, island enlargement and partial infilling.
- Partial infilling/narrowing to create space for the new river channel and to create marginal planting areas and larger islands.
- Wetland creation/planting on the banks of the lake, as well as plants that root on the bed, and floating plants.
- Removing carp from the lakes and introducing a more controlled mix of species to include predator species such as rudd and perch.
- Slightly increasing flows from the River Ver into the lake, whilst ensuring the Ver is not adversely affected.
- Island enlargement.

Each of these can be undertaken along with the proposed hybrid river option.

4.4 The Preferred Option for Reach 1

4.4.1 Option description

The Reach 1 preferred option/ outline proposals, prior to engagement, are summarised in Figure 4.3.

The combination of measures we are proposing will significantly help to address the issues with the lakes, transform the river and improve the park for St Albans residents and visitors.

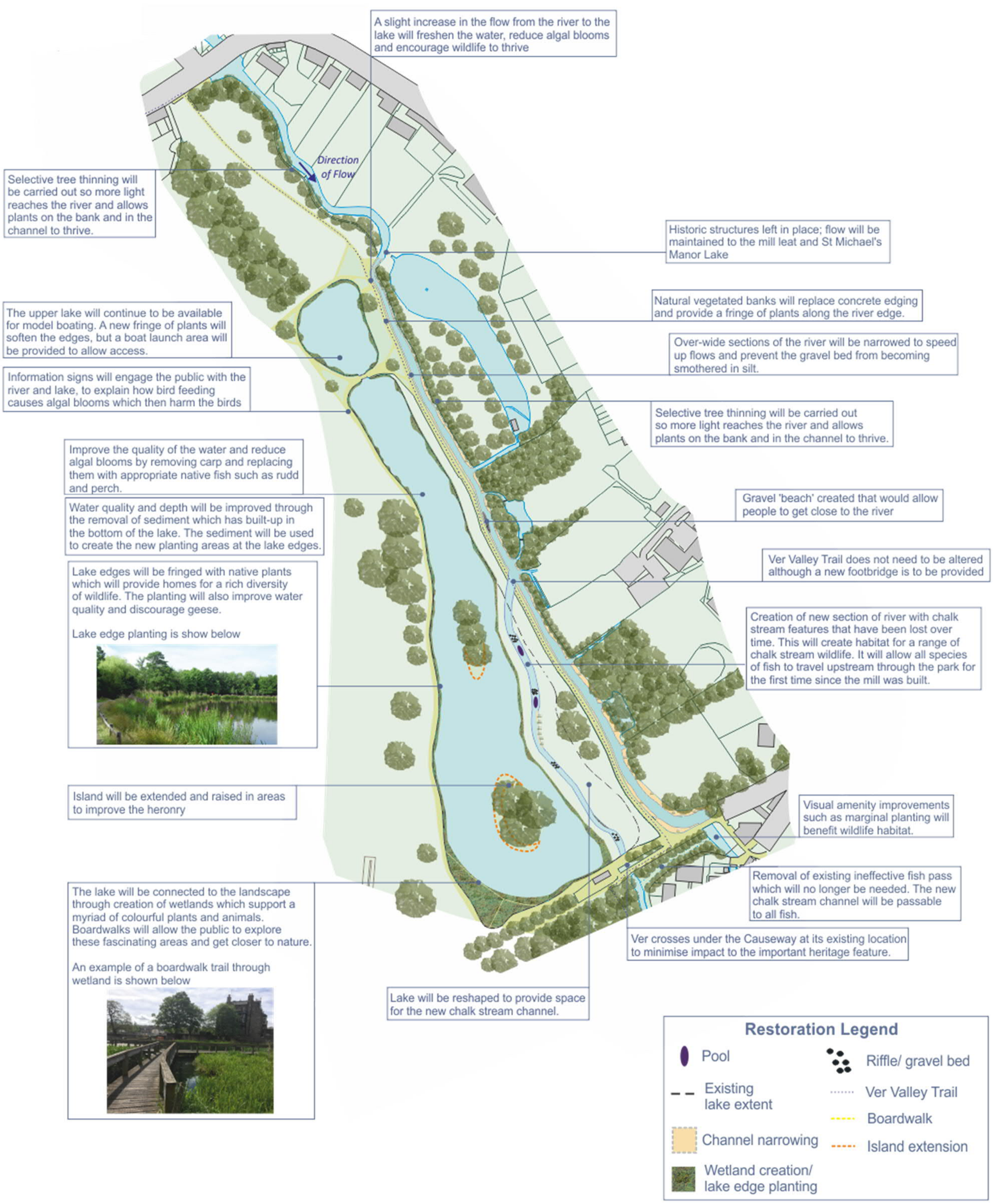


Figure 4.3 Reach 1 Preferred Option/ Outline Proposals (prior to engagement)

The concrete lined, slow, silty river will be transformed to a beautiful, meandering chalk stream, able to support a wide variety of wildlife; a new river channel will be created alongside the lake; wetland habitats teeming with wildlife will be accessible by boardwalks; marginal plants will improve the look of the lakes and improve the water quality.

The proposed hybrid option keeps the upper part of the river on its existing course, but with in-channel feature improvement works. It then moves the lower part of the river through the south eastern corner of the larger lake and Causeway, bypassing the ineffective fish pass and weirs. It also enables flow to be maintained in the mill leat channel by the Abbey Mill, as well as inflow to the lake. This option would be undertaken together with the proposed lake improvement options detailed below.

The following outlines the rationale for the features that were included within the outline design (shown in Figure 4.3).

Reach 1 is a low to moderate gradient reach with low sinuosity, the gradient is steep enough to support functional riffles and gravel bars but sediment supply is too low to allow these to develop naturally. The likely sequence would be plane bed-riffle, however diversity can be enhanced by constructing pools. Riparian connectivity is poor and can be enhanced using in-channel berm areas. Floodplain enhancement is restricted as much of it is occupied by the lake.

New habitats would include:

- Riffles; placed approximately 6 channel widths apart along this very low sinuosity reach to increase and improve area of open gravel.
- Pools; These will form behind riffles as these features impound water upstream, however depths have been further increased to enhance shear stress levels during higher flows to keep these units flushed.
- Moderate energy runs; these are hydraulic habitats formed in transition zones between pools and riffles
- Lower energy shallow glides; these hydraulic habitats are already common on the watercourse and will remain so due to the low energy nature of the system.
- Slowly eroding vertical banks; the creation of a slightly increased sinuosity to the planform will act to concentrate flood flows into the outer banks increasing the possibility of channel erosion. The cohesive nature of the banks, vegetation and the overall low energy flow environment will mean that erosion and channel movement will only be slow and well within natural rates of migration for this channel type. Slow rates of erosion must be anticipated and accepted.
- Gravel bars; introduced gravel will supplement the system which is currently quite starved of new coarse sediment due to very low input and transport rates. These features must be designed with a high proportion of immobile material to ensure that they are not washed out in floods.
- In-channel berms; poor floodplain connectivity has reduced the area of frequently wetted margin along the river, reintroducing fine sediment berms will increase connectivity and create lost habitat. They will act to trap silt and will maintain a wetland plant community.
- Loose gravel bed; seeding of gravel along the entire reach will further supplement low gravel supplies to the system, there is a likelihood that these sediments will become choked with fines unless catchment diffuse inputs are moderated.
- Bankside trees and shrubs; riparian diversity is lacking and planting will enhance both species composition and mimicking succession and seral stage development.
- Floodplain wetland and wet woodland; the floodplain through this reach is severely degraded with no near natural vegetation communities, these should be planted where possible.
- Silted lower energy areas; these units are valuable in terms of low energy soft sediment habitat and will form wherever shear stresses are low across the flow regime. They do not require introduction.

The lakes will remain an artificial feature; as such they will always require a certain degree of maintenance and will likely still suffer from occasional issues particularly in drought conditions. However, we are confident that this combination of measures will significantly improve the habitat and water quality of the lakes in the longer term and substantially reduce the frequency and severity of issues such as algal blooms. They also offer added value in terms of amenity, recreation, and wildlife.

The anticipated benefits of the main lake improvement measures are outlined in Table 4.2 below. A combination of these measures is considered to present the best balance of feasibility, sustainability and cost effectiveness.

Table 4.2 Preferred option lake improvement measures and their anticipated benefits

Measure	Anticipated Benefit
Dredging of all sediments within the lake.	Although this would entail a substantial capital spend, it is an essential component of lake improvements. Importantly, this would create a slightly greater water depth. In addition, the soft organic sediments are likely to be resulting in the persistent recycling of nutrients. They are also a poor rooting substrate for macrophytes (which are important for maintaining healthy dissolved oxygen levels, reducing turbidity, and removing and locking away nutrients) and can be mobilised into the water column increasing turbidity by benthic fish bioturbation (increasing turbidity levels, which then has a negative feedback on the ability of submerged macrophytes to photosynthesise). The other measures proposed will substantially help to reduce future build-up of sediment, in particular those measures that will reduce the risk of algal blooms (increased through flow, marginal planting, removal of fish). The dredged sediment will have a high water content, but once dried sufficiently to increase its cohesion it would be used within the infilling/narrowing and also the island enlargement measures identified below.
Measures to discourage Canada geese/ other wildfowl	Likely to include measures to reduce feeding birds, such as increased signage.
Partial infilling/ narrowing of the lake	This would increase flow-through, particularly during the most critical times of the year during summer period with higher temperatures, increase sunlight levels and lower direct input from precipitation. It is hoped that some of the dredged sediment may be able to be dried and used as part of the infilling work. Some breakout of concrete edges may be possible, or else tethered planting structures. (note the river works would also increase flow through the lakes, see Section 4.3.3 below)
Wetland creation/ planting of marginal, submergent and floating plants	Marginal and aquatic plants would help to oxygenate the lake and trap/lock away nutrients. In addition, the marginal planting is the only measure taken forward that would help to discourage Canada geese, as other measures were considered costly and could detract from the visual amenity of the lake. Dredged sediment will be used to create the wetland and marginal areas.
Varying abstraction regime from the River Ver	The lake would benefit from increased through flow of any amount, though care would need to be taken to ensure that the reduction in flow on the River would not have a detrimental effect on this section of the river and the efficacy of the river restoration works proposed. See Section 4.3.3 for further information on the outline design hydrology.
Removing fish from the lake	The large number of carp are detrimental for two reasons: they add nutrients to the lake and they disturb sediments, putting nutrients back in the water column and causing increased turbidity which reduces the ability of aquatic plants to photosynthesise. Fish would need to be removed irrespective, to allow the other proposed works to take place. Once water quality in the lake improves it is proposed that some fish species would be reintroduced; this is essential to sustain the heronry. However, this reintroduction would be a carefully controlled mix of species to include predator species such as rudd and perch.
Island enlargement	This is considered to be a relatively low cost intervention that would help reduce the areal extent of the lake (which aligns with the partial infilling/narrowing sub-option) whilst also benefitting the heronry, which is a Local Wildlife Site.

In addition to these active interventions, there are also management maintenance activities that would support the overall suite of actions intended to improve the lake in terms of water quality, reduction of the occurrence of algal blooms, reducing the risk of avian botulism and improving the visual and recreational amenity of the lake. These additional measures include:

- Management of new riparian planting, to control excessive growth, although this may not be an issue with careful species selection.
- Regular action and campaigns to educate visitors about the impacts caused by bird feeding, and how it is harmful, particularly if there is an algal bloom.
- Regular maintenance of any new flow control structures to ensure correct operation is possible.
- Selective removal of branches overhanging the lake to reduce leaf litter.

4.4.2 Improvements role in combating the risk of avian botulism events

There has been concern previously that the water quality in the lake has contributed to historic bird deaths which may be due to outbreaks of avian botulism. This is not an uncommon occurrence in municipal park lakes, many of which suffer similar water quality pressures as the Verulamium Lake.

The UK Animal and Plant Health Agency has published an information note about avian botulism[22]:

'Avian botulism is a paralytic and often fatal disease caused by ingestion of toxin produced by the bacterium Clostridium botulinum. Avian botulism outbreaks in wild waterbirds occur relatively frequently in England and Wales. Large numbers of birds may be affected which can result in hundreds of deaths. Outbreaks of avian botulism can last for several weeks and may recur. C. botulinum is an anaerobic (oxygen intolerant) bacterium that multiplies in putrefying plant and animal material and is thus often found in lakes in periods of anoxic conditions and poor water quality. C. botulinum toxin Type C is considered to be responsible for most avian botulism outbreaks in the UK. The toxin produced is relatively stable and persistent in the environment, and in animal and insect tissues (including maggots feeding on dead birds)'.

The advice note provides a list of preventative measures taken by the London Royal Park authorities which have prevented the recurrence of the disease or reduced its effects. Table 4.3 describes these measures, and how the lake restoration measures will help achieve the same results.

Table 4.3 Preferred option lake improvement measures and their anticipated benefits

Preventative measure	Benefit of proposed lake measures
Maintaining good circulation of water.	The proposed offtake modifications would increase through flow as much as possible without impacting on the river
Maintaining healthy communities of oxygenating plants.	Proposed marginal planting would introduce oxygenating plants.
Prevention of the water level falling in the lake, preventing deoxygenation and the exposure of putrefying material.	The removal of silt would increase water depth and reduce the risk of exposed material, and the increased flows would help maintain lake levels. Reduced amounts of bread, as well as fish and bird excrement, would help remove putrefying material. Reducing the extent of the lake would also improve this aspect.
Removal of decaying plant material (including leaves) from the water. In particular removing vegetative material that collects on branches dipping into the surface of the water. These branches should be removed.	Removal of silt would remove existing decaying plant material. Management of trees surrounding the lake to reduce branches dipping into the water would also help.
If appropriate, removal of silts by pump action (in the face of an incident this may temporarily exacerbate the disease due to agitation of material).	There would be less sediment in future due to fewer algal blooms, the die-back of which generates silt. Management of fish would help reduce disturbance of silt. Less silt also through reduced extent of lake, so less prone to siltation (with slightly higher through flow too).
Searching and removal of dead animals in high risk periods for example warm summer months.	This is a measure that is already undertaken by the council.
The aim is to keep water levels high and reduce or lower the levels of silt.	Both the increased flows and removal of silt will help, in addition to the partial narrowing/infilling.

4.4.3 Summary of the Proposed Option Modelling

Hydraulic modelling was undertaken to refine the restoration features that were included in the design and determine the potential hydrological, hydromorphological and ecological effects of the preferred river restoration option. Full results of the modelling are included within Appendix D. A summary of the effects is provided below.

Hydrology

A summary of the flow modelling results through Reach 1 is presented in Figure 4.4. This shows that:

- The restoration would not impact upon flows past the Ye Old Cock Inn.

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[22] Animal and Plant Health Agency, July 2017, Avian botulism in UK wild waterbirds

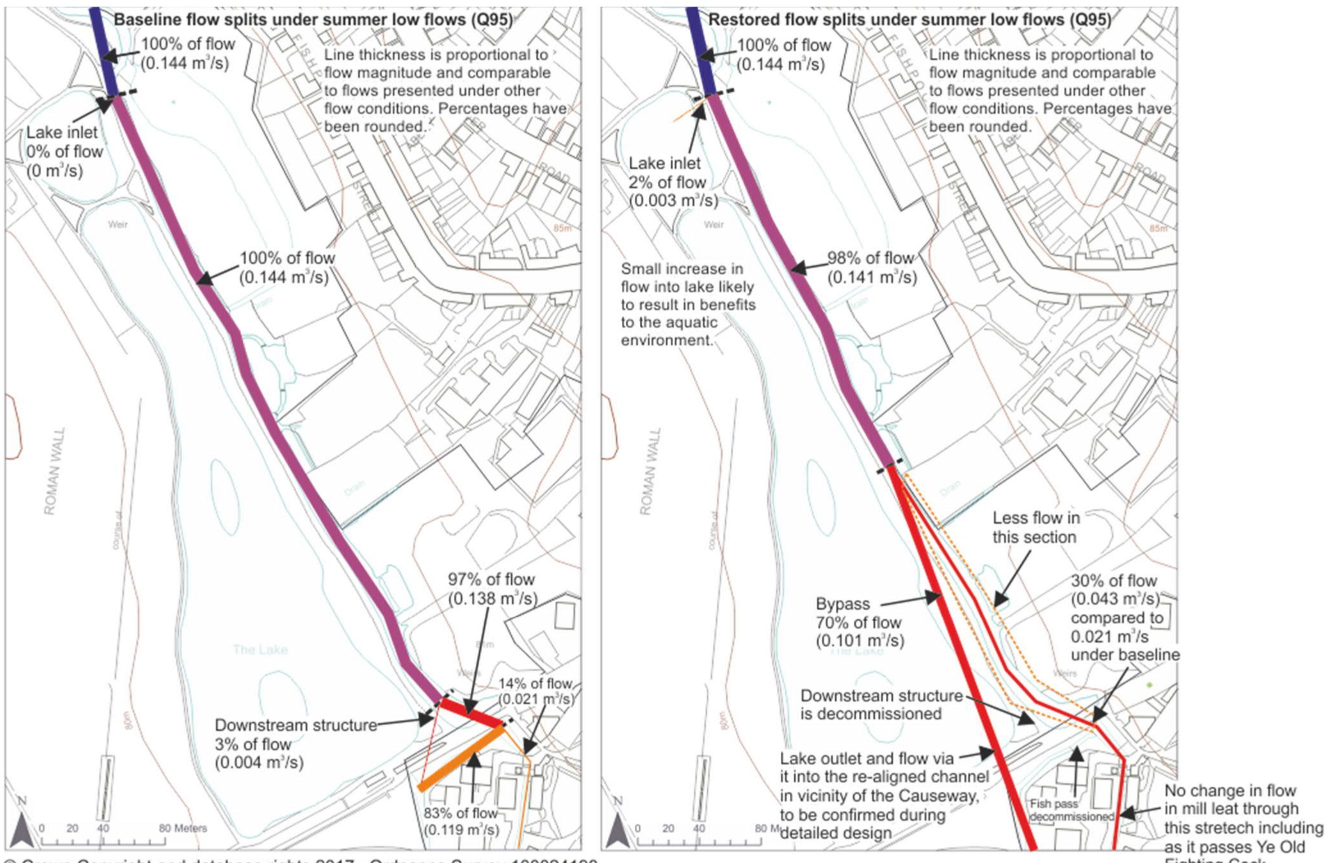
- Flow would be reduced in the mill leat between the start of the re-aligned channel and the existing fish pass that would be decommissioned.
- Increased flow into the lakes at times of low and median flows (with levels being slightly raised in the upstream end of the reach so that additional flow can overtop the control structure).

As a result of increased flow into the lakes the following was determined:

- At times of low flow (Q_{95}), throughflow would take 63 days from entering to leaving the lake (with no inflow under the existing rate there would be no throughflow i.e. the throughflow time would be infinite) so the design results in an improvement.
- Under average flows (Q_{50}) the rate of flow through the lake is reduced from 24 days to 19 days under the proposed restoration, which also provides an improvement.
- There is no significant change at high flows.

In addition, the scheme would potentially provide flood risk benefit with the lowering of the re-aligned section potentially providing flood storage. Flood modelling suggested no adverse effects throughout the reach.

Modelling may be refined into detailed design and flow and overall water balance should be considered through this process. A number of structures influence the hydrology through the reach and these should be suitably designed so that they achieve the flow splits that are intended. Most notably these include the flow split between the existing mill leat channel and the new bypass and a new outlet structure from the lake into the bypass.



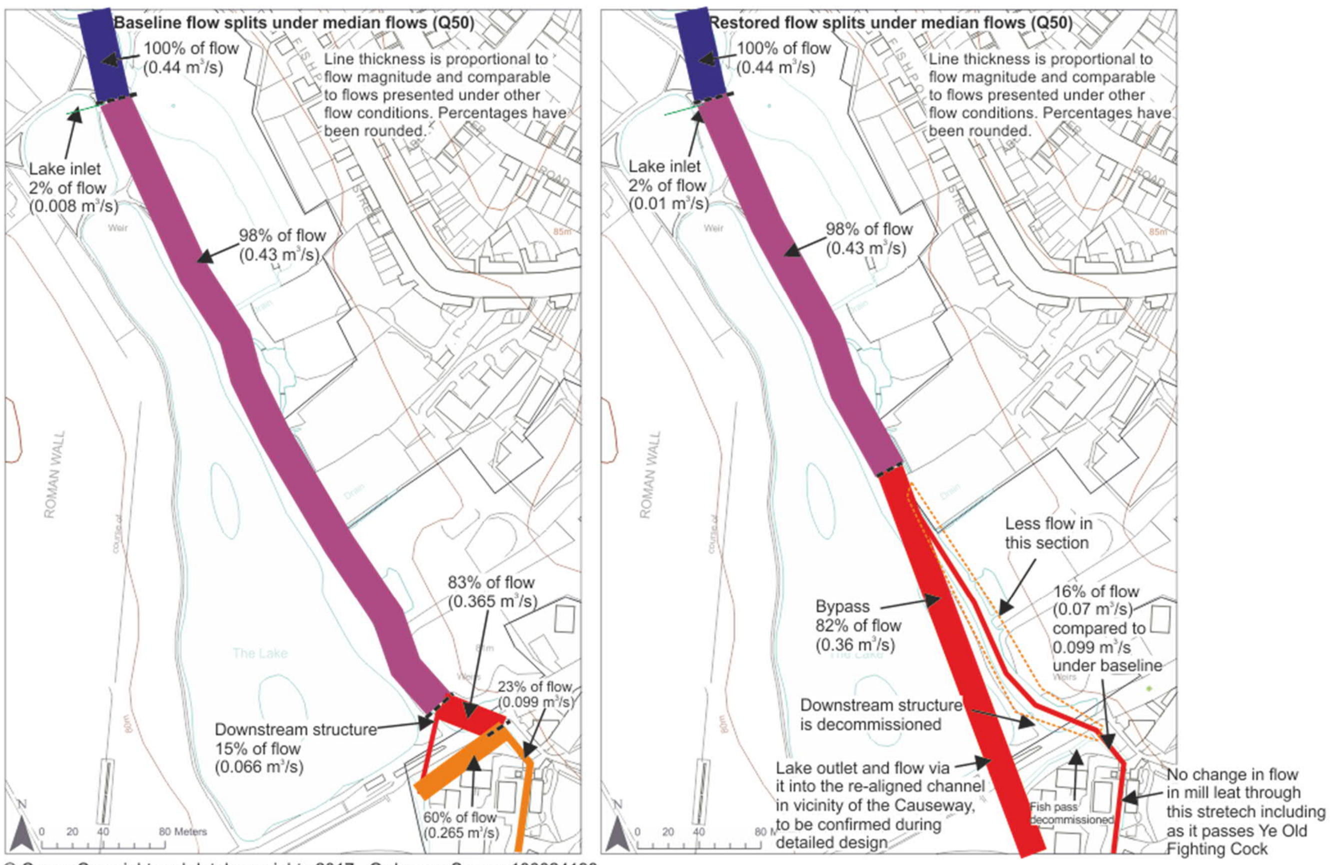


Figure 4.4 Baseline and Preferred Option Flow Modelling Results under low, median and high flow circumstances

Hydromorphology

The re-aligned river channel would have a more appropriate narrower width (the existing channel is too wide and overdeep), with natural river features installed, such as riffles (areas of rippled flow) and gravel bars (gravel features on the channel margins). Steeper channel features (riffle/rapids) would be required through the channel section realigned through the south east corner of the lake. Although the small section of rapid would not represent a natural chalk stream feature, it would allow coarser substrate to remain stable and would oxygenate the water.

These features provide habitat for chalk stream flora and fauna such as mayfly and brown trout with a suitable source of habitat. Berm (low sections of banks next to the river) features would also be incorporated, adding further diversity to the river form, providing the ideal conditions for wetland grasses and flowering plants such as yellow flag iris. An example of a similarly restored river channel is provided in Plate 4.5 below.

Plate 4.5 An established section of restored river channel on the River Bulbourne, Hertfordshire, with vegetated berms developing in the margins (Photo courtesy of Five Rivers Ltd)

Potential effects of the option on bank erosion and sedimentation are indicated in Figures 4.5 and 4.6, respectively.

Results indicate a notable reduction in siltation through the reach. With flow needing to be retained in the mill leat, then it is inevitable that siltation through the section will continue to occur. The overall reduction in siltation through the reach would provide ecological benefits.

Bank erosion in the bypass reach and in the small upper part of Reach 1 (at two riffles) has been identified. Bank erosion can be a positive aspect of the restoration maintaining important and rare clean bank habitat on the river although this should be explored further through detailed design to ensure that it is not excessive or in particular locations where it is not desired (for example eroding a private garden).

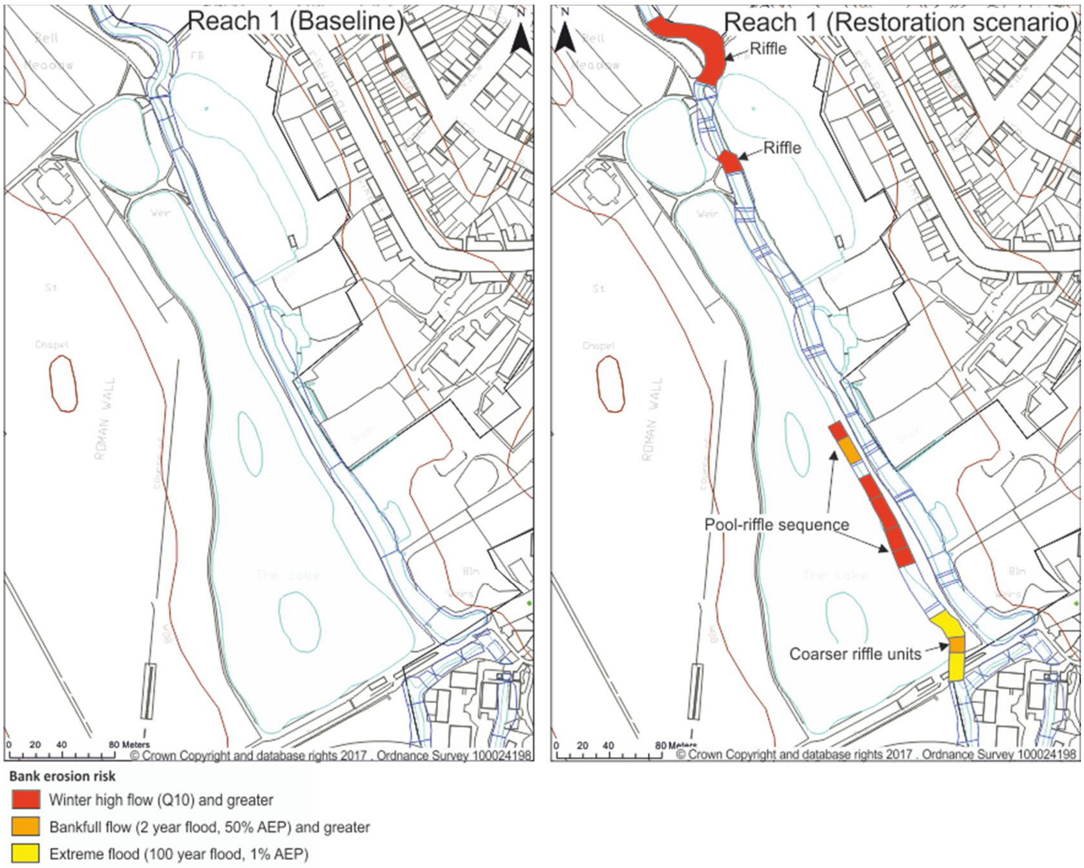


Figure 4.5 Bank erosion risk at Reach 1 under baseline and proposed restoration scenarios

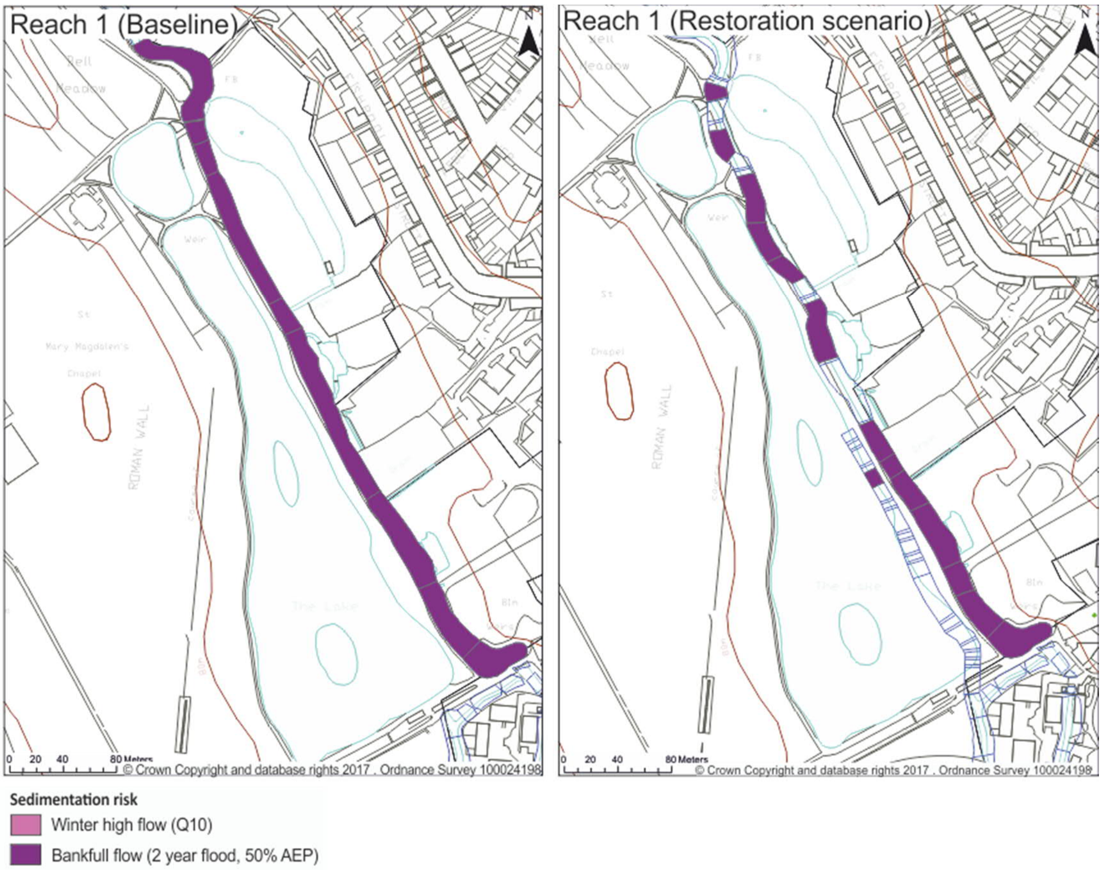


Figure 4.6 Sedimentation risk at Reach 1 under baseline and proposed restoration scenarios

Modelling confirmed that the restoration features were functioning as intended although some would need to be refined so that their performance would not deteriorate over time (i.e. by narrowing they would be less prone to the effects of siltation).

River Habitats

The flow modelling of the new watercourse in Reach 1 has shown that under current conditions Reach 1 is highly degraded with only pool habitat present (Figure 4.7). The preferred option increases the gradient (slope) along the part of the reach where a new channel is created, and elsewhere the channel narrowing would allow newly created chalk stream features to function well. The predicted new habitat distribution is shown in Figure 1. 55% of the reach would be transformed, with almost a quarter of the original Reach 1 habitat becoming low energy glide habitat and around a third improving to higher energy environments including runs and riffles. Pools would make up the remaining habitat. The model shows that the steep nature of some of the lower riffles would create a small amount of 'chute' habitat, not normally associated with chalk rivers. Although chute habitat is not necessarily in character, it would allow coarser substrate to remain stable and would oxygenate the water, as highlighted above.

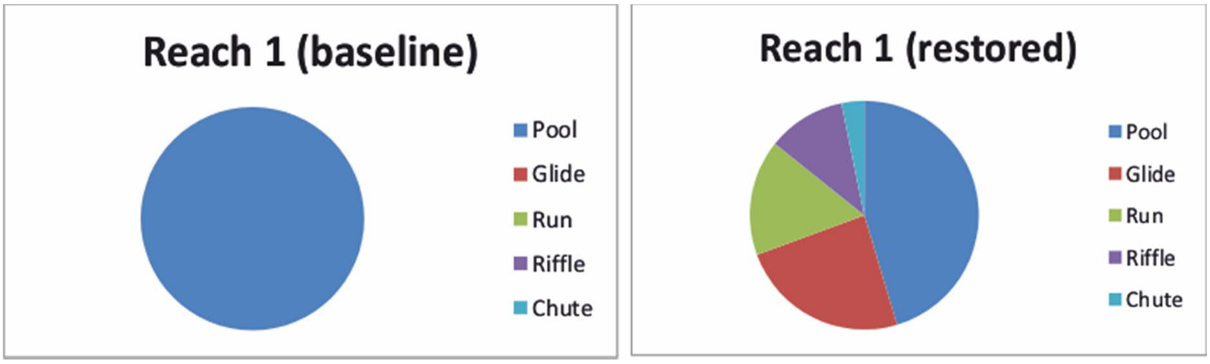


Figure 4.7 Current and restored in-channel habitats for Reach 1 on the River Ver

It is anticipated that refining of the option through detailed design should result in further habitat gains.

4.5 Engagement

Our outline proposals for Reach 1 were unveiled to the public in March 2018 at the start of a public engagement period. Several engagement events were also held during engagement and members of the public were invited to fill out a survey to record their views on the Reach 1 proposals.

The survey resulted in the following positive feedback being received:

- Good to see improvements to the lake after so long, especially tackling the problem of excess silt.
- Improving the flow of water and water quality in the lake.
- Naturalising the river in the park and improving it for wildlife is a great idea.
- Expanding the heronry will be very beneficial.
- Boardwalk will allow access to the lake without erosion.
- Verulamium Park has even more to offer for families and other users if these plans go ahead.
- Excellent proposals. Improvements to lake and stream urgently needed.

A number of concerns were also raised and these are indicated in Table 4.4 along with our response.

Table 4.4 Survey Concerns and Our Response

Concern	Response
Increased flood risk to riparian properties.	• Flood risk has been considered as part of the hydraulic modelling that was undertaken in support of the outline design. No adverse effects predicted with the outline design. • As the design progresses to detailed design, flood risk should continue to be considered to to ensure that there would be no flood risk increase to people or properties as part of the design.
Boardwalks will require ongoing maintenance, especially with high visitor numbers in Verulamium Park.	• This view is noted and we anticipate that the access means (through the wetland) are considered further and confirmed as part of the detailed design.
Splitting the mill leat in to two could quite easily leave the original as a muddy ditch and won't do anything to improve the water quality in the lake.	• Modelling of the outline design predicts a flow reduction between the split with the bypass channel and up to where the existing fish pass is located. Inclusion of restoration features would reduce the amount of siltation through this reach and should be considered through the detailed design. • Elsewhere in the mill leat no perceptible changes in flow are predicted. • Improvements to the lake are predicted as a result of the flow changes and minor levels effects.
Lack of published, scientific data for Reach 1.	• Full results of the project are now presented within this report, which makes references to scientific papers when required. We produced our engagement documents with a broad audience in mind.
Proposals do not really address the issues in the Lake – SADC should plan/budget for routine maintenance/silt removal.	• We consider that the proposals would result in a more sustainable solution to the issues in the lake. Routine dredging does not help solve the problems but tackles a side effect of the problems and is expensive.
Reducing the distance between the islands and the public access paths could increase potential disturbance to sensitive breeding birds.	• Public access is not proposed along the realigned river and so any reduction would be as a result of island extension or access through the proposed wetland. It is considered that there would be sufficient distance once the site is operational for this not to be an effect. This should be considered further during the detailed design.
Priority may be placed on Reaches 2-6 first, but need to be placed on the lakes.	• A number of factors, including funding, will need to be considered regarding ordering of the schemes. • Order of the schemes will be confirmed as detailed design progresses.
The effects of bird feeding and high bird populations on the lake and how this can be overcome.	• Lake improvement measures include information signs discouraging bird feeding and lake edge planting to discourage geese from the lake/ general area. This will be examined further detailed design.
Historical importance of the mill leat and the lake - the lake is approaching its centenary and is a valuable resource for the City, residents and visitors.	• We recognise the importance of the lake although consider that the issues it currently faces require a well considered plan to be implemented to deal with the issues. This should result in an improved environment that will provide amenity benefit to local residents and encourage visitors.
Question whether the existing fish pass is as ineffective as the proposals indicate	• The Environment Agency have advised that the fish pass is ineffective under most conditions. Proposals will create a channel passable by a wide range of fish species.
Drawbacks from using dredged silt along the lake edge – lots of treatment needed, unsuccessful past attempts.	• It is considered that re—using the material in the lake would be appropriate, with analysis indicating that the material is not considered hazardous. Further testing may be needed to confirm this. Prior to be re-used the material may need to be dried on land.
Guaranteeing sufficient water supply to the lake with reduced abstraction.	• Outline proposals would result in slightly more water entering the lake without any change to the inlet structure (with levels in the river at the structure being slightly higher more flow could enter the lake). This should be explored further as the detailed design advance the Environment Agency should be consulted with over any abstraction requirements and consenting.

Concern	Response
Guaranteeing long-term maintenance of the lake.	• Our outline option should require minimal river maintenance and a reduced level of lake maintenance. On-going maintenance would still be required and should be accounted for within St Albans City and District Council's planning (as they have done to date).
Tree clearance and effects on riparian properties.	• Removal of some trees that overshade the river is still proposed although we will work with residents as to which ones are removed. This will be considered further through detailed design.

Historic England were also consulted on the outline plans. They are supportive of the scheme but have advised that:

- any ground disturbance or depositing of material within the scheduled monument is likely to require scheduled monument consent to be obtained.
- any signage and infrastructure should be located outside of the scheduled monument to avoid impacting on undisturbed archaeological remains.
- further advice should be sought from Historic England when the detailed designs have been put together.

Herts and Middlesex Wildlife Trust were consulted and were supportive of the scheme to improve the Ver's morphology, wildlife and amenity value.

In addition to the survey further engagement responses from park users and resident groups were received. These are summarised in Table4.5 along with our responses.

Table 4.5 Other Engagement Feedback and Our Response

Concern	Response	Next Steps/ Further Work
Concern about loss of existing amenity including loss of lake edge path, loss of slipway and boating lake.	• Path around lake will be maintained and improved. • Slipway maintained. • Use of boating lake to be retained.	• We will engage with users of the boating lake through detailed designs.
Concern about the change in visual amenity	• Proposals aim to maintain the lakes and retain the character of the park. Some changes are necessary to create a more sustainable lake within the constraints and objectives of the project.	• We will engage with residents in this area through detailed designs.
Previous attempts at riparian planting have not been successful	• Previous attempts at lake margin planting have been piecemeal and not part of wider plan. The proposed lake margin planting would need to be fully considered during detailed design to ensure it is successful.	• Lake side planting and riparian planting along the re-aligned river to be considered in detail through detailed design.
Treatment of silt in park during works	• Prior to be re-used the material may need to be dried on land.	• Treatment would be confirmed during detailed design, along with any consents that would be required. Further testing would likely be needed in advance.
Access during works	• There will be some disruption during works. Footpaths including a Public Right of Way would need to be diverted and traffic management may be needed through the durations of the works.	• Access to be considered further during detailed design and through construction. It is acknowledged that any disruption impacts upon the local community and endeavours will be made to minimise the impact. It is considered that the ultimate end point will make the temporary impacts worthwhile.

4.6 Final Outline Reach 1 Plans

Following engagement we have revised the plans for Reach 1. The final outline restoration plans for Reach 1 are provided in Figure 4.8. Two indicative visualisations of the scheme have been included as Figures 4.9 and 4.10.

An Outline Environmental Appraisal of the option has also been undertaken to not only identify the benefits of the restoration but also provide an initial indication as to where further work during detailed design and/ or mitigation is required. The appraisal assumes that all best practice, such as Pollution Prevention Guidelines and Working in Water methods are adhered to and standard ecological surveys and resultant mitigation would be undertaken, and during construction. The appraisal is included as Table 4.6.

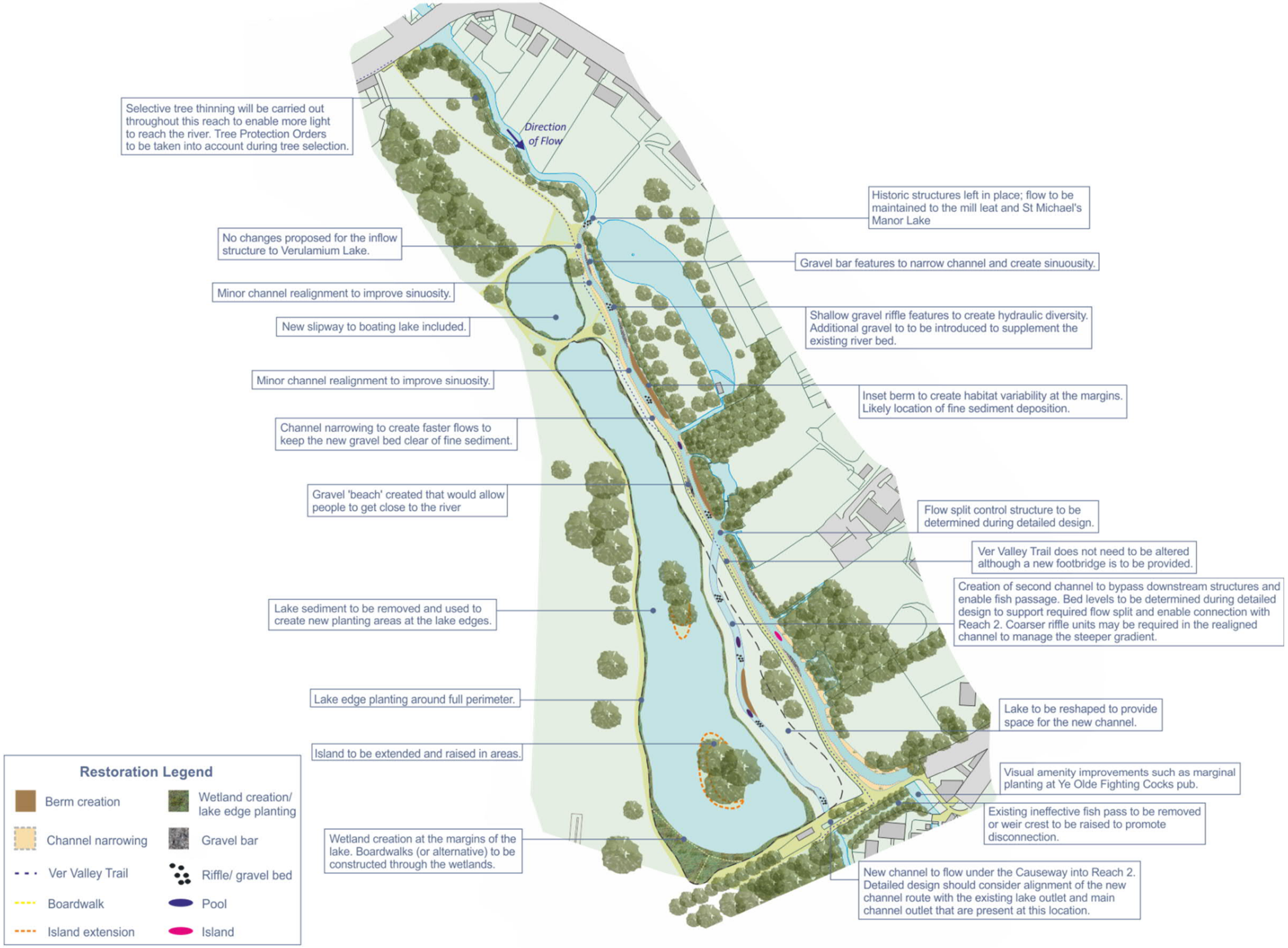


Figure 4.8 Reach 1 Final Outline Proposal Plan (post engagement)

Figure 4.9 Reach 1 Visualisation - looking eastwards towards the lake and Cathedral.

Figure 4.10 Reach 1 Visualisation - looking northwards from the Causeway.

Table 4.6 Outline Environmental Appraisal of the Reach 1 Preferred Option

Resource/ Feature	Overview	Effect or Potential Effect of Scenario	Potential Mitigation	Likely Significance
Hydrogeology/ Groundwater connectivity	Does the scheme affect connectivity between surface water and groundwater?	• The river bed through Reach 1 is not concrete lined therefore connectivity with a natural bed would be maintained • The re-aligned section may result in groundwater levels being closer to surface water levels and more baseflow entering the river. However, the reach is considered to be a losing reach and flow reductions would be expected more often than flow gains. • Ultimately the system will be more naturalised which is a positive effect.	• We recommend that groundwater monitoring is undertaken in Reach 1 to gain a better understanding of groundwater in the area and how this could influence the hydrology of the river. • The results should in turn inform the detailed design.	• Beneficial
Geo-environmental	Does the scheme potentially result in a new pathway for contaminants to enter the river?	• Removal or containment of sediment (for example within geotextiles) within the lake should reduce the effects of these material on the water environment (analysis has determined that they are not hazardous although they contain high levels of faeces). • Proposed river re-alignment is not through an area identified as being potentially contaminated (with lake sediments being identified as not hazardous). Such areas are also unlikely to be encompassed during construction works too. • St Albans City and District Council undertook asbestos sampling from the concrete (bed and base) of the lake in January 2018 at four locations. The results confirmed no asbestos was present.	• Further silt testing is recommended as this would inform the final strategy for dealing with the excessive silt in the lake (i.e. whether it can be re-used within the landscaping of the lake margins). • Soil samples should also be taken from along the length of the re-aligned	• Beneficial regarding the lake; With inclusion of suitable mitigation , if required, there would be a neutral effect on the river.
Flood Risk	Does the scheme result in an increase of decrease in flood risk to people and properties?	• There are unlikely to be any significant flood risk impacts as a result of the modifications proposed for this option.	• As part of detailed design is it likely that the scheme will be refined and iterated. Revised schemes should be hydraulically modelling and flood risk should be assessed throughout, to ensure that there is no increase in flood risk to people or properties as part of the works.	• Neutral
Other hydrology	Does the scheme result in other changes to the hydrology that could impact upon other water users or receptors?	• A summary of the hydrological effects was presented in Section 4.3.3. • Flow reductions are only predicted in the mill leat and the bypass channel and the existing fish pass. Elsewhere no flow changes to the existing river are predicted, including past Ye Old Cock Inn (aside from where existing routes are closed or new routes are created). • The reduction in flow in the mill leat (between the bypass and fish pass) would manifest as a reduction in velocities rather than levels with the weirs remaining present in this reach. As such no effects to level-controlled offtakes are anticipated.	• None required	• Neutral
Hydromorphology	Does the scheme improve the hydromorphological functioning of the reach?	• The increased hydraulic gradient through the realigned section and upstream should reduce fine sediment accumulation and create an improved gravel bed more characteristic of a chalk system as a result of bypassing the influence of the downstream weir • The hydraulic changes would mean less glide and ponded habitats through the existing main channel with an increased quantity of higher energy riffled flow.	• Hydromorphological gains should continue to be sought from the scheme as detailed design progresses.	• Beneficial
Water quality	Does the scheme result in a deterioration or improvement of water quality, for example less flow would result in less dilution of consented discharges?	• Lake measures and river restoration should result in improvements to the water quality of the lake and river. • One discharge is located on the left bank midway down Reach 1. The nature of this discharge is not stated although it is located at a similar location as the surface water runoff sewer. Given the minimal anticipated changes in flow in this reach the any effects of this discharge on water quality in the Ver as a result of the scheme would be minor. During construction, the discharge should be accounted so that it is not disrupted.	• None required	• Beneficial
Statutory Sites or Non-statutory Designated Sites	Does the scheme affect designated and or wildlife sites?	• The two islands are Local Wildlife Sites. These are to be extended and improved as part of the works so while effects during construction could occur ultimately there would be a benefit to the wildlife sites.	• The potential effects to the wildlife on the islands during construction should be considered fully and suitable mitigation should be included. • The proposed scheme should result in an improvement to the islands although other effects of the scheme, such as wetland bringing people closer should be considered as part of the detailed design.	• Beneficial
Other Biodiversity	Wildlife can be impacted during construction while scheme may result in positive, neutral or	• Scheme would result in an improvement to the health of the river and lake, as	• Potential ecological gains to continue to be	• Major Beneficial

	negative effects to species.	well as provide additional habitats • Fish passage for multi-species would also be achieved by re-aligning the river and careful design of any culvert under the Causeway	considered through the detailed design to maximise these.	
Heritage	Does the scheme potentially impact upon Scheduled Monuments or other archaeological features?	• Re-alignment not considered to affect the Scheduled Ancient Monument. • Crossing the Causeway heritage feature at the same location is considered acceptable although Heritage requirements have influence the design of any crossing and construction means. • Significant excavation associated with the re-alignment may result in Heritage features being discovered.	• Detailed design should continue to suitably account for Heritage, for example regarding Causeway crossing. • A Heritage officer with a Watching Brief during the works is anticipated.	• Neutral/ minor adverse
Tree Protection Orders (TPO)	Consideration of the effect of Tree Protection Orders on the option	• TPOs are extensive on the left bank of the existing channel and may have an impact upon access, construction and tree works to improve channel light levels.	• Tree thinning will need to be carefully considered to avoid impacting trees that have a TPO. • We will work with others to plan which trees could be removed, pollarded or thinned to achieve better levels of light for the river whilst minimise any impacts to properties.	• Neutral/ minor adverse
Landscape impact	Does the option have a significant visual impact?	• The option would result in a small reduction in the surface area of the larger of the Verulamium Lakes and a change to the river. The improvements to both are likely to improve their appearance.	• None required	• Beneficial
Recreation and amenity	Does the option have significant impacts upon recreation and/ or amenity	• The option would result in a small reduction in the surface area of the larger of the Verulamium Lakes. This is not considered to have a significant impact upon recreation or amenity. The improvements to the river are likely to improve its appearance which may increase the number of people wishing to walk along the river. A riverside path would be maintained. • Associated improvements works, such as boardwalk paths through newly created wetland areas, could help improve access through the reach although would be an additional maintenance commitment for the council.	• Public access needs to be planned thoroughly to allow people to access nature in a way that is sympathetic to wildlife whilst enabling learning and engagement experiences. This may include some access restrictions in sections that contain higher wildlife value. This should be considered through the detailed design.	• Beneficial
Riparian ownership issues	Does the option affect properties?	• No riparian ownership issues are predicted (see other hydrology and flood risk above).	• None required, subject to detailed design continuing to result in no adverse hydrological effects.	• Neutral
Construction only				
Water Mains and Sewers (foul and surface water)	Consideration of the potential effect of these on buildability of the scheme.	• There is a Thames Water foul sewer that extends along the reach between the River Ver and Lakes. This is at a depth of ~3.8m bgl and should not be impacted by the works. There is also a foul sewer that runs partially along the causeway at a depth of ~2.5m bgl. This would likely be impacted by the works at the lower end of the lake and would need to be accounted for (which could be costly). • Two separate below ground surface water sewer pipelines (owned by Thames Water) enter the River Ver on the left-hand bank. The depth of the more northern of these is unknown while the other is at 4m bgl. These should be acknowledged during the works although are not considered to be prohibitive.	• Utilities should be considered through the detailed design and should be suitably accounted for during any construction works. • Thames Water may insist on no excavation works with 10m of their sewer .and have indicated that sewer may also be in a slightly different location to what is shown on their mapping. Early consultation with Thames water is recommended. They are also likely to ask for CCTV survey before and after the works to prove that the integrity of the sewer has not been compromised by the works. • Further surveys are recommended.	• Neutral
Other Utilities	Consideration of the potential effect of these on buildability of the scheme.	• There are no other known utilities close to the area that would be restored under this option.		• Neutral
Pedestrian access	Consideration of the potential need for footpaths to be diverted. For example Public Rights of Way may need to be re-routed if works are planned over their route.	• A public right of way extends throughout the route of the river works proposed by this scenario and would need to be diverted for the duration of the works. The diversion will probably be to the other side of the lake so that works may need to be undertaken in two halves. • Overall, public access throughout the area would be improved as a result of the works.	• Access should be considered during detailed design and a strategy devised in advance of any construction occurring.	• Minor adverse
Access	Consideration of access to the works area. Access may be difficult and even prohibitively expensive under certain circumstances	• Access for works likely to come from the east of Reach 1 or from the south. Important Heritage to the west and limited space elsewhere in Reach 1 may result in the working area being located in the Events Meadow to the south.	• Access should be determined during detailed design and confirmed by the contractor delivering the works. • Traffic management order may be required.	• Neutral

4.7 Reach 1 Next Steps

4.7.1 Detailed design

The detailed design will need to examine the following:

- A screening opinion should be sought from the local authority as to whether an EIA would be required. The topics for consideration during detailed design should also be confirmed.
- Surveys of the structures under the causeway, such as the lake outlet structure and the piped flow from the river to the top of Reach 2, should be undertaken as detailed information on these has not been found during the outline design.
- Design of flow control structures will need to be undertaken for the final scheme. This would include the culvert under the Causeway where the re-aligned river will flow and include the outlet from the lake (which could include an ability to draw the lake down if need be). The design of the culvert would need to ensure it had suitable conveyance capacity. A flow control structure, or equivalent, would also be needed to suitably split flow between the mill leat and re-aligned river.
- Undertake groundwater monitoring to improve the understanding of the groundwater levels in the area and whether some flow losses or gains would be expected as a result of naturalising the system and providing improved connectivity between groundwater and the river. Clay lining may be needed if potential losses are significant (though this is not predicted to be needed).
- Further Heritage assessment would be needed as the detailed design progress and scheme is refined. A watching brief during any works is likely to be required.
- Further ecological surveys and appraisal should be undertaken. The former would inform construction requirements and mitigation while the latter would help ensure that ecological gains are maximised as part of the works.
- New wetland, riparian and lake margin habitat should be determined that take into account the site conditions (soil type etc.) and anticipated moisture levels. The choice of species should reference the Herts Habitat Inventory (held by HMWT Records Office) to create a section of Living Landscape in St Albans.
- Modelling for the outline design has demonstrated hydraulic habitat diversity and functionality of the River Ver is significantly improved through Reach 1. Detailed design, and associated modelling, should iterate the design to further improve the functioning of the restoration features to ensure they deliver maximum benefits while avoiding any effects considered detrimental.
- Further silt testing is recommended as this would inform the final strategy for dealing with the excessive silt in the lake (i.e. whether it can be re-used within the landscaping of the lake margins or if there is too much of it whether it is suitable for spreading on agricultural land). Soil samples should also be taken from along the length of the re-aligned river to inform its design. This would inform if any consents or permissions would need to be gained.
- From the outline design plans, 8,800 m^3 (wet volume) of sediment are proposed to be removed and 4,500m^3 (wet volume) would be re-used elsewhere in the lake (30% to be infilled)[23]. The other half could be used elsewhere as part of the restoration work (for example for berm creation - though noting that although we found the sediment to be not hazardous, further analysis may be needed to confirm the potential re-use elsewhere in accordance with UK waste management legislation and best practices). If any sediment remained it would need to be taken off site. These should be considered further during detailed design.
- Constructions methods, including phasing of the works, should be considered further during detailed design and discussed with riparian owners. The lakes would need to be drained during the works and re-aligned river and culvert under the river should be constructed in advance of flow being diverted down it.

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[23] Please note volumes are wet volumes – dry volumes will be considerably less as water content of sediments is high.

- We will work with residents to plan which trees could be removed, pollarded or thinned to achieve better levels of light for the river whilst minimising impact to properties.
- An access plan should be developed. This should include how public and their pets can interact with the river, for example at controlled access points, and access through the wetland area.
- Long term maintenance of the scheme should be considered as part of the detailed design. For example, the design life of boardwalks may be of the order of 10 years and a more sustainable option may be appropriate. New structures and riparian planting may also need to be maintained intermittently.
- A planting plan for the riparian/ floodplain/ wetland/ lake margin areas should be developed.
- Produce detailed design drawings that can be used for construction.

DERIVATION OF THE PREFERRED OPTION FOR REACH 2

05

5. The Preferred Option for Reach 2

5.1 Overview

Reach 2 covers the River Ver from the Causeway through the lower section of Verulamium Park down to Holywell Hill (see Figure 5.1 below).

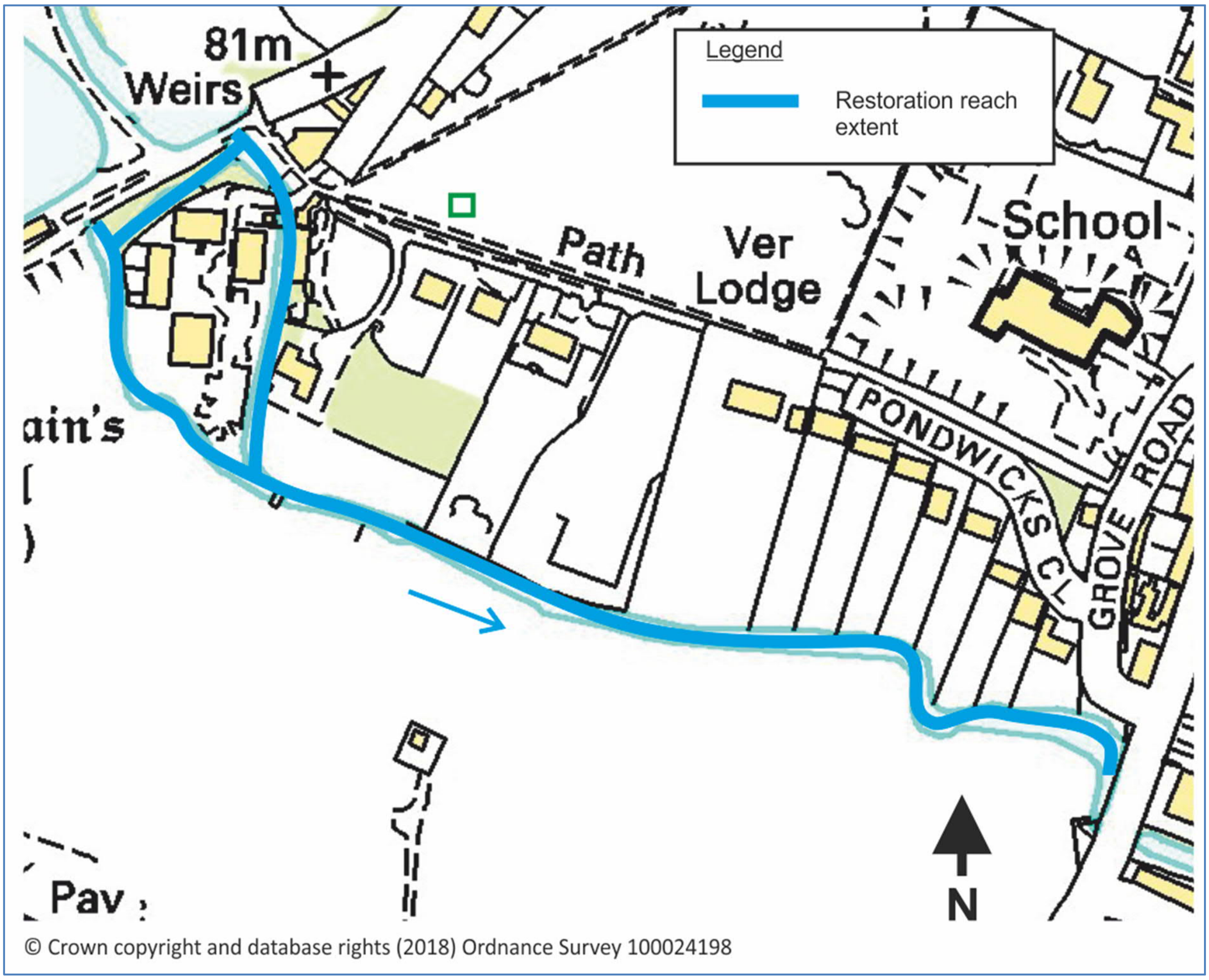


Figure 5.1 Reach 2 of the study area (Downstream section of Verulamium Park to Holywell Hill)

There is open parkland to the south of the River Ver and residential properties to the north. The river here has some sections that are fairly natural and meandering in form, but it still has many issues which impact its chalk stream characteristics.

Abstraction of groundwater from the underlying chalk aquifer is planned to be reduced soon. This will return the groundwater table and river flows to more natural levels (chalk streams naturally have a 'base flow' from groundwater). As a result, some of the low-lying areas of the park that are already boggy and marshy for some of the time will be wetter more often.

5.2 Issues in Reach 2

Although some sections of the channel are fairly natural in form through Reach 2, the majority of the reach suffers from a range of issues that reduce the quality and diversity of the habitat. There is little in the way of characteristic chalk stream features and the value of the river for wildlife suffers as a result. The reach suffers from the following issues:

- Over-wide, over-deep and straight – in many places through this reach the river is too wide, too deep and unnaturally straight.

- Low flows – due to abstraction pressures.
- Silty – as a result of the above factors, the gravel river bed is smothered in silt in many places.
- Lack of habitat and flow diversity – the river habitat is all very similar and degraded in nature which severely limits the wildlife it can support.
- Heavy shading – trees line the banks of the river for much of this reach and the resulting heavy shade blocks light to the river and restricts plant growth.
- Disconnected from the floodplain – The channel is disconnected from the floodplain as it is too wide and deep.
- Bank protection – there is piecemeal bank protection through this reach.
- Groundwater re-emergence – the floodplain is anticipated to become wetter more often as a result of planned abstraction reductions.

Restoration in this design should account for each of these issues and result in the project objectives being achieved. Further information on the river issues is provided in Appendix A.

Figure 5.2 presents a visual summary of the issues within Reach 2.

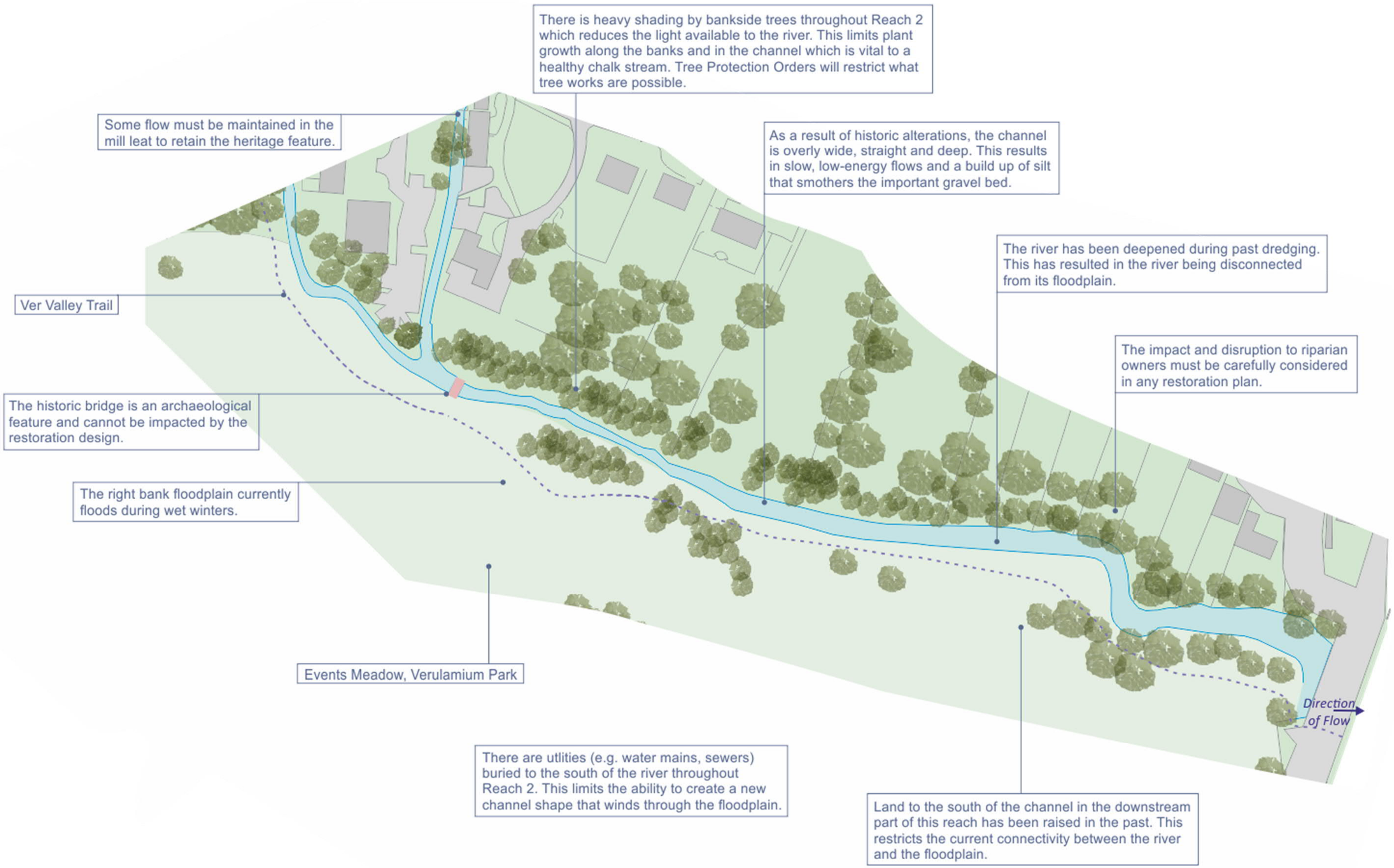


Figure 5.2 Reach 2 Issues and Constraints Overview

5.3 Derivation of the Preferred Option for Reach 2

5.3.1 Long Listing and Short-listing Appraisal

Full results of the long listing and short-listing appraisal of Reach 2 options is included within Appendix L. The appraisals considered the issues indicated in Section 5.2 and constraints identified in Section 3.10.

At the start of the project, we developed four potential restoration options for Reach 2 which we then assessed as part of the long list appraisal. Following this, three of the options that were longlisted were in turn shortlisted. These were:

- Option 2 Part re-alignment of the channel to the south with floodplain reconnection and creation of wet woodland.
- Option 3 Re-alignment of the channel close to the existing river course.
- Option 4 Retain the existing channel course, but with in-channel improvements and bank/floodplain works.

Each of these was examined as part of the detailed short list appraisal.

Although options 2 and 3 offered the greatest potential for river improvements, the location and shallow nature of underground services to the south of the channel severely restricted the potential for realignment. As such we reached a decision to take forward a hybrid of options 3 and 4 (maximising the environmental gains while accounting for the prohibitive underground services).

The preferred option for Reach 2 (a hybrid of options 3 and 4) is discussed further below.

5.4 The Preferred Option for Reach 2

5.4.1 Option description

The Reach 2 preferred option/ outline proposals, prior to engagement, are summarised in Figure 5.3.

Our proposals will transform the sometimes unusable, boggy area of the park to create a rare area of wetland habitat accessible by boardwalks which will allow St Albans residents and visitors to get closer to nature. The Ver Valley Trail will follow the improved river. In-channel features – such as the installation of riffles, berms and gravel bars will create a more natural chalk stream which will provide habitats for a range of wildlife.

The preferred option retains the current course of the river but creates in-channel sinuosity through alternate bank narrowing and includes restoration of natural channel features. Selective tree works will be carried out to increase light levels reaching the river to encourage marginal and in-channel plants to establish. It also includes floodplain reconnection and the creation of wetland and ponds in the area of groundwater emergence. Access and amenity improvements are also included.

In addition the hybrid option offers a solution to the issues with the river and also accommodates the upcoming changes as a result of reduced groundwater abstraction. It also includes opportunities to improve the area around the river for people and wildlife.

The following outlines the rationale for the features that were included within the outline design (shown in Figure 5.3). Reach 2 is a low to moderate gradient reach with low sinuosity, the gradient is steep enough to support functional riffles upstream while gravel bars have been used to increase the low flow sinuosity. Sediment supply is too low to allow these to develop naturally, hence they will have to be constructed. The likely sequence would be plane bed-riffle, however diversity can be enhanced by constructing occasional pools. Riparian connectivity is poor and can be enhanced using in-channel berm areas. Floodplain enhancement is possible through the development of a wet woodland or wetland reintroducing more appropriate species, which could be tied into the area where groundwater emergence is expected.

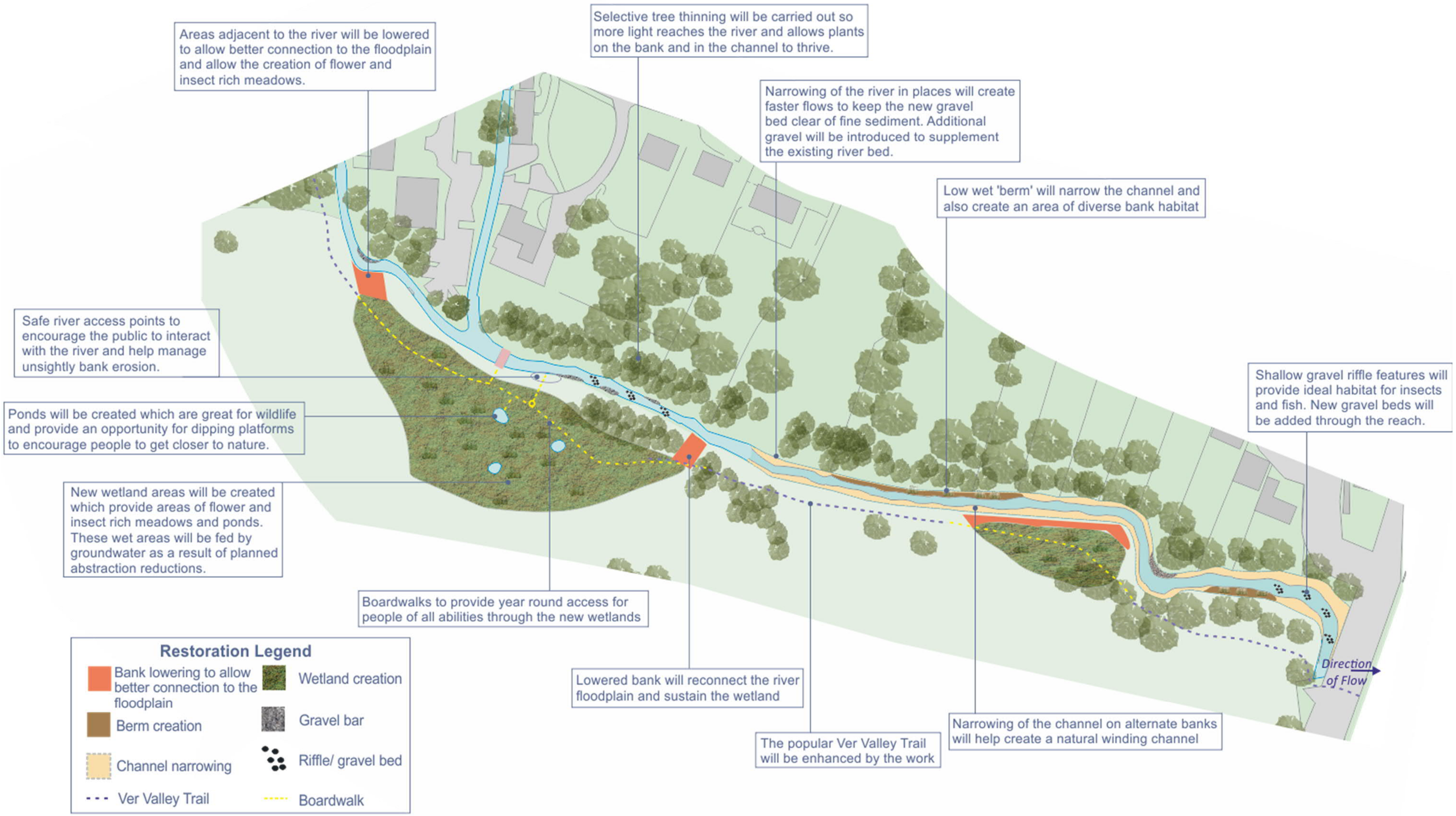


Figure 5.3 Reach 2 Preferred Option/ Outline Proposals (prior to engagement)

5.4.2 Summary of the Proposed Option Modelling

Hydraulic modelling was undertaken to refine the restoration features that were included in the design and determine the potential hydrological, hydromorphological and ecological effects of the preferred river restoration option. Full results of the modelling are included within Appendix D. A summary of the effects is provided below.

Hydrology

The amount of flow in the river would be unaffected by the restoration option, other than at high flow events when connection with the floodplain would be increased.

Flood modelling of the outline scheme indicated that right bank floodplain connection with the area where groundwater emergence would not occur until the 10 year flood flow. During detailed design it may be desirable to increase this connection and so some right bank lowering should be included within the design and associated modelling.

Under baseline conditions, fluvial flooding downstream did not occur in this reach until the 10 year flood event, when it occurs on the right bank floodplain in a natural topographic depression and at the downstream end at the left bank riparian properties.

The outline design includes bank lowering for wetland creation, and model results indicated increased local flooding into the right bank floodplain under the 10 year and 100 year flood events. Inundation increases with the current option and is as a result of the influence of in-channel features. The increase in levels were less than 0.01 m however, and so it is considered that alteration of the features, inclusion of additional inset features (for example berms) or minor land raising as part of the detailed design, should result in no adverse effect to people or properties.

Hydromorphology

In terms of the in-channel features, the riffle-bar sequence after the mill leat junction effectively creates an area of low flow sinuosity. This is valuable as overall the planform sinuosity of this reach remains low and constrained by the Thames Water assets through the right bank floodplain.

Large woody debris structures could be used as an alternative to gravel bar formation through Reach 2. These would be stabilised through partial burying into the bed and banks of the reach, which also provides for a more natural aesthetic.

The upper half of the section is in reasonable morphological condition although the lower half is heavily silted. The current restoration results in the channel becoming slightly more energetic although there would be more apparent local improvements at the features themselves.

Three features were linked to potential bank erosion (see Figure 5.4). One of these is predicted during the 100 year flood when erosion is normally to be expected. Erosion at the other two areas, upstream, would occur under winter high flows which although erosion can be viewed positively (in that it helps create a varied habitat). Bank erosion at these locations, and through the reach in general, should be considered further during detailed design. No increased erosion should occur within the margins of the Scheduled Monument and this should be confirmed during detailed design (as advised by Historic England during consultation).

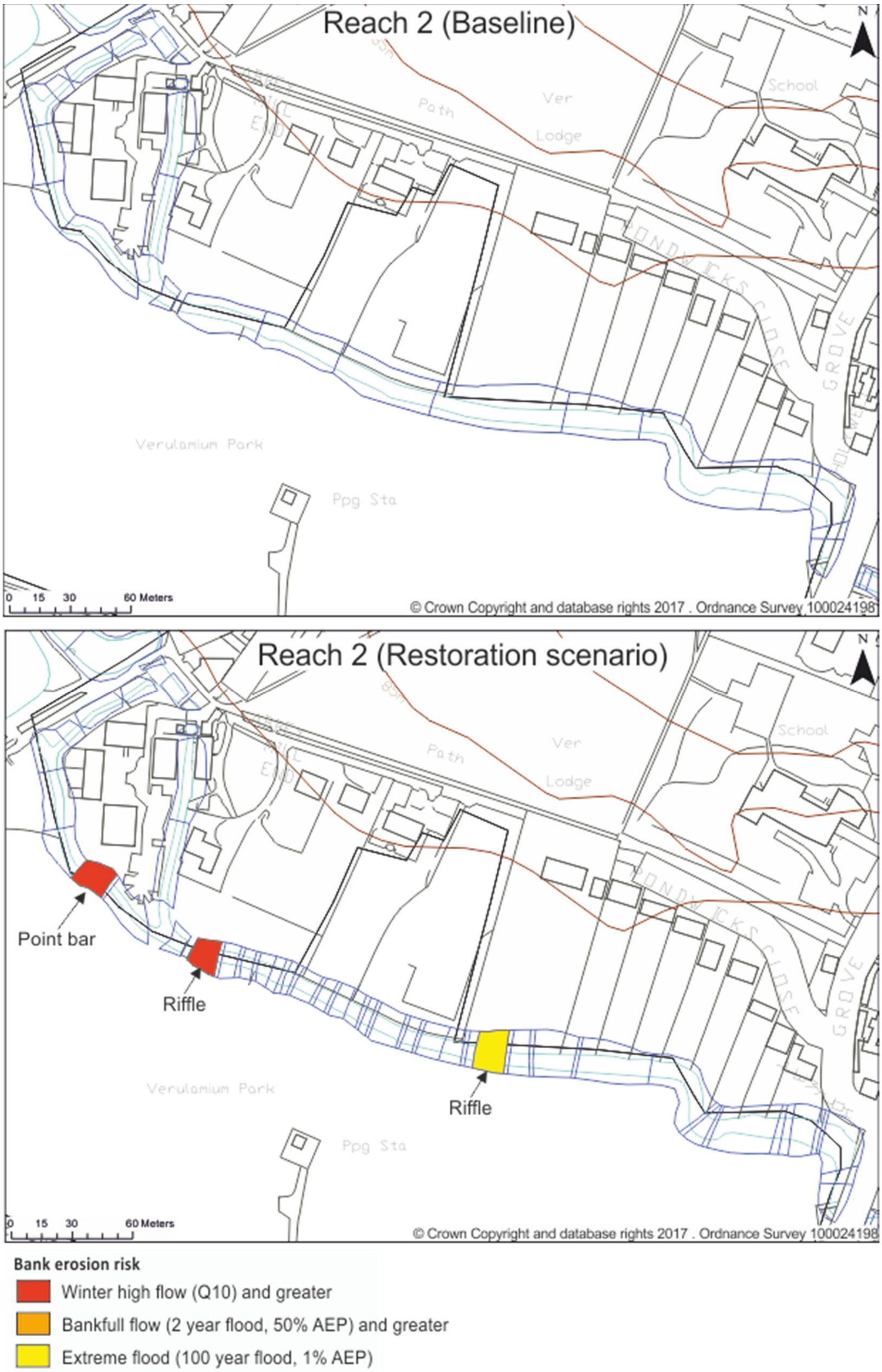


Figure 5.4 Bank erosion risk at Reach 2 under baseline and proposed restoration scenarios

Sediment transport calculations determined that winter flows would flush sand sized material through the reach, while any introduced gravel (10 mm plus width) is likely to remain stable and should not silt heavily. No gravels look likely to be supplied downstream as a result. The outline design modelling results still indicate sedimentation in the lower half of the reach (Figure 5.5) although the scheme could be reviewed during detailed design, to try to reduce sedimentation, though noting that this would need to balanced against other constraints (such as flood risk and utilities).

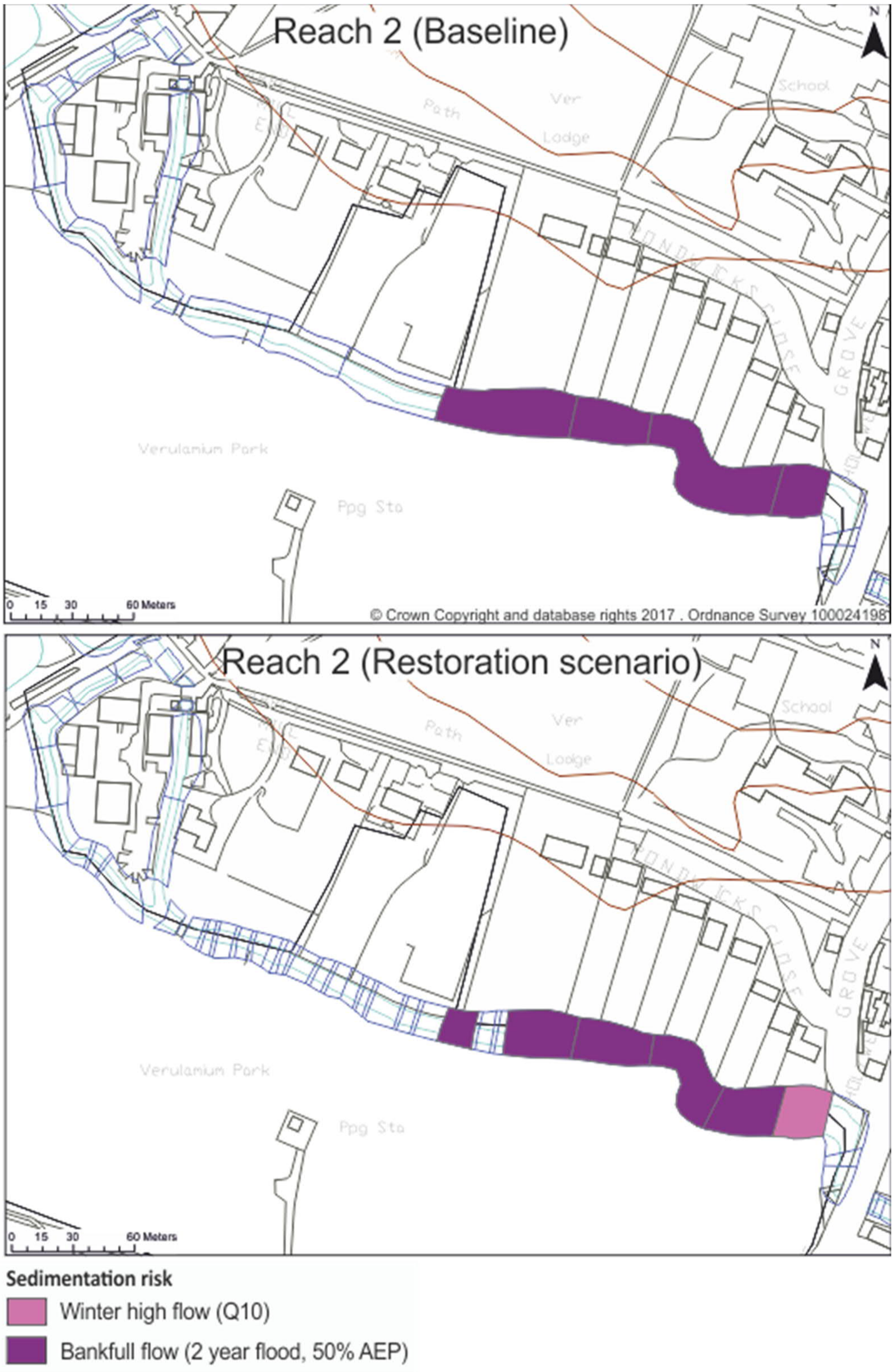


Figure 5.5 Sedimentation risk at Reach 2 under baseline and proposed restoration scenarios

Ecology

The baseline and restoration features were modelled across a range of flows ranging from summer low flow (Q_{95}), typical winter flow (Q_{10}), a bankfull flow (2 year return period) and an extreme flood (100 year return period). Figure 5.6 illustrates the change in hydraulic habitats predicted for the restored reach. The current low energy pool/glide dominated reach displays only poor habitat quality. This situation will be improved slightly following restoration with increased glide and run habitat created at the expense of pool areas. Riffle area will remain constant.

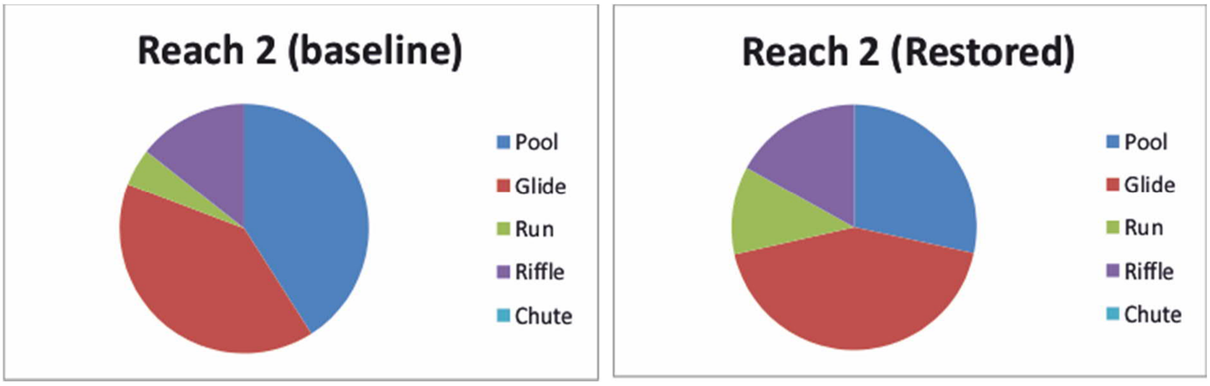


Figure 5.6 Current and restored in-channel habitats for Reach 2 on the River Ver

5.5 Engagement

Our outline proposals for Reach 2 were unveiled to the public in March 2018 at the start of a public engagement period. Engagement events were also held and members of the public were invited to fill out a survey to record their views on the Reach 2 proposals.

The survey resulted in the following positive feedback being received:

- Boardwalk would improve access to the Ver Valley Trail for walkers, pushchairs and wheelchairs.
- Not over-complicated and measures are really practical.
- Will allow the river to connect to the flood plain again.
- Will improve flow in the river.
- Improves access to river and will give a reason to visit this part of the park.
-

A number of concerns were raised, and these are indicated in Table 5.1 along with our response.

Table 5.1 Survey Concerns and Our Response

Concern	Response
Improvements to lake in Verulamium Park should resolve the issues without the need for drastic changes.	• There are several issues in the River through this Reach, and the lake improvements would not remedy these. Bank and riparian and inset reconnected floodplain creation as flood risk benefit?
Risk of increased flood risk to riparian properties in this reach. Therefore strongly oppose narrowing of the channel in this reach.	• Flood risk has been considered as part of the hydraulic modelling that was undertaken in support of the outline design. Minor changes were predicted as a result while the inclusion of bank and riparian features and reconnected floodplain provides a flood risk benefit (to people and properties). • As the design progresses to detailed design, flood risk should continue to be considered to to ensure that there would be no flood risk increase to people or properties as part of the design.
Loss of trees which currently screen riparian properties from light, noise and pollution.	• Selective tree thinning is necessary to increase the amount of natural light reaching the river. Without this, the river can't support the plants which the river ecology relies on. We will work with residents to plan which trees should be removed, pollarded or thinned to achieve better levels of light for the river whilst minimising impact to properties. We will also consider additional tree planting in the park away from the channel, in order to screen properties on the left bank of the channel through Reach 2, from light pollution.
Boardwalks are unsuitable for high visitor numbers.	• This view is noted and we anticipate that the access means are considered further and confirmed as part of the detailed design.

Concern	Response
Loss of events meadow if converted to wetland habitat.	• Groundwater emergence in the proposed wetland area is expected by 2024 and the plans account for expected changes by sustainably using the area where more frequent inundation is expected. The proposals offer a positive solution for people and wildlife. St Albans City and District Council own the land and support the proposals.
Threats to chalk stream habitats and wildlife with increased public access to the river.	• This is noted although the plans would not necessarily result in greater access to the river but encourage them to the riparian area. Access at specified locations can be considered further during detailed design.
Concerns over the water flow around the Abbey Mills Development, particularly in the Mill Stream.	• Hydraulic modelling associated with the Reach 1 plans indicated that flow in the Mill Stream would not be affected.
How the silt will be removed.	• This will be confirmed during detailed design and any necessary permissions will be gained in advance of any silt being removed.
The river is only 25 - 40 cm deep. Concerns over river drying up when there is prolonged drought. If this happens, unclear how water will then be sourced.	• The proposed modifications would make the River Ver more resilient to the effects of drought (for example channel narrowing would result in water levels being increased).

Historic England were also consulted on the scheme. They raised no objections to the proposals although raised concern if any of the measures inadvertently lead to erosion of banks within the scheduled monument or areas of archaeological significance. As discussed in Section 5.4.2 this should be avoided and should be investigated through the detailed design. They also advised that any ground disturbance or sediment depositing within the scheduled monument is likely to require scheduled monument consent to be obtained and further advice should be sought from Historic England when the options have been agreed.

Herts and Middlesex Wildlife Trust were consulted and were supportive of the scheme to improve the Ver's morphology, wildlife and amenity value.

In addition to the survey further engagement responses were received. These are summarised in Table 5.2 along with our responses.

Table 5.2 Other Engagement Feedback and Our Response

Concern	Response	Next Steps/ Further Work
Tree thinning	• As a rule of thumb, chalk streams need about 70% light to 30% dappled shade to support the habitats and wildlife that they are so well known for. The river through this reach is heavily shaded and some selective tree thinning may be necessary to increase the amount of natural light reaching the river. Without this, the river can't support the plants which the river ecology relies on.	• We will work with residents to plan which trees could be removed, pollarded or thinned to achieve better levels of light for the river whilst minimising impact to properties. • Additional tree planting in the park away from the channel, to replace trees and screen properties from light pollution, is also now included within the outline plans.
Wetland creation	• The area of upstream wetland is already wet most winters and will become wetter more often as a result of the future abstraction reductions. The proposals look to create a new amenity feature and a valuable area for wildlife. • Lowering banks and creating the downstream wetland area was included to encourage water away from the gardens on the left hand bank during high flows.	• We will engage with residents in this area through detailed designs.

Concern	Response	Next Steps/ Further Work
Channel narrowing	• One of the methods that we would consider to narrow the river is to create a two-stage channel. We would do this by creating berms. These are low-level vegetated shelves at the river banks. Berms have the effect of narrowing the channel at low and normal flows while higher flows will spill over onto the berms and fill the overall channel width. This creates a diversity of depths and flow types. It also provides the river ecology with more resilience in low flow conditions as a greater depth of water and flow diversity can be maintained within a narrower channel, providing refuge for fish, invertebrates etc. The marginal berms will offer key riparian habitat along the river and will be of great benefit to wildlife but will also maintain a barrier to properties adjacent to the park.	• We will engage with residents in this area through detailed designs.

5.6 Final Outline Reach 2 Plans

Following engagement we have revised the plans for Reach 2. The final outline restoration plans for Reach 2 are provided in Figure 5.7.

An Outline Environmental Appraisal of the option has also been undertaken to not only identify the benefits of the restoration but to also provide an initial indication as to where further work during detailed design and/ or mitigation is required. The appraisal assumes that all best practice, such as Pollution Prevention Guidelines and Working in Water methods are adhered to and standard ecological surveys and resultant mitigation would be undertaken, and during construction. The appraisal is included as Table 5.3.

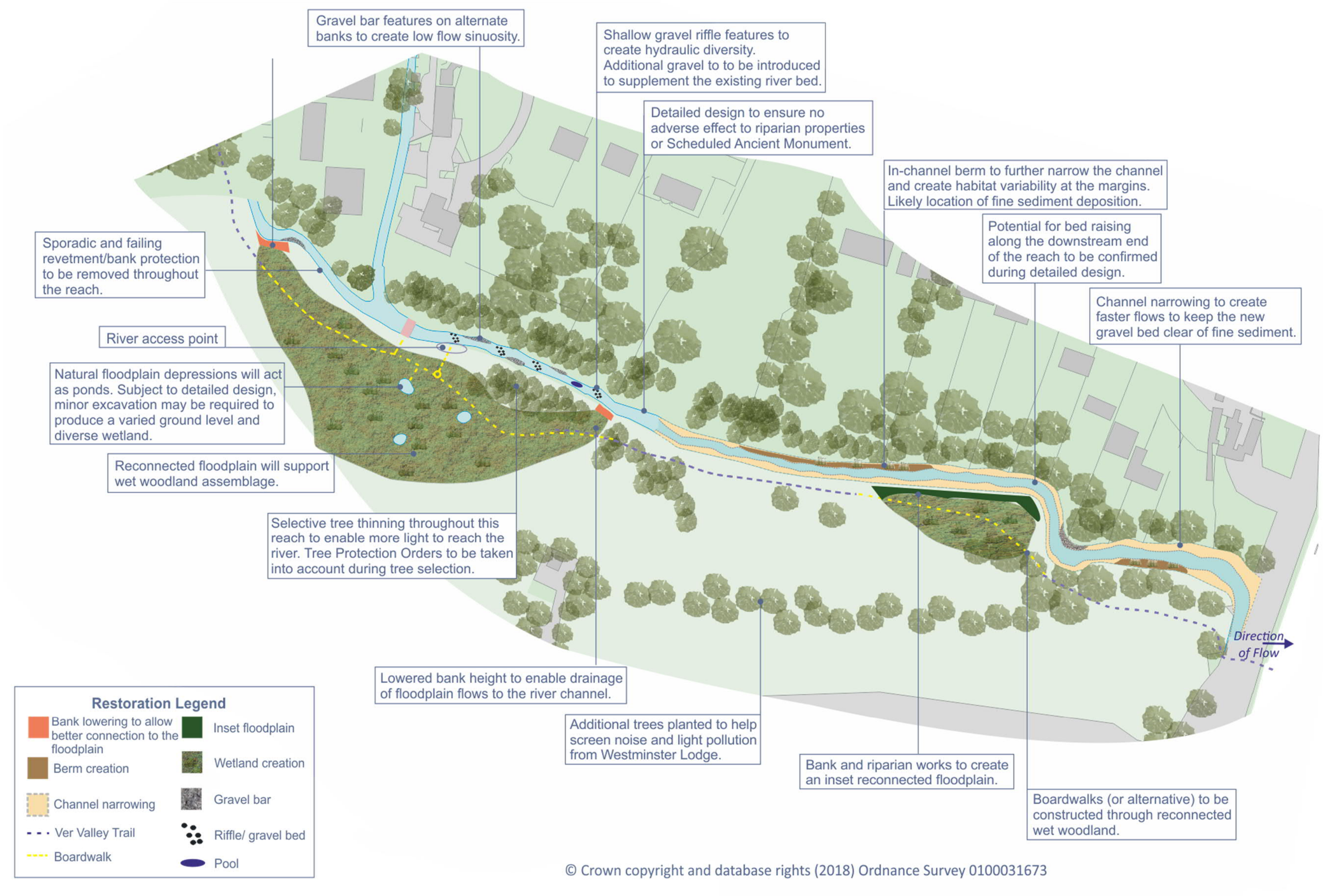


Figure 5.7 Reach 2 Final Outline Proposal Plan (post engagement)

Table 5.3 Outline Environmental Appraisal of the Reach 2 Preferred Option

Resource/ Feature	Overview	Effect or Potential Effect of Scenario	Potential Mitigation	Likely Significance
Hydrogeology/ Groundwater connectivity	Does the scheme affect connectivity between surface water and groundwater?	• There are unlikely to be any significant improvements to the existing groundwater connectivity as a result of the proposed morphological works associated with this option although groundwater emergence, as a result of the sustainability reductions, should improve connectivity. • Proposed wetland would primarily be sourced by groundwater that is predicted to rise in that area, with increasing groundwater emergence expected to increase the duration that the park is waterlogged. Further excavations would result in a varied wetland community developing.	• Groundwater monitoring should be undertaken to improve the hydrogeological understanding and inform the detailed design.	• Beneficial
Geo-environmental	Does the scheme potentially result in a new pathway for contaminants to enter the river?	• The floodplain works, in terms of land take, would occur through an area that was formerly agricultural land. This may provide a direct route for contaminants to be introduced into the river, noting that they would previously have had an indirect route (via runoff).	• A soil sampling strategy should be devised and enacted during the detailed design to confirm any risk and what mitigation should be undertaken, if any.	• With inclusion of suitable mitigation there would be a neutral effect.
Flood Risk	Does the scheme result in an increase of decrease in flood risk to people and properties?	• Flood risk has been considered as part of the hydraulic modelling that was undertaken in support of the outline design. Small increases were predicted to the gardens of riparian properties on the left bank.	• As part of detailed design is it likely that the scheme will be refined and retested. Revised schemes should be hydraulically modelling and flood risk should be assessed throughout, to ensure that there is no increase in flood risk to people or properties as part of the works.	• Neutral
Other hydrology	Does the scheme result in other changes to the hydrology that could impact upon other water users or receptors?	• Hydrology through this reach unaffected by the proposed restoration in Reach 2, or up-stream (including no effect to flow in the mill leat around the Ye Old Fighting Cock (PH)). • No surface water abstractions in this reach and so no effect of the scheme on these.	• None required	• Neutral
Hydromorphology	Does the scheme improve the hydromorphological functioning of the reach?	• Incorporation of an appropriate morphology would help to reduce the tendency for fine sediment deposition on the gravel bed and increase the hydraulic habitat diversity through the reach with a greater quantity of higher energy riffle units.	• Hydromorphological gains should continue to be sought from the scheme as detailed design progresses. • Any increased erosion should be kept to appropriate levels and outside of Scheduled Monument	• Beneficial (Moderate or Major if more significant improvements can be determined through detailed design)
Water quality	Does the scheme result in a deterioration or improvement of water quality, for example less flow would result in less dilution of consented discharges?	• There are no consented discharges in this reach and there would be no changes as a result of this option. • Riparian planting and hydromorphological improvements should help improve general water quality through the reach.	• None required	• Beneficial
Statutory Sites or Non-statutory Designated Sites	Does the scheme affect designated and or wildlife sites?	• There are no designated or Local Wildlife Sites in this reach and so this option would not impact upon them.	• n/a	• n/a
Other Biodiversity	Wildlife can be impacted during construction while scheme may result in positive, neutral or negative effects to species.	• Scheme would result in an improvement to the health of the river and provide additional habitats	• None required	• Beneficial
Heritage	Does the scheme potentially impact upon Scheduled Monuments or other archaeological features?	• Scheme should be designed to avoid the possible medieval bridge of low heritage significance and would require archaeological mitigation. • Detailed design should confirm that • Costs may be high if remains are found during the works.	• Detailed design should continue to suitably account for Heritage, for example not result in excessive excavation to areas of archaeological significance. • A Heritage officer with a Watching Brief during the works is anticipated.	• Neutral/ minor adverse
Tree Protection Orders (TPO)	Consideration of the effect of Tree Protection Orders on the option	• TPOs are extensive on the left (north) bank through the upper half of this reach. The option is unlikely to impact upon the works being undertaken within the existing channel or to the south of it apart from if these trees are overhanging the river channel substantially.	• Tree thinning will need to be carefully considered to avoid impacting trees that have a TPO. • We will work with others to plan which trees could be removed, pollarded or thinned to achieve better levels of light for the river whilst minimise any impacts to properties.	• Neutral/ minor adverse
Landscape impact	Does the option have a significant visual impact?	• The option should result in a slightly improved looking river.	• None required	• Beneficial
Recreation and amenity	Does the option have significant impacts upon recreation and/ or amenity	• Floodplain reconnection would result in a minor loss of recreational ground although the recreational value of this land may have been lost due to groundwater emergence in this	• Public access needs to be planned thoroughly to allow people to access nature in a way that	• Beneficial

		area as a result of sustainability reductions planned by Affinity Water. • Proposed that the inclusion of a wetland area, and more formal access (boardwalks or similar) would increase the amenity value of the area and increase the public's connection with the River Ver.	is sympathetic to wildlife whilst enabling learning and engagement experiences. This may include some access restrictions in sections that contain higher wildlife value. This should be considered through the detailed design.	
Riparian ownership issues	Does the option affect properties?	• There are a few owners of the riparian area to the north of the river through this reach. The option would not result in a re-alignment of the river through the north of the river and so no significant or prohibitive impacts are anticipated. • Channel works have the potential to affect flooding close to the river.	• See response regarding flood risk, described above.	• As above
Construction only				
Water Mains and Sewers (foul and surface water)	Consideration of the potential effect of these on buildability of the scheme.	• Affinity Water mains are located at lower end of Reach 1/ start of Reach 2. These would not be impacted by this option. They also have mains further down the reach. Works are upstream of these and so the mains are unlikely to be impacted by the works, assuming the mains are at least 1m bgl. A trial hole may be required to establish depth. • There are two Thames Water foul sewers that extend along the reach approximately 20m south of the river. These are at depths of between 1.5 m and 3.5 m bgl. The floodplain works may potentially cross these sewers, requiring works to mitigate this risk (such as bed protection) and / or need to be avoided by the floodplain works (impacting upon the benefit of the scheme).	• Utilities should be considered through the detailed design and should be suitably accounted for during any construction works. • Thames Water may insist on no excavation works with 10m of their sewer .and have indicated that sewer may also be in a slightly different location to what is shown on their mapping. Early consultation with Thames water is recommended. They are also likely to ask for CCTV survey before and after the works to prove that the integrity of the sewer has not been compromised by the works. • Further surveys are recommended.	• Neutral
Other Utilities	Consideration of the potential effect of these on buildability of the scheme.	• There is a below ground electricity line noted as a 'Private Line' at the lower end of the reach –details on the line status are unavailable (further investigation would be required). The presence of this may impact upon the amount of floodplain works that are undertaken near the line. • There are no other utilities near the area that would be restored under this option		• Neutral
Pedestrian access	Consideration of the potential need for footpaths to be diverted. For example Public Rights of Way may need to be re-routed if works are planned over their route.	• Works would occur downstream of causeway, beyond which the nearest public right of way is around 100m from the works. As such the option would not affect public rights of way.	• None regarding Public Rights of Way although the Ver Valley Trail, a recreational route, will be affected by the works during construction and should be diverted.	• Neutral
Access	Consideration of access to the works area. Access may be difficult and even prohibitively expensive under certain circumstances	• Access for works likely to come from the south of Reach 2 and be relatively straightforward. Not considered to be prohibitive.	• Access should be determined during detailed design and confirmed by the contractor delivering the works. • Traffic management order may be required.	• Neutral

5.7 Reach 2 Next Steps

5.7.1 Detailed design

The detailed design will need to examine the following:

- A screening opinion from the local authority should be sought as to whether an EIA would be required. The topics for consideration during detailed design should also be confirmed.
- Undertake groundwater monitoring to improve the understanding as to the extent of groundwater emergence that is expected through Reach 2. This would help inform the design of the wetland area.
- New habitat, such as the wetland, should be determined that consider the site conditions (soil type etc.) and anticipated levels of inundation. The choice of species should reference the Herts Habitat Inventory (held by HMWT Records Office) to create a section of Living Landscape in St Albans. A planting plan for the riparian/ floodplain and wetland areas should ultimately be developed.
- Modelling for the outline design has demonstrated hydraulic habitat diversity and functionality of the River Ver is improved through Reach 2. Detailed design, and associated modelling, should iterate the design to further improve the functioning of the restoration features to ensure they deliver maximum benefits. The modelling should acknowledge the effect of the sustainability reductions on groundwater and flow.
- Construction methods should be considered further during detailed design and discussed with riparian owners.
- We will work with residents to plan which trees could be removed, pollarded or thinned to achieve better levels of light for the river whilst minimising impact to properties.
- Further Heritage assessment would be needed as the detailed design progress and scheme is refined. A watching brief during any works is likely to be required.
- An access plan should be developed. This should include how public and their pets can interact with the river, for example at controlled access points, and access through the wetland area.
- Long term maintenance of the scheme should be considered as part of the detailed design. For example, the design life of boardwalks may be of the order of 10 years and a more sustainable option may be appropriate.
- A tree planting plan for the south eastern corner of the park should be developed to screen/ block out lights and noise from Westminster lodge.
- Produce detailed design drawings that can be used for construction.

THE PREFERRED OPTION FOR REACH 3

06

6. The Preferred Option for Reach 3

6.1 Overview

Reach 3 covers the River Ver from Holywell Hill to the start of Cottonmill Allotments (see Figure 6.1 below).

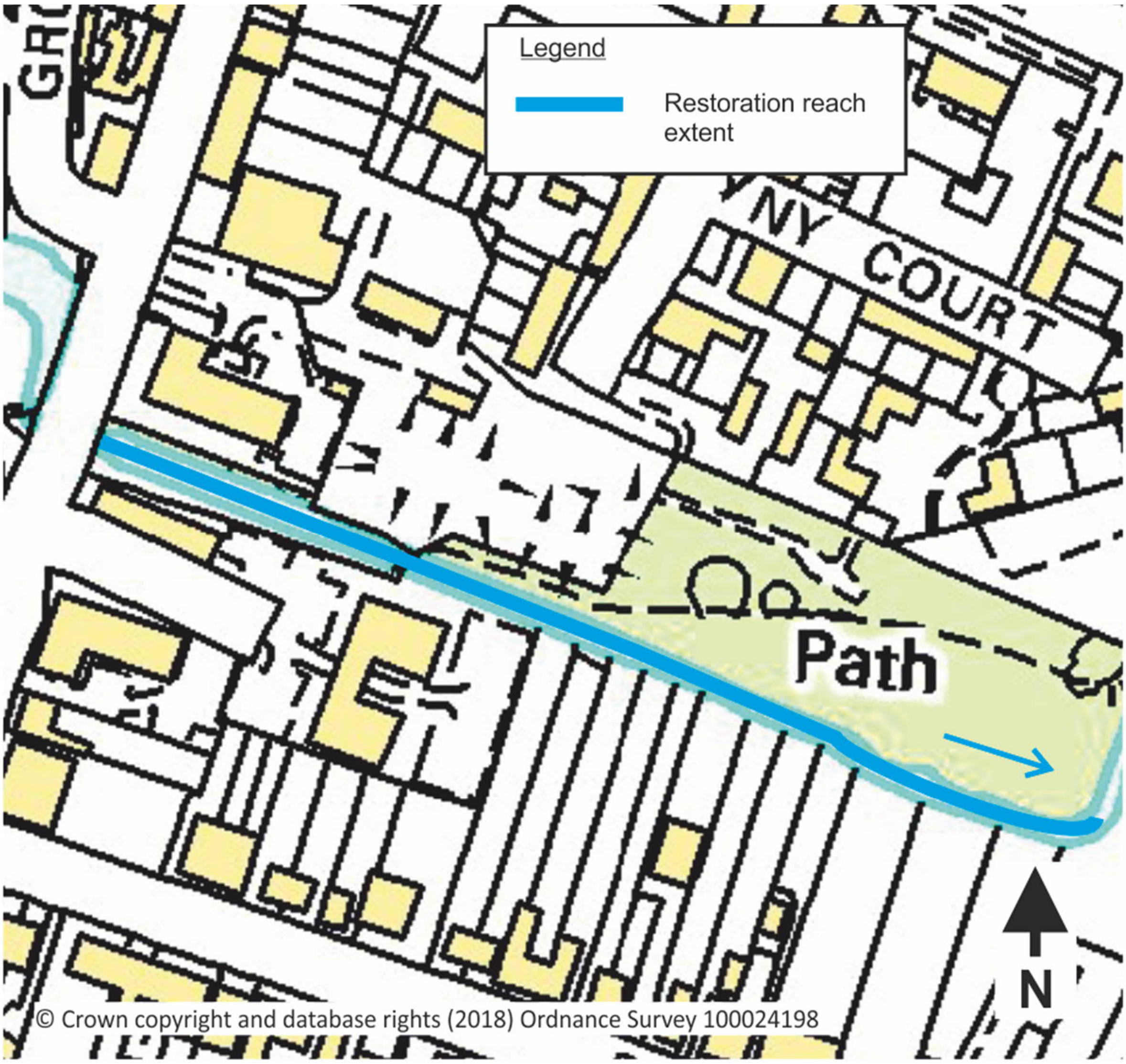


Figure 6.1 Reach 3 of the study area (From Holywell Hill to Cottonmill Lane Allotments)

In this reach the River Ver has a straight, over-wide channel, constrained by properties to the south and woodland to the north. The channel is very heavily shaded by trees over the entire reach, which limits aquatic and marginal plant growth. The river is in a poor condition and shows very few chalk stream characteristics. Access along the river is uneven and very narrow in places.

Current levels of groundwater abstraction from the underlying chalk aquifer are planned to be reduced in 2024 This will return the groundwater table and river flows to more natural levels. As a result, some of the low-lying areas in the woodland that are already boggy and marshy for some of the time, will become wetter more often.

Our proposed plans will significantly improve the river habitat and offer improvements to access and amenity along with accommodating the upcoming changes as a result of the abstraction reductions.

6.2 Issues in Reach 3

The river in Reach 3 is very straight and suffers from a range of issues which compromise habitat quality and diversity. Little in the way of characteristic chalk stream features can be seen and the value of the river for wildlife is low as a result. The issues with this reach are:

- Over-wide and straight – all through this reach the river is too wide and unnaturally straight, which slows the flow.
- Low flows – due to abstraction pressure.
- Silty – due to the above factors, the gravel river bed is smothered in silt in many places.
- Lack of habitat and flow diversity – the river habitat is all very similar and degraded in nature which severely limits the wildlife it can support.
- Heavy shading – trees line the banks of the river for all of this reach and the resulting heavy shade blocks light to the river and restricts plant growth.
- Bank protection – there is piecemeal concrete bank protection through this reach.
- Groundwater re-emergence – it is likely that some areas of the woodland to the north of the channel will become wetter more often as a result of planned abstraction reductions.

Restoration in this design should account for each of these issues and result in the project objectives being achieved. Further information on the river issues is provided in Appendix A.

Figure 6.2 presents a visual summary of the issues within Reach 3.

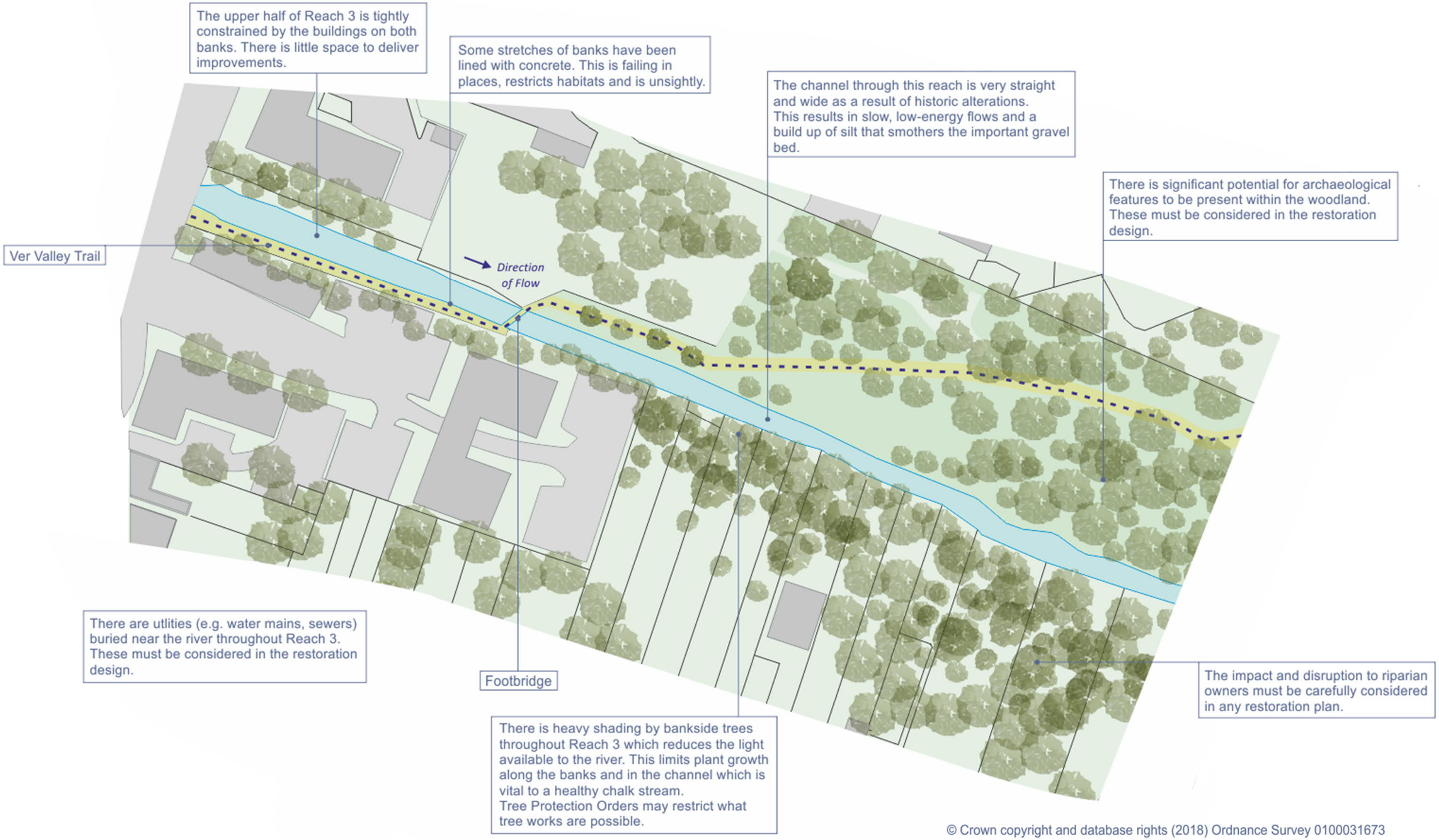


Figure 6.2 Reach 3 Issues and Constraints Overview

6.3 Derivation of the Preferred Option for Reach 3

6.3.1 Long Listing and Short-listing Appraisal

Full results of the long listing and short-listing appraisal of Reach 3 options is included within Appendix M. The appraisals considered the issues indicated in Section 6.3 and constraints identified in Section 3.10.

At the start of the project, we developed four potential restoration options for Reach 3 which we then assessed as part of the long list appraisal. Following this, two of the options that were longlisted were in turn shortlisted. These were:

- Option 2 Re-alignment of the downstream half of the river channel through the woodland to the north. Pond creation in the woodland

- Option 4 Maintain the existing river course and improve the channel.

Both were examined as part of the detailed short list appraisal. The decision we reached was to take forward option 4.

Although option 2 offered slightly greater potential for improvements to the river, the existing ecological value of the woodland area and could have been too severely affected. It was also considered that most of the benefits to the river could be achieved through works within the current channel extent, so option 4 still offered a positive environmental outcome.

The preferred option for Reach 3 (option 4) is discussed further below.

6.4 The Preferred Option for Reach 3

6.4.1 Option description

The Reach 3 preferred option/ outline proposals, prior to engagement, are summarised in Figure 6.3.

Our proposals will dramatically improve the state of the river through this reach. By narrowing the channel, installing in-channel features and letting more light into the channel we can expect a much more natural looking and healthy chalk stream. Another key improvement will be to improve the degraded path to allow better access.

Option 4 retains the current course of the river but creates in-channel flow diversity through restoration of natural channel features. It also narrows the over-wide river channel to enable faster river flows to keep the gravel bed free of silt. Selective tree works will be carried out to increase light levels reaching the river to encourage marginal and in-channel plants to establish. It also includes floodplain reconnection to the north and the creation of wet woodland in the area of groundwater emergence. Improvements to the Ver Valley Trail, including the footbridge, are also included within this option.

The following outlines the rationale for the features that were included within the outline design (shown in Figure 6.3). Reach 3 is a low to moderate gradient reach with low sinuosity, the gradient is steep enough to support functional riffles and inset berm/riparian features have been used to increase the low flow variability and concentrate flow diversifying the hydraulic habitat. Sediment supply is too low to allow these to develop naturally, hence they will have to be constructed. The likely sequence would be plane bed-riffle; however, diversity can be enhanced by constructing occasional pools. Floodplain enhancement is possible through the development of a wet woodland or wetland reintroducing more appropriate species. This will be enhanced through the anticipated increased groundwater emergence on the left bank.

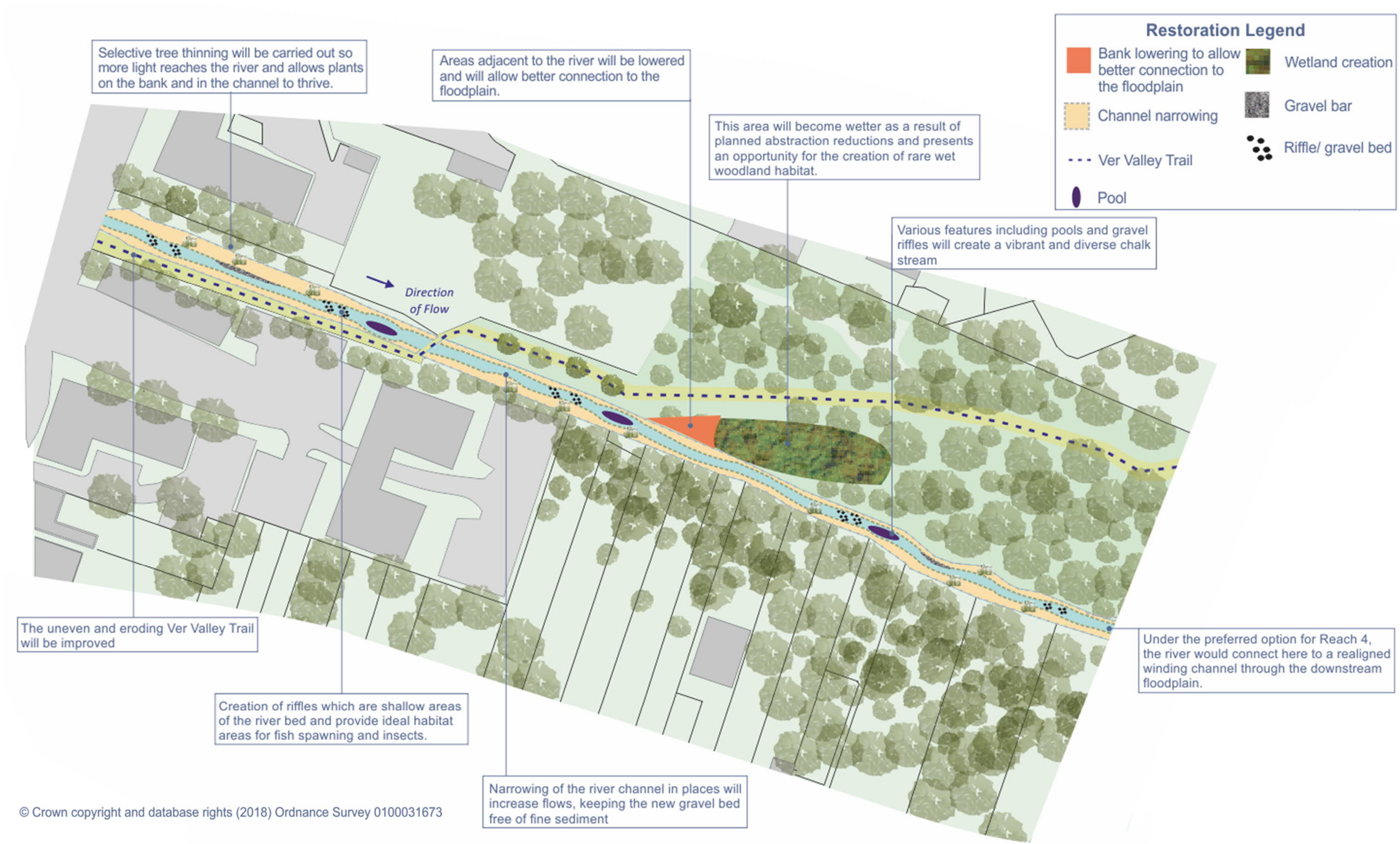


Figure 6.3 Reach 3 Preferred Option/ Outline Proposals (prior to engagement)

6.4.2 Summary of the Proposed Option Modelling

Hydraulic modelling was undertaken to refine the restoration features that were included in the design and determine the potential hydrological, hydromorphological and ecological effects of the preferred river restoration option. Full results of the modelling are included within Appendix D. A summary of the effects is provided below.

Hydrology

No changes to the amount of flow in the river are predicted as a result of the restoration.

Flood risk modelling indicates a minor increase to flood risk to right bank gardens of riparian properties at the downstream end of the reach. This is likely due to local restoration features and the placement and nature of these should be varied during detailed design. Similarly, inclusion of raised land between the affected garden and rivers may be sufficient to remove the increased risk and should be considered during detailed design.

Hydromorphology

Modelling results indicated there was no risk of sedimentation through Reach 3 under baseline or the proposed restoration scenario.

Bank erosion looks likely at several of the riffle and point bars features (Figure 6.3). This was not considered to be excessive and should be seen as a positive aspect of the restoration maintaining important and rare clean bank habitat on the river. This should be considered through detailed design to ensure that the final scheme does any areas at risk of bank erosion are suitably located and excessive erosion is not predicted.

Figure 6.3 Bank erosion risk at Reach 3 under baseline and proposed restoration scenarios

River Habitats

Figure 6.4 suggests that Reach 3 is presently in a recovering state with a high percentage and diversity of glide, run and riffle habitat and this is reflected on the ground in a more diverse channel. The proposed restoration measures further enhance this using the gradient through the reach by increasing high energy flow areas that are lacking along the wider watercourse resulting in a more varied habitat.

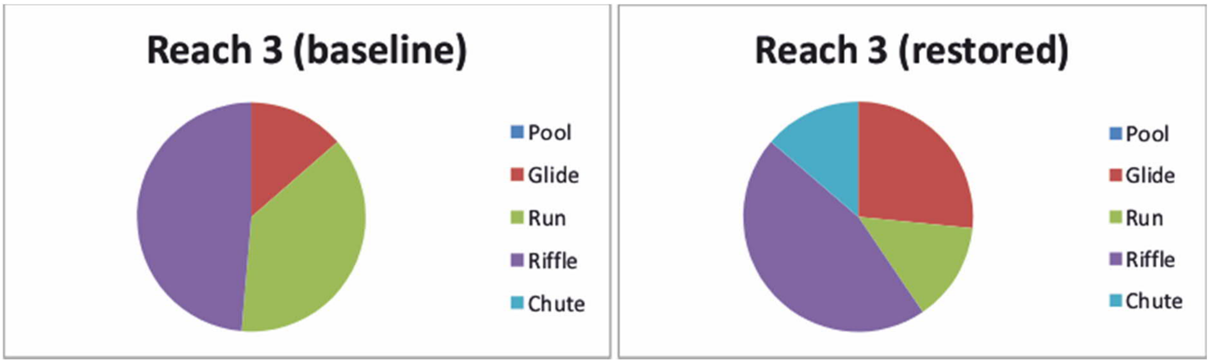


Figure 6.4 Current and restored in-channel habitats for Reach 3 on the River Ver

6.5 Engagement

Our outline proposals for Reach 3 were unveiled to the public in March 2018 at the start of a public engagement period. Events were also held during engagement and members of the public were invited to fill out a survey to record their views on the Reach 3 proposals.

The survey resulted in the following positive feedback being received:

- Creation of new wetland area.
- Benefits to habitats and wildlife.
- Some thinning of tree canopy.
- Improvements to Ver Valley Trail.

A number of concerns were raised, and these are indicated in Table 6.1 along with our response.

Table 6.1 Survey Concerns and Our Response

<table>
<tr><th>Concern</th><th>Response</th></tr>
<tr><td>Clearance of trees and vegetation on the north bank for new wetland. This would also destroy the current privacy of landowners along this stretch.</td><td>• Process for creating the wetland would be clarified during the detailed design. Wetland could form relatively naturally as groundwater emergence occurs or be facilitated in its creation, for example through some limited clearing and planting. Limited effects to privacy are anticipated as trees between the existing path and homes to the north unlikely to be affected.</td></tr>
<tr><td>On the south side of the river, it is not clear from the proposals how any proposed changes to the south bank of the river would be negotiated with riparian owners.</td><td rowspan="2">• Modelling of the outline design predicted some bank erosion in a few locations and increased flood risk to the gardens under extreme flow events (with shallow flooding).
• As the design progresses to detailed design, erosion and flood risk should be determined to ensure that there would be increase in flood risk to people or properties as part of the design.
• We will engage with riparian owners through the detailed design process.</td></tr>
<tr><td>Increased risk of flooding of riparian properties in this reach, especially by narrowing the river channel.</td></tr>
<tr><td>How the river channel will actually be narrowed - concrete banks or graduated natural banking?</td><td>• Concrete would not be used to narrow the channels. Final channel narrowing methods should be investigated during detailed design and confirmed by the contractor, in advance of construction.</td></tr>
<tr><td>Existing footpath being moved closer to residential properties on the other side of the river.</td><td>• No change to footpath position is proposed although would be considered further as part of the detailed design. Improvements to the footpath are recommended including levelling it off and replacing the surface with binding materials, that would not be washed into the river.</td></tr>
</table>

Historic England were also consulted and raised no concerns with the proposals.

Herts and Middlesex Wildlife Trust were consulted and were supportive of the scheme to improve the Ver's morphology, wildlife and amenity value. They recommended using binding materials for the footpaths through this reach, so that these would not be washed into the river.

6.6 Final Outline Reach 3 Plans

Following engagement we have revised the plans for Reach 3. The final outline restoration plans for Reach 3 are provided in Figure 6.4.

An Outline Environmental Appraisal of the option has also been undertaken to not only identify the benefits of the restoration but also provide an initial indication as to where further work during detailed design and/ or mitigation is required. The appraisal assumes that all best practice, such as Pollution Prevention Guidelines and Working in Water methods are adhered to and standard ecological surveys and resultant mitigation would be undertaken, and during construction. The appraisal is included as Table 6.2.

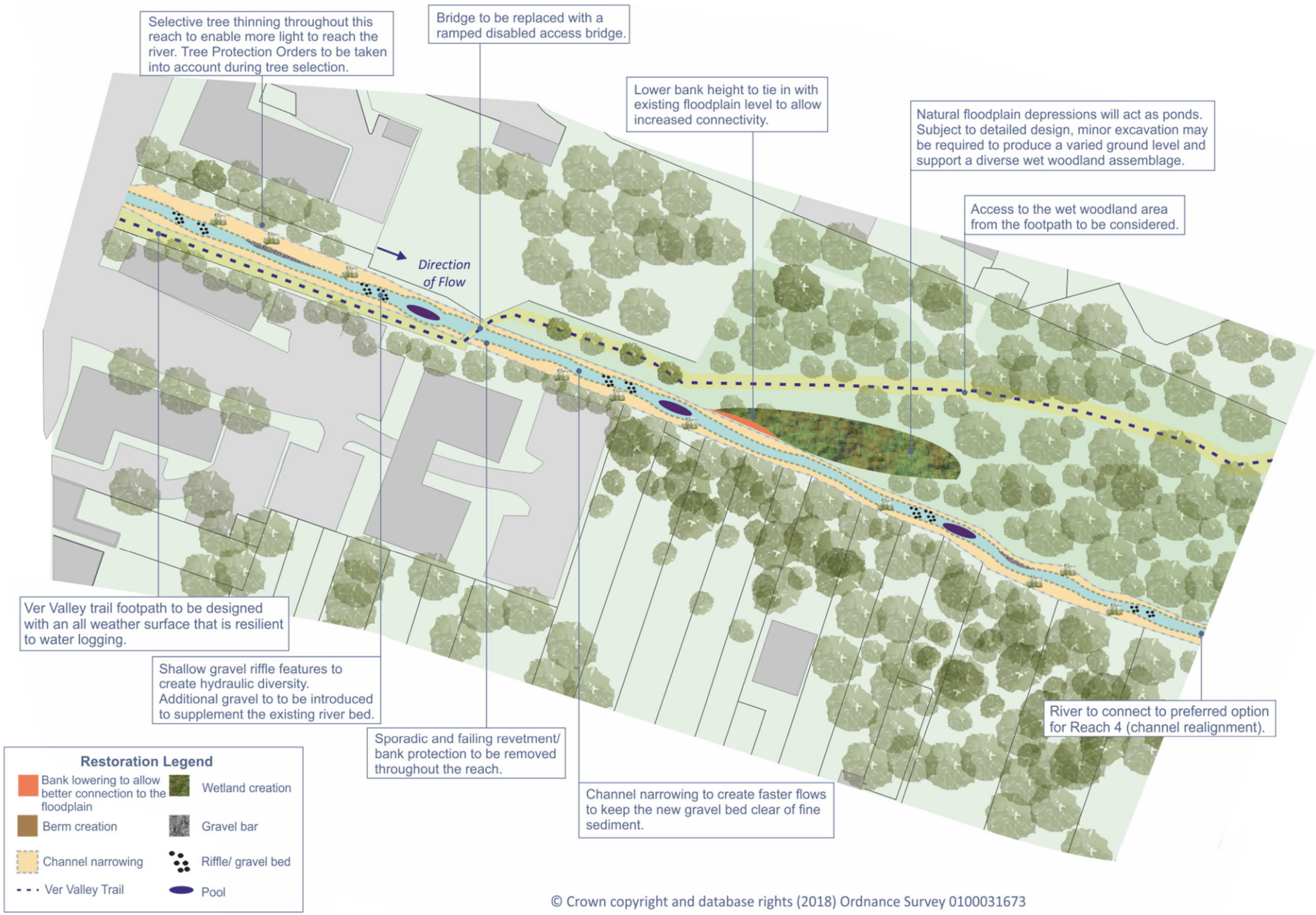


Figure 6.4 Reach 3 Final Outline Proposal Plan (post engagement)

Table 6.2 Outline Environmental Appraisal of the Reach 3 Preferred Option

Resource/ Feature	Overview	Effect or Potential Effect of Scenario	Potential Mitigation	Likely Significance
Hydrogeology/ Groundwater connectivity	Does the scheme affect connectivity between surface water and groundwater?	• There are unlikely to be any significant improvements to the existing groundwater connectivity because of the proposed morphological works associated with this option although groundwater emergence, as a result of the sustainability reductions, should improve connectivity. • Proposed wetland would primarily be sourced by groundwater that is predicted to rise in that area, with increasing groundwater emergence expected to increase the duration that the park is waterlogged. Further excavations would result in a varied wetland community developing.	• None required	• Beneficial
Geo-environmental	Does the scheme potentially result in a new pathway for contaminants to enter the river?	• The river is not re-aligned through areas identified as being potentially contaminated. Such areas are also unlikely to be encompassed during construction works too.	• A soil sampling strategy should be devised and enacted during the detailed design to confirm no risk. If risk is found, then suitable mitigation should be undertaken.	• Neutral
Flood Risk	Does the scheme result in an increase of decrease in flood risk to people and properties?	• Increased flood risk to the right bank gardens at the downstream end of the reach and this would be shallow even under extreme events. However, any increase in flood risk to properties is not considered suitable and so the design will need to be iterated to remove this risk.	• As part of detailed design is it likely that the scheme will be refined and iterated. Revised schemes should be hydraulically modelling, and flood risk should be assessed throughout, to ensure that there is no increase in flood risk to people or properties as part of the works. Minor mitigation, should as localised land raising can be included as part of the scheme to ensure that this occurs.	• Neutral
Other hydrology	Does the scheme result in other changes to the hydrology that could impact upon other water users or receptors?	• Hydrology through this reach unaffected by the proposed restoration in Reach 3, or upstream. • No surface water abstractions in this reach and so no effect of the scheme on these.	• None required	• Neutral
Hydromorphology	Does the scheme improve the hydromorphological functioning of the reach?	• Incorporation of an appropriate morphology and associated narrowing shown would help to reduce the tendency for fine sediment deposition on the gravel bed and increase the hydraulic habitat diversity through the reach with a greater quantity of higher energy riffle units.	• Hydromorphological gains should continue to be sought from the scheme as detailed design progresses.	• Beneficial
Water quality	Does the scheme result in a deterioration or improvement of water quality, for example less flow would result in less dilution of consented discharges?	• There are two consented discharges at the end of this reach. These belong to Affinity Water and are linked to their groundwater abstractions in St Albans. As such they are likely to of good water quality. The option would not impact upon the hydrology within this reach and so, or their effect on water quality, would not be impacted by the scheme. • Riparian planting and hydromorphological improvements should help improve general water quality through the reach.	• None required	• Beneficial
Statutory Sites or Non-Statutory Designated Sites	Does the scheme affect designated and or wildlife sites?	• There are no designated or Local Wildlife Sites in this reach and so this option would not impact upon them.	• n/a	• n/a
Other Biodiversity	Wildlife can be impacted during construction while scheme may result in positive, neutral or negative effects to species.	• Scheme would result in an improvement to the health of the river and provide additional habitats	• None required	• Beneficial
Heritage	Does the scheme potentially impact upon Scheduled Monuments or other archaeological features?	• The option is unlikely to have a significant effect of features of archaeological importance.	• Detailed design should continue to suitably account for Heritage, for example not result in excessive excavation to areas of archaeological significance. • A Heritage officer with a Watching Brief during the works is anticipated.	• Neutral/ minor adverse
Tree Protection Orders (TPO)	Consideration of the effect of Tree Protection Orders on the option	• A number of TPOs are present in the wooded area where the works are proposed although not within footprint of where restoration is proposed. The TPOs may impact upon construction and access although not on the scheme itself.	• Tree thinning will need to be carefully considered to avoid impacting trees that have a TPO. • We will work with others to plan which trees could be removed, pollarded or thinned to achieve better levels of light for the river whilst minimise any impacts to properties.	• Neutral

Landscape impact	Does the option have a significant visual impact?	• River works associated with this option are unlikely to have any significant landscape effects.	• None required	• Neutral
Recreation and amenity	Does the option have significant impacts upon recreation and/ or amenity	• River works associated with this option will improve the access route to the river.	• Public access needs to be planned thoroughly to allow people to access nature in a way that is sympathetic to wildlife whilst enabling learning and engagement experiences. This may include some access restrictions in sections that contain higher wildlife value. This should be considered through the detailed design.	• Beneficial
Riparian ownership issues	Does the option affect properties?	• St Albans City and District Council and Affinity Water are the riparian owners of the wooded area where the works are proposed. • Some localised bank erosion (providing varied habitat for wildlife) may occur although this can be considered further during detailed design.	• Further hydraulic modelling would be needed in support of the detailed design. • Riparian owners should be consulted over the precise locations of features and their localised effects, to confirm the design in advance of it being constructed.	• Neutral
Construction only				
Water Mains and Sewers (foul and surface water)	Consideration of the potential effect of these on buildability of the scheme.	• Affinity Water mains are located at start of Reach 3. The proposed works would occur close downstream of these and they should be accounted for during construction. • There is a Thames Water foul sewer (depth approximately 2.9m bgl) that extends along this reach to the north of the existing river. The proposed works would not impact upon the pipeline directly although it should be accounted for during construction.	• Utilities should be considered through the detailed design and should be suitably accounted for during any construction works. • Thames Water may insist on no excavation works with 10m of their sewer .and have indicated that sewer may also be in a slightly different location to what is shown on their mapping. Early consultation with Thames water is recommended. They are also likely to ask for CCTV survey before and after the works to prove that the integrity of the sewer has not been compromised by the works. • Further surveys are recommended.	• Neutral
Other Utilities	Consideration of the potential effect of these on buildability of the scheme.	• There are below ground electricity line that extend through the upper half of the reach and cross the river close to the footbridge. The depth of this would need to be established and the line may impact upon construction costs and require mitigation. • There are a number of other utilities at the top of the reach. The proposed works would occur close downstream of these and they should be accounted for during construction.		• Neutral
Pedestrian access	Consideration of the potential need for footpaths to be diverted. For example Public Rights of Way may need to be re-routed if works are planned over their route.	• No public rights of way in vicinity of the works although a public path extends alongside the river and would require to be diverted for the duration of the works. • Overall, public access to the river would be improved as a result of the works.	• None regarding Public Rights of Way although the Ver Valley Trail, a recreational route, will be affected by the works during construction and should be diverted.	• Neutral during construction (beneficial operationally)
Access	Consideration of access to the works area. Access may be difficult and even prohibitively expensive under certain circumstances	• Access for works likely to come from the north of Reach 3. For the works in the lower half of this reach access is not considered to be prohibitive (some TPOs present in the area where the channel re-routing is proposed) although it would be difficult to access and work in the top half as the working area is constrained.	• Access should be determined during detailed design and confirmed by the contractor delivering the works. • Traffic management order may be required.	• Neutral

6.7 Reach 3 Next Steps

6.6.1 Detailed design

The detailed design will need to examine the following:

- A screening opinion from the local authority should be sought as to whether an EIA would be required. The topics for consideration during detailed design should also be confirmed.
- Undertake groundwater monitoring to improve the understanding as to the extent of groundwater emergence that is expected through Reach 3. This would help inform the design of the wetland area.
- New habitat, such as the wetland, should be determined that consider the site conditions (soil type etc.) and anticipated levels of inundation. The choice of species should reference the Herts Habitat Inventory (held by HMWT Records Office) to create a section of Living Landscape in St Albans. A planting plan for the riparian/ floodplain and wetland areas should ultimately be developed.
- Modelling for the outline design has demonstrated hydraulic habitat diversity and functionality of the River Ver is significantly improved through Reach 3. Detailed design, and associated modelling, should iterate the design to further improve the functioning of the restoration features to ensure they deliver maximum benefits. The modelling should acknowledge the effect of the sustainability reductions on groundwater and flow.
- Constructions methods should be considered further during detailed design and discussed with riparian owners.
- We will work with others to plan which trees could be removed, pollarded or thinned to achieve better levels of light for the river whilst minimising impact to properties.
- An access plan should be developed to inform the final scheme. This should consider improving disabled access through the reach/ replacing the existing bridge with one with ramps; improvements to the Ver Valley Trail including the choice of surface (for example making it an all-weather surface) and access, if any, through the wetland area.
- Further Heritage assessment may be needed as the detailed design progresses and the scheme is refined. A watching brief during any works may be required.
- Long term maintenance of the scheme should be considered as part of the detailed design.
- Produce detailed design drawings that can be used for construction.

THE PREFERRED OPTION FOR REACH 4

07

7. The Preferred Option for Reach 4

7.1 Overview

Reach 4 covers the River Ver along the Cottonmill Lane Allotments to Cottonmill Lane (see Figure 7.1 below).

Figure 7.1 Reach 4 of the study area (Cottonmill Lane Allotments to Cottonmill Lane)

The River Ver flows around the northern edge of Cottonmill Lane Allotments before crossing under Cottonmill Lane.

The natural valley bottom is in the middle of the allotment site but the channel has been historically realigned to its current position. As a result, the allotments are prone to flooding from both the river and groundwater.

The realigned channel has been raised to a higher level and as a result, there is little gradient, and flows are slow. This allows fine silts to smother the river bed, which would naturally be gravelly. The river is also heavily shaded, too straight and too wide; all of which reduce the diversity and quality of the river habitat.

In the coming years, to restore and protect the River Ver, Affinity Water plan to reduce the amount of groundwater that is abstracted for drinking water at pumping stations in St Albans.

This reduction will mean that groundwater will most likely re-emerge to more natural levels in the allotment site and it will be wetter more frequently. As a result, some parts of the site will become unsuitable for use as allotments in the future. The allotments are already prone to groundwater flooding (see Plates 7.1 and 7.2).

Plate 7.1 Flooded Cottonmill Allotments in 1979. Courtesy of St. Albans Museum

Plate 7.2 Flooded Cottonmill Allotments in 2009

7.2 Issues in Reach 4

The River Ver through Reach 4 is in a particularly bad condition, having lost most of its chalk stream characteristics through historic alteration and realignments. The issues that affect the river in Reach 4 are:

- Perched channel – the river has been moved northward to a higher elevation out of the valley bottom.
- Weir – there is a small weir that reduces the natural bed gradient and reduces the river flow in this reach.
- The channel is over-wide and straight, which again reduces the speed of flow.
- Silty – as a result of the above factors, the river bed is smothered in silt.
- Bank protection – there is piecemeal bank protection through this reach.
- Lack of habitat and flow diversity – the river habitat is all very similar and degraded in nature which severely limits the wildlife it can support.
- Heavy shading – the overhanging trees block light to the river and the resulting heavy shade blocks light to the river and restricts plant growth.
- Disconnected from the floodplain – the natural valley bottom is in the middle of the allotment site.
- Groundwater re-emergence – the natural valley bottom, which is in the middle of the allotment site, is anticipated to become wetter more often as a result of planned reductions to groundwater abstraction.

Restoration in this design should account for each of these issues and result in the project objectives being achieved. Further information on the river issues is provided in Appendix A.

Figure 7.2 presents a visual summary of the issues within Reach 4.

Figure 7.2 Reach 4 Issues and Constraints Overview

7.3 Derivation of the Preferred Option for Reach 4

7.3.1 Long Listing and Short-listing Appraisal

Full results of the long listing and short-listing appraisal of Reach 4 options are included within Appendix N. The appraisals considered the issues indicated in Section 7.2 and constraints identified in Section 3.10.

At the start of the project, we developed four potential restoration options for Reach 4 which we then assessed as part of the long list appraisal. Following this, three of the options that were longlisted were in turn shortlisted. These were:

- Option 1 Realignment of the River Ver to valley bottom through the allotments.
- Option 2 Realignment of the River Ver to valley bottom through the allotments and connecting to Reach 5 through a new crossing further south on Cottonmill Lane at valley bottom.
- Option 3 Creation of a more winding (or 'sinuous'), improved channel close to the course of the existing river.

Each of these was examined as part of the detailed short list appraisal.

Following the short list appraisal, the decision we reached was to take forward option 1.

The best outcomes for the river would be where the channel is returned to the valley bottom – as proposed by options 1 and 2. Option 2 would involve building a new bridge or culvert for the river to cross under Cottonmill Lane. This would be extremely expensive – made much more so by the presence of buried services within the road. Option 3 would have offered some potential to improve the river but would not address the issue of the disconnected floodplain, or the future increases in groundwater as abstraction is reduced. It was therefore decided that option 1 gave the best overall outcome.

7.4 The Preferred Option for Reach 4

7.4.1 Option description

The Reach 4 preferred option (Option 1)/ outline proposals, prior to engagement, are summarised in Figure 7.3. The proposals addressed the issues with the river and the re-emergence of groundwater.

Our proposals will have a dramatic effect on this reach. Our proposed plan is to move the river back to the valley bottom, where it would originally have been, and to reconnect the river with its original floodplain. With the increase in groundwater levels, the area surrounding the river will become wetter. We plan to take advantage of this to create precious wetland habitat that would be opened to the public with boardwalks, or alternatives.

As a result of these measures the river will be greatly improved – creating a much more natural chalk stream able to support a wide variety of habitats and wildlife. St Albans residents will be able to get close to nature with the creation of wetland habitats, teeming with wildlife.

Reach 4 is a low to moderate gradient single bend with low local sinuosity, the gradient is presently not steep enough to support functional riffles and the bed is choked with finer sediment. By reducing overall river length channel slope will increase and local sinuosity may be reintroduced. This may be achieved through the introduction of a set of wide gravel point bars which will develop a succession of vegetation towards the floodplain where flood energy drops off grading to clean gravels nearer the channel. In the channel a series of riffle units will be created at meander inflections integrated with the point bar features and apical pools will add further diversity mimicking the natural deepening seen opposite point bars. Flow concentration around outer bends will maintain these features and will generate slow directional movement of the channel.

By reconnecting the river with the floodplain, these proposals will address the flooding issues in the area that will only get worse when nearby groundwater abstraction is reduced. However, we do not underestimate the impact that these measures would have on allotment tenants in Cottonmill Lane. St Albans City and District Council are committed to providing replacement allotments locally to all allotment tenants affected by these proposals, with no loss overall. No tenants would be expected to move before 2021 . The proposals seek to maximise the number of allotments that can remain on site in areas not affected by groundwater re-emergence and flooding.

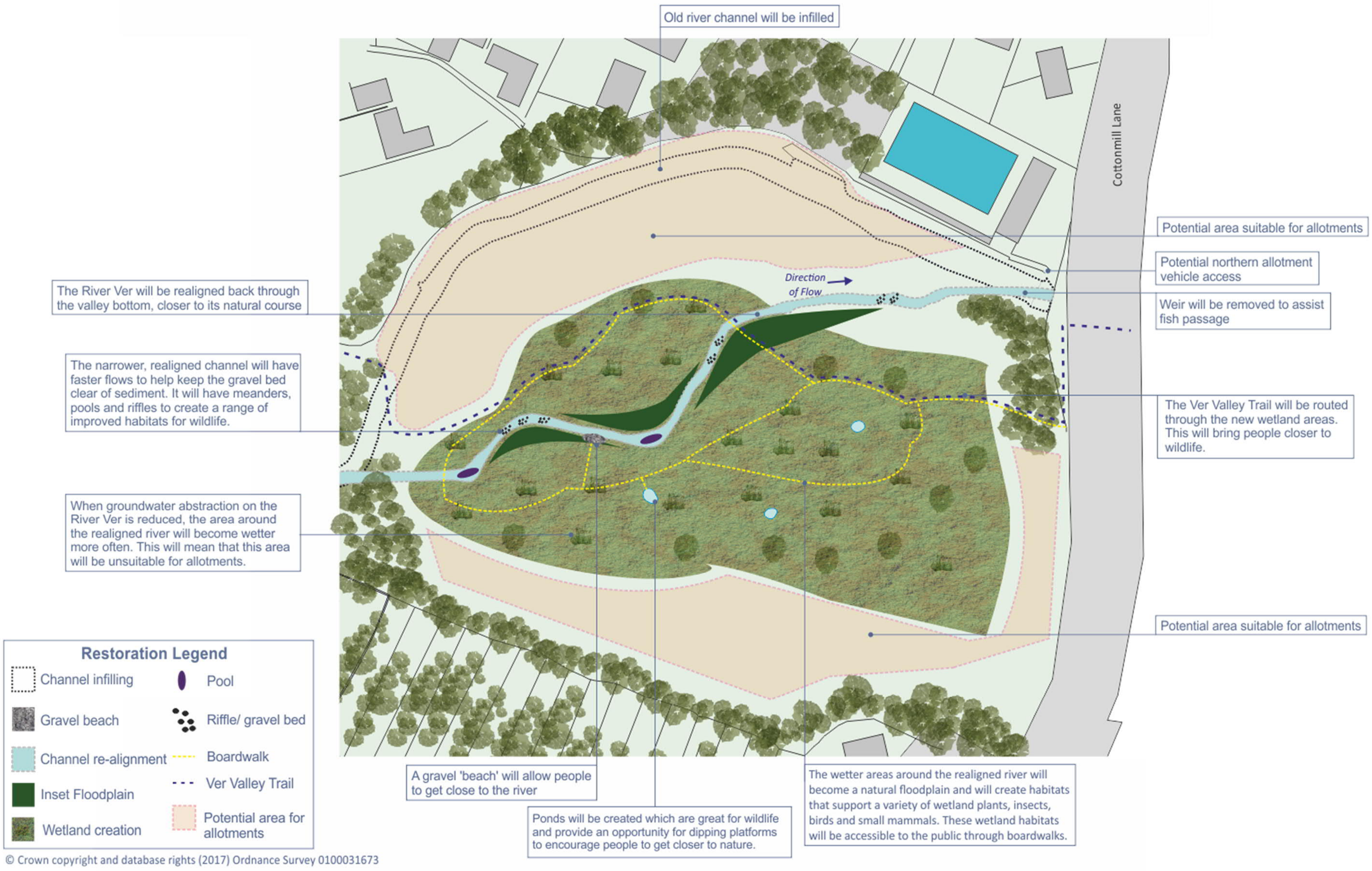


Figure 7.3 Reach 4 Preferred Option/ Outline Proposals (prior to engagement)

7.4.2 Summary of the Proposed Option Modelling

Hydraulic modelling was undertaken to refine the restoration features that were included in the design and determine the potential hydrological, hydromorphological and ecological effects of the preferred river restoration option. Full results of the modelling are included within Appendix D. A summary of the effects is provided below.

Hydrology

No changes to the amount of flow in the river are predicted as a result of the restoration.

With the re-alignment, the nature of flood risk through the reach is drastically altered. Under the existing situation the allotments would flood from the river under the 1 in 10-year flood although with restoration they would flood under a lower flood event (with river being re-aligned through them). However more significant flood events would be reduced in extent if they do occur. With groundwater emergence predicted in this reach in most winters the area is predicted to be wet and the future use of the site as a wetland is compatible with the predictions.

The risk to riparian properties to the south is reduced slightly within the restoration. As the scheme is iterated through detailed design this should remain the case so that no adverse effect to people or private properties results from the scheme.

Hydromorphology

Following restoration, the levels of energy (shear stress) available to prevent siltation, erode the banks and erode established in-channel features (berms) was also reviewed. The riffle units proposed look set to function well with no siltation anticipated. It would appear that these outline design features are having an impact on the rest of the reach with very low energy pools being created. These look to be strongly subject to siltation with little chance of winter or 2-year flow flushing. Silty pools are not necessarily a bad habitat to have in the reach but the overall energy balance through the reach could be improved during detailed design by modifying the location and height of the proposed riffles and/or modifying downstream connection levels.

Figures 7.4 and 7.5 summarise the hydraulic results through Reach 4 under the proposed restoration scenario.

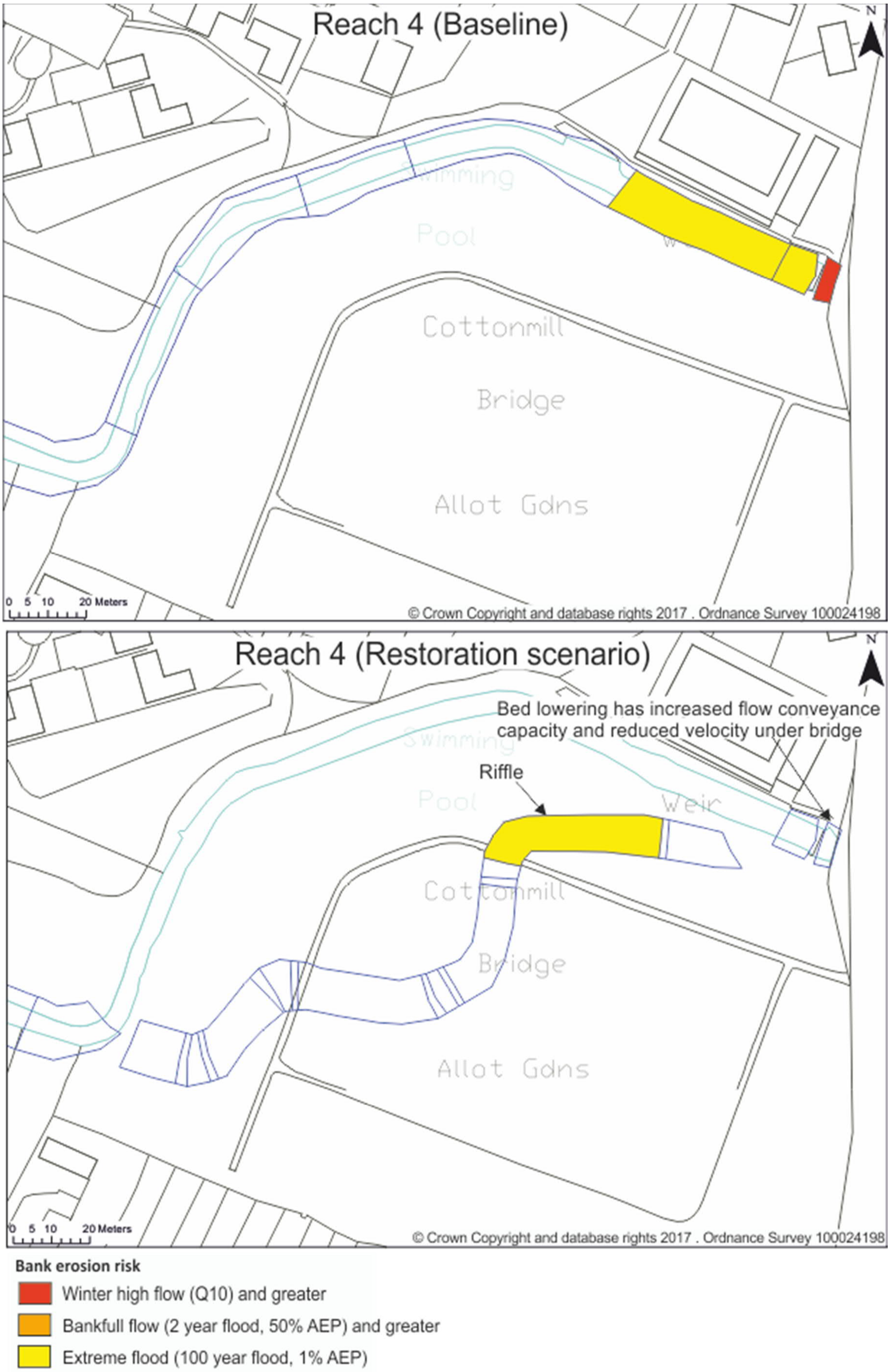


Figure 7.4 Bank erosion risk at Reach 4 under baseline and proposed restoration scenarios

Figure 7.5 Sedimentation risk at Reach 4 under baseline and proposed restoration scenarios

River Habitats

Reach 4 is currently dominated by glide habitat with only around a quarter of the reach displaying higher energy habitats (Figure 7.6). The introduction of the proposed restoration features sees a considerable increase in riffle habitat at the expense of glide. Because hydraulic energy is being concentrated across riffle areas some glide is transformed to pool. Whilst this is more susceptible to siltation, in proportion with other habitats in the reach it would provide valuable habitat diversity.

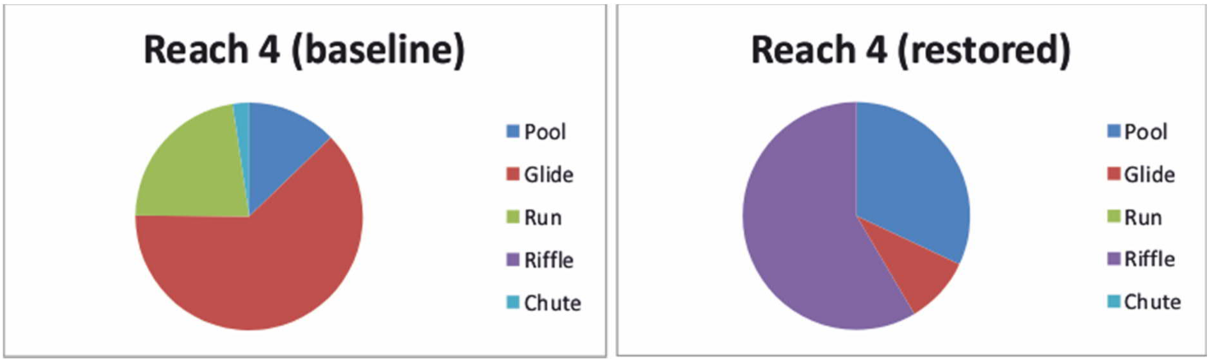


Figure 7.6 Current and restored in-channel habitats for Reach 4 on the River Ver

7.5 Engagement

Our outline proposals for Reach 4 were unveiled to the public in March 2018 at the start of a public engagement period. Engagement events were also held and members of the public were invited to fill out a survey to record their views on the Reach 4 proposals.

The survey resulted in the following positive feedback being received:

- This is the only real opportunity to return the River Ver to its natural course at the lowest point of the valley. Great project, though unfortunate about the impacts on the allotments.
- Welcome any increase to the wildlife area and environs. So much has been done around the green space behind Sopwell Nunnery which is to be applauded. The WWA behind Riverside Road is an excellent model of what can be achieved.
- More tree removal to allow light to reach the river and allow a natural chalk stream flora.
- If it goes according to plan it could be good for wildlife and a scenic area and very pleasant for the limited numbers who will still have an allotment.
- Support the introduction of new wetland areas and the new route for the Ver Valley Trail. This should improve the walking route from Holywell Hill to Cottonmill Lane. It will be a great natural asset for the local community.
- Improved river management, creating accessible wetlands.
- This will create a really interesting and beautiful asset for the city. It would be fantastic for children.

A number of concerns were raised through the survey and these are indicated in Table 7.1 along with our response.

Table 7.1 Survey Concerns and Our Response

Concern	Response
More information/evidence needed to show the increase in flood risk to the Cottonmill and Nunnery 1 Allotment sites after water abstraction is reduced.	• Further monitoring and analysis is recommended that will help demonstrate the extent of the groundwater emergence that is predicted. • These plans are based on the best available evidence

Concern	Response
Cottonmill Allotments site rarely floods - long-term allotment holders remember the site flooding only twice in the last forty years.	• We have records of flooding occurring in the allotments in 1979, 1994, 2001, 2009, 2010, 2011, 2013 and 2014. • This period doesn't reflect the near future baseline when the effects of the sustainability reductions will have occurred.
Doubts over future flooding - demand for water set to increase as housing pressures increase.	• Sustainability reductions have been agreed and Affinity Water Water Resources Management Plans account for future growth/ resource requirements.

If the river is re-routed through the allotment site, there will be significant nutrient leaching into the lower reaches which would be detrimental to the restoration of a chalk stream environment.	• This will be investigated through the detailed design. However, the risk is not considered to be significant due to the following:
	  • As outlined in Section 7.4.2, it is unlikely that there would be substantial bank or bed erosion, due to the relatively low energy environment of the restored Ver.
	  • It is highly likely that substantial amounts of the existing topsoil would be removed from the site of the restoration works – in particular from the riparian zone as part of the proposed wetland creation. This would most likely be removed from site and sold, given the high value of good topsoil.
	  • The creation of the wetland areas would act as a substantial buffer zone, reducing the potential for phosphorous laden silt to ever enter the watercourse, in particular through natural filtration as a result of the vegetation present, and uptake by wetland plants.
	  • The potential sources of phosphorous enrichment are limited to the existing soil, and the extent of that source is very small when compared to a chalk stream in an agricultural catchment.
	  • The lack of farm tracks, cattle poaching etc.

Minor dredging works and improving the existing channel under Cottonmill Lane ought to (especially combined with the admirable flood plain improvements in Reach 2) deal with any increased flood risk.	• Dredging is not sustainable and would not result in any of the environmental benefits that the restoration would provide.
Destruction to allotment wildlife and habitats.	• Noted although the proposed wetland would provide an overall gain for wildlife and habitats and plans should be developed further during the detailed design, to ensure this happens.
Concerns over risks of flooding to riparian properties in this reach.	• Fluvial flood risk to people and properties is predicted to decrease as a result of the works. Flood risk should continue to be investigated and accounted for through the detailed design.
Loss of high quality allotment soil, which takes years to produce.	• This point is noted, and we would recommend that exporting this material to any replacement allotment grounds is undertaken.
The dispute over the allotments might derail the whole scheme. The river in this reach doesn't seem so bad.	• The range of issues through this reach have been outlined Section 7.2.
Public access may inhibit wildlife objectives	• This is noted. Access will need to be considered fully during detailed design to allow people to access nature in a way that is sympathetic to wildlife whilst enabling learning and engagement experiences. This may include some access restrictions in sections that will contain higher wildlife value.
Fears that the allotment site will be closed, but then the project will not go ahead, and the land will be put to other use.	• St Albans City and District Council is committed to both the restoration and re-location of the allotments, so this fear can be dispelled.
New wetland would be less managed and more insecure than the current allotment site.	• Maintenance of the site and security would be considered as part of the detailed design.
There have been many barriers to allotment tenants providing feedback.	• Survey was open for 10 weeks and several engagement events were held.

Concern	Response
How serious is the proposal that some allotments could be positioned on either side of the new river? Is this simply a sweetener to avoid an immediate heavy backlash from allotment tenants?	• We are committed to retaining as many plots on the site as possible. • We have responded to concerns and carried out further investigation to produced revised plans in order to accommodate increased plots on site
Of the 124 current plots, how many may be accommodated in these 'potential' sites?	• This is subject to the final design, which endeavours to maximise the number of plots that would be retained at the site (remainder being moved to the new site).
How will new plots be distributed amongst current plot holders?	• This is yet to be determined but will be done in consultation with allotment tenants and the Cottonmill and Nunnery Allotment Association.
What size might individual plots on these potential sites be?	• The exact size of plots is yet to be determined and will depend largely on current plot sizes (mostly half size plots with some full-size plots).
What security will be provided for these potential sites?	• The new site will be secured with a perimeter fence with one vehicular gate and at least two pedestrian gates.
What privacy will be provided for these potential sites?	• This is yet to be determined and will be worked up during the detailed design stage of the project.
There is a paucity of information regarding where alternative new plots could be established.	• A new allotment site will be created on land currently known as Sopwell Mill Open Space.
What recompense will be provided to tenants for loss of mature plants such as apple trees, fruits bushes and annual plants such as rhubarb?	• This is yet to be determined.
What recompense or assistance will be provided for the loss or the removal of sheds/greenhouses to a new site?	• Sheds and greenhouses will be provided for those tenants who currently have one on their existing plot.
Given this proposal is the Council continuing to take on new tenants to the Cottonmill site?	• Yes, however they are being made aware of the groundwater emergence issue.
What will you do about the outflows from the waterworks which discharge into the river?	• This will be determined during the detailed design.
What consideration has been given to archaeological features on the allotment site?	• We have undertaken a Heritage assessment which will continue into the detailed design.
What provisions will be put in place for those plots that are unaffected by the proposals - security, water supply, avoidance of disruption whilst work is going on, retaining soil conditions, etc.?	• All plots at the site will be affected.
If plots are relocated, will the soil conditions be as good?	• Yes, details will be confirmed during the next stage.

Where possible the above points have been considered as part of finalising the outline option (see Section 7.5), however many will require further consideration, including during detailed design.

Allotment tenants affected by the plans were contacted directly by post and invited to a drop-in information and engagement event held at Marlborough Club on March 22 2018. Approximately 50 tenant holders attended and at the event all tenants were invited to comment on the plans.

A follow up information event was held on July 12 2018. In addition, the project team have regularly visited the allotment site to discuss the proposals with tenants. They have also met with the Cottonmill and Nunnery Allotment Association (CNAA) Chairman. The project team responded to numerous further enquiries. These are summarised in Table 7.2 along with our responses.

Table 7.2 Other Engagement Feedback and Our Response

Concern	Response	Next Steps/ Further Work
There has been concern about the effect of the plans on the existing biodiversity of the site, including kingfishers being negatively affected by realigning the river and the loss of foraging/nesting.	• There will be no net-loss of allotment plots and it is expected that the new site will develop similar ecological value. • The improved river will improve habitat, suitable for a wider range of fish species. • Kingfisher are versatile with wide foraging territories. The Boxmoor project on the River Bulbourne included significant river works. Volunteers have stated that the kingfishers were unaffected.	• Further ecological surveys and impact appraisal will be undertaken to ensure that construction effects are suitably mitigated for and that the final scheme provides a net and significant ecological/ habitat gain. • We will work with partners, including the Herts and Middlesex Wildlife Trust to make sure the plans are acceptable and positive for wildlife.
Concern about lack of ecology reports.	• Surveys need to be informed by the final chosen option as different schemes may require different activities and approaches and therefore different impacts to consider	• Further ecological surveys and impact appraisal will be undertaken at detailed design stage.
Issues about security and anti-social behaviour on future Cottonmill site.	• The Ver Valley Trail is currently dark and over shaded through this reach. It is likely that the proposed plans will increase safety and security.	• Through detailed design we can engage with community police unit/safer neighbourhoods unit and explore potential options that may help improve the situation, for example looking into lighting. • St Albans City and District Council will make sure relocated allotments have the same level of security.
More detail required as to type of wetland and the required maintenance.	• Through detailed designs the type of wetland most appropriate to the area will be developed.	• Landscape management plan to be submitted and approved as part of the detailed designs.
Extent and impact of future groundwater flooding	• Based on the best available information and studies, the change in groundwater levels following abstraction reductions will mean that much of the site will be impacted by groundwater emergence and flooding most years.	• Further monitoring and analysis is recommended that will help demonstrate the extent of the groundwater emergence that is predicted.
Concern about the loss of the allotment site	• There will be no net-loss of allotments. The proposals seek to maximise the number of allotments that remain on site in areas not affected by groundwater emergence. • Project partners are committed to providing an alternative site and providing assistance and support in the move.	• We will work with allotment tenants to manage the change in the least disruptive and fairest way possible.

Historic England were also consulted and raised no concerns with the proposals.

Herts and Middlesex Wildlife Trust were consulted and were supportive of the scheme to improve the Ver's morphology, wildlife and amenity value on the assumption that there would be no net loss to the number of allotments with tenants relocated to a suitable new site.

7.6 Final Outline Reach 4 Plans

Following engagement, we have revised the proposed plans for Reach 4. The final outline restoration plans for Reach 4 are provided in Figure 7.4. The final alignment would need to be investigated during detailed design although it may be similar to that indicated in Figure 7.4 which endeavours to maximise the number of allotments that could be retained on the site whilst also providing a scheme that is sustainable by accounting for increased groundwater emergence that is expected as a result of the sustainability reductions.

To inform the proposed realignment planform further investigations were undertaken. These confirmed the suitability of the re-alignment including the re-connection of the river at the end of the reach. Our work found that berms, channel narrowing and riparian/ narrow floodplain reconnection would be most appropriate (with riffles considered not to be). With the river being in its valley bottom and with a steady gradient these features should result in a much improved and better functioning river reach compared to the existing perched channel.

An Outline Environmental Appraisal of the option has also been undertaken to not only identify the benefits of the restoration but also provide an initial indication as to where further work during detailed design and/ or mitigation is required. The appraisal assumes that all best practice, such as Pollution Prevention Guidelines and Working in Water methods are adhered to and standard ecological surveys and resultant mitigation would be undertaken, and during construction. The appraisal is included as Table 7.3.

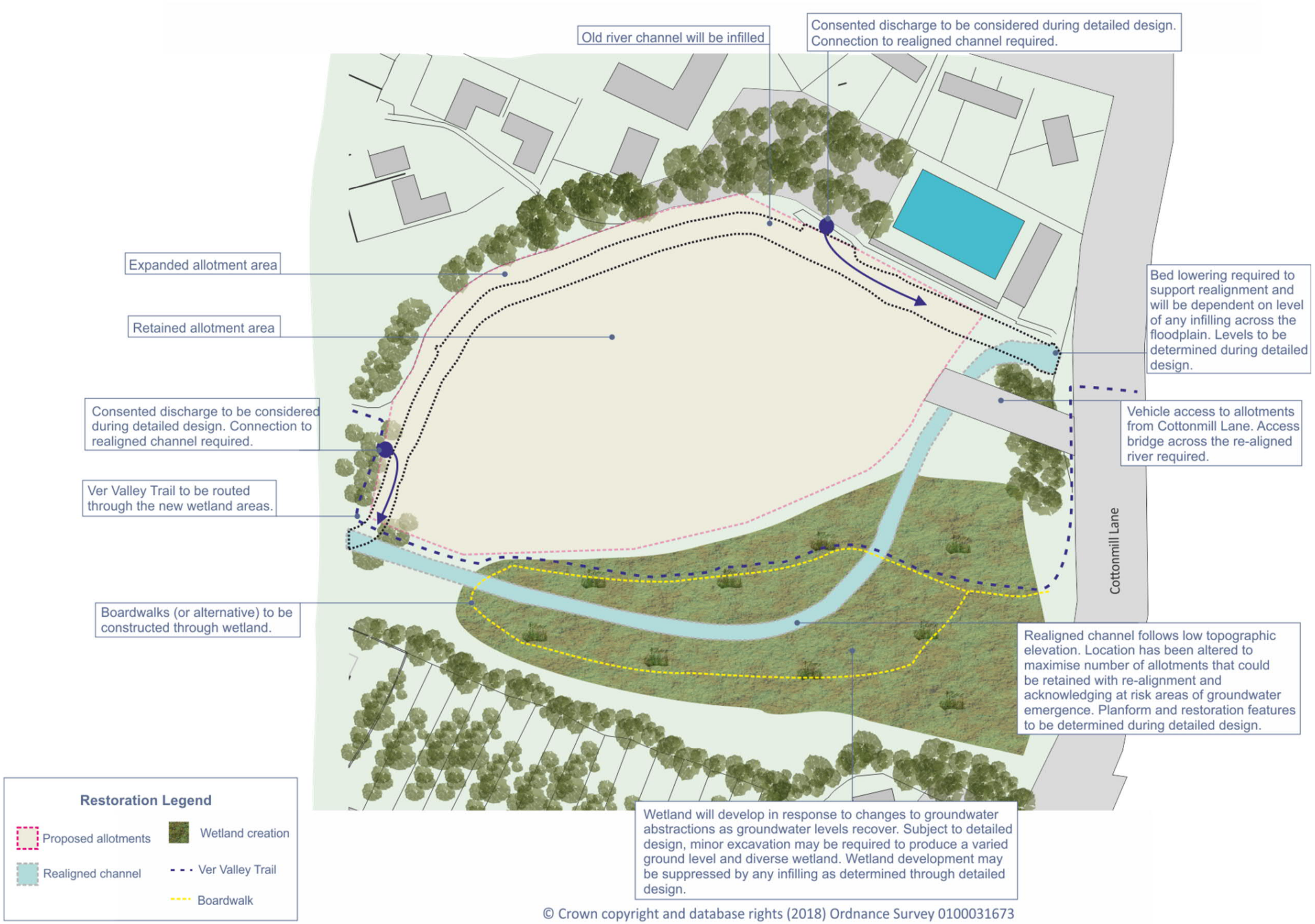


Figure 7.4 Reach 4 Final Outline Proposal Plan (post engagement)

Table 7.3 Outline Environmental Appraisal of the Reach 4 Preferred Option

Resource/ Feature	Overview	Effect or Potential Effect of Scenario	Potential Mitigation	Likely Significance
Hydrogeology/ Groundwater connectivity	Does the scheme affect connectivity between surface water and groundwater?	• The river and groundwater would be re-connected by realigning the channel through the natural valley bottom. This would represent a naturalisation of the system and enable natural chalk stream functioning.	• Groundwater monitoring should be undertaken to improve the hydrogeological understanding and inform the detailed design.	• Beneficial
Geo-environmental	Does the scheme potentially result in a new pathway for contaminants to enter the river?	• Re-alignment would occur through an area that is presently allotments. This would provide a direct route for contaminants and nutrients to be introduced into the river and would have an impact upon water quality in the river for the short term at least. It is noted that there is currently a pathway for these to enter the river indirectly, via runoff. • Our view is that this is a significant constraint although not insurmountable. Further studies and analysis would be needed, such as soil testing through the allotments, to better inform the risk and ultimately the design. Inclusion of wetlands through this reach would help retain some of the pollutants.	• A soil sampling strategy should be devised and enacted during the detailed design to confirm any risk and what mitigation should be undertaken, if any.	• With inclusion of suitable mitigation there would be at least a neutral effect that may end up being beneficial.
Flood Risk	Does the scheme result in an increase of decrease in flood risk to people and properties?	• The allotment site is threatened by rising groundwater levels as a result of future sustainability reductions. Our study / appendix C predicts a rise of groundwater levels of more than 1 m in this area and it is expected that the site will flood most years. This option provides an opportunity to address these issues and provide a sustainable solution. • The option would reconnect the river to valley bottom and its floodplain. The area around the new channel will flood more often and will not be used for allotments. • Our modelling indicated that fluvial flood risk to people and properties is predicted to decrease as a result of the works.	• As part of detailed design is it likely that the scheme will be refined and iterated. Revised schemes should be hydraulically modelling, and flood risk should be assessed throughout, to ensure that there is no increase in flood risk to people or properties as part of the works. Minor mitigation, should as land raising can be included as part of the scheme to ensure that this occurs.	• Neutral (potentially beneficial)
Other hydrology	Does the scheme result in other changes to the hydrology that could impact upon other water users or receptors?	• Significant existing channel re-profiling works would be required at the downstream end where the realigned channel reconnects with the main channel as a result of the level discrepancy with the channel in the natural valley bottom reconnecting to the current perched channel. • There are no surface water abstractions in or close to this reach and so no effect of the scheme on these (note sustainability reductions influence flow through the reach however).	• Detailed design modelling should ultimately ensure that a hydrologically functioning river system is created, bearing in mind other aspects (like minimising service crossing).	• Neutral
Hydromorphology	Does the scheme improve the hydromorphological functioning of the reach?	• The realignment works would locate the channel back in the natural valley bottom and is therefore likely to improve the flow and habitat diversity, particularly with the inclusion of an appropriate morphology as specified. This should increase the hydraulic habitat diversity with a greater frequency of higher energy riffle units.	• Hydromorphological gains should continue to be sought from the scheme as detailed design progresses.	• Beneficial
Water quality	Does the scheme result in a deterioration or improvement of water quality, for example less flow would result in less dilution of consented discharges?	• There are two consented discharges at the top of this reach. These belong to Affinity Water and are linked to their groundwater abstractions in St Albans . As such they are likely to of good water quality (so no impact upon river water quality anticipated as a result of the option due to the hydrological changes) although they would need to be accounted for during the works (i.e. connected to the re-routed river). The quality of the discharges should be tested to confirm this theory. • In general, hydromorphological improvements should help improve general water quality through the reach.	• Detailed design should account for these. Some work may be required to re-connect these to the river before it is re-aligned.	• Neutral to beneficial if water quality improvements can be made as part of the reconnection (for example by including reeds beds downstream of the outfalls as part of the reconnections).
Statutory Sites or Non-Statutory Designated Sites	Does the scheme affect designated and or wildlife sites?	• There are no designated or Local Wildlife Sites in this reach and so this option would not impact upon them.	• n/a	• n/a
Other Biodiversity	Wildlife can be impacted during construction while scheme may result in positive, neutral or negative effects to species.	• The river and groundwater would be re-connected by realigning the channel through the natural valley bottom. This would represent a naturalisation of the system and enable natural chalk stream functioning. • Scheme would result in an improvement to the health of the river and provide additional habitats	• None required	• Beneficial
Heritage	Does the scheme potentially impact upon Scheduled Monuments or other archaeological features?	• The option is unlikely to have a significant effect of features of archaeological importance. Two features are located on the northern/ left bank at the downstream end of the reach. They should be accounted for as part of any reconnection works although are not considered to be prohibitive to the option. • Costs may be high if remains are found during the works.	• Detailed design should continue to suitably account for Heritage, for example not result in excessive excavation to areas of archaeological significance. • A Heritage officer with a Watching Brief during the works is anticipated.	• Neutral/ minor adverse
Tree Protection Orders (TPO)	Consideration of the effect of Tree Protection Orders on the option	• There are no TPOs in this reach and so no effect on the scheme.	• A limited number of trees may need to be removed in order for channel to be re-aligned. These should be considered further during detailed design (regarding ecological effect). • Plan for fruit trees in allotment yet to be	• Neutral regarding TPOs

			determined.	
Landscape impact	Does the option have a significant visual impact?	• The option should result in an improved looking and more natural appearing river that is better connected to its flood plain.	• None required	• Beneficial
Recreation and amenity	Does the option have significant impacts upon recreation and/ or amenity	• The option includes re-alignment through a popular allotment site with strong community feeling. However, much of the site is threatened by future sustainability reductions irrespective of these proposals. • This option offers a much-improved river, with an accessible wetland area that should be appealing for people to visit and is considered to be a sustainable long term option.	• A detailed plan that can maximise plots that can remain on the site and for re-locating allotment holders should be devised and implemented. • Public access needs to be planned thoroughly to allow people to access nature in a way that is sympathetic to wildlife whilst enabling learning and engagement experiences. This may include some access restrictions in sections that contain higher wildlife value. This should be considered through the detailed design.	• Minor adverse for allotment holders with mitigation/ beneficial for other recreation and amenity
Riparian ownership issues	Does the option affect properties?	• St Albans City and District Council own the land throughout this reach and so no riparian ownership issues are anticipated.	• None required	• Neutral
Construction only				
Water Mains and Sewers (foul and surface water)	Consideration of the potential effect of these on buildability of the scheme.	• There is an Affinity Water distribution main running through the middle of the allotments that is likely to be crossed by the re-aligned channel. This is at a depth of around 1.4m bgl and would need to be accounted for during any works, which would be expensive. There is also a pair of distribution mains under the Cottonmill Lane Bridge that would need to be accounted for if culvert adjustment works are anticipated there. Replacement of a more appropriate service crossing would likely be required as a result of this option due to the necessary re-profiling works to allow this option to function. • Similarly, there is a pair of Thames Water surface water sewers running parallel with Cottonmill Lane, ending either side of the actual bridge crossing. The pipeline located on the upstream side of the bridge is approximately 1m bgl. Both would need to be accounted for if culvert adjustment works are anticipated where the re-aligned channel is proposed to re-join the existing channel course.	• Utilities should be considered through the detailed design and should be suitably accounted for during any construction works. • Thames Water may insist on no excavation works with 10m of their sewer .and have indicated that sewer may also be in a slightly different location to what is shown on their mapping. Early consultation with Thames water is recommended. They are also likely to ask for CCTV survey before and after the works to prove that the integrity of the sewer has not been compromised by the works. • Further surveys are recommended.	• Neutral
Other Utilities	Consideration of the potential effect of these on buildability of the scheme.	• A BT Openreach line follows the course of Cottonmill Lane, crossing the bridge at a minimum depth of 0.35m bgl. This would need to be accounted for if culvert adjustment works are anticipated where the re-aligned channel is proposed to re-join the existing channel course. • Both high and low voltage UK Power Networks cables follow the course of Cottonmill Lane, with the high voltage line crossing the bridge at a depth of 0.80m bgl. Additional pair of lines following the same course are set at unknown depths; therefore further site investigation would be required to inform line status. • A pair of National Grid low pressure gas mains follow the course of Cottonmill Lane, crossing the bridge at an unknown depth. This would need to be further investigated and accounted for if culvert adjustment works are anticipated where the re-aligned channel is proposed to re-join the existing channel course. • Replacement of a more appropriate service crossing would likely be required as a result of this option due to the necessary re-profiling works to allow this option to function.		• Neutral
Pedestrian access	Consideration of the potential need for footpaths to be diverted. For example Public Rights of Way may need to be re-routed if works are planned over their route.	• No public right of way near the site. Ver Valley Trail follows existing river through this reach. This may need to be diverted during the re-connecting works at the downstream end of the reach.	• None regarding Public Rights of Way although the Ver Valley Trail, a recreational route, will be affected by the works during construction and should be diverted appropriately.	• Neutral
Access	Consideration of access to the works area. Access may be difficult and even prohibitively expensive under certain circumstances	• Access for works should be straightforward from Cottonmill Lane. • This is a popular allotment site. While disruption to allotments should be minimised H&S considerations mean that parts or all of the site would need to be closed while work takes place. • Works should be carried out at the time of the year least disruptive to tenants although it must be acknowledged that high groundwater levels, which can occur in the allotment area, may affect plant operations and works. • It is assumed that the allotments would be decommissioned in advance of the works. High groundwater levels, which can occur in the allotment area, would affect plant operations and works should be undertaken at times when these are low.	• Access should be determined during detailed design and confirmed by the contractor delivering the works. • Traffic management order may be required.	• Neutral

7.7 Reach 4 Next Steps

7.7.1 Detailed design

The detailed design will need to examine the following:

- A screening opinion from the local authority should be sought as to whether an EIA would be required. The topics for consideration during detailed design should also be confirmed.
- Undertake groundwater monitoring to improve the understanding as to the extent of groundwater emergence that has occurred in Reach 4 and is expected to become more frequent once the sustainability reductions occur.
- New habitat, such as the wetland, should be determined that consider the site conditions (soil type etc.) and anticipated levels of inundation. The choice of species should reference the Herts Habitat Inventory (held by HMWT Records Office) to create a section of Living Landscape in St Albans.
- Further and more detailed utilities survey should be undertaken to inform the design.
- Modelling for the outline design has demonstrated hydraulic habitat diversity and functionality of the River Ver is significantly improved through Reach 4. Detailed design, and associated modelling, should iterate the design to further improve the functioning of the restoration features to ensure they deliver maximum benefits. The modelling should acknowledge the effect of the sustainability reductions on groundwater and flow.
- Design should account for utilities as well as result in a hydrologically functioning river being achieved (the latter is complex in this reach due to existing channel being perched above the valley bottom). Some land raising through the allotments may be needed for this to be achieved.
- Existing discharges and the Holywell Hill storm overflow should be re-connected to the re-aligned river and how this is achieved should be determined during detailed design.
- Further Heritage assessment would be needed as the detailed design progress and scheme is refined. A watching brief during any works is likely to be required.
- A formal plan for the allotments should be devised and implemented. This should account for the following:
    - plots that can be retained;
    - seperation and retention of existing topsoil for reuse on the new allotment plots
    - access to the site;
    - replacement allotment site details (location, soil conditions/ moving high quality soil from the existing site, provision of composting, new sheds, security, water availability, vehicular access/ parking, community facilities); and
    - timeframes for any re-location (one year's notice to allotment holders is required before re-location occurs and the replacement site with pre-prepared plots should be ready in advance).
- Constructions methods should be considered further during detailed design and discussed with riparian owners.
- An access plan should be developed. This should include how public and their pets can interact with the river, for example at controlled access points, and access through the wetland area.
- Long term maintenance of the scheme should be considered as part of the detailed design. For example, the design life of boardwalks may be of the order of 10 years and a more sustainable option may be appropriate.
- Produce detailed design drawings that can be used for construction.

THE PREFERRED OPTION FOR REACH 5

8

8. The Preferred Option for Reach 5

8.1 Overview

Reach 5 covers the River Ver from Cottonmill Lane to just upstream of the Watercress Wildlife Site (see Figure 8.1 below).

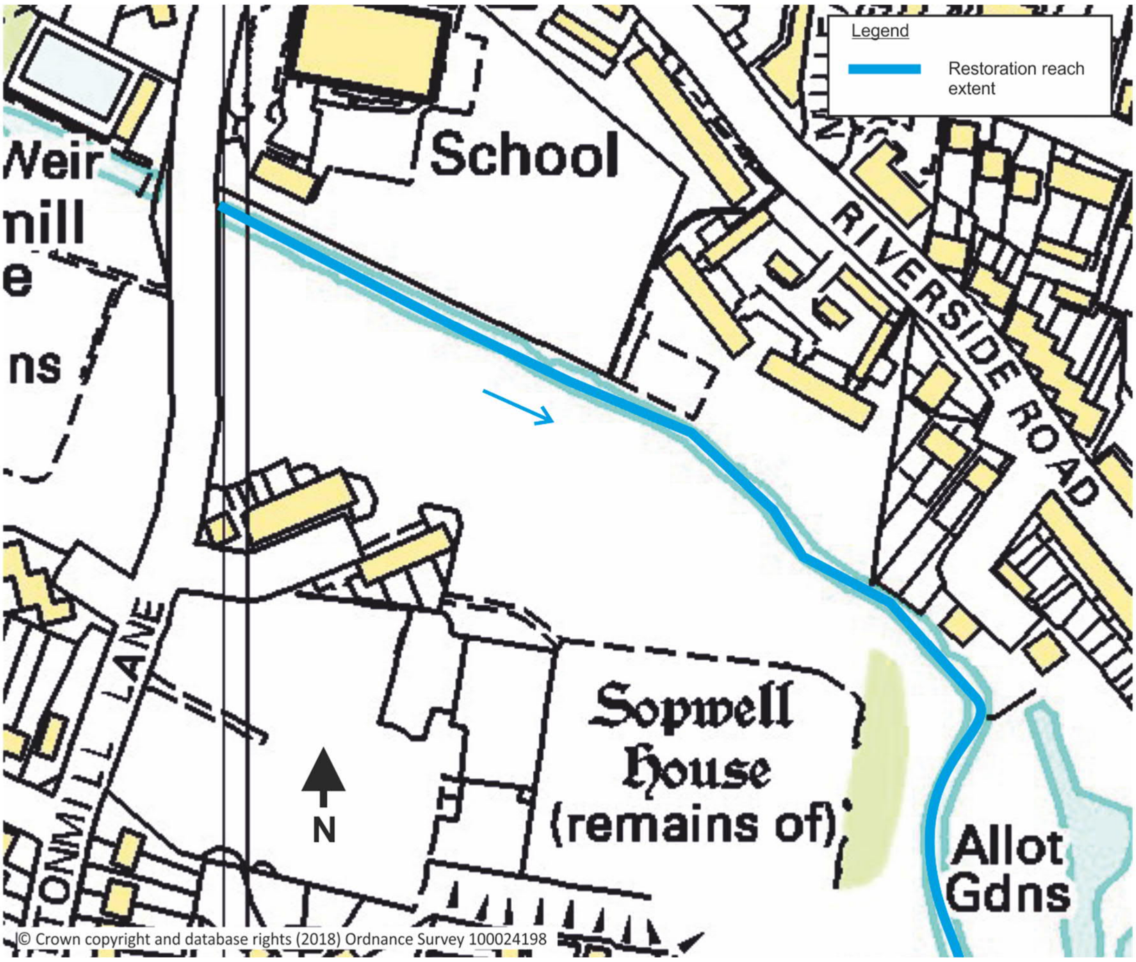


Figure 8.1 Reach 5 of the study area (From Cottonmill Lane to just upstream of the Watercress Wildlife Site)

Although the river through Reach 5 is raised above the valley bottom and is not therefore in its natural location, it has naturalised well due to a good bed gradient and the development of natural in-channel features that have helped to narrow the over-wide river channel. This has helped to increase the speed of river flows which keep sections of the gravel bed fairly free from silt and means there are some areas of valuable chalk stream habitat.

However, there are raised mounds of dredged material along the south bank of the river which restrict views and the connection between the river and its floodplain. There is open parkland and Sopwell Nunnery to the south of the river and a school and residential properties to the north.

Our proposals will extend and enhance the natural chalk stream characteristics that already exist in Reach 5. We will look to deliver some in-channel improvements, introducing features such as riffles and low wet river margins to provide habitats for wildlife. Some marginal planting and narrowing in the over-wide areas will create faster flows to improve the bed by stopping silt building up.

In the coming years, to restore and protect the River Ver, Affinity Water plan to reduce the amount of groundwater that is abstracted for drinking water at pumping stations in St Albans. This will return the groundwater table and river flows to more natural levels. As a result, some of the low-lying areas to the south of the river that are already boggy and marshy for some of the time, will become wetter more often.

We will lower the raised river banks in places to reconnect the river to the floodplain. This will also help develop enhanced areas of wetland and wet woodland habitats alongside the river, particularly in those areas that will be wetter more often as a result of abstraction reductions. Access will be maintained along the river, potentially by extending the current boardwalks if required.

8.2 Issues in Reach 5

The river in Reach 5 has some areas of good habitat, but it still suffers from a range of issues that limit the quality and diversity of habitats. The issues with this reach are:

- Over-wide and deep – through some parts of this reach the river has been over-deepened and widened in the past, reducing the speed of flows.
- Low flows – due to abstraction pressure
- Silty – as a result of the above factors, some of the gravel river bed is smothered in silt.
- Perched channel – the river was moved northward to a higher elevation in the past so is no longer in the bottom of the valley.
- Disconnected from the floodplain – the natural valley bottom is to the south of the river and the river is further disconnected from the floodplain as a result of the mounds of dredged material on the south banks.
- Lack of habitat and flow diversity – some sections of this reach have little diversity of habitat or flow.
- Heavy shading – trees line the banks of the downstream section of this reach and the resulting heavy shade blocks light to the river and restricts plant growth.
- Groundwater re-emergence – it is likely that some areas of the woodland to the north of the channel will become wetter more often as a result of planned abstraction reductions. A number of photographs of groundwater flooding, from the 9th February 2014, were provided to us and indicated widespread flooding of the park immediately north of Old Sopwell Gardens.

Restoration in this design should account for each of these issues and result in the project objectives being achieved. Further information on the river issues is provided in Appendix A.

Figure 8.2 presents a visual summary of the issues within Reach 5.

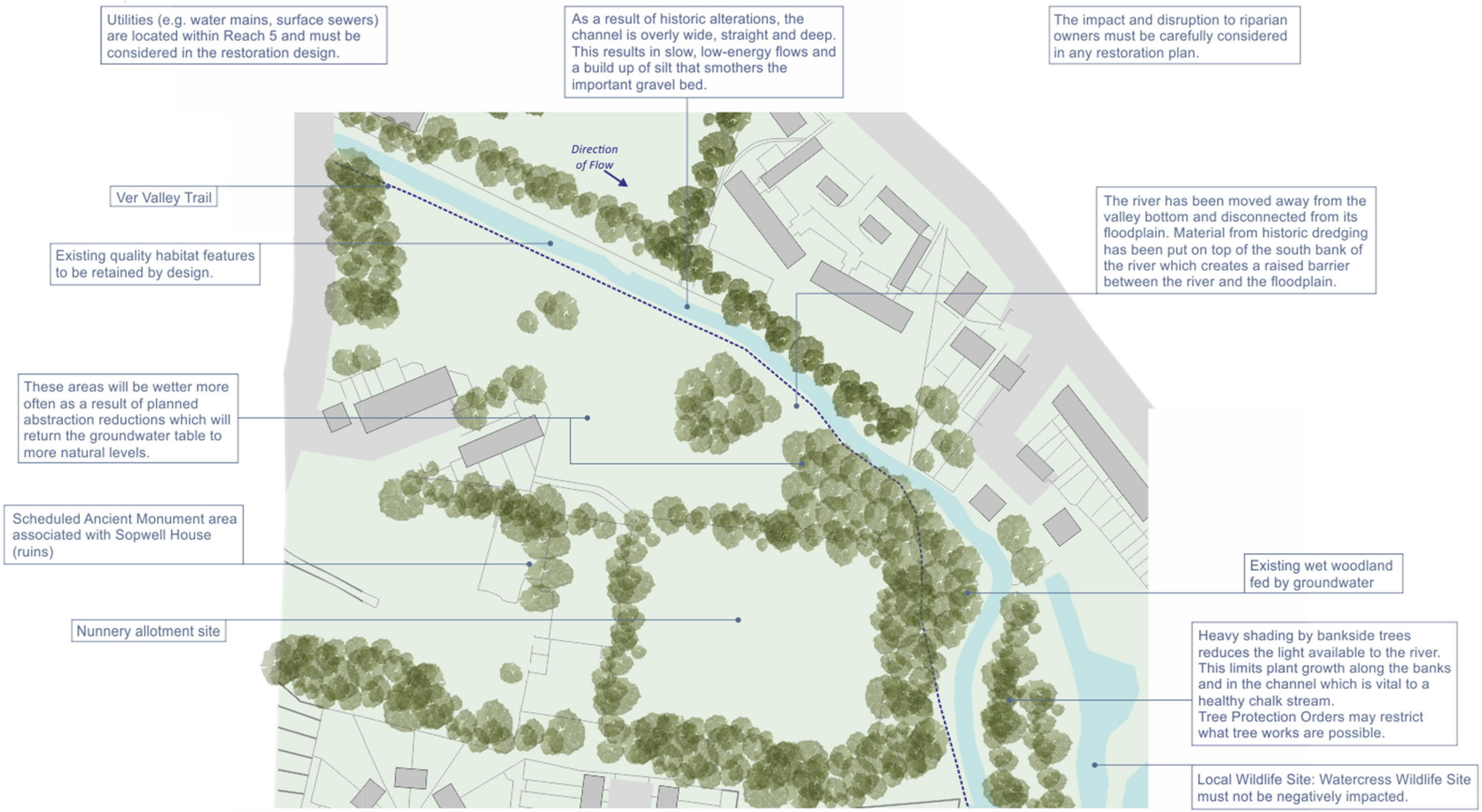


Figure 8.2 Reach 5 Issues and Constraints Overview

8.3 Derivation of the Preferred Option for Reach 5

8.3.1 Long Listing and Short-listing Appraisal

Full results of the long listing and short-listing appraisal of Reach 5 options is included within Appendix O. The appraisals considered the issues indicated in Section 8.2 and constraints identified in Section 3.10.

At the start of the project, we developed four potential restoration options for Reach 5 which we then assessed as part of the long list appraisal. Following this, each of the four options that were longlisted were in turn shortlisted. These were:

- Option 1 Full re-alignment of existing channel to the valley bottom, connecting to Reach 4 through new structure under road.
- Option 2 Full re-alignment of existing channel but connecting to Reach 4 through existing structure under road.
- Option 3 Small re-alignment of the existing channel through the woodland.
- Option 4 Retain and improve the existing channel.

Each of these was examined as part of the detailed short list appraisal. Following the appraisal, the decision we reached was to take forward a modified version of Option 4 to form the proposed option.

Option 1 was discounted due to the excessive costs of creating a new road crossing over the realigned river. Options 2 and 3 would have had slightly better outcomes for the river, but most of the benefits could be achieved through option 4 at a much lower cost. Option 2 was also considered to have potential to increase flood risk. As such Option 4 became the preferred option.

The preferred option for Reach 5 (Option 4) is discussed further below.

8.4 The Preferred Option for Reach 5

8.4.1 Option description

The Reach 5 preferred option/ outline proposals, prior to engagement, are summarised in Figure 8.3.

The proposed option includes in-channel improvements through channel narrowing and feature creation. It also includes lowering sections of the south bank of the river to improve floodplain connectivity and creating space for marginal plants to grow. Wetland would be created in areas we expect to become wetter because of abstraction reductions. Some bed regrading will be necessary at the upstream end of this reach due to the bed lowering under Cottonmill Lane, which is necessary to enable the proposed option for Reach 4. Access and amenity improvements will also be incorporated, making the most of the new areas of wetland and wet woodland habitat that will be created (in an area where increased groundwater emergence is expected).

There are already nice, natural parts of the river through Reach 5 which our proposals will enhance. In-channel features such as pools and riffles will create habitats for a range of wildlife. Narrowing the channel will improve the energy of the flow. We will remove bunds that will reconnect the river with the floodplain, as well as giving a public a better view of the river.

When abstraction for water is reduced in the coming years, some areas of this reach may be wetter more often. We plan to make the most of this, with the creation of rare wetland habitats.

The following outlines the rationale for the features that were included within the outline design (shown in Figure 8.3). Reach 5 is a moderate gradient reach with limited sinuosity, the gradient is steep enough to support functional riffles. The likely sequence would be pool-riffle and pools have been left to develop naturally behind constructed riffles. Riparian connectivity is poor and can be enhanced using in-inset floodplain units. Floodplain enhancement is possible through the development of a wet woodland or wetland reintroducing more appropriate species. This will be enhanced through groundwater emergence on the right bank.

Figure 8.3 Reach 5 Preferred Option/ Outline Proposals (prior to engagement)

8.4.2 Summary of the Proposed Option Modelling

Hydraulic modelling was undertaken to refine the restoration features that were included in the design and determine the potential hydrological, hydromorphological and ecological effects of the preferred river restoration option. Full results of the modelling are included within Appendix D. A summary of the effects is provided below.

Hydrology

No changes to the amount of flow in the river are predicted as a result of the restoration.

Under the proposed restoration scenario there was a minor increase in inundation of the riparian zone along the first half of the reach under the 10-year and 100-year flood events, however connectivity with the floodplain was minimal despite inset floodplain features. The lowering of the right bank through the middle of the reach produced the intended increase in flood extent at the right floodplain under the 10 year and 100-year events, compared with baseline conditions. Modelled water depths were up to 0.4 m for the 10-year flood event and 0.6 m for the 100-year event.

Model results indicated increased connectivity between the River Ver and Watercress Wildlife Site under the 2-year flood event with increased inundation extent and depth in this area under the proposed restoration. Discussion is necessary to establish if this increase is acceptable, otherwise option could be iterated during detailed design to ensure no change to the wildlife site.

There were no significant changes in relative flood risk to the private gardens at the back of the Watercress Wildlife Site.

Hydromorphology

The outline restoration would increase the risk of bank erosion at two of the riffles located in the public park area (Figure 8.4). This would provide varied habitat, and should be viewed positively, although should be considered through detailed design to ensure that any erosion is not deemed excessive.

Sedimentation through Reach 5 is limited, and this would be maintained with the outline restoration (Figure 8.5). Of the four proposed riffles, three will maintain a good gravel bed while the fourth may silt slightly in summer but will flush in winter. The berm area too could accumulate some silt helping to lock this up to reduce water quality issues downstream. Intermediate areas will be low to moderate energy and look likely to accumulate some silt in summer, but winter flows look energetic enough to flush this new sediment through.

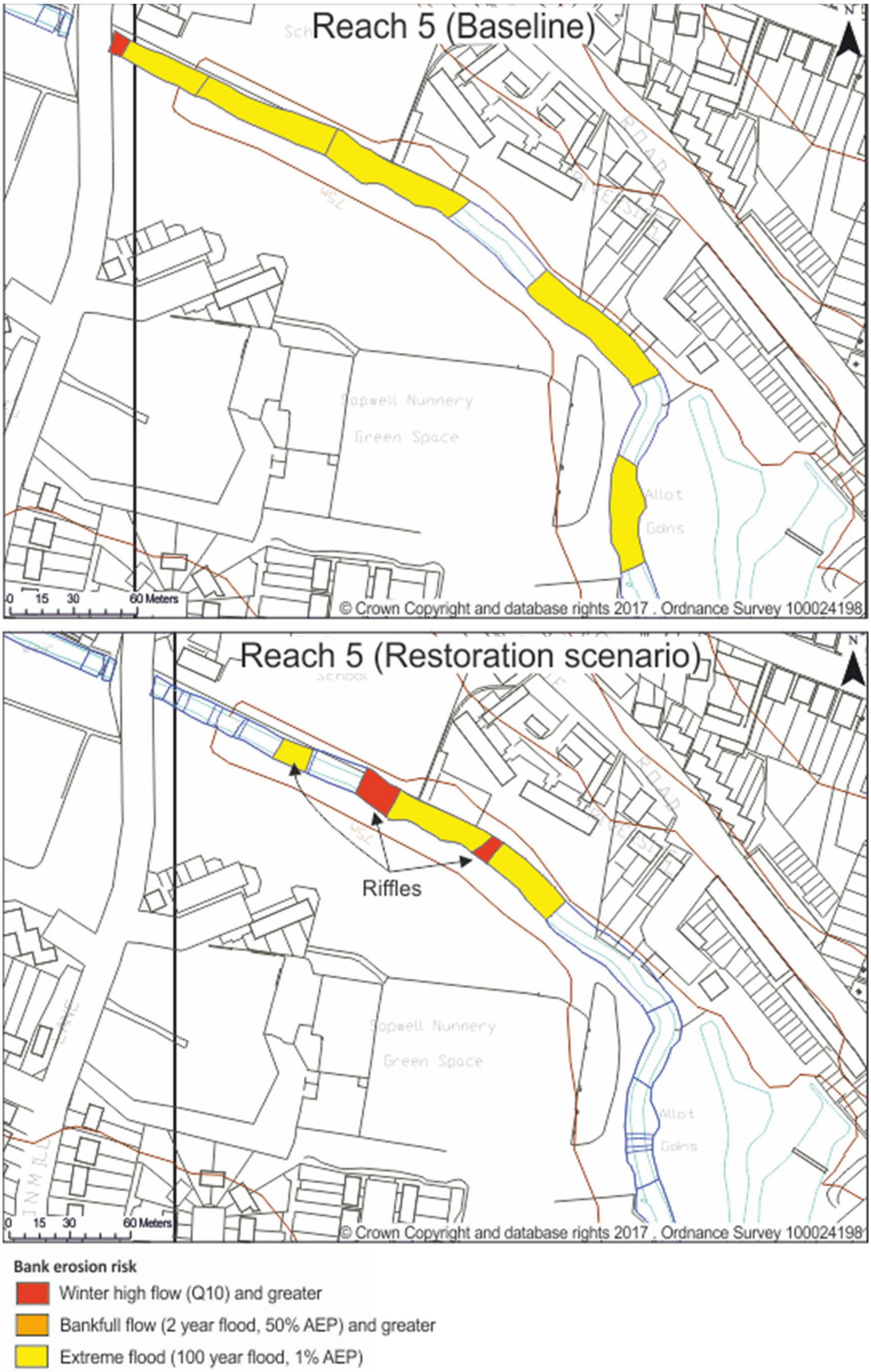


Figure 8.4 Bank erosion risk at Reach 5 under baseline and proposed restoration scenarios

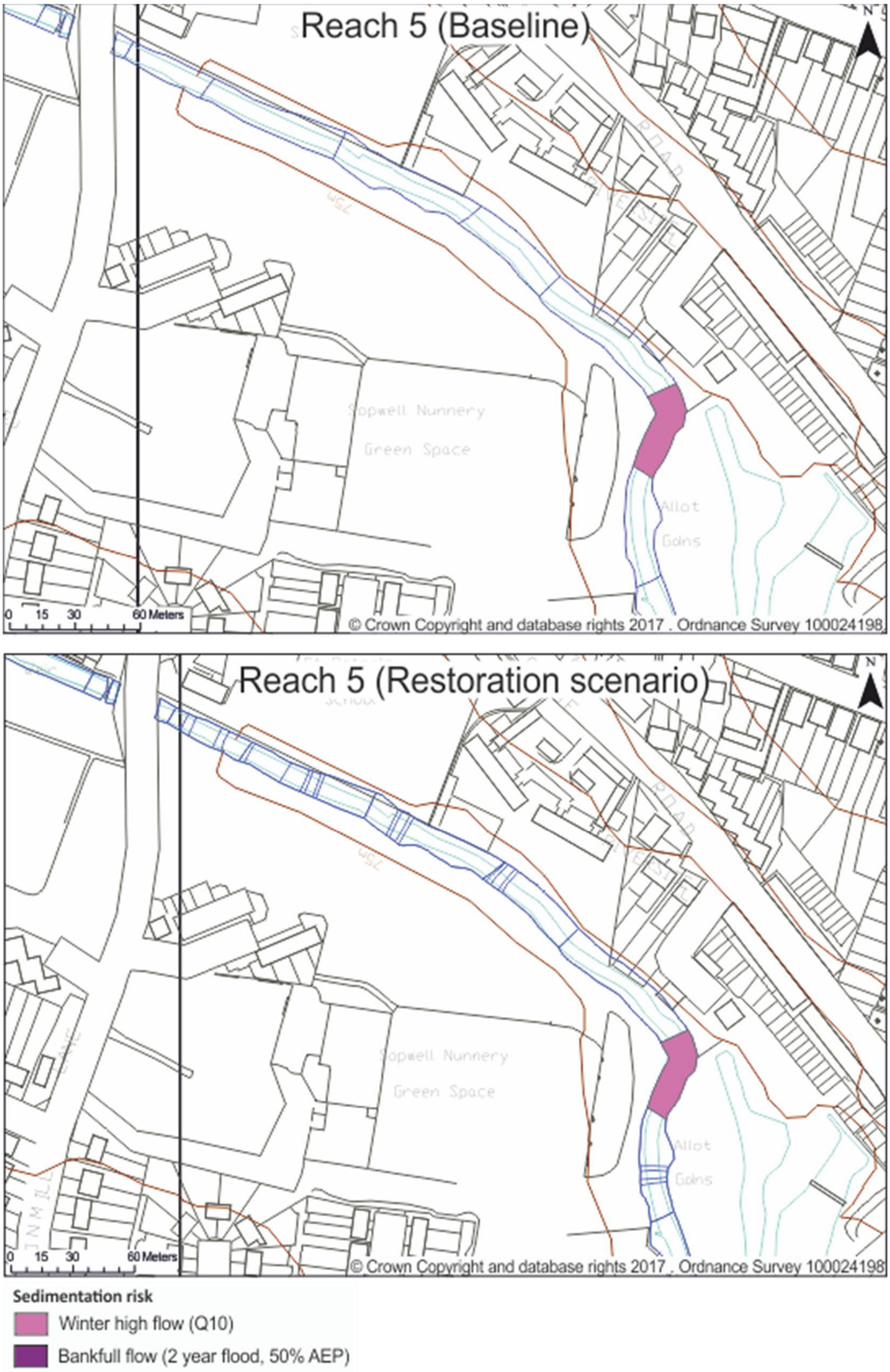
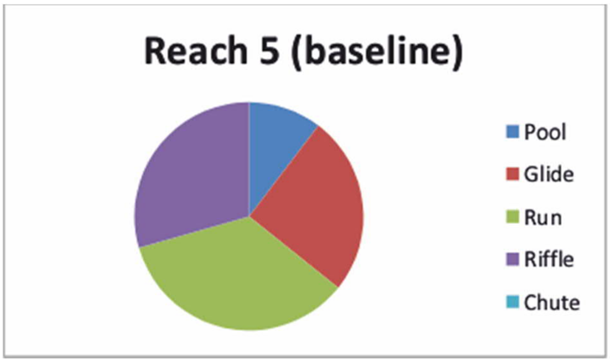


Figure 8.5 Sedimentation risk at Reach 5 under baseline and proposed restoration scenarios

River Habitats

Reach 5 is in a recovering state and has a reasonably varied hydraulic habitat character (Figure 8.6). Restoration along this reach is primarily concerned with reconnection with the floodplain and this will cause overall in-channel energy levels to drop resulting in increased run/glide habitat. Some riffle areas remain, however and this is proportionate within the reach.



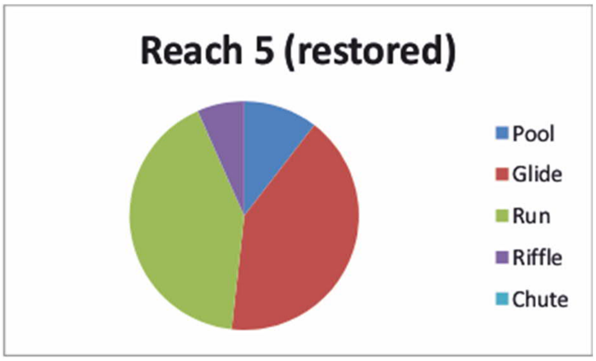


Figure 8.6 Current and restored in-channel habitats for Reach 5 on the River Ver

8.5 Engagement

Our outline proposals for Reach 5 were unveiled to the public in March 2018 at the start of a public engagement period. Engagement events were also and members of the public were invited to fill out a survey to record their views on the Reach 5 proposals.

The survey resulted in the following positive feedback being received:

- Proposals are modest and working within the current overall layout of the river.
- Creation of wet woodland.
- Tree reduction - improving light quality for growth/river health.
- Proposals for this reach will improve the flow of the river, help to remove silt and produce a better habitat.
- The footpath along the river gives good access to the river and Sopwell Nunnery without leading to erosion of the bank.
- Bank improvements.
- Improving this lovely stretch of river for wildlife and people, especially reducing the banks to give access to the river. In places this is currently dangerous for small children.
- Lowering the bank to reconnect the river to the floodplain.

A number of concerns were raised, and these are indicated in Table 8.1 along with our response.

Table 8.1 Survey Concerns and Our Response

Concern	Response
Potential increased flood risk to riparian properties in this reach, especially in the absence of changing the position of the bridge in the proposals and the narrowing of the river channel.	• Flood risk has been considered as part of the hydraulic modelling that was undertaken in support of the outline design, and results are discussed above. • As the design progresses to detailed design, flood risk should continue to be considered to to ensure that there would be no flood risk increase to people or properties as part of the design.
Unclear whether the off take from the river to the Watercress LNR will be retained. This is an important reserve particularly in winter for birds such as Siskin, Redpoll sp. and Water Rail. Water levels here have fluctuated in recent years, so an improved control mechanism is desirable.	• The offtake to the LNR has been acknowledged through the design work so that there would be no detrimental effect to the site as a result of less flowing from the river making it to the site. This should remain the case going into the detailed design. • If a more formal control mechanism is desired, we recommend that the operators liaise with the Environment

Concern	Response
	Agency regarding whether additional water is available from the river via abstraction.
Unclear how works to the river bank will be carried out - will large machinery be used and trucks to remove the spoil?	• Working methods should be explored further during the detailed design and confirmed by a contractor in advance of construction being undertaken. Bankside cranes/ excavators and small trucks for moving material around may be suitable for this reach.
How much extra water flow are we talking in this reach as a result of reduced groundwater abstraction?	• The result of the sustainability reduction on flow on the river is complex as it would depend on the level of groundwater rises throughout the catchment and antecedent conditions. Irrespective the sustainability reductions are expected to increase flow which will benefit the communities within the river.

The Wildlife Water Cress Association responded to the project plans with additional comments. The Environment Agency met with members on site to discuss the project.

We received a large number of enquiries from residents of Old Sopwell Gardens with concerns about flood risk. The Environment Agency has carried out further investigations in this area. All residents were invited to the second information event held on July 12 2018 to discuss this issue.

Historic England were also consulted on the proposals. They confirmed that the reach runs near Sopwell Priory and remains of post-medieval Sopwell House, which are designated as a scheduled monument (National List Entry 1019137). The proposals include enlarging the area of wet woodland that surrounds the allotments, which form part of the scheduled monument. However, they did not consider this will adversely impact the scheduled monument, providing that the woodland does not extend into the protected area (which should be confirmed through detailed design) and raised no objection to the proposals.

Herts and Middlesex Wildlife Trust were consulted and were supportive of the scheme to improve the Ver's morphology, wildlife and amenity value.

In addition to the survey further engagement responses were received. These are summarised in Table 8.2 along with our responses.

Table 8.2 Other Engagement Feedback and Our Response

Concern	Response	Next Steps/ Further Work
Concern about increased fluvial flood risk from for Old Sopwell Gardens	• The project plans will not increase flood risk to any properties.	• The main risk to theses properties is from groundwater flooding. Proposed scheme to include a connection to the river from area of groundwater flooding so that this water can be conveyed away/ dcresing flood risk. • As the design progresses to detailed design, flood risk should continue to be considered to to ensure that there would be no flood risk increase to people or properties as part of the design.
Concern about groundwater flooding following abstraction reductions Old Sopwell Gardens	• Our initial studies show that the planned abstraction reductions will not increase the risk of groundwater flooding to any properties in St Albans, including Old Sopwell Gardens. We are carrying out further investigations to ensure our position remains robust.	• We will examine options to minimise pooling of water in the Sopwell Nunnery open space area during high groundwater events

8.6 Final Outline Reach 5 Plans

Following engagement, we have revised the plans for Reach 5. The final outline restoration plans for Reach 5 are provided in Figure 8.4.

An Outline Environmental Appraisal of the option has also been undertaken to not only identify the benefits of the restoration but also provide an initial indication as to where further work during detailed design and/ or mitigation is required. The appraisal assumes that all best practice, such as Pollution Prevention Guidelines and Working in Water methods are adhered to and standard ecological surveys and resultant mitigation would be undertaken, and during construction. The appraisal is included as Table 8.3.

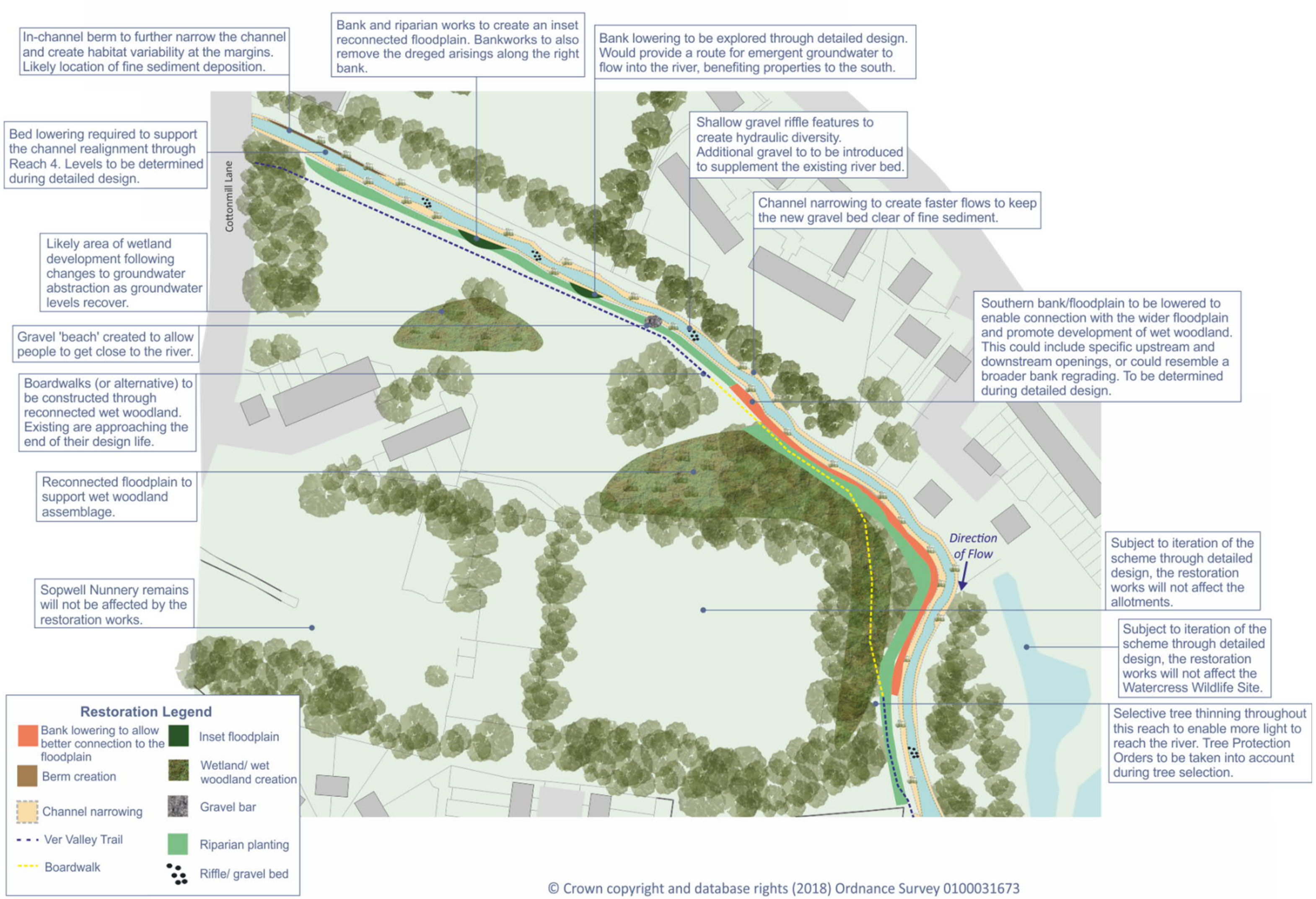


Figure 8.4 Reach 5 Final Outline Proposal Plan (post engagement)

Table 8.3 Outline Environmental Appraisal of the Reach 5 Preferred Option

Resource/ Feature	Overview	Effect or Potential Effect of Scenario	Potential Mitigation	Likely Significance
Hydrogeology/ Groundwater connectivity	Does the scheme affect connectivity between surface water and groundwater?	• The wet woodland creation within the identified high groundwater level zone would improve the groundwater connectivity to the fluvial system • Approximate bed levels would be confirmed following completion of the hydraulic modelling, at which point any improvements in river flow the connectivity with the groundwater table can be discussed further.	• Groundwater monitoring should be undertaken to improve the hydrogeological understanding and inform the detailed design.	• Beneficial
Geo-environmental	Does the scheme potentially result in a new pathway for contaminants to enter the river?	• Increased floodplain connection would provide a direct route for contaminants and nutrients to be introduced into the river (if present in the floodplain sediments) and would have an impact upon water quality in the river for the short term at least. It is noted that there is currently a pathway for these to enter the river indirectly, via runoff.	• A soil sampling strategy should be devised and enacted during the detailed design to confirm any risk and what mitigation should be undertaken, if any.	• With inclusion of suitable mitigation, if required, there would be a beneficial effect as wetland plants will help filter out any contaminants.
Flood Risk	Does the scheme result in an increase of decrease in flood risk to people and properties?	• The outline design shows limited floodplain connection to right bank/ field adjacent to Old Sopwell Gardens (largely due to bed lowering at the top of the reach to tie in with the Reach 4 restoration). • Groundwater emergence is likely to be a more significant issue in this reach and outflow from this area to the river can be included within the detailed design to ultimately reduce the risk of flooding to these properties. • Outline scheme would slightly increase flows to Watercress Wildlife Site. This may be acceptable as having met with the operator's additional flow is sought, although detailed design should look into the further in consultation with the operators and the Environment Agency water resources licensing team.	• As part of detailed design is it likely that the scheme will be refined and iterated. Revised schemes should be hydraulically modelling, and flood risk should be assessed throughout, to ensure that there is no increase in flood risk to people or properties as part of the works. Minor mitigation, should as land raising can be included as part of the scheme to ensure that this occurs. • Detailed design and modelling should acknowledge the effect of the sustainability reductions on groundwater levels and river flow.	• Neutral
Other hydrology	Does the scheme result in other changes to the hydrology that could impact upon other water users or receptors?	• Hydrology through this reach unaffected by the proposed restoration in Reach 5, or upstream. • No surface water abstractions in this reach and so no effect of the scheme on these. • Effect to Watercress Wildlife Association is discussed above under Flood Risk.	• Detailed design should continue to look at the hydrology and ensure no detrimental effect to other users.	• Neutral
Hydromorphology	Does the scheme improve the hydromorphological functioning of the reach?	• The in-channel features, creation of a wet woodland zone and floodplain reconnection works would improve the flow and habitat diversity as well as overall morphological functionality of this reach. This should increase the hydraulic habitat diversity with a greater frequency of higher energy riffle units. The wet woodland zone would extend the existing wet woodland area.	• Hydromorphological gains should continue to be sought from the scheme as detailed design progresses.	• Beneficial
Water quality	Does the scheme result in a deterioration or improvement of water quality, for example less flow would result in less dilution of consented discharges?	• Restoration and wetland should help improve water quality through this reach (for example reeds could filter out pollutants). • There are no consented discharges in this reach and there would be no changes as a result of this option.	• None required	• Beneficial
Statutory Sites or Non-Statutory Designated Sites	Does the scheme affect designated and or wildlife sites?	• Inflows into the Watercress Wildlife Site may increase as a consequence of the design and would be assessed using hydraulic modelling. Such changes may be beneficial though should be considered further. This is discussed under Flood Risk above.	• As under Flood Risk above.	• As under Flood Risk above.
Other Biodiversity	Wildlife can be impacted during construction while scheme may result in positive, neutral or negative effects to species.	• Scheme would result in an improvement to the health of the river and provide additional habitats	• None required	• Beneficial
Heritage	Does the scheme potentially impact upon Scheduled Monuments or other archaeological features?	• The option would result in works close to Sopwell Nunnery scheduled monument. The asset is of high heritage value and its surrounding landscape is of importance regarding its designation. No significant impacts on the monument are anticipated as a result of the option, however, though Heritage should continue to be considered throughout the project lifetime.	• Detailed design should continue to suitably account for Heritage, for example not result in excessive excavation to areas of archaeological significance. • A Heritage officer with a Watching Brief during the works is anticipated.	• Neutral/ minor adverse
Tree Protection Orders (TPO)	Consideration of the effect of Tree Protection Orders on the option	• There are a few TPOs in this reach although north of the river and the scheme can be designed so that these would not be impacted by the option or associated construction activities.	• None required	• Neutral
Landscape impact	Does the option have a significant visual impact?	• The option should result in an improved looking and more natural appearing river that is better connected to its flood plain.	• None required	• Beneficial
Recreation and amenity	Does the option have significant impacts upon	• The scheme should result in accessible wet woodland and more visually	• Public access needs to be planned thoroughly to allow	• Beneficial

	recreation and/ or amenity	interesting river that would encourage visitors	people to access nature in a way that is sympathetic to wildlife whilst enabling learning and engagement experiences. This may include some access restrictions in sections that contain higher wildlife value. This should be considered through the detailed design.	
Riparian ownership issues	Does the option affect properties?	• There are a number of owners of the riparian area to the north of the river through this reach. The option would not result in a re-alignment of the river through the north of the river and so no significant or prohibitive impacts are anticipated. • Channel works have the potential to affect flooding close to the river.	• See response regarding flood risk, described above.	•
Construction only				
Water Mains and Sewers (foul and surface water)	Consideration of the potential effect of these on buildability of the scheme.	• Affinity Water mains (depths to be confirmed through trial holes) and Thames Water foul sewers (depths approximately 2.7m bgl) would likely be crossed by plant and should be accounted for. No works are anticipated close to mains or sewers, however. • There are 3 surface water sewers in this reach which discharge into the existing channel via the northern/ left bank. The scheme would not result in significant changes to the hydrology through this reach and so no impact upon the rivers ability to dilute these discharges is anticipated. • It should be noted that there are assets under Cottonmill Lane that may be impacted, although any effect would likely depend on the Reach 4 option that is progressed with.	• Utilities should be considered through the detailed design and should be suitably accounted for during any construction works. • Further surveys are recommended.	• Neutral
Other Utilities	Consideration of the potential effect of these on buildability of the scheme.	• There are a number of utilities at the top end of reach, under Cottonmill Lane. These would need to be accounted for if culvert/ structural adjustment works are required.		• Neutral
Pedestrian access	Consideration of the potential need for footpaths to be diverted, for example Public Rights of Way may need to be diverted if works are would occur over their route	• A footpath extends throughout the route of the works proposed by this scenario and parts of it may need to be diverted for the duration of the works. The path is also boardwalk for much of the reach and this is apparently near the end of its design life so should be replaced as part of any works.	• None regarding Public Rights of Way although the Ver Valley Trail, a recreational route, will be affected by the works during construction and should be diverted if possible. This might not be possible through the boardwalk area unless a new path is installed before the old path is removed.	• Neutral
Access	Consideration of access to the works area. Access may be difficult and even prohibitively expensive under certain circumstances	• Access for works should be relatively straightforward and be from Cottonmill Lane or Old Sopwell Gardens. • High groundwater levels, which can occur in the Sopwell Nunnery area, would affect plant operations and works should be undertaken at times when these are low. • Works would require that the boardwalks are temporarily removed which would have cost and timing implications.	• Access should be determined during detailed design and confirmed by the contractor delivering the works. • Traffic management order may be required.	• Neutral

8.7 Reach 5 Next Steps

8.7.1 Detailed design

The detailed design will need to examine the following:

- A screening opinion from the local authority should be sought as to whether an EIA would be required. The topics requiring further assessment should also be confirmed.
- Undertake groundwater monitoring to improve the understanding as to the extent of groundwater emergence that is expected through Reach 5.
- Refine the design of the scheme through hydraulic modelling. The modelling should acknowledge the effect of the sustainability reductions on groundwater and flow.
- Constructions methods should be considered further during detailed design.
- We will work with residents to plan which trees could be removed, pollarded or thinned to achieve better levels of light for the river whilst minimising impact to properties.
- An access plan should be developed. This should include how public and their pets can interact with the river, for example at controlled access points, and access through the wetland area.
- Long term maintenance of the scheme should be considered as part of the detailed design. For example, the design life of boardwalks may be of the order of 10 years and a more sustainable option may be appropriate.
- New habitats, such as the wetland, should be determined that consider the site conditions (soil type etc.) and anticipated levels of inundation. The choice of species should reference the Herts Habitat Inventory (held by HMWT Records Office) to create a section of Living Landscape in St Albans. A planting plan for the riparian/ floodplain and wetland areas should ultimately be developed.
- Produce detailed design drawings that can be used for construction.

THE PREFERRED OPTION FOR REACH 6

9

9. The Preferred Option for Reach 6

9.1 Overview

Reach 6 covers the River Ver from the Watercress Wildlife Site to Sopwell Mill Farm (see Figure 9.1 below).

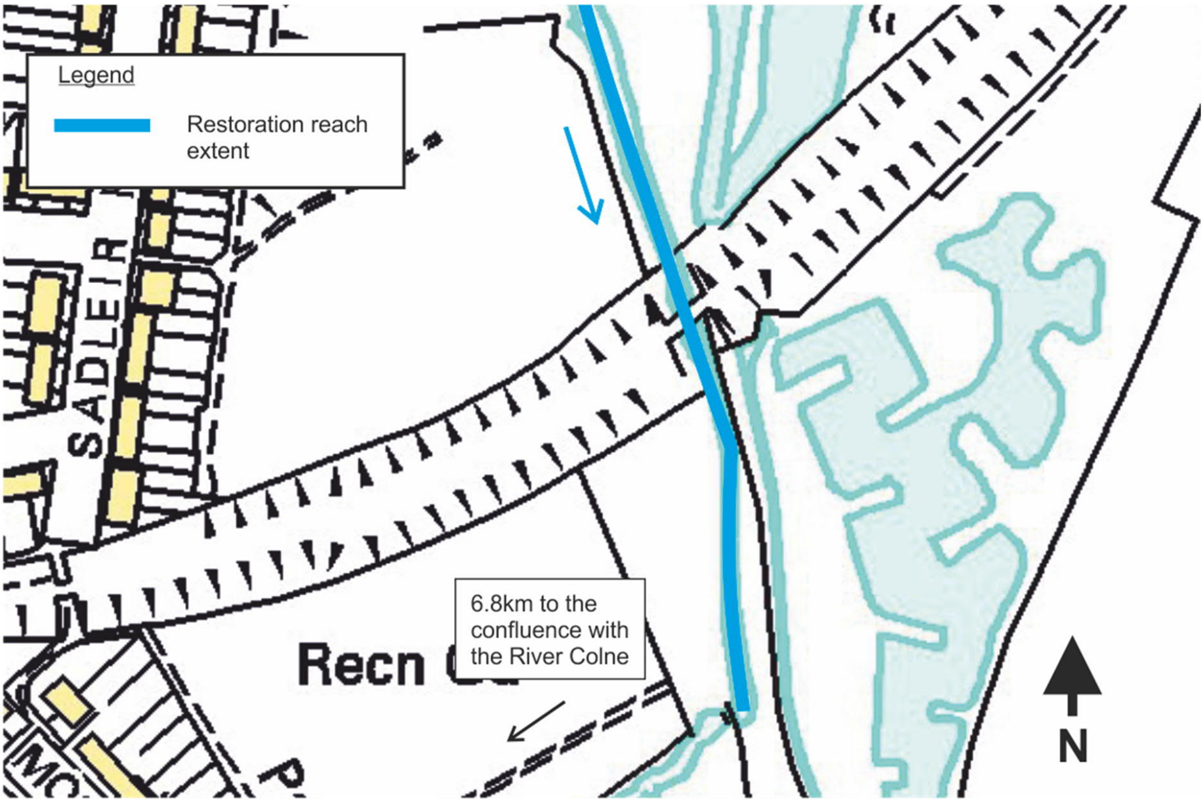


Figure 9.1 Reach 6 of the study area (From the Watercress Wildlife Site to Sopwell Mill Farm)

To the north of the Alban Way, there is a wildlife site to the east of the river and allotments to the west. To the south of the Alban Way, there are fishing lakes to the east and Sopwell Mill Open Space to the west.

The Ver Valley Trail runs very close to the river along its west bank upstream of the Alban Way. The banks are very steep, and the path is eroding in places.

As a result of historic alterations, the channel is overly-wide, straight and deep. This results in slow flows and consequently a build-up of silt that smothers the natural gravel bed.

9.2 Issues in Reach 6

The river in Reach 6 above the Alban Way is in a poor condition and the path alongside is narrow and eroding in many places. The downstream section of channel is in a better state, mainly due to recent tree works to let in more light which has improved the habitat. The issues which affect this reach are:

- Over-wide and deep – the river has been over deepened and widened in the past. It is particularly over-deep upstream of the Alban Way.
- Low flows – due, in part, to abstraction pressure
- Silty – as a result of the above factors, some of the gravel river bed is smothered in silt.
- Disconnected from the floodplain – the river is disconnected from the floodplain as a result of being over-deep and the mounds of previously dredged material on the bank.

- Lack of habitat and flow diversity – some sections of this reach have little diversity of habitat or flow.
- Bank and path erosion - the path is on the edge of the steep right bank of the river and is eroding in several places due to its close proximity to the river. This erosion is made worse by dogs accessing the river from the path.

Restoration in this design should account for each of these issues and result in the project objectives being achieved. Further information on the river issues is provided in Appendix A.

Figure 9.2 presents a visual summary of the issues within Reach 6.

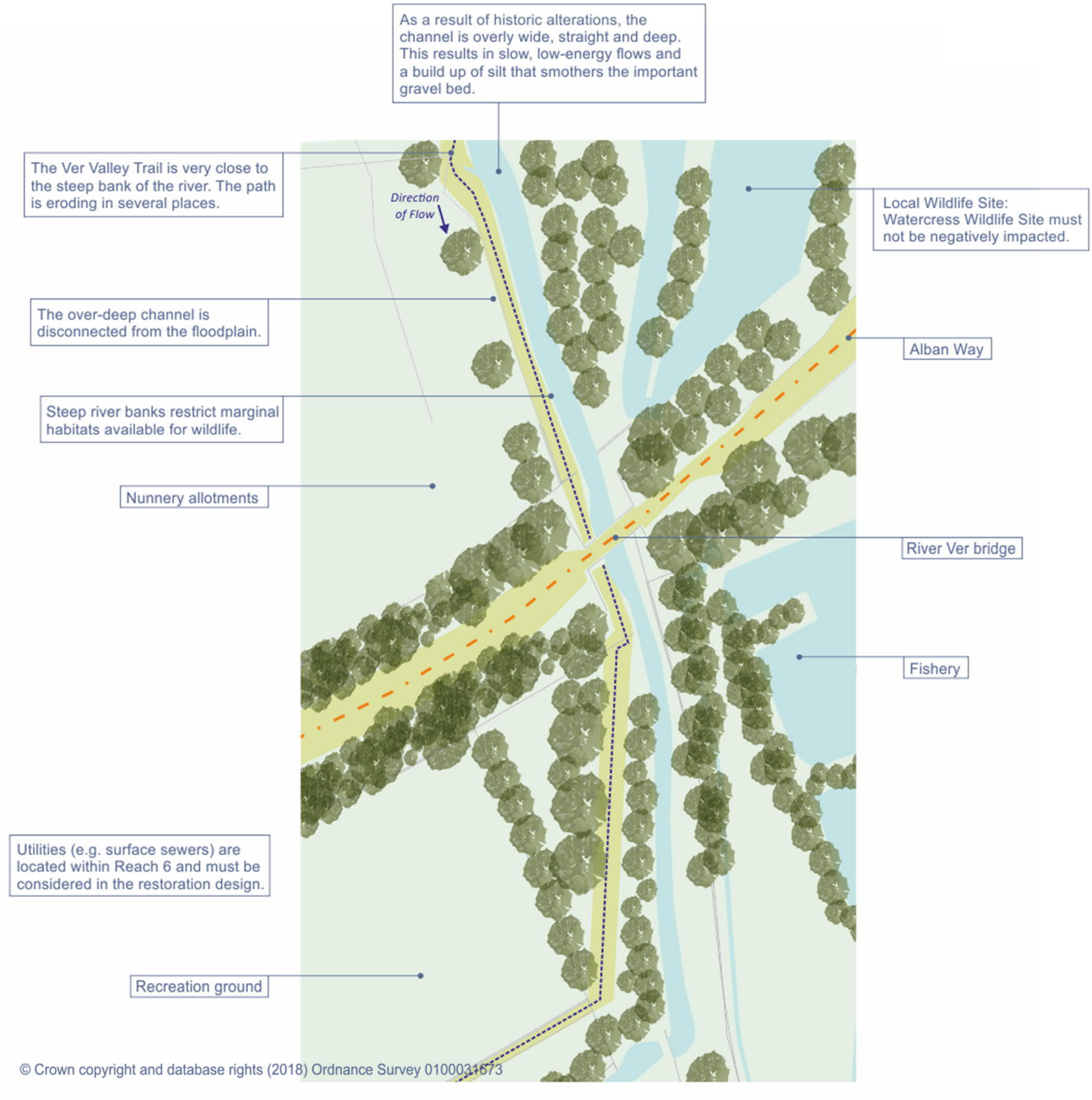


Figure 9.2 Reach 6 Issues and Constraints Overview

9.3 Derivation of the Preferred Option for Reach 6

9.3.1 Long Listing and Short-listing Appraisal

Full results of the long listing and short-listing appraisal of Reach 6 options is included within Appendix L. The appraisals considered the issues indicated in Section 5.2 and constraints identified in Section 3.10.

At the start of the project, we developed two potential restoration options for Reach 6 which we then assessed as part of the long list appraisal. Following this, one of the two options that were longlisted was in turn shortlisted. This was:

- Option 2 Retain and improve the existing channel.

This was then examined as part of the detailed short list appraisal when more detailed appraisal of the option was undertaken. The option is discussed further below.

9.4 The Preferred Option for Reach 6

The Reach 6 preferred option/ outline proposals, prior to engagement, are summarised in Figure 9.3.

Our proposals will introduce channel enhancements to narrow the channel, improve the flows and re-establish the gravel bed. Upstream of the Alban Way, they also include improvements to the path and regrading of the river banks to create space for marginal plants that provide vital habitat for a range of species.

In the top half of the reach (upstream of the Alban Way), the existing channel course would be maintained, however to provide space for access improvements and stabilisation of the west bank of the river, one row of allotments closest to the river would be lost. This would provide room for the path to be set back away from the bank top and improved. The west bank would be regraded to allow marginal plants to establish and in-channel improvements would be delivered.

In the bottom half of the reach, the west bank would be lowered to create an area of marginal vegetation and in-channel enhancements would be made. The path would be set back, which would provide improved views into the river channel.

As well as making significant improvements to the river which will create a more natural chalk stream, our proposals will restore the Ver Valley Trail through this reach. At present the footpath is in a poor state. Lowering the banks will allow the public to get closer to the river which will run alongside beautiful wild flower meadows, rich in wildlife.

The following outlines the rationale for the features that were included within the outline design (shown in Figure 9.3).

Reach 6 is a low gradient reach increasing to moderate downstream with low sinuosity. The gradient is steep enough to support functional riffles downstream, sediment supply is too low to allow these to develop naturally, hence they will have to be constructed. Upstream restoration has focussed on berm creation to narrow the low flow channel and increase low flow energy levels and inset berm/riparian features have been used to improve riparian connectivity and support riparian wetland. Floodplain enhancement is possible through the development of a wide riparian strip, reintroducing more appropriate species.

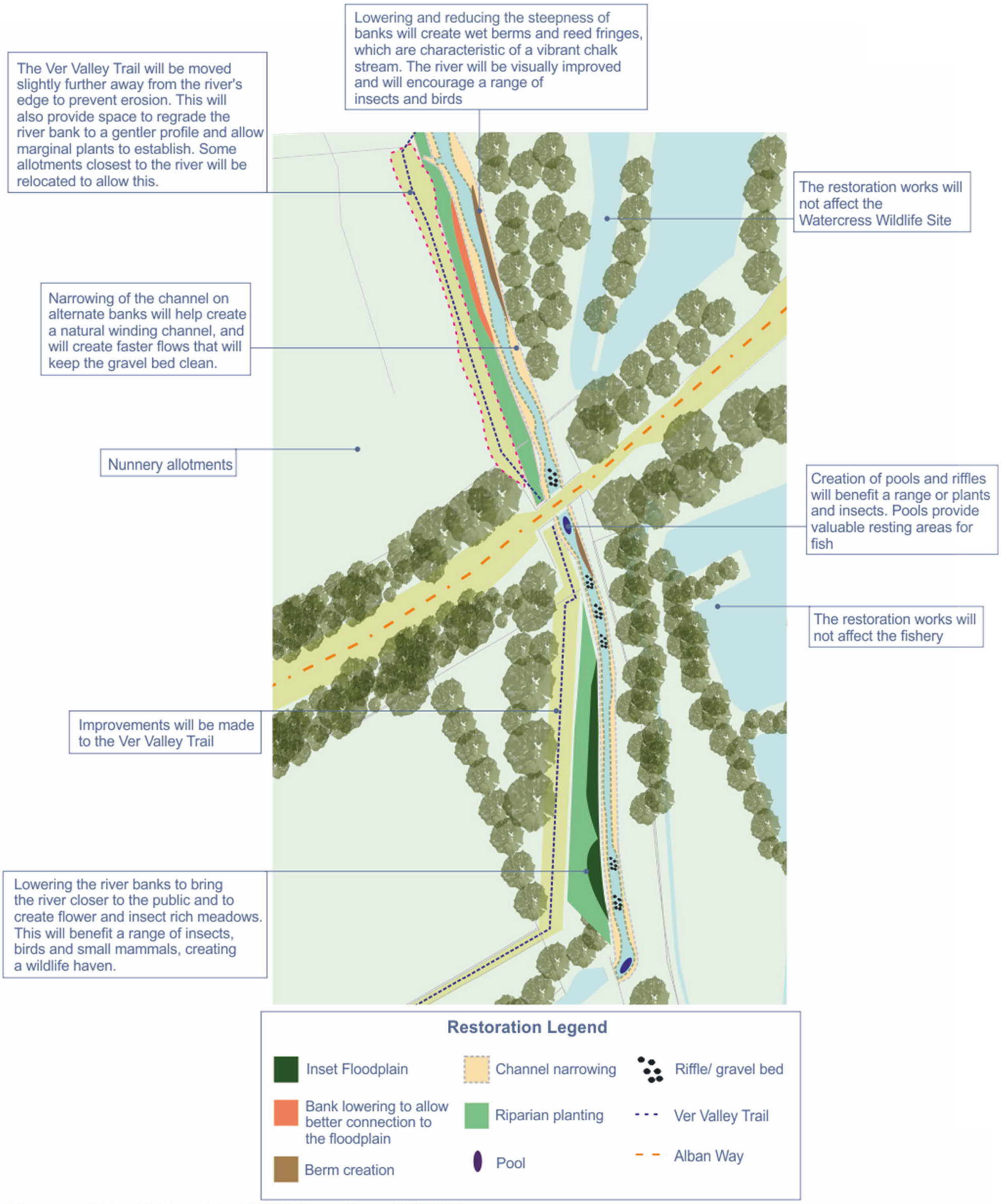


Figure 9.3 Reach 6 Preferred Option/ Outline Proposals (prior to engagement)

9.4.2 Summary of the Proposed Option Modelling

Hydraulic modelling was undertaken to refine the restoration features that were included in the design and determine the potential hydrological, hydromorphological and ecological effects of the preferred river restoration option. Full results of the modelling are included within Appendix D. A summary of the effects is provided below.

Hydrology

No changes to the amount of flow in the river are predicted as a result of the restoration.

The proposed restoration scenario did not result in significant changes to localised flood risk compared with the baseline. The lowering of the right bank upstream of the bridge produced a minor increase in inundation extent at the right bank floodplain, however modelled water depths were shallow being <0.1 m. Model results indicated increased connectivity between the River Ver and Watercress Wildlife Site under 2-year flood conditions with increased inundation extent and depth in this area under the proposed restoration. Discussion is necessary to establish if this increase is acceptable.

The inset floodplain features downstream of the bridge received flood flows however the extent of inundation did not extend beyond these features, where increased inundation is intended.

Hydromorphology

All riffles along the reach look likely to function well and pools will be flushed of any accumulated sediment during a flood. Some gravel movement appears possible and feature gravels will need to be appropriately sized at the detailed design stage. These results are not surprising as the baseline conditions through the reach are moderately energetic, suggesting that this reach is in a recovering state and the ‘light touch’ option chosen is therefore appropriate.

Bank erosion (Figure 9.4) looks to be a possibility at some berm and riffle locations but will be minor and in keeping with the new naturalised channel. No protection is suggested although appropriate bank edge planting would reduce any bank loss and should be considered at the detailed design stage.

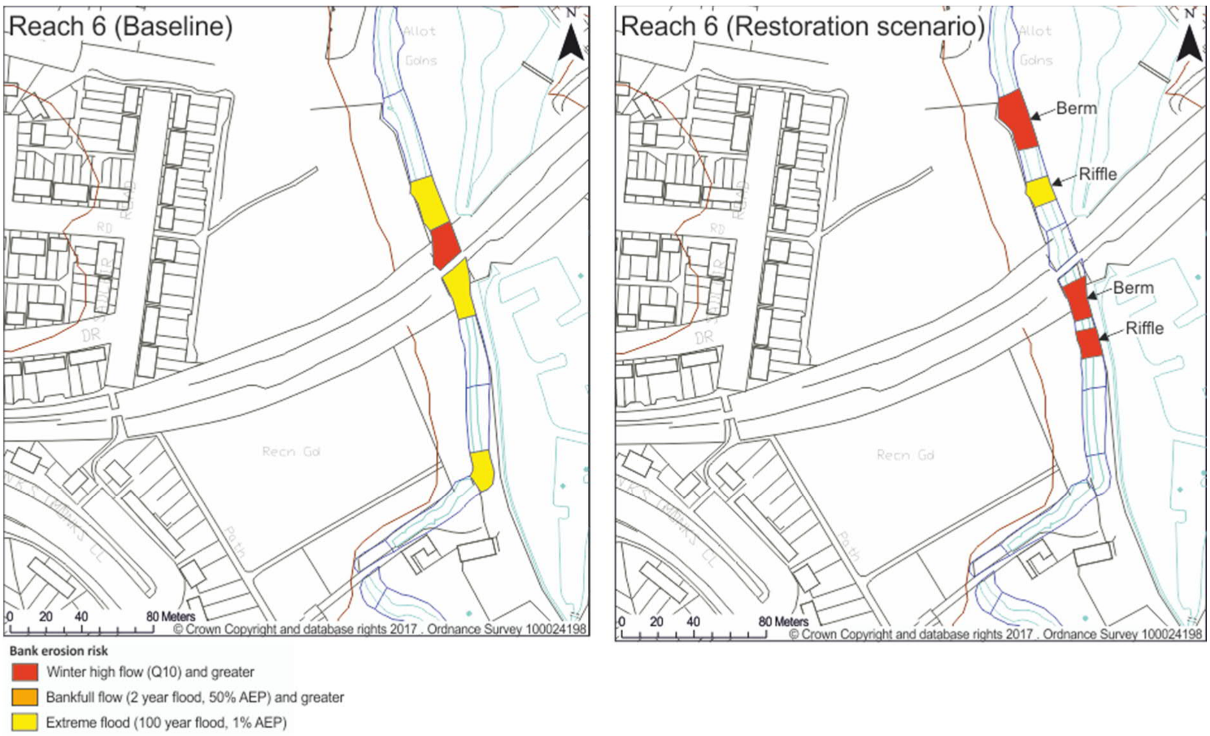


Figure 9.4 Bank erosion risk at Reach 6 under baseline and proposed restoration scenarios

The reach is currently not particularly prone to excessive sedimentation and this will continue with the restoration (Figure 9.5). The modelling indicated that features in the outline design were performing as intended any low flow sedimentation would be flushed out by higher flows.

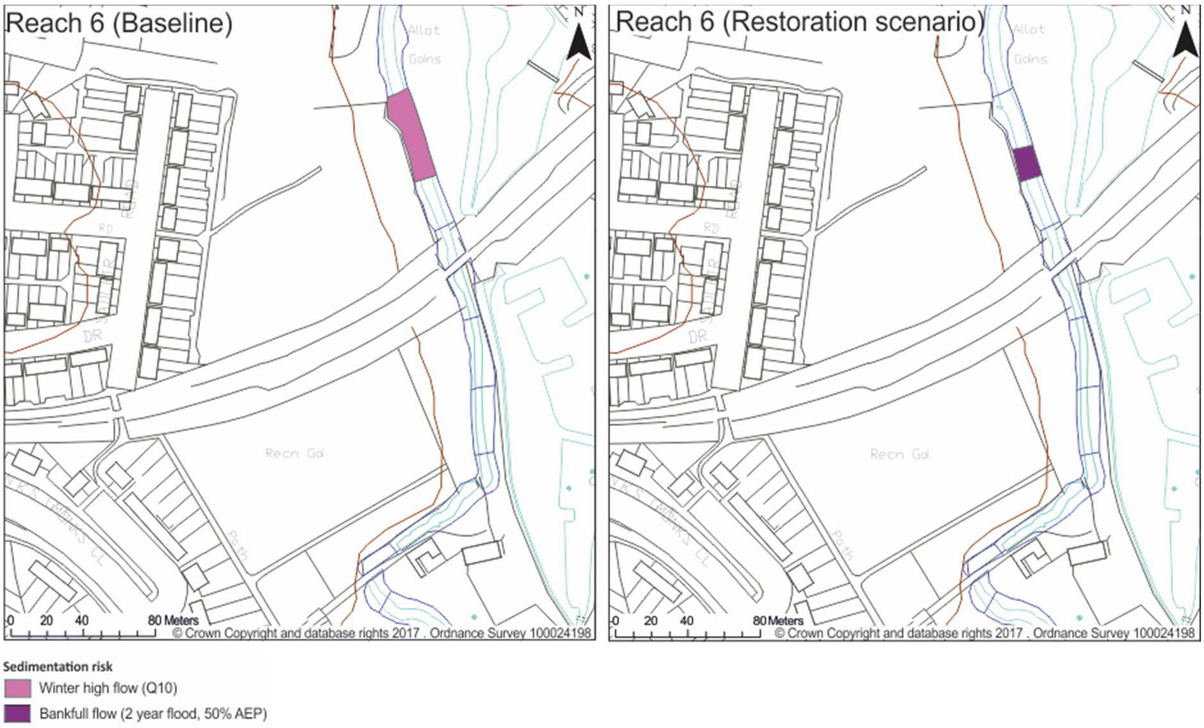


Figure 9.5 Sedimentation risk at Reach 6 under baseline and proposed restoration scenarios.

River Habitats

Reach 6 is highly degraded with glide/pool habitat dominating at present (Figure 54). This contrasts with the restored reach where around 30% of the channel is transformed from glide to run/riffle habitat this generating a more diverse and energetic reach.

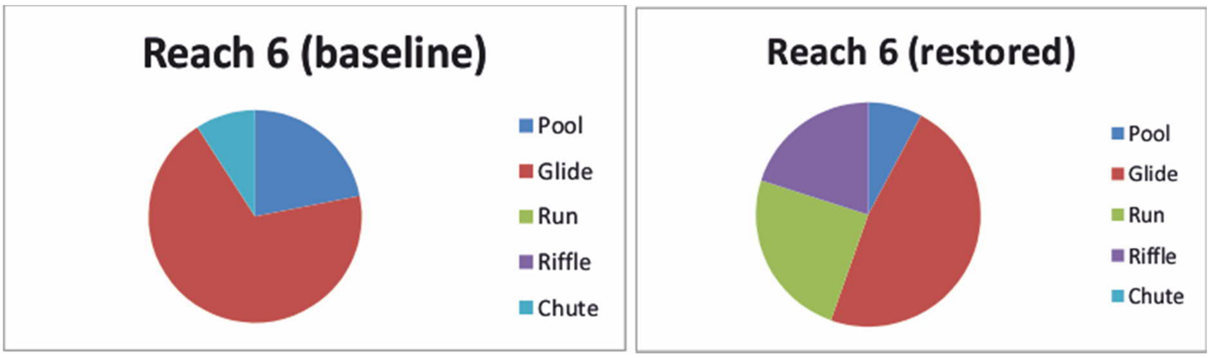


Figure 9.6 In-channel habitat in Reach 6 under baseline and proposed restoration scenarios

9.5 Engagement

Our outline proposals for Reach 6 were unveiled to the public in March 2018 at the start of a public engagement period. Engagement events were also and members of the public were invited to fill out a survey to record their views on the Reach 6 proposals.

The survey resulted in the following positive feedback being received:

- Improvements to the existing channel are welcome and additional strengthening of the bank where the inlet to the Watercress Wildlife Site is would assist in maintaining this Local Nature Reserve.
- The improvements to the Ver Valley Trail are a very attractive idea alongside some improvements to the stream, so that it can be better enjoyed and appreciated. There is so much potential for this site to be used more by families and also schools for science and geography purposes.

A number of concerns were raised, and these are indicated in Table 9.1 along with our response.

Table 9.1 Survey Concerns and Our Response

Concern	Response
This Reach already provides habitats for Kingfisher, Water Rail and would be suitable for re-introduction of vole is the funding could be found. WWA was involved with Herts and Middlesex Wildlife Trust in monitoring this stretch for mink and would have assisted with water vole reintroduction had the project not ended.	• This view is noted. The proposals would result in the issues presented in Section 9.2 being tackled which will lead to further significant ecological improvements.
Damage to river banks through increased public access.	• This is noted although the plans would not necessarily result in greater access to the river but encourage them to the riparian area. Access at specified locations can be considered further during detailed design.
Re-thinking of the dog ladders would reduce wear on the banks as these are not used by dogs that go down the bank. There is already extensive marginal planting in this section so a proposal to introduce more is a puzzle.	• Public access, including for dogs, should be considered through holistically through detailed design so that access is not only improved but better controlled.
No need to enlarge the path and remove allotments, this path has been absolutely fine for the past 15 years and no sign of it disappearing into the river.	• Erosion is noted at a number of locations through the reach and the current banks beside the path are too steep for the situation to be considered sustainable. The council has confirmed that through careful planning and rejigging of the allotment site there would be no net loss of plots in this allotment as a result of the works.
The work undertaken a few years ago to strengthen the banks and reduce dog walker access to the river has worked well - some simple modifications to this is all that is required. No consideration given to allotment holders who will be losing their plots for little benefit.	
Concern that rising ground water and narrowing of river bank will increase flood risk on WWA site.	• We acknowledge that flood risk is a critical consideration of the restoration. • Flood risk has been considered as part of the hydraulic modelling that was undertaken in support of the outline design and indicates that additional, but limited, flow to the site may occur as a result of the outline design (which may even be considered as beneficial). • As the design progresses to detailed design flood risk should be determined to ensure that there would be no detrimental effect to people or properties as part of the design and we would engage with the operators of the site through the process. • We have discussed the possibility of a controllable sluice and can look at this further as the project progresses
Apart from maintenance of trees along river, not clear how much is to be gained from proposals.	• Some of the gains are indicated in Section 9.4.2 above.
Ensuring that work does not impact heron population.	• The works should benefit wildlife including heron. Careful consideration of ecological impacts will be undertaken through the detailed design.
Unclear how far the bottom will be dredged out.	• Dredging is not planned as part of the works. Bed lowering is proposed as part of creating the pools though the methods for this would be confirmed during the detailed design (for example may be created by encouraging sediment to be transported downstream rather than through excavating material).
If the banks had already been properly maintained and managed, they would not currently be in such a bad state of repair.	• This view is noted.
Risk and effects of increased fly tipping and litter levels.	• These views are noted. Access through the reach should be considered during detailed design though opening up of the path beside the river may discourage such activities.

In addition to the survey the project team met with allotment tenants to discuss the potential effect on the allotment site and the operators of the Watercress Wildlife Association.

Historic England were also consulted and raised no concerns with the proposals.

Herts and Middlesex Wildlife Trust were consulted and were supportive of the scheme to improve the Ver's morphology, wildlife and amenity value.

9.6 Final Outline Reach 6 Plans

Following engagement, we have revised the plans for Reach 6. The final outline restoration plans for Reach 6 are provided in Figure 9.4.

An Outline Environmental Appraisal of the option has also been undertaken to not only identify the benefits of the restoration but also provide an initial indication as to where further work during detailed design and/ or mitigation is required. The appraisal assumes that all best practice, such as Pollution Prevention Guidelines and Working in Water methods are adhered to and standard ecological surveys and resultant mitigation would be undertaken, and during construction. The appraisal is included as Table 9.2.

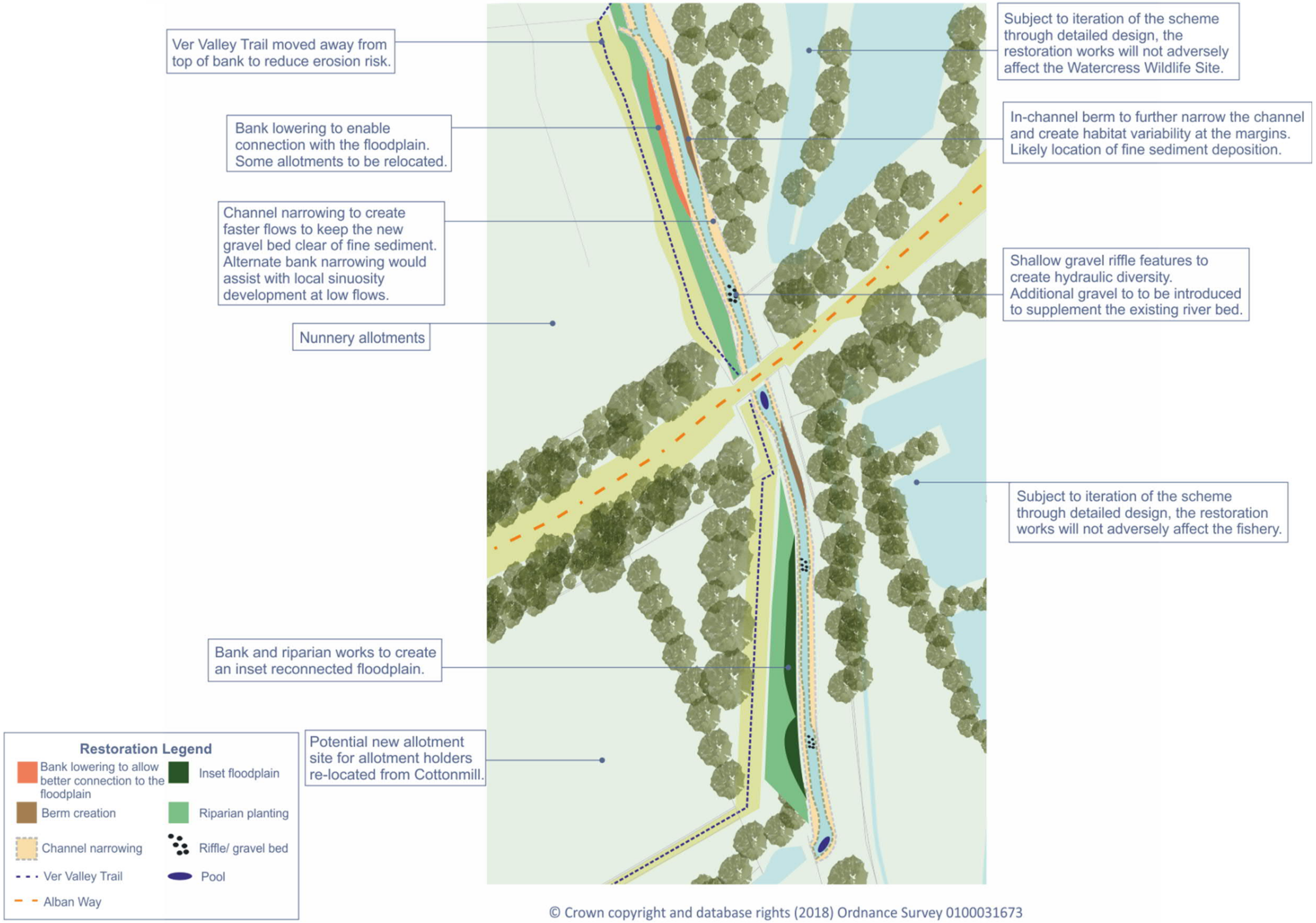


Figure 9.4 Reach 6 Final Outline Proposal Plan (post engagement)

Table 9.2 Outline Environmental Appraisal of the Reach 6 Preferred Option

Resource/ Feature	Overview	Effect or Potential Effect of Scenario	Potential Mitigation	Likely Significance
Hydrogeology/ Groundwater connectivity	Does the scheme affect connectivity between surface water and groundwater?	• There are unlikely to be any significant improvements to groundwater connectivity through this reach as the existing channel alignment is being retained.	• None required	• Neutral
Geo-environmental	Does the scheme potentially result in a new pathway for contaminants to enter the river?	• Increased floodplain connection would provide a direct route for contaminants and nutrients to be introduced into the river (if present in the floodplain sediments) and would have an impact upon water quality in the river for the short term at least. It is noted that there is currently a pathway for these to enter the river indirectly, via runoff.	• A soil sampling strategy should be devised and enacted during the detailed design to confirm any risk and what mitigation should be undertaken, if any.	• With inclusion of suitable mitigation there would be a neutral effect.
Flood Risk	Does the scheme result in an increase of decrease in flood risk to people and properties?	• Some changes to Wildlife Watercress Association and downstream fish farm during extreme flood events are associated with the current outline design. • There is unlikely to be any other significant flood risk impact associated to the modifications to the existing channel for this option.	• As part of detailed design is it likely that the scheme will be refined and iterated. Revised schemes should be hydraulically modelling, and flood risk should be assessed throughout, to ensure that there is no increase in flood risk to people or properties as part of the works or detrimental hydrological effects to others.	• Neutral
Other hydrology	Does the scheme result in other changes to the hydrology that could impact upon other water users or receptors?	• There are no abstractions in this reach or any flow splits so no other hydrological effects are anticipated. • Outline scheme would slightly increase flows to Watercress Wildlife Site. This may be acceptable as having met with the operator's additional flow is sought, although detailed design should look into the further in consultation with the operators and the Environment Agency water resources licensing team.		• Neutral
Hydromorphology	Does the scheme improve the hydromorphological functioning of the reach?	• The proposed morphological improvements to the existing channel for this option would help to reduce the tendency for fine sediment deposition and create a more diverse hydraulic habitat through the reach. This would include a higher proportion of higher energy riffled units. Local riparian zone improvements would be created as a result of the proposed right bank works.	• Hydromorphological gains should continue to be sought from the scheme as detailed design progresses.	• Beneficial
Water quality	Does the scheme result in a deterioration or improvement of water quality, for example less flow would result in less dilution of consented discharges?	• There are no active consented discharges in this reach and there would be no changes as a result of this option. • Riparian planting and hydromorphological improvements should help improve general water quality through the reach.	• None required	• Beneficial
Statutory Sites or Non-Statutory Designated Sites	Does the scheme affect designated and or wildlife sites?	• Minor changes linked to the hydrology may occur with the outline design. These are described above and may even be beneficial.	• See response to Flood Risk/ Other hydrology above	• Neutral
Other Biodiversity	Wildlife can be impacted during construction while scheme may result in positive, neutral or negative effects to species.	• Scheme would result in an improvement to the health of the river and provide additional habitats	• None required	• Beneficial
Heritage	Does the scheme potentially impact upon Scheduled Monuments or other archaeological features?	• The option is unlikely to have a significant effect of features of archaeological importance.	• Detailed design should continue to suitably account for Heritage, for example not result in excessive excavation to areas of archaeological significance. • A Heritage officer with a Watching Brief during the works may be required.	• Neutral/ minor adverse
Tree Protection Orders (TPO)	Consideration of the effect of Tree Protection Orders on the option	• There are no TPOs in this reach and so no effect on the scheme.	• None required	• Neutral
Landscape impact	Does the option have a significant visual impact?	• The option should result in a slightly improved looking and more natural appearing river that is better connected to its flood plain.	• None required	• Beneficial
Recreation and amenity	Does the option have significant impacts upon recreation and/ or amenity	• The option would result in a more accessible river which should be appealing for people to visit. • Works would not extend in the recreational area and so no loss of playing grounds is anticipated (although some of this land may be used for new allotments to replace some of those relocated from Reach 4).	• Public access needs to be planned thoroughly to allow people to access nature in a way that is sympathetic to wildlife whilst enabling learning and engagement experiences. This may include some access restrictions in sections that contain higher wildlife value. This should be considered through the detailed design.	• Neutral
Riparian ownership issues	Does the option affect properties?	• See other hydrology regarding Watercress Wildlife Association site. • St Albans City and District Council have advised that they own all the area that would be affected by this option and so no other riparian ownership issues are anticipated.	• See response to Flood Risk/ Other hydrology above	• Neutral
Construction only				
Water Mains and Sewers (foul and surface water)	Consideration of the potential effect of these on buildability of the scheme.	• There is a Thames Water surface water sewer that enters the river towards the top end of Reach 6. This enters at the right bank where works are proposed. The works would	• Utilities should be considered through the detailed design and should be suitably	• Neutral

		need to account for this and depth of the structure should be confirmed to determine how this is accounted for. • The scheme would not result in significant changes to the hydrology through this reach and so no impact upon the rivers ability to dilute the associated discharge is anticipated.	accounted for during any construction works. • Thames Water may insist on no excavation works with 10m of their sewer .and have indicated that sewer may also be in a slightly different location to what is shown on their mapping. Early consultation with Thames water is recommended. They are also likely to ask for CCTV survey before and after the works to prove that the integrity of the sewer has not been compromised by the works. • Further surveys are recommended.	
Other Utilities	Consideration of the potential effect of these on buildability of the scheme.	• No impacts on other utilities are anticipated with this option.		• Neutral
Pedestrian access	Consideration of the potential need for footpaths to be diverted, for example Public Rights of Way may need to be diverted if works are would occur over their route	• A public right of way extends throughout the route of the works proposed by this scenario and would need to be diverted for the duration of the works.	• None regarding Public Rights of Way although the Ver Valley Trail, a recreational route, will be affected by the works during construction and could be diverted.	• Neutral
Access	Consideration of access to the works area. Access may be difficult and even prohibitively expensive under certain circumstances	• Access for works should be relatively straightforward and likely be from the west/ south west.	• Access should be determined during detailed design and confirmed by the contractor delivering the works. • Traffic management order may be required.	• Neutral

9.7 Reach 6 Next Steps

9.7.1 Detailed design

The detailed design will need to examine the following:

- A screening opinion from the local authority should be sought as to whether an EIA would be required. The topics for consideration during detailed design should also be confirmed.
- Refine the design of the scheme through hydraulic modelling. The modelling should acknowledge the effect of the sustainability reductions on groundwater and flow.
- Constructions methods should be considered further during detailed design and discussed with riparian owners.
- An access plan should be developed and integrated within the final scheme. This should include how public and their pets can interact with the river, for example at controlled access points, and access through the wetland area.
- Further Heritage assessment may be needed as the detailed design progress and scheme is refined. A watching brief during any works may be required.
- New riparian habitat species should be determined that consider the site conditions (soil type etc.) and anticipated levels of inundation. The choice of species should reference the Herts Habitat Inventory (held by HMWT Records Office) to create a section of Living Landscape in St Albans. A planting plan for the riparian areas should ultimately be developed.
- A planting plan for the riparian area should be developed.
- Produce detailed design drawings that can be used for construction.
- St Albans City and District Council have advised that they could make alterations to the layout of the existing allotment site (to the north west of the reach) so that no replacement allotments would be needed for restoration works in this reach. New allotments are intended to the south west of the reach to replace those that may be lost if restoration through Cottonmill Allotments were to occur. Environmental assessment (for example additional ecological surveys) may be needed in advance of this occurring.
- Produce design for the reconfiguration of the existing allotment at the Nunnery 1 site

CONCLUSIONS & RECOMMENDATIONS

10

10. Conclusions

10.1 Conclusions

This report provides a summary of the feasibility studies we have undertaken that have helped us to identify preferred river restoration options for six reaches of the River Ver through St Albans. We have produced outline designs for these restoration options, which have included a range of chalk river restoration features, as well as other environmental improvements, such as accessible wetlands and bankside habitats.

The objectives of the project are to ensure that:

- The River Ver through St Albans achieves Good Ecological Status under the Water Framework Directive;
- The issues with Verulamium Park lakes are addressed and they are improved for people and wildlife;
- The areas around the river and lakes are improved; and
- Issues with increased groundwater emergence as a result of sustainability reductions are addressed.

In addition, there is an opportunity to improve the wider river areas for people and wildlife. This is particularly important because of planned groundwater abstraction in the coming years. This will mean that groundwater will return to more natural levels in some areas, which may become wetter more often as a result. This presents a risk to some existing land uses, but also an opportunity for wetland habitat creation and associated amenity benefits. Finally the proposed restoration works should be cost effective and sustainable.

These objectives and other matters have been considered throughout the feasibility study, to help determine the preferred options for each reach.

The important historic setting of St Albans, the complex nature of the river, its urban setting, and the historical modifications made by man, all presented constraints, issues and opportunities, which we had to consider in order to determine the preferred option for each reach. The process of determining the preferred option was undertaken through a partnership approach between AECOM, the Environment Agency, Affinity Water, St Albans City and District Council and Countryside Management Services.

Once we had established a preferred option we then engaged with the public and wider stakeholders over a period of four months. Engagement included an online survey, hosted by St Albans City and District Council, several workshops and walk in events, informal meetings with small groups as well as formal events wherein our plans were presented to key stakeholders.

228 responses to the online survey were made received, and we are pleased to report that of these 74.1% of respondents broadly supported the proposals; however, 10.2% did not support them, while 15.7% were undecided.

We have collated the individual consultation responses that have been received and responded to them. Where possible, these responses have been used to inform the final outline designs that have been presented within this report.

The final outline restoration designs for each reach are as follows:

Reach 1 - Our outline design would transform the concrete lined, slow, silty river to a beautiful, meandering chalk stream, able to support a wide variety of wildlife. In addition the lake will be re-sculpted to include a wetland habitat that will be accessible by boardwalks and provide valuable habitat for wildlife, and marginal plants that will improve the look of the lakes and ultimately improve the water quality.

Reach 2- Our proposals will transform the sometimes unusable, boggy area of Verulamium Park to create a rare area of wetland habitat accessible by boardwalks, which will allow St Albans residents and visitors to get closer to nature. The Ver Valley Trail will follow the improved river. In-channel features – such as the installation of riffles, berms and gravel bars - will create a more natural chalk stream and provide habitats for a range of wildlife.

Reach 3 - Our proposals will dramatically improve the state of the river through this reach. By narrowing the channel, installing in-channel features and letting more light into the channel we can expect a much more natural looking and healthy chalk stream. Another major benefit will be improvements to the degraded path to allow better access.

Reach 4 - Our proposals will have a dramatic effect on this reach. Our proposed plan is to move the river back to the valley bottom, , and to reconnect the river with its original floodplain. Groundwater levels are expected to rise significantly when Affinity Water reduce their nearby groundwater abstractions. With the increase in groundwater levels, the area surrounding the river will become wetter and much of the existing Cottonmill Allotment site would not be sustainable. We plan to take advantage of this to create precious wetland habitat, which would be opened up to the public with boardwalks, or alternatives. At the same time we would look to safegaurd the furture of the allotment site and retain as many allotments on site, or re-provide allotments on more sustainable sites.

Reach 5 - There are already some good natural features in the river through Reach 5 which our proposals will enhance. In-channel features such as pools and riffles will create habitats for a range of wildlife. Narrowing the channel will improve the energy of the flow. When abstraction for water is reduced in the coming years, some areas of this reach may be wetter more often; we plan to make the most of this through the creation of rare wetland habitats. We will also remove bunds to reconnect the river with the floodplain, allowing a path for groundwater to flow into the river and away from properties, as well as giving a public a better view of the river.

Reach 6 - Our proposals will introduce channel enhancements to narrow the channel, improve the flows and re-establish the gravel bed. Upstream of the Alban Way, they also include improvements to the path and regrading of the river banks to create space for marginal plants that provide vital habitat for a range of species.

Of these proposals, the public response to Reach 4 has been the most contentious, due to the significant changes that are planned, and the associated impact on allotments. However, with rising groundwater levels the current site in its entirety would not be sustainable to continue under this land use. Our outline design plans have been updated to maximise the number of allotments that could remain at the existing site, while another nearby allotment site would be constructed for those allotments that are re-located. St Albans City and District Council have made a number of commitments with regard to the allotments that have been indicated within the Reach 4 section of this report.

10.2 Recommendations

At the end of the outline design work we have identified a number of recommendations for further studies, monitoring, assessment etcthat should be undertaken during the detailed design stage. These recommendations are outlined below. .

A number of reach specific recommendations have been made, as presented in each reach section earlier in this report. These have included the following studies:

- A screening opinion from the local authority should be sought as to whether a formal EIA would be required. The topics for consideration during detailed design should also be confirmed. Further information regarding this process is provided in Appendix R.
- Further structural surveys are required to address remaining uncertainties. For example, depth information for some utilities is inconsistent, while surveys underneath the Causeway (at the end of Verulamium Lake) are proposed as this location has been difficult to access.
- Further groundwater monitoring should be undertaken in areas where groundwater emergence is expected. This will improve our understanding of the extent of groundwater emergence and allow detailed restoration plans to account for emergent groundwater. Similarly, further investigations should be undertaken to consider the effects of the sustainability reductions.
- Further soil and lake silt sampling should be undertaken. This will inform the management of this material and whether there is a risk of contamination or nutrient enrichment as a result of any of the options.
- Further heritage assessment is needed, particularly in reaches that contain reaches of significant heritage value and sensitivity (such as Scheduled Ancient Monuments).

- Further ecological survey and appraisal is required. This will help ensure that the maximum benefits are delivered by the project, and also inform the need for any species mitigation or the need for protected species licences. For example, artificial / semi-natural kingfisher banks in wet woodlands or river corridor could be integrated into the scheme at a number of locations, while benefits to roosting bats could also be included.

- Where tree thinning is proposed, we propose to work with residents to plan which trees could be removed, pollarded or thinned to achieve better levels of light reaching the river, whilst at the same time minimising impact to properties.

We recommend that detailed design should include:

- Applying an iterative process to the restoration design, to ensure that it maximises environmental gains while minimising adverse effects, especially any increase in flood risk to people or property.

- Hydraulic modelling should be undertaken to inform the detailed design. In reaches where emergent groundwater is anticipated, this will need to be accounted for. The modelling should also acknowledge the effect of the sustainability reductions on groundwater and flow.

- Developing planting plans for the riparian/ floodplain/ wetland/ lake margin areas. This would ensure that species are native to the area and provide maximum benefit to wildlife. A sound understanding of the levels of inundation anticipated following the improvement works, and emergent groundwater, would be necessary to develop these, and they would also need to be informed by some of further the studies outlined above.

- Developing access plans, to ensure people can access nature in a way that is sympathetic to wildlife, whilst also enabling learning and engagement experiences. This may include some access restrictions in sections that contain higher wildlife value.

- Long term maintenance plans. For example, the design life of boardwalks may be of the order of 10 years and a more sustainable option may be appropriate. New structures and riparian planting may also need to be maintained intermittently. Ongoing funding should be considered as part of this process.

- Suitable engineering involvement to ensure that Health and Safety duties are met in accordance with, for example, the Construction (Design and Management) Regulations. This applies to the detailed design drawings, the proposed construction methods, and maintenance plans developed in accordance with the above bullet point.

APPENDICES

LIST OF APPENDICES

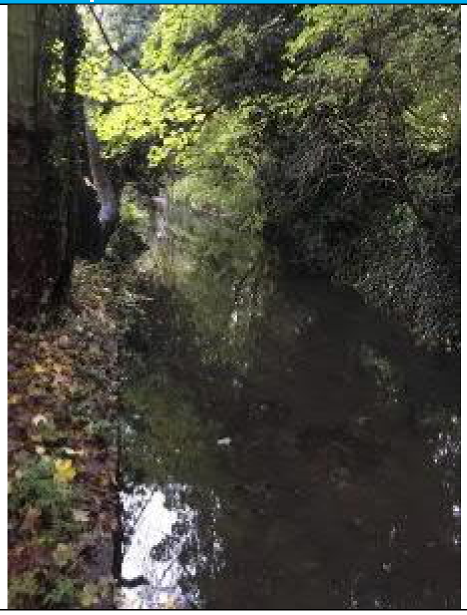
APPENDIX A – Existing problems with the river

The River Ver is a chalk stream. Chalk streams are a globally rare habitat, found largely in the South and East of England. Deriving the majority of their base flow from the chalk based groundwater aquifer, healthy chalk streams are characterised by crystal clear water and gleaming gravel beds. These conditions provide a unique set of habitats for a wide variety of plants and animals, including iconic species such as wild brown trout and kingfishers, water crowfoot and water forget-me-nots. They are also home to unique species including the southern damselfly and the fine lined pea mussel.

Many chalk streams, including the River Ver, have been historically altered and changed and are subject to pressures such as pollution and abstraction for drinking water. Table A.1 below lists some of the issues that exist with the River Ver as it passes through St. Albans.

Table A.1 Long List Hydromorphology and Naturalisation Appraisal

Issue	Description	Why this is a problem?
Over-wide	The river is over-wide through much of St Albans. This is often due to historic alterations for industry. 	If the river is over-wide it results in slow (low energy) flows. This can cause a build-up of silt on the river bed which covers the natural gravel bed. This is bad for wildlife and is also unsightly.
Over-straight	The channel is unnaturally straight in a lot of places. The picture below shows reach one where the current channel, next to the lake, was created in the 18th century to feed the Abbey Mill which was opposite Ye Olde Fighting Cocks. 	A natural, healthy chalk stream will meander. This creates a variety of habitats and speeds of flow. A straight river channel has limited diversity of flows which leads to a build-up of silt and affects habitats for wildlife
Silty	Where the river is over-wide/ over-deep/ straight the river bed is very silty in places. 	A natural, healthy chalk stream should have a clean gravel bed which supports a huge variety and quantity of wildlife (fish, aquatic plants, invertebrates). If the gravels become choked with silt the river is less able to support fish and other wildlife. Excessive siltation also makes the river look unsightly.
Lack of habitat and flow diversity	Much of the river has lost its classic chalk stream features such as riffles and pools and has lots of very similar habitat as a result of the degraded nature of the channel.	The lack of habitat and feature diversity means that there are fewer ‘niches’ for different species to occupy. This limits the number of species the river can support and significantly reduces the abundance of wildlife we see.
Over-shaded	A lot of the river through St Albans is heavily shaded by trees.	Some leaf litter and tree roots in the river bank can be beneficial, but too much shading means little or no light reaches the river.

Issue	Description	Why this is a problem?
		Healthy chalk streams rely on a variety of bank and in-channel vegetation to provide habitats for wildlife. As a ‘rule of thumb’, a healthy chalk stream requires about 70% light to 30% dappled shade. Excessive shading and tree growth also restricts the ability for people to see and appreciate the river.
Perched channel	The historic milling industry needed a ‘head drop’ of water to power the mill wheels. This means that the river was often moved, or ‘perched’, above the valley bottom to provide this drop of gradient at the mill.	Chalk streams derive most of their flow from the underlying chalk aquifer. If the river is moved out of the lowest lying area, the bed will be disconnected from the groundwater table as it is at too high a level. This can impact the amount and quality of water flowing in the river, both as a result of water loss through the permeable bed, or lack of flow from the aquifer into the river. A perched river is also disconnected from its natural floodplain (see below).
Disconnected from floodplain	Raised banks or an over-wide, over-deep or perched channel mean the river is disconnected from its floodplain. This photo was taken facing east through Verulamium Park. It shows the perched River Ver in flood conditions where the water is flowing downhill from the river (on the left) to the valley bottom (on the right) where the lakes now are. 	Over-wide or over-deep channel: Reduced connectivity between a river and its floodplain restricts healthy nutrient exchange processes and limits the development of bank and floodplain habitats that are important for wildlife. It also means in times of high flows, more water is confined to the channel rather than spilling into the floodplain. This reduces the ecological value of the floodplain as well as having the potential to increase flood risk elsewhere. Perched channel: In high flows, water overtops the river banks and flows down to valley bottom. When river flows return to normal, the flood water cannot get back into the river channel which is uphill. This means that water can pond on the floodplain for longer and for a greater extent than it should naturally. Raised banks: Where the river banks have been raised above the level of the surrounding land the river becomes disconnected from the floodplain. In times of high flows, water is confined to the channel for longer before it can overtop the banks. This reduces the functionality and ecological value of the floodplain as well as having the potential to increase flood risk elsewhere.
Weirs	Weirs are structures that raise the bed level of the river and act like a dam to impound flows upstream. There are weirs in Reach 1 and 4. Weirs were built in the past for a variety of reasons for example milling in Reach 1.	Weirs impact the natural river gradient as they cause an impoundment to water levels upstream. This disrupts natural river flow and sediment transport processes and the variety of habitats the river is able to support. Weirs often lead to excessive siltation and slower flows upstream. Weirs also restrict fish and other wildlife from moving up and down the river which impacts their resilience to climatic changes as well as their ability to reach suitable spawning grounds.
Concrete banks	Concrete banks have been historically introduced in Reaches 1 and 3.	As well as being unsightly, concrete banks restrict the plants and wildlife that should live on the banks of a healthy, natural chalk stream.
Low flows	The causes of low flows in the River Ver are complex. Reasons include flow splits – for example to feed the lakes – as well as upstream and localised abstraction for drinking water.	Low water levels, often seen in summer, can have a damaging effect on the river and the wildlife it supports.
Groundwater re-emergence	Affinity Water are reducing the amount of water they abstract from the chalk aquifers that feed chalk streams such as the River Ver. This should have a positive overall effect on river flows and help reduce the frequency and severity of low flow events.	Abstraction reductions will mean there is more water available for the chalk streams. It will also mean that groundwater may re-emerge to more natural levels in some areas. This will mean that some areas of land will be wetter more often.

APPENDIX B – River Restoration Long List Appraisal Scoring Matrices

Table B.1 Long List Hydromorphology and Naturalisation Appraisal

Does the scheme potentially provide a benefit or disbenefit regarding hydromorphology and naturalisation?		
Score	**Effect**	**Descriptor**
2	Strong positive	Changes that are likely to be considered a significant improvement from a hydromorphological and naturalisation perspective (for example flow and sediment processes significantly improved through creation of a diverse, functional re-aligned channel and/or removal of a significant number of structures that lead to significant ecological improvement).
1	Mild positive	Changes that are likely to be considered a minor improvement from a hydromorphological and naturalisation perspective (for example flow and sediment processes slightly improved through minor creation of functional in channel habitat and/or removal of a few structures).
0	Neutral	Status quo maintained
-1	Mild negative	Introduction of minor non-natural/ hard engineering structures into the channel or in its banks, leading to minor hydromorphological and ecological disbenefit and a less natural system.
-2	Strong negative	Introduction of multiple non-natural/ hard engineering structures into the channel or in its banks or additional embankments next to the channel, leading to significant hydromorphological and ecological disbenefit and a significantly more artificial system.

Table B.2 Long List Habitat Appraisal

Does the scheme potentially provide a benefit or disbenefit regarding habitat?		
Score	**Effect**	**Descriptor**
2	Strong positive	Sustainable creation of new functional re-aligned river channel or significant in-channel enhancement of existing channel, riparian and floodplain habitat.
1	Mild positive	Minor in-channel enhancement of existing channel, riparian and floodplain habitat and maintenance of existing habitat.
0	Neutral	Status quo maintained (for example no habitat created or lost)
-1	Mild negative	Minor deterioration of existing river channel habitat, riparian and floodplain habitat
-2	Strong negative	Significant loss of existing river channel habitat, riparian and floodplain habitat

Table B.3 Long List Water Quality Appraisal

Does the scheme potentially provide a benefit or disbenefit regarding water quality?		
Score	**Effect**	**Descriptor**
2	Strong positive	Option would result in significant enhancements which would allow for major improvements to water quality. Regarding the lake in Reach 1 strong positive benefits would be those that would reduce the likelihood of avian botulism (for example introduced plants filtering out pollutants or a diverse flow regime being introduced that would increase oxygenation). Strong positive benefits for the river would be actions that resulted in significant improvements to dissolved oxygen levels or reductions in nutrient levels.
1	Mild positive	Option would result in enhancements which would allow minor improvements to water quality for example via plants filtering out pollutants, increased oxygenation through a diverse flow regime and settling onto the limited surrounding floodplain.
0	Neutral	Status quo maintained (for example no change in water quality as a result of the option)
-1	Mild negative	Potential to slightly reduce water quality (for example decreased rates of flow resulting in more prolonged episodes of algal growth).
-2	Strong negative	Potential to reduce water quality at and downstream of the site (for example cessation of flows in channel resulting in a reduction in the dissolved oxygen levels and dilution of any urban run-off or option likely to increase the frequency of avian botulism outbreaks in the lake occurring).

Table B.4 Long List Flood Risk Appraisal

Does the scheme potentially provide a benefit or disbenefit regarding flood risk?		
Score	**Effect**	**Descriptor**
2	Strong positive	Creation of significant amount of flood storage on site which would result in a decrease in flood risk downstream (for example resulting in significant decreased threat to infrastructure and/ or property). Significant attenuation of flow through site resulting in flood risk downstream being reduced.
1	Mild positive	Creation of minor amount of flood storage on site which would result in a decrease in flood risk downstream (for example resulting in significant decreased threat to infrastructure and/ or property). Minor attenuation of flow through site resulting in flood risk downstream being reduced.
0	Neutral	Status quo maintained
-1	Mild negative	Minor increase in the rate of flow through site resulting in flood risk downstream being slightly elevated. Minor loss of flood storage in the site resulting in flood risk downstream being slightly elevated.
-2	Strong negative	Potentially major increase in the rate of flow through site resulting in flood risk downstream being significantly elevated. Major loss of flood storage in the site resulting in flood risk downstream being significantly elevated.

Table B.5 Long List Landscape & Visual Appraisal

Does the scheme potentially provide a benefit or disbenefit from a physical landscape or visual perspective?		
Score	**Effect**	**Descriptor**
2	Strong positive	Changes that are likely to be considered a significant improvement from a landscape and visual perspective (for example creation of significant greenery or opening up views).
1	Mild positive	Changes that are likely to be considered a minor improvement from a landscape and visual perspective (for example creation of marginal in-channel vegetation to a previously degraded river channel encouraging wildlife).
0	Neutral	Status quo maintained
-1	Mild negative	Changes that are likely to be considered a minor disbenefit from a landscape and visual perspective (for example restoration options result in the removal of several trees).
-2	Strong negative	Changes that are likely to be considered a significant disbenefit from a landscape and visual perspective (for example a section of channel drying up close to a key viewpoint).

Table B.6 Long List Recreation & Amenity Appraisal

Does the scheme potentially provide a benefit or disbenefit regarding recreation and amenity?		
Score	**Effect**	**Descriptor**
2	Strong positive	Changes that are likely to be considered as a significant improvement from a recreation and amenity perspective (for example creation of significant recreational ground or wildlife area with good public access).
1	Mild positive	Changes that are likely to be considered as a minor improvement from a recreation and amenity perspective (for example creation of a wildlife area with limited access).
0	Neutral	Status quo maintained
-1	Mild negative	Changes that are likely to be considered as a minor disbenefit from a recreation and amenity perspective (for example minor reduction in area accessible to public (for example if small area that was accessible is fenced off for wildlife protection purposes).
-2	Strong negative	Changes that are likely to be considered as a major disbenefit from a recreation and amenity perspective (for example significant reduction in area accessible to public (for example if a large area of land that was accessible is completely fenced off for wildlife protection purposes).

Table B.7 Long List Heritage Appraisal

Does the scheme potentially provide a benefit or disbenefit regarding the heritage of the reach?		
Score	**Effect**	**Descriptor**
2	Strong positive	Restoration options that provide major contributions towards the heritage value of the reach (for example options do not cause any physical impact to heritage assets and provides an improved level of information to members of the public surrounding the historical use of the river (information board installation etc.)).
1	Mild positive	Restoration options that provide minor contributions towards the heritage value of the reach (for example restoration options do not cause any physical impact to heritage assets and provide an improved level of information to members of the public surrounding the historical use of the river (information board installation etc.)).
0	Neutral	Status quo maintained (for example restoration measures have limited or no impact on the heritage of the reach).
-1	Mild negative	Minor physical impact upon any heritage assets, and/ or minor impacts to their significance relating to changes to their setting (for example partial re-alignment of river channel physically impacting upon a known heritage asset located in the direct course of the newly proposed channel route).
-2	Strong negative	Major physical impact upon any heritage assets, and/ or major impacts to their significance relating to changes to their setting (for example major re-alignment of river channel physically impacting upon a number of known heritage assets located in the direct course of the newly proposed channel route).

Table B.8 Long List Contaminated Land and Sediment Appraisal

Does the scheme potentially provide a benefit or disbenefit regarding contaminated land or sediment? (note that for the purposes of long listing appraisal opposing effects have been accounted for within the final scoring)		
Score	**Effect**	**Descriptor**
2	Strong positive	Changes that are likely to be considered a significant improvement from a contaminated land or sediment perspective (for example removal of significant amounts of contaminated sediment or remediation of contaminated sediments).
1	Mild positive	Changes that are likely to be considered a minor improvement from a contaminated land and sediment perspective (for example works result in a small amount of contaminated land being removed as part of the works).
0	Neutral	Status quo maintained
-1	Mild negative	Changes that are likely to be considered a minor disbenefit from a contaminated land and sediment perspective (for example river re-aligned close to an area of contaminated land that would increase the chance of contaminants entering the water environment).
-2	Strong negative	Changes that are likely to be considered a significant disbenefit from a contaminated land and sediment perspective (for example river re-aligned through an area of significant contaminated land that would likely be disturbed and release contaminants into the water environment).

Table B.9 Long List Fish Passage Appraisal

Does the scheme potentially provide a benefit or disbenefit regarding fish passage?		
Score	**Effect**	**Descriptor**
2	Strong positive	Unrestricted fish passage for all species and age classes.
1	Mild positive	Fish passage provided for a small number of species (for example salmonids and the strongest swimming coarse fish are able to pass in-river obstructions).
0	Neutral	Status quo maintained
-1	Mild negative	Fish passage slightly decreased (for example introduction of structures into the channel or in its banks resulting in a minor obstruction to fish passage).
-2	Strong negative	Fish passage significantly decreased (for example introduction of structures into the channel or in its banks resulting in a significant obstruction to fish passage).

Table B.10 Long List Sustainability/ Ongoing Maintenance Appraisal

Does the scheme potentially provide a benefit or disbenefit regarding future maintenance requirements?		
Score	**Effect**	**Descriptor**
2	Strong positive	Options implemented are largely self-sustainable and would require minimal maintenance (for example re-aligned river channel and restored floodplain achieve environmental balance through natural processes with minimal management input).
1	Mild positive	Options implemented are mildly self-sustainable and would require less maintenance than existing (for example in-channel enhancements to river channel require management input to support plant growth in bank softening, and gravel cleaning to clear gravel beds of silt prior to fish spawning season).
0	Neutral	Status quo maintained - Options implemented (if any) do not address the issues currently impacting upon the waterbody, with continued levels of management required
-1	Mild negative	Options implemented require slightly higher level of management than the current status quo (for example system may silt up more frequently and require (more frequent) dredging).
-2	Strong negative	Options implemented require a high level of management compared to the current status quo (for example system would be unstable and would require extensive management so that it did not attempt an alternate state).

Table B.11 Long List Cost Appraisal

Does the scheme potentially provide a benefit or disbenefit regarding cost?		
Score	**Effect**	**Descriptor**
2	Strong positive	Low cost (for example lowest cost option/s available relative to other proposed options for the reach).
1	Mild positive	Moderately low cost
0	Neutral	Status quo maintained (for example no change to current cost of maintaining reach)
-1	Mild negative	Reasonably high cost
-2	Strong negative	Significantly high cost (for example the most expensive option/s available relative to other proposed options for the reach).

APPENDIX C – Groundwater Emergence Note

AECOM

This note has been redacted in accordance with the Security and Emergency Measures Directive as it includes specific location details of public water supply sources

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Project name:
Ver Groundwater Emergence

Project ref: 60525824

To: Environment Agency

Nancy Baume

From: Travis Kelly

CC: Rudi Liu

Date:
4 October 2017

Technical Memo

Background

This technical note assesses the risk of groundwater emergence following the planned sustainability reductions in the Ver catchment.

Groundwater emergence investigations came about as a response to groundwater flooding in the Mimram catchment in relation to the [redacted]. It was also known that groundwater flooding occurred in the St Albans area following a stoppage at [redacted] public water supply groundwater abstractions in 2011 as part of the Ver NEP study. Consequently the Environment Agency (Environment Agency) is looking specifically at whether groundwater emergence is likely from the permanent reduction in abstraction of 4.42 Mld from each of these abstractions in future (total reduction 8.84 Mld). Groundwater flooding is known to have occurred at two locations: the Cotton Mill allotment, and the large grass pitch south of the Verulamium Lake, [redacted].

As part of river restoration work currently being undertaken by AECOM and the Environment Agency, AECOM has been requested to include consideration of the risk of groundwater emergence from sustainability reductions at [redacted] in the Ver catchment.

Scope of Work

The tasks were as follows.

Task 1: review anecdotal evidence from Environment Agency reports as well as street names for historic insights and local authority reporting of flooding.

Task 2: develop local conceptual understanding of the reaches of interest around the influence of these abstractions using the Vale of St Albans conceptual model report. Consider superficial geology and potential for made ground to influence flow to the surface. Collate 2001 peak groundwater level data and river elevation to construct groundwater level contours for the highest recorded levels.

Task 3: review signal test information, historic abstraction and flow data and Environment Agency groundwater model runs (switching off these abstractions) to estimate groundwater level rise in the area of interest and create a new contour map of highest recorded levels plus groundwater rebound.

Task 4: Compare contours with surface elevation from LiDAR to identify areas with potential to flood, and consider likelihood based on geology (e.g. flooding may be predicted based on Chalk contouring but superficial deposits may be of low permeability or the Chalk may have low permeability horizons).

Consider, in discussion with the Environment Agency, whether the findings warrant a walk through the potentially affected areas to ask residents whether they have any knowledge of past flooding.

The study area is the River Ver between St Michael's Street and Cottonmill Lane, St Albans, and is shown in Figure 1.

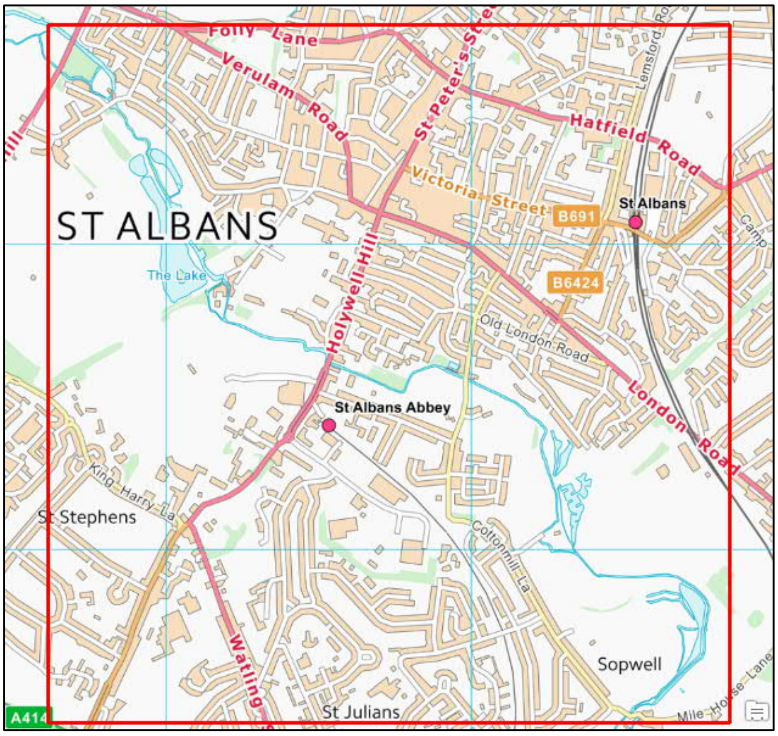


Figure 1 Study Area

Data Availability

The Environment Agency provided groundwater level data for the highest groundwater level period recorded in the Ver catchment, the winter of 2000-2001. The Environment Agency had also conducted a modelling scenario comparing the simulated historic period and a simulation without [redacted] abstracting using the Vale of St Albans Groundwater Model. Simulated groundwater levels for these scenarios were provided.

A number of reports containing conceptual information relevant to groundwater in the St Albans area were also provided. These were:

1. Halcrow, 1988. Study of Alleviation of Low River Flows Resulting from Groundwater Abstraction
2. Halcrow, 2004. Ver River Park Project Feasibility Study
3. Clayton, 2005. An evaluation of the impact of measures to restore flows in the River Ver
4. Affinity Water, 2013. River Ver NEP. Final Investigation report
5. Affinity Water, 2014. River Ver NEP: [redacted] Signal Test and Options Appraisal

6. APEM, 2016. Thermal and Topographic Aerial Surveys of the River Ver, Hertfordshire
7. Jacobs, 2007. River Ver Fluvial Audit
8. Atkins, 2006. Vale of St Albans Conceptual Model

AECOM also used available LiDAR data and geological mapping.

Historical Evidence of Flooding

Street names in the Ver valley and adjacent areas of St Albans were reviewed. In places of long occupation it is not uncommon for place names to reflect the natural environment prior to large scale industrial development.

Street names which could be indicators of historical areas prone to flooding, such as ‘marsh’ or ‘water’ or ‘watery’ lane etc. were not identified. One place name containing ‘meadow’ was identified; Bell Meadow to the north of the Verulamium Lake. Fishpool street runs along the northern side of the river valley from St Michael’s street in the northern part of the study area. Pondswick Close is located in the central part of the study area from the valley side down into the valley. Riverside Road runs along the northern side of the valley in the southern part of the study area. Both Fishpool street and Riverside Road appear to be elevated above the floor of the valley for the most part and are not associated with dry valleys.

Historical maps were reviewed to identify whether the river had been re-routed and what buildings were present prior to re-routing and the commencement of abstraction. Built-up areas that pre-date these activities can be considered to be safe from flooding after groundwater rebounds when abstraction reduces (assuming that basements have not been constructed in the intervening period). Vegetation types prior to abstraction were also checked for evidence of marshy ground.

[redacted] abstraction (which marks the beginning of groundwater drawdown) pre-dates most modern developments in St Albans, so buildings prior to 1899 are unlikely to be affected by groundwater rebound. [redacted] abstraction commenced in the 1960s. Therefore the built-up areas of interest for flooding from groundwater rebound are those developed after 1899 and in particular post 1960s when the drawdown increased.

The northern part of the study area around St Michael’s street has been built-up since before the commencement of abstraction. Figure 2 shows the 1899 Ordnance Survey (OS) map. The River Ver flows along the eastern side of the study area (shown in pink), with a mill, public house and farm adjacent to it. The river flows south easterly and a fishing pond is evident.

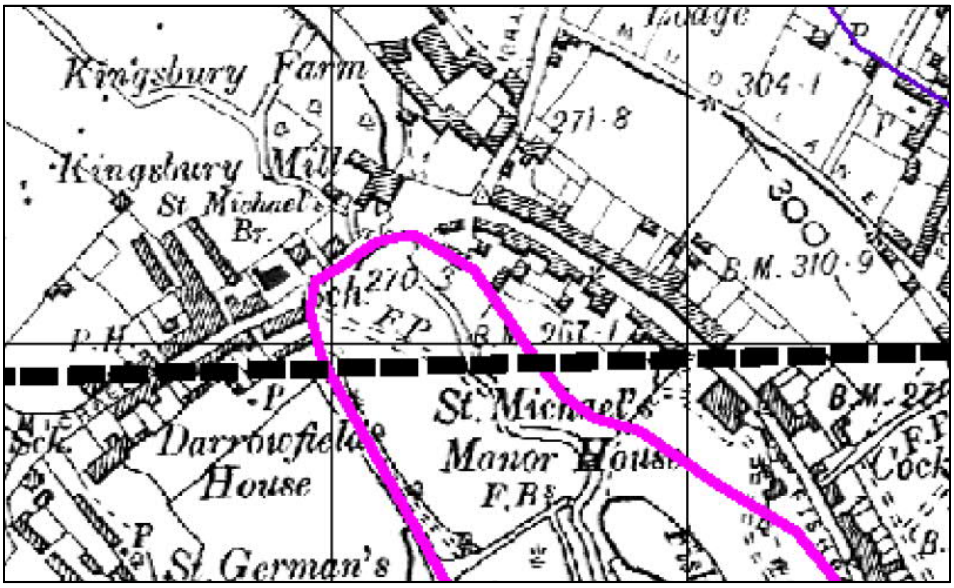


Figure 2 St Michael’s street area 1899 OS map

The Cotton Mill allotments experienced groundwater flooding as a result of the [redacted] signal test in 2011. At the western end of the allotments the river takes a sharp turn north then sharp turn east around the Cotton Mill Bridge allotments, which does not look like a natural bend. The river appears in a different position in historical maps up until 1925, after which it appears to have been re-routed along an existing road now no longer present. However, following feedback received from allotment holders it seems that Figure 3 shows two channels of the river being present at this time. One is quite straight and matches the current planform while the other looks like a road on the map, is more sinuous and more closely follows the low points in the valley.

That is, the former river route is to the south of the current route and would flow through the centre of the present allotment site.

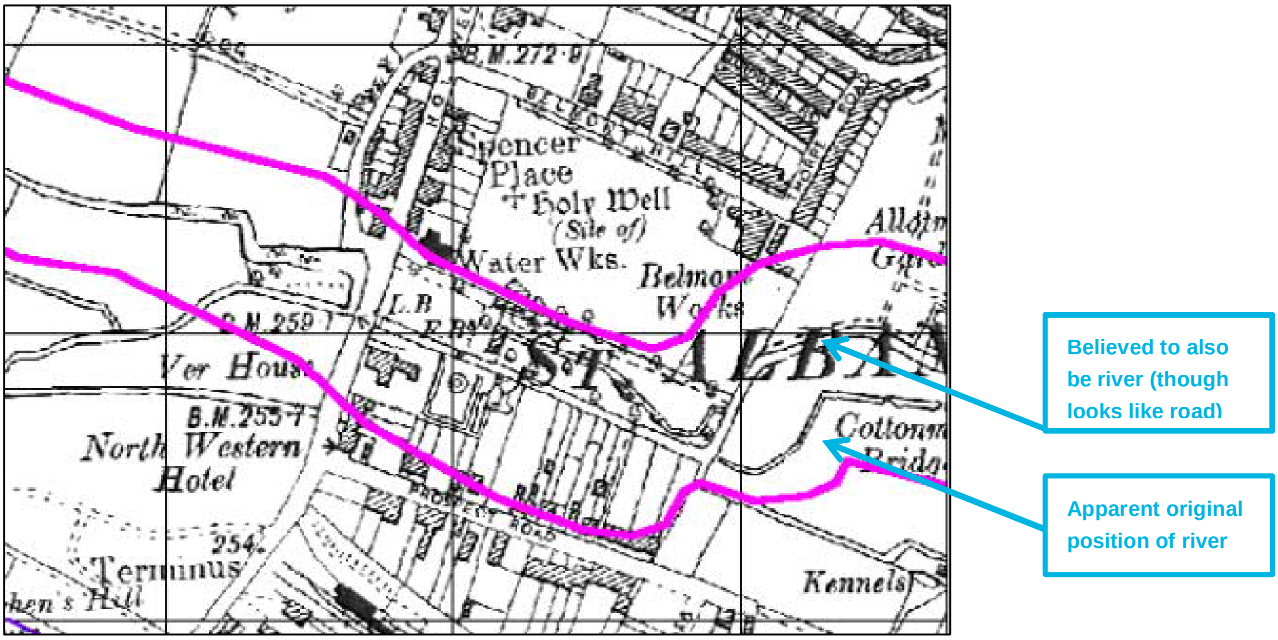


Figure 3 Area west of Cotton Mill allotments circa 1925

East of Cotton Mill Lane allotments the River Ver flows along a straight south easterly course. The earliest historic map in 1883 also shows this route. The presence of the remains of a medieval nunnery (Sopwell Nunnery) indicates that this route is likely to be the natural course of the river. The eastern part of this reach before the river turns south is marked as marshy ground and may be a natural discharge area for groundwater. This area is the current Sopwell Nunnery Green Space.

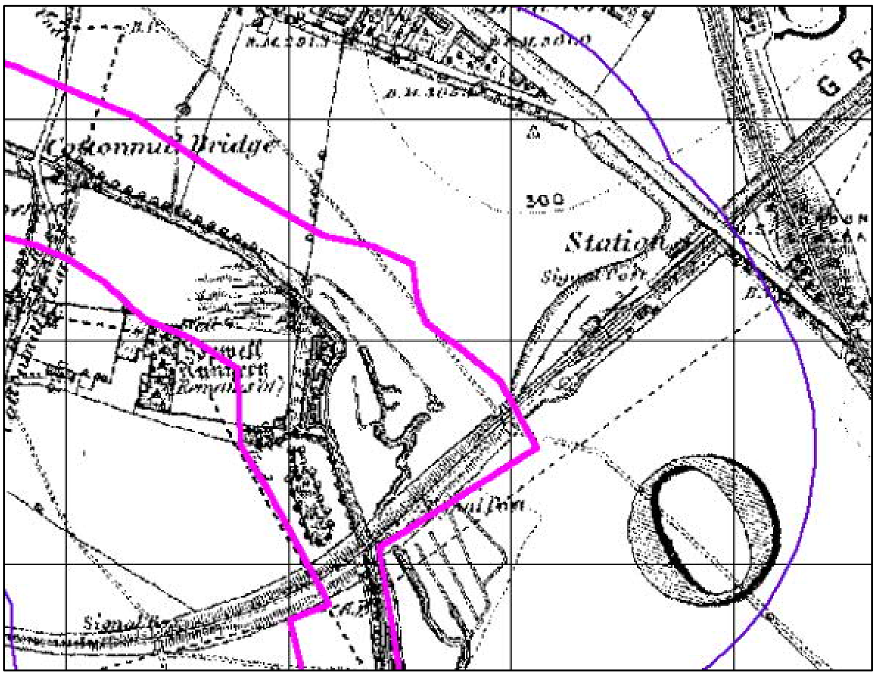


Figure 4 Marshy ground east of Sopwell Nunnery circa 1883

The River Ver flows south from Sopwell Nunnery with a series of lakes alongside its path. These lakes are former watercress beds as shown in the 1899 OS map. At the southern end of this reach is the Sopwell Mill. The lakes, the present course of the river and the mill are likely to represent modifications to the original course of the river. These modifications are also evident in the 1883 OS map. At the southern end of this reach is a modern recreation ground.

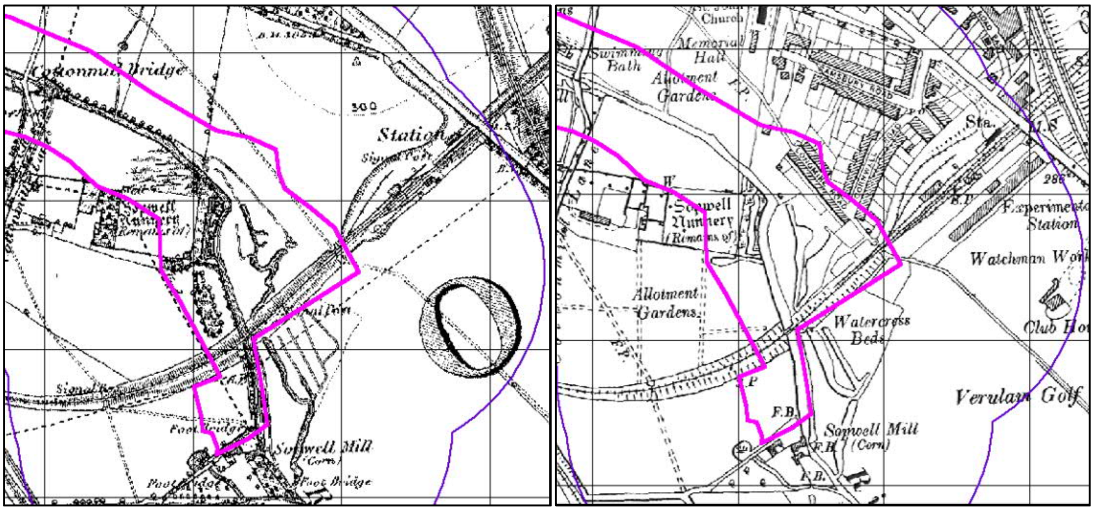


Figure 5 Watercress Beds and Sopwell Mill circa 1883 (left) and 1899 (right)

No Section 19 flood investigation reports in the study area were found on the Hertfordshire County Council (HCC) website. Lead Local Flood Authorities (LLFA) such as HCC must investigate flood incidents under Section 19 of the Flood and Water Management Act 2010 and so it is assumed that no significant flooding has occurred in the study area.

Geology and Hydrogeology

Geology

The geology of the area based on geological mapping by the British Geological Survey comprises Lewes Nodular Chalk Formation and Seaford Chalk Formation (undifferentiated) overlain by alluvium comprising clay, silt, sand and gravel. Geological logs available along the river valley were reviewed for evidence of made ground. Logs typically showed that the area comprises gravel and clay overlying Chalk. The logs are not detailed enough to identify individual Chalk horizons in order to judge whether there are high and low permeability horizons locally. However logs along the valley floor identify gravels overlying chalk and typically 3m of clay overlying this. There is no evidence of significant earthworks creating low permeability barriers that may affect groundwater flow.

Hydrogeology

The groundwater abstractions at [redacted] are from the Chalk, a principal aquifer.

There are limited water strike details but where available indicate a shallow water strike similar to the level measured when the Chalk has been drilled through, so despite the clay layer there does not appear to be a significant confining layer locally. Though there are no dual piezometer installations to observe whether there is a shallow aquifer interacting with the river and the deeper chalk aquifer under pressure to a similar elevation. In other boreholes no water strike is noted but the water level may be several metres above the top of the Chalk horizons.

In areas of known historical water cress production boreholes do not appear to be artesian. In the Verulamium Park area boreholes were described as overflowing on construction and subsequently water levels falling and stabilising at depth.

In comparison to other Chalk rivers in the Chilterns, the upper reaches of the Ver catchment are steeper and contain numerous bournes. There are large ranges in Chalk groundwater levels beneath the dry valleys and crest of the Chilterns escarpment which result in intermittent flows. In the valleys Chalk is overlain by alluvial deposits that may be locally clay rich, which may act to confine Chalk groundwater and prevent its flow to surface locally.

The spot flow data shows that during summer months the head of the Ver can migrate downstream as far as Redbournbury. In winter periods the head of the Ver is usually recorded between Friars Wash and Redbournbury, while in the wettest winters it has been recorded upstream of Markyate.

The patterns in accretion are thought to be related to the locations of groundwater abstractions as in many places the river appears to lose water to the underlying Chalk such as in the [redacted] area. However, more typical accretion profiles can be observed during the wetter periods, with the Ver gaining along the majority of its length, with particular inflows in the Sopwell Mill area in the study area, with the other significant area of accretion upstream between the Ver and Red confluence and Shafford Farm (Atkins, 2006). Thus the river is in hydraulic continuity with the Chalk aquifer.

Landforms

LiDAR data was visualised in GIS software with a colour coding to identify low points in the landscape for indications of areas that may be at risk of flooding from high groundwater levels. Generally the low points of the landscape were along the present route of the river. The exceptions are described below, which may represent former routes of the river and may begin to flow again (or flood if there are surface barriers to flow) with a high watertable.

In the north of the study area low lying land is present north of Verulamium Lake and marked on the OS map as Bell Meadow. The Ver River Park Project Feasibility Study (Halcrow, 2004) describes the river in the area of the present lake to Verulamium Park as being entirely within the Mill Leat to Abbey Mill. This study also reported on vegetation with the area containing weeping willows, indicative of a shallow water table. This study also describes the river flowing through the valley of the present lake to enable water cress cultivation in the 1820s. The present lake was constructed with concrete lining as part of an employment scheme in 1929. Watercress farming appears to have been using run-of-river water as no artesian boreholes are recorded.

Therefore it may be that the original river course turned south across Bell Meadow then south easterly along the valley floor under the lake. The LiDAR data suggests the lake floor is at a lower elevation than the current river bed.

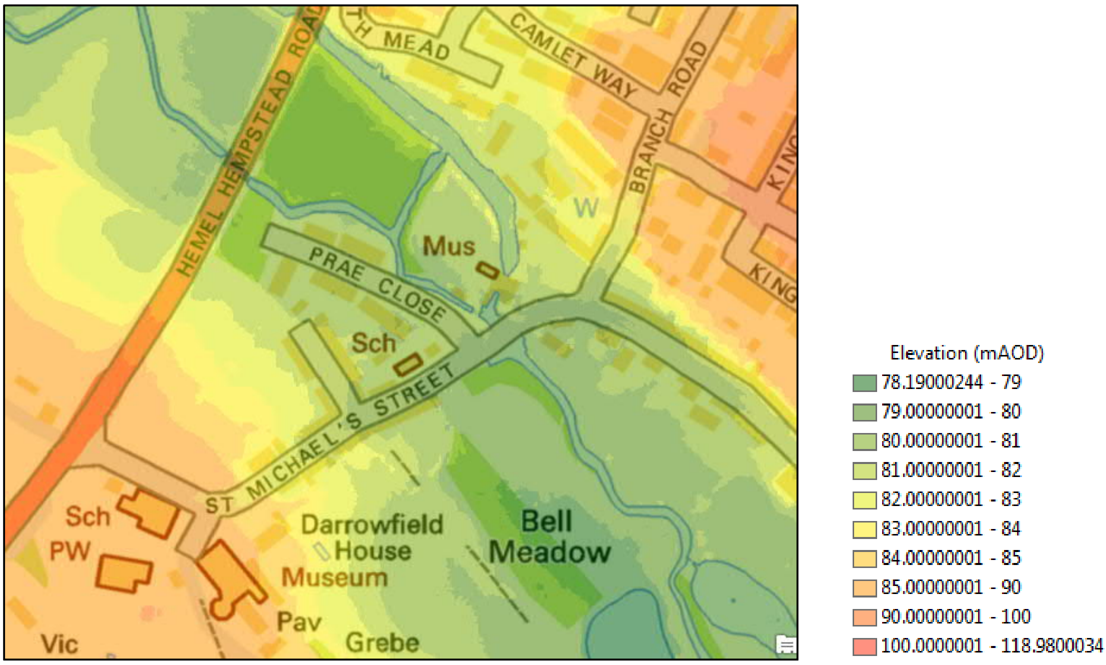


Figure 6 LiDAR image showing low lying ground in dark green at Bell Meadow

In Verulamium Park [redacted] there are areas lower than the present river indicating a possible river meander or shallow depression that may have been filled with water at higher groundwater level periods in this area. However the historical maps show the straightened river and no indications that this ground was wet prior to abstraction commencing. The straightening is likely to relate to Abbey Mill leat and therefore would pre-date OS mapping. Due to the low elevation and imperfect historical record it is an area of potential concern for flooding. This area is now used for recreation.

Figure 7 Low lying area whose shape indicates a possible river meander in Verulamium Park

Beyond the Mill Leat, Halcrow (2004) suggest that the river is in a more natural position which would correlate well with the river being within the lowest land shown in LiDAR imaging.

East of Holywell Lane the river follows a straight path and then takes a sharp bend left and then right again, around the Cotton Mill allotments as described in the historical mapping in relation to Figure 3. LiDAR shows that the central allotments area is more than 0.5 m lower than the present river channel curving around the allotments site. The LiDAR data therefore supports the historical mapping evidence that the original stream is likely to have been in the central part of the allotments.

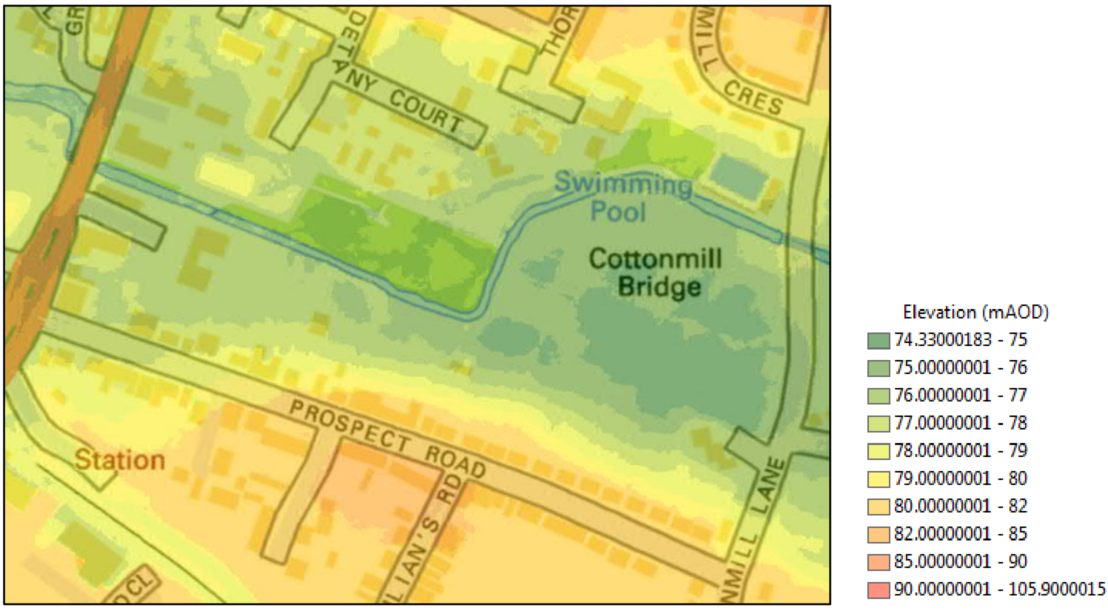


Figure 8 Sharp bends in the River Ver and low lying area within Cotton Mill allotments in dark green

Beyond the allotments the river flows east before turning south at the Sopwell Nunnery Green Space, in the area of the ruins of a medieval nunnery. LiDAR shows low lying areas away from the river channel encroaching on the recreation space which correlates with the historical mapping indicating marshy land in the this area (Figure 4). The low lying area of the former watercress beds is also evident. The historic ruins are on the high ground in the area.

Figure 9 Low lying areas around the Sopwell Nunnery (lower lying areas in green)

Further downstream low lying areas are also evident on the recreation ground south east of Sadler Road and in particular the gardens of Sopwell Mill Farm to the south. This area and the lakes on the eastern side of the current river channel are of similar elevation to the river channel and generally up to 0.5 m above the current channel. As the recreation ground may be raised and levelled ground, this area may have formed a wider bend in the stream than the current river profile, or a series of tributaries or a braided channel pre-dating OS mapping showing the watercress beds in 1883. Historic buildings are present in this area pre dating abstraction, associated with Sopwell Mill.

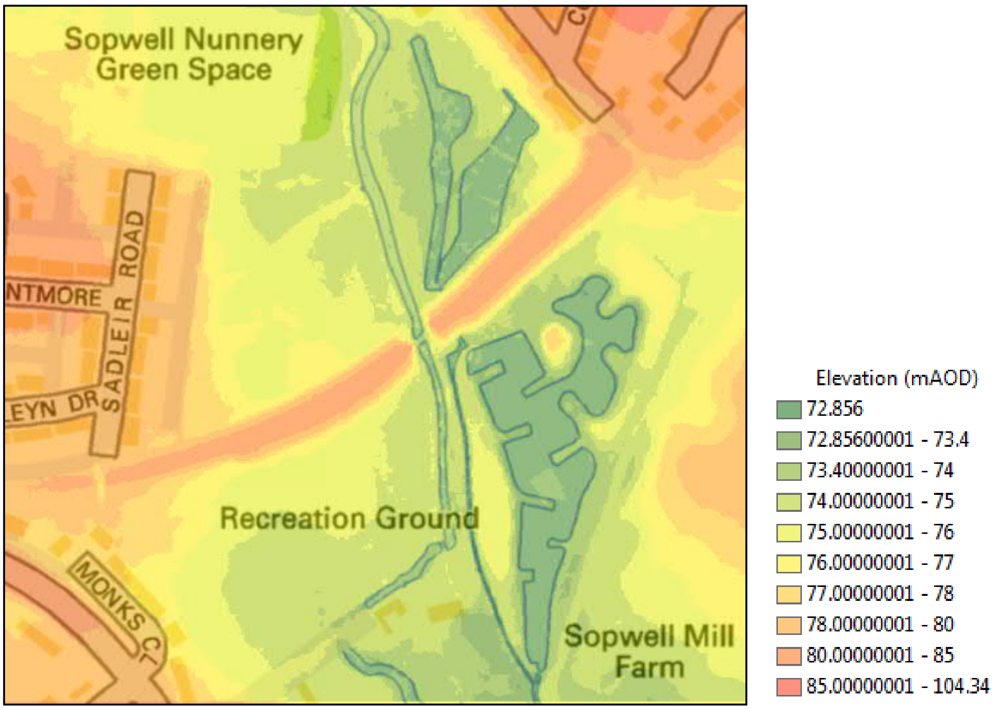


Figure 10 Southern extent of former watercress beds (lower lying areas in green)

Signal Test

Affinity Water conducted a signal test as part of the River Ver NEP study (Affinity Water, 2013). The duration of the outage was from 07/11/2011 to 28/11/2011 with both [redacted] out of operation. Water levels in monitoring boreholes in the vicinity of the abstractions rose rapidly by approximately 1.7m and, after the outage ended and abstraction recommenced, the levels fell back quickly to a level very similar to their starting levels.

Monitoring extended up to 470m upgradient at Abbey Mill. The change in water level during the test indicated that groundwater level rebound would extend further upgradient before the effect of cessation of pumping became undetectable.

Spot flow gauging recorded an increase in flow soon after the outage at most sites though this could relate to the rainfall events immediately prior to the outage and the timing of the end of the seasonal recession. A notable difference was observed at Sopwell where flows increased significantly, from approximately 1 Ml/d to approximately 10 Ml/d, approximately two days after the outage began. Gauged flows at Colney Street on the Lower Ver recorded an approximate 5 Mld increase in flows over the signal test period. Being a low flow period some of the increased flow near the [redacted] abstractions may have been lost to the aquifer downstream. We are not able to verify the accuracy of the spot flow gauging.

However the increase in flow around Sopwell correlates with observations of groundwater flooding just upstream of this gauging point in the allotments, and the historical mapping showing the area as marshy before abstraction, so is likely to be a significant accretion zone in the area.

Recovery test analysis shows a good match of observed data to theoretical Theis type curves. The type curve suggests that groundwater levels would have risen by at least another 0.5 m at Abbey Mill if abstraction had not recommenced and may give an indication of the equilibrium level to be expected when abstraction permanently reduces and when hydrological conditions are comparable.

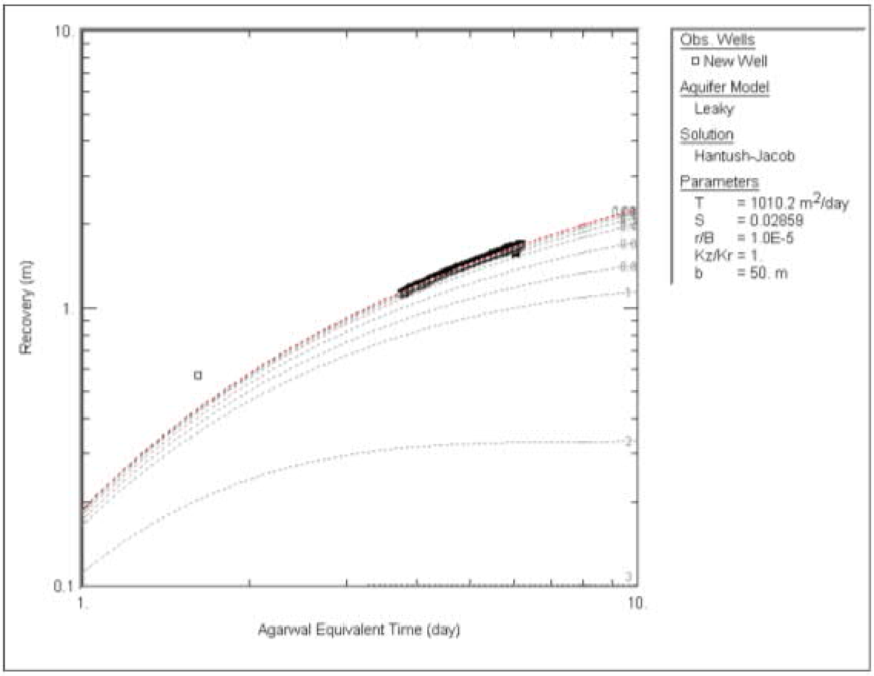


Figure 7.21 Agarwal (1980) Recovery Plot for Water Level Data at Abbey Mill OBH

Figure 11 Affinity Water signal test interpretation (Affinity Water, 2013)

The northern extent of the study area around St Michael's street is a further 750 m upgradient from Abbey Mill and may form part of the abstraction drawdown zone. Using the aquifer properties derived from the pumping test in Figure 11 (Affinity Water, 2013), the recovery of groundwater levels at St Michael's Street can be estimated. Application of the Dupuit-Thiem equation for estimating drawdown (or recovery) at a given distance gives recovery estimates of approximately 0.5m at St Michael's Street compared to 1.7m at Abbey Mills.

Allowing for the full recovery at Abbey Mills assuming an additional 0.5m water level rise based on the recovery curve described above, then the estimated recovery at St Michael's street is 1.2m.

The downgradient extent of the drawdown zone has extended to at least Cotton Mill Lane where groundwater flooding was observed in the allotments during the signal test. The allotments are 320m downgradient of the pumping well. At this location the Dupuit-Theim equation estimates a rise in groundwater level of 2.7m assuming a uniform drawdown cone at this point.

Further downstream the drawdown cone will taper off rapidly compared to the upstream side and so the formula assumptions will break down, because the drawdown cone will not be a circle of equal radius around the abstraction point, but elliptical extending in the upgradient direction. For example the spot flow monitoring observed a rapid increase in flow at Sopwell Gardens. Here the formula predicts a rise in water level to full recovery of 1.2m and correlates with the large increases in flow observed during the signal test

The LiDAR shows the land around the river here to be 0.2m to 0.5m higher than the river channel If the outage had continued full recovery this may have led to some flooding in this area.

As the sustainability reductions will be approximately half the volume reduced in the signal test, then approximately half the recovery effects calculated here may be a reasonable estimate.

Aerial Surveys

Aerial surveys were conducted in March 2016 (APEM, 2016). They identified no areas of shallow groundwater or emergent groundwater (either as flooding or as baseflow) in the study area, with emergence being interpreted at the downstream margins of the study area.

This correlates with the central area of drawdown from the signal test, however AECOM cannot verify the APEM method of correlation of thermal imaging with groundwater levels and emergence. AECOM did not have access to the DSM created from the aerial surveys to compare against the LiDAR data used herein.

Groundwater Levels in 2001

The period February to May 2001 represents the highest groundwater levels ever recorded in the Chilterns. In the Ver catchment the peak groundwater level varies between boreholes but typically occurred between late February and early March 2001. Groundwater contours were interpreted from Environment Agency data for this period and then compared to the predicted water table rise when [redacted] abstractions are permanently reduced.

Therefore as part of this study a local Ver catchment Chalk groundwater contour interpretation for peak groundwater levels has been made and is shown in Figure 12. Groundwater flows to the south east along the axis of the Ver valley, with discharge to the River Ver along its length. In the southern part of the study area in St Albans groundwater flow is to the southeast and not as closely connected to the River Ver, which is reflected in the reduced flow accretion (Atkins 2006), with groundwater likely to discharge to the River Colne to the south. The results are consistent with the Vale of St Albans conceptual study interpretation (Atkins, 2006) with one noticeable difference, that the contours turn south on the west side of the Ver catchment before turning west to Hemel Hempstead.

Atkins, 2006 does not show this feature because contours were drawn at a different time. While the peak groundwater level in the Ver catchment was in February-March 2001, Atkins (2006) chose the time of April 2001 across the whole study area representing peak or near peak conditions in most places. In the Ver catchment in April 2001 observation points on the western side of the Ver catchment had lower levels than their peak and some observation points had no data for April, 2001.

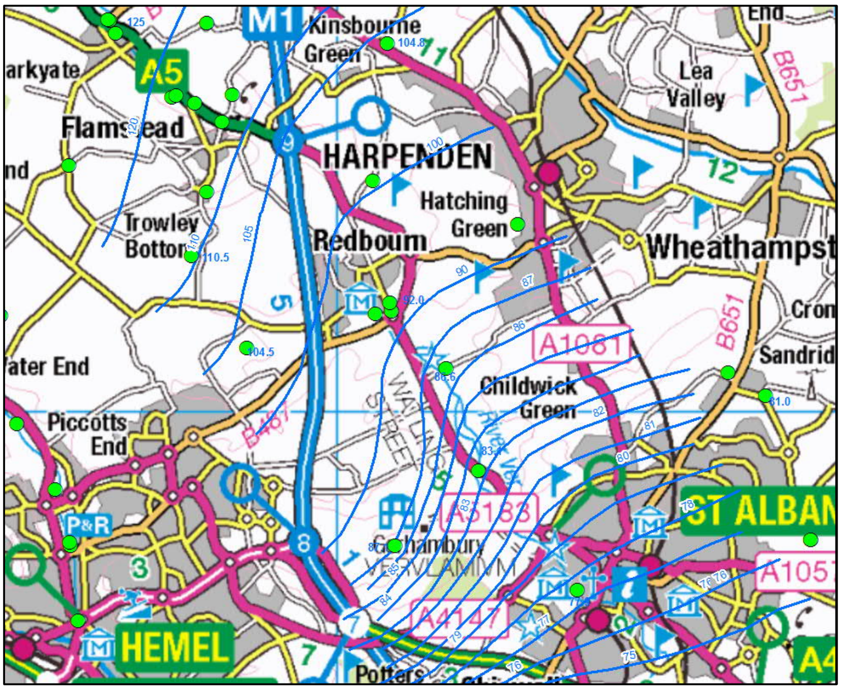


Figure 12 Peak groundwater level interpretation February - March 2001

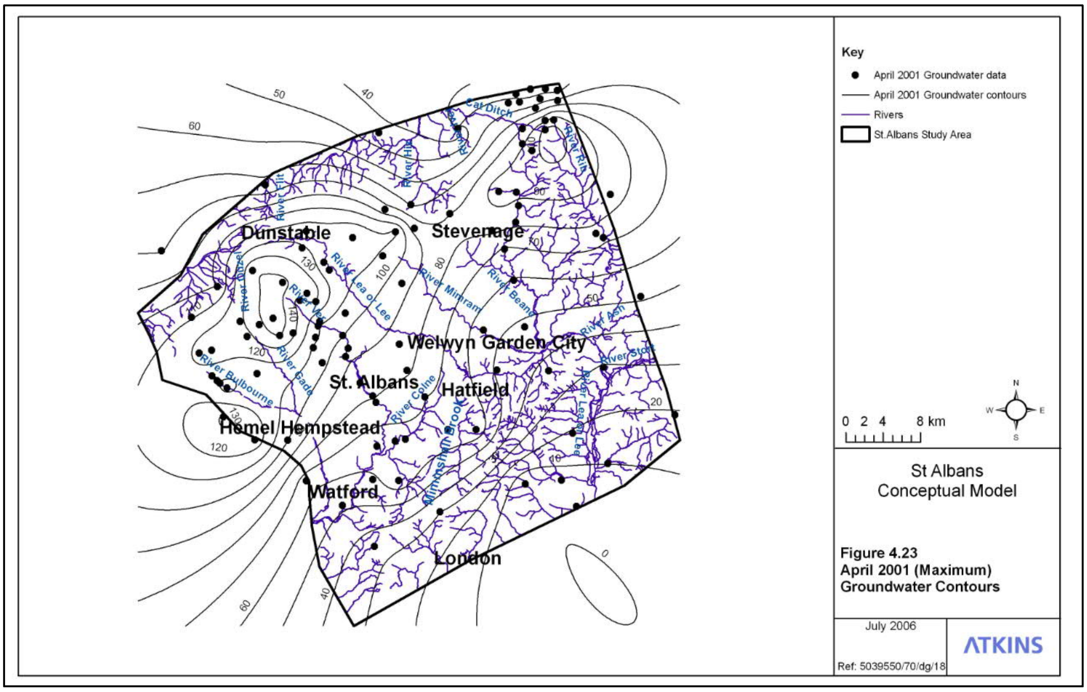


Figure 13 Vale of St Albans model groundwater level interpretation (Atkins, 2006)

Groundwater levels within the study area are shown in Figure 14.

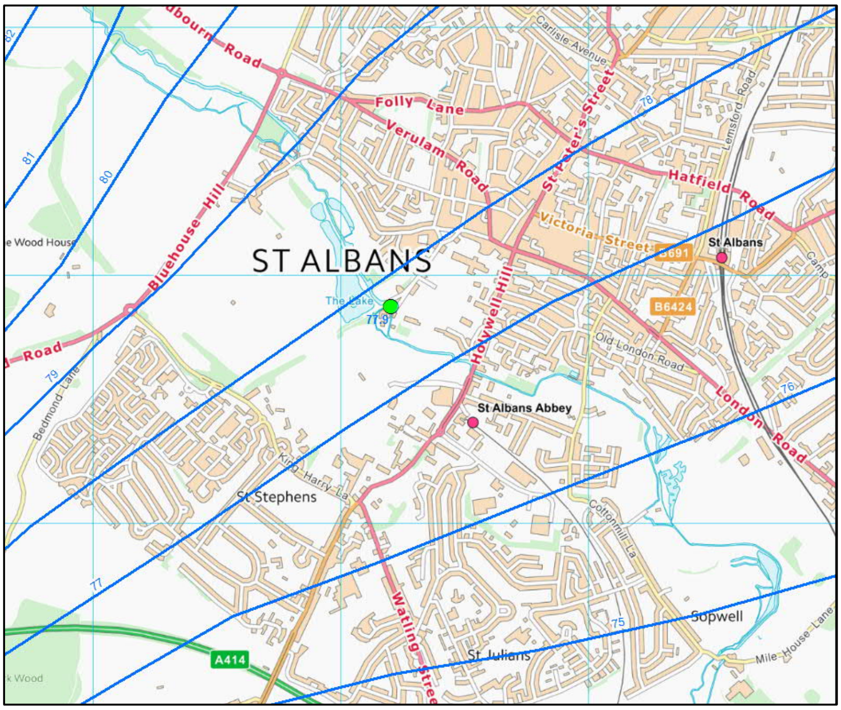


Figure 14 Peak groundwater level interpretation February-March 2001 in the study area

Comparing the estimated groundwater levels to the LiDAR surface elevations indicates that most of the valley in the zone of influence is lower than the estimated winter 2001 water table.

This interpretation (zoomed in from Figure 12) indicates groundwater discharging to the river in certain locations and the river losing flow to groundwater in other areas along the Ver valley. That is, it can be seen that contours converge to the river on one side of the valley and diverge on the other in some locations (the monitoring point data does not allow for convergence around the river in all locations and groundwater levels are tied to observation points toward the Lee valley directing the contours north easterly). Groundwater may discharge to the river in one reach and gain from the river further downstream. The river and groundwater levels are similar with a relatively flat water table surface east-west across the valley such that small elevation changes lead to local gain and loss to and from the aquifer. Groundwater may also flow down valley and discharge to the River Colne which is at a significantly lower elevation.

This interpretation is limited to the sparse data and also assumed each monitored groundwater level represents the active Chalk aquifer as a whole. It is known at different locations in the Colne system that dual piezometry exists within the Chalk where multiple water tables are present separated by confining layers. It is not known whether the specific Chalk layers [redacted] abstract from are confined or partially confined from other layers and from the surface.

The limited geological logging information about potential confining layers was discussed in the hydrogeology chapter. The limited indications of flooded areas in historical mapping despite an interpreted water table above ground suggests there is local confinement of a limited number of Chalk fractures conveying groundwater and interacting with the surface and the River Ver, and other identified discharge areas such as the allotments where groundwater flooding was observed and the marshy ground in historical mapping at Sopwell.

Groundwater Level Rebound

The predicted rise in groundwater levels in the Chalk as a result of the reductions to abstraction at [redacted] is based on signal test data and groundwater model scenario runs. The Environment Agency provided groundwater levels from the Vale of St Albans groundwater model for the historic scenario and a scenario where [redacted] abstractions are reduced. However the model calibration points in the St Albans area were limited to Gorhambury OBH and Orchard Garage Chalk observation boreholes.

The shape of the groundwater level contours in the Chalk aquifer is drawn along the valley axis where the highest transmissivity can be expected and is in a generally upgradient direction when compared to the groundwater level contour interpretation. The impact of the cessation of abstraction is confined to the St Albans area.

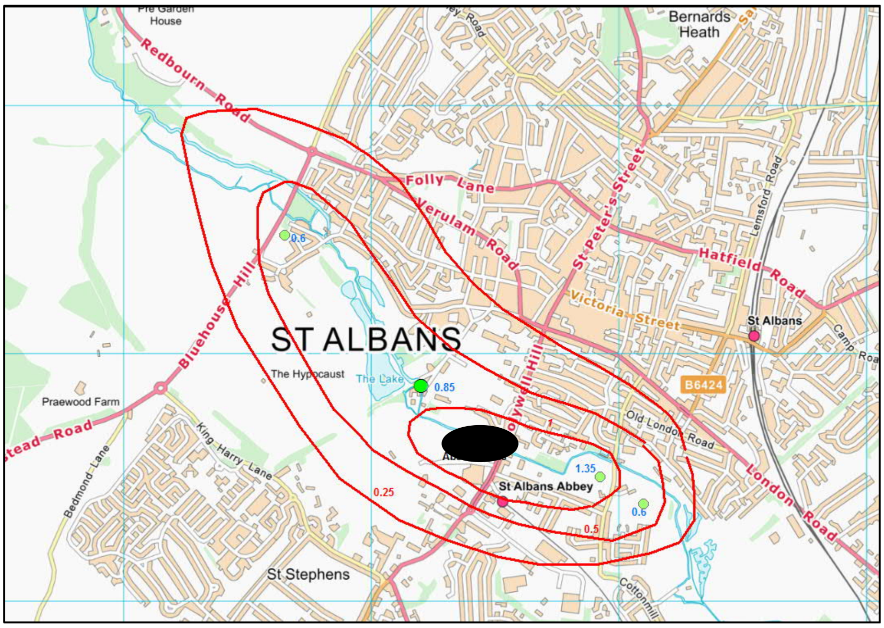


Figure 15 Interpreted groundwater level rebound after reductions in abstraction at [redacted]

This groundwater level recovery cone has been overlaid onto the interpreted contours for the highest groundwater levels in February-March 2001 to give a high water table interpretation with [redacted] abstractions at their reduced rates operating in the study area.

This is likely to be an over-estimate because at high groundwater levels abstraction may cause less drawdown, as there is more aquifer storage available for the abstraction to draw upon, reducing the depth and spatial extent of the drawdown cone.

That is, it is possible that the water table would not be higher if a 2001 event occurred again if there was so much groundwater that the abstractions did not cause any drawdown. For example, during the 2001 and 2014 groundwater flooding events, some abstractions pumping in the order of 20 Ml/d experienced the water table rising, risking flooding site electrics and cutting out pumps, rather than a drawdown.

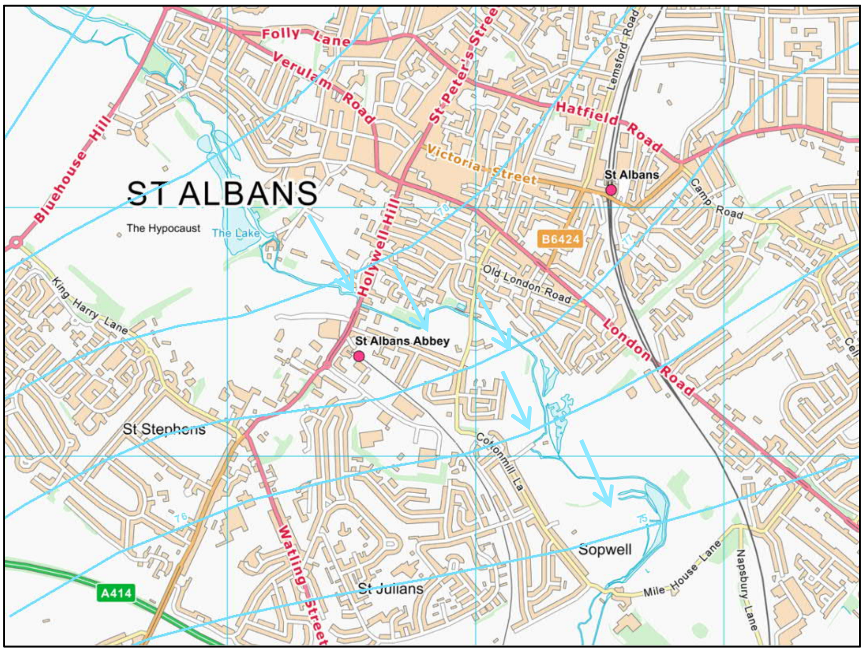


Figure 16 Interpreted February-March 2001 groundwater levels with reduced abstraction at [redacted] Abstractions

The interpretation in Figure 16 shows groundwater flow toward the river in some areas and away from it in other areas, indicating gain and loss from along the valley with general groundwater flow south east toward the Colne Valley as described in the previous section.

Comparing the estimated groundwater levels without abstraction to the LiDAR surface elevations indicates that most of the valley in the zone of influence is lower than the predicted future water table, while historical mapping shows a built environment pre-dating abstraction in parts of the valley. These areas may not be prone to groundwater flooding because locally preferential pathways direct groundwater flow to discharge into the river via discrete Chalk fractures, or there are low permeability layers in the Chalk (or overlying clay alluvium) preventing flow to surface in low lying areas.

Some areas are predicted to be significantly below the predicted future water table and therefore these areas could be considered to be at higher risk of flooding in the future. The Cotton Mill allotments area is potentially at risk because the land surface is approximately 3m below the predicted high water table.

Other areas where there is in excess of 2m difference between the estimated future water table and the land surface are the low lying area in Verulamium Park, and around the lakes downstream of Sopwell Gardens. These were identified in the LiDAR data and historical mapping as potential areas for groundwater emergence.

Other parts of the valley are typically 1m lower than the predicted water table, as these areas have not recorded flooding it can be assumed that Chalk groundwater levels may be pressurised beneath low permeability horizons or there are no significant Chalk fractures to surface, and instead these high groundwater levels may be expressed as higher stream flows, such as the strong accretion observed in the signal test around Sopwell Gardens.

However as flooding may not be recorded or notified to the Environment Agency or local authority it cannot be taken as proof that an area is not susceptible to flooding.

Conclusions and Further Work

The conclusions in this report are based on interpretation and hydrogeological principles where limited data exists. It is the result of following a certain methodology of comparison of land and water table elevation, with historical mapping and documented and anecdotal evidence for flooding.

Conclusions

Areas at Risk of Surface Flooding

The evaluation described above gives an indication of areas that may be at risk of flooding when the groundwater abstractions are reduced. This also aligns with the observations during the signal test of flooding at Cotton Mill allotments and Verulamium Park near [redacted] abstraction.

Additional areas that may be at risk of flooding are identified down gradient of Sopwell Gardens, including where historical mapping indicates the land may have been marshy prior to abstraction. The recreation ground south east of Sadler Road; note here the Sopwell Mill is present within the area identified at risk based on an extensive area of low lying land. As this structure pre-dates abstraction it is considered unlikely to be affected but groundwater may emerge somewhere within the area as it tries to re-establish its original discharge and flow routes. The final area is the open space on the south side of the river opposite the Verulam golf club where LiDAR indicates a possible former stream channel.

Five areas are illustrated on Figure 17; from west (upstream) to south east (downstream) these are: Verulamium Park, Cotton Mill Allotments, Sopwell Gardens Green Space, Sadlers Road Recreation Ground and Ver valley.

Groundwater levels during the very high water table recorded in 2000-1 are estimated to be approximately 1 m above ground level at Verulamium Lake, indicating that if the lake was not lined with concrete, and being the likely location of the original stream, then groundwater would discharge to the lake rather than the current stream location in the Mill Leat. LiDAR and Abbey Mills groundwater levels indicate that groundwater would only discharge through this reach at high groundwater levels, with most winter groundwater levels not reaching lake bed (or the current river bed) assuming these are 1 m below ground level.

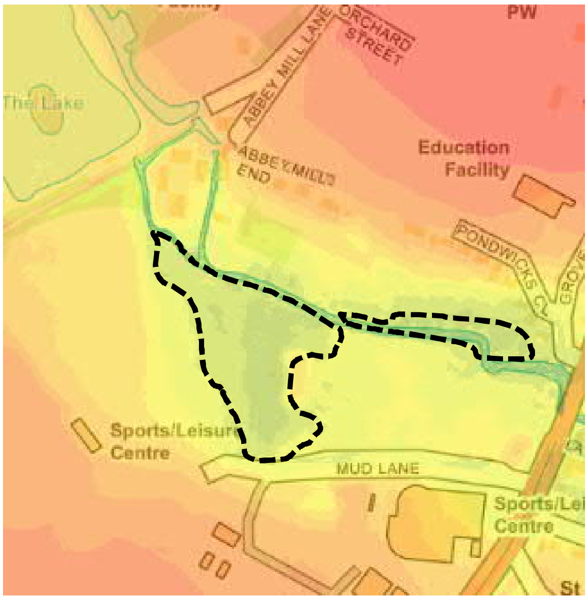
Therefore there is a low flood risk in the lake area, and also limited potential for the lake water level to be maintained by groundwater discharge (if it were not sourced from river water). A summary map of areas of potential flood risk is given below with detailed area maps following.

Figure 17 Areas Predicted to be at Risk of Flooding When Abstraction is Reduced

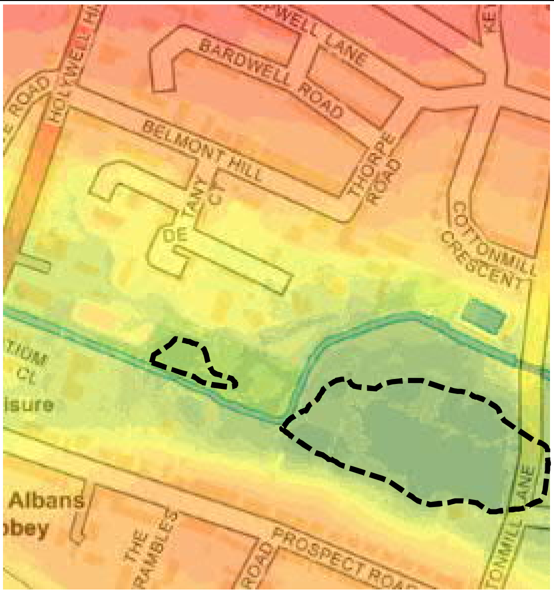
The signal test was conducted at a time when groundwater levels were not particularly high, and reflect a level nearer the average than the peak. Most winters have groundwater levels higher than those recorded during the test. Therefore it is possible that these areas could flood in most winters. This is logical if these areas are the original river route as postulated because they would be expected to be gaining flow for a significant part of the year (winter to spring at least).

The possible frequency of flooding in the other areas identified (Sopwell Nunnery Green Space and downstream) is more uncertain. These areas may have flooded during the signal test if full recovery was allowed to occur indicating that, like the areas described above, they would be vulnerable to flooding in most winters. This is likely to include the Sopwell Nunnery area where historical mapping indicates marshy ground. Other areas further downstream are expected to be on the margins of the area of groundwater rebound as interpreted in Figure 15 and may be only at risk in wet winters.

Detailed maps for each risk area are given below.

Verulamium Park	
	
Confidence	Moderate to High, anecdotal evidence of past flooding
Frequency	Most winters – nearby Abbey Mill groundwater level is above ground level here most winters
Other Comments	Flooding dependent on pathway through aquifer to surface, may result in higher flows in river only, low lying area appears to be former stream path so possibility of aquifer connection and flooding here. Parts of dashed area above current river elevation but low lying and may have connection to aquifer. Grove Road / Pondwicks area not considered to be at risk because development here pre-dates abstraction.

Cotton Mill Allotments

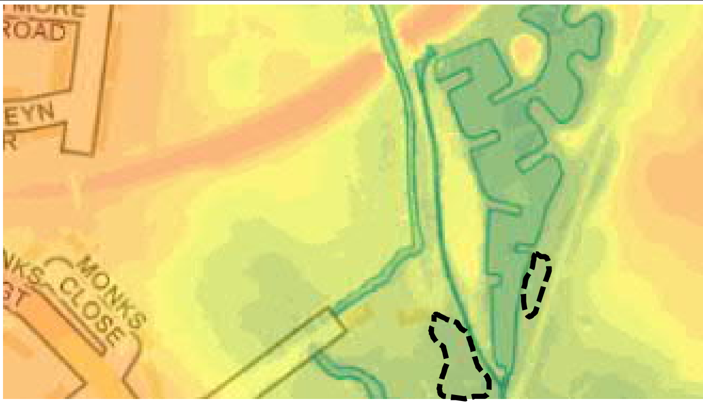


Confidence	High, evidence of past flooding after signal test
Frequency	Most winters – nearby Abbey Mill groundwater level is above ground level here most winters
Other Comments	Flooding dependent on pathway through aquifer to surface, flooding observed so likely to flood rather than higher baseflows in local river reach. Risk of Cotton Mill Lane flooding. River under road is lower than land here so likely higher baseflow under bridge.

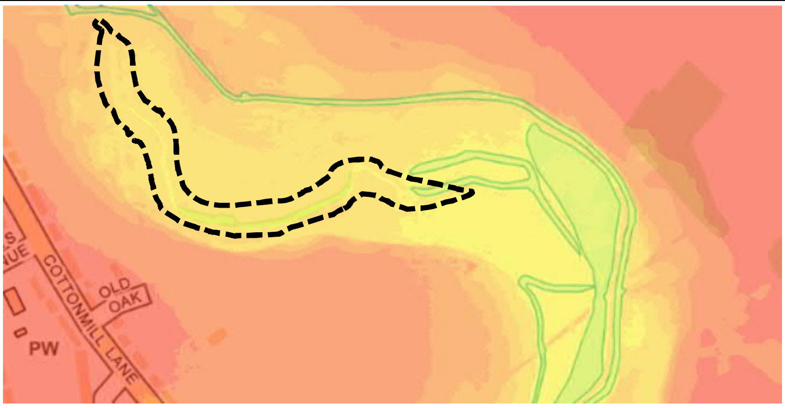
Sopwell Nunnery

Confidence	High, historic mapping showing marshy ground
Frequency	Most winters – nearby Abbey Mill groundwater level is above ground level here most winters
Other Comments	Flooding dependent on pathway through aquifer to surface, high baseflows in local river reach during signal test. Potential flooding as well as high baseflows. Historic buildings at Sopwell Nunnery not considered to be at risk as they pre-date abstraction.

Sadler Road Recreation Ground



Confidence	Low, area similar elevation to river, extensive cress beds and channel reworking indicated by number of channels
Frequency	Wet winters – on margins of groundwater rebound
Other Comments	Flooding dependent on pathway through aquifer to surface, high baseflows may occur rather than flooding depending on aquifer connection to local reach. Existing buildings around Sopwell Mill not considered to be at risk as they pre-date abstraction.

Ver Valley	
	
Confidence	Low, area lower elevation to river, apparent former channel in LIDAR data
Frequency	Wet winters – on margins of groundwater rebound (assuming new channel has better hydraulic contact with aquifer after former channel backfilled to have made it flow in present conditions). Alternatively small change in upgradient groundwater head may be enough to drive groundwater flow back into former channel creating naturalised flow channel.
Other Comments	Flooding dependent on pathway through aquifer to surface, high baseflows may occur rather than flooding depending on aquifer connection to local reach. Assuming area is a former reach then aquifer connection should be good.

Sewer Surcharging

The areas of water table rebound described in previous sections were compared to the locations of sewers provided by the Environment Agency.

A sewer runs through Bell Meadow and along the north eastern side of Verulamium Lake. In the Bell Meadow area the water table is anticipated to be in excess of 1 m higher. Sewers also run under Verulamium Park in the area identified as low lying which may have formed part of the stream or ponding area before the Abbey Mill Leat was constructed. In this area the water table is anticipated to be in the order of 1.7 m higher. A sewer underlies Cottonmill Lane east of the Cotton Mill allotments where groundwater flooding occurred during the signal test and is the former route of the river in OS mapping.

If it is assumed that the sewers are 1-2 m below ground then in each of these areas the sewers can be expected to be at or below the future water table elevation and therefore depending on the integrity of their construction, may be prone to groundwater infiltration. It cannot be quantified what effect this would have on sewer flows and the risk of foul water rising to surface through manholes with the information available, but is identified here as an issue for further investigation. For example, in the first instance it could be raised with Thames Water in terms of the capacity of the sewer network in the area.

Further Work

Field data would help refine, validate and improve the accuracy of the conclusions of the current study.

As part of the on-going Chalk Streams project, further data could be collected by:

- Installing boreholes to monitor groundwater levels as the abstraction reductions occur in order to confirm the predicted levels made herein. Boreholes in the higher confidence areas of flood risk would help improve the conceptual understanding, such as Cotton Mill Allotments, Sopwell Nunnery and Verulamium Park.
- A borehole installed in the Verulamium Lake area would also help confirm whether the lake or former reach of river may only receive baseflow in winter, and hence whether breaching the lake bed to improve water quality with groundwater is feasible.
- The monitoring boreholes could consist of multiple installations, screened at different depths, to improve the understanding of groundwater flow through stratified layers (if present). Affinity Water have described how in many places the Chalk is stratified into locally permeable and low-permeability horizons, which may influence where the groundwater rebound can reach the river and surface to cause flooding. The evidence of the LiDAR elevations and predicted future water table indicates confining layers may be present in this area either from low permeability layers in the Chalk, or the overlying alluvium.
- If groundwater flooding does not occur after abstractions are reduced then higher baseflows may occur in the existing river channel if a sufficient hydraulic connection exists. Spot flow gauging at a high resolution (e.g 100m) alongside groundwater monitoring would enable a conceptual understanding to emerge of where baseflows increase compared to groundwater rebound and any groundwater flooding.

APPENDIX D – River Ver Restoration Modelling Report

River Ver Restoration Modelling note

Quality information

Document name	Prepared for	Prepared by	Checked by	Date	Verified by
River Ver Restoration St Albans	Environment Agency	Kate de Smeth	Seb Bentley	12-02-18	George Heritage

Revision history

Revision	Revision date	Details	Name	Position
1.0	29-01-2018	Incorporated edits from George Heritage. Added flood risk information.	Kate de Smeth	Senior Water Scientist
2.0	01-02-2018	Incorporated edits from Seb Bentley	Kate de Smeth	Senior Water Scientist
3.0	08-02-2018	Final edits	Kate de Smeth	Senior Water Scientist

CONTENTS

METHODOLOGY

01

1. METHODOLOGY

1.1 Introduction

The modelling component of the River Ver Restoration project at St Albans aimed to investigate the flow dynamics across the study area under baseline conditions and multiple restoration scenarios assessing:

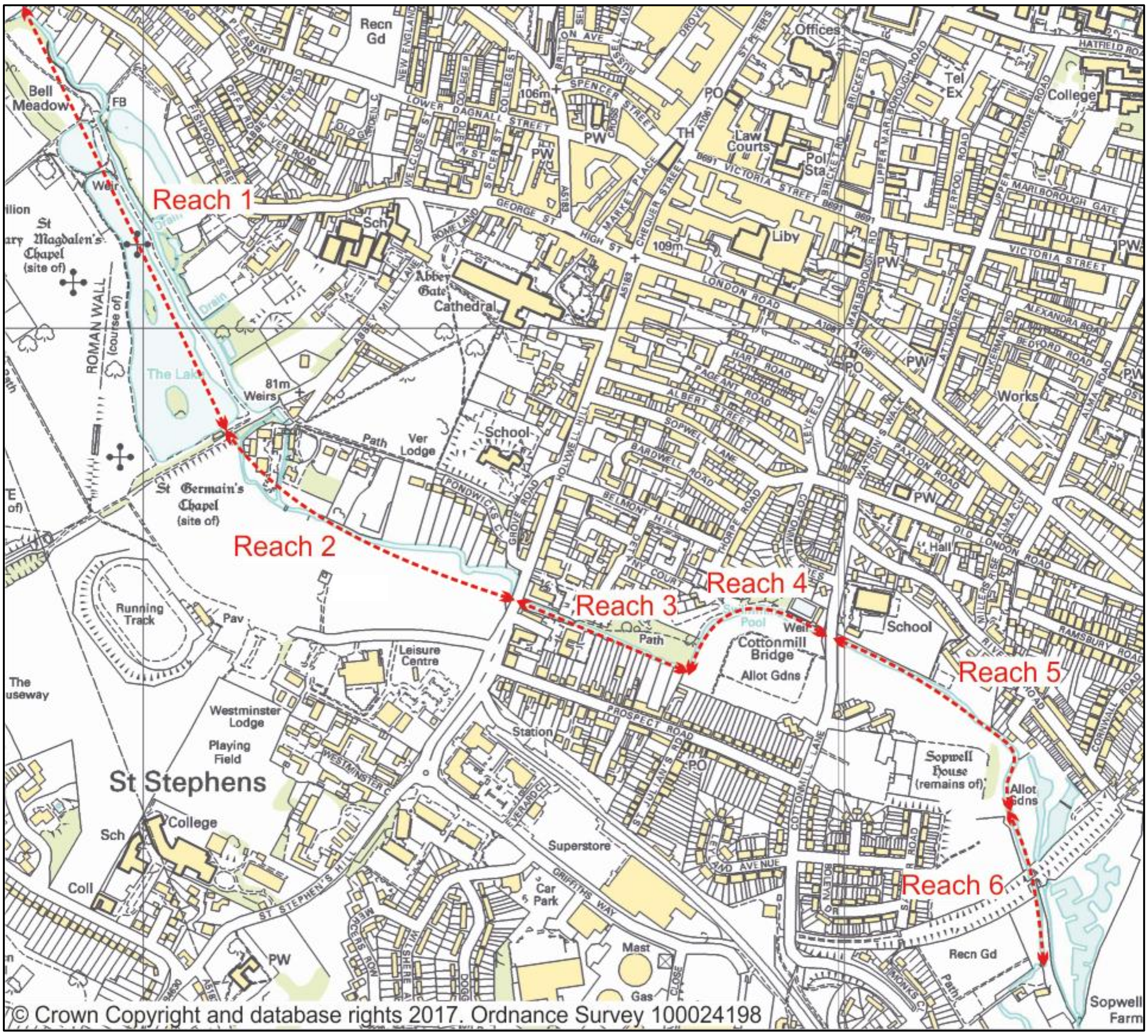
a) Hydromorphological functionality of proposed restoration features (stability, sustainability, erosion risk, siltation risk);

b) Habitat creation; and

c) Flood risk.

To this end, models have been developed to simulate a range of annual and flood flow conditions under baseline conditions (one model) and restoration scenarios (six models – one per river reach). Figure 1 shows the different river reaches for which restoration scenarios were designed.

Figure 1. River reaches of the River Ver Restoration Project



This note outlines the model build process and presents the findings of the modelling work, including hydromorphological interpretation of results and impact to flood risk for each restoration scenario.

1.2 Supplied model

1.2.1 Supplied model

The models used for the evaluation of restoration scenarios were developed from a supplied Environment Agency ISIS-TUFLOW model of the River Ver. The river channel was represented in 1D, while the floodplain and Verulamium Lake were represented in the 2D domain by a 2 m resolution LiDAR-based Digital Terrain Model (DTM). Figures 2 and 3 illustrate the extent of the 1D and 2D domains relative to the study area.

Figure 2. Extent (red line boundary) of the 1D and 2D domain of the River Ver model upstream of Verulamium Lake

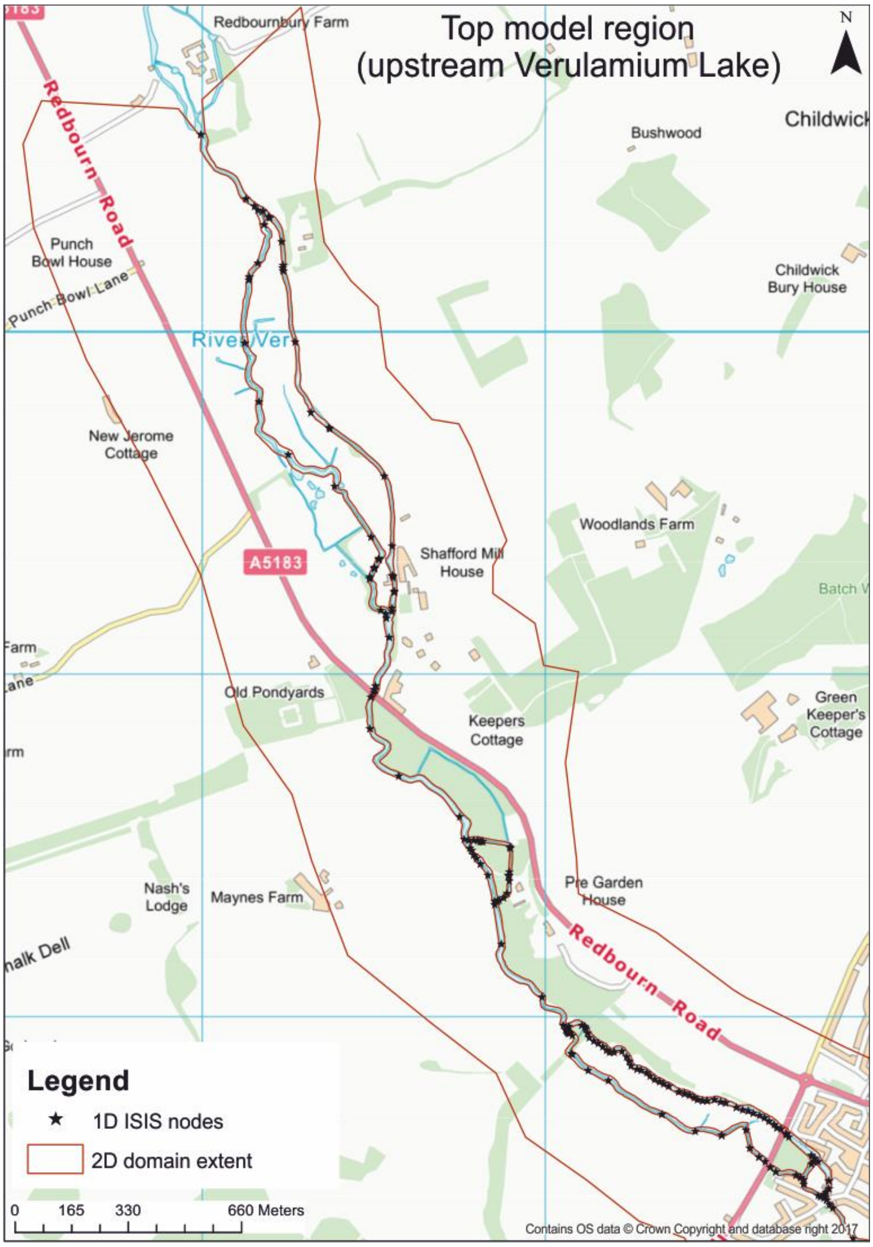


Figure 3. Extent of the 1D and 2D domain of the River Ver model from Verulamium Lake

The supplied model extent was greater than the required area for this project, extending approximately 4.5 km upstream and 2 km downstream of the study area. The decision was taken not to sub-divide the supplied model to isolate the study area in order to avoid the stability issues with the model and to allow wider upstream and downstream flood impacts to be reviewed.

The supplied model was noted to have stability issues by its developers JBA, particularly through Reach 1 where there are various side channels connected to the River Ver. The model review undertaken by AECOM and note circulated to the Environment Agency noted the stability issues raised by JBA in the vicinity of Reach 1 linked to deeper flow within side channels re-entering the main channel. Therefore, a modelling approach was developed that sought to reduce the impacts of the known stability issues and to allow suitable yet efficient modelling of the proposed restoration options.

In the original model Verulamium Lake was represented as a 0.5 m deep unit covering the lake footprint with flow into the lake restricted to overbanking from the River Ver. Outflow from the lake was simulated using the 1D ESTRY function of the ISIS model feeding outflows into Reach 2. An initial water level was applied across the lake depression. This representation does not allow lake dynamics to be investigated in the detail needed for this project.

1.3 Model build: Revised baseline model

The model instability and detail issues described precluded its immediate use in examining the current and restored channel and floodplain hydraulics. Below we set out how extra data was collected and used to improve the model for use.

1.3.1 Additional data

Revision of the supplied baseline model was required given it had been developed largely for general flood modelling purposes meaning river sections in the 1D domain were generally spaced 100-200 m apart, providing limited representation of existing channel geometry and morphology. Without additional data, existing hydraulic habitat diversity (particularly under low flows) would not be well represented in the baseline model and as such would not provide a suitable comparison for restoration scenarios. In addition, survey data of the numerous structures along the main channel by Verulamium Lake were not available and were required in order to more accurately simulate the dynamics of the system through Reach 1. On AECOM's recommendation, the Environment Agency commissioned additional channel survey for inclusion in the revised baseline model.

1.3.2 Building the revised baseline model

There were two main components to revising the baseline model which were:

a) incorporation of new river channel survey data in the 1D domain, and
b) more accurate representation of flow dynamics into Verulamium Lake, requiring both 1D and 2D domain modifications.

Incorporating river channel survey data into the 1D domain

New survey data was incorporated into the model as 22 river cross sections (distinguished in the model by an alphabetic suffix). This improved the representation of existing channel geometry throughout the study area and targeted areas where supplied information was sparse.

Several side channels along the left bank of the River Ver (primarily along Reach 1) were also included in the survey. While the channels themselves were represented in the 2D domain, survey of the connection between these channels and the River Ver was incorporated into the 1D domain via changes in bank elevations to reflect the elevation and width of these openings. This improved the simulation of flow connections but did not solve all of the model stability issues linked to them. However, the instabilities are unlikely to be significantly impacting predicted flood impacts.

Improving the accuracy of flow dynamics into Verulamium Lake

Several new datasets were available for this project in order to improve the representation of Verulamium Lake in the revised baseline model. These included:

- Bathymetric survey (soft bed and hard bed)
- Water level data (associated with the bathymetry survey)
- Survey of the upstream and downstream structures on the right bank of the River Ver in Reach 1.

Bathymetric survey

AECOM were provided with both soft and hard bed bathymetric data in TIN format, collected during May 2017. Soft bed data was preferentially used to update the 2D domain because it is highly unlikely there will be significant movement of the stored fine sediment during flood flows given very low flow velocities.

Some erroneous data points in the top section of the bottom lake required manual adjustment before the soft bed data could be added to the 2D domain. These can be attributed to issues with the GPS signal during the surveying exercise, which meant few data points were collected in this area causing issues when the TIN interpolation was performed [Pers. comm. J. Herriot (Environment Agency) 07 August 2017]. Incorrect cells were manually increased by 0.45 m to match approximate soft bed levels found across the remainder of the bottom lake. Using ArcGIS the corrected soft bed TIN was cut to match the precise geometry of the lake and then merged with the existing 2D model domain to create an updated 2D surface.

Similar issues with the TIN interpolation occurred in the top lake and a revised soft bed TIN was provided by the Environment Agency in November 2017. The revised TIN was minimally different to that prevoiously supplied and so it was considered unnecessary to replace the TIN that had been incorporated into the model. The client was advised of this and deemed this to be acceptable. This was not considered to have had a residual impact on modelling

The connection between the two lakes is represented using LiDAR data, in which the connecting weir under the bridge is captured. The weir height is approximately 0.5 m above bottom lake bed level.

Water level information

Initial water levels were adjusted to 78.7 metres Above Ordnance Datum (m AOD) in the top lake and 78.5 m AOD in the bottom lake based on updated bathymetry data and the precedent set with the supplied model where there was a 0.2 m difference between lake water levels. These levels are consistent with the water levels measured during the bathymetry survey[1].

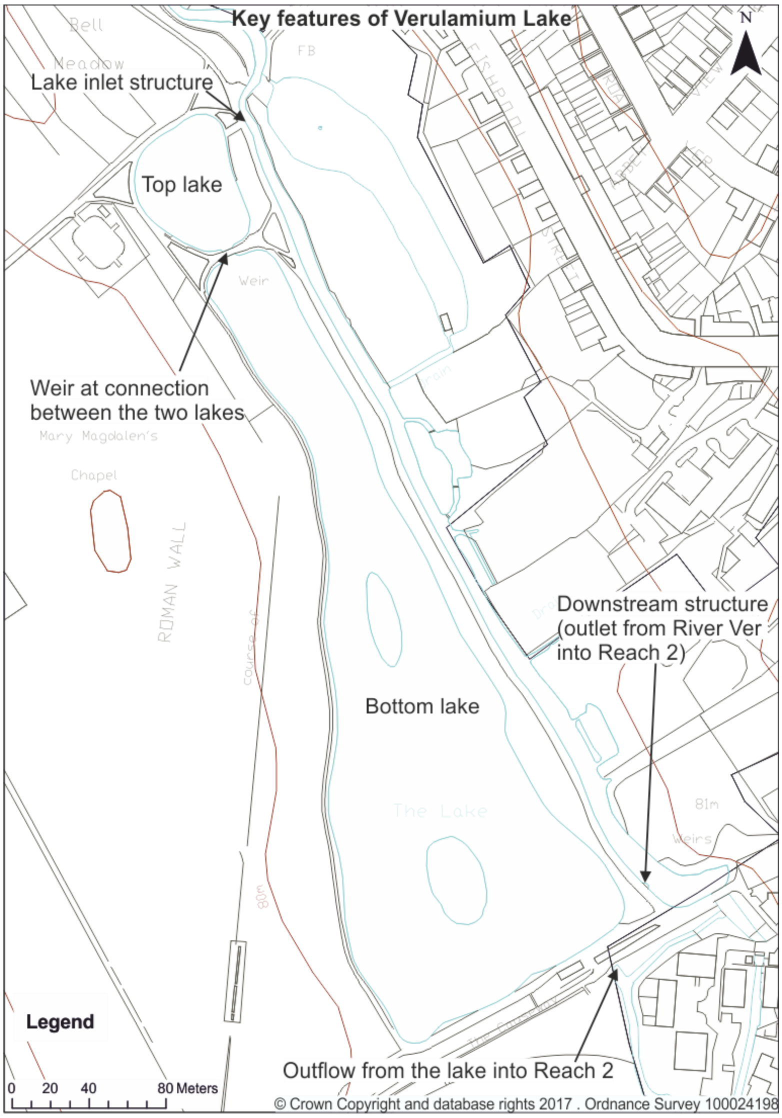
Survey of Reach 1 structures alongside Verulamium Lake

The flow dynamics at Verulamium Lake were a key complication for the development of the revised baseline model. Multiple model iterations were required as new information on Reach 1 structures was obtained, and several different model configurations were tested in order to accurately represent the complexity of the inlet at the top of Reach 1. This was complicated by the fact that the original survey did not pick up enough information on the inlets to the lake from the river to accurately represent flow conveyance into the lake. Further information was subsequently provided by the Environment Agency and based on the information available, the model now incorporates the best possible representation of these structures. The lake dynamics of the revised baseline model are significantly improved compared with the original supplied model.

Figure 4 illustrates key structures at Verulamium Lake.

[1] The bathymetric survey on 22 May 2017 recorded a level of 78.7 m AOD in the top lake and 78.4 m AOD in the bottom lake.

Figure 4. Key structures at Verulamium Lake



The inlet structure at the top of Reach 1 was surveyed twice during this project. This structure has two openings at different invert levels where flow from the River Ver can enter the lake via a culvert. These two openings were approximated using the combination of an ORIFICE unit in the 1D domain (spilling into the lake along an SX boundary) and bank lowering at the connection between 1D and 2D domains.

The supplied model report refers to a number of inflows into the lake from the channel however the additional survey only identified one other inflow point located at the northern end of the bottom lake. Given this additional inlet was not part of any discussion during project development, and was not located during the field survey, it is believed to be blocked and was therefore excluded from consideration.

Towards the downstream end of Reach 1 a second structure was surveyed on the right bank that provides a conduit for flow from the River Ver directly into Reach 2 and bypassing the lake. This culvert connects to the lake outflow location. During the site visit when approximately median river flow conditions were observed, the outflow volume was approximately 20% of the volume through the fish pass. It was represented using an ORIFICE unit in the 1D model domain.

1.3.3 Testing the revised baseline model

The supplied and revised baseline models were run for the 100 year flood event (1% AEP) in order to compare the extent of flooding and establish the impact of the model changes on flood extent. The outputs from the two models were comparable with only minor increases for the revised model at Reaches 3 and 5. These minor differences can be attributed to the incorporation of new bed level detail in the revised model from survey. Other model check results (dVol and cumulative mass error) were within acceptable ranges of variation compared with the supplied baseline model.

1.4 Model build: Restoration scenarios

1.4.1 Restoration scenarios to be modelled

A number of potential restoration scenarios were identified through AECOM's initial investigations (desktop studies and site walkover) and in discussion with the client and other stakeholders. Two appraisal processes were subsequently completed to identify the final preferred restoration scenario for each reach. The main report details the development of the preferred option for each reach in more detail.

1.4.2 Scenario modelling approach

The restoration scenarios include various in-channel features (riffles, pools, berms and bars), riparian and floodplain features (inset floodplains, inset berms, inset riparian zones, ponds, wet woodland and riparian planting) as well as channel realignment and sinuosity improvements.

In order to combat the known model stability issues, in-channel features were modelled in the 1D domain using a combination of changes to channel width (to simulate their effect on channel conveyance and flow hydraulics) and roughness (to accommodate likely future roughness changes as features naturalise). Features were created using the nearest up and downstream cross-sections. Bed levels were interpolated as required and bank levels taken from LiDAR.

Feature performance was seen to be sensitive to the degree of channel narrowing as this concentrated flow energy, and iterative modelling of channel width was undertaken for the scenario models to determine an appropriate channel width that provided the best possible impacts on channel hydraulics linked to each of the preferred options selected for each reach.

Riparian and floodplain features were modelled in the 2D domain by altering ground elevation and modifying roughness to mimic revegetation/planting (Manning's n values were increased to between 0.045-0.075 depending on the feature). At these locations bank levels of any river cross-sections were adjusted to ensure consistency between 1D and 2D domains.

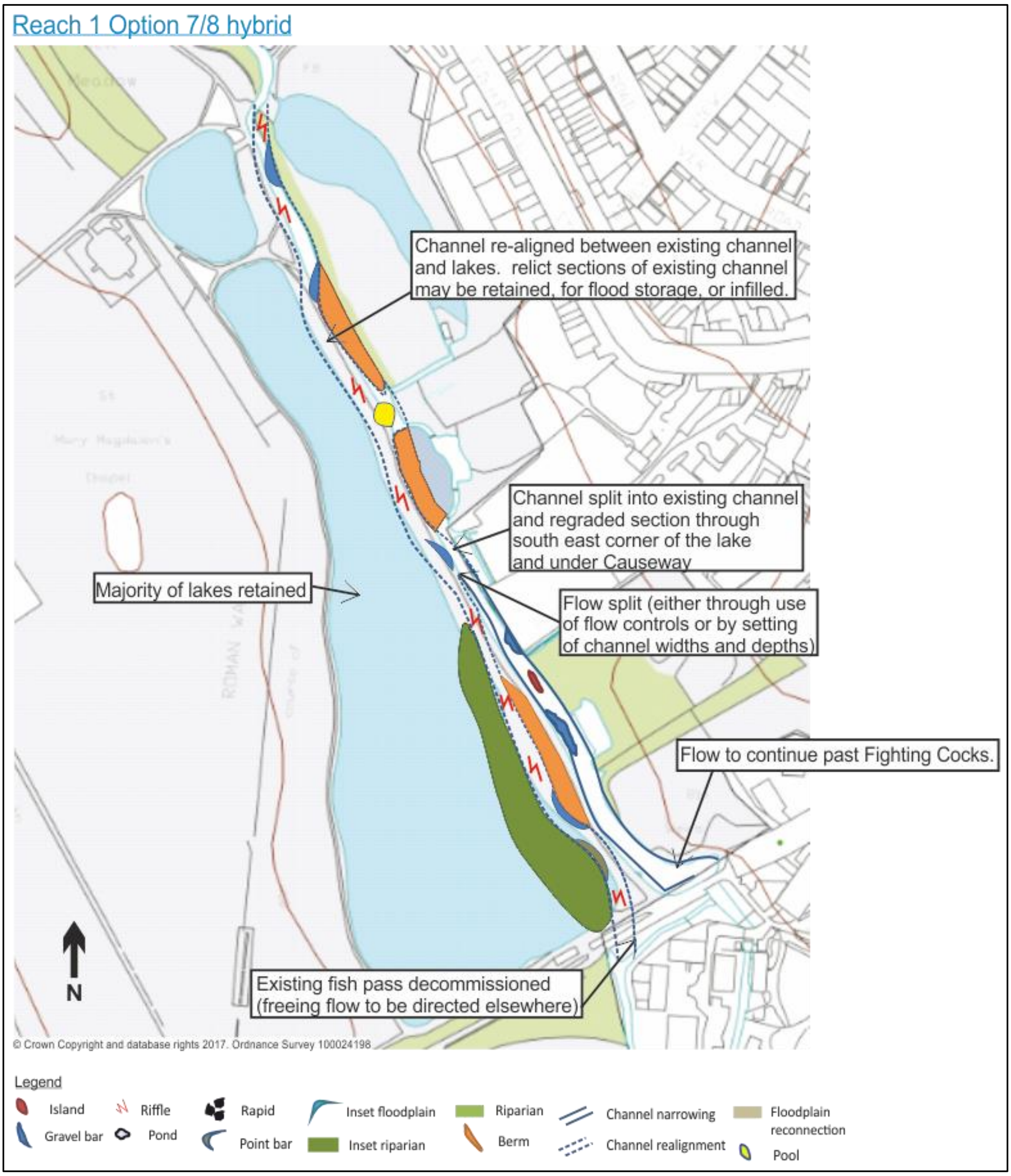
Channel planform change (sinuosity and/or realignment) involved adjustment of both 1D and 2D model domains to allow planform roughness to be explicitly accounted for in the model. River sections were created using copies of the existing river channel sections and the suffix '_E' was added. Along the proposed new river course bank levels were taken from LiDAR and bed levels were set to approximately 1 m below bank elevation (deemed to be a broad suitable depth to balance floodplain connectivity and impacts to flood risk). See sections 1.4.3 Reach 1 and 1.4.6 Reach 4 for more detail on how this was implemented in these reaches.

Sections 1.4.3 to 1.4.8 provide the design overview figures for each restoration scenario and also outline any additional information on how each scenario was modelled.

1.4.3 Reach 1 Option 7/8 hybrid

Figure 5 outlines the restoration scenario for Reach 1.

Figure 5. Restoration scenario for Reach 1 (Option 7/8 hybrid)



Under this proposed restoration scenario a second channel is created to bypass the existing fish pass. The bypass channel was created in the 1D domain, replicating bed levels in the existing main channel to maintain a reasonable flow split between the bypass and main channel through to the mill weir and so that this replicated the baseline condition flow split as much as possible (see Results section for flow split information). The constraint imposed on the restoration to maintain flow to the mill leat channel generates an unnaturally steep section in Reach 1. To accommodate this we have used a set of coarser riffle units. These would not normally be seen on a chalk system but will provide excellent higher energy habitat.

Initial versions of this model had issues with accurately representing the flow splits associated with the channel width changes, and as a result bed level changes were also required to mimic the features. Due to existing model stability issues in the supplied model linked to deeper flows in the various channels in the floodplain, inset berm areas were represented in 1D rather than 2D.

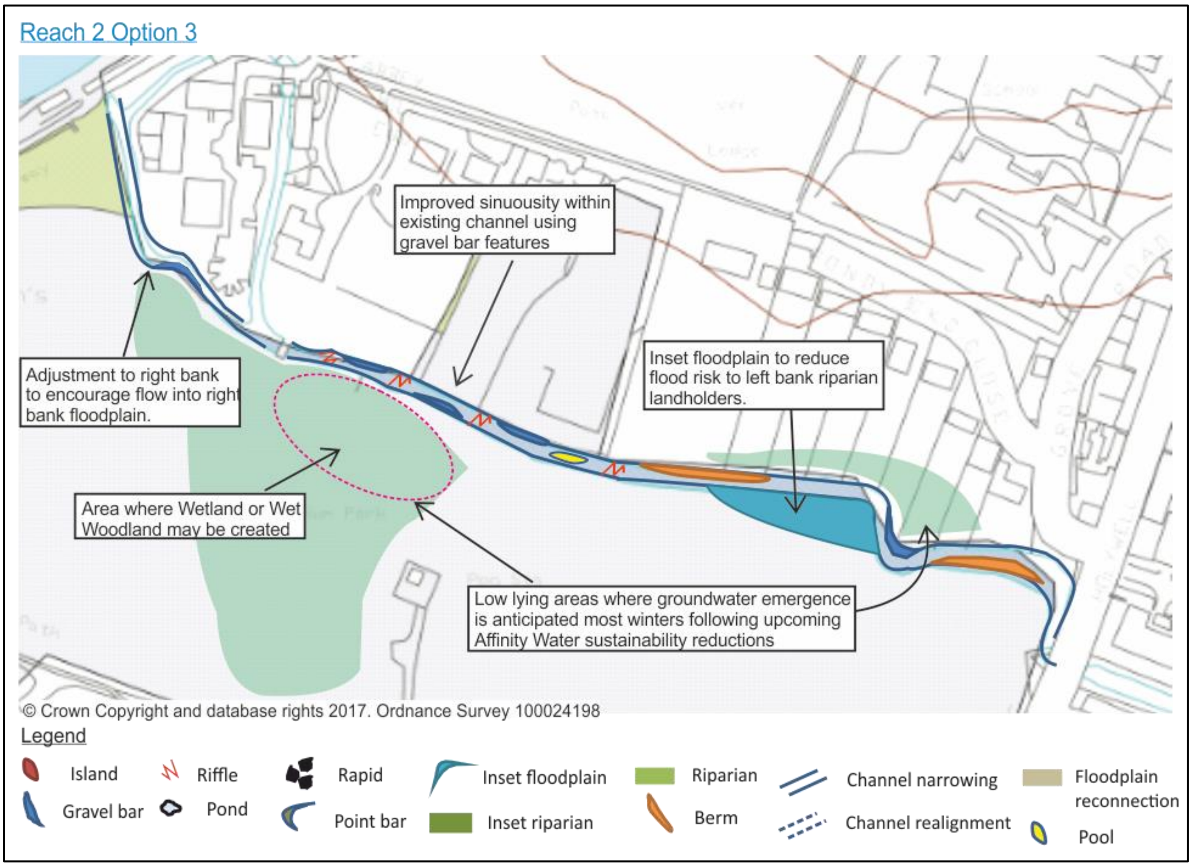
The downstream overflow structure in Reach 1 is decommissioned in this scenario. The existing fish pass is also decommissioned in this scenario, and this has been simulated by raising of the crest level at the top of the pass.

A smaller sweetener flow had to be added to the existing fish pass sections to prevent them drying out during the model run, which would otherwise cause the model not to run. This is a common model technique for channels that dry out and does not impact the hydraulic analysis for this study.

1.4.4 Reach 2 Option 3

Figure 6 outlines the restoration scenario for Reach 2.

Figure 6. Restoration scenario for Reach 2 Option 3

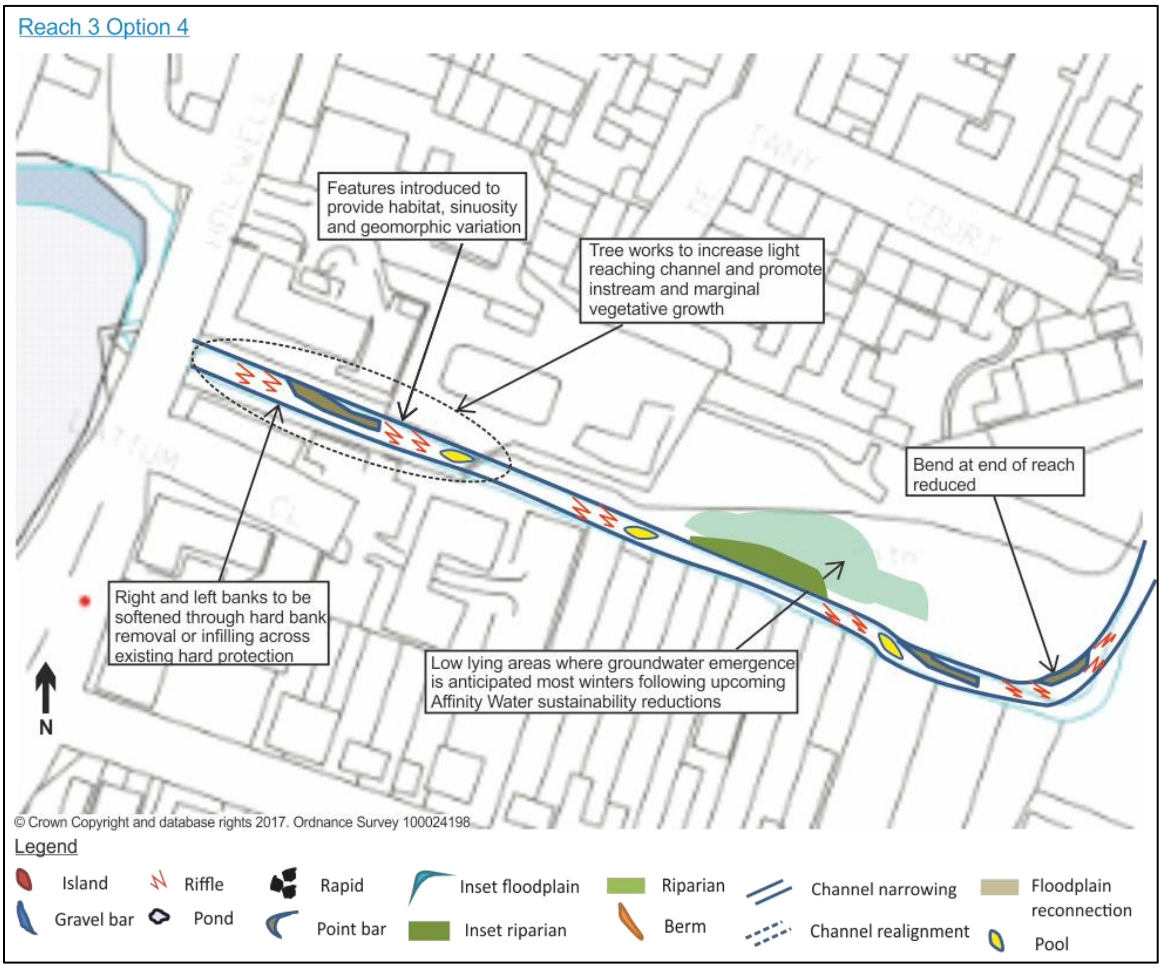


For this model, a connection was created at the top of the reach to enable river flows to enter the floodplain and create an area of wetland/wet woodland. This connection was set at approximately half right bank height and was represented using bank line and ground elevation changes. See the Results section 2.2.2 for comment on the functionality of this connection.

1.4.5 Reach 3 Option 4

Figure 7 outlines the restoration scenario for Reach 3.

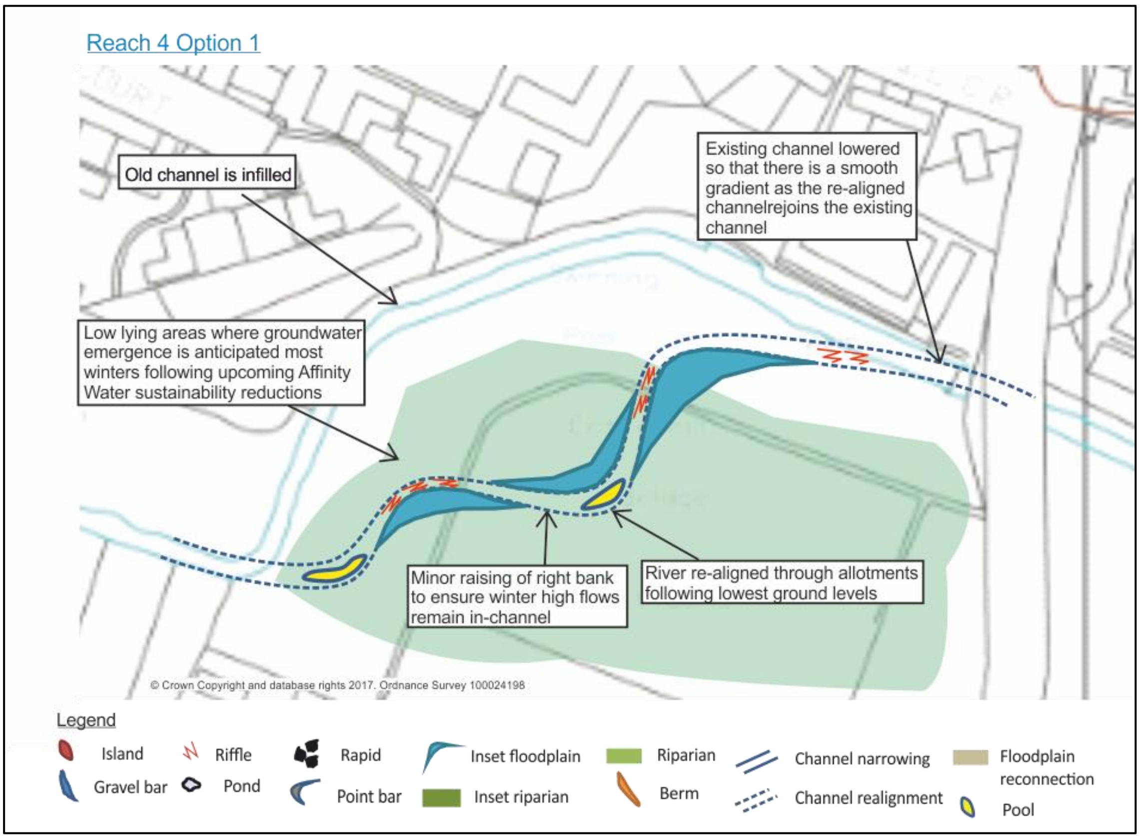
Figure 7. Restoration scenario for Reach 3 Option 4



1.4.6 Reach 4 Option 1

Figure 8 outlines the restoration scenario for Reach 4.

Figure 8. Restoration scenario for Reach 4 Option 1



This restoration scenario involved careful consideration of bed levels at the upstream and downstream connection points for the realigned channel due to the perched nature of the existing river channel flowing at a higher general elevation relative to the right bank floodplain. There was also significant model stability issues associated with these connections, with the model being highly sensitive to the gradient change into and out of the realigned section. In order to combat model stability issues and best represent the connection between the existing and realigned channel:

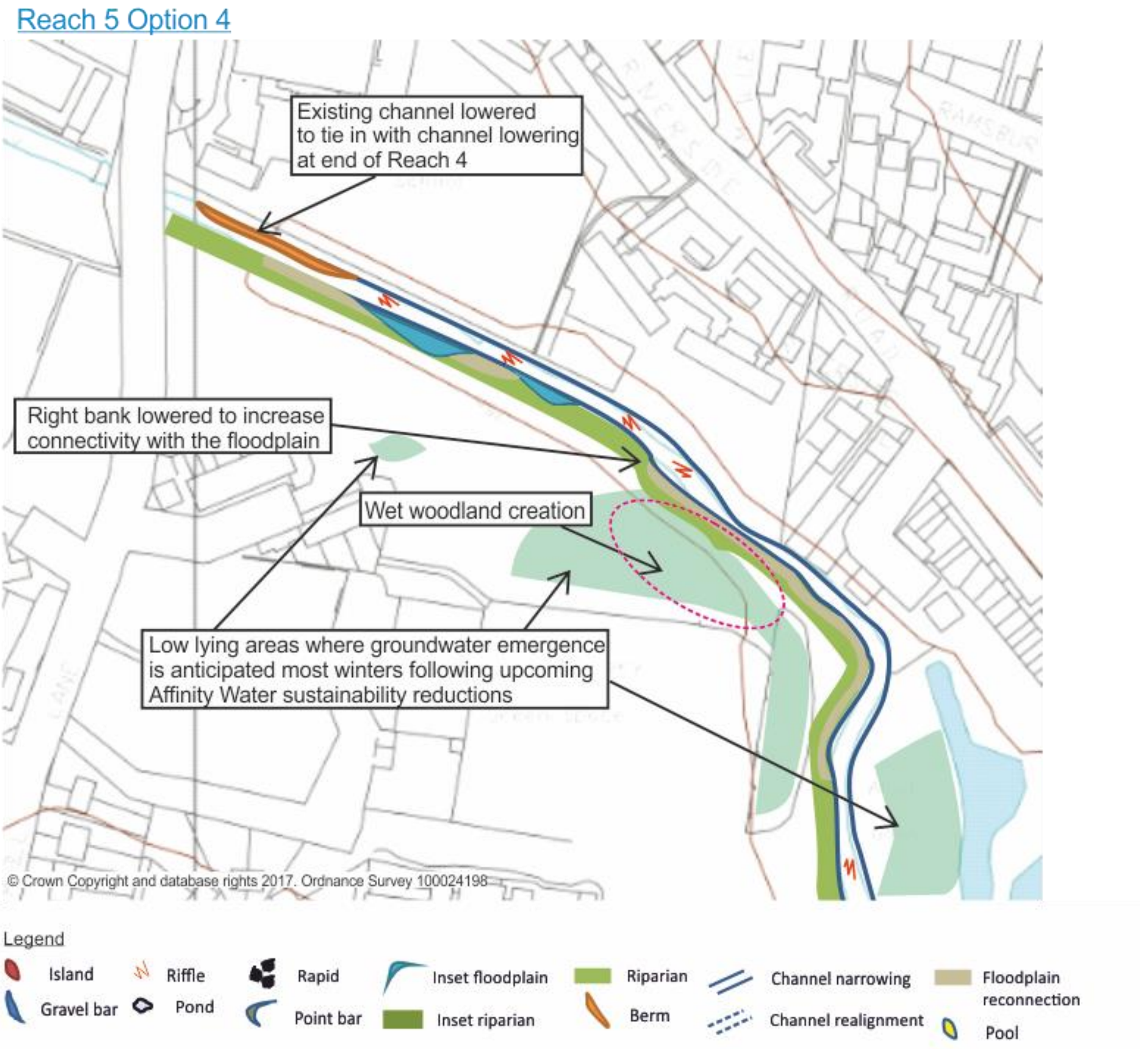
a) The revised baseline model was cut mid-way through Reach 2 after the junction with the mill leat (the point at which all flows through reaches 1 and 2 are rejoined). This required a re-calculation of inflows for input into the shortened model (see Section 1.5). The elimination of reaches 1 and 2 and Verulamium Lake significantly improved model stability.
b) Approximately 50 m of Reach 3 was gradually regraded to enable a smooth gradient for the upstream connection into the realigned channel creating run and glide habitat.
c) At the downstream connection the main river channel, weir and bridge culvert have been lowered by approximately 1 m to enable a smooth gradient out of the realigned channel back into the main channel.

Under the proposed design, the relic main channel is infilled i.e. it offers no capacity to take water during times of high flows.

1.4.7 Reach 5 Option 4

Figure 9 outlines the restoration scenario for Reach 5.

Figure 9. Restoration scenario for Reach 5 Option 5

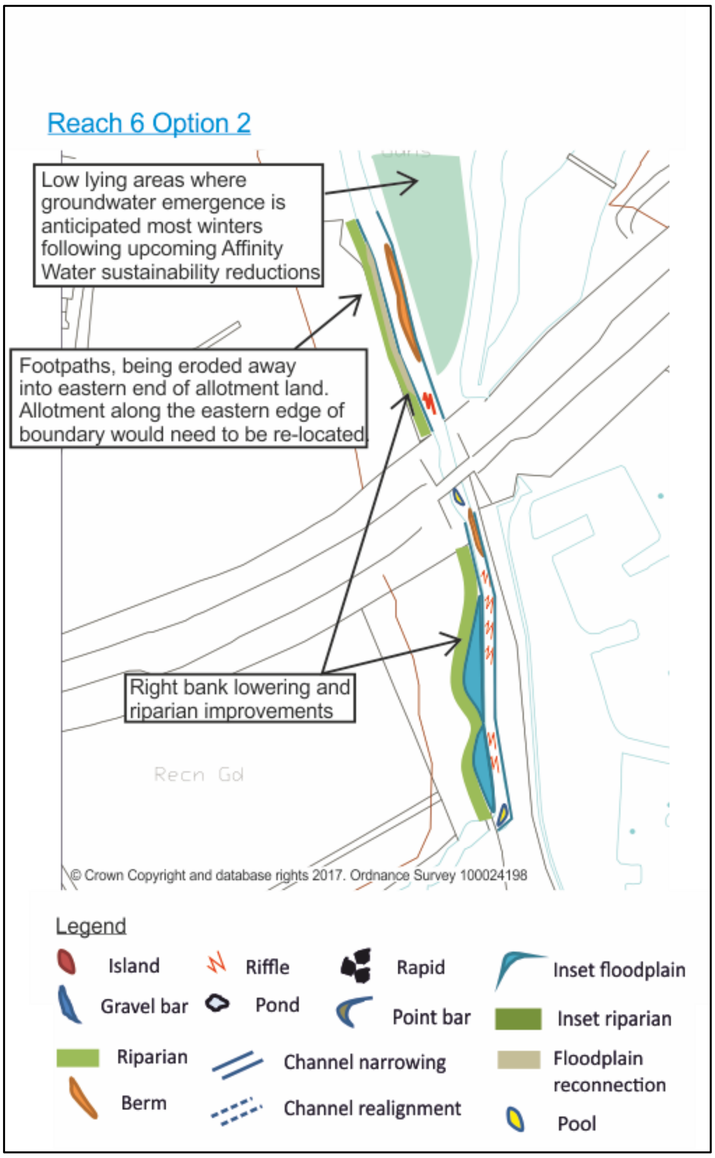


For this model, connection to the wet woodland was enabled through lowering of the right bank via ground elevation changes in the 2D domain. Corresponding bank elevations and river cross-sections were also adjusted in the 1D domain. The lowering of the right bank set the bank height at half its original elevation. The wet woodland itself has developed on natural depressions in the topography. Model roughness was increased here to simulate the growth of wet floodplain species over time.

1.4.8 Reach 6 Option 2

Figure 10 outlines the restoration scenario for Reach 6.

Figure 10. Restoration scenario for Reach 6 Option 2



For this model, lowering of the right bank upstream of the bridge was carried out through adjusting ground elevation in the 2D domain. Bank elevations and river cross-sections were then altered in the 1D domain. The lowering of the right bank set the bank height to three-quarters of the original elevation.

1.5 Hydrology

The supplied baseline model included flow statistics for several flow return periods and low flow conditions (Q_{95}). Flow rates from the supplied model relating to flood flows were applied in the revised baseline model. However in order to adequately assess the proposed restoration scenarios, a range of annual flow conditions needed to be modelled and further work to derive these annual flow statistics was required.

To derive the annual flow statistics, flow data from the National River Flow Archive was sourced for the River Ver downstream of the study area at Hansteads (ID: 39014). A flow duration curve (FDC) was derived from the data and relevant flow statistics were calculated for the river at that flow gauge. These were the Q_{95} (summer low flow), Q_{50} (median flow) and Q_{10} (winter high flow). Correspondent flow statistics for the beginning of the model at Redbournbury Farm were then apportioned based on catchment size.

The flow statistics were then reviewed in consideration of additional hydrological data for the River Ver through St Albans. The first dataset related to the planned sustainability reduction that will reduce the volume of abstractions from the River Ver. The planned reduction was assessed and found to equal an approximate 1% change in flow volumes to the Ver in the study area. As such, no change was required for the flow statistics derived.

Secondly the flow statistics were reviewed in consideration of the extent of groundwater and surface water interaction. As the River Ver is a chalk stream, groundwater plays an important role in the magnitude of flow. This makes estimating flow through catchment apportionment unrealiable. Our review of extensive spot flow measurements through the catchment found that applying the catchment apportionment to flow statistics derived from the downstream gauge at Hansteads would over-estimate inflow values for the model by approximately 30%. The apportioned flow statistics were adjusted accordingly. The calculated Q_{95} value (0.065 m^3/s) was consistent with the same flow rate in the supplied model (0.063 m^3/s), providing confidence in our approach.

The supplied River Ver model also included two lateral inflows and a sweetener flow that enter the model domain downstream of the main channel inflow point. These values were adjusted for use in the model based on their proportion relative to the supplied model's low flow value. For example, the lateral inflows Lat01 and Lat02 are both 0.01 m^3/s, representing approximately 15% of the magnitude of the supplied low flow rate. As such, these inflows were calculated to be 15% of the apportioned flow rates calculated for the main channel for each of the calculated annual flow statistic.

The results of the annual flow statistics derivation exercise for the main channel and other model inflows are summarised in Table 1.

Table 1: Flow statistics for each inflow in the revised baseline model

Flow statistic	Flow rate (m^3/s)			
	River Ver at start of model	Lat01	Lat02	Swtner_01
Q_{95}	0.063	0.01	0.01	0.05
Q_{50}	0.213	0.03	0.03	0.16
Q_{10}	0.462	0.07	0.07	0.36

The revised baseline and all scenario models were run using these annual flow conditions and a selection of the flood return periods from the supplied model, these being the 2 year flood (50% AEP), 10 year flood (10% AEP) and 100 year flood (1% AEP).

Reach 4 inflows

Further to the need to reduce the extent of the Reach 4 model (see section 1.4.5), inflows to the shortened model were exported from revised baseline model runs at section 1.148A in Reach 2 for each modelled flow. Additionally several sweetener and lateral inflows could be removed from the model where these inflows enter upstream of the revised model area. The remaining lateral inflows were adjusted accordingly.

1.6 Analysis of model results

The analysis of model results involved several steps:

1. Flood risk analysis.
2. Summarising reach flow dynamics.
3. Calculation of shear stress, critical bed sediment size, bank and berm erosion resistance to enable identification of erosion and siltation risk, feature stability etc.
4. Calculation of hydraulic biotopes to inform the in-channel habitat assessment.

Steps 2-4 enabled hydromorphological interpretation regarding the functionality, stability and sustainability of the features associated with each restoration scenario.

Flood risk analysis

The potential flood risk associated with each restoration scenario was investigated by comparing the 2 year, 10 year and 100 year flood extents for each reach with the revised baseline model results. Where a difference in extent has been observed, comments have been made about average flow depths and the level of risk presented.

Flow dynamics

The in-channel 1D component of the models was used to output characteristic flow conditions for a range of discharges including a typical summer low flow (Q_{95}), a typical winter high flow (Q_{10}), a 'bankfull' flow (2 year return period/ 50% AEP) and an extreme flood (100 year return period/1% AEP). Parameter outputs include average flow depth, velocity and Froude number (the latter is used to map in-channel hydraulic habitat and is only relevant up to the 2 year flood event), allowing for analysis of the functionality of restoration features across the flow regime.

Information on flow splits under baseline and restored conditions are also provided to demonstrate key flow splits are maintained in the restoration scenarios represented.

Shear stress and critical bed sediment size

Shear Stress

The hydraulic data were used to assess the ability of the channel to transport sediment and the subsequent risk of siltation by calculating the shear stress acting on the bed of the channel using the DuBoys equation (equation 1).

$$\tau = C_f \rho_w U^2 \qquad (1)$$

where τ= Shear stress (N/m^2), Cf= Coefficient, ρw= Density of water (1000kg/m^2) and U= Depth averaged point velocity (m/s).

The coefficient Cf is calculated from equation 2

$$Cd = \frac{g}{\left(M\, h^{1/6}\right)^2} \qquad (2)$$

where g is the acceleration due to gravity as a constant, M is the Manning's M (1/n) and h is the total water depth. For the River Ver, a uniform Manning's n of 0.04 has been applied as per the supplied model.

Critical bed sediment size

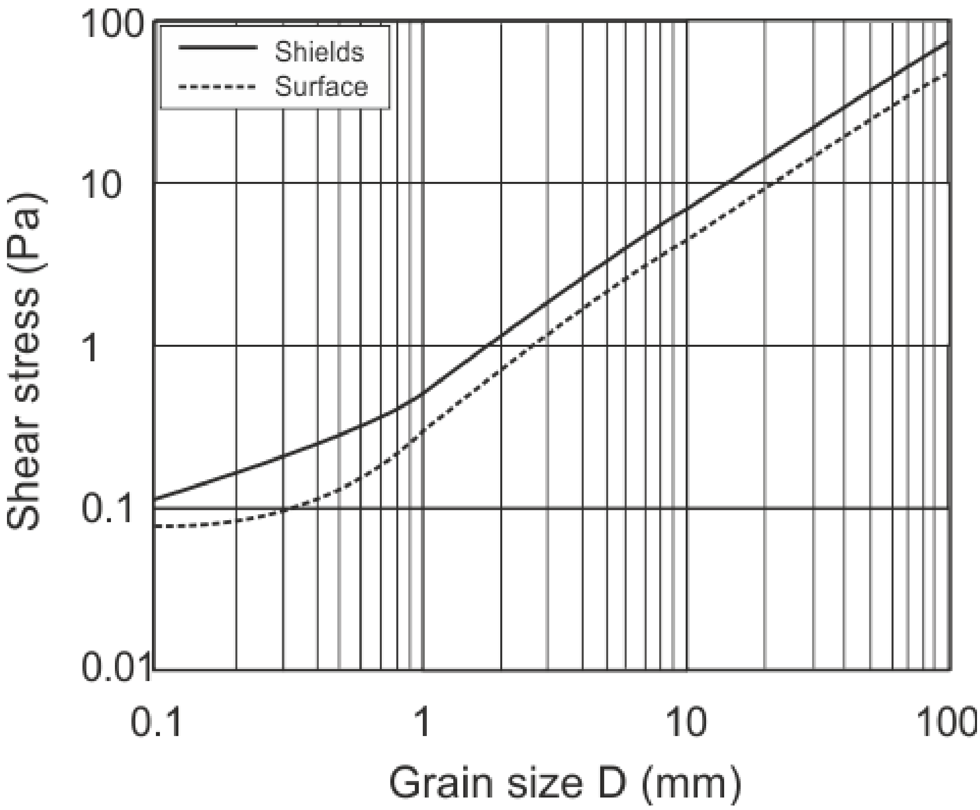
The critical shear stress required to initiate movement of unconsolidated sediment of sand size and above may be estimated from equation 3.

$$\tau_{cr} = 0.045(\rho_s - \rho_w) g D_g \qquad (3)$$

where τ_{cr}= Critical shear stress (N/m^2), ρ_s= Density of sediment (2650kg/m^2), ρ_w= Density of water (1000kg/m^2), g= gravitational acceleration (9.81m/s^2) and D_g= Sediment size (intermediate axis) (m).

This is also illustrated graphically in Figure 11.

Figure 11. Dimensional Shields entrainment curve for unconsolidated sediment



Calculating the critical bank and berm erosion threshold

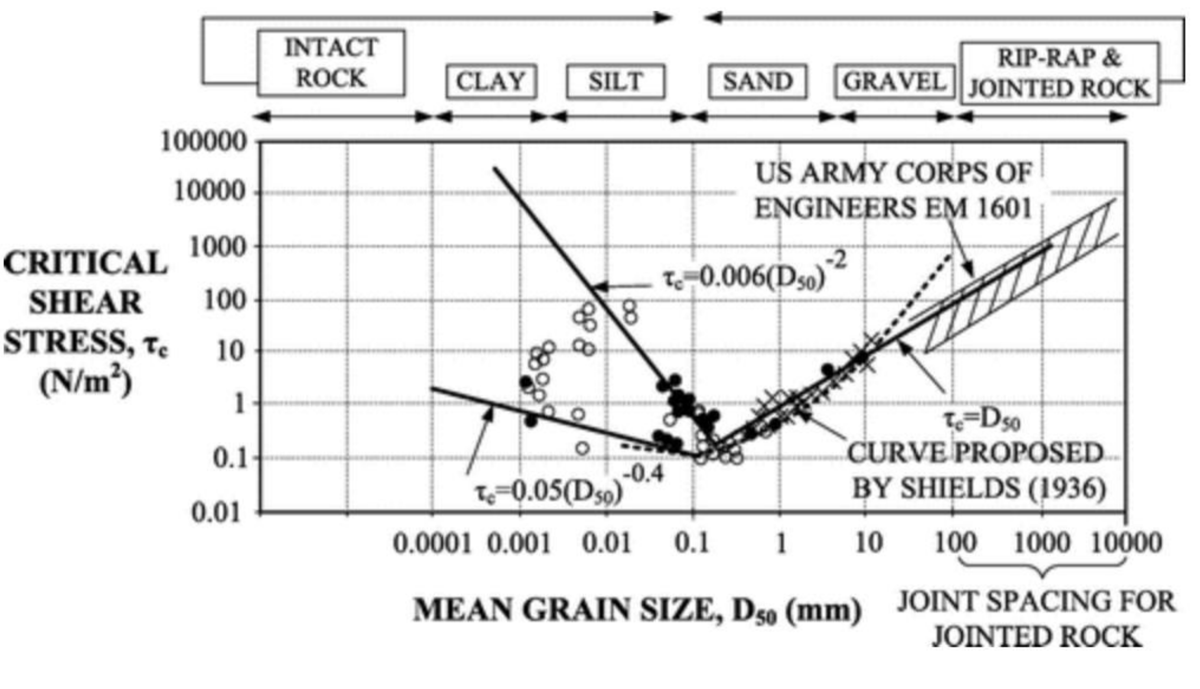
Sediment displaying a low cohesive strength (sand grade and above) will behave as unconsolidated particles and Equation 3 and Figure 11 may be used to determine the approximate shear stress required to initiate erosion.

With banks/berms comprising silts and clays the amount of flow shear required to initiate erosion is dependent on a number of factors including the type of sediment making up the deposit and the degree of sediment cohesiveness, level of consolidation and influence of vegetation. This may be measured directly through shear strength testing. In the absence of such data, empirical relationships may be used to bracket the level of shear stress required dependent on the rough composition of the banks/berm (Figure 12). Much of the floodplain sediment on the River Ver is silty sand with grain diameters between 0.01 mm and 0.1 mm. Taking a median value from Figure 12 (0.05 mm) the range of shear stress required to initiate erosion is 0.2 to 8 N/m^2. The bank deposits through the restoration reach are generally quite consolidated so an upper figure of 8 N/m^2 has been chosen as the threshold to identify at risk banks.

Berms on the river tend to be composed of silts with some clay and sand and are strongly consolidated and vegetated. As such an upper limit of 75 N/m^2 has been used to threshold the stability of these features.

Loose silts and organics would require shear stress levels above a threshold of 0.4 N/m^2 to begin being flushed downstream, where clays are also present this rises to around 1 N/m^2 (Figure 12). Although not quantified at this stage, visual inspection of the fine sediment in the River Ver study reaches suggests that a clay fraction is present along with the silts and organics and the upper limit of 1 N/m^2 is used later as the threshold for flushing of recently deposited fine sediment.

Figure 12. Critical shear stress thresholds for cohesive sediments[2]



In-channel habitat assessment

The physical character of the water surface in a river reflects the local hydraulic conditions, leading to the development of the 'physical' or 'hydraulic' biotope[3] as a way of characterising instream habitat. Biotopes have assumed recent importance in defining system biodiversity under the Water Framework Directive[4] and in the development of typologies to underpin the 'Habitat Quality Index'[5] as they provide a means of integrating ecological, geomorphological and water resource variables for management purposes.

Physical biotopes may be characterised through variations in velocity, depth and bed roughness, various combinations of which produce different characteristics on the water surface such as standing waves, free fall, or upwelling, and collective known as 'water surface flow types'. These can be identified visually and linked to the biotope through the use of a descriptive table[6] and has been incorporated into the River Habitat Survey. With research suggesting a robust link between biotope variety and extent and biotic diversity, physical biotopes are now key aspects of the river inventory and river rehabilitation design process[3,7]. Newson et al., (1998) proposed a method of assessing

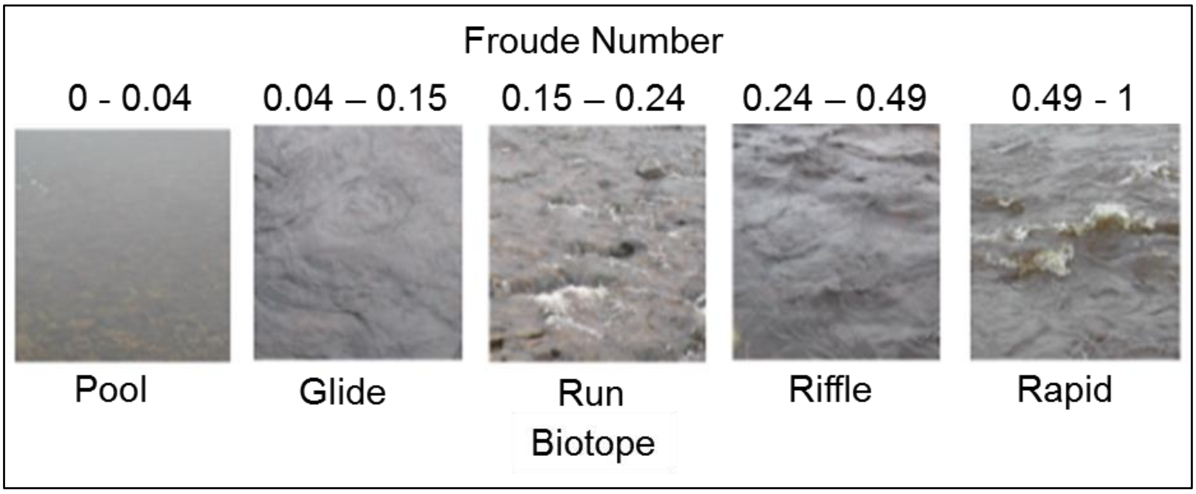
[2] Briaud, J.L. (2008). Case Histories in Soil and Rock Erosion: Woodrow Wilson Bridge, Brazos River Meander, Normandy Cliffs, and New Orleans Levees. Journal of Geotechnical and Geoenvironmental Engineering, Volume 134 Issue 10.
[3] Newson, M.D., Harper, D.M., Padmore C.L., Kemp J.L. and Vogel, B. 1998. A cost-effective approach for linking habitats, flow types and species requirements. Aqua. Conserv: Mar. Freshwater Ecosystems 8, 431–446.
[4] Dodkins, I., Rippey B., Harrington, T.J. *et* al. (2005). Developing an optimal river typology for biological elements within the Water Framework Directive. Water Research 39: 3479-3486.
[5] Raven, Paul & P, Fox & Everard, Mark & H.T.H., Holmes & Dawson, F. (1997). River Habitat Survey: a new system to classify rivers according to their habitat quality. Aquatic Conser6: Mar. Freshw. Ecosyst.. 8. 215-234.
[6] Newson, Malcolm & L. Newson, C. (2000). Geomorphology, ecology and river channel habitat: Mesoscale approaches to basin-scle chailenges. Progress in Physical Geography - PROG PHYS GEOG. 24. 95-17.
[7] Large, A. and Heritage, G. (2012) Ground based LiDAR and its Application to the Characterisation of Fluvial Forms, in Fluvial Remote Sensing for Science and Management (eds P. E. Carbonneau and H. Piégay), John Wiley & Sons, Ltd, Chichester, UK.

hydraulic habitat through the characterisation of flow into biotopes based on Froude number variation (Equation 4). Distinct biotope types have been associated with a characteristic range of Froude values (Figure 13).

$$\mathrm{Fr} = \frac{\mathrm{V}}{\sqrt{\mathrm{gd}}} \quad (4)$$

where V = local flow velocity (m/s), g = gravitational acceleration (9.81m/s^2) and d = local flow depth (m).

Figure 13. Biotope character and Froude number associations (after Large & Heritage 2013)[8]



Calculating the biotope distribution for a length of watercourse allows quantification of hydraulic habitat area, diversity and patchiness all of which are important aspects of defining hydromorphological and ecological quality, diversity and resilience. This has been achieved for the River Ver for both the baseline (existing) and restored state under summer flow conditions when habitat diversity is likely to be at its highest.

[8] Large, A. R. G. & Heritage, G. L. (2012), Ground based LiDAR and its application to the characterisation of fluvial forms, In Carbonneau, P.E. & Piégay, H. (eds), Fluvial Remote Sensing for River Science and Management. Wiley, p323-340.

MODEL RESULTS AND HYDROMORPHOLOGICAL ASSESSMENT

02

2. Model results and hydromorphological assessment

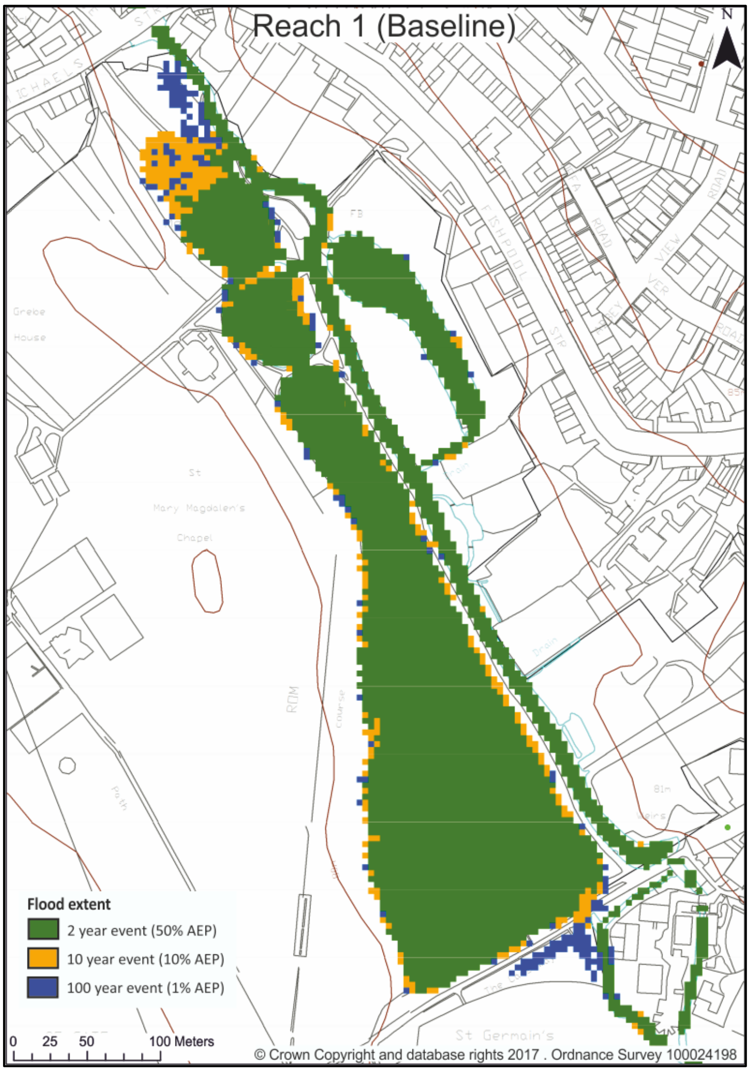
2.1 Baseline model results

Flood risk analysis

Reach 1

Model results indicated overbanking upstream of the lake inlet under the 2 year, 10 year and 100 year events, with flow overtopping the right bank and flowing towards the top lake (Figure 14). This overbanking also occurs under winter high flow conditions. There was good connectivity with the left floodplain lake feature at all flood flows. No properties are affected.

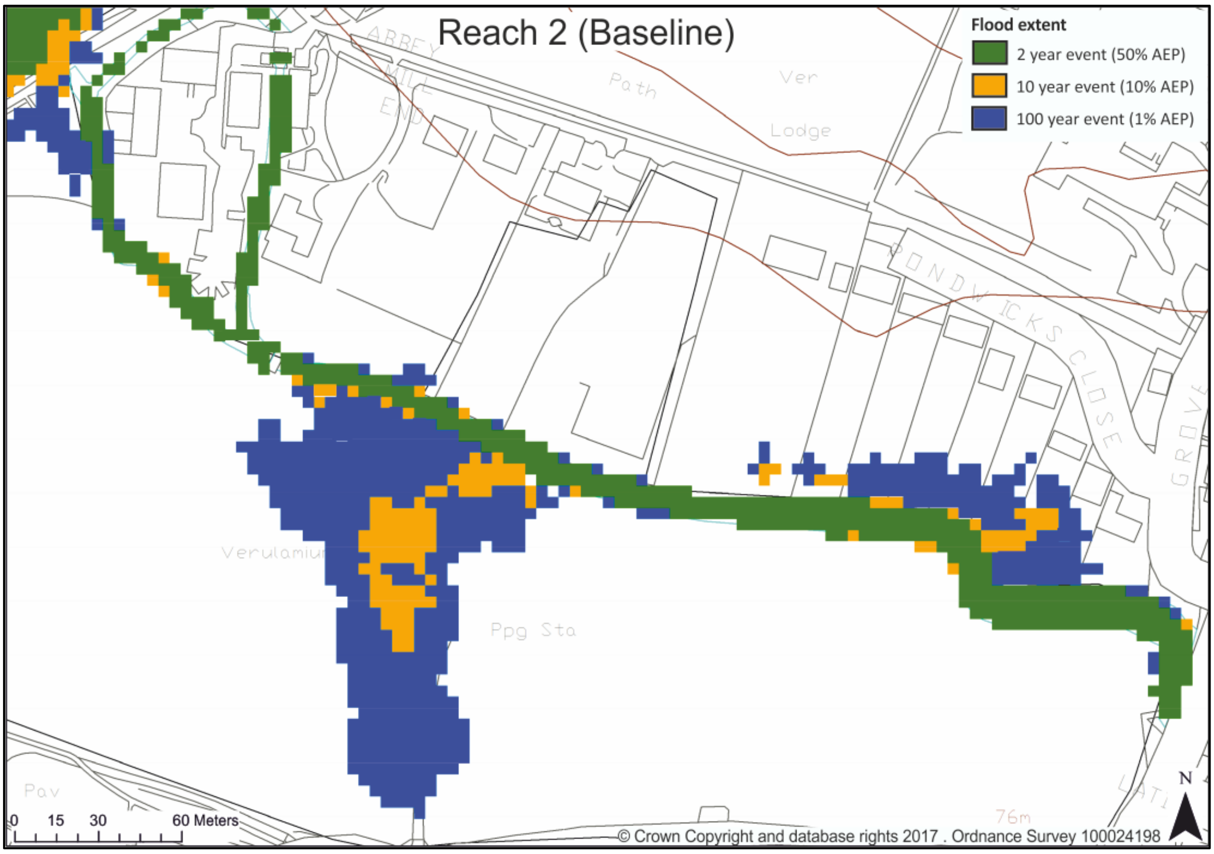
Figure 14. Baseline model results at Reach 1 for 2 year, 10 year and 100 year flood events (increased areas of yellow indicate increased flood extent at the 2 year RP flow and increase in blue area is related to increased flood extent at the 100 year RP flow)



Reach 2

For Reach 2 (Figure 15), results indicate flooding of the right bank floodplain between the river and the pumping station at the 10 year and 100 year flood events with water ponding in the natural topographic depression in this area. Depth of water was less than 0.15 m for a 10 year flood, and up to 0.5 m for a 100 year event. Flooding was not observed to impact the left bank downstream riparian landholders (gardens only) until the 10 year event, where flood depths of up to 0.2 m occurred.

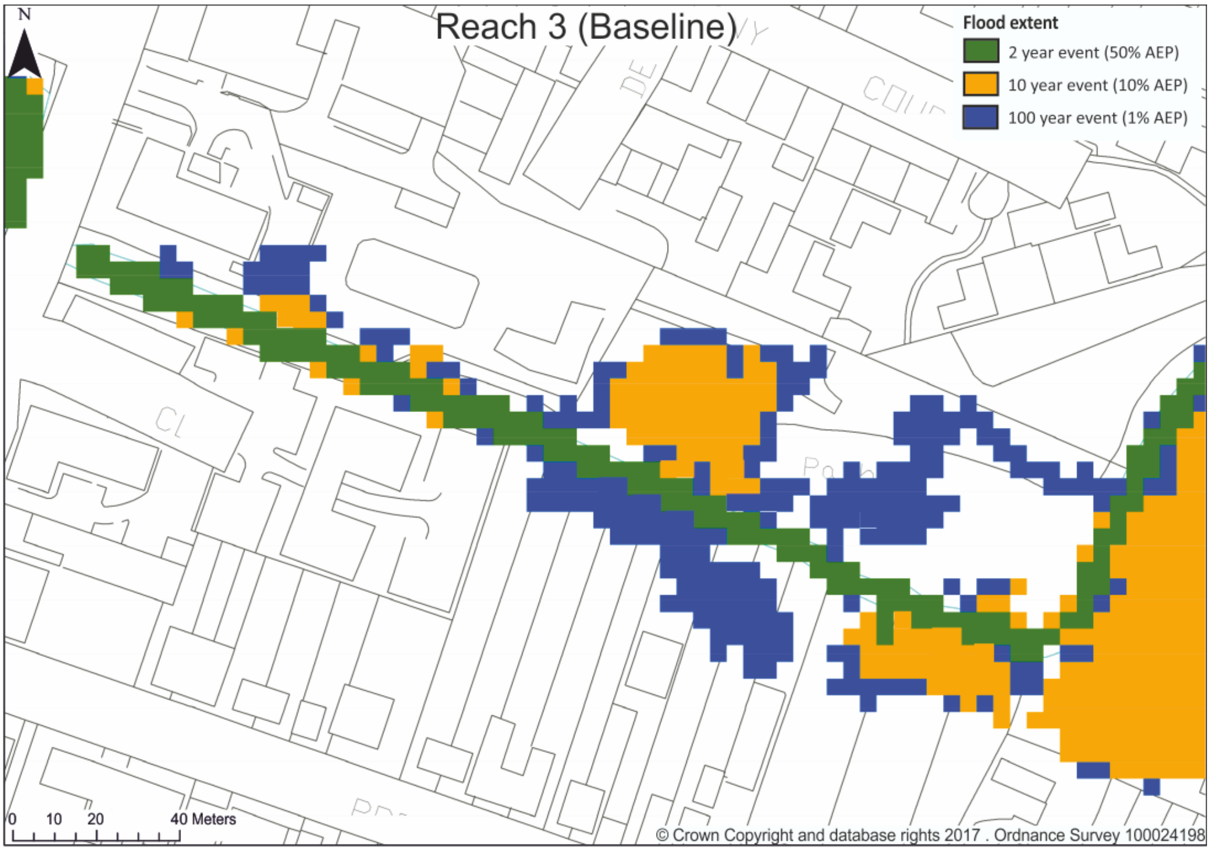
Figure 15. Baseline model results at Reach 2 for 2 year, 10 year and 100 year flood events (increased areas of yellow indicate increased flood extent at the 2 year RP flow and increase in blue area is related to increased flood extent at the 100 year RP flow)



Reach 3

For Reach 3 (Figure 16), model results indicated minimal flooding at the 2 year flood event. For the 10 year event there would be overbanking and ponding of water on the left bank floodplain with depths ranging from 0.2-0.4 m, and on the right bank at the downstream end before the river bends (depths up to 0.25 m). Under the 100 year event the extent of flooding increased across the right bank floodplain through riparian landholder gardens and in close proximity to residential housing. An alternative flow pathway was also activated in the left bank floodplain connecting Reaches 3 and 4.

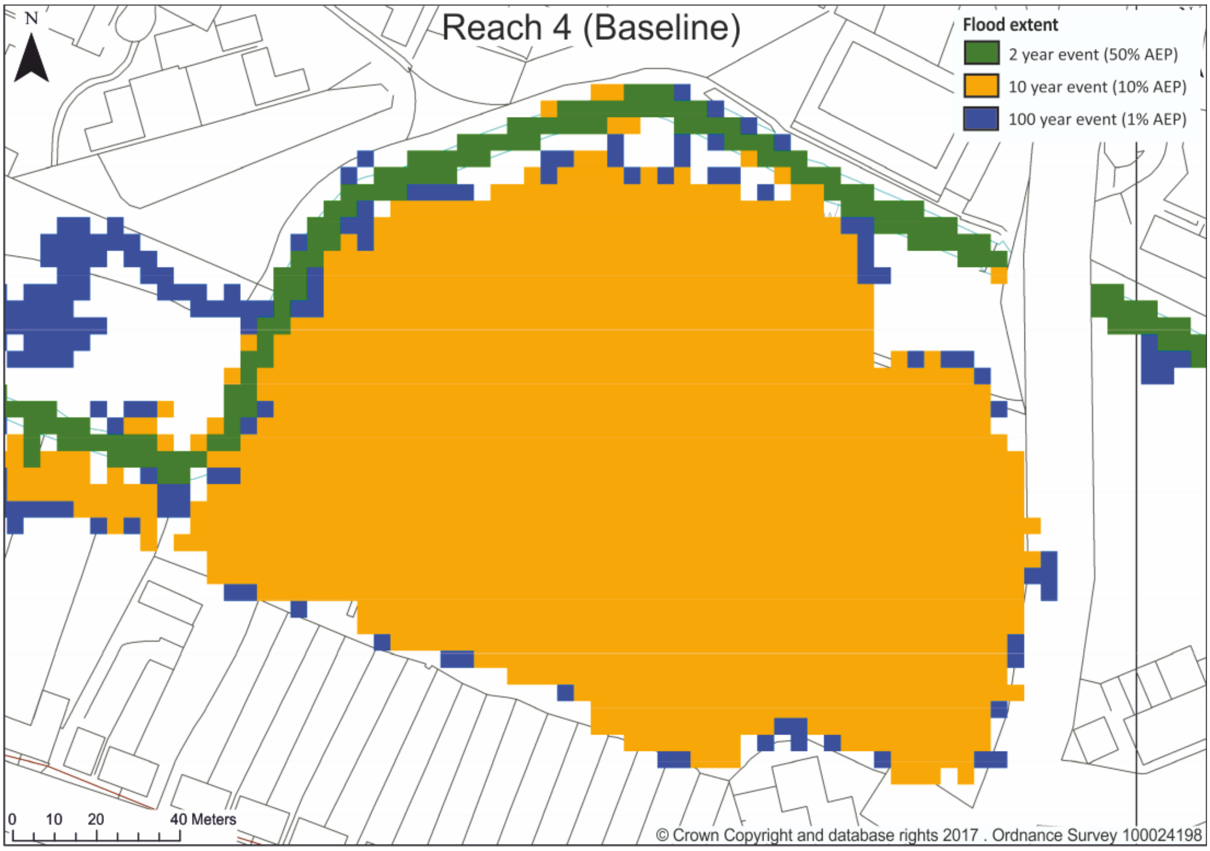
Figure 16. Baseline model results at Reach 3 for 2 year, 10 year and 100 year flood events (increased areas of yellow indicate increased flood extent at the 2 year RP flow and increase in blue area is related to increased flood extent at the 100 year RP flow)



Reach 4

For Reach 4 (Figure 17), model results indicated no overbanking for the 2 year event. However, for the 10 year and 100 year events the model indicated there would be extensive flooding across the right bank floodplain across the allotments with depths ranging from 0.2 m to over 1 m towards the south east corner of the allotments. Flooding extended almost up to the residential property in the south eastern corner of the floodplain.

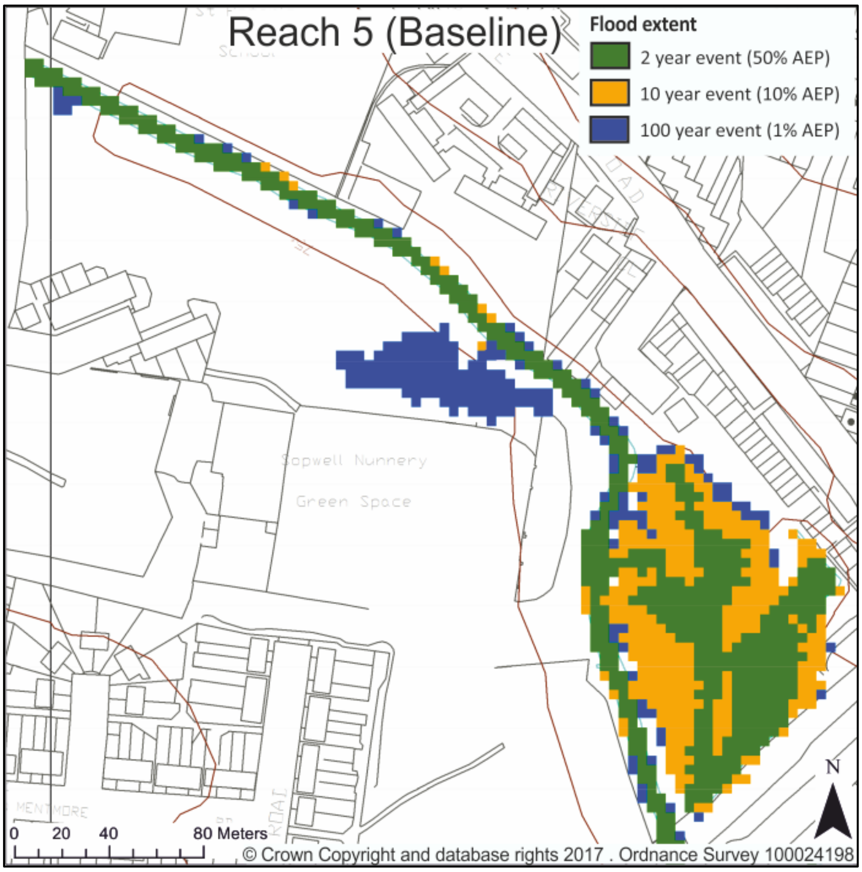
Figure 17. Baseline model results at Reach 4 for 2 year, 10 year and 100 year flood events (increased areas of yellow indicate increased flood extent at the 2 year RP flow and increase in blue area is related to increased flood extent at the 100 year RP flow)



Reach 5

For Reach 5 (Figure 18), model results indicated flows would remain in channel for the 2 year event with river flows connecting to the Watercress Wildlife Site. Under the 10 year flood event, minor inundation of the riparian zone occurred and there were increased inflows into the wildlife site. Some inundation of the right bank floodplain occurred under the 100 year event with depths up to 0.3 m. Inundation extent under all flood flows is close to, but does not flood, the private gardens at the back of the Watercress Wildlife Site.

Figure 18. Baseline model results at Reach 5 for 2 year, 10 year and 100 year flood events (increased areas of yellow indicate increased flood extent at the 2 year RP flow and increase in blue area is related to increased flood extent at the 100 year RP flow)



Reach 6

For Reach 6 (Figure 19), model results indicated flows would remain in channel for the 2 year event. Minor overbanking was produced under the 10 year and 100 year flood events but was limited in extent and no overbank connection with the fishery was observed. No private property appeared to be affected.

Figure 19. Baseline model results at Reach 6 for 2 year, 10 year and 100 year flood events (increased areas of yellow indicate increased flood extent at the 2 year RP flow and increase in blue area is related to increased flood extent at the 100 year RP flow)

Flow dynamics

The average reach hydraulics under current baseline conditions are summarised in Table 2. As would be anticipated on a low gradient system, the Froude number reduces with increasing flow as flow depths increase more rapidly than velocity causing higher energy biotopes to transition into lower energy ones. Low flow hydraulic diversity decreases and a more uniform flow type dominates.

		Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6
Summer low flow (Q_{95})	**Flow depth (m)**	0.98	0.45	0.30	0.30	0.32	0.49
	Flow velocity (m/s)	0.01	0.15	0.20	0.19	0.20	0.12
	Froude number	0.01	0.18	0.23	0.19	0.22	0.12
Winter high flow (Q_{10})	**Flow depth (m)**	1.12	0.50	0.48	0.48	0.46	0.63
	Flow velocity (m/s)	0.12	0.30	0.46	0.44	0.56	0.42
	Froude	0.05	0.16	0.26	0.25	0.35	0.23
Bankfull flow (2 year flood)	**Flow depth (m)**	1.23	0.66	0.53	0.58	0.55	0.70
	Flow velocity (m/s)	0.14	0.33	0.51	0.50	0.62	0.48
	Froude	0.04	0.15	0.25	0.24	0.35	0.23
Extreme flood (100 year flood)	**Flow depth (m)**	1.27	1.07	0.85	0.88	0.90	1.06
	Flow velocity (m/s)	0.21	0.48	0.79	0.72	0.88	0.72

Table 2. Baseline average hydraulics for the River Ver restoration sub-reaches.

It should be noted that flow depths are often higher than anticipated for a chalk system due to impounding, and these structures also have an impact on flow velocities by reducing flow speeds and creating lower energy hydraulic habitat. This is exacerbated by historic channel widening and deepening when realignment has occurred and also where flow is split between various channels. In combination this leads to low Froude numbers throughout the study area with few high energy environments present.

Under current conditions river flow is split at multiple locations throughout Reach 1. Table 3 summarises the flow splits extracted from the revised baseline model. The median Q_{50} flow results are consistent with what was observed during the site visit. A constraint for the Reach 1 option is that flow to the mill leat must be maintained in any restoration scenario.

All flow values in m³/s	**Summer low flow (Q_{95})**	**Median flow (Q_{50})**	**Winter high flow (Q_{10})**
River Ver vefore the lake inlet	0.144	0.44	0.93
Lake inflow	0	0.008	0.08
Downstream structure in Reach 1	0.004	0.063	0.135
River Ver at the end of Reach 1	0.14	0.365	0.715
Fish pass	0.119 (86% of Reach 1 outflow)	0.265 (73% of Reach 1 outflow)	0.508 (71% of Reach 1 outflow)
Mill leat	0.021 (14% of Reach 1 outflow)	0.099 (27% of Reach 1 outflow)	0.205 (29% of Reach 1 outflow)

Table 3. Flow splits between the River Ver, mill leat and existing fish pass under baseline conditions

Shear stress and critical bed sediment size

A review of the hydraulic outputs from the modelling suggests that several of the reaches display summer shear stress values below the stated threshold of 1 N/m^2 to prevent excessive fine sediment build up and consolidation. Sub-reaches 1, 2, 4 and 6 are worst affected and are prone to high levels of sedimentation in the summer. Importantly, winter flow energy levels do not increase sufficiently in many of the summer problem areas to flush fines and in some sub-reaches, most notably reaches 1 and 2 this persists at bankfull flow (2 year flow) and above. This is unsurprising for Reach 1 given the impacts of the weir structures at the downstream end of the reach. Sedimentation and channel narrowing are thus ongoing issues for these sub-reaches. Table 4 summarises the shear stress model results (units as N/m^2).

Node label	**Q_{95}**	**Q_{10}**	**2 year flood**	**100 year flood**
Reach 1				
VER_09430	0.07	0.84	1.39	5.07
1.184A_d	0.02	0.37	0.6	1.21

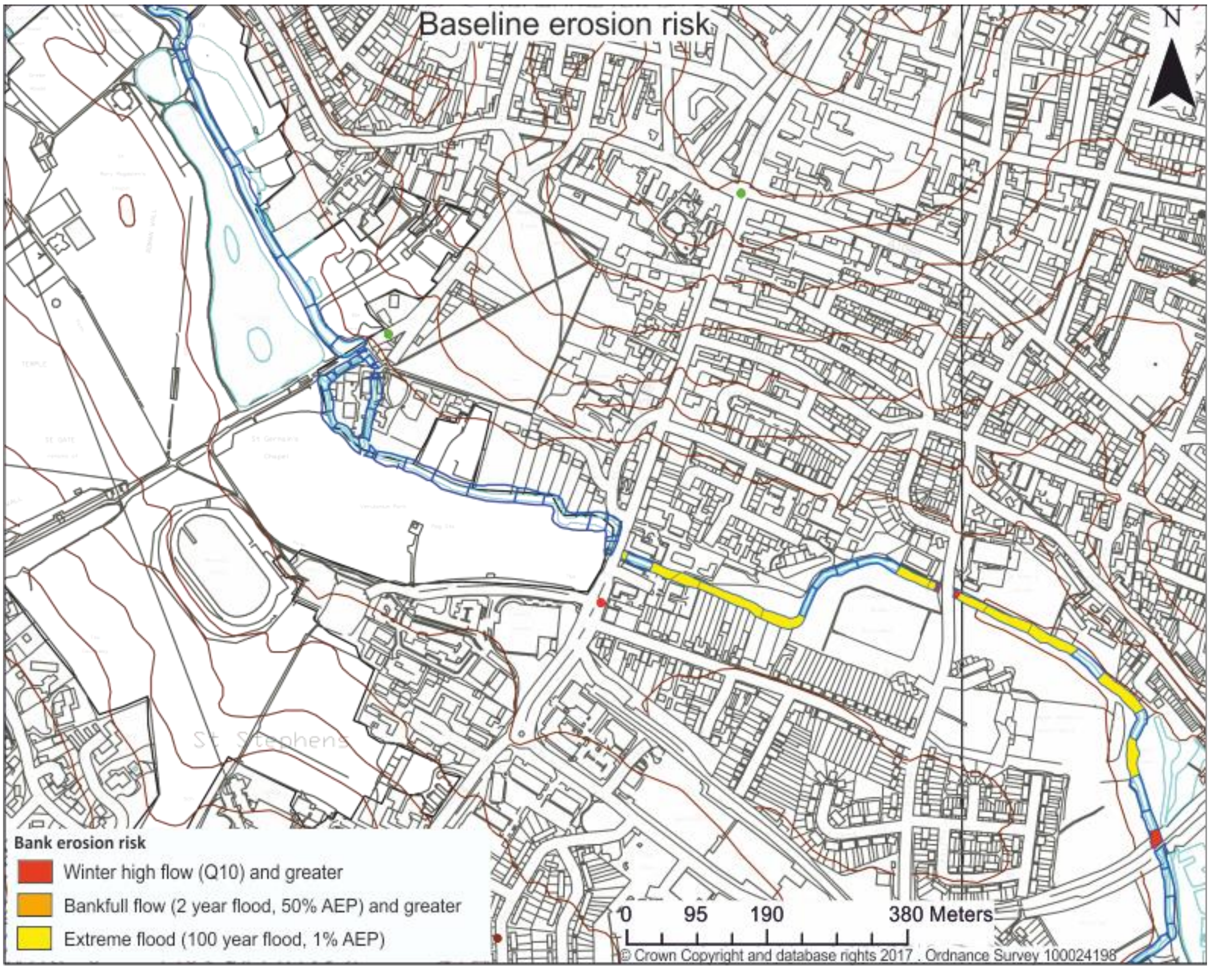
1.184A	0.02	0.33	0.44	0.72
VER_09292	0.02	0.25	0.33	0.56
VER_09185	0.01	0.08	0.11	0.2
1.182A	0.06	0.74	0.92	1.5
VER_09021	0	0.07	0.1	0.18
1.181A	0	0.05	0.07	0.13
VER_08882	0	0.02	0.02	0.04
VER_08842	0.01	0.15	0.19	0.33
Reach 2				
VER_08701	3.75	7.89	7.64	**9.66**
VER_08636	2.81	3.74	3.71	6.42
VER_08632d	3.35	5.85	5.35	**8.33**
1.149A	0.95	2.46	2.58	4.45
VER_08546	0.25	1.03	1.21	2.26
1.148A	0.53	1.66	1.85	3.27
VER_08429	0.07	0.38	0.45	0.74
1.147B	0.07	0.5	0.68	1.74
1.147A	0.02	0.15	0.21	0.69
VER_08287	0.1	0.5	0.6	1.15
1.146A	1.64	2.72	2.79	4.37
VER_08258	0.79	2.64	3.04	5.78
VER_08244	0.89	2.78	3.17	5.97
Reach 3				
VER_08244d	0.97	3.2	3.79	7.67
VER_08227	1.94	5.03	5.74	**11.78**
VER_08223	3.07	5.69	6.1	**9.33**
1.142B	0.25	1.2	1.6	2.91
1.142A	1.46	3.53	4.4	**8.37**
VER_08118	3.09	7.69	9.37	**16.82**
1.141A	3.82	5.36	5.95	**14.34**
VER_07960	2.17	4.99	6.06	**18.4**
Reach 4				
1.140B	2.44	5.24	5.97	7.61
1.140A	0.52	2.49	3.19	4.69
VER_07849	0.12	0.86	1.19	2.18
1.139A	0.35	2.13	2.89	4.54
VER_07743	0.84	3.82	5.15	**12.51**
VER_07734a	2	6.77	**9.03**	**16.99**
VER_07732	0.41	2.48	3.12	**8.36**
VER_07728	**9.81**	**13.76**	**13.86**	**22.35**
Reach 5				
VER_07728d	19.49	34.69	34.74	**50.32**
VER_07700	5.46	**12.52**	**15.51**	**20.06**
1.133A	3.01	5.91	6.43	**9.61**
VER_07593	1.92	5.46	6.65	**11.49**
1.132A	3.71	5.45	5.89	**11.3**

VER_07476	1.1	3.21	3.85	6.74
1.131A	1.86	4.92	5.96	**14.91**
VER_07364	0.1	0.76	1.06	4.19
1.130B	0.7	4.36	5.31	6.74
Reach 6				
1.130A	0.07	0.75	1.09	3.57
VER_07234	0.37	3.33	4.41	**9.86**
VER_07213	5.33	**8.92**	**8.59**	**10.78**
VER_07213d	5.33	**8.92**	**8.59**	**10.78**
VER_07180	1.01	3.01	3.76	**8.3**
1.127A	0.21	1.39	2	5.21
VER_07104	0.62	3.3	4.69	7.49
VER_07084	0.8	3.76	5.33	**12.7**

Table 4. Critical shear stress values (N/m^2) for fine sediment deposition (pink shading) and bank (bold) and berm (red) erosion for the current River Ver.

With regard to bed and bank erosion at no time is the critical threshold of 75 N/m^2 exceeded allowing berm erosion. This means that once consolidated berm features will persist as fixed features into the future. Some localised bank erosion may be possible during 2 year flood flows and above when the 8 N/m^2 threshold is exceeded but field observations by the project hydromorphologists (see main report) suggest that erosion issues are minor and localised (Figure 20).

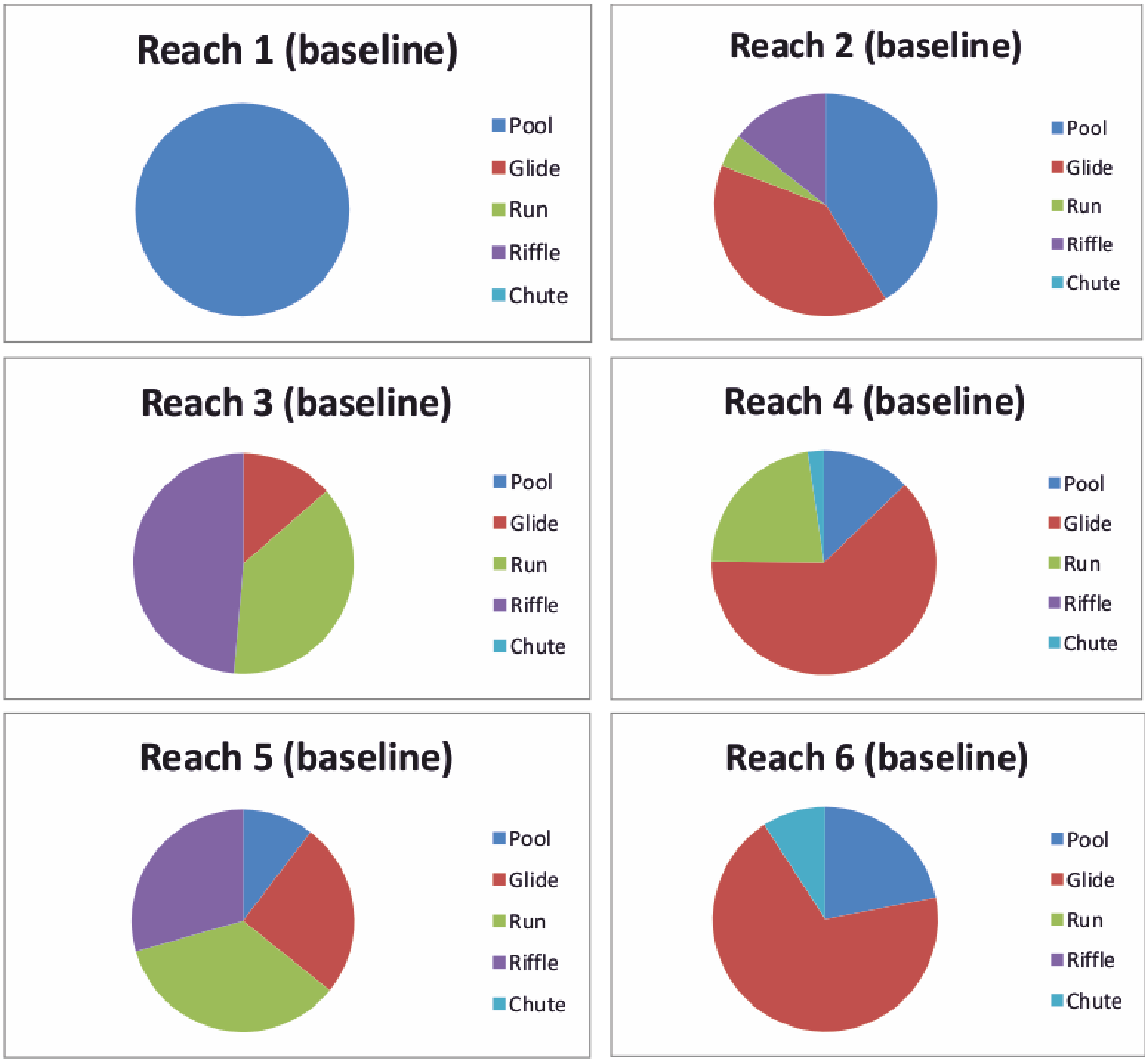
Figure 20. Bank erosion risk across the study area under baseline conditions



In-channel habitat assessment

As is detailed further below, the hydraulic habitat range and variety is currently poor, most notably for reaches 1, 2, 4 and 6 as is consistent with the propensity for these reaches to sediment. Pools and glides dominate over more energetic runs and riffles (Figure 21). Reach 3 and to a slightly lesser extent Reach 5 are showing signs of naturalisation with the channel morphology and consequent hydraulics displaying good diversity. Developing functional features in these reaches will be incorporated into the proposed restoration design.

Figure 21. Current in-channel habitats for the River Ver study area



2.2 Scenario model results

2.2.1 Reach 1 Option 7/8 hybrid

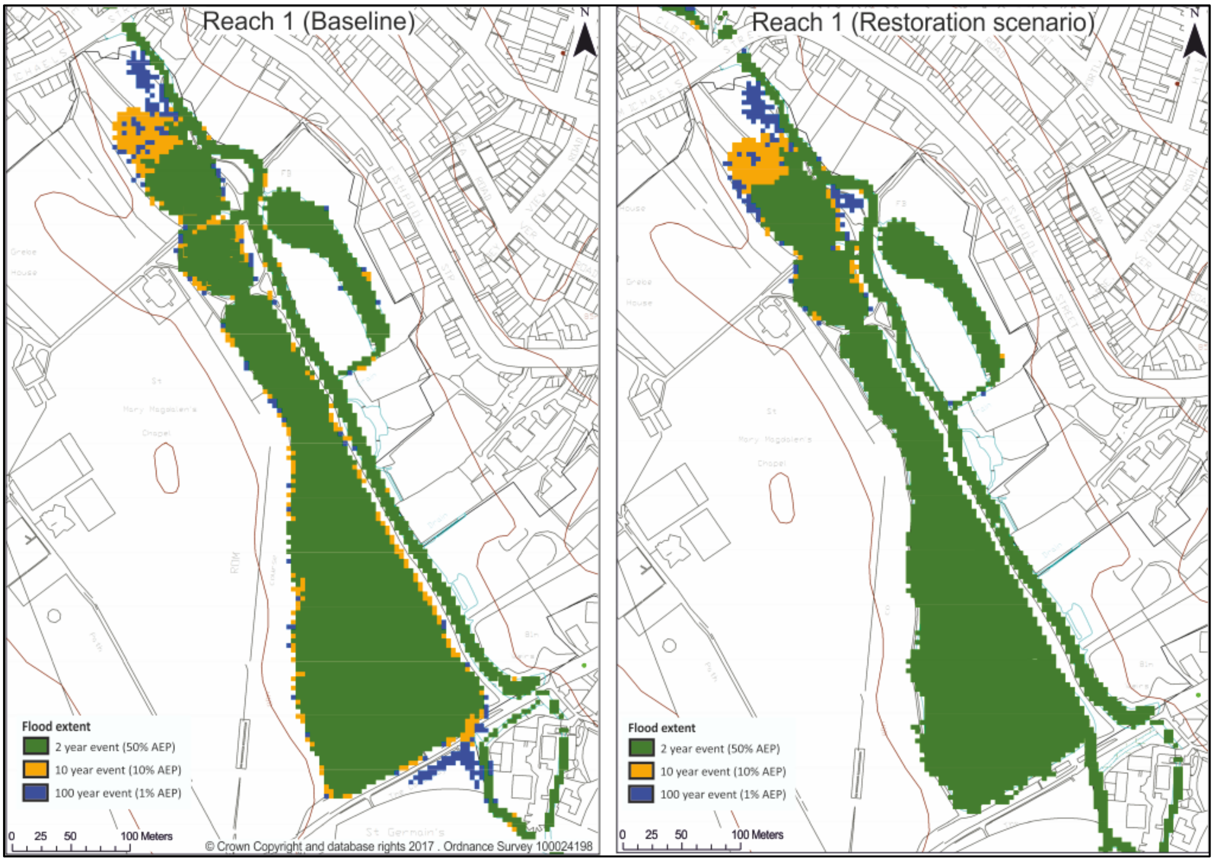
Flood risk analysis

Figure 22 illustrates that there would be a minor increase in local flood extent as a result of the proposed restoration scenario at the northern end of the top lake, with a slightly larger flood extent in the area between the River Ver and the top of the lake. As occurred under baseline conditions, the overbanking in this area was concentrated in the section immediately upstream of the meander before the lake inlet. Under the proposed restoration, the depth of overbanking flow increased from baseline conditions under winter high flows and flood flow conditions. This is a result of the narrowing undertaken to incorporate new morphological features. Embanking along the right bank could be investigated if this is undesireable relative to what already occurs under the baseline or a further inset floodplain section that may mitigate this affect under low order floods.

The proposed restoration would result in a reduction in extent for the 100 year flood event at the end of the fish pass in Reach 2 as flow is more effectively transferred downstream on account of the bypass channel created.

Based on water level results in the 1D model, the modelled flood flows are not expected to produce overbanking from the River Ver bypass towards Verulamium Lake given the flow volume is split between the bypass and the existing main channel.

Figure 22. Flood modelling results at Reach 1 under baseline and proposed restoration scenarios (increased areas of yellow indicate increased flood extent at the 2 year RP flow and increase in blue area is related to increased flood extent at the 100 year RP flow)



Flow dynamics

Table 5 summarises the average hydraulic conditions for Reach 1 under the proposed restoration scenario.

		Summer low flow (Q_{95})	Winter high flow (Q_{10})	Bankfull flow (2 year flood)	Extreme flood (100 year flood)
Main channel	**Flow depth (m)**	0.61 (0.98)	0.69 (1.12)	0.69 (1.23)	0.71 (1.27)
	Flow velocity (m/s)	0.07 (0.01)	0.08 (0.12)	0.19 (0.14)	0.23 (0.21)
	Froude	0.01 (0.01)	0.10 (0.05)	0.09 (0.04)	N/A
Bypass	**Flow depth (m)**	0.23	0.24	0.23	0.35
	Flow velocity (m/s)	0.34	0.37	0.75	0.78
	Froude	0.16	0.46	0.52	N/A

Table 5. Restored and baseline (bracketed) average hydraulics for Reach 1.

Average depth conditions are reduced as a result of incorporating the bypass channel, however velocities are increased slightly reflecting the influence of riffle features on concentrating flow energy. This then reflects on the reach average Froude number which is increased slightly as higher energy hydraulic habitats start to function. However, the reach is still influenced to a degree by the weir into the mill leat channel as a result of the constraint of having to retain flow into this channel. Therefore, hydraulic gains are limited by this. Flow velocities are higher across the riffle/rapid features through the bypass channel and will require larger material for stabilisation for extreme flow conditions.

The model results show wetting of the inset berm features under winter high flows but not under summer low flows which should help to concentrate flows in the main channel and help to mobilise fine sediments.

The creation of the bypass channel and decommissioning/blocking of the existing fish pass affected the flow dynamics through Reaches 1 and 2. Figures 23-25 illustrate the modelled flow splits extracted from the Reach 1 restoration model and compare these with the baseline model. Under the proposed design the existing fish pass was successfully blocked with all main channel flow exiting Reach 1 passing down the mill leat.

The proposed restoration ensured that approximately 70%, 82% and 76% of flow in Reach 1 at the top end of the Verulamium Lake travelled down the bypass under summer low flow, median flow and winter high flow conditions respectively. Under summer low flows, more water passed down the mill leat than under baseline conditions due to the blocking of the fish pass. For median and greater flows, flow down the mill leat was reduced by between 30 – 55% compared with baseline conditions. This will impact flow at the mill weir with some parts potentially drying. This is an inevitable consequence of splitting the flow.

To enable the flow split to be maintained into the mill leat channel downstream of the new bypass channel, significant riffle feature creation is required to maintain low flow water levels. Whilst narrowing of these features creates some hydraulic improvements, they are still influenced to a degree by this weir structure. The hydraulic gradient through this reach could only be improved through either reducing the mill leat weir height or removing/lessening the split flow into it. To ensure flow splits are maintained long term, it is recommended an engineered structure is constructed and/or larger bed material is incorporated into the main channel approach and inlet to the bypass channel due to the criticality of this level to maintain the desired flow split.

Figure 23. Summer low flow splits through Reach 1 under baseline and proposed restoration scenarios

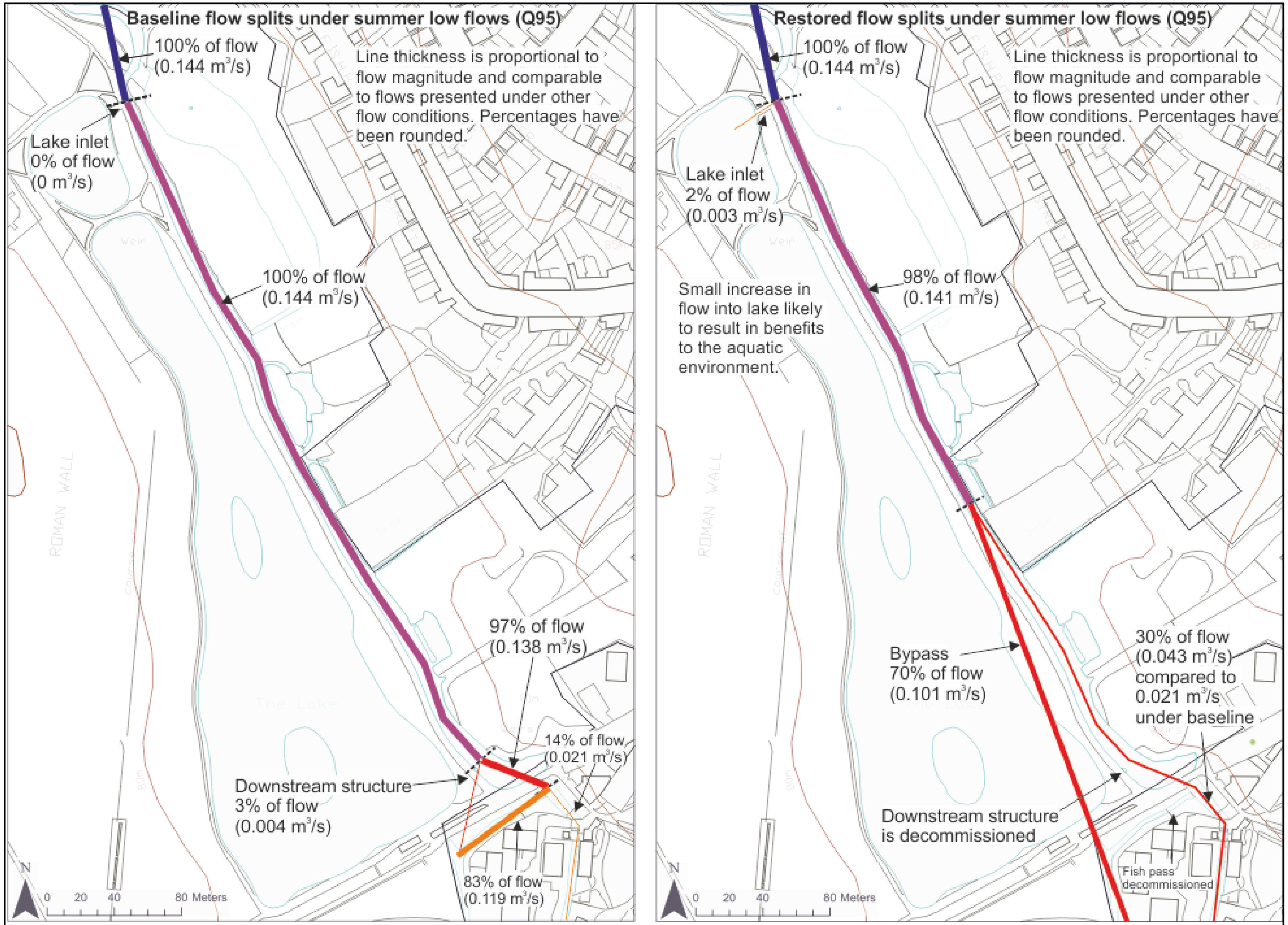


Figure 24. Median flow splits through Reach 1 under baseline and proposed restoration scenarios

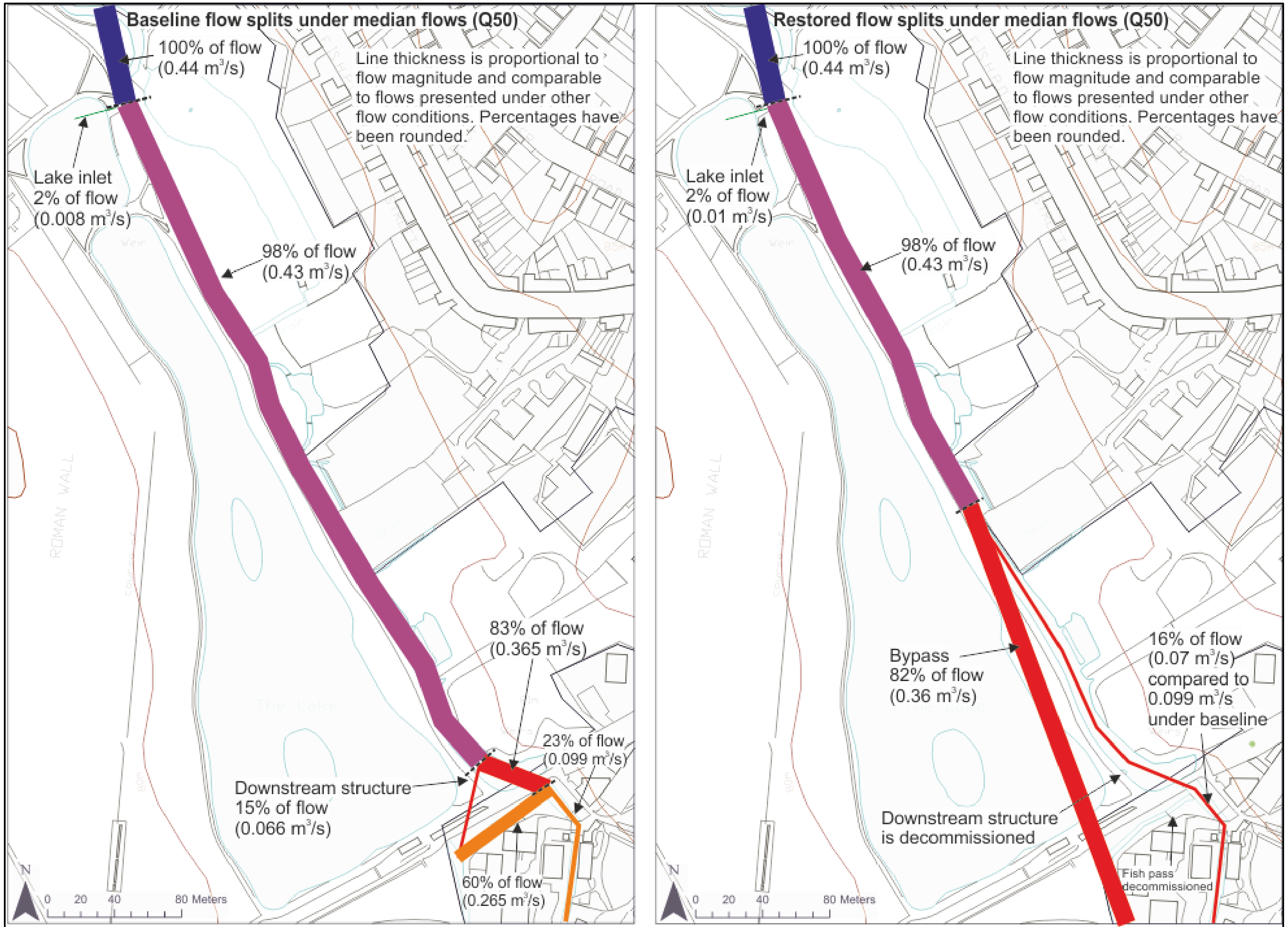
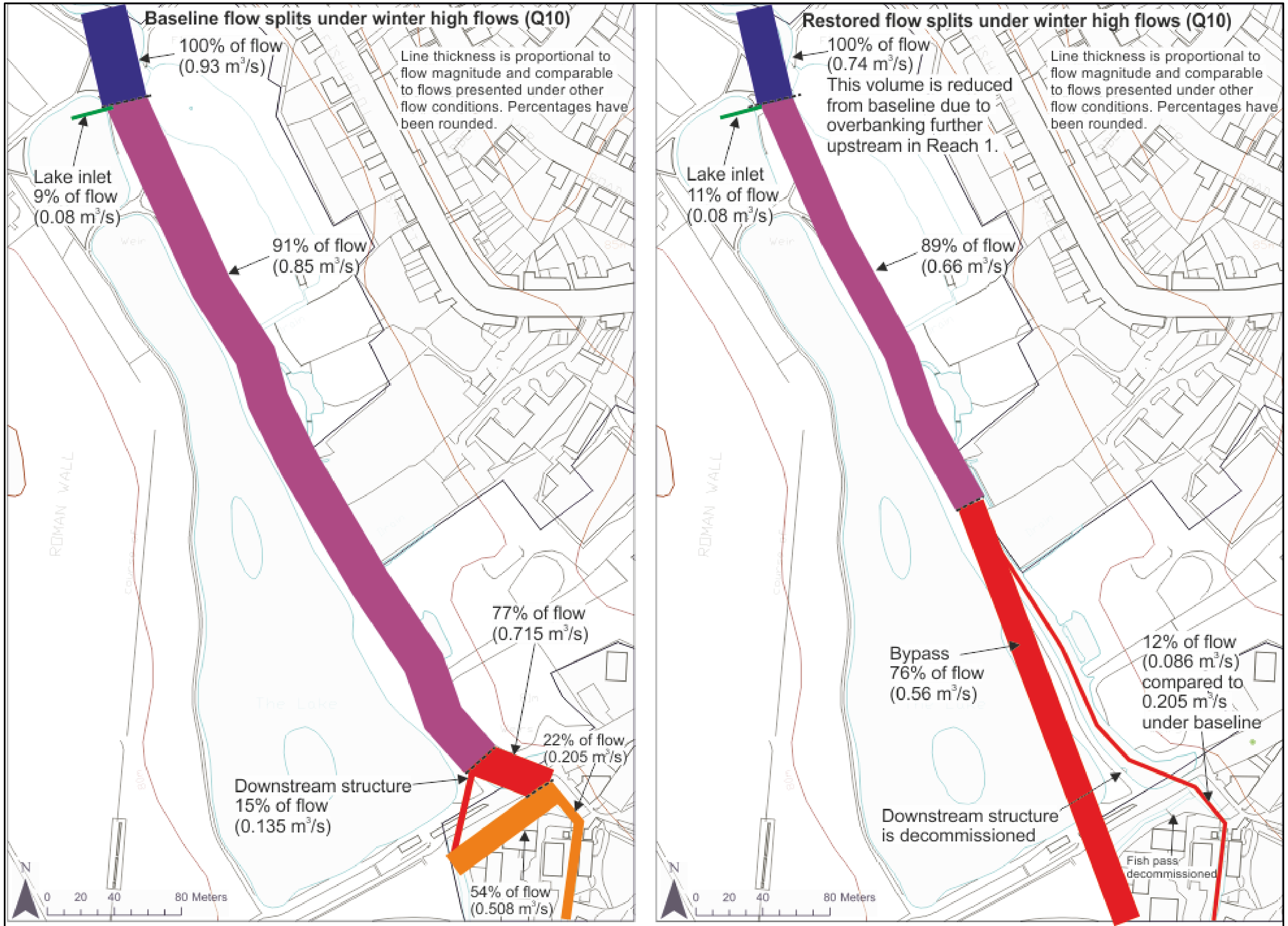


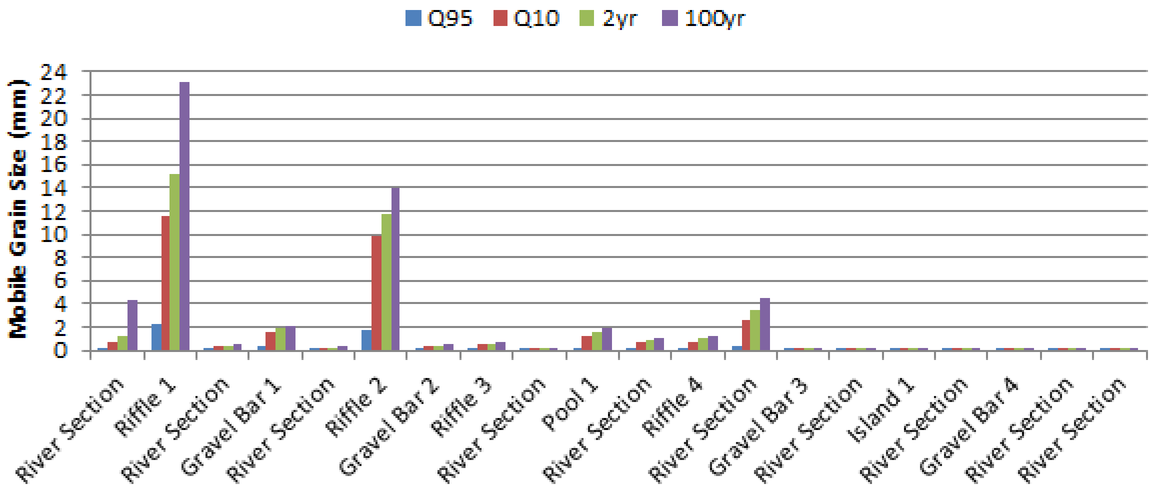
Figure 25. Winter high flow splits through Reach 1 under baseline and proposed restoration scenarios



Shear stress and critical bed sediment size

Figures 26 to 27 summarise the hydraulic results through Reach 1 under the proposed restoration scenario. These data are used to map sub-reaches susceptible to change following the suggested restoration (Figures 28 and 29). Following restoration the levels of energy (shear stress) available to prevent siltation, erode the banks and erode established in-channel features (berms) was also reviewed. Baseline conditions suggest that the current reach is strongly depositional. Whilst habitat creation will see increased diversity, there would be a lack of available gradient on the reach, particularly upstream of the flow split. Riffles 1, 2, 5, 6, 7 and gravel bar 1 would function as intended, although there could be some minor bank erosion in bigger floods. Riffle 3 and 4 display a lower energy regime than needed and are therefore likely to silt up. Riffle 8, Gravel Bar 5 and Point Bar 1 are on the cusp of silting; however all three pools should operate correctly. As such the general hydraulic performance would be improved along this reach however some features look likely to deteriorate over time, and their design would need to be adjusted during detailed design (i.e. they would need to be narrowed).

Figure 26. Summary shear stress values and implications for sediment transport, erosion and deposition through Reach 1 main channel. Key shear stress thresholds of sedimentation (1 N/m^2) and bank erosion (8 N/m^2) are marked.



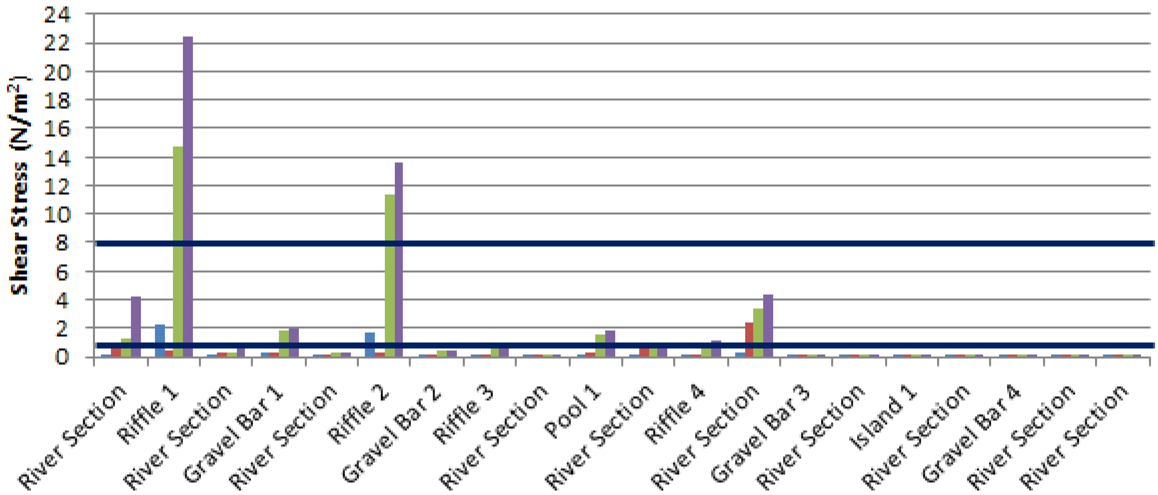


Figure 27. Summary shear stress values and implications for sediment transport, erosion and deposition through Reach 1 bypass channel. Key shear stress thresholds of sedimentation (1 N/m²) and bank erosion (8 N/m²) are marked.

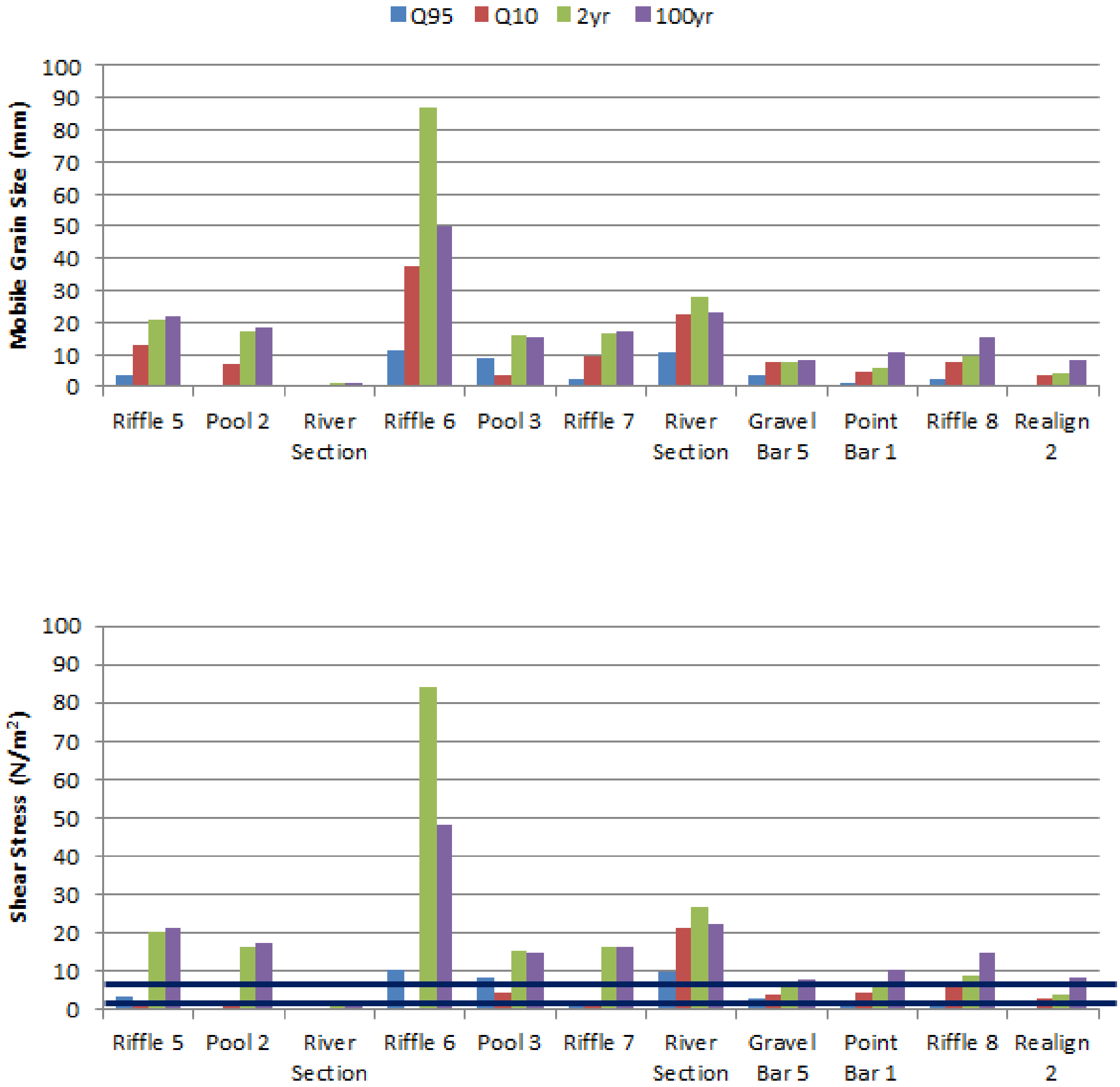


Figure 28. Bank erosion risk at Reach 1 under baseline and proposed restoration scenarios

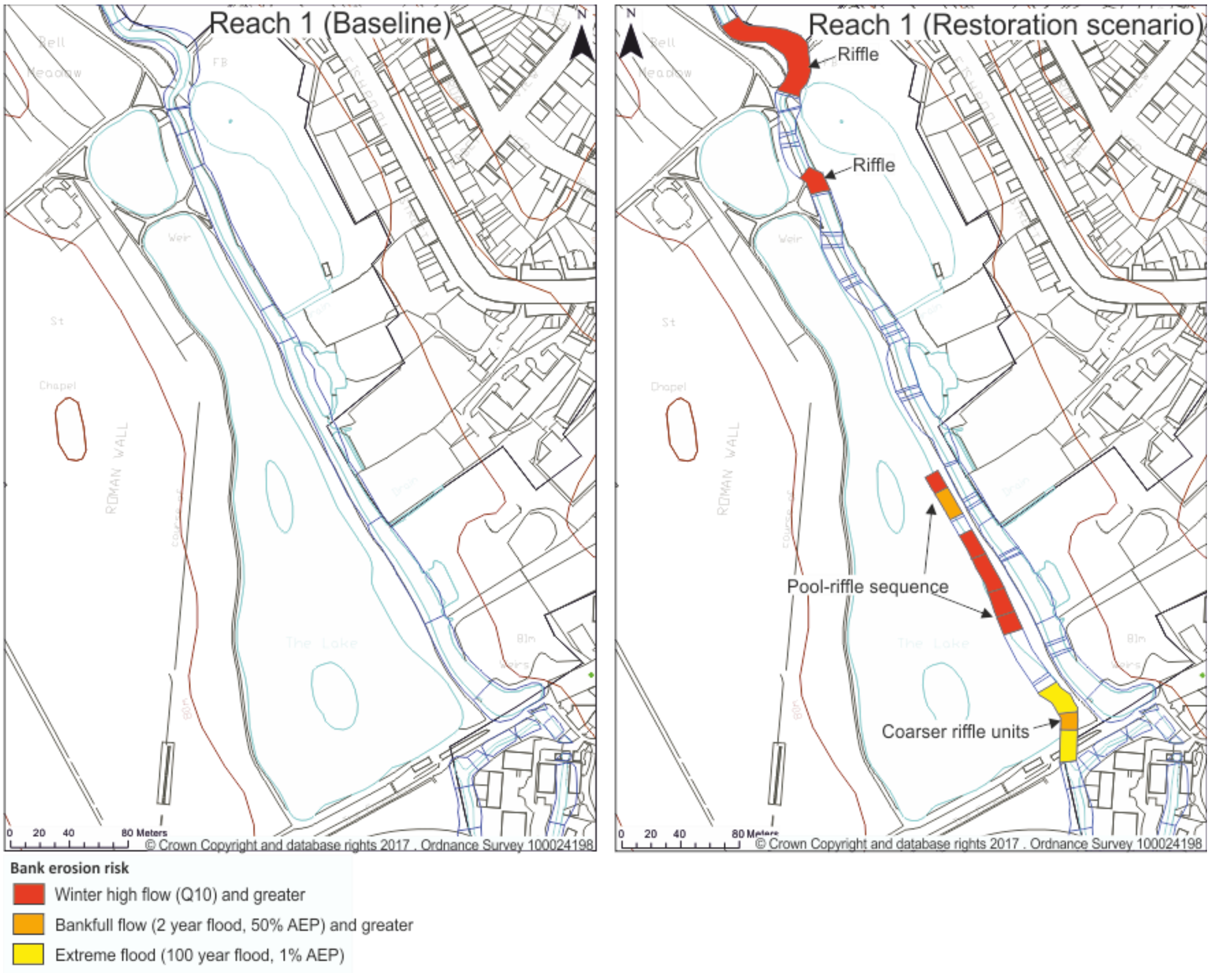
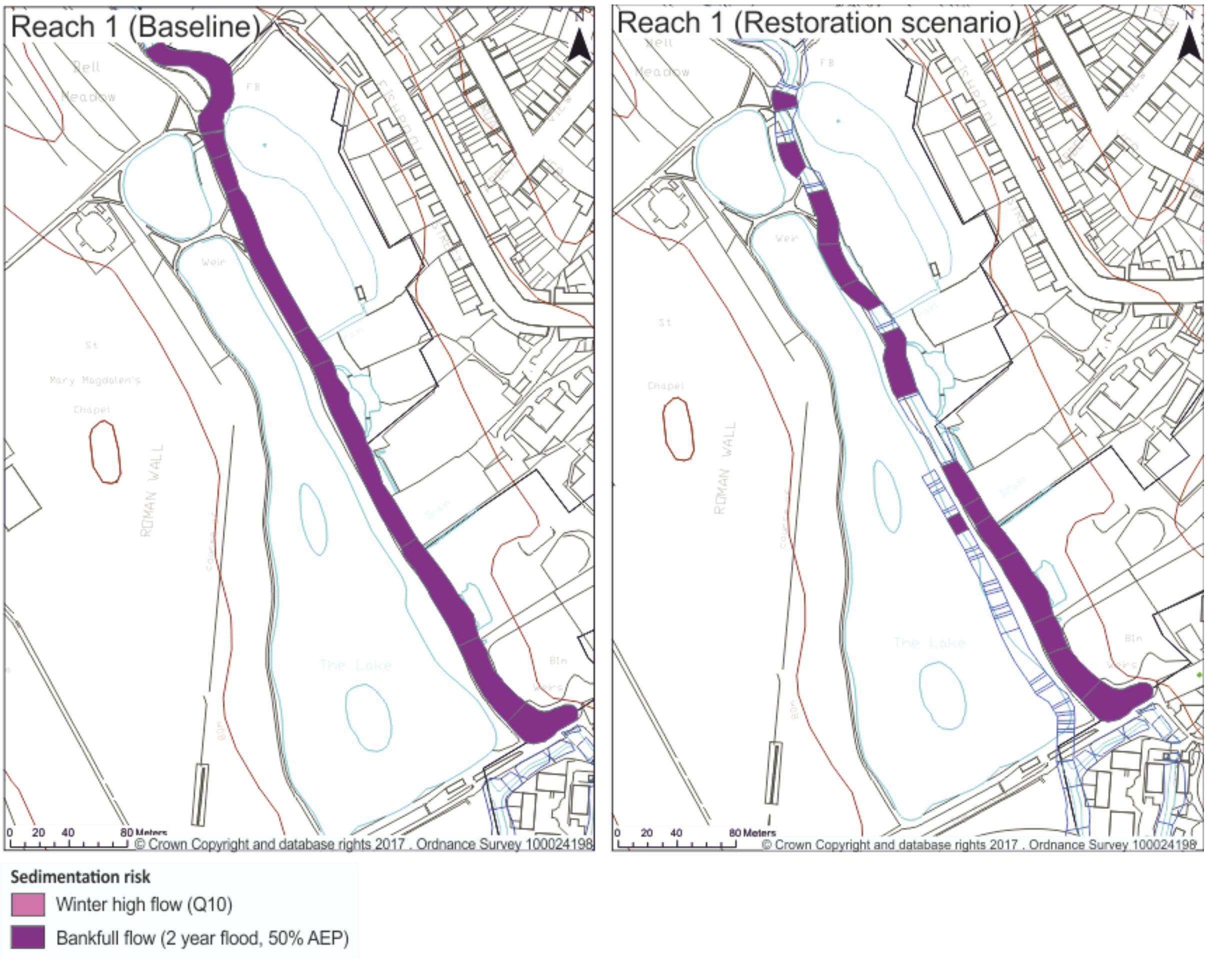


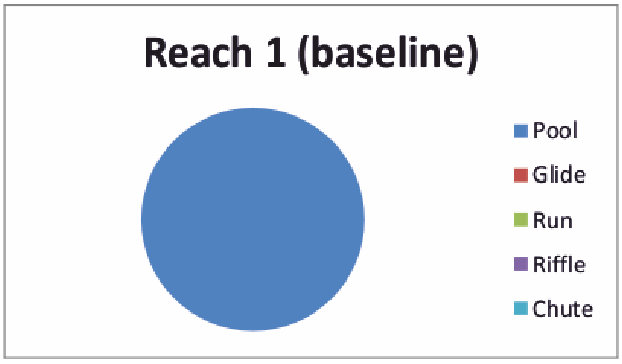
Figure 29. Sedimentation risk at Reach 1 under baseline and proposed restoration scenarios. Note: Model results also indicated low shear stress values under summer low flow conditions, however this is not likely to result in such widespread sedimentation given the low volume of flow and reduced sediment volumes being transported within the low flow channel. As such, only sedimentation risks associated with a winter high flow or bankfull flow have been identified.

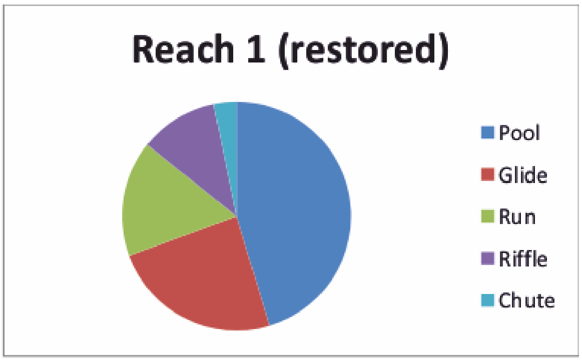


In-channel habitat assessment

Flow modelling of the new watercourse in Reach 1 has shown that under current conditions Reach 1 is highly degraded with only pool habitats present (Figure 30). The preferred option releases considerable gradient along part of the reach, and elsewhere the channel narrowing would allow created features to function well. The predicted new habitat distribution is shown in Figure 27. 55% of the reach would be transformed, with almost a quarter of the original Reach 1 habitat becoming low energy glide habitat and around a third improving to higher energy environments including runs and riffles. Pools make up the remaining habitat. The model shows that the steep nature of some of the lower riffles would create a small amount of chute habitat, not normally associated with chalk rivers. Although chute habitat is not necessarily in character, it would allow coarser substrate to remain stable and would oxygenate the water.

Figure 30. Current and restored in-channel habitats for Reach 1 on the River Ver





2.2.2 Reach 2 Option 3

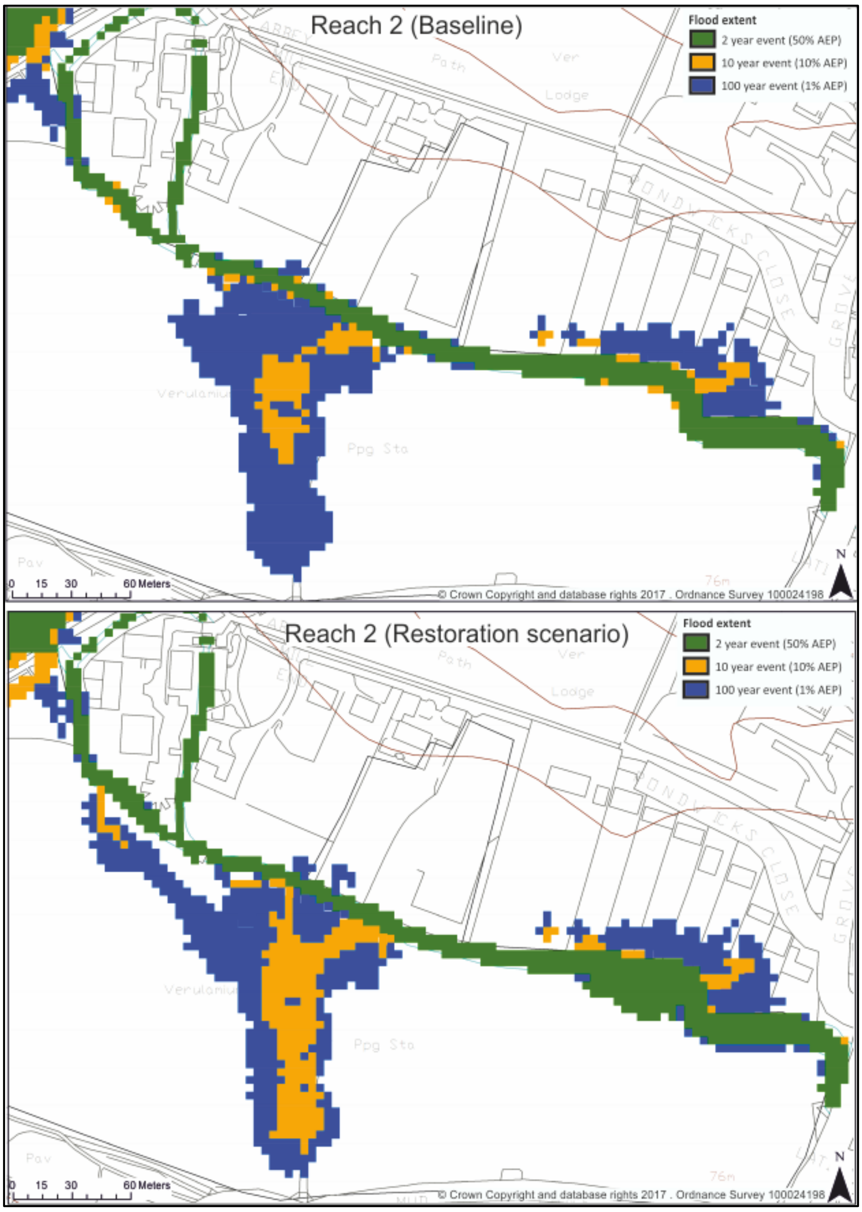
Flood risk analysis

Under baseline conditions, flooding did not occur in this reach until the 10 year flood event and occurs on the right bank floodplain in a natural topographic depression and at the downstream end at the left bank riparian properties.

The restoration design includes bank lowering for wetland creation, and model results indicated increased local flooding into the right bank floodplain under the 10 year and 100 year flood events (Figure 31). However inundation from the upstream right bank lowering would be restricted under the 10 year flood event, rather the majority of additional inundation would occur from overbanking downstream of the mill leat junction as a result of the influence of the in-channel features. Modelled water depths under the 10 year flood ranged from 0.05-0.2 m and were up to 0.5 m under the 100 year event.

Under the proposed restoration, there would be a minor increase in flood extent at the downstream left bank riparian properties (gardens only). A minor increase in flood extent was indicated under the 2 and 10 year flood events however modelled water depths were less than 0.01 m. For those areas that flooded under both baseline and restored scenarios, the modelled water depths did not increase under the restoration scenario. The inset floodplain at the downstream end of Reach 2 received flow at the 2 year event however, due to its size, it did not significantly reduce flood risk to the left bank riparian landholders. Additional inset features e.g. berms, a small embankment at the left riparian gardens or increased right bank lowering could be explored as part of the detailed design process.

Figure 31. Flood modelling results at Reach 2 under baseline and proposed restoration scenarios (increased areas of yellow indicate increased flood extent at the 2 year RP flow and increase in blue area is related to increased flood extent at the 100 year RP flow)



Flow dynamics

Table 6 summarises the average hydraulic conditions for Reach 2 under the proposed restoration scenario. Average depth conditions remain quite constant, however velocities are increased slightly reflecting the influence of riffle features on concentrating flow energy. This then reflects on the reach average Froude number which is increased slightly as higher energy hydraulic habitats start to function.

	Summer low flow (Q_{95})	Winter high flow (Q_{10})	Bankfull flow (2 year flood)	Extreme flood (100 year flood)
Flow depth (m)	0.40 (0.45)	0.67 (0.50)	0.70 (0.66)	1.12 (1.07)
Flow velocity (m/s)	0.20 (0.15)	0.35 (0.30)	0.38 (0.33)	0.52 (0.48)
Froude	0.14 (0.18)	0.17 (0.16)	0.19 (0.15)	

Table 6. Restored and baseline (bracketed) average hydraulics for Reach 2.

The proposed restoration design creates a connection into the wetland/wet woodland feature by lowering a small section of the right bank to approximately half its existing height. Model results indicated that under this design the open connection was not wetting up until the 10 year flood event, suggesting the channel is overwide upstream of the mill leat junction despite the inclusion of an in-channel bar here to narrow the channel cross-section. Further iteration of this design, potentially lowering the feature further, will be required to enable connectivity between the River Ver and the wet woodland at a range of flows.

The inset floodplain at the downstream end of the reach was functional at winter high flow (0.05 m depth) and flood conditions. It should be noted that this feature also aids in smoothing the transition into the next restoration reach downstream.

In terms of the in-channel features, the riffle-bar sequence after the mill leat junction effectively creates an area of low flow sinuosity. This is valuable as overall the planform sinuosity of this reach remains low and constrained by the Thames Water assets through the right bank floodplain. Large woody debris structures could be used as an alternative to gravel bar formation through Reach 2. These would be stabilised through partial burying into the bed and banks of the reach, which also provides for a more natural aesthetic.

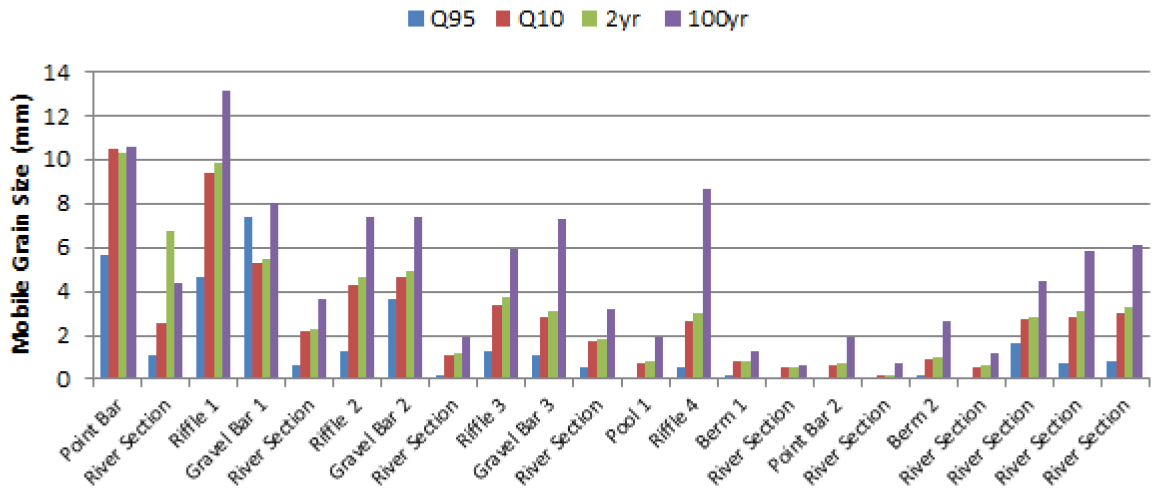
Shear stress influence on critical bed sediment size, erosion and deposition

As detailed above hydraulic conditions through Reach 2 become slightly more energetic. These averages do not, however, reflect local improvements to the watercourse caused by the restored features. Figure 32 shows the maximum sediment size that would be moved in the restored channel. No real transport is predicted in summer (Q_{95}) flows with winter flows flushing sand sized material and below (provided the silts and clays have not consolidated). Gravels of the order of 5 mm diameter and above will be mobile in the 2 year flood with occasional sections moving material up to 10 mm. These mobile sizes change little for more extreme floods. As such any introduced gravel is likely to remain stable but should not silt heavily. No gravels look likely to be supplied downstream as a result.

With regard to erosion and deposition Figure 32 shows that the 1 N/m^2 threshold for clay/silt mobilisation is reached for most sections during winter flows although several are on the cusp of being continuously sedimenting. These sections are likely to narrow naturally. Bank erosion (shear stresses > 8 N/m^2) is generally low risk with only a couple of sections exceeding this value during the 2 year flood and above. Erosion at these sections should be allowed to continue to provide variety in bankside habitat.

Following restoration the levels of energy (shear stress) available to prevent siltation, erode the banks and erode established in-channel features (berms) was also reviewed. Baseline conditions suggest a strongly depositional reach with the central section unable to flush deposited silt. This situation is improved upon through the introduction of new channel features with less chance of significant silt build up through the reach. All riffles should function normally and the introduced gravel bars will not generally silt up. Bank erosion may occur following bankfull floods at the upstream point bar and riffle, this will be localised and is a natural process that should be allowed to continue. New inset features will not be eroded. Figures 32 to 34 summarise the hydraulic results through Reach 2 under the proposed restoration scenario.

Figure 32. Summary shear stress values and implications for sediment transport, erosion and deposition through Reach 2. Key shear stress thresholds of sedimentation (1 N/m^2) and bank erosion (8 N/m^2) are marked.



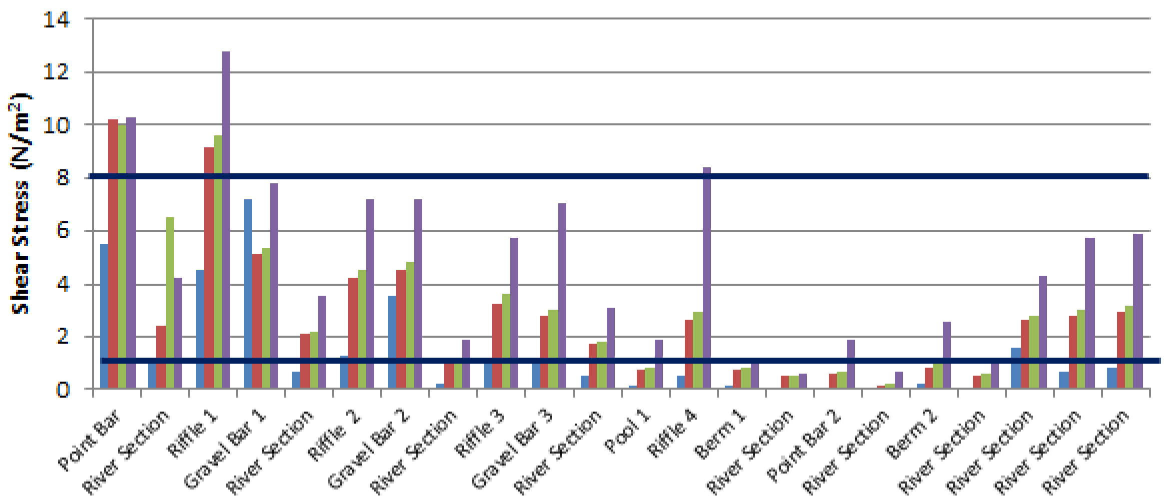


Figure 33. Bank erosion risk at Reach 2 under baseline and proposed restoration scenarios

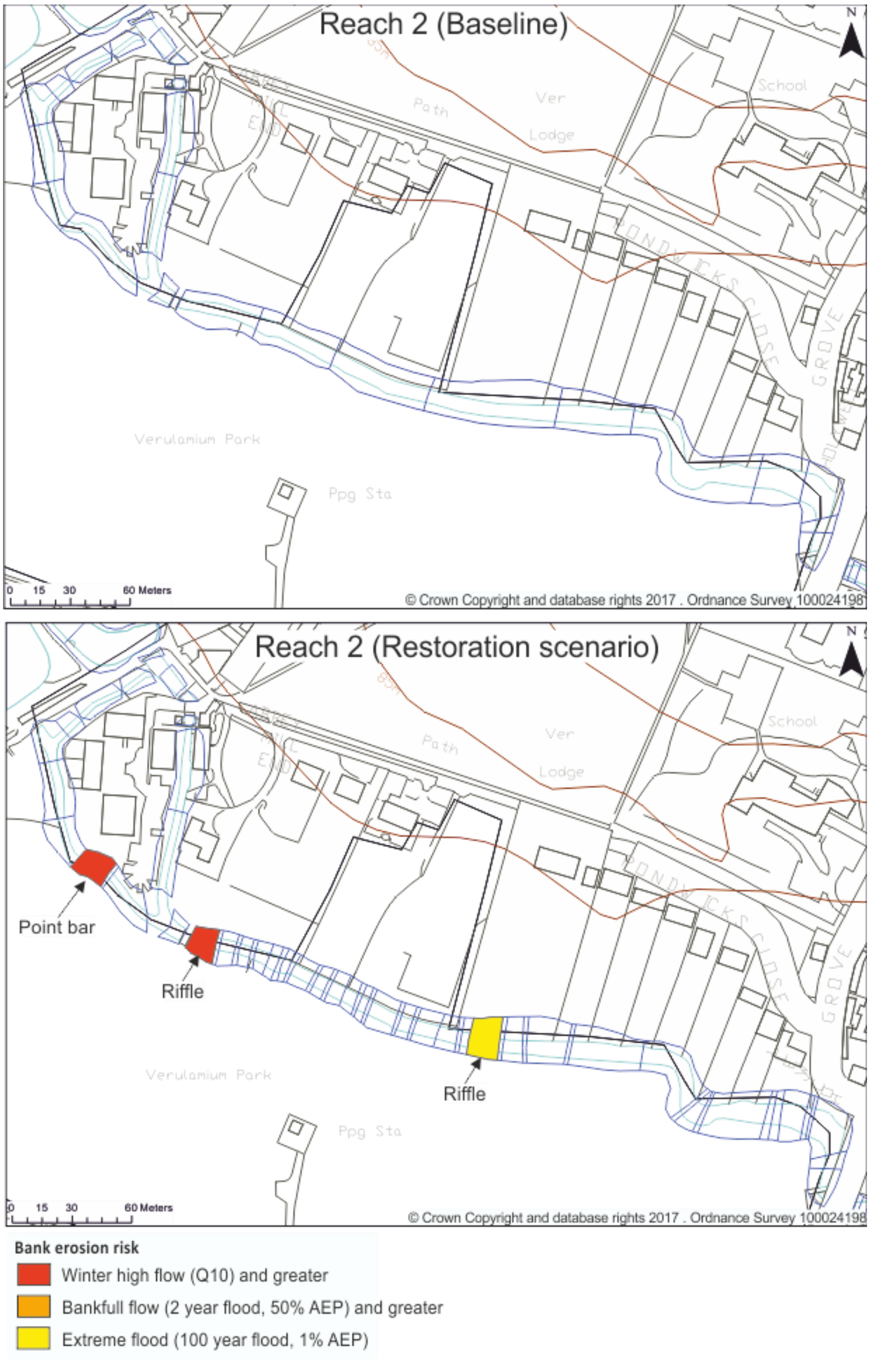
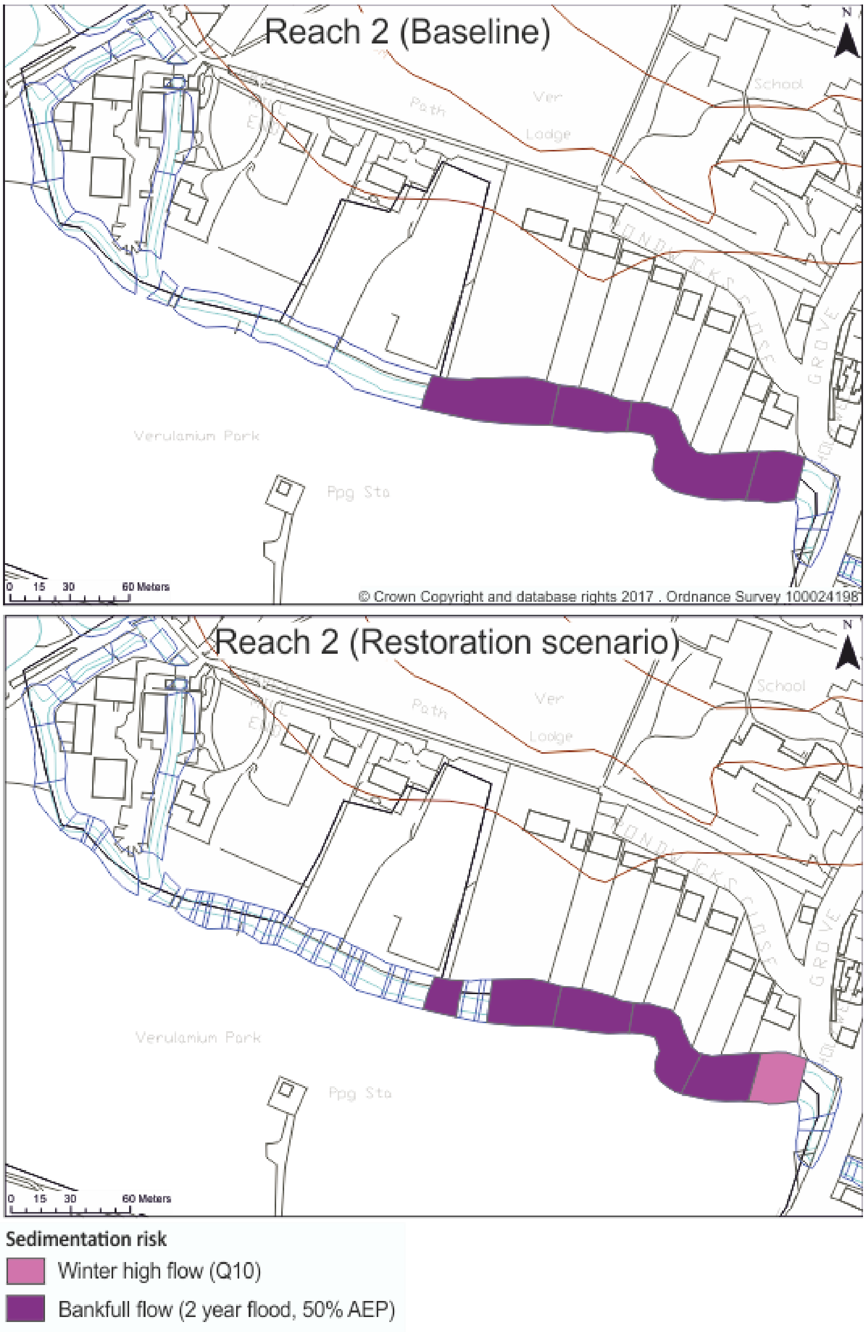


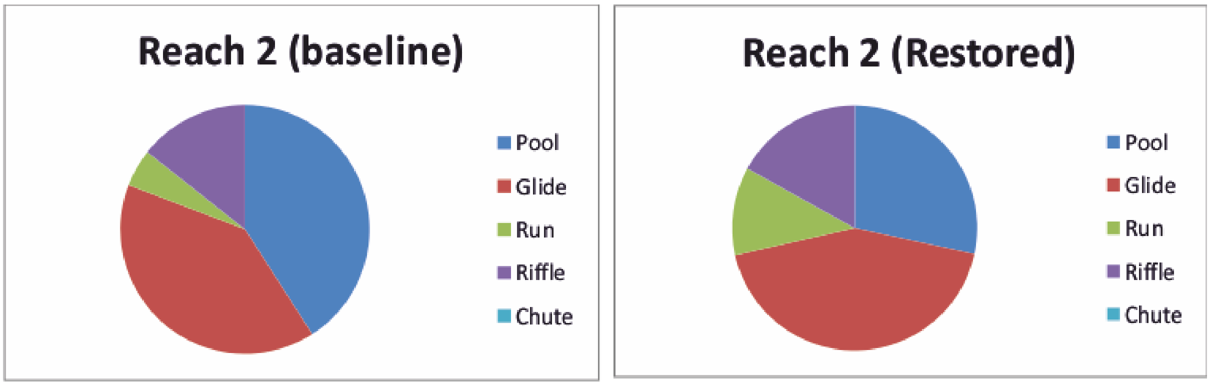
Figure 34. Sedimentation risk at Reach 2 under baseline and proposed restoration scenarios. Note: Model results also indicated low shear stress values under summer low flow conditions, however this is not likely to result in such widespread sedimentation given the low volume of flow and reduced sediment volumes being transported within the low flow channel. As such, only sedimentation risks associated with a winter high flow or bankfull flow have been identified.



In-channel habitat assessment

The baseline and restoration features were modelled across a range of flows ranging from summer low flow (Q_{95}), typical winter flow (Q_{10}), a bankfull flow (2 year return period) and an extreme flood (100 year return period). Figure 35 illustrates the change in hydraulic habitats predicted for the restored reach. The current low energy pool/glide dominated reach displays only poor habitat quality. This situation will be improved slightly following restoration with increased glide and run habitat created at the expense of pool areas. Riffle area will remain constant.

Figure 35. Current and restored in-channel habitats for Reach 2 on the River Ver



2.2.3 Reach 3 Option 4

Flood risk analysis

Model results indicated the inset riparian zone on the left bank created minor local flood extent increase on its north western edge under 2 year flood conditions compared with the baseline scenario, although depths were very shallow at <0.05 m (Figure 36). In areas inundated under both baseline and the restoration scenario, water depths were approximately 0.05 m deeper under the restored scenario for the 10 year and 100 year events. At the north eastern edge of the inset feature there was increased flood extent at the 10 year flood, with water depths up to 0.15 m in areas that were not inundated under the baseline scenario.

Results show that the restoration plan produced an increase in flood extent during winter high flow conditions (and larger flow events) over the right bank in the section before the bend into Reach 4. This area consists of private residential properties and the increase in flood extent and depth was restricted to gardens only. Depth of flooding during winter high flow conditions is <0.1 m, increasing to 0.15 m under the 2 year event and 0.25 m at the 10 year flood. The detailed design process could explore the creation of a raised flood bank on the right side of the channel to protect these properties or lowering of the immediate left bank.

Figure 36. Flood modelling results at Reach 3 under baseline and proposed restoration scenarios (increased areas of yellow indicate increased flood extent at the 2 year RP flow and increase in blue area is related to increased flood extent at the 100 year RP flow)

Flow dynamics

Table 7 summarises the average hydraulic conditions for Reach 3 under the proposed restoration scenario.

	Summer low flow (Q_{95})	Winter high flow (Q_{10})	Bankfull flow (2 year flood)	Extreme flood (100 year flood)
Flow depth (m)	0.27 (0.30)	0.50 (0.48)	0.57 (0.53)	0.84 (0.85)
Flow velocity (m/s)	0.37 (0.20)	0.58 (0.46)	0.64 (0.51)	0.86 (0.79)
Froude	0.25 (0.23)	0.30 (0.26)	0.37 (0.25)	

Table 7. Restored and baseline (bracketed) average hydraulics for Reach 3

Average depth conditions remain quite constant, however velocities are increased slightly reflecting the influence of restored riffle features on concentrating flow energy. This then reflects on the reach average Froude number which is increased slighty as higher energy hydraulic habitats start to appear.

The inset floodplain was functional at winter high flow with depths ranging from 0.05-0.1m.

Shear stress and critical bed sediment size

Following restoration the levels of energy (shear stress) available to prevent siltation, erode the banks and erode established in-channel features (berms) was also reviewed. Model results indicated there was no risk of sedimentation through Reach 3 under baseline or the proposed restoration scenario. Energy levels are particularly high along the lower section of Reach 3 and some bank erosion is predicted to have occurred. The banks here do show signs of some sediment loss. Under the restored scenario all riffles look to be functional with little chance of widespread silting. The point bars too look likely to function well and to exhibit some outer bank erosion during floods. This is desirable at these features maintaining a steep outer bank as a result. As would be expected pool features are lower energy and may accumulate some silt in the summer. This will be flushed in winter.

Bank erosion looks likely at several of the riffle and point bars features. This will not be excessive and should be seen as a positive aspect of the restoration maintaining important and rare clean bank habitat on the river.

Figures 37 and 38 summarise the hydraulic results through Reach 3 under the proposed restoration scenario.

Figure 37. Summary shear stress values and implications for sediment transport, erosion and deposition through Reach 3. Key shear stress thresholds of sedimentation (1 N/m^2) and bank erosion (8 N/m^2) are marked.

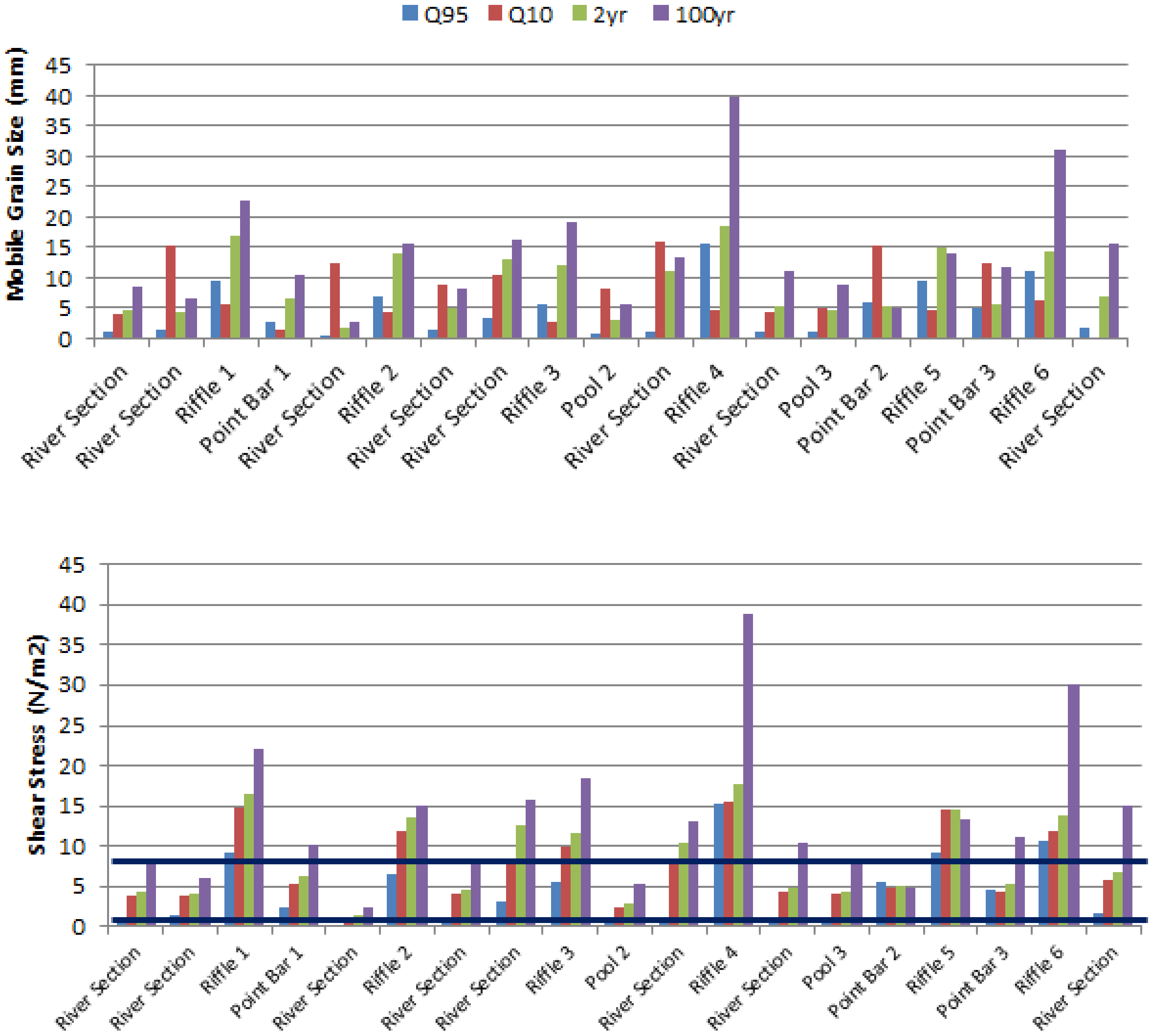
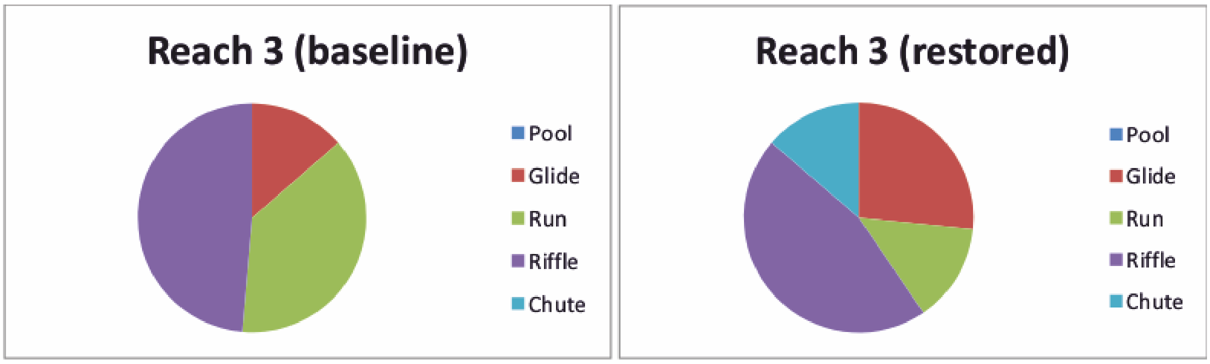


Figure 38. Bank erosion risk at Reach 3 under baseline and proposed restoration scenarios

In-channel habitat assessment

Figure 39 suggests that Reach 3 is presently in a recovering state with a high percentage and diversity of glide, run and riffle habitat and this is reflected on the ground in a more diverse channel. The proposed restoration measures further enhance this using the gradient through the reach to develop increased high energy flow areas that a lacking along the wider watercourse.

Figure 39. Current and restored in-channel habitats for Reach 3 on the River Ver



2.2.4 Reach 4 Option 1

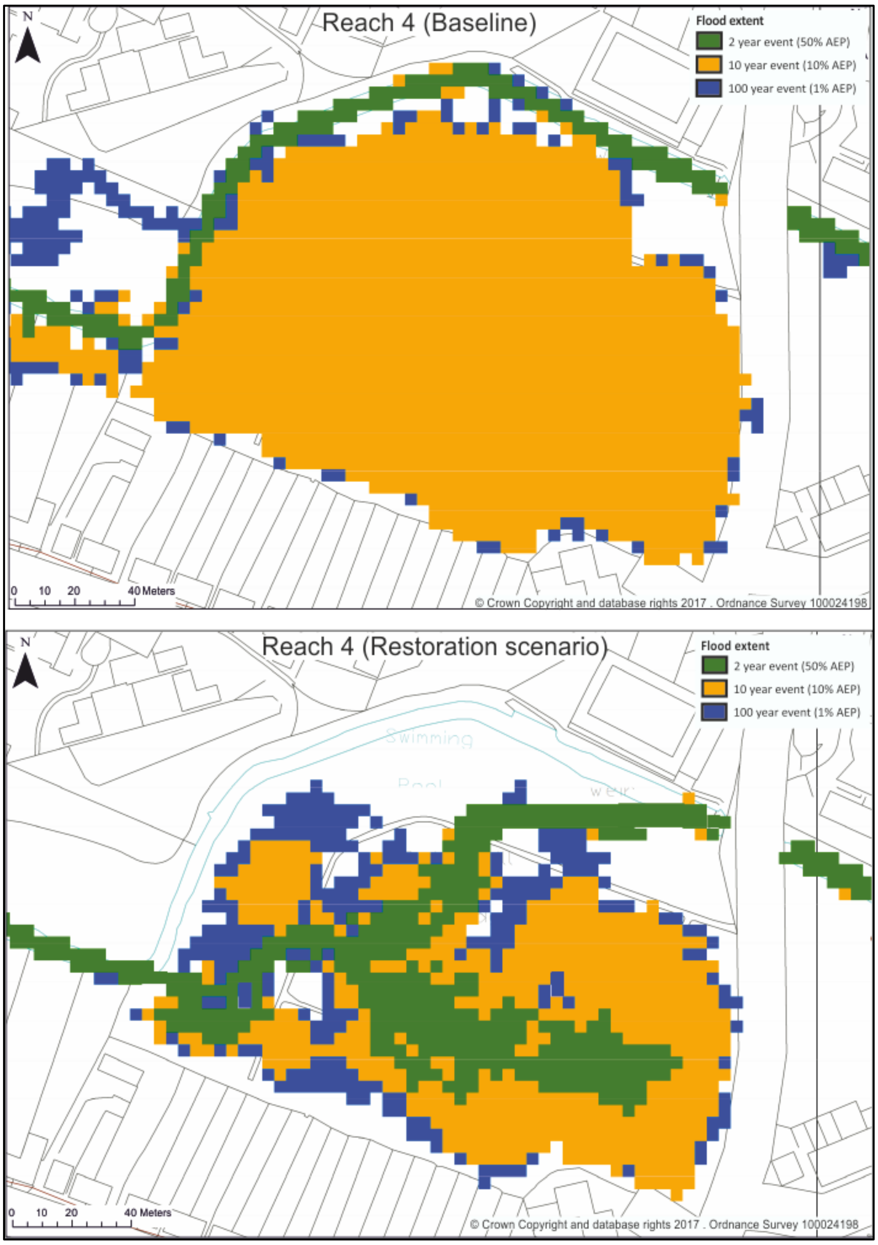
Flood risk analysis

The development of this restoration scenario involved iteration of right bank levels due to early model runs indicating significant inundation across the right bank floodplain. The undulating topography through Reach 4 means that if right bank height matches existing ground elevation between the first riffle and second pool then winter high flows will spill out across the floodplain. Some stretches of bank will need to be raised slightly above existing ground level from the start of the realigned channel to its mid-point in order to reduce flood extents. This should be investigated further during detailed design.

Under the current design, winter flows are contained within the realigned river channel and associated inset floodplain features. At the 2 year flood flow, overbanking occurs in several locations along the right bank and ponds across the floodplain with modelled water depths between 0.05-0.3 m, whereas no overbanking occurs in the baseline (Figure 40).

Under the 10 year flood, flood extent is reduced relative to the private property at the south eastern corner of the allotment area. Modelled water depths are up to half of the baseline model results in some locations on the floodplain, with restored scenario water depths up to 0.7 m compared with 1.1 m under the baseline. This is because of reduced ponding of water across the right bank floodplain as a result of realigning the channel through the allotments compared to baseline where, when water is out of bank, it is unable to return to the channel efficiently and therefore continues to fill and extents increase. It is also partly due to improved conveyance through the bridge downstream through bed lowering (this does not impact any flood risk to people or property downstream). Similar results were observed under the 100 year event.

Figure 40. Flood modelling results at Reach 4 under baseline and proposed restoration scenarios (increased areas of yellow indicate increased flood extent at the 2 year RP flow and increase in blue area is related to increased flood extent at the 100 year RP flow)



Flow dynamics

Table 8 summarises the average hydraulic conditions for Reach 4 (realigned channel only) under the proposed restoration scenario.

	Summer low flow (Q_{95})	Winter high flow (Q_{10})	Bankfull flow (2 year flood)	Extreme flood (100 year flood)
Flow depth (m)	0.45 (0.30)	0.76 (0.48)	0.83 (0.58)	1.25 (0.88)
Flow velocity (m/s)	0.28 (0.19)	0.34 (0.44)	0.38 (0.50)	0.51 (0.72)
Froude	0.19 (0.19)	0.16 (0.25)	0.20 (0.24)	

Table 8. Restored and baseline (bracketed) average hydraulics for Reach 4

Average depth conditions are increased under low flows as a result of relocating the channel to the valley bottom. Velocities are increased slightly under low flows but are slightly reduced for higher flows as a result of improved floodplain connectivity. Restored features remain functional with these changes.

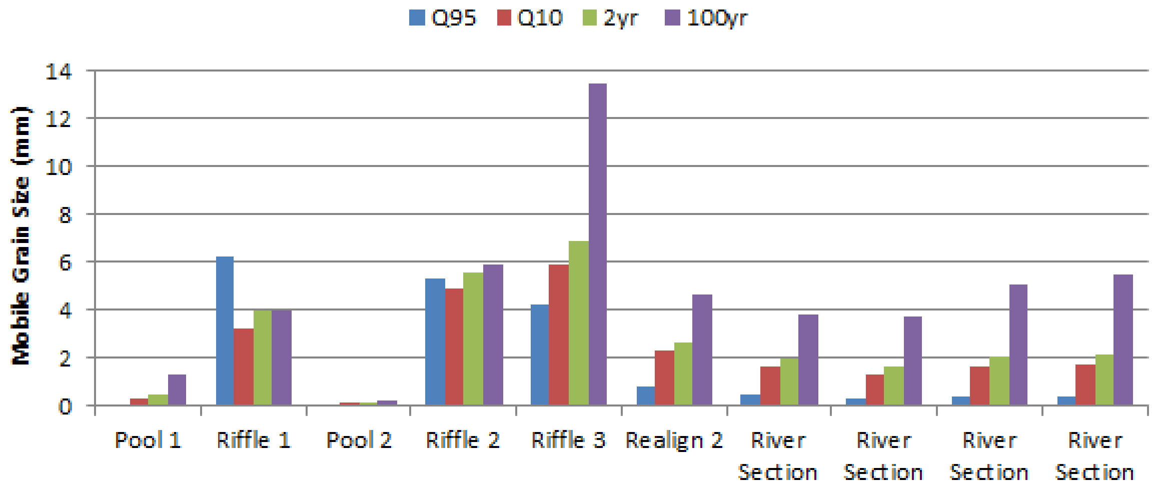
The inset floodplain features varied as to their wet and dry nature across the annual flow regime, with the left bank inset floodplain displaying good functionality from low to high annual flow conditions. While inundation was very shallow under low flow conditions, depths ranged from 0.15-0.35 m under median and high annual flows. The upstream right bank inset floodplain received inflows under median and high annual flow conditions with depths ranging from 0.05-0.2 m respectively, while the downstream inset floodplain only received flows during winter high flows (depths < 0.08 m).

Shear stress and critical bed sediment size

Following restoration the levels of energy (shear stress) available to prevent siltation, erode the banks and erode established in-channel features (berms) was also reviewed. The riffle units proposed look set to function well with no siltation anticipated. It would appear that these outline design features are having an impact on the rest of the reach with very low energy pools being created. These look to be strongly subject to siltation with little chance of winter or 2 year flow flushing. Silty pools are not necessarily a bad habitat to have in the reach but the overall energy balance through the reach could be improved by modifying the location and height of the proposed riffles at the detailed design stage, and/or modifying downstream connection levels.

Figures 41 to 43 summarise the hydraulic results through Reach 4 under the proposed restoration scenario.

Figure 41. Summary shear stress values and implications for sediment transport, erosion and deposition through Reach 4. Key shear stress thresholds of sedimentation (1 N/m^2) and bank erosion (8 N/m^2) are marked.



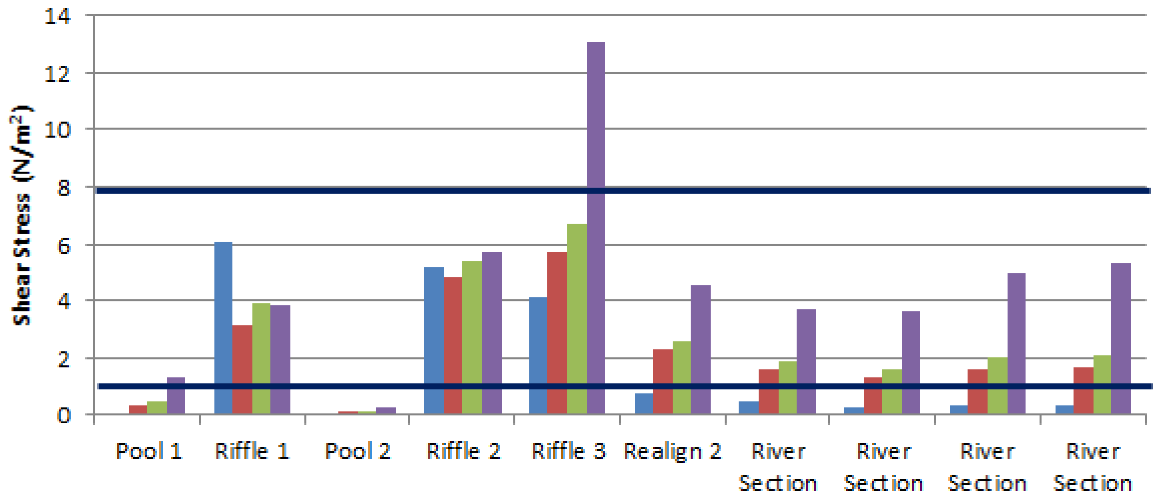


Figure 42. Bank erosion risk at Reach 4 under baseline and proposed restoration scenarios

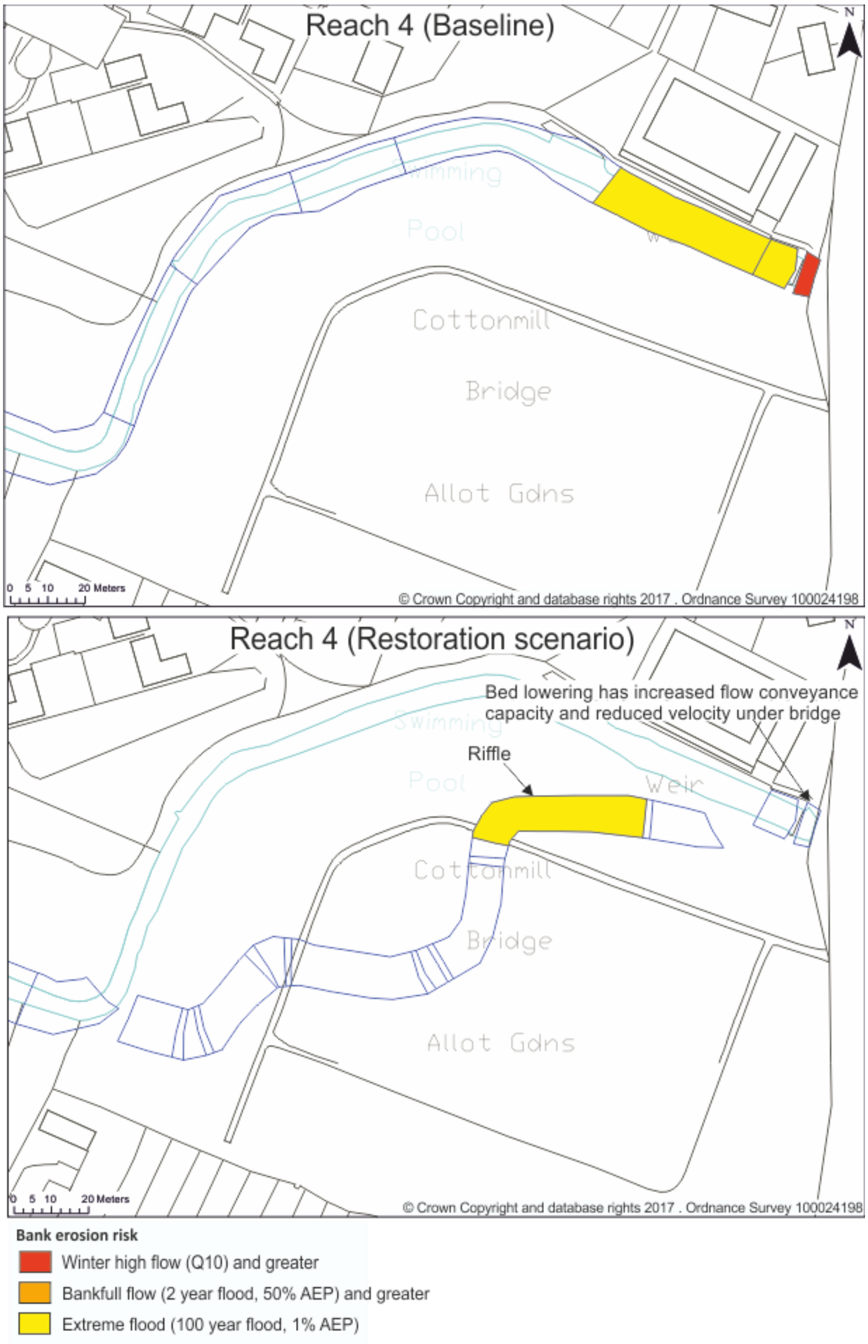
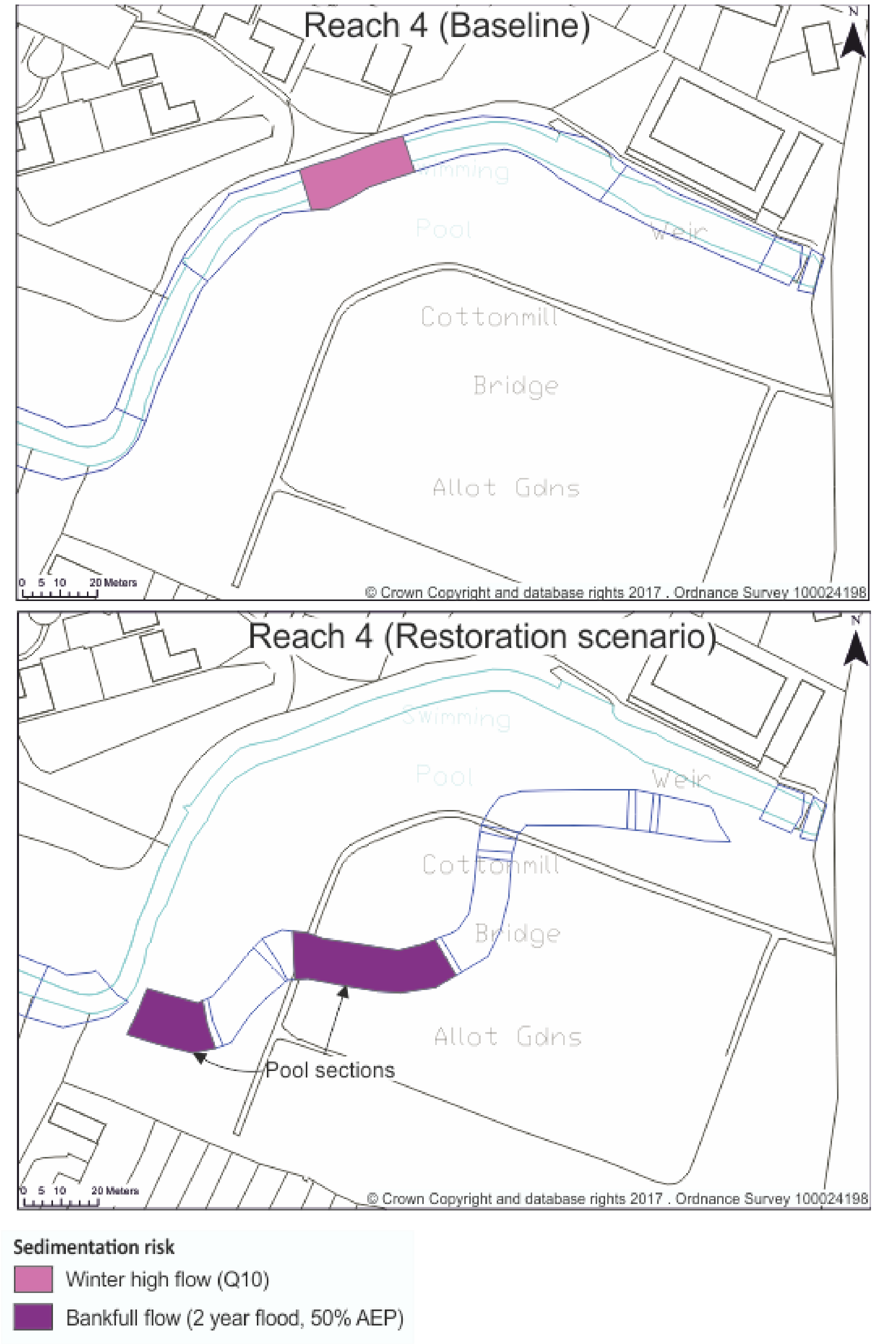


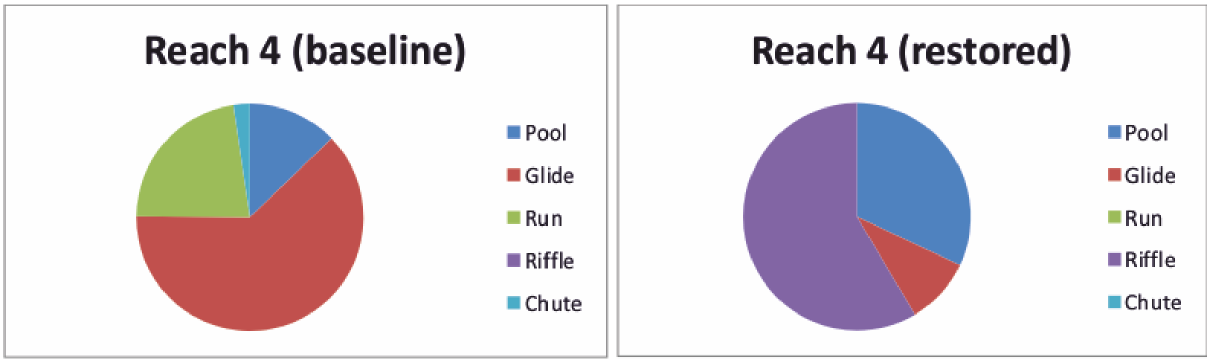
Figure 43. Sedimentation risk at Reach 4 under baseline and proposed restoration scenarios. Note: Model results also indicated low shear stress values under summer low flow conditions, however this is not likely to result in such widespread sedimentation given the low volume of flow and reduced sediment volumes being transported within the low flow channel. As such, only sedimentation risks associated with a winter high flow or bankfull flow have been identified.



In-channel habitat assessment

Reach 4 is currently dominated by glide habitat with only around a quarter of the reach displaying higher energy habitats (Figure 44). The introduction of the proposed restoration features sees a considerable increase in riffle habitat at the expense of glide. Because hydraulic energy is being concentrated across riffle areas some glide is transformed to pool. Whilst this is more susceptible to siltation, as a habitat in proportion with other habitats in the reach it provides valuable habitat diversity.

Figure 44. Current and restored in-channel habitats for Reach 4 on the River Ver



2.2.5 Reach 5 Option 4

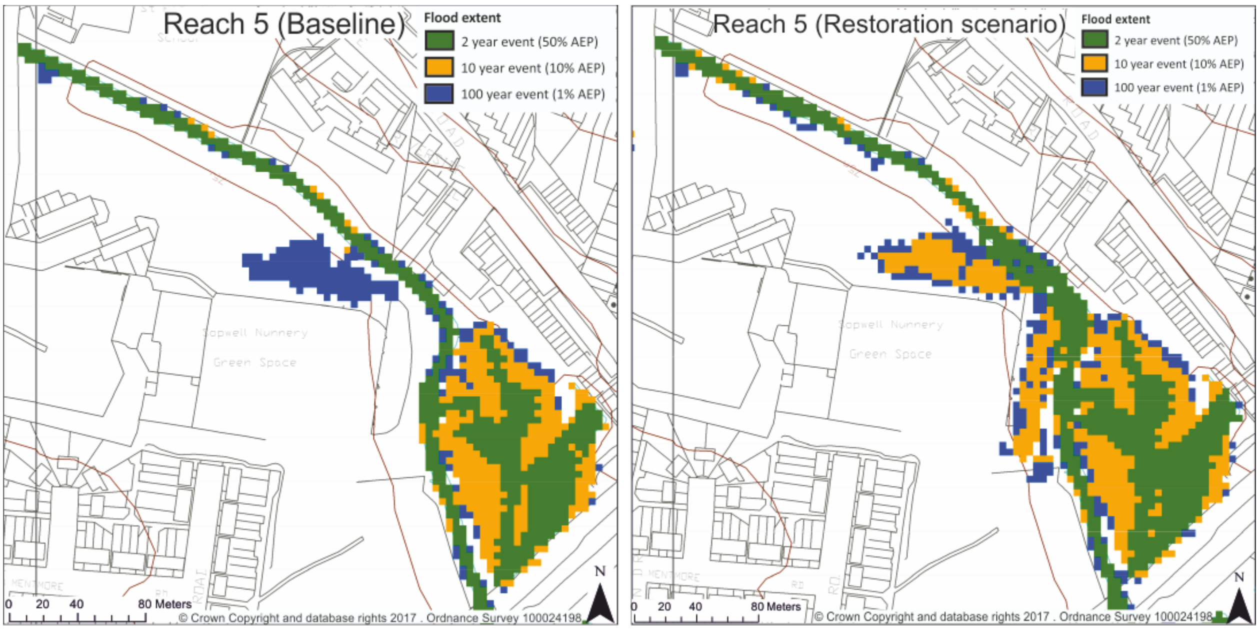
Flood risk analysis

Under the proposed restoration scenario there was a minor increase in inundation of the riparian zone along the first half of the reach under the 10 year and 100 year flood events, however connectivity with the floodplain was minimal despite inset floodplain features (see Flow dynamics section and Figure 45). The lowering of the right bank through the middle of the reach produced the intended increase in flood extent at the right floodplain under the 10 year and 100 year events, compared with baseline conditions. Modelled water depths were up to 0.4 m for the 10 year flood event and 0.6 m for the 100 year event.

Model results indicated increased connectivity between the River Ver and Watercress Wildlife Site under the 2 year flood event with increased inundation extent and depth in this area under the proposed restoration. Discussion is necessary to establish if this increase is acceptable.

There were no significant changes in relative flood risk to the private gardens at the back of the Watercress Wildlife Site.

Figure 45. Flood modelling results at Reach 5 under baseline and proposed restoration scenarios (increased areas of yellow indicate increased flood extent at the 2 year RP flow and increase in blue area is related to increased flood extent at the 100 year RP flow)



Flow dynamics

Table 9 summarises the average hydraulic conditions for Reach 5 under the proposed restoration scenario.

	Summer low flow (Q_{95})	Winter high flow (Q_{10})	Bankfull flow (2 year flood)	Extreme flood (100 year flood)
Flow depth (m)	0.37 (0.32)	0.64 (0.46)	0.69 (0.55)	1.05 (0.90)
Flow velocity (m/s)	0.22 (0.20)	0.45 (0.56)	0.48 (0.62)	0.75 (0.88)
Froude	0.14 (0.22)	0.22 (0.35)	0.23 (0.35)	

Table 9. Restored and baseline (bracketed) average hydraulics for Reach 5

For this reach, bed levels along the first 100 m were lowered in order to match the levels required for the Reach 4 restoration scenario. This has affected the functionality of the floodplain connection and two inset floodplains through this part of the reach, despite the inset floodplains being set to half existing bank height. Minimal connectivity is seen with the floodplain until the 100 year event meaning iteration of bank levels should be further developed during detail design, although this will be dependent on any decision taken for Reach 4. Alternatively a slightly drier inset feature would favour a different floristic assemblage contrasting with other wetter features.

For the wet woodland, the lowering of the right bank produced wetting of the riparian zone under winter high flow and bankfull conditions, with water depths between 0.05-0.1 m. Species selection for the area should reflect this with willows and alder favoured over birch and hawthorne. Significant inundation of the wet woodland area occurred during the 10 year flood, with average depths of 0.15 m up to a maximum of 0.4 m. Inflows to the wet woodland followed localised topographic depressions. Some ground works should be considered here to create more unified wet woodland, rather than the two distinct sections as seen in Figure 42.

Impacts on water depths and levels through this reach are minimal and are unlikely to impact any flow splits into the left hand pond. A future detailed design phase should confirm this.

Shear stress and critical bed sediment size

The baseline and proposed features were modelled across a range of flows ranging from summer low flow (Q_{95}), typical winter flow (Q_{10}), a bankfull flow (2 year return period) and an extreme flood (100 year return period). Figure 46 illustrates the change in hydraulic habitats predicted for the restored reach. It is clear from this that Reach 5 is currently quite diverse so the light touch restoration proposed will work with the already functioning features to improve overall habitat quality.

Of the four proposed riffles, three will maintain a good gravel bed while the fourth may silt slightly in summer but will flush in winter. The berm area too could accumulate some silt helping to lock this up to reduce water quality issues downstream. Intermediate areas will be low to moderate energy and look likely to accumulate some silt in summer but winter flows look energetic enough to flush this new sediment through.

Figures 46 to 48 summarise the hydraulic results through Reach 5 under the proposed restoration scenario.

Figure 46. Summary shear stress values and implications for sediment transport, erosion and deposition through Reach 5. Key shear stress thresholds of sedimentation (1 N/m^2) and bank erosion (8 N/m^2) are marked.

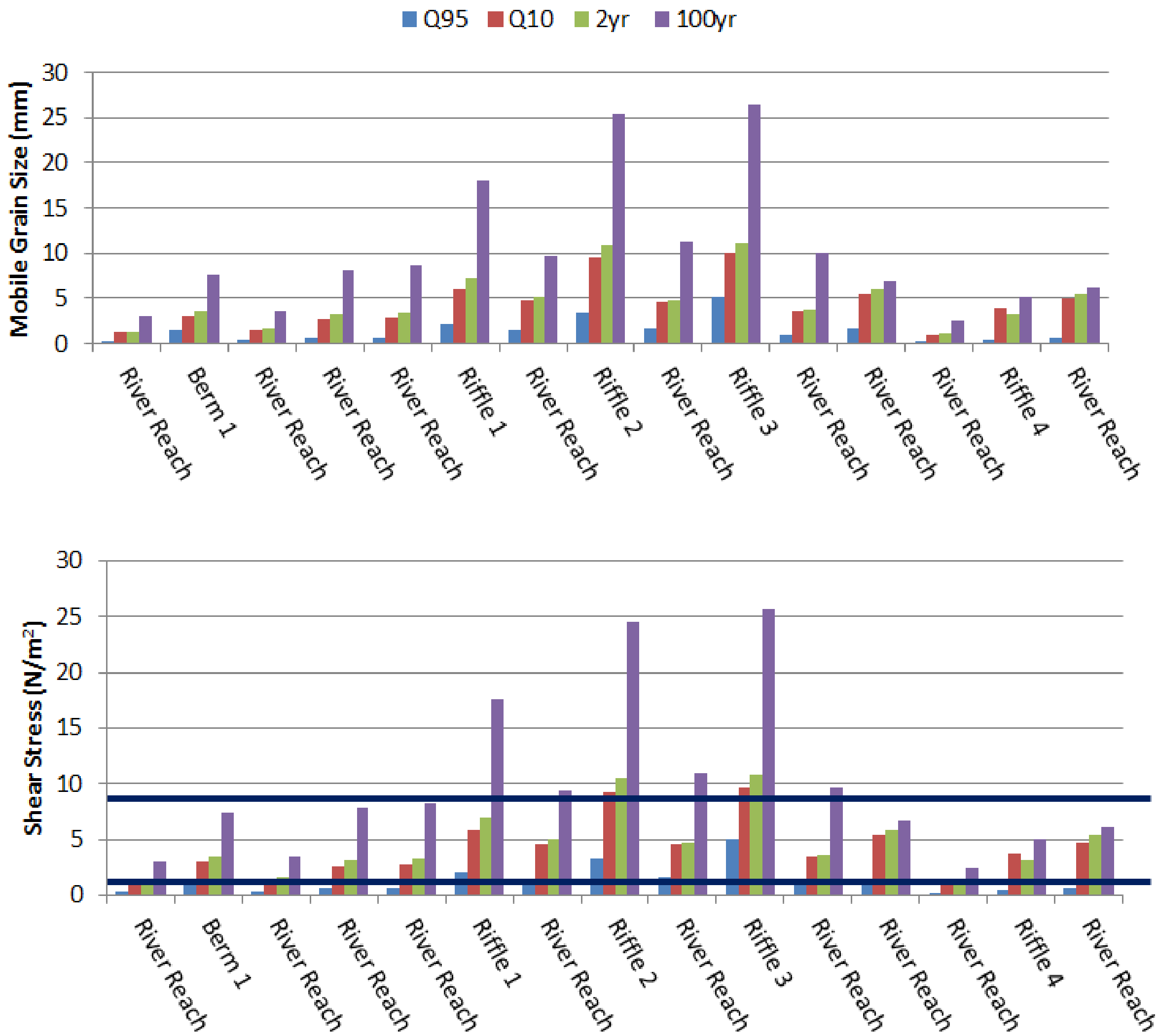


Figure 47. Bank erosion risk at Reach 5 under baseline and proposed restoration scenarios

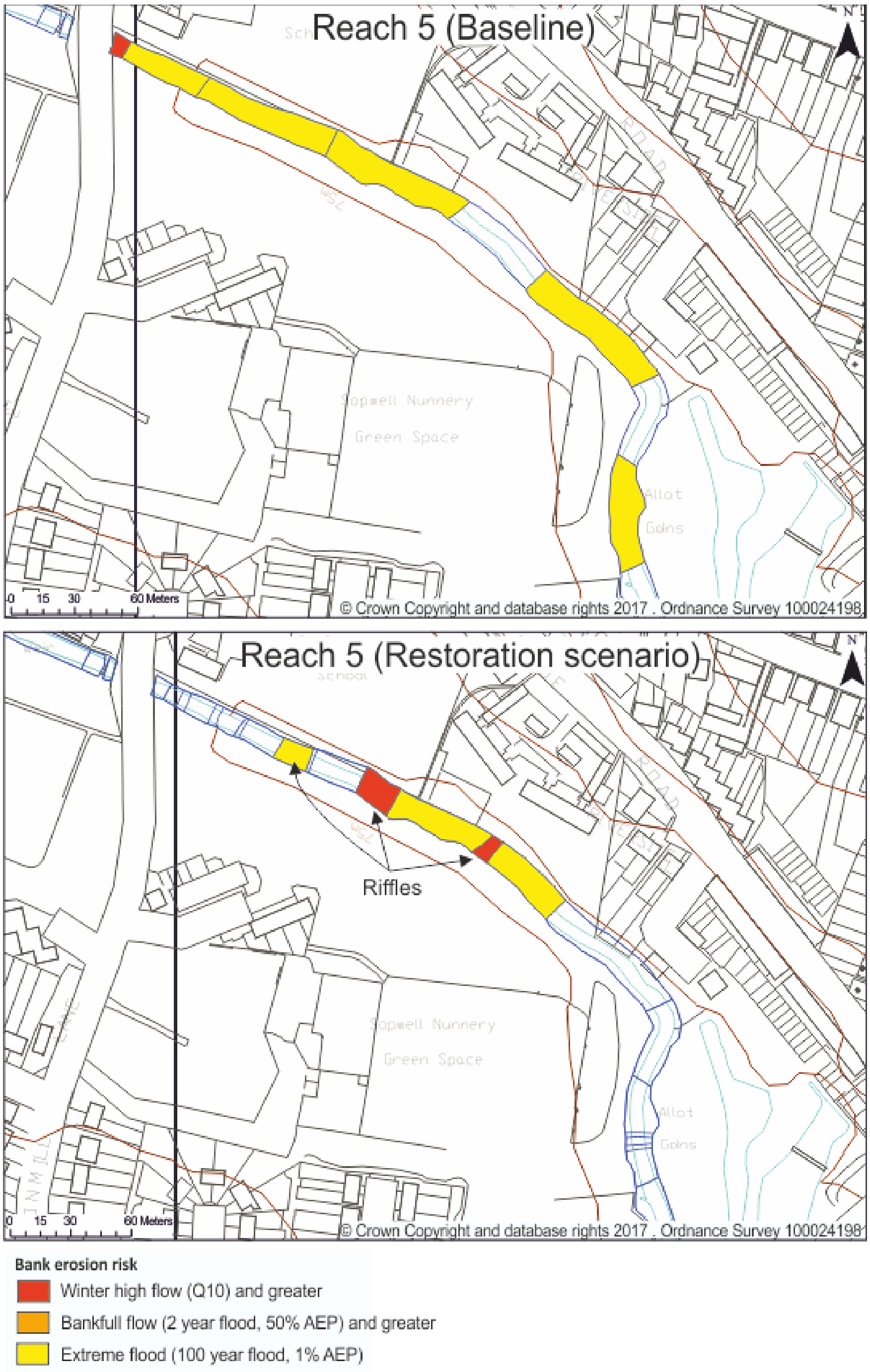
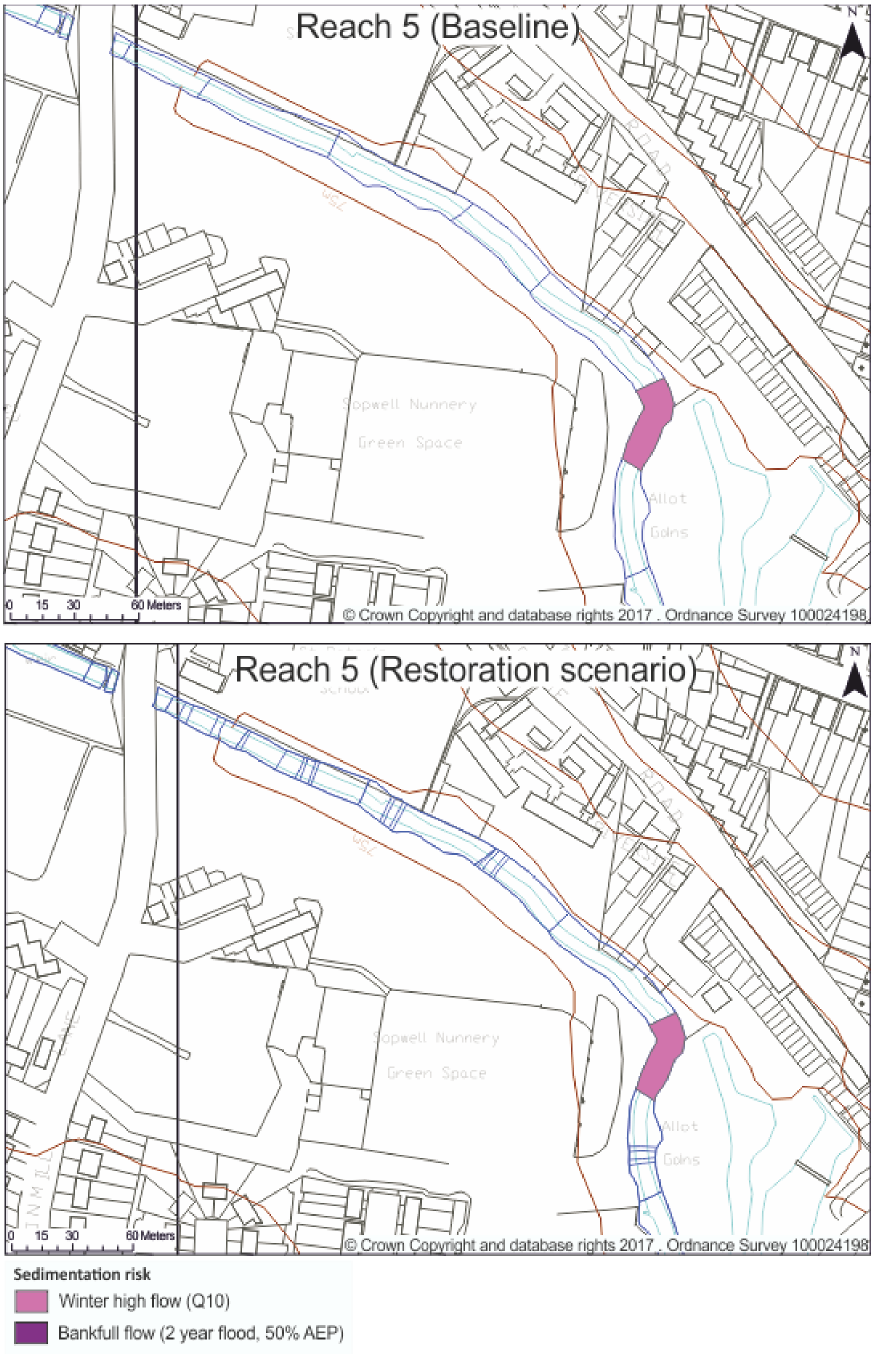


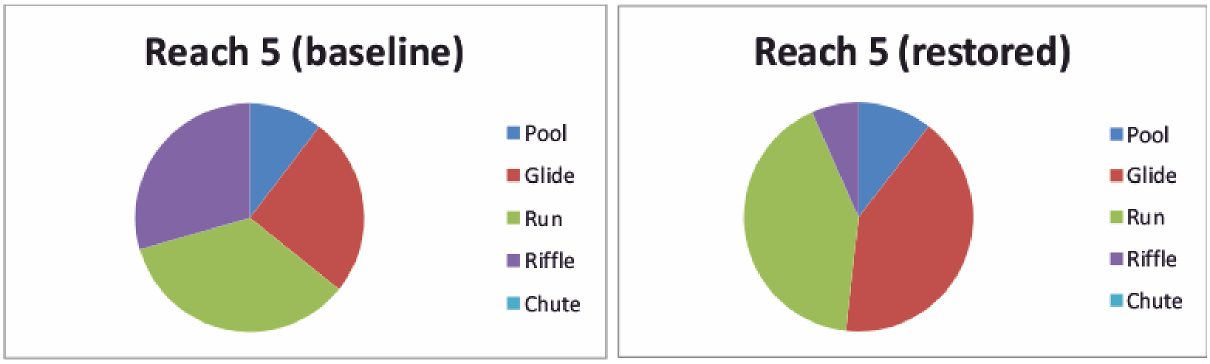
Figure 48. Sedimentation risk at Reach 5 under baseline and proposed restoration scenarios. Note: Model results also indicated low shear stress values under summer low flow conditions, however this is not likely to result in such widespread sedimentation given the low volume of flow and reduced sediment volumes being transported within the low flow channel. As such, only sedimentation risks associated with a winter high flow or bankfull flow have been identified.



In-channel habitat assessment

Reach 5, like reach 3, is in a recovering state and has a reasonably varied hydraulic habitat character (Figure 49). Restoration along this reach is primarily concerned with reconnection with the floodplain and this will cause overall in-channel energy levels to drop resulting in increased run/glide habitat. Some riffle areas remain, however and this is proportionate within the reach.

Figure 49. Current and restored in-channel habitats for Reach 5 on the River Ver



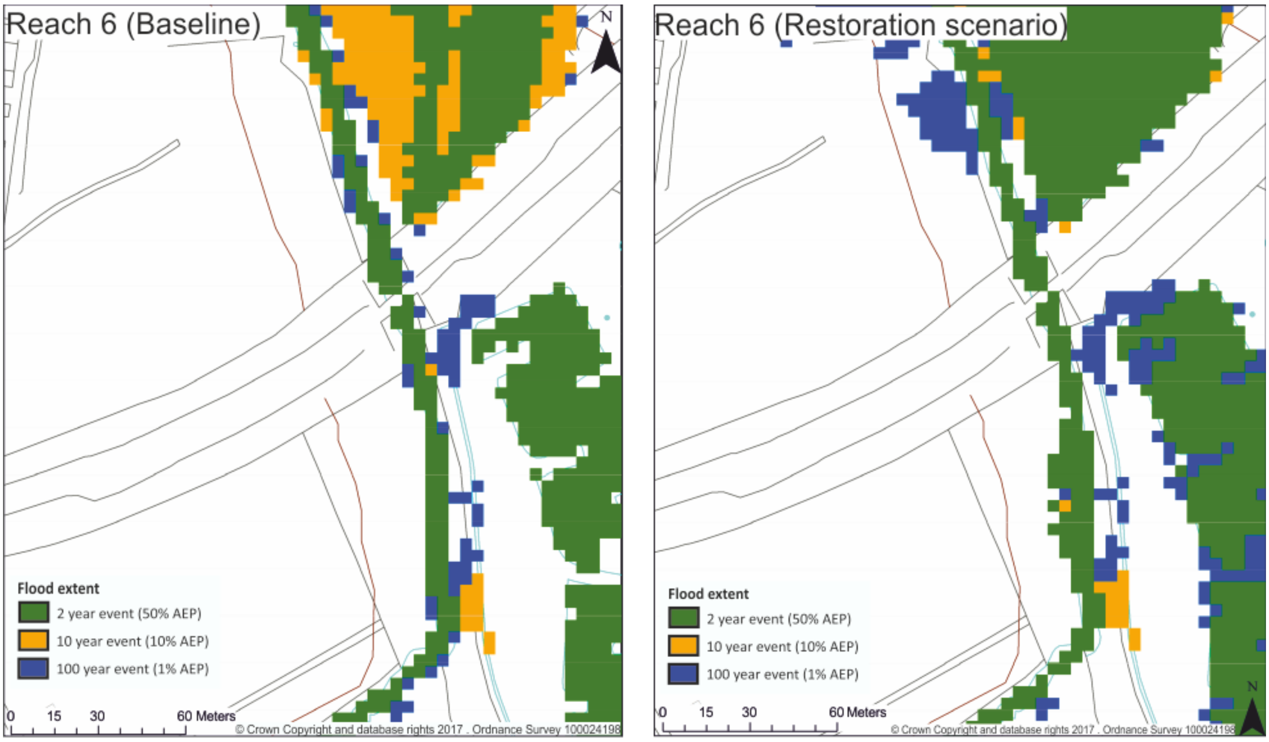
2.2.6 Reach 6 Option 2

Flood risk analysis

The proposed restoration scenario did not result in significant changes to localised flood risk compared with the baseline (Figure 50). The lowering of the right bank upstream of the bridge produced a minor increase in inundation extent at the right bank floodplain, however modelled water depths were shallow being <0.1 m. Model results indicated increased connectivity between the River Ver and Watercress Wildlife Site under 2 year flood conditions with increased inundation extent and depth in this area under the proposed restoration. Discussion is necessary to establish if this increase is acceptable.

The inset floodplain features downstream of the bridge received flood flows however the extent of inundation did not extend beyond these features.

Figure 50. Flood modelling results at Reach 6 under baseline and proposed restoration scenarios (increased areas of yellow indicate increased flood extent at the 2 year RP flow and increase in blue area is related to increased flood extent at the 100 year RP flow)



Flow dynamics

Table 10 summarises the average hydraulic conditions for Reach 6 under the proposed restoration scenario.

	Summer low flow (Q_{95})	Winter high flow (Q_{10})	Bankfull flow (2 year flood)	Extreme flood (100 year flood)
Flow depth (m)	0.47 (0.49)	0.71 (0.63)	0.75 (0.70)	1.06 (1.06)
Flow velocity (m/s)	0.24 (0.12)	0.47 (0.42)	0.48 (0.48)	0.74 (0.72)
Froude	0.15 (0.12)	0.24 (0.23)	0.23 (0.23)	

Table 10. Restored and baseline (bracketed) average hydraulics for Reach 6

Lowering of the right bank level upstream of the bridge did not produce significant riparian or floodplain benefits, and it is recommended that detailed design investigate additional bank lowering through this area.

The inset floodplain features downstream of the bridge were functional at winter high flow and bankfull conditions, with depths ranging from 0.1-0.3 m. Model results showed deeper water depths at the downstream inset feature than the upstream one, with the downstream feature also displaying minor wetting under median annual flows.

In order to evaluate the potential impact of the restoration on the connection to the left bank pond (fishery), water levels under baseline and the restoration were compared around the area of the pond offtake. The restoration scenario provided increased inflows to the pond compared to baseline conditions. For median annual flow conditions (Q_{50}) the ponds do not receive water under baseline conditions, however a small volume of inflow was observed under the restoration scenario due primarily to narrowing through this section with the berm feature. Inflows were also increased above the baseline condition for winter high flows. To avoid this, changes to the invert level of the pond connection could be investigated during the detailed design phase if desired.

Shear stress and critical bed sediment size

All riffles along the reach look likely to function well and pools will be flushed of any accumulated sediment during a flood. Some gravel movement appears possible and feature gravels will need to be appropriately sized at the detailed design stage. These results are not surprising as the baseline conditions through the reach are moderately energetic suggesting that this reach is in a recovering state and the light touch option chosen is therefore appropriate.

Following restoration the levels of energy (shear stress) available to prevent siltation, erode the banks and erode established in-channel features (berms) was also reviewed. Two of the proposed riffles may suffer minor siltation in summer but will be flushed in winter as will one of the pools. River lengths between new features look to be areas where fine sediment will accumulate, this is a natural phenomenon and most will flush in larger floods. The berm areas are more energetic and will maintain a clean gravel bed in the reduced width channel. Bank erosion looks to be a possibility at some berm and riffle locations but will be minor and in keeping with the new naturalised channel. No protection is suggested although appropriate bank edge planting would reduce any bank loss and should be considered at the detailed design stage.

Figures 51 to 53 summarise the hydraulic results through Reach 6 under the proposed restoration scenario.

Figure 51. Summary shear stress values and implications for sediment transport, erosion and deposition through Reach 6. Key shear stress thresholds of sedimentation (1 N/m2) and bank erosion (8 N/m2) are marked.

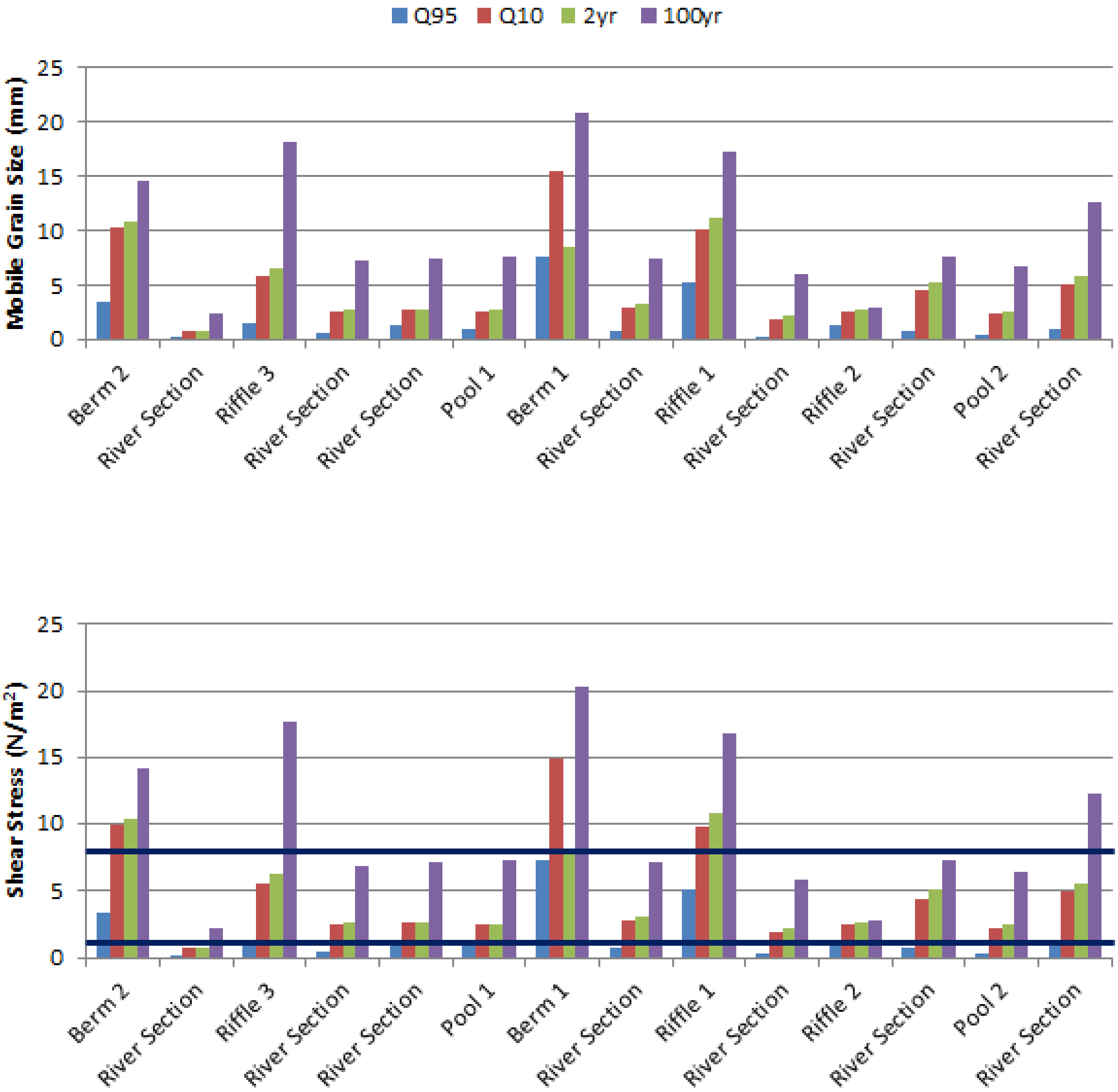


Figure 52. Bank erosion risk at Reach 6 under baseline and proposed restoration scenarios

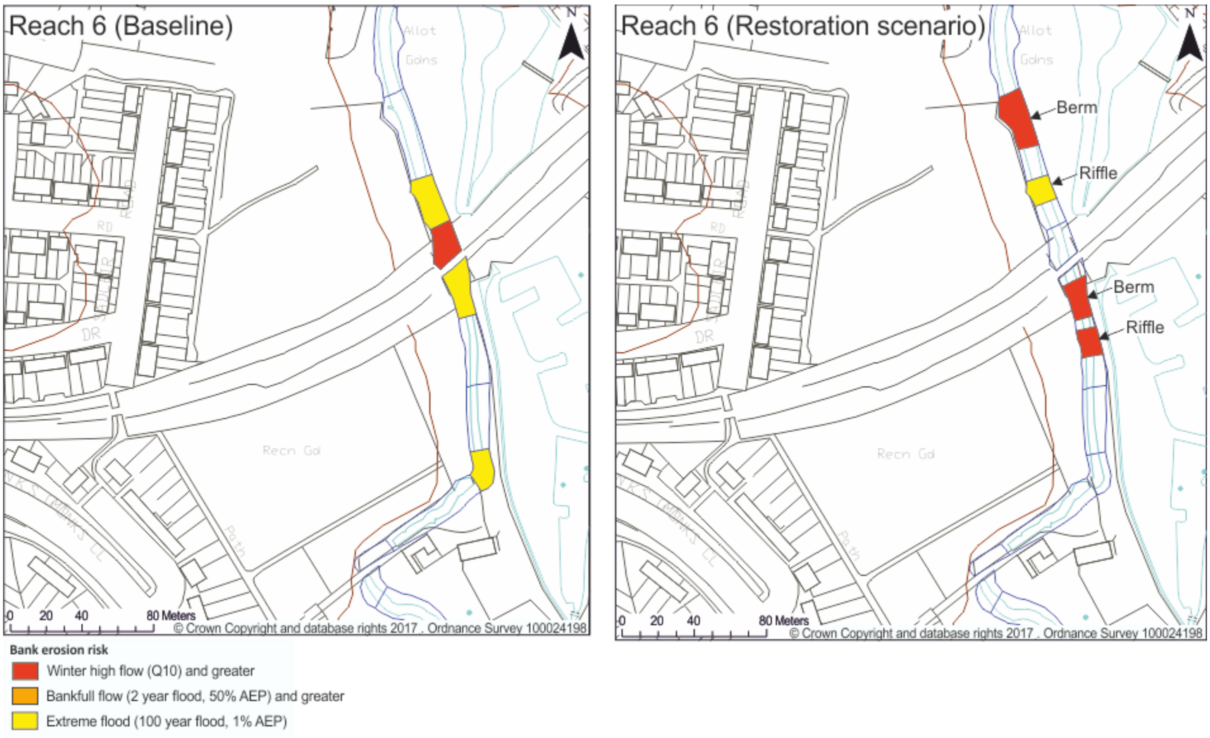
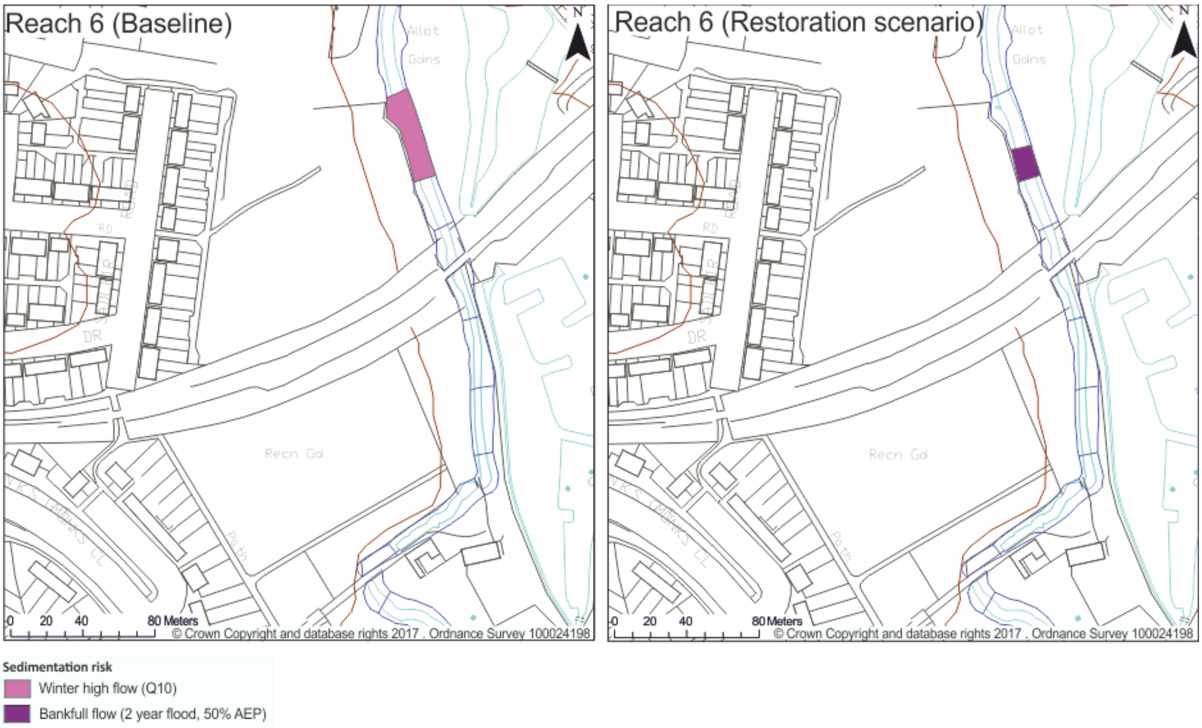


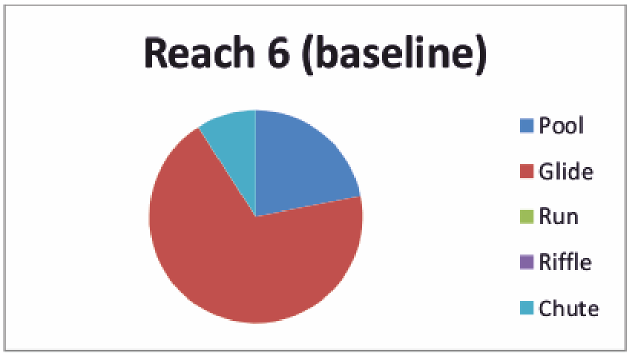
Figure 53. Sedimentation risk at Reach 6 under baseline and proposed restoration scenarios. Note: Model results also indicated low shear stress values under summer low flow conditions, however this is not likely to result in such widespread sedimentation given the low volume of flow and reduced sediment volumes being transported within the low flow channel. As such, only sedimentation risks associated with a winter high flow or bankfull flow have been identified.

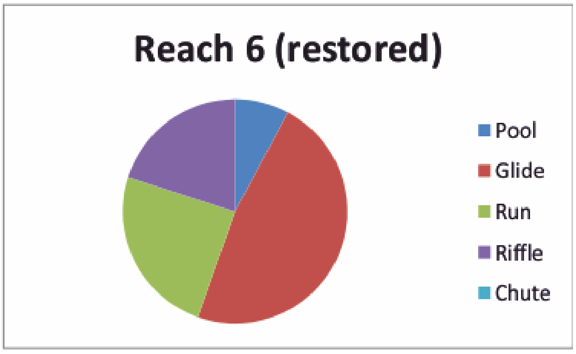


In-channel habitat assessment

Reach 6 is highly degraded with glide/pool habitat dominating at present (Figure 54). This contrasts with the restored reach where around 30% of the channel is transformed from glide to run/riffle habitat this generating a more diverse and energetic reach.

Figure 54. In-channel habitat in Reach 6 under baseline and proposed restoration scenarios





3. Summary and Recommendations

Summary

The modelling described in this report has simulated hydraulic conditions across all features proposed at the outline design stage for the River Ver. Overall hydraulic habitat variety and complexity is improved and importantly a number of higher energy run and riffle sites have been shown to be functional. Erosion issues are likely to be minor and localised. The propensity to deposit silts remains at a number of locations, however winter flows are generally sufficient to flush this sediment through the system.

The constrained flow split along Reach 1 has impacted on optimal channel restoration, however it has been demonstrated more generally that functionality of higher energy features can be achieved through channel narrowing and it is likely that with a further narrowed channel the restored Reach 1 will support functional runs and riffles.

Riparian and floodplain features are also generally functioning well becoming wet in winter, although one or two features should be further adjusted at the detailed design stage if wetter areas are desirable. However inset levels not subject to winter inundation can be seen as a positive by adding to overall riparian diversity by supporting vegetation slightly less tolerant of waterlogging.

Recommendations

As would be anticipated, iterative model results have led to a restoration plan that has indicated that the restoration work would result in local alterations to flood extent but overall providing a neutral flood impact across all 6 reaches as a result of localised minor increases and decreases, which was shown to impact private property / gardens in a few places (for details see Section 2.2 'Flood risk analysis' sub-sections). As such the following recommendations are made for the detailed design process:

- Reach 1: Embanking along the right bank upstream of the meander before the lake inlet could be investigated if the additional overbanking here is undesireable relative to what already occurs under the baseline, or an additional inset floodplain area to manage impacts under low order floods.

- Reach 2: Additional inset features e.g. berms, a small embankment at the left riparian gardens or increased right bank lowering could be explored to manage flood extent at the left bank riparian properties.

- Reach 3: The creation of a raised flood bank could be explored to protect the downstream right bank riparian properties. It could also explore the possibility of lowering the immediate left bank.

- Reach 4: Depending on the acceptable level of floodplain inundation, some stretches of bank could be raised slightly above existing ground level from the start of the realigned channel to its mid-point in order to reduce flood extent.

- Reach 5: Model results indicated increased connectivity between the River Ver and Watercress Wildlife Site under the 2 year flood event with increased inundation extent and depth in this area. Discussion should occur to establish if this increase is acceptable.

- Reach 6: Model results indicated increased connectivity between the River Ver and Watercress Wildlife Site under the 2 year flood event with increased inundation extent and depth in this area. Discussion should occur to establish if this increase is acceptable. Increased inflows were shown to occur into the left bank pond (fishery) downstream of the bridge for median and high winter flow conditions. If this is deemed unacceptable, changes to the invert level of the pond connection could be investigated.

Other recommendations for the detailed design phase include:

- Modelling of the proposed restoration in consideration of the effects of climate change.
- Cumulative effects of the proposed restoration.
- Any design iterations as outlined in Section 2.2 ‘Flow dynamics’ sub-sections.

APPENDIX E – Water Quality & Sediment Sampling at Verulamium Lake (2017 and 2018 sampling)

AECOM

Water Quality & Sediment Sampling at Verulamium Lake 2017

1. Introduction

In order to inform the feasibility study, options appraisal and develop outline designs for the River Ver restoration through St Albans, water quality and sediment samples from the Verulamium Lake (i.e. within Reach 1 of the project) have been collected and analysed to understand any potential risks to the environment and to human health.

2. Site

The Verulamium Lake is situated within Verulamium Park to the south west of St Albans (see Figure 1). The park and lake were created in 1930 from agricultural land. The lake is composed of two areas:

i) The small circular upper lake with an area of around 4,300 m^2 and referred to locally as the 'boating lake' as it is commonly used for model boating, and
ii) The lower lake with an area of around 33,600 m^2.

A low flow of water intermittently enters the upper lake from the adjacent River Ver (permitted through an Environment Agency abstraction license) from an adjustable weir, and a further weir separates the upper and lower lake. Water flows back to the River Ver through an outlet at the southeast extent of the lower lake.

The base and sheer sides of the lake are entirely concrete lined. Pedestrian paths surround the lake margin on all sides and grass is present up to the lake edge. The western margin is characterised by mown grassland while the eastern edge has overhanging deciduous trees, the fallen leaves from which are a significant allochthonous source of organic matter into the lake each autumn. Two small islands in the lower lake are also colonised by deciduous trees. .

Verulamium Lake is home to a large population of waterfowl, most notably *Branta Canadensis* (Canada Geese) and cyprinid fish population (predominantly carp). Faecal wastes from waterfowl (and fish) combined with food given to them by the public represents a significant nutrient source that may be enriching the lake, which is further exacerbated by the relatively high surface area to volume ratio and low flushing rates.

Water and sediment depths were not systematically measured as part of the current sampling investigation, but a previous study[1] in 2012 found water depths of only 16-40 cm in the upper lake and 13-59 cm in the lower lake. Sediment depths in the same study were found to be in the region of 49 cm at the northernmost extent of the lower lake and 41 cm toward the outlet area. Strategic removal of sediment has previously been carried out, for instance the upper lake was drained and sediment removed in 2008 and taken to a contaminated waste landfill due to heavy metals. Further silt removal has been undertaken in 2016, notably towards the lake outlet and below the weir into the lower lake[2].

A site survey and analysis of the lake was also undertaken in 1991[3], and the lake was subsequently subject to a bioremediation treatment and biomanipulation programme. This included removal of approximately 8 tonnes of roach with the aim of reducing direct pollution inputs, reducing silt disturbance from bioturbation and predatory pressure on invertebrates. Further fish removal was performed in later years. Remedial biological sachets have been used sporadically at the site since 2003. There is considerable public concern about the condition of Verulamium Lake, particularly given an outbreak of avian botulism in 2015[4].

[1] Symbio, Verulamium Lake, Survey and Analysis 2012
[2] St Albans City and District Council website, Information about the condition of the Lakes, 2016.
[3] Symbio, Verulamium Lake, Site Survey and Analysis 1991
[4] St Albans City and District Council website, Information about the condition of the Lakes, 2016.

3. Approach and Methodology

Water and sediments have been collected and tested for a range of biophysicochemical parameters to provide an indication of the water and sediment quality conditions in the Verulamium Lake. It should be noted, however, that water quality data provides only a snapshot of conditions on the day of sampling. The sediment will be a more robust indicator of longer term conditions as this would not be expected to change significantly spatially (given the stable environment and limited sediment sources) or temporally. The analyses will inform whether the sediments could be reused elsewhere on site following any restoration works, or whether they would need to be disposed of off-site as waste. As such, this data will also be used to help develop restoration options that support a healthy functioning lake ecosystem.

At Verulamium Lake, three water and three sediment samples (for bulk sediment and leachate analysis) were collected on 14th November 2016. Samples were collected from the locations shown in Figure 1. Water quality samples were first collected in appropriate jars and vials provided by the laboratory, along with necessary preservatives for the analysis suite. Samples were collected in accordance with relevant British Standards. Dissolved oxygen and water temperature were recorded in situ using a fully calibrated YSI Pro20 probe and meter.

The upper half meter of lake sediment (or until concrete was reached) was collected using an Eijkelkamp Multisampler deployed from a small boat, with bulk sediment extruded in the field into storage containers provided by the laboratory. The sediments were homogenous with depth and sampling location, being dark brown, organic rich and consisting mainly of leaf detritus. More extensive sampling will be required in future if full determination of distribution of contaminants around the lake is required, although where similar sediment is identified it may be reasonable to assume it has a similar quality to the tested sediment.

Both water and sediment samples were couriered immediately to ALcontrol Laboratories where analyses were undertaken for a range of parameters including heavy metals and hydrocarbons to reflect substances that could be a risk to the environment or to human health.

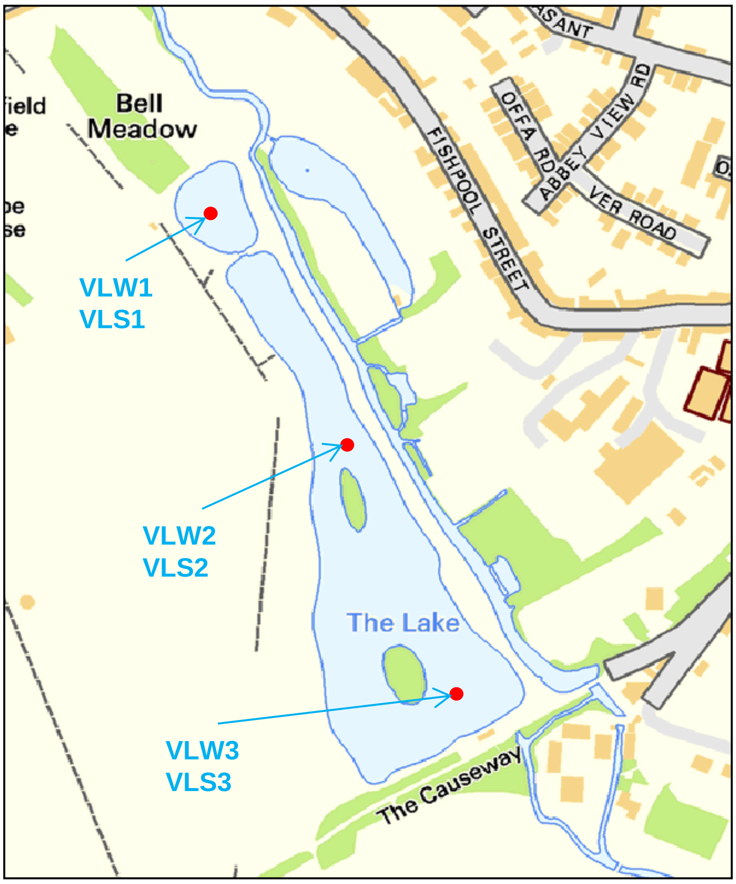


Figure 1 Sampling locations in Verulamium Lake (VLW – water sample; VLS = sediment sample) (Basemap ©Ordnance Survey).

Table 1 provides a full list of the parameters analysed:

Table 1 List and Description of the Tested Parameters

Parameter	Sample Type	Notes
Total Suspended Solids (TSS)	Water	Relevant for water clarity, lake biology and water quality.
Biochemical Oxygen Demand (BOD)	Water	Measure of quantity of oxygen used by microorganisms.
Particle Size Distribution	Sediment	Lake sediment physical parameter.
Organic Content	Sediment	Relevant to biochemical and geochemical processes.
Acid Volatile Sulphide	Sediment	Relevant to metal-binding capacity of sediments.
Sodium	Water, Sediment	Relevant to electrical conductivity.
Sulphate	Water, Sediment	Relevant to biogeochemical processes.
Chlorine	Water, Sediment	Relevant to biogeochemical processes.
Cadmium	Water, Sediment, Leachate	Heavy metals – naturally occurring in certain amounts and commonly sourced from various industrial processes and anthropogenic discharges to the water environment.
Chromium		
Copper		
Iron		
Lead		
Manganese		
Nickel		
Selenium		
Zinc		
Vanadium		
Boron Water Soluble		
Nitrate	Water	Relevant for nutrient availability and biological uptake.
Nitrite	Water	Relevant for nutrient availability and biological uptake.
Total Phosphorus	Water	Relevant for nutrient availability and biological uptake.
Orthophosphate	Water	Relevant for nutrient availability and biological uptake.
Ammoniacal Nitrogen	Water, Leachate	Potentially toxic to aquatic life at certain levels.
Cyanide Total	Water, Sediment	Potentially toxic to fish and aquatic invertebrates at low levels. Relevant under the Water Framework Directive. Sources include gas works, coal and hydrocarbon processing and industrial processes.
Speciated Phenols by HPLC	Water, Sediment, Leachate	Cresols etc. Sources include the treatment of timber, industrial processes and hydrocarbon spillages.
PAH 16 EPA GC-MS	Water, Sediment, Leachate	Polycyclic Aromatic Hydrocarbons. Common sources include incomplete combustion of organic matter (e.g. fuel, wood burning, biofuels etc).
PCB 7 Congeners	Water, Sediment, Leachate	Heavy compounds sourced from solvents, degreasers, incomplete combustion processes etc.
TPH CWG incl BTEX	Water, Sediment, Leachate	Total petroleum hydrocarbons includes hydrocarbons originally sourced from crude oil and include fuels and mineral oils. BTEX stands for Benzene, Toluene, Ethylbenzene, and Xylenes.
pH (S)	Water	Contextual information for analysis of other parameters (e.g. toxicity of some metals).
Alkalinity		
Dissolved Organic Carbon		
Dissolved Oxygen	Water	Relevant to lake biology and other water quality parameters and an indicator of the health of a water environment.
Eschericia coli	Water	Coliform bacteria that indicate faecal pollution from warm-blooded animals.
Intestinal Enterococci	Water	Bacterial group used as an index of faecal pollution in recreational water.
Clostridium perfringens	Water	Bacterial group used as an index of faecal pollution in recreational water.

4. Sediments

Results of sediment chemical testing were analysed against known human health screening values to assess potential risks to human health and any public nuisance potential, in terms of smell, aesthetic values etc. Screening value sources included the Chartered Institute of Environmental Health's Suitable 4 Use Levels (LQM/CIEH S4ULs) for Human Health Risk Assessment and DEFRA Category 4 Screening Levels (C4SLs) 12/2014 and both were derived from AECOM's Stage 2 Workbook v1.45 (2016). It should be noted that not all of the parameters measured have standards assigned to them. Full results are shown in Appendix 1. No individually measured determinand was found to be in excess of human health screening values for those that can be obtained through the Stage 2 Workbook.

In general, metal concentrations are higher in concentration in the lower lake (samples VLS-2 and VLS-3) than in the upper lake (VLS-1), and so appear to be more prone to accumulate in this area where there is low through flow of water. Organic content on the other hand (as indicated by loss on ignition) is greatest in the shallower upper lake sample (VLS-1).

Sediment results have been run through HazWaste Online by AECOM's contaminated land team. The samples have been classified as 'potentially hazardous' as a result of HP3(i) Hazard Property exceedances as follows:

Sample ID	Hazard Property Exceedance	Reported Analyte Concentration (mg/kg)
VLS-1 (upper lake)	HP3(i)	Toluene (0.012 mg/kg), TPH C6-C40 (578 mg/kg), MTBE (2.11 mg/kg)
VLS-2 (lower lake)	HP3(i)	TPH C6-C40 (192 mg/kg)
VLS-3 (lower lake)	HP3(i)	TPH C6-C40 (1330 mg/kg)

The upper lake sample, VLS-1, has shown detectable concentrations of toluene, MTBE and TPH C6 – C40 that may be a consequence of the shallow sample depth (~0.5m bgl). This area is used for model boating and the results indicating presence of light TPH (i.e. fuels) are not inconsistent with what might be expected from some recreational activities (potentially including fuels related to model boating). Further sediment investigation in this sample area is recommended to better understand the extent of any fuels within the vicinity of VLS-1.

For VLS-2 and VLS-3 the TPH data reports mid-range and heavier carbon fractions, and it is likely that the waste classification for the samples may be reclassified, subject to further field investigation indicating the conclusive absence of 'free oil' in the sediment.

Leachate was derived from the sediments for testing of Waste Acceptance Criteria (WAC) and to test against Water Framework Directive (WFD) standards. Preparation followed the National River Authority (NRA) method, whereby soluble and suspended species are leached using water with a pH of approximately 5.6 at a ratio of 1:10, and this is performed for 24 hours.

For the available leachate data, none of the recorded variables relevant for Waste Acceptance Criteria (WAC) testing are above the thresholds for inert landfill (Table 2). However, when compared to water quality standards obtained through the Stage 2 Workbook, some of the leachate results do fail to meet 'good' requirements (see Appendix 2). This mainly concerns VLS-3 where copper, iron and a number of PAHs exceed the WFD thresholds. These metals and PAHs may have derived from sources of industrial pollution and highway runoff into the River Ver, or from leaks from model boats using the upper lake. The upper lake sample (VLS-1) records one failure for the data available, which is for ammoniacal nitrogen. These WFD standard exceedances do not preclude sediment disposal which depends on the WAC.

Table 2. Leachate testing against WAC critria.

Analyte	Units	WAC Inert Waste Landfill	WAC Stable non-reactive / non-hazardous	WAC Hazardous Waste Landfill	VLS-1	VLS-2	VLS-3
Sum of detected EC7 PCB's	mg/kg	1			<0.00105	<0.00105	<0.00105
Sum of BTEX	mg/kg	6			<0.28	<0.28	<0.28
Sum of PAH	mg/kg	100			<0.0034	<0.0034	<0.0034
Cadmium (diss.filt)	mg/kg	0.04	1	5	<0.008	<0.008	<0.008
Chromium (diss.filt)	mg/kg	0.5	10	70	<0.012	<0.012	<0.012
Lead (diss.filt)	mg/kg	0.5	10	50	<0.00319	<0.00878	<0.0161
Selenium (diss.filt)	mg/kg	0.1	0.5	7	<0.0081	<0.0081	<0.0081
Zinc (diss.filt)	mg/kg	4	50	200	<0.013	<0.013	<0.013
Phenols, Total	mg/kg	1			0.00002	0.00002	0.00002

The standards for different types of waste are indicated in the shaded columns. All samples are suitable for inert waste landfill based on the parameters measured.

The most significant issue arising from the analysis is the hazardous nature of the Verulamium Lake silts based on the HazWasteOnline assessment, based upon HP3(i) hazard exceedance.

5. Bacteriological Quality

There are currently no standards for bacteriological sediment quality, and so here we use water samples as a proxy. The WFD does not include bacteriological water quality and so the Bathing Water Directive (2006/7/EC) standards were used to assess the three water samples (Appendix 3). The water samples met ‘excellent quality’ standards for inland waters for *Intestinal enterococci* (<200 CFU/100 ml) and ‘good’ standards for *Escherichia coli* (<1000 CFU/100 ml). *E.coli* also meets the standards for the human consumption of shellfish (so long as subsequent purification is undertaken), as described in Regulation (EC) No 854/2004 on rules on products of animal origin for human consumption (standard <4600/100 ml). Thus, while the large wildfowl population is a significant source of faecal bacteria, these samples do not suggest that concentrations are so high as to breach standards used for bathing waters, for these parameters.

Clostridium perfringens is not included in the Bathing Water Directive, but is a Schedule 2 indicator under the Water Supply (Water Quality) Regulations 2000, meaning that it requires monitoring at the point where water leaves a treatment works or at supply points rather than within inland waters. It should not exceed 0 CFU/100ml upon leaving a treatment works. It is reasonably abundant in the upper lake (VLW-1) at 143 CFU/100 ml, and least abundant at VLW-2 (22 CFU/100 ml). Its presence is unsurprising given the abundance of wildfowl. It is suggested that similar sampling is undertaken from late spring through to early autumn to provide an indication of the extent of seasonal differences.

Although beyond the budget of the current optioneering study, AECOM would recommend commissioning a pathogen analysis specifically for *Clostridium botulinum* in the sediment of the Verulamium Lake, if it is decided that any sediment is to be excavated from the site. This is recommended in light of the outbreak of avian botulism in 2015. This will help determine whether the bacterium is present in greater quantity than is typically encountered in similar environments. Bacterial spores can survive for years but only give rise to bacteria that produce toxins under particular environmental conditions, including hot temperatures, anoxic conditions and an organic nutrient source[5]. As such, if affected sediment was to be excavated from the site, then allowed to dry and warm up then this *may* inadvertently cause the bacteria to reactivate and potentially produce the toxin that causes botulism. Subject to the intended end-use (re-use on site or off-site disposal) and given the material is likely to be in close proximity to both wildfowl and humans then potential risks in terms of occupational health exposure and wildfowl protection must be further considered.

[5] USGS, National Wildlife Health Center, Disease Fact Sheets, Avian Botulism.

6. Water Quality

As previously mentioned, it is important to note that the three water quality samples discussed here represent a snapshot in time and values are likely to show substantial variation seasonally. Further longer term sampling is recommended to highlight any seasonal differences and trends. Surface water sampling results are provided in Appendix 3. All Phenols, TPH, PCBs and VOCs were below the limits of detection for Alcontrol laboratories and so have not been included.

Although the Verulamium Lake is not designated in terms of the WFD, it is instructive to compare against standards for lakes of this type (based on alkalinity). Nitrate in the lake is below the recommended level of 50 mg/l for drinking water, as described in the Water Supply (Water Quality) Regulations 2016. However, it should be noted that the site is within a Nitrate Vulnerable Zone (NVZ). The nitrate values are considerably higher than any value recorded in the previous water quality investigation in 2012 (maximum 1.29 mg/l), and is especially high at the upper lake, sample VLW-1 (10.5 mg/l). It was noted in the previous study that the River Ver inlet to the lake is a significant source of nitrate, with levels gradually decreasing towards the outlet which is located close to VLW-3. This reduction of nitrate (and related variables) toward the outlet is also noted in our newly surveyed data (Figure 2). The average nitrate concentration of the River Ver recorded at the nearest upstream water quality monitoring site at Gorhambury was 5.66 mg/l between 2003 and 2015. On top of this input of nitrate into the upper lake, there is likely to be a considerable input from wildfowl waste in the lake. This may be more concentrated in the shallower upper lake than the lower lake due to the former’s small surface area.

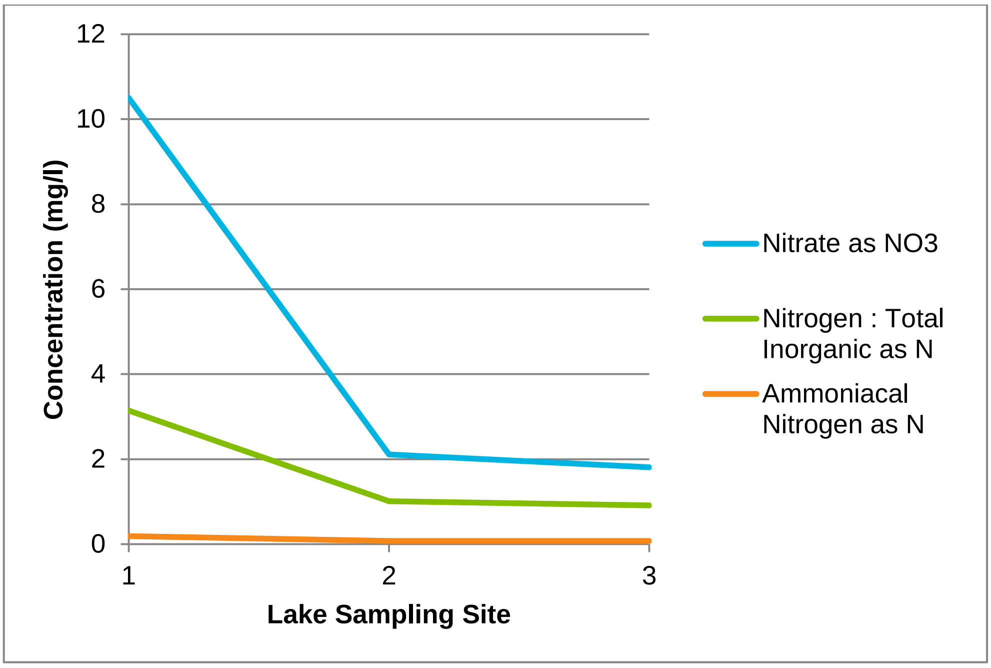


Figure 2 Variability in concentration of example water quality parameters across the three lake sampling sites (VLW-1 = 1 and is closest to the inlet; VLW2 = 2; VLW-3 = 3 and is closest to the outlet).

Ammoniacal nitrogen is elevated above the WFD Good standard (>0.6 mg/l) at VLW-1 and VLW-2, with the greatest value in the boating lake (0.873 mg/l which is within the Moderate class boundary). Total phosphorus (TP) is below the limits of detection in the lower lake, but is in breach of the standard at VLW-1 (0.0889 mg/l). Eutrophic lakes typically have a mean average TP in the range of 0.035-0.1mg/l, and so the upper lake sits within this range based on this one-off sample. Further sampling would be required to determine the true mean annual extent of this potential nutrient enrichment. The Good standard for TP of 0.049 mg/l used here was estimated for Verulamium Lake using the UKTAG Guide to Lake Phosphorus standards (based on altitude, estimated depth, alkalinity and lake type). Overall, our indicative data suggests that nutrient enrichment (nitrates and phosphates) may be an issue at the site, and may be especially problematic in the upper lake. This could be a factor supporting the perceived eutrophic conditions and risk of algal blooms.

Heavy metals and micronutrients are generally within the WFD standards (Appendix 3) with the exception of lead at VLW-1 in the boating lake (1.46 µg/l). The generally low metal concentrations agree with the previous water sampling undertaken at the site in 2012. All samples from VLW-2 and VLW-3 are beneath limits of detection for Phenols, PAHs, TPHs, PCBs and VOCs. This is also the case for VLW-1 (upper lake) with the exception of PAHs. For this latter group, a number of species are present at sufficient quantity to be detected, with numerous breaches of WFD standards including fluoranthene, benzo(a)pyrene and benzo(g,h,i)perylene. These are commonly sourced from incomplete combustion of organic matter (e.g. fuel, wood burning, biofuels), and could be derived from model boating activities.

Suspended solid concentrations were considerably lower during this survey (<9 mg/l for all sites) compared to values recorded in 2012 (17-25 mg/l). Suspended solids in the lake are most probably derived from sediment bioturbation by fish and waterfowl and fine organic effluent in the lake from waterfowl excreta.

Dissolved oxygen at the time of sampling met WFD good ecological status for lakes[6] at all three sampling points (above 8.5 mg/l at all sites). Biochemical Oxygen Demand (BOD) was only above the limits of detection at the upper lake (VLW-1), but was relatively low at 2.41 mg/l. BOD is a measure of oxygen use by aerobic organisms as they break down contaminants, and higher levels generally suggest organic pollution.

7. Summary

Based on the limited data available, it appears that the water quality of the shallow VLW-1 upper lake site is poorer and potentially more polluted and nutrient enriched than the lower lake (VLW-2 & VLW-3). This may be due in part to the inflow from the adjacent River Ver combined with the shallow site conditions causing a greater concentration of pollutants and nutrients in this area. Recreational activities (model boating) may also be an important local source of some of the contaminants present. Once the water has passed over the weir into the lower lake it is expected that it is diluted by a greater volume of water with deeper cycling of nutrients and metals, and consequently the high concentrations from VLW-1 are no longer apparent. As noted above, these conclusions are based on limited water quality data that provide only a 'snapshot' in time and should be used with some caution. Further water quality sampling, particularly from late spring to early autumn, would provide a more robust data set and would enable a more thorough assessment against EQS and help to identify any seasonal trends in water quality over the longer term, where interpreted in the context of water quality in the River Ver.

Sediment quality is less variable that water quality over short time periods and the few samples collected provide a more reliable indication of sediment quality. The results from bulk sediment samples suggest that lake sediments are 'potentially hazardous', with the upper lake being the most contaminated. This has consequences in terms of sediment re-use, and further sampling to determine the full extent of fuel pollution (potentially relating to model boating) in this area is recommended. However, leachate analysis suggested that lake sediments would be suitable for inert landfill. There were, however, a number of failures of the leachate data with WFD standards, which mainly affected the sample nearest the outflow of the lower lake. Leachate tests typically overestimate the risk in the natural environment and dilution, dispersion and duration factors would need to be considered, but this suggests that significant mobilisation of sediments could potentially have an impact on the lake ecosystem and potentially the River Ver downstream. This risk should be assessed in more detail before any works that affect lake sediments are undertaken. Regardless of the contamination risk, such works would need to be carefully planned and implemented using appropriate techniques and mitigation to minimise this risk. Finally, a pathogen analysis is recommended should lake sediments need to be excavated from the site in order to determine the viability of *Clostridium botulinum* in the sediment of the Verulamium Lake, and to what extent it poses a risk to the health of waterfowl and humans.

[6] Joint Nature Conservation Committee, Common Standards Monitoring Guidance for Freshwater Lakes, March 2015.

AECOM

Appendix 1 Results of the sediment contaminant testing at three sites at the Verulamium Lake. Screening values are given where possible, and green shading indicates that the sample is below the screening value.

Determinant	Units	Limit of Detection	Screening Value	Sample VLS1 (green shading indicates lower than screening value whilst orange indicates above)	Sample VLS2 (green shading indicates lower than screening value whilst orange indicates above)	Sample VLS3 (green shading indicates lower than screening value whilst orange indicates above)	Screening Value Source (HH Soil. Public Open Space - Park. TOC >=3.48%)
Aluminium	mg/kg	<11		3740	5210	4010	
Arsenic	mg/kg	<0.6	170	1.74	2.82	2.78	AECOM (modified LQM/CIEH S4ULs)
Cadmium	mg/kg	<0.02	560	0.232	1.03	0.795	AECOM (modified LQM/CIEH S4ULs)
Chromium	mg/kg	<0.9		8.76	11.1	8.94	
Copper	mg/kg	<1.4	44,000	23.6	34.6	24.8	AECOM (modified LQM/CIEH S4ULs)
Iron	mg/kg	<1000		4670	5820	4160	
Lead	mg/kg	<0.7	2,300	43.4	157	126	Defra C4SL 12/2014
Manganese	mg/kg	<0.13		98.7	95.2	111	
Mercury	mg/kg	<0.14	58	<0.14	<0.14	<0.14	LQM/CIEH S4ULs 2014
Nickel	mg/kg	<0.2	800	5.95	9.47	7.25	AECOM (modified LQM/CIEH S4ULs)
Selenium	mg/kg	<1	1,800	1.41	1.76	1.42	AECOM (modified LQM/CIEH S4ULs)
Zinc	mg/kg	<1.9	170,000	105	176	146	LQM/CIEH S4ULs 2014
Water Soluble Boron	mg/kg	<0.1	n/a	<1	1.05	<1	LQM/CIEH S4ULs 2014
Chromium, Hexavalent	mg/kg	<0.6	220	<0.6	<0.6	<0.6	LQM/CIEH S4ULs 2014
Chromium, Trivalent	mg/kg	<0.9	33,000	8.76	11.1	8.94	LQM/CIEH S4ULs 2014
Polycyclic Aromatic Hydrocarbon							
Naphthalene	mg/kg	<0.009	3,000	<0.009	0.07	0.0528	AECOM (modified LQM/CIEH S4ULs)
Acenaphthylene	mg/kg	<0.012	30,000	0.0423	0.159	0.165	AECOM (modified LQM/CIEH S4ULs)
Acenaphthene	mg/kg	<0.008	30,000	<0.08	0.0565	0.0722	AECOM (modified LQM/CIEH S4ULs)
Fluorene	mg/kg	<0.01	20,000	0.0313	0.0487	0.0517	AECOM (modified LQM/CIEH S4ULs)
Phenanthrene	mg/kg	<0.015	6,300	0.26	0.581	0.666	AECOM (modified LQM/CIEH S4ULs)
Anthracene	mg/kg	<0.016	150,000	0.0988	0.238	0.282	AECOM (modified LQM/CIEH S4ULs)
Fluoranthene	mg/kg	<0.017	6,400	0.911	2.96	3.1	AECOM (modified LQM/CIEH S4ULs)
Pyrene	mg/kg	<0.015	15,000	0.818	2.71	2.73	AECOM (modified

							LQM/CIEH S4ULs)
Benzo(a)anthracene	mg/kg	<0.024	62	0.616	1.94	1.69	AECOM (modified LQM/CIEH S4ULs)
Chrysene	mg/kg	<0.010	120	0.721	2.2	2.26	AECOM (modified LQM/CIEH S4ULs)
Benzo(b)fluoranthene	mg/kg	<0.015	16	1.24	4.25	4.8	AECOM (modified LQM/CIEH S4ULs)
Benzo(k)fluoranthene	mg/kg	<0.014	440	0.441	1.43	1.53	AECOM (modified LQM/CIEH S4ULs)
Benzo(a)pyrene	mg/kg	<0.015	13	0.862	2.94	2.92	AECOM (modified LQM/CIEH S4ULs)
Indeno(123cd)pyrene	mg/kg	<0.018	180	0.523	2.05	2.37	AECOM (modified LQM/CIEH S4ULs)
Dibenzo(ah)anthracene	mg/kg	<0.023	1.4	0.144	0.563	0.599	AECOM (modified LQM/CIEH S4ULs)
Benzo(ghi)perylene	mg/kg	<0.024	1,600	0.697	2.33	2.62	AECOM (modified LQM/CIEH S4ULs)
PAH Total Detected USEPA 16	mg/kg	<0.118		7.4	24.5	25.9	
Total Petroleum Hydrocarbons							
Aliphatics							
>C5-C6	mg/kg	<0.01		0.0155	<0.01	<0.01	
>C6-C8	mg/kg	<0.01		0.0279	<0.01	0.0216	
>C8-C10	mg/kg	<0.01		0.0279	<0.01	0.024	
>C10-C12	mg/kg	<0.01		0.0217	<0.01	0.048	
>C12-C16	mg/kg	<0.1		0.403	<0.01	7.79	
>C16-C21	mg/kg	<0.1		24.3	11.4	116	
>C21-C35	mg/kg	<0.1		158	69.6	589	
>C35-C44	mg/kg	<0.1		46.4	22.6	205	
Total aliphatics C12-44	mg/kg	<0.1		229	104	917	
Aromatics							
>EC5-EC7		<0.01	92,000	<0.01	<0.01	<0.01	AECOM (modified LQM/CIEH S4ULs)
>EC7-EC8	mg/kg	<0.01	100,000	0.0124	<0.01	<0.01	AECOM (modified LQM/CIEH S4ULs)
>EC8-EC10	mg/kg	<0.01	9,300	0.0248	<0.01	0.0168	AECOM (modified LQM/CIEH S4ULs)
>EC10-EC12	mg/kg	<0.01	10,000	0.0155	<0.01	0.0312	AECOM (modified LQM/CIEH S4ULs)
>EC12-EC16	mg/kg	<0.1	10,000	<0.1	<0.1	<0.1	AECOM (modified LQM/CIEH S4ULs)
>EC16-EC21	mg/kg	<0.1	7,800	12.4	4.97	30.7	AECOM (modified LQM/CIEH S4ULs)
>EC21-EC35	mg/kg	<0.1	7,900	229	54.3	265	AECOM (modified LQM/CIEH S4ULs)

>EC35-EC44	mg/kg	<0.1	7,900	107	29.5	117	AECOM (modified LQM/CIEH S4ULs)
>EC40-EC44	mg/kg	<0.1		33.5	12.1	42.2	
Total aromatics EC12-EC44	mg/kg	<0.1		348	88.8	413	
Total aliphatics and aromatics(C5-C44)	mg/kg	<0.1		578	192	1330	
MTBE	ug/kg	<5		2110	<5	<5	
Benzene	ug/kg	<10	110	<10	<10	<10	AECOM (modified LQM/CIEH S4ULs)
Toluene	ug/kg	<2	100,000	12.4	<2	<2	AECOM (modified LQM/CIEH S4ULs)
Ethylbenzene	ug/kg	<3	27,000	<3	<3	<3	AECOM (modified LQM/CIEH S4ULs)
m/p-Xylene	ug/kg	<6		<6	<6	<6	
o-Xylene	ug/kg	<3		<3	<3	<3	
Sum of detected mpo xylene	ug/kg	<9	31,000	<9	<9	<9	AECOM (modified LQM/CIEH S4ULs)
Sum of detected BTEX	ug/kg	<24		<24	<24	<24	
Polychlorinated Biphenyls							
PCB 28	ug/kg	<3		<15	<15	<15	
PCB 52	ug/kg	<3		<15	<15	<15	
PCB 101	ug/kg	<3		<15	<15	<15	
PCB 118	ug/kg	<3		<15	<15	<15	
PCB 138	ug/kg	<3		<15	<15	<15	
PCB 153	ug/kg	<3		<15	<15	<15	
PCB 180	ug/kg	<3		<15	<15	<15	
Total 7 PCBs	ug/kg	<21		<105	<105	<105	
Phenols							
Phenol	mg/kg	<0.01	1,300	<0.01	<0.01	<0.01	AECOM (modified LQM/CIEH S4ULs)
Cresol	mg/kg	<0.01		<0.01	<0.01	<0.01	
Xylenols	mg/kg	<0.015		<0.015	<0.015	<0.015	
2,3,5-trimethylphenol	mg/kg	<0.01		<0.01	<0.01	<0.01	
2-isopropylphenol	mg/kg	<0.015		<0.015	<0.015	<0.015	
Phenols, Total Detected 5 speciated	mg/kg	<0.06		<0.06	<0.06	<0.06	
Other Items							
Natural Moisture Content	%	<0.1		68	64	59	
Grain size	mm			0.002-0.063 (Silt)	0.002-0.063 (Silt)	0.002-0.063 (Silt)	
Sample Colour	None			Dark Brown	Dark Brown	Dark brown	
Total Cyanide	mg/kg	<1		<1	<1	<1	

Water Soluble Sulphate as SO_4 2:1 Extract	g/l	<0.004		0.311	0.168	0.0632	
Total Sulphate	mg/kg	<48		2320	2250	1760	
Loss on Ignition	%	<0.7		20	16.1	10.3	
Oxidisable Sulphide	%	<0.03		0.503	0.905	0.727	
Total Sulphur	%	<0.02		0.245	0.375	0.301	
Total Potential Sulphate	%	<0.06		0.735	1.13	0.903	
Sodium	mg/kg	<7		169	166	160	

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Appendix 2 Results of the sediment leachate testing at three sites at the Verulamium Lake. WFD screening values are given where possible. Green shading indicates that the sample is below the screening value, orange indicates that the value is surpassed. Only those parameters where at least one sample is above the limit of detection have been included.

Test	*Units*	*LOD*	*Screening Value*	VLL-1	VLL-2	VLL-3
NRA - Ammoniacal Nitrogen as N	mg/l	<0.2	0.6	1.94	<0.2	0.448
Dissolved Metals						
NRA - Chromium, Hexavalent	mg/l	<0.03	0.0034	<0.03	<0.03	<0.03
NRA - Chromium, Trivalent	mg/l	<0.03	0.0047	<0.03	<0.03	<0.03
NRA - Aluminium (diss.filt)	µg/l	<2	200	35.6	38.5	36.9
NRA - Iron (diss.filt)	mg/l	<0.019	1000	0.039	0.0202	0.0227
NRA - Boron (diss.filt)	µg/l	<5	1000	10.4	11.1	10.6
NRA - Cadmium (diss.filt)	µg/l	<0.08	0.25	<0.08	<0.08	<0.08
NRA - Chromium (diss.filt)	µg/l	<1.2	50	<1.2	<1.2	<1.2
NRA - Copper (diss.filt)	µg/l	<0.85	1	0.873	<0.85	1.85
NRA - Lead (diss.filt)	µg/l	<0.1	1.2	0.319	0.878	1.61
NRA - Manganese (diss.filt)	µg/l	<0.76	123	15.1	13.4	10.5
NRA - Selenium (diss.filt)	µg/l	<0.81	10	<0.81	<0.81	<0.81
NRA - Vanadium (diss.filt)	µg/l	<1.3		<1.3	<1.3	4.36
NRA - Zinc (diss.filt)	µg/l	<1.3	10.9	<1.3	<1.3	<1.3
PAHs						
NRA - Acenaphthene (diss.filt)	µg/l	<0.015	18	<0.015	<0.015	0.0841
NRA - Fluoranthene (diss.filt)	µg/l	<0.017	0.0063	0.031	0.0409	0.19
NRA - Anthracene (diss.filt)	µg/l	<0.015	0.1	<0.015	<0.015	0.0175
NRA - Phenanthrene (diss.filt)	µg/l	<0.022	4	0.029	<0.022	0.0755
NRA - Chrysene (diss.filt)	µg/l	<0.013		<0.013	<0.013	0.0219
NRA - Pyrene (diss.filt)	µg/l	<0.015	9	0.024	0.0299	0.128
NRA - Benzo(a)anthracene (diss.filt)	µg/l	<0.017	3.5	<0.017	<0.017	0.0374
NRA - Benzo(b)fluoranthene (diss.filt)	µg/l	<0.023	0.0017	<0.023	<0.023	0.0458
NRA - Benzo(a)pyrene (diss.filt)	µg/l	<0.009	0.00017	<0.009	<0.009	0.0148
NRA - Dibenzo(a,h)anthracene (diss.filt)	µg/l	<0.016	0.07	<0.016	<0.016	<0.016
NRA - Benzo(g,h,i)perylene (diss.filt)	µg/l	<0.016	0.0082	<0.016	<0.016	0.0384
NRA - Indeno(1,2,3-cd)pyrene (diss.filt)	µg/l	<0.014		<0.014	<0.014	0.0247
NRA - PAH Sum of EPA 16 detected (Diss filt)	µg/l	<0.344		<0.344	<0.344	0.678

Appendix 3 Results of the surface water quality testing at three sites at the Verulamium Lake. Screening values are given where possible. Green shading indicates that the sample is below the screening value, orange indicates that the value is surpassed. All Phenols, TPH, PCBs and VOCs were below the limits of detection for the laboratory and so have not been included.

Analyte	*Units*	*Limits of Detection*	*Screening Value*	VLW1	VLW2	VLW3	Screening Source
Dissolved Oxygen	%			73	72	69	
Dissolved Oxygen	mg/L			9	8.9	8.5	
BOD 5 Day ATU	mg/l	1		2.41	<1	<1	
Cyanide as CN	mg/l	0.05	0.001	<0.05	<0.05	<0.05	WFD Eng/Wales 2015
Carbon, Organic, Dissolved as C :- {DOC}	mg/l	0.2		3.99	3.87	4.98	
Alkalinity to pH 4.5 as CaCO3	mg/l	5		210	180	180	
Ammoniacal Nitrogen as N	mg/l	0.003	0.6	0.873	0.614	0.578	WFD Eng/Wales 2015
Nitrite as N	mg/l	0.004	0.5	0.187	0.077	0.073	WS Regs 2016 (Eng/Wal)
Orthophosphate, reactive as P	mg/l	0.01		<0.02	0.0225	0.033	
Conductivity at 20C	uS/cm	10		0.513	0.43	0.43	
pH	pH Units	0.05		7.8	7.86	7.85	
Chromium Hexavalent, Dissolved	ug/l	0.03	3.4	<0.03	<0.03	<0.03	WFD Eng/Wales 2015
Solids, Suspended at 105 C	mg/l	2		<9	<9	<9	
Arsenic Dissolved	ug/l	0.51	10	0.659	0.62	0.597	WS Regs 2016 (Eng/Wal)
Boron, Dissolved	ug/l	<5	1000	29.9	28.5	28.4	WS Regs 2016 (Eng/Wal)
Lead, Dissolved	ug/l	0.1	1.2	0.206	0.765	0.612	WFD Eng/Wales 2015
Lead	ug/l	0.1	1.2	1.46	0.806	0.603	WFD Eng/Wales 2015
Aluminium, Dissolved	ug/l	2	200	3.92	5.68	<2	WS Regs 2016 (Eng/Wal)
Cadmium, Dissolved	ug/l	0.08	0.25	<0.08	<0.08	<0.08	WS Regs 2016 (Eng/Wal)
Chromium, Dissolved	ug/l	1.2	1.2	<1.2	<1.2	<1.2	WS Regs 2016 (Eng/Wal)
Copper, Dissolved	ug/l	0.85	1	<0.85	<0.85	<0.85	WFD Eng/Wales 2015
Zinc, Dissolved	ug/l	3	10.9	4.47	3.81	1.95	WFD Eng/Wales 2015
Aluminium	ug/l	50	200	178	<50	<50	WS Regs 2016 (Eng/Wal)
Cadmium	ug/l	0.5	0.25	<0.5	<0.5	<0.5	WS Regs 2016 (Eng/Wal)
Chromium	ug/l	3	3.4	<3	<3	<3	WS Regs 2016 (Eng/Wal)
Copper	ug/l	4	1 (bioavailable)	<4	<4	<4	WFD Eng/Wales 2015
Nickel	ug/l	0.5	4	2.74	1.67	1.26	WFD Eng/Wales 2015
Zinc	ug/l	0.024	10.9	5.38	3.78	<3	WFD Eng/Wales 2015
Iron, Dissolved	ug/l	0.019	1000	28.8	23.3	29.8	WS Regs 2016 (Eng/Wal)
Manganese, Dissolved	ug/l	0.76	123	9.68	9.13	8.06	WS Regs 2016 (Eng/Wal)
Iron	ug/l	24	1000	166	39.6	31.3	WFD Eng/Wales 2015
Manganese	ug/l	0.5	123 (bioavailable)	14.8	6.69	6.43	WFD Eng/Wales 2015
Sodium	mg/l	<0.076	200	21.8	14	14	WS Regs 2016 (Eng/Wal)
Sulphate as SO4	mg/l	2	250	20.5	28.3	27.7	WFD Eng/Wales 2015
Mercury, Dissolved	ug/l	0.01	0.07	<0.01	<0.01	<0.01	WFD Eng/Wales 2015
Mercury	ug/l	0.01	0.07	<0.02	<0.02	<0.02	WFD Eng/Wales 2015
Nitrate as NO3	mg/l	0.3	50	10.5	2.11	1.81	WS Regs 2016 (Eng/Wal)
Nitrogen : Total Inorganic as N	mg/l	0.2		3.14	1.01	0.908	
Total Phosphorus	mg/l	0.02	0.049 (est.)	0.0889	<0.02	<0.02	Lake Phosphorus Calculator
PAH							
Anthracene	ug/l	0.015	0.1	<0.015	<0.015	<0.015	WFD Eng/Wales 2015
Benzo(a)anthracene	ug/l	0.017	3.5	0.0456	<0.017	<0.017	AECOM DWG (WHO method)
Benzo(a)pyrene	ug/l	0.009	0.00017	0.0352	<0.009	<0.009	WFD Eng/Wales 2015
Benzo(b)fluoranthene	ug/l	0.023	0.017	0.0578	<0.023	<0.023	WFD Eng/Wales 2015
Benzo(k)fluoranthene	ug/l	0.027	0.017	0.0578	<0.023	<0.023	
Benzo(g,h,i)perylene	ug/l	0.016	0.0082	0.0462	<0.016	<0.016	WFD Eng/Wales 2015
Indeno(1,2,3-cd)pyrene	ug/l	0.014		0.0303	<0.014	<0.014	
Chrysene	ug/l	0.013		0.0465	<0.013	<0.013	WFD Eng/Wales 2015

Fluoranthene	ug/l	0.017	0.0063	0.0714	<0.017	<0.017	WFD Eng/Wales 2015
Naphthalene	ug/l	0.1	2	<0.1	<0.1	<0.1	WFD Eng/Wales 2015
Phenanthrene	ug/l	0.01	4	0.0566	<0.022	<0.022	AECOM DWG (WHO method)
Pyrene	ug/l	0.01	9	0.0724	<0.015	<0.015	AECOM DWG (WHO method)
Bacteria							
Eschericia coli	CFU/100ml		<1000 CFU/100 ml	928	930	928	Bathing Water Directive 2006
Intestinal Enterococci	CFU/100ml		<200 CFU/100 ml	24	10	23	Bathing Water Directive 2006
Clostridium perfringens	CFU/100ml			143	22	77	

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Water Quality Sampling at Verulamium Lake: 23 August 2018

1. Introduction

AECOM was commissioned by St Albans City and District Council to undertake water quality sampling at Verulamium Lake in August 2018. This sampling aimed to determine the prevailing water quality conditions in the lake in the late summer of 2018 following a number of instances of bird deaths. The sampling enabled comparison of conditions against previous data collected by AECOM and the Environment Agency in 2016 and 2017, respectively. Any potential improvements or deteriorations in water quality at the lake could therefore be identified.

The sampling was undertaken on 23 August 2018 and six samples were collected from across the lake as well as two samples from locations in the adjacent River Ver. The data has been analysed against relevant Environmental Quality Standards (EQS) where appropriate to understand any potential risks to the environment and to human health.

2. Site

The Verulamium Lake is situated within Verulamium Park to the south west of St Albans (see Figure 1). The park and lake were created in 1930 from agricultural land. The lake is composed of two areas:

i) The small circular 'upper lake' with an area of around 4,300 m^2 and referred to locally as the 'boating lake' as it is commonly used for model boating, and
ii) The 'lower lake' with an area of around 33,600 m^2.

A low flow of water intermittently enters the upper lake from the adjacent River Ver via an adjustable sluice. A further weir separates the upper and lower lake. Water flows back to the River Ver through an outlet at the southeast extent of the lower lake.

The base and sheer sides of the lake are entirely concrete lined. Pedestrian paths surround the lake margin on all sides and grass is present up to the lake edge. The western margin is characterised by mown grassland while the eastern edge has overhanging deciduous trees, the fallen leaves from which are a significant source of organic matter into the lake each autumn. Two small islands in the lower lake are also colonised by deciduous trees.

Verulamium Lake is home to a large population of waterfowl, most notably *Branta canadensis* (Canada Geese) and cyprinid fish population (predominantly carp). Faecal wastes from waterfowl and fish combined with food given to them by the public represents a significant nutrient source that may be enriching the lake, which is further exacerbated by the relatively high surface area to volume ratio and low flushing rate.

Water depths were not systematically measured as part of the current sampling investigation, but a previous study[1] in 2012 found water depths of only 16-40 cm in the upper lake and 13-59 cm in the lower lake. Sediment depths in the same study were found to be in the region of 49 cm at the northernmost extent of the lower lake and 41 cm toward the outlet area. However, strategic removal of sediment has been carried out since, for instance the upper lake was drained and sediment removed in 2008 and taken to a contaminated waste landfill due to heavy metals. Further silt removal has been undertaken in 2016[2] and 2017[3], notably towards the lake outlet and below the weir into the lower lake.

[1] Symbio, Verulamium Lake, Survey and Analysis 2012
[2] St Albans City and District Council website, Information about the condition of the Lakes, 2016.
[3] Pers comm Daniel Flitton, St Albans City and District Counil

A site survey and analysis of the lake was also undertaken in 1991[4], and the lake was subsequently subject to a bioremediation treatment and biomanipulation programme. This included removal of approximately 8 tonnes of roach with the aim of reducing direct pollution inputs, reducing silt disturbance from bioturbation and predatory pressure on invertebrates. Further fish removal was performed in later years. Remedial biological sachets have been used sporadically at the site since 2003. There is considerable public concern about the condition of Verulamium Lake, particularly given an outbreak of avian botulism in 2015[5] and again in the summer of 2018.

3. Approach and Methodology

Six water samples were collected from Verulamium Lake on 23rd August 2018 and tested for a range of biophysicochemical parameters to provide an indication of the water quality conditions. In addition two samples were collected from the River Ver, including one immediately upstream of the abstraction point to Verulamium Lake, and one from the main channel downstream of the outfall from the southern end of the lake. All sampling points are shown in Figure 1. It should be noted that water quality data provides only a snapshot of conditions on the day of sampling. This is particularly the case for the river where water quality is strongly influenced by prevailing flow conditions. The lake water quality will be slower to vary through time due to its greater residence time, particularly when lake levels are low and there is no water moving through the outfall at the south of the lake. However, weather conditions on a particular day can still have a significant influence. For instance, rainfall may mobilise pollutants from the surrounding catchment through runoff on wet days or increased microbial activity may occur on warm days.

Water quality samples were collected in appropriate bottles and vials provided by the appointed laboratory (National Laboratory Service), along with necessary preservatives for the analysis suite. Samples were collected in accordance with relevant British Standards. They were then couriered to the laboratory under temperature controlled conditions to keep them cool. Dissolved oxygen and water temperature were recorded in situ using a fully calibrated YSI Pro20 probe and meter. Table 1 provides a full list of the parameters analysed.

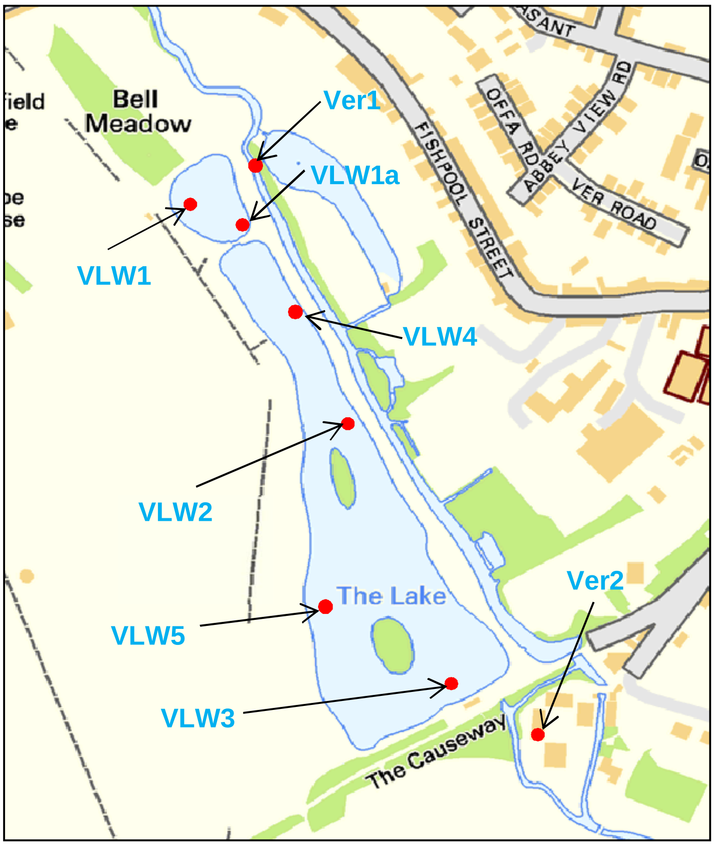

Figure 1 Sampling locations in Verulamium Lake (Basemap © Ordnance Survey, 2018)

[4] Symbio, Verulamium Lake, Site Survey and Analysis 1991
[5] St Albans City and District Council website, Information about the condition of the Lakes, 2016.

Table 1 List and Description of the Tested Parameters

Parameter	Notes
Total Suspended Solids (TSS)	Relevant for water clarity, lake biology and water quality.
Biochemical Oxygen Demand (BOD)	Measure of quantity of oxygen used by microorganisms.
Chemical Oxygen Demand (COD)	Measure of quantity of oxygen that can be consumed by reactions in a solution, and so quantifies the amount of oxidisable pollutants in the water.
Sodium	Relevant to electrical conductivity.
Sulphate	Relevant to biogeochemical processes.
Chlorine	Relevant to biogeochemical processes.
Aluminium	Heavy metals (total and dissolved) – naturally occurring in certain amounts and commonly sourced from various industrial processes and anthropogenic discharges to the water environment.
Arsenic	
Barium	
Boron	
Cadmium	
Chromium	
Chromium Hexavalent	
Copper	
Iron	
Lead	
Lithium	
Manganese	
Mercury	
Nickel	
Selenium	
Strontium	
Zinc	
Vanadium	
Boron Water Soluble	
Nitrate	Relevant for nutrient availability and biological uptake.
Nitrite	Relevant for nutrient availability and biological uptake.
Total Phosphorus	Relevant for nutrient availability and biological uptake.
Orthophosphate	Relevant for nutrient availability and biological uptake.
Ammoniacal Nitrogen	Potentially toxic to aquatic life at certain levels.
Total Nitrogen	Relevant for nutrient availability and biological uptake.
Total Oxidised Nitrogen	Relevant for nutrient availability and biological uptake.
Chlorophyll	Indication of the quantity of algae
Sulphate (including dissolved)	Relevant for nutrient availability and biological uptake.
Cyanide Total	Potentially toxic to fish and aquatic invertebrates at low levels. Relevant under the Water Framework Directive. Sources include gas works, coal and hydrocarbon processing and industrial processes.
PAH 16 EPA GC-MS	Polycyclic Aromatic Hydrocarbons. Common sources include incomplete combustion of organic matter (e.g. fuel, wood burning, biofuels etc).
pH (S)	Contextual information for analysis of other parameters (e.g. toxicity of some metals).
Alkalinity	
Dissolved Organic Carbon	
Total Organic Carbon	
Dissolved Oxygen	Relevant to lake biology and other water quality parameters and an indicator of the health of a water environment.
Escherichia coli	Coliform bacteria that indicate faecal pollution from warm-blooded animals.
Intestinal Enterococci	Bacterial group used as an index of faecal pollution in recreational water.
Clostridium perfringens	Bacterial group used as an index of faecal pollution in recreational water.

4. Site Conditions

The sampling on 23 August 2018 followed a prolonged dry spell lasting approximately 3 months during which there had only been sporadic rainfall events. The morning of the sampling was overcast and followed light rain showers in the early- to mid-morning period. All samples were collected between 09:30 and 12:00.

Lake level at the site was low following the dry summer with large patches of exposed, foul-smelling sediment around the margins of the upper lake (Photo 1), below the bridge between the upper and lower lake (Photo 2) and at the south of the lower lake (Photo 3).

Photo 1 (top left) Exposed sediment at the margins of the upper lake; Photo 2 (top right) Exposed sediment downstream of the weir between the upper and lower lake; Photo 3 (bottom left) Exposed sediment at the southwestern corner of the lower lake; Photo 4 (bottom right) Algal accumulations on the surface of the lower lake

The upper lake had a dark green tinge to the water on the day of sampling and algae was dense in the water column, and so the lake was experiencing algal bloom. The green tinge was present in the lower lake but less marked than at the upper lake However, floating algal accumulations were found across the lake although were more abundant in the northern half of the lower lake (Photo 4).

The outfall to the River Ver at the southern extent of the lake was not flowing due to the low lake levels at the time of sampling. A small dead bird was noted on the grass to the west of the lake between the two islands.

5. Lake Water Quality

August 2018 surface water sampling results are provided in Appendix 1 along with the results of samples previously collected in November 2016, June 2017 and August 2017. As noted previously, these results represent snapshots of conditions in the lake, and regular monthly and seasonal sampling has not been undertaken from which significant long-term trends could be identified. Where applicable, results have been compared to Water Framework Directive (WFD) Environmental Quality Standards (EQS) for lakes of this type (based on alkalinity). Other useful standards used in Appendix 1 include the Water Supply (Water Quality) Regulations 2016 (England and Wales), although these apply to treated water only.

The lakes are slightly alkaline due to the surrounding geology (the River Ver is chalk river), with average pHs observed from the 23rd August 2018 sampling of 7.71 for the two samples from the upper lake and 8.07 for the four samples from the lower lake. This was less alkaline than recorded in summer 2017 but marginally increased from November 2016 (see Appendix 1). The River Ver downstream of the lake (sample Ver 2) tended to be less alkaline than the lake in 2017, but was broadly similar (pH 8.11) to the lake in the 2018 sample. However, it should be noted that river pH is highly dynamic and is partly driven by hydrological conditions which can have a significant impact on acidity due to mobilisation of hydrogen ions from the surrounding catchment. All 2018 samples indicated that both lakes have moderate electrical conductivity values ranging from 390 µS/cm in the middle of the lower lake (VLW2) to 424 µS/cm above the bridge in the upper lake (VLW1a).

Water temperatures were warm at the time of sampling with an average of 19.9°C in the upper lake and 20.4°C in the lower lake.

Dissolved oxygen was markedly lower in the August 2018 lake samples when compared to all previous samples, averaging just 21% saturation in the upper lake and 65% saturation in the lower lake. This is much lower than all previous lake samples and is likely to be a consequence of the heavy algal growth which can utilise oxygen during the night when photosynthesis ceases but respiration continues. In addition, due to the overcast conditions on the morning of sampling there would have been limited contribution to dissolved oxygen concentrations from photosynthesis. Low lake levels and lack of through flow following the summer heatwave of 2018 would also have contributed to the low concentrations. This is also commensurate with the general trend for lake water quality to decline in summer when there is less flushing through with rainwater and increased evaporation. The low dissolved oxygen levels described above could impact upon organisms living within the lake.

The River Ver above the abstraction to the upper lake also had low dissolved oxygen levels (49% saturation) due to the low flow conditions and modifications to the channel that have resulted in an overdeep and overwide channel that lacks diversity and results in reduced velocity. However, the sample downstream of the lake had higher dissolved oxygen (86% saturation), and reflects introduction of oxygen through the pool and traverse fish pass that is located shortly upstream of the sampling location.

Biochemical Oxygen Demand (BOD) is a measure of oxygen used by micro-organisms to decompose organic matter and is often used to indicate organic pollution. The highest value was recorded in the upper lake (5.79 mg/l at VLW1), while the highest value in the lower lake was much lower at 1.6 mg/l at VLW5 (towards the lake centre). These values were noticeably reduced compared to August 2017 where 9.68 mg/l was recorded in the upper lake and 14.7 mg/l in the lower lake. BOD does not have a standard for lakes under the WFD, but the adjacent River Ver would fall within Good standards for BOD. Chemical Oxygen Demand (COD) indicates the total level of organic pollution including those compounds that cannot be broken down through biological activity. Higher values indicate potential for oxygen stress in warm weather, and in keeping with the dissolved oxygen results, described above, the COD was higher on average (34 mg/l) in the upper lake than lower lake (28 mg/l).

Alkalinity in the August 2018 samples averaged 112 mg/l in the upper lake and 137 mg/l in the lower lake. This was broadly in line with the sampling from August 2017 but lower than values recorded in November 2016.

Dissolved Organic Carbon (DOC) averaged 7.1 mg/l in the upper lake and 7.8 mg/l in the lower lake in August 2018. This was somewhat lower than values seen in August 2017, when the upper lake had 8.76 mg/l and the lower lake averaged 11.2 mg/l. DOC will largely be related to decomposition of organic material derived from terrestrial plants and soils, with leaf litter being particularly prevalent at the site. Total Organic Carbon (TOC) in August 2018 ranged from 8.7 mg/l in the upper lake (VLW1a) to 11.0 mg/l in the lower lake (VLW3). Both TOC and DOC were higher in the lake than adjacent river samples as would be expected due to leaf litter accumulation in the lake and lack of flushing.

Nitrate concentrations in both lakes were below the limits of detection, with higher values having been recorded on the earlier sampling visits in 2017 and 2016. Sources of nitrogen to the lake would include water entering via the inflow from the River Ver (potentially containing agricultural diffuse pollution) and wildfowl waste deposited directly into the lake. However, the low nitrate concentrations suggest rapid uptake of nitrates by algal and microbial communities within the lake. Nitrite is also below the limits of detection in the lower lake, but with one sample in the upper lake recording 5.8 µg/l (VLW1a). The low values suggest that nitrites are being quickly oxidised up to nitrates through the nitrogen cycle. Both nitrate and nitrite concentrations were higher in the adjacent river samples, where there would be less algal and microbial uptake in comparison to the lakes. Total nitrogen averaged 3.55 mg/l in the upper lake and 1.17 mg/l in the lower lake.

There is one ammoniacal nitrogen sample at the upper lake elevated above the WFD Good standard (>0.6 mg/l) in the upper lake (1.98 mg/l at VLW1a), which would fall within the Moderate WFD classification for lakes of this type and indicate organic pollution. All other samples are within Good standards, which is to some extent surprising given the high organic loading to the lake. Samples exceeded the WFD standard in both lakes in November 2016, but were all within Good standards in 2017.

Total phosphorus (TP) is elevated in both the upper lake (average 0.545 mg/l) and lower lake (average 0.138 mg/l). Eutrophic lakes typically have a mean average TP in the range of 0.035-0.1mg/l, and so TP elevated above this indicates that the lakes are into the hypereutrophic range, and algal blooms are expected. The Good standard for TP of 0.049 mg/l used here was estimated for Verulamium Lake using the UKTAG Guide to Lake Phosphorus standards (based on altitude, estimated depth, alkalinity and lake type). TP levels were greater in the upper lake during the 2018 August sampling and this was also the case during November 2016 sampling. This was not the case during the 2017 sampling, however. In contrast to TP, chlorophyll concentration was higher in the lower lake (average 15.6 mg/l) than upper lake (10.95 mg/l) in 2018, with both values being in the range generally considered to be mesotrophic (8-25 µg/l). This is lower than might be expected given the elevated TP values.

Sulphate values were relatively low across both lakes in August 2018 and were in the range 10-11 mg/l, and were approximately halved in comparison to samples taken in November 2018 when all values surpassed 20 mg/l across both lakes. The low levels are within screening values and limits potential for hydrogen sulphide formation in areas of deeper, anaerobic silt which could lead to foul odours. However, odour issues could still occur during warm conditions when silt is exposed, and this was noticed when on site.

Silicate values vary in the August 2018 samples from below the limits of detection in the upper lake (VLW1) to 9.79 mg/l in the centre portion of the lower lake (VLW5), and the higher values would stimulate algal growth in appropriate conditions. Cyanide was below the limits of detection for all lake and river samples.

Heavy metals were generally within the WFD standards (Appendix 1) with the exception of lead at sampling locations VLW3 (2.71 µg/l), VLW4 (2.14 µg/l) and VLW5 (2.69 µg/l) within the lower lake, as well as in the River Ver below the lake (5.02 µg/l at Ver 2). The upper lake had lead concentrations below the limits of detection. This is an improvement for the upper lake against November 2016 and August 2017 when this also breached the EQS. The lower lake also failed against the lead WFD standard in August 2017, when values were as high as 8.29 µg/l. Lead is commonly sourced from road runoff and it is considered that it could have accumulated in the lake after entering via the inflow from the River Ver. Values in 2017 and 2018 were highest near the outflow of the lake, suggesting that lead may be gradually moving through the system and will be flushed through to the downstream river to some extent when the lake overtops. Similarly, lead concentration was greatest at southern extent of the lower lake in 2018 (2.71 µg/l at VLW3).

Polycyclic Aromatic Hydrocarbons (PAHs) are commonly sourced from incomplete combustion of organic matter (e.g. fuel, wood burning, biofuels). In the recent August 2018 sampling, only fluoranthene in the lower lake surpassed EQS, averaging 0.0127 µg/l against a standard of 0.0063 µg/l. However, not all of the laboratory limits of detection were low enough to determine failure against EQS. Despite this, greater numbers of failures for PAHs against EQS were noted in August 2017 in both lakes (Benzo(a)pyrene, Benzo(k)fluoranthene, Benzo(g,h,i)perylene, Fluoranthene) and in November 2016 at the upper lake (Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Benzo(g,h,i)perylene, Fluoranthene) .

Suspended solid concentrations were broadly similar in the upper lake in August 2018 (average 20.96 mg/l) compared to August 2017 (19.1 mg/l). On the other hand, suspended solids in the lower lake were much reduced in August 2018 (6.00 mg/l) in comparison to August 2017 (47.25 mg/l). Suspended solid concentrations generally increase in warmer weather with increased activity of microflora in the lake. Other sources include sediment bioturbation by fish and waterfowl, fine organic effluent in the lake from waterfowl excreta and inflows from the upstream River Ver. Suspended solid concentrations in the River Ver were much lower upstream of the Verulamium lake inflow (3.37 mg/l) than in the sample below the lake (49.9 mg/l), indicating a source of sediment disturbance or input between the two locations.

6. Bacteriological Quality

The WFD does not include water quality standards for faecal indicator organisms and so the Bathing Water Directive (2006/7/EC) standards were used for screening (Appendix 1). The lake water samples all surpassed or were equal to 'excellent quality' standards for inland waters for *Intestinal enterococci* (<200 CFU/100 ml, based on 95th percentile) and 'good' standards for *Escherichia coli* (<1000 CFU/100 ml, based on 95th percentile). *E.coli* also meets the standards for the human consumption of shellfish (so long as subsequent purification is undertaken), as described in Regulation (EC) No 854/2004 on rules on products of animal origin for human consumption (standard <4600/100 ml). Thus, while the large wildfowl population on the lake could be a significant source of faecal bacteria, these samples do not suggest that concentrations are so high as to breach standards used for bathing waters or shellfish consumption, for these parameters. Highest *E.coli* values were recorded in the lower lake between the two islands (550 CFU/100ml in VLW5) and adjacent to the lake outfall (280 CFU/100ml in VLW3). All *E. coli* concentrations were significantly reduced across both lake sections in comparison to concentrations recorded in November 2016 (>900 CFU/100ml). Peak *I. enterococci* values were recorded between the two islands (200 CFU/100ml at VLW5), and in all cases values were elevated in comparison with concentrations from November 2016.

Clostridium perfringens is not included in the Bathing Water Directive, but is a Schedule 2 indicator under the Water Supply (Water Quality) Regulations 2000, meaning that it requires monitoring at the point where water leaves a treatment works or at supply points rather than within inland waters. It should not exceed 0 CFU/100ml upon leaving a treatment works. It is unsurprising that *C. perfringens* is present in Verulamium Lake given the abundance of wildfowl and that the water is untreated. Lower values were recorded in the upper lake in August 2018 (92 CFU/100ml) in comparison to November 2016 (143 CFU/100ml). Despite this, there is clearly a high degree of spatial variability with an adjacent sample in the upper lake in August 2018 being below the limits of detection. All values in the lower lake were higher in August 2018 than those recorded in November 2016, but again are spatially variable.

Comparison of the lake faecal indicator results with the adjacent results from the River Ver shows that concentrations are much reduced in the lake in comparison to the river for *E Coli* and *I. enterococci*. This is the case at both the upstream and downstream River Ver sampling locations. Values in the river would be within the 'poor' classification under the Bathing Waters Directive. Due to low flows in the river, water from it was not entering the lake on the day of sampling. Given the dry summer experienced in 2018 this is also likely to have been the case throughout most of the summer. Thus the lake would not have been subject to bacterial sources that are impacting upon the river itself. These sources could include livestock within the upstream catchment, permitted discharges (e.g. from sewage treatment works), unpermitted discharges or sewer misconnections. *C. perfringens* is elevated in the River Ver downstream of the lake, but the upstream sample is within the range seen in the lake, and indicates that the bacterial source is located between the two river sampling points. As the lake outfall was not flowing at the time of sampling, the lake is unlikely to be the source and the source may influence the lake and river.

7. Summary

Water quality sampling of the Verulamium Lake was undertaken on 23 August 2018. In total, six samples were collected from across the lake with two further samples collected from the adjacent River Ver. The data has been analysed against relevant EQS and compared against previous water quality surveys undertaken in 2016 and 2017.

Verulamium Lake, including the upper and lower lakes, continues to be under pressure from nutrient enrichment, eutrophication and algal blooms. Algae were visibly abundant during the sampling visit, and are most likely contributing to the significantly reduced dissolved oxygen concentrations in both lakes in comparison to previous years. High total phosphorus concentrations were recorded, particularly in the upper lake, and would be contributing to the algal bloom. Nitrates were at lower concentrations than previously recorded, suggestive of greater uptake by the abundant algal populations. Metals and PAHs were generally within the EQS, with the exceptions of lead and fluoranthene in the lower lake.

Despite the abundance of wildfowl known to use the lake, the faecal indicators *E coli* and *I. enterococci* were within Good or Excellent standards for Bathing Water Quality and were reduced in concentration in comparison to samples from November 2016. Water samples from the adjacent River Ver had markedly higher values of *E Coli* and *I. enterococci* than the lake. Concentrations of C. *perfringens* were higher in the lower lake in 2018 than 2016, but reduced in the upper lake.

Overall, the lake as a whole appears to be under the same pressures as previously reported, particularly nutrient enrichment and eutrophication. While some notable differences have been observed between samples from the various years, these are most probably related to seasonal differences (e.g. comparing autumn (November) to summer (June/ August) samples), variable inputs from the River Ver due to differing hydrological flows at the time of sampling, and the particularly low lake levels in 2018 resulting from the unusually warm summer.

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Appendix 1 Results of the water quality analysis undertaken on August 23 2018 alongside previous data collected in 2017 and 2018. Screening values are given where possible, and green shading indicates that the sample is below the screening value, orange indicates that the screening value is exceeded.

Analyte	Units	Limits of Detection 2016 analysis	Limits of detection 2018 analysis	Screening Value	Screening Source	14th November 2016 (AECOM sampling)			14th June 2017 (Environment Agency sampling)				3rd August 2017 (Environment Agency Sampling)				23rd August 2018 (AECOM sampling)							
						VLW1 (upper lake)	VLW2 (lower lake)	VLW3 (lower lake)	(River) Ver downstream of Lake	VLW1a (upper lake)	VWL2 (lower lake)	VLW3 (lower lake)	(River) Ver downstream of Lake	VLW1a (upper lake)	VWL2 (lower lake)	VLW3 (lower lake)	(River) Ver 1 upstream of boating lake	VLW1	VLW1a	VLW2	VLW3	VLW4	VLW5	(River) Ver 2 downstream of boating lake
Dissolved Oxygen	%		0	River 60% (for Good WFD status, 10th percentile)		73	72	69	70.8	153.7	147.7	203	46.4	130.3	103.2	108	49	17	25	73	67	61	58	86
Dissolved Oxygen	mg/L		0	Lake - 6 (for Good WFD status, mean July/August)		9	8.9	8.5	6.72	12.87	12.95	17.4					4.8	1.6	2.4	6.5	6	5.5	5.2	8.3
BOD 5 Day ATU	mg/l	1	1	River - 5 (for Good WFD status, 90th percentile)		2.41	<1	<1					<1	9.68	8.93	14.7	<1.00	5.79	<2.75	<2.75	<2.75	1.53	1.6	1.84
COD	mg/l		10														10	38	30	28	29	27	28	28
Cyanide as CN	mg/l	0.05	0.005	0.001	WFD Eng/Wales 2015	<0.05	<0.05	<0.05					<.005	<.005	<.005	<.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Carbon, Organic, Dissolved as C :- {DOC}	mg/l	0.2	0.2			3.99	3.87	4.98	1.68	5.32	7.54	7.65	3.77	8.76	11.3	11	2.03	7.09	7.11	7.94	7.75	7.8	7.65	2.02
Carbon, Organic Total as C:- (TOC)	mg/l		0.7														3.5	9.7	8.7	9.4	11	10.2	9.2	2.6
Alkalinity to pH 4.5 as CaCO3	mg/l	5	5			210	180	180	264	75	104	106	174	144	123	127	276	50	174	135	138	137	137	275
Ammoniacal Nitrogen as NH_3	mg/l	0.003		0.6	WFD Eng/Wales 2015 (lake only)	0.873	0.614	0.578					0.0316	0.0219	0.0023	0.0027								
Ammoniacal Nitrogen, Filtered as N	mg/l	0.003	0.03	0.6	WFD Eng/Wales 2015 (lake only)				0.0159	0.0499	0.0116	0.0551	0.0325	0.0056	<.002	<.002	<0.0300	<0.0300	1.98	0.092	0.129	0.116	0.141	0.04
Nitrite as N	mg/l	0.004	0.004	0.5	WS Regs 2016 (Eng/Wal)	0.187	0.077	0.073					0.0232	0.00107	<.001	<.001	0.0101	<0.004	0.0058	<0.004	<0.004	<0.004	<0.004	0.0116
Nitrate as N	mg/l	0.3	0.2	50	WS Regs 2016 (Eng/Wal)							c	1.77	0.00403	<.004	<.004	1.76	<0.200	<0.194	<0.200	<0.200	<0.200	<0.200	1.4
Nitrate as NO_3	mg/l	0.3		50	WS Regs 2016 (Eng/Wal)	10.5	2.11	1.81																
Nitrogen : Total Inorganic as N	mg/l	0.2	0.23			3.14	1.01	0.908									<1.80	<0.230	<2.18	<0.292	<0.329	<0.316	<0.341	1.45
Nitrogen, Total as N	mg/l		0.2						4.07	1.3	0.9	0.97	2.23	2.05	2.61	3.25	2	4.06	3.04	1.2	1.16	1.12	1.2	1.92
Nitrogen, Total Oxidised as N	mg/l		0.2										1.79	0.0051	<.005	<.005	1.77	<0.200	<0.200	<0.200	<0.200	<0.200	<0.200	1.41
Nitrogen, Total Oxidised, Filtered as N	mg/l								3.83	0.0852	0.0072	0.0163	1.81	0.0092	<.005	<.005								
Orthophosphate, reactive as P	mg/l	0.01	0.01			<0.02	0.0225	0.033	0.0285	0.0158	0.126	0.125	0.0539	0.0718	0.174	0.164	0.03	<0.0100	0.379	0.091	0.095	0.094	0.099	0.044
Orthophosphate, filtered as P	mg/l		0.01														0.035	0.346	0.343	0.083	0.09	0.089	0.096	0.043
Total Phosphorus	mg/l	0.02	0.01	0.049 (est.)	Lake Phosphorus Calculator (lake only)	0.0889	<0.02	<0.02	0.0524	0.106	0.166	0.165	0.0741	0.285	0.554	0.647	0.0393	0.648	0.441	0.147	0.133	0.128	0.144	0.136
Sulphate as SO4	mg/l	2		250	WS Regs 2016 (Eng/Wal)	20.5	28.3	27.7					17.5	<10	<10	<10	18.5	10.1	<10	10	11	10.5	10.9	18.4
Sulphate, Dissolved as SO4	mg/l		10	250	WS Regs 2016 (Eng/Wal)												17.8	<10	<10	<10	10.6	10.3	10.7	17.7
Colour, Filtered HAZEN	HAZEN	-		-					5	13	17	17	12	20	20	20								
Temperature	Deg Celsius	-		-					16.8	23.6	21.9	22.5	15.9	19.4	18.2	18.7		20.2	19.5	20.4	20.2	20.3	20.7	16.8
Conductivity at 20C	uS/cm	10	10			513	430	430	679	277	327	322	592	381	347	347	581	426	424	390	398	395	403	576
pH	pH Units	0.05	0.05			7.8	7.86	7.85	7.89	9.44	9.58	9.85	7.53	8.93	9.64	9.67	8.02	7.68	7.74	8.08	8.03	8.1	8.06	8.11
Solids, Suspended at 105 C	mg/l	2	3			<9	<9	<9					3.7	19.1	40.4	54.1	3.37	36.1	5.62	4.12	6.32	5.27	8.27	49.9

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Appendix 1 (continued) Results of the water quality analysis undertaken on August 23 2018 alongside previous data collected in 2017 and 2018. Screening values are given where possible, and green shading indicates that the sample is below the screening value, orange indicates that the screening value is exceeded.

Analyte	Units	Limits of Detection 2016 analysis	Limits of detection 2018 analysis	Screening Value	Screening Source	14th November 2016 (AECOM sampling)			14th June 2017 (Environment Agency sampling)				3rd August 2017 (Environment Agency Sampling)				23rd August 2018 (AECOM sampling)							
						VLW1 (upper lake)	VLW2 (lower lake)	VLW3 (lower lake)	(River) Ver downstream of Lake	VLW1a (upper lake)	VWL2 (lower lake)	VLW3 (lower lake)	(River) Ver downstream of Lake	VLW1a (upper lake)	VWL2 (lower lake)	VLW3 (lower lake)	(River) Ver 1 upstream of boating lake	VLW1	VLW1a	VLW2	VLW3	VLW4	VLW5	(River) Ver 2 downstream of boating lake
Arsenic Dissolved	ug/l	0.51	1	10	WS Regs 2016 (Eng/Wal)	0.659	0.62	0.597					<1	1.02	2.84	2.67	<1	<1	<1	<1	<1	<1	<1	<1
Arsenic	ug/l	0.51	1	10	WS Regs 2016 (Eng/Wal)												<1	<1	<1	<1	1.05	<1	1.03	<1
Boron, Dissolved	ug/l	<5	100	1000	WS Regs 2016 (Eng/Wal)	29.9	28.5	28.4					<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
Boron	ug/l	<5	100	1000	WS Regs 2016 (Eng/Wal)												<100	<100	<100	<100	<100	<100	<100	<100
Lead, Dissolved	ug/l	0.1	2	1.2	WFD Eng/Wales 2015	0.206	0.765	0.612					0.385	0.347	2.68	0.916	<2	<2	<2	<2	<2	<2	<2	<2
Lead	ug/l	0.1	2	1.2	WFD Eng/Wales 2015	1.46	0.806	0.603					2.95	1.41	7.02	8.29	<2	<2	<2	<2	2.71	2.14	2.69	5.02
Aluminium, Dissolved	ug/l	2	10	200	WS Regs 2016 (Eng/Wal)	3.92	5.68	<2									<10	<10	<10	<10	<10	<10	<10	<10
Aluminium	ug/l	50	10	200	WS Regs 2016 (Eng/Wal)	178	<50	<50									17.3	34.3	34.1	16.9	24.9	17.9	25.1	146
Cadmium, Dissolved	ug/l	0.08	0.1	0.25	WS Regs 2016 (Eng/Wal)	<0.08	<0.08	<0.08					<.01	<.01	<.01	<.01	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Cadmium	ug/l	0.5	0.1	0.25	WS Regs 2016 (Eng/Wal)	<0.5	<0.5	<0.5					0.0269	<.01	0.0244	0.0349	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Chromium Hexavalent, Dissolved	ug/l	0.03		3.4	WFD Eng/Wales 2015	<0.03	<0.03	<0.03																
Chrimium Hexavalent	ug/l	0.03	3	3.4	WFD Eng/Wales 2015												<3	<3	<3	<3	<3	<3	<3	<3
Chromium, Dissolved	ug/l	1.2	0.5	1.2	WS Regs 2016 (Eng/Wal)	<1.2	<1.2	<1.2					<.5	<.5	<.5	<.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Chromium	ug/l	3	0.5	3.4	WS Regs 2016 (Eng/Wal)	<3	<3	<3					0.74	<.5	<.5	<.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Copper, Dissolved	ug/l	0.85	1	1	WFD Eng/Wales 2015	<0.85	<0.85	<0.85					4.27	0.637	2.37	1.87	<1	1.45	1.3	<1	<1	1.21	<1	<1
Copper	ug/l	4	1	1 (bioavailable)	WFD Eng/Wales 2015	<4	<4	<4					5.2	1.08	2.59	2.63	<1	1.83	1.69	<1	1.07	<1	<1	2.42
Iron, Dissolved	ug/l	0.019	30	1000	WFD Eng/Wales 2015	28.8	23.3	29.8									<30	121	161	71	66.1	65.7	86.8	39.1
Iron	ug/l	24	30	1000	WFD Eng/Wales 2015	166	39.6	31.3					188	162	374	448	44	268	309	114	149	120	169	282
Manganese, Dissolved	ug/l	0.76	10	123	WS Regs 2016 (Eng/Wal)	9.68	9.13	8.06									<10	50.5	51.4	12.3	18	15	20.9	13.3
Manganese	ug/l	0.5	10	123 (bioavailable)	WFD Eng/Wales 2015	14.8	6.69	6.43					<10	19.7	29.2	30.9	<10	53.6	55.9	16.6	24.8	19.8	25.6	17.2
Mercury, Dissolved	ug/l	0.01	0.01	0.07	WFD Eng/Wales 2015	<0.01	<0.01	<0.01									<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Mercury	ug/l	0.01	0.01	0.07	WFD Eng/Wales 2015	<0.02	<0.02	<0.02									<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Nickel Dissolved	ug/l	0.5	1	4	WFD Eng/Wales 2015												<1	<1	<1	<1	<1	<1	<1	<1
Nickel	ug/l	0.5	1	4	WFD Eng/Wales 2015	2.74	1.67	1.26					0.86	0.859	1.39	1.44	<1	<1	1.02	<1	<1	<1	<1	<1
Sodium	mg/l	<0.076	2	200	WS Regs 2016 (Eng/Wal)	21.8	14	14					40.3	19.8	20.9	20.9	16.2	20.6	20.9	30.5	29.8	30	30.3	17

Appendix 1 (continued) Results of the water quality analysis undertaken on August 23 2018 alongside previous data collected in 2017 and 2018. Screening values are given where possible, and green shading indicates that the sample is below the screening value, orange indicates that the screening value is exceeded.

Analyte	Units	Limits of Detection 2016 analysis	Limits of detection 2018 analysis	Screening Value	Screening Source	14th November 2016 (AECOM sampling)			14th June 2017 (Environment Agency sampling)				3rd August 2017 (Environment Agency Sampling)				23rd August 2018 (AECOM sampling)							
						VLW1 (upper lake)	VLW2 (lower lake)	VLW3 (lower lake)	(River) Ver downstream of Lake	VLW1a (upper lake)	VWL2 (lower lake)	VLW3 (lower lake)	(River) Ver downstream of Lake	VLW1a (upper lake)	VWL2 (lower lake)	VLW3 (lower lake)	(River) Ver 1 upstream of boating lake	VLW1	VLW1a	VLW2	VLW3	VLW4	VLW5	(River) Ver 2 downstream of boating lake
Zinc, Dissolved	ug/l	3	5	10.9	WFD Eng/Wales 2015	4.47	3.81	1.95									<5	<5	<5	<5	<5	<5	<5	<5
Zinc	ug/l	0.024	5	10.9	WFD Eng/Wales 2015	5.38	3.78	<3					8.46	0.87	1.97	0.503	<5	<5	<5	<5	<5	<5	<5	8.18
Selenium Dissolved	ug/l		1														<1	<1	<1	<1	<1	<1	<1	<1
Selenium	ug/l		1														<1	<1	<1	<1	<1	<1	<1	<1
Vanadium, Dissolved	ug/l		2.16	86	USEPA RSL (tapwater)												<2	<2	<2	2.16	2.21	2.11	2.13	<2
Vanadium	ug/l		2.1	86	USEPA RSL (tapwater)												<2	<2	<2	2.1	2.28	2.11	2.25	<2
Barium, Dissolved	ug/l		10	700	WHO DWG 2011												42	53.4	54.6	34	33.5	35	36.4	41.8
Barium	ug/l		10	700	WHO DWG 2011												43	57.3	57.6	35	36.4	36	37.8	46.3
Calcium, Dissolved	mg/l		1														118	69.6	69.3	55	56.5	55.8	58.3	118
Calcium	mg/l		1														122	70	71	57.5	59	57.6	59.4	125
Lithium, Dissolved	ug/l		100	40	USEPA RSL (tapwater)												<100	<100	<100	<100	<100	<100	<100	<100
Lithium	ug/l		100	40	USEPA RSL (tapwater)												<100	<100	<100	<100	<100	<100	<100	<100
Magnesium, Dissolved	mg/l		0.3														2.06	2	1.99	2.19	2.21	2.22	2.24	2.06
Magnesium	mg/l		0.3														2.13	2.06	2.05	2.27	2.3	2.28	2.28	2.23
Potassium, Dissolved	mg/l		0.1														1.1	4.05	4.06	2.02	2.24	2.19	2.25	1.15
Potassium	mg/l		0.1														1.13	4.1	4.09	2.08	2.27	2.2	2.3	1.23
Sodium, Dissolved	mg/l		2	200	WS Regs 2016 (Eng/Wal)												15.5	20.2	20.5	29.3	28.5	28.9	28.8	16.2
Strontium, Dissolved	ug/l		20	120	USEPA RSL (tapwater)												270	200	200	195	196	198	199	272
Strontium	ug/l		20	120	USEPA RSL (tapwater)												276	202	203	199	202	201	202	280

AECOM

Appendix 1 (continued) Results of the water quality analysis undertaken on August 23 2018 alongside previous data collected in 2017 and 2018. Screening values are given where possible, and green shading indicates that the sample is below the screening value, orange indicates that the screening value is exceeded.

Analyte	Units	*Limits of Detection 2016 analysis*	*Limits of detection 2018 analysis*	*Screening Value*	Screening Source	14th November 2016 (AECOM sampling)			14th June 2017 (Environment Agency sampling)				3rd August 2017 (Environment Agency Sampling)				23rd August 2018 (AECOM sampling)							
						VLW1 (upper lake)	VLW2 (lower lake)	VLW3 (lower lake)	(River) Ver downstream of Lake	VLW1a (upper lake)	VWL2 (lower lake)	VLW3 (lower lake)	(River) Ver downstream of Lake	VLW1a (upper lake)	VWL2 (lower lake)	VLW3 (lower lake)	(River) Ver 1 upstream of boating lake	VLW1	VLW1a	VLW2	VLW3	VLW4	VLW5	(River) Ver 2 downstream of boating lake
PAH																								
Anthracene	ug/l	0.015	0.1	0.1	WFD Eng/Wales 2015	<0.015	<0.015	<0.015					<.01	<.01	<.01	<.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Benzo(a)anthracene	ug/l	0.017	0.1	3.5	AECOM DWG (WHO method)	0.0456	<0.017	<0.017					<.01	<.01	0.011	<.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Benzo(a)pyrene	ug/l	0.009	0.1	0.00017	WFD Eng/Wales 2015	0.0352	<0.009	<0.009					0.00062	0.00288	0.0338	0.0201	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Benzo(b)fluoranthene	ug/l	0.023	0.1	0.017	WFD Eng/Wales 2015	0.0578	<0.023	<0.023					0.00128	0.00376	0.0466	0.033	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Benzo(k)fluoranthene	ug/l	0.027	0.1	0.017		0.0578	<0.023	<0.023					0.00037	0.00177	0.0196	0.015	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Benzo(g,h,i)perylene	ug/l	0.016	0.1	0.0082	WFD Eng/Wales 2015	0.0462	<0.016	<0.016					0.00073	0.00583	>.05	0.0461	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Indeno(1,2,3-cd)pyrene	ug/l	0.014	0.1			0.0303	<0.014	<0.014					0.00073	0.00659	>.05	0.0482	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Chrysene	ug/l	0.013	0.1		WFD Eng/Wales 2015	0.0465	<0.013	<0.013					<.01	<.01	0.0108	0.0102	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Fluoranthene	ug/l	0.017	0.1	0.0063	WFD Eng/Wales 2015	0.0714	<0.017	<0.017					0.0029	0.0164	0.0355	0.0281	<0.01	<0.01	<0.01	0.015	0.0116	0.0122	0.0118	0.0165
Naphthalene	ug/l	0.1	0.1	2	WFD Eng/Wales 2015	<0.1	<0.1	<0.1					<.1	<.1	<.1	<.1	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Phenanthrene	ug/l	0.01	0.1	4	AECOM DWG (WHO method)	0.0566	<0.022	<0.022					<.01	0.0137	<.01	<.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Pyrene	ug/l	0.01	0.1	9	AECOM DWG (WHO method)	0.0724	<0.015	<0.015					<.01	<.01	0.0138	0.0118	<0.01	<0.01	<0.01	0.0104	<0.01	<0.01	<0.01	0.0149
Acenaphthene	ug/l		0.1	18	AECOM DWG (WHO method)												<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Acenaphthylene	ug/l		0.1	18	AECOM DWG (WHO method)												<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Benzo(e)pyrene	ug/l		0.1														<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Dibenzo(ah)anthracene	ug/l		0.1	0.07	AECOM DWG (WHO method)												<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Fluorene	ug/l		0.1	12	AECOM DWG (WHO method)												<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Perylene	ug/l		0.1														<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
PAH Total	ug/l																<0.160	<0.160	<0.160	<0.165	<0.162	<0.162	<0.162	<0.171
Chlorine : Total Available as Cl2	mg/l		0.05	0.002	WFD Eng/Wales 2015												<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Chloride	mg/l		1	250	WS Regs 2016 (Eng/Wal)												29	<1.00	36.3	49.9	50.6	50.5	50.5	29.6
Silicate, reactive as SiO2	mg/l		0.2														15	<0.200	6.78	8.87	9.43	9.15	9.79	14.9
Chlorophyll, Acetone Extract	ug/l		0.5														1.5	15.8	6.1	10.9	15.3	17.5	18.7	2.6
Escherichia coli	CFU/100ml	1	1	<1000 CFU/100 ml (95th percentile)	Bathing Water Directive 2006	928	930	928									1545	126	21	47	280	153	550	1273
Intestinal Enterococci	CFU/100ml	1	1	<200 CFU/100 ml (95th percentile)	Bathing Water Directive 2006	24	10	23									3200	56	87	42	79	42	200	3800
Clostridium perfringens	CFU/100ml	1	1			143	22	77									144	<22	92	220	136	90	165	773

APPENDIX F – Lake Studies to Inform Review of Shortlisted Options

Lake Studies to Inform Review of Shortlisted Options

Introduction

This note presents the results of the additional lake studies that have been undertaken in order to inform the appraisal of the potential lake restoration and improvement options.

Unlike the river only options, potential lake measures have not been shortlisted.

The following have been undertaken and presented within this review:

- Bathymetry data of the lake has been collected and reviewed. This has identified areas prone to sedimentation;
- Groundwater levels in the vicinity of the lake have been reviewed. This has informed the potential for the lake to be sourced from groundwater, that is likely to be of better quality than the river which currently provides a water supply to the lake;
- Consideration of the flow of water through the lake and water residence time within it;
- Review of water quality sampling (sampling undertaken by the Environment Agency); and
- Review of sediment quality sampling.

Lake bathymetry and depth of sediment

Overview

The Environment Agency undertook a programme of bathymetry sampling throughout the lake on the 3rd May 2017. This involved taking hard and soft bed measurements at approximately 20m intervals throughout the lake. Sampling was undertaken by boat, withGPS and dGPS used to derive latitude and longitudes, and to inform depths.

Data review

A review of the information found all surfaces to be projected appropriately and observed elevations were sufficient relative to the LiDAR.

The soft bed TIN appeared to be off in the top section of the larger lake where it has lower elevation values compared to the hard bed TIN. On review the received soft bed layer did not include the bridge (see Figure 1 below) between the two lakes. Following discussions with Jack Herriot of the Environment Agency, this was inserted into the soft bed TIN layer.

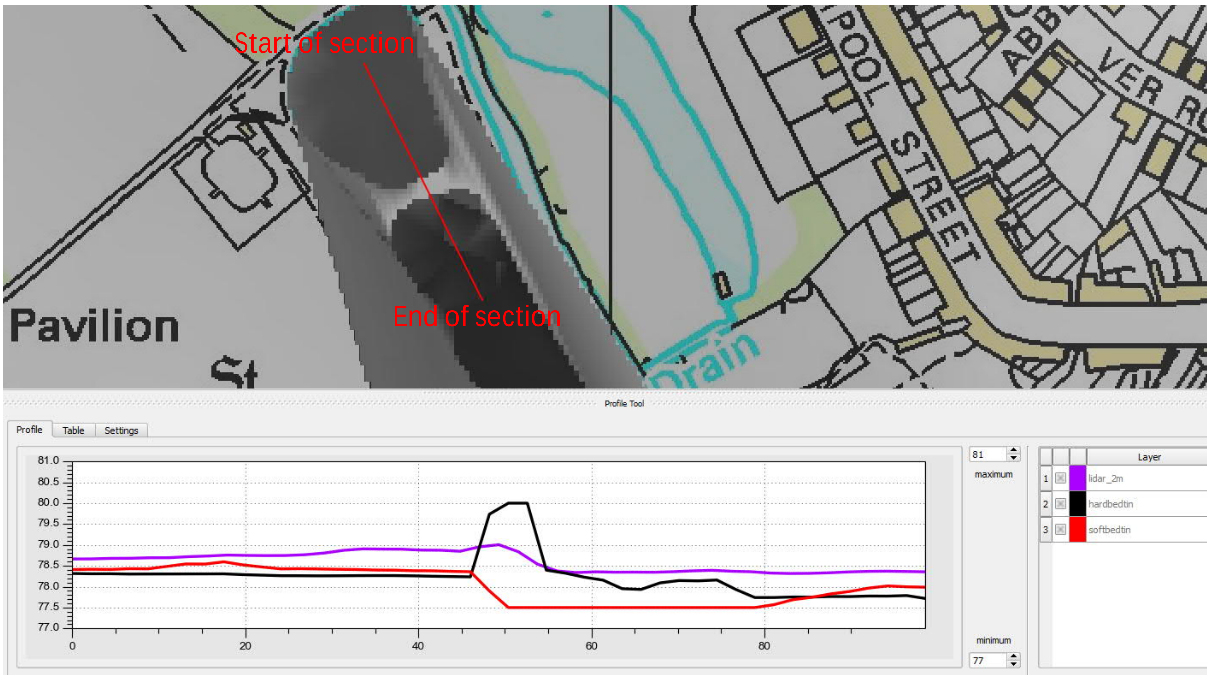

Figure 1 Illustration of error in received soft bed TIN layer (absence of bridge)

By reviewing the information it was possible to establish the lake bathymetry at the time of sampling (depth to soft bed/ sediments noting that sediments can be moved by the flow of water and are intermittently dredged by St Albans District Council). Soft bed and hard bed elevations are presented in Figure 2 below. Soft bed elevations at the margins of the upper lake were found to be generally between 78.7 and 78.9 mAOD while in the centre they were generally between 78.4 and 78.6 mAOD. Soft bed elevations in the northern half of the lower lake were found to be between 77.9 and 78.0 mAOD and in the southern half they were between 77.8 and 77.9 mAOD. This suggests there is little variation in bed levels within the lake (i.e. it is relatively flat) with a slight reduction in elevation with distance down the catchment.

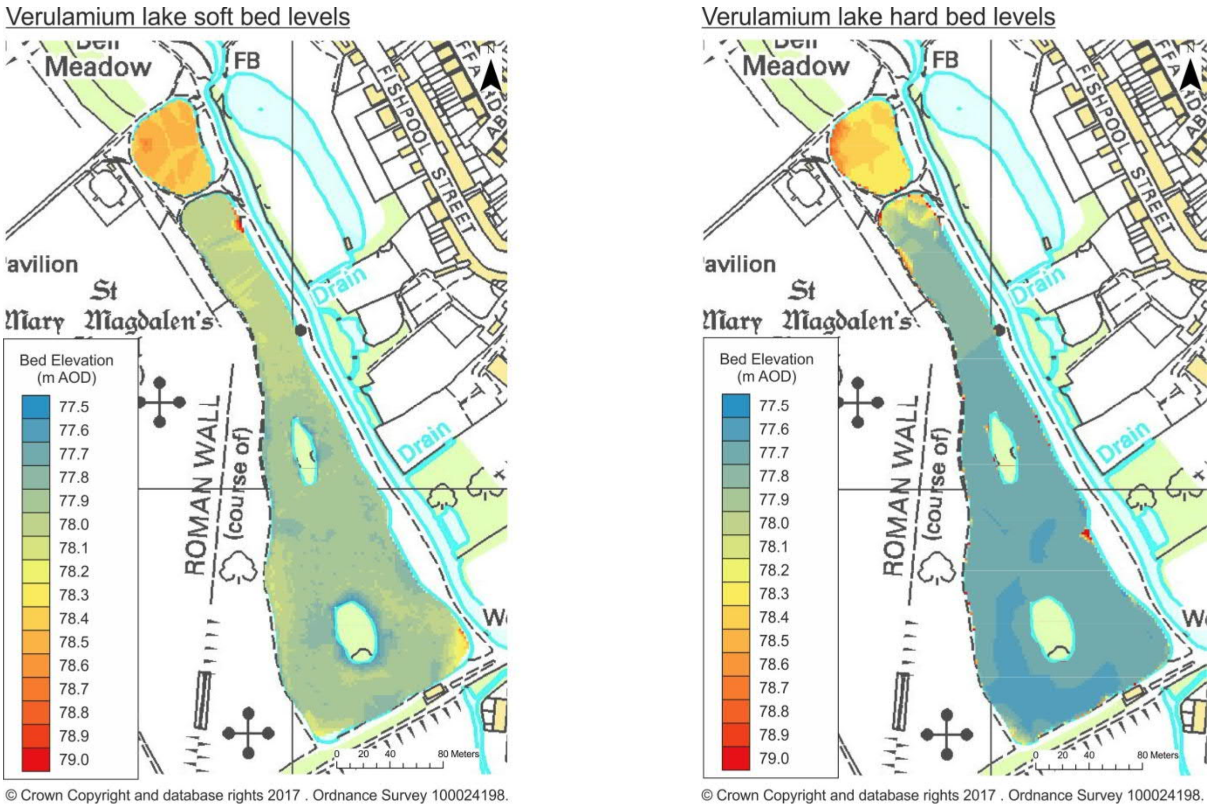

Figure 2 Illustration of error in received soft bed TIN layer (absence of bridge)

Hard bed elevations in the upper lake were found to be generally between 78.2 and 78.4 mAOD. Hard bed elevations in the northern half of the lower lake were found to be around 77.7 mAOD and in the southern half they were around 77.6 mAOD.

By subtracting the hard bed levels from the soft bed levels it was also possible to establish the depth of sediments, at the time of sampling. The results of these are presented in Figure 3 below.

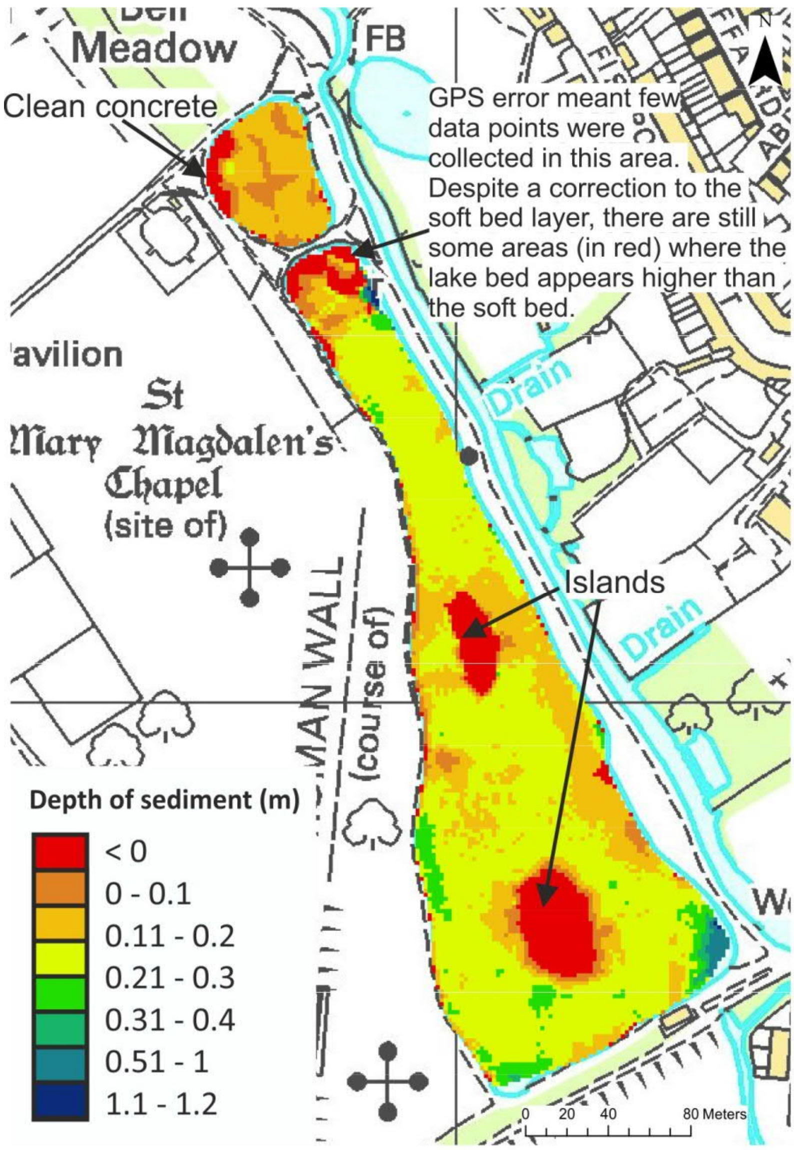

Figure 3 Depth of sediments determined by subtracting hard bed from soft bed elevations

Negative values are apparent at the top of the lower lake. This likely reflects an imperfect correction as a result of inserting the bridge into the soft bed TIN, and the surveyors not being able to sample at shallower depths. The north east area at the top of the lower lake is essentially land, with the sediment that has gathered in this area now being vegetated.

Aside from this area, depths of sediment were found to be generally greater in the upper lake where depths range from 0.1-0.65 m. In the lower lake sediment depths range from 0.1-0.4 m with some isolated deeper sections (particularly in the south eastern corner of the larger lake with sediment depths of up to 1m). On average, sediment deposition was found to be approximately 0.25 m thick in the larger lower lake and 0.4 m thick in the smaller upper lake. The upper lake has an area of around 4,300 m^2 so the approximate volume of sediment in it, when sampled on 3rd May 2017, was 1,720 m^3. The lower lake has an area of around 33,600 m^2 so the approximate volume of sediment in it, when sampled on 3rd May 2017, was 8,400 m^3.

Groundwater Review in and around Verulamium Lake

Review of Groundwater levels at Abbey Mill OBH

Approximately monthly groundwater levels for Abbey Mill OBH were obtained for the period November 1991 to March 2017. These have been plotted against flow in the Ver (at Hansteads, downstream of St Albans and just upstream of the confluence with the River Colne) in Figure 4 below. Groundwater levels are presented with regard to ground levels (m below ground level (bgl)), which were found to be 79.85m AOD at the borehole (based on LiDAR data).

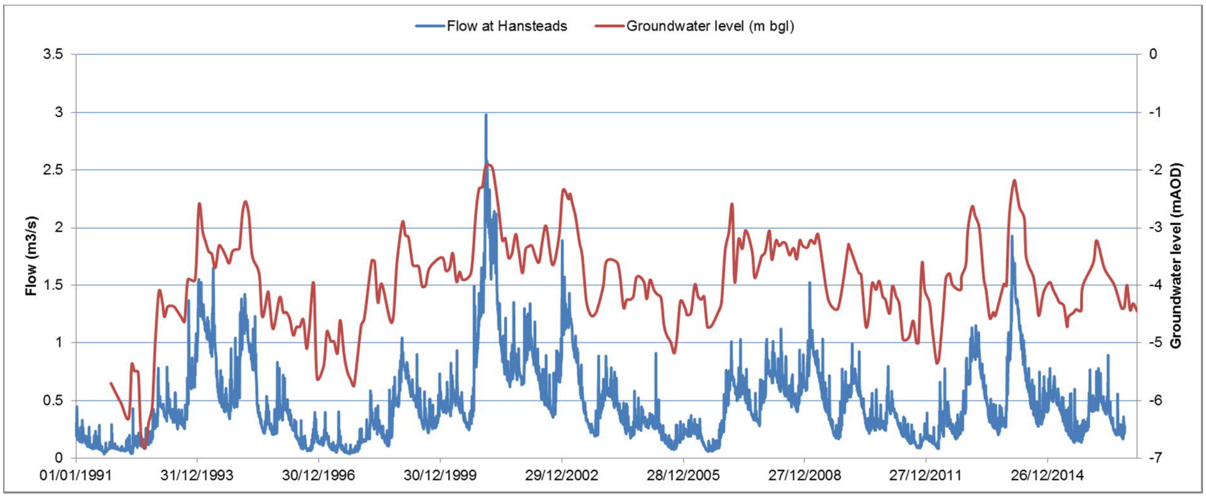

Figure 4 Time series of flow in the Ver and groundwater levels at Abbey Mill OBH (with respect to ground level)

Table 1 below also indicates groundwater level statistics for the Abbey Mill OBH record.

Table 1 Groundwater level statistics (with regard to groundwater level)

Statistics	Groundwater level (m below ground level)
Minimum	-6.83
Level exceeded for 95% of the time	-5.47
Level exceeded for 70% of the time	-4.40
Level exceeded for 50% of the time	-3.98
Level exceeded for 20% of the time	-3.30
Level exceeded for 10% of the time	-3.02
Maximum	-1.94

This shows that groundwater levels are typically 4m (~76 mAOD) bgl at the borehole and that they have been observed to fall to almost 7m bgl (~73 mAOD). With regard to high groundwater levels, they have been found to only be less than 3m bgl (~77 mAOD) for 10% of the time and the highest observed level was just under 2m bgl (~78 mAOD).

Potential groundwater levels under Verulamium Lake

Land elevations in and around the Abbey Mill OBH and Verulamium Lake, from LiDAR data, are indicated in Figure 5 below. Hard bed elevations in the northern half of the lower lake were found to be around 77.7 mAOD and in the southern half they were around 77.6 mAOD (discussed above in the *Lake Bathymetry and Depth of Sediment* section). Groundwater levels under the lake would be expected to be lower than they are at the borehole, with the borehole being nearer the valley side and the lake being on the valley floor (the lowest point and original discharge point for groundwater), although the magnitude of any difference is not known. The above suggests that groundwater levels would be at least 1m below hard bed levels for at least 90% of the time.

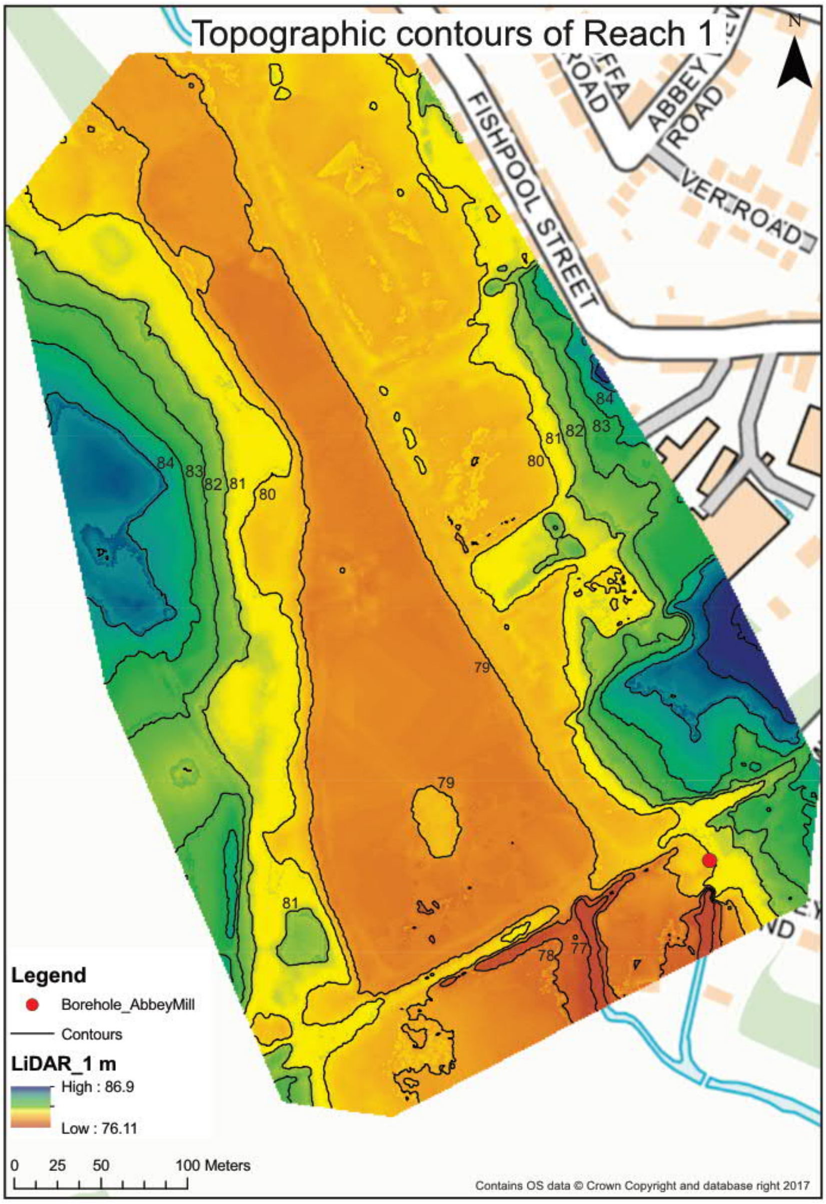

Figure 5 Ground Elevations in and around Abbey Mill OBH (borehole)

Effect of Groundwater Rebound

Affinity Water has planned sustainability reductions in the Ver catchment.

AECOM has investigated the potential for groundwater emergence to occur in the catchment separately[1]. As part of this study an interpreted groundwater level rebound contour map was produced. This is replicated by Figure 6 below. This was considered to be an upper-estimate because at high groundwater levels abstraction may cause less drawdown, as there is more aquifer storage available for the abstraction to draw upon, reducing the depth and spatial extent of the drawdown cone.

[1] AECOM (2017) Groundwater Emergence Note Technical Memo 14 July 2017

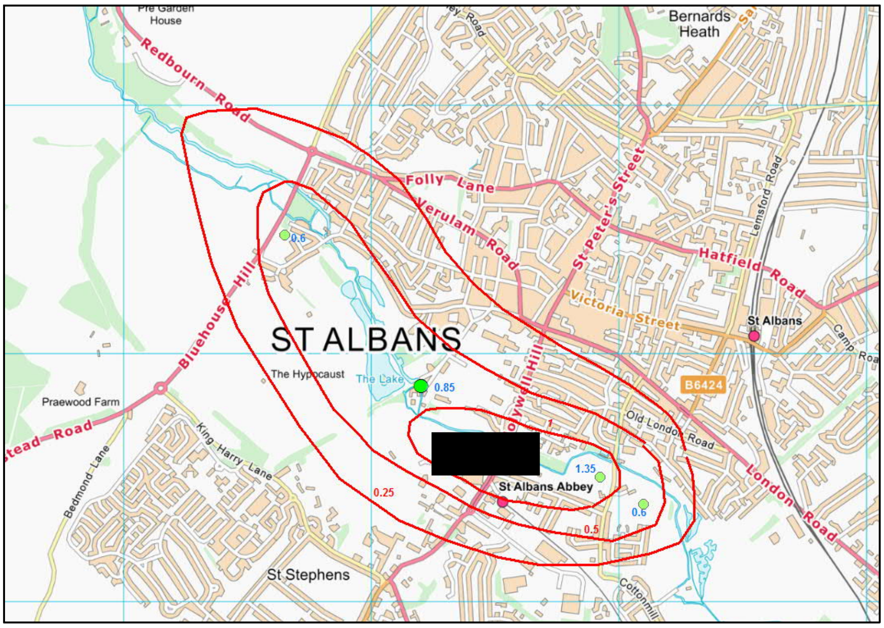

Figure 6 Interpreted groundwater level rebound after reductions in abstraction

Even with a rebound of 0.85m, high groundwater levels (exceeded for 10% of the time) would still be below hard bed levels, indicating that groundwater should not be considered a reliable source of water for the lake. It is noted that bed levels in the lake could be reduced if the hard bed is removed although the Environment Agency have requested that they remain higher than Reach 1 river bed so that groundwater would preferentially flow into the river (maintaining river flow) rather than the lake.

Water Quality

Overview

Water quality sampling of Verulamium Lake was undertaken at 3 locations (VLW1 in the upper lake and at VLW2 and VLW3 in the lower lake, see Figure 7 below) on the 14 November 2016 by AECOM. The results of this, as well as sampling methodology, were presented in the note entitled “Water Quality & Sediment Sampling at Verulamium Lake” dated January 2017.

The previous review, which also considered earlier and limited water quality sampling, found that the water quality of the shallow upper lake site is poorer and potentially more polluted and nutrient enriched than the lower lake. It was considered that this may be due in part to the inflow from the adjacent River Ver combined with the shallow site conditions causing a greater concentration of pollutants and nutrients in this area. Recreational activities (model boating) were considered to also be an important local source of some of the contaminants present. Once the water has passed over the weir into the lower lake it is expected that it is diluted by a greater volume of water with deeper cycling of nutrients and metals, and consequently the high concentrations from VLW-1 are no longer apparent.

The results were considered to be a ‘snapshot’ in time and caution was advised when reviewing the data. Further water quality sampling was proposed and this has since been undertaken by the Environment Agency (on two occasions, 14 June 2017 and 3 August 2017). Sampling was undertaken at four locations (on the River Ver, at the location labelled Ver, and at VLW1a (upper lake) and VLW2 and VLW3- locations indicated on Figure 7).

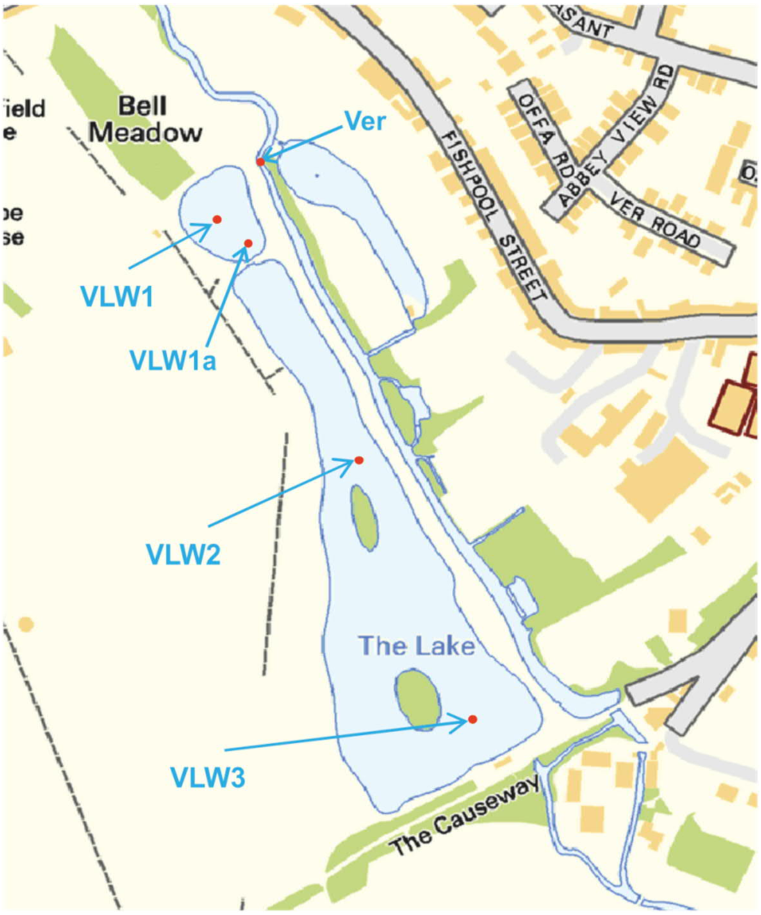

Figure 7 Location of Water Quality Sampling undertaken by AECOM and the Environment Agency in 2016 and 2017

Water quality review

A review of the AECOM and Environment Agency sampling has been undertaken. The primary purpose of the review was to establish if sufficient sampling had been undertaken in order to inform the determination of a Reach 1 preferred option and if not advise on a reduced set of determinants that should be sampled going forward. The results of the sampling are provided in Table 2 below.

The difference in the River Ver between the two sample periods shows the value of repeated sampling through the year as the two snapshots of conditions vary considerably. For instance between June and August sampling periods dissolved oxygen reduced substantially while DOC more than doubled. Alkalinity was substantially reduced, while pH and electrical conductivity also declined. The latter sampling period did not follow a period of heavy rain which may have explained these results. Further sampling through the various seasons is recommended to better understand the longer term average conditions.

The river does not appear to be contributing significant loads of nutrients or other parameters into the lake. For instance, total nitrogen in the lake increases between June and August 2017 despite substantially reduced levels in the river over the same period. The levels of physico-chemical parameters in the lake are more likely related to internal processes such as recycling of sediments, and inputs from wildfowl and organic material from the immediate catchment. This should, however, be confirmed with subsequent sampling throughout the various seasons. The decrease in nitrate and ammoniacal nitrogen from the upper lake to the lower lake which was observed in 2016 and tentatively related to river inputs is still apparent albeit to a lesser degree. The extent that this is driven by the river appears to be limited.

Biochemical Oxygen Demand (BOD) is a measure of oxygen used by microorganisms to decompose organic matter and is often used to indicate organic pollution. Values were considerably elevated throughout the lake in the June 2017 sampling in comparison to November 2016, indicating the greater input of organic waste, presumably from wildfowl, in the summer. Conversely dissolved oxygen was much increased during the summer 2017 sampling likely due to algae photosynthesising during the day and crashing at night. Further seasonal sampling would show further year round variability in these and other water quality variables.

The data suggests that nutrient enrichment (particularly for phosphorus) is an issue at the site, and this supports the perceived eutrophic conditions and risk of algal blooms. Such high levels should not ideally be fed back into the river due to the potential to cause detrimental impacts in terms of the WFD requirements. Further sampling would be required to determine the true mean annual extent of this nutrient enrichment.

Suspended solid concentrations were far higher in the summer 2017 surveys compared to 2016. Suspended solids in the lake are most probably derived from sediment bioturbation by fish and waterfowl and fine organic effluent in the lake from waterfowl excreta. The increase in summer may be a consequence of increased use of the lake by waterfowl in the summer months.

Table 2 Results of the surface water quality testing for the River Ver and Verulamium Lake. Screening values are given where possible. Green shading indicates that the sample is below the screening value, orange indicates that the value is surpassed. All Phenols, TPH, PCBs and VOCs were below the limits of detection for the laboratory and so have not been included.

Analyse	Units	Limits of Detection	Screening Value	Screening Source	14th November 2016			14th June 2017				3rd August 2017			
					VLW1 (upper lake)	VLW2 (lower lake)	VLW3 (lower lake)	(River) Ver	VLW1a (upper lake)	VWL2 (lower lake)	VLW3 (lower lake)	(River) Ver	VLW1a (upper lake)	VWL2 (lower lake)	VLW3 (lower lake)
Dissolved Oxygen	%				73	72	69	70.8	153.7	147.7	203	46.4	130.3	103.2	108
Dissolved Oxygen	mg/L				9	8.9	8.5	6.72	12.87	12.95	17.4				
BOD 5 Day ATU	mg/l	1			2.41	<1	<1					<1	9.68	8.93	14.7
Cyanide as CN	mg/l	0.05	0.001	WFD Eng/Wales 2015	<0.05	<0.05	<0.05					<.005	<.005	<.005	<.005
Carbon, Organic, Dissolved as C :- {DOC}	mg/l	0.2			3.99	3.87	4.98	1.68	5.32	7.54	7.65	3.77	8.76	11.3	11
Alkalinity to pH 4.5 as CaCO3	mg/l	5			210	180	180	264	75	104	106	174	144	123	127
Ammoniacal Nitrogen as NH_3	mg/l	0.003	0.6	WFD Eng/Wales 2015 (lake only)	0.873	0.614	0.578					0.0316	0.0219	0.0023	0.0027
Ammoniacal Nitrogen, Filtered as N	mg/l	0.003	0.6	WFD Eng/Wales 2015 (lake only)				0.0159	0.0499	0.0116	0.0551	0.0325	0.0056	<.002	<.002
Nitrite as N	mg/l	0.004	0.5	WS Regs 2016 (Eng/Wal)	0.187	0.077	0.073					0.0232	0.00107	<.001	<.001
Nitrate as N	mg/l	0.3	50	WS Regs 2016 (Eng/Wal)								1.77	0.00403	<.004	<.004
Nitrate as NO_3	mg/l	0.3	50	WS Regs 2016 (Eng/Wal)	10.5	2.11	1.81								
Nitrogen : Total Inorganic as N	mg/l	0.2			3.14	1.01	0.908								
Nitrogen, Total as N	mg/l							4.07	1.3	0.9	0.97	2.23	2.05	2.61	3.25
Nitrogen, Total Oxidised as N	mg/l											1.79	0.0051	<.005	<.005
Nitrogen, Total Oxidised, Filtered as N	mg/l							3.83	0.0852	0.0072	0.0163	1.81	0.0092	<.005	<.005
Orthophosphate, reactive as P	mg/l	0.01			<0.02	0.0225	0.033	0.0285	0.0158	0.126	0.125	0.0539	0.0718	0.174	0.164
Total Phosphorus	mg/l	0.02	0.049 (est.)	Lake Phosphorus Calculator (lake only)	0.0889	<0.02	<0.02	0.0524	0.106	0.166	0.165	0.0741	0.285	0.554	0.647
Sulphate as SO4	mg/l	2	250	WS Regs 2016 (Eng/Wal)	20.5	28.3	27.7					17.5	<10	<10	<10
Colour, Filtered HAZEN	HAZEN	-	-					5	13	17	17	12	20	20	20
Temperature	Deg Celsius	-	-					16.8	23.6	21.9	22.5	15.9	19.4	18.2	18.7
Conductivity at 20C	uS/cm	10			513	430	430	679	277	327	322	592	381	347	347
pH	pH Units	0.05			7.8	7.86	7.85	7.89	9.44	9.58	9.85	7.53	8.93	9.64	9.67
Solids, Suspended at 105 C	mg/l	2			<9	<9	<9					3.7	19.1	40.4	54.1
Arsenic Dissolved	ug/l	0.51	10	WS Regs 2016 (Eng/Wal)	0.659	0.62	0.597					<1	1.02	2.84	2.67
Boron, Dissolved	ug/l	<5	1000	WS Regs 2016 (Eng/Wal)	29.9	28.5	28.4					<100	<100	<100	<100
Lead, Dissolved	ug/l	0.1	1.2	WFD Eng/Wales 2015	0.206	0.765	0.612					0.385	0.347	2.68	0.916
Lead	ug/l	0.1	1.2	WFD Eng/Wales 2015	1.46	0.806	0.603					2.95	1.41	7.02	8.29
Aluminium, Dissolved	ug/l	2	200	WS Regs 2016 (Eng/Wal)	3.92	5.68	<2								
Aluminium	ug/l	50	200	WS Regs 2016 (Eng/Wal)	178	<50	<50								
Cadmium, Dissolved	ug/l	0.08	0.25	WS Regs 2016 (Eng/Wal)	<0.08	<0.08	<0.08					<.01	<.01	<.01	<.01
Cadmium	ug/l	0.5	0.25	WS Regs 2016 (Eng/Wal)	<0.5	<0.5	<0.5					0.0269	<.01	0.0244	0.0349
Chromium Hexavalent, Dissolved	ug/l	0.03	3.4	WFD Eng/Wales 2015	<0.03	<0.03	<0.03								
Chromium, Dissolved	ug/l	1.2	1.2	WS Regs 2016 (Eng/Wal)	<1.2	<1.2	<1.2					<.5	<.5	<.5	<.5
Chromium	ug/l	3	3.4	WS Regs 2016 (Eng/Wal)	<3	<3	<3					0.74	<.5	<.5	<.5
Copper, Dissolved	ug/l	0.85	1	WFD Eng/Wales 2015	<0.85	<0.85	<0.85					4.27	0.637	2.37	1.87
Copper	ug/l	4	1 (bioavailable)	WFD Eng/Wales 2015	<4	<4	<4					5.2	1.08	2.59	2.63
Iron, Dissolved	ug/l	0.019	1000	WS Regs 2016 (Eng/Wal)	28.8	23.3	29.8								

Analyse	Units	Limits of Detection	Screening Value	Screening Source	14th November 2016			14th June 2017				3rd August 2017			
					VLW1 (upper lake)	VLW2 (lower lake)	VLW3 (lower lake)	(River) Ver	VLW1a (upper lake)	VWL2 (lower lake)	VLW3 (lower lake)	(River) Ver	VLW1a (upper lake)	VWL2 (lower lake)	VLW3 (lower lake)
Iron	ug/l	24	1000	WFD Eng/Wales 2015	166	39.6	31.3					188	162	374	448
Manganese, Dissolved	ug/l	0.76	123	WS Regs 2016 (Eng/Wal)	9.68	9.13	8.06								
Manganese	ug/l	0.5	123 (bioavailable)	WFD Eng/Wales 2015	14.8	6.69	6.43					<10	19.7	29.2	30.9
Mercury, Dissolved	ug/l	0.01	0.07	WFD Eng/Wales 2015	<0.01	<0.01	<0.01								
Mercury	ug/l	0.01	0.07	WFD Eng/Wales 2015	<0.02	<0.02	<0.02								
Nickel	ug/l	0.5	4	WFD Eng/Wales 2015	2.74	1.67	1.26					0.86	0.859	1.39	1.44
Sodium	mg/l	<0.076	200	WS Regs 2016 (Eng/Wal)	21.8	14	14					40.3	19.8	20.9	20.9
Zinc, Dissolved	ug/l	3	10.9	WFD Eng/Wales 2015	4.47	3.81	1.95								
Zinc	ug/l	0.024	10.9	WFD Eng/Wales 2015	5.38	3.78	<3					8.46	0.87	1.97	0.503
PAH															
Anthracene	ug/l	0.015	0.1	WFD Eng/Wales 2015	<0.015	<0.015	<0.015					<.01	<.01	<.01	<.01
Benzo(a)anthracene	ug/l	0.017	3.5	AECOM DWG (WHO method)	0.0456	<0.017	<0.017					<.01	<.01	0.011	<.01
Benzo(a)pyrene	ug/l	0.009	0.00017	WFD Eng/Wales 2015	0.0352	<0.009	<0.009					0.00062	0.00288	0.0338	0.0201
Benzo(b)fluoranthene	ug/l	0.023	0.017	WFD Eng/Wales 2015	0.0578	<0.023	<0.023					0.00128	0.00376	0.0466	0.033
Benzo(k)fluoranthene	ug/l	0.027	0.017		0.0578	<0.023	<0.023					0.00037	0.00177	0.0196	0.015
Benzo(g,h,i)perylene	ug/l	0.016	0.0082	WFD Eng/Wales 2015	0.0462	<0.016	<0.016					0.00073	0.00583	>.05	0.0461
Indeno(1,2,3-cd)pyrene	ug/l	0.014			0.0303	<0.014	<0.014					0.00073	0.00659	>.05	0.0482
Chrysene	ug/l	0.013		WFD Eng/Wales 2015	0.0465	<0.013	<0.013					<.01	<.01	0.0108	0.0102
Fluoranthene	ug/l	0.017	0.0063	WFD Eng/Wales 2015	0.0714	<0.017	<0.017					0.0029	0.0164	0.0355	0.0281
Naphthalene	ug/l	0.1	2	WFD Eng/Wales 2015	<0.1	<0.1	<0.1					<.1	<.1	<.1	<.1
Phenanthrene	ug/l	0.01	4	AECOM DWG (WHO method)	0.0566	<0.022	<0.022					<.01	0.0137	<.01	<.01
Pyrene	ug/l	0.01	9	AECOM DWG (WHO method)	0.0724	<0.015	<0.015					<.01	<.01	0.0138	0.0118

Metal concentrations are significantly increased in several of the 2017 samples in comparison to 2016 and are particularly noticeable for dissolved copper, dissolved arsenic and total and dissolved lead. These increases include several breaches of EQS (See Table 2). Similarly, numerous PAHs (including fluoranthene, benzo(a)pyrene and benzo(g,h,i)perylene) in the lower lake are increased in August 2016 in comparison to November 2015, again with thresholds for EQS being surpassed in some cases. These are commonly sourced from incomplete combustion of organic matter (e.g. fuel, wood burning, biofuels). Further sampling of these parameters is also recommended in autumn and spring to enable a better understanding of longer term fluctuations.

The extent to which the water quality results are reflected in the character of the lake sediments has been explored through sediment sampling described below. Overall, lake water quality doesn't seem a matter that would make potential options unfeasible. Nutrient levels in the lake are higher than desired, as expected, which would make those options where the lake did not discharge into the river preferred from a water quality perspective.

It is considered that there is sufficient information on heavy metal levels in the lake to inform the selection of a preferred Reach 1 option. We recommend that further monitoring of the Lake Suites WFD suite of determinants is continued as this would provide a more robust data set and would enable a more thorough assessment against EQS and help to identify any seasonal trends in water quality over the longer term, where interpreted in the context of water quality in the River Ver.

Sediment Quality

Overview

Sediment quality sampling of Verulamium Lake was undertaken at 3 locations (VLS1 in the upper lake and at VLS2 and VLS3 in the lower lake, see Figure 8 below) on the 14 November 2016 by AECOM. The results of this, as well as sampling methodology, were presented in the note entitled "Water Quality & Sediment Sampling at Verulamium Lake" dated January 2017.

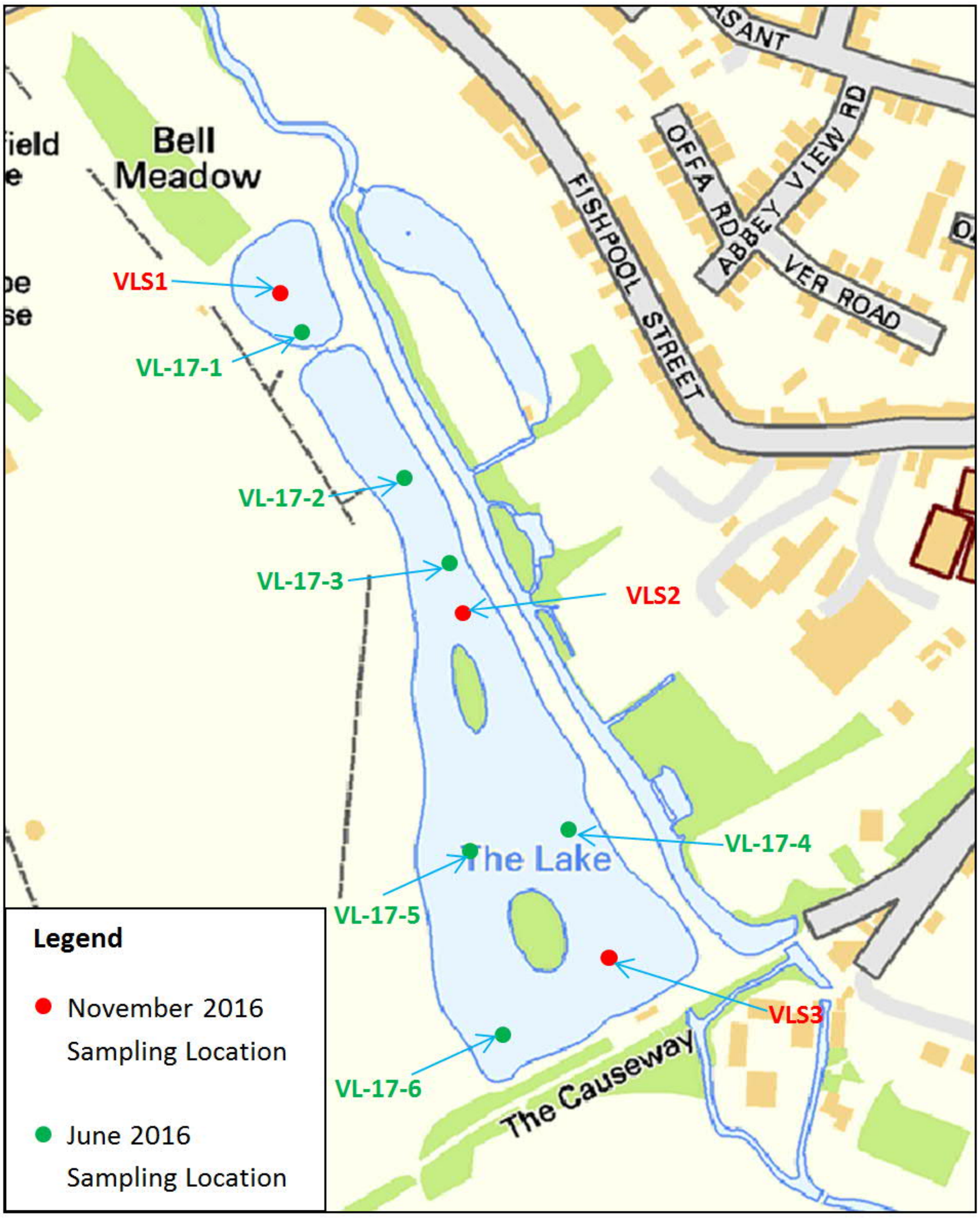

Figure 8 AECOM sediment sampling locations 2016 and 2017

The study found that sediment quality seemed to be less variable than water quality. The results from bulk sediment samples suggest that lake sediments are ‘potentially hazardous’, with the upper lake being the most contaminated. This would have consequences in terms of sediment re-use, and further sampling to determine the full extent of fuel pollution (potentially relating to model boating) in this area was recommended. However, leachate analysis suggested that lake sediments would be suitable for inert landfill. There were, however, a number of failures of the leachate data with WFD standards, which mainly affected the sample nearest the outflow of the lower lake. Leachate tests typically overestimate the risk in the natural environment and dilution, dispersion and duration factors would need to be considered, but this suggests that significant mobilisation of sediments could potentially have an impact on the lake ecosystem and potentially the River Ver downstream.

Following the review we advised that the risk should be assessed in more detail before any works that affect lake sediments are undertaken. Regardless of the contamination risk, such works would need to be carefully planned and implemented using appropriate techniques and mitigation to minimise this risk.

Further sampling was recommended and on this we basis AECOM were commissioned to collect further sediment samples from Verulamium Lake which would be analysed to establish their quality. Sampling was undertaken at 6 locations (5 in the lower lake and one in the upper lake) on the 28 July 2017. The sampling locations are indicated in Figure 8.

Sediment quality review

Results of sediment chemical testing undertaken in 2016 and 2017 were analysed against known human health screening values to assess potential risks to human health and any public nuisance potential, in terms of smell, aesthetic values etc. Data obtained from the Veolia sediment sampling in 2017 and Symbio sediment reports (2012) were also incorporated into the analysis and data from these reports are also shown in Table 3. Screening value sources included the Chartered Institute of Environmental Health's Suitable 4 Use Levels (LQM/CIEH S4ULs) for Human Health Risk Assessment and DEFRA Category 4 Screening Levels (C4SLs) 12/2014 and both were derived from AECOM's Stage 2 Workbook v1.45 (2016). It should be noted that not all of the parameters measured have standards assigned to them. Full results are shown in Table 2. No individually measured determinant was found to be in excess of human health screening values for those that can be obtained through the Stage 2 Workbook.

In general, metal concentrations are higher in concentration in the lower lake (samples VL-17-2 through to VL-17-6, plus VLS 2 and VLS 3) than in the upper boating lake (VL17-1), and so appear to be more prone to accumulate in this area where there is low through flow of water. VL-17-2 which was located below the weir between the two lakes where the lake is very shallow had high concentrations of cadmium, lead and zinc, and must be particularly susceptible to accruing heavy metal deposits.

Organic content (as indicated by loss on ignition) varies between 8 and 20% across the two lakes, with the lower values found towards the south of the lower lake. Orthophosphate was noticeably elevated in VL-17-1 in the upper lake and may be related to a greater concentration of faecal inputs in the upper lake from wildfowl. Fluoride and chloride are also elevated in VL-17-1 in comparison to the samples from the lower lake.

Sediment samples from 2017 have been run through HazWaste Online by AECOM's contaminated land team. The samples have been classified as 'non-hazardous waste' in all cases. The HazWaste Online report is provided in Appendix 1 with further details.

Leachate testing was undertaken on the sediments in order to understand hypothetically what the impact of dewatering sediment close to watercourses might be in terms of contaminants leaching from the matrix. Results have been screened against water quality standards obtained through the Stage 2 Workbook in Table 3. Preparation followed the National River Authority (NRA) method, whereby soluble and suspended species are leached using water with a pH of approximately 5.6 at a ratio of 1:10, and this is performed for 24 hours.

When compared to water quality standards, some of the leachate results fail to meet 'good' requirements. For the 2016 samples this mainly concerns VLS-3 where copper, iron and a number of PAHs exceeded the Water Framework Directive (WFD) thresholds. These metals and PAHs may have derived from sources of industrial pollution and highway runoff into the River Ver, or from leaks from model boats using the upper lake. All of the 2017 leachate samples exceed the WFD threshold for ammoniacal nitrogen, an indicator of sanitary pollution. Any dewatering of sediment close to waterbodies could therefore have detrimental impacts downstream if not mitigated against.

Table 2 Results of the sediment analysis at the Verulamium Lake between 2012 and 2017. Screening values are given where possible, and green shading indicates that the sample is below the screening value, orange indicates above the screening value.

Determinant	Units	Screening Value	VLS1 (2016)	VLS2 (2016)	VLS3 (2017)	VL-17-1 (2017)	VL-17-2 (2017)	VL-17-3 (2017)	VL-17-4 (2017)	VL-17-5 (2017)	VL-17-6 (2017)	Veolia (28/4/17)	Symbio 2012 – Site 2	Symbio 2012 – Site 4	Symbio 2012 – Site 6	Screening Value Source (HH Soil. Public Open Space - Park. TOC >=3.48%)
Aluminium	mg/kg		3740	5210	4010	3516	5888	5637	5060	4058	4585	1283				
Arsenic	mg/kg	170	1.74	2.82	2.78	1.8	3	3	2.9	1.9	2.9		<3		3.8	AECOM (modified LQM/CIEH S4ULs)
Cadmium	mg/kg	560	0.232	1.03	0.795	0.4	1.5	1.4	1.2	1.1	1.1	<10	0.30		0.93	AECOM (modified LQM/CIEH S4ULs)
Chromium	mg/kg		8.76	11.1	8.94	31.7	33	33.3	31	25.8	31	<10	<10		10.9	
Copper	mg/kg	44,000	23.6	34.6	24.8	33	51	47	49	34	40	26.8	23.5		36.8	AECOM (modified LQM/CIEH S4ULs)
Iron	mg/kg		4670	5820	4160	5235	8351	8015	7345	5422	7225	2336	3799	7194	5898	
Lead	mg/kg	2,300	43.4	157	126	44	185	171	144	125	148	99.5	38.2	135	119	Defra C4SL 12/2014
Manganese	mg/kg		98.7	95.2	111	95	111	116	118	97	117		85		115	
Mercury	mg/kg	58	<0.14	<0.14	<0.14	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1		0.06	0.16		LQM/CIEH S4ULs 2014
Nickel	mg/kg	800	5.95	9.47	7.25	5.6	11.8	11.6	9.8	8	10.2	<10	<10		<10	AECOM (modified LQM/CIEH S4ULs)
Selenium	mg/kg	1,800	1.41	1.76	1.42	<1	1	1	1	<1	<1	<10	1.28		1.77	AECOM (modified LQM/CIEH S4ULs)
Zinc	mg/kg	170,000	105	176	146	121	214	195	168	178	171	223.9	91.1	165	144	LQM/CIEH S4ULs 2014
Water Soluble Boron	mg/kg	46,000	<1	1.05	<1								3.1		2.4	LQM/CIEH S4ULs 2014
Chromium, Hexavalent	mg/kg	220	<0.6	<0.6	<0.6	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3					LQM/CIEH S4ULs 2014
Chromium, Trivalent	mg/kg	33,000	8.76	11.1	8.94	31.7	33	33.3	31	25.8	31					LQM/CIEH S4ULs 2014
Barium	mg/kg					80	102	100	100	79	84	28.9				
Antimony	mg/kg					1	1	2	1	<1	1					
Molybdenum	mg/kg					1	1	1	0.9	0.7	0.9	<10				
Sodium	mg/kg					299	255	267	249	215	236					
Vanadium	mg/kg	5000				9	17	17	14	11	15	<10				LQM/CIEH S4ULs 2014
Polycyclic Aromatic Hydrocarbon																

Determinant	Units	Screening Value	VLS1 (2016)	VLS2 (2016)	VLS3 (2017)	VL-17-1 (2017)	VL-17-2 (2017)	VL-17-3 (2017)	VL-17-4 (2017)	VL-17-5 (2017)	VL-17-6 (2017)	Veolia (28/4/17)	Symbio 2012 – Site 2	Symbio 2012 – Site 4	Symbio 2012 – Site 6	Screening Value Source (HH Soil. Public Open Space - Park. TOC >=3.48%)
Naphthalene	mg/kg	3,000	<0.009	0.07	0.0528	<0.01	0.083	<0.01	0.038	<0.01	0.059					AECOM (modified LQM/CIEH S4ULs)
Acenaphthylene	mg/kg	30,000	0.0423	0.159	0.165	<0.01	0.269	0.148	0.138	0.144	0.209					AECOM (modified LQM/CIEH S4ULs)
Acenaphthene	mg/kg	30,000	<0.08	0.0565	0.0722	<0.01	0.139	<0.01	<0.01	<0.01	0.065					AECOM (modified LQM/CIEH S4ULs)
Fluorene	mg/kg	20,000	0.0313	0.0487	0.0517	<0.01	0.095	<0.01	<0.01	<0.01	0.059					AECOM (modified LQM/CIEH S4ULs)
Phenanthrene	mg/kg	6,300	0.26	0.581	0.666	0.197	1.029	0.48	0.299	0.277	0.608					AECOM (modified LQM/CIEH S4ULs)
Anthracene	mg/kg	150,000	0.0988	0.238	0.282	<0.01	0.578	0.172	0.142	0.136	0.314					AECOM (modified LQM/CIEH S4ULs)
Fluoranthene	mg/kg	6,400	0.911	2.96	3.1	0.741	5.909	2.158	1.581	1.455	2.856					AECOM (modified LQM/CIEH S4ULs)
Pyrene	mg/kg	15,000	0.818	2.71	2.73	0.681	5.462	2.162	1.543	1.463	2.748					AECOM (modified LQM/CIEH S4ULs)
Benzo(a)anthracene	mg/kg	62	0.616	1.94	1.69	0.407	2.616	1.149	0.806	1.106	1.471					AECOM (modified LQM/CIEH S4ULs)
Chrysene	mg/kg	120	0.721	2.2	2.26	0.553	3.895	1.788	1.167	1.148	1.961					AECOM (modified LQM/CIEH S4ULs)
Benzo(b)fluoranthene	mg/kg	16	1.24	4.25	4.8	0.662	5.754	2.452	1.885	1.847	2.958					AECOM (modified LQM/CIEH S4ULs)
Benzo(k)fluoranthene	mg/kg	440	0.441	1.43	1.53	0.257	2.237	0.953	0.733	0.718	1.15					AECOM (modified LQM/CIEH S4ULs)
Benzo(a)pyrene	mg/kg	13	0.862	2.94	2.92	0.411	3.669	1.51	1.151	1.072	1.837					AECOM (modified LQM/CIEH S4ULs)
Indeno(123cd) pyrene	mg/kg	180	0.523	2.05	2.37	0.311	2.399	1.243	0.875	0.818	1.301					AECOM (modified LQM/CIEH S4ULs)
Dibenzo(ah)anthracene	mg/kg	1.4	0.144	0.563	0.599	0.11	0.772	0.349	0.28	0.261	0.412					AECOM (modified LQM/CIEH S4ULs)
Benzo(ghi)perylene	mg/kg	1,600	0.697	2.33	2.62	0.416	3.016	1.427	1.086	1.015	1.552					AECOM (modified LQM/CIEH S4ULs)
Benzo(bk)fluoranthene	mg/kg					0.919	7.991	3.405	2.618	2.565	4.108					
Total Petroleum Hydrocarbons																
Aliphatics																
>C5-C6	mg/kg		0.0155	<0.01	<0.01	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1					

Determinant	Units	Screening Value	VLS1 (2016)	VLS2 (2016)	VLS3 (2017)	VL-17-1 (2017)	VL-17-2 (2017)	VL-17-3 (2017)	VL-17-4 (2017)	VL-17-5 (2017)	VL-17-6 (2017)	Veolia (28/4/17)	Symbio 2012 – Site 2	Symbio 2012 – Site 4	Symbio 2012 – Site 6	Screening Value Source (HH Soil. Public Open Space - Park. TOC >=3.48%)
>C6-C8	mg/kg		0.0279	<0.01	0.0216	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1					
>C8-C10	mg/kg		0.0279	<0.01	0.024	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1					
>C10-C12	mg/kg		0.0217	<0.01	0.048	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2					
>C12-C16	mg/kg		0.403	<0.01	7.79	<4	20	<4	<4	<4	<4					
>C16-C21	mg/kg		24.3	11.4	116	59	162	123	77	76	88					
>C21-C35	mg/kg		158	69.6	589	274	843	619	495	481	520					
>C35-C44	mg/kg		46.4	22.6	205											
Total aliphatics C12-44	mg/kg		229	104	917											
Total aliphatics C5-35						333	1025	742	572	557	608					
Aromatics																
>EC5-EC7	mg/kg	92,000	<0.01	<0.01	<0.01	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1					AECOM (modified LQM/CIEH S4ULs)
>EC7-EC8	mg/kg	100,000	0.0124	<0.01	<0.01	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1					AECOM (modified LQM/CIEH S4ULs)
>EC8-EC10	mg/kg	9,300	0.0248	<0.01	0.0168	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1					AECOM (modified LQM/CIEH S4ULs)
>EC10-EC12	mg/kg	10,000	0.0155	<0.01	0.0312	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2					AECOM (modified LQM/CIEH S4ULs)
>EC12-EC16	mg/kg	10,000	<0.1	<0.1	<0.1	<4	<4	<4	<4	<4	<4					AECOM (modified LQM/CIEH S4ULs)
>EC16-EC21	mg/kg	7,800	12.4	4.97	30.7	32	44	33	31	<7	29					AECOM (modified LQM/CIEH S4ULs)
>EC21-EC35	mg/kg	7,900	229	54.3	265	736	946	599	618	512	572					AECOM (modified LQM/CIEH S4ULs)
>EC35-EC44	mg/kg	7,900	107	29.5	117											AECOM (modified LQM/CIEH S4ULs)
>EC40-EC44	mg/kg		33.5	12.1	42.2											
Total aromatics EC12-EC44	mg/kg		348	88.8	413											
Total aromatics C5-35						768	990	632	649	512	601					
Total aliphatics and aromatics(C5-C44)	mg/kg		578	192	1330											

Determinant	Units	Screening Value	VLS1 (2016)	VLS2 (2016)	VLS3 (2017)	VL-17-1 (2017)	VL-17-2 (2017)	VL-17-3 (2017)	VL-17-4 (2017)	VL-17-5 (2017)	VL-17-6 (2017)	Veolia (28/4/17)	Symbio 2012 – Site 2	Symbio 2012 – Site 4	Symbio 2012 – Site 6	Screening Value Source (HH Soil. Public Open Space - Park. TOC >=3.48%)
Total aliphatics and aromatics(C5-C35)						1101	2015	1374	1221	1069	1209					
MTBE	ug/kg		2110	<5	<5											
Toluene	ug/kg	100,000	12.4	<2	<2											AECOM (modified LQM/CIEH S4ULs)
PCBSs, Phenols, Phthalates & SVOCs (if over LOD)																
Carbazole	ug/kg					<10	174	<10	61	61	101					
Surrogate Recovery 2-Fluorobiphenyl	ug/kg					71	81	74	81	79	84					
Surrogate Recovery p-Terphenyl-d14	ug/kg					93	94	114	98	105	111					
Other Items																
Natural Moisture Content	%		68	64	59	357.1	295.8	310.2	283.8	278.9	226.8					
Grain size	mm		0.002-0.063 (Silt)	0.002-0.063 (Silt)	0.002-0.063 (Silt)											
Sample Colour	None		Dark Brown	Dark Brown	Dark brown	Dark brown	Dark brown	Dark brown	Dark brown	Dark brown	Dark brown					
Total Cyanide	mg/kg		<1	<1	<1	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5		<1		<1	
Water Soluble Sulphate as SO_4 2:1 Extract	g/l		0.311	0.168	0.0632	0.7152	0.55	0.3452	0.4195	0.3482	0.1631		0.33		0.28	
Total Sulphate	mg/kg		2320	2250	1760											
Loss on Ignition	%		20	16.1	10.3	12.2	11.3	10.2	9.5	8.8	7.8		11.6	10.0	9.6	
Oxidisable Sulphide	%		0.503	0.905	0.727											
Sulphide	mg/kg					<10	<10	<10	<10	<10	<10					
Total Sulphur	%		0.245	0.375	0.301											

Determinant	Units	Screening Value	VLS1 (2016)	VLS2 (2016)	VLS3 (2017)	VL-17-1 (2017)	VL-17-2 (2017)	VL-17-3 (2017)	VL-17-4 (2017)	VL-17-5 (2017)	VL-17-6 (2017)	Veolia (28/4/17)	Symbio 2012 – Site 2	Symbio 2012 – Site 4	Symbio 2012 – Site 6	Screening Value Source (HH Soil. Public Open Space - Park. TOC >=3.48%)
Total Potential Sulphate	%		0.735	1.13	0.903											
Sodium	mg/kg		169	166	160											
Ammoniacal Nitrogen	mg/kg					2.7	6.3	<0.6	<0.6	<0.6	5.6					
Chloride	mg/kg					209	147	165	152	140	123					
Fluoride	mg/kg					26.1	<1.5	<1.5	<1.5	<1.5	<1.5					
Nitrate as NO_3	mg/kg					<2.5	12.8	<2.5	15.5	<2.5	<2.5					
Nitrite as NO_2	mg/kg					0.36	0.23	0.23	0.36	0.26	0.2					
Orthophosphate as PO_4	mg/kg					25.4	1	0.5	0.9	1	0.4					
Inorganic Nitrogen	mg/kg					2.8	9.3	<2.5	3.6	<2.5	5.7					
Total Nitrogen	mg/kg					0.83	0.72	0.78	0.7	0.61	0.6					

Table 3 Results of sediment leachate testing at Verulamium Lake between 2012 and 2017. Screening values are given where possible, derived from the AECOM Stage 2 Workbook v1.45 (2016). Green shading indicates that the sample is below the screening value, orange indicates that the value is surpassed. Only those parameters where at least one sample is above the limit of detection have been included with the exception of TPHs.

Test	Units	Screening Value	VLL-1 (NRA method) - 2016	VLL-2 (NRA method) - 2016	VLL-3 (NRA method) - 2016	VL-17-1 (CEN 10:1) - 2017	VL-17-2 (CEN 10:1) - 2017	VL-17-3 (CEN 10:1) - 2017	VL-17-4 (CEN 10:1) - 2017	VL-17-5 (CEN 10:1) - 2017	VL-17-6 (CEN 10:1) - 2017	Symbio 2012 – Site 2 - 2012	Symbio 2012 – Site 6 - 2012	Screening Value Source
Ammoniacal Nitrogen as N	mg/l	0.6	1.94	<0.2	0.448	4.08	3.29	1.58	1.02	0.83	0.89			WFD England/Wales 2015
Sulphate as SO_4	mg/l	250				5.51	12.39	12.79	10.79	25.45	23.63	45.9	39.0	WS Regs 2016 (Eng/Wal)
Chloride	mg/l	250				18.2	11.3	15.5	12.3	9.1	7.5	7.0	6.0	WS Regs 2016 (Eng/Wal)
Nitrate as NO3	mg/l	50				0.4	0.4	0.4	0.3	<0.2	0.4			WS Regs 2016 (Eng/Wal)
Inorganic Nitrogen	mg/l					4.16	3.38	1.66	1.09	0.83	0.97			
BOD (Shaken)	mg/l					640	120	63	90	70	50			
Dissolved Organic Carbon (DOC)	mg/l					8	5	6	5	4	4			
pH						7.9	7.97	8.11	8.03	7.95	8.04	7.8	8.1	
Electrical Conductivity	µS/cm					477	309	299	287	295	270	307	202	
Dissolved Metals														
Aluminium (diss.filt)	µg/l	200	35.6	38.5	36.9	<20	<20	24	<20	<20	<20			WS Regs 2016 (Eng/Wal)
Iron (diss.filt)	mg/l	1000	0.039	0.0202	0.0227	0.044	<0.02	<0.02	<0.02	<0.02	<0.02	<0.1	4.4	WFD England/Wales 2015
Boron (diss.filt)	µg/l	1000	10.4	11.1	10.6									WS Regs 2016 (Eng/Wal)
Copper (diss.filt)	µg/l	1	0.873	<0.85	1.85	<7	<7	<7	<7	<7	<7	2.5	2.0	WFD England/Wales 2015
Lead (diss.filt)	µg/l	1.2	0.319	0.878	1.61	<5	<5	<5	<5	<5	<5	3.2	0.2	WFD England/Wales 2015
Manganese (diss.filt)	µg/l	123	15.1	13.4	10.5	44	30	3	17	26	12			WFD England/Wales 2015
Selenium (diss.filt)	µg/l	10	<0.81	<0.81	<0.81	<3	<3	<3	<3	<3	<3	0.1	1.1	WS Regs 2016 (Eng/Wal)
Vanadium (diss.filt)	µg/l	20	<1.3	<1.3	4.36	<1.5	2.3	3	3.2	2.8	2.9			SEPA WAT-SG-53
Zinc (diss.filt)	µg/l	10.9	<1.3	<1.3	<1.3	<3	8	4	<3	<3	9	7.2	5.7	WFD England/Wales 2015
Arsenic (diss. filt)	µg/l	10				<2.5	3.1	6.1	3.8	3.3	4	<1	<1	WS Regs 2016 (Eng/Wal)

Test	Units	Screening Value	VLL-1 (NRA method) - 2016	VLL-2 (NRA method) - 2016	VLL-3 (NRA method) - 2016	VL-17-1 (CEN 10:1) - 2017	VL-17-2 (CEN 10:1) - 2017	VL-17-3 (CEN 10:1) - 2017	VL-17-4 (CEN 10:1) - 2017	VL-17-5 (CEN 10:1) - 2017	VL-17-6 (CEN 10:1) - 2017	Symbio 2012 – Site 2 - 2012	Symbio 2012 – Site 6 - 2012	Screening Value Source
Barium (diss. filt)	µg/l	700				111	40	38	38	43	39			WHO DWG 2011
Molybdenum (diss. filt)	µg/l	70				<2	3	8	6	3	5			WHO DWG 2011
Phosphorus (diss. filt)	µg/l					13	23	25	21	14	31			
Sodium (diss. filt)	µg/l	200				12.4	9	10.8	9.3	7.4	6.8			WS Regs 2016 (Eng/Wal)
Cadmium (diss. filt)	µg/l	0.15										1.3	<0.1	WFD England/Wales 2015
Nickel (diss. filt)	µg/l	4										0.4	0.4	WFD England/Wales 2015
PAHs														
Acenaphthene (diss.filt)	µg/l	18	<0.015	<0.015	0.0841	<5	<5	<5	<5	<5	<5			AECOM DWG (WHO Method)
Fluoranthene (diss.filt)	µg/l	0.0063	0.031	0.0409	0.19	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5			WFD England/Wales 2015
Anthracene (diss.filt)	µg/l	0.1	<0.015	<0.015	0.0175	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5			WFD England/Wales 2015
Phenanthrene (diss.filt)	µg/l	4	0.029	<0.022	0.0755	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5			AECOM DWG (WHO Method)
Chrysene (diss.filt)	µg/l		<0.013	<0.013	0.0219	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5			
Pyrene (diss.filt)	µg/l	9	0.024	0.0299	0.128	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5			AECOM DWG (WHO Method)
Benzo(a)anthracene (diss.filt)	µg/l	3.5	<0.017	<0.017	0.0374	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5			AECOM DWG (WHO Method)
Benzo(b)fluoranthene (diss.filt)	µg/l	0.0017	<0.023	<0.023	0.0458									WFD England/Wales 2015
Benzo(a)pyrene (diss.filt)	µg/l	0.00017	<0.009	<0.009	0.0148	<5	<5	<5	<5	<5	<5			WFD England/Wales 2015
Dibenzo(a,h)anthracene (diss.filt)	µg/l	0.07	<0.016	<0.016	<0.016	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5			AECOM DWG (WHO Method)
Benzo(g,h,i)perylene (diss.filt)	µg/l	0.0082	<0.016	<0.016	0.0384	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5			WFD England/Wales 2015
Indeno(1,2,3-cd)pyrene (diss.filt)	µg/l		<0.014	<0.014	0.0247	<5	<5	<5	<5	<5	<5			
PAH Sum of EPA 16 detected (Diss filt)	µg/l		<0.344	<0.344	0.678									
SVOCs						65	59	40	63	62	66			

Test	Units	Screening Value	VLL-1 (NRA method) - 2016	VLL-2 (NRA method) - 2016	VLL-3 (NRA method) - 2016	VL-17-1 (CEN 10:1) - 2017	VL-17-2 (CEN 10:1) - 2017	VL-17-3 (CEN 10:1) - 2017	VL-17-4 (CEN 10:1) - 2017	VL-17-5 (CEN 10:1) - 2017	VL-17-6 (CEN 10:1) - 2017	Symbio 2012 – Site 2 - 2012	Symbio 2012 – Site 6 - 2012	Screening Value Source
Surrogate Recovery 2-Fluorobiphenyl	%					60	55	37	60	60	61			
Surrogate Recovery p-Terphenyl-d14	%					65	59	40	63	62	66			
TPH CWG														
Aliphatics >C5-C6	µg/l					<10	<10	<10	<10	<10	<10			
>C6-C8	µg/l					<10	<10	<10	<10	<10	<10			
>C8-C10	µg/l					<10	<10	<10	<10	<10	<10			
>C10-C12	µg/l	300				<5	<5	<5	<5	<5	<5			WHO Petroleum DWG 2008
>C12-C16	µg/l	300				<10	<10	<10	<10	<10	40			WHO Petroleum DWG 2008
>C16-C21	µg/l					<10	<10	<10	<10	<10	290			
>C21-C35	µg/l	300				<10	<10	<10	<10	<10	<10			WHO Petroleum DWG 2008
Total aliphatics C5-35	µg/l					<10	<10	<10	<10	<10	330			
Aromatics >C5-EC7	µg/l					<10	<10	<10	<10	<10	<10			
>EC7-EC8	µg/l					<10	<10	<10	<10	<10	<10			
>EC8-EC10	µg/l	300				<10	<10	<10	<10	<10	<10			WHO Petroleum DWG 2008
>EC10-EC12	µg/l	90				<5	<5	<5	<5	<5	<5			WHO Petroleum DWG 2008
>EC12-EC16	µg/l	90				<10	<10	<10	<10	<10	<10			WHO Petroleum DWG 2008
>EC16-EC21	µg/l	90				<10	<10	<10	<10	<10	<10			WHO Petroleum DWG 2008
>EC21-EC35	µg/l	90				<10	<10	<10	<10	<10	<10			WHO Petroleum DWG

Test	Units	Screening Value	VLL-1 (NRA method) - 2016	VLL-2 (NRA method) - 2016	VLL-3 (NRA method) - 2016	VL-17-1 (CEN 10:1) - 2017	VL-17-2 (CEN 10:1) - 2017	VL-17-3 (CEN 10:1) - 2017	VL-17-4 (CEN 10:1) - 2017	VL-17-5 (CEN 10:1) - 2017	VL-17-6 (CEN 10:1) - 2017	Symbio 2012 – Site 2 - 2012	Symbio 2012 – Site 6 - 2012	Screening Value Source
														2008
Total aromatics C5-35	µg/l					<10	<10	<10	<10	<10	<10			
Total aliphatics and aromatics(C5-35)	µg/l					<10	<10	<10	<10	<10	330			

Calculating the Rate of Flow through the Lake

Determining the rate of flow through the lake is important, specifically the number of days for water that flows into the lake to travel through, would help determine what the preferred Reach 1 option would be. A lower number of days is associated with better health in the lake and would suggest that further modifications, such as reducing lake volumes, may lead to further improvements. A high number of days would likely mean such modifications may be insufficient to improve the situation. Ultimately the calculation should help inform what the preferred Reach 1 restoration option that is taken forward should be.

The volume of the lakes and inflow into the lake from the river is required in order to calculate the rate of flow through the lake.

The areas of the upper and lower lakes are 4,300 m^2 and 33,600 m^2. Approximate average depths of the upper and lower lakes are around 0.3 m and 0.45 m, respectively. As such their respective volumes are around 1,290 m^3 and 15,120 m^3 and total Verulamium Lake volume is around 16,410 m^3 (noting this may vary under different climatic conditions).

Flow into the lake under both the existing situation and the preferred river restoration option has been determined for a low flow, median flow and high flow as part of the modelling of the preferred option. This is documented in Appendix C and flows are presented in Table 4 along with an estimate of the number of days for water to flow through the lake.

Table 4 Modelled Flow in Verulamium lake and number of days for water to flow through the lake (existing scenario and with the preferred river restoration option)

River flow statistic	Existing Situation		Preferred Option	
	Flow into the lake (m^3/s)	Number of days for water to flow through the lake	Flow into the lake (m^3/s)	Number of days for water to flow through the lake
Q_{95} (low flow)	0	Infinite	0.003	63.3
Q_{50} (median flow)	0.008	23.7	0.01	19.0
Q_{10} (high flow)	0.08	2.4	0.08	2.4

The results show that the river restoration would result in a slight change in water level in the river which in turn would improve flow into the lake. This reduces the number of days for water to flow through the lake which would likely see a benefit to the lake and wildlife living in and around it. The increase of flow into the lake amounts to up to 2% of flow in the river and this is not to have a detrimental effect on the river itself.

Appendix 1 Waste Classification Report for Samples Collected from Verulamium Lake

AECOM HazWasteOnline™

Waste Classification Report

ZMBX2-5XY3K-AZWG8

Job name

River Ver

Description/Comments

Project

Site

Waste Stream Template

URS Default (Updated June 2015)

Classified by

Name:
Adam Yusaf
Date:
12/13/2016 3:02:10 PM UTC
Telephone:
0787 684 5807

Company:
AECOM URS Infrastructure & Environment UK Limited
4th Floor, Bridgewater house
Whitworth street
Manchester
M1 6LT

Report

Created by: Adam Yusaf
Created date: 12/13/2016 15:02 UTC

Job summary

#	Sample Name	Depth [m]	Classification Result	Hazard properties	Page
1	VLS-1[1]	0.00-1.00	Potentially Hazardous	HP 3(i)	2
2	VLS-2[1]	0.00-1.00	Potentially Hazardous	HP 3(i)	5
3	VLS-3[1]	0.00-1.00	Potentially Hazardous	HP 3(i)	8

Classification of sample: VLS-1[1]

Potentially Hazardous Waste
Classified as **17 05 04** or **17 05 03 ***
in the List of Waste

Sample details

Sample Name:		LoW Code:	
VLS-1[1]		Chapter:	17: Construction and Demolition Wastes (including excavated soil from contaminated sites)
Sample Depth:			
0.00-1.00 m		Entry:	17 05 04 or 17 05 03 * (Soil and stones other than those mentioned in 17 05 03 or Soil and stones containing hazardous substances)
Moisture content:			
68% (wet weight correction)			

Hazard properties (substances considered hazardous until shown otherwise)

HP 3(i): Flammable "flammable liquid waste: liquid waste having a flash point below 60°C or waste gas oil, diesel and light heating oils having a flash point > 55°C and <= 75°C"

Hazard Statements hit:

Flam. Liq. 2; H225 "Highly flammable liquid and vapour."

Because of determinands:

toluene: (conc.: 0.000000397%)
tert-butyl methyl ether; MTBE; 2-methoxy-2-methylpropane: (conc.: 0.0000675%)

Flam. Liq. 3; H226 "Flammable liquid and vapour."

Because of determinand:

TPH (C6 to C40) petroleum group: (conc.: 0.0185%)

Determinands

Moisture content: 68% Wet Weight Moisture Correction applied (MC)

#		Determinand / CLP index number	EC Number	CAS Number	CLP Note	User entered data		Conv. Factor	Compound conc.		Classification value	MC Applied	Conc. Not Used
1		benzene 601-020-00-8	200-753-7	71-43-2		<0.001	mg/kg		<0.00032	mg/kg	<0.000000032 %	✓	<LOD
2		toluene 601-021-00-3	203-625-9	108-88-3		0.012	mg/kg		0.004	mg/kg	0.000000397 %	✓	
3		ethylbenzene 601-023-00-4	202-849-4	100-41-4		<0.003	mg/kg		<0.00096	mg/kg	<0.000000096 %	✓	<LOD
4		xylene 601-022-00-9	202-422-2 [1] 203-396-5 [2] 203-576-3 [3] 215-535-7 [4]	95-47-6 [1] 106-42-3 [2] 108-38-3 [3] 1330-20-7 [4]		<0.009	mg/kg		<0.003	mg/kg	<0.000000288 %	✓	<LOD
5		arsenic { arsenic trioxide } 033-003-00-0	215-481-4	1327-53-3		1.74	mg/kg	1.32	0.735	mg/kg	0.000074 %	✓	
6		boron { boron tribromide/trichloride/trifluoride (combined) }		10294-33-4, 10294-34-5, 7637-07-2		<1	mg/kg	13.43	<4.298	mg/kg	<0.00043 %	✓	<LOD
7		cadmium { cadmium sulfide } 048-010-00-4	215-147-8	1306-23-6	1	0.232	mg/kg	1.29	0.095	mg/kg	0.000007 %	✓	

#	Determinand	CLP index number	EC Number	CAS Number	CLP Note	User entered data		Conv. Factor	Compound conc.		Classification value	MC Applied	Conc. Not Used
8	chromium in chromium(III) compounds { chromium(III) oxide }		215-160-9	1308-38-9		8.76	mg/kg	1.46	4.097	mg/kg	0.00041 %	✓	
9	copper { copper sulphate pentahydrate }	029-023-00-4	231-847-6	7758-99-8		23.6	mg/kg	3.93	29.672	mg/kg	0.00297 %	✓	
10	chromium in chromium(VI) compounds { chromium (VI) compounds, with the exception of barium chromate and of compounds specified elsewhere in this Annex }	024-017-00-8				<0.6	mg/kg	1.92	<0.369	mg/kg	<0.000037 %	✓	**<LOD**
11	lead { lead chromate }	082-004-00-2	231-846-0	7758-97-6	1	43.4	mg/kg	1.56	21.663	mg/kg	0.001389 %	✓	
12	mercury { mercury difulminate }	080-005-00-2	211-057-8	628-86-4		<0.14	mg/kg	1.42	<0.064	mg/kg	<0.000006357 %	✓	**<LOD**
13	nickel { nickel dichromate }	028-047-00-2	239-646-5	15586-38-6	H	5.95	mg/kg	4.68	8.911	mg/kg	0.000891 %	✓	
14	selenium { selenium compounds with the exception of cadmium sulphoselenide and those specified elsewhere in this Annex }	034-002-00-8				1.41	mg/kg	2.55	1.152	mg/kg	0.000115 %	✓	
15	zinc { zinc chromate }	024-007-00-3				105	mg/kg	2.77	93.211	mg/kg	0.00932 %	✓	
16	acenaphthene		201-469-6	83-32-9		<0.008	mg/kg		<0.003	mg/kg	<0.000000256 %	✓	**<LOD**
17	acenaphthylene		205-917-1	208-96-8		0.042	mg/kg		0.014	mg/kg	0.000001354 %	✓	
18	anthracene		204-371-1	120-12-7		0.099	mg/kg		0.032	mg/kg	0.000003162 %	✓	
19	benzo[a]anthracene	601-033-00-9	200-280-6	56-55-3		0.616	mg/kg		0.197	mg/kg	0.00002 %	✓	
20	benzo[a]pyrene; benzo[def]chrysene	601-032-00-3	200-028-5	50-32-8		0.862	mg/kg		0.276	mg/kg	0.000028 %	✓	
21	benzo[b]fluoranthene	601-034-00-4	205-911-9	205-99-2		1.24	mg/kg		0.397	mg/kg	0.00004 %	✓	
22	benzo[ghi]perylene		205-883-8	191-24-2		0.697	mg/kg		0.223	mg/kg	0.000022 %	✓	
23	benzo[k]fluoranthene	601-036-00-5	205-916-6	207-08-9		0.441	mg/kg		0.141	mg/kg	0.000014 %	✓	
24	chrysene	601-048-00-0	205-923-4	218-01-9		0.721	mg/kg		0.231	mg/kg	0.000023 %	✓	
25	dibenz[a,h]anthracene	601-041-00-2	200-181-8	53-70-3		0.144	mg/kg		0.046	mg/kg	0.000004608 %	✓	
26	fluoranthene		205-912-4	206-44-0		0.911	mg/kg		0.292	mg/kg	0.000029 %	✓	
27	fluorene		201-695-5	86-73-7		0.031	mg/kg		0.01	mg/kg	0.000001002 %	✓	
28	indeno[123-cd]pyrene		205-893-2	193-39-5		0.523	mg/kg		0.167	mg/kg	0.000017 %	✓	
29	naphthalene	601-052-00-2	202-049-5	91-20-3		<0.009	mg/kg		<0.003	mg/kg	<0.000000288 %	✓	**<LOD**
30	phenanthrene		201-581-5	85-01-8		0.26	mg/kg		0.083	mg/kg	0.00000832 %	✓	
31	pyrene		204-927-3	129-00-0		0.818	mg/kg		0.262	mg/kg	0.000026 %	✓	
32	TPH (C6 to C40) petroleum group			TPH		578	mg/kg		184.96	mg/kg	0.0185 %	✓	
33	tert-butyl methyl ether; MTBE; 2-methoxy-2-methylpropane	603-181-00-X	216-653-1	1634-04-4		2.11	mg/kg		0.675	mg/kg	0.000068 %	✓	
34	polychlorobiphenyls; PCB	602-039-00-4	215-648-1	1336-36-3		<0.105	mg/kg		<0.034	mg/kg	<0.00000336 %	✓	**<LOD**

#		Determinand CLP index number / EC Number / CAS Number	CLP Note	User entered data		Conv. Factor	Compound conc.		Classification value	MC Applied	Conc. Not Used
35		sulfur { sulfur } 016-094-00-1 / 231-722-6 / 7704-34-9		2450	mg/kg		784	mg/kg	0.0784 %	✓	
								Total:	0.113 %		

Key

(yellow)	User supplied data
(grey)	Determinand values ignored for classification, see column 'Conc. Not Used' for reason
(orange)	Potentially Hazardous result
●	Determinand defined or amended by HazWasteOnline (see Appendix A)
	Speciated Deteminand - Unless the Determinand is Note 1, the Conversion Factor is used to calculate the compound concentration
<LOD	Below limit of detection
CLP: Note 1	Only the metal concentration has been used for classification
CLP: Note H	Known incomplete entry, should not be used as is

Classification of sample: VLS-2[1]

Potentially Hazardous Waste
Classified as **17 05 04** or **17 05 03 ***
in the List of Waste

Sample details

Sample Name:		LoW Code:	
VLS-2[1]		Chapter:	17: Construction and Demolition Wastes (including excavated soil from contaminated sites)
Sample Depth:			
0.00-1.00 m		Entry:	17 05 04 or 17 05 03 * (Soil and stones other than those mentioned in 17 05 03 or Soil and stones containing hazardous substances)
Moisture content:			
64% (wet weight correction)			

Hazard properties (substances considered hazardous until shown otherwise)

HP 3(i): Flammable "flammable liquid waste: liquid waste having a flash point below 60°C or waste gas oil, diesel and light heating oils having a flash point > 55°C and <= 75°C"

Hazard Statements hit:

Flam. Liq. 3; H226 "Flammable liquid and vapour."

Because of determinand:

TPH (C6 to C40) petroleum group: (conc.: 0.00691%)

Determinands

Moisture content: 64% Wet Weight Moisture Correction applied (MC)

#	Determinand	CLP index number	EC Number	CAS Number	CLP Note	User entered data	Conv. Factor	Compound conc.	Classification value	MC Applied	Conc. Not Used
1	benzene	601-020-00-8	200-753-7	71-43-2		<0.001 mg/kg		<0.00036 mg/kg	<0.000000036 %	✓	<LOD
2	toluene	601-021-00-3	203-625-9	108-88-3		<0.002 mg/kg		<0.00072 mg/kg	<0.000000072 %	✓	<LOD
3	ethylbenzene	601-023-00-4	202-849-4	100-41-4		<0.003 mg/kg		<0.001 mg/kg	<0.000000108 %	✓	<LOD
4	xylene	601-022-00-9	202-422-2 [1] 203-396-5 [2] 203-576-3 [3] 215-535-7 [4]	95-47-6 [1] 106-42-3 [2] 108-38-3 [3] 1330-20-7 [4]		<0.009 mg/kg		<0.003 mg/kg	<0.000000324 %	✓	<LOD
5	arsenic { arsenic trioxide }	033-003-00-0	215-481-4	1327-53-3		2.82 mg/kg	1.32	1.34 mg/kg	0.000134 %	✓	
6	boron { boron tribromide/trichloride/trifluoride (combined) }			10294-33-4, 10294-34-5, 7637-07-2		1.05 mg/kg	13.43	5.077 mg/kg	0.000508 %	✓	
7	cadmium { cadmium sulfide }	048-010-00-4	215-147-8	1306-23-6	1	1.03 mg/kg	1.29	0.477 mg/kg	0.000037 %	✓	
8	chromium in chromium(III) compounds { chromium(III) oxide }		215-160-9	1308-38-9		11.1 mg/kg	1.46	5.84 mg/kg	0.000584 %	✓	
9	copper { copper sulphate pentahydrate }	029-023-00-4	231-847-6	7758-99-8		34.6 mg/kg	3.93	48.94 mg/kg	0.00489 %	✓	

#	Determinand	CLP index number	EC Number	CAS Number	CLP Note	User entered data		Conv. Factor	Compound conc.		Classification value	MC Applied	Conc. Not Used
10	chromium in chromium(VI) compounds { chromium (VI) compounds, with the exception of barium chromate and of compounds specified elsewhere in this Annex }	024-017-00-8				<0.6	mg/kg	1.92	<0.415	mg/kg	<0.000042 %	✓	<LOD
11	lead { lead chromate }	082-004-00-2	231-846-0	7758-97-6	1	157	mg/kg	1.56	88.161	mg/kg	0.005652 %	✓	
12	mercury { mercury difulminate }	080-005-00-2	211-057-8	628-86-4		<0.14	mg/kg	1.42	<0.072	mg/kg	<0.000007151 %	✓	<LOD
13	nickel { nickel dichromate }	028-047-00-2	239-646-5	15586-38-6	H	9.47	mg/kg	4.68	15.955	mg/kg	0.0016 %	✓	
14	selenium { selenium compounds with the exception of cadmium sulphoselenide and those specified elsewhere in this Annex }	034-002-00-8				1.76	mg/kg	2.55	1.618	mg/kg	0.000162 %	✓	
15	zinc { zinc chromate }	024-007-00-3				176	mg/kg	2.77	175.77	mg/kg	0.0176 %	✓	
16	acenaphthene		201-469-6	83-32-9		0.057	mg/kg		0.02	mg/kg	0.000002034 %	✓	
17	acenaphthylene		205-917-1	208-96-8		0.159	mg/kg		0.057	mg/kg	0.000005724 %	✓	
18	anthracene		204-371-1	120-12-7		0.238	mg/kg		0.086	mg/kg	0.000008568 %	✓	
19	benzo[a]anthracene	601-033-00-9	200-280-6	56-55-3		1.94	mg/kg		0.698	mg/kg	0.00007 %	✓	
20	benzo[a]pyrene; benzo[def]chrysene	601-032-00-3	200-028-5	50-32-8		2.94	mg/kg		1.058	mg/kg	0.000106 %	✓	
21	benzo[b]fluoranthene	601-034-00-4	205-911-9	205-99-2		4.25	mg/kg		1.53	mg/kg	0.000153 %	✓	
22	benzo[ghi]perylene		205-883-8	191-24-2		2.33	mg/kg		0.839	mg/kg	0.000084 %	✓	
23	benzo[k]fluoranthene	601-036-00-5	205-916-6	207-08-9		1.43	mg/kg		0.515	mg/kg	0.000051 %	✓	
24	chrysene	601-048-00-0	205-923-4	218-01-9		2.2	mg/kg		0.792	mg/kg	0.000079 %	✓	
25	dibenz[a,h]anthracene	601-041-00-2	200-181-8	53-70-3		0.563	mg/kg		0.203	mg/kg	0.00002 %	✓	
26	fluoranthene		205-912-4	206-44-0		2.96	mg/kg		1.066	mg/kg	0.000107 %	✓	
27	fluorene		201-695-5	86-73-7		0.049	mg/kg		0.018	mg/kg	0.000001753 %	✓	
28	indeno[123-cd]pyrene		205-893-2	193-39-5		2.05	mg/kg		0.738	mg/kg	0.000074 %	✓	
29	naphthalene	601-052-00-2	202-049-5	91-20-3		0.07	mg/kg		0.025	mg/kg	0.00000252 %	✓	
30	phenanthrene		201-581-5	85-01-8		0.581	mg/kg		0.209	mg/kg	0.000021 %	✓	
31	pyrene		204-927-3	129-00-0		2.71	mg/kg		0.976	mg/kg	0.000098 %	✓	
32	TPH (C6 to C40) petroleum group			TPH		192	mg/kg		69.12	mg/kg	0.00691 %	✓	
33	tert-butyl methyl ether; MTBE; 2-methoxy-2-methylpropane	603-181-00-X	216-653-1	1634-04-4		<0.005	mg/kg		<0.002	mg/kg	<0.00000018 %	✓	<LOD
34	polychlorobiphenyls; PCB	602-039-00-4	215-648-1	1336-36-3		<0.105	mg/kg		<0.038	mg/kg	<0.00000378 %	✓	<LOD
35	sulfur { sulfur }	016-094-00-1	231-722-6	7704-34-9		3750	mg/kg		1350	mg/kg	0.135 %	✓	
										Total:	0.174 %		

Key

	User supplied data
	Determinand values ignored for classification, see column 'Conc. Not Used' for reason
	Potentially Hazardous result
	Determinand defined or amended by HazWasteOnline (see Appendix A)
	Speciated Deteminand - Unless the Determinand is Note 1, the Conversion Factor is used to calculate the compound concentration
<LOD	Below limit of detection
CLP: Note 1	Only the metal concentration has been used for classification
CLP: Note H	Known incomplete entry, should not be used as is

Classification of sample: VLS-3[1]

Potentially Hazardous Waste
Classified as **17 05 04** or **17 05 03 ***
in the List of Waste

Sample details

Sample Name:		LoW Code:	
VLS-3[1]		Chapter:	17: Construction and Demolition Wastes (including excavated soil from contaminated sites)
Sample Depth:			
0.00-1.00 m		Entry:	17 05 04 or 17 05 03 * (Soil and stones other than those mentioned in 17 05 03 or Soil and stones containing hazardous substances)
Moisture content:			
59% (wet weight correction)			

Hazard properties (substances considered hazardous until shown otherwise)

HP 3(i): Flammable "flammable liquid waste: liquid waste having a flash point below 60°C or waste gas oil, diesel and light heating oils having a flash point > 55°C and <= 75°C"

Hazard Statements hit:

Flam. Liq. 3; H226 "Flammable liquid and vapour."

Because of determinand:

TPH (C6 to C40) petroleum group: (conc.: 0.0545%)

Determinands

Moisture content: 59% Wet Weight Moisture Correction applied (MC)

#	Determinand	CLP index number	EC Number	CAS Number	CLP Note	User entered data	Conv. Factor	Compound conc.	Classification value	MC Applied	Conc. Not Used
1	benzene	601-020-00-8	200-753-7	71-43-2		<0.001 mg/kg		<0.00041 mg/kg	<0.000000041 %	✓	**<LOD**
2	toluene	601-021-00-3	203-625-9	108-88-3		<0.002 mg/kg		<0.00082 mg/kg	<0.000000082 %	✓	**<LOD**
3	ethylbenzene	601-023-00-4	202-849-4	100-41-4		<0.003 mg/kg		<0.001 mg/kg	<0.000000123 %	✓	**<LOD**
4	xylene	601-022-00-9	202-422-2 [1] 203-396-5 [2] 203-576-3 [3] 215-535-7 [4]	95-47-6 [1] 106-42-3 [2] 108-38-3 [3] 1330-20-7 [4]		<0.009 mg/kg		<0.004 mg/kg	<0.000000369 %	✓	**<LOD**
5	arsenic { arsenic trioxide }	033-003-00-0	215-481-4	1327-53-3		2.78 mg/kg	1.32	1.505 mg/kg	0.00015 %	✓	
6	boron { boron tribromide/trichloride/trifluoride (combined) }			10294-33-4, 10294-34-5, 7637-07-2		<1 mg/kg	13.43	<5.506 mg/kg	<0.000551 %	✓	**<LOD**
7	cadmium { cadmium sulfide }	048-010-00-4	215-147-8	1306-23-6	1	0.795 mg/kg	1.29	0.419 mg/kg	0.000033 %	✓	
8	chromium in chromium(III) compounds { chromium(III) oxide }		215-160-9	1308-38-9		8.94 mg/kg	1.46	5.357 mg/kg	0.000536 %	✓	
9	copper { copper sulphate pentahydrate }	029-023-00-4	231-847-6	7758-99-8		24.8 mg/kg	3.93	39.951 mg/kg	0.004 %	✓	

#	Determinand	CLP index number	EC Number	CAS Number	CLP Note	User entered data		Conv. Factor	Compound conc.		Classification value	MC Applied	Conc. Not Used
10	chromium in chromium(VI) compounds { chromium (VI) compounds, with the exception of barium chromate and of compounds specified elsewhere in this Annex }	024-017-00-8				<0.6	mg/kg	1.92	<0.473	mg/kg	<0.000047 %	✓	<LOD
11	lead { lead chromate }	082-004-00-2	231-846-0	7758-97-6	1	126	mg/kg	1.56	80.58	mg/kg	0.005166 %	✓	
12	mercury { mercury difulminate }	080-005-00-2	211-057-8	628-86-4		<0.14	mg/kg	1.42	<0.081	mg/kg	<0.000008145 %	✓	<LOD
13	nickel { nickel dichromate }	028-047-00-2	239-646-5	15586-38-6	H	7.25	mg/kg	4.68	13.911	mg/kg	0.00139 %	✓	
14	selenium { selenium compounds with the exception of cadmium sulphoselenide and those specified elsewhere in this Annex }	034-002-00-8				1.42	mg/kg	2.55	1.487	mg/kg	0.000149 %	✓	
15	zinc { zinc chromate }	024-007-00-3				146	mg/kg	2.77	166.06	mg/kg	0.0166 %	✓	
16	acenaphthene		201-469-6	83-32-9		0.072	mg/kg		0.03	mg/kg	0.00000296 %	✓	
17	acenaphthylene		205-917-1	208-96-8		0.165	mg/kg		0.068	mg/kg	0.000006765 %	✓	
18	anthracene		204-371-1	120-12-7		0.282	mg/kg		0.116	mg/kg	0.000012 %	✓	
19	benzo[a]anthracene	601-033-00-9	200-280-6	56-55-3		1.69	mg/kg		0.693	mg/kg	0.000069 %	✓	
20	benzo[a]pyrene; benzo[def]chrysene	601-032-00-3	200-028-5	50-32-8		2.92	mg/kg		1.197	mg/kg	0.00012 %	✓	
21	benzo[b]fluoranthene	601-034-00-4	205-911-9	205-99-2		4.8	mg/kg		1.968	mg/kg	0.000197 %	✓	
22	benzo[ghi]perylene		205-883-8	191-24-2		2.62	mg/kg		1.074	mg/kg	0.000107 %	✓	
23	benzo[k]fluoranthene	601-036-00-5	205-916-6	207-08-9		1.53	mg/kg		0.627	mg/kg	0.000063 %	✓	
24	chrysene	601-048-00-0	205-923-4	218-01-9		2.26	mg/kg		0.927	mg/kg	0.000093 %	✓	
25	dibenz[a,h]anthracene	601-041-00-2	200-181-8	53-70-3		0.599	mg/kg		0.246	mg/kg	0.000025 %	✓	
26	fluoranthene		205-912-4	206-44-0		3.1	mg/kg		1.271	mg/kg	0.000127 %	✓	
27	fluorene		201-695-5	86-73-7		0.052	mg/kg		0.021	mg/kg	0.00000212 %	✓	
28	indeno[123-cd]pyrene		205-893-2	193-39-5		2.37	mg/kg		0.972	mg/kg	0.000097 %	✓	
29	naphthalene	601-052-00-2	202-049-5	91-20-3		0.053	mg/kg		0.022	mg/kg	0.000002165 %	✓	
30	phenanthrene		201-581-5	85-01-8		0.666	mg/kg		0.273	mg/kg	0.000027 %	✓	
31	pyrene		204-927-3	129-00-0		2.73	mg/kg		1.119	mg/kg	0.000112 %	✓	
32	TPH (C6 to C40) petroleum group			TPH		1330	mg/kg		545.3	mg/kg	0.0545 %	✓	
33	tert-butyl methyl ether; MTBE; 2-methoxy-2-methylpropane	603-181-00-X	216-653-1	1634-04-4		<0.005	mg/kg		<0.002	mg/kg	<0.000000205 %	✓	<LOD
34	polychlorobiphenyls; PCB	602-039-00-4	215-648-1	1336-36-3		<0.105	mg/kg		<0.043	mg/kg	<0.000004305 %	✓	<LOD
35	sulfur { sulfur }	016-094-00-1	231-722-6	7704-34-9		3010	mg/kg		1234.1	mg/kg	0.123 %	✓	
										Total:	0.208 %		

Key

	User supplied data
	Determinand values ignored for classification, see column 'Conc. Not Used' for reason
	Potentially Hazardous result
	Determinand defined or amended by HazWasteOnline (see Appendix A)
	Speciated Deteminand - Unless the Determinand is Note 1, the Conversion Factor is used to calculate the compound concentration
<LOD	Below limit of detection
CLP: Note 1	Only the metal concentration has been used for classification
CLP: Note H	Known incomplete entry, should not be used as is

Appendix A: Classifier defined and non CLP determinands

ethylbenzene (EC Number: 202-849-4, CAS Number: 100-41-4)

CLP index number: 601-023-00-4
Data source: Commission Regulation (EU) No 605/2014 – 6th Adaptation to Technical Progress for Regulation (EC) No 1272/2008. (ATP6)
Additional Risk Phrases: None.
Additional Hazard Statement(s): Carc. 2 H351
Reason for additional Hazards Statement(s)/Risk Phrase(s):
6/3/2015 - Carc. 2 H351 hazard statement sourced from: IARC Group 2B (77) 2000

boron tribromide/trichloride/trifluoride (combined) (CAS Number: 10294-33-4, 10294-34-5, 7637-07-2)

Conversion factor: 13.43
Description/Comments: Combines the hazard statements and the average of the conversion factors for boron tribromide, boron trichloride and boron trifluoride
Data source: N/A
Data source date: 8/6/2015
Risk Phrases: R14 , T+ R26/28 , C R34 , C R35
Hazard Statements: EUH014 , Acute Tox. 2 H330 , Acute Tox. 2 H300 , Skin Corr. 1A H314 , Skin Corr. 1B H314

chromium(III) oxide (EC Number: 215-160-9, CAS Number: 1308-38-9)

Conversion factor: 1.462
Description/Comments: Data from C&L Inventory Database
Data source: http://echa.europa.eu/web/guest/information-on-chemicals/cl-inventory-database
Data source date: 7/17/2015
Risk Phrases: R20 , R22 , R36 , R37 , R38 , R42 , R43 , R50/53 , R60 , R61
Hazard Statements: Acute Tox. 4 H332 , Acute Tox. 4 H302 , Eye Irrit. 2 H319 , STOT SE 3 H335 , Skin Irrit. 2 H315 , Resp. Sens. 1 H334 , Skin Sens. 1 H317 , Repr. 1B H360FD , Aquatic Acute 1 H400 , Aquatic Chronic 1 H410

copper sulphate pentahydrate (EC Number: 231-847-6, CAS Number: 7758-99-8)

CLP index number: 029-023-00-4
Data source: Regulation (EU) 2016/1179 of 19 July 2016 (ATP9)
Additional Risk Phrases: N R50/53 , N R50/53 >= 2.5 %
Additional Hazard Statement(s): None.
Reason for additional Hazards Statement(s)/Risk Phrase(s):
10/10/2016 - N R50/53 risk phrase sourced from: WM3 v1 still uses ecotoxic risk phrases
10/10/2016 - N R50/53 >= 2.5 % risk phrase sourced from: WM3 v1 still uses ecotoxic risk phrases

acenaphthene (EC Number: 201-469-6, CAS Number: 83-32-9)

Description/Comments: Data from C&L Inventory Database
Data source: http://echa.europa.eu/web/guest/information-on-chemicals/cl-inventory-database
Data source date: 7/17/2015
Risk Phrases: R36 , R37 , R38 , N R50/53 , N R51/53
Hazard Statements: Eye Irrit. 2 H319 , STOT SE 3 H335 , Skin Irrit. 2 H315 , Aquatic Acute 1 H400 , Aquatic Chronic 1 H410 , Aquatic Chronic 2 H411

acenaphthylene (EC Number: 205-917-1, CAS Number: 208-96-8)

Description/Comments: Data from C&L Inventory Database
Data source: http://echa.europa.eu/web/guest/information-on-chemicals/cl-inventory-database
Data source date: 7/17/2015
Risk Phrases: R22 , R26 , R27 , R36 , R37 , R38
Hazard Statements: Acute Tox. 4 H302 , Acute Tox. 1 H330 , Acute Tox. 1 H310 , Eye Irrit. 2 H319 , STOT SE 3 H335 , Skin Irrit. 2 H315

anthracene (EC Number: 204-371-1, CAS Number: 120-12-7)

Description/Comments: Data from C&L Inventory Database
Data source: http://echa.europa.eu/web/guest/information-on-chemicals/cl-inventory-database
Data source date: 7/17/2015
Risk Phrases: R36 , R37 , R38 , R43 , N R50/53
Hazard Statements: Eye Irrit. 2 H319 , STOT SE 3 H335 , Skin Irrit. 2 H315 , Skin Sens. 1 H317 , Aquatic Acute 1 H400 , Aquatic Chronic 1 H410

benzo[ghi]perylene (EC Number: 205-883-8, CAS Number: 191-24-2)

Description/Comments: Data from C&L Inventory Database; SDS Sigma Aldrich 28/02/2015
Data source: http://echa.europa.eu/web/guest/information-on-chemicals/cl-inventory-database
Data source date: 7/23/2015
Risk Phrases: N R50/53
Hazard Statements: Aquatic Acute 1 H400 , Aquatic Chronic 1 H410

fluoranthene (EC Number: 205-912-4, CAS Number: 206-44-0)

Description/Comments: Data from C&L Inventory Database
Data source: http://echa.europa.eu/web/guest/information-on-chemicals/cl-inventory-database
Data source date: 8/21/2015
Risk Phrases: Xn R22 , N R50/53
Hazard Statements: Acute Tox. 4 H302 , Aquatic Acute 1 H400 , Aquatic Chronic 1 H410

fluorene (EC Number: 201-695-5, CAS Number: 86-73-7)

Description/Comments: Data from C&L Inventory Database
Data source: http://echa.europa.eu/web/guest/information-on-chemicals/cl-inventory-database
Data source date: 8/6/2015
Risk Phrases: N R50/53
Hazard Statements: Aquatic Acute 1 H400 , Aquatic Chronic 1 H410

indeno[123-cd]pyrene (EC Number: 205-893-2, CAS Number: 193-39-5)

Description/Comments: Data from C&L Inventory Database
Data source: http://echa.europa.eu/web/guest/information-on-chemicals/cl-inventory-database
Data source date: 8/6/2015
Risk Phrases: R40
Hazard Statements: Carc. 2 H351

phenanthrene (EC Number: 201-581-5, CAS Number: 85-01-8)

Description/Comments: Data from C&L Inventory Database
Data source: http://echa.europa.eu/web/guest/information-on-chemicals/cl-inventory-database
Data source date: 8/6/2015
Risk Phrases: R22 , R36 , R37 , R38 , R40 , R43 , N R50/53
Hazard Statements: Acute Tox. 4 H302 , Eye Irrit. 2 H319 , STOT SE 3 H335 , Carc. 2 H351 , Skin Sens. 1 H317 , Aquatic Acute 1 H400 , Aquatic Chronic 1 H410 , Skin Irrit. 2 H315

pyrene (EC Number: 204-927-3, CAS Number: 129-00-0)

Description/Comments: Data from C&L Inventory Database; SDS Sigma Aldrich 2014
Data source: http://echa.europa.eu/web/guest/information-on-chemicals/cl-inventory-database
Data source date: 8/21/2015
Risk Phrases: Xi R36/37/38 , N R50/53
Hazard Statements: Skin Irrit. 2 H315 , Eye Irrit. 2 H319 , STOT SE 3 H335 , Aquatic Acute 1 H400 , Aquatic Chronic 1 H410

TPH (C6 to C40) petroleum group (CAS Number: TPH)

Description/Comments: Hazard statements taken from WM3 1st Edition 2015; Risk phrases: WM2 3rd Edition 2013
Data source: WM3 1st Edition 2015
Data source date: 5/25/2015
Risk Phrases: R10 , R45 , R46 , R51/53 , R63 , R65
Hazard Statements: Flam. Liq. 3 H226 , Asp. Tox. 1 H304 , STOT RE 2 H373 , Muta. 1B H340 , Carc. 1B H350 , Repr. 2 H361d , Aquatic Chronic 2 H411

polychlorobiphenyls; PCB (EC Number: 215-648-1, CAS Number: 1336-36-3)

CLP index number: 602-039-00-4
Data source: Regulation 1272/2008/EC - Classification, labelling and packaging of substances and mixtures. (CLP)
Additional Risk Phrases: None.
Additional Hazard Statement(s): Carc. 1A H350
Reason for additional Hazards Statement(s)/Risk Phrase(s):
9/29/2015 - Carc. 1A H350 hazard statement sourced from: IARC Group 1 (23, Sup 7, 100C) 2012

Appendix B: Rationale for selection of metal species

arsenic {arsenic trioxide}

Worst case species based on hazard statements

boron {boron tribromide/trichloride/trifluoride (combined)}

Worst case species based on hazard statements

cadmium {cadmium sulfide}

Worst case species based on hazard statements

chromium in chromium(III) compounds {chromium(III) oxide}

Worst case highest conversion factor

copper {copper sulphate pentahydrate}

Most likely common species

chromium in chromium(VI) compounds {chromium (VI) compounds, with the exception of barium chromate and of compounds specified elsewhere in this Annex}

Worst case highest conversion factor

lead {lead chromate}

Worst case species based on hazard statements

mercury {mercury difulminate}

Worst case species based on hazard statements

nickel {nickel dichromate}

Worst case species based on hazard statements

selenium {selenium compounds with the exception of cadmium sulphoselenide and those specified elsewhere in this Annex}

Worst case species based on hazard statements

zinc {zinc chromate}

Worst case species based on hazard statements

sulfur {sulfur}

Based on lab analysis

Appendix C: Version

HazWasteOnline Classification Engine: WM3 1st Edition, May 2015
HazWasteOnline Classification Engine Version: 2016.317.3166.6295 (12 Nov 2016)
HazWasteOnline Database: 2016.315.3165.6292 (10 Nov 2016)

This classification utilises the following guidance and legislation:
WM3 - Waste Classification - May 2015
CLP Regulation - Regulation 1272/2008/EC of 16 December 2008
1st ATP - Regulation 790/2009/EC of 10 August 2009
2nd ATP - Regulation 286/2011/EC of 10 March 2011
3rd ATP - Regulation 618/2012/EU of 10 July 2012
4th ATP - Regulation 487/2013/EU of 8 May 2013
Correction to 1st ATP - Regulation 758/2013/EU of 7 August 2013
5th ATP - Regulation 944/2013/EU of 2 October 2013
6th ATP - Regulation 605/2014/EU of 5 June 2014
WFD Annex III replacement - Regulation 1357/2014/EU of 18 December 2014
Revised List of Wastes 2014 - Decision 2014/955/EU of 18 December 2014
7th ATP - Regulation 2015/1221/EU of 24 July 2015
8th ATP - Regulation (EU) 2016/918 of 19 May 2016
9th ATP - Regulation (EU) 2016/1179 of 19 July 2016
POPs Regulation 2004 - Regulation 850/2004/EC of 29 April 2004
1st ATP to POPs Regulation - Regulation 756/2010/EU of 24 August 2010
2nd ATP to POPs Regulation - Regulation 757/2010/EU of 24 August 2010

APPENDIX G – Contaminated Land Preliminary Risk Assessment for the Feasibility Study, Options Appraisal and Outline Designs for the River Ver through St Albans

Contaminated Land Preliminary Risk Assessment for the Feasibility Study, Options Appraisal and Outline Designs for the River Ver through St Albans

1. Development History

The historical Ordnance Survey (OS) maps obtained with the Landmark Envirocheck report date between 1880 and 2016. Tables 1.1 - 1.6 summarise the immediate site history of each River Ver reach, as well as that of the wider surroundings.

Table 1.1 Summary of Historical OS Mapping – Reach 1

Year	Features on-site	Features off site
1879-80	- Kingsbury Mill found to the north of Reach 1 - The River Ver flows through the grounds of St Michael's Manor House in a straight mill leat channel section. There is a fish pond in the grounds surrounded by a mix of coniferous and deciduous woodland. - The River Ver flows along the SW edge of the fish pond and also appears to bifurcate into two parallel channels. - There are drainage and/or leat channels marked between St German's Farm to the west and the River Ver. There are foot bridges over these channels. - An additional channel drains from farmland and connects to the River Ver further south in Reach 1. This is likely to be a drainage channel. - There is a larger fishpond to the SW of the River Ver leat channel on the site of the present Verulamium Lake. - The river crosses The Causeway embankment at two fords. There is also an engine house on the causeway. - There channel continues to be split between the main River Ver and a leat channel feeding Abbey Mill at the south of the reach.	- The surrounding area is comprised of residential properties of St Albans to the north and southeast, along with amenities such as schools and public houses (along Fishpool Street). - There are roman ruins to the west of the larger fishpond (in the modern day recreational park). - There is agricultural land to the west and south of the reach.
1898	- The site remains generally unchanged except for much reduced tree cover around the fish pond in the Manor House grounds, and development of marshland to the west of the Manor House fishpond.	- The area surrounding the site remains generally unchanged.
1924	- Allotment gardens are now found to the west of the northernmost section of Reach 1. - A weir is now marked where the leat channel breaks from the main channel at the southern extent of the allotments, as well as a sluice between the River Ver and the fish pond at St	- Increase in urban cover north of the reach, with increasing signs of industry (e.g. Motor Body Building Works) and an altered road layout.

Year	Features on-site	Features off site
	Michael's Manor House. - Marshland has grown in area. - A dam is marked to the south of the apparent drainage channel that emanates from St George's Farm, prior to its reconnection with the River Ver. - A weir is now marked rather than a ford at the southeast of the larger fishpond at the Causeway. - A timber yard has been constructed alongside the larger fish pond and adjacent to the Ver.	
1939	- Allotment gardens have been replaced by an area of broadleaved vegetation and a small building at the far north of the reach. - The larger fish pond has been extended north to become a larger lake as part of development of a recreational park. - A smaller, circular upper lake is now also marked. A weir is located between the new upper and lower lake, and both are surrounded by footpaths. - The main lake has two wooded islands. - Lavatories are now found on The Causeway adjacent to the larger lake at the south of the reach. - A ford previously marked at The Causeway is no longer marked and so may now be a bridge under Abbey Mill Lane.	- Farmland adjacent to Reach 1 has become recreational ground. This includes a car park, tennis courts, a museum and a pavilion. - Urban expansion has occurred to the north including many new properties.
1963-64	- The site remains generally unchanged except for altered vegetation cover in the park (reduced woodland). - A paddling pool has been built adjacent to the upper, small lake in the park.	- Allotment gardens are now found to the east of the River Ver adjacent to the main lake. Alongside these is a playing field with tennis courts, and a depot is also marked.
1975-77	- The maps are incomplete during this period. - Kingsbury Mill has been replaced by a museum just to the north of Reach 1. - An electricity substation is marked at Abbey Mill as the River Ver flows south of The Causeway. - A swimming pool is now marked in the park adjacent to the northernmost extent of Reach 1.	- A dairy and electricity substation is now recorded around 250-300 m north of the northernmost extent of Reach 1.
1999	- The 1:2500 maps are incomplete post 1977 and little change is observable on the 1:10,000 maps. - Additional buildings have been erected on the Abbey Mill site.	- The 1:2500 maps are incomplete post 1977 and little change is observable on the 1:10,000 maps.

Year	Features on-site	Features off site
2016	- Little change can be observed on the 1:10,000 maps.	- Little change can be observed on the 1:10,000 maps except for changes in building configurations in the wider urban area..

Table 1.2 Summary of Historical OS Mapping – Reach 2

Year	Features on-site	Features off site
1880	- The River Ver reach is split between the mill leat channel that flows through Abbey Mill and a channel slightly further west. These channels join together south of the mill. - As well as the mill, a school is also located between the two channels. - The reach extends to Holywell Hill (road). There are numerous properties along this road heading north. - Verulamhills Farm was located immediately to the south of the channel in this reach. There are fields and scattered trees on both sides of the channel. A drainage channel from the farm connects with the main River Ver just before it reaches Holywell Road. The river flows under the bridge before becoming Reach 2 to the east of the bridge.	- The St Albans Cathedral is located to the north of Reach 2 (approx. 500 m). There are numerous properties in the vicinity.
1898	- The site remains generally unchanged with the exception of the development of marshland immediately south of the River Ver through this reach. - There appears to be generally less tree cover.	- The area surrounding the site remains generally unchanged. - A hotel is marked heading south away from the river on Holywell Hill (road).
1924	- The River Ver is marked with marshland as it approaches the end of this Reach at Holywell Hill (road). This suggests low flows and vegetation development. - Farmland has been given over to allotment gardens immediately south of this reach. The drainage channels from the farm remain in situ.	- The area surrounding the site remains generally unchanged although allotment gardens are now also found in the grounds of St Alban's Cathedral.
1939	- New properties have been built immediately north of the River Ver on two new roads (Pondwicks Close and Lady Spencer's Grove), and their plots of land extend as far as the river.	- The area surrounding the site remains generally unchanged.
1962-1964	- A TA Centre consisting of numerous buildings has been built around 250m south of the River Ver off Holywell Hill (A5). - A new road also parallels the river to the south and extends towards the Verulamhills farm buildings. - The Abbey Mill is now labelled as 'works'.	- There is now a recreation ground to the north of Lady Spencer's Grove.
1970-77	- The area immediately surrounding the site remains generally unchanged.	- The Abbey School and associated buildings and recreation ground have been built around 250m north of Reach 2 off Lady Spencer's Grove. - A scout hut has also been constructed to the north of the Abbey School.

Year	Features on-site	Features off site
		- Recreational amenities, including an athletics track, a pavilion, a sports hall, swimming pools and a theatre have been built adjacent to the TA centre around 250m south of the river, and are part of the Westminster Lodge site.
1975-1978	- Additional properties developed adjacent to the River along Abbey Mill End (road), with plots extending to the River.	- The area remains generally unchanged.
1992	- Verulamhills Farm to the south of the River is no longer present. The farm buildings are gone and the land has become a recreation ground. - An additional building has been constructed between the River Ver and mill leat channel on the old Abbey Mill site.	- The area remains generally unchanged..
1999	- The site remains generally unchanged.	- The old TA centre site has become a leisure centre.
2016	- Pumping station is marked for the first time just south of the River in Verulamium Park. The building has however been in place since 1960.	- The area remains generally unchanged.

Table 1.3 Summary of Historical OS Mapping – Reach 3

Year	Features on-site	Features off site
1880	- This is a short straight reach of the River Ver adjacent to the parallel Prospect Road. It flows from the bridge at Holywell Hill (road) to the ninety degree bend in the river shortly downstream. - Properties (including the large Ver House) and their gardens (including a fish pond) back on to the southern bank of Reach 3. - Immediately to the north of the river is open land attached to Holywell House, including the site of a 'Holy Well'.	- Further properties and gardens are found to the south of the river. - A railway terminus and gas works are found to the south of the properties over 250 m from the river. - To the north of the Holywell House grounds is a predominantly urban area with amenities such as a hospital, and signs of industry including a Malthouse, hat factory and Holywell Brewery.
1898	- Holywell House to the north of the River Ver has been removed and a number of buildings have taken its place along Holywell Hill (road). - A private water works has been developed immediately north of the river. There are buildings and a new (drainage) channel associated with this. This reconnects with the River Ver in reach 4.	- New roads (Belmont Hill, Thorpe Road) and properties have been developed encroaching onto the previous grounds of the former Holywell House.
1925	- The area remains largely unchanged except for greater tree cover to the immediate north of the reach between the river and the (drainage) channel.	- The open area adjacent to the water works to the north of the river has become a recreation ground and includes a miniature rifle range and a pavilion.
		- A cardboard box machine factory has also been developed around 250m to the north of the reach adjacent to the recreation ground. - To the south of the railway terminus adjacent to the gas works there has been further industrial development (marine chronometer works) and also development of allotment gardens.
1939	- Ver House to the south of Reach 3 has been removed and a skating rink and associated building built in its place. The fish pond in the gardens has also been removed.	- A swimming bath has been built on the recreation ground to the north of the river reach. - There has been an increase in properties on Prospect Road to the south of the river, and also further south of the railway terminus adjacent to the gas works.
1963-64	- The small (drainage) channel to the immediate north of the River Ver has been removed. - The skating rink to the south of the channel has been replaced by works and a garage.	- The urban area to the north of the playing field/recreation ground has developed, with the malthouses being developed into numerous other properties. Several changes in building configuration have occurred, and there are car parks and further

Year	Features on-site	Features off site
		works.
1977	- A closed reservoir has been built at the water works to the immediate north of the River Ver.	- The area remains generally unchanged except for minor changes in building configurations.
1986	- The playing field north of Reach 3 has been built on with a residential estate.	- The railway terminus has downsized to a station.
1994	- The large works and garage to the immediate south of the reach has been replaced by five smaller buildings.	- Part of the gas works to the south of the river has become a superstore associated roads.
2016	- The site remains generally unchanged except for slight changes to building structures. - The area previously marked as a garage has been developed into flats after closing in 2001.	- The site remains generally unchanged except for slight changes to building structures. - Dry cleaners listed on Everard Close south of the reach.

Table 1.4 Summary of Historical OS Mapping – Reach 4

Year	Features on-site	Features off site
1880	- Reach 4 bifurcates with the main River Ver heading north and then turning towards the east and the bridge at Cotton Mill Lane. The other smaller branch flows south for a few metres before turning east. This then turns north just shy of Cottonmill Lane, and reconnects with the main channel just to the east of the Cottonmill Road bridge. This separate water was presumably used for the fields in this area. - This reach flows through the open grounds of Holywell House and Sportsman Hall. The Sportsman Hall is located to the south of the reach. - There is a drainage channel paralleling the reach to the south of the main channel. This meets the River Ver at Cotton Mill Lane Bridge.	- There are fields around Sportsman Hall to the south, plus railway tracks and a signalling box around 250m to the south. - Around 150-200m to the north of the reach are roads and properties of St Albans, which still has a considerable amount of open areas/parkland at this time
1898	- New footpaths cut across the open ground towards the River Ver, where baths are now marked. - There is little other change except reduced deciduous trees alongside the lower drainage ditch.	- There is little change in the wider area except for encroachment of buildings onto the grounds of Holywell Hall towards the River Ver, as also described in Reach 3.
1924-1925	- A swimming pool has been constructed immediately north of the reach. - Allotment gardens have been developed on the open ground to the north of the reach. - There is a kennels south of the reach adjacent to Sportsman Hall.	- There has been further development of the urban area over 250m to the north of the reach, particularly around Paxton Road where many new properties have been built. - To the south there has been property development to the north of the railway tracks, but south of Prospect Road (100-150m from Reach 4)
1939	- A small area of allotment gardens remains north of the reach adjacent to the swimming pool, but much of the allotment area has been built on with houses along a new road (Cottonmill Crescent). - The drainage channel to the south of the reach is no longer marked. - Houses have been built on the northern side of prospect road which back on to the southern bank of the river channel.	- A nursery area close to Watson's Walk (road) has been developed with further properties.
1963-1964	- The River Ver is now marked as just the one channel that initially heads north before turning towards Cottonmill Lane Bridge.	- There have been changes in the configuration of the urban area to the north, with new car parks, a garage and various works.

Year	Features on-site	Features off site
	- Tracks are marked on the allotment gardens, presumably for access.	
1977	- The reach remains generally unchanged.	- The area remains generally unchanged.
1994	- The reach remains generally unchanged except for development of more properties on the previous kennels site around 100m south of Reach 3.	- The area remains generally unchanged.
2016	- The reach remains generally unchanged.	- The area remains generally unchanged except for slight changes in building configuration in the urban area.

Table 1.5 Summary of Historical OS Mapping – Reach 5

Year	Features on-site	Features off site
1880	- Reach 5 sees the River Ver travel southeast from the Cottonmill Lane bridge to the site of the Sopwell Nunnery (remains). - The river is lined with deciduous trees on the northbank through the fields. - There are drainage ditches heading south through the field to join the River Ver. - There is marshland to the south of the river.	- To the north of the fields, further on from Old London Road, are numerous properties and signs of industry. These include and iron works (around 500 m north of the reach). There are amenities for the population including St Peter's School and a railway station. - To the south are fields and a railway line is around 250m to the south.
1898	- The trees lining the northern bank are no longer present and watercress banks are now marked. - A new road (Ramsbury Road) has been built through the field to the north of the reach, and a cluster of buildings have been built around this. - Deciduous tree cover has been replaced by marshland south of the reach by the Sopwell Nunnery.	- There has been significant urban development to the north of the London Road around the iron works with new roads and associated properties having been built. - The southern area adjacent to the site is largely unchanged.
1924-1925	- Further development has occurred on the floodplain north of the reach around Ramsbury Road. This appears to include residential properties, plus a church and memorial hall.	- Allotment gardens are now marked south of the Sopwell Nunnery.
1939	- More residential properties and a cul-de-sac have been built on the open ground north of the reach (Cottonmill Close). The school site has also expended and there is now a chemical works adjacent to the school. - The remainder of the open ground north of the reach has become allotment gardens.	- The wider area remains generally unchanged except for slight changes in building configuration in the urban area to the north. - There is also urban expansion to the east of Cottonmill Lane to the south, which encroaches onto the allotment site.
1963-1964	- There is a small building within the allotment field to the north of the river (probably sheds). - Further properties have been built with plots backing directly onto the northern reach of the River Ver where the river begins to bend towards the south. - The chemical works has become a Cereals Research Station and further buildings have been built adjacent to the school.	- There has been significant urban expansion to the south between the Sopwell Nunnery and railway line with new roads and dozens of properties. - The old gas works site to the north of the river has become offices.
1977	- The allotment gardens to the north of the river have become playing fields. - Riverside Road has been built on the floodplain to the north of the river and roughly parallels the river course. Further properties have been developed alongside this road.	- The wider area remains generally unchanged except for slight changes in building configuration in the urban areas.

Year	Features on-site	Features off site
	- The allotment gardens to the south of the river remain in place.	
1989	- A primary school has been built on the playing field immediately north of the River Ver. - The land of the Cereals Research Centre north of the river has been developed into more properties and a cul-de-sac. -	- The wider area remains generally unchanged except for slight changes in building configuration in the urban areas.
1994	- A cul-de-sac and associated properties have been built on the allotment garden to the south of the river, just off Cottonmill Lane. - There is a new large building next to the northern bank of the River Ver midway through this reach. - There is a depot marked adjacent to the Sopwell Nunnery remains south of the river.	- The wider area remains generally unchanged except for slight changes in building configuration in the urban areas.
1999	- Additional large buildings have been erected between the depot and the southern bank of the river. These may be warehouses.	- The wider area remains generally unchanged.
2016	- The Sopwell Nunnery land and ruins south of the reach are now marked as the Sopwell Nunnery Green Space	- The wider area remains generally unchanged.

Table 1.6 Summary of Historical OS Mapping – Reach 6

Year	Features on-site	Features off site
1880	- Reach 6 flows from the Sopwell Nunnery in a roughly southerly direction towards Sopwell Mill. - There are waterbodies adjacent to both the left and right banks and these appear to be fed by drainage ditches. - The railway (Hatfield and St Alban's Branch) situated on an embankment crosses the river midway through the reach. - Drainage ditches feed a waterbody that connects with the River Ver at Sopwell Mill (corn) downstream of Reach 6. - There is a sluice at the downstream end of the reach, through which water is redirected around the mill. - There is deciduous vegetation on the river bank adjacent to the Sopwell Nunnery grounds.	- The surrounding area is predominantly made up of fields, aside from the railway line which follows a southeast to northeast axis through the area.
1898	- The land adjacent to Sopwell Nunnery is now shown to be predominantly marshland, and deciduous trees are no longer as prevalent, according to the symbology. - The waterbody on the floodplain opposite to the Sopwell Nunnery has grown in extent.	- The wider area remains generally unchanged.
1924-1925	- The waterbodies are now marked as watercress beds. - There has been urban development less than 100m to the northeast of the reach, with the construction of Longmire Road and associated properties. - There are allotment gardens south of the railway line close to these new properties (to the east of the Reach).	- Some of the field below the Sopwell Nunnery are now marked as allotment gardens. - To the east of the River Ver is now a golf course with club house, plus a watchmen works and experimental station.
1937-1939	- More extensive allotment gardens are now marked to the east of the River Ver around the watercress beds. - The waterbody to the west of the reach now appears to be isolated from the river.	- The wider area remains generally unchanged.
1963-1964	- Below the railway line crossing with the river on the western floodplain there is now a recreation ground and associated playground. - Trees are marked on the waterbody to the west of the river reach suggesting that it is drying up. - Additional properties have been built off Longmire Road to the northeast.	- There has been considerable urban expansion on the western floodplain, growing eastwards from Cottonmill Lane, across what were previously allotment gardens. - The experimental station is now marked as general works.
1972-78	- The site remains generally unchanged.	- The wider area remains generally unchanged.
1994	- The lower watercress beds adjacent to the River Ver (to the	- The wider area remains generally unchanged.

Year	Features on-site	Features off site
	east) have been remodelled into a larger lake. - Additional drainage ditches are marked to the north of the railway line.	
2006	- The site is largely unchanged.	- The works to the east of the river have been developed into a larger industrial estate; otherwise the area is largely unchanged.

2. Review of Geoenvironmental Risk

This section is aimed at identifying possible risks, if any, arising from substances used or deposited on-site, or from other sources of land contamination. Both past and current potentially contaminative land uses have been considered.

The DoE industry profiles have been consulted to determine potential contaminants associated with key former or present land uses. Identified contaminants, sources, pathways, receptors and consideration of risk are given for each reach in Tables 2.1-2.6:

Table 2.1 Contaminated Land Preliminary Risk Assessment for Reach 1

Previous uses along the reach (see Table 1.1)	Potential contaminants (mainly based on DoE industrial profiles)	Source Pathway Receptor	Risk consideration / Potentially unacceptable risks
- Agriculture - Recreational park and gardens (including Made Ground) - Ornamental Lake - Mills - Allotments - Timber Yard - Electricity Substation	No site or installations with hazard substances are reported in the 250m buffer zone either side of the reach by Envirocheck. No current or historic landfill sites present in 250m buffer zone either side of the reach. Verulamium Lake – full details of lake water and sediment quality in Lake Verulamium Water Quality and Sediment Technical Note. Includes 'Potentially Hazadous' sediment on the basis of elevated TPHs. Mills – metals (Cd, Cr); Semi/non metals (As) Inorganic chemicals (SO_4^{2-}, S^{2-}); Phenol; Aromatic hydrocarbons; PAHs; Chlorinated Aliphatic hydrocarbons; Dieldrin Timber yard – metals (Be, Cd, Cr, Cu, Pb, Zn), Semi/non metals (As, B); Inorganic chemicals (SO_4^{2-}); Asbestos, Phenol, Acetone, Chlorophenols, Oil/fuel hydrocarbons, Aromatic hydrocarbons, PAHs, Chlorinated aliphatic hydrocarbons, hexachlorocyclohexane; Dieldrin; Organotin compounds. Electricity Substation - metals (Ba, Cd, Cr, Cu,	**Source:** - Potentially contaminated Verulamium Lake sediments and surface water - Potentially contaminated surface water (River Ver and drainage ditches) - Potentially contaminated groundwater (superficial layers are Secondary (A) Aquifer and may provide localised aquifers and baseflow; Principal aquifer is chalk bedrock) - Water Mains pipeline (below ground) - Foul sewer pipeline (below ground) - Surface Sewer pipeline - Permitted discharges to surface water (1 undefined for Reach 1) **Pathways** - Surface water run-off and/or direct percolation from surface - Leaching of contaminants and vertical migration of groundwater - Lateral migration of groundwater providing baseflow to surface watercourses - Direct human or animal contact with soil/sediment (ingestion and dermal) **Human Health Receptors:**	**Human Health Receptors:** *Construction and maintenance workers - moderate risk* - further chemical testing of lake sediment is necessary to characterise possible contamination and/or health risk before any works. If soils are to be disturbed and/or re-used then an intrusive ground investigation including chemical testing of soils may be necessary to further quantify and characterise possible contamination. If soils or sediments are found to be contaminated then appropriate mitigation measures will be required to ensure that health and safety risks are minimised during construction. *Final End Users/Adjacent Site Users – low risk*. It is assumed that publicly accessible sites will be covered with hardstanding (or equivalent) and that there will be no pathway between end users and potentially contaminated soils/sediment. *(To be reviewed once*

Previous uses along the reach (see Table 1.1)	Potential contaminants (mainly based on DoE industrial profiles)	Source Pathway Receptor	Risk consideration / Potentially unacceptable risks
	Pb, Hg, Ni, V, Zn); Semi/non metals (As, B, Se); Inorganic chemicals (Free Cn^-, NO^{3-} SO_4^{2-}, S^{2-}), Asbestos; Phenols; Acetones; Chlorophenols; Oil/fuel hydrocarbons; PAHs, Chlorinated aliphatic hydrocarbons; hexachlorocyclohexane; chlorinate aromatic hydrocarbons; PCBs; Dioxins and furans; Organotin compounds. Agriculture/Allotments/Recreational Park – nutrients / fertilisers / pesticides / insecticides Public lavatory – bacteria, pathogens, disinfectants, soaps Recorded Pollution Incidents (NIRS): 1. TL 14015 07126, 22/4/14 – Verulamium Park - flooding (natural causes) – no category given 2. TL 14025 06991, 17/6/14 – St Stephens – algal activity (natural causes) – category 3 (minor impact)	- Final End Users - Adjacent Site users - Maintenance Workers - Construction Workers **Water receptors:** - Surface Water (River Ver and Verulamium Lake) - Primary Aquifer (chalk bedrock) - Secondary (A) Aquifer - Current surface water or groundwater abstractions (3 known from groundwater in Reach 1) **Vegetation/Ecosystem Receptors:** - Lake ecosystem and associated wildlife - River Ver ecosystem - Recreational Park vegetation **Property Receptors:** - Future proposed services and structures - Existing services and structures	*final options decided, and if hardstanding is not proposed in publically accessible areas further risk assessment will be required to determine whether contaminated soils would need covering or removal).* **Water receptors:** *Low Risk:* Implement mitigation measures during construction phase to minimise the risk of surface run-off entering surface water courses, and to minimise risk of leaching and vertical migration. *(To be reviewed once final options decided).* If lake sediments do not meet guidelines for sediment re-use on site, then off-site disposal is required. **Vegetation/Ecosystem Receptors:** *Low Risk*: Implement mitigation measures during construction phase to minimise the risk of surface run-off entering surface water courses and thereby impacting aquatic ecosystems. Efforts should be made to restrict animal access to works. **Property:** *Low Risk*: Works are constrained by known existing structures (sewer pipelines, water main pipelines) and will not interfere with these, thereby lowering any potential risk.

Table 2.2 Contaminated Land Preliminary Risk Assessment for Reach 2

Previous uses along the reach (see Table 1.2)	Potential contaminants (mainly based on DoE industrial profiles)	Source Pathway Receptor	Risk consideration / Potentially unacceptable risks
- Agriculture - Recreation ground (including Made Ground) - Mill (Abbey Mill) - Allotments - Unspecified 'works' - Pumping Station	No site or installations with hazard substances are reported in the 250m buffer zone either side of the reach by Envirocheck. No current or historic landfill sites present in 250m buffer zone either side of the reach. Mills – metals (Cd, Cr); Semi/non metals (As) Inorganic chemicals (SO_4^{2-}, S^{2-}); Phenol; Aromatic hydrocarbons; PAHs; Chlorinated Aliphatic hydrocarbons; Dieldrin Agriculture/Allotments/Recreational Park – nutrients / fertilisers / pesticides / insecticides Unspecified works – may include metals (Ba, Cd, Cr, Cu, Pb, Hg, Ni, V, Zn); Semi/non metals (As, B, Se); Inorganic chemicals (Free Cn^{-}, NO^{3-} SO_4^{2-}, S^{2-}), Asbestos; Phenols; Acetones; Chlorophenols; Oil/fuel hydrocarbons; PAHs, Chlorinated aliphatic hydrocarbons; hexachlorocyclohexane; chlorinate aromatic hydrocarbons; PCBs; Dioxins and furans; Organotin compounds. Recorded Pollution Incidents (NIRS): 1. TL 14214 06879, 1/5/10 – St Stephens – no further details. 2. TL 14249 06638, 3/3/10 – Pipe failure at pumping station – contaminated water (suspended solids) – category 4 (no impact). 3. TL 14499 06643, 16/8/11 – St Stephens pipe failure – contaminated water – category 3 (minor impact).	**Source:** - Potentially contaminated surface water (River Ver and drainage ditches) - Potentially contaminated groundwater (superficial layers are Secondary (A) Aquifer and may provide localised aquifers and baseflow; Principal aquifer is chalk bedrock) - Gas Mains Pipeline (low pressure) - Telecom Line (below ground) - Water Mains Pipeline (below ground) - Electricity – Secondary Distribution Cable - Permitted discharges to surface water (0 for Reach 2) - Pollution incidents **Pathways** - Surface water run-off and/or direct percolation from surface - Leaching of contaminants and vertical migration of groundwater - Lateral migration of groundwater providing baseflow to surface watercourses - Direct human or animal contact with soil/sediment (ingestion and dermal) **Human Health Receptors:** - Final End Users - Adjacent Site users - Maintenance Workers - Construction Workers **Water receptors:**	**Human Health Receptors:** *Construction and maintenance workers - moderate risk* - If soils are to be disturbed and/or re-used then an intrusive ground investigation including chemical testing of soils may be necessary to further quantify and characterise possible contamination. If soils are found to be contaminated then appropriate mitigation measures will be required to ensure that health and safety risks are minimised during construction. *Final End Users/Adjacent Site Users – low risk*. It is assumed that publicly accessible sites will be covered with hardstanding (or equivalent) and that there will be no pathway between end users and potentially contaminated soils/sediment. *(To be reviewed once final options decided, and if hardstanding is not proposed in publically accessible areas further risk assessment will be required to determine whether contaminated soils would need covering or removal).* **Water receptors:** *Low Risk* - Implement mitigation measures during construction phase to minimise the risk of surface run-off entering surface water courses, and

Previous uses along the reach (see Table 1.2)	Potential contaminants (mainly based on DoE industrial profiles)	Source Pathway Receptor	Risk consideration / Potentially unacceptable risks
	4. TL 14464 06667, 24/1/12 – St Stephens – no further details. 5. TL 14387 06685, 29/10/12 – no further details. 6. TL 14113 06711, 4/3/13 – St Stephens, sewer failure of overflow (crude sewage) – category 3 (minor impact). 7. TL 14517 06610, 21/4/13 – St Stephens, sewer failure of overflow (crude sewage) – category 3 (minor impact). 8. TL 14524 06646, 16/6/14 – unauthorised discharge (not identified) – category 3 (minor impact). 9. TL 14539 06644, 7/7/14 – surface water outflow control failure (sewage material, grey water) – category 3 (minor impact). 10. TL 14135 06835, 12/8/14 – natural blockage in watercourse – no further details. 11. TL 14153 06738, 9/9/14 - St Stephens, sewer failure of overflow (grey water) – category 3 (minor impact). 12. TL 14144 06783, 10/10/14 – blockage in watercourse (suspected domestic or residential source) – no further detail. 13. TL 14481 06656, 15/10/14 – sewerage containment and control failure – contaminated water (suspended solids) - category 3 (minor impact). 14. TL 14518 06654 – 25/11/14 – sewerage pipe failure – contaminated water (suspended solids) – category 3 (minor impact). 15. TL 14104 06727, 8/5/15 – sewer failure or overflow – crude sewage - category 3 (minor impact). 16. TL 14518 06620, 20/6/14 – water pollution -	- Surface Water (River Ver) - Primary Aquifer (chalk bedrock) - Secondary (A) Aquifer - Current surface water or groundwater abstractions (1 known from surface water in Reach 2) **Vegetation/Ecosystem Receptors:** - River Ver ecosystem - Recreation ground/allotment vegetation **Property Receptors:** - Future proposed services and structures - Existing services and structures	to minimise risk of leaching and vertical migration. *(To be reviewed once final options decided).* **Vegetation/Ecosystem Receptors:** *Low Risk*: Implement mitigation measures during construction phase to minimise the risk of surface run-off entering surface water courses and thereby impacting aquatic ecosystems. Efforts should be made to restrict animal access to works. **Property:** *Low Risk*: Works are constrained by known existing structures (gas mains pipeline, telecom pipeline, water mains pipeline) and will not interfere with these, thereby lowering any potential risk.

Previous uses along the reach (see Table 1.2)	Potential contaminants (mainly based on DoE industrial profiles)	Source Pathway Receptor	Risk consideration / Potentially unacceptable risks
	category 4 (no impact), no further details. 17. TL 14525 06618, 1/8/14 - water pollution - category 3 (minor impact), no further details. 18. TL 14527 06642, 26/9/14 – blockage in watercourse (natural source) – no further details. 19. TL 14518 06616, 03/10/14 – blockage in watercourse (natural source) – no further details		

Table 2.3 Contaminated Land Preliminary Risk Assessment for Reach 3

Previous uses along the reach (see Table 1.3)	Potential contaminants (mainly based on DoE industrial profiles)	Source Pathway Receptor	Risk consideration / Potentially unacceptable risks
- Recreation ground / Playing fields - Allotments - Urban (properties) - Garage (fuel station) - Vehicle servicing - Water works - Unspecified works - Dry cleaners - Railway station	No site or installations with hazard substances are reported in the 250m buffer zone either side of the reach by Envirocheck. No current or historic landfill sites present in 250m buffer zone either side of the reach. Water Works – metals (Ba, Cd, Cr, Cu, Pb, Hg, Ni, V, Zn); Semi/non metals (As, B, Se); Inorganic chemicals (Free Cn^-, NO^{3-} SO_4^{2-}, S^{2-}), Asbestos; Phenols; Acetones; Chlorophenols; Oil/fuel hydrocarbons; PAHs, Chlorinated aliphatic hydrocarbons; hexachlorocyclohexane; chlorinate aromatic hydrocarbons; PCBs; Dioxins and furans; Organotin compounds. Petrol garage (Aventine Court) / vehicle servicing - metals (Cr, Cu, Pb, Ni, V, Zn); Semi/non metals (As, B, Se); Inorganic chemicals (Free Cn^-, S^{2-}), Asbestos; Phenols; Acetones; Oil/fuel hydrocarbons; Aromatic hydrocarbons; PCBs; Organolead compounds. Petrol garage closed in 2001. Site investigation by Environ UK Ltd showed low level of contaminants with low risk to human health but risk to groundwater. Remediation undertaken in 2003, total of 400 tonnes of soil and $90m^3$ of groundwater removed from the site, and monitoring undertaken. Post remediation results in 2004 indicated hydrocarbon concentrations below those predicted by simplistic risk models. Offsite results generally measured low non-detect	**Source:** - Potentially contaminated surface water (River Ver and drainage ditches) - Potentially contaminated groundwater (superficial layers are Secondary (A) Aquifer and may provide localised aquifers and baseflow; Principal aquifer is chalk bedrock) - Gas Mains Pipeline (low pressure) - Surface Sewer Pipeline (below ground) - Foul sewer pipeline (below ground) - Electricity – Secondary Distribution Cable - Telecom Line (below ground) - Water Mains Pipeline (below ground) - Permitted discharges to surface water (0 for Reach 3) - Pollution incidents **Pathways** - Surface water run-off and/or direct percolation from surface - Leaching of contaminants and vertical migration of groundwater - Lateral migration of groundwater providing baseflow to surface watercourses - Direct human or animal contact with soil/sediment (ingestion and dermal) **Human Health Receptors:** - Final End Users - Adjacent Site users - Maintenance Workers	**Human Health Receptors:** *Construction and maintenance workers - moderate risk* - If soils are to be disturbed and/or re-used then an intrusive ground investigation including chemical testing of soils may be necessary to further quantify and characterise possible contamination. If soils are found to be contaminated then appropriate mitigation measures will be required to ensure that health and safety risks are minimised during construction. *Final End Users/Adjacent Site Users – low risk*. It is assumed that publicly accessible sites will be covered with hardstanding (or equivalent) and that there will be no pathway between end users and potentially contaminated soils/sediment. *(To be reviewed once final options decided, and if hardstanding is not proposed in publically accessible areas further risk assessment will be required to determine whether contaminated soils would need covering or removal).* **Water receptors:** *Low Risk* - Implement mitigation measures during construction phase to minimise the risk of surface run-off entering surface water courses, and

Previous uses along the reach (see Table 1.3)	Potential contaminants (mainly based on DoE industrial profiles)	Source Pathway Receptor	Risk consideration / Potentially unacceptable risks
	hydrocarbon concentrations. Groundwater from deeper wells mainly measured non-detect levels of hydrocarbons, although some diesel range organics were measured. No petrol range organics or BTEX compounds were detected. Allotments/Recreational Park – nutrients / fertilisers / pesticides / insecticides Unspecified works – may include metals (Ba, Cd, Cr, Cu, Pb, Hg, Ni, V, Zn); Semi/non metals (As, B, Se); Inorganic chemicals (Free Cn^-, NO^{3-} SO_4^{2-}, S^{2-}), Asbestos; Phenols; Acetones; Chlorophenols; Oil/fuel hydrocarbons; PAHs, Chlorinated aliphatic hydrocarbons; hexachlorocyclohexane; chlorinate aromatic hydrocarbons; PCBs; Dioxins and furans; Organotin compounds. Dry cleaners - metals (Cd, Cr, Cu, Pb, Hg, Zn); Semi/non-metals (As, Se); Inorganic chemicals (Free Cn^-, S^{2-}, NO^{3-}, SO_4^{2-}), Asbestos; Aromatic hydrocarbons; Chlorinated aliphatic hydrocarbons, PCBs. Railway - metals (Cd, Cr, Cu, Pb, Ni, V); Inorganic chemicals (SO_4^{2-}); Asbestos; Phenols; Acetones; Chlorophenols; Oil/fuel hydrocarbons; PAHs, Chlorinated aliphatic hydrocarbons; PCBs. Recorded Pollution Incidents (NIRS): 1. TL 14870 06594, 22/3/11 – no further details given. 2. TL 14735 06525, 13/2/13 – St Julians, no further details given.	- Construction Workers **Water receptors:** - Surface Water (River Ver) - Primary Aquifer (chalk bedrock) - Secondary (A) Aquifer - Current surface water or groundwater abstractions **Vegetation/Ecosystem Receptors:** - River Ver ecosystem - Recreation Ground/Field/Allotment vegetation **Property Receptors:** - Future proposed services and structures - Existing services and structures	to minimise risk of leaching and vertical migration. *(To be reviewed once final options decided).* **Vegetation/Ecosystem Receptors:** *Low Risk*: Implement mitigation measures during construction phase to minimise the risk of surface run-off entering surface water courses and thereby impacting aquatic ecosystems. Efforts should be made to restrict animal access to works. **Property:** *Low Risk*: Works are constrained by known existing structures (gas mains pipeline, telecom pipeline, water mains pipeline etc) and will not interfere with these, thereby lowering any potential risk.

Previous uses along the reach (see Table 1.3)	Potential contaminants (mainly based on DoE industrial profiles)	Source Pathway Receptor	Risk consideration / Potentially unacceptable risks
	3. TL 14686 06546, 22/12/14 – blockage in watercourse, natural cause, no further details.		

Table 2.4 Contaminated Land Preliminary Risk Assessment for Reach 4

Previous uses along the reach (see Table 1.4)	Potential contaminants (mainly based on DoE industrial profiles)	Source Pathway Receptor	Risk consideration / Potentially unacceptable risks
- Allotments - Electricity sub-station - Urban (properties) - Swimming Pool - Vehicle service garages - Rubbish clearance / waste storage	No site or installations with hazard substances are reported in the 250m buffer zone either side of the reach by Envirocheck. No current or historic landfill sites present in 250m buffer zone either side of the reach. Electricity Substation - metals (Ba, Cd, Cr, Cu, Pb, Hg, Ni, V, Zn); Semi/non metals (As, B, Se); Inorganic chemicals (Free Cn^-, NO^{3-} SO_4^{2-}, S^{2-}), Asbestos; Phenols; Acetones; Chlorophenols; Oil/fuel hydrocarbons; PAHs, Chlorinated aliphatic hydrocarbons; hexachlorocyclohexane; chlorinate aromatic hydrocarbons; PCBs; Dioxins and furans; Organotin compounds. Allotments/Recreational Park – nutrients / fertilisers / pesticides / insecticides Vehicle servicing - metals (Cr, Cu, Pb, Ni, V, Zn); Semi/non metals (As, B, Se); Inorganic chemicals (Free Cn^-, S^{2-}), Asbestos; Phenols; Acetones; Oil/fuel hydrocarbons; Aromatic hydrocarbons; PCBs; Organolead compounds. Waste recycling, treatment, storage, disposal - metals (Ba, Cd, Cr, Cu, Pb, Hg, Ni, Zn); Semi/non metals (As); Inorganic chemicals (Free Cn^-, SO_4^{2-}, S^{2-}), Asbestos; Phenols; Acetones; Oil/fuel hydrocarbons; Aromatic hydrocarbons; PAHs, Chlorinated aliphatic hydrocarbons; hexachlorocyclohexane; Dieldrin; chlorinate aromatic hydrocarbons;	**Source:** - Potentially contaminated surface water (River Ver and drainage ditches) - Potentially contaminated groundwater (superficial layers are Secondary (A) Aquifer and may provide localised aquifers and baseflow; Principal aquifer is chalk bedrock) - Gas Mains Pipeline (low pressure) - Surface Sewer Pipeline (below ground) - Foul sewer pipeline (below ground) - Electricity – Secondary Distribution Cable - Telecom Line (below ground) - Water Mains Pipeline (below ground) - Permitted discharges to surface water (4 for Reach 4 at 2 locations) - Pollution incidents **Pathways** - Surface water run-off and/or direct percolation from surface - Leaching of contaminants and vertical migration of groundwater - Lateral migration of groundwater providing baseflow to surface watercourses - Direct human or animal contact with soil/sediment (ingestion and dermal) **Human Health Receptors:** - Final End Users - Adjacent Site users - Maintenance Workers	**Human Health Receptors:** *Construction and maintenance workers - moderate risk* - If soils are to be disturbed and/or re-used then an intrusive ground investigation including chemical testing of soils may be necessary to further quantify and characterise possible contamination. If soils are found to be contaminated then appropriate mitigation measures will be required to ensure that health and safety risks are minimised during construction. *Final End Users/Adjacent Site Users – low risk*. It is assumed that publicly accessible sites will be covered with hardstanding (or equivalent) and that there will be no pathway between end users and potentially contaminated soils/sediment. *(To be reviewed once final options decided, and if hardstanding is not proposed in publically accessible areas further risk assessment will be required to determine whether contaminated soils would need covering or removal).* **Water receptors:** *Low Risk* - Implement mitigation measures during construction phase to minimise the risk of surface run-off entering surface water courses, and

Previous uses along the reach (see Table 1.4)	Potential contaminants (mainly based on DoE industrial profiles)	Source Pathway Receptor	Risk consideration / Potentially unacceptable risks
	PCBs. Recorded Pollution Incidents (NIRS): 1. TL 14954 06569, 13/8/16 – water pollution, cause not identified, no further details given.	- Construction Workers **Water receptors:** - Surface Water (River Ver) - Primary Aquifer (chalk bedrock) - Secondary (A) Aquifer - Current surface water or groundwater abstractions (0 known in Reach 4) **Vegetation/Ecosystem Receptors:** - River Ver ecosystem - Allotment vegetation **Property Receptors:** - Future proposed services and structures - Existing services and structures	to minimise risk of leaching and vertical migration. *(To be reviewed once final options decided).* **Vegetation/Ecosystem Receptors:** *Low Risk*: Implement mitigation measures during construction phase to minimise the risk of surface run-off entering surface water courses and thereby impacting aquatic ecosystems. Efforts should be made to restrict animal access to works. **Property:** *Low Risk*: Works are constrained by known existing structures (gas mains pipeline, telecom pipeline, water mains pipeline etc) and will not interfere with these, thereby lowering any potential risk.

Table 2.5 Contaminated Land Preliminary Risk Assessment for Reach 5

Previous uses along the reach (see Table 1.5)	Potential contaminants (mainly based on DoE industrial profiles)	Source Pathway Receptor	Risk consideration / Potentially unacceptable risks
- Fields - Allotments - Urban (e.g. properties, school) - Industry (depots, warehouses) - Chemical works –north of reach, but worth noting - Vehicle servicing	No site or installations with hazard substances are reported in the 250m buffer zone either side of the reach by Envirocheck. No current or historic landfill sites present in 250m buffer zone either side of the reach. Chemical Works - metals (Ba, Cd, Cr, Cu, Pb, Hg, Ni, V, Zn); Semi/non metals (As, B, Se, S); Inorganic chemicals (Free Cn^-, NO^{3-} SO_4^{2-}, S^{2-}), Asbestos; Phenols; Acetones; Chlorophenols; Oil/fuel hydrocarbons; PAHs, Chlorinated aliphatic hydrocarbons; hexachlorocyclohexane; chlorinate aromatic hydrocarbons; PCBs; Dioxins and furans; Organotin compounds. Unspecified Works/depots - may include metals (Ba, Cd, Cr, Cu, Pb, Hg, Ni, V, Zn); Semi/non metals (As, B, Se); Inorganic chemicals (Free Cn^-, NO^{3-} SO_4^{2-}, S^{2-}), Asbestos; Phenols; Acetones; Chlorophenols; Oil/fuel hydrocarbons; PAHs, Chlorinated aliphatic hydrocarbons; hexachlorocyclohexane; chlorinate aromatic hydrocarbons; PCBs; Dioxins and furans; Organotin compounds. Allotments/Recreational Park – nutrients / fertilisers / pesticides / insecticides Vehicle servicing - metals (Cr, Cu, Pb, Ni, V, Zn); Semi/non metals (As, B, Se); Inorganic chemicals (Free Cn^-, S^{2-}), Asbestos; Phenols; Acetones; Oil/fuel hydrocarbons; Aromatic hydrocarbons; PCBs; Organolead	**Source:** - Potentially contaminated surface water (River Ver and drainage ditches) - Potentially contaminated groundwater (superficial layers are Secondary (A) Aquifer and may provide localised aquifers and baseflow; Principal aquifer is chalk bedrock). - Water Mains Pipeline (below ground) - Surface Sewer Pipeline (below ground). - Foul sewer pipeline (below ground) - Permitted discharges to surface water (0 for Reach 5) - Pollution incidents **Pathways** - Surface water run-off and/or direct percolation from surface - Leaching of contaminants and vertical migration of groundwater - Lateral migration of groundwater providing baseflow to surface watercourses - Direct human or animal contact with soil/sediment (ingestion and dermal) **Human Health Receptors:** - Final End Users - Adjacent Site users - Maintenance Workers - Construction Workers **Water receptors:** - Surface Water (River Ver)	**Human Health Receptors:** *Construction and maintenance workers - moderate risk* - If soils are to be disturbed and/or re-used then an intrusive ground investigation including chemical testing of soils may be necessary to further quantify and characterise possible contamination. If soils are found to be contaminated then appropriate mitigation measures will be required to ensure that health and safety risks are minimised during construction. *Final End Users/Adjacent Site Users – low risk*. It is assumed that publicly accessible sites will be covered with hardstanding (or equivalent) and that there will be no pathway between end users and potentially contaminated soils/sediment. *(To be reviewed once final options decided, and if hardstanding is not proposed in publically accessible areas further risk assessment will be required to determine whether contaminated soils would need covering or removal).* **Water receptors:** *Low Risk* - Implement mitigation measures during construction phase to minimise the risk of surface run-off entering surface water courses, and

Previous uses along the reach (see Table 1.5)	Potential contaminants (mainly based on DoE industrial profiles)	Source Pathway Receptor	Risk consideration / Potentially unacceptable risks
	compounds. Embankments – unknown origin and composition and could be made ground. Recorded Pollution Incidents (NIRS): 1. TL 15102 06500, 05/07/10 – sewage containment and control failure (private dwelling, grey water) - category 3 (minor impact). 2. TL 15123 06496, 8/3/13 – Old Sopwell Gardens, urban run-off (contaminated water), category 3 (minor impact). 3. TL 15238 06419, 10/11/13 – Sopwell, category 3 (minor impact), no further details. 4. TL 14999 06550, 24/5/14 – water pollution (unauthorised discharge), category 3 (minor impact). 5. TL 15001 06557, 5/12/14 – urban run-off (containment and control failure) - category 3 (minor impact). 6. TL 15100 06506, 21/9/15 – unauthorised discharge (sewage materials), category 3 (minor impact).	- Primary Aquifer (chalk bedrock) - Secondary (A) Aquifer - Current surface water or groundwater abstractions (0 known in Reach 5) **Vegetation/Ecosystem Receptors:** - River Ver ecosystem - Field/allotment vegetation **Property Receptors:** - Future proposed services and structures - Existing services and structures	to minimise risk of leaching and vertical migration. *(To be reviewed once final options decided).* **Vegetation/Ecosystem Receptors:** *Low Risk*: Implement mitigation measures during construction phase to minimise the risk of surface run-off entering surface water courses and thereby impacting aquatic ecosystems. Efforts should be made to restrict animal access to works. **Property:** *Low Risk*: Works are constrained by known existing structures (water mains pipeline etc) and will not interfere with these, thereby lowering any potential risk.

Table 2.6 Contaminated Land Preliminary Risk Assessment for Reach 6

Previous uses along the reach (see Table 1.6)	Potential contaminants (mainly based on DoE industrial profiles)	Source Pathway Receptor	Risk consideration / Potentially unacceptable risks
- Fields / Recreation grounds - Allotments - Watercress beds - Fisheries Lakes - Urban (e.g. properties, school) - Railway line - Unspecified works - Vehicle servicing - Embankments	No site or installations with hazard substances are reported in the 250m buffer zone either side of the reach by Envirocheck. No current or historic landfill sites present in 250m buffer zone either side of the reach. Railway line - metals (Cd, Cr, Cu, Pb, Ni, V); Inorganic chemicals (SO_4^{2-}); Asbestos; Phenols; Acetones; Chlorophenols; Oil/fuel hydrocarbons; PAHs, Chlorinated aliphatic hydrocarbons; PCBs. Allotments/Recreational Park – nutrients / fertilisers / pesticides / insecticides Unspecified Works - may include metals (Ba, Cd, Cr, Cu, Pb, Hg, Ni, V, Zn); Semi/non metals (As, B, Se); Inorganic chemicals (Free Cn^-, NO^{3-} SO_4^{2-}, S^{2-}), Asbestos; Phenols; Acetones; Chlorophenols; Oil/fuel hydrocarbons; PAHs, Chlorinated aliphatic hydrocarbons; hexachlorocyclohexane; chlorinate aromatic hydrocarbons; PCBs; Dioxins and furans; Organotin compounds. Vehicle servicing - metals (Cr, Cu, Pb, Ni, V, Zn); Semi/non metals (As, B, Se); Inorganic chemicals (Free Cn^-, S^{2-}), Asbestos; Phenols; Acetones; Oil/fuel hydrocarbons; Aromatic hydrocarbons; PCBs; Organolead compounds. Recorded Pollution Incidents (NIRS): 1. TL 15507 05421, 7/2/14 – Sopwell –	**Source:** - Potentially contaminated surface water (River Ver, lakes/fisheries and drainage ditches) - Potentially contaminated groundwater (superficial layers are Secondary (A) Aquifer and may provide localised aquifers and baseflow; Principal aquifer is chalk bedrock) - Potentially contaminated embankments (unknown origin). - Water Mains Pipeline (below ground) - Surface Sewer Pipeline (below ground) - Foul sewer pipeline (below ground) - Permitted discharges to surface water (3 in the vicinity of Reach 6) - Pollution incidents **Pathways** - Surface water run-off and/or direct percolation from surface - Leaching of contaminants and vertical migration of groundwater - Lateral migration of groundwater providing baseflow to surface watercourses - Direct human or animal contact with soil/sediment (ingestion and dermal) **Human Health Receptors:** - Final End Users - Adjacent Site users - Maintenance Workers - Construction Workers	**Human Health Receptors:** *Construction and maintenance workers - moderate risk* – If lake sediments or soils are to be disturbed and/or re-used then chemical testing may be necessary to further quantify and characterise possible contamination (particularly for the embankments of unknown origin). If soils or sediments are found to be contaminated then appropriate mitigation measures will be required to ensure that health and safety risks are minimised during construction. *Final End Users/Adjacent Site Users – low risk*. It is assumed that publicly accessible sites will be covered with hardstanding (or equivalent) and that there will be no pathway between end users and potentially contaminated soils/sediment. *(To be reviewed once final options decided, and if hardstanding is not proposed in publically accessible areas further risk assessment will be required to determine whether contaminated soils would need covering or removal).* **Water receptors:** *Low Risk* - Implement mitigation measures during construction phase to minimise the risk of surface run-off entering surface water courses, and

Previous uses along the reach (see Table 1.6)	Potential contaminants (mainly based on DoE industrial profiles)	Source Pathway Receptor	Risk consideration / Potentially unacceptable risks
	flooding (natural source), no further details. 2. TL 15339 05995, 17/6/14 - Sopwell, unidentified oil - category 3 (minor impact). 3. TL 15234 06330, 25/2/11 – Sopwell, mixed waste/oils - category 3 (minor impact). 4. TL 15256 06240, 5/8/11 – Sopwell, no further details given - 5. TL 15346 05986, 9/11/12 – Sopwell, pollutant not identified - category 3 (minor impact). 6. TL 15278 06185, 24/5/13 – Sopwell, unidentified oil - category 3 (minor impact). 7. TL 14518 06654, 25/11/14 – Sopwell, below ground pipe failure (suspended solids) - category 3 (minor impact).	**Water receptors:** - Surface Water (River Ver, lakes, fisheries) - Primary Aquifer (chalk bedrock) - Secondary (A) Aquifer - Current surface water or groundwater abstractions (0 known in Reach 6) **Vegetation/Ecosystem Receptors:** - River Ver ecosystem - Lake ecosytems - Recreation ground/allotment vegetation **Property Receptors:** - Future proposed services and structures - Existing services and structures	to minimise risk of leaching and vertical migration. **Vegetation/Ecosystem Receptors:** *Low Risk*: Implement mitigation measures during construction phase to minimise the risk of surface run-off entering surface water courses and thereby impacting aquatic ecosystems. Efforts should be made to restrict animal access to works. **Property:** *Low Risk*: Works are constrained by known existing structures (water mains pipeline etc) and will not interfere with these, thereby lowering any potential risk.

APPENDIX H – Preliminary Ecological Appraisal

AECOM

River Ver Restoration

Preliminary Ecological Appraisal

17 November 2016

Quality information

Prepared by	Checked by	Approved by
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Revision History

Revision	Revision date	Details	Authorized	Name	Position

Table of Contents

1.1 Ecological Surveys and Impact Assessment

1.1.1 Desk Study

A desk study was carried out to identify nature conservation designations, and protected and notable habitats and species potentially relevant to the proposed works.

The desk study area was defined based on the likely zone of influence of the proposed works on different ecological receptors, and an understanding of the maximum distances typically considered by statutory consultees. The impact of the proposed restoration works is likely to be largely restricted to the river channel and therefore a 1 km search radius was considered more than appropriate for both statutory and non-statutory nature conservation designations, as well as records of protected and notable species.

A search was made for any ponds within a 250 m radius of the proposed works, using the data sources detailed in Table 1.2, as this has a bearing on the potential for impacts to great crested newt (*Triturus cristatus*). The search for ponds was limited to a 250 m radius in accordance with Natural England's Rapid Risk Assessment tool for great crested newt, which indicates that small scale works are highly unlikely to encounter or impact newts where breeding ponds are further than 250 m from the works site.

Table 1.1 Ecological Desk Study Data Sources

Data Source	Accessed	Data Obtained
Hertfordshire Environmental Records Centre (HERC)	16th November 2016	Statutory and non-statutory nature conservation designations within 1km Ancient woodlands within 50m Protected and notable species records within 1km
Multi-Agency Geographic Information for the Countryside (MAGIC) website (www.magic.gov.uk)	16th November 2016	Ponds within 250m Nationally notable habitats within 50m, including priority habitats under Section 41 of the NERC Act.
Ordnance Survey (OS) 1:25000 Pathfinder maps and aerial photography	17th November 2016	Ponds within 250m Information on habitats and habitat connectivity in the wider area to inform the assessment of potential ecological constraints
Hertfordshire Environmental Forum website (www.hef.org.uk)	17th November 2016	Hertfordshire Biodiversity Action Plan documents

Notable habitats and ancient woodland sites were searched for within a 50 m radius of the proposed works, reflecting the limited potential for impacts to such habitats beyond the immediate footprint of the restoration works.

The desk study was carried out using the data sources detailed in Table 1.1 Ecological Desk Study Data Sources. Protected habitats and species include those listed under Schedules 1, 5 and 8 of the Wildlife and Countryside Act 1981 (as amended) and under Schedules 2 and 5 of The Conservation of Habitat & Species Regulations 2010 (as amended). Notable species and habitats include nationally important species and habitats of Principal Importance for nature conservation in England as listed under Section 41 of the Natural Environment and Rural Communities (NERC) Act 2006, as well as locally important species and habitats included in the local biodiversity action plan (BAP). Records of non-native controlled weed species were also collated where available; such species are listed under Schedule 9 of the Wildlife and Countryside Act 1981 (as amended).

1.1.2 Field Survey

A Phase 1 Habitat Survey was undertaken along the affected reaches, in accordance with the standard survey method[1]. Phase 1 Habitat Survey is a standard method of environmental audit. It involves categorising different habitat types and habitat features within a survey area. The information gained from the survey can be used to determine the likely ecological value of a site, and to direct any more specific survey work which may need to be carried out. The habitat survey was extended to take account of the potential for protected, notable and invasive species within the habitats recorded.

The survey was undertaken on Monday 14th November 2016 by a suitably qualified ecologist.

Where possible due to seasonal constraints, typical and notable plant species were recorded for different habitat types, in order to reflect the conditions at the time of the survey. This was not intended to be a detailed inventory of the plant species present, as this is not a requirement of a Phase 1 Habitat Survey.

An appraisal was made of the potential suitability of the habitats present to support protected and notable species of plants or animals (as defined above). Field signs, habitat features with the potential to support protected species and any sightings or auditory evidence were recorded when encountered, but no detailed surveys were carried out for any particular species.

A note was made of any visible instances of invasive non-native plant species listed under Schedule 9 of the Wildlife and Countryside Act 1981 (as amended), such as Japanese knotweed (*Fallopia japonica*). Locations of any plants or stands found were recorded and target noted.

1.1.3 Limitations

The aim of the ecological desk study was to help characterise the baseline context of the proposed works and provide valuable background information that would not be captured by a single site survey alone.
Information obtained during the course of a desk study is dependent upon people and organisations having made and submitted records for the area of interest. As such, a lack of records for a particular habitat or species does not necessarily mean that the habitats or species do not occur in the study area. Likewise, the presence of records for particular habitats and species does not automatically mean that these still occur within the area of interest or are relevant in the context of the proposed works.

The identification of typical and notable plant species was also constrained by the time of year that the survey was completed, though this did not prevent the characterisation of the habitats present or adversely affect the appraisal of their potential to support protected or notable species.

The recording of invasive non-native plant species listed on Schedule 9 of the Wildlife and Countryside Act was constrained by the time of year that the survey was undertaken. Many such species are not visible or cannot be reliably mapped outside the growing season (May to September), and some species are only apparent during certain months. Populations of annual plant species may fluctuate markedly between years dependent on the growing conditions present in any given season. As the field survey that was used to inform this report was conducted during November a number of invasive non-native plant species may not have been immediately visible to the surveyor.

Where habitat boundaries coincide with physical boundaries recorded on OS maps the resolution is as determined by the scale of mapping. Elsewhere, habitat mapping is as estimated in the field and/or recorded by hand-held GPS. Where areas of habitat are given they are approximate and should be verified by measurement on site where required for design or construction. While indicative locations of trees are recorded this does not replace requirements for detailed specialist arboricultural survey to British Standard 5837:2012 Trees in Relation to Design, Demolition and Construction.

1.2 Ecology

1.2.1 Nature Conservation Designations

There is one statutory nature conservation designation present within a 1km radius of the proposed works, as detailed in Table 1.2

[1] Joint Nature Conservation Committee. (2010) *Handbook for Phase 1 habitat survey. A technique for environmental audit*. JNCC, Peterborough

Table1.2: Sites with Statutory Nature Conservation Designations within 1km of the Study Area

Designation	Reason(s) for Designation	Distance and Direction from the Proposed Works
Watercress Wildlife Site Local Nature Reserve (LNR)/ Sopwell House Watercress Beds	Shallow lake and wetland area that is known to support a range of birds, wildfowl and insects.	Located adjacent to eastern bank of Reach 6 of River Ver.

The proposed works have the potential to directly affect the Watercress Wildlife Site LNR; this is given further consideration in Table 1.5 in Appendix D.Several non-statutory nature conservation designations are present within 1km radius of the proposed works, as detailed in Table 1.3

Table Error! No text of specified style in document.**.3 Sites with Non-statutory Nature Conservation Designations within 1km of Study Area**

Designation	Reason(s) for Designation	Distance and Direction from the Proposed Works
Verulamium Lake Local Wildlife Site (LWS)	Important for local bird and bat populations: a heronry can be found on one of the lake's islands and numerous bat species use it as a foraging site.	Located adjacent to Reach 1 of River Ver.
Abbey Mill Lane Area LWS	Building and environment important for protected species.	Located approx. 50m east of Reach 1 of River Ver.
Sopwell Meadows LWS	Alluvial meadows formed of semi-improved neutral grassland, unimproved wet marshy grassland, swamp and fen (9.6ha). Water vole has been recorded here. The site is also of importance to inverts and birds.	Located approx. 100m south east of Reach 6 of River Ver.
Ver Valley Meadows LWS	Valuable unimproved grassland habitat (27.9ha). Supports both neutral and acid grassland. Grassland ranges from damp to very vet with marshy/fen areas at low points.	Located approx. 750m south east of Reach 6 of River Ver.

It is understood that the proposed works are likely to directly affect the Verulamium Lake; this is given further consideration in Table 1.5 in Appendix D.

Sopwell Meadows and the Ver Valley Meadows are located directly downstream of Reach 6 of the River Ver. It is therefore possible that they will be indirectly affected by the proposed works. However, with the implementation of standard pollution / siltation control methods, the proposed restoration works should not have any adverse impacts on the either of the non-statutorily designated sites.

1.2.2 Habitats

The terrestrial and aquatic habitats present along the affected reaches are described below. An illustrative summary of the habitats and features associated with the proposed works is provided as a River Corridor Survey map in Appendix A. Target notes providing more detail on features of interest are included as Appendix B. Representative photographs are provided in Appendix C.

The wetted channel along the affected reaches of the River Ver was between 1m and 10m with shallow water typically up to 0.5m deep (on the day of the survey). The channel substrate was a combination of silt, gravel and pebbles. Submerged/ floating vegetation was largely absent from the channel at the time of survey. The extent and depth of silt deposits results in conditions that are sub-optimal for most aquatic plant species, and therefore it is considered that the present habitat conditions are unlikely to allow development of an extensive and diverse aquatic plant community.

Reach 1 (~500m)

This was the most upstream of the affected reaches of the River Ver, its wetted channel was between 5 and 10m wide with shallow water less than 0.5m in depth, the banks of this reach was constructed from concrete (Photo 1). The Verulamium Lake, a large body of standing water with concrete bed and banks occurs adjacent to the western bank of this Reach. Both the River Ver and associated Verulamium Lake had deep, silt substrate and no visible instances of aquatic plant species. The lake had two small islands at its centre that were covered with broadleaved woodland (Photo 2) as well as a small patch of marginal sedge vegetation at its northern end which contained an instance of giant rhubarb (*Gunnera tinctoria*)(Photo 3). The River and lake were separated by an approximately 5m wide strip of hardstanding path and improved grassland which supported species such as silverweed (*Argentina anserina*), cinquefoil (*Potentilla reptans*), bristly oxtongue (*Helmithotheca echioides*) and ribwort plantain (*Plantago lanceolata*) (Photo 4).

The eastern bank of Reach 1 was covered by mixed plantation woodland with many trees overhanging the river channel. Species of tree present along the east bank included sycamore (*Acer pseudoplatanus*), willow (*Salix* sp.), alder (*Alnus gutinosa*), oak (*Quercus robur*) and a number of conifers (Photos 5). There were also instances of common nettle (*Urtica dioica*), ivy (*Hedera helix*), field maple (*Acer campestre*) and dogwood (*Cornus* sp.) present within the understorey.

Reach 2 (~550m)

Reach 2 was separated from Reach 1 by a weir. The section of river immediately following the weir was approximately 1.5m wide, concrete banked and fast flowing with a thin strip of broadleaved trees planted either side of it (Photo 5). This section then joined with another stream flowing from a weir connected directly to the Verulamium Lake. This section of the river was approximately 5m in width, had gently sloping soft earth banks and a pebble/ gravel bed (Photo 6). The river flowed through a short section of deciduous woodland before entering an open area covered by species poor semi-improved grassland (Photo 7). The right hand bank of the river was covered by a strip of tall ruderal vegetation dominated by common nettle but also containing hogweed (*Heracleum sphondylium*) and scattered willows (Photo 8). The left hand bank of the river was covered by another strip of broad leaved plantation woodland that appeared very similar to the woodland present along Reach 1, many trees overhung the reach and a few large branches had even fallen in. There were some areas of marginal sedge vegetation present along thinner, meandering sections of the river before the reach ends and the A5138 Bridge (Photo 9 & 10).

Reach 3 (~250m)

Reach 3 was a mostly straight, concrete banked section of the river Ver that ran through a residential housing area (Photo 12). The river still remained very shallow although siltation levels appeared to be higher than previous reaches. A thin strip of broadleaved woodland with an understorey of common ivy ran along each bank of the river and fences and brick walls separated it from private residential buildings and gardens (Photo 13). There was also a track on the right bank of the river which crossed over to the left bank via a thin footbridge. After the footbridge the space around the river opened up into an area dominated by dense bramble scrub, nettles and a large stand of cherry laurel (*Prunus laurocerasus*) (Photo 14 & 15). Further down the reach the banks once again became dominated by deciduous woodland with an ivy understory.

Reach 4 (~250m)

The river then meandered sharply to the left and the left bank became dominated by common nettles interspersed with scattered trees, this then extended into an area of species poor semi-improved grassland and scattered trees (Photo 16). There was a hedgerow separating this area of grassland from a number of residential gardens which contained a variety of non-native shrubs such as Oregon grape *(Mahonia aquifolium*), Japanese laurel (*Aucuba japonica*) and cotoneaster (*Cotoneaster* sp.). On the right hand bank of the river there was a combination of deciduous woodland with a ruderal understorey which surrounded a large area of allotments (Photo 17).

Reach 5 (~300m)

There was a small patch of broadleaved woodland on the right hand bank of the Ver after it flowed under the Cottonmill Lane Bridge. This then opened up into an area of semi-improved grassland; however the right hand bank of the river itself was covered by nettle dominated tall ruderal (Photo 19). The river appeared to maintain its width and depth through this reach, however levels of siltation increased, obscuring the river bed. The left hand bank of the river was covered by willow dominated woodland with a ruderal understorey. Eventually the grassland on the right hand side of the river merged into an area of deciduous woodland made up of willow, alder and ash (*Fraxinus excelsior*).

Reach 6 (~300m)

The River Ver then turns sharply to the right. On the inside of this bend the broadleaved woodland was more inundated and became an area of wet woodland, however with a continued abundance of alder, willow and ash (Photo 20). The wet woodland extended until another area of allotments was reached. At this point both banks of the river were covered by a mosaic of tall ruderal, bramble scrub and scattered trees. This continued until the river passed under a tall brick footbridge (Photo 21). After the bridge the banks of the river maintained the same ruderal and scrub habitat as before however there was a recreation ground covered by semi-improved grassland adjacent to the right hand bank of the River (Photo 22).

Protected and Notable Habitats

All affected Reaches of the River Ver, as chalk rivers, are of a type that is considered a habitat of principal importance for nature conservation under Section 41 of the NERC Act. However, current levels of siltation and the impact of this on the ecology of the river are likely to mean that the relevant reaches are not currently good examples of the habitat. The wet woodland that is present adjacent to Reach 6 of the river is also considered to be a habitat of principal importance under Section 41 of the NERC Act. The restoration scheme is consistent with nature conservation objectives for the improvement and restoration of priority habitats, so Section 41 status is unlikely to be overly material to the planning and implementation of the proposed works.

Rivers and woodlands are also notable at a local level, with Habitat Action Plans for Wetlands and Woodlands in the Hertfordshire BAP. There is a minor conflict with this, given the localised requirements for works, and the likely associated impacts, in area of woodland habitat. However, given the nature conservation objectives of the restoration scheme and the likely benefits for the wider river reach, the proposed works would likely be considered consistent with the objectives of the Hertfordshire BAP and therefore any associated short term temporary disturbance of habitats is unlikely to be overly material to the planning and implementation of the proposed works.

1.2.3 Invasive Non-Native Plant Species

One stand of the Schedule 9 non-native invasive plant Giant Rhubarb (*Gunnera tinctoria*) was noted within an area of marginal vegetation on Verulamium Lake.

A cotoneaster (*Cotoneaster* sp.) was noted on the banks of Reach 5. The stand was located on the far bank and therefore its exact species could not be determined.

A cotoneaster was noted in a garden hedgerow surrounding a residential area adjacent to Reach 4.

1.2.4 Protected/ Notable Species

Table 1.4 summarises the potential for the presence of protected and notable species of fauna and flora that may constrain restoration works. The assessment is based on the results of the desk study and consideration of the suitability of the habitats for protected and notable species. Additional information is provided below the table to support the assessment where necessary.

Where species are identified in Table 1.4 as possibly present they may represent legal constraints to the proposed works and further surveys may be required to establish presence or likely absence, depending on the potential impacts. Requirements for further survey are identified in Table 1.5 in Appendix D.

Table 1.4 Protected and Notable Species Relevant or Potentially Relevant to Proposed Works

Species	Legally Protected Species?	Species of Principal Importance?	Other Notable Species?	Present on Site?	Present / Potentially Present in Wider Zone of Influence?	Supporting Comments
Water Vole (*Arvicola amphibius*)	ü	ü	ü	-	ü	The affected reaches are potentially suitable for water vole. Numerous old records of this species were found in the desk study area however none of them were from within the past 10 years.
Otter (*Lutra lutra*)	ü	ü	ü	-	ü	The affected reaches are potentially suitable for otters however no records of the species were found in the desk study area.
Bats	ü	ü	ü	-	ü	There are a number of mature trees present along the banks of the river that possess features potentially suitable for use by roosting bats. However a detailed survey of all trees was not undertaken. There are a number of bridges along the affected reaches of the river that may have potential to support roosting bats. Five species of bat were recorded in the desk study area.
Nesting Birds	ü	ü	ü	-	ü	The trees and scrub along the banks of the river provide potential nesting bird habitat. The Verulamium Lake is known to support large populations of waterfowl and the island at its centre is a heronry.

Schedule 1 Birds - **Kingfisher (*Alcedo atthis)***	ü	ü	ü	-	ü	Some of the rivers more steep sided banks may provide suitable breeding habitat for kingfishers. Ninety records of this species from the past 10 years were recorded in the desk study area. Most of these records were concentrated around the Verulamium Park area and Watercress Wildlife Site LNR.
Reptiles	ü	ü	-	-	ü	The river and its surrounding woodland and grassland provide potentially suitable habitat for reptiles. Multiple records of grass snake and slow worm were recorded in the desk study area.
Fish	ü	ü	-	-	ü	Fish known to be present in the River Ver include brown trout, gudgeon, roach, perch, pike, feral goldfish and chub.
Badger (*Meles meles)*	ü	-	-	-	ü	Suitable habitat for this species is found adjacent to the banks of the River Ver. A small number of records of this species were recorded in the desk study area.
Species Unlikely to be Present						
White-clawed crayfish (*Austropotamobius pallipes*	ü	ü	ü	-	-	No records of this species were recorded in the desk study area. The low flows and extensive silt deposition along the reaches of the River Ver provide poor quality habitat for native crayfish and so they are unlikely to be present.
Great crested newt (*Triturus cristatus*)	ü	ü	ü	-	-	There are no ponds suitable for great crested newt visible on OS maps/ aerial imagery within 250m of the affected reaches of the River Ver. There are bodies of standing water in within the Verulamium Park and within the Watercress Wildlife Site LNR however these are considered unsuitable for GCN because of their large size, concrete banks and abundance of fish and waterfowl.

Key to symbols: ü = yes, x = no, ? = possibly, see Supporting Comments for further rationale.

Species present on site are those for which recent direct observation or field signs confirmed presence. Species which are possibly present are those for which there is potentially suitable habitat based on the results of the Phase 1 Habitat survey, or this combined with desk study records.

Legally protected species are those listed under Schedules 1, 5 and 8 of the Wildlife and Countryside Act 1981 (as amended); and, Schedules 2 and 4 of The Conservation of Habitat & Species Regulations 2010 (as amended).

Species of Principal Importance as those listed under Section 41 of the NERC Act. Planning Authorities have a legal duty under Section 40 of the same Act to consider such species when determining planning applications.

Other notable species include native species of conservation concern listed in the LBAP (except species that are also of Principal Importance), those that are Nationally Rare, Scarce or Red Data List, and non-native controlled weed species listed under Schedule 9 of the Wildlife and Countryside Act 1981 (as amended).

Bats

The River Ver itself provides habitat suitable for foraging and commuting bats whilst a number of mature trees and structures present within the survey area may also provide suitable roosting habitat.

The first of these structures was a small utilities building present in the middle of the area of semi-improved grassland adjacent to Reach 2 at TN9. Depending on the level of re-profiling works that are due to be made to the river, this building may need to be removed. The building was constructed from red brick and had a flat roof, it was located close to suitable foraging habitat (i.e. river and woodland) and did not appear to be in use (its windows were boarded up). The building appeared to be in relatively good condition and no obvious bat entrance/ exit points could be seen (Photo 11). It was therefore considered that this building had ‘low’ habitat suitability for roosting bats.

The A5138 road bridge was found at the end of Reach 2 at TN11. This bridge was constructed from red brick and had no visible cracks/ crevices or gaps of missing mortar that could be used as entrance points by roosting bats. The apex of this bridge was <1m above the water level on the day of the survey. It was impossible to view the underside of the bridge without entering the water; therefore a confident preliminary roost assessment of the structure could not be made.

The Cottonmill Lane road bridge was found at the end of Reach 4 at TN14. This bridge was constructed from a mixture of red brick and concrete and certain section of the bridge deck and abutments showed weathering that may have provided entrance points for roosting bats. Therefore this bridge has been provisionally considered to have a ‘moderate’ potential of supporting roosting bats however as the underside of the bridge deck could not be inspected this classification may change.

The Alban Way bridge was a tall, brick structure present within Reach 6 at TN18. The bridge straddled both the River Ver and the track that ran alongside it, therefore it was possible to get a full view of the structure. The bridge appeared to be well maintained and in good condition, the mortar between its bricks appeared to be fully intact and no cracks/ crevices or gaps that could be used as entrance points by roosting bats were noticed. Therefore it was considered that this bridge had a ‘negligible’ suitability for roosting bats.

1.2.5 Ecological Considerations during Restoration

The following ecological receptors have been identified as present or potentially present along the affected reaches:

- The Watercress Wildlife Site LNR;
- The Verulamium Lake non-statutorily designated site;
- Chalk river and wet woodland habitats of principal importance;
- River and woodland habitats of local importance;
- Invasive non-native plant species: giant rhubarb and cotoneaster;

- Water vole;
- Otter;
- Fish;
- Roosting bats;
- Nesting Birds;
- Kingfisher;
- Badgers; and
- Reptiles.

These ecological features may constrain implementation of the restoration scheme and should be considered further when planning and implementing site works. In the case of the identified species these have potential, if present, to be key constraints that will require specific consideration and action to avoid conflicts with, and potential breaches of, relevant nature conservation legislation. Where potential ecological risks are identified, their actual presence/ absence would need to be determined through specialist surveys at the appropriate time of year.

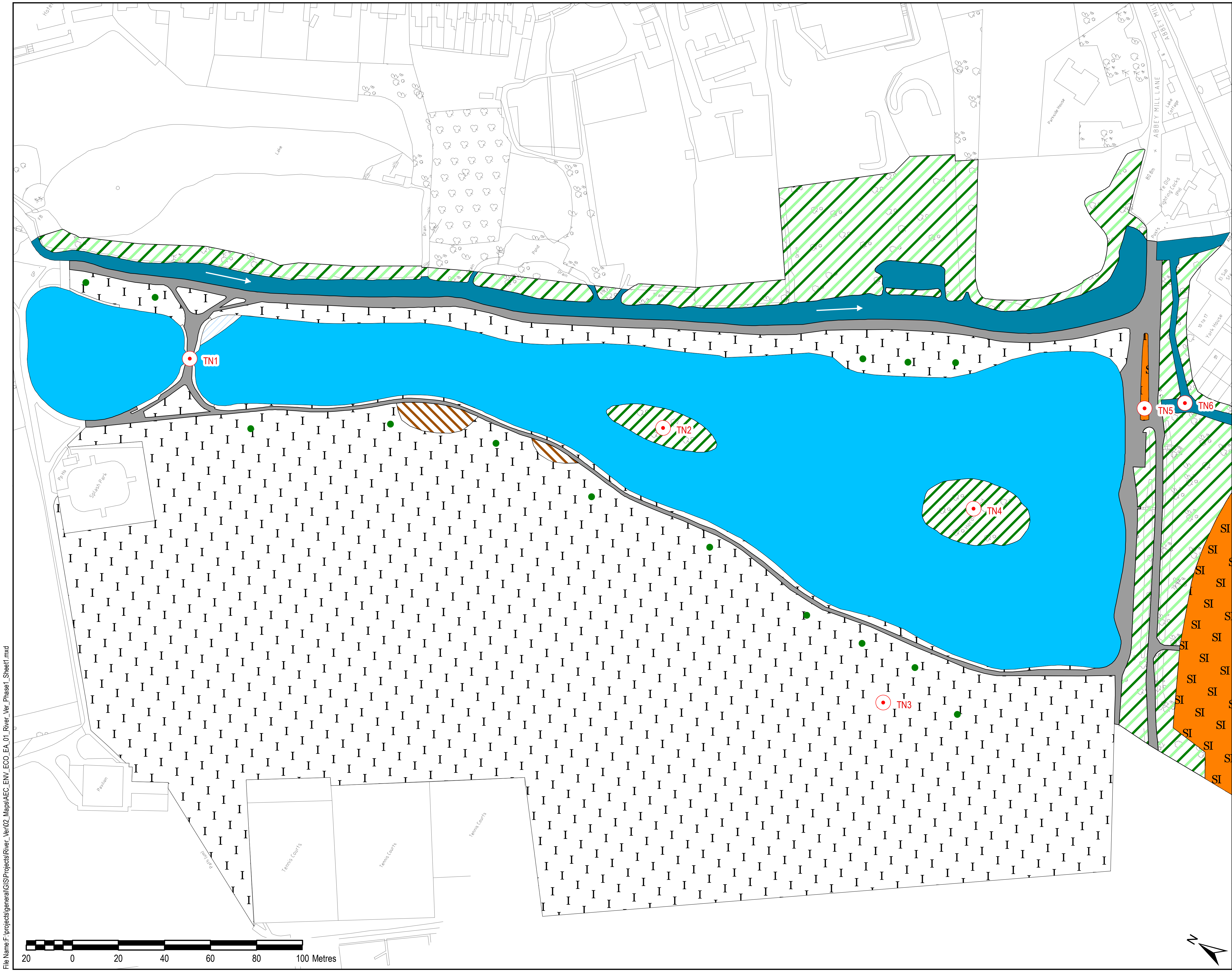
Further surveys which are recommended before restoration commences include:

- Water vole/ otter survey along affected reaches to determine the presence/ absence and the need for any mitigation avoidance;
- A preliminary ground level bat roost assessment of all trees and bridges that may be impacted during proposed works, further surveys to determine mitigation requirements are likely to be required if potential roosting features which cannot be avoided are found;
- A breeding bird survey of the river corridor, in particular to identify kingfisher holes / nests between March and August.; and
- A survey of the river channel for aquatic macrophytes and invasive plant species during their growing season (May to September inclusive) as they may not have been detectable at the time of the survey.

The implications for the proposed works due to presence of receptors in considered further in Table 1.5 in Appendix D, which also includes (where relevant) recommendations for further survey work or mitigation measures that may be necessary to ensure compliance with relevant legislation.

The data collected can also be used a baseline for which to assess the proposed restoration in terms of benefits to ecology/biodiversity.

Appendix A Phase 1 Habitat Map



LEGEND

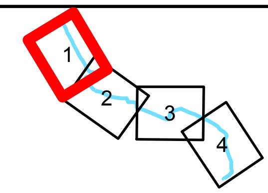
- Target Note

Phase 1 Habitat

- Individual Broad-leaved Tree
- Fence
- Intact Hedge - Species-Poor
- Buildings
- Dense Scrub
- Hard Standing
- I Improved Grassland
- Introduced Shrub
- Inundation Vegetation
- Planted Broadleaved Woodland
- Planted Mixed Woodland
- Running Water
- Scattered Scrub
- SI Semi-improved Neutral Grassland
- Semi-natural Broadleaved Woodland
- Standing Water
- Tall Ruderal Herb

Additional Features

- Allotments
- Path



Purpose of Issue:
FINAL

Client:
ENVIRONMENT AGENCY

Project Title:
RIVER VER RESTORATION

Drawing Title:
PHASE 1 HABITAT SURVEY
PAGE 1 OF 4

Drawn:	Chk'd:	App'd:	Date:
KLD	ST	MP	02/12/2016

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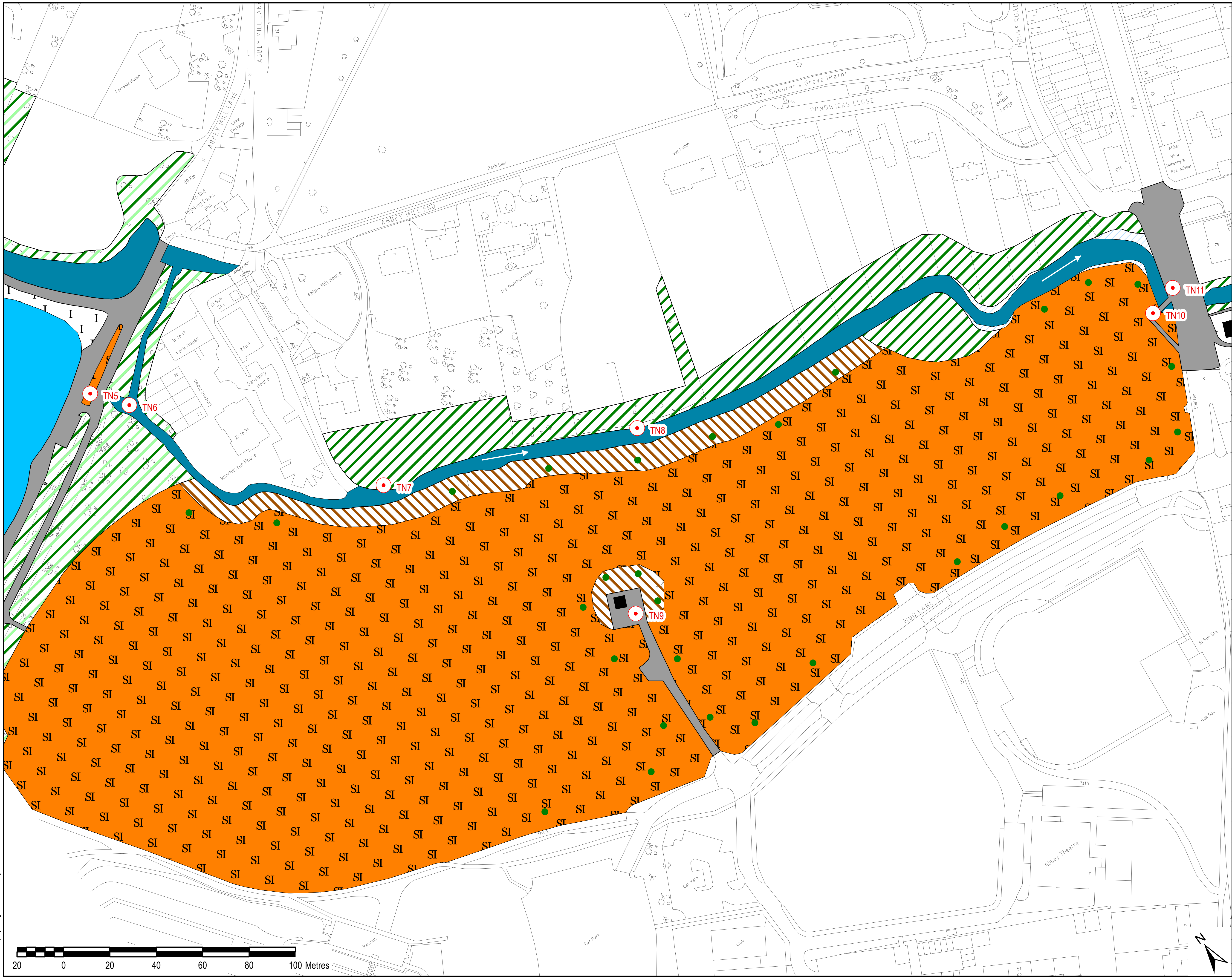
Rev: **01**



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LEGEND

Target Note

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- Tall Ruderal Herb

Additional Features

- Allotments
- Path

Purpose of Issue: FINAL

Client: ENVIRONMENT AGENCY

Project Title: RIVER VER RESTORATION

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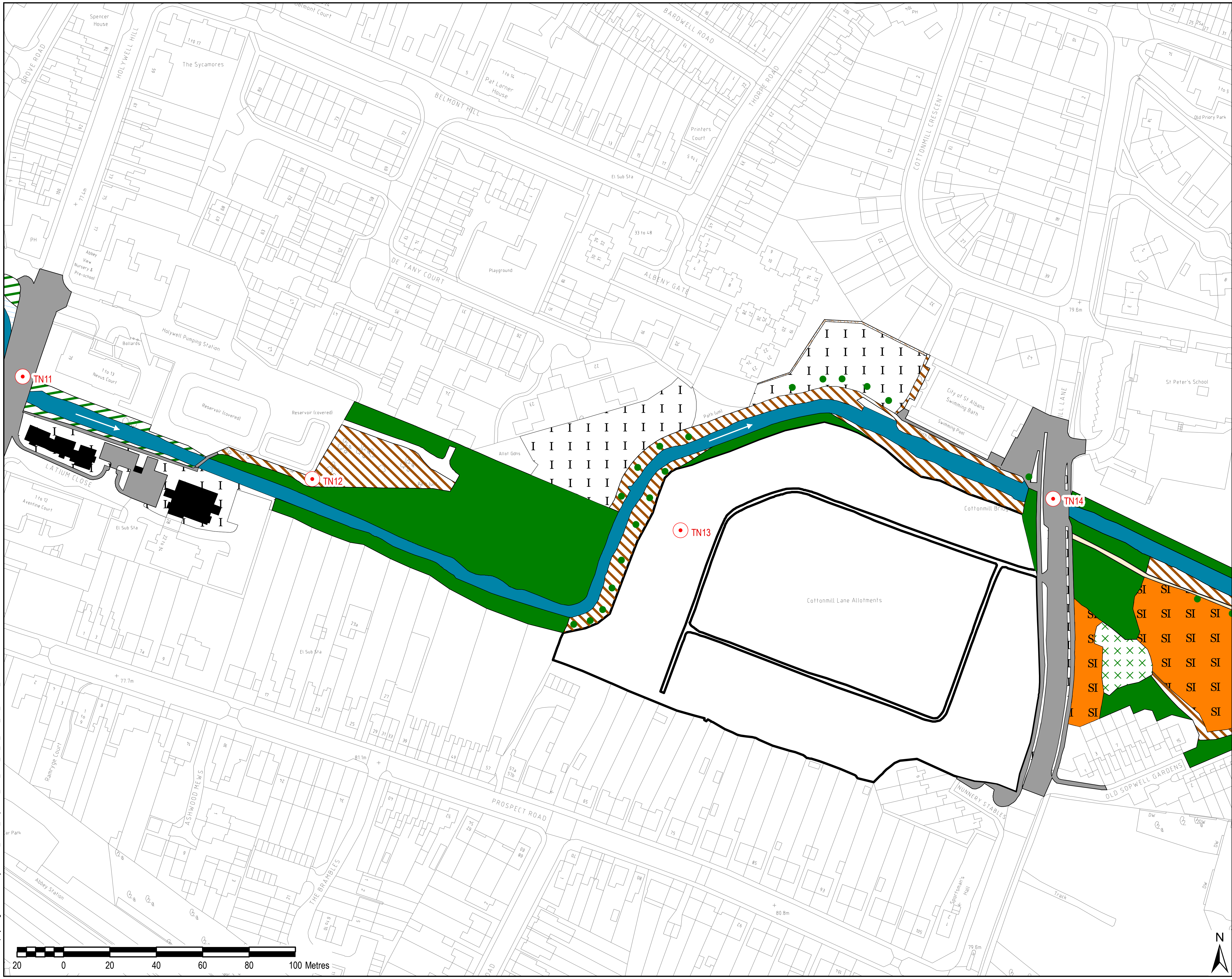

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LEGEND

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- Semi-natural Broadleaved Woodland
- Standing Water
- Tall Ruderal Herb

Additional Features

- Allotments
- Path

Purpose of Issue: FINAL

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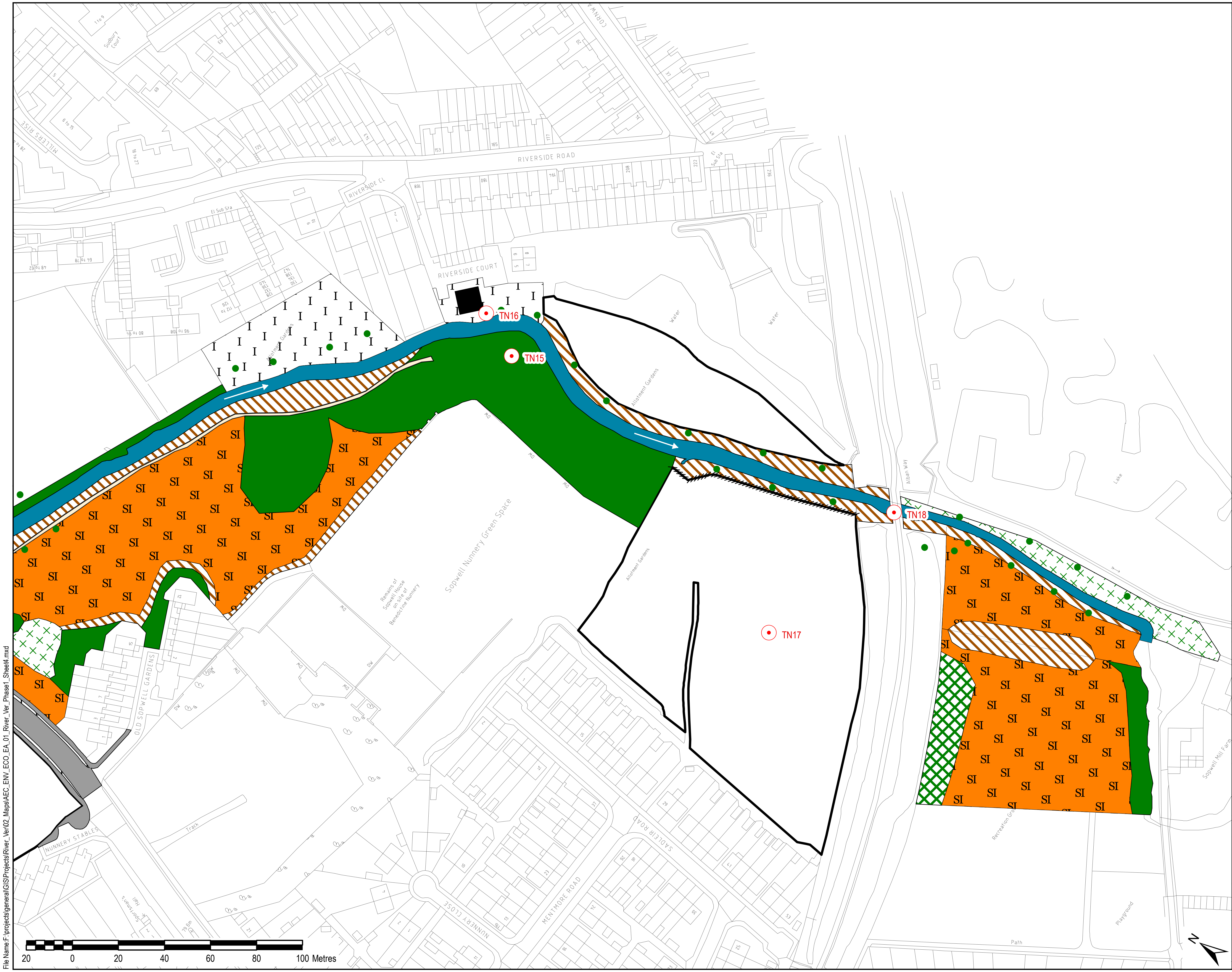

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LEGEND

Target Note

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- Semi-natural Broadleaved Woodland
- Standing Water
- Tall Ruderal Herb

Additional Features

- Allotments
- Path

Purpose of Issue: FINAL

Client: ENVIRONMENT AGENCY

Project Title: RIVER VER RESTORATION

Drawing Title: PHASE 1 HABITAT SURVEY PAGE 4 OF 4

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Appendix B Target Notes

Target Note	Description
1	Small redbrick foot bridge intersecting north and south sections of Verulamium Lake.
2	Small island covered by broadleaved woodland. Appeared to be fully inundated at time of survey.
3	Section of roman wall.
4	Second small island covered by broadleaved deciduous woodland, this island is known to be used by nesting grey herons
5	Pile of deadwood.
6	Confluence between water flowing from River Ver and Verulamium Lake.
7	Small footbridge crossing river.
8	Fallen tree in river channel.
9	Small utility buildingprovisionally considered to have a low potential of supporting bats.
10	Second small footbridge crossing river.
11	A5138 Bridge – preliminary roost assessment could not be made as underside of bridge deck was not visible
12	Stand of cherry laurel.
13	Large area of allotments.
14	Cottonmill Lane Bridge – provisionally considered to have a moderate potential of supporting roosting bats.
15	Area of wet woodland dominated by alder and willow. A raised wooden track allows the public to walk through this area.
16	Stand of cotoneaster present on left bank of river.
17	Large area of allotments.
18	Tall footbridge – provisionally considered to have a negligible potential of supporting roosting bats.

Appendix C Photos

Photo 1: Concrete path and overhanging trees on banks of Reach 1.

Photo 2: Verulamium Lake with heronry island covered by broadleaved trees.

Photo 3: Marginal vegetation containing giant rhubarb.

Photo 4: Hardstanding and improved grassland separating River Ver and Verulamium Lake

Photo 5: Upstream section of Reach 2.

Photo 6: Shallow, gravel/ pebble bedded section of

Reach 2, flowing through deciduous woodland.

	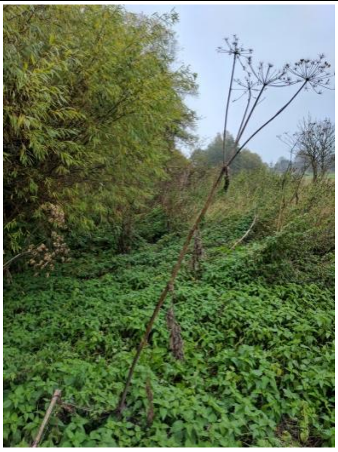
Photo 7: Expanse of semi-improved grassland adjacent to Reach 2	Photo 8: Tall ruderal vegetation and willow trees present on right bank of Reach 2
	
Photo 9: Marginal vegetation at end of Reach 2.	Photo 10: Bridge that separates Reaches 2 & 3.
	
Photo 11: Utility building within area of semi-improved grassland adjacent to Reach 2.	Photo 12: Concrete banked section of Reach 3.

Photo 13: Woodland and ruderal covered banks of Reach 3. Also shows proximity to residential housing.

Photo 14: Bramble and nettle scrub at beginning of Reach 4.

Photo 15: Stand of cherry laurel at Reach 4.

Photo 16: Grassland and scattered trees adjacent to left bank of Reach 4.

Photo 17: Allotments adjacent to right bank of Reach 4.

Photo 18:Cottonmill Bridge at end of Reach 4.

Photo 19: Tall ruderal on right bank of Reach 5.

Photo 20: Walkway through wet woodland.

Photo 21: Bridge at end of Reach 5.

Photo 22: Area of semi-improved grassland and tall ruderal adjacent to Reach 6.

Appendix D Summary Appraisal of Ecological Features and Recommended Further Action

Table 1.5: Summary Appraisal of Ecological features and Recommended Further Action

Ecological Receptor	Potential Impacts	Legal Context	Recommendations for Further Surveys and Survey Timings	Recommendations for mitigation
The Watercress Wildlife Site LNR, Sopwell Meadows, Ver Valley Meadows	The WWS LNR is adjacent to a section of the River Ver that is due to be restored. The River Ver flows through Sopwell Meadows and Ver Valley Meadows downstream of the proposed works.	LNRs are statutorily designated sites. Non-statutorily designated sites are protected from adverse effects by planning policy.	No further surveys are recommended	The working corridor should be kept as narrow as possible to minimise impacts on the nature reserve. Standard best practice construction, pollution and siltation measures should also be implemented as part of a Construction Environmental Management Plan (CEMP) in order to minimise any affects or disturbance to downstream habitats.
Verulamium Lake	The Verulamium Lake is a medium sized lake that is adjacent to Reach 1 of the River Ver. The proposed works are due to directly affect the lake in some form. Either by naturalising its banks or by re-routing the River Ver through where the lake currently stands. The larger of two islands present within the Lake is a heronry that supports 16-20 active grey heron nests.	Non-statutorily designated sites are protected from adverse effects by planning policy.	No further surveys are recommended	The works are likely to lead to an improvement in the condition of the river habitat through re-profiling to create a more natural channel, improvements in flow regimes and reduction in silt deposition. Any disturbance to the lake as a result of works is likely to be balanced by these improvements. Works affecting the island should be completed outside the bird nesting season where possible (March to August inclusive) so as not to cause disturbance to the herons.
River and associated bank habitats	The river is the focus of the proposed works. There will be localised in-channel works, along with more extensive re-profiling of river banks. This will	Rivers are habitats of Principal Importance under Section 41 of the NERC act. Decision makers such as Local Authorities have a duty to have	Aquatic plant surveys between May and September (preferably July and August) to identified location of aquatic flora and to inform restoration	The working corridor should be kept as narrow as possible to minimise impacts on the Watercress Wildlife Site Local Nature Reseve. Standard best practice construction,

Ecological Receptor	Potential Impacts	Legal Context	Recommendations for Further Surveys and Survey Timings	Recommendations for mitigation
	result in temporary habitat disturbance and loss; habitats would be reinstated or re-establish to an appropriate condition on completion of works. Certain works may have potential to result in localised temporary disturbance of sediment within the channel, and after works there is likely to be flushing of silt deposits from the reach. The works are likely to lead to an improvement in the condition of the river habitat through re-profiling to create a more natural channel, improvements in flow regimes and reduction in silt deposition. Any temporary effect as a result of the flushing tilts is likely to be balances by these improvements.	regard to the conservation of such habitats when carrying out their normal functions. This includes consideration of options to deliver habitat improvement through the planning process.		pollution and siltation measures should also be implemented as part of a CEMP in order to minimise any affects or disturbance to downstream habitats.
Wet Woodland	There is a small section of wet woodland present adjacent to Reach 6 of the River Ver. Certain works have the potential to result in temporary disturbance to this habitat. However the works are likely to lead to improvement and	Wet woodlands are habitats of Principal Importance under Section 41 of the NERC act. Decision makers such as Local Authorities have a duty to have regard to the conservation of such habitats when carrying out their normal functions. This	No further surveys are required	Any major changes to the banks or profile of the river should be avoided in the sections where it flows through wet woodland. Standard best practice construction, pollution and siltation measures should also be implemented as part of a CEMP in order to minimise any affects or disturbance to

Ecological Receptor	Potential Impacts	Legal Context	Recommendations for Further Surveys and Survey Timings	Recommendations for mitigation
	expansion of this habitat in the longer term.	includes consideration of options to deliver habitat improvement through the planning process.		downstream habitats.
Water vole	Damage/ destruction of water vole burrows and harm to individuals.	Water vole and its habitat are fully protected under WCA 1981. Any requirement for temporary displacements of water vole would be subject to requirements of the relevant Class Licence, which dictates timings and appropriate methods.	Further survey will be required along the affected reaches to determine presence / absence of water vole. Water vole surveys can be undertaken between April and September inclusive.	Mitigation would only be required if present and if works cannot avoid the species. Mitigation specifications need to take account of the findings of the water vole survey and the specifics of the scheme. Where works would be subject to a Class Licence then it may only be possible undertake these works between February and mid-April under supervision of a licensed ecologist. An Ecological Clerk of works is likely to be required.
Otter	Disturbance of otters occupying places of shelter, or direct impacts to holts / couches.	Otter is fully protected under the WCA 1981 and the Habitats Regulation.	A survey for otter holts / couches should be completed in advance of works. This can be combined with other species surveys where practicable, Otter surveys can be completed year round, though the optimum time of year is spring.	Mitigation would only be required if present and works cannot avoid the species. Mitigation specifications need to take account of the findings of the otter survey and the specifics of the scheme.
Giant Rhubarb (*Gunnera tinctoria)* and Cotoneaster species	Two stands of Cotoneaster species and one stand of Giant Rhubarb were present within the survey area. If works are due to affect this section of the river there will be	Controlled weed species listed on Schedule 9 of the WCA 1981. It is illegal to plant or otherwise cause to grow in the wild any plant species listed on Schedule 9 of the Act.	Further survey to define the extent of the plant. Survey should also be seen as an opportunity to confirm there are no other relevant controlled plant species that were not	Measure will be required to manage the risks associated with the proposed works. An Invasive Non- Native Species (INNS) Management Plan should be commissioned to guide works in accordance with legal requirements. This likely to include control

Ecological Receptor	Potential Impacts	Legal Context	Recommendations for Further Surveys and Survey Timings	Recommendations for mitigation
	potential to spread this species through seed dispersal on tools, equipment and vehicles.		visible at the time of survey e.g. Japanese knotweed (*Fallopia japonica*), especially as survey was conducted outside of main growing season.	of plant, appropriate stand-off distances, hygiene measures and procedures for off-site disposal of any contaminated arisings.
Fish: the River Ver is known to support several fish species including brown trout.	Potential for localised impacts only if significant in-channel works are required, such as drawdown of sections of the river. Otherwise, impacts will be entirely positive as the works will improve habitat quality and remove barriers to fish migration.	Brown trout is a species of Principal Importance under Section 41 of the NERC Act. Decision makers such as Local Authorities have a duty to have regard to the conservation of such species when carrying out their normal functions. This includes consideration of options to deliver habitat improvement through planning process.	No further surveys are likely to be required.	Mitigation may be necessary to reduce impacts on fish if significant in-channel works are required, Specific requirements would depend on the nature of any in-channel works. Any impact on fish is likely to be localised and temporary, and the proposed works will deliver improvements to the river that will benefit fish populations in the long term.
Roosting bats	Destruction / damage / disturbance of roost sites in trees that may be affected by the proposed works. Destruction / damage / disturbance of roost sites any built structures that may be affected by the proposed works.	Bats and their roosts are fully protected under the WCA 1981 and the Habitats Regulations.	A roost assessment will be required of any structures/ bridges or mature trees that may be impacted during the proposed works. Preliminary roost assessments can be completed all year round. Where potential roosting features are identified AND cannot be avoided, further surveys will be required to determine the status of bat roosting and the need for any mitigation. Further surveys to	The need for mitigation will depend of the findings of the survey work, Where possible, the best course of action would be to avoid impacts on potential roost sites, as requirements for survey and licence applications (if bat roosts are found) may be protracted and expensive.

Ecological Receptor	Potential Impacts	Legal Context	Recommendations for Further Surveys and Survey Timings	Recommendations for mitigation
			establish roosting activity are restricted to the bat active period between May and September (core period June to August inclusive).	
Nesting birds	Vegetation clearance has the potential to result in injury to nesting birds and their dependent young and destruction of active bird nests. Bank works have the potential to disturb breeding kingfisher and cause destruction of nesting sites.	Breeding birds are protected under the WCA 1981. It is an offence to damage / destroy / obstruct active bird nests. Kingfishers are listed on Schedule 1 of the WCA 1981 which extends protection to adults and dependent you at all times when breeding.	A breeding bird survey of the river banks, particularly for kingfisher holes / nests (as well as other species) is recommended between (March to August, inclusive). This will inform the bank works, proposed mitigation and provide baseline information for the restoration scheme. Further nest checks of trees/ scrub may be required if vegetation clearance cannot be scheduled outside of the breeding bird season.	Any necessary vegetation clearance / pruning should be completed outside the bird nesting season where possible (March to August inclusive). If this is not possible, suitable habitat should be inspected for active nests by an ecologist prior to clearance operations. Any active nests found should be left undisturbed until confirmed by an ecologist as being no longer in use for breeding/ An Ecological Clerk of works is likely to be required. The need for mitigation of kingfisher will depend on the results of the survey of nest sites. If breeding is confirmed along the affected reaches, measures to avoid disturbance during the breeding season will need to be implemented, where necessary.
Badgers	Potential disturbance of setts as a result of nearby river channel re-profiling works.	Badgers and their setts are protected under the Protection of Badgers Act 1992.	Further survey for badger is unlikely to be required, other than Ecological Clerk of Works supervision to confirm that no new setts have established in the run up to proposed works.	If a sett is discovered on site an appropriate stand-off will be established to avoid risk of disturbance. Where a complete stand-off is not possible, then working requirements should be reviewed with an ecologist to confirm

Ecological Receptor	Potential Impacts	Legal Context	Recommendations for Further Surveys and Survey Timings	Recommendations for mitigation
				whether or not an offence is likely and what mitigation is required to address this.
Reptiles	Localised risk of injury to reptiles using river bank and open woodland and grassland habitats.	Reptiles are protected from injury under the WCA 1981. They are also species of Principal Importance under Section 41 of the NERC act. Decision makers such as Local Authorities have a duty to have regard for the conservation of such species when carrying out their normal functions.	No further reptile surveysare considered necessary, given the limited potential for impact.	An Ecological Clerk of Works is likely to be required e.g. to check work areas prior to the start of works, to supervise any localised requirements for vegetation clearance and to advise on appropriate working methods.

APPENDIX I – Fish Population Survey

Fish Population Data for the River Ver

a. Environment Agency owned, non-third party data. Data adapted from the Environment Agency (2016) Freshwater Fish Counts for all Species, all Areas and all Years https://ea.sharefile.com/ds5b6918d01884a129, accessed 10/11/2016 for the River Ver (Colne)

SITE_	SITE_	SITE_NAME	SURVEY_	EVENT_D	EVENT_D	SURVEY_	SURVEY_	SURVEY_	SURVEY_	FISHED_V	FISHED_A	SURVEY_METHOD	SURVEY_STRATEGY	NO_	LATIN_NAME	ALL_	SPCS	SPCS	SPCSPV	SPCSPV_SE	OBSERVED_ABUNDA
Ver	54884	Gorehambury Mill	140925	15/04/2014	2014	TL13404076	110	8	880	8	880	PDC ELECTRIC FISHING	SINGLE CATCH SAMPLE	1	Leuciscus cephalus	6					
Ver	54884	Gorehambury Mill	140925	15/04/2014	2014	TL13404076	110	8	880	8	880	PDC ELECTRIC FISHING	SINGLE CATCH SAMPLE	1	Gobio gobio	1					
Ver	54884	Gorehambury Mill	140925	15/04/2014	2014	TL13404076	110	8	880	8	880	PDC ELECTRIC FISHING	SINGLE CATCH SAMPLE	1	Rutilus rutilus	7					
Ver	54884	Gorehambury Mill	140925	15/04/2014	2014	TL13404076	110	8	880	8	880	PDC ELECTRIC FISHING	SINGLE CATCH SAMPLE	1	Cottus gobio						10 to 99 [Best Run]
Ver	54884	Gorehambury Mill	140925	15/04/2014	2014	TL13404076	110	8	880	8	880	PDC ELECTRIC FISHING	SINGLE CATCH SAMPLE	1	Phoxinus phoxinus						10 to 99 [Best Run]
Ver	54884	Gorehambury Mill - closest u/s	140925	15/04/2014	2014	TL13404076	110	8	880	8	880	PDC ELECTRIC FISHING	SINGLE CATCH SAMPLE	1	Salmo trutta	7					
Ver	18090	Moor Mill	119465	20/10/2009	2009	TL14977030	100	4.5	450	4.5	450	ELECTRIC FISHING	CATCH DEPLETION SAMPLE	2	Salmo trutta	1	1	0	1	0	
Ver	18090	Moor Mill	119465	20/10/2009	2009	TL14977030	100	4.5	450	4.5	450	ELECTRIC FISHING	CATCH DEPLETION SAMPLE	2	Rutilus rutilus	10	10	0.346	0.909091	0.104447	
Ver	18090	Moor Mill	119465	20/10/2009	2009	TL14977030	100	4.5	450	4.5	450	ELECTRIC FISHING	CATCH DEPLETION SAMPLE	2	Perca fluviatilis	41	42	1.707	0.82	0.078532	
Ver	18090	Moor Mill	119465	20/10/2009	2009	TL14977030	100	4.5	450	4.5	450	ELECTRIC FISHING	CATCH DEPLETION SAMPLE	2	Gasterosteus aculeatus						10 to 99 [Best Run]
Ver	18090	Moor Mill	119465	20/10/2009	2009	TL14977030	100	4.5	450	4.5	450	ELECTRIC FISHING	CATCH DEPLETION SAMPLE	2	Cottus gobio						100 to 999 [Best Run]
Ver	42046	Redbourne	139549	16/10/2013	2013	TL10952117	178.2	3.8	677.16	3.8	677.16	ELECTRIC FISHING	SINGLE CATCH SAMPLE	1	Salmo trutta	9					
Ver	42046	Redbourne	139549	16/10/2013	2013	TL10952117	178.2	3.8	677.16	3.8	677.16	ELECTRIC FISHING	SINGLE CATCH SAMPLE	1	Gasterosteus aculeatus						100 to 999 [Best Run]
Ver	42046	Redbourne	139549	16/10/2013	2013	TL10952117	178.2	3.8	677.16	3.8	677.16	ELECTRIC FISHING	SINGLE CATCH SAMPLE	1	Pungitius pungitius						100 to 999 [Best Run]
Ver	42046	Redbourne	139549	16/10/2013	2013	TL10952117	178.2	3.8	677.16	3.8	677.16	ELECTRIC FISHING	SINGLE CATCH SAMPLE	1	Cottus gobio						10 to 99 [Best Run]
Ver	13145	Shafford Mill	139154	01/10/2013	2013	TL12488092	160.5	3.72	597.06	3.72	597.06	PDC ELECTRIC FISHING	CATCH DEPLETION SAMPLE	2	Salmo trutta	43	45	2.569	0.767857	0.090983	
Ver	13145	Shafford Mill	139154	01/10/2013	2013	TL12488092	160.5	3.72	597.06	3.72	597.06	PDC ELECTRIC FISHING	CATCH DEPLETION SAMPLE	2	Rutilus rutilus	15	17	3.669	0.625	0.220294	
Ver	13145	Shafford Mill	139154	01/10/2013	2013	TL12488092	160.5	3.72	597.06	3.72	597.06	PDC ELECTRIC FISHING	CATCH DEPLETION SAMPLE	2	Gasterosteus aculeatus						10 to 99 [Best Run]
Ver	13145	Shafford Mill	139154	01/10/2013	2013	TL12488092	160.5	3.72	597.06	3.72	597.06	PDC ELECTRIC FISHING	CATCH DEPLETION SAMPLE	2	Cottus gobio						100 to 999 [Best Run]
Ver	13145	Shafford Mill	139154	01/10/2013	2013	TL12488092	160.5	3.72	597.06	3.72	597.06	PDC ELECTRIC FISHING	CATCH DEPLETION SAMPLE	2	Phoxinus phoxinus						10 to 99 [Best Run]
Ver	13138	Verulam Golf Course	139156	02/10/2013	2013	TL15549059	105	3.2	336	3.2	336	PDC ELECTRIC FISHING	CATCH DEPLETION SAMPLE	3	Leuciscus cephalus	12	14	4.176	0.428571	0.223697	
Ver	13138	Verulam Golf Course	139156	02/10/2013	2013	TL15549059	105	3.2	336	3.2	336	PDC ELECTRIC FISHING	CATCH DEPLETION SAMPLE	3	Gobio gobio	2	2	0	1	0	
Ver	13138	Verulam Golf Course	139156	02/10/2013	2013	TL15549059	105	3.2	336	3.2	336	PDC ELECTRIC FISHING	CATCH DEPLETION SAMPLE	3	Rutilus rutilus	15	23	14.34	0.277778	0.239814	
Ver	13138	Verulam Golf Course	139156	02/10/2013	2013	TL15549059	105	3.2	336	3.2	336	PDC ELECTRIC FISHING	CATCH DEPLETION SAMPLE	3	Perca fluviatilis	3	3	0.266	0.75	0.265908	
Ver	13138	Verulam Golf Course	139156	02/10/2013	2013	TL15549059	105	3.2	336	3.2	336	PDC ELECTRIC FISHING	CATCH DEPLETION SAMPLE	3	Gasterosteus aculeatus						10 to 99 [Best Run]
Ver	13138	Verulam Golf Course	139156	02/10/2013	2013	TL15549059	105	3.2	336	3.2	336	PDC ELECTRIC FISHING	CATCH DEPLETION SAMPLE	3	Cottus gobio						100 to 999 [Best Run]
Ver	13138	Verulam Golf Course	139156	02/10/2013	2013	TL15549059	105	3.2	336	3.2	336	PDC ELECTRIC FISHING	CATCH DEPLETION SAMPLE	3	Phoxinus phoxinus						100 to 999 [Best Run]
Ver	13138	Verulam Golf Course - closest d/s	139156	02/10/2013	2013	TL15549059	105	3.2	336	3.2	336	PDC ELECTRIC FISHING	CATCH DEPLETION SAMPLE	3	Salmo trutta	12	12	0.355	0.8	0.11849	

b. Environment Agency supplied data via data request process, 2016

ENVIRONMENT AGENCY NATIONAL FISH POPULATIONS DATABASE - ENTERPRISE v5.1.1 SITE SURVEY REPORT

Location:	Thames North East
Report Date:	17/11/16
Site Name:	Moor Mill
Site Reference:	VEBE
Survey Date:	11/11/2016
Catchment:	Colne
Sub Catchment:	Ver
Fisheries Management Unit:	
Upstream NGR:	TL1497703065
Midstream NGR:	
Downstream NGR:	
Gradient (m/km):	9999
Distance to Confluence (km):	9999
Survey Length (m):	100
Survey Width (m):	5.31
Survey Area (m2):	531
Mean Survey Depth (m):	0.68

Carle & Strub MWL [Quantitative] Population Estimates — **All Fish**

	Catch 1		Catch 2		Survey Totals				Carle & Strub Numbers Estimate			Carle & Strub Weights Estimate			Carle & Strub Density Estimate			Carle & Strub Standing Crop Estimate		
Species	**Nos**	**Wt(g)**	**Nos**	**Wt(g)**	**Nos**	**Wt(g)**	**Nos / Are**	**Wt(g) / Are**	**Nos**	**S Error**	**Limits (+/-**	**Wt(g)**	**S Error**	**Limits (+/-**	**Nos / Are**	**S Error**	**Limits (+/-**	**Wt(g) / Are**	**S Error**	**Limits (+/-)**
Brown / sea trout [Salmo trutta]	1	15.04	0	0	1	15.04	0.188	2.833	1	0	0	15.04	0	0	0.188	0	0	2.833	0	0
Gudgeon [Gobio gobio]	2	5.95	1	8.85	3	14.8	0.565	2.787	3	0.745356	1.460898	14.8	3.67731	7.207527	0.565	0.140368	0.275122	2.787	0.692525	1.35735
Roach [Rutilus rutilus]	2	268.14	0	0	2	268.14	0.377	50.496	2	0	0	268.14	0	0	0.377	0	0	50.496	0	0
Perch [Perca fluviatilis]	0	0	1	1.58	1	1.58	0.188	0.297	1	1.732051	3.39482	1.58	2.731315	5.353376	0.188	0.326187	0.639326	0.297	0.514372	1.008169
Pike [Esox lucius]	6	3258.98	1	56.02	7	3315.01	1.318	624.295	7	0.428571	0.84	3315.01	202.95945	397.80052	1.318	0.08071	0.158192	624.295	38.222119	74.915353
Total	**11**	**3548.12**	**3**	**66.45**	**14**	**3614.57**	**2.637**	**680.709**	**14**	**1.933709**	**3.790069**	**3614.57**	**203.01114**	**397.90183**	**2.637**	**0.364164**	**0.713761**	**680.709**	**38.231852**	**74.934431**

ENVIRONMENT AGENCY NATIONAL FISH POPULATIONS DATABASE - ENTERPRISE v5.1.1 SITE SURVEY REPORT

Location:	Thames North East
Report Date:	17/11/16
Site Name:	Verulam Golf Course
Site Reference:	VCN6
Survey Date:	20/10/2016
Catchment:	Colne
Sub Catchment:	Ver
Fisheries Management Unit:	
Upstream NGR:	TL1554905910
Midstream NGR:	
Downstream NGR:	
Gradient (m/km):	0
Distance to Confluence (km):	0
Survey Length (m):	105
Survey Width (m):	3
Survey Area (m2):	315
Mean Survey Depth (m):	

Carle & Strub MWL [Quantitative] Population Estimates — **All Fish**

	Catch 1		Catch 2		Survey Totals				Carle & Strub Numbers Estimate			Carle & Strub Weights Estimate			Carle & Strub Density Estimate			Carle & Strub Standing Crop Estimate		
Species	**Nos**	**Wt(g)**	**Nos**	**Wt(g)**	**Nos**	**Wt(g)**	**Nos / Are**	**Wt(g) / Are**	**Nos**	**S Error**	**Limits (+/-**	**Wt(g)**	**S Error**	**Limits (+/-**	**Nos / Are**	**S Error**	**Limits (+/-**	**Wt(g) / Are**	**S Error**	**Limits (+/-)**
Brown / sea trout [Salmo trutta]	7	2441.71	1	25.35	8	2467.05	2.54	783.192	8	0.395285	0.774758	2467.05	121.89858	238.92121	2.54	0.125487	0.245955	783.192	38.697961	75.848003
Chub [Leuciscus cephalus]	6	3274.06	1	98.54	7	3372.59	2.222	1070.665	7	0.428571	0.84	3372.59	206.48513	404.71085	2.222	0.136054	0.266666	1070.665	65.550834	128.47964
Feral [brown] goldfish [Carassiu	1	92.37	0	0	1	92.37	0.317	29.325	1	0	0	92.37	0	0	0.317	0	0	29.325	0	0
Roach [Rutilus rutilus]	14	257.09	5	73.23	19	330.32	6.032	104.863	20	2.171399	4.255942	347.7	37.750124	73.990243	6.349	0.689333	1.351093	110.382	11.984166	23.488966
Perch [Perca fluviatilis]	32	379.09	8	53.84	40	432.93	12.698	137.437	42	2.459268	4.820166	454.57	26.61698	52.16928	13.333	0.78072	1.530211	144.308	8.449835	16.561676
Total	**60**	**6444.32**	**15**	**250.95**	**75**	**6695.26**	**23.81**	**2125.481**	**78**	**3.332101**	**6.530918**	**6734.3**	**244.19031**	**478.613**	**24.762**	**1.05781**	**2.073307**	**2137.872**	**77.520733**	**151.94064**

APPENDIX J – Heritage Desk Based Assessment

River Ver Restoration Optioneering Project

Historic Environment Desk-Based Assessment

Environment Agency

Project Number: 60525824

6 December 2016

Quality information

Prepared by	Checked by	Approved by
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Revision History

Revision	Revision date	Details	Authorized	Name	Position
Re01	March 2017	Issued for client comment		Helen Maclean	Technical Director
Re02	May 2017	Updated following comment		Helen Maclean	Technical Director
Re03	December 2017	Updated following comment		Helen Maclean	Technical Director
Re04	March 2018	Updates following meeting		Helen Maclean	Technical Director

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Tables

1 Introduction

1.1 Project Introduction

1.1.1 This historic environment desk-based assessment is to allow for the initial assessment of proposed options to enable the River Ver to reach Good Ecological Status under the Water Framework Directive. This report details the historic environment of the river corridor to allow for potential heritage constraints to be determined. The site is to the south-west of St Albans city centre (see Figure 1).

1.1.2 This statement forms a historic environment desk-based assessment.

1.2 Archaeological Desk-Based Assessment

1.2.1 AECOM was commissioned the Environment Agency to undertake a historic environment desk-based assessment in advance of the proposals to improve the River Ver.

1.2.2 The aim of this assessment is to inform on of the potential constraints along the river corridor and to assess the potential effects of the proposed options. The assessment has examined heritage assets as well as considering the potential for previously unrecorded archaeological remains.

1.2.3 The desk-based assessment involved gathering information from the Hertfordshire Historic Environment Record (HER), the Historic England Archives Services (HEAS), the National Heritage List (www.historicengland.org.uk) and documentary sources. Historic maps were also examined.

1.3 Site Location and Description

1.3.1 The stretch of the river runs from TL 13834 07447 to TL 15281 06103. It encompasses the river itself, and parkland and other amenity grassland either side of the River Ver.

1.4 Topography and Geology

1.4.1 The geology of the area is largely influenced by the presence of the River Ver itself. The superficial geology comprises alluvium deposits of clay, silt, sand and gravels which are common to river channels (http://mapapps.bgs.ac.uk/geologyofbritain/home.html). The underlying bedrock consists of Lewes nodular chalk formation and Seaford chalk. This is a chalk, sedimentary bedrock formed in warm shallow chalk shelf seas 84 to 94 million years ago.

1.4.2 Following the end of the last ice age the fall in sea level lead to the formation of gravel terraces along the Ver valley. Along the valley of the Ver is a narrow, well defined band of alluvium with interspersed thin deposits of peat (Niblett and Thompson, 2005, 11). The course of the river has been altered many times from at least the Roman period due to the need for dry land, provision of water for mills, canalisation and the construction of lakes, ponds and watercress beds in the 19th century (*ibid*).

1.5 Scope of the Assessment

1.5.1 The scope of the assessment was to:

- Identify the cultural archaeological assets within the study area;
- Assess the archaeological potential of the development site;

- Identify potential impacts; and
- Make recommendations for further work, where required.

2 Legislation and Planning Policy

2.1 Legislative framework

2.1.1 National legislation which is relevant to archaeology and cultural heritage comprises the following.

The Ancient Monuments and Archaeological Areas Act 1979

2.1.2 The Act imposes a requirement for Scheduled Monument Consent for any works of demolition, repair, and alteration that might affect a Scheduled Monument. For non-designated archaeological assets, protection is afforded through the development management process as established both by the Town and Country Planning Act 1990 and the National Planning Policy Framework (NPPF 2012).

The Planning (Listed Buildings and Conservation Areas) Act 1990

2.1.3 The Act sets out the principal statutory provisions which must be considered in the determination of any application affecting either listed buildings or conservation areas.

2.1.4 Section 66 of the Act states that in considering whether to grant planning permission for development which affects a listed building or its setting, the local planning authority or, as the case may be, the Secretary of State shall have special regard to the desirability of preserving the building or its setting or any features of special architectural or historic interest which it possesses. By virtue of Section 1(5) of the Act a listed building includes any object or structure within its curtilage.

2.2 National and Local Planning Policy

National Planning Policy Framework

2.2.1 The NPPF establishes a set of core land-use planning principles that should underpin both plan-making and decision-taking. The conservation of heritage assets in a manner appropriate to their significance, so that they can be enjoyed for their contribution to the quality of life of this and future generations, is one of these core planning principles (paragraph 17). Section 12 of the NPPF sets out a series of policies that are a material consideration to be taken into account in development management decisions in relation to the heritage consent regimes established in the Ancient Monuments and Archaeological Areas Act 1979 and the Planning (Listed Buildings and Conservation Areas) Act 1990.

2.2.2 The NPPF sets out the importance of being able to assess the significance of heritage assets that may be affected by a development proposal. Significance is defined in Annex 2 as the value of an asset because of its heritage interest. This interest may be archaeological, architectural, artistic or historic and can extend to its setting. The setting of a heritage asset is defined in Annex 2 as "*the surroundings in which a heritage asset is experienced".* In determining applications, local planning authorities should require an applicant to describe the significance of any heritage assets affected, including any contribution made by their setting. The level of detail should be proportionate to the asset's importance and no more than is sufficient to understand the potential impact of the proposal on their significance (paragraph 128). Similarly there is a requirement on local planning authorities to identify and assess the particular significance of any heritage asset that may be affected by a proposal; and that they should take this assessment into account when considering the impact of a proposal on a heritage asset (paragraph 129).

2.2.3 In determining planning applications, local planning authorities should take account of the following three points:

- the desirability of sustaining and enhancing the significance of heritage assets and putting them to viable uses consistent with their conservation;
- the positive contribution that conservation of heritage assets can make to sustainable communities including their economic vitality; and
- the desirability of new development making a positive contribution to local character and distinctiveness (paragraph 131).

2.2.4 Paragraphs 132 to 134 of the NPPF introduce the concept that heritage assets can be harmed or lost through alteration or destruction or development within their setting. This harm ranges from less than substantial through to substantial. With regard to designated assets, paragraph 132 states that the more important the asset, the greater the weight should be on its conservation. Distinction is drawn between those assets of exceptional interest (e.g. grade I and grade II* listed buildings), and those of special interest (e.g. grade II listed buildings). Any harm or loss of heritage significance requires clear and convincing justification, and substantial harm or loss should be wholly exceptional with regard to those assets of greatest interest.

2.2.5 In instances where development would cause substantial harm to or total loss of significance of a designated asset consent should be refused unless that harm or loss is ‘necessary to achieve substantial public benefits that outweigh that harm or loss’ (para 133). In instances where development would cause less than substantial harm to the significance of a designated asset the harm should be weighed against the public benefits of the proposal including its optimum viable use (paragraph 134). In relation to non-designated assets a balanced judgment is required taking into account the scale of harm or loss and the significance of the asset (paragraph 135).

2.2.6 Guidance on the application of heritage policy within the NPPF is provided by on-line Planning Practice Guidance and best practice advice is provided by a series of Historic England Advice notes (see below).

Local Plan Policy

2.2.7 The local planning policies for St Albans District are set out in The District Local Plan Review (1994). In September 2007 this plan was reviewed and appropriate polices saved. The following policies were saved in relation to the historic environment:

§ 85 – Development in Conservation Areas;

§ 86 - Buildings of Special Architectural or Historic Interest;

§ 87 – Locally Listed Buildings;

§ 109 – Scheduled Ancient Monuments;

§ 110 – Archaeological Sites for Local Preservation; and

§ 111 - Archaeological Sites Where Planning Permissions May Be Subject to a Recording Condition.

2.2.8 The St Albans District is also in the process of developing a Strategic Local Plan (SLP) and a Detailed Local Plan (DLP). The current timetable states that the SLP will be adopted in May 2017 and the DLP in March 2018.

2.3 Planning practice and best guidance

Planning Practice Guidance

2.3.1 The Planning Practice Guidance (PPG) is a government produced interactive on-line document that provides further advice and guidance that expands the policy outlined in the NPPF. It expands on terms such as ‘significance’ and its importance in decision making. The PPG clarifies that being able to properly assess the nature, extent and the importance of the significance of the heritage asset and the contribution of its setting, is very important to understanding the potential impact and acceptability of development proposals (Paragraph: 009) .

2.3.2 The PPG states that in relation to setting, a thorough assessment of the impact on setting needs to take in to account, and be proportionate to, the significance of the heritage asset under consideration and the degree to which proposed changes enhance or detract from that significance and the ability to appreciate it (Paragraph: 013).

2.3.3 The PPG usefully discusses how to assess if there is substantial harm. It states that what matters in assessing if a proposal causes substantial harm is the impact on the significance of the asset. It is the degree of harm to the asset's significance rather than the scale of the development that is to be assessed (Paragraph: 017). Generally harm to heritage assets can be avoided or minimised if proposals are based on a clear understanding of the heritage asset and its setting (Paragraph: 019).

2.3.4 The NPPF indicates that the degree of harm should be considered alongside any public benefits that can be delivered by development. The PPG states that these benefits should flow from the proposed development and should be of a nature and scale to be of benefit to the public and not just a private benefit and would include securing the optimum viable use of an asset in support of its long term conservation (Paragraph: 020).

3 Methodology of Assessment

3.1 Methodology for determining the heritage baseline

3.1.1 A study area of 250m either side of the River Ver from TL 13834 07447 to TL 15281 06103 was used to identify heritage assets.

3.1.2 In consideration of the potential for archaeological deposits to be affected by the development, archaeological evidence within the study area was considered so to provide a synthesis and understanding of the nature and extent of past activity and thereby enable an assessment of the potential for remains to occur within or in close proximity to the River Ver.

3.1.3 All assets identified within the study area, irrespective of whether they would be affected by the proposed options, are listed in Appendix 1 and shown on Figure 2.

3.1.4 This desk-based assessment has been carried out in accordance with the published Standard and Guidance for Historic Environment Desk-Based Assessments (CIfA 2014a) and the Code of Conduct (CIfA 2014b) of the Chartered Institute for Archaeologists (CIfA). AECOM is a Registered Archaeological Organisation of CIfA.

3.2 Data Sources

3.2.1 Data sources collected and assessed in the course of the desk-based research include:

- Hertfordshire Historic Environment Record;
- The Historic England Archive Service;
- National Heritage List for England;
- St Albans Central Library;
- Hertfordshire Archives; and
- Online sources:
  - British Geological Survey;
  - Heritage Gateway; and
  - The National Library of Scotland Mapping Library.

3.3 Assessment Methodology

3.3.1 This report provides an overview of the archaeological and historical background of the study area in order to better understand its historical context and the significance of any heritage assets within it.

3.3.2 NPPF defines significance of heritage assets as "The value of a heritage asset to this and future generations because of its heritage interest." (NPPF, Annex 2 Glossary). In addition the NPPF and English Heritage guidance set out criteria which should be considered when assessing the significance of cultural heritage assets, which include archaeological, architectural, artistic and historic values (NPPF). These criteria have therefore been used in the assessment of significance for each asset.

3.3.3 The information, in conjunction with professional judgement, has been used to assess the significance of heritage assets. The assessment of significance is based on current knowledge and understanding of the assets.

3.3.4 The criteria for assessing the significance of heritage assets is presented in Table 1.

Table 1. Criteria for assessing the significance (heritage value) of heritage assets.

Significance (heritage value)	Criteria
High	Assets of inscribed international importance, such as World Heritage Sites, Grade I and II* listed buildings, Grade I and II* registered historic parks and gardens, Registered battlefields, Scheduled monuments, Non-designated archaeological assets of schedulable quality and importance.
Medium	Grade II listed buildings, Grade II listed registered historic parks and gardens, Conservation Areas, Locally listed buildings included within a Conservation Area Non-designated heritage assets of a regional resource value.
Low	Non-designated heritage assets of a local resource value as identified through consultation, Locally listed buildings Non-designated heritage assets whose heritage values are compromised by poor preservation or damaged so that too little remains to justify inclusion into a higher grade

3.3.5 Archaeological sites/features where the importance of the resource cannot be ascertained or buildings with some hidden (i.e. inaccessible) potential for historic significance will be noted as unknown.

3.3.6 When professional judgement is considered, some sites may not fit into the specified category in this table. Each heritage asset is assessed on an individual basis and takes into account regional variations and individual qualities of sites.

3.4 Options Appraisal Criteria

For each option a rating has been provided based on the criterial provided in table 2.

Table 2. Criteria for assessing the significance (heritage value) of heritage assets

Does the scheme potentially provide a benefit or disbenefit with regard to the heritage of the reach?		
Score	**Effect**	**Descriptor**
2	Strong positive	Restoration options that provide major contributions towards the heritage value of the reach e.g. options do not cause any physical impact to heritage assets. Provides an improved level of information to members of the public surrounding the historical use of the river (e.g.information board installation etc).
1	Mild positive	Restoration options that provide minor contributions towards the heritage value of the reach e.g. restoration options do not cause any physical impact to heritage assets and provide an improved level of information to members of the public surrounding the historical use of the river (information board installation etc).
0	Neutral	Status quo maintained e.g. restoration measures have limited or no impact on the heritage of the reach.
-1	Mild negative	Minor physical impact upon any heritage assets, and/ or minor impacts to their significance relating to changes to their setting e.g. partial re-alignment of river channel physically impacting upon a known heritage asset located in the direct course of the newly proposed channel route.
-2	Strong negative	Major physical impact upon any heritage assets, and/ or major impacts to their significance relating to changes to their setting e.g. major re-alignment of river channel physically impacting upon a number of known heritage assets located in the direct course of the newly proposed channel route.

4 Heritage Baseline

4.1 Introduction

4.1.1 There are 225 heritage assets recorded within the study area. The bracketed numbers after sites within the text refer to the number on Figure 2 and in Appendix A, with the exception of the listed buildings. These are contained within Appendix B.

4.2 Designated Sites

4.2.1 There are no World Heritage Sites, registered parks and gardens or registered battlefields within the study area.

4.2.2 There are three scheduled monuments within the study area. These are Verulamium Roman settlement (1), St Albans Abbey (2) and the ruins of Sopwell Nunnery (3).

4.2.3 All Reaches of the river covered in the assessment lie within the St Albans Conservation Area. The Conservation Area was defined and extended to encompass the Roman town, the medieval centre of the town and the 19th century residential area. The size of the area, the complexity of its history and the range of building styles and uses contributes to the character and significance of the of the Conservation Area.

4.2.4 A number of historic buildings lie within the study area. Of these, 82 are statutorily designated and include six grade **II*** listed buildings. A single grade **II*** listed building belongs to the medieval period. This is Kingsbury Barn (B64), a monastic barn built in the 1390s and associated with St Albans Abbey. The remaining five are examples of housing developed outside of the historic core of St Albans during the post-medieval period. These comprise Darrowfield House (B9), Manor Garden House (B13), 13 Fishpool Street (B25), St Michaels Manor (B59) belonging to the late 16th to early 18th centuries, and Abbey Gate House constructed in the early 19th century.

4.2.5 Seventy-six grade **II** listed buildings lie within the study area. These primarily comprise post-medieval domestic buildings, with a total of 55 houses and associated structures attesting to the gradual growth of St Albans during the period. Amenities accompanying such development include nine public houses (B2, B5, B6, B26, B44, B55, B62), and these largely focus around Fishpool Street north of the River Ver, and Michael Street, which runs approximately north-south and crosses the River Ver at St Michael's Bridge (B47). Four mills (B4, B29, B30, B53) and a forge (B73) are demonstrative of limited small scale industrial activity which took place near the River Ver during the post-medieval period, and the survival of a barn (B54) from this period attests to a continuity in the open rural character during the period (Runcie, 1977).

4.3 Archaeological Baseline

Prehistoric (to *c.* AD43)

4.3.1 The earliest recorded evidence in the study area dates to the Palaeolithic (to *c.*10,000 BC). This comprises the find spot of a Palaeolithic hand axe (56). However, this may have been found in made ground deposits, so may not be in its original context. The next evidence is a Mesolithic (10,000 to 3500 BC) tranchet axe (50) which probably represents casual loss of an artefact, rather than an indicator of settlement.

4.3.2 Rivers across the east and south east of England have been identified as having potential for Pleistocene deposits. Research projects in the wider region have identified environmental remains and buried soil deposits that provide details on the prehistoric environment (Austin, 2000, 5).

4.3.3 An Iron Age settlement was located at St Albans on the higher ground to the western side of the river, in the north-western part of the study area. There are also indications for Iron Age activity below the Abbey in the area of the Abbey Primary School and Pondwicks Close. This Iron Age settlement was known as *Verlamion,* which once extended beyond area later used for the Roman town. This was inhabited by the Catuvellauni. The main site within the study areas is the site of an Iron Age cemetery (92), later used for Roman burials and late Roman occupation. This cemetery was used in the late first century until the start of the Roman period and contained 21 cremation burials. Further burials outside of the area excavated cannot be discounted.

4.3.4 Iron Age enclosures (49) have also been recorded within the former precincts of St Albans Abbey from aerial photographs, which may represent either settlement on the periphery of the Iron Age town or were perhaps used for agricultural purposes. Belgic pottery was found close by.

4.3.5 The other evidence within the study area is related to a Belgic mint that was located in this area (51). Other assets related to this include clay pits, found with a coin mould and Belgic pottery (54).

4.3.6 The remaining evidence of Iron Age date is made up of ditches (64, 73 & 114), late Iron Age/early Romano-British kiln fragments (56) and the find spot of a Celtic pin (133).

Roman (*c.* AD43 to 450 AD)

4.3.7 The north-western part of the study area falls within the Roman town of Verulamium (1), designated as a scheduled monument. The town was established before 50 AD, when it was became a *municipium*. The earliest reference to Verulamium is found on the Bloomberg tablets. Four hundred and five wood and wax writing tablets, many with writing on, were found in London during an excavation of the Bloomberg building and are believed to date from 50-80AD. Writing on the tablets included a reference to 'twenty loads of provisions for Verulamium' (www. Bloomberg.com)

4.3.8 Verulamium in also included in Tacitus's description of the Boudiccan revolt and on the coins of Tasicovamus (Niblett and Thompson, 1995, 43). The name – Verulamion – was Latinised in this period and is thought to mean 'the place above the pool' or 'settlement above the marsh' referring to the marshy land adjacent to the River Ver. The place-name likely had its origins in the late Iron Age. It is believed the river was canalised on the north side of St Albans (c230-50AD). In the park the current river running north of the lakes is believed to run close to this alignment (Banfield-Taylor, 2012, 28).

4.3.9 The Claudian fort (48), which was later incorporated into the city defences, is recorded on the HER as one of the earliest elements of the Roman town. Later assessment showed that the 'tower' actually dated to later in the period (Niblett and Thompson, 1995, 73). The town was sacked by Bouddica in 61 AD. Wall defences (82) were added in the 3rd century, and this is still traceable for most of its two mile's length. This wall was built from mortared flint rubble with layers of brick bonding. Behind the wall were an earthen bank (123) and a ditch 6m deep and 29m wide. Other remains include a forum, basilica, theatre, the foundations of two towers and London Gate, where Watling Street entered the city.

4.3.10 It grew steadily; by the early 3rd century, it covered an area of about 125 acres (0.51 km2), behind a deep ditch and wall. It was encircled by gated walls, possibly as early as AD 275, though a later date may be more likely. Verulamium was characterised by a regular grid of streets the pattern of which is believed to have changed and improved following two major fires in the town (155 and around 250AD) (Banfield-Taylor, 2012, 52) demonstrating a level of town planning. Following the sacking of the town in 61AD and the fires much of the town was replaced by masonry building of flint and mortar. The city has been found to contain a forum, basilica and a theatre, a baths, workshops and houses.

4.3.11 In 1929 St Albans Council purchased the site of Verulamium from the Earl of Verulam. Since the reformation the land had been farmland and the intention was to turn the land into a municipal park laying out several of the Roman buildings as part of the parks design (Banfield-Taylor, 2012, 28). In 1930 Mortimer Wheeler (Later to become Sir Wheeler) and his wife Tessa started a programme of excavation to identify appropriate buildings. The wheelers work significantly increased the understanding of the both the Roman Town and the earlier Iron Age settlement. Later phases of archaeological evacuation continued to build on this knowledge of the Roman town.

4.3.12 As expected with a major Roman town, there are a number of Roman roads recorded in the area. The main one of these is Watling Street (86) which ran from the south coast to the north west with an extension into London. Other recorded roads include a road from Verulamium to Mill Hill in London (66), a route linking Verulamium to Braughing (67), which includes large pits which may represent quarries and an early line of Colchester Road (108 7&118). The Colchester Road ran between Colchester and Silchester and was a another of the key roads (120). It crossed the Ver within the study area, upstream of Verulamium and the importance of the town was increased due to this crossing point (Niblett and Thompson, 1995, 57). There are a number of other possible road alignments recorded, such as a road from Verulamium to Cheshunt (63), a minor road from Ware to St Albans (65), and other possible traces of roads or tracks (14, 112, 113 & 122).

4.3.13 A number of Roman cemetery sites are recorded outside of the town. These include a cremation cemetery (58) and Roman burials at the site of the Iron Age cemetery (92), which includes several phases of Roman burials throughout the Roman period, which includes a 4th century shrine built over the Iron Age cremation cemetery. An inhumation cemetery (110) was excavated on the site of Park Lake and while it is thought that the full extent of the cemetery was located, further burials are recorded to the west. Other burials include a cist burial (60) and group of cinerary urns and an inhumation (80).

4.3.14 There are a number of other sites of Roman date outside of the scheduled area, and outside of the core of the Roman town. Some of this may represent industrial activity, such as a possible Romano-British kiln (56), an oven (97), a malting oven and well (98), a pit containing animal bone, pottery and some cess (101), which may represent leatherworking debris, a furnace with ironworking debris (137) and a pottery kiln (140). Other assets represent activity not wanted in the town such as rubbish disposal (111), although this may have been used to form a bank along the side of the river. A possible mill (28), represented by a masonry building, is also recorded.

4.3.15 Other evidence outside of the town includes evidence of perhaps more domestic occupation, including a well, hearth and floor surface at Kingsbury House (32), part of a masonry building near Kingsbury Barn (105), Roman foundations at Kingsbury dairy (107), a substantial building (94), and the sites of three other buildings (141-143), one of which is apsed (143). A well (72), a fragment of masonry wall (136), and traces of a wall (138) are also recorded.

4.3.16 A number of fragments of ditches are also recorded (34, 73, 78 & 87). Some of these are located in the valley bottom and may be related to revetments or early attempts at flood defence for the River Ver. Other evidence for this includes a clay and chalk bank that forms a possible revetment (104), a timber structure composed of three rows of posts revetting a Claudian bank (121), which formed an exit into a marshy area, and a timber causeway (139), formed by oak and alder branches laid down as a ‘raft’.

4.3.17 A wreck of possible Roman date is recorded on the HER as being found in the study area in the early 11th century (135). Although recorded as a wreck it is likely to have been a bridge or causeway.

4.3.18 The final sites of Roman date are find spots of Roman material, including stone implements (6), metalwork and coins found in the river (75), a pot of Roman coins (76), and a single Roman coin (132). Small bronze figurines of Mercury and Harpocrates have also been found close to the river in Cottonmill and recorded by the Portable Antiquities Scheme. The exact location of their discovery is unknown.

Early Medieval (450 to 1066)

4.3.19 The withdrawal of the last of the Roman field army from Britain was started in 409AD but it took around 100 years for the Roman influence to diminish (Niblett and Thompson, 1995, 166). Archaeological evidence for this time is not common and this is reflected in St Albans.

4.3.20 There are ten sites with evidence of early medieval date. It is believed that following the decline of Roman authority over Britain, the Saxon influence became predominant in the area. It has been speculated that a 'Saxon burh' named Kingsbury Castle (129) was established as a fortified centre, complete with earthen ramparts on all sides. Later research has shown that there is little evidence to support this (Niblett and Thompson, 1995, 179). It is speculated that the assumption of a fortified town is based on an interpretation that 'King burh' was a fortified town, rather than the fortified house which is likely to have been located in this area (Niblett and Thompson, 1995, 182).

4.3.21 Other evidence of early medieval date is more ephemeral and includes a Saxon fish pool (12), the site of two chapels, one to St Germanus (44) and one to St Mary Magdalene (52). Neither of these chapels is extant, although that to St Mary Magdalene was shown as extant on a map of 1634.

4.3.22 The other sites are those described in the Roman section above, which may have early medieval evidence (71 & 135).

4.3.23 The remaining sites are the find spot of two Saxon coin hoards (56 & 59), the find spot of a Saxon coin (45) and the find spot of an imitation Saxon coin (130).

Medieval (1066 to 1500)

4.3.24 There are 42 recorded sites with evidence of medieval date. These include two religious scheduled monuments of medieval date. These are St Albans Abbey and its grounds (2) and the ruins of Sopwell Nunnery (3). The nunnery was founded on the riverbank in 1140 by women who built themselves a shack to live in for a life of "vigil, prayer and abstinent" (Niblett and Thompson, 1995, 297). The small community grew as was recognised by Abbot Geoffery De Gorham (d1146). The size of the community was limited to 13 women, who were given exclusive rights to be buried in the cemetery adjacent to the nunnery. A number of other sites are also associated with these scheduled monuments, including part of a flint wall which was assumed to belong to the monastic grange (102), masonry foundations which may have formed a gate in the abbey precinct (103) and a fish pond for the nunnery (115). Some evidence of possible human burials has also been recorded in the location of the allotments. Another possible fish pond near the Abbey precinct is also recorded (89). The final religious site was the churchyard to St Michael's church (90), which was potentially much larger in size in the medieval period than it is now.

4.3.25 The study area was located on the edge of the medieval town, away from the core of settlement. As a consequence, the types of remains recorded in the study area reflect this. A number of roads cross the area, including a medieval highway from St Albans to Barnet (70), a minor road from Kingsbury Manor (79) and an early line of Holywell Hill (119). A medieval lane (88) and track (84) are also recorded. The site of two bridges is also recorded. The foundations of a bridge pier are recorded in the River Ver near the junction of Millstream with Floodgate Stream (106) and the site of the medieval Holywell Bridge (116).

4.3.26 Some of the boundaries to the medieval town are located within the study area. The town's north-east gate is recorded (57), as is part of Tonman ditch (68), a medieval borough boundary ditch, and part of the line of a medieval town boundary (117). Finally, a boundary marker (99), known as the 'Gonnerstone' is recorded on St Michael's Street and it is believed that this was a medieval boundary marker.

4.3.27 The main activity outside of the town was related to industrial practices, where activities which may be noisy or smelly are kept away from the main residential areas. Examples within the study area include ovens (5 & 9), evidence of milling, such as Abbey Mills (18), which was used for grain processing, a brewhouse or grain processing site (46). The Abbey Mill was built outside of the precinct boundary of the abbey. The whole of the riverbank between the mill and Holywell Hill is likely to have been used by the Abbey. As there is no record of the construction of a mill in the *Gesta Abbatum* three may have been a Saxon mill here (Niblett and Thompson, 1995, 260).

4.3.28 A barn, possibly for corn storage (93), which may have been used by the monastery, a knacker's yard (69), clay pits (100), a quarry (126), and assets related to water management, including a leat (10) and a medieval dam (55), surviving in places as earthworks and known as the Causeway, are also recorded around the medieval abbey complex. As well as industrial activity, a hospital (128) is recorded in the study area. This was St Giles Hospital for the poor, which was documented in 1327.

4.3.29 While the River Ver was an important influence on the growth of industrial practices throughout the medieval period little is known about changes to the course of the river and attempts to control it. Evidence suggests that a previously wide, marshy river between Causeway (55) and Holywell Hill were canalised and controlled into its current line sometime in the 13th and 14th centuries (Niblett and Thompson, 1995). A trench excavated in 1997 contained evidence of deliberate infilling of wet areas, possibly for timber revetments for use as flood prevention measures. This canalisation left room for the construction of ponds on the north bank, for which there is some evidence.

4.3.30 Although most of the activity was related to these industrial practices, or to the religious establishments, there was some evidence for residential occupation. Sites include two wells (8 & 15), timber framed houses (27 & 30), one of which may have been used as a public house (27), and evidence of domestic occupation in the form of post-holes, hearths and a possible courtyard (95). A section of wall (96) at St Michael's Manor may have formed part of a boundary to a medieval property. Other sites which may represent domestic activity include a sequence of floor surfaces outside the Six Bells Public House (83) and a pit (35).

4.3.31 Evidence of the Civil War, known as The Anarchy, in the 1140s and 1150s between King Stephen and the Empress Matilda is found in the study area, where a site of a skirmish at 'Haliwell Water' is recorded. This skirmish was between King Stephen and the Abbey's men. Matilda was a benefactor of the Abbey.

4.3.32 The remaining sites are find spots of medieval pottery (25, 29, 31 & 36).

Post-Medieval (1500 to 1900)

4.3.33 There are 34 heritage assets with evidence of post-medieval date. Some of these are earlier sites which continued in use from the medieval period. The pattern of settlement in the study area is similar to that in the medieval period, with industrial activity dominating the record, although there is evidence for residential occupation as well.

4.3.34 Evidence of industrial activity was dominated by mills and brewing. The site of the medieval Abbey Mills (18) was reused in the post-medieval period, when a new silk mill was constructed in 1804. A cotton mill (24) was recorded on Cottonmill Lane on the 1847 Tithe Award. It had been used for a variety of uses in the post-medieval period, including as a water house, to provide water to the town, for diamond polishing. Corn mills are also recoded, including

Kingsbury Mill (41). Evidence of brewing includes a former brewery (21), and malthouses (22 & 23).

4.3.35 Other industrial activity included St Albans Waterworks (20), a tile kiln (91) and a 16th century tannery (109). The River Ver provided the essential supply of water and leather associated with this tannery has been found in the lake, identified during low water levels in 1976 (Banfield-Taylor, 2012, 81). The tannery was owned by a family of tanners known as the Gape family, who bought the land from the Abbey.

4.3.36 Residential sites included some which continued in use from the medieval period (e.g. 30). Once house (74) as built around 1500. Some buildings are extant, such as a locally listed 19th century house (7), a 17th century building with an 18th century front (47), and St Michael's Court (134), while others are no longer surviving (43). As the period progressed, the area outside of the town became inhabited by larger houses, with larger gardens, such as Godersham House (53), Darrowfield House (62) and Kitchener's Meads (127). Holywell House (124) and its gardens (4) are also recorded. The house itself no longer survives, although part of the 16th century house survived as the garden front. Another 18th century garden feature (61) is recorded. This was originally thought to be a medieval well. The site of a farm (39) is also recorded. This was Verulam Hills Farm, which is recorded from 19th century mapping.

4.3.37 The site of Sopwell Park (13), which was owned by Sir Richard Lee, was enclosed in 1562 and caused the closure of part of the road between London and St Albans that ran via Shenley. The area is now largely built over by the Verulam golf course.

4.3.38 As the town and its associated industries grew in size, new transport links were developed, including the railway. In the study are this is represented by a branch of the Great Northern Railway (11), which closed in 1964, and the site of Abbey Station (17, which first opened in 1858. The roads also saw improvements, including a new Holywell Bridge (16) and a tollhouse at Pondyards Gate (26).

4.3.39 Two boundary ditches are recorded. The earlier Tonman ditch (68) continued in use into at least the 17th century, while a 16th century boundary wall (77) round Sir Richard Lee's Sopwell estate has also been found. This was found to contain fragments of masonry salvaged from the abbey after the dissolution. Other ditches and pits have also been found, although their exact purpose is unclear (32, 37 & 38)

4.3.40 The final category of asset of post-medieval date are those that served a public service. These include the Six Bells public house (33) and the Duke of Marlborough public house (42). St Albans swimming baths (131) originally opened in the late 19th century, and formed part of the River Ver. In 1905 a new outdoor pool was opened to the north of the river.

Modern (1900 to date)

4.3.41 There is one recorded site of modern date in the study area. This is a World War II transit camp (5) which was used for mainly Italian prisoners of war. Concrete foundations of some buildings survive, and while one timber hut is reported as surviving in the grounds of the leisure centre, it is unclear whether this is still extant.

4.3.42 The lake within Verulamium Park was created in the 1930 by order of the Mayor of St Albans to "attract an additional number of visitors to the city" (Banfield-Taylor, 2012, 87). The project was used as a work creation scheme for unemployed solders returning from World War I and the men were paid by the day for their work. The lake covered 9.5 acres and is feed with water from the river. To allow the lake to be built the river was moved and straightened on the northern side and diverted to the top by St Michael's (*ibid*).

Unknown

4.3.43 There are two sites of unknown date. These are palaeochannels to the River Ver (40), which could be of early origin, and a ditch on the line of the medieval borough boundary (85). While this is almost certainly medieval in date, it has not been dated securely.

4.4 Historic Maps

4.4.1 The development of St Albans during the post-medieval period is documented in the maps of the area. A map of St Albans Abbey from *c*.1677 held in the Hertfordshire Archive shows the abbey and precinct including the Abbey Mill and river The river is shown as an almost straight boundary to the south of the Abbey which suggests that the river had been realigned and canalised well before this date.

4.4.2 The 1874 Tithe Map of St Michael's Parish depicts Reach One. The plan shows the spread of the town along Fispool (*sic*) Street away from the core of the town. It also records multiple channels and pools crossing the area now under the modern lake (see Plate 1).

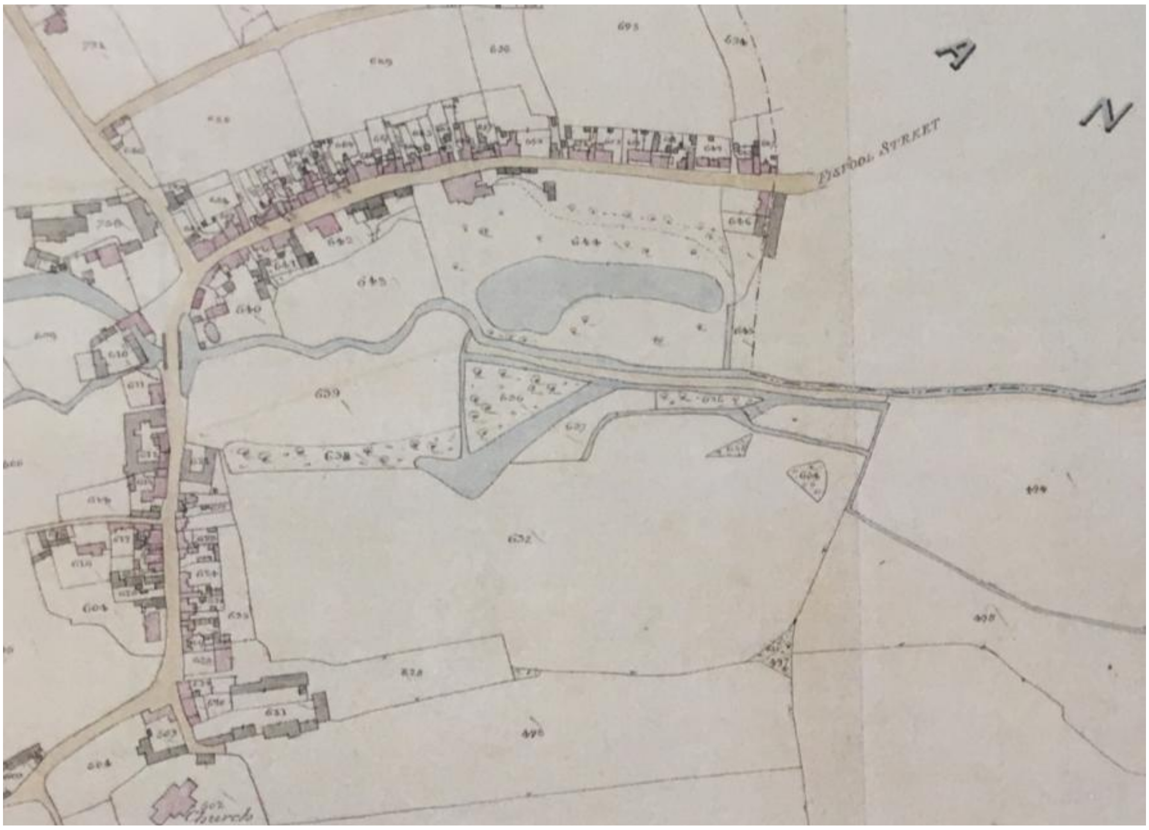

Plate 1 Tithe Map of St Michael's Parish (1874) (Reproduced with the permission of HALS)

4.4.3 As with the Tithe Map, the first edition Ordnance Survey records the line of the river in the 1870s. The site of a "fish pool" is recorded in Reach One where the lake is currently located. The map also records the line of a second channel running to the western side on the lake, likely at the line of the western side of the lake (see Plate 3)

Plate 3 1879 Ordnance Survey Plan – Reach One and Two

4.4.4 Further downstream the first edition plan also records a channel crossing through the area of the modern allotments (see Plate 4). It is likely that this was a mill leat supplying water to the cotton mill (24). Also shown on Plate 4 is the area of Sopwell Nunnery. The map records the remains of the nunnery as occupying the land adjacent to the river.

4.4.5 The land adjacent to the river is still recorded as being open fields with some evidence of the spread of the urban extent of St Albans that continued into the late19th and early 20th century. The land adjacent to the river remains largely unaltered with the open fields maintained throughout the early 20th century. The open landscape was finally overtaken by the expanding town as part of the grown of St Albans following World War II.

Plate 4 1879 Ordnance Survey Plan – Reach Three to Six

5 Option Appraisal

5.1 Potential Impacts

5.1.1 An impact is defined as a change resulting from the proposed development on the significance of a heritage asset. Impacts on heritage assets can relate to either physical impacts on the heritage assets or impacts to their significance relating to changes to their setting.

5.1.2 The following could have an impact upon heritage assets by the proposed development:

- Physical impacts upon archaeological features; and
- Impacts on the setting of heritage assets.

5.2 Reaches

5.2.1 This study supports the production of options for the proposed restoration of the River Ver at St Albans. The stretch of river being considered has been divided into six reaches, from the upstream end of Verulamium Lake down to the Recreation Ground adjacent to Monks Close.

- Reach 1 – From the upstream end of Verulamium Lake to the weirs adjacent to Abbey Mills.
- Reach 2 – Abbey Wills to Holywell Hill
- Reach 3 – Holywell Hill to the river adjacent to De Tany Court
- Reach 4 – De Tany Court to Cottonmill Lane
- Reach 5 – Cottonmill Lane to the former railway line
- Reach 6 - Former railway line to Watercress Nature Reserve to the Recreation Ground.

5.2.2 For each reach, a long list of options has been identified. Following an initial assessment of the potential effects several of the options were discounted. Table 3 below details the options that have been carried forward to this assessment.

Table 3 Assessment Options

Reach	Option	Description
1	5	Maintain most of the current river channels with some improvement works. Small realignment of the river at the downstream end of the reach, through lower end of the lake. Some upstream re-profiling.
	8	Maintain the current river channels with some improvement works. Redesign of the fish pass and weir.
	9	Realignment of the river channel to the west of the lakes and create a new connection into Reach 2 to the west of the causeway. The lakes would be retained as a feature but may be retained as an off [river] line feature.
	10	Realignment of the channel to between the lakes and the current river channel. Possible de-watering of the leat channel.
	15	Close off the abstractions into the lake to that it becomes offline would dry. Flow in the River Ver would increase.
2	2	Part realignment of the channel over the right bank with the floodplain reconnection and wet woodland creation. Possible reconnection location linked to Reach one option 9.
	3	Realignment of the channel close to the existing course.
	4	Retain existing channel course with morphological improvements and local bank/floodplain works.
3	2	Part realignment of the existing channel with an off line pond creation.
	4	Maintain the existing channel and make improvements.
4	1	Realign the channel through the allotments.
	2	Realign the channel through the allotments and connect to the realigned Reach five option 1.
	3	Create a more sinuous channel close to the existing channel course.

Reach	Option	Description
5	1	Full realignment of the existing channel (connecting to Reach 4 through a new structure under the road.
	2	Part realignment of the existing channel.
	3	Small realignment of the existing channel through the woodland.
	4	Retain the existing Channel and make improvements.
6	2	Retain the existing channel and make improvements.

5.3 Potential Effects

5.3.1 The following section summarises the heritage assets located within each Reach that could be affected by the various options. Their heritage significance is assessed based on current knowledge and understanding of the assets. The potential effects of each option are then presented.

5.3.2 All the Reaches fall within the St Albans Conservation Area which is of medium heritage significance (heritage value). The size of the area, the complexity of its history and the range of building styles and uses contributes to the historic and architectural significance of the Conservation Area.

5.3.3 Any of the options would have a physical effect on the Conservation Area. In addition some of the alteration to the river proposed may also have an effect on the setting of the Conservation Area. These effects may be negative or positive.

Reach One – Heritage Assets

5.3.4 There are six heritage assets within Reach 1 that would potentially be affected by improvement to the river (see Figure 2).

5.3.5 The Roman Town of Verulamium (1) is a scheduled monument of high heritage significance (heritage value). It is of archaeological significance due to the information that it has provided and could provide on the Roman influence on Britain, how the Roman city was built and functioned and how people lived.

5.3.6 The St Albans Abbey and grounds (2 and 18) is a scheduled monument of high heritage significance (heritage value). It is significant for its archaeological and historical information on the abbey and the ecclesiastical history of St Albans during the medieval and post-medieval periods.

5.3.7 The approximate location of a late Saxon fish pool (12) is also believed to lie within this area and may have been partially or wholly under the modern lake. Although the exact details of its location are unknown it assumed that it lay within the valley with water fed from the river (Banfield-Taylor, 2012, 183). The asset is of low heritage significance (heritage value). Due to the exact location of the pool being unknown its significance is limited to its historic value due to the knowledge regarding Saxon society that its location and use would provide. If the exact location of the pool is defined it would also potentially have greater archaeological significance if waterlogged deposits are found to survive. The causeway (55) is located at the south-east end of the current lake. No archaeological investigation of the causeway has been undertaken so its exact age and nature is unknown, although documentary evidence suggests it could date from as early as the 4th century (Niblett and Thompson, 1995, 187). It has the potential to be of high heritage significance (heritage value). The causeway has archaeological significance for the knowledge of how it was used and constructed that may be discovered should an archaeological evaluation be undertaken. It also has historic significance in relation to the information it contains about water management in the area from the Roman period. Its original setting has been lost due to subsequent development of Verulum Lake and the park that has been developed around it. However, its riverside location is still evident, and that part of its setting still contributes to its significance.

5.3.8 In 1934, 15 late Roman inhumations were excavated during the construction of the lake (110). It is likely that other burials existed in the area but may have been disturbed by the 19th and 20th century watercress beds (Banfield-Taylor, 2012, 183). The burials are considered to be of medium heritage significance (heritage value) due to the association with the Roman town. However, the excavation and removal of the remains in 1934 prevents any further impact on their heritage significance. There is a potential that other, previously unrecorded, burials may survive in the wider area. If found, these burials would also be of medium heritage significance (heritage value). They would be archaeologically significant due to the information they may provide on the Roman population of Verulamium.

5.3.9 The River Ver and the lake within Verulamium Park can be considered heritage assets of medium significance (heritage value). The course of the river has been slightly altered several times since the Roman period with the lake being created and the River Ver set to its current course in the 1930s, although its board alignment is shown on maps form the 18th and 19th centuries. The river and lake holds historic significance due to their association with the history of St Albans and their continued use and alteration.

5.3.10 The presence of the Roman town alongside, but not directly beneath, the subsequent medieval town provides an opportunity to understand the relationship between the two and the development of Britain from the end of the Roman period into the medieval. Much of the previous archaeological evaluation works concentrated on the recording of the layout of the town itself and its key buildings. Very little investigation has been undertaken into the plots surrounding the key buildings, the yards, pens and other low status buildings within the section of the town which lies within the potential development area, (Banfield-Taylor, 2012, 165). In the wider area detailed investigations has been undertaken at site such as Saracens Head Yard, White Hart Inn, and Butlers Yard, which provide insight into how the town was utilised on a day to day basis. The area retains the potential for remains of high heritage significance (heritage value) and would be of archaeological significance for the information they could provide on the day to day use life of the town.

Reach One - Potential effects

Option 5 – River diverted through the lower end of the lake.

5.3.11 Option 5 would have a physical effect on the lake and river, both of which are of medium heritage significance (heritage value). The proposed re-profiling of the current channel and creation of berms will alter the current course and profile of the river. The proposed new section of river channel would cut through the lower end of the lake directly affecting the lake.

5.3.12 There would also be an effect on the causeway (55) which is potentially of high heritage significance (heritage value). The option proposes a new section of river channel. The new channel would pass through the causeway further west than the current channel, requiring a new gap to be created in the causeway.

5.3.13 The proposed re-grading of the lake banks and re-profiling of the river may have an effect on archaeological deposit associated with the Roman and medieval towns.

Option 8 - Maintain the current river channels with some improvement works. Redesign of the fish pass an weir.

5.3.14 The option would potentially affect a section of St Albans Abbey grounds (2), which is a scheduled monument and of high heritage significance (heritage value). The causeway, weir and fish pass all form a section of the boundary of the scheduled monument. Any alterations to these elements would potentially have a physical effect on the scheduled monument. The design of the alterations may also have an effect on the setting of the abbey.

5.3.15 Option 8 would have a physical effect on the river, which is of medium heritage significance (heritage value). The proposed re profiling of the current channel and creation of berms will alter the current course and profile of the river.

5.3.16 There would also be an effect on the causeway (55) which is potentially of high heritage significance (heritage value). The option proposes a re design of the fish pass and the weir. This would potentially alter the style of the weir.

5.3.17 The proposed re-profiling of the river may have an effect on archaeological deposit associated with the Roman and medieval towns.

Option 9 – Realignment of the river channel to the west of the lake.

5.3.18 The realignment of the river channel to the west of the lakes would have a physical effect on the on the scheduled monument of the Roman Town of Verulamium (1) which is an asset of high heritage significance (heritage value). The cutting of a new channel would potentially have a significant effect of the buried remains of the Roman town.

5.3.19 There would also be an effect on the causeway (55) which is potentially of high heritage significance (heritage value). The realignment of the river to the new channel would require a cut through the causeway further west than the current channel.

5.3.20 Option 9 would also have a physical effect on the lake which is of medium heritage significance (heritage value). The proposed re-routeing of the river channel would potentially leave the lake independent from the river. A potential result of this would be the lake drying out at times. This would affect the lake but would also potentially affect archaeological deposits that survive beneath the lake and any surviving evidence of the Saxon fish pool (12), which is of low heritage significance (heritage value). If waterlogged deposits are found to survive within the area of the fish pool their heritage significance (heritage value) would increase to high.

Option 10 – Realignment of the channel to between the lakes and the current river channel.

5.3.21 Option 10 proposes the cutting of a new river channel between the current channel and the lake. This will potentially have an effect on archaeological deposit associated with the Roman and medieval towns. The new channel would also cross the location of where 15 late Roman inhumations were recovered. While it is speculated that any other burials in the area would have previously disturbed, there is still limited potential for other burials to survive below the modern lake.

5.3.22 There would also potentially be an effect on the lake which is of medium heritage significance (heritage value). The proposal would require the infilling of a section of the lake to create the space for the new river channel. The proposed re–routeing of the river channel would potentially leave the lakes independent from the river. A potential result of this would be the lake drying out at times. This would affect the lake but also potentially effecting archaeological deposits that survive beneath the lake including evidence of the Saxon fish pool, an asset of low heritage value.

5.3.23The proposed re-profiling of the river may have an effect on archaeological deposit associated with the Roman and medieval towns.

Option 15 Close off the abstractions into the lake to that it becomes offline would dry.

5.3.24Option 15 would have a physical effect on the lake which is of medium heritage significance (heritage value). The proposed ending of water abstraction from the river channel into the lake would leave the lakes independent from the river and they would eventually dry out. This would affect the lake and also potentially affect archaeological deposits that survive beneath the lake, including evidence of the Saxon fish pool, an asset of low heritage significance (heritage value).

5.3.25The proposed softening of the edges of the river may have an effect on archaeological deposits associated with the Roman and medieval towns.

Reach Two – Heritage Assets

5.3.26Within Reach Two are six heritage assets that would potentially be affected by improvement to the river (see Figure 3).

5.3.27The St Albans Abbey, grounds and mill (2 and 18) is a scheduled monument of high heritage significance (heritage value)It is significant for its archaeological and historical information on the abbey and the ecclesiastical history of St Albans during the medieval and post-medieval periods. The Abbey Mill, where the river is dammed by the Causeway, while outside of the abbey precinct, was used by the abbey (Niblett and Thompson, 1995, 260). The mill building lies on 'an island' between the river and the mill leat. The River Ver, which was canalised during the medieval period, provides the southern boundary for a section of the scheduled monument.

5.3.28On the southern bank of the River Ver is the site of two mid-14th century to 15th century buildings that were archaeologically excavated in 1988. One was found to contain an oven and may have been a brewhouse. The second is believed to have been a barn. The site is of low heritage significance (heritage value). The site has historic significance for the information it provided on the working life of the abbey and medieval St Albans. The extent of the archaeological excavation is unknown at this stage. There is potential that the site may retain archaeological significance outside of the areas of excavation.

5.3.29The causeway (55) is located at the south-east end of the current lake. No archaeological investigation of the causeway has been undertaken so its exact age and nature is unknown, although documentary evidence suggests it could date from as early as the 4th century (Niblett and Thompson, 1995, 187). It has the potential to be of high heritage significance (heritage value). The causeway has archaeological significance for the knowledge of how it was used and constructed that may be discovered should an archaeological evaluation be undertaken. It also has historic significance in relation to the information it contains about water management in the area from the Roman period. Its original setting has been lost due to subsequent development of Verulum Lake and the park that has been developed around it. However, its riverside location is still evident, and that part of its setting still contributes to its significance.

5.3.30 The possible site of a medieval bridge (106) crossing the river adjacent to the abbey lies within Reach Two. It has previously been noted that foundations of a pier survived in the River Ver just past the junction of the millstream. The extent of the surviving remains is unknown. The asset if of low heritage significance (heritage value). Potentially the remains of the bridge would have archaeological, architectural and historical significance due to its association with the abbey and the information that may be gathered on medieval building techniques.

5.3.31 The presence of the Roman town alongside, but not directly beneath, the subsequent medieval town provides an opportunity to understand the relationship between the two and the development of Britain from the end of the Roman period into the medieval. The abbey on the northern side of the river was an integral part of the lift of the abbey. The area retains the potential for remains of high heritage significance (heritage value) and would be of archaeological significance for the information they could provide on the day to day use life of the town.

5.3.32 The River Ver can itself be considered to be a heritage asset of medium significance (heritage value). The course of the river has been altered several times since the Roman period and was a key watercourse for both the mill building and the inhabitants of the abbey. The river holds historic significance due to its association with the history of St Albans and its continued use and alteration.

Reach Two - Potential effects

Option 2 – Part realignment of the channel over the right bank with the floodplain reconnection and wet woodland creation

5.3.33 The cutting of a new channel and creation of wet woodland as proposed by Option 2 would have an effect on the location of ancillary building associated with the abbey on the south side of the river, which is of low heritage significance (heritage value). Although previously excavated, archaeological remain outside of the extent of the excavations may survive.

5.3.34 There would also be an effect on the causeway (55) which is potentially of high significance (heritage value). The option proposes a potential new section of river channel. The new channel would pass through the causeway further west than the current channel, requiring a new gap to be created in the causeway.

5.3.35 This option would also affect the location of a possible medieval bridge of low heritage significance (heritage value). Remains of the bridge within the water channel may be lost as a result of works within the channel or along the bank in this location.

5.3.36 The proposed morphological improvements (including lowering of the banks and narrowing of the channel) to the edges of the river may have an effect on archaeological deposits associated with the abbey, the medieval town and the use of the river as a key water source.

Option 3 – Realignment of the channel close to the existing course.

5.3.37 The re-cutting of the river channel close to the current course of the river by would have an effect on archaeological deposits associated with the abbey, the medieval town and the use of the river as a key water source. Any works undertaken on the northern bank of the river may fall within the scheduled monument of St Albans Abbey, which is of high heritage significance (heritage value).

5.3.38 If the new section of channel associated with Reach One, option 9 is required it will have an effect on the location of ancillary building associated with the abbey on the south side of the river, which is of low heritage significance (heritage value). Although previously excavated, archaeological remains outside of the extent of the excavations may survive. This new section of channel would also affect the Causeway (55), which potentially of high heritage significance (heritage value). The new channel would pass through the causeway further west than the current channel, requiring a new gap to be created in the causeway.

5.3.39 This option would also affect the location of a possible medieval bridge of low heritage significance (heritage value). Remains of the bridge within the water channel may be lost as a result of works within the channel or along the bank in this location.

Option 4 – Retain existing channel course with morphological improvements and local bank/floodplain works.

5.3.40 Option 4 would retain the existing channel and undertake morphological improvements (including lowering of the banks, narrowing of the channel and creation of riffles and bars) to the bank of the river and the within the channel itself. These works may have an effect on archaeological deposits associated with the abbey, the medieval town and the use of the river as a key water source. Any works undertaken on the northern bank of the river may fall within the scheduled monument of St Albans Abbey, which is of high heritage significance (heritage value).

5.3.41 This option would also affect the location of a possible medieval bridge of low heritage significance (heritage value). Remains of the bridge within the water channel may be lost as a result of works within the channel or along the bank in this location.

Reach Three – Heritage Assets

5.3.42 There are no previously recorded heritage assets adjacent to the river within Reach Three (see Figure 4).

5.3.43 However the presence of the Roman town alongside, but not directly beneath, the subsequent medieval town provides an opportunity to understand the relationship between the two and the development of Britain from the end of the Roman period into the medieval. The river continued to be a key feature of the development of the medieval town throughout the period and into the post-medieval period. The area retains the potential for remains of low heritage significance (heritage value)and of archaeological significance for the information they could provide on the day to day life of the town.

5.3.44 The River Ver can be also be considered as a heritage assets of medium significance (heritage value). The course of the river has been altered several times since the Roman period and was a key watercourse for both the mill building and the inhabitants of the abbey. The river is considered to be of medium heritage significance (heritage value). The river holds historic significance due to its association with the history of St Albans and its continued use and alteration.

Reach Three - Potential effects

Option 2 – Part realignment of the existing channel with an off line pond creation.

5.3.45 The option proposes the cutting of a new channel and off line ponds within the wooded area on the northern bank of the reach. These works may have an effect on archaeological deposits associated with the development of the medieval town and the use of the river as a key water source. Any such archaeological deposits are likely to be of low heritage significance (heritage value).

5.3.46 Option 2 would retain the western section of the existing channel and undertake morphological improvements (including softening of the banks and improvements to the gravel bar) to the river banks and the within the channel itself and could also affect archaeological deposits associated with the medieval town and the use of the river as a key water source.

Option 4 – Maintain the existing channel and make improvements.

5.3.47 Option 4 would retain the existing channel and undertake morphological improvements (including softening of the banks and improvements to the gravel bar) to the river banks and the within the channel itself. These works may have an effect on archaeological deposit associated with the medieval town and the use of the river as a key water source. Any such archaeological deposits are likely to be of low heritage significance (heritage value).

Reach Four – Heritage Assets

5.3.48 There is one recorded heritage assets adjacent to the river within Reach Four (See Figure 4). A cotton mill (24) was formally located adjacent to the river on Cottonmill Lane. The water from the river helped to power the cotton production and the mill once bridged the river at this point (Banfield-Taylor, 2012, 106). The site of the former mill is of low heritage significance (heritage value). The site has archaeological and historic significance due to its association with the industrial history of St Albans and the development of the mill. There is potential for remains for remains of the mill building to survive within the banks of the river.

5.3.49 The presence of the Roman town alongside, but not directly beneath, the subsequent medieval town provides an opportunity to understand the relationship between the two and the development of Britain from the end of the Roman period into the medieval. Individual finds of Roman date have also been found by metal detectorists in this area. The river continued to be a key feature of the development of the medieval town throughout the period and into the post-medieval period. The area retains the potential for remains of low heritage significance (heritage value) and would be of archaeological significance for the information they could provide on the day to day life of the town.

5.3.50 The River Ver itself can be considered to be a heritage asset of medium significance (heritage value). The course of the river has been altered several times since the Roman period and was a key watercourse for both the mill building and the inhabitants of the abbey. The river holds historic significance due to its association with the history of St Albans and its continued use and alteration.

Reach Four - Potential effects

Option 1 – Realign the channel through the allotments.

5.3.51 The option proposes the cutting of a new channel through the allotments on the southern bank of the reach. These works may have an effect on archaeological deposits associated with the development of the medieval town and the use of the river as a key water source. Any such archaeological deposits are likely to be of low heritage significance (heritage value).

5.3.52 The connection point between the new channel and the original channel may affect the site of the former cotton mill and any associated features that remain within the river and its bank. These remains are likely to be of low heritage significance (heritage value).

Option 2 – Realign the channel through the allotments and connect to the realigned Reach Five, Option 1.

5.3.53 The option proposes the cutting of a new channel through the allotments on the southern bank of the reach. These works may have an effect on archaeological deposits associated with the development of the medieval town and the use of the river as a key water source. Any such archaeological deposits are likely to be of low heritage significance (heritage value).

Option 3 - Create a more sinuous channel close to the existing channel course.

5.3.54 The re-cutting and softening of the river channel close to the current course of the river would have an effect on archaeological deposits, both along the banks and within the river channel, associated with the development of the medieval town and the use of the river as a key water source. Any such archaeological deposits are likely to be of low heritage significance (heritage value).

5.3.55 Improvement to the channel may also affect the site of the former cotton mill and any associated features that remain within the river and banking. These remains are likely to be of low heritage significance (heritage value).

Reach Five – Heritage Assets

5.3.56 Two previously recorded heritage assets are located adjacent to the river with Reach Five (see Figure 4).

5.3.57 Within Reach Five is the scheduled monument of Sopwell Nunnery (3). The monument includes several upstanding elements of the medieval nunnery and its surrounding landscape. This asset is of high heritage significance (heritage value). It has archaeological and historic significance for the information that the site holds regarding the history and development of the nunnery and the ecclesiastical history of St Albans.

5.3.58 The potential line of the Roman road from Verulamium to Mill Hill in London (66) crosses close to Reach Five. No evidence of the road has been recorded in this area although research into the Roman roads in the area indicates that is may have passed through here. Any remains surviving would be of medium heritage significance (heritage value). The line of the road holds historic significance for the information it may provide on the spread of the Romans in Britain and the infrastructure linking the towns. Any surviving remains would also hold archaeological significance for the information of the construction methodology they would provide.

5.3.59 The presence of the Roman town alongside, but not directly beneath, the subsequent medieval town provides an opportunity to understand the relationship between the two and the development of Britain from the end of the Roman period into the medieval. In addition, archaeological remains associated with Sopwell Nunnery may extend beyond the boundary of the scheduled monument. The area retains the potential for remains of medium heritage significance (heritage value) and would be of archaeological significance for the information they could provide on the day to day life of the town and the development of the Nunnery.

5.3.60 The River Ver can itself be considered a heritage asset of medium significance (heritage value). The course of the river has been altered several times since the Roman period and Sopwell Nunnery was founded in this location due to its proximity to the river. The river holds historic significance due to its association with the history of St Albans and its continued use and alteration.

Reach Five – Potential effects

Option 1 - Full realignment of the existing channel (connecting to Reach 4 through a new structure under the road.

5.3.61 The option proposes the cutting of a new channel and creating a wet woodland through the green space and allotments on the southern bank of the reach. These works may have a direct effect on the scheduled Sopwell Nunnery (3) and archaeological deposits associated with it. The scheduled monument is of high heritage significance (heritage value) and any additional archaeological deposits are likely to be of medium heritage significance (heritage value).

Option 2 - Part realignment of the existing channel.

5.3.62 The option proposes the cutting of a large section of new channel and creating wet woodland through the green space and allotments on the southern bank of the reach. These works may have a direct effect on the scheduled Sopwell Nunnery (3) and archaeological deposits associated with it. The scheduled monument is of high heritage significance (heritage value) and the archaeological deposits are likely to be of medium heritage significance (heritage value).

Option 3 - Small realignment of the existing channel through the woodland.

5.3.63 The option proposes the cutting of a large section of new channel through the woodland on the western side of the reach. These works may have a direct effect on the scheduled Sopwell Nunnery (3) and archaeological deposits associated with it. The scheduled monument is of high heritage significance (heritage value) and the archaeological deposits are likely to be of medium heritage significance (heritage value).

5.3.64 Option 3 also includes proposals to undertake morphological improvements (re-connecting the river to the floodplain and reinstating gravel beds and riffling) to the river banks and within the channel itself. These works may have an effect on archaeological deposits associated with Sopwell Nunnery, the medieval town and the use of the river as a key water source. Any such archaeological deposits are likely to be of medium heritage significance (heritage value).

Option 4 - Retain the existing Channel and make improvements.

5.3.65 Option 4 proposes to retain the river in its current channel and undertake morphological improvements (bank lowering and reinstating gravel beds and riffling) to the river banks and the within the channel itself. These works would potentially affect the line of the Roman road running between Verulamium to Mill Hill in London (66). There is a potential for remains of the road to survive within the river bank, which would be of low heritage significance (heritage value).

5.3.66 These works may also have an effect on archaeological deposits associated with the Roman road, Sopwell Nunnery and medieval town and the use of the river as a key water source. Any such archaeological deposits are likely to be of low heritage significance (heritage value).

Reach Six – Heritage Assets

5.3.67 One previously recorded heritage asset is located adjacent to the river with Reach Six (see Figure 4).

5.3.68 The scheduled monument of Sopwell Nunnery (3) is located adjacent to Reach Six. The monument includes several upstanding elements of the medieval nunnery and its surrounding landscape. This asset is of high heritage significance (heritage value). It has archaeological and historic significance for the information that the site holds regarding the history and development of the nunnery and the ecclesiastical history of St Albans.

5.3.69 The presence of the Roman town alongside, but not directly beneath, the subsequent medieval time provides an opportunity to understand the relationship between the two and the development of Britain from the end of the Roman period into the medieval. The area retains the potential for remains of low heritage significance (heritage value) and of archaeological significance for the information they could provide on the day to day life of the town.

5.3.70 The River Ver can itself be considered a heritage asset of medium significance (heritage value). The course of the river has been altered several times since the Roman period and Sopwell Nunnery was founded in this location due to its proximity to the river. The river holds historic significance due to its association with the history of St Albans and its continued use and alteration.

Reach Six- Potential effects

Option 2 - Retain the existing channel and make improvements

5.3.71 The option proposes the cutting of a new section of new channel to link with the Reach Five Options 2, 3 and 5. These works may have a direct effect on the archaeological deposits associated with Sopwell Nunnery. The archaeological deposits are likely to be of medium heritage significance (heritage value).

5.3.72 The option also proposes to retain the river in its current channel and undertake morphological improvements (bank lowering and reinstating gravel beds and gravel bar introduction) to the river banks and the within the channel itself. These works may have an affect on archaeological deposits associated with the medieval town and the use of the river as a key water source. These archaeological deposits are likely to be of low heritage significance (heritage value)..

5.4 Summary of Assessment

5.4.1 Table 4 provides a summary of the potential effects on the heritage assets based on the criteria presented in section 3.4 .

Table 4 Summary of Assessment

Reach	Option	Description	Potential effect on heritage assets - RAG
1	5	Maintain most of the current river channels with some improvement works. Small realignment of the river at the downstream end of the reach, through lower end of the lake. Some upstream re-profiling.	-1
	8	Maintain the current river channels with some improvement works. Redesign of the fish pass and weir.	0
	9	Realignment of the river channel to the west of the lakes and create a new connection into Reach 2 to the west of the causeway. The lakes would be retained as a feature but may be retained as an off [river] line feature.	-2
	10	Realignment of the channel to between the lakes and the current river channel. Possible de-watering of the leat channel.	-1
	15	Close off the abstractions into the lake to that it becomes offline would dry. Flow in the River Ver would increase.	-1

Reach	Option	Description	Potential effect on heritage assets - RAG
2	2	Part realignment of the channel over the right bank with the floodplain reconnection and wet woodland creation. Possible reconnection location linked to Reach 1 option 9.	-1
	3	Realignment of the channel close to the existing course.	-2
	4	Retain existing channel course with morphological improvements and local bank/floodplain works.	0
3	2	Part realignment of the existing channel with an off line pond creation.	-1
	4	Maintain the existing channel and make improvements.	0
4	1	Realign the channel through the allotments.	-1
	2	Realign the channel through the allotments and connect to the realigned Reach 5 option.	-1
	3	Create a more sinuous channel close to the existing channel course.	-1
5	1	Full realignment of the existing channel (connecting to Reach 4 through a new structure under the road.	-2
	2	Part realignment of the existing channel.	-2
	3	Small realignment of the existing channel through the woodland.	-2
	4	Retain the existing Channel and make improvements.	-1
6	2	Retain the existing channel and make improvements.	0

6 Further Work

6.1 Further Work

6.1.1 For any option selected to be taken forward, a detailed impact assessment will be required. In addition an assessment of the potential effect of de-watering of archaeological deposits as a result of the proposed works will be undertaken. The full scope of this study must be agreed with Historic England and the archaeological advisor for St Albans Council. The assessment must be undertaken following guidance from CIfA (2014a).

6.1.2 The following section provides a brief outline of further archaeological evaluation and mitigation works that may be required following the completion of the impact assessment for the chosen option. The impact assessment will contain detailed recommendations for evaluation and mitigation works.

6.1.3 All the Reaches fall within the St Albans Conservation Area which is of medium heritage significance (heritage value). Depending on the nature and extent of the works Conservation Area consent may be required. Consultation with the Conservation Office for St Albans Council should be undertaken in advance of any option being progressed.

6.1.4 Any works on the boundary of, or within, the scheduled monuments of Verulamium Roman settlement (1), St Albans Abbey (2) and the ruins of Sopwell Nunnery (3) would require scheduled monument consent (SMC). This work would include the collection of samples, geotechnical investigations and other studies not related to the historic environment. SMC is granted by Historic England and would require an application to include an agreed methodology for the archaeological excavation and recording and the river improvement and engineering works. Works within scheduled monuments without consent are illegal.

6.1.5 Any new stretches of river channel, both within the scheduled monuments and in other locations along all the Reaches, would need to be excavated following the guidance for undertaking full archaeological excavation produced by CIfA (2014c). This will include the systematic excavation, recording and sampling of the entire footprint of the new channel and an agreed area on each side to allow the archaeological deposits to be understood in their wider context.

6.1.6 Any works to the banks or within the channel of the current river will require archaeological mitigation. This may include, but is not limited to, archaeological evaluation works in advance of the improvement works commencing or the monitoring of the works by a suitably qualified archaeologist following guidance for undertaking an archaeological watching brief produced by CIfA (2014d).

References

CIfA (2014a) *Standards and Guidance for Historic Environment Desk-Based Assessment* Chartered Institute for Archaeologists, Reading

CIfA (2014b) *Code of Conduct* Chartered Institute for Archaeologists, Reading

CIfA (2014c) *Standards and Guidance for archaeological excavation* Chartered Institute for Archaeologists, Reading

CIfA (2014d) *Standards and Guidance for an archaeological watching brief* Chartered Institute for Archaeologists, Reading

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Runcie, R. (1977) *Cathedral and City: St Albans Ancient and Modern.* London: Martyn Associates

<u>Maps</u>

Anon (*c.* 1677) A Map of St Albans

Anon (1874) Tithe Map of St Michael's Parish

OS 1879 1:2,500 Hampshire Sheet XXXIV.7, 8 and 12

OS 1898 1:2,500 Hampshire Sheet XXXIV.7, 8 and 12

OS 1912 1:2,500 Hampshire Sheet XXXIV.7, 8 and 12

OS 1924 1:2,500 Hampshire Sheet XXXIV.7, 8 and 12

OS 1934 1:2,500 Hampshire Sheet XXXIV.7, 8 and 12

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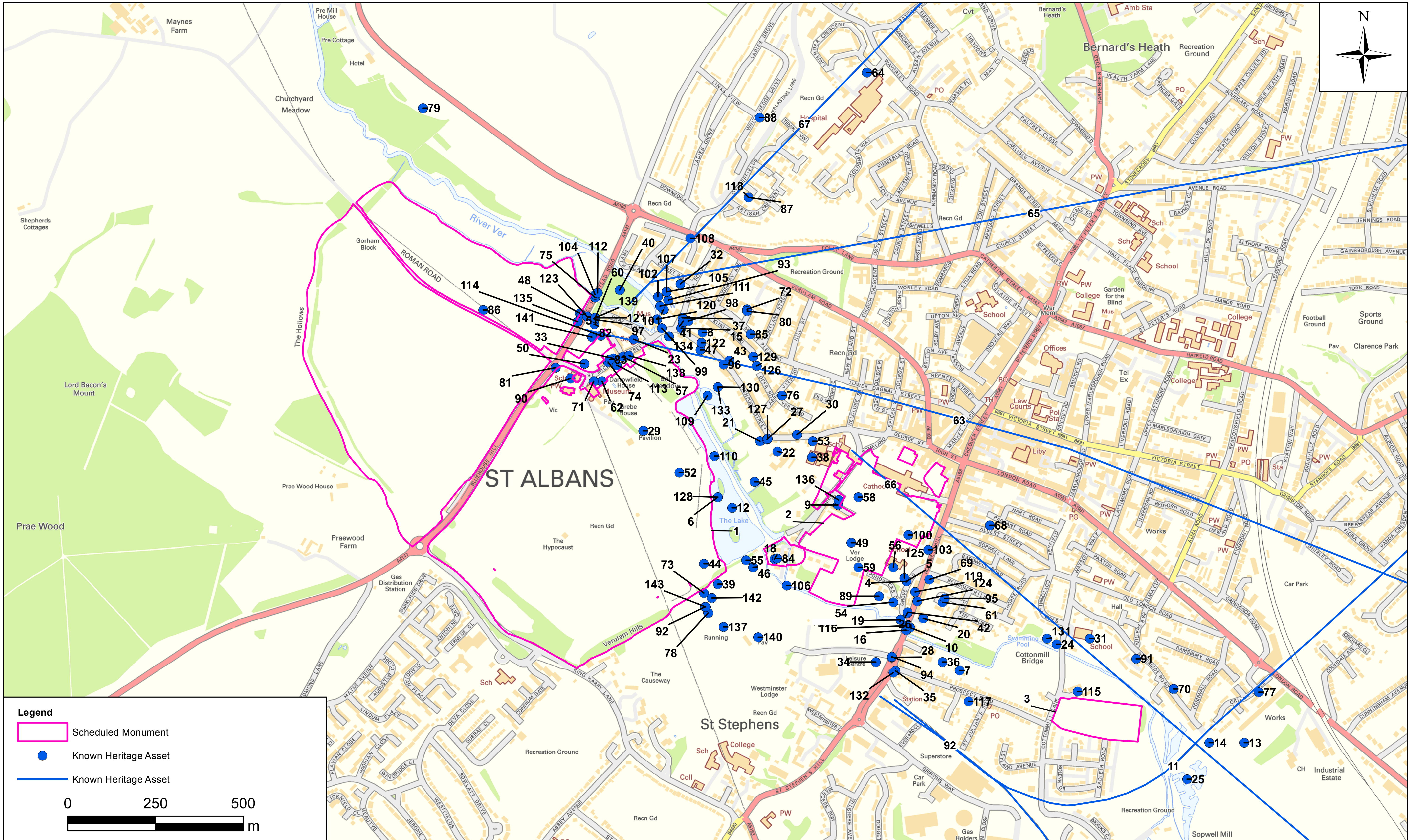
Figures



Client: Environment Agency

Title: KNOWN HERITAGE ASSETS

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Design:	DM	Drawn:	DM
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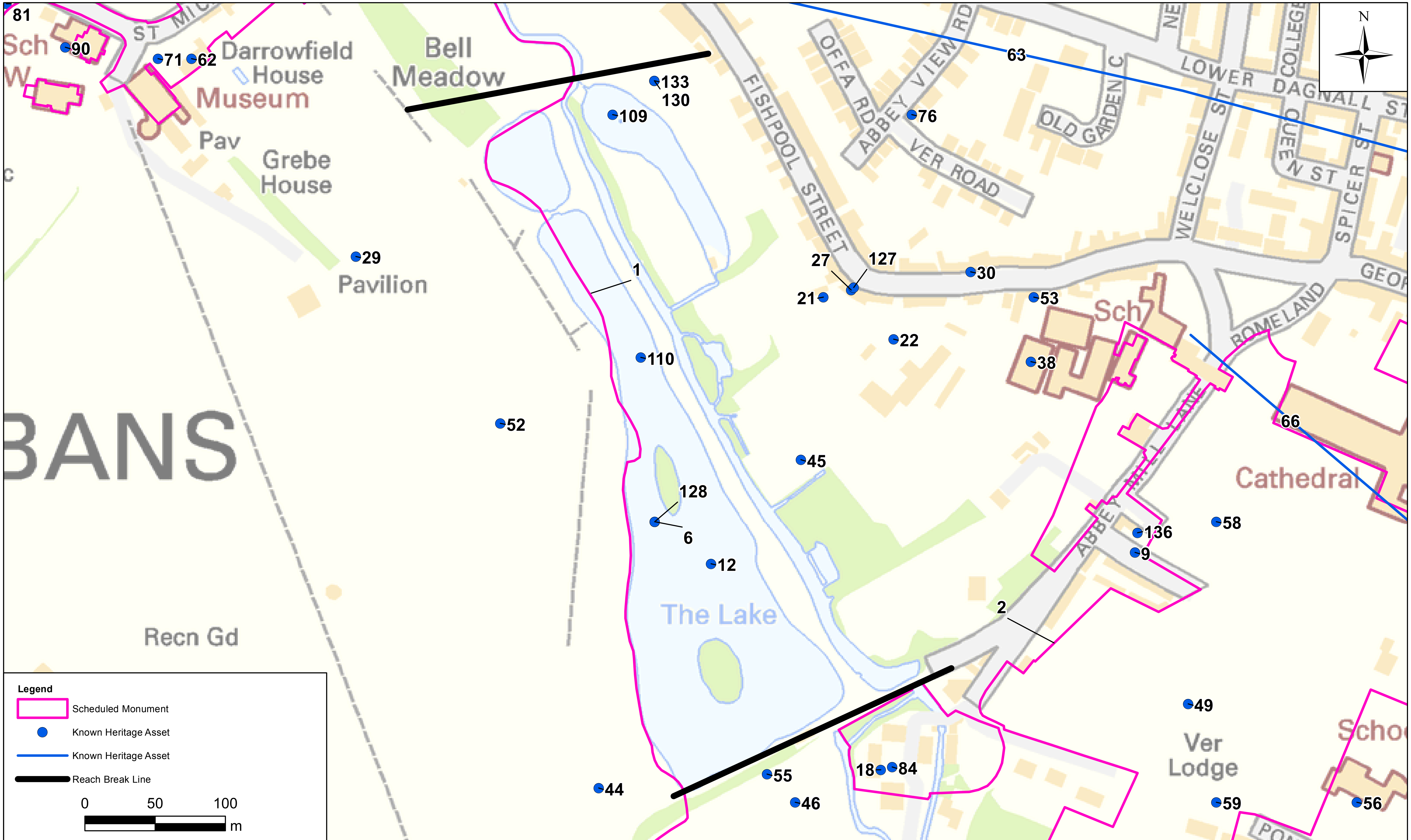
Date:	08/02/2017	Scale at A3:	1:10,000
Drawing Number:	FIGURE 1		A3



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Environment Agency	REACH 1 KNOWN HERITAGE ASSETS	AECOM 5th Floor, 2 City Walk, LEEDS, LS11 9AR Tel: +44 (0) 113 391 6800 Fax: +44 (0) 113 391 6899 www.aecom.com	Design: DM	Drawn: DM		
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			Date: 08/02/2017	Scale at A3: 1:2,500		
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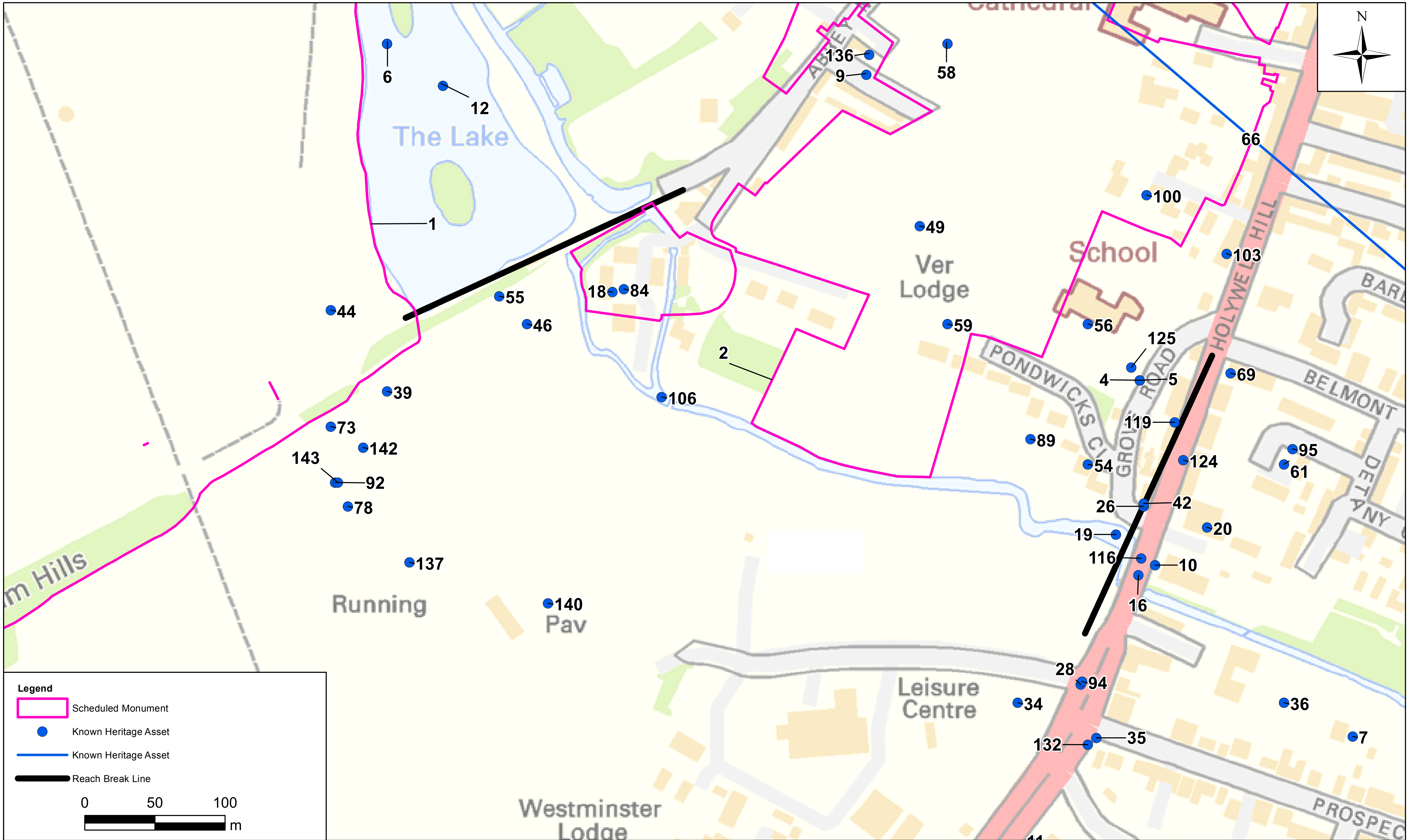

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Date:	08/02/2017	Scale at A3:	1:2,500
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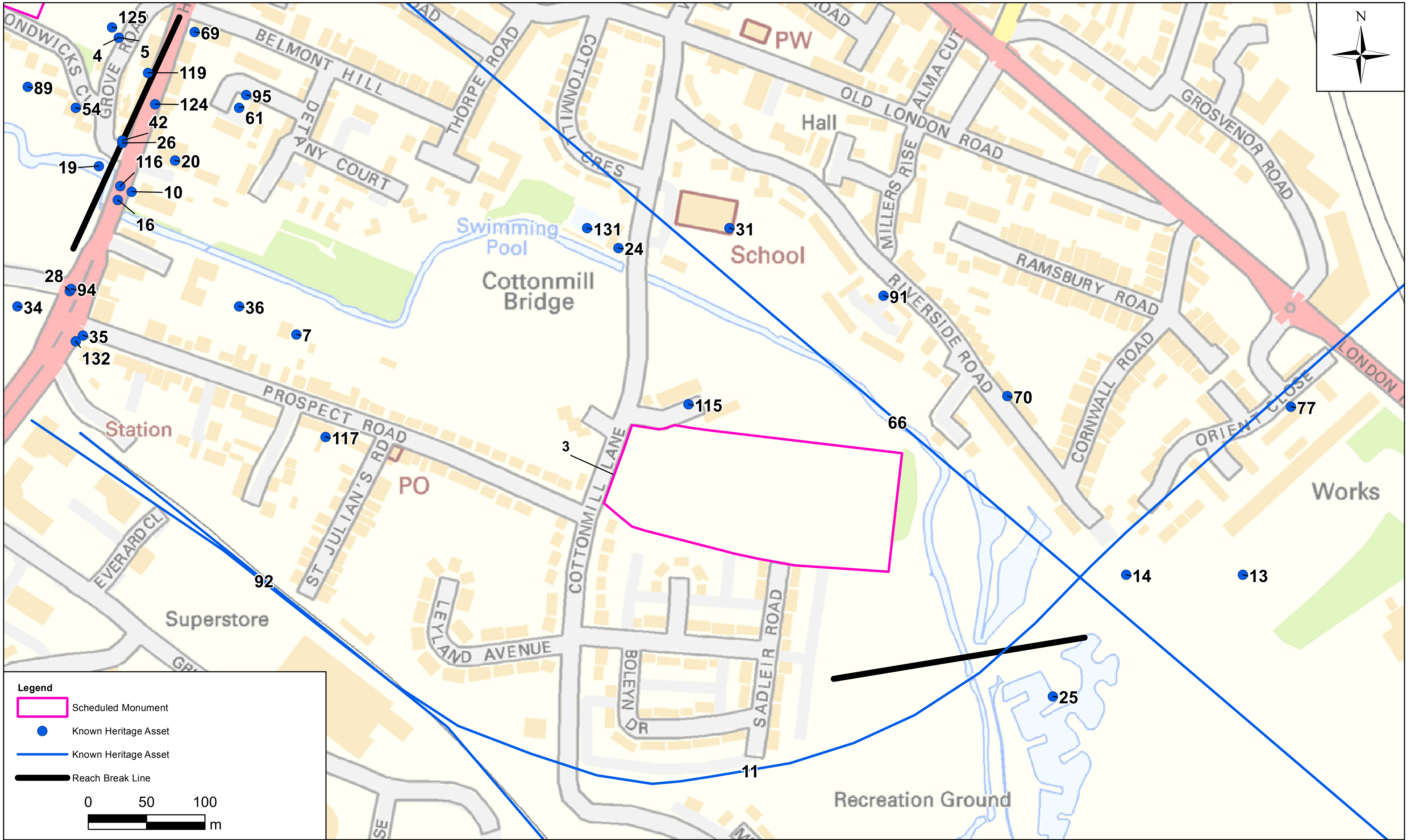

Client: ENVIRONMENT AGENCY

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Chk'd:	HM	App'd:	HM
Date:	08/02/2017	Scale at A3:	1:3,000
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Appendix A Known Heritage Assets

Reference	Easting	Northing	Period	Description	Number on Figures
MHT14431, MHT14293 MHT16476, MHT16477, MHT1424, MHT14490, MHT14311, MHT14491, MHT14217, MHT14258, MHT14352, MHT14492, MHT14496, MHT14341, MHT14220, MHT14351, MHT14279, MHT14406, MHT14425, MHT14407, MHT14348, MHT14514, MHT14411, MHT14366, MHT14357, MHT14426, MHT14375, MHT14265, MHT14346, MHT14356, MHT14698, MHT14269,	513624	207333	Roman	Verulamium, Roman settlement at St Albans. **Scheduled Monument**.	1

Reference	Easting	Northing	Period	Description	Number on Figures
MHT14697, MHT14392, MHT14336, MHT14494, MHT14196, MHT14218, MHT14495, MHT14358, MHT14427, MHT14488, MHT14194, MHT14195, MHT14259, MHT14690, MHT14409, MHT14366, MHT14315, MHT14489, MHT14219, HOB_UID 361861, 361866, 361974, 361856, Design UID DHT10816, DHT10839					
DHT10871, MHT14098, MHT14114, MHT14054, MHT14123, MHT14064, MHT14057, MHT14058, MHT14112, MHT14075,	514504	206906	Medieval	St Albans Abbey grounds and associated sites and monuments. **Scheduled Monument**.	2

Reference	Easting	Northing	Period	Description	Number on Figures
MHT14519, MHT14074, MHT14046, MHT2715, MHT14045, MHT14059					
Design UID DHT10799, Monument UID MHT14547, MHT14547, MHT14546, MHT14604, MHT14603, MHT14611, HOB_UID 361833	515080	206370	Medieval	Ruins of Sopwell Nunnery and associated buildings. **Scheduled Monument**.	3
MHT16609, MHT12828, MHT14649	514537	206760	Post-Medieval	Post-medieval gardens at Holywell House.	4
MHT16228, MHT16229	514537	206760	Medieval and Modern	Medieval ovens and a possible medieval ditch at Westminster Lodge. A Second World War transit camp for prisoners of war (largely Italian) also stood by the road at Westminster Lodge. One timber hut survives within the grounds of the leisure centre. Concrete foundations of other camp buildings also survive.	5
MHT590	514000	207000	Roman	Find spot of stone implements of Roman date.	6
MHT30419	514689	206506	Post-Medieval	25 Prospect Road, 19th century detached house with white render. Locally listed.	7
MHT15409	513956	207470	Medieval	Medieval well behind 167-8 Fishpool Street.	8
MHT17721	514342	206978	Medieval	Possible medieval oven or kiln, Orchard Street.	9
MHT12826	514548	206628	Medieval	Medieval building and site of a medieval leat.	10
MHT9628, HOB_UID 361840	519200	207088	Post-Medieval	A branch of the Great Northern Railway, opened in 1865, closed to passengers in October 1951 and closed completely in October 1964.	11
MHT4069	514040	206970	Early Medieval	Approximate site of a late Saxon fish pool.	12
MHT4087	515500	206300	Post-Medieval	Site of Sopwell Park. Sir Richard Lee's park, enclosed in 1562.	13

Reference	Easting	Northing	Period	Description	Number on Figures
MHT4180	515400	206300	Roman	Supposed line of a Roman road. There is no archaeological confirmation of this as a Roman road.	14
MHT18810, MHT18809	513895	207482	Medieval	Medieval well and pits at the Black Lion public house.	15
MHT5121	514536	206621	Post-Medieval	Holywell Bridge.	16
MHT5467, HOB_UID 497847, HOB_UID 1364190	514531	206391	Post-Medieval	Site of Abbey Station, terminus of the Watford and St Albans Branch Railway, opened in 1858.	17
HOB_UID 1552005, MON_UID MHT14066, MHT14118, MHT14049, MHT14048, MHT14119, MHT14041, MHT5830	514161	206823	Medieval and Post-Medieval	Site of St Albans Abbey Mills. **Scheduled Monument**	18
MHT12880	514520	206650	Medieval	Site of skirmish at 'Haliwell Water'. Skirmish in 1142 between King Stephen and the Abbey's men.	19
MHT7069	514585	206655	Post-Medieval	St Albans Waterworks. Waterworks consisting of a complex of red brick buildings with slate roofs. Originally identified from the 1897 OS map.	20
MHT7071	514120	207160	Post-Medieval	Former brewery, identified from the 1847 Tithe Map.	21
MHT7072	514170	207130	Post-Medieval	Former malt house, Fishpool Street.	22
MHT7073	513760	207450	Post-Medieval	Site of malt house, St Michaels Street.	23
MHT7272	514965	206580	Post-Medieval	Site of cotton mill, Cottonmill Lane.	24
MHT9895	515337	206196	Medieval	Medieval pottery found at Verulam Angling Club lake.	25
MHT9904	514540	206670	Post-Medieval	Site of Pondyards Gate toll house.	26

Reference	Easting	Northing	Period	Description	Number on Figures
MHT13468	514140	207165	Medieval	Timber framed house at 57-9 Fishpool Street, possible public house.	27
MHT13674	514495	206543	Roman	Roman masonry building, possibly a mill, at Holywell Hill/Prospect Road.	28
MHT15388	513787	207189	Medieval	Medieval pottery found at Verulamium Park.	29
MHT15924, MHT15925, HOB_UID 537881	514225	207178	Medieval to Post-Medieval	Timber framed Wealden House at 38-40 Fishpool Street.	30
MHT17371	515060	206597	Medieval	Medieval pottery found at St Peter's School, Cottonmill Lane.	31
MHT17625, MHT17626	513893	207608	Roman	Roman well, hearth and surface found at Kingsbury House, along with a post-medieval ditch and demolition material.	32
MHT18012, MHT18011, MHT18013, MHT14142, NHLE163404, HOB_UID 361975	513702	207395	15924	Six Bells public house, a 17th century timber framed house, currently the Six Bells public house. Two Roman buildings, alleged to be temples, Belgic coin moulds and pottery, late Saxon pottery and a post-medieval lime kiln were found here.	33
MHT18008	514450	206530	Roman	Roman ditches at Westminster Lodge.	34
MHT18301	514506	206505	Medieval	Medieval pit.	35
MHT18303	514640	206530	Medieval	Medieval pottery.	36
MHT18811	513899	207511	Post-Medieval	Nineteenth century pit.	37
MHT30112	514268	207114	Post-Medieval	Post-medieval pits or ditches found at St Albans School.	38
MHT30379	514000	206752	Post-Medieval	Site of Verulam Hills Farm, shown on 19th century maps at The Causeway, Verulamium Park.	39
MHT30633	513720	207590	Unknown	River Ver palaeochannels.	40
MHT5804, HOB_UID 1552007	513900	207500	Post-Medieval	Kingsbury Mill. Complex of late 17th century and 18th century buildings. A mill race flows up St Michaels Street.	41
MHT30801	514540	206672	Post-Medieval	The Duke of Marlborough public house.	42
MHT31105	514032	207389	Post-Medieval	Site of a post-medieval building, Fishpool Street.	43
HOB_UID 361900,	513960	206810	Early Medieval to Post-Medieval	Chapel dedicated to St Germanus in the reign of Edmund the Martyr (975-8). Supposedly ruinous in 1723.	44

Reference	Easting	Northing	Period	Description	Number on Figures
MHT14160					
HOB_UID 361950	514104	207044	Early Medieval	Find spot of an Anglo-Saxon coin (Offa 756-796).	45
HOB_UID 1396792	514100	206800	Medieval	Two mid-14th century to 15th century buildings, excavated west of Abbey Mill House. The first building was a brewhouse, or for drying grain, while the second was possibly a barn.	46
HOB_UID 361987	513950	207420	Post-Medieval	Seventeenth century house with later alterations including 18th century front.	47
HOB_UID 361961	513607	207524	Roman	The site of Claudian Fort. The defences consisted of an earth bank 20 feet wide, fronted with turf and revetted with timber.	48
HOB_UID 361998	514380	206870	Iron Age	Iron Age enclosures situated within the former precincts of St Albans Abbey.	49
HOB_UID 362004	513620	207380	Mesolithic	A Mesolithic tranchet axe was found at the corner of St Germain's House.	50
HOB_UID 361898	513610	207520	Iron Age	Site of a Belgic Mint.	51
HOB_UID 361901, MHT14161	513890	207070	Early Medieval to Post-Medieval	Chapel built to St Mary Magdalene in the reign of Ethelred II. The chapel is shown as extant on a map of 1634.	52
HOB_UID 361985	514270	207160	Post-Medieval	Godermersham House, late 16th or early 17th century.	53
HOB_UID 361949	514500	206700	Iron Age	Possible Iron Age clay pits, found with Belgic pottery and a coin mould.	54
HOB_UID 361907 MHT14178, MHT14178	514080	206820	Medieval	The Causeway. A medieval dam.	55
HOB_UID 1151360, MHT4081, MHT6809, MHT18111, MHT14025, MHT14043	514500	206800	Palaeolithic, Iron Age, Roman and Early Medieval	Clay pits at Abbey Orchard. A Palaeolithic handaxe was found, possibly in made ground, as was late Iron Age/Romano-British kiln fragments, the parchmarks of a large Roman building and a rectilinear enclosure, as well as a late Saxon coin hoard.	56
HOB_UID 362028	513730	207400	Medieval	The site of the medieval town's North-East gate.	57
HOB_UID 362000, 361953, DHT10871, MHT14098,	514400	207000	Roman	Romano-British cremation cemetery near the south west angle of St Alban's Abbey Church.	58

Reference	Easting	Northing	Period	Description	Number on Figures
MHT14114, MHT14054, MHT14123, MHT14064, MHT14057, MHT14058, MHT14112, MHT14075, MHT14519, MHT14074, MHT14046					
HOB_UID 361953, DHT10871, MHT14098, MHT14114, MHT14054, MHT14123, MHT14064, MHT14057, MHT14058, MHT14112, MHT14075, MHT14519, MHT14074, MHT14046	514400	206800	Early Medieval	Anglo-Saxon silver coin hoard.	59
HOB_UID 361982	513650	207510	Roman	Late Romano-British tile cist burial containing an infant burial, found in 1966 outside the town wall.	60
MHT14642, HOB_UID 361910	514640	206700	Post-Medieval	Alleged site of a medieval holy well, found to be an 18th century garden feature.	61
361995, NHLE1103086	513670	207330	Post-Medieval	Darrowfield House, the former Dower House of Gorhambury sometimes known as "New House", built c.1700.	62
HOB_UID	525484	204558	Roman	Possible Roman road suggested in 1728 from Verulamium (St Albans) to Cheshunt.	63

Reference	Easting	Northing	Period	Description	Number on Figures
1044880				Agger was identified in the 1960s but not confirmed in the 1970s. The excavated section was revealed at a depth 12 feet.	
HOB_UID 362029	514425	208210	Iron Age	Part of Beech Bottom Earthworks, a late Iron Age defensive dyke or boundary ditch on the outskirts of St. Albans.	64
HOB_UID 1044859	523853	212044	Roman	Suggested minor Roman road running from Ware to St Albans via Welwyn, suggested in the 1960s but not confirmed during investigation in 1970s.	65
HOB_UID 1325700	521692	193433	Roman	Roman road from Verulamium (St Albans) to Mill Hill - London.	66
HOB_UID 1044928	524036	217079	Roman	Route linking Roman settlements at St Albans and Braughing. Seventeen large pits one mile apart may have been quarries for building the road.	67
HOB_UID 361891, 361999, MHT14637,	514775	206920	Medieval to Post-Medieval	Tonman ditch, a medieval borough boundary ditch, pre-1142, documented during the 14th and 17th century.	68
MHT14593	514602	206765	Medieval	Belmont hill knackers' yard.	69
MHT14632	515298	206453	Medieval	Course of medieval highway from St Albans to Barnet & London.	70
MHT14221	513646	207330	Roman to Early Medieval	The floor of a late or post-Roman (5th century) building.	71
MHT14006, MHT14004, MHT14005	514083	207536	Roman	Roman well.	72
MHT14179	513960	206727	Iron Age to Roman	A length of ditch found in Verulam Hills Field, close to the boundary of the late Iron Age cemetery.	73
MHT14225	513687	207385	Medieval to Post-Medieval	Nos.38-40 Fishpool Street, built c.1500, has a crown-post roof of two bays.	74
MHT14515	513650	207569	Roman	Metalwork and coins thrown into River Ver.	75
MHT14002	514183	207290	Roman	Find spot of a pot with Roman coins.	76
MHT14640,	515541	206444	Post-Medieval	A 16th century boundary wall, containing fragments of medieval masonry salvaged from the abbey after the Dissolution.	77
MHT14309	513972	206670	Roman	A substantial Roman ditch and counterscarp bank in the valley bottom, near Verulam	78

Reference	Easting	Northing	Period	Description	Number on Figures
				Hills Farm.	
MHT14631	513159	208109	Medieval?	A minor road from Kingsbury Manor along the north-east bank of the River Ver to The Prae and Prae Mill. It was mapped in 1634 so it may be medieval.	79
MHT14001	514083	207530	Roman	Many Roman cinerary urns and other vessels, and at least one inhumation, have been found on the hilltop since the 1880s.	80
MHT14175	513538	207369	Roman	Central sewer, masonry with arched roof, from the Forum area downhill towards the river.	81
MHT14513	513648	207493	Roman	The Roman city wall from the North Gate to the North-East Gate, in the river valley.	82
MHT14227	513692	207392	Medieval or later	Sequence of floor layers outside the Six Bells Public House.	83
MHT14065	514169	206825	Medieval or later	A track leading into the Abbey Mill area from the bottom of the Abbey Orchard.	84
MHT14014	514093	207464	Unknown	A deep ditch on the line of the medieval borough boundary, seen but not recorded archaeologically.	85
MHT14353	513331	207534	Roman	Watling Street within the north end of Verulamium, from its junction with the Colchester Road to the Chester Gate.	86
MHT14359	514087	207855	Roman?	A curvilinear clay bank along part of the north-east side of the Roman city, in the valley bottom, was assumed by Frere to be part of a Claudian fort (as he was expecting to find one). Its actual extent and function are unknown, as despite several attempts no more of it was found, and his assumption that it was a Roman fort cannot be sustained.	87
MHT14629	514119	208082	Medieval	Probable medieval lane, the southern course of which was closed in 1826.	88
MHT14047	514459	206718	Medieval?	A peat deposit with structural timber, perhaps a fishpond, was found at the edge of the River Ver below the Abbey precinct.	89
MHT14159	513580	207338	Medieval and later	The churchyard to St Michael's Church. It was much larger in the medieval period than it is now.	90
MHT14605	515192	206539	Post-Medieval	A structure recorded before the building of new garages appeared to be a tile kiln.	91
MHT14144, 361984, HOB_UID 361885, MHT14151	513963	206687	Iron Age and Roman	An extensive Iron Age and Romano-British settlement and cemeteries, excavated in 1963-4. The first phase consisted of 21 cremation burials dating from the late 1st century BC to AD 43. A second phase dating from AD 43 to the late 1st century consisted of eight inhumation burials, possibly slaves. The third phase consisted of three pottery kilns associated with pits and gullies and six Roman cremations dating to the 2nd century AD. A fourth phase consisted of fifteen inhumation burials and a	92

Reference	Easting	Northing	Period	Description	Number on Figures
				large flint tomb with three coffin burials probably dating from the late 3rd to the early 4th century. In the 4th century an apsidal building, possibly a shrine was built over the earlier Belgic cremation cemetery. Late 4th century occupation was recorded.	
MHT14722	513859	207562	Medieval	A medieval monastic barn in the river valley in Branch Road.	93
MHT14501	514496	206545	Roman	A substantial Roman building at the foot of Holywell Hill, at the corner of 'Mud Lane'.	94
MHT14590	514646	206711	Medieval	Apparent domestic occupation, post-holes and hearths, perhaps a courtyard, near the River Ver south of the medieval town.	95
MHT14520	514016	207378	Medieval	Site of a skirmish in 1142 between King Stephen and the Abbey's men.	96
MHT14527	513648	207506	Roman	Foundation trench and possible oven behind bulge in city wall.	97
MHT14276	513916	207502	Roman	A Roman malting oven on the natural chalk bank, and a Roman well, in the yard behind the Black Lion.	98
MHT14538, 361912	513840	207482	Medieval	The 'Gonnerstone', reputed medieval boundary marker, St Michael's Street.	99
MHT14063	514542	206892	Medieval	Five clay pits dug into the hillside in the Abbey Orchard. None of them could be better dated than 'medieval'.	100
MHT14723	513845	207535	Roman	Part of a large pit with animal bone and pottery, and some cess, was seen in a builders' trench in 2002. It could be a large cess pit, or debris from leatherworking.	101
MHT14650	513829	207571	Medieval	Part of a flint wall, assumed to belong to the medieval monastic grange.	102
MHT14120	514599	206850	Medieval	Massive' masonry foundations beneath Ivy House on Holywell Hill. They were of stone and brick, and he suggested they might represent a gate in the abbey precinct wall.	103
MHT14312	513650	207577	Roman	A low clay and chalk bank at least 7.6m wide, acting as a revetment of the River Ver on the north-east side of the Roman city in the valley floor.	104
MHT14725	513854	207585	Roman	Part of a Roman masonry building at this position extends northwards and may also extend south under Kingsbury Barn.	105
MHT14042	514196	206748	Medieval	Possible site of a medieval bridge. It was noted that the foundations of a pier in the River Ver just past the junction of the Millstream and Floodgate Stream, which are assumed to be medieval, connected with the Abbey Mill and the Derngate.	106
MHT14725	513854	207585	Roman	Roman foundations found at the Kingsbury Dairy.	107
MHT14656	513922	207738	Roman	Early line of Colchester Road.	108

Reference	Easting	Northing	Period	Description	Number on Figures
MHT14303	513970	207290	Post-Medieval	A 16th century tannery on the site of St Michael's Manor lake, in the valley bottom. The tannery belonged to the Gape family, who are documented as tanners in Fishpool Street from at least 1456 and bought land from the Abbey in 1539.	109
MHT14153	513990	207117	Roman	Roman inhumation cemetery on the site of Park Lake. Over 15 burials were found when Verulamium Park Lake was dug out in 1930 in the valley bottom; traces of others were seen. The burials were fairly close together and no others were seen in the whole area of the lake, so it is thought the extent of the cemetery was found. However, earlier discoveries under the area of the larger lake are shown on the 1880 OS map, just west of the existing western island	110
MHT14724	513835	207545	Roman	An apparent tip of rubbish, containing a good deal of 1st-late 3rd century pottery and animal bone, and some ceramic building material, was possibly intended to form a bank along the north side of the river.	111
MHT14337	513657	207582	Roman	Possible late Roman track or cobbled area by the River Ver. Pottery and coins in the rubble make-up suggest a date of c.AD 364-70.	112
MHT14681	513712	207376	ROman	Possible Roman road surface at 31 St Michael's Street. A black earth deposit over a good cobbled surface, almost certainly of the street from the basilica to the north-east gate, was seen in a small evaluation trench but not excavated.	113
MHT14181	513667	207460	Iron Age	Site of a late Iron Age ditch.	114
MHT14594	515025	206446	Medieval	Sopwell Nunnery fishpond.	115
MHT14539	514538	206633	Medieval	Site of the medieval Holywell Bridge.	116
MHT14638	514714	206418	Medieval	Line of medieval town boundary	117
MHT14359	514087	207855	Roman	Line of Roman road - Street 20.	118
MHT14648	514562	206730	Medieval	Early line of Holywell Hill. Slightly curving line of the 10th century road, diverted in the 18th century.	119
MHT14358	513827	207507	Roman	Part of Colchester Road; Street 19.	120
MHT14525	513649	207511	Roman	Roman or earlier timber revetment. A timber structure composed of three rows of posts, revetting a Claudian bank. It formed an exit through the bank into a marshy area.	121
MHT14338	513953	207440	Roman	Ditch containing Roman pottery, associated with the earliest metalling. It may be the line of a Roman road.	122

Reference	Easting	Northing	Period	Description	Number on Figures
MHT14304	513627	207515	Roman	Frere's Claudian bank, or Marsh Bank. A curvilinear clay bank along part of the north-east side of the Roman city, in the valley bottom. Its actual extent and function are unknown.	123
MHT14602	514568	206703	Post-Medieval	Site of Holywell House. Built by Ralph Rowlett on former abbey lands at the foot of Holywell Hill, by the river. Part of the 16th century house apparently survived as the garden front.	124
MHT14674	514531	206769	Medieval	Medieval features containing Roman, Saxon and medieval pottery, including a late medieval quarry pit used for the extraction of flint and/or chalk.	126
537880	514111	207374	Post-Medieval	Kitchners Meads. A late 18th century range of 2-storey buildings.	127
1346400	514141.7212	207166.7134	Medieval	St Giles Hospital for the poor, documented at St Albans in 1327.	128
361997	514000	206999	Early Medieval	Kingsbury Castle. Remains of a possible Anglo-Saxon burh. Excavation uncovered post-Roman features, and Roman and medieval finds.	129
361951	514100	207400	Early Medieval	Find spot of a possible imitation Anglo-Saxon coin.	130
1440196	513999.77	207314.2029	Post-Medieval	St Albans Swimming Baths. The original swimming baths date to the late 19th century and were part of the River Ver. In 1905 a new outdoor swimming pool was opened, just north of the river. This pool was designed by George Ford. The pool closed to for public swimming in the 1970s.	131
361923	514938.1772	206596.9004	Roman	Find spot of a Carthaginian bronze coin.	132
361922	514500	206500.0002	Iron Age	Find spot of an Iron Age Celtic pin.	133
1586667	513999.77	207314.2029	Post-Medieval	St Michael's Court was built by 1879 and it is thought the buildings have timber framed origins. The dwellings may have been constructed as workers cottages. The cottages are two storeys with attics and dormer windows in the roof.	134
1534860	513860.5603	207457.9455	Roman to Early Medieval	Wreck of oared vessel discovered in the River Ver in the time of Abbot Ealdred in the early 11th century, identified as Roman from its context. It was discovered while digging for building materials in the remains of the Roman town.	135
MHT14121	513600	207500	Roman	A fragment of masonry wall seen in 1895 by builders behind a house called Monastery Close.	136
MHT14316	514344	206992	Roman	An oval clay-walled furnace with ironworking debris. Its exact date is uncertain but it may be Roman.	137
MHT14519	514016	206630	Roman	Traces of a wall just outside the north-east gate of the Roman town, in St Michael's	138

Reference	Easting	Northing	Period	Description	Number on Figures
				Street, are thought to be 'probably Roman'.	
MHT14524	513746	207403	Roman	Possible timber causeway. Oak and alder branches laid down as a 'raft' inside the bulge in the city wall.	139
MHT14327	513650	207511	Roman	Verulam Hills Field Kiln IV. Traces of a pottery kiln, close to a pit of wasters, at the side of Verulam Hills Field. One of a group.	140
MHT14429	514115	206601	Roman	Parts of a building with cellar and semi-basement towards north end of Insula XIX, in the river valley, in an area still largely unexplored. The building is known only from minimal excavation.	141
MHT14534	513641	207456	Roman	Early Roman building, Verulam Hills Field.	142
MHT14500	513983	206712	Roman	Verulam Hills field apsed building. A rectangular masonry structure with an apsed NW end, tessellated floor and tiled roof, outside the London Gate. It was excavated in 1963-4 in advance of the construction of the running rack at Westminster Lodge.	143

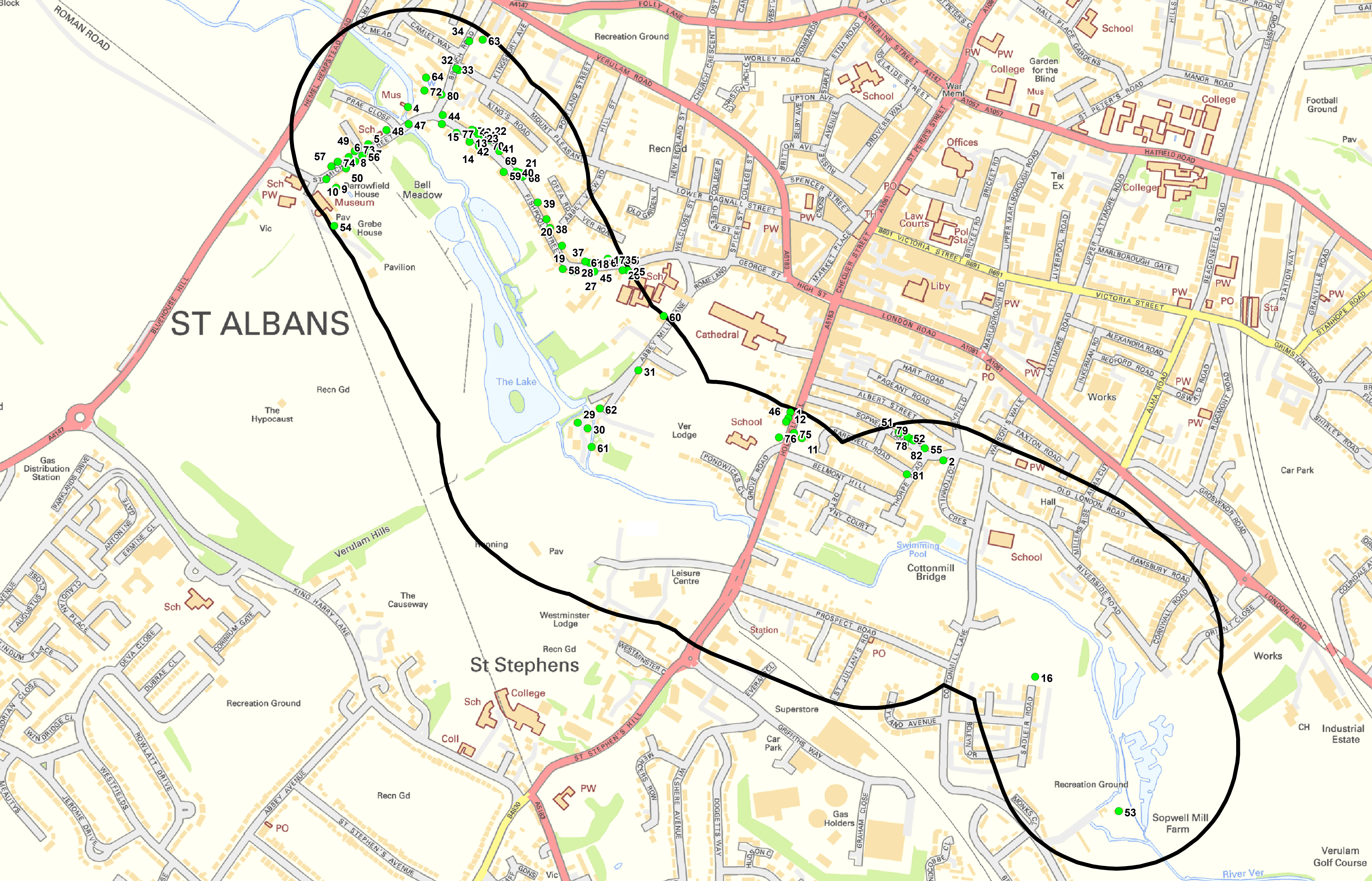
Appendix B Listed Buildings

Reference	Easting	Northing	Description	Grade	Number on Figures
1103010	514608	206871.3608	PICKWICK HOUSE	II	B 1
1103059	514922	206772.3608	HARE AND HOUNDS PUBLIC HOUSE	II	B 2
1103061	514856	206816.3608	81 AND 81A, SOPWELL LANE	II	B 3
1103081	513823	207497.3608	KINGSBURY MILL	II	B 4
1103082	513742	207421.3608	ROSE AND CROWN PUBLIC HOUSE	II	B 5
1103083	513702	207395.3608	THE SIX BELLS	II	B 6
1103084	513747	207404.3608	17, ST MICHAEL'S STREET	II	B 7
1103085	513715	207386.3608	29, ST MICHAELS STREET	II	B 8
1103086	513676	207331.3608	DARROWFIELD HOUSE	II*	B 9
1103087	513656	207349.3608	GATES, GATEPIERS AND RAILINGS TO DARROWFIELD HOUSE	II	B 10
1103097	514632	206818.3608	TORRINGTON HOUSE	II	B 11
1103102	514604	206859.3608	68, HOLYWELL HILL	II	B 12
1103113	513950	207426.3608	MANOR GARDEN HOUSE	II*	B 13
1103114	513969	207417.3608	GARDEN WALLS AND STABLE WITH WALLS TO NUMBER 135	II	B 14
1103115	513893	207462.3608	THE BLUE ANCHOR	II	B 15
1103135	515111	206328.3608	SOPWELL NUNNERY RUINS	II	B 16
1103142	514234	207186.3608	THE LOWER RED LION	II	B 17
1103143	514200	207178.3608	50, FISHPOOL STREET	II	B 18
1103144	514139	207213.3608	78 AND 80, FISHPOOL STREET	II	B 19
1103145	514108	207267.3608	98 AND 100, FISHPOOL STREET	II	B 20
1103146	514053	207362.3608	PYKE HOUSE	II	B 21
1103147	513990	207429.3608	152-158, FISHPOOL STREET	II	B 22
1103148	513974	207435.3608	166 AND 168, FISHPOOL STREET	II	B 23
1103149	513967	207442.3608	170, FISHPOOL STREET	II	B 24
1103153	514274	207162.3608	13, FISHPOOL STREET	II*	B 25

Reference	Easting	Northing	Description	Grade	Number on Figures
1103154	514264	207162.3608	THE OLD CROW	II	B 26
1103155	514195	207156.3608	41A, FISHPOOL STREET	II	B 27
1103156	514168	207160.3608	51-55, FISHPOOL STREET	II	B 28
1103164	514172	206849.3608	THE ABBEY MILLS (WESTERN BLOCK)	II	B 29
1103165	514192	206838.3608	THE ABBEY MILLS (EASTERN SIDE)	II	B 30
1103166	514296	206957.3608	25, ABBEY MILL LANE	II	B 31
1103167	513927	207573.3608	3, BRANCH ROAD	II	B 32
1103168	513922	207576.3608	WALL TO NUMBER 3	II	B 33
1103169	513949	207632.3608	WALL ALONG ROAD SIDE WITH ENTRANCE GATE TO KINGSBURY LODGE	II	B 34
1172805	514257	207186.3608	30 AND 32, FISHPOOL STREET	II	B 35
1172812	514220	207180.3608	38-42, FISHPOOL STREET	II	B 36
1172835	514196	207178.3608	52, FISHPOOL STREET	II	B 37
1172853	514115	207249.3608	92, FISHPOOL STREET	II	B 38
1172868	514090	207301.3608	114-118, FISHPOOL STREET	II	B 39
1172888	514046	207365.3608	128-132, FISHPOOL STREET	II	B 40
1172908	514006	207414.3608	150, FISHPOOL STREET	II	B 41
1172909	513980	207432.3608	162 AND 164, FISHPOOL STREET	II	B 42
1172910	513959	207448.3608	172, FISHPOOL STREET	II	B 43
1172914	513895	207481.3608	THE BLACK LION PUBLIC HOUSE	II	B 44
1172982	514206	207160.3608	37-41, FISHPOOL STREET	II	B 45
1173513	514599	206852.3608	IVY HOUSE	II	B 46
1173828	513825	207462.3608	ST MICHAEL'S BRIDGE	II	B 47
1173832	513779	207450.3608	8, ST MICHAELS STREET	II	B 48
1173842	513714	207407.3608	14, ST MICHAEL'S STREET	II	B 49
1173895	513696	207371.3608	OAKEN HOUSE	II	B 50
1174493	514830	206830.3608	63-69, SOPWELL LANE	II	B 51
1174501	514849	206820.3608	79, SOPWELL LANE	II	B 52

Reference	Easting	Northing	Description	Grade	Number on Figures
1245424	515282	206053.3608	SOPWELL MILL	II	B 53
1251277	513672	207253.3608	BARN APPROXIMATELY 33 METRES SOUTH SOUTH EAST OF VERULAMIUM MUSEUM (NOT INCLUDED)	II	B 54
1295719	514884	206797.3608	THE WHITE LION PUBLIC HOUSE	II	B 55
1296012	513730	207397.3608	19 AND 21, ST MICHAELS STREET	II	B 56
1296045	513666.298	207375.9278	ST GERMAINS	II	B 57
1296453	514141	207165.3608	KITCHENER'S MEADS	II	B 58
1347093	514020	207364.3608	ST MICHAEL'S MANOR HOUSE	II*	B 59
1347098	514348	207069.3608	ABBEY GATE HOUSE	II*	B 60
1347099	514200	206800.3608	ABBEY MILL HOUSE	II	B 61
1347100	514217	206879.3608	THE FIGHTING COCKS PUBLIC HOUSE	II	B 62
1347101	513977	207635.3608	KINGSBURY LODGE	II	B 63
1347102	513860.378	207557.3848	KINGSBURY BARN	II*	B 64
1347126	514262	207185.3608	28, FISHPOOL STREET	II	B 65
1347127	514216	207180.3608	44 AND 46, FISHPOOL STREET	II	B 66
1347128	514187	207180.3608	54, FISHPOOL STREET	II	B 67
1347129	514059	207354.3608	BANK HOUSE	II	B 68
1347130	514011	207407.3608	142-148, FISHPOOL STREET	II	B 69
1347131	513985	207432.3608	160, FISHPOOL STREET	II	B 70
1347132	513955	207451.3608	174, FISHPOOL STREET	II	B 71
1347138	513857	207531.3608	KINGSBURY MANOR FARMHOUSE	II	B 72
1347139	513720	207412.3608	OLD FORGE	II	B 73
1347140	513679	207385.3608	OUTBUILDING TO NUMBER 18 (ST GERMAINS)	II	B 74
1347144	514616	206828.3608	GATEPOSTS AND WALL TO NUMBER 47	II	B 75
1347148	514585	206819.3608	PHOENIX COTTAGE	II	B 76
1347151	513923	207444.3608	137, FISHPOOL STREET	II	B 77
1347168	514832	206828.3608	71, SOPWELL LANE	II	B 78

Reference	Easting	Northing	Description	Grade	Number on Figures
1347169	514861	206813.3608	83-89, SOPWELL LANE	II	B 79
1388372	513892	207522.3608	BARN AND ATTACHED WALL AT ENTRANCE TO EXPRESS DAIRIES YARD	II	B 80
1425765	514847.1	206744.05	War Memorial Plaque attached to 1 Bardwell Road and 22 Thorpe Road	II	B 81
1425767	514843.22	206806.98	War Memorial Plaque attached to 80 and 82 Sopwell Lane	II	B 82



ST ALBANS
St Stephens
Cathedral
The Lake
Bell Meadow
Verulam Hills
The Hypocaust
Verulam Golf Course
Sopwell Mill Farm
Cottonmill Bridge
Industrial Estate
Leisure Centre
Westminster Lodge
The Causeway
Ver Lodge
Gas Distribution Station
Gas Holders
Superstore
Recreation Ground
Recn Gd
Museum
Verulamium House
Grebe House
Pavilion
Swimming Pool
Garden for the Blind
Football Ground
Law Courts
Offices
School
College
Station
Works
Car Park
ROMAN ROAD
HEMEL HEMPSTEAD ROAD
BLUEHOUSE HILL
KING HARRY LANE
ST STEPHEN'S HILL
HOLYWELL HILL
LONDON ROAD
VERULAM ROAD
CATHERINE STREET
ST PETER'S STREET
VICTORIA STREET
HATFIELD ROAD
FOLLY LANE
FISHPOOL STREET
ABBEY MILL LANE
GEORGE ST
HIGH ST
CHEQUER STREET
PROSPECT ROAD
COTTONMILL LANE
OLD LONDON ROAD
GROSVENOR ROAD
RIVERSIDE ROAD
RAMSBURY ROAD
GRIFFITHS WAY
ST STEPHEN'S AVENUE
ABBEY AVENUE
River Ver

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APPENDIX K – Determination of the Reach 1 Preferred Option

K.1 Overview

A summary of the derivation of the preferred option for Reach 1 (see Figure K.1) is presented within this Appendix. The included the following steps:

- Reach 1 Long List Appraisal.
- Reach 1 Short List Appraisal.

These results of the appraisals are outlined below.

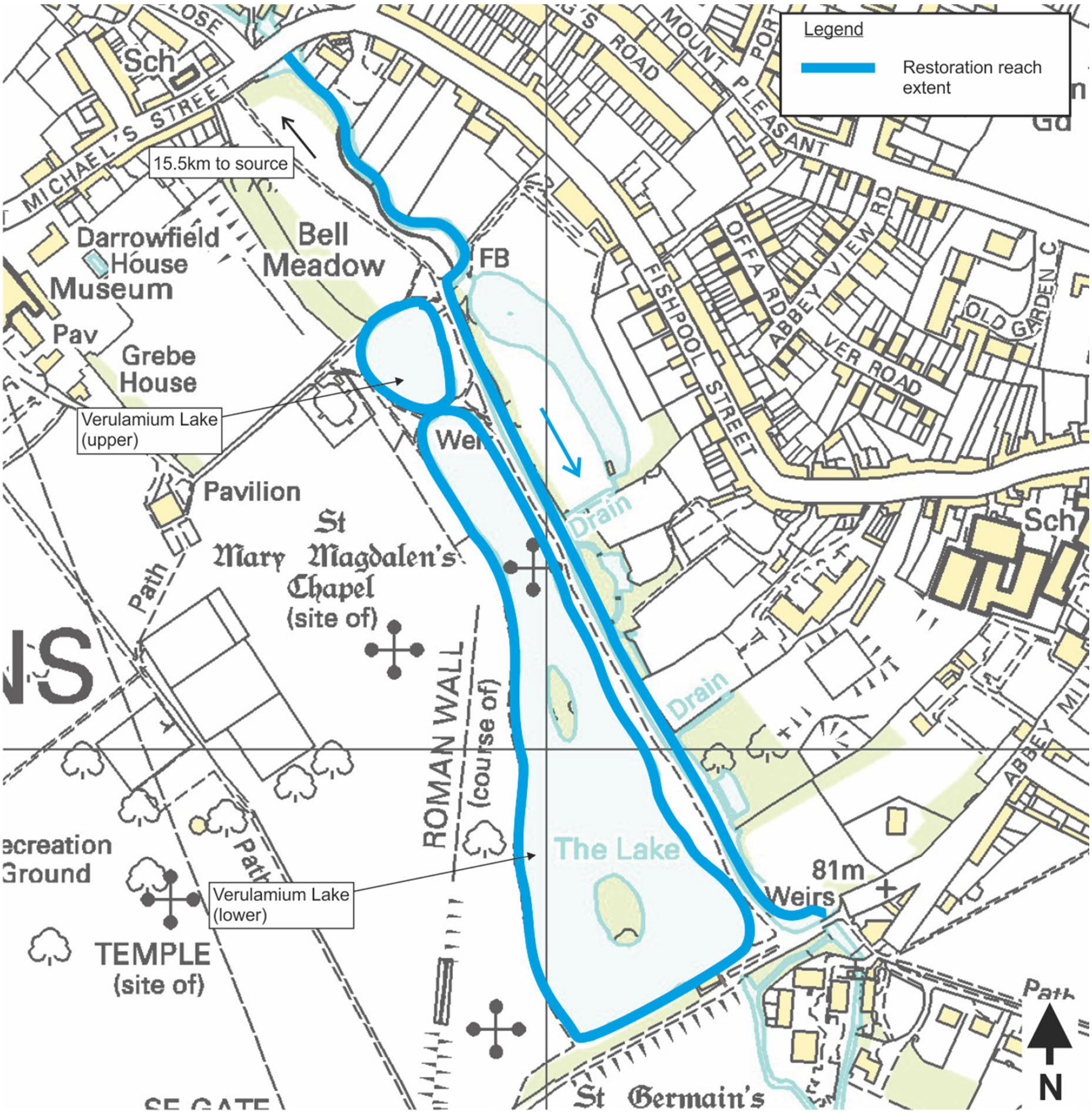


Figure K.1 Reach 1 of the study area (Upper section of Verulamium Park including the lakes)

K.2 Reach 1 Long List Appraisal (Lake & River and River Only Options)

Options Identification

The long list of lake & river and river only options for Reach 1 are outlined in Table K.1. The options have been split into those which include measures for both the river and lake in an integrated manner and those which present measures for just the river. Measures for just the lake are described in Section K.3.

Table K.1 Long List Options Reach 1

Option	Description
River and Lake Integrated	
1	Re-align Ver through lakes and infill lakes
2	Part realign Ver through lakes, infill small lake and top half of large lake
3	Part re-align Ver through lakes, retain small lake and top half of large lake, leave isolated lake sections either side for lower half of lakes, part offline/ online possible
4	Part re-align Ver through lakes, retain small lake and top half of large lake, create features in remaining (lower half of large lake) either side, part offline/ online possible
5	Small re-alignment of Ver at downstream end of the reach, through lower end of large lake. Upstream reprofiling
6	Small re-alignment of Ver at downstream end of the reach, through lower end of large lake. No upstream reprofiling
7	Re-align channel to west of lakes and connect to Reach 2 to the west of the Causeway
8	Re-align channel to between lakes and current channel
9	Re-align channel through lakes but maintain lakes as online features
10	Re-align Ver through lakes, infill lakes and re-align river through Bell Meadow
11	Re-align Ver through lakes and remove dam
12	Re-align Ver through lakes and remove concrete base throughout lakes
River Only	
13	Maintain current channels, re-design fish pass and lower weir
River and Lake Separated (can be an add on to other options)	
14	Close off abstractions into lake so that it becomes offline. Flow in mainstream of the Ver would increase

A schematic of these options is provided in Figures K.2 –K.15 below.

Long List Appraisal

A summary of the long list appraisal and scoring is provided in Table K.2 below. Individual options are appraised in subsequent sub-sections. The long list appraisal methodology was presented in Section 2.3 and Appendix B.

Table K.2 Appraisal of Reach 1 Long List Options

Option	Fulfil Project WFD Objectives for WB?	No constraints that would make option unfeasible?	Acceptable from an H&S perspective?	Not result in significant detrimental or loss of characteristic features?	Hydromorphology & Naturalisation	Habitat	Water Quality*	Flood Risk	Landscape/ Visual	Recreation & Amenity	Heritage	Contaminated Land & Sediment	Fish Passage	Sustainability/ Ongoing Maintenance	Total Score
	Y/N	Y/N	Y/N	Y/N	-2 to 2	-2 to 2	-2 to 2	-2 to 2	-2 to 2	-2 to 2	-2 to 2	-2 to 2	-2 to 2	-2 to 2	
Do nothing/ Baseline															
0	N	Y	Y	Y	0	0	0	0	0	0	0	0	0	0	0
River and Lake Integrated															
1	Y	Y	Y	N	-	-	-	-	-	-	-	-	-	-	-
2	Y	Y	Y	N	-	-	-	-	-	-	-	-	-	-	-
3	N	Y	N	Y	-	-	-	-	-	-	-	-	-	-	-
4	N	Y	N	Y	-	-	-	-	-	-	-	-	-	-	-
5	Y	Y	Y	Y	2	2	1	0	1	1	0	-1	1	2	9
6	Y	Y	Y	Y	1	0	0	0	0	0	0	-1	1	2	3
7	Y	Y	Y	Y	2	2	2	2	-2	-1	-2	-1	2	2	6
8	Y	Y	Y	Y	2	2	1	0	1	-1	0	-1	2	2	8
9	N	Y	Y	Y	-	-	-	-	-	-	-	-	-	-	-
10	Y	Y	Y	N	-	-	-	-	-	-	-	-	-	-	-
11	N	Y	Y	N	-	-	-	-	-	-	-	-	-	-	-
12	N	Y	Y	N	-	-	-	-	-	-	-	-	-	-	-
River Only															
13	Y	Y	Y	Y	1	1	0	0	1	0	0	0	1	1	5
River and Lake Separated (can be an add on to other options)															
14	Y	Y	Y	Y	1	0	1	-1	-2	-2	0	2*	1*	0	0

*see following sub-sections for justification of these scores

Reach 1 Option 1

This option is illustrated in Figure K.2 below. Option 1 did not fulfil the criteria of the initial long list appraisal process (Table K.2) as the substantial infilling of the lake would result in a significant loss of this characteristic feature. Therefore this option was screened out and not scored within the long listing appraisal process.

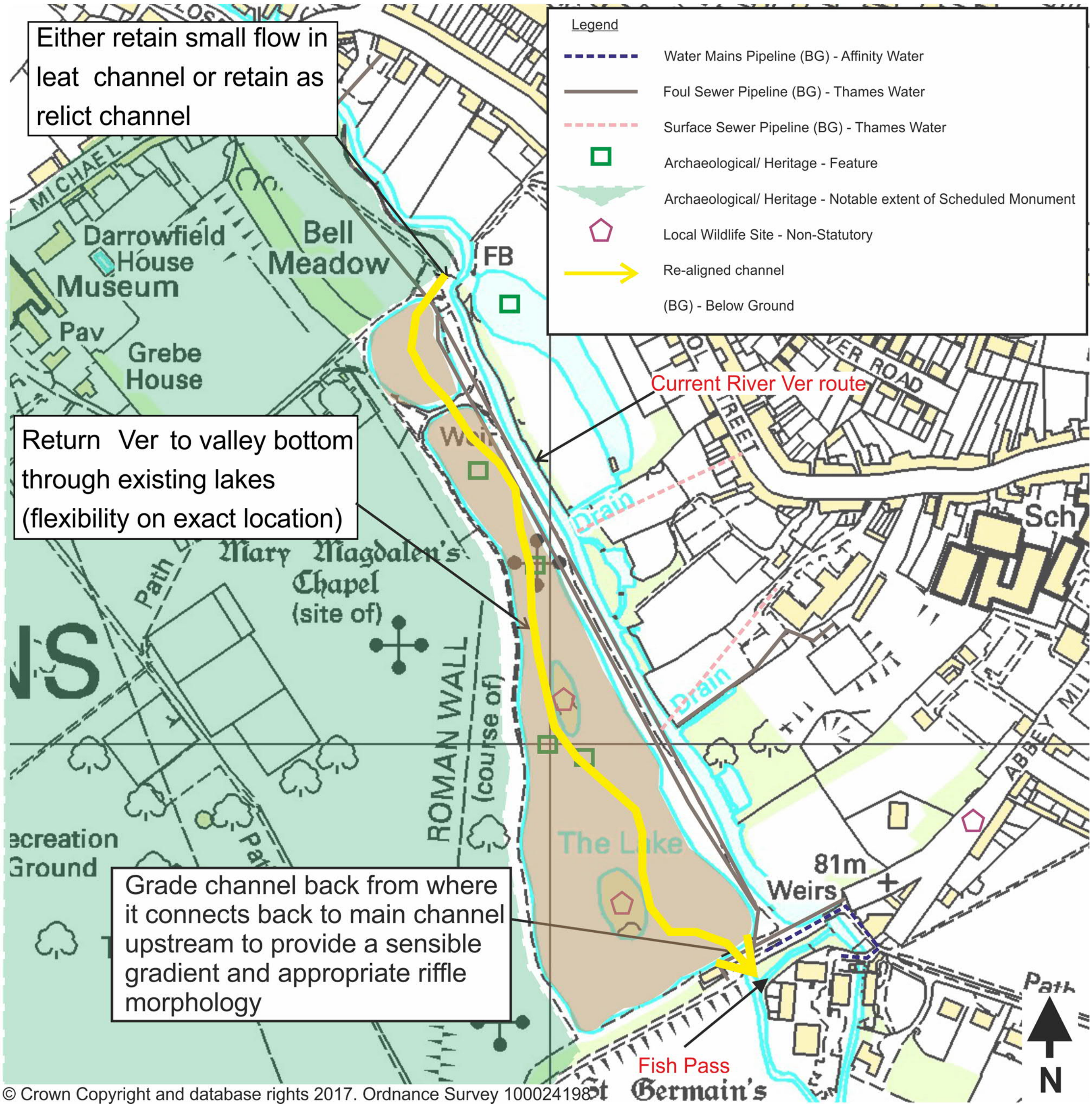


Figure K.2 Option 1 – Re-align Ver through lakes and infill lakes

Reach 1 Option 2

This option is illustrated in Figure K.3 below. Option 2 did not fulfil the criteria of the initial long list appraisal process (Table K.2) as the substantial infilling of the lake would result in a significant loss of this characteristic feature. Therefore this option was screened out and not scored within the long listing appraisal process.

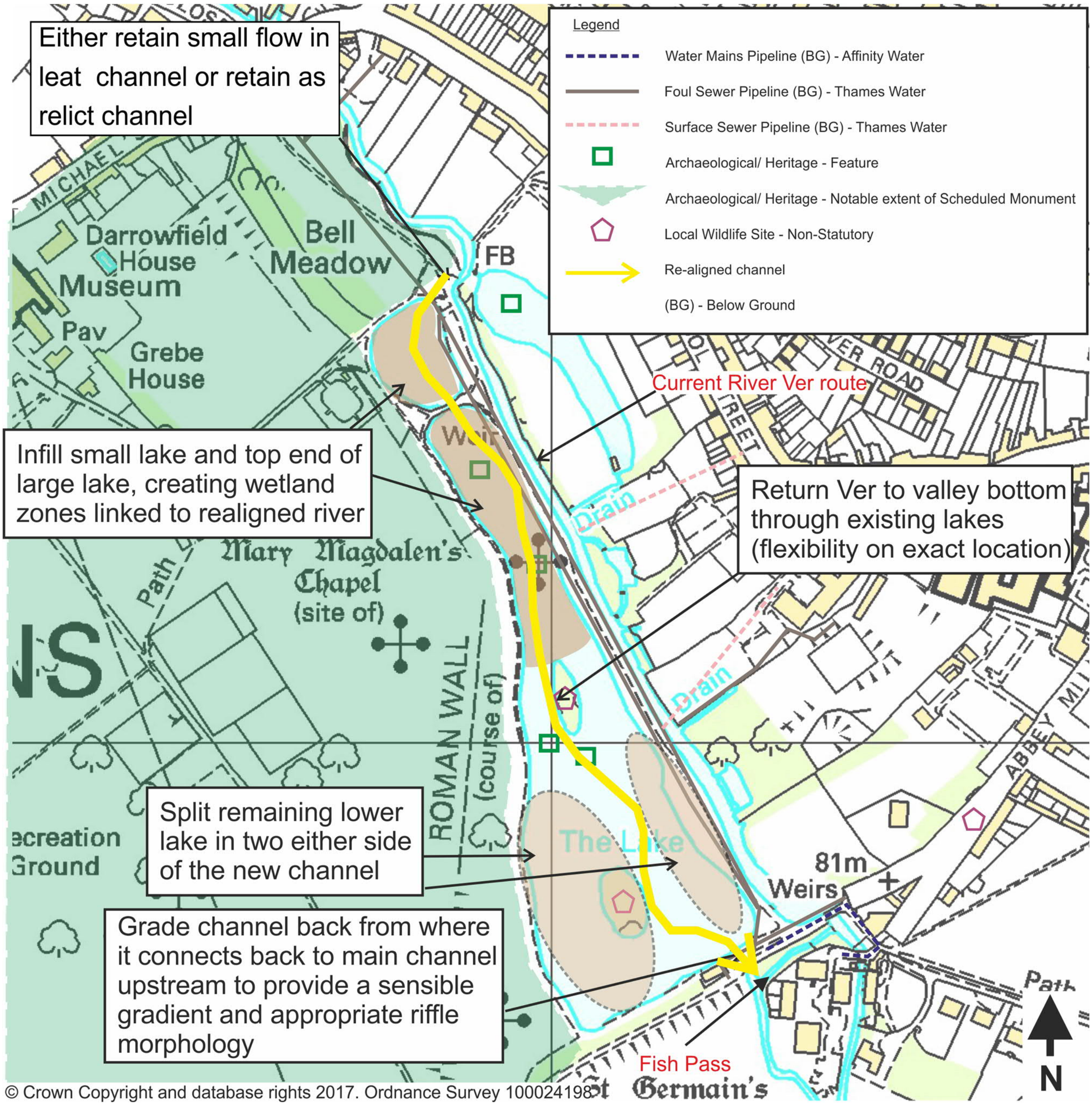


Figure K.3 Option 2 – Part re-align Ver through lakes, infill small lake and top half of large lake

Reach 1 Option 3

This option is illustrated in Figure K.4 below. Option 3 did not fulfil the criteria of the initial long list appraisal process (Table K.2) in that it would likely not be acceptable from a health and safety perspective and that it would likely not fulfil the WFD project objectives (channel would likely need to be very deep and so would be prone to excessive sedimentation that would not result in a diverse habitat). Therefore this option was screened out and not scored within the long listing appraisal process.

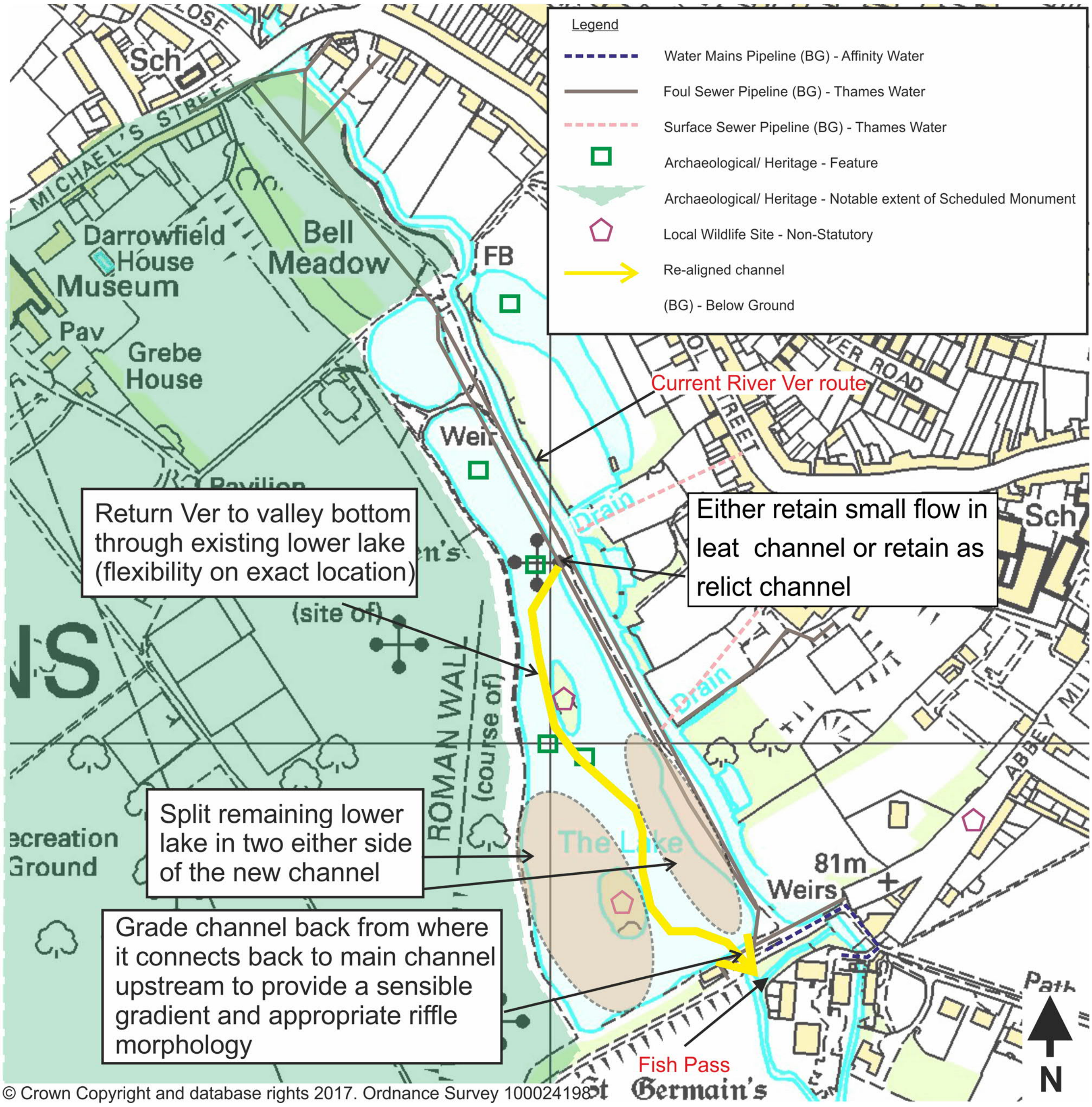


Figure K.4 Option 3 – Part re-align Ver through lakes, retain small lake and top half of large lake, leave isolated lake sections either side for lower half of lakes, part offline/ online

Reach 1 Option 4

This option is illustrated in Figure K.5 below. Option 4 did not fulfil the criteria of the initial long list appraisal process (Table K.2) in that it would likely not be acceptable from a health and safety perspective and that it would likely not fulfil the WFD project objectives (channel would likely need to be very deep and so would be prone to excessive sedimentation that would not result in a diverse habitat). Therefore this option was screened out and not scored within the long listing appraisal process.

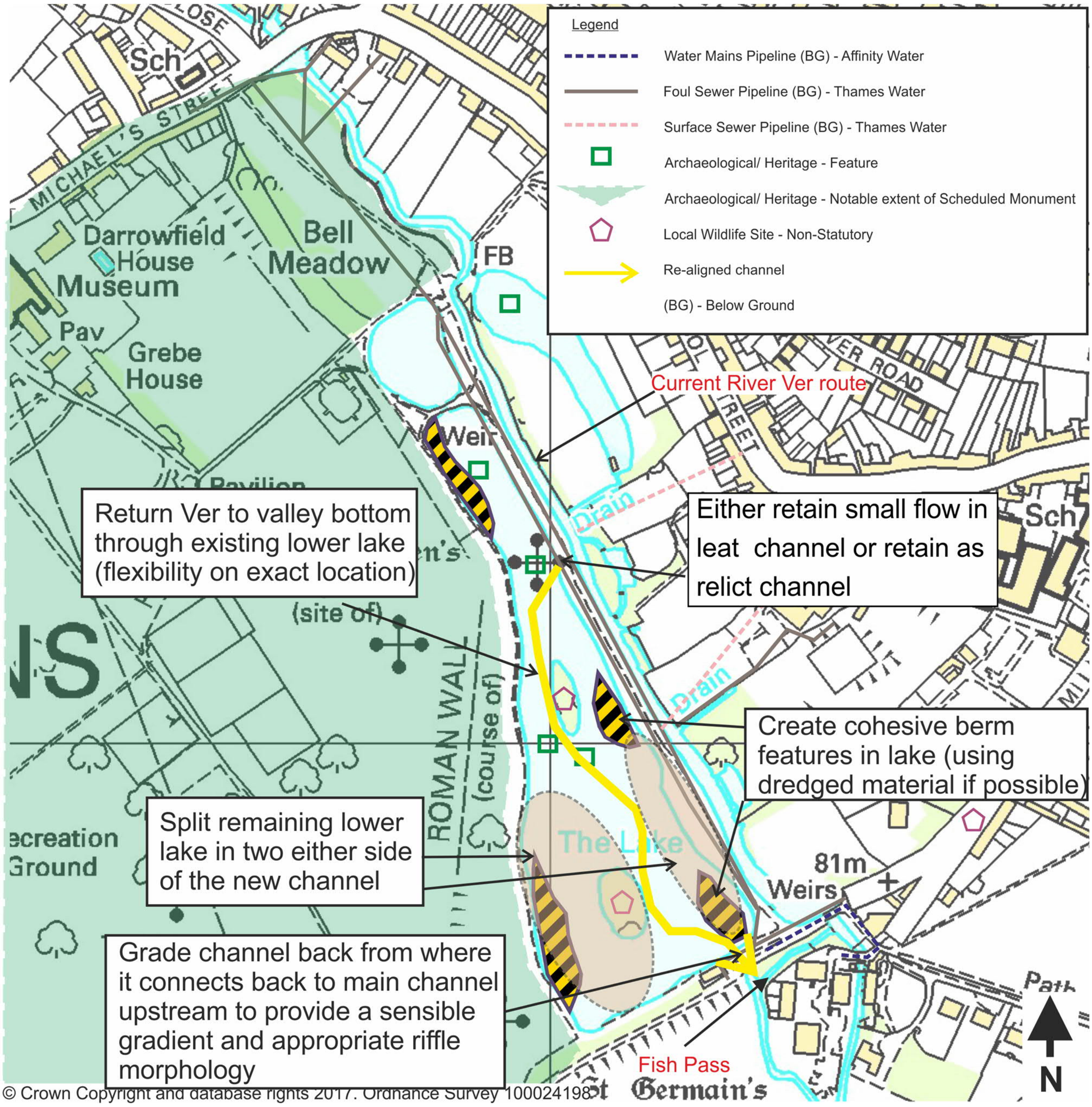


Figure K.5 Option 4 – Part re-align Ver through lakes, retain small lake and top half of large lake, create features in remaining (lower half of large lake) either side, part offline/ online possible

Reach 1 Option 5

This option is illustrated in Figure K.6 below. This option was considered to fulfil the necessary long listing criteria and was scored as part of the long listing appraisal. The option scored well (scoring 9 in total) and was thus shortlisted for more detailed consideration. A score of one was provided for water quality as a result of channel improvements leading to a more dynamic system that could improve water quality such as increasing dissolved oxygen.

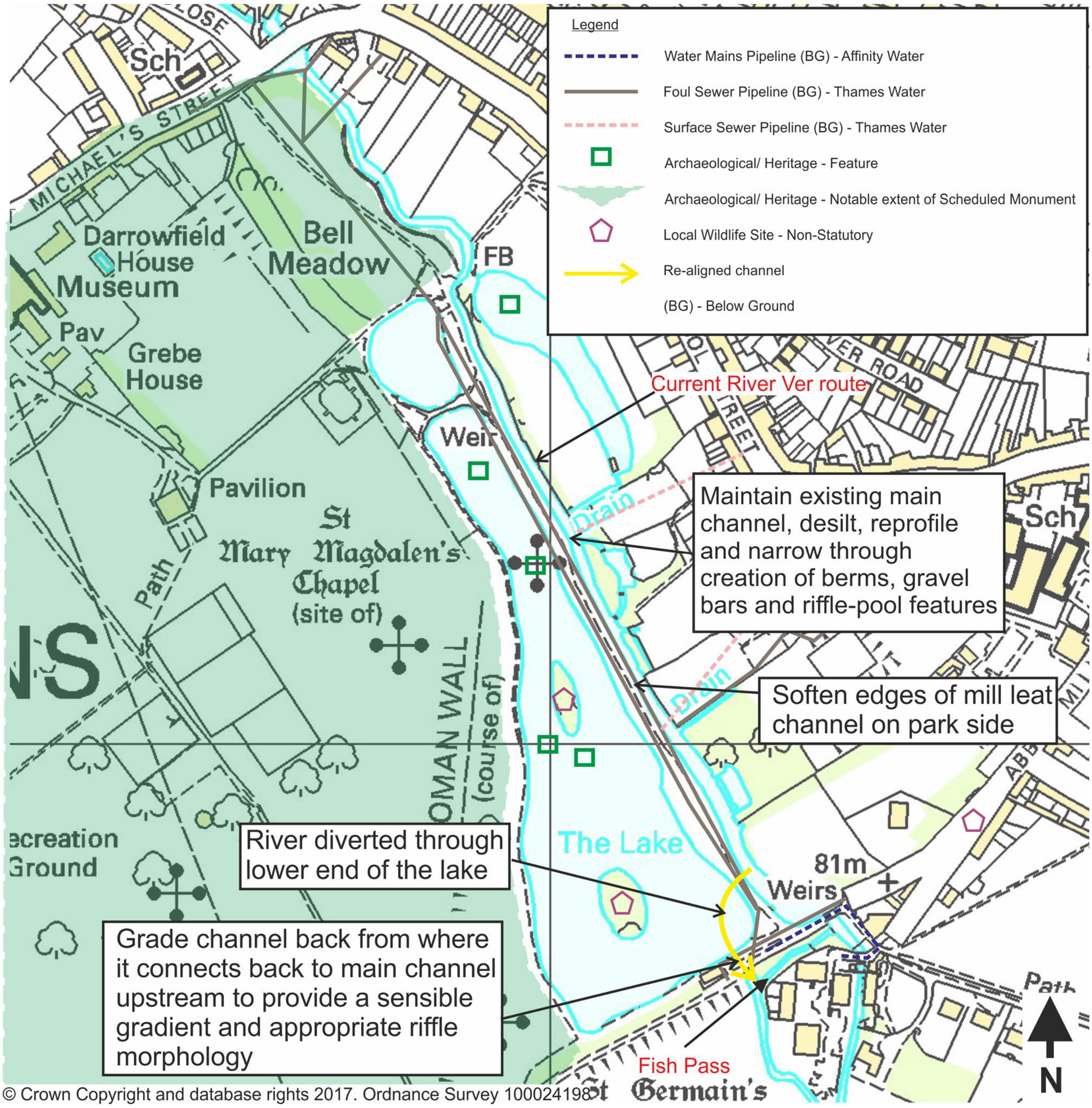


Figure K.6 Option 5 – Small re-alignment of Ver at downstream end of the reach, through lower end of large lake. Upstream re-profiling

Reach 1 Option 6

This option is illustrated in Figure K.7 below. This option was considered to fulfil the necessary long listing criteria and was scored as part of the long listing appraisal. The option scored fairly (scoring 3 in total) as limited benefits are anticipated due to no in-channel works. It was thus not shortlisted for more detailed consideration (with several other river and lake options scoring more).

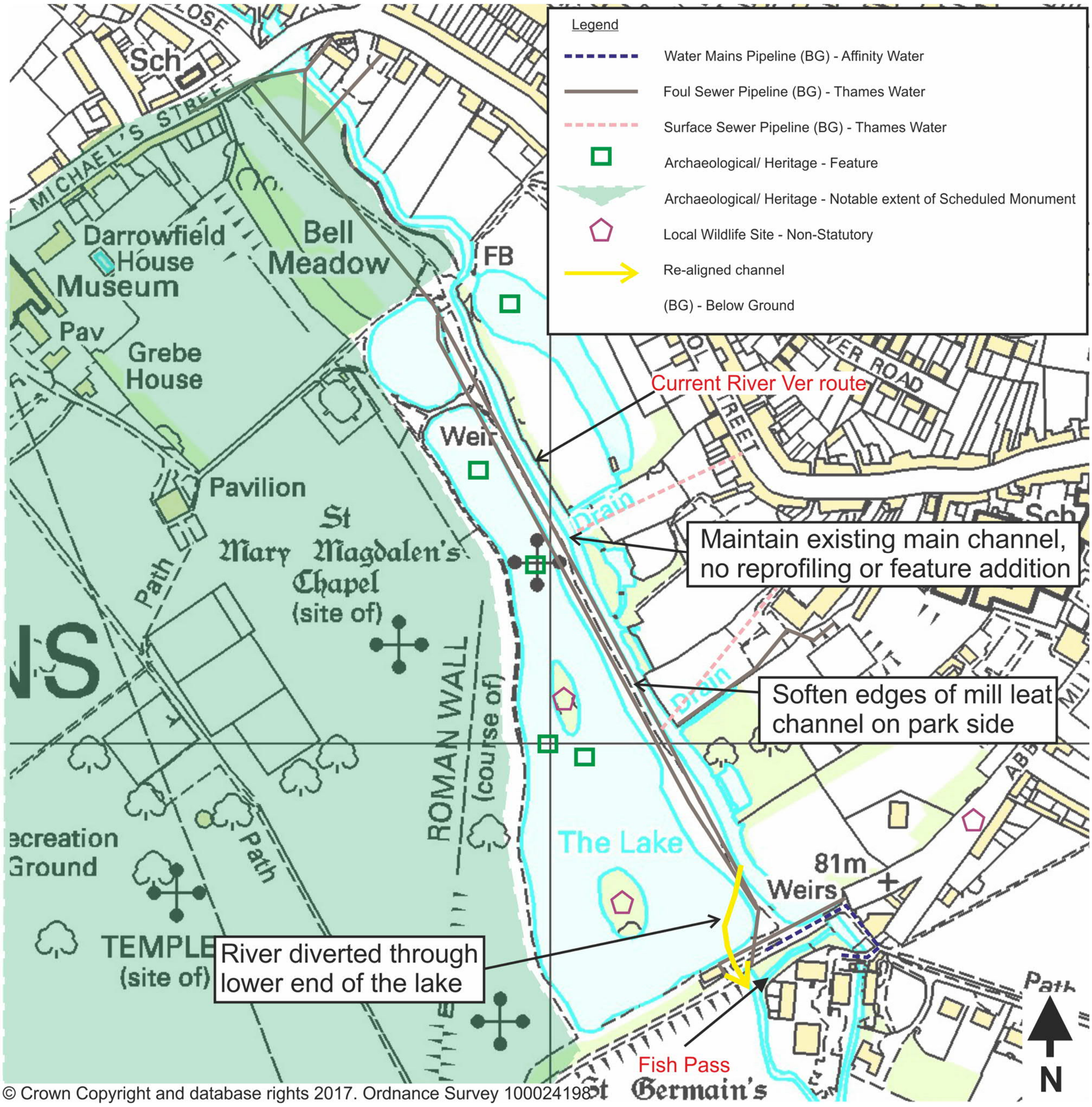


Figure K.7 Option 6 – Small re-alignment of Ver at downstream end of the reach, through lower end of large lake. No upstream reprofiling

Reach 1 Option 7

This option is illustrated in Figure K.8 below. This option was considered to fulfil the necessary long listing criteria and was scored as part of the long listing appraisal. The option scored well (scoring 6 in total) and was thus shortlisted for more detailed consideration. A score of two was provided for water quality as a result of channel improvements leading to a more dynamic system that could improve water quality such as increasing dissolved oxygen. In addition the re-aligned river would separate the field from the lake, so that less nutrient rich runoff would end up in the lake (benefiting lake water quality).

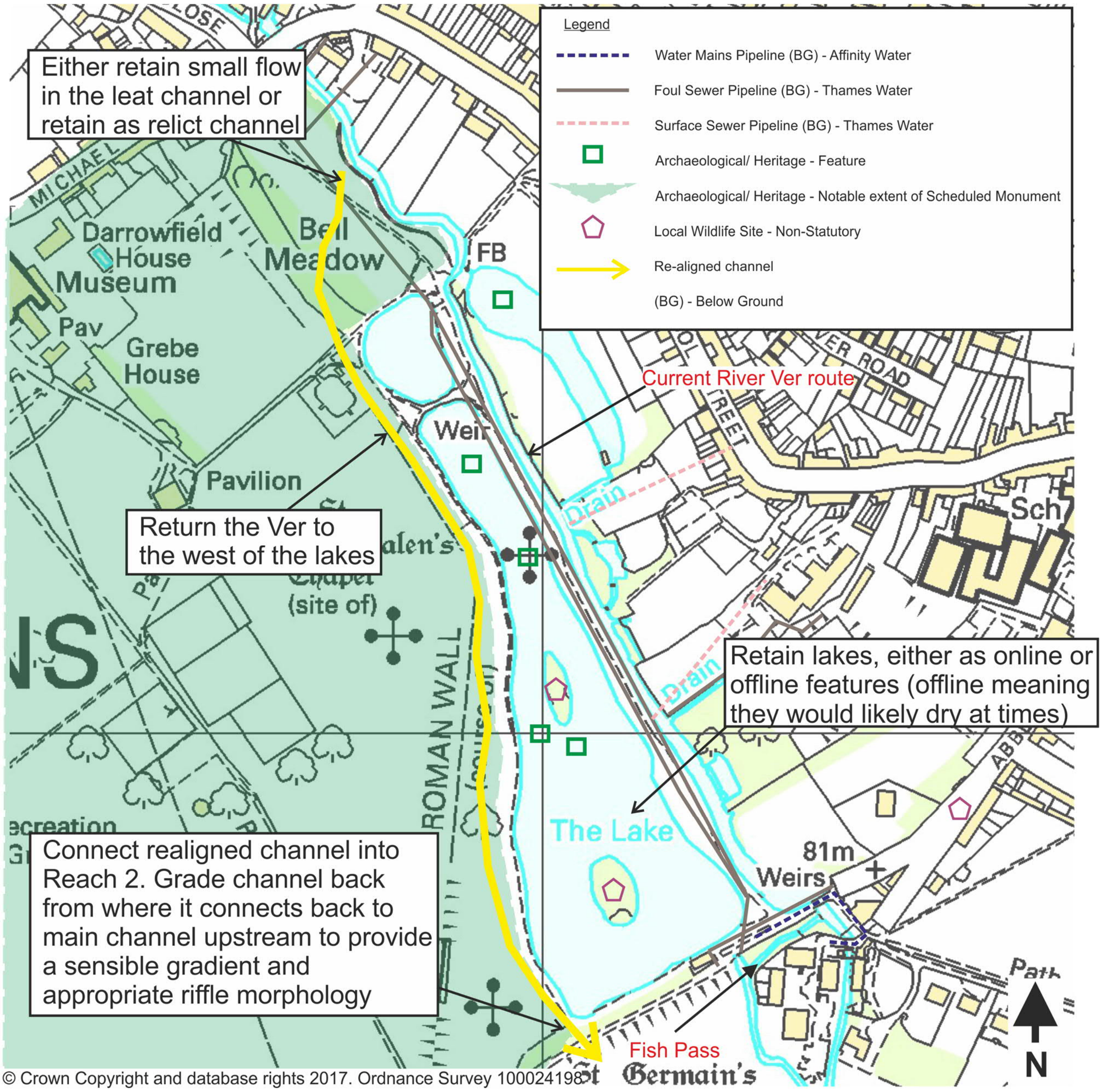


Figure K.8 Option 7 – Re-align channel to west of lakes and connect to Reach 2 to the west of the Causeway

Reach 1 Option 8

This option is illustrated in Figure K.9 below. This option was considered to fulfil the necessary long listing criteria and was scored as part of the long listing appraisal. The option scored well (scoring 8 in total) and was thus shortlisted for more detailed consideration. A score of one was provided for water quality as a result of channel improvements leading to a more dynamic system that could improve water quality such as increasing dissolved oxygen.

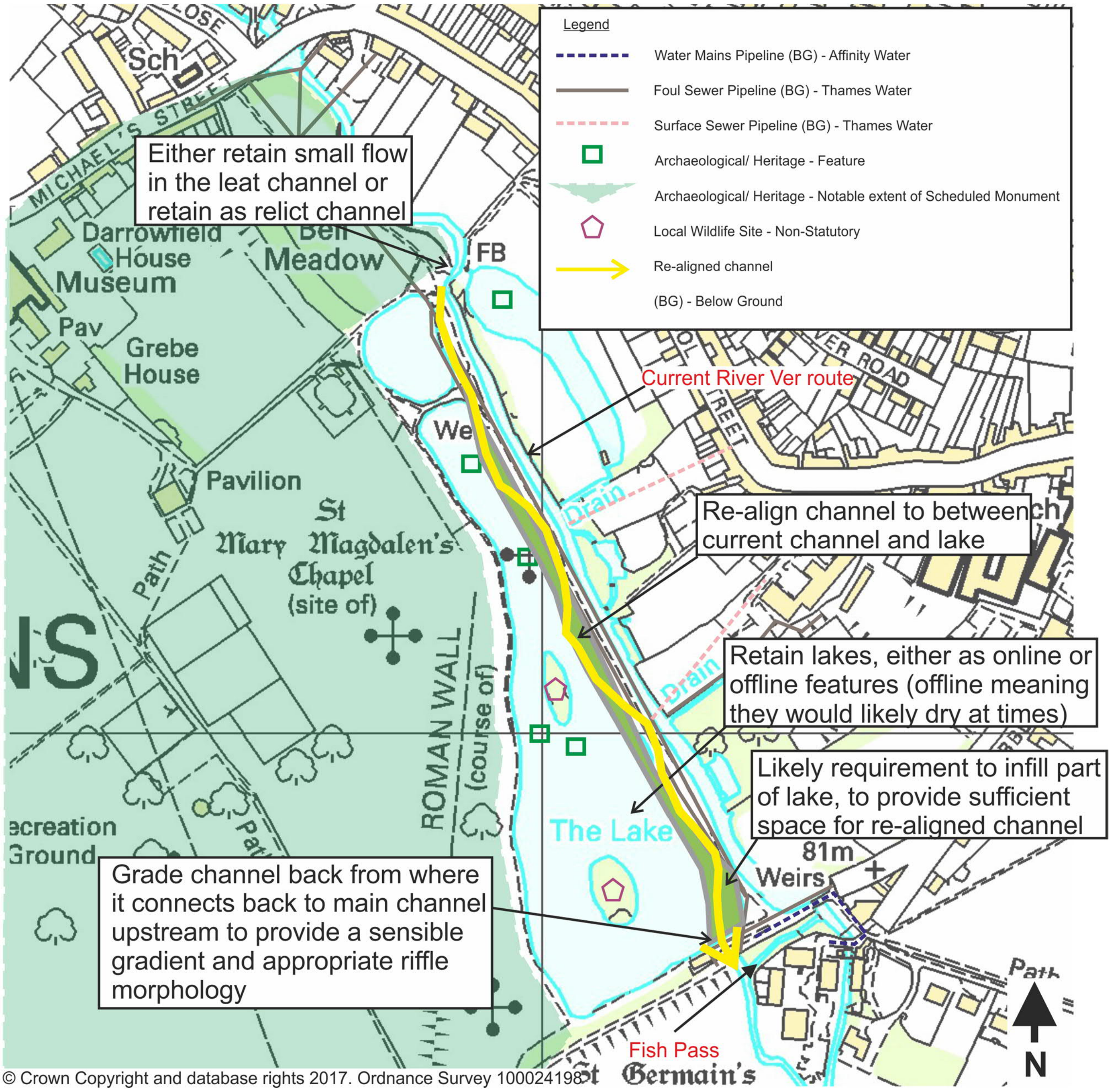


Figure K.9 Option 8 – Re-align channel to between lakes and current channel

Reach 1 Option 9

This option is illustrated in Figure K.10 below. Option 9 did not fulfil the criteria of the initial long list appraisal process (Table K.2) in that it would likely not be acceptable from a health and safety perspective and that it would likely not fulfil the WFD project objectives (as chalk stream would be lost for this reach). Therefore this option was screened out and not scored within the long listing appraisal process.

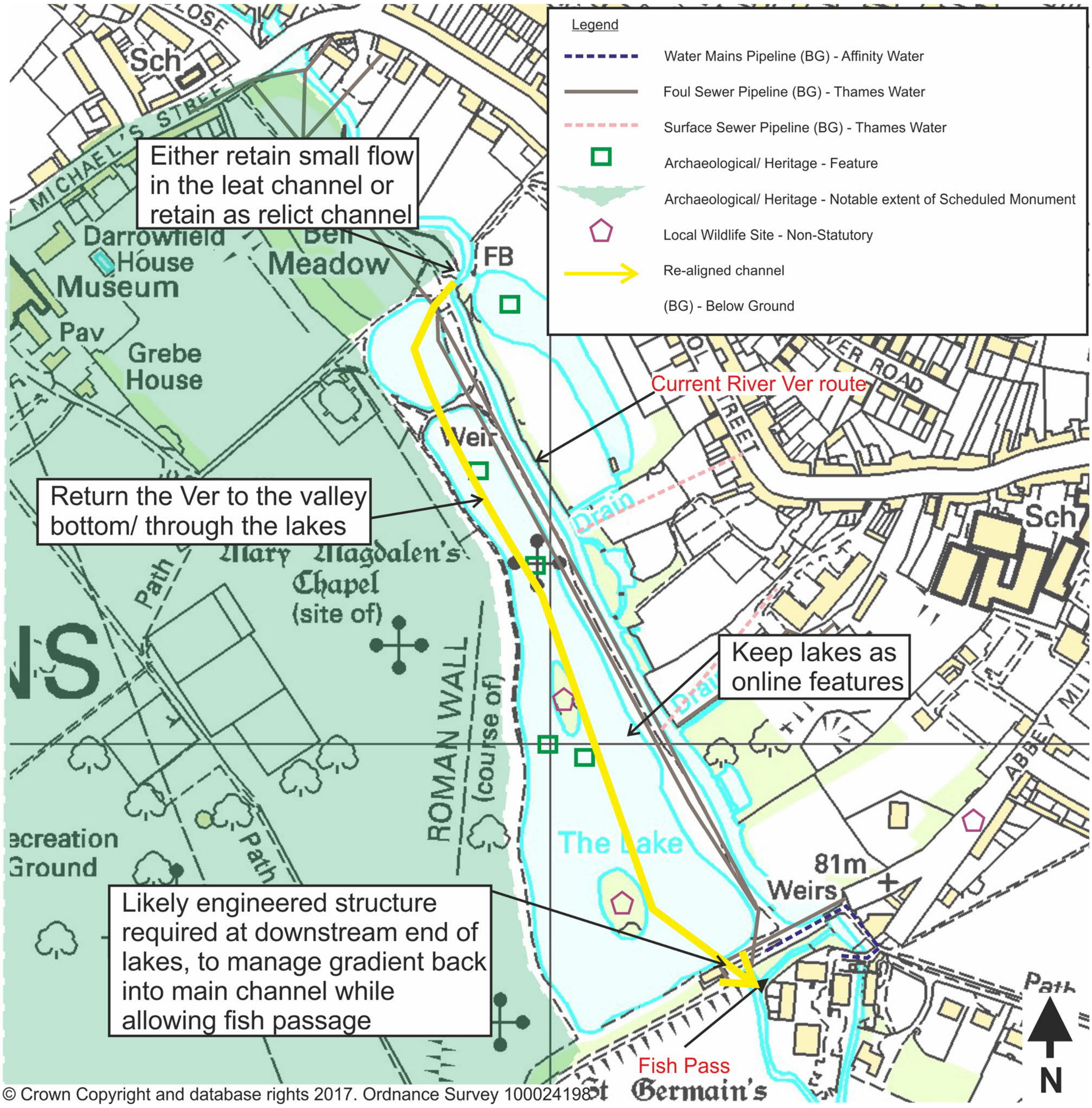


Figure K.10 Option 9 – Re-align through lakes but maintain lakes as online feature

Reach 1 Option 10

This option is illustrated in Figure K.11 below. Option 10 did not fulfil the criteria of the initial long list appraisal process (Table K.2) as the substantial infilling of the lake would result in a significant loss of this characteristic feature. Therefore this option was screened out and not scored within the long listing appraisal process.

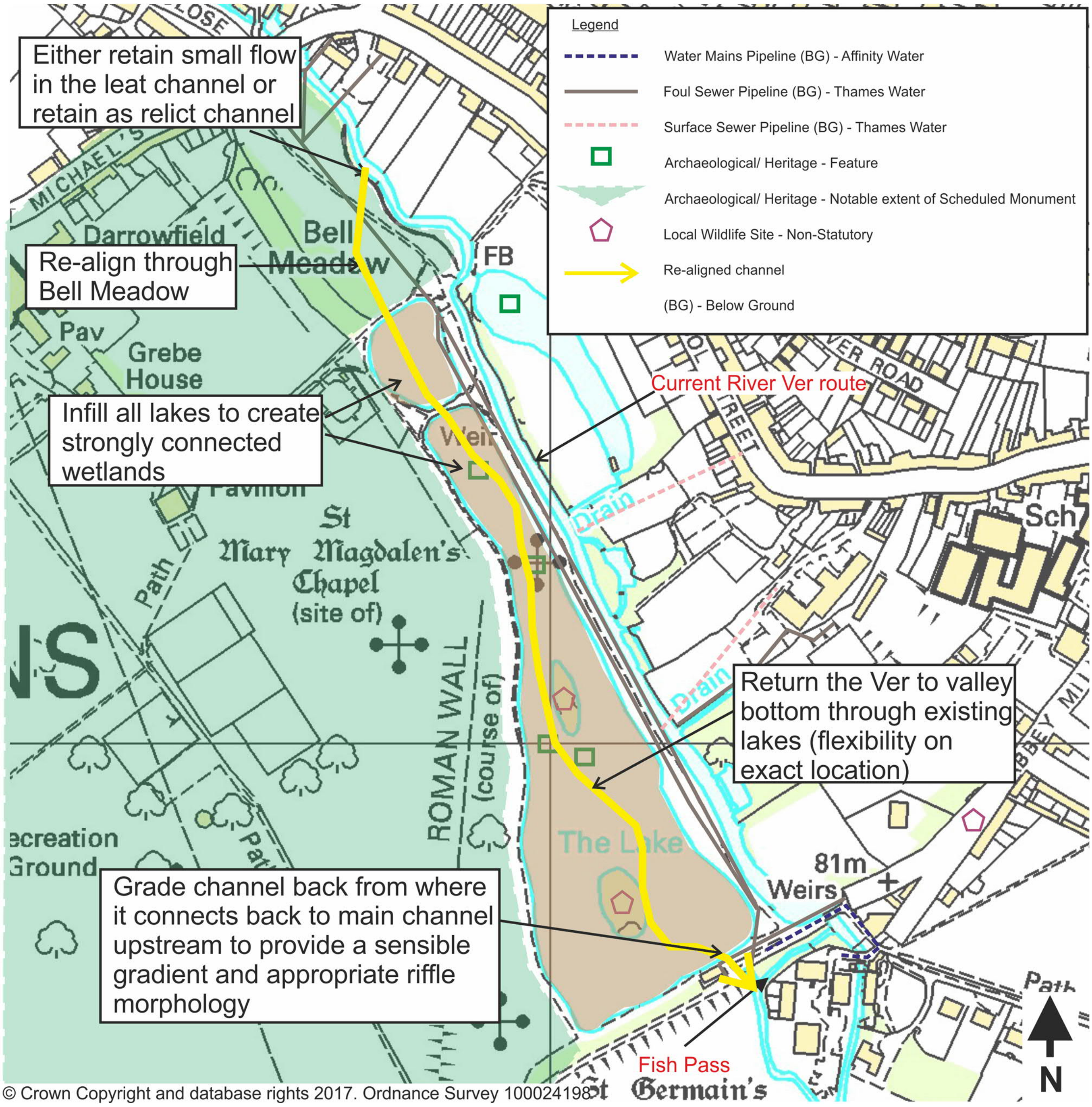


Figure K.11 Option 10 – Re-align Ver through lakes, infill lakes and re-align river through Bell Meadow

Reach 1 Option 11

This option is illustrated in Figure K.12 below. Option 11 did not fulfil the criteria of the initial long list appraisal process (Table K.2) as the substantial infilling of the lake would result in a significant loss of this characteristic feature and WFD objectives would not be fulfilled for this reach (chalk stream lost). Therefore this option was screened out and not scored within the long listing appraisal process.

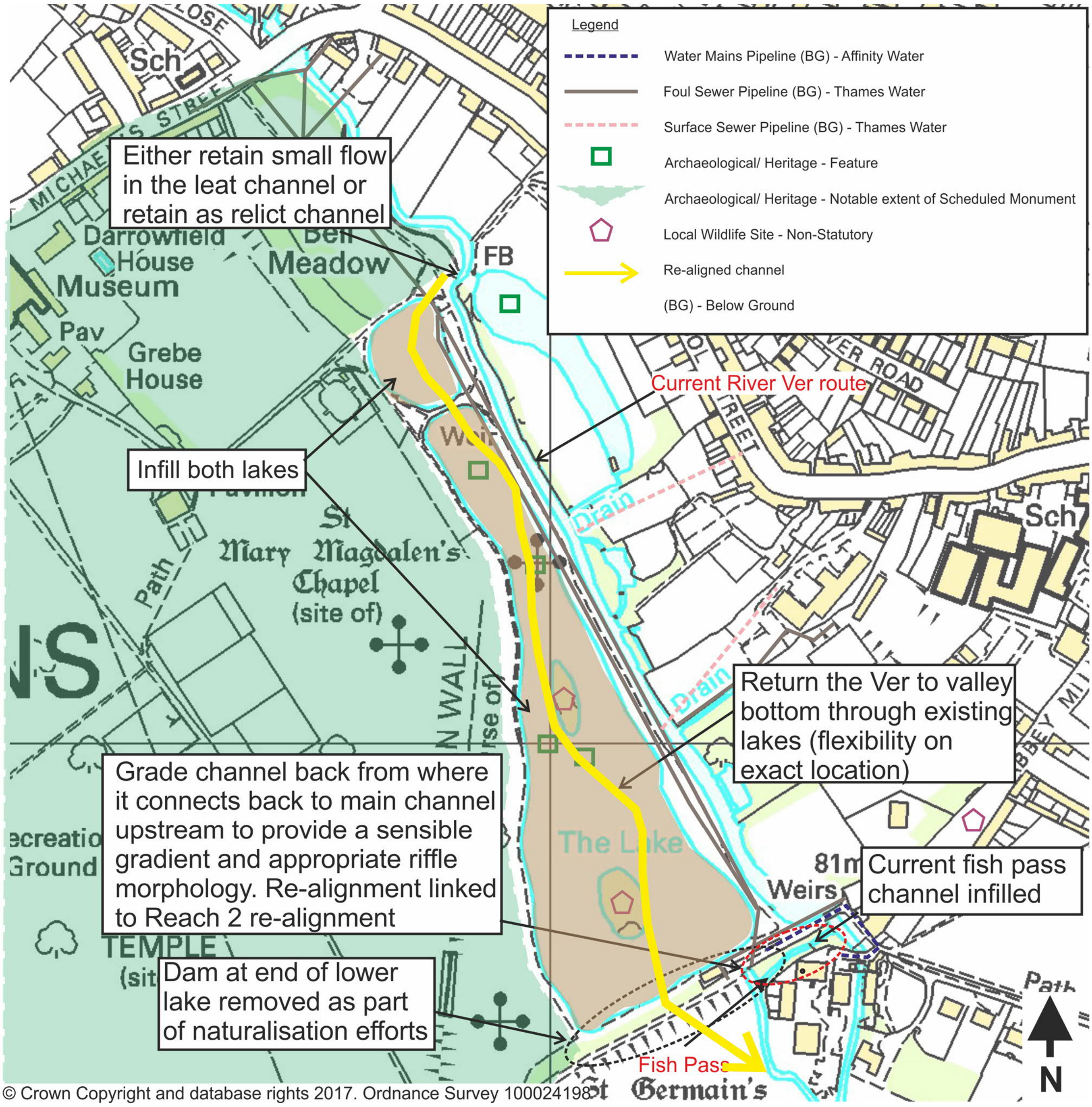


Figure K.12 Option 11 – Re-align Ver through lakes and remove dam

Reach 1 Option 12

This option is illustrated in Figure K.13 below. Option 12 did not fulfil the criteria of the initial long list appraisal process (Table K.2) as the substantial infilling of the lake would result in a significant loss of this characteristic feature and WFD objectives would not be fulfilled for this reach (chalk stream lost). Therefore this option was screened out and not scored within the long listing appraisal process.

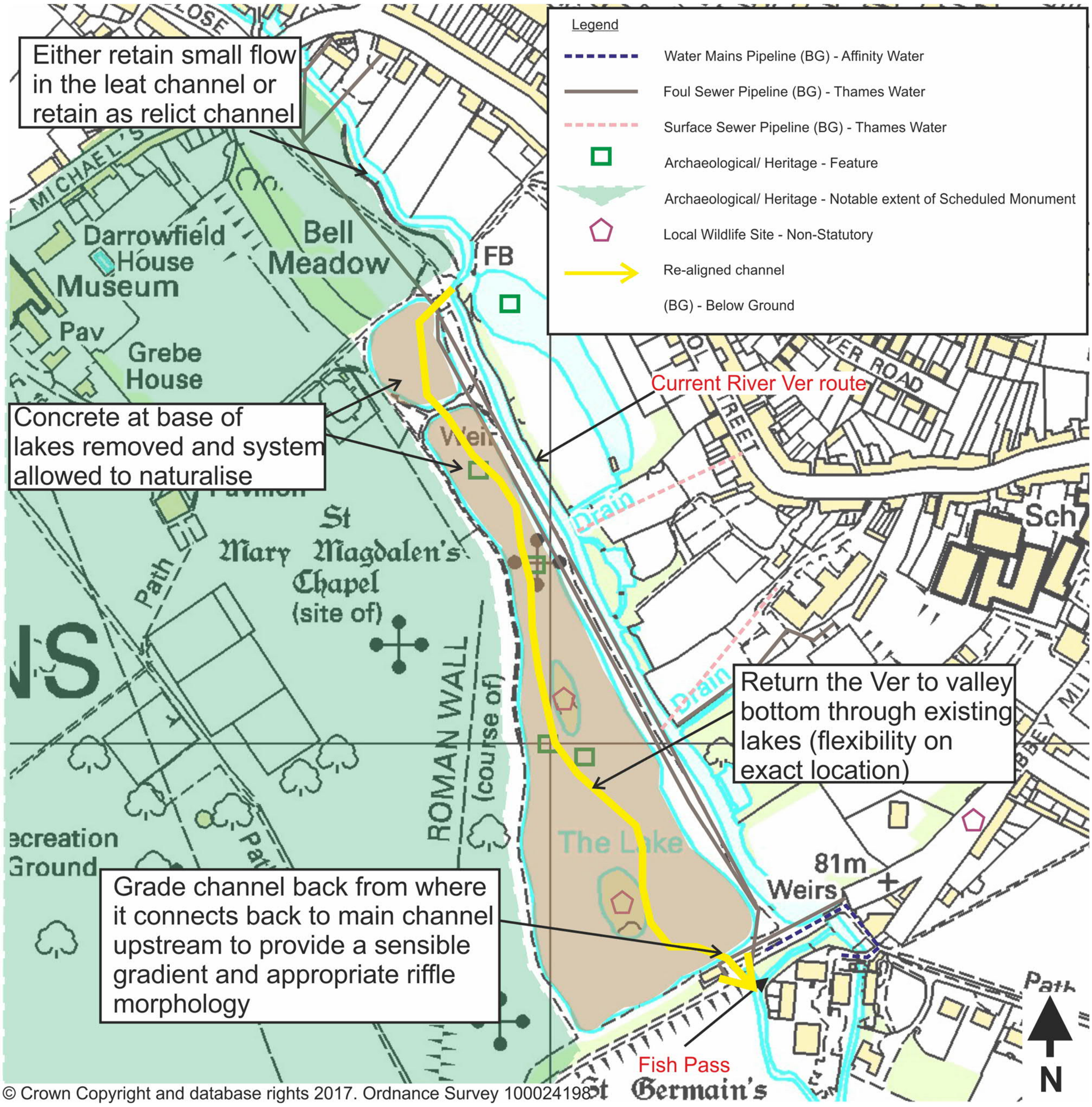


Figure K.13 Option 12 – Re-align Ver through lakes and remove concrete base throughout lakes

Reach 1 Option 13

This option, a river only option, is illustrated in Figure K.14 below. This option was considered to fulfil the necessary long listing criteria and was scored as part of the long listing appraisal. The option scored fairly (scoring 5 in total) due to it having limited hydromorphological benefits with the weirs being retained and as the existing fish pass is only suitably for certain species.

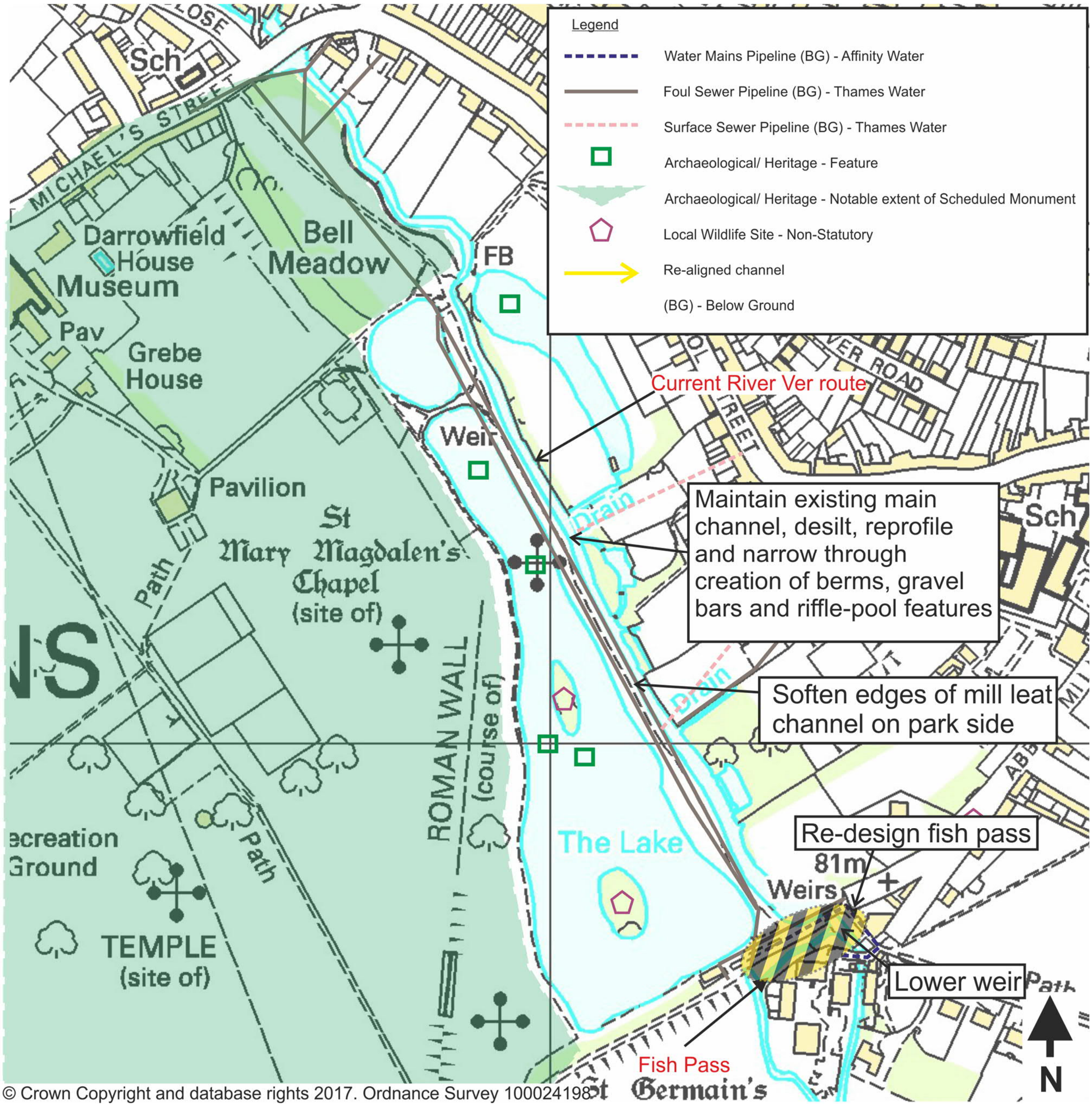


Figure K.14 Option 14 – Maintain current channels, re-design fish pass and lower weir

Reach 1 Option 14

This option, which involves disconnecting the lake from the river, is illustrated in Figure K.15 below. This option was considered to fulfil the necessary long listing criteria and was scored as part of the long listing appraisal. The option scored neutral (scoring 0 in total). A score of one was provided for this option regarding water quality and fish passage as retaining more flow within the river channel should improve these slightly (for example increasing dissolved oxygen and flow over the existing fish pass respectively). A score of two was given regarding contaminated land and sediment as the increased disconnect between the lake and river would mean that sediments, within the lake, that are potentially hazardous would be less likely to end up in the river.

This option, or aspects of it, could potentially be included within the other shortlisted options however. This will be explored further during the modelling that is part of studies on the shortlisted options (even though it scored low during the long listing appraisal when examined on its own).

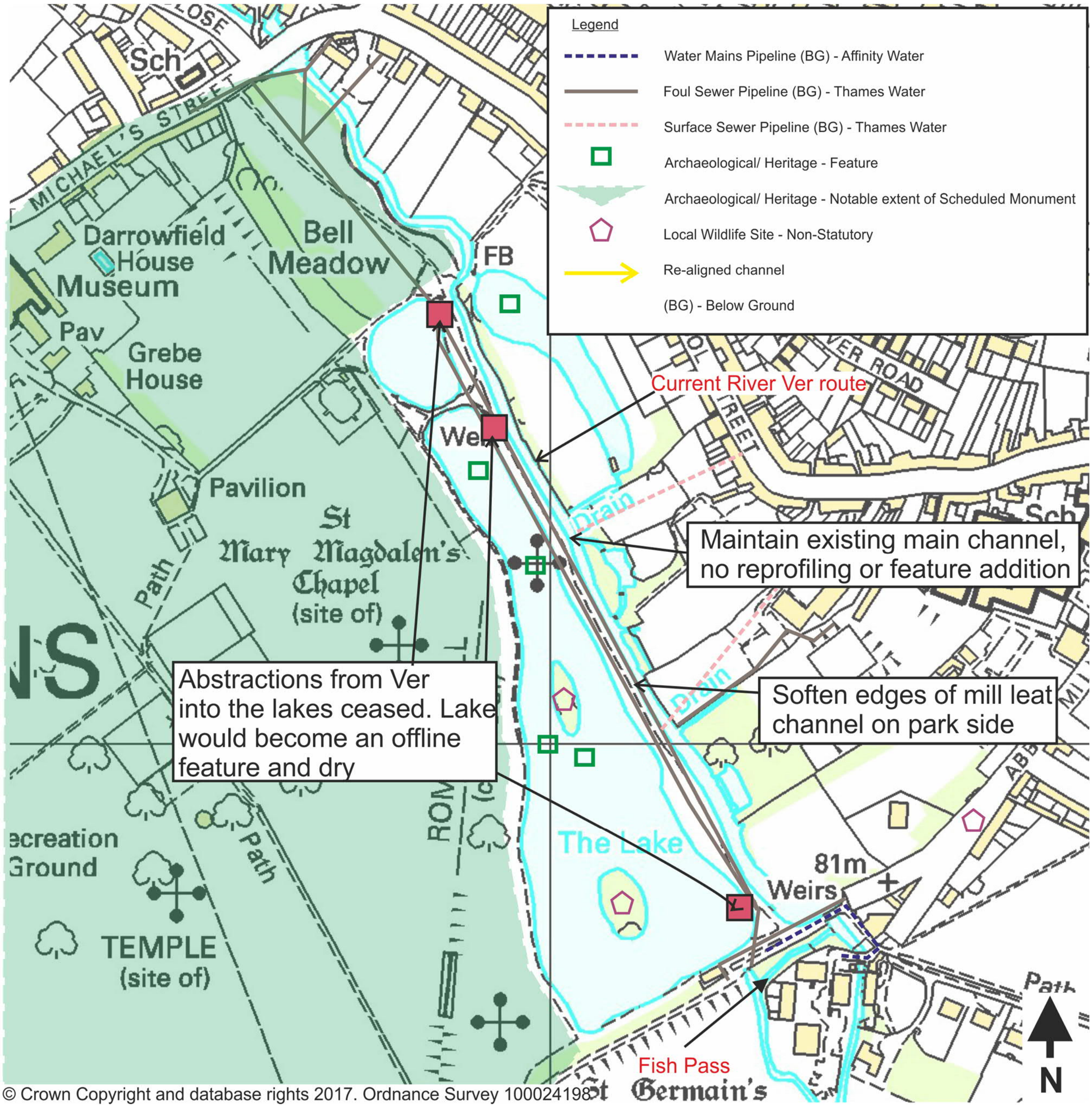


Figure K.15 Option 14 – Close off abstractions into lake so that it becomes offline. Flow in mainstream of the Ver would increase

Reach 1 Long List Appraisal (Lake & River and River Only Options) Summary

As a result of the long list appraisal process, the following Reach 1 options were shortlisted for further consideration:

- Options 5, 7 and 8 from the long list of 'River & Lake Integrated' options; and
- Options 13 from the long list of 'River Only' options.

Option 14 (closing off abstractions into lake so that it becomes offline) will not be shortlisted explicitly though elements of it will be considered as part of the options that have been shortlisted.

K.3 Reach 1 Long List Appraisal (Lake Only Options)

A number of lake only options could be undertaken. These could be undertaken along with river only options appraised in Section K.2. A long list was derived through consultation with the wider Project Steering Group. The long list included the following:

- Complete lake infilling;
- Partial infilling/ narrowing;
- Full removal of the concrete bed removal and reprofiling;
- Partial removal of the concrete bed removal and reprofiling;
- Wetland creation/ planting of marginal, submergent and floating plants;
- Disconnecting lake and river;
- Varying abstraction regime from the River Ver;
- Removing fish from the lake;
- Physical aeration or oxygenation of the lake;
- Chemical Oxygenation of the lake;
- Physical mixing of the lake;
- Use of algicidal chemicals;
- Physical measures to discourage Canadian Geese;
- Other measures to discourage Canadian Geese;
- Dredging of all sediments within the lake; and
- Island enlargement.

These were appraised during the long listing appraisal stage of the project. The appraisal is included as Appendix Q.

Following the long listing review the following options were considered as viable and were to be considered further during the short-listing appraisal. It was considered that the preferred option would include a number of the individual options with many of them being complimentary to one another.

- Partial infilling/ narrowing;
- Full removal of the concrete bed removal and reprofiling;
- Partial removal of the concrete bed removal and reprofiling;
- Wetland creation/ planting of marginal, submergent and floating plants;
- Disconnecting lake and river;
- Varying abstraction regime from the River Ver;
- Removing fish from the lake;
- Physical aeration or oxygenation of the lake;
- Physical mixing of the lake;
- Dredging of all sediments within the lake; and
- Island enlargement.

The remaining lake only options were considered further during the short-listing appraisal stage of the project, discussed in Section K.5, which accounted for additional studies and investigations that were undertaken following completion of the long listing appraisal. Physical or other measures to discourage Canadian Geese were tentatively ruled out during the long list appraisal, as they are unlikely to be the main restoration measure, although measures to discourage the geese are likely to be part of the final preferred option.

K.4 Reach 1 Short-listing Appraisal (River and lake options)

Reach 1 Option Overview

The options outlined in Table K.3 were derived from the long listing appraisal and have been reviewed as part of the Short-listing appraisal. The short-listing appraisal methodology is described in Section 2.4 of the main report while project objectives were presented in Section 1.3.

Table K.3 Reach 1 Short Listed Options following Long List Appraisal

Option	Description
Reach 1	
5	Small re-alignment of Ver at downstream end of the reach, through lower end of large lake. Upstream re-profiling *(river and lake integrated option)*
7	Re-align channel to west of lakes and connect to Reach 2 to the west of the Causeway *(river and lake integrated option)*
8	Re-align channel to between lakes and current channel *(river and lake integrated option)*
14	Maintain current channels, re-design fish pass and lower weir *(river only option)*

Review of Constraints and Opportunities

A plan of potential constraints for Reach 1 is provided in Figure K.16

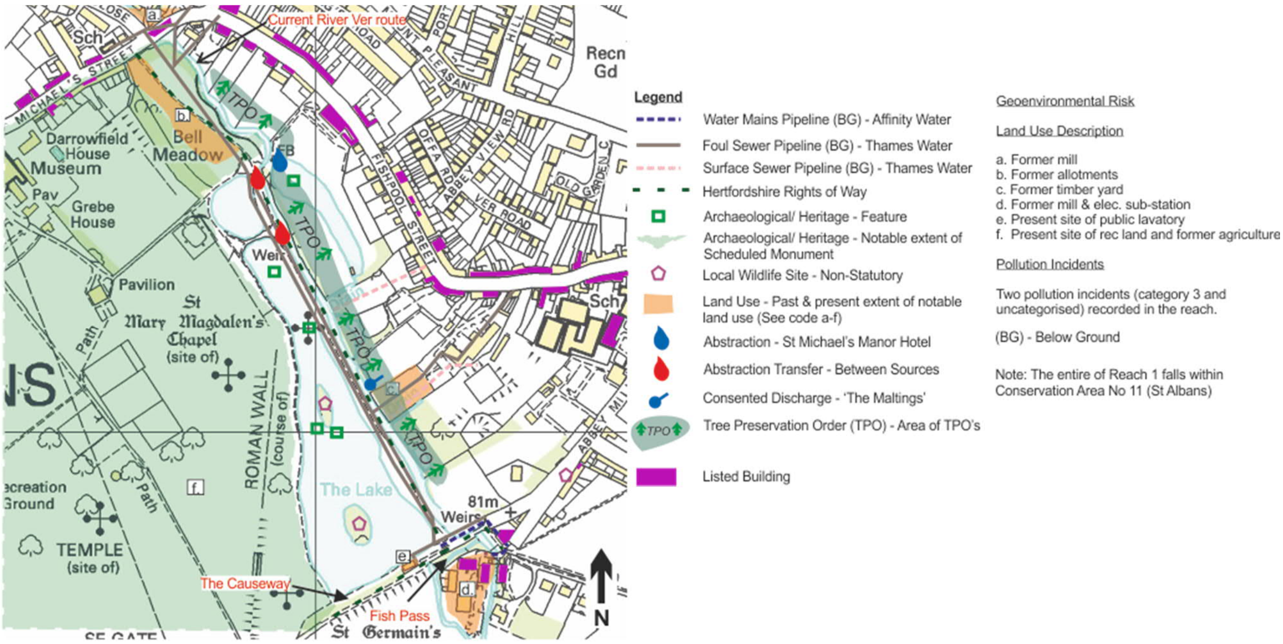


Figure K.16 Reach 1 Constraints Plan

Reach 1 Option 5

Option Description and Restoration Plan

This option (Figure K.17) would involve a small re-alignment of the River Ver at the downstream end of the reach, through lowering the end of the main lake and through the Causeway. The main channel would be subject to re-profiling and bank softening works.

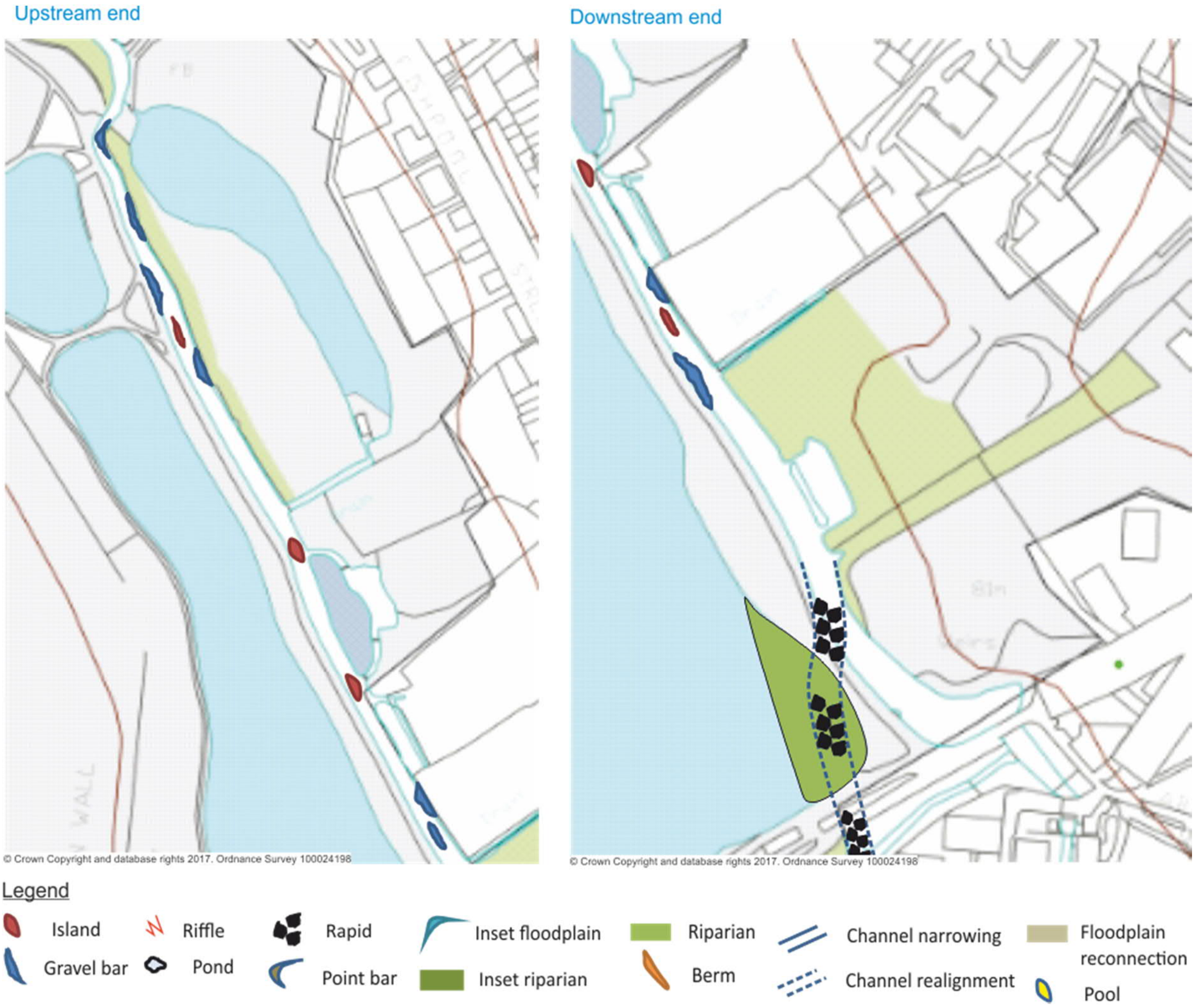


Figure K.17 Restoration Features Plan for Reach 1 Option 5

Under this option, the existing course of the River Ver running adjacent to the Verulamium Park Lakes would be maintained for the majority of its course until it reaches the downstream end of the reach. There, the south eastern corner of the main lake would be infilled and the river diverted through a newly dug channel (Figure K.17, which also includes the features included within the modelling), re-joining the existing river course in Reach 2. The feature plan includes a rapid section although the drop in gradient could be achieved by other means more typical of a chalk stream. The flow split around the Ye Olde Fighting Cock (public house, PH) and mill weir are to be retained as part of this option. The river would be subject to de-silting, in-channel re-profiling and incorporation of a suitable morphology through the creation of numerous gravel/point bar and island features (as illustrated in Figure K.17). The small rapid features are required to manage the gradient at the downstream end of the reach through the reclaimed section of lake.

Review of Constraints and Opportunities

A plan of potential constraints for Reach 1 was provided in Figure K.16 above. The effects of these constraints on the feasibility of this option are described in Table K.4 below, along with potential advantages/ opportunities.

Table K.4 Review of constraints and opportunities for Reach 1 Option 5

Topic	Potential Issues	Assessment of the Effect or Potential Effect of the Option
Access	Access may be difficult and even prohibitively expensive under certain circumstances	• Access for works likely to come from the east of Reach 1. Not considered to be prohibitive.
Flood Risk	As a result of re-alignment or floodplain works, flood risk from the river may decrease or increase in areas	• It is unlikely to significantly impact the flooding extent compared to baseline as the connectivity to the left and right bank floodplains should be maintained through incorporation of the described morphology. This would be confirmed following completion of the modelling.
Hydromorphology	Does the scheme improve the hydromorphological functioning of the reach?	• The increased hydraulic gradient through the realigned section and upstream should reduce fine sediment accumulation and create an improved gravel bed more characteristic of a chalk system; and • The hydraulic changes would mean less glide and ponded habitats through the existing main channel with an increased quantity of higher energy riffled flow. • These would be confirmed following completion of the modelling.
Water transfer from the River Ver into Verulamium Lake	Water is transferred from River Ver into Verulamium Park Lakes via two culverts although one of these is blocked. The flow is level dependent and so significant alternations to level in the existing channel of the Ver, close to the sluices, would result in more or less flow entering the lake.	• It is unlikely that this option would result in significant changes to this, although this would be confirmed following completion of the modelling. If it does some structural adjustments at the sluice(s) may be required.
Abstractions and other hydrological concerns	Consideration as to whether the scheme may result in other adverse or beneficial hydrological effects. For example re-routing of the river may impact upon distributaries as well as the main river.	• Water abstracted from the River Ver for St Michael's Manor Hotel at upstream end of the reach is level dependent and so significant changes in the Ver would impact upon the abstraction. At the end of Reach 1, the current channel splits into a section that flows down the fish pass and another that flows past the Ye Olde Fighting Cock PH. • It is unlikely that this option would result in significant changes to inflows to the other online lakes at the left bank although this would be confirmed following completion of the modelling. • There may be a change in flow distribution between the lake and Ye Olde Fighting Cock PH mill leat channel without further works to alter the invert levels into these zones
Groundwater connectivity	Does the scheme affect connectivity between surface water and groundwater?	• The river bed through Reach 1 is not concrete lined therefore connectivity with a natural bed would be maintained. Reach is considered to be a losing reach and scheme would be unlikely to have a significant effect on the amount of flow losses, with minimal additional connectivity between the surface and groundwater.
Environmental Permits / consented discharges	Significant re-routing of the system may result in less flow being in the river at the point where a consented discharge enters and less dilution of that discharge.	• One discharge is located on the left bank midway down Reach 1. The nature of this discharge is not stated although it is located at a similar location as the surface water runoff sewer. Given the minimal anticipated changes in flow in this reach the any effects of this discharge on water quality in the Ver as a result of the scheme would be minor. During construction, the discharge should be accounted so that it is not disrupted.
Heritage	Scenario has the potential to impact upon Scheduled Monument or other archaeological feature	• Re-alignment not considered to affect Scheduled Monuments or other archaeological features, including during works. It would have a potential effect on the causeway although this is considered to be of low heritage significance.
Water Mains and Sewers (foul and surface water)	Under certain scenarios, construction may be routed close to other water mains and sewers. If so, these may have substantive effects on the cost of the scheme, its feasibility and duration of its construction.	• There is a Thames Water foul sewer that extends along the reach between the River Ver and Lakes. This is at a depth of ~3.8m bgl and should not be impacted by the works. There is also a foul sewer that runs partially along the causeway at a depth of ~2.5m bgl. This would likely be impacted by the works at the lower end of the lake and would need to be accounted for (which could be costly). • Two separate below ground surface water sewer pipelines (owned by Thames Water) enter the River Ver on the left hand bank. The depths of the more northern of these is unknown while the other is at 4m bgl. These should be acknowledged during the works although are not considered to be prohibitive. • Affinity Water mains also lie below ground and in the eastern end of the Causeway, though works not anticipated to affect these.
Other Utilities	Under certain scenarios, construction may be routed close to other utilities, such as BT or gas mains. If so, these may have substantive effects on the cost of the scheme, its feasibility and duration of its construction.	• There are no other utilities close to the area that would be restored under this option
Geo-environmental	A potential issue if river is re-aligned through areas which may potentially be contaminated	• River is not re-aligned through areas identified as being potentially contaminated. Such areas are also unlikely to be encompassed during construction works too.
Wildlife Sites	Wildlife sites lie throughout the study area and could potentially be impacted by the scenarios	• The necessary works are close to Local Wildlife Sites though these are not likely to be directly impacted by the works.
Fish passage	At present the fish pass at the lower end of Reach 1 is not considered to function and is serving as a barrier for upstream fish passage	• Scheme would provide a bypass around the existing fish pass enabling fish passage. Rapid features not ideal for passage of all species although inclusion of other lower gradient features may achieve this. This would be explored further if this option is the preferred option.
Tree Protection Orders (TPO)	Consideration of the effect of Tree Protection Orders on the option	• TPOs are extensive on the left bank of the existing channel and may have an impact upon access, construction and tree works to improve channel light levels.
Public Rights of Way	Public Rights of Way may need to be diverted if works are would occur over their route	• A public right of way extends throughout the route of the works proposed by this scenario and would need to be diverted for the duration of the works. • Overall, public access to the river would be improved as a result of the works.
Lake works	Identification of issues and potential costs associated with works through the lake	• Costs anticipated to be moderately high for lake reclaiming works (Noting that the hard bed would need to be broken out in this area although the soft sediment in the lake was not found to be hazardous) • Costs anticipated to be high for works to the causeway.
Landscape impact	Review whether option would have a significant visual impact	• River works along the existing channel would visually improve the appearance of the river and works at the lower of the lake should have minimal visual impacts as the river/ land would be lowered in the area.
Recreation and amenity	Review whether option would have significant impacts upon recreation and amenity	• The option would result in a small reduction in the surface area of the larger of the Verulamium Lakes. This is not considered to have a significant impact upon recreation or amenity. The improvements to the river are likely to improve its appearance which may increase the number of people wishing to walk along the river.
Riparian ownership issues	Consideration as to whether option may require re-routing through lands that are privately owned or result in riparian changes that may be unacceptable.	• Potential impacts to the offline lakes are discussed above under abstraction and other hydrological information. Through detailed investigations it should be possible that these would not be adversely impacted under this scenario.

Reach 1 Option 7

Option Description and Restoration Plan

In this option, the Ver would be re-aligned to run round the western side of the lakes (closer to its natural route), re-joining at the boundary of Reach 2 (see Figure K.18). The channel would be diverted into the small lake and beneath the existing stone bridge arch feature. The re-aligned channel would then return to its former, natural course along the west side of the main lake, regraded to an appropriate gradient to address the elevation difference between the lake and main channel downstream, ensuring fish passage requirements are met.

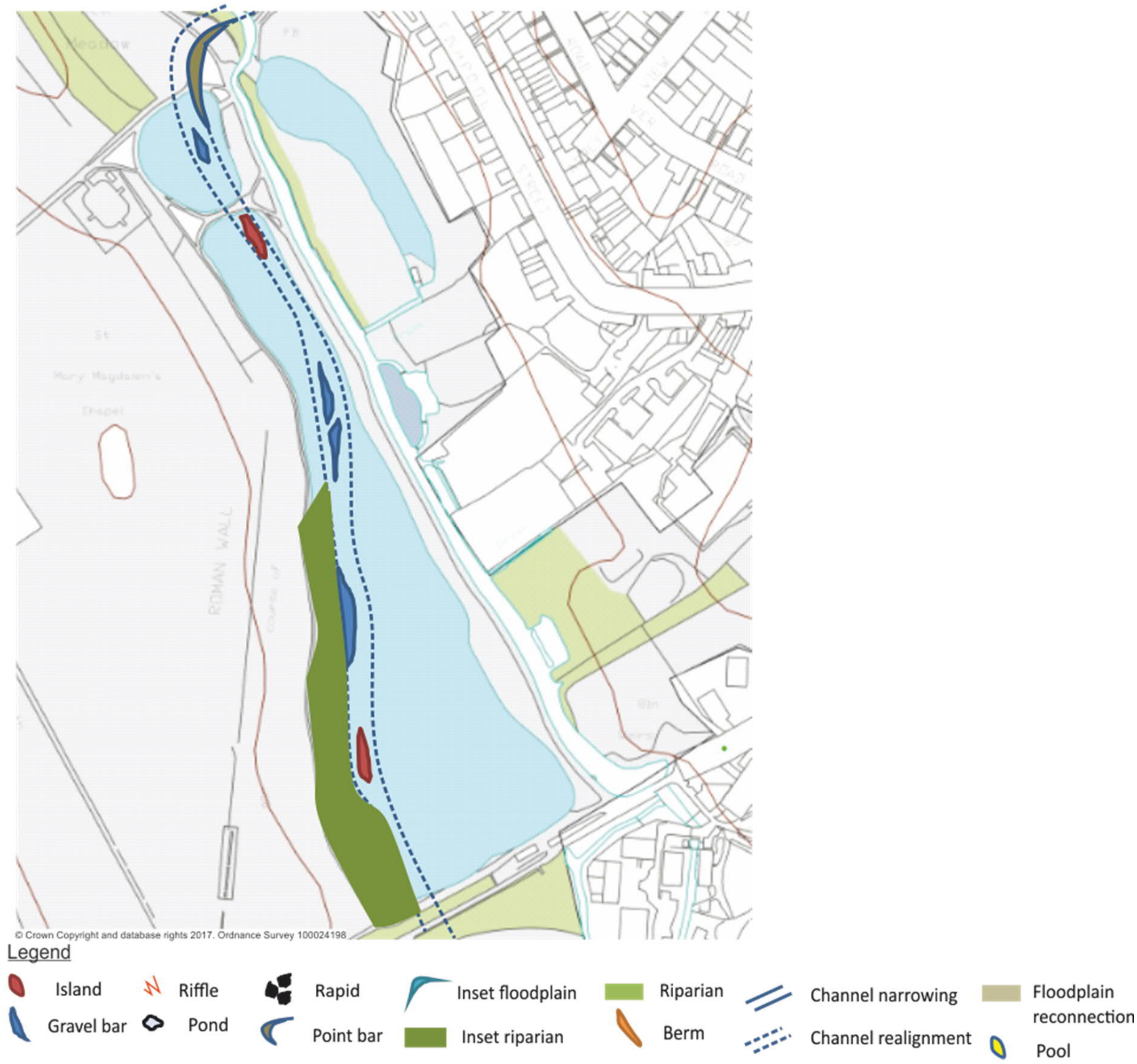


Figure K.18 Feature plans for Reach 1 Option 7

The re-aligned channel would be subject to in-channel re-profiling and incorporation of a suitable morphology through the creation of numerous gravel/point bar and island features (as illustrated in Figure K.18, which also includes the features included within the modelling). The channel could be directed through the existing causeway which would limit some of the impacts identified within this section.

The existing channel may become a high flow channel, subject to the hydrology, although it could be designed so that a residual flow would be maintained within the channel past the Ye Olde Fighting Cock PH as part of this option, again subject to hydrology. The remainder of the main lake would either be retained as online or offline features, with the latter option meaning they would likely dry at times).

Review of Constraints and Opportunities

A plan of potential constraints for Reach 1 was provided in Figure K.16 above. The effects of these constraints on the feasibility of this option are described in Table K.5 below, along with potential advantages/ opportunities.

Table K.5 Review of constraints and opportunities for Reach 1 Option 7

Topic	Potential Issues	Assessment of the Effect or Potential Effect of the Option
Access	Access may be difficult and even prohibitively expensive under certain circumstances	• Access for the works could be complex and come from the east and north west of the lake. It may also be disruptive for park users?.
Flood Risk	As a result of re-alignment or floodplain works, flood risk from the river may decrease or increase in areas	• The option may pose a flood risk increase to the Scheduled Monument over the right hand bank close to the realigned section of channel. This would be confirmed following completion of the modelling.
Hydromorphology	Does the scheme improve the hydromorphological functioning of the reach?	• bypassing the influence of the weirs into the fish pass would improve flow hydraulics through the realigned section of channel, encouraging transport of finer sediments • the predominant glide and pooled habitats in the existing main channel would be replaced by higher energy riffle and shorter pool units through the realigned section of channel. • These would be confirmed following completion of the modelling.
Water transfer from the River Ver into Verulamium Lake	Water is transferred from River Ver into Verulamium Park Lakes via two culverts although one of these blocked. The flow is level dependent and so significant alternations to level in the existing channel of the Ver, close to the sluices, would result in more or less flow entering the lake.	• It is likely that new structures would be required to achieve the desired inflow to the lake (or remaining parts of it where an inflow is desired) and the location of these would need to be determined through detailed design.
Abstractions and other hydrological concerns	Consideration as to whether the scheme may result in other adverse or beneficial hydrological effects. For example re-routing of the river may impact upon distributaries as well as the main river.	• The option would result in flow being diverted away from the existing channel. The current plan shows the re-alignment beginning upstream of the abstraction to the online lake at the left bank although the re-alignment could begin downstream of it. As such, though iteration of the design, it would be possible that there would be no significant impact. • The significant re-routing would reduce flow in the existing Reach1 channel and past the Ye Olde Fighting Cock PH. This would be difficult to mitigate for and if necessary to maintain could make this option infeasible.
Groundwater connectivity	Does the scheme affect connectivity between surface water and groundwater?	• Breaking out of the lake bed lining would help to restore a more natural connection with groundwater although the reach was found to be a losing reach, so this may result in a reduction in flow in the river at most times.
Environmental Permits / consented discharges	Significant re-routing of the system may result in less flow being in the river at the point where a consented discharge enters and less dilution of that discharge.	• One discharge is located on the left bank midway down Reach 1. Given that much of the flow would be re-routed this discharge would need to be re-routed too, or else it may have a significant impact upon on water quality in the channel that remains (noting that the nature of this discharge is not stated and it may be linked with a surface water runoff sewer).
Heritage	Scenario has the potential to impact upon Scheduled Monument or other archaeological feature	• Re-alignment would bring the river closer to the Scheduled Monument. It has been positioned to be outside of the boundaries of the site although the option itself could have an effect of its setting, which may be problematic to mitigate for. Other archaeological feature in the lake may be disrupted and require additional archaeological inputs, such as watching brief. The option would also have a potential effect on the causeway although this is considered to be of high heritage significance. • Water levels and flow velocities through the Mill Leat channel would be likely to change, and the degree to which waterlogged deposits may be affected is uncertain.
Water Mains and Sewers (foul and surface water)	Under certain scenarios, construction may be routed close to other water mains and sewers. If so, these may have substantive effects on the cost of the scheme, its feasibility and duration of its construction.	• Affinity Water mains are located at lower end of Reach 1- this would be unaffected by this option. • There is a Thames Water foul sewer that extends along the reach between the River Ver and Lakes. Works are only intended at the northern end of this sewer and in this region the sewer is at a depth of ~3.8m bgl and should not be impacted by the works. • Two separate below ground surface water sewer pipelines (owned by Thames Water) enter the River Ver on the left hand bank downstream of where it is re-routed. The works should not impact upon these although a reduction in flow would mean there would be less dilution capacity within the relict river. • Affinity Water mains also lie below ground and in the eastern end of the Causeway, though works not anticipated to affect these.
Other Utilities	Under certain scenarios, construction may be routed close to other utilities, such as BT or gas mains. If so, these may have substantive effects on the cost of the scheme, its feasibility and duration of its construction.	• There are no other utilities close to the area that would be restored under this option
Geo-environmental	A potential issue if river is re-aligned through areas which may potentially be contaminated	• River is not re-aligned through areas identified as being potentially contaminated (with lake sediments being identified as not hazardous). Such areas are also unlikely to be encompassed during construction works too.
Local Wildlife Sites (Non-statutory)	Wildlife sites lie throughout the study area and could potentially be impacted by the scenarios	• The re-routing through the lakes would be in the immediate vicinity of the two islands that are Local Wildlife Sites. This would have an impact upon the construction activities and require suitable approval. The works may provide an opportunity to improve wildlife, such as the heronry, through the lake.
Fish passage	At present the fish pass at the lower end of Reach 1 is not considered to function and is serving as a barrier for upstream fish passage	• Scheme would provide a bypass around the existing fish pass enabling fish passage
Tree Protection Orders (TPO)	Consideration of the effect of Tree Protection Orders on the option	• TPOs are extensive on the left bank of the existing channel although the proposed works are not likely to be significantly impacted upon by these.
Public Rights of Way	Public Rights of Way may need to be diverted if works are would occur over their route	• A public right of way extends along the reach between the River Ver and Lakes. This would be impacted by the option at the northern end of the works and would need to be diverted for the duration of the works. • Overall, public access to the river would be improved as a result of the works.
Lake works	Identification of issues and potential costs associated with works through the lake	• Costs anticipated to be high for the extensive lake reclaiming works (Noting that the hard bed may need to be broken out through the reach although the soft sediment in the lake was not found to be hazardous) • Costs also anticipated to be high for works to the causeway.
Landscape impact	Review whether option would have a significant visual impact	• Extensive re-alignment of the river through the lakes would result in significant visual changes that could be considered negatively, without significant mitigation.

Recreation and amenity	Review whether option would have significant impacts upon recreation and amenity	• The option would result in a large change to river and lake throughout reach one, which would have a significant impact upon recreation and amenity in the watercourses. For example, the boating lake would likely no longer be functioning however a new boating lake could be developed. • Re-routing of the river and associated improvements works, such as boardwalk paths through newly created wetland areas, could help improve access to the river through the reach.
Riparian ownership issues	Consideration as to whether option may require re-routing through lands that are privately owned or result in riparian changes that may be unacceptable.	• Water levels in the mill leat channel are likely to be impacted by the option and there may be some drying of the channel under low flow conditions. This would likely make the channel less visually appealing to riparian owners. Their ability to obtain water from the river, for example through existing offtakes may also be impacted.

5.2.5 Reach 1 Option 8

Option Description and Restoration Plan

Option 8 (Figure K.19) involves the re-alignment of the River Ver between the lake and the existing course of the river channel. In order for the re-aligned channel to bypass the impounding mill weir features and defunct fish pass at the downstream end of the reach, the channel would be regraded through the south eastern corner of the main lake. This would be dug to an appropriate gradient to address the elevation difference between the lake and main channel downstream, ensuring fish passage requirements are met.

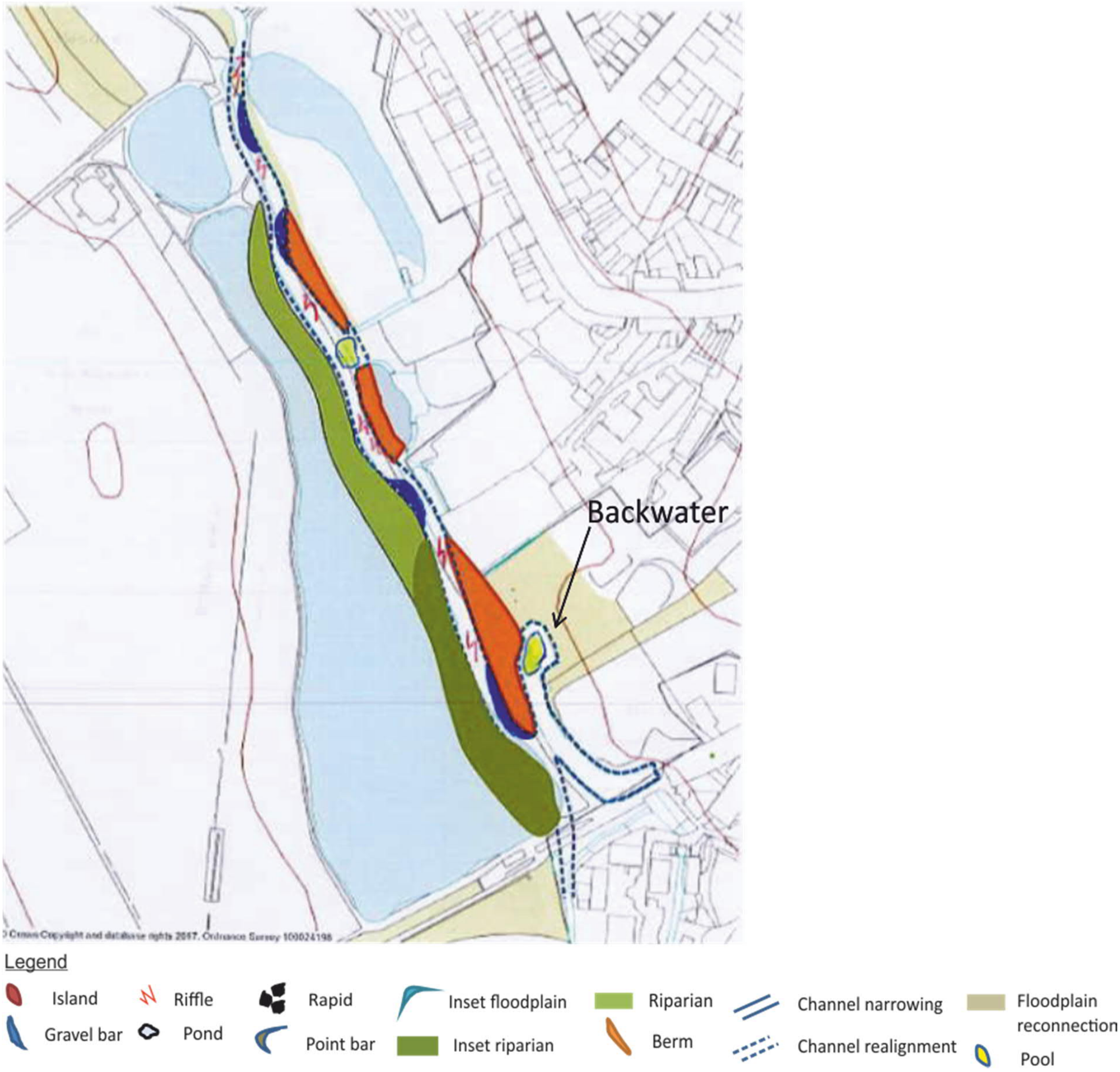


Figure K.19 Feature plans for Reach 1 Option 8

The existing course of the river would retain either a small flow, or infilled as a relict river channel. The channel around the Ye Olde Fighting Cock (PH) and mill weir are to be retained as part of this option and detailed design should ensure that flow down this channel would be minimally impacted. The point at which the gradient in the channel increases down to the end of the reach could be varied. For example the drop in gradient could occur downstream of the offtakes, so that they would be minimally impacted. However, this would reduce any hydromorphological and habitat gains in the upper half of the reach. The drop in gradient could begin downstream of the upper Verulamium lake offtake although this may mean that the offtakes downstream are impacted and further detailed design work may be needed.

To provide the space for the creation of a morphologically diverse re-aligned channel, riparian works to the east bank of the main lake would be required. The remainder of the main lake would either be retained as online or offline features, with the latter option meaning they would likely dry at times).

A plan of the features that have been included within the modelling is included as Figure K19.

Review of Constraints and Opportunities

A plan of potential constraints for Reach 1 was provided in Figure K.16. The effects of these constraints on the feasibility of this option are described in Table K.6 below, along with potential advantages/ opportunities.

Table K.6 Review of constraints and opportunities for Reach 1 Option 8

Topic	Potential Issues	Assessment of the Effect or Potential Effect of the Option
Access	Access may be difficult and even prohibitively expensive under certain circumstances	• Access for works likely to come from the east of Reach 1. Not considered to be prohibitive.
Flood Risk	As a result of re-alignment or floodplain works, flood risk from the river may decrease or increase in areas	• This option is unlikely to significantly impact existing flood risk as the channel is broadly being maintained in the same location. This would be confirmed following completion of the modelling.
Hydromorphology	Does the scheme improve the hydromorphological functioning of the reach?	• the increased hydraulic gradient through the realigned section and upstream should reduce fine sediment accumulation and create an improved gravel bed more characteristic of a chalk system as a result of bypassing the influence of the downstream weir • the hydraulic changes would mean less glide and ponded habitats through the existing main channel with an increased quantity of higher energy riffled flow.
Water transfer from the River Ver into Verulamium Lake	Water is transferred from River Ver into Verulamium Park Lakes via two culverts although one of these blocked. The flow is level dependent and so significant alternations to level in the existing channel of the Ver, close to the sluices, would result in more or less flow entering the lake.	• It is unlikely that this option would result in significant changes to this, although this would be confirmed following completion of the modelling. If it does some structural adjustments at the sluice(s) may be required.
Abstractions and other hydrological concerns	Consideration as to whether the scheme may result in other adverse or beneficial hydrological effects. For example re-routing of the river may impact upon distributaries as well as the main river.	• Water abstracted from the River Ver for St Michael's Manor Hotel at upstream end of the reach is level dependent and so significant changes in the Ver would impact upon the abstraction. At the end of Reach 1, the current channel splits into a section that flows down the fish pass and another that flows past the Ye Olde Fighting Cock PH. • It is unlikely that this option would result in significant changes to inflows to the other online lakes at the left bank although this would be confirmed following completion of the modelling. • There may be a change in flow distribution between the lake and Ye Olde Fighting Cock PH mill leat channel without further works to alter the invert levels into these zones.
Groundwater connectivity	Does the scheme affect connectivity between surface water and groundwater?	• The river bed through Reach 1 is not concrete lined therefore connectivity with a natural bed would be maintained through the minor realignment close to the existing course. Reach is considered to be a losing reach and scheme would be unlikely to have a significant effect on the amount of flow losses, with minimal additional connectivity between the surface and groundwater.
Environmental Permits / consented discharges	Significant re-routing of the system may result in less flow being in the river at the point where a consented discharge enters and less dilution of that discharge.	• One discharge is located on the left bank midway down Reach 1. The nature of this discharge is not stated although it is located at a similar location as the surface water runoff sewer. Given the minimal anticipated changes in flow in this reach the any effects of this discharge on water quality in the Ver as a result of the scheme would be minor. During construction, the discharge should be accounted so that it is not disrupted.
Heritage	Scenario has the potential to impact upon Scheduled Monument or other archaeological feature	• Reduction in water levels in the mill leat may impact upon unknown waterlogged deposits that are present. • Re-alignment not considered to affect Scheduled Monument. • Crossing The Causeway heritage feature at the same location is considered acceptable.
Water Mains and Sewers (foul and surface water)	Under certain scenarios, construction may be routed close to other water mains and sewers. If so, these may have substantive effects on the cost of the scheme, its feasibility and duration of its construction.	• Affinity Water mains are located at lower end of Reach 1. Affinity Water have advised that the depth of the water mains is unknown (and would only be known if there had been a recent burst, which seems to not be the case). A trial hole may be required to establish depth. • There is a Thames Water foul sewer that extends along the reach between the River Ver and Lakes. This is at a depth of ~3.8m bgl and should not be impacted by the works. There is also a foul sewer that runs partially along the causeway at a depth of ~2.5m bgl. This would likely be impacted by the works at the lower end of the lake and would need to be accounted for (which could be costly). • Two separate below ground surface water sewer pipelines (owned by Thames Water) enter the River Ver on the left hand bank. The depths of the more northern of these is unknown while the other is at 4m bgl. These should be acknowledged during the works although are not considered to be prohibitive. • Affinity Water mains also lie below ground and in the eastern end of the Causeway, though works not anticipated to affect these.
Other Utilities	Under certain scenarios, construction may be routed close to other utilities, such as BT or gas mains. If so, these may have substantive effects on the cost of the scheme, its feasibility and duration of its construction.	• There are no other utilities close to the area that would be restored under this option.
Geo-environmental	A potential issue if river is re-aligned through areas which may potentially be contaminated	• River is not re-aligned through areas identified as being potentially contaminated. These are also unlikely to be encompassed during construction works too.
Local Wildlife Sites (Non-statutory)	Wildlife sites lie throughout the study area and could potentially be impacted by the scenarios	• The necessary works are close to Local Wildlife Sites though these are not likely to be directly impacted by the works.
Fish passage	At present the fish pass at the lower end of Reach 1 is not considered to function and is serving as a barrier for upstream fish passage	• Scheme would provide a bypass around the existing fish pass enabling fish passage
Tree Protection Orders (TPO)	Consideration of the effect of Tree Protection Orders on the option	• TPOs are extensive on the left bank of the existing channel and may have an impact upon access, construction and tree works to improve channel light levels.
Public Rights of Way	Public Rights of Way may need to be diverted if works are would occur over their route	• A public right of way extends throughout the route of the works proposed by this scenario and would need to be diverted for the duration of the works. • Overall, public access to the river would be improved as a result of the works.
Landscape impact	Review whether option would have a significant visual impact	• The option would result in a small reduction in the surface area of the larger of the Verulamium Lakes and a change to the river. The improvements to the river are likely to improve its appearance which may increase the number of people wishing to walk along the river.
Recreation and amenity	Review whether option would have significant impacts upon recreation and amenity	• The option would result in a small reduction in the surface area of the larger of the Verulamium Lakes. This is not considered to have a significant impact upon recreation or amenity. The improvements to the river are likely to improve its appearance which may increase the number of people wishing to walk along the river. A riverside path would be maintained. • Associated improvements works, such as boardwalk paths through newly created wetland areas, could help improve access to the river through the reach although would be an additional maintenance commitment for the council.
Riparian ownership issues	Consideration as to whether option may require re-routing through lands that are privately owned or result in riparian changes that may be unacceptable.	• The river would be altered and riparian owners on the left bank could be adversely impacted. Their ability to obtain water from the river, for example through existing offtakes may also be impacted. • Work would also be undertaken from their land.

Reach 1 Option 14

Option Description and Restoration Plan

Under this option, the existing channel course would be maintained, the mill weir lowered and the fish pass re-designed. The river would be subject to de-silting, in-channel re-profiling and incorporation of a suitable morphology through the creation of numerous gravel/point bar and island features (as illustrated in Figure K.20, which also shows the features including within the modelling). In addition, bank softening works along the course of the existing channel would aim to tie in with the in-channel enhancement works.

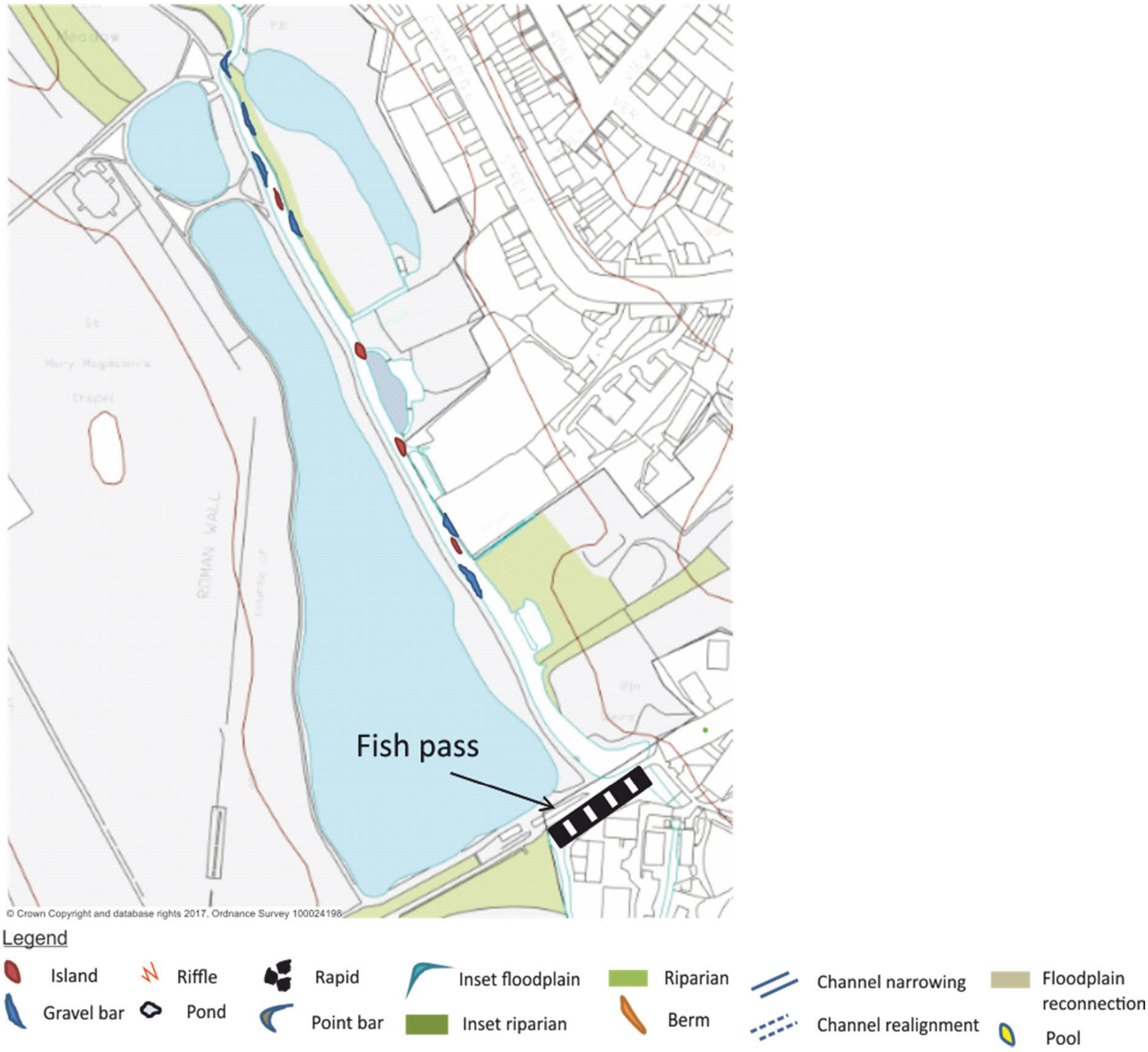


Figure K.20 Feature plans for Reach 1 Option 14

A re-design of the existing (defunct) fish pass would need to provide passage for the widest range of species across the widest range of flows where possible.

Lowering the mill weir at the downstream end of the reach would aim to reduce impoundment in the restored reach upstream. The flow split around the Ye Olde Fighting Cock (PH) and mill weir are to be retained as part of this option.

Review of Constraints and Opportunities

A plan of potential constraints for Reach 1 was provided in Figure K.16. The effects of these constraints on the feasibility of this option are described in Table K.7 below, along with potential advantages/ opportunities.

Table K.7 Review of constraints and opportunities for Reach 1 Option 14

Topic	Potential Issues	Assessment of the Effect or Potential Effect of the Option
Access	Access may be difficult and even prohibitively expensive under certain circumstances	• Access for works likely to come from the east of Reach 1. Not considered to be prohibitive.
Flood Risk	As a result of re-alignment or floodplain works, flood risk from the river may decrease or increase in areas	• This option is unlikely to significantly impact the current flood risk due to the channel being retained in the same position and the works unlikely to cause a significant impact under flood flows. This would be confirmed following completion of the modelling.
Hydromorphology	Does the scheme improve the hydromorphological functioning of the reach?	• Without any weir lowering, the current flow splits between the lakes and the Ye Olde Fighting Cock PH channel are unlikely to be significantly altered dependent on the fish pass design chosen • Without works to alter the weir crest level into the fish pass, the proposed morphological changes may create only minor hydromorphological improvements through the reach with local narrowing creating small areas of gravel bed improvement • Without works to alter the weir crest level, the proposed morphological improvements would likely create only localised improvements in hydraulics within the current impounded zone.
Water transfer from the River Ver into Verulamium Lake	Water is transferred from River Ver into Verulamium Park Lakes via two culverts although one of these blocked. The flow is level dependent and so significant alternations to level in the existing channel of the Ver, close to the sluices, would result in more or less flow entering the lake.	• It is unlikely that this option would result in significant changes to inflows to the other online lakes at the left bank , although this would be confirmed following completion of the modelling. If it does some structural adjustments at the sluice(s) may be required.
Abstractions and other hydrological concerns	Consideration as to whether the scheme may result in other adverse or beneficial hydrological effects. For example re-routing of the river may impact upon distributaries as well as the main river.	• Water abstracted from the River Ver for St Michael's Manor Hotel at upstream end of the reach is level dependent and so significant changes in the Ver would impact upon the abstraction. At the end of Reach 1, the current channel splits into a section that flows down the fish pass and another that flows past the Ye Olde Fighting Cock PH. • It is unlikely that this option would result in significant changes to the abstraction although this would be confirmed following completion of the modelling. • The option may not significantly improve the hydromorphological functioning of the reach without works to lower the invert into the fish pass. This may consequently impact the flow split into the Ye Olde Fighting Cock PH channel without works to this weir level as well
Groundwater connectivity	Does the scheme affect connectivity between surface water and groundwater?	• The river bed through Reach 1 is not concrete lined therefore connectivity with a natural bed would be maintained. Reach is considered to be a losing reach and scheme would be unlikely to have a significant effect on the amount of flow losses, with minimal additional connectivity between the surface and groundwater.
Environmental Permits / consented discharges	Significant re-routing of the system may result in less flow being in the river at the point where a consented discharge enters and less dilution of that discharge.	• One discharge is located on the left bank midway down Reach 1. The nature of this discharge is not stated although it is located at a similar location as the surface water runoff sewer. Given the minimal anticipated changes in flow in this reach the any effects of this discharge on water quality in the Ver as a result of the scheme would be minor. During construction, the discharge should be accounted so that it is not disrupted.
Heritage	Scenario has the potential to impact upon Scheduled Monument or other archaeological feature	• Weir lowering and fish pass re-design works not considered to affect Scheduled Monument or other archaeological features, including during works. It would also not have a potential effect on the causeway (considered to be of high heritage significance).
Water Mains and Sewers (foul and surface water)	Under certain scenarios, construction may be routed close to other water mains and sewers. If so, these may have substantive effects on the cost of the scheme, its feasibility and duration of its construction.	• Affinity Water mains are located at lower end of Reach 1. . A trial hole may be required to establish depth. • There is a Thames Water foul sewer that extends along the reach between the River Ver and Lakes. This is at a depth of ~3.8m bgl and should not be impacted by the works. There is also a foul sewer that runs partially along the causeway at a depth of ~2.5m bgl. This may be impacted by any works to the fish pass. • Two separate below ground surface water sewer pipelines (owned by Thames Water) enter the River Ver on the left hand bank. The depths of the more northern of these is unknown while the other is at 4m bgl. These should be acknowledged during the works although are not considered to be prohibitive. • Affinity Water mains also lie below ground and in the eastern end of the Causeway, though works not anticipated to affect these.
Other Utilities	Under certain scenarios, construction may be routed close to other utilities, such as BT or gas mains. If so, these may have substantive effects on the cost of the scheme, its feasibility and duration construction.	• There are no other utilities close to the area that would be restored under this option
Geo-environmental	Consideration as to whether scheme could result in pathways for contaminants to enter the water environment.	• Weir lowering and fish pass re-design works are not undertaken in areas identified as being potentially contaminated. Such areas are also unlikely to be encompassed during construction works too.
Local Wildlife Sites (Non-statutory)	Wildlife sites lie throughout the study area and could potentially be impacted by the scenarios	• The necessary works are close to Local Wildlife Sites though these are not likely to be directly impacted by the works.
Fish passage	At present the fish pass at the lower end of Reach 1 is not considered to function and is serving as a barrier for upstream fish passage	• Scheme would result in an improved fish pass that would improve upstream fish passage from Reach 2 into Reach 1 (although the barrier would still remain and not be bypassed). Work would be restricted to the existing fish pass channel which would likely mean that passage for all species and ages may not be achievable.
Tree Protection Orders (TPO)	Consideration of the effect of Tree Protection Orders on the option	• TPOs are extensive on the left bank of the existing channel and may have an impact upon access, construction and tree works to improve channel light levels.
Public Rights of Way	Public Rights of Way may need to be diverted if works are would occur over their route	• A public right of way extends throughout the route of the works proposed by this scenario and would need to be diverted for the duration of the works. • Overall, public access to the river would be improved as a result of the works.
Other Costs	Identification of potentially significant costs or aspects that are comparably low cost	• Compared to the other Reach 1 options, this option would not result in significant changes to the lake and so there are no costs associated with this option and lake improvements. • There would be costs associated with any fish passage improvements or re-design. These are likely to be relatively costly.
Landscape impact	Review whether option would have a significant visual impact	• River and fish pass works associated with this option are unlikely to have any significant landscape effects.
Recreation and amenity	Review whether option would have significant impacts upon recreation and amenity	• The option would not have a significant effect on recreation or amenity, although on its own may be deemed as a wasted opportunity to improve the situation.
Riparian ownership issues	Consideration as to whether option may require re-routing through lands that are privately owned or result in riparian changes that may be unacceptable.	• Changes to the weir would require owner permissions and this not be straightforward.

Determination of the Preferred Reach 1 Option

From a hydromorphological perspective, Options 5, 7 and 8 represent the greatest potential improvement given they bypass the impact of the weirs at the downstream end of the reach meaning features and habitats more closely associated with a chalk stream would be created. Of these, Options 7 and 8 offer the greatest benefit through the development of functional morphology and generation of valuable marginal habitat. Option 5 offers similar benefit in terms of bypassing the impact of the downstream weirs, however marginal habitat improvement is reduced without re-alignment and significant bank works. Option 14 offers the least significant environmental benefit due to retaining the impact of the weirs (although this impact would be reduced).

Considering only those options with significant environmental benefit (Options 5, 7 and 8), the constraints to each option were of critical importance. The most significant constraint in Reach 1 is Verulamium Lake, with modifications to the lake having both cost and amenity implications. On this basis, Option 5 would provide the best restoration option due to the limited impact on the existing lake landscape and recreation and amenity value. In contrast, the lake modifications in Options 7 and 8 represent higher costs and changes to current amenity and recreation value. Aspects of Option 7 are also likely to negatively impact the Scheduled Monument, the landscape of the area and would not be likely to be viewed favourably by the public.

The option selected for Reach 1 was a combination of Options 7 and 8 given these options represented the greatest potential environmental gain and taking a hybrid approach could resolve some of the issues presented by each of the options when considered separately. The preferred option keeps part of the river on its existing course with in-channel feature improvement works and then moves the channel through the south eastern corner of the lake (Plate 2), and through the Causeway, to bypass the fish pass and associated weirs. It also enables flow to be maintained in the mill leat channel by the Abbey Mill and inflow to the lake to be maintained which were key requirements of the restoration design. This can be undertaken in tandem with a number of lake only improvement options (described in Section K.3).

Table K.8 provides a compiled review of the constraints and opportunities for the Reach 1 options. The discussion of each constraint/ opportunity for each option has been coloured accordingly:

- Green – Desired improvements and project objectives achieved. No constraints identified in relation to the category in question.
- Yellow - Desired improvements and project objectives achieved. Low or moderate mitigation costs and/ or constraints identified in relation to the category in question.
- Orange - Desired improvements and project objectives achieved. Moderate or high mitigation costs and/ or constraints identified in relation to the category in question.
- Red – Desired improvements and project objectives may not be achieved and/ or high mitigation costs and/ or major constraints identified in relation to the category in question that may be difficult or expensive to overcome.

Table K.9 Reach 1 Summary Table (see text for legend colouring)

Constraint/ Opportunity	Effect or Potential Effect of Reach 1 Option 5	Effect or Potential Effect of Reach1 Option 7	Effect or Potential Effect of Reach 1 Option 8	Effect or Potential Effect of Reach 1 Option 14
Access	• Access for works likely to come from the east of Reach 1. Not considered to be prohibitive.	• Access for the works could be complex and come from the east and north west of the lake. It may also be disruptive.	• Access for works likely to come from the east of Reach 1. Not considered to be prohibitive.	• Access for works likely to come from the east of Reach 1. Not considered to be prohibitive.
Flood Risk	• It is unlikely to significantly impact the flooding extent compared to baseline as the connectivity to the left and right bank floodplains should be maintained through incorporation of the described morphology. This would be confirmed following completion of the modelling.	• The option may pose a flood risk increase to the Scheduled Monument over the right hand bank close to the realigned section of channel. This would be confirmed following completion of the modelling.	• This option is unlikely to significantly impact existing flood risk as the channel is broadly being maintained in the same location. This would be confirmed following completion of the modelling.	• This option is unlikely to significantly impact the current flood risk due to the channel being retained in the same position and the works unlikely to cause a significant impact under flood flows. This would be confirmed following completion of the modelling.
Hydro-morphology	• The increased hydraulic gradient through the realigned section and upstream should reduce fine sediment accumulation and create an improved gravel bed more characteristic of a chalk system; and • The hydraulic changes would mean less glide and ponded habitats through the existing main channel with an increased quantity of higher energy riffled flow. • These would be confirmed following completion of the modelling.	• Bypassing the influence of the weirs into the fish pass would improve flow hydraulics through the realigned section of channel, encouraging transport of finer sediments • The predominant glide and ponded habitats in the existing main channel would be replaced by higher energy riffle and shorter pool units through the realigned section of channel. • These would be confirmed following completion of the modelling.	• The increased hydraulic gradient through the realigned section and upstream should reduce fine sediment accumulation and create an improved gravel bed more characteristic of a chalk system as a result of bypassing the influence of the downstream weir • The hydraulic changes would mean less glide and ponded habitats through the existing main channel with an increased quantity of higher energy riffled flow.	• Without any weir lowering, the current flow splits between the lakes and the Ye Olde Fighting Cock PH channel are unlikely to be significantly altered dependent on the fish pass design chosen • Without works to alter the weir crest level into the fish pass, the proposed morphological changes may create only minor hydromorphological improvements through the reach with local narrowing creating small areas of gravel bed improvement • Without works to alter the weir crest level, the proposed morphological improvements would likely create only very localised improvements in hydraulics within the current impounded zone.
Water transfer from the River Ver into Verulamium Lake	• It is unlikely that this option would result in significant changes to this, although this would be confirmed following completion of the modelling. If it does some structural adjustments at the sluice(s) may be required.	• It is likely that new structures would be required to achieve the desired inflow to the lake (or remaining parts of it where an inflow is desired) and the location of these would need to be determined through detailed design.	• It is unlikely that this option would result in significant changes to this, although this would be confirmed following completion of the modelling. If it does some structural adjustments at the sluice(s) may be required.	• It is unlikely that this option would result in significant changes to this, although this would be confirmed following completion of the modelling. If it does some structural adjustments at the sluice(s) may be required.
Abstractions and other hydrological concerns	• It is unlikely that this option would result in significant changes to inflows to the other online lakes at the left bank although this would be confirmed following completion of the modelling. • There may be a change in flow distribution between the lake and Ye Olde Fighting Cock PH mill leat channel without further works to alter the invert levels into these zones	• Water abstracted from the River Ver for St Michael's Manor Hotel at upstream end of the reach is level dependent and so significant changes in the Ver would impact upon the abstraction. At the end of Reach 1, the current channel splits into a section that flows down the fish pass and another that flows past the Ye Olde Fighting Cock PH. • It is unlikely that this option would result in significant changes to inflows to the other online lakes at the left bank although this would be confirmed following completion of the modelling. • There may be a change in flow distribution between the lake and Ye Olde Fighting Cock PH mill leat channel without further works to alter the invert levels into these zones.	• Water abstracted from the River Ver for St Michael's Manor Hotel at upstream end of the reach is level dependent and so significant changes in the Ver would impact upon the abstraction. At the end of Reach 1, the current channel splits into a section that flows down the fish pass and another that flows past the Ye Olde Fighting Cock PH. • It is unlikely that this option would result in significant changes to inflows to the other online lakes at the left bank although this would be confirmed following completion of the modelling. • There may be a change in flow distribution between the lake and Ye Olde Fighting Cock PH mill leat channel without further works to alter the invert levels into these zones.	• Water abstracted from the River Ver for St Michael's Manor Hotel at upstream end of the reach is level dependent and so significant changes in the Ver would impact upon the abstraction. At the end of Reach 1, the current channel splits into a section that flows down the fish pass and another that flows past the Ye Olde Fighting Cock PH. • It is unlikely that this option would result in significant changes to the abstraction although this would be confirmed following completion of the modelling. • The option may not significantly improve the hydromorphological functioning of the reach without works to lower the invert into the fish pass. This may consequently impact the flow split into the Ye Olde Fighting Cock PH channel without works to this weir level as well
Ground-water connectivity	• The river bed through Reach 1 is not concrete lined therefore connectivity with a natural bed would be maintained. Reach is considered to be a losing reach and scheme would be unlikely to have a significant effect on the amount of flow losses, with minimal additional connectivity between the surface and groundwater.	• Breaking out of the lake bed lining would help to restore a more natural connection with groundwater although the reach was found to be a losing reach, so this may result in a reduction in flow in the river at most times.	• The river bed through Reach 1 is not concrete lined therefore connectivity with a natural bed would be maintained through the minor realignment close to the existing course. Reach is considered to be a losing reach and scheme would be unlikely to have a significant effect on the amount of flow losses, with minimal additional connectivity between the surface and groundwater.	• The river bed through Reach 1 is not concrete lined therefore connectivity with a natural bed would be maintained. Reach is considered to be a losing reach and scheme would be unlikely to have a significant effect on the amount of flow losses, with minimal additional connectivity between the surface and groundwater.
Environ-mental Permits / consented discharges	• One discharge is located on the left bank midway down Reach 1. The nature of this discharge is not stated although it is located at a similar location as	• One discharge is located on the left bank midway down Reach 1. Given that much of the flow would be re-routed this discharge would need to be re-	• One discharge is located on the left bank midway down Reach 1. The nature of this discharge is not stated although it is located at a similar location as	• One discharge is located on the left bank midway down Reach 1. The nature of this discharge is not stated although it is located at a similar location as the surface

	the surface water runoff sewer. Given the minimal anticipated changes in flow in this reach the any effects of this discharge on water quality in the Ver as a result of the scheme would be minor. During construction, the discharge should be accounted so that it is not disrupted.	routed too, or else it may have a significant impact upon on water quality in the channel that remains (noting that the nature of this discharge is not stated and it may be linked with a surface water runoff sewer).	the surface water runoff sewer. Given the minimal anticipated changes in flow in this reach the any effects of this discharge on water quality in the Ver as a result of the scheme would be minor. During construction, the discharge should be accounted so that it is not disrupted.	water runoff sewer. Given the minimal anticipated changes in flow in this reach the any effects of this discharge on water quality in the Ver as a result of the scheme would be minor. During construction, the discharge should be accounted so that it is not disrupted.
Heritage	• Re-alignment not considered to affect Scheduled Monuments or other archaeological features, including during works. • It would have a potential effect on The Causeway which is considered to be of high heritage significance.	• Re-alignment would bring the river closer to the Scheduled Monument. It has been positioned to be outside of the boundaries of the site although the option itself could have an effect of its setting, which may be problematic to mitigate for. Other archaeological feature in the lake may be disrupted and require additional archaeological inputs, such as watching brief. The option would also have a potential effect on The Causeway which is considered to be of high heritage significance. • Water levels and flow velocities through the mill leat channel would be likely to change, and the degree to which waterlogged deposits may be affected is uncertain.	• Reduction in water levels at the Mill Leat may impact upon unknown waterlogged deposits that are present. • Re-alignment not considered to affect Scheduled Monument. • Crossing The Causeway heritage feature at the same location is considered acceptable.	• Weir lowering and fish pass re-design works not considered to affect Scheduled Monument or other archaeological features, including during works. It would also not have a potential effect on the causeway (considered to be of high heritage significance).
Water Mains and Sewers (foul and surface water)	• There is a Thames Water foul sewer that extends along the reach between the River Ver and Lakes. This is at a depth of ~3.8m bgl and should not be impacted by the works. There is also a foul sewer that runs partially along the causeway at a depth of ~2.5m bgl. This would likely be impacted by the works at the lower end of the lake and would need to be accounted for (which could be costly). • Two separate below ground surface water sewer pipelines (owned by Thames Water) enter the River Ver on the left hand bank. The depths of the more northern of these is unknown while the other is at 4m bgl. These should be acknowledged during the works although are not considered to be prohibitive. • Affinity Water mains also lie below ground and in the eastern end of the Causeway, though works not anticipated to affect these.	• There is a Thames Water foul sewer that extends along the reach between the River Ver and Lakes. Works are only intended at the northern end of this sewer and in this region the sewer is at a depth of ~3.8m bgl and should not be impacted by the works. • Two separate below ground surface water sewer pipelines (owned by Thames Water) enter the River Ver on the left hand bank downstream of where it is re-routed. The works should not impact upon these although a reduction in flow would mean there would be less dilution capacity within the relict river. • Affinity Water mains also lie below ground and in the eastern end of the Causeway, though works not anticipated to affect these.	• There is a Thames Water foul sewer that extends along the reach between the River Ver and Lakes. This is at a depth of ~3.8m bgl and should not be impacted by the works. There is also a foul sewer that runs partially along the causeway at a depth of ~2.5m bgl. This would likely be impacted by the works at the lower end of the lake and would need to be accounted for (which could be costly). • Two separate below ground surface water sewer pipelines (owned by Thames Water) enter the River Ver on the left hand bank. The depths of the more northern of these is unknown while the other is at 4m bgl. These should be acknowledged during the works although are not considered to be prohibitive. • Affinity Water mains also lie below ground and in the eastern end of the Causeway, though works not anticipated to affect these.	• There is a Thames Water foul sewer that extends along the reach between the River Ver and Lakes. This is at a depth of ~3.8m bgl and should not be impacted by the works. There is also a foul sewer that runs partially along the causeway at a depth of ~2.5m bgl. This may be impacted by any works to the fish pass. • Two separate below ground surface water sewer pipelines (owned by Thames Water) enter the River Ver on the left hand bank. The depths of the more northern of these is unknown while the other is at 4m bgl. These should be acknowledged during the works although are not considered to be prohibitive. • Affinity Water mains also lie below ground and in the eastern end of the Causeway, though works not anticipated to affect these.
Other Utilities	• There are no other utilities close to the area that would be restored under this option	• There are no other utilities close to the area that would be restored under this option	• There are no other utilities close to the area that would be restored under this option.	• There are no other utilities close to the area that would be restored under this option
Geo-environ-mental	• River is not re-aligned through areas identified as being potentially contaminated. Such areas are also unlikely to be encompassed during construction works too.	• River is not re-aligned through areas identified as being potentially contaminated (with lake sediments being identified as not hazardous). Such areas are also unlikely to be encompassed during construction works too.	• River is not re-aligned through areas identified as being potentially contaminated. These are also unlikely to be encompassed during construction works too.	• Weir lowering and fish pass re-design works are not undertaken in areas identified as being potentially contaminated. Such areas are also unlikely to be encompassed during construction works too.
Wildlife Sites	• The necessary works are close to Local Wildlife Sites though these are not likely to be directly impacted by the works.	• The re-routing through the lakes would be in the immediate vicinity of the two islands that are Local Wildlife Sites. This would have an impact upon the construction activities and require suitable approval. The works may provide an opportunity to improve wildlife, such as the heronry, through the lake.	• The necessary works are close to Local Wildlife Sites though these are not likely to be directly impacted by the works.	• The necessary works are close to Local Wildlife Sites though these are not likely to be directly impacted by the works.
Fish passage	• Scheme would provide a bypass around the existing fish pass enabling fish passage. Rapid features not ideal for passage of all species although inclusion of other lower gradient features may achieve this. This would be explored further if	• Scheme would provide a bypass around the existing fish pass enabling fish passage	• Scheme would provide a bypass around the existing fish pass enabling fish passage	• Scheme would result in an improved fish pass that would improve upstream fish passage from Reach 2 into Reach 1 (although the barrier would still remain and not be bypassed). Work would be restricted to the existing fish pass channel which would likely mean that

	this option is the preferred option.			passage for all species and ages may not be achievable.
Tree Protection Orders (TPO)	• TPOs are extensive on the left bank of the existing channel and may have an impact upon access, construction and tree works to improve channel light levels.	• TPOs are extensive on the left bank of the existing channel although the proposed works are not likely to be significantly impacted upon by these.	• TPOs are extensive on the left bank of the existing channel and may have an impact upon access, construction and tree works to improve channel light levels.	• TPOs are extensive on the left bank of the existing channel and may have an impact upon access, construction and tree works to improve channel light levels.
Public Rights of Way	• A public right of way extends throughout the route of the works proposed by this scenario and would need to be diverted for the duration of the works. • Overall, public access to the river would be improved as a result of the works.	• A public right of way extends along the reach between the River Ver and Lakes. This would be impacted by the option at the northern end of the works and would need to be diverted for the duration of the works. • Overall, public access to the river would be improved as a result of the works.	• A public right of way extends throughout the route of the works proposed by this scenario and would need to be diverted for the duration of the works. • Overall, public access to the river would be improved as a result of the works.	• A public right of way extends throughout the route of the works proposed by this scenario and would need to be diverted for the duration of the works. • Overall, public access would be improved as a result of the works.
Landscape impact	• River works along the existing channel would visually improve the appearance of the river and works at the lower of the lake should have minimal visual impacts as the river/ land would be lowered in the area.	• Extensive re-alignment of the river through the lakes would result in significant visual changes that could be considered negatively, without significant mitigation.	• The option would result in a small reduction in the surface area of the larger of the Verulamium Lakes and a change to the river. The improvements to the river are likely to improve its appearance which may increase the number of people wishing to walk along the river.	• River and fish pass works associated with this option are unlikely to have any significant landscape effects.
Recreation and amenity	• The option would result in a small reduction in the surface area of the larger of the Verulamium Lakes. This is not considered to have a significant impact upon recreation or amenity. The improvements to the river are likely to improve its appearance which may increase the number of people wishing to walk along the river.	• The option would result in a large change to river and lake throughout reach one, which would have a significant impact upon recreation and amenity in the watercourses. For example, the boating lake would likely no longer be functioning, however a new boating lake could be developed. • Re-routing of the river and associated improvements works, such as boardwalk paths through newly created wetland areas, could help improve access to the river through the reach although would be an additional maintenance commitment for the council.	• The option would result in a small reduction in the surface area of the larger of the Verulamium Lakes. This is not considered to have a significant impact upon recreation or amenity. The improvements to the river are likely to improve its appearance which may increase the number of people wishing to walk along the river. A riverside path would be maintained. • Associated improvements works, such as boardwalk paths through newly created wetland areas, could help improve access to the river through the reach although would be an additional maintenance commitment for the council.	• The option would not have a significant effect on recreation or amenity, although on its own may be deemed as a wasted opportunity to improve the situation.
Riparian ownership issues	• Potential impacts to the offline lakes are discussed above under abstraction and other hydrological information. Through detailed investigations it should be possible that these would not be adversely impacted under this scenario. • Water levels past the public house may be reduced as a result of splitting the flow. This would be confirmed following completion of the modelling.	• Water levels in the Mill Leat channel are likely to be impacted by the option and there may be some drying of the channel under low flow conditions. This would likely make the channel less visually appealing to riparian owners. • Their ability to obtain water from the river, for example through existing offtakes may also be impacted.	• The river would be altered and riparian owners on the left bank could be adversely impacted. Work would also be undertaken from their land. • Their ability to obtain water from the river, for example through existing offtakes may also be impacted. • Water levels past the public house may be reduced as a result of splitting the flow. This would be confirmed following completion of the modelling.	• Changes to the weir would require permission from its owner and this may be difficult to achieve.

K.5 Further Appraisal of Shortlisted Lake only Restoration Measures

Introduction

Further to the long-listing appraisal of potential lake only restoration measures, a review of those measures that were shortlisted (for further consideration) has been undertaken acknowledging the results of additional studies on the lake that have been recently completed. These studies are discussed separately in the note entitled "Lake Studies to Inform Review of Shortlisted Options" which was issued on the 6th October 2017.

Review

The preferred lake/river option for Reach 1 is a hybrid of options 7 and 8. The appraisal of these options and the other Reach 1 options is provided in the accompanying Short List Appraisal chapter.

Accounting for the results of the recent studies the review has looked at the key requirements of the lake restoration, namely that solutions are feasible, sustainable and considered to be value for money. The results of the review are presented in Table K.9 overleaf. The review of the longlisting was completed by the Project Steering Group while the subsequent Feasibility Review was undertaken by AECOM and reviewed by the Project Steering Group.

Following the review, the remaining lake only measures are as follows:

- Partial infilling/ narrowing;
- Partial removal of the concrete bed and re-profiling;
- Wetland creation/ planting of marginal, submergent and floating plants;
- Removing fish from the lake, and replacement with more appropriate species;
- Varying abstraction from the River Ver into the lake (noting that the current flow rate needs to be investigated further);
- Dredging of all sediments within the lake; and
- Island enlargement.

It is considered that these measures are complimentary to one another. Funding may limit certain aspects, for example the dredging of all materials which may be expensive if it cannot be re-used..

Table K.9 Further Review of Lake only restoration measures

Sub-option		Option description and Rationale	Longlisting Review and whether ruled in or out at long listing stage (18-4-2017)	Feasibility review (13-10-17) based on results of additional lake studies	Considered Sustainable (13-10-17)	Considered to be Value for Money (if considered feasible and sustainable) (13-10-17)
A	Complete lake infilling	Lake would be infilled with soil, then grassed and landscaped. Would remove the risk of algal blooms and associated avian botulism.	This option would result in an important characteristic feature of the area with amenity and recreational benefits. It was hence ruled out at long listing stage.	n/a	n/a	n/a
B	Partial infilling/ narrowing	Lake could be partially infilled. This would increase the rate of throughflow through the system which would help with flushing.	On its own this would need to be a significant piece of remediation work to make a difference to nutrient levels and algal blooms. This would not be considered appropriate given the value of the lakes. More limited narrowing may be complimentary to other options.	Additional lake studies suggest that this would still be feasible. Although would still be subject to a degree of sedimentation.	Would be considered sustainable subject to careful and integrated design	This would be considered as value for money if undertaken as part of a well-considered re-design scheme of the lake that included the other measures, discussed below in this column below.
C1	Full removal of the concrete bed removal and re-profiling	Concrete bed removal (full/ partial or banks) would help create a more natural feature through re-profiling and deepening of parts. Varying depths could potentially help improve circulatory patterns in the system which in turn would help improve water quality/ dissolved oxygen levels through increased mixing. Option would also improve the substrate and make it more suitable for macrophytes to establish. Removal of concrete on banks could allow better establishment of marginal vegetation.	Ruled in. In addition to potential water quality and naturalisation benefits, the option may result in lake becoming groundwater fed and hydrologically self-sustaining. This would be considered a positive (assuming that sediments are removed if they are found to be hazardous and if groundwater levels are high enough to feed the lake following anticipated groundwater recharge in the area) and would also mean that river improvements could be greater as more flow would be retained in that system. Removal of concrete bed may result in contamination of groundwater unless potentially hazardous sediment is removed or remediated.	Studies looking into the effect of the forthcoming Affinity Water sustainability reductions on groundwater emergence, and consideration of groundwater levels close to the lake suggest that groundwater would not be a reliable source of water to the lake. Furthermore the groundwater studies have indicated that it is considered to be a losing reach so the lake may lose flow into the ground through the reach. Removal of concrete on sections of the bank could lead to water loss, though it may be possible to lower sections of the concrete bank to just above the average water level.	No, given that flow would be lost through the lake.	n/a
C2	Partial removal of the concrete bed and re-profiling. To possibly include deepening and relining sections of the lake.				Yes, but only if restricted to discrete areas, where other improvements are proposed (for example the south east corner of the lake where the river may be re-aligned through).	Should be limited to small areas where river re-alignment through part of the lake is recommended. Large scale removal, deepening and relining may not be value for money compared to other options.
D	Wetland creation/ planting of marginal, submergent and floating plants	A variety of macrophytes could be introduced into the lake. These would be marginal (for example phragmites), floating (for example Nuphar lilies) or submerged . Introduction of these should help improve water quality in the lake as these would absorb nutrients.	Ruled in. Introduction of vegetation would not on its own improve the situation but could be part of a package of restoration measures. Vegetation should be selected that is not desired by Canada geese for grazing, for example they do not like to graze of established Phragmites. There is a risk of non-natives being introduced when introducing vegetation. Potential stockists should be screened carefully so that this does not occur. Avoiding marginal areas which support water plants would also restrict the food supply for the geese, but this may adversely affect other waterfowl and/or limit the ecological potential.	Yes	Yes, subject to other measures being implemented to limit Canada geese in the lake and to protect the vegetation from being grazed.	Yes, subject to other measures being implemented to limit Canada geese in the lake and to protect the vegetation from being grazed. Should be part of a wider package of works.

Sub-option		Option description and Rationale	Longlisting Review and whether ruled in or out at long listing stage (18-4-2017)	Feasibility review (13-10-17) based on results of additional lake studies	Considered Sustainable (13-10-17)	Considered to be Value for Money (if considered feasible and sustainable) (13-10-17)
E	Disconnecting lake and river	This would involve closing off abstractions into the lake and/ or the discharge from the lake. This could improve water quality in the river (as water of poorer water quality from the lake would not enter it).	Tentatively ruled in, but warranting further investigation. Would result in potential improvements to the River Ver by providing more flow to that system and lowering the risk of water of poorer quality entering the river from the lake. Not an ideal sub-option for the lake though, due to reduced flow through the lake which would result in it becoming more eutrophic over time and so this sub-option should only be considered in combination with other sub-options (for example if the lake became groundwater fed as a result of sub-option C, or if groundwater can be pumped into the lake, though capital and operational/maintenance costs may be prohibitive).	As a result of the additional groundwater studies, it was not considered to be sufficient to maintain flow in the lake and so disconnecting from the river is not considered feasible (with water quality in and visual appearance of the lake likely to deteriorate).	Groundwater pumping is not considered to be a sustainable option, as it would require active pumping, and associated maintenance, compared with the more passive operational measures considered.	There would be capital, operational and maintenance costs associated with this option, which could be avoided through the selection of more passive interventions.
G	Varying abstraction regime from the River Ver	This would involve the river only providing flows at times of high flow.	The current arrangements of flow into the lake are yet to be established (hydraulic model not yet complete). The current inflow(s) are gravity fed and so flows from the river only occur at higher flows. Option not discounted and could potentially form part of a larger in-combination option.	The flow into the upstream lake yet to be confirmed and is considered to be complicated by the upstream structure being currently set at a level that would only let flow over it in winter flows and above. It is unclear whether this sluice structure is operated to allow flow in at certain times of year. The structure may need to be replaced to ensure a degree of flow split is retained, linked to some of the options that may impact river water levels at this point.	Would be considered sustainable subject to careful and integrated design	Yes, subject to an appropriate structure design and preferably one that can be operated to adjust inlet levels at times of low flow.
H	Removing fish from the lake	Remove carp from the lake. This would increase the zooplankton population that graze on algae, whilst also reducing the amount of lake bed sediment disturbance, helping maintain a clear lake water environment.	Fish removal and relocation would likely be required for in-lake works and so this option would likely be included within the preferred option.	Yes	Yes as wouldn't need repeating, unless local anglers restock the lake without permission.	Yes, as would be undertaken anyway if lake works were being done. Reintroduction of more appropriate species may be necessary to sustain the heronry, but unlikely to be prohibitively expensive.
I	Physical aeration or oxygenation of the lake	Would occur through air or oxygen injection (for example via an injection system or boat based bubblers) or via a fountain (pump driven).	Potential to help improve oxygen levels in the system. Current and proposed depths in the lake may be insufficient for a number of aerator or mixing systems to be installed. Boat based system may be preferred unless lay out of the lakes changes substantially. Benefits would be maximised in combination with a number of other sub-options.	Yes	No as would be required for the foreseeable future with ongoing running and maintenance costs	n/a
J	Chemical Oxygenation of the lake	Dosing of the system with chemicals that would generate oxygen once released into the lake.	Could include dosing of chemicals such as hydrogen peroxide or Ozone dosing. Expensive chemicals ruled out. Potentially hazardous and chemical dosing is not considered sustainable.	Yes	No as would be required for the foreseeable future with ongoing costs of purchase and labour	n/a
K	Physical mixing of the lake	Mechanical measures (such as surface or floating agitators and paddlewheels) could be introduced that would oxygenate the water. Some potential physical aeration/	Sub-option has the potential to improve. Current and proposed depths in the lake may be insufficient for a number of mixing systems to be installed. Current layout may make it difficult for fixed point systems to be effective. Thus a boat based system may be preferred unless lay out of the lakes changes substantially.	Yes	No as would be required for the foreseeable future with ongoing running and maintenance costs	n/a

Sub-option		Option description and Rationale	Longlisting Review and whether ruled in or out at long listing stage (18-4-2017)	Feasibility review (13-10-17) based on results of additional lake studies	Considered Sustainable (13-10-17)	Considered to be Value for Money (if considered feasible and sustainable) (13-10-17)
		oxygenation measures would help physically mix the system too.				
L	Use of algicidal chemicals	Algicidal chemicals, such as copper or aluminium sulphate, could be spread into the lakes to supress algal growth (through inactivating phosphorous which is an essential nutrient for algal growth). This option is currently undertaken by the Council and is not sufficient to remediate the water quality problems. It is not considered sustainable and so is ruled out.	Use of algicidal chemicals, such as copper or aluminium sulphate, to supress algal growth (for example through inactivating phosphorous, and essential nutrient for algal growth); Would require repeat application, for example annually. Some dosing of the system currently occurs and has not solved the issue. Not a sustainable solution.	Yes	No as would be required for the foreseeable future with ongoing running and maintenance costs	n/a
M	Physical measures to discourage Canadian Geese	Measures, such as lake edge planting and fencing areas off, may physically discourage/prevent Canada geese from the lakes, as geese like to land on water then waddle out to loaf on grassy areas.	Physical measures may play a part in the final scheme though not considered ideal, so tentatively ruled out. Fencing areas off or steepening banks to make access more difficult for Canada geese to access the riparian areas of the lake or water, may just shift the problem elsewhere. Fencing may also look visually unappealing. Canada geese prefer to breed on islands and so removal of the islands could have been a potential sub-option. However, the islands in the lake are considered important habitat (Local Wildlife Sites) and so this is not considered appropriate.	Only marginal planting to be taken forward	n/a – ruled out during long listing stage	n/a – ruled out during long listing stage
N	Other measures to discourage Canadian Geese	This could include visual or acoustic scaring measures. Could include population controls, such as culling or egg control. St Albans City and District Council previously implemented an egg control programme called "Mother Goose" where eggs were removed and rehomed elsewhere[24].	The Canada goose is protected under the EC Wild Birds Directive implemented in the United Kingdom through the Wildlife and Countryside Act (1981) (as amended). This makes it an offence to capture, kill or injure Canada geese, to damage their nests or eggs, or to disturb them on a breeding site. Any control technique which involves breaking the protected status of the Geese requires a licence from the appropriate government authority. Could also include increased signage for people to not feed the birds. Some measures that would discourage Canada geese may form part of a final preferred option though these are tentatively ruled out at this stage.	n/a – ruled out during long listing stage	n/a – ruled out during long listing stage	n/a – ruled out during long listing stage
O	Dredging of all sediments within the lake	Would remove a significant source of nutrients from the lake and on its own, reduce the likelihood of algal blooms occurring in the short term.	The sediment in the lakes is potentially hazardous and may need to be disposed of offsite (for example in a landfill) at significant cost given the large volume of material. Otherwise it may be included in features on site or to enlarge the existing island features. On its own dredging is expensive and not a sustainable option. In order for a scheme to operate to work it is likely sediment dredging would be needed and so this sub-option is ruled in and should be undertaken in combination with other options	Results of HazWaste analysis indicated that the material was not hazardous. This suggests that the material could be disposed of in landfill or that it would be possible to tip elsewhere with suitable dispensation.	Would be considered sustainable subject to careful and integrated design	The disposal of this material (8,800m^3 in vol15,000 – 18,000 tonnes in weight) would be expensive (~£1M with costs depending on water content and if lakes were drained as part of the lake works). Would be worth re-using as much within a partially infilled/ narrowed lake and should be considered from a Geotechnical perspective.

[24] Pers. comm from Daniel Flitton (St Albans District Council) 24 March 2017. Programme implemented approximately 10 years ago.

Sub-option		Option description and Rationale	Longlisting Review and whether ruled in or out at long listing stage (18-4-2017)	Feasibility review (13-10-17) based on results of additional lake studies	Considered Sustainable (13-10-17)	Considered to be Value for Money (if considered feasible and sustainable) (13-10-17)
P	Island enlargement	Extending the size of these through soft engineering techniques and backfilling of the enlarged areas (potentially with dredged material).	Has the potential to increase ecological value and aesthetic appearance of the lake. Would also help achieve some of the potential benefits outlined for sub-option B.	Additional lake studies suggest that this would still be feasible	Would be considered sustainable subject to careful and integrated design and approval would be necessary for works on the islands	This would be considered as value for money, if part of a well-considered re-design of the lake that included the other measures discussed in this column above.

Determination of the suitable restoration lake measures

Based upon the review of options presented in section 5.3.2, a combination of the following measures are considered to present the best balance of feasibility, sustainability and cost effectiveness:

Dredging of all sediments within the lake. Although this would entail a substantial capital spend, it is an essential component of lake improvements. Importantly, this would this create a slightly greater water depth. In addition, the soft organic sediments are likely to be resulting in the persistent recycling of nutrients. They are also a poor rooting substrate for macrophytes (which are important for maintaining healthy dissolved oxygen levels, reducing turbidity, and removing and locking away nutrients) and can be mobilised into the water column increasing turbidity by benthic fish bioturbation (increasing turbidity levels, which then has a negative feedback on the ability of submerged macrophytes to photosynthesise). The other measures proposed will substantially help to reduce future build-up of sediment, in particular those measures that will reduce the risk of algal blooms (increased through flow, marginal planting, and removal of fish). The dredged sediment will have a high water content, but once dried sufficiently to increase its cohesion it would be used within the infilling/narrowing and also the island enlargement measures identified below.

Partial infilling/ narrowing of the lake: this would increase flow-through, particularly during the most critical times of the year during summer period with higher temperatures, increase sunlight levels and lower direct input from precipitation. It is hoped that some of the dredged sediment may be able to be dried and used as part of the infilling work. Some breakout of concrete edges may be possible, or else tethered planting structures.

Wetland creation/ planting of marginal, submergent and floating plants. Marginal and aquatic plants would help to oxygenate the lake and trap/lock away nutrients. In addition, the marginal planting is the only measure taken forward that would help to discourage Canada geese, as other measures were considered costly and could detract from the visual amenity of the lake.

Varying abstraction regime from the River Ver: the lake would benefit from increased through flow of any amount, though care would need to be taken to ensure that the reduction in flow on the River would not have a detrimental effect on this section of the river and the efficacy of the river restoration works proposed.

Removing fish from the lake. The large number of carp are detrimental for two reasons: they add nutrients to the lake and they disturb sediments, putting nutrients back in the water column and causing increased turbidity which reduces the ability of aquatic plants to photosynthesise. Fish would need to be removed irrespective, to allow the other proposed works to take place. Once water quality in the lake improves it is proposed that some fish species would be reintroduced; this is essential to sustain the heronry. However, this reintroduction would be a carefully controlled mix of species to include predator species such as rudd and perch. Any reintroduction of carp should be discouraged.

Island enlargement. This is considered to be a relatively low cost intervention that would help reduce the areal extent of the lake (which aligns with the partial infilling/narrowing sub-option) whilst also benefitting the heronry, which is a Local Wildlife Site.

In addition to these active interventions, there are also management maintenance activities that would support the overall suite of actions intended to improve the lake in terms of water quality, reduction of the occurrence of algal blooms, reducing the risk of avian botulism and improving the visual and recreational amenity of the lake. These additional measures include:

- Management of new riparian planting, to control excessive growth, although this may not be an issue with careful species selection.
- Regular action and campaigns by Park Wardens to educate visitors about the impacts caused by bird feeding, and how it is actually harmful, particularly if there is an algal bloom.
- Regular maintenance of any new flow control structures to ensure correct operation is possible.
- Selective removal of branches overhanging the lake to reduce leaf litter.

Avian Botulism

There has been concern previously that the water quality in the lake has contributed to an outbreak of avian botulism. This is not an uncommon occurrence in municipal park lakes, many of which suffer similar water quality pressures as the Verulamium Lake.

The UK Animal and Plant Health Agency has published an information about avian botulism[25].:

'Avian botulism is a paralytic and often fatal disease caused by ingestion of toxin produced by the bacterium Clostridium botulinum. Avian botulism outbreaks in wild waterbirds occur relatively frequently in England and Wales. Large numbers of birds may be affected which can result in hundreds of deaths. Outbreaks of avian botulism can last for several weeks and may recur. C. botulinum is an anaerobic (oxygen intolerant) bacterium that multiplies in putrefying plant and animal material and is thus often found in lakes in periods of anoxic conditions and poor water quality. C. botulinum toxin Type C is considered to be responsible for most avian botulism outbreaks in the UK. The toxin produced is relatively stable and persistent in the environment, and in animal and insect tissues (including maggots feeding on dead birds)'.

The advice note provides a list of preventative measures taken by the London Royal Park authorities which have prevented the recurrence of the disease or reduced its effects. The following table describes these measures, and how the lake restoration measures will help achieve the same results

Preventative measure	Benefit of proposed lake measures
Maintaining good circulation of water.	The proposed offtake modifications would increase through flow as much as possible without impacting on the river
Maintaining healthy communities of oxygenating plants.	Proposed marginal planting would introduce oxygenating plants.
Prevention of the water level falling in the lake, preventing deoxygenation and the exposure of putrefying material.	The removal of silt would increase water depth and reduce the risk of exposed material, and the increased flows would help maintain lake levels. Reduced amounts of bread, as well as fish and bird excrement, would help remove putrefying material. Reducing the extent of the lake would also improve this aspect.
Removal of decaying plant material (including leaves) from the water. In particular removing vegetative material that collects on branches dipping into the surface of the water. These branches should be removed.	Removal of silt would remove existing decaying plant material. Management of trees surrounding the lake to reduce branches dipping into the water would also help.
If appropriate, removal of silts by pump action (in the face of an incident this may temporarily exacerbate the disease due to agitation of material).	There would be less sediment in future due to fewer algal blooms, the die-back of which generates silt. Management of fish would help reduce disturbance of silt. Less silt also through reduced extent of lake, so less prone to siltation (with slightly higher through flow too).
Searching and removal of dead animals in high risk periods for example warm summer months.	This is a measure that is already undertaken by the council.
The aim is to keep water levels high and reduce or lower the levels of silt.	Both the increased flows and removal of silt will help, in addition to the partial narrowing/infilling.

[25] Animal and Plant Health Agency, July 2017, Avian botulism in UK wild waterbirds

APPENDIX L – Determination of the Reach 2 Preferred Option

L.1 Overview

A summary of the derivation of the preferred option for Reach 2 (see Figure L.1) is presented within this Appendix. The included the following steps:

- Reach 2 Long List Appraisal.
- Reach 2 Short List Appraisal.

These results of the appraisals are outlined below.

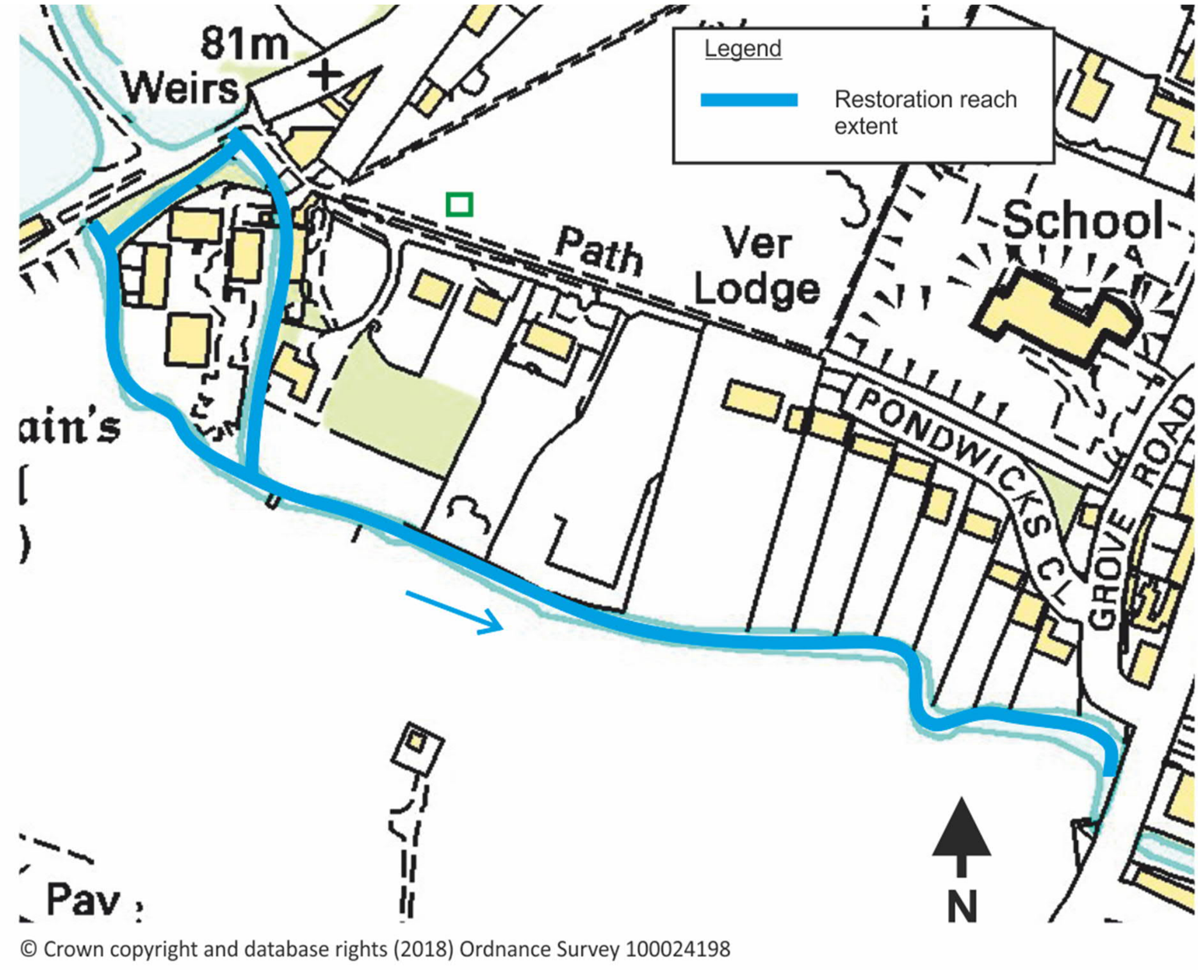


Figure L.1 Reach 2 of the study area (Downstream section of Verulamium Park to Holywell Hill)

L.2 Reach 2 Long List Appraisal

Long Listing Options Identification

The long list of options for Reach 2 are outlined in Table L.1.

Table L.1 Long List Options Reach 2

Option	Description
1	Re-align Ver over right bank, full floodplain reconnection/ wet woodland
2	Part re-alignment of channel over right bank with floodplain reconnection/ wet woodland
3	Re-alignment of channel close to existing course
4	Retain existing channel course with morphological improvements and local bank/ floodplain works

A schematic of these options is provided in Figures 4.22 - 4.25 below.

Long List Appraisal

A summary of the long list appraisal and scoring is provided in Table L.2 below. Individual options are appraised in subsequent sub-sections. The long list appraisal methodology was presented in Section 2.3 and Appendix B.

Table L.2 Appraisal of Reach 2 Long List Options

Option	Fulfil Project WFD Objectives for WB?	No constraints that would make option unfeasible?	Acceptable from a H&S perspective?	Not result in significant detrimental or loss of characteristic features?	Hydromorphology & Naturalisation*	Habitat	Water Quality	Flood Risk	Landscape/ Visual	Recreation & Amenity	Heritage	Contaminated Land & Sediment	Fish Passage	Sustainability/ Ongoing Maintenance	Total Score
	Y/N	Y/N	Y/N	Y/N	-2 to 2	-2 to 2	-2 to 2	-2 to 2	-2 to 2	-2 to 2	-2 to 2	-2 to 2	-2 to 2	-2 to 2	
Do nothing/ Baseline															
0	N	Y	Y	Y	0	0	0	0	0	0	0	0	0	0	0
1	Y	N	Y/N	Y	-	-	-	-	-	-	-	-	-	-	-
2	Y	Y	Y	Y	1	2	2	2	2	-1	0	0	0	2	10
3	Y	Y	Y	Y	1	1	1	1	1	0	-1**	0	0	2	6
4	Y	Y	Y	Y	1	1	1	1	0	0	-1**	0	0	1	4

* The hydromorphology in this reach is currently considered to be acceptable and so gains in this reach would be minimal (hence hydromorphology gains for the different options are no greater than 1)

** Due to potential effects on small bridge across the existing channel that is an archaeological feature

Reach 2 Option 1

This option is illustrated in Figure L.2 below. Option 1 did not fulfil the criteria of the initial long list appraisal process (Table L.2) as it was considered that physical (historic ground raising) and economic (associated loss of significant area of event space) constraints would make the option infeasible. Therefore this option was screened out and not scored within the long listing appraisal process.

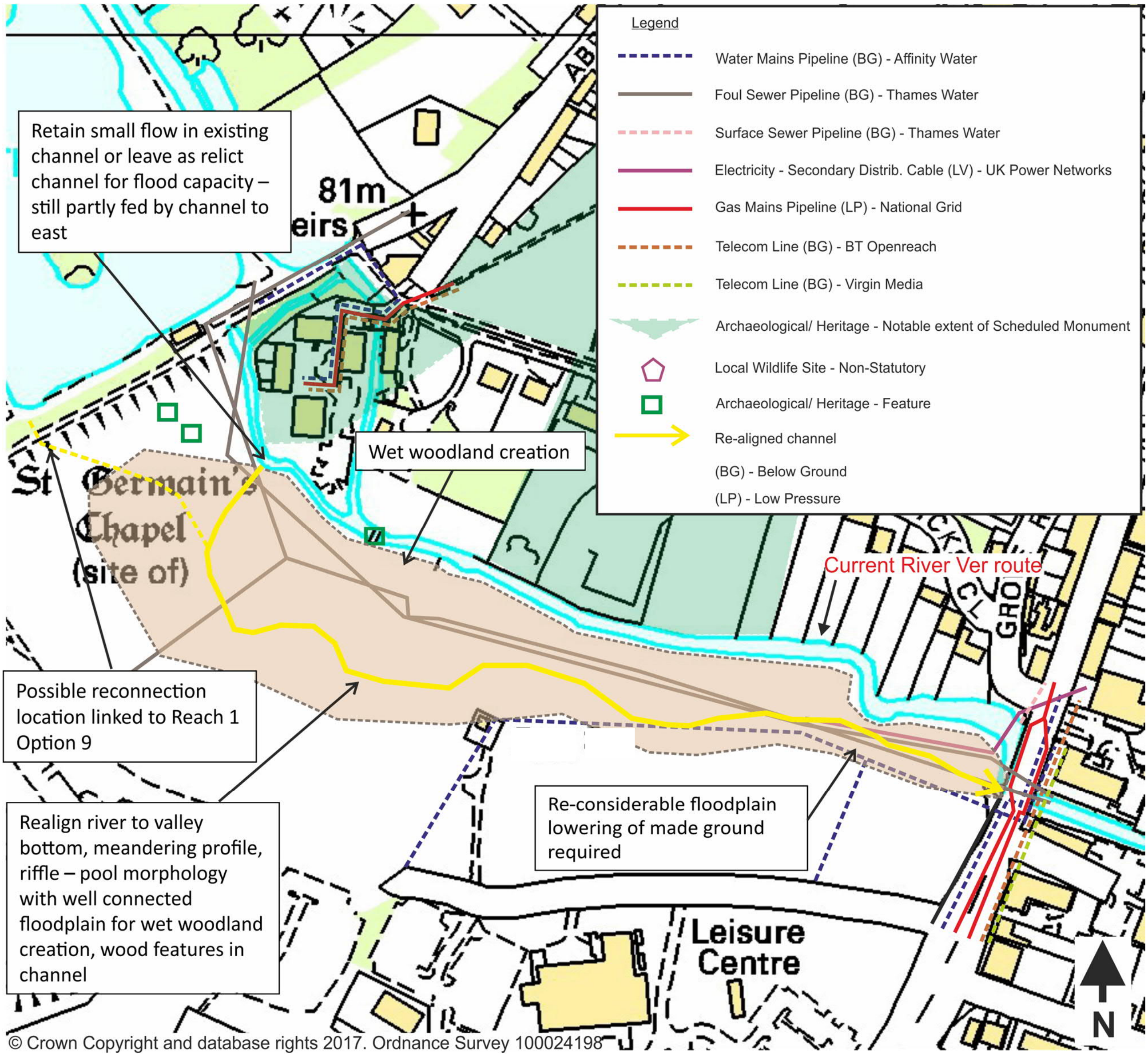


Figure L.2 Option 1 – Re-align Ver over right bank, full floodplain reconnection/ wet woodland

Reach 2 Option 2

This option is illustrated in Figure L.3 below. This option was considered to fulfil the necessary long listing criteria and was scored as part of the long listing appraisal. The option scored well (scoring 10 in total) and was thus shortlisted for more detailed consideration.

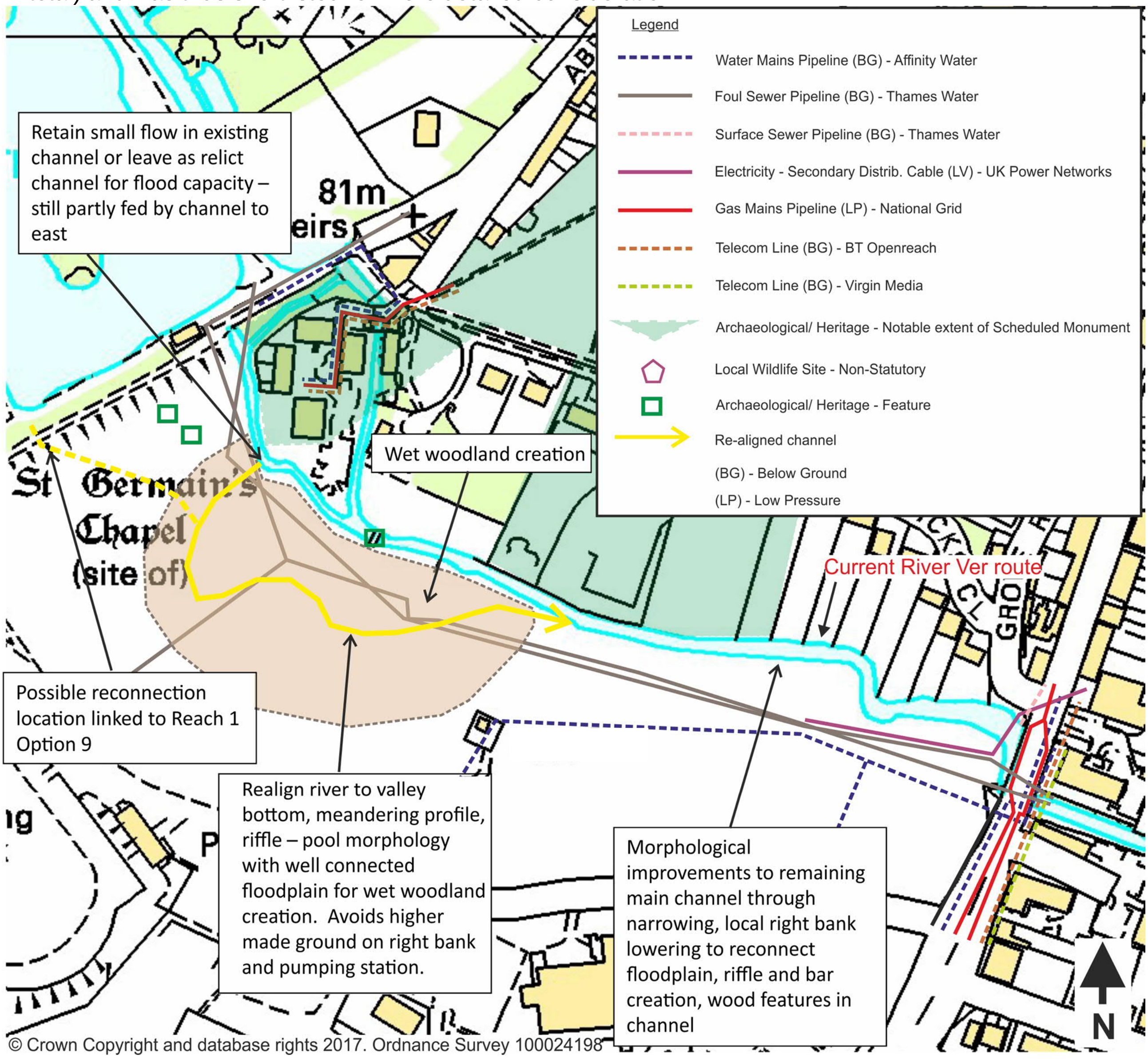


Figure L.3 Option 2 – Part re-alignment of channel over right bank with floodplain reconnection/ wet woodland

Reach 2 Option 3

This option is illustrated in Figure L.4 below. This option was considered to fulfil the necessary long listing criteria and was scored as part of the long listing appraisal. The option scored well (scoring 6 in total) and was thus shortlisted for more detailed consideration.

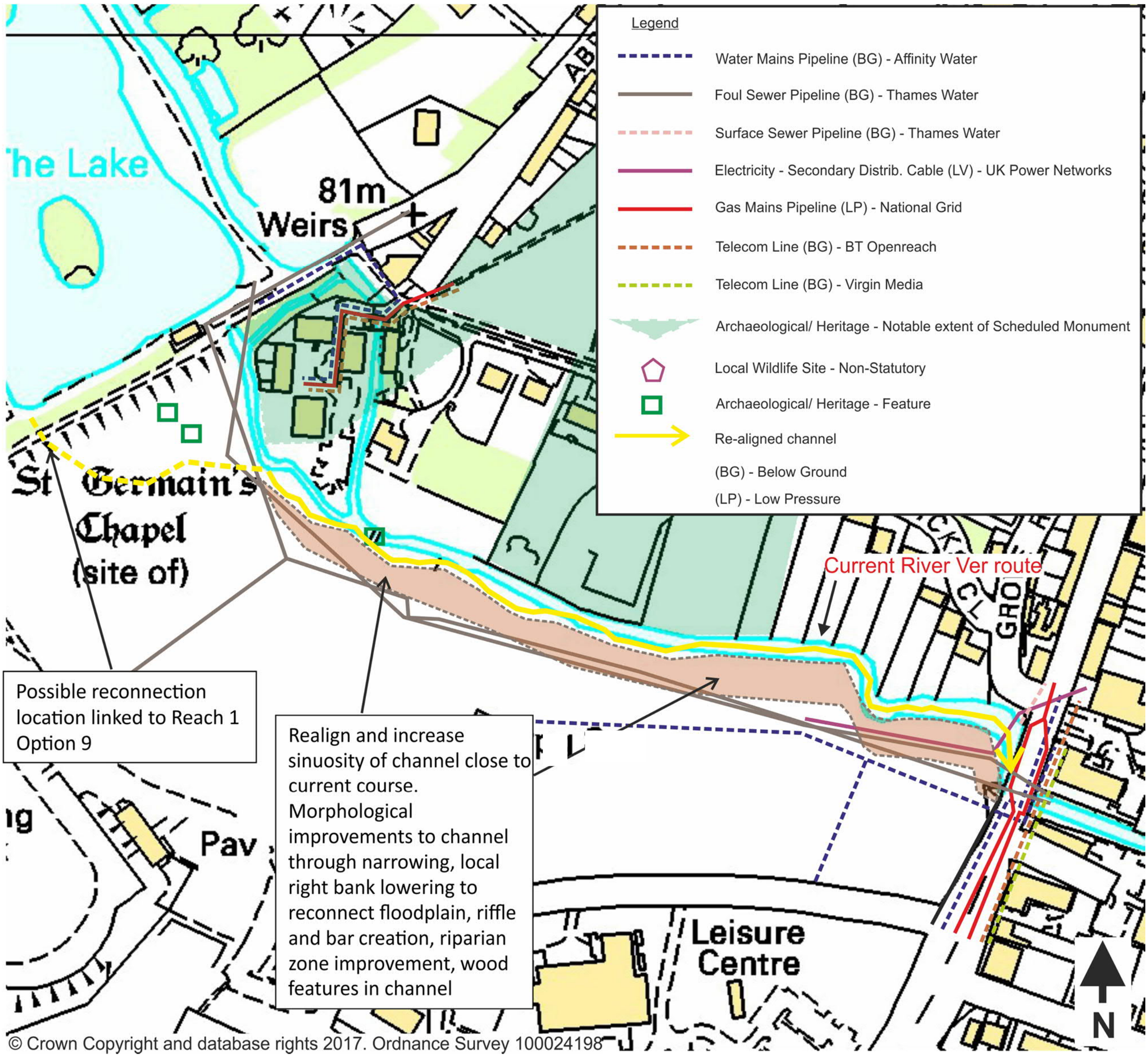


Figure L.4 Option 3 – Re-alignment of channel close to existing course

Reach 2 Option 4

This option is illustrated in Figure L.5 below. This option was considered to fulfil the necessary long listing criteria and was scored as part of the long listing appraisal. The option scored fairly (scoring 4 in total). As the hydromorphology in this reach is reasonably good this option has shortlisted despite the fair score, since only small improvements may be needed to obtain the WFD objective. This may option may also be easier to enact due to potential riparian landownership issues (gardens to the north of the channel). In addition at the time of the appraisal the effects of groundwater emergence were not yet known although it is expected that groundwater levels in this area may rise significantly (favouring this option over the others where the channel is re-aligned more and potentially into areas that may be inundated by groundwater).

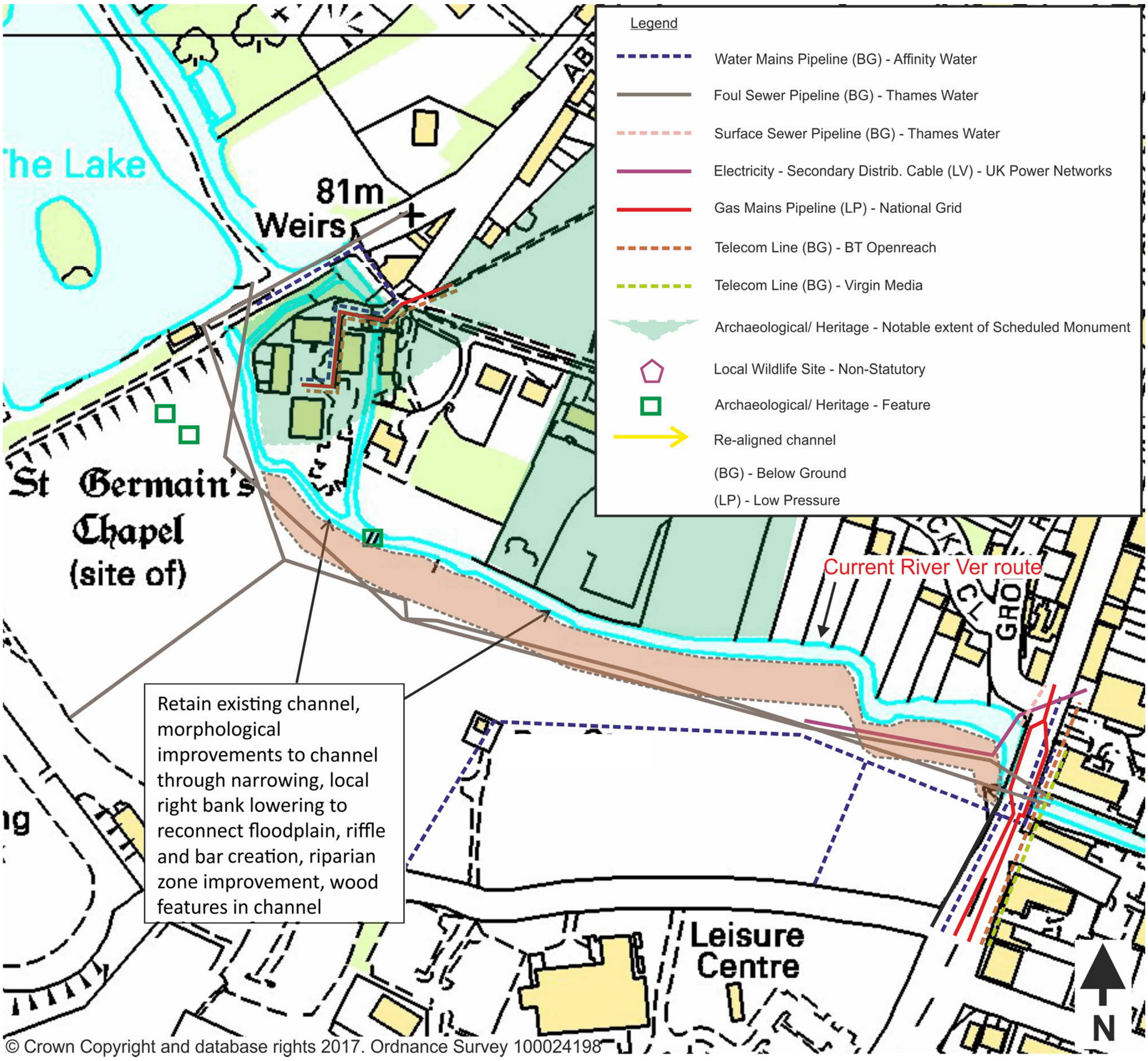


Figure L.5 Option 4 – Retain existing channel course with morphological improvements and local bank/ floodplain works

Reach 2 Long Listing Summary

As a result of the long list appraisal process, Reach 2 Options 2 and 3 were selected for shortlisting. Option 4 has also been shortlisted, despite a fair score from the long list appraisal. This was due to potential groundwater emergence in the area potentially undermining the feasibility of the other options and as hydromorphological gains in this reach may only need to be minor to obtain the WFD objective for this reach.

L.3 Reach 2 Short-listing Appraisal

Reach 2 Option Overview

The options outlined in Table L.3 were derived from the long listing appraisal and have been reviewed as part of the Short-listing appraisal. The short-listing appraisal methodology is described in Section 2.4 of the main report while project objectives were presented in Section 1.3.

Table L.3 Reach 2 Short Listed Options following Long List Appraisal

Option	Description
Reach 2	
2	Part re-alignment of channel over right bank with floodplain reconnection/ wet woodland
3	Re-alignment of channel close to existing course
4	Retain existing channel course with morphological improvements and local bank/ floodplain works

Review of Constraints and Opportunities

A plan of potential constraints for Reach 2 is provided in Figure L.6.

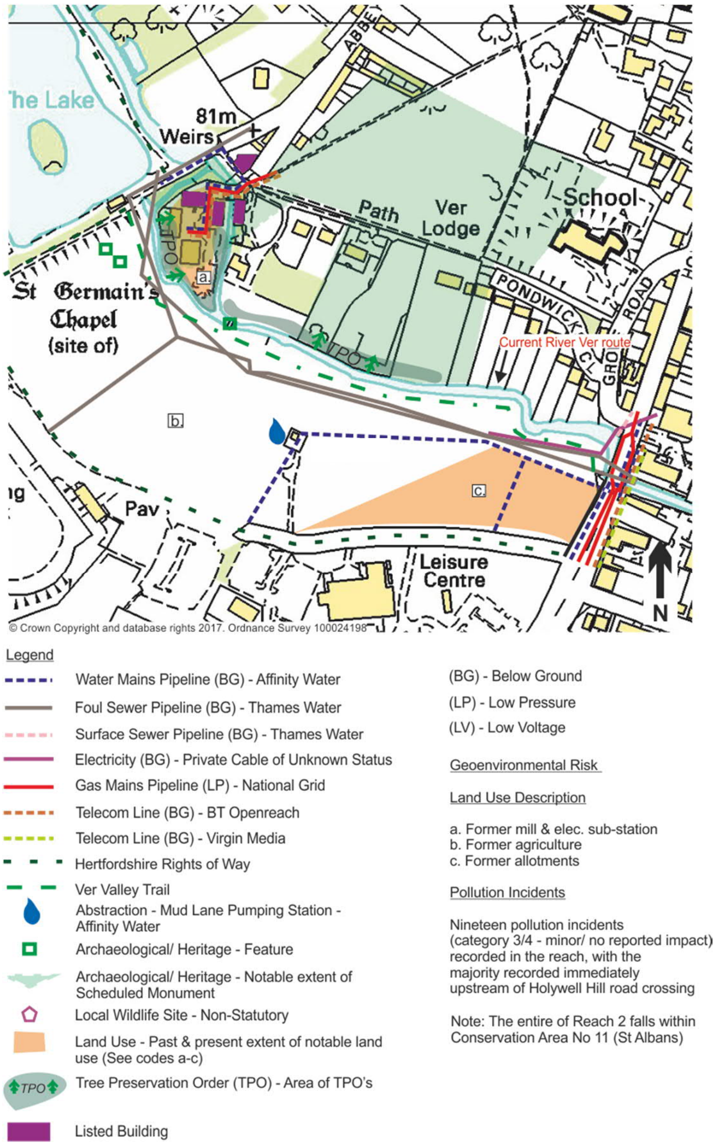


Figure L.6 Reach 2 constraints plan

Reach 2 Option 2

Option Description and Restoration Plan

In Reach 2 Option 2, the Ver would be re-aligned at the upstream end of Reach 2 to follow the valley bottom to the south of the existing channel course, before re-joining mid-way through the park (Figure L.7).

The re-aligned channel would be subject to in-channel re-profiling and incorporation of a suitable morphology through the creation of riffle features interspersed accordingly with point bar and berms. There is an opportunity to develop wetland/ wet woodland around the realigned channel where groundwater emergence is expected. The existing channel downstream of the re-connection point would also be subject to in-channel enhancement works, including berm and bar feature installation.

Flow from the Fighting Cock (PH) may be sufficient to maintain flows in the existing channel, if not it may provide storage for flood risk.

Review of Constraints and Opportunities

A plan of potential constraints for Reach 2 was provided in Figure L.6. The effects of these constraints on the feasibility of this option are described in Table L.4 below, along with potential advantages/ opportunities.

Figure L.7 Feature plans for Reach 2 Option 2

Table L.4 Review of constraints and opportunities for Reach 2 Option 2

Topic	Description	Effect or Potential Effect of Scenario
Access	Access may be difficult and even prohibitively expensive under certain circumstances	• Access for works likely to come from the south of Reach 2 and be relatively straightforward. Not considered to be prohibitive.
Flood Risk	As a result of re-alignment or floodplain works, flood risk from the river may decrease or increase in areas	• This option is unlikely to impact flood risk to surrounding people or property but may increase the flood risk to the Affinity Water assets over the right bank floodplain.
Hydromorphology	Does the scheme improve the hydromorphological functioning of the reach?	• A more natural planform associated to the realignment for this option with incorporation of the morphology shown would help to reduce the tendency for fine sediment deposition on the gravel bed and increase the hydraulic habitat diversity through the reach with a greater quantity of higher energy riffle units
Abstractions and other hydrological concerns	Consideration as to whether the scheme may result in other adverse or beneficial hydrological effects. For example re-routing of the river may impact upon distributaries as well as the main river.	• No surface water abstractions in this reach and so no effect of the scheme on these. • Scheme in itself would not impact upon flow around the Fighting Cock and this would provide a residual flow to the existing channel.
Groundwater connectivity	Does the scheme affect connectivity between surface water and groundwater?	• There is likely to be a small improvement in groundwater connectivity associated with this option through the identified realignment works. This would be enhanced with the groundwater emergence that is expected in this area which would follow the planned Affinity Water sustainability reductions in the catchment. • Approximate bed levels would be confirmed following completion of the hydraulic modelling, at which point any improvements in river flow the connectivity with the groundwater table can be discussed further.
Environmental Permits / consented discharges	Significant re-routing of the system may result in less flow being in the river at the point where a consented discharges enters and less dilution of that discharge.	• There are no consented discharges in this reach and there would be no changes as a result of this option.
Heritage	Scenario has the potential to impact upon Scheduled Monument or other archaeological feature	• Option unlikely to have a significant effect of features of archaeological importance.
Water Mains and Sewers (foul and surface water)	Under certain scenarios, construction may be routed close to other water mains and sewers. If so, these may have substantive effects on the cost of the scheme, its feasibility and duration of its construction.	• Affinity Water mains are located at lower end of Reach 1/ start of Reach 2. These would not be impacted by this option. They also have mains further down the reach. Works are upstream of these and so the mains are unlikely to be impacted by the works, assuming the mains are at least 1m bgl. A trial hole may be required to establish depth. • There are two Thames Water foul sewers that extend along the reach approximately 20m south of the river. These are at depths of between 1.5 m

		and 3.5 m bgl. This is a significant complication for the proposed realignment, requiring works to mitigate this risk (such as bed protection above the shallower pipe) and / or need to be avoided by the re-route (impacting upon the benefit of the scheme). Loss of groundwater connectivity within the immediate vicinity of the river bed would occur as a result of bed protection. The use of bed protection would preclude the creation of a natural channel.
Other Utilities	Under certain scenarios, construction may be routed close to other utilities, such as BT or gas mains. If so, these may have substantive effects on the cost of the scheme, its feasibility and duration of its construction.	• There is a below ground electricity line noted as a 'Private Line' at the lower end of the reach –details on the line status are unavailable (further investigation would be required). Only minor in channel changes are proposed in this reach as part of this option and so this utility is not anticipated to be a prohibitive constraint (though should be suitably accounted for as part of the works). • There are no other utilities close to the area that would be restored under this option
Geo-environmental	Consideration as to whether scheme could result in pathways for contaminants to enter the water environment.	• Re-alignment would occur through an area that was formerly agricultural land. This may provide a direct route for contaminants to be introduced into the river, noting that they would previously have had an indirect route (via runoff).
Local Wildlife Sites (Non-statutory)	Wildlife sites lie throughout the study area and could potentially be impacted by the scenarios	• There are no Local Wildlife Sites in this reach and so this option would not impact upon them.
Tree Protection Orders (TPO)	Consideration of the effect of Tree Protection Orders on the option	• TPOs are extensive on the left (north) bank through the upper half of this reach. The option is unlikely to impact upon these with the river being re-routed to the south apart from if these trees are overhanging the river channel substantially.
Public Rights of Way	Public Rights of Way may need to be diverted if works are would occur over their route	• Works would occur downstream of causeway, beyond which the nearest public right of way is around 100m from the works. As such the option would not affect public rights of way. • Access across the footbridge downstream of the mill leat junction would require further investigation given complementary access across the re-aligned channel would be required if this pathway is actively used.
Other Costs	Identification of potentially significant costs or aspects that are comparably low cost	• The presence of the Thames Water sewers will potentially create the greatest cost impact given bed protection would likely be required. There may be a requirement to provide flood protection to the Affinity Water assets over the right bank floodplain.
Landscape impact	Review whether option would have a significant visual impact	• The option should result in an improved looking river which would lie within its valley. The wetland area will also be visually appealing.
Recreation and	Review whether option would have significant impacts upon	• The option should result in a more accessible river lying within its valley. Re-

amenity	recreation and amenity	routing it would result in a loss of recreational ground although the recreational value of this land may have been lost due to groundwater emergence in this area as a result of sustainability reductions planned by Affinity Water.
Riparian ownership issues	Consideration as to whether option may require re-routing through lands that are privately owned or result in riparian changes that may be unacceptable.	• There are a number of owners of the riparian area to the north of the river through this reach and this option would affect the flow route and volume relative to their properties. • This option would change the existing channel which may not be acceptable to the landowners.

Reach 2 Option 3

Option Description and Restoration Plan

Similarly to Option 2, the Ver would be subject to channel re-alignment in the upstream end of the reach, but to a lesser degree, following the existing course of the channel instead of the wider valley bottom. The remaining channel would be narrowed to a more appropriate naturalised channel width.

Both the re-aligned and narrowed areas of the channel would be subject to in-channel re-profiling and incorporation of a suitable morphology through the creation of a riffle-pool regime interspersed with gravel bar and berm features (as illustrated in Figure L.8, which also includes a plan of the restoration features that have been included within the modelling). There is an opportunity to develop wetland/ wet woodland around the realigned channel where groundwater emergence is expected, provided additional surface water inputs are acceptable in this area.

Review of Constraints and Opportunities

A plan of potential constraints for Reach 2 was provided in Figure L.6. The effects of these constraints on the feasibility of this option are described in Table L.5 below, along with potential advantages/ opportunities.

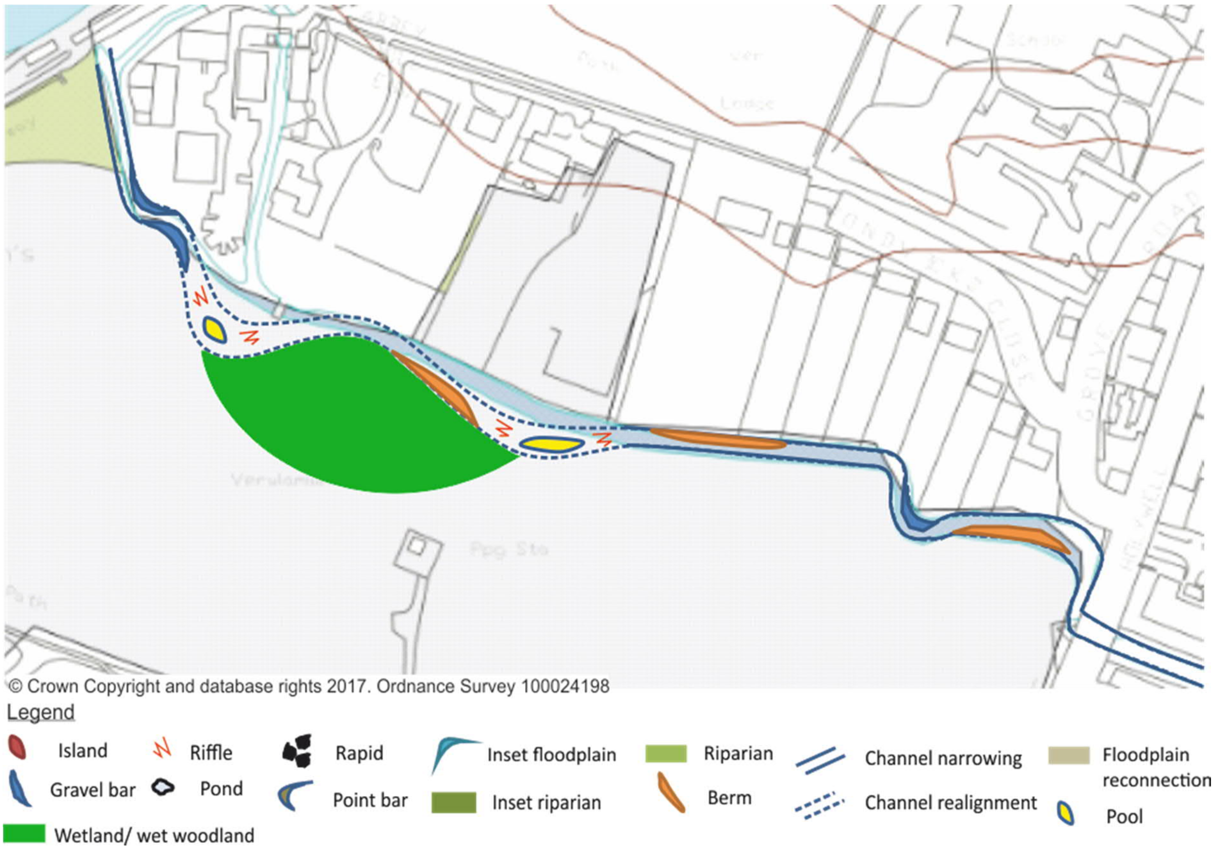


Figure L.8 Feature plans for Reach 2 Option 3

Table L.5 Review of constraints and opportunities for Reach 2 Option 3

Topic	Potential Issues	Assessment of the Effect or Potential Effect of the Option
Access	Access may be difficult and even prohibitively expensive under certain circumstances	• Access for works likely to come from the south of Reach 2 and be relatively straightforward. Not considered to be prohibitive.
Flood Risk	As a result of re-alignment or floodplain works, flood risk from the river may decrease or increase in areas	• There are unlikely to be any significant flood risk impacts as a result of the modifications proposed for this option.
Hydromorphology	Does the scheme improve the hydromorphological functioning of the reach?	• A more natural planform associated with the realignment for this option, with incorporation of the morphology shown, would help to reduce the tendency for fine sediment deposition on the gravel bed and increase the hydraulic habitat diversity through the reach with a greater quantity of higher energy riffle units.
Abstractions and other hydrological concerns	Consideration as to whether the scheme may result in other adverse or beneficial hydrological effects. For example re-routing of the river may impact upon distributaries as well as the main river.	• No surface water abstractions in this reach and so no effect of the scheme on these. • Scheme in itself would not impact upon flow around the Fighting Cock.
Groundwater connectivity	Does the scheme affect connectivity between surface water and groundwater?	• There are unlikely to be any significant improvements to the existing groundwater connectivity as a result of the partial realignment works associated to this option although groundwater emergence, as a result of the sustainability reductions, should improve connectivity. • Approximate bed levels would be confirmed following completion of the hydraulic modelling, at which point any improvements in river flow the connectivity with the groundwater table can be discussed further.
Environmental Permits / consented discharges	Significant re-routing of the system may result in less flow being in the river at the point where a consented discharges enters and less dilution of that discharge.	• There are no consented discharges in this reach and there would be no changes as a result of this option.
Heritage	Scenario has the potential to impact upon Scheduled Monument or other archaeological feature	• Option could potentially impact upon the possible medieval bridge of low Heritage significance and would require archaeological mitigation. It should be possible to iterate scheme to avoid this bridge however, and reduce the impact accordingly. • Costs may be high if remains are found during the works.
Water Mains and Sewers (foul and surface water)	Under certain scenarios, construction may be routed close to other water mains and sewers. If so, these may have substantive effects on the cost of the scheme, its feasibility and duration of its construction.	• Affinity Water mains are located at lower end of Reach 1/ start of Reach 2. These would not be impacted by this option. They also have mains further down the reach . Works are upstream of these and so the mains are unlikely to be impacted by the works, assuming the mains are at least 1m bgl. A trial hole may be required to establish depth. • There are two Thames Water foul sewers that extend along the reach approximately 20m south of the river. These are at depths of between 1.5 m and 3.5 m bgl. This is a significant complication for the proposed realignment, requiring works to mitigate this risk (such as bed protection above the shallower pipe) and / or need to be avoided by the re-

		route (impacting upon the benefit of the scheme). Loss of groundwater connectivity would occur in the immediate vicinity of the river bed as a result of bed protection. The use of bed protection would preclude the creation of a natural channel.
Other Utilities	Under certain scenarios, construction may be routed close to other utilities, such as BT or gas mains. If so, these may have substantive effects on the cost of the scheme, its feasibility and duration of its construction.	• There is a below ground electricity line noted as a 'Private Line' at the lower end of the reach –details on the line status are unavailable (further investigation would be required). Only minor in channel changes are proposed in this reach as part of this option and so this utility is not anticipated to be a prohibitive constraint (though should be suitably accounted for as part of the works). • There are no other utilities close to the area that would be restored under this option
Geo-environmental	Consideration as to whether scheme could result in pathways for contaminants to enter the water environment.	• The relatively minor re-alignment, in terms of land take, would occur through an area that was formerly agricultural land. This may provide a direct route for contaminants to be introduced into the river, noting that they would previously have had an indirect route (via runoff).
Local Wildlife Sites (Non-statutory)	Wildlife sites lie throughout the study area and could potentially be impacted by the scenarios	• There are no Local Wildlife Sites in this reach and so this option would not impact upon them.
Tree Protection Orders (TPO)	Consideration of the effect of Tree Protection Orders on the option	• TPOs are extensive on the left (north) bank through the upper half of this reach. The option is unlikely to impact upon these with the river being re-routed to the south apart from if these trees are overhanging the river channel substantially.
Public Rights of Way	Public Rights of Way may need to be diverted if works are would occur over their route	• Works would occur downstream of causeway, beyond which the nearest public right of way is around 100m from the works. As such the option would not affect public rights of way.
Other Costs	Identification of potentially significant costs or aspects that are comparably low cost	• The presence of the Thames Water sewers will potentially create the greatest cost impact given bed protection would likely be required. The archaeological costs will potentially being high, if remains are found. There would be a potential additional small cost associated with a new footbridge.
Landscape impact	Review whether option would have a significant visual impact	• The option should result in a slightly improved looking river which would lie closer to its natural route. The wetland area will also be visually appealing.
Recreation and amenity	Review whether option would have significant impacts upon recreation and amenity	• The option should result in a slightly more accessible river. Re-routing it would result in a minor loss of recreational ground although the recreational value of this land may have been lost due to groundwater emergence in this area as a result of sustainability reductions planned by Affinity Water.
Riparian ownership issues	Consideration as to whether option may require re-routing through lands that are privately owned or result in riparian changes that may be unacceptable.	• There are a number of owners of the riparian area to the north of the river through this reach and this option would affect the flow route and volume relative to their properties. • This option would change the existing channel which may not be acceptable to the landowners.

Reach 2 Option 4

Option Description and Restoration Plan

The existing course of the Ver in Option 4 would be retained, but narrowed throughout the course of Reach 2 (see Figure L.9). The right bank of the river would be lowered to help re-connect the river with the floodplain. As a result of historical dredging, the channel is over-deep and partially disconnected from the floodplain, and lowering the banks would create valuable inset berm wetland areas.

The re-aligned channel would be subject to in-channel re-profiling and incorporation of a suitable morphology through the creation of gravel bar, inset floodplains, islands and berm features.

Review of Constraints and Opportunities

A plan of potential constraints for Reach 2 was provided in Figure L.6. The effects of these constraints on the feasibility of this option are described in Table L.6below, along with potential advantages/ opportunities.

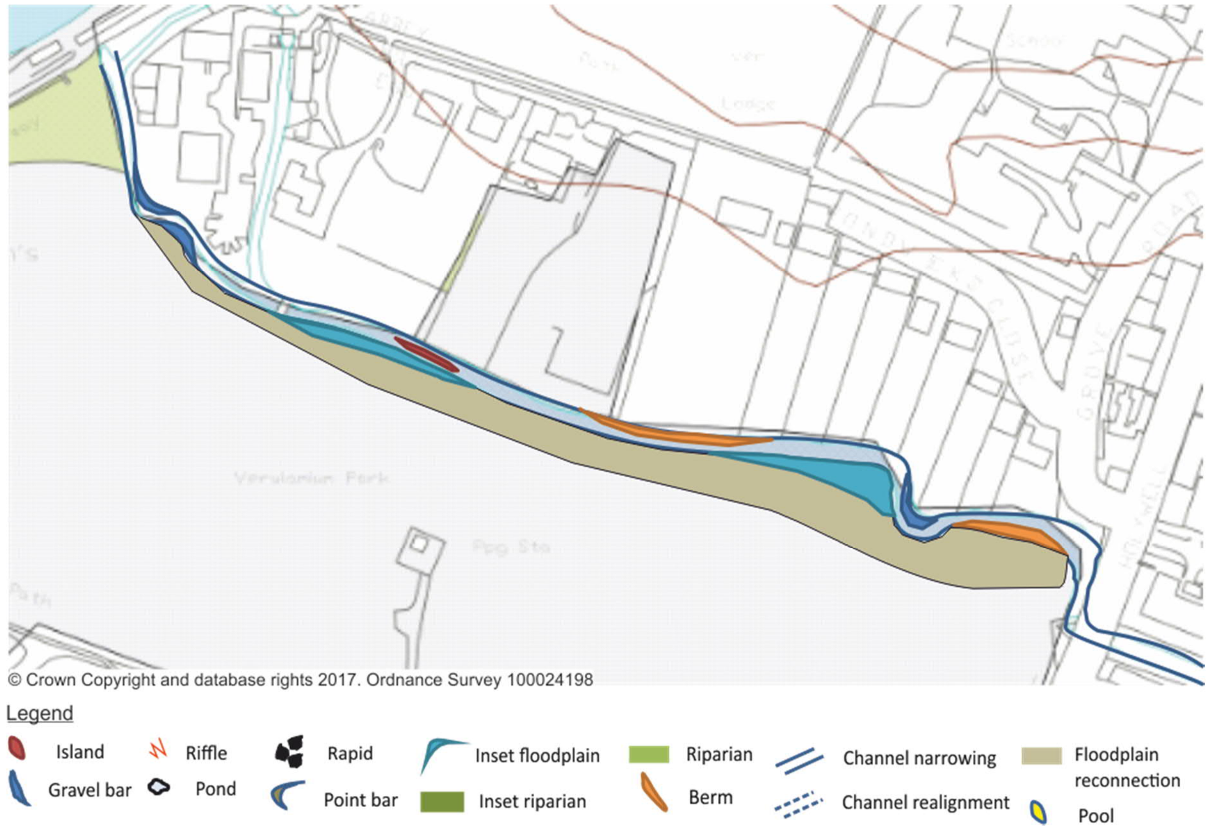


Figure L.9 Feature plans for Reach 2 Option 4

Table L.6 Review of constraints and opportunities for Reach 2 Option 4

Topic	Potential Issues	Assessment of the Effect or Potential Effect of the Option
Access	Access may be difficult and even prohibitively expensive under certain circumstances	• Access for works likely to come from the south of Reach 2 and be relatively straightforward. Not considered to be prohibitive.
Flood Risk	As a result of re-alignment or floodplain works, flood risk from the river may decrease or increase in areas	• There are unlikely to be any significant flood risk impacts as a result of the modifications proposed for this option.
Hydromorphology	Does the scheme improve the hydromorphological functioning of the reach?	• Incorporation of an appropriate morphology and associated narrowing shown would help to reduce the tendency for fine sediment deposition on the gravel bed and increase the hydraulic habitat diversity through the reach with a greater quantity of higher energy riffle units.
Abstractions and other hydrological concerns	Consideration as to whether the scheme may result in other adverse or beneficial hydrological effects. For example re-routing of the river may impact upon distributaries as well as the main river.	• No surface water abstractions in this reach and so no effect of the scheme on these. • Scheme in itself would not impact upon flow around the Ye Old Fighting Cock (PH).
Groundwater connectivity	Does the scheme affect connectivity between surface water and groundwater?	• There are unlikely to be any significant improvements to the existing groundwater connectivity as a result of the proposed morphological works associated with this option although groundwater emergence, as a result of the sustainability reductions, should improve connectivity. • Approximate bed levels would be confirmed following completion of the hydraulic modelling, at which point any improvements in river flow the connectivity with the groundwater table can be discussed further.
Environmental Permits / consented discharges	Significant re-routing of the system may result in less flow being in the river at the point where a consented discharges enters and less dilution of that discharge.	• There are no consented discharges in this reach and there would be no changes as a result of this option.
Heritage	Scenario has the potential to impact upon Scheduled Monument or other archaeological feature	• Option could potentially impact upon the possible medieval bridge of low Heritage significance and would require archaeological mitigation. It should be possible to iterate scheme to avoid this bridge however, and reduce the impact accordingly. • Costs may be high if remains are found during the works.
Water Mains and Sewers (foul and surface water)	Under certain scenarios, construction may be routed close to other water mains and sewers. If so, these may have substantive effects on the cost of the scheme, its feasibility and duration of its construction.	• Affinity Water mains are located at lower end of Reach 1/ start of Reach 2. These would not be impacted by this option. They also have mains further down the reach. Works are upstream of these and so the mains are unlikely to be impacted by the works, assuming the mains are at least 1m bgl. A trial hole may be required to establish depth. • There are two Thames Water foul sewers that extend along the reach approximately 20m

		south of the river. These are at depths of between 1.5 m and 3.5 m bgl. The floodplain works may potentially cross these sewers, requiring works to mitigate this risk (such as bed protection) and / or need to be avoided by the floodplain works (impacting upon the benefit of the scheme).
Other Utilities	Under certain scenarios, construction may be routed close to other utilities, such as BT or gas mains. If so, these may have substantive effects on the cost of the scheme, its feasibility and duration of its construction.	• There is a below ground electricity line noted as a 'Private Line' at the lower end of the reach –details on the line status are unavailable (further investigation would be required). The presence of this may impact upon the amount of floodplain works that are undertaken close to the line. • There are no other utilities close to the area that would be restored under this option
Geo-environmental	Consideration as to whether scheme could result in pathways for contaminants to enter the water environment.	• The floodplain works, in terms of land take, would occur through an area that was formerly agricultural land. This may provide a direct route for contaminants to be introduced into the river, noting that they would previously have had an indirect route (via runoff).
Local Wildlife Sites (Non-statutory)	Wildlife sites lie throughout the study area and could potentially be impacted by the scenarios	• There are no Local Wildlife Sites in this reach and so this option would not impact upon them.
Tree Protection Orders (TPO)	Consideration of the effect of Tree Protection Orders on the option	• TPOs are extensive on the left (north) bank through the upper half of this reach. The option is unlikely to impact upon the works being undertaken within the existing channel or to the south of it apart from if these trees are overhanging the river channel substantially.
Public Rights of Way	Public Rights of Way may need to be diverted if works are would occur over their route	• Works would occur downstream of causeway, beyond which the nearest public right of way is around 100m from the works. As such the option would not affect public rights of way.
Other Costs	Identification of potentially significant costs or aspects that are comparably low cost	• The works should be relatively low cost, with the presence of the Thames Water sewers potentially having the greatest cost impact.
Landscape impact	Review whether option would have a significant visual impact	• The option should result in a slightly improved looking river.
Recreation and amenity	Review whether option would have significant impacts upon recreation and amenity	• Floodplain reconnection would result in a minor loss of recreational ground although the recreational value of this land may have been lost due to groundwater emergence in this area as a result of sustainability reductions planned by Affinity Water.
Riparian ownership issues	Consideration as to whether option may require re-routing through lands that are privately owned or result in riparian changes that may be unacceptable.	• There are a number of owners of the riparian area to the north of the river through this reach. The option would not result in a re-alignment of the river through the north of the river and so no significant or prohibitive impacts are anticipated.

Determination of the Preferred Reach 2 Option

Table L.7 provides a compiled review of the constraints and opportunities for the Reach 2 options. The discussion of each constraint/ opportunity for each option has been coloured accordingly:

- Green – Desired improvements and project objectives achieved. No constraints identified in relation to the category in question.
- Yellow - Desired improvements and project objectives achieved. Low or moderate mitigation costs and/ or constraints identified in relation to the category in question.
- Orange - Desired improvements and project objectives achieved. Moderate or high mitigation costs and/ or constraints identified in relation to the category in question.
- Red – Desired improvements and project objectives may not be achieved and/ or high mitigation costs and/ or major constraints identified in relation to the category in question that may be difficult or expensive to overcome.

From a hydromorphological perspective, Options 2 and 3 represent the greatest potential improvement as a result of a more appropriate planform and wider riparian zone improvements. Option 4 offers some riparian zone improvement but broader floodplain benefits are reduced in comparison without the creation of the wetland/wet woodland zone, and the unimproved planform also offers comparatively less benefit.

However the presence of foul sewers throughout the reach is a significant constraint on floodplain works and is therefore a constraint for all of the restoration options but particularly for Options 2 and 3 that include re-meandering. Modifications to Options 2 and 3 were explored in terms of the extent of the re-meandering proposed but ultimately the foul sewers constraint represents an unavoidable restriction on achieving the desired planform improvements. Additionally, the potential to impact the flow route and volume at riparian properties is also a significant constraint for Options 2 and 3, as is the need to avoid impacts to the remains of a potentially medieval bridge.

To best manage for these key constraints, a hybrid option was preferred that combines Options 3 and 4. This hybrid option retains the original course of the river to minimise impacts to riparian landowners, but creates some in-channel sinuosity through a bar-riffle sequence. It also includes floodplain works where possible, such as the creation of wetland/ wet woodland in the area of groundwater emergence.

Table L.7 Reach 2 Summary Table

Topic	Effect or Potential Effect of Reach 2 Option 2	Effect or Potential Effect of Reach 2 Option 3	Effect or Potential Effect of Reach 2 Option 4
Access	• Access for works likely to come from the south of Reach 2 and be relatively straightforward. Not considered to be prohibitive.	• Access for works likely to come from the south of Reach 2 and be relatively straightforward. Not considered to be prohibitive.	• Access for works likely to come from the south of Reach 2 and be relatively straightforward. Not considered to be prohibitive.
Flood Risk	• This option is unlikely to impact flood risk to surrounding people or property but may increase the flood risk to the Affinity Water assets over the right bank floodplain.	• There are unlikely to be any significant flood risk impacts as a result of the modifications proposed for this option.	• There are unlikely to be any significant flood risk impacts as a result of the modifications proposed for this option.
Hydromorphology	• A more natural planform associated to the realignment for this option with incorporation of the morphology shown would help to reduce the tendency for fine sediment deposition on the gravel bed and increase the hydraulic habitat diversity through the reach with a greater quantity of higher energy riffle units	• A more natural planform associated with the realignment for this option, with incorporation of the morphology shown, would help to reduce the tendency for fine sediment deposition on the gravel bed and increase the hydraulic habitat diversity through the reach with a greater quantity of higher energy riffle units.	• Incorporation of an appropriate morphology and associated narrowing shown would help to reduce the tendency for fine sediment deposition on the gravel bed and increase the hydraulic habitat diversity through the reach with a greater quantity of higher energy riffle units.
Abstractions and other hydrological concerns	• No surface water abstractions in this reach and so no effect of the scheme on these. • Scheme in itself would not impact upon flow around the Fighting Cock and this would provide a residual flow to the existing channel.	• No surface water abstractions in this reach and so no effect of the scheme on these. • Scheme in itself would not impact upon flow around the Fighting Cock.	• No surface water abstractions in this reach and so no effect of the scheme on these. • Scheme in itself would not impact upon flow around the Ye Old Fighting Cock (PH).
Groundwater connectivity	• There is likely to be a small improvement in groundwater connectivity associated with this option through the identified realignment works. This would be enhanced with the groundwater emergence that is expected in this area which would follow the planned Affinity Water sustainability reductions. • Approximate bed levels would be confirmed following completion of the hydraulic modelling, at which point any improvements in river flow the connectivity with the groundwater table can be discussed further.	• There are unlikely to be any significant improvements to the existing groundwater connectivity as a result of the partial realignment works associated to this option although groundwater emergence, as a result of the sustainability reductions, should improve connectivity. • Approximate bed levels would be confirmed following completion of the hydraulic modelling, at which point any improvements in river flow the connectivity with the groundwater table can be discussed further.	• There are unlikely to be any significant improvements to the existing groundwater connectivity as a result of the proposed morphological works associated with this option although groundwater emergence, as a result of the sustainability reductions, should improve connectivity. • Approximate bed levels would be confirmed following completion of the hydraulic modelling, at which point any improvements in river flow the connectivity with the groundwater table can be discussed further.
Environmental Permits / consented discharges	• There are no consented discharges in this reach and there would be no changes as a result of this option.	• There are no consented discharges in this reach and there would be no changes as a result of this option.	• There are no consented discharges in this reach and there would be no changes as a result of this option.
Heritage	• Option unlikely to have a significant effect of features of archaeological importance.	• Option could potentially impact upon the possible medieval bridge of low Heritage significance and if so this would require some archaeological mitigation. However it should be possible to avoid this asset through adjusting the design.	• Option could potentially impact upon the possible medieval bridge of low Heritage significance and if so this would require some archaeological mitigation. However it should be possible to avoid this asset through adjusting the design.
Water Mains and Sewers (foul and surface water)	• Affinity Water mains are located at lower end of Reach 1/ start of Reach 2. These would not be impacted by this option. They also have mains further down the reach . Works are upstream of these and so the mains are unlikely to be impacted by the works, assuming the mains are at least 1m bgl. A trial hole may be required to establish depth. • There are two Thames Water foul sewers that extend along the reach approximately 20m south of the river. These are at depths of between 1.5 m and 3.5 m bgl. This is a significant complication for the proposed realignment, requiring works to mitigate this risk (such as bed protection above the shallower pipe) and / or need to be avoided by the re-route (impacting upon the benefit of the scheme). Loss of groundwater connectivity would occur in the immediate vicinity of the river bed as a result of bed protection. The use of bed protection would preclude the creation of a natural channel.	• Affinity Water mains are located at lower end of Reach 1/ start of Reach 2. These would not be impacted by this option. They also have mains further down the reach . Works are upstream of these and so the mains are unlikely to be impacted by the works, assuming the mains are at least 1m bgl. A trial hole may be required to establish depth. • There are two Thames Water foul sewers that extend along the reach approximately 20m south of the river. These are at depths of between 1.5 m and 3.5 m bgl. This is a significant complication for the proposed realignment requiring works to mitigate this risk (such as bed protection above the shallower pipe) and / or need to be avoided by the re-route (impacting upon the benefit of the scheme). Loss of groundwater connectivity would occur in the immediate vicinity of the river bed as a result of bed protection. The use of bed protection would preclude the creation of a natural channel.	• Affinity Water mains are located at lower end of Reach 1/ start of Reach 2. These would not be impacted by this option. They also have mains further down the reach . Works are upstream of these and so the mains are unlikely to be impacted by the works, assuming the mains are at least 1m bgl. A trial hole may be required to establish depth. • There are two Thames Water foul sewers that extend along the reach approximately 20m south of the river. These are at depths of between 1.5 m and 3.5 m bgl. The floodplain works may potentially impact these sewers, requiring works to mitigate this risk (such as bed protection) and / or need to be avoided by the floodplain works (impacting upon the benefit of the scheme).
Other Utilities	• There is a below ground electricity line noted as a ‘Private Line’ at the lower	• There is a below ground electricity line noted as a ‘Private Line’ at the lower end of the	• There is a below ground electricity line noted as a ‘Private Line’ at the lower end of the

	end of the reach –details on the line status are unavailable (further investigation would be required). Only minor in channel changes are proposed in this reach as part of this option and so this utility is not anticipated to be a prohibitive constraint (though should be suitably accounted for as part of the works). • There are no other utilities close to the area that would be restored under this option	reach –details on the line status are unavailable (further investigation would be required). Only minor in channel changes are proposed in this reach as part of this option and so this utility is not anticipated to be a prohibitive constraint (though should be suitably accounted for as part of the works). • There are no other utilities close to the area that would be restored under this option	reach –details on the line status are unavailable (further investigation would be required). The presence of this may impact upon the amount of floodplain works that are undertaken close to the line. • There are no other utilities close to the area that would be restored under this option
Geo-environmental	• Re-alignment would occur through an area that was formerly agricultural land. This may provide a direct route for contaminants to be introduced into the river, noting that they would previously have had an indirect route (via runoff).	• The relatively minor re-alignment, in terms of land take, would occur through an area that was formerly agricultural land. This may provide a direct route for contaminants to be introduced into the river, noting that they would previously have had an indirect route (via runoff).	• The floodplain works, in terms of land take, would occur through an area that was formerly agricultural land. This may provide a direct route for contaminants to be introduced into the river, noting that they would previously have had an indirect route (via runoff).
Local Wildlife Sites (Non-statutory)	• There are no Local Wildlife Sites in this reach and so this option would not impact upon them.	• There are no Local Wildlife Sites in this reach and so this option would not impact upon them.	• There are no Local Wildlife Sites in this reach and so this option would not impact upon them.
Tree Protection Orders (TPO)	• TPOs are extensive on the left (north) bank through the upper half of this reach. The option is unlikely to impact upon these with the river being re-routed to the south apart from if these trees are overhanging the river channel substantially.	• TPOs are extensive on the left (north) bank through the upper half of this reach. The option is unlikely to impact upon these with the river being re-routed to the south apart from if these trees are overhanging the river channel substantially.	• TPOs are extensive on the left (north) bank through the upper half of this reach. The option is unlikely to impact upon the works being undertaken within the existing channel or to the south of it apart from if these trees are overhanging the river channel substantially.
Public Rights of Way	• Works would occur downstream of causeway, beyond which the nearest public right of way is around 100m from the works. As such the option would not affect public rights of way. • Access across the footbridge downstream of the mill leat junction would require further investigation given complementary access across the re-aligned channel would be required if this pathway is actively used.	• Works would occur downstream of causeway, beyond which the nearest public right of way is around 100m from the works. As such the option would not affect public rights of way.	• Works would occur downstream of causeway, beyond which the nearest public right of way is around 100m from the works. As such the option would not affect public rights of way.
Other Costs	• The presence of the Thames Water sewers will potentially create the greatest cost impact given bed protection would likely be required. There may be a requirement to provide flood protection to the Affinity Water assets over the right bank floodplain.	• The presence of the Thames Water sewers will potentially create the greatest cost impact given bed protection would likely be required. The archaeological costs will potentially being high, if remains are found. There would be a potential additional small cost associated with a new footbridge.	• The works should be relatively low cost, with the presence of the Thames Water sewers potentially having the greatest cost impact.
Landscape impact	• The option should result in an improved looking river which would lie within its valley. The wetland area will also be visually appealing.	• The option should result in a slightly improved looking river which would lie closer to its natural route. The wetland area will also be visually appealing.	• The option should result in a slightly improved looking river.
Recreation and amenity	• The option should result in a more accessible river lying within its valley. Re-routing it would result in a loss of recreational ground although the recreational value of this land may have been lost due to groundwater emergence in this area as a result of sustainability reductions planned by Affinity Water.	• The option should result in a slightly more accessible river. Re-routing it would result in a minor loss of recreational ground although the recreational value of this land may have been lost due to groundwater emergence in this area as a result of sustainability reductions planned by Affinity Water.	• Floodplain reconnection would result in a minor loss of recreational ground although the recreational value of this land may have been lost due to groundwater emergence in this area as a result of sustainability reductions planned by Affinity Water.
Riparian ownership issues	• There are a number of owners of the riparian area to the north of the river through this reach and this option would affect the flow route and volume relative to their properties. • This option would change the existing channel which may not be acceptable to the landowners.	• There are a number of owners of the riparian area to the north of the river through this reach and this option would affect the flow route and volume relative to their properties. • This option would change the existing channel which may not be acceptable to the landowners.	• There are a number of owners of the riparian area to the north of the river through this reach. The option would not result in a re-alignment of the river through the north of the river and so no significant or prohibitive impacts are anticipated.

APPENDIX M – Determination of the Reach 3 Preferred Option

M.1 Overview

A summary of the derivation of the preferred option for Reach 3 (see Figure M.1) is presented within this Appendix. The included the following steps:

- Reach 3 Long List Appraisal.
- Reach 3 Short List Appraisal.

These results of the appraisals are outlined below.

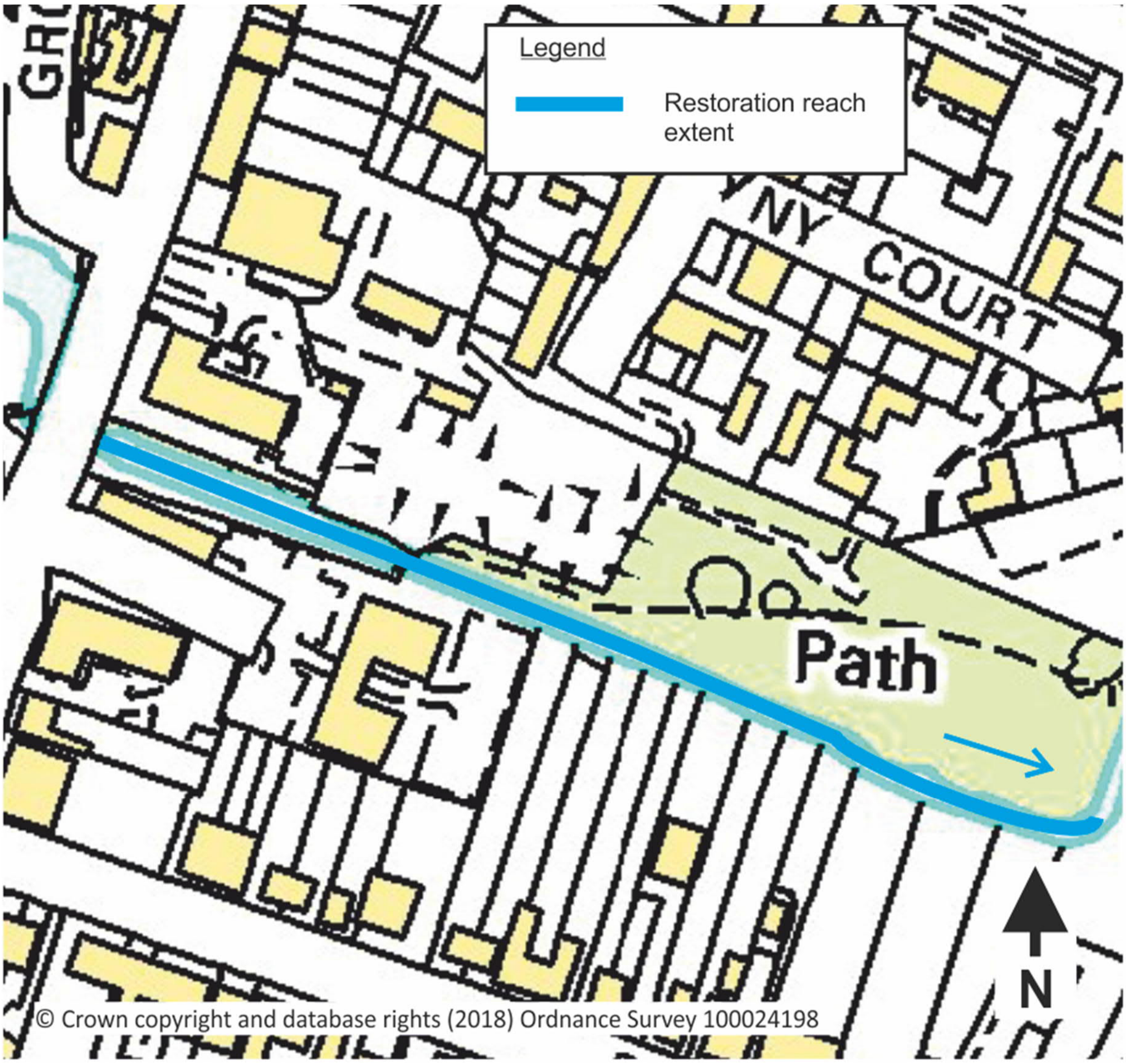


Figure M.1 Reach 3 of the study area (From Holywell Hill to Cottonmill Lane Allotments)

M.2 Reach 3 Long List Appraisal

Options Identification

The long list of options for Reach 3 are outlined in Table M.1.

Table M.1 Long List Options Reach 3

Option	Description
1	Part re-alignment of existing channel
2	Part re-alignment of existing channel, offline pond creation

3	Part re-alignment of channel but connected to re-aligned Reach 4 Options
4	Maintain existing channel and improve

A schematic of these options is provided in Figures M.2 – M.5 below.

Long List Appraisal

A summary of the long list appraisal and scoring is provided in Table M.2 below. Individual options are appraised in subsequent sub-sections. The long list appraisal methodology was presented in Section 2.3 and Appendix B.

Table M.2 Appraisal of Reach 3 Long List Options

Option	Fulfil Project WFD Objectives for WB?	No constraints that would make option unfeasible?	Acceptable from a H&S perspective?	Not result in significant detrimental or loss of characteristic features?	Hydromorphology & Naturalisation	Habitat	Water Quality	Flood Risk	Landscape/ Visual	Recreation & Amenity	Heritage	Contaminated Land & Sediment	Fish Passage	Sustainability/ Ongoing Maintenance	Total Score
	Y/N	Y/N	Y/N	Y/N	-2 to 2	-2 to 2	-2 to 2	-2 to 2	-2 to 2	-2 to 2	-2 to 2	-2 to 2	-2 to 2	-2 to 2	
Do nothing/ Baseline															
0	N	Y	Y	Y	0	0	0	0	0	0	0	0	0	0	0
1	Y	Y	Y	Y	2	1	2	0*	-1	-2	0	0	0	2	4
2	Y	Y	Y	Y	2	2	2	0*	0	-1	0	0	0	1	6
3	Y	Y	Y	Y	1	1	1	-1	-1	-1	0	0	0	1	1
4	Y	Y	Y	Y	1	1	1	0*	1	1	0	0	0	1	6

* Rising groundwater levels in the area may counter any minor benefit to flood risk from increasing channel conveyance and creation of ponds or wetland capacity as a result of these options

Reach 3 Option 1

This option is illustrated in Figure M.2 below. This option was considered to fulfil the necessary long listing criteria and was scored as part of the long listing appraisal. The option scored fairly (scoring 4 in total) and was thus not shortlisted for more detailed consideration.

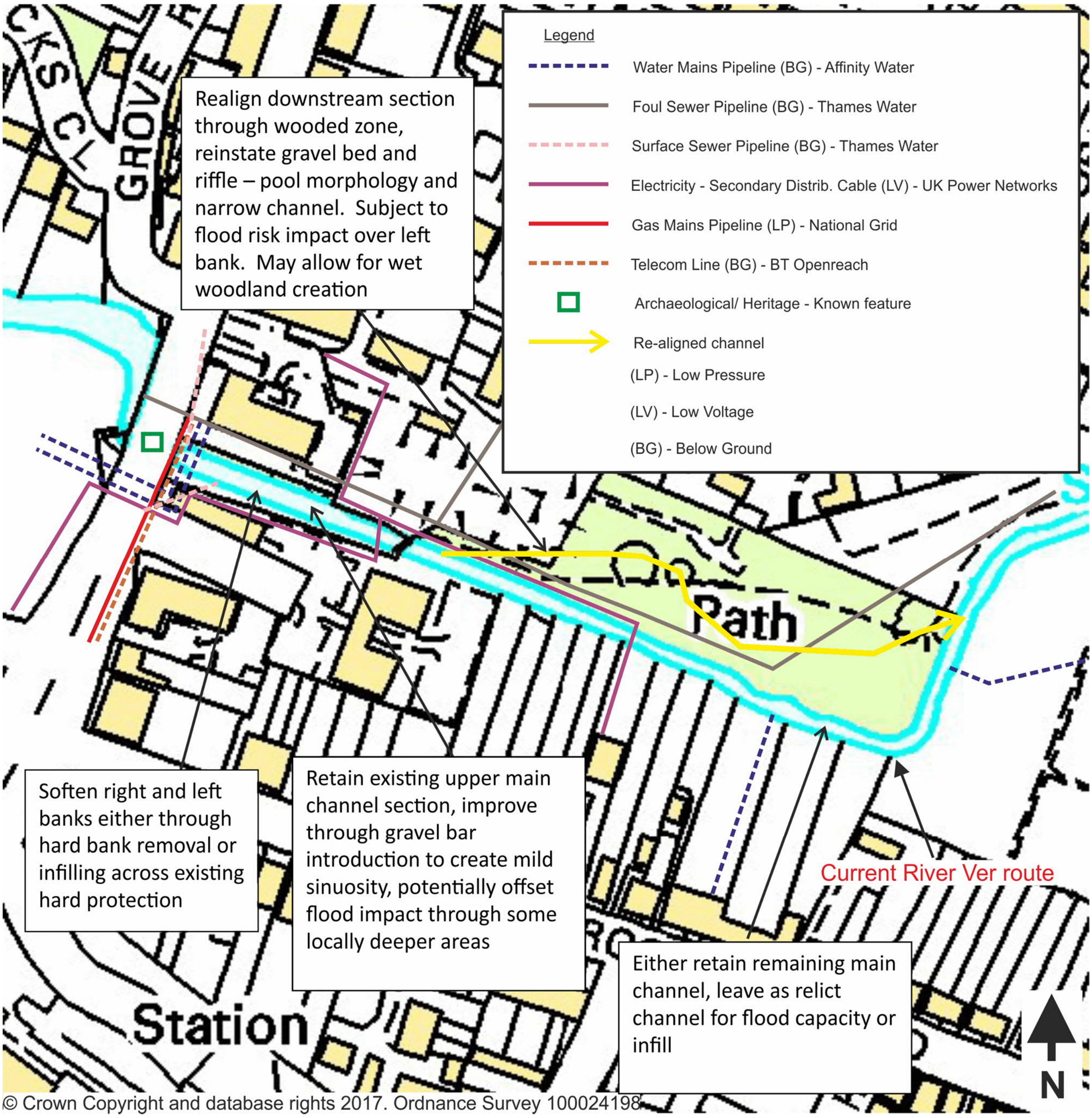


Figure M.2 Option 1 – Part re-alignment of existing channel

Reach 3 Option 2

This option is illustrated in Figure M.3 below. This option was considered to fulfil the necessary long listing criteria and was scored as part of the long listing appraisal. The option scored well (scoring 6 in total) and was thus shortlisted for more detailed consideration.

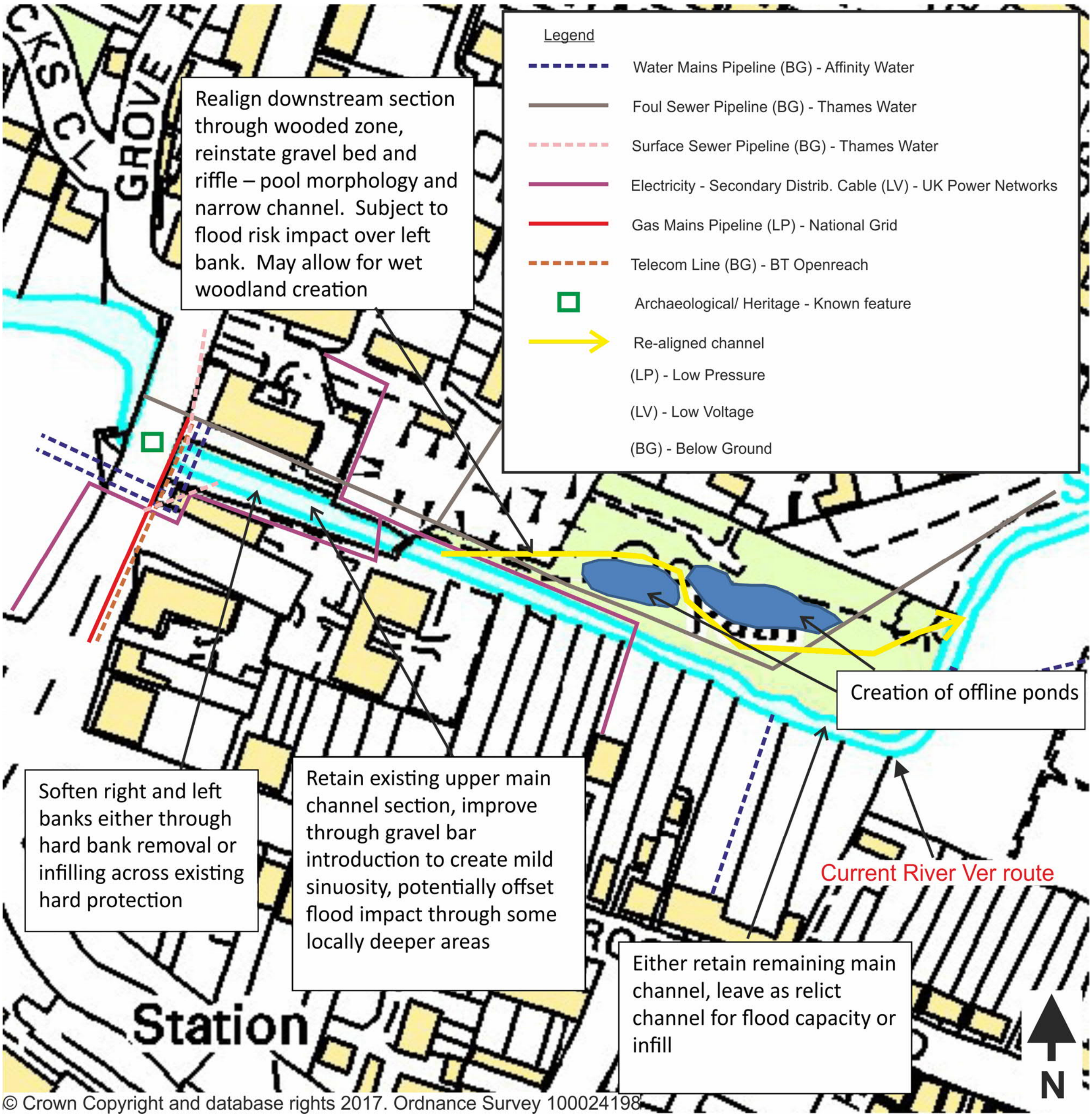


Figure M.3 Option 2 – Part re-alignment of existing channel, offline pond creation

Reach 3 Option 3

This option is illustrated in Figure M.4 below. This option was considered to fulfil the necessary long listing criteria and was scored as part of the long listing appraisal. The option scored almost neutral (scoring 1 in total) and was thus not shortlisted for more detailed consideration.

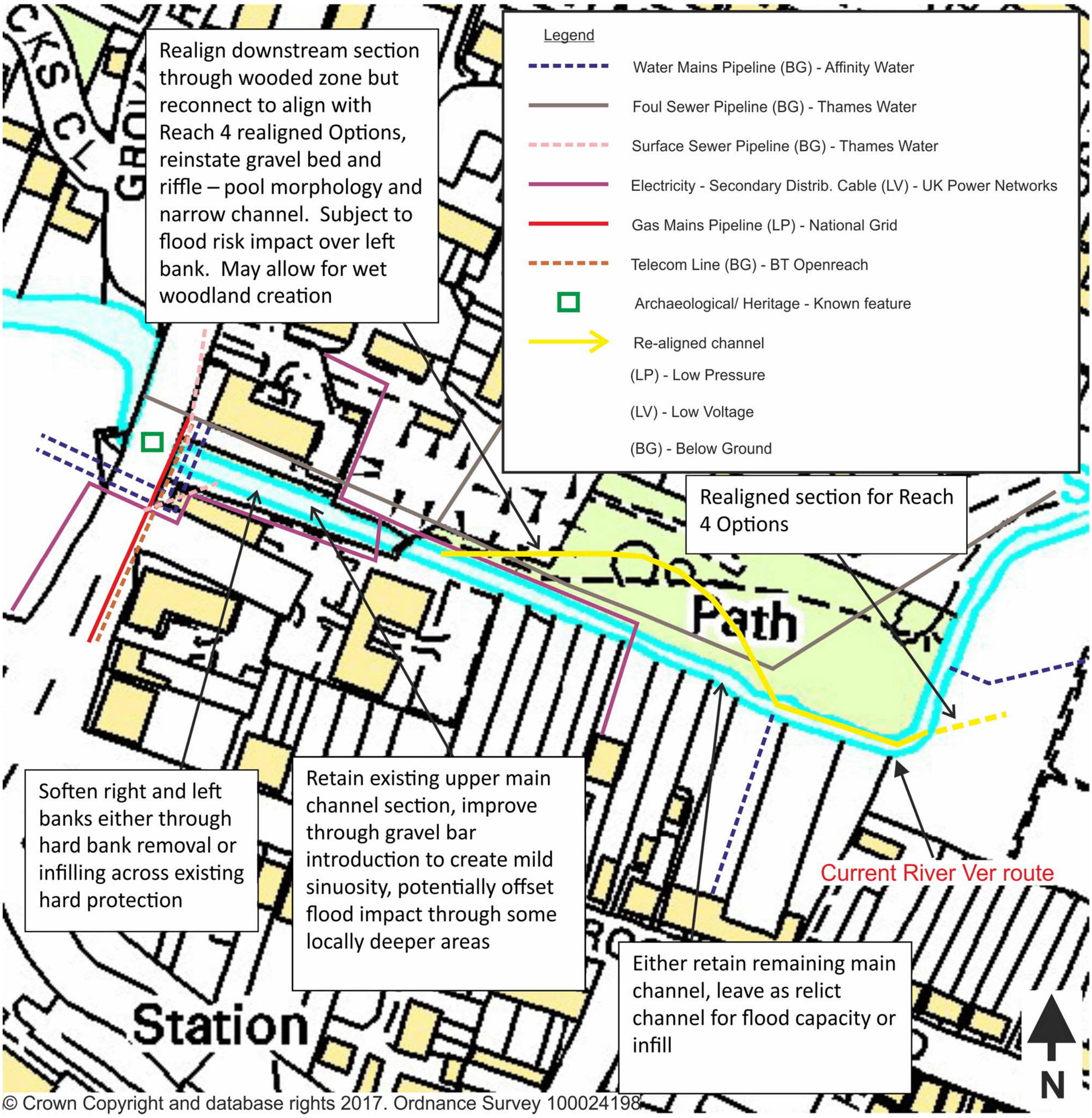


Figure M.4 Option 3 – Part re-alignment of channel but connected to re-aligned Reach 4 Options

Reach 3 Option 4

This option is illustrated in Figure M.5 below. This option was considered to fulfil the necessary long listing criteria and was scored as part of the long listing appraisal. The option scored well (scoring 6 in total) and was thus shortlisted for more detailed consideration.

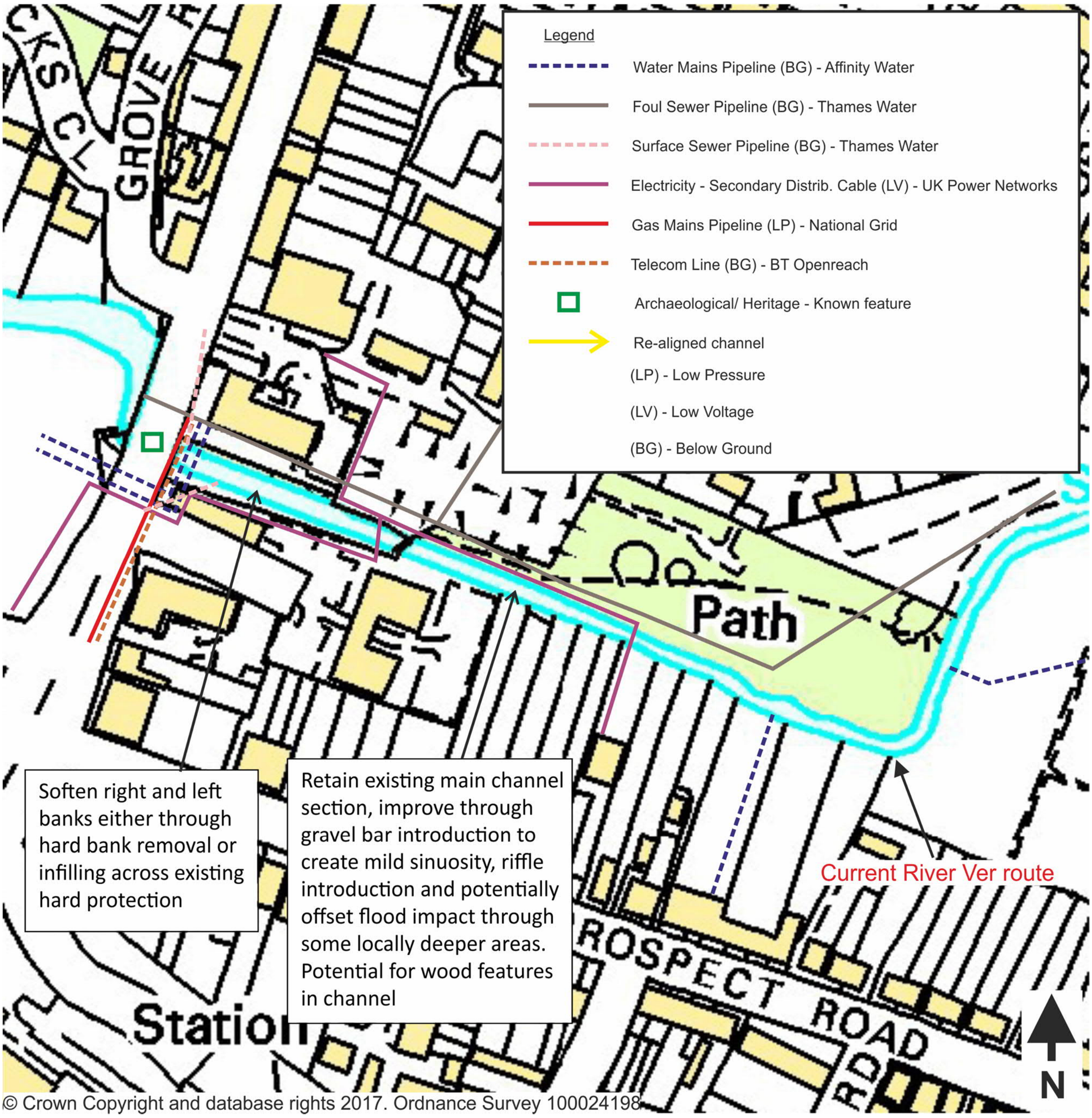


Figure M.5 Option 4 – Maintain existing channel and improve

Reach 3 Summary

As a result of the long list appraisal process, Reach 3 Options 2 and 4 were selected for shortlisting.

M.3 Reach 3 Short-listing Appraisal

Reach 3 Option Overview

The options outlined in Table M.3 were derived from the long listing appraisal and have been reviewed as part of the Short-listing appraisal. The short-listing appraisal methodology is described in Section 2.4 of the main report while project objectives were presented in Section 1.3.

Table M.3 Reach 3Short Listed Options following Long List Appraisal

Option	Description
Reach 3	
2	Part re-alignment of existing channel, offline pond creation
4	Maintain existing channel and improve

Review of Constraints and Opportunities

A plan of potential constraints for Reach 3 is provided in Figure M.6.

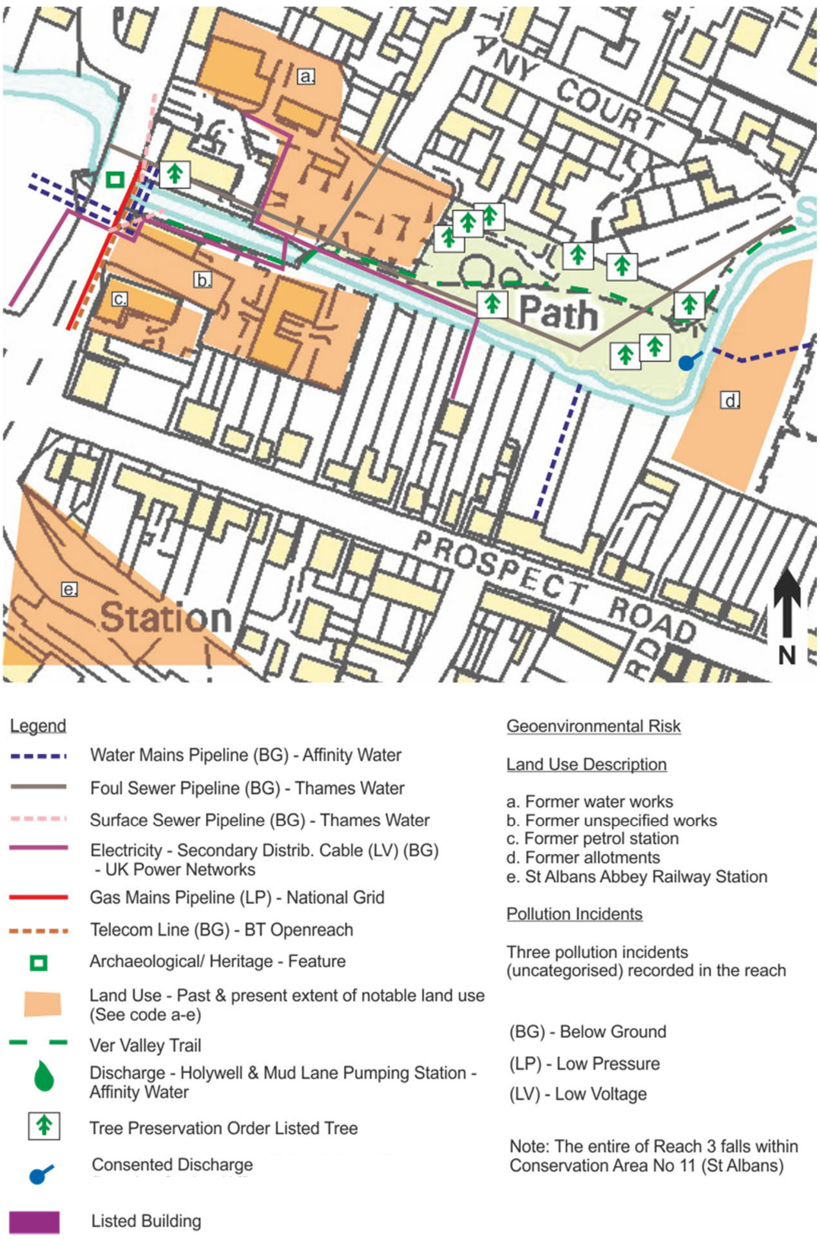


Figure M.6 Reach 3 constraints plan

Reach 3 Option 2

Option Description and Restoration Plan

This option would involve re-alignment of the Ver through the wooded, green space located at the downstream end of Reach 3, re-joining the existing channel prior to its course through the allotments.

The re-aligned channel would be subject to in-channel re-profiling and incorporation of a suitable morphology through the creation of gravel/point bar and berm features (as illustrated in Figure M.7, which also indicates the features that have been included within the modelling).

An offline pond would be created alongside the re-aligned channel in the green space to the north the river while the existing footpath would be re-aligned to follow the course of the new channel through the green space.

Review of Constraints and Opportunities

A plan of potential constraints for Reach 3 was provided in Figure M.6. The effects of these constraints on the feasibility of this option are described in Table M.4 below, along with potential advantages/ opportunities.

Figure M.7 Feature plans for Reach 3 Option 2

Table M.4 Review of constraints and opportunities for Reach 3 Option 2

Topic	Potential Issues	Assessment of the Effect or Potential Effect of the Option
Access	Access may be difficult and even prohibitively expensive under certain circumstances	• Access for works likely to come from the north of Reach 3 and not considered to be prohibitive (some TPOs present in the area where the channel re-routing is proposed).
Flood Risk	As a result of re-alignment or floodplain works, flood risk from the river may decrease or increase in areas	• There are some potential flood risk impacts to the left hand bank properties close to the realigned section of channel.
Hydromorphology	Does the scheme improve the hydromorphological functioning of the reach?	• A more natural planform associated with the realignment for this option with incorporation of the morphology shown would help to reduce the tendency for fine sediment deposition on the gravel bed and increase the hydraulic habitat diversity through the reach with a greater quantity of higher energy riffle units. The inclusion of an offline pond would also provide other valuable habitat gains.
Abstractions and other hydrological concerns	Consideration as to whether the scheme may result in other adverse or beneficial hydrological effects. For example re-routing of the river may impact upon distributaries as well as the main river.	• No surface water abstractions in this reach and so no effect of the scheme on these.
Groundwater connectivity	Does the scheme affect connectivity between surface water and groundwater?	• There is likely to be a small improvement in groundwater connectivity associated with this option through the identified realignment works.
Environmental Permits / consented discharges	Significant re-routing of the system may result in less flow being in the river at the point where a consented discharges enters and less dilution of that discharge.	• There are two consented discharges at the end of this reach. These belong to Affinity Water and are linked to their groundwater abstractions in St Albans. As such they are likely to of good water quality (so no impact upon river water quality anticipated as a result of the option due to hydrological changes) although they would need to be accounted for during the works (i.e. connected to the re-routed river).
Heritage	Scenario has the potential to impact upon Scheduled Monument or other archaeological feature	• The option is unlikely to have a significant effect of features of archaeological importance.
Water Mains and Sewers (foul and surface water)	Under certain scenarios, construction may be routed close to other water mains and sewers. If so, these may have substantive effects on the cost of the scheme, its feasibility and duration of its construction.	• Affinity Water mains are located within this reach, for example at its upstream end, although not close to any areas that are to be modified and outwith areas likely to be within the working area. • There is a Thames Water foul sewer that extends along this reach and through the area where work is proposed under this option. In this area it is at a depth of around 2.9m bgl. The proposed re-alignment through this reach may potentially impact upon this, requiring works to mitigate this risk and / or in the scheme to be modified to avoid it (impacting upon the benefit of the scheme).
Other Utilities	Under certain scenarios, construction may be routed close	• There is a below ground electricity line that extends along the top half of this

	to other utilities, such as BT or gas mains. If so, these may have substantive effects on the cost of the scheme, its feasibility and duration of its construction.	reach including the top end of where the river is to be re-aligned. The depth of this is not known and should be determined to inform the significance it would have on the feasibility of this option. • There are a number of utilities at the top end of reach, including below and above ground lines. The option would not impact upon these as river changes occur further downstream.
Geo-environmental	Consideration as to whether scheme could result in pathways for contaminants to enter the water environment.	• The river is not re-aligned through areas identified as being potentially contaminated. Such areas are also unlikely to be encompassed during construction works too.
Local Wildlife Sites (Non-statutory)	Wildlife sites lie throughout the study area and could potentially be impacted by the scenarios	• There are no Local Wildlife Sites in this reach and so this option would not impact upon them.
Tree Protection Orders (TPO)	Consideration of the effect of Tree Protection Orders on the option	• A number of TPOs are present in the wooded area which may be accessed through during construction. These should be avoided during the works and are not considered to be prohibitive.
Public Rights of Way	Public Rights of Way may need to be diverted if works are would occur over their route	• No public rights of way in vicinity of the works although a public path extends alongside the river and would require to be diverted for the duration of the works. • Overall, public access to the river would be improved as a result of the works.
Other Costs	Identification of potentially significant costs or aspects that are comparably low cost	• The works should be relatively low cost, with the presence of the Thames Water sewer and electricity line potentially having the greatest cost impact.
Landscape impact	Review whether option would have a significant visual impact	• The option should result in an improved looking and more natural appearing river that is better connected to its flood plain.
Recreation and amenity	Review whether option would have significant impacts upon recreation and amenity	• The option should result in a more accessible river lying within a wet woodland, which should be appealing for people to visit.
Riparian ownership issues	Consideration as to whether option may require re-routing through lands that are privately owned or result in riparian changes that may be unacceptable.	• St Albans City and District Council and Affinity Water are the riparian owners of the wooded area where the works are proposed. • Riparian owners on the right bank may not find the loss of a river flowing adjacent to their property acceptable.

Reach 3 Option 4

Option Description and Restoration Plan

In Option 4 the existing channel course would be maintained and subject to narrowing throughout the length of the reach, along with the incorporation of a suitable riffle-pool morphology (as illustrated in Figure M.8, which also includes the features included within the modelling).

Both banksides would be softened, either through hard bank structure removal, or infilling across the existing hard protection.

Review of Constraints and Opportunities

A plan of potential constraints for Reach 3 was provided in Figure M.6. The effects of these constraints on the feasibility of this option are described in Table M.5 below, along with potential advantages/ opportunities.

Figure M.8 Feature plans for Reach 3 Option 4

Table M.5 Review of constraints and opportunities for Reach 3 Option 4

Topic	Potential Issues	Assessment of the Effect or Potential Effect of the Option
Access	Access may be difficult and even prohibitively expensive under certain circumstances	• Access for works likely to come from the north of Reach 3. For the works in the lower half of this reach access is not considered to be prohibitive (some TPOs present in the area where the channel re-routing is proposed) although it would be difficult to access and work in the top half as the working area is constrained.
Flood Risk	As a result of re-alignment, in-channel or floodplain works, flood risk from the river may decrease or increase in areas	• There are unlikely to be any significant flood risk impacts as a result of the modifications proposed for this option although the proximity to residential housing may means that the reach may be sensitive to these small changes at this location.
Hydromorphology	Does the scheme improve the hydromorphological functioning of the reach?	• Incorporation of an appropriate morphology and associated narrowing shown would help to reduce the tendency for fine sediment deposition on the gravel bed and increase the hydraulic habitat diversity through the reach with a greater quantity of higher energy riffle units.
Abstractions and other hydrological concerns	Consideration as to whether the scheme may result in other adverse or beneficial hydrological effects. For example re-routing of the river may impact upon distributaries as well as the main river.	• No surface water abstractions in this reach and so no effect of the scheme on these.
Groundwater connectivity	Does the scheme affect connectivity between surface water and groundwater?	• There are unlikely to be any significant improvements to the existing groundwater connectivity as a result of the proposed morphological works associated to this option.
Environmental Permits / consented discharges	Significant re-routing of the system may result in less flow being in the river at the point where a consented discharges enters and less dilution of that discharge.	• There are two consented discharges at the end of this reach. These belong to Affinity Water and are linked to their groundwater abstractions in St Albans . As such they are likely to of good water quality. The option would not impact upon the hydrology within this reach and so, or their effect on water quality, would not be impacted by the scheme.
Heritage	Scenario has the potential to impact upon Scheduled Monument or other archaeological feature	• The option is unlikely to have a significant effect of features of archaeological importance.
Water Mains and Sewers (foul and surface water)	Under certain scenarios, construction may be routed close to other water mains and sewers. If so, these may have substantive effects on the cost of the scheme, its feasibility and duration of its construction.	• Affinity Water mains are located at start of Reach 3. The proposed works would occur close downstream of these and they should be accounted for during construction. • There is a Thames Water foul sewer (depth approximately 2.9m bgl) that extends along this reach to the north of the existing river. The proposed works would not impact upon the pipeline directly although it should be accounted for during construction.
Other Utilities	Under certain scenarios, construction may be routed close to other utilities, such as BT or gas mains. If so, these may have substantive effects on the cost	• There are below ground electricity line that extend through the upper half of the reach and cross the river close to the footbridge. The depth of this would need to be established and the line may impact upon construction costs and require mitigation.

	of the scheme, its feasibility and duration of its construction.	• There are a number of other utilities at the top of the reach. The proposed works would occur close downstream of these and they should be accounted for during construction.
Geo-environmental	Consideration as to whether scheme could result in pathways for contaminants to enter the water environment.	• The river is not re-aligned through areas identified as being potentially contaminated. Such areas are also unlikely to be encompassed during construction works too.
Local Wildlife Sites (Non-statutory)	Wildlife sites lie throughout the study area and could potentially be impacted by the scenarios	• There are no Local Wildlife Sites in this reach and so this option would not impact upon them.
Tree Protection Orders (TPO)	Consideration of the effect of Tree Protection Orders on the option	• A number of TPOs are present in the wooded area where the works are proposed although not within footprint of where restoration is proposed. The TPOs may impact upon construction and access although not on the scheme itself.
Public Rights of Way	Public Rights of Way may need to be diverted if works are would occur over their route	• No public rights of way in vicinity of the works although a public path extends alongside the river and would require to be diverted for the duration of the works. • Overall, public access to the river would be improved as a result of the works.
Other Costs	Identification of potentially significant costs or aspects that are comparably low cost	• The works should be relatively low cost although the presence of utilities and difficulties posed regarding access and working in the upper half of the reach, may result in additional costs. These may outweigh the moderate hydromorphological benefits of this scheme.
Landscape impact	Review whether option would have a significant visual impact	• River works associated with this option are unlikely to have any significant landscape effects.
Recreation and amenity	Review whether option would have significant impacts upon recreation and amenity	• River works associated with this option will improve the access route to the river.
Riparian ownership issues	Consideration as to whether option may require re-routing through lands that are privately owned or result in riparian changes that may be unacceptable.	• St Albans City and District Council and Affinity Water are the riparian owners of the wooded area where the works are proposed. • Some localised bank erosion (providing varied habitat for wildlife) may occur although this can be considered further during detailed design.

Determination of the Preferred Reach 3 Option

Table M.6 provides a compiled review of the constraints and opportunities for the Reach 3 options. The discussion of each constraint/ opportunity for each option has been coloured accordingly:

- Green – Desired improvements and project objectives achieved. No constraints identified in relation to the category in question.
- Yellow - Desired improvements and project objectives achieved. Low or moderate mitigation costs and/ or constraints identified in relation to the category in question.
- Orange - Desired improvements and project objectives achieved. Moderate or high mitigation costs and/ or constraints identified in relation to the category in question.
- Red – Desired improvements and project objectives may not be achieved and/ or high mitigation costs and/ or major constraints identified in relation to the category in question that may be difficult or expensive to overcome.

From a hydromorphological perspective, Option 2 represents the greatest potential improvement given the restoration of a more appropriate planform compared to Option 4. Option 2 would also create wider riparian zone improvements, although these are at the expense of existing woodland habitat. Option 4 would provide improved morphological functioning compared to existing conditions.

However there are multiple constraints that affect the viability of Option 2 including the likely unpopularity of losing an area of existing woodland as a result of the channel re-alignment, and the potential complications around the re-alignment given the presence of utilities in this area. For both options, access in the upper half of the reach could be difficult with the working area being quite narrow.

On the basis of these constraints, Option 4 was consequently progressed as the preferred option given it avoids channel re-alignment.

Table M.6 Reach 3 Summary Table

Topic	Effect or Potential Effect of Reach 3 Option 2	Effect or Potential Effect of Reach 3 Option 4
Access	• Access for works likely to come from the north of Reach 3 and not considered to be prohibitive (some TPOs present in the area where the channel re-routing is proposed).	• Access for works likely to come from the north of Reach 3. For the works in the lower half of this reach access is not considered to be prohibitive (some TPOs present in the area where the channel re-routing is proposed) although it would be difficult to access and work in the top half as the working area is constrained.
Flood Risk	• There are some potential flood risk impacts to the left hand bank properties close to the realigned section of channel.	• There are unlikely to be any significant flood risk impacts as a result of the modifications proposed for this option although the proximity to residential housing may means that the reach may be sensitive to these small changes at this location.
Hydromorphology	• A more natural planform associated with the realignment for this option with incorporation of the morphology shown would help to reduce the tendency for fine sediment deposition on the gravel bed and increase the hydraulic habitat diversity through the reach with a greater quantity of higher energy riffle units. The inclusion of an offline pond would also provide other valuable habitat gains.	• Incorporation of an appropriate morphology and associated narrowing shown would help to reduce the tendency for fine sediment deposition on the gravel bed and increase the hydraulic habitat diversity through the reach with a greater quantity of higher energy riffle units.
Abstractions and other hydrological concerns	• No surface water abstractions in this reach and so no effect of the scheme on these.	• No surface water abstractions in this reach and so no effect of the scheme on these.
Groundwater connectivity	• There is likely to be a small improvement in groundwater connectivity associated with this option through the identified realignment works.	• There are unlikely to be any significant improvements to the existing groundwater connectivity as a result of the proposed morphological works associated to this option.
Environmental Permits / consented discharges	• There are two consented discharges at the end of this reach. These belong to Affinity Water and are linked to their groundwater abstractions in St Albans. As such they are likely to of good water quality (so no impact upon river water quality anticipated as a result of the option due to hydrological changes) although they would need to be accounted for during the works (i.e. connected to the re-routed river).	• There are two consented discharges at the end of this reach. These belong to Affinity Water and are linked to their groundwater abstractions in St Albans. As such they are likely to of good water quality. The option would not impact upon the hydrology within this reach and so, or their effect on water quality, would not be impacted by the scheme.
Heritage	• The option is unlikely to have a significant effect of features of archaeological importance.	• The option is unlikely to have a significant effect of features of archaeological importance.
Water Mains and Sewers (foul and surface water)	• Affinity Water mains are located within this reach, for example at its upstream end, although not close to any areas that are to be modified and outwith areas likely to be within the working area. • There is a Thames Water foul sewer that extends along this reach and through the area where work is proposed under this option. In this area it is at a depth of around 2.9m bgl. The proposed re-alignment through this reach may potentially impact upon this, requiring works to mitigate this risk and / or in the scheme to be modified to avoid it (impacting upon the benefit of the scheme).	• Affinity Water mains are located at start of Reach 3. The proposed works would occur close downstream of these and they should be accounted for during construction. • There is a Thames Water foul sewer (depth approximately 2.9m bgl) that extends along this reach to the north of the existing river. The proposed works would not impact upon the pipeline directly although it should be accounted for during construction.
Other Utilities	• There is a below ground electricity line that extends along the top half of this reach including the top end of where the river is to be re-aligned. The depth of this is not known and should be determined to inform the significance it would have on the feasibility of this option. • There are a number of utilities at the top end of reach, including below and above ground lines. The option would not impact upon these as river changes occur further downstream.	• There are below ground electricity line that extend through the upper half of the reach and cross the river close to the footbridge. The depth of this would need to be established and the line may impact upon construction costs and require mitigation. • There are a number of other utilities at the top of the reach. The proposed works would occur close downstream of these and they should be accounted for during construction.
Geo-environmental	• The river is not re-aligned through areas identified as being potentially contaminated. Such areas are also unlikely to be encompassed during construction works too.	• The river is not re-aligned through areas identified as being potentially contaminated. Such areas are also unlikely to be encompassed during construction works too.
Local Wildlife Sites (Non-statutory)	• There are no Local Wildlife Sites in this reach and so this option would not impact upon them.	• There are no Local Wildlife Sites in this reach and so this option would not impact upon them.
Tree Protection Orders (TPO)	• A number of TPOs are present in the wooded area which may be accessed through during construction. These should be avoided during the works and are not considered to be prohibitive.	• A number of TPOs are present in the wooded area where the works are proposed although not within footprint of where restoration is proposed. The TPOs may impact upon construction and access although not on the scheme itself.
Public Rights of Way	• No public rights of way in vicinity of the works although a public path extends alongside the river and would require to be diverted for the duration of the works. • Overall, public access to the river would be improved as a result of the works.	• No public rights of way in vicinity of the works although a public path extends alongside the river and would require to be diverted for the duration of the works. • Overall, public access to the river would be improved as a result of the works.
Other Costs	• The works should be relatively low cost although the presence of utilities and difficulties posed regarding access and working in the upper half of the reach, may result in additional costs. These may outweigh the moderate hydromorphological benefits of this scheme.	• The works should be relatively low cost, with the presence of the Thames Water sewer and electricity line potentially having the greatest cost impact.
Landscape impact	• The option should result in an improved looking and more natural appearing river that is better connected to its flood plain.	• River works associated with this option are unlikely to have any significant landscape effects.
Recreation and amenity	• The option should result in a more accessible river lying within a wet woodland, which should be appealing for people to visit.	• River works associated with this option will improve the access route to the river.
Riparian ownership issues	• St Albans City and District Council and Affinity Water are the riparian owners of the wooded area where the works are proposed. • Riparian owners on the right bank may not find the loss of a river flowing adjacent to their property acceptable.	• St Albans City and District Council and Affinity Water are the riparian owners of the wooded area where the works are proposed. • Some localised bank erosion (providing varied habitat for wildlife) may occur although this can be considered further during detailed design.

APPENDIX N – Determination of the Reach 4 Preferred Option

N.1 Overview

A summary of the derivation of the preferred option for Reach 4 (see Figure N.1) is presented within this Appendix. The included the following steps:

- Reach 4 Long List Appraisal.
- Reach 4 Short List Appraisal.

These results of the appraisals are outlined below.

Figure N.1 Reach 4 of the study area (Cottonmill Lane Allotments to Cottonmill Lane)

N.2 Reach 4 Long List Appraisal

Options Identification

The long list of options for Reach 4 are outlined in Table N.1.

Table N.1 Long List Options Reach 4

Option	Description
1	Re-align channel through allotments
2	Re-align channel through allotments and connect to re-aligned Reach 5 Options
3	Create more sinuous channel close to existing channel course
4	Maintain and improve existing channel

A schematic of these options is provided in Figures N.2 – N.5 below.

Long List Appraisal

A summary of the long list appraisal and scoring is provided in Table N.2 below. Individual options are appraised in subsequent sub-sections. The long list appraisal methodology was presented in Section 2.3 and Appendix B.

Table N.2 Appraisal of Reach 4 Long List Options

Option	Fulfil Project WFD Objectives for WB?	No constraints that would make option unfeasible?	Acceptable from a H&S perspective?	Not result in significant detrimental or loss of characteristic features?	Hydromorphology & Naturalisation	Habitat	Water Quality	Flood Risk	Landscape/ Visual	Recreation & Amenity	Heritage	Contaminated Land & Sediment	Fish Passage	Sustainability/ Ongoing Maintenance	Total Score
	Y/N	Y/N	Y/N	Y/N	-2 to 2	-2 to 2	-2 to 2	-2 to 2	-2 to 2	-2 to 2	-2 to 2	-2 to 2	-2 to 2	-2 to 2	
Do nothing/ Baseline															
0	N	Y	Y	Y	0	0	0	0	0	0	0	0	0	0	0
1	Y	Y	Y	Y	2	2	2	2	1	-2	0	0	0	2	9
2	Y	To be confirmed	Y	Y	2	2	2	-2	1	-2	0	0	0	-1*	2
3	Y	Y	Y	Y	2	1	1	0	1	-1	0	0	0	1	5
4	Y	Y	Y	Y	1	1	1	0	1	-1	0	0	0	1	4

* New culvert may require additional maintenance.

Reach 4 Option 1

This option is illustrated in Figure N.2 below. This option was considered to fulfil the necessary long listing criteria and was scored as part of the long listing appraisal. The option scored well (scoring 9 in total) and was thus shortlisted for more detailed consideration.

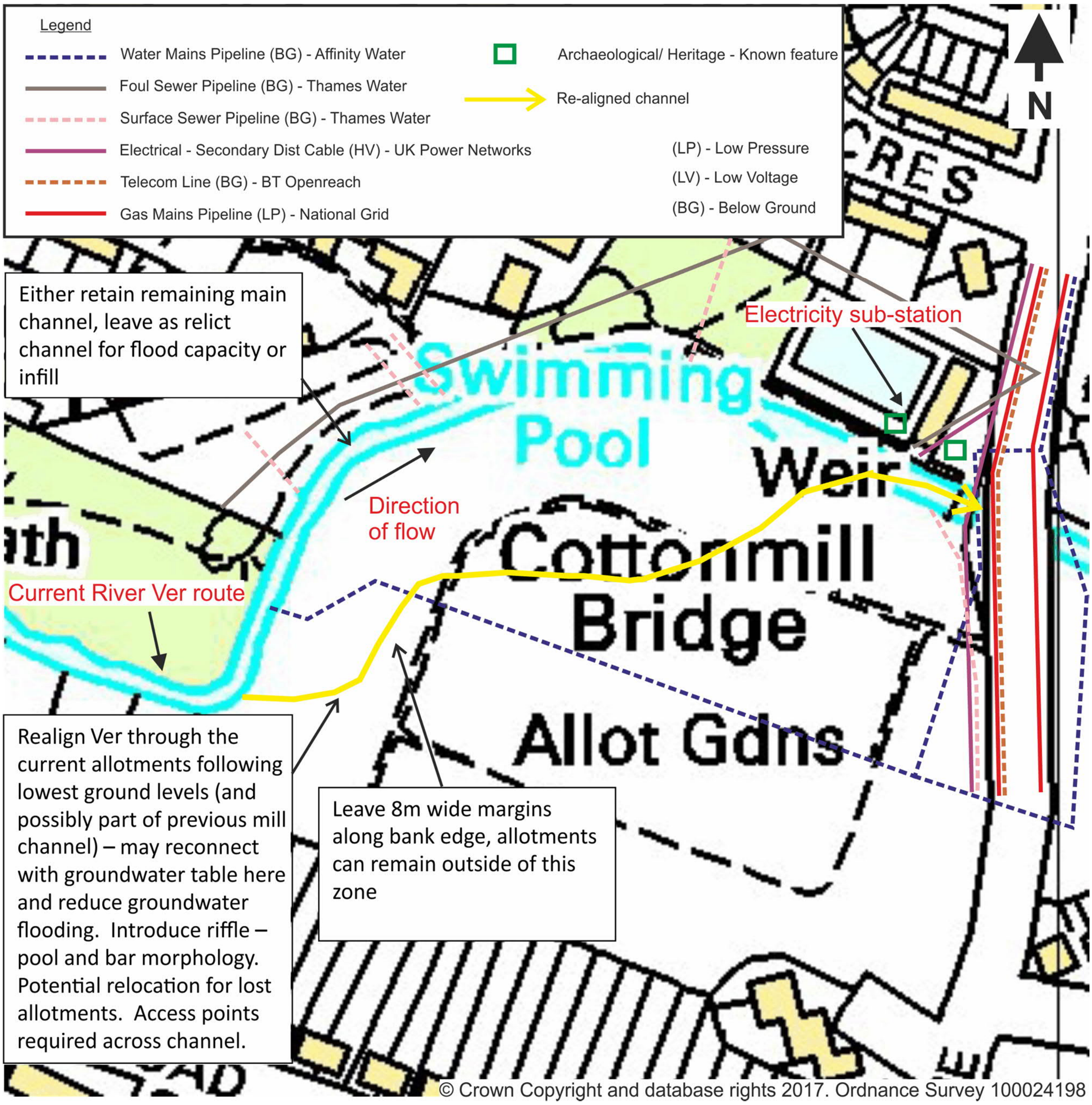


Figure N.2 Option 1 – Re-align channel through allotments

Reach 4 Option 2

This option is illustrated in Figure N.3 below. Additional investigations (groundwater recharge and flood risk modelling) are currently ongoing which will better inform the feasibility of this option and so it is to be confirmed whether or not this option would fulfil the criteria of the initial long list appraisal process (Table N.2). A tentative long list score of 2 has been determined based on what is currently known although the ongoing further studies may improve this score. Given this, and the fact that this option is the most naturalised option, this option has been retained for further investigation during the short-listing stage of the assessment.

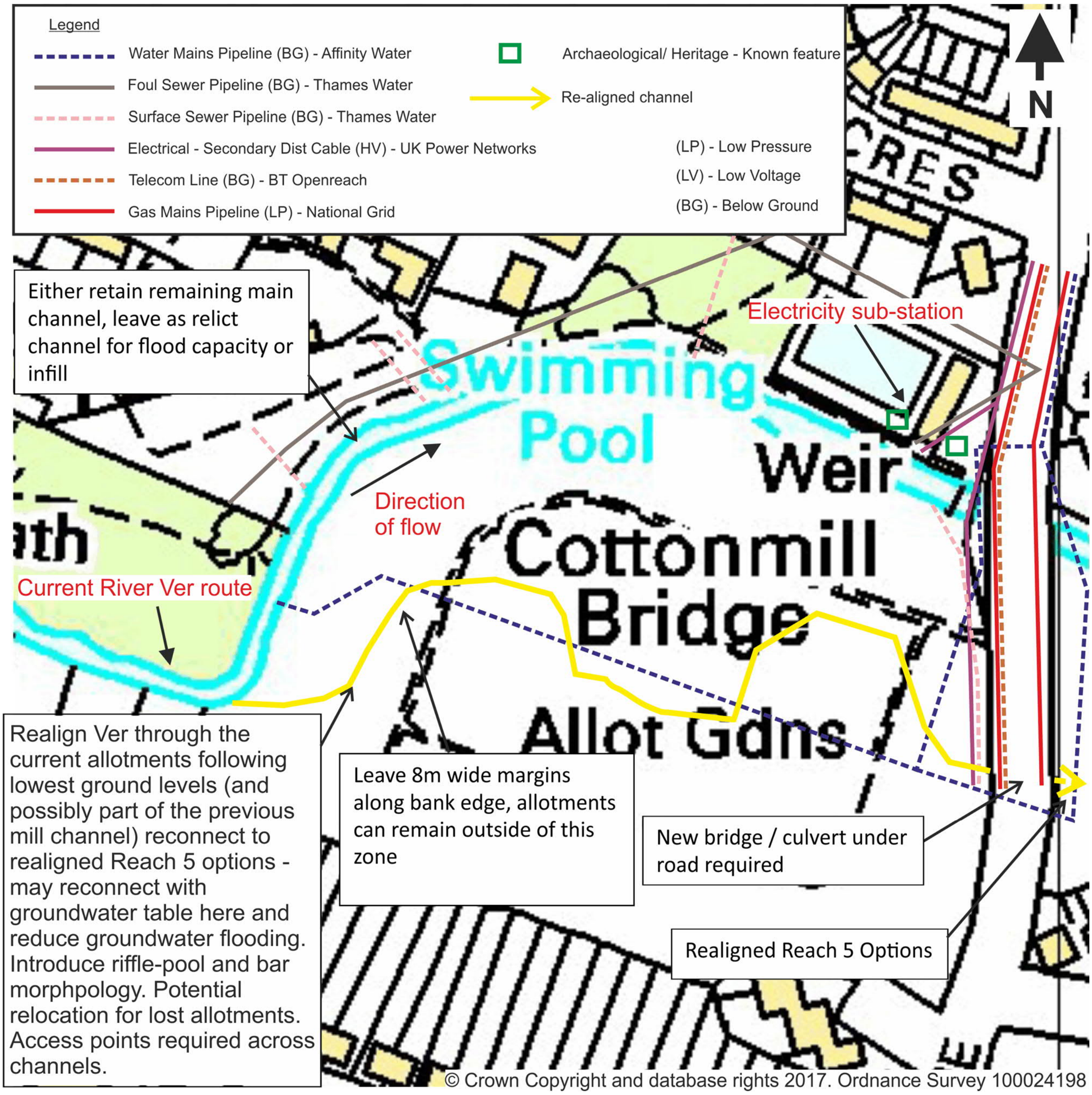


Figure N.3 Option 2 – Re-align channel through allotments and connect to re-aligned Reach 5 Options

Reach 4 Option 3

This option is illustrated in Figure N.4 below. This option was considered to fulfil the necessary long listing criteria and was scored as part of the long listing appraisal. The option scored well (scoring 5 in total) and was thus shortlisted for more detailed consideration. Groundwater emergence is anticipated through this reach however and although this option would not explicitly result in effects on the allotment users, the option does not counter the effects of groundwater emergent that is expected to impact those users. A score of -1 has hence been given to this option regarding recreation and amenity.

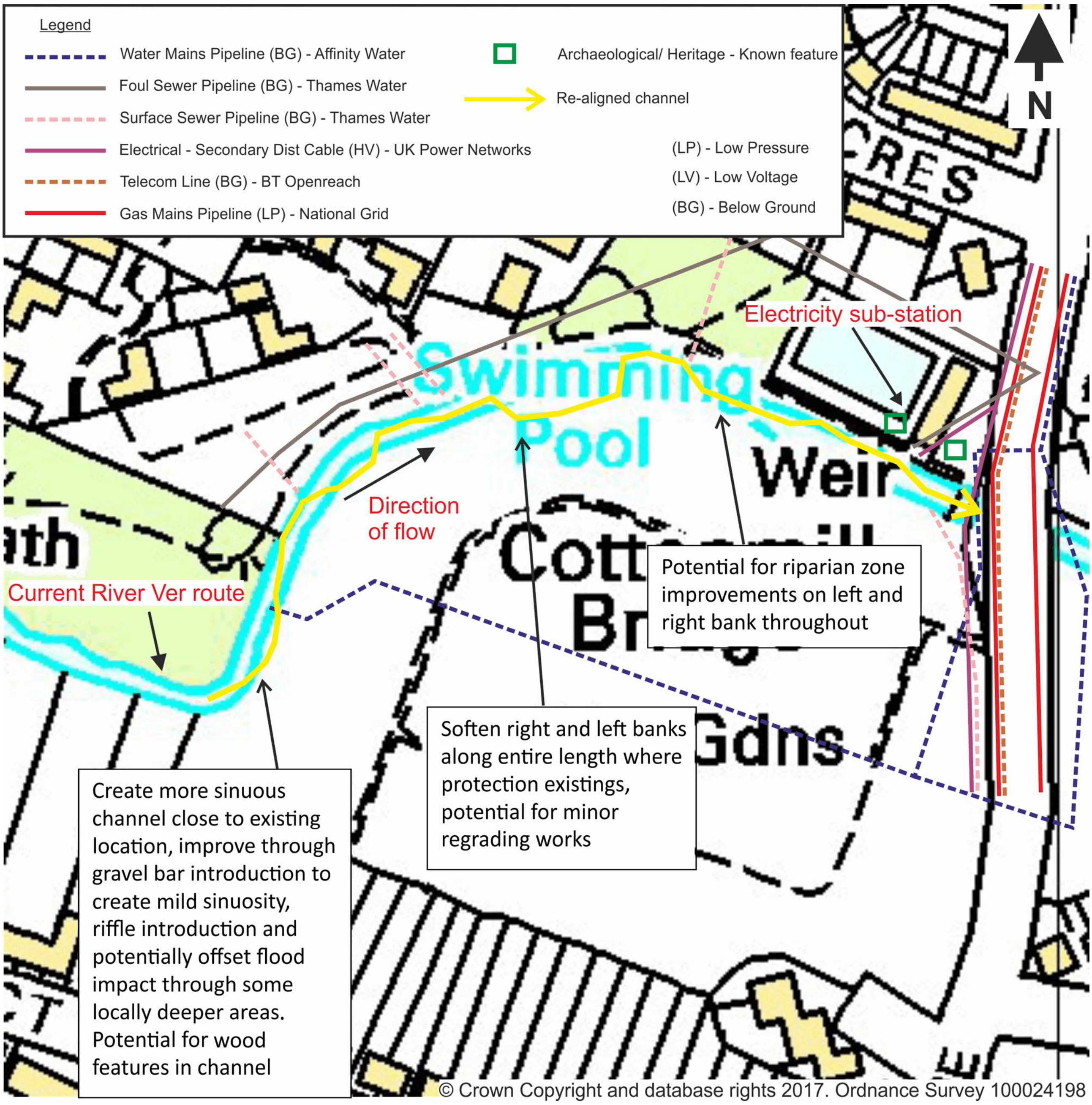


Figure N.4 Option 3 – Create more sinuous channel close to existing channel course

Reach 4 Option 4

This option is illustrated in Figure N.5 below. This option was considered to fulfil the necessary long listing criteria and was scored as part of the long listing appraisal. The option scored fairly (scoring 4 in total) although was not shortlisted for more detailed consideration as Reach 4 Option 3 is a similar option which scored better and has been shortlisted for further consideration.

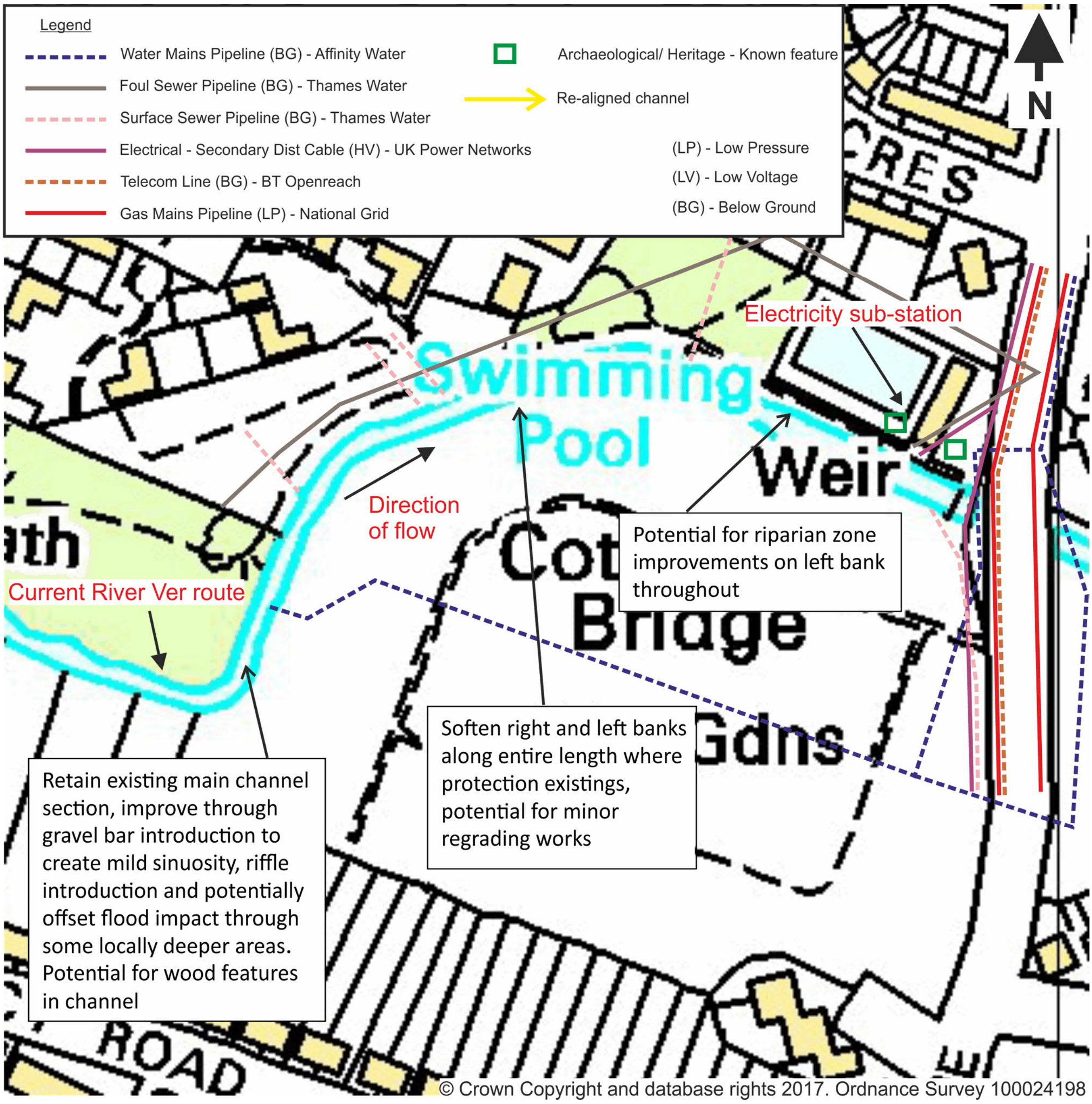


Figure N.5 Option 4 – Maintain and improve existing channel

Reach 4 Summary

As a result of the long list appraisal process, Reach 4 Options 1 and 3 were selected for shortlisting. Option 2 has been taken forward for further consideration since ongoing studies may improve its long listing score and as it represents the most naturalised restoration option for this reach (linked to Reach 5).

N.3 Reach 4 Short-listing Appraisal

Reach 4 Option Overview

The options outlined in Table N.3 were derived from the long listing appraisal and have been reviewed as part of the Short-listing appraisal. The short-listing appraisal methodology is described in Section 2.4 of the main report while project objectives were presented in Section 1.3.

Table N.3 Reach 4 Short Listed Options following Long List Appraisal

Option	Description
Reach 4	
1	Re-align channel through allotments
2	Re-align channel through allotments and connect to realigned Reach 5 Options
3	Create more sinuous channel close to existing channel course

Review of Constraints and Opportunities

A plan of potential constraints for Reach 4 is provided in Figure N.6.

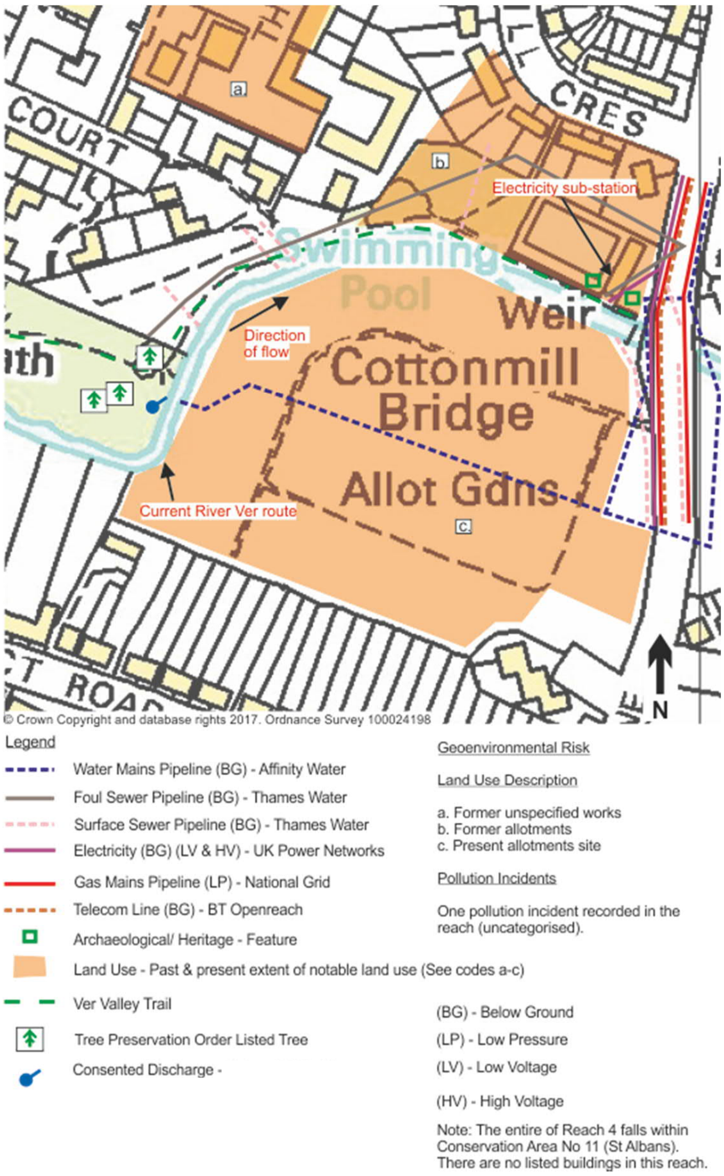


Figure N.6 Reach 4 Option 1 constraints plan

Reach 4 Option 1

Option Description and Restoration Plan

In Option 1 the Ver would be re-aligned throughout the course of Reach 4, leaving the existing course as the channel turns sharply north, following a broadly straight path (with meanders) through the low lying allotment area before re-joining at the Cottonmill Lane crossing. Given future groundwater emergence, a wetland around the re-aligned channel would be included, making use of this land that would otherwise be wasted. An overview of the plan is provided in Figure N.7.

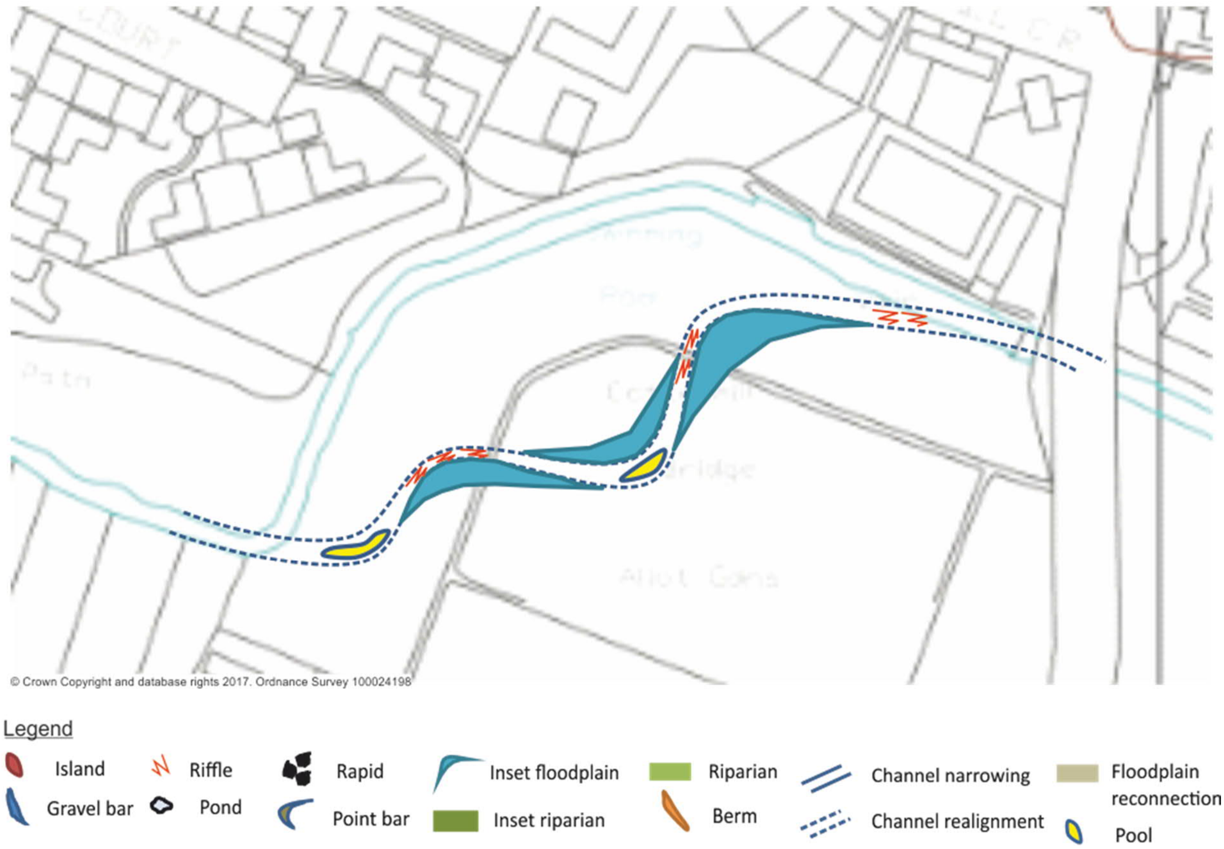


Figure N.7 Feature plans for Reach 4 Option 1

The re-aligned channel would be subject to in-channel re-profiling and incorporation of a suitable morphology including a riffle-pool regime along with the creation of inset floodplain features (as illustrated in Figure N.7).

The remaining channel course would either be retained as a relict channel, providing flood capacity, or infilled, potentially providing land for relocated allotments. Significant re-profiling works would be required at the up and downstream connection points due to the level discrepancies as a result of the lower bed levels through the realigned section of channel compared to the bed levels at the connections points in the current main channel.

Review of Constraints and Opportunities

A plan of potential constraints for Reach 4 was provided in Figure N.6. The effects of these constraints on the feasibility of this option are described in Table N.4 below, along with potential advantages/ opportunities.

Table N.4 Review of constraints and opportunities for Reach 4 Option 1

Topic	Potential Issues	Assessment of the Effect or Potential Effect of the Option
Access	Access may be difficult and even prohibitively expensive under certain circumstances	• Access for works should be straightforward from Cottonmill Lane. • This is a popular allotment site. While disruption to allotments should be minimised H&S considerations mean that parts or all of the site would need to be closed while work takes place. • Works should be carried out at the time of the year least disruptive to tenants although it must be acknowledged that high groundwater levels, which can occur in the allotment area, may affect plant operations and works. • It is assumed that the allotments would be decommissioned in advance of the works. High groundwater levels, which can occur in the allotment area, would affect plant operations and works should be undertaken at times when these are low.
Flood Risk	As a result of re-alignment or floodplain works, flood risk from the river may decrease or increase in areas	• The allotment site is threatened by rising groundwater levels as a result of future sustainability reductions. Our study / appendix C predicts a rise of groundwater levels of more than 1 m in this area and it is expected that the site will flood most years. This option provides an opportunity to address these issues and provide a sustainable solution. • The option would reconnect the river to valley bottom and its floodplain. The area around the new channel will flood more often and will not be used for allotments.
Hydromorphology	Does the scheme improve the hydromorphological functioning of the reach?	• The realignment works would locate the channel back close to the natural valley bottom and is therefore likely to improve the flow and habitat diversity, particularly with the inclusion of an appropriate morphology as specified. This should increase the hydraulic habitat diversity with a greater frequency of higher energy riffle units.
Main channel bed level modifications	Realignment options to the natural valley bottom would require works to the main channel up and downstream connection points to ensure correct functioning.	• Significant existing channel re-profiling works would be required at the downstream end where the realigned channel reconnects with the main channel as a result of the level discrepancy with the channel in the natural valley bottom reconnecting to the current perched channel.
Abstractions and other hydrological concerns	Consideration as to whether the scheme may result in other adverse or beneficial hydrological effects. For example re-routing of the river may impact upon distributaries as well as the main river.	• There are no surface water abstractions in or close to this reach and so no effect of the scheme on these (note sustainability reductions influence flow through the reach however).
Groundwater connectivity	Does the scheme affect connectivity between surface water and groundwater?	• The river and groundwater would be re-connected by realigning the channel through the natural valley bottom. This would represent a naturalisation of

		the system and enable natural chalk stream functioning.
Environmental Permits / consented discharges	Significant re-routing of the system may result in less flow being in the river at the point where a consented discharges enters and less dilution of that discharge.	• There are two consented discharges at the top of this reach. These belong to Affinity Water and are linked to their groundwater abstractions in St Albans. As such they are likely to of good water quality (so no impact upon river water quality anticipated as a result of the option due to the hydrological changes) although they would need to be accounted for during the works (i.e. connected to the re-routed river). The quality of the discharges should be tested to confirm this theory. Some work may be required to re-connect these to the river before it is re-aligned.
Heritage	Scenario has the potential to impact upon Scheduled Monument or other archaeological feature	• The option is unlikely to have a significant effect of features of archaeological importance. Two features are located on the northern/ left bank at the downstream end of the reach. They should be accounted for as part of any reconnection works although are not considered to be prohibitive to the option.
Water Mains and Sewers (foul and surface water)	Under certain scenarios, construction may be routed close to other water mains and sewers. If so, these may have substantive effects on the cost of the scheme, its feasibility and duration of its construction.	• There is an Affinity Water distribution mains running through the middle of the allotments that is likely to be crossed by the re-aligned channel. This is at a depth of around 1.4m bgl and would need to be accounted for during any works, which would be expensive. There are also a pair of distribution mains under the Cottonmill Lane bridge that would need to be accounted for if culvert adjustment works are anticipated there. Replacement of a more appropriate service crossing would likely be required as a result of this option due to the necessary re-profiling works to allow this option to function. • Similarly, there is a pair of Thames Water surface water sewers running parallel with Cottonmill Lane, ending either side of the actual bridge crossing. The pipeline located on the upstream side of the bridge is approximately 1m bgl. Both would need to be accounted for if culvert adjustment works are anticipated where the re-aligned channel is proposed to re-join the existing channel course.
Other Utilities	Under certain scenarios, construction may be routed close to other utilities, such as BT or gas mains. If so, these may have substantive effects on the cost of the scheme, its feasibility and duration of its construction.	• A BT Openreach line follows the course of Cottonmill Lane, crossing the bridge at a minimum depth of 0.35m bgl. This would need to be accounted for if culvert adjustment works are anticipated where the re-aligned channel is proposed to re-join the existing channel course. • Both high and low voltage UK Power Networks cables follow the course of Cottonmill Lane, with the high voltage line crossing the bridge at a depth of 0.80m bgl. An additional pair of lines following the same course are set at unknown depths, therefore further site investigation would be required to inform line status.

		• A pair of National Grid low pressure gas mains follow the course of Cottonmill Lane, crossing the bridge at an unknown depth. This would need to be further investigated and accounted for if culvert adjustment works are anticipated where the re-aligned channel is proposed to re-join the existing channel course. • Replacement of a more appropriate service crossing would likely be required as a result of this option due to the necessary re-profiling works to allow this option to function.
Geo-environmental	Consideration as to whether scheme could result in pathways for contaminants to enter the water environment.	• Re-alignment would occur through an area that is presently allotments. This would provide a direct route for contaminants and nutrients to be introduced into the river and would have an impact upon water quality in the river for the short term at least. It is noted that there is currently a pathway for these to enter the river indirectly, via runoff. • Our view is that this is a significant constraint although not insurmountable. Further studies and analysis would be needed, such as soil testing through the allotments, to better inform the risk and ultimately the design. Inclusion of wetlands through this reach would help retain some of the pollutants.
Local Wildlife Sites (Non-statutory)	Wildlife sites lie throughout the study area and could potentially be impacted by the scenarios	• There are no Local Wildlife Sites in this reach and so this option would not impact upon them. Re-alignment and creation of a wetland through the area where groundwater emergence provides an opportunity for habitat and biodiversity gains to be made (with replacement allotments being found too).
Tree Protection Orders (TPO)	Consideration of the effect of Tree Protection Orders on the option	• There are no TPOs in this reach and so no effect on the scheme.
Public Rights of Way	Public Rights of Way may need to be diverted if works are would occur over their route	• No public right of way near the site. Ver Valley Trail follows existing river through this reach. Small parts of this may need to be diverted during the re-connecting works at the downstream end of the reach.
Other Costs	Identification of potentially significant costs or aspects that are comparably low cost	• St Albans City and District Council would need to replace affected plots to other site(s) which would have administrative and other costs. The feasibility of the site would be undermined by the groundwater rebound when abstraction is reduced in 2024 so these costs may be incurred irrespective of the scheme. • There would be a large cost associated to the likely required service crossing modification and potential works to the culvert structure to get the correct bed levels in order for this option to function correctly.
Landscape impact	Review whether option would have a significant visual impact	• The option should result in an improved looking and more natural appearing river that is better connected to its flood plain.

Recreation and amenity	Review whether option would have significant impacts upon recreation and amenity	• The option includes re-alignment through a hugely popular allotment site with strong community feeling. However, much of the site is threatened by future sustainability reductions. • This option offers much improved river, accessible wetland area should be appealing for people to visit and is considered to be a long term sustainabale option. • Plans can be developed that can maximise plots that can remain on the site with nearby sites being available for replacement allotments.
Riparian ownership issues	Consideration as to whether option may require re-routing through lands that are privately owned or result in riparian changes that may be unacceptable.	• St Albans City and District Council own the land throughout this reach and so no riparian ownership issues are anticipated.

Reach 4 Option 2

Option Description and Restoration Plan

Similarly to Option 1, the Ver would be re-aligned through the allotments under Option 2 although would be connected to a newly re-aligned channel course through Reach 5 downstream. Given future groundwater emergence, a buffer area around the re-aligned channel would be included. This would require a new culvert to be installed under the road that separates Reach 4 from Reach 5. An overview of the option is provided in Figure N.8.

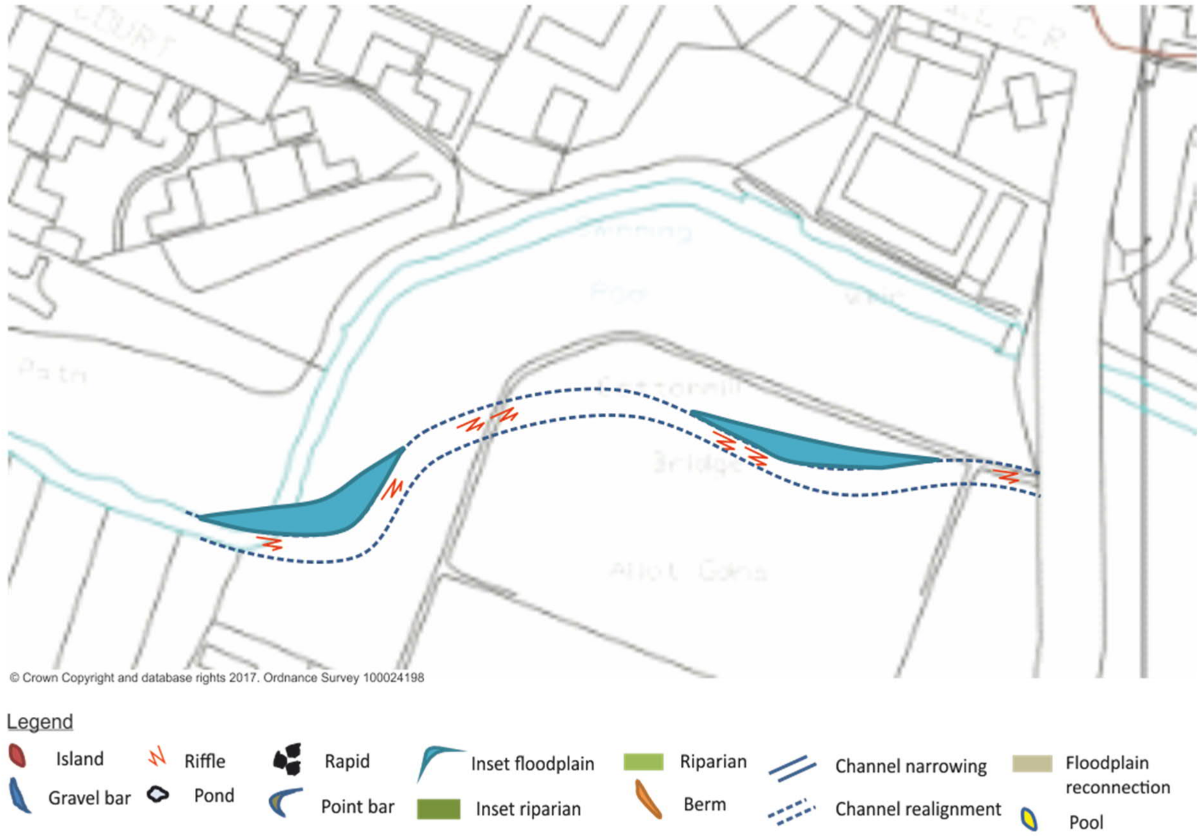


Figure N.8 Feature plans for Reach 4 Option 2

The re-aligned channel would be subject to in-channel re-profiling and incorporation of a suitable morphology including riffles and inset floodplain features.

The remaining channel course would either be retained as a relict channel, providing flood capacity, or infilled, potentially providing land for re-located allotments.

Review of Constraints and Opportunities

A plan of potential constraints for Reach 4 was provided in Figure N.6. The effects of these constraints on the feasibility of this option are described in Table N.5 below, along with potential advantages/ opportunities.

Table N.5 Review of constraints and opportunities for Reach 4 Option 2

Topic	Potential Issues	Assessment of the Effect or Potential Effect of the Option
Access	Access may be difficult and even prohibitively expensive under certain circumstances	• Access for works should be straightforward from Cottonmill Lane. • This is a popular allotment site. While disruption to allotments should be minimised H&S considerations mean that parts or all of the site would need to be closed while work takes place. • Works should be carried out at the time of the year least disruptive to tenants although it must be acknowledged that high groundwater levels, which can occur in the allotment area, may affect plant operations and works. • It is assumed that the allotments would be decommissioned in advance of the works. High groundwater levels, which can occur in the allotment area, would affect plant operations and works should be undertaken at times when these are low.
Flood Risk	As a result of re-alignment or floodplain works, flood risk from the river may decrease or increase in areas	• The allotment site is threatened by rising groundwater levels as a result of future sustainability reductions. Our study / appendix C predicts a rise of groundwater levels of more than 1 m in this area and it is expected that the site will flood most years. This option provides an opportunity to address these issues and provide a sustainable solution. • The option would reconnect the river to valley bottom and its floodplain. The area around the new channel will flood more often and will not be used for allotments.
Hydromorphology	Does the scheme improve the hydromorphological functioning of the reach?	• The realignment works would locate the channel back in the natural valley bottom and is therefore likely to improve the flow and habitat diversity, particularly with the inclusion of an appropriate morphology as specified. This should increase the hydraulic habitat diversity with a greater frequency of higher energy riffle units. It would also connect with Reach 5 realigned option at a more natural bed level.
Main channel bed level modifications	Realignment options to the natural valley bottom would require works to the main channel up and downstream connection points to ensure correct functioning.	• Whilst some upstream channel re-profiling would be required to get the correct levels to work with the current main channel, the downstream connection points would be aligned to a more appropriate downstream level as a result of the realigned Reach 5 option and new structure through the road. Therefore, impacts to services would be less compared to Option 1 but would still require expensive structural works. • Cost of around £250k quoted for culvert works on its own plus the cost of any utility diversions.
Abstractions and other hydrological concerns	Consideration as to whether the scheme may result in other adverse or beneficial hydrological effects. For example re-routing of the river may impact upon distributaries as well as the main river.	• There are no surface water abstractions in or close to this reach and so no effect of the scheme on these (note sustainability reductions influence flow through the reach however).
Groundwater	Does the scheme affect connectivity between	• The river and groundwater would be re-connected by realigning the channel through the

connectivity	surface water and groundwater?	natural valley bottom. This would represent a naturalisation of the system and enable natural chalk stream functioning.
Environmental Permits / consented discharges	Significant re-routing of the system may result in less flow being in the river at the point where a consented discharges enters and less dilution of that discharge.	• There are two consented discharges at the top of this reach. These belong to Affinity Water and are linked to their groundwater abstractions in St Albans. As such they are likely to of good water quality (so no impact upon river water quality anticipated as a result of the option due to the hydrological changes) although they would need to be accounted for during the works (i.e. connected to the re-routed river). The quality of the discharges should be tested to confirm this theory. Some minor work may be required to re-connect these to the river before it is partially re-aligned.
Heritage	Scenario has the potential to impact upon Scheduled Monument or other archaeological feature	• The option is unlikely to have a significant effect of features of archaeological importance.
Water Mains and Sewers (foul and surface water)	Under certain scenarios, construction may be routed close to other water mains and sewers. If so, these may have substantive effects on the cost of the scheme, its feasibility and duration of its construction.	• There is an Affinity Water distribution mains running through the middle of the allotments that is likely to be crossed by the re-aligned channel. This is at a depth of around 1.4m bgl and would need to be accounted for during any works, which would be expensive. An adjoining distribution mains runs parallel with the Cottonmill Lane road crossing at a depth of approximately 1m bgl and would need to be accounted for during any works, which would be expensive. • There are a pair of Thames water surface sewer lines running parallel beneath Cottonmill Lane . These are approximately 0.42-1m bgl and should be accounted for during the works, which could be expensive.
Other Utilities	Under certain scenarios, construction may be routed close to other utilities, such as BT or gas mains. If so, these may have substantive effects on the cost of the scheme, its feasibility and duration of its construction.	• A BT Openreach line follows the course of Cottonmill Lane at a minimum depth of 0.35m bgl. These would need to be accounted for if a new culverted crossing at the downstream end of this reach was constructed. This would be expensive and potentially be prohibitive. • Both high and low voltage UK Power Networks cables follow the course of Cottonmill Lane at a depth of 0.80m bgl. An additional pair of lines following the same course are set at unknown depths, therefore further site investigation would be required to inform line status. • A pair of National Grid low pressure gas mains follow the course of Cottonmill Lane, at an unknown depth. These would need to be further investigated and accounted for if a new culverted crossing at the downstream end of this reach was constructed. This would be expensive and potentially be prohibitive.
Geo-environmental	Consideration as to whether scheme could result in pathways for contaminants to enter the water environment.	• Re-alignment would occur through an area that is presently allotments. This would provide a direct route for contaminants and nutrients to be introduced into the river and would have an impact upon water quality in the river for the short term at least. It is noted that there is currently a pathway for these to enter the river indirectly, via runoff.

		• Our view is that this is a significant constraint although not insurmountable. Further studies and analysis would be needed, such as soil testing through the allotments, to better inform the risk and ultimately the design. Inclusion of wetlands through this reach would help retain some of the pollutants.
Local Wildlife Sites (Non-statutory)	Wildlife sites lie throughout the study area and could potentially be impacted by the scenarios	• There are no Local Wildlife Sites in this reach and so this option would not impact upon them. Re-alignment and creation of a wetland through the area where groundwater emergence provides an opportunity for habitat and biodiversity gains to be made (with replacement allotments being found too).
Tree Protection Orders (TPO)	Consideration of the effect of Tree Protection Orders on the option	• There are no TPOs in this reach and so no effect on the scheme.
Public Rights of Way	Public Rights of Way may need to be diverted if works are would occur over their route	• No public right of way near the site. Ver Valley Trail follows existing river through this reach. Small parts of this may need to be diverted during the re-connecting works at the downstream end of the reach.
Other Costs	Identification of potentially significant costs or aspects that are comparably low cost	• St Albans City and District Council would need to re-locate the allotment users to other site(s) which would have administrative and other costs. The feasibility of the site would be undermined by the groundwater rebound that would be expected if Affinity's Water's sustainability reductions at their nearby groundwater abstractions occur and so these costs may arguably be incurred irrespective of the scheme. • In addition to the cost of the new culvert being high, the Environment Agency, or other, may still need to retain and maintain the old culvert if the relict channel is being retained as a flood channel • Traffic Management Order may be required if a new culvert is needed under the road, which would be disruptive. A new pedestrian crossing, even temporary, may also be required.
Landscape impact	Review whether option would have a significant visual impact	• The option should result in an improved looking and more natural appearing river that is better connected to its flood plain.
Recreation and amenity	Review whether option would have significant impacts upon recreation and amenity	• The option includes re-alignment through a hugely popular allotment site with strong community feeling. However, much of the site is threatened by future sustainability reductions. • This option offers much improved river, accessible wetland area should be appealing for people to visit and is considered to be a long term sustainabale option. • Plans can be developed that can maximise plots that can remain on the site with nearby sites being available for replacement allotments.
Riparian ownership issues	Consideration as to whether option may require re-routing through lands that are privately owned or result in riparian changes that may be unacceptable.	• St Albans City and District Council own the land throughout this reach and so no riparian ownership issues are anticipated.

Reach 4 Option 3

Option Description and Restoration Plan

As with Reach 4 Options 1 and 2, the Ver under Option 3 would be re-aligned from the same location at the top of the reach although would follow a new course closer to the existing channel (instead of the lowest ground levels through the middle of the allotments). The newly re-aligned channel would re-join the Ver at the Cottonmill Lane crossing.

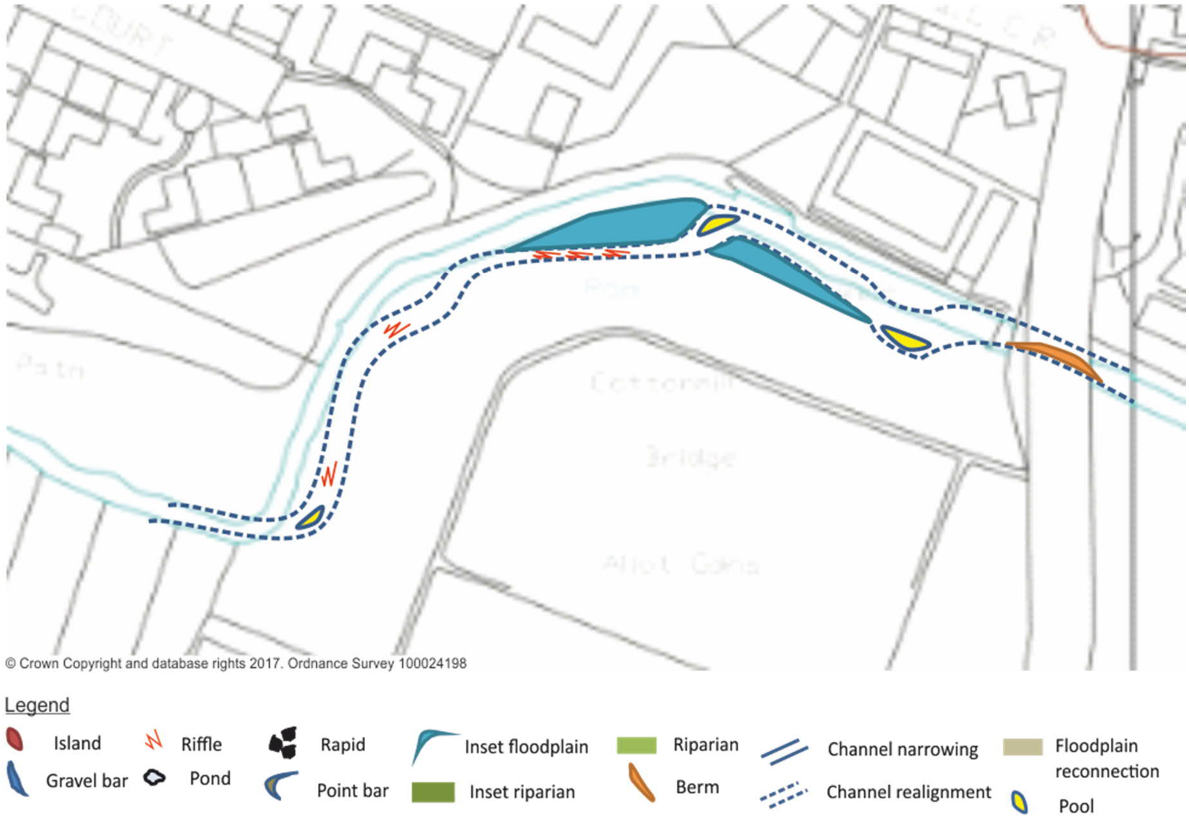


Figure N.9 Feature plans for Reach 4 Option 3

The re-aligned channel would be subject to in-channel re-profiling and incorporation of a suitable morphology including a riffle-pool regime along with the creation of inset floodplain and berm features (as illustrated in Figure N.9).

Review of Constraints and Opportunities

A plan of potential constraints for Reach 4 was provided in Figure N.6. The effects of these constraints on the feasibility of this option are described in Table N.6 below, along with potential advantages/ opportunities.

Table N.6 Review of constraints and opportunities for Reach 4 Option 3

Topic	Potential Issues	Assessment of the Effect or Potential Effect of the Option
Access	Access may be difficult and even prohibitively expensive under certain circumstances	• Access for works should be straightforward and be from Cottonmill Lane. Some disruption to the allotments would be expected though attempts could be made to minimise this.
Flood Risk	As a result of re-alignment or floodplain works, flood risk from the river may decrease or increase in areas	• The allotment site is threatened by rising groundwater levels as a result of future sustainability reductions. Our study / appendix C predicts a rise of groundwater levels of more than 1 m in this area and it is expected that the site will flood most years. • This option does little to address this issue and does not provide a sustainable solution to the problem that will emerge.
Hydromorphology	Does the scheme improve the hydromorphological functioning of the reach?	• The smaller scale realignment works within the proximity of the existing channel would not relocate the channel back to its valley bottom but an improved planform and the proposed morphology improvements would improve the flow and habitat diversity and help to reduce the tendency for fine sediment deposition. This should increase the hydraulic habitat diversity with a greater frequency of higher energy riffle units.
Main channel bed level modifications	Realignment options to the natural valley bottom would require works to the main channel up and downstream connection points to ensure correct functioning.	• This option is unlikely to require any significant bed re-profiling works as the realignment is located within close proximity to the existing channel.
Abstractions and other hydrological concerns	Consideration as to whether the scheme may result in other adverse or beneficial hydrological effects. For example re-routing of the river may impact upon distributaries as well as the main river.	• There are no abstractions in this reach and so no effect of the scheme on these.
Groundwater connectivity	Does the scheme affect connectivity between surface water and groundwater?	• The minor realignment works are unlikely to significantly improve the groundwater connectivity along this reach as it does not reconnect to the natural valley bottom. • Approximate bed levels would be confirmed following completion of the hydraulic modelling, at which point any improvements in river flow the connectivity with the groundwater table can be discussed further.
Environmental Permits / consented discharges	Significant re-routing of the system may result in less flow being in the river at the point where a consented discharges enters and less dilution of that discharge.	• There are two consented discharges at the top of this reach. These belong to Affinity Water and are linked to their groundwater abstractions in St Albans. As such they are likely to of good water quality (so no impact upon river water quality anticipated as a result of the option due to the hydrological changes) although they would need to be accounted for during the works (i.e. connected to the re-routed river). The quality of the discharges should be tested to confirm this theory. Some work may be required to re-connect these to the river before it is re-aligned.
Heritage	Scenario has the potential to impact upon Scheduled Monument or other archaeological feature	• The option is unlikely to have a significant effect of features of archaeological importance. Two features are located on the northern/ left bank at the downstream end of the reach. They should be accounted for as part of the works at the bottom end of the reach although are not considered to be prohibitive to the option.
Water Mains and Sewers (foul and surface water)	Under certain scenarios, construction may be routed close to other water mains and sewers. If so, these may have substantive effects on the cost of the scheme, its feasibility and duration of its construction.	• There is an Affinity Water distribution mains running through the middle of the allotments that is likely to be crossed by the re-aligned channel. This is at a depth of around 1.4m bgl and would need to be accounted for during any works, which would be expensive. There are also a pair of distribution mains under the Cottonmill Lane bridge that would need to be accounted for if culvert adjustment works are anticipated there. Replacement of a more appropriate service crossing would likely be required as a result of this option due to the necessary re-profiling works to allow this option to function. • Similarly, there is a pair of Thames Water surface water sewers running parallel with Cottonmill Lane, ending either side of the actual bridge crossing. The pipeline located on the upstream side of the bridge is approximately 1m bgl. Both would need to be accounted for if culvert adjustment works are anticipated where the re-aligned channel is proposed to re-join the existing channel course.
Other Utilities	Under certain scenarios, construction may be routed close to other utilities, such as BT or gas mains. If so, these may have substantive effects on the cost of the scheme, its feasibility and duration of its construction.	• A BT Openreach line follows the course of Cottonmill Lane, crossing the bridge at a minimum depth of 0.35m bgl. This would need to be accounted for if culvert adjustment works are anticipated where the re-aligned channel is proposed to re-join the existing channel course. • Both high and low voltage UK Power Networks cables follow the course of Cottonmill Lane, with the high voltage line crossing the bridge at a depth of 0.80m bgl. An additional pair of lines following the same course are set at unknown depths, therefore further site investigation would be required to inform line status. • A pair of National Grid low pressure gas mains follow the course of Cottonmill Lane, crossing the bridge at an unknown depth. This would need to be further investigated and accounted for if culvert adjustment works are anticipated where the re-aligned channel is proposed to re-join the existing channel course. • Replacement of a more appropriate service crossing would likely be required as a result of this option due to the necessary re-profiling works to allow this option to function.
Geo-environmental	Consideration as to whether scheme could result in pathways for contaminants to enter the water environment.	• Some of the re-alignment would occur through an area that is presently allotments. This would provide a direct route for contaminants and nutrients to be introduced into the river and would have an impact upon water quality in the river for the short term at least. It is noted that there is currently a pathway for these to enter the river indirectly, via runoff. The re-alignment is less extensive than the other two Reach 4 options and so any impact is considered to be lower for this option.
Local Wildlife Sites (Non-statutory)	Wildlife sites lie throughout the study area and could potentially be impacted by the scenarios	• There are no Local Wildlife Sites in this reach and so this option would not impact upon them.
Tree Protection Orders (TPO)	Consideration of the effect of Tree Protection Orders on the option	• There are no TPOs in this reach and so no effect on the scheme.
Public Rights of Way	Public Rights of Way may need to be diverted if works are would occur over their route	• No public right of way near the site. Ver Valley Trail follows existing river through this reach. This would need to be diverted during works through this reach.
Other Costs	Identification of potentially significant costs or aspects that are comparably low cost	• St Albans City and District Council would need to re-locate some of the allotment users to other site(s) which would have administrative and other costs. The feasibility of the site would be undermined by the groundwater rebound that would be expected if Affinity's Water's sustainability reductions at their nearby groundwater abstractions occur and so these costs may arguably be incurred irrespective of the scheme.
Landscape impact	Review whether option would have a significant visual impact	• The option should result in an improved looking and more natural appearing river that is better connected to its flood plain.
Recreation and amenity	Review whether option would have significant impacts upon recreation and amenity	• The option would result in a more accessible river which should be appealing for people to visit although the loss of a number of allotments would outweigh this benefit (noting that the

		anticipated groundwater rebound may result in allotments being lost irrespective of this scheme).
Riparian ownership issues	Consideration as to whether option may require re-routing through lands that are privately owned or result in riparian changes that may be unacceptable.	• St Albans City and District Council own the land throughout this reach and so no riparian ownership issues are anticipated.

Determination of the Preferred Reach 4 Option

From a hydromorphological perspective, Options 1 and 2 represent the greatest potential improvement given they return the river to its natural valley bottom and reconnect the channel to its floodplain. Option 3 offers comparatively less benefit given the current perched river course is maintained, although this option will provide some ecological and hydromorphological benefit through the minor planform adjustment and inclusion of an appropriate morphology.

The allotment site is threatened by rising groundwater levels as a result of future sustainability reductions. Our study / appendix C predicts a rise of groundwater levels of more than 1 m in this area and it is expected that the site will flood most years. Options 1 and 2 provide an opportunity to address this issue and provide a sustainable solution for the area.

Based on the comparatively reduced environmental gains and that it does not tackle the groundwater emergence issue faced by the area, Option 3 was not preferred.

The wider structural works associated with the re-alignment options were the critical constraint for Reach 4, however they are not considered to render Options 1 and 2 unfeasible. Option 2 is considered less feasible in terms of cost than Option 1 given it would require a new culvert through the road separating Reach 4 and 5, whereas Option 1 requires adjustment of the existing culvert. Further investigation into the structural viability of adjusting the downstream culvert and the depth to any utilities in this area would be required at the detailed design stage, however the preliminary analysis indicates adjustment could be feasible. On this basis Option 1 was progressed as the preferred option.

Table N.7 provides a compiled review of the constraints and opportunities for the Reach 4 options. The discussion of each constraint/ opportunity for each option has been coloured accordingly:

- Green – Desired improvements and project objectives achieved. No constraints identified in relation to the category in question.
- Yellow - Desired improvements and project objectives achieved. Low or moderate mitigation costs and/ or constraints identified in relation to the category in question.
- Orange - Desired improvements and project objectives achieved. Moderate or high mitigation costs and/ or constraints identified in relation to the category in question.
- Red – Desired improvements and project objectives may not be achieved and/ or high mitigation costs and/ or major constraints identified in relation to the category in question that may be difficult or expensive to overcome.

Table N.7 Reach 4 Summary Table

Topic	Effect or Potential Effect of Reach 4 Option 1	Effect or Potential Effect of Reach 4 Option 2	Effect or Potential Effect of Reach 4 Option 3
Access	• Access for works should be straightforward from Cottonmill Lane. • This is a popular allotment site. While disruption to allotments should be minimised H&S considerations mean that parts or all of the site would need to be closed while work takes place. • Works should be carried out at the time of the year least disruptive to tenants although it must be acknowledged that high groundwater levels, which can occur in the allotment area, may affect plant operations and works. • It is assumed that the allotments would be decommissioned in advance of the works. High groundwater levels, which can occur in the allotment area, would affect plant operations and works should be undertaken at times when these are low.	• Access for works should be straightforward from Cottonmill Lane. • This is a popular allotment site. While disruption to allotments should be minimised H&S considerations mean that parts or all of the site would need to be closed while work takes place. • Works should be carried out at the time of the year least disruptive to tenants although it must be acknowledged that high groundwater levels, which can occur in the allotment area, may affect plant operations and works. • It is assumed that the allotments would be decommissioned in advance of the works. High groundwater levels, which can occur in the allotment area, would affect plant operations and works should be undertaken at times when these are low.	• Access for works should be straightforward and be from Cottonmill Lane. Some disruption to the allotments would be expected though attempts could be made to minimise this.
Flood Risk	• The allotment site is threatened by rising groundwater levels as a result of future sustainability reductions. Our study / appendix C predicts a rise of groundwater levels of more than 1 m in this area and it is expected that the site will flood most years. This option provides an opportunity to address these issues and provide a sustainable solution. • The option would reconnect the river to valley bottom and its floodplain. The area around the new channel will flood more often and will not be used for allotments.	• The allotment site is threatened by rising groundwater levels as a result of future sustainability reductions. Our study / appendix C predicts a rise of groundwater levels of more than 1 m in this area and it is expected that the site will flood most years. This option provides an opportunity to address these issues and provide a sustainable solution. • The option would reconnect the river to valley bottom and its floodplain. The area around the new channel will flood more often and will not be used for allotments.	• The allotment site is threatened by rising groundwater levels as a result of future sustainability reductions. Our study / appendix C predicts a rise of groundwater levels of more than 1 m in this area and it is expected that the site will flood most years. • This option does little to address this issue and does not provide a sustainable solution to the problem that will emerge.
Hydro-morphology	• The realignment works would locate the channel back in the natural valley bottom and is therefore likely to improve the flow and habitat diversity, particularly with the inclusion of an appropriate morphology as specified. This should increase the hydraulic habitat diversity with a greater frequency of higher energy riffle units.	• The realignment works would locate the channel back in the natural valley bottom and is therefore likely to improve the flow and habitat diversity, particularly with the inclusion of an appropriate morphology as specified. This should increase the hydraulic habitat diversity with a greater frequency of higher energy riffle units. It would also connect with Reach 5 realigned option at a more natural bed level.	• The smaller scale realignment works within the proximity of the existing channel would not relocate the channel back to its valley bottom but an improved planform and the proposed morphology improvements would improve the flow and habitat diversity and help to reduce the tendency for fine sediment deposition. This should increase the hydraulic habitat diversity with a greater frequency of higher energy riffle units.
Main channel bed level modifications	• Significant existing channel re-profiling works would be required at the downstream end where the realigned channel reconnects with the main channel as a result of the level discrepancy with the channel in the natural valley bottom reconnecting to the current perched channel.	• Whilst some upstream channel re-profiling would be required to get the correct levels to work with the current main channel, the downstream connection points would be aligned to a more appropriate downstream level as a result of the realigned Reach 5 option and new structure through the road. Therefore, impacts to services would be less compared to Option 1 but would still require expensive structural works. • Cost of around £250k quoted for culvert works on its own plus the cost of any utility diversions.	• This option is unlikely to require any significant bed re-profiling works as the realignment is located within close proximity to the existing channel.
Abstractions and other hydrological concerns	• There are no surface water abstractions in or close to this reach and so no effect of the scheme on these (note sustainability reductions influence flow through the reach however).	• There are no surface water abstractions in or close to this reach and so no effect of the scheme on these (note sustainability reductions influence flow through the reach however).	• There are no abstractions in this reach and so no effect of the scheme on these.
Groundwater connectivity	• The river and groundwater would be re-connected by realigning the channel through the natural valley bottom. This would represent a naturalisation of the system and enable natural chalk stream functioning.	• The river and groundwater would be re-connected by realigning the channel through the natural valley bottom. This would represent a naturalisation of the system and enable natural chalk stream functioning.	• The minor realignment works are unlikely to significantly improve the groundwater connectivity along this reach as it does not reconnect to the natural valley bottom. • Approximate bed levels would be confirmed following completion of the hydraulic modelling, at which point any improvements in river flow the connectivity with the groundwater table can be discussed further.
Environmental Permits / consented discharges	• There are two consented discharges at the top of this reach. These belong to Affinity Water and are linked to their groundwater abstractions in St Albans. As such they are likely to of good water quality (so no impact upon river water quality anticipated as a result of the option due to the hydrological changes) although they would need to be accounted for during the works (i.e. connected to the re-routed river). The quality of the discharges should be tested to confirm this theory. Some work may be required to re-connect these to the river before it is re-aligned.	• There are two consented discharges at the top of this reach. These belong to Affinity Water and are linked to their groundwater abstractions in St Albans. As such they are likely to of good water quality (so no impact upon river water quality anticipated as a result of the option due to the hydrological changes) although they would need to be accounted for during the works (i.e. connected to the re-routed river). The quality of the discharges should be tested to confirm this theory. Some minor work may be required to re-connect these to the river before it is partially re-aligned.	• There are two consented discharges at the top of this reach. These belong to Affinity Water and are linked to their groundwater abstractions in St Albans. As such they are likely to of good water quality (so no impact upon river water quality anticipated as a result of the option due to the hydrological changes) although they would need to be accounted for during the works (i.e. connected to the re-routed river). The quality of the discharges should be tested to confirm this theory. Some work may be required to re-connect these to the river before it is re-aligned.

Heritage	• The option is unlikely to have a significant effect of features of archaeological importance. Two features are located on the northern/ left bank at the downstream end of the reach. They should be accounted for as part of any reconnection works although are not considered to be prohibitive to the option.	• The option is unlikely to have a significant effect of features of archaeological importance.	• The option is unlikely to have a significant effect of features of archaeological importance. Two features are located on the northern/ left bank at the downstream end of the reach. They should be accounted for as part of the works at the bottom end of the reach although are not considered to be prohibitive to the option.
Water Mains and Sewers (foul and surface water)	• There is an Affinity Water distribution mains running through the middle of the allotments that is likely to be crossed by the re-aligned channel. This is at a depth of around 1.4m bgl and would need to be accounted for during any works, which would be expensive. There are also a pair of distribution mains under the Cottonmill Lane bridge that would need to be accounted for if culvert adjustment works are anticipated there. Replacement of a more appropriate service crossing would likely be required as a result of this option due to the necessary re-profiling works to allow this option to function. • Similarly, there is a pair of Thames Water surface water sewers running parallel with Cottonmill Lane, ending either side of the actual bridge crossing. The pipeline located on the upstream side of the bridge is approximately 1m bgl. Both would need to be accounted for if culvert adjustment works are anticipated where the re-aligned channel is proposed to re-join the existing channel course.	• There is an Affinity Water distribution mains running through the middle of the allotments that is likely to be crossed by the re-aligned channel. This is at a depth of around 1.4m bgl and would need to be accounted for during any works, which would be expensive. An adjoining distribution mains runs parallel with the Cottonmill Lane road crossing at a depth of approximately 1m bgl and would need to be accounted for during any works, which would be expensive. • There are a pair of Thames water surface sewer lines running parallel beneath Cottonmill Lane . These are approximately 0.42-1m bgl and should be accounted for during the works, which could be expensive.	• There is an Affinity Water distribution mains running through the middle of the allotments that is likely to be crossed by the re-aligned channel. This is at a depth of around 1.4m bgl and would need to be accounted for during any works, which would be expensive. There are also a pair of distribution mains under the Cottonmill Lane bridge that would need to be accounted for if culvert adjustment works are anticipated there. Replacement of a more appropriate service crossing would likely be required as a result of this option due to the necessary re-profiling works to allow this option to function. • Similarly, there is a pair of Thames Water surface water sewers running parallel with Cottonmill Lane, ending either side of the actual bridge crossing. The pipeline located on the upstream side of the bridge is approximately 1m bgl. Both would need to be accounted for if culvert adjustment works are anticipated where the re-aligned channel is proposed to re-join the existing channel course.
Other Utilities	• A BT Openreach line follows the course of Cottonmill Lane, crossing the bridge at a minimum depth of 0.35m bgl. This would need to be accounted for if culvert adjustment works are anticipated where the re-aligned channel is proposed to re-join the existing channel course. • Both high and low voltage UK Power Networks cables follow the course of Cottonmill Lane, with the high voltage line crossing the bridge at a depth of 0.80m bgl. An additional pair of lines following the same course are set at unknown depths, therefore further site investigation would be required to inform line status. • A pair of National Grid low pressure gas mains follow the course of Cottonmill Lane, crossing the bridge at an unknown depth. This would need to be further investigated and accounted for if culvert adjustment works are anticipated where the re-aligned channel is proposed to re-join the existing channel course. • Replacement of a more appropriate service crossing would likely be required as a result of this option due to the necessary re-profiling works to allow this option to function.	• A BT Openreach line follows the course of Cottonmill Lane at a minimum depth of 0.35m bgl. These would need to be accounted for if a new culverted crossing at the downstream end of this reach was constructed. This would be expensive and potentially be prohibitive. • Both high and low voltage UK Power Networks cables follow the course of Cottonmill Lane at a depth of 0.80m bgl. An additional pair of lines following the same course are set at unknown depths, therefore further site investigation would be required to inform line status. • A pair of National Grid low pressure gas mains follow the course of Cottonmill Lane, at an unknown depth. These would need to be further investigated and accounted for if a new culverted crossing at the downstream end of this reach was constructed. This would be expensive and potentially be prohibitive.	• A BT Openreach line follows the course of Cottonmill Lane, crossing the bridge at a minimum depth of 0.35m bgl. This would need to be accounted for if culvert adjustment works are anticipated where the re-aligned channel is proposed to re-join the existing channel course. • Both high and low voltage UK Power Networks cables follow the course of Cottonmill Lane, with the high voltage line crossing the bridge at a depth of 0.80m bgl. An additional pair of lines following the same course are set at unknown depths, therefore further site investigation would be required to inform line status. • A pair of National Grid low pressure gas mains follow the course of Cottonmill Lane, crossing the bridge at an unknown depth. This would need to be further investigated and accounted for if culvert adjustment works are anticipated where the re-aligned channel is proposed to re-join the existing channel course. • Replacement of a more appropriate service crossing would likely be required as a result of this option due to the necessary re-profiling works to allow this option to function.
Geo-environmental	• Re-alignment would occur through an area that is presently allotments. This would provide a direct route for contaminants and nutrients to be introduced into the river and would have an impact upon water quality in the river for the short term at least. It is noted that there is currently a pathway for these to enter the river indirectly, via runoff. • Our view is that this is a significant constraint although not insurmountable. Further studies and analysis would be needed, such as soil testing through the allotments, to better inform the risk and ultimately the design. Inclusion of wetlands through this reach would help retain some of the pollutants.	• Re-alignment would occur through an area that is presently allotments. This would provide a direct route for contaminants and nutrients to be introduced into the river and would have an impact upon water quality in the river for the short term at least. It is noted that there is currently a pathway for these to enter the river indirectly, via runoff. • Our view is that this is a significant constraint although not insurmountable. Further studies and analysis would be needed, such as soil testing through the allotments, to better inform the risk and ultimately the design. Inclusion of wetlands through this reach would help retain some of the pollutants.	• Some of the re-alignment would occur through an area that is presently allotments. This would provide a direct route for contaminants and nutrients to be introduced into the river and would have an impact upon water quality in the river for the short term at least. It is noted that there is currently a pathway for these to enter the river indirectly, via runoff. The re-alignment is less extensive than the other two Reach 4 options and so any impact is considered to be lower for this option.
Local Wildlife Sites (Non-statutory)	• The river and groundwater would be re-connected by realigning the channel through the natural valley bottom. This would represent a naturalisation of the system and enable natural chalk stream functioning.	• There are no Local Wildlife Sites in this reach and so this option would not impact upon them. Re-alignment and creation of a wetland through the area where groundwater emergence provides an opportunity for habitat and biodiversity gains to be made (with replacement allotments being found too).	• There are no Local Wildlife Sites in this reach and so this option would not impact upon them. Other benefits would be limited compared to the other options though.
Tree Protection Orders (TPO)	• There are no TPOs in this reach and so no effect on the scheme.	• There are no TPOs in this reach and so no effect on the scheme.	• There are no TPOs in this reach and so no effect on the scheme.

Public Rights of Way	• No public right of way near the site. Ver Valley Trail follows existing river through this reach. Small parts of this may need to be diverted during the re-connecting works at the downstream end of the reach.	• No public right of way near the site. Ver Valley Trail follows existing river through this reach. Small parts of this may need to be diverted during the re-connecting works at the downstream end of the reach.	• No public right of way near the site. Ver Valley Trail follows existing river through this reach. This would need to be diverted during works through this reach.
Other Costs	• St Albans City and District Council would need to re-locate the allotment users to other site(s) which would have administrative and other costs. The feasibility of the site would be undermined by the groundwater rebound that would be expected if Affinity's Water's sustainability reductions at their nearby groundwater abstractions occur and so these costs may arguably be incurred irrespective of the scheme. • There would be a large cost associated to the likely required service crossing modification and potential works to the culvert structure to get the correct bed levels in order for this option to function correctly.	• St Albans City and District Council would need to re-locate the allotment users to other site(s) which would have administrative and other costs. The feasibility of the site would be undermined by the groundwater rebound that would be expected if Affinity's Water's sustainability reductions at their nearby groundwater abstractions occur and so these costs may arguably be incurred irrespective of the scheme. • In addition to the cost of the new culvert being high, the Environment Agency, or other, may still need to retain and maintain the old culvert if the relict channel is being retained as a flood channel • Traffic Management Order may be required if a new culvert is needed under the road, which would be disruptive. A new pedestrian crossing, even temporary, may also be required.	• St Albans City and District Council would need to re-locate some of the allotment users to other site(s) which would have administrative and other costs. The feasibility of the site would be undermined by the groundwater rebound that would be expected if Affinity's Water's sustainability reductions at their nearby groundwater abstractions occur and so these costs may arguably be incurred irrespective of the scheme.
Landscape impact	• The option should result in an improved looking and more natural appearing river that is better connected to its flood plain.	• The option should result in an improved looking and more natural appearing river that is better connected to its flood plain.	• The option should result in an improved looking and more natural appearing river that is better connected to its flood plain.
Recreation and amenity	• The option includes re-alignment through a hugely popular allotment site with strong community feeling. However, much of the site is threatened by future sustainability reductions. • This option offers much improved river, accessible wetland area should be appealing for people to visit and is considered to be a long term sustainabale option. • Plans can be developed that can maximise plots that can remain on the site with nearby sites being available for replacement allotments.	• The option includes re-alignment through a hugely popular allotment site with strong community feeling. However, much of the site is threatened by future sustainability reductions. • This option offers much improved river, accessible wetland area should be appealing for people to visit and is considered to be a long term sustainabale option. • Plans can be developed that can maximise plots that can remain on the site with nearby sites being available for replacement allotments.	• The option would result in a more accessible river which should be appealing for people to visit although the loss of a number of allotments would outweigh this benefit (noting that the anticipated groundwater rebound may result in allotments being lost irrespective of this scheme).
Riparian ownership issues	• St Albans City and District Council own the land throughout this reach and so no riparian ownership issues are anticipated.	• St Albans City and District Council own the land throughout this reach and so no riparian ownership issues are anticipated.	• St Albans City and District Council own the land throughout this reach and so no riparian ownership issues are anticipated.

APPENDIX O – Determination of the Reach 5 Preferred Option

O.1 Overview

A summary of the derivation of the preferred option for Reach 5 (see Figure O.1) is presented within this Appendix. The included the following steps:

- Reach 5 Long List Appraisal.
- Reach 5 Short List Appraisal.

These results of the appraisals are outlined below.

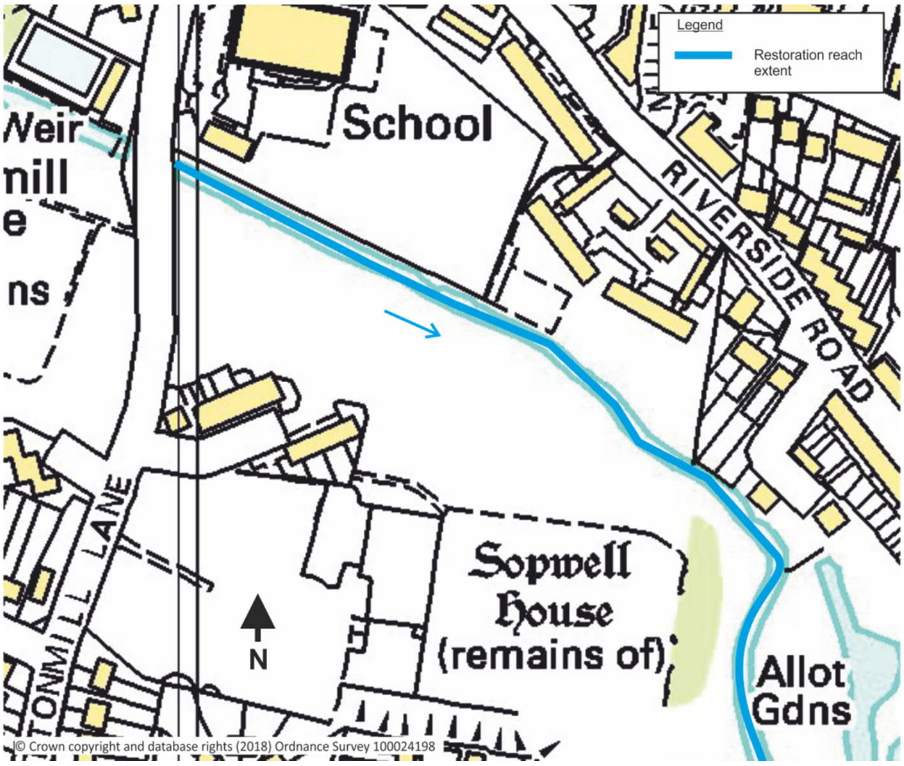


Figure O.1Reach 5 of the study area (From Cottonmill Lane to just upstream of the Watercress Wildlife Site)

O.2 Reach 5 Long List Appraisal

Options Identification

The long list of options for Reach 5 are outlined in Table O.1.

Table O.1 Long List Options Reach 5

Option	Description
1	Full re-alignment of existing channel (connect to Reach 4 through new structure under road)
2	Part re-alignment of existing channel
3	Small re-alignment of existing channel through woodland
4	Retain existing channel and improve

A schematic of these options is provided in Figures O.2 – O.5 below.

Long List Appraisal

A summary of the long list appraisal and scoring is provided in Table O.2 below. Individual options are appraised in subsequent sub-sections. The long list appraisal methodology was presented in Section 2.3 and Appendix B.

Table O.2 Appraisal of Reach 5 Long List Options

Option	Fulfil Project WFD Objectives for WB?	No constraints that would make option unfeasible?	Acceptable from a H&S perspective?	Not result in significant detrimental or loss of characteristic features?	Hydromorphology & Naturalisation	Habitat	Water Quality	Flood Risk	Landscape/ Visual	Recreation & Amenity	Heritage	Contaminated Land & Sediment	Fish Passage	Sustainability/ Ongoing Maintenance	Total Score
	Y/N	Y/N	Y/N	Y/N	-2 to 2	-2 to 2	-2 to 2	-2 to 2	-2 to 2	-2 to 2	-2 to 2	-2 to 2	-2 to 2	-2 to 2	
Do nothing/ Baseline															
0	N	Y	Y	Y	0	0	0	0	0	0	0	0	0	0	0
1	Y	N	Y	Y	1*	2	2	-2**	1	2	-2	0	0	1***	5
2	Y	Y	Y	Y	1*	2	2	-1**	1	2	-2	0	0	2	7
3	Y	Y	Y	Y	1*	1	1	2	1	2	-2	0	0	1	8
4	Y	Y	Y	Y	1	1	1	-1**	1	1	0	0	0	1	5

* The hydromorphology in this reach is currently considered to be acceptable and so gains in this reach would be minimal (hence hydromorphology gains for the different options are no greater than 1)
** Negative scores associated with potentially increasing flood risk to properties to the south
*** A score of 1 has been given balancing that whilst the new channel may be considered sustainable and that this option could address current issues with the footpath (+2) here with the new culvert potentially requiring additional maintenance (-1).

Reach 5 Option 1

This option is illustrated in Figure O.2 below. The option scored well (scoring 5 in total) and was thus shortlisted for more detailed consideration. Additional investigations (groundwater recharge and flood risk modelling) are currently ongoing (at the time of this appraisal) which will better inform the feasibility of this option and so it is to be confirmed whether or not this option would fulfil the criteria of the initial long list appraisal process. These will be considered further as part of the short list appraisal.

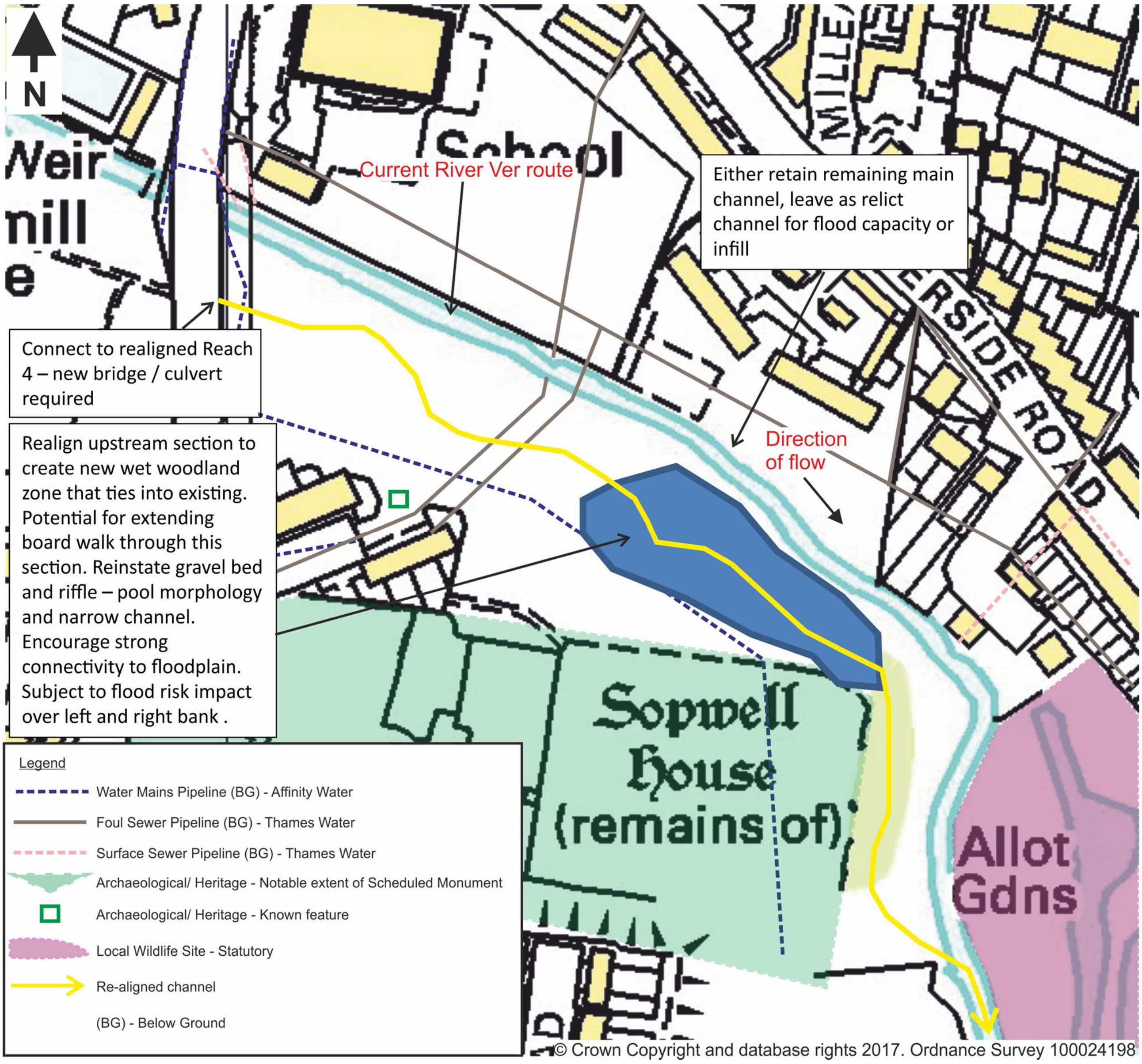


Figure O.2 Option 1 – Full re-alignment of existing channel (connect to Reach 4 through new structure under road)

Reach 5 Option 2

This option is illustrated in Figure O.3 below. This option was considered to fulfil the necessary long listing criteria and was scored as part of the long listing appraisal. The option scored well (scoring 7 in total) and was thus shortlisted for more detailed consideration.

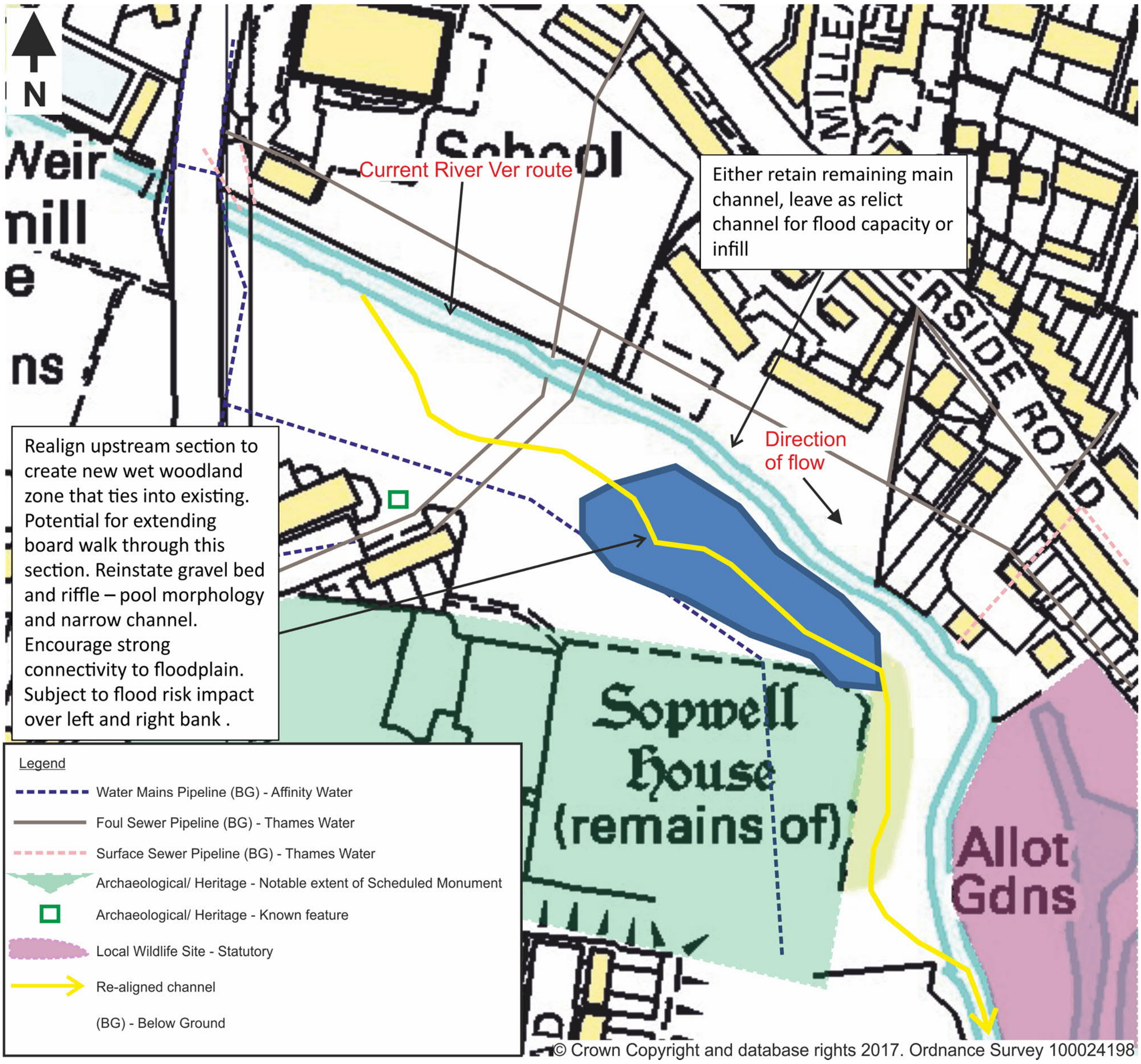


Figure O.3 Option 2 – Part re-alignment of existing channel

Reach 5 Option 3

This option is illustrated in Figure O.4 below. This option was considered to fulfil the necessary long listing criteria and was scored as part of the long listing appraisal. The option scored well (scoring 8 in total) and was thus shortlisted for more detailed consideration.

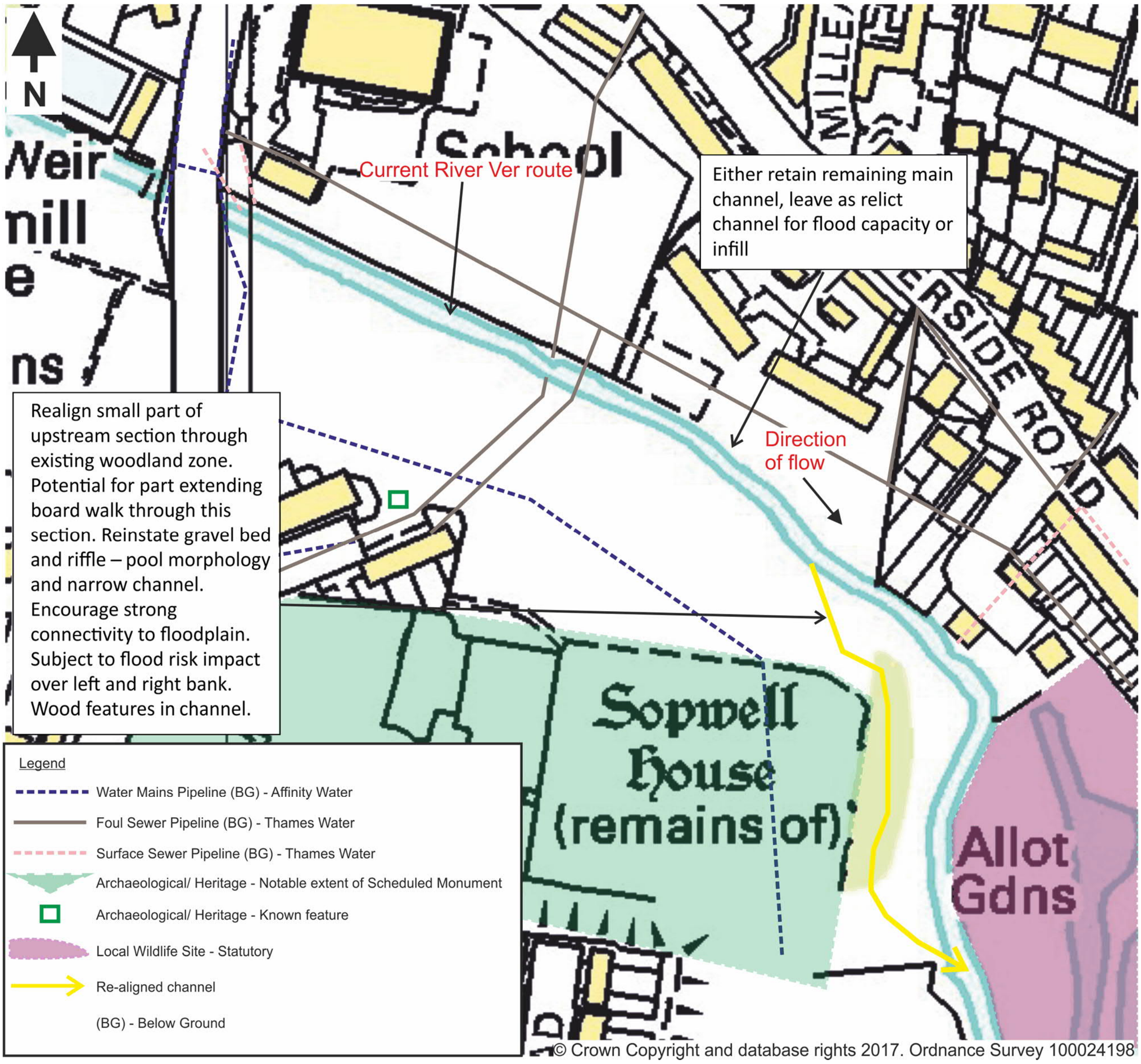


Figure O.4 Option 3 – Small re-alignment of existing channel through woodland

Reach 5 Option 4

This option is illustrated in Figure O.5 below. This option was considered to fulfil the necessary long listing criteria and was scored as part of the long listing appraisal. The option scored fairly (scoring 4 in total) and was thus not shortlisted for more detailed consideration (with several other river and lake options scoring more).

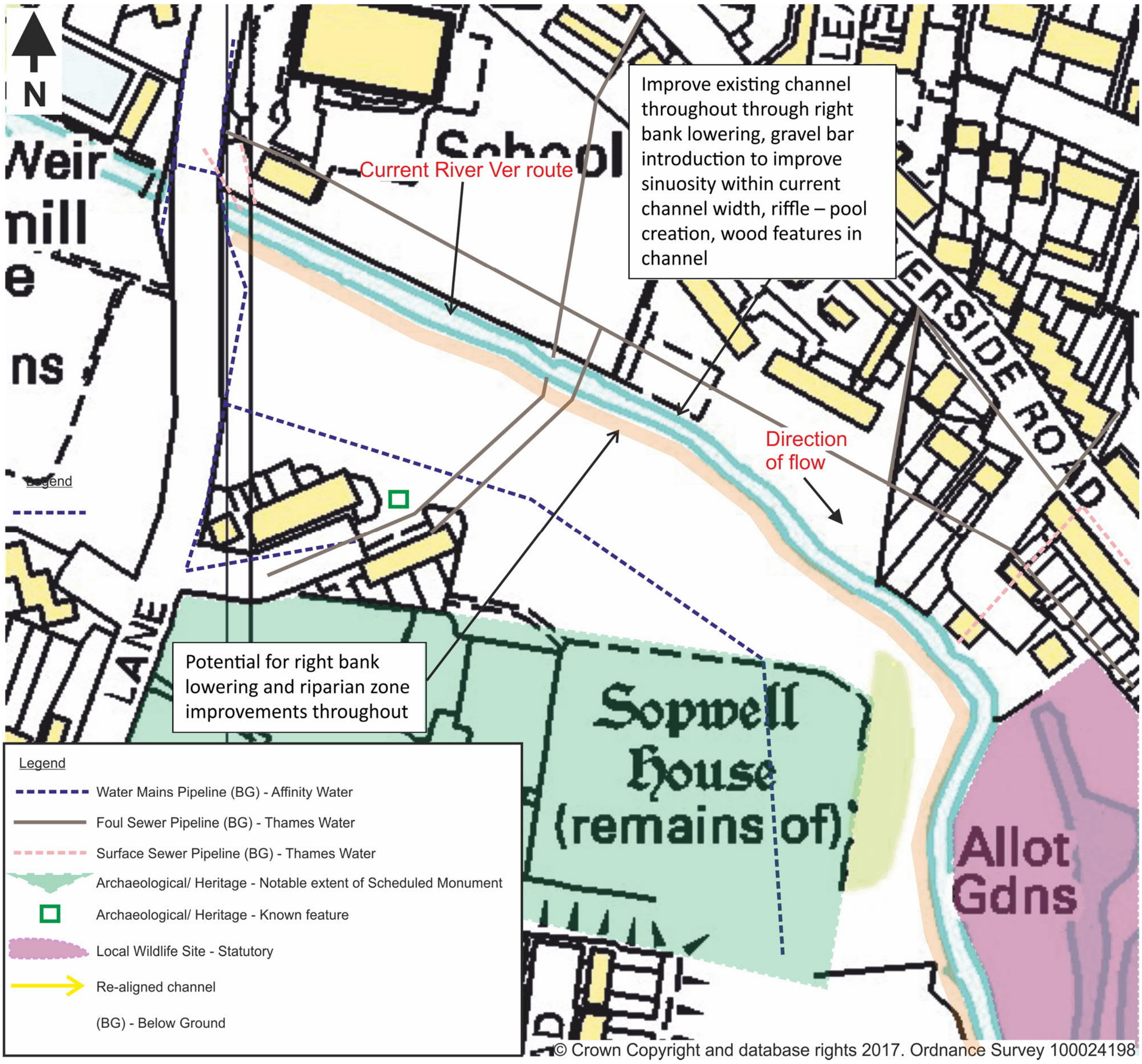


Figure O.5 Option 4 – Retain existing channel and improve

Reach 5 Long Listing Summary

As a result of the long list appraisal process each of the Reach 5 options were selected for shortlisting.

O.3 Reach 5 Short-listing Appraisal

Reach 5 Option Overview

The options outlined in Table O.3 were derived from the long listing appraisal and have been reviewed as part of the Short-listing appraisal.

Table O.3 Reach 5 Short Listed Options following Long List Appraisal

Option	Description
Reach 5	
1	Full re-alignment of existing channel (connect to Reach 4 through new structure under road)
2	Part re-alignment of existing channel
3	Small re-alignment of existing channel through woodland
4	Retain existing channel and improve

Review of Constraints and Opportunities for Reach 5

A plan of potential constraints for Reach 5 is provided in Figure O.6.

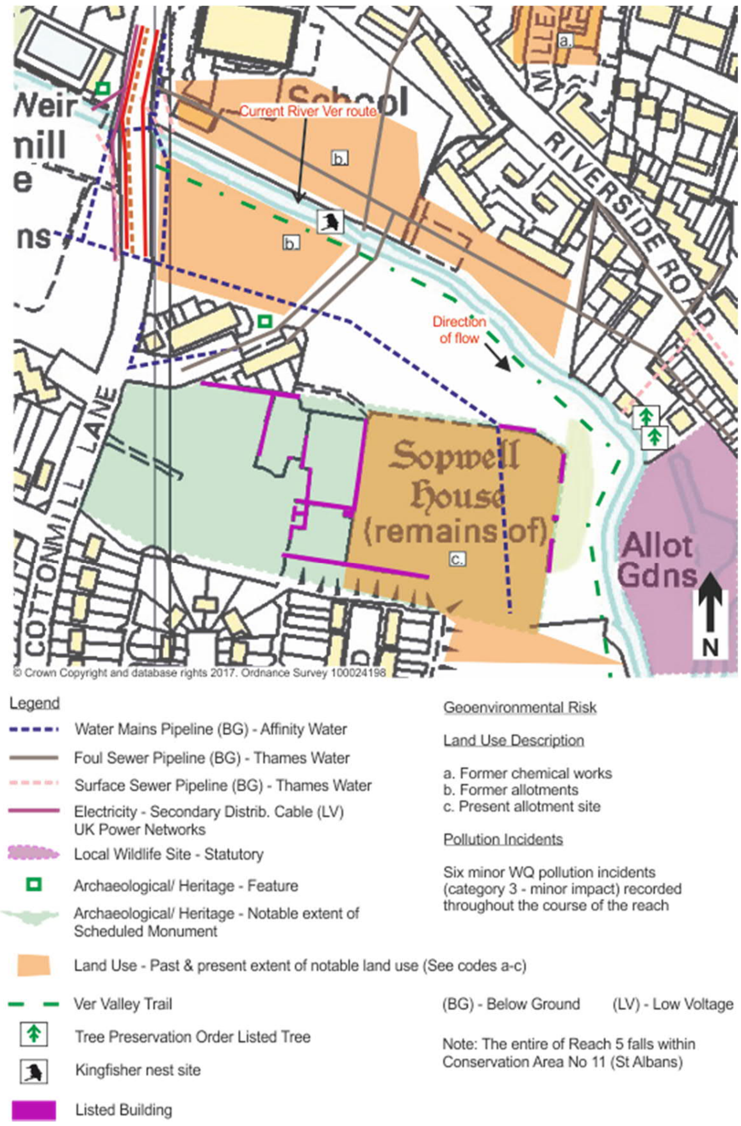


Figure O.6 Reach 5 constraints plan

Reach 5 Option 1

Option Description and Restoration Plan

The upstream end of the Ver in Reach 5 would be re-aligned to connect to the downstream end of the new channel outlined in Reach 4 Option 2 via a new structure beneath Cottonmill Lane. The re-aligned channel course would be subject to in-channel re-profiling and incorporation of a suitable morphology including a riffle-pool regime, berm features and inset floodplains (as illustrated in Figure O.7, which also includes the features included within the modelling).

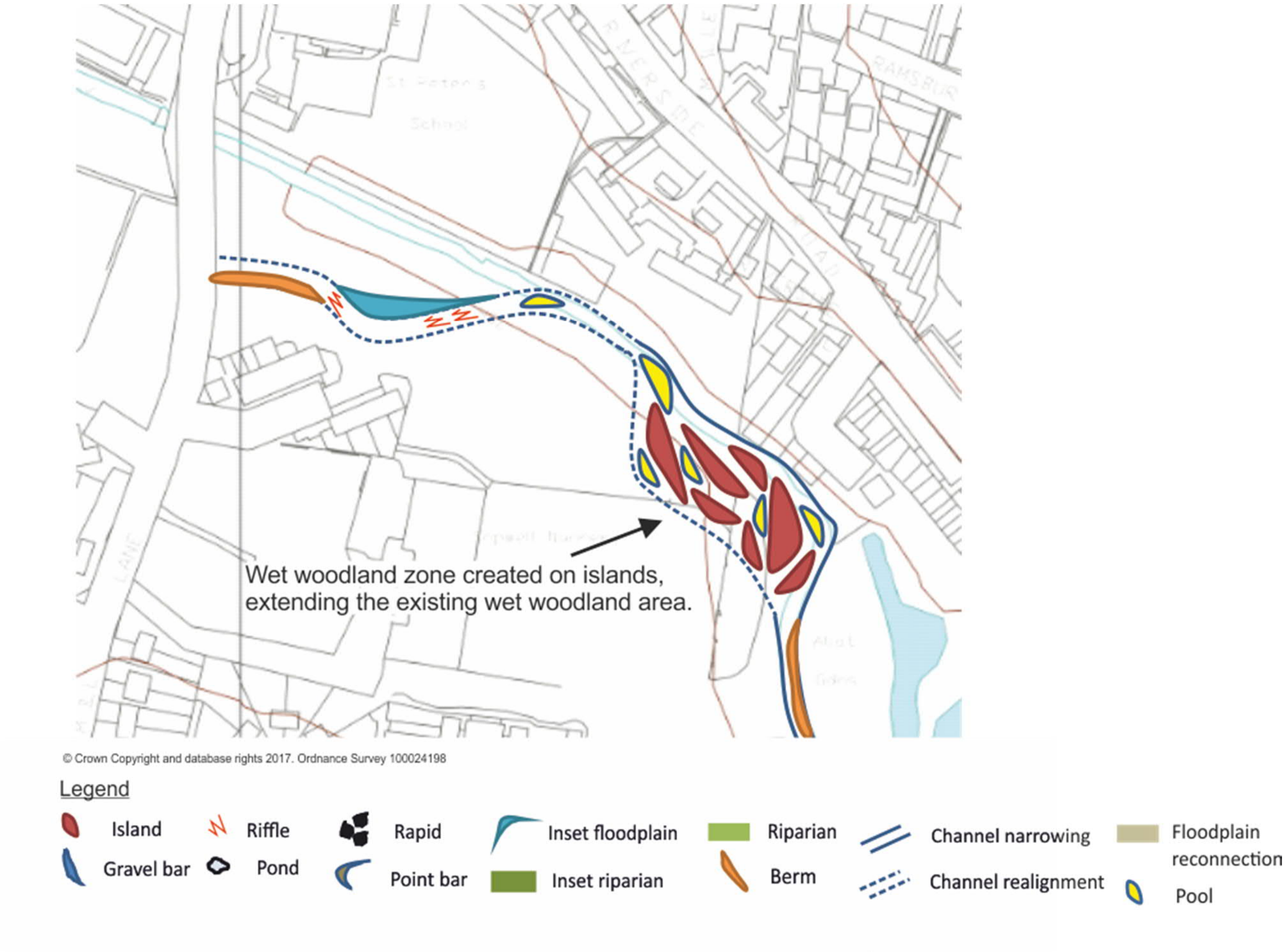


Figure O.7 Feature plans for Reach 5 Option 1

An area of wet woodland would be created midway through the reach where the existing course of the river turns to head in a southerly direction, avoiding the Nunnery allotments and Scheduled Ancient Monument. Numerous pool and island features would be incorporated into the wet woodland design which would also include a low flow pathway through the woodland, before the river exits via its existing course.

The existing course of the channel in the downstream end of the reach would be narrowed, with berm and pool features incorporated into the design. Please note Figure O.7 is coarsely drawn and if progressed this option would not run through current allotment land towards the downstream end of the reach.

Review of Constraints and Opportunities

A plan of potential constraints for Reach 5 was provided in Figure O.6. The effects of these constraints on the feasibility of this option are described in Table O.4 below, along with potential advantages/ opportunities.

Table O.4 Review of constraints and opportunities for Reach 5 Option 1

Topic	Potential Issues	Assessment of the Effect or Potential Effect of the Option
Access	Access may be difficult and even prohibitively expensive under certain circumstances	• Access for works should be relatively straightforward and be from Cottonmill Lane or Old Sopwell Gardens. • High groundwater levels, which can occur in the Sopwell Nunnery area, would affect plant operations and works should be undertaken at times when these are low. • Works would require that the boardwalks are temporarily removed which would have cost and timing implications.
Flood Risk	As a result of re-alignment or floodplain works, flood risk from the river may decrease or increase in areas	• There is potential of increased flood risk to the properties over the right hand bank off of Cottonmill Lane as a result of realigning the channel closer to these properties. This will be clarified through modelling.
Hydromorphology	Does the scheme improve the hydromorphological functioning of the reach?	• The realignment works to connect this to the realigned Reach 4 Option, creation of a wet woodland zone and narrowing / further morphological improvements would improve the flow and habitat diversity. This should increase the hydraulic habitat diversity with a greater frequency of higher energy riffle units. The wet woodland zone would extend the existing wet woodland area.
Connection with Reach 4	Modifications may be required to the upstream structure associated to some of the realignment options proposed for Reach 4.	• This option would require a new structure through the road at the upstream end to reconnect with the realigned Reach 4 option. • Cost of around £250k quoted for culvert works on its own plus the cost of any utility diversions.
Abstractions and other hydrological concerns	Consideration as to whether the scheme may result in other adverse or beneficial hydrological effects. For example re-routing of the river may impact upon distributaries as well as the main river.	• There are no abstractions in this reach and so no effect of the scheme on these.
Groundwater connectivity	Does the scheme affect connectivity between surface water and groundwater?	• The wet woodland creation within the identified high groundwater level zone would improve the groundwater connectivity to the fluvial system.
Environmental Permits / consented discharges	Significant re-routing of the system may result in less flow being in the river at the point where a consented discharges enters and less dilution of that discharge.	• There are no consented discharges in this reach and there would be no changes as a result of this option.
Heritage	Scenario has the potential to impact upon Scheduled Monument or other archaeological feature	• The option would result in the channel being closer to Sopwell Nunnery scheduled monument. The asset is of high heritage value and its surrounding landscape is of importance regarding its designation. The re-aligned river would also be brought closer to the potential site of an Old Roman Road. Given these, the works may result in significant heritage effects that would need to be mitigated and/ or accounted for which may be problematic.

Water Mains and Sewers (foul and surface water)	Under certain scenarios, construction may be routed close to other water mains and sewers. If so, these may have substantive effects on the cost of the scheme, its feasibility and duration of its construction.	• There are Affinity Water mains that would likely be crossed at least once by the re-aligned channel. A trial hole may be required to establish depth. • There are foul water sewers under Cottonmill Lane that would need to be accounted for if a new culverted crossing at the upstream end of this reach was constructed. This would be expensive and potentially be prohibitive. • There are two Thames foul water sewers that the re-aligned channel would cross. These are at depths of approximately 2.7m bgl. With the re-alignment through this reach these may potentially be impacted, requiring works to mitigate this risk. • There are 3 surface water sewers in this reach which discharge into the existing channel via the northern/ left bank. The furthest downstream sewer enters once the channel has rejoined the main channel and so no impact upon the rivers ability to dilute this discharge is anticipated. However, the two other sewers enter at the upstream end of the reach where the river is re-aligned. Given that much of the flow would be re-routed this discharge would need to be re-routed too, or else it may have a significant impact upon on water quality in the relict channel that remains.
Other Utilities	Under certain scenarios, construction may be routed close to other utilities, such as BT or gas mains. If so, these may have substantive effects on the cost of the scheme, its feasibility and duration of its construction.	• There are a number of utilities at the top end of reach, under Cottonmill Lane. These would need to be accounted for if a new culverted crossing at the upstream end of this reach was constructed. This would be expensive and potentially be prohibitive.
Geo-environmental	Consideration as to whether scheme could result in pathways for contaminants to enter the water environment.	• Re-alignment would occur through an area that was formerly allotments and a small area that is currently allotments. This would provide a direct route for contaminants and nutrients to be introduced into the river and would have an impact upon water quality in the river for the short term at least. It is noted that there is currently a pathway for these to enter the river indirectly, via runoff.
Statutory and non-statutory sites conservation sites	These sites lie throughout the study area and could potentially be impacted by the scenarios	• Watercress Wildlife Site Local Nature Reserve (LNR)/ Sopwell House Watercress Beds lies at the downstream end of this reach although at the left bank. This is the other side from where the works would be undertaken. • Inflows into the Watercress Wildlife Site may alter as a consequence of the design and would be assessed using hydraulic modelling. Design iteration may occur at the detailed design stage based on the outcomes of this exercise.
Tree Protection Orders (TPO)	Consideration of the effect of Tree Protection Orders on the option	• There are a few TPOs in this reach although north of the river and these would not be impacted by the option or associated construction activities.
Public Rights of Way	Public Rights of Way may need to be diverted if works are would occur over their route	• A public right of way extends throughout the route of the works proposed by this scenario and would need to be diverted for the duration of the works. The path is also boardwalk for much of the reach and this would need to be re-instated as part of any works, which would add additional expense.

Other Costs	Identification of potentially significant costs or aspects that are comparably low cost	• Traffic Management Order may be required if a new culvert is needed under the road, which would be disruptive. A new pedestrian crossing, even temporary, may also be required. • Scheme may necessitate footpath realignment works and new crossing points.
Landscape impact	Review whether option would have a significant visual impact	• The option should result in an improved looking and more natural appearing river that is better connected to its flood plain.
Recreation and amenity	Review whether option would have significant impacts upon recreation and amenity	• The scheme is likely to be publically well received as it should result in accessible wet woodland and more visually interesting river that would encourage visitors.
Riparian ownership issues	Consideration as to whether option may require re-routing through lands that are privately owned or result in riparian changes that may be unacceptable.	• No significant riparian ownership issues are anticipated although there are riparian landowners on the left bank who may not find the scheme acceptable.

Reach 5 Option 2

Option Description and Restoration Plan

Similar to Option 1 in Reach 5, the Ver would be subject to re-alignment in the upstream end of the reach, but exiting the existing course of the channel from the existing Cottonmill Lane crossing. Bed re-profiling work at the top of the reach would be required to complement Reach 4 realignment options that re-link to the existing channel course.

Prior to entering the newly created wet woodland feature (that would avoid the Nunnery allotments and Scheduled Ancient Monument area), the re-aligned channel would be subject to in-channel re-profiling and incorporation of a suitable morphology including riffle and point bar features, and the creation of inset floodplains (as illustrated in Figure O.8, which also includes the features included within the modelling). The design would complement existing kingfisher habitat at the top of the reach. Please note Figure O.8 has been coarsely drawn and if progressed this option would not run through current allotment land towards the downstream end of the reach.

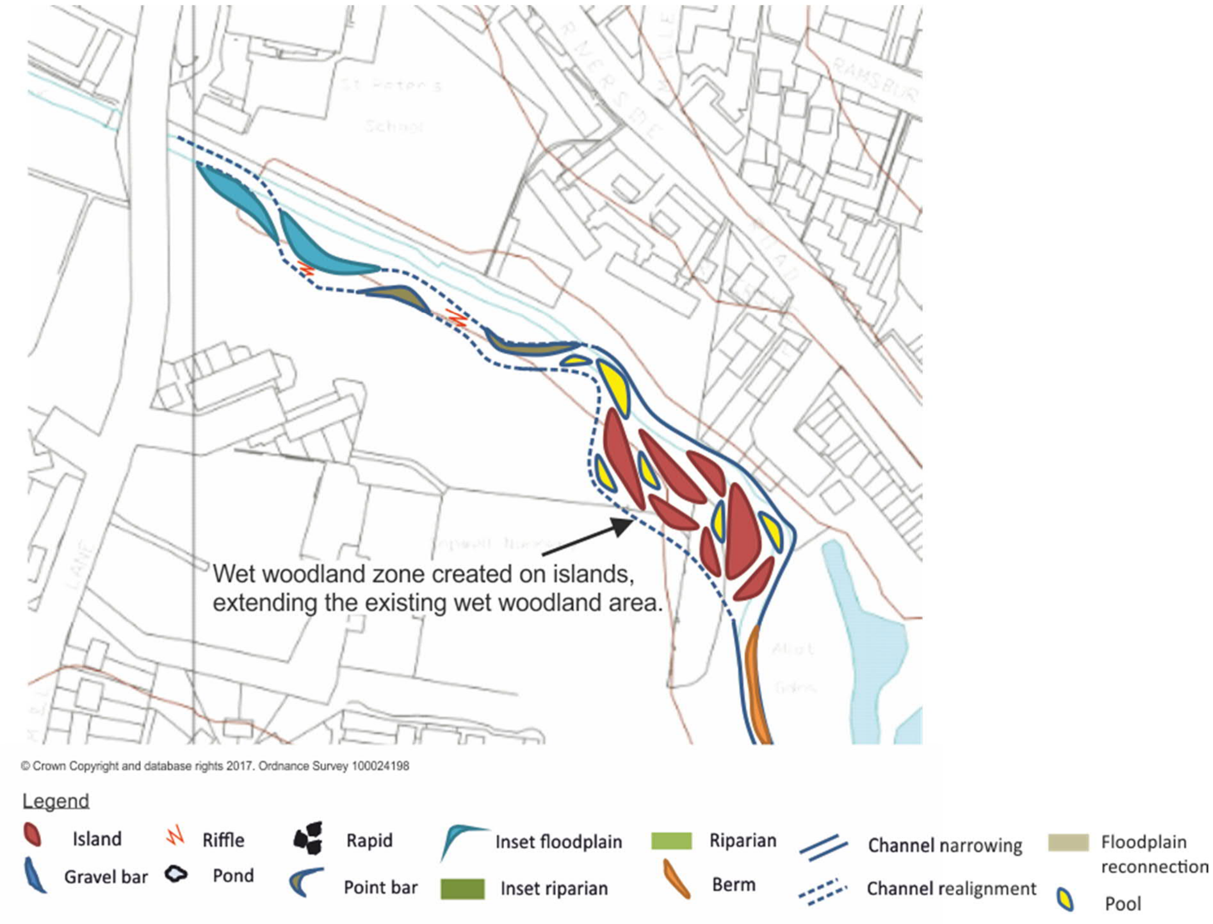


Figure O.8 Feature plans for Reach 5 Option 2

Review of Constraints and Opportunities

A plan of potential constraints for Reach 5 was provided in Figure O.6. The effects of these constraints on the feasibility of this option are described in Table O.5 below, along with potential advantages/ opportunities.

Table O.5 Review of constraints and opportunities for Reach 5 Option 2

Topic	Potential Issues	Assessment of the Effect or Potential Effect of the Option
Access	Access may be difficult and even prohibitively expensive under certain circumstances	• Access for works should be relatively straightforward and be from Cottonmill Lane or Old Sopwell Gardens. • High groundwater levels, which can occur in the Sopwell Nunnery area, would affect plant operations and works should be undertaken at times when these are low. • Works would require that the boardwalks are temporarily removed which would have cost and timing implications.
Flood Risk	As a result of re-alignment or floodplain works, flood risk from the river may decrease or increase in areas	• There is potential of increased flood risk to the properties over the right hand bank off of Cottonmill Lane as a result of realigning the channel closer to these properties. This will be clarified through modelling.
Hydromorphology	Does the scheme improve the hydromorphological functioning of the reach?	• The realignment works, creation of a wet woodland zone and narrowing / further morphological improvements would improve the flow and habitat diversity. This should increase the hydraulic habitat diversity with a greater frequency of higher energy riffle units. The wet woodland zone would extend the existing wet woodland area
Connection with Reach 4	Modifications may be required to the upstream structure associated to some of the realignment options proposed for Reach 4.	• Work would be required to allow reconnection to the Reach 4 options that relink to the existing main channel course.
Abstractions and other hydrological concerns	Consideration as to whether the scheme may result in other adverse or beneficial hydrological effects. For example re-routing of the river may impact upon distributaries as well as the main river.	• There are no abstractions in this reach and so no effect of the scheme on these.
Groundwater connectivity	Does the scheme affect connectivity between surface water and groundwater?	• The wet woodland creation within the identified high groundwater level zone would improve the groundwater connectivity to the fluvial system • Approximate bed levels would be confirmed following completion of the hydraulic modelling, at which point any improvements in river flow the connectivity with the groundwater table can be discussed further.
Environmental Permits / consented discharges	Significant re-routing of the system may result in less flow being in the river at the point where a consented discharges enters and less dilution of that discharge.	• There are no consented discharges in this reach and there would be no changes as a result of this option.
Heritage	Scenario has the potential to impact upon Scheduled Monument or other archaeological feature	• The option would result in the channel being slightly closer to Sopwell Nunnery scheduled monument. The asset is of high heritage value and its surrounding landscape is of importance regarding its designation. The re-aligned river would also be brought closer to the potential site of an Old Roman Road. Given these, the works may result in heritage effects that would need to be mitigated and/ or accounted for which may be problematic although the risk is considered to be relatively low.

Water Mains and Sewers (foul and surface water)	Under certain scenarios, construction may be routed close to other water mains and sewers. If so, these may have substantive effects on the cost of the scheme, its feasibility and duration of its construction.	• There are two Thames foul water sewers that the re-aligned channel would cross. These are at depths of approximately 2.7m bgl. With the re-alignment through this reach these may potentially be impacted, requiring works 9such as bed protection) to mitigate this risk. • There are 3 surface water sewers in this reach which discharge into the existing channel via the northern/ left bank. The scheme would not result in significant changes to the hydrology through this reach and so no impact upon the rivers ability to dilute these discharges is anticipated. • It should be noted that there are assets under Cottonmill Lane that may be impacted, although any effect would likely depend on the Reach 4 option that is progressed with.
Other Utilities	Under certain scenarios, construction may be routed close to other utilities, such as BT or gas mains. If so, these may have substantive effects on the cost of the scheme, its feasibility and duration of its construction.	• There are a number of utilities at the top end of reach, under Cottonmilll Lane. These would need to be accounted for if culvert/ structural adjustment works are required.
Geo-environmental	Consideration as to whether scheme could result in pathways for contaminants to enter the water environment.	• Re-alignment would occur through an area that was formerly allotments and a small area that is currently allotments. This would provide a direct route for contaminants and nutrients to be introduced into the river and would have an impact upon water quality in the river for the short term at least. It is noted that there is currently a pathway for these to enter the river indirectly, via runoff.
Statutory and non-statutory sites conservation sites	These sites lie throughout the study area and could potentially be impacted by the scenarios	• Watercress Wildlife Site Local Nature Reserve (LNR)/ Sopwell House Watercress Beds lies at the downstream end of this reach although at the left bank. This is the other side from where the works would be undertaken. • Inflows into the Watercress Wildlife Site may alter as a consequence of the design and would be assessed using hydraulic modelling. Design iteration may occur at the detailed design stage based on the outcomes of this exercise.
Tree Protection Orders (TPO)	Consideration of the effect of Tree Protection Orders on the option	• There are a few TPOs in this reach although north of the river and these would not be impacted by the option or associated construction activities.
Public Rights of Way	Public Rights of Way may need to be diverted if works are would occur over their route	• A public right of way extends throughout the route of the works proposed by this scenario and would need to be diverted for the duration of the works. The path is also boardwalk for much of the reach and this would need to be re-instated as part of any works, which would add additional expense.
Other Costs	Identification of potentially significant costs or aspects that are comparably low cost	• Scheme may necessitate footpath realignment works and new crossing points.
Landscape impact	Review whether option would have a significant visual impact	• The option should result in an improved looking and more natural appearing river that is better connected to its flood plain.

Recreation and amenity	Review whether option would have significant impacts upon recreation and amenity	• The option would result in a more accessible river which should be appealing for people to visit.
Riparian ownership issues	Consideration as to whether option may require re-routing through lands that are privately owned or result in riparian changes that may be unacceptable.	• No significant riparian ownership issues are anticipated although there are riparian landowners on the left bank who may not find the scheme acceptable.

Reach 5 Option 3

Option Description and Restoration Plan

In Option 3 the upstream end of the Ver would maintain its existing course, before being realigned through the lower end of the reach as the river heads in a southerly direction. Bed re-profiling work at the top of the reach would be required to complement Reach 4 realignment options that re-link to the existing channel course.

The re-aligned channel course would be subject to in-channel re-profiling and incorporation of a suitable morphology including a riffle-pool regime.

Review of Constraints and Opportunities

A plan of potential constraints for Reach 5 was provided in Figure O.9. The effects of these constraints on the feasibility of this option are described in Table O.6 below, along with potential advantages/ opportunities.

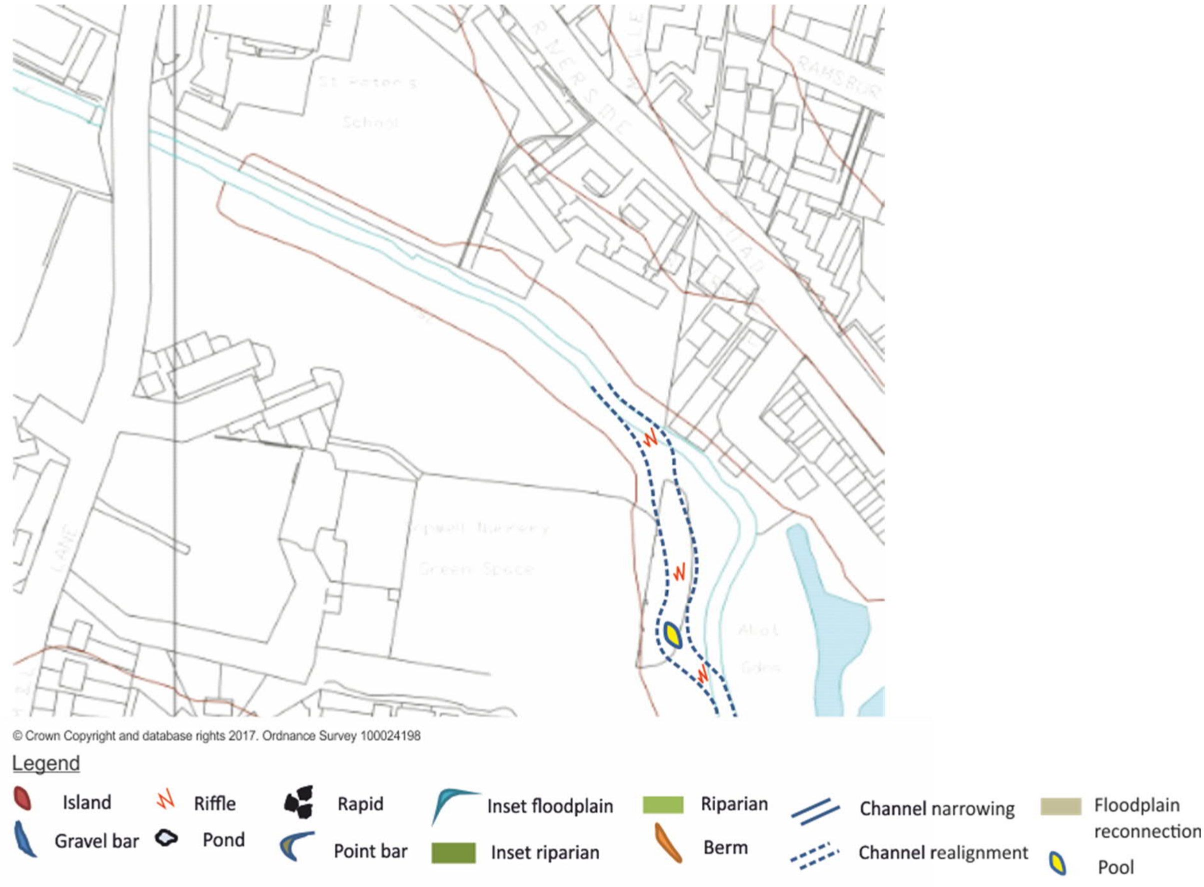


Figure O.9 Feature plans for Reach 5 Option 3

Table O.6 Review of constraints and opportunities for Reach 5 Option 3

Topic	Potential Issues	Assessment of the Effect or Potential Effect of the Option
Access	Access may be difficult and even prohibitively expensive under certain circumstances	• Access for works should be relatively straightforward and be from Cottonmill Lane or Old Sopwell Gardens. • High groundwater levels, which can occur in the Sopwell Nunnery area, would affect plant operations and works should be undertaken at times when these are low. • Works would require that the boardwalks are temporarily removed which would have cost and timing implications.
Flood Risk	As a result of re-alignment or floodplain works, flood risk from the River may decrease or increase in areas	• There is unlikely to be a significant flood risk impact as a result of this option.
Hydromorphology	Does the scheme improve the hydromorphological functioning of the reach?	• The realignment works to re-direct the main channel through the existing wet woodland zone would further improve the wet habitat in this area and also create an improved morphology and the increase the diversity of the hydraulic habitat through this reach.
Connection with Reach 4	Modifications may be required to the upstream structure associated to some of the realignment options proposed for Reach 4.	• Work would be required to allow reconnection to the Reach 4 options that relink to the existing main channel course.
Abstractions and other hydrological concerns	Consideration as to whether the scheme may result in other adverse or beneficial hydrological effects. For example re-routing of the river may impact upon distributaries as well as the main river.	• There are no abstractions in this reach and so no effect of the scheme on these.
Groundwater connectivity	Does the scheme affect connectivity between surface water and groundwater?	• The wet woodland creation within the identified high groundwater level zone would improve the groundwater connectivity to the fluvial system • Approximate bed levels would be confirmed following completion of the hydraulic modelling, at which point any improvements in river flow the connectivity with the groundwater table can be discussed further.
Environmental Permits / consented discharges	Significant re-routing of the system may result in less flow being in the river at the point where a consented discharges enters and less dilution of that discharge.	• There are no consented discharges in this reach and there would be no changes as a result of this option.
Heritage	Scenario has the potential to impact upon Scheduled Monument or other archaeological feature	• The option would result in works close to Sopwell Nunnery scheduled monument. The asset is of high heritage value and its surrounding landscape is of importance regarding its designation. No significant impacts on the monument are anticipated as a result of the option, however.
Water Mains and Sewers (foul and surface water)	Under certain scenarios, construction may be routed close to other water mains and sewers. If so, these may have substantive effects on the cost of the scheme, its	• Affinity Water mains (depths to be confirmed through trial holes) and Thames Water foul sewers (depths approximately 2.7m bgl) would likely be crossed by plant and should be accounted for. No works are anticipated close to mains or sewers,

	feasibility and duration of its construction.	however. • There are 3 surface water sewers in this reach which discharge into the existing channel via the northern/ left bank. The scheme would not result in significant changes to the hydrology through this reach and so no impact upon the rivers ability to dilute these discharges is anticipated.
Other Utilities	Under certain scenarios, construction may be routed close to other utilities, such as BT or gas mains. If so, these may have substantive effects on the cost of the scheme, its feasibility and duration of its construction.	• No impacts on other utilities are anticipated with this option..
Geo-environmental	Consideration as to whether scheme could result in pathways for contaminants to enter the water environment.	• Re-alignment would occur through a small area that is currently allotments. This would provide a direct route for contaminants and nutrients to be introduced into the river and would have an impact upon water quality in the river for the short term at least. It is noted that there is currently a pathway for these to enter the river indirectly, via runoff.
Statutory and non-statutory sites conservation sites	These sites lie throughout the study area and could potentially be impacted by the scenarios	• Watercress Wildlife Site Local Nature Reserve (LNR)/ Sopwell House Watercress Beds lies at the downstream end of this reach although at the left bank. • Inflows into the Watercress Wildlife Site would be affected by the design, effectively limiting the connection between the channel and the conservation site to overbank flows.
Tree Protection Orders (TPO)	Consideration of the effect of Tree Protection Orders on the option	• There are a few TPOs in this reach although north of the river and these would not be impacted by the option or associated construction activities.
Public Rights of Way	Public Rights of Way may need to be diverted if works are would occur over their route	• A public right of way extends throughout the route of the works proposed by this scenario and would need to be diverted for the duration of the works. The path is also boardwalk for much of the reach and this would need to be re-instated as part of any works, which would add additional expense.
Other Costs	Identification of potentially significant costs or aspects that are comparably low cost	• May require footpath realignment works and new crossing points.
Landscape impact	Review whether option would have a significant visual impact	• The option should result in a slightly improved looking and more natural appearing river that is better connected to its flood plain (though less so than the other options).
Recreation and amenity	Review whether option would have significant impacts upon recreation and amenity	• The option would result in a more accessible river which should be appealing for people to visit (though less so than the other options).
Riparian ownership issues	Consideration as to whether option may require re-routing through lands that are privately owned or result in riparian changes that may be unacceptable.	• There are riparian landowners on the left bank who would likely find the routing of the river away from their properties unacceptable.

Reach 5 Option 4

Option Description and Restoration Plan

The existing course of the Ver in Option 4 would be retained, but narrowed throughout the course of Reach 5. The right bank of the river would be lowered to help re-connect the river with the floodplain, given the channel is over-deep and over-wide and there is significant disconnection at present. Bed re-profiling work at the top of the reach may be required to complement Reach 4 realignment options that re-link to the existing channel course.

Prior to entering the newly created wet woodland feature, the re-aligned channel would be subject to in-channel re-profiling and incorporation of a suitable morphology including riffle and point bar features, and the creation of inset floodplains (as illustrated in Figure O.10, which also includes the features included within the modelling). The design would complement existing kingfisher habitat at the top of the reach.

Figure O.10 Feature plans for Reach 5 Option 4

Review of Constraints and Opportunities

A plan of potential constraints for Reach 5 was provided in Figure O.6. The effects of these constraints on the feasibility of this option are described in Table 0.7 below, along with potential advantages/ opportunities.

Table O.7 Review of constraints and opportunities for Reach 5 Option 4

Topic	Potential Issues	Assessment of the Effect or Potential Effect of the Option
Access	Access may be difficult and even prohibitively expensive under certain circumstances	• Access for works should be relatively straightforward and be from Cottonmill Lane or Old Sopwell Gardens. • High groundwater levels, which can occur in the Sopwell Nunnery area, would affect plant operations and works should be undertaken at times when these are low. • Works would require that the boardwalks are temporarily removed which would have cost and timing implications.
Flood Risk	As a result of re-alignment or floodplain works, flood risk from the river may decrease or increase in areas	• At the time of the assessment it was considered that there would be a potential of increased flood risk to the properties over the right hand bank off of Cottonmill Lane as a result of bank lowering work to encourage floodplain re-connection, however this is less likely than for options 1 and 2.
Hydromorphology	Does the scheme improve the hydromorphological functioning of the reach?	• The in-channel features, creation of a wet woodland zone and floodplain reconnection works would improve the flow and habitat diversity as well as overall morphological functionality of this reach. This should increase the hydraulic habitat diversity with a greater frequency of higher energy riffle units. The wet woodland zone would extend the existing wet woodland area.
Connection with Reach 4	Modifications may be required to the upstream structure associated to some of the realignment options proposed for Reach 4.	• Work would be required to allow reconnection to the Reach 4 options that relink to the existing main channel course.
Abstractions and other hydrological concerns	Consideration as to whether the scheme may result in other adverse or beneficial hydrological effects. For example re-routing of the river may impact upon distributaries as well as the main river.	• There are no abstractions in this reach and so no effect of the scheme on these.
Groundwater connectivity	Does the scheme affect connectivity between surface water and groundwater?	• The wet woodland creation within the identified high groundwater level zone would improve the groundwater connectivity to the fluvial system • Approximate bed levels would be confirmed following completion of the hydraulic modelling, at which point any improvements in river flow the connectivity with the groundwater table can be discussed further.
Environmental Permits / consented discharges	Significant re-routing of the system may result in less flow being in the river at the point where a consented discharges enters and less dilution of that discharge.	• There are no consented discharges in this reach and there would be no changes as a result of this option.
Heritage	Scenario has the potential to impact upon Scheduled Monument or other archaeological feature	• The option would result in works close to Sopwell Nunnery scheduled monument. The asset is of high heritage value and its surrounding landscape is of importance regarding its designation. However no significant impacts on the monument are anticipated as a result of the option,

Water Mains and Sewers (foul and surface water)	Under certain scenarios, construction may be routed close to other water mains and sewers. If so, these may have substantive effects on the cost of the scheme, its feasibility and duration of its construction.	• Affinity Water mains (depths to be confirmed through trial holes) and Thames Water foul sewers (depths approximately 2.7m bgl) would likely be crossed by plant and should be accounted for. No works are anticipated close to mains or sewers, however. • There are 3 surface water sewers in this reach which discharge into the existing channel via the northern/ left bank. The scheme would not result in significant changes to the hydrology through this reach and so no impact upon the rivers ability to dilute these discharges is anticipated. • It should be noted that there are assets under Cottonmill Lane that may be impacted, although any effect would likely depend on the Reach 4 option that is progressed with.
Other Utilities	Under certain scenarios, construction may be routed close to other utilities, such as BT or gas mains. If so, these may have substantive effects on the cost of the scheme, its feasibility and duration of its construction.	• There are a number of utilities at the top end of reach, under Cottonmill Lane. These would need to be accounted for if culvert/ structural adjustment works are required.
Geo-environmental	Consideration as to whether scheme could result in pathways for contaminants to enter the water environment.	• Increased floodplain connection would provide a direct route for contaminants and nutrients to be introduced into the river (if present in the floodplain sediments) and would have an impact upon water quality in the river for the short term at least. It is noted that there is currently a pathway for these to enter the river indirectly, via runoff.
Statutory and non-statutory sites conservation sites	These sites lie throughout the study area and could potentially be impacted by the scenarios	• Watercress Wildlife Site Local Nature Reserve (LNR)/ Sopwell House Watercress Beds lies at the downstream end of this reach although at the left bank. • Inflows into the Watercress Wildlife Site may alter as a consequence of the design and would be assessed using hydraulic modelling. Design iteration may occur at the detailed design stage based on the outcomes of this exercise.
Tree Protection Orders (TPO)	Consideration of the effect of Tree Protection Orders on the option	• There are a few TPOs in this reach although north of the river and these would not be impacted by the option or associated construction activities.
Public Rights of Way	Public Rights of Way may need to be diverted if works are would occur over their route	• A public right of way extends throughout the route of the works proposed by this scenario and would need to be diverted for the duration of the works. The path is also boardwalk for much of the reach and this would need to be re-instated as part of any works, which would add additional expense.
Other Costs	Identification of potentially significant costs or aspects that are comparably low cost	• May require footpath realignment works and new crossing points.
Landscape impact	Review whether option would have a significant visual impact	• The option should result in an improved looking and more natural appearing river that is better connected to its flood plain.
Recreation and amenity	Review whether option would have significant impacts upon recreation and amenity	• The option would result in a more accessible river which should be appealing for people to visit.

Riparian ownership issues	Consideration as to whether option may require re-routing through lands that are privately owned or result in riparian changes that may be unacceptable.	• No significant riparian ownership issues are anticipated although there are riparian landowners on the left bank who may not find the scheme acceptable.

Determination of the Preferred Reach 5 Option

From a hydromorphological perspective, Options 1 and 2 represent the greatest potential improvement with the re-alignment of the river channel and design of a more appropriate planform, as well as the creation of the wet woodland zone. Without this planform adjustment the benefit presented by Option 4 is reduced to a degree, although the wet woodland zone and extensive riparian works will provide significant environmental improvement. In comparison Option 3 offers planform improvements but without significant riparian benefits and is considered the least beneficial option.

Considering only those options with significant environmental benefit (Options 1, 2 and 4), the constraints to each option were of critical importance. Option 1 would require expensive structural works and may increase the fluvial flood risk to the properties over the right hand bank close to the re-aligned channel. Option 2 may also create a similar risk to the right bank properties through re-alignment of the channel closer to these properties. Option 4 may create minor flood risk as a result of floodplain reconnection, however this is considered to pose less risk to the right bank properties given the channel remains in its current course.

Given Option 4 did not require structural works and presented a comparatively lower flood risk, it was progressed as the preferred option.

Table 0.8 provides a compiled review of the constraints and opportunities for the Reach 5 options. The discussion of each constraint/ opportunity for each option has been coloured accordingly:

- Green – Desired improvements and project objectives achieved. No constraints identified in relation to the category in question.
- Yellow - Desired improvements and project objectives achieved. Low or moderate mitigation costs and/ or constraints identified in relation to the category in question.
- Orange - Desired improvements and project objectives achieved. Moderate or high mitigation costs and/ or constraints identified in relation to the category in question.
- Red – Desired improvements and project objectives may not be achieved and/ or high mitigation costs and/ or major constraints identified in relation to the category in question that may be difficult or expensive to overcome.

Table O.8 Reach 5 Summary Table

Topic	Effect or Potential Effect of Reach 5 Option 1	Effect or Potential Effect of Reach 5 Option 2	Effect or Potential Effect of Reach 5 Option 3	Effect or Potential Effect of Reach 5 Option 4
Access	• Access for works should be relatively straightforward and be from Cottonmill Lane or Old Sopwell Gardens. • High groundwater levels, which can occur in the Sopwell Nunnery area, would affect plant operations and works should be undertaken at times when these are low. • Works would require that the boardwalks are temporarily removed which would have cost and timing implications.	• Access for works should be relatively straightforward and be from Cottonmill Lane or Old Sopwell Gardens. • High groundwater levels, which can occur in the Sopwell Nunnery area, would affect plant operations and works should be undertaken at times when these are low. • Works would require that the boardwalks are temporarily removed which would have cost and timing implications.	• Access for works should be relatively straightforward and be from Cottonmill Lane or Old Sopwell Gardens. • High groundwater levels, which can occur in the Sopwell Nunnery area, would affect plant operations and works should be undertaken at times when these are low. • Works would require that the boardwalks are temporarily removed which would have cost and timing implications.	• Access for works should be relatively straightforward and be from Cottonmill Lane or Old Sopwell Gardens. • High groundwater levels, which can occur in the Sopwell Nunnery area, would affect plant operations and works should be undertaken at times when these are low. • Works would require that the boardwalks are temporarily removed which would have cost and timing implications.
Flood Risk	• At the time of the assessment it was considered that there would be a potential of increased flood risk to the properties over the right hand bank off of Cottonmill Lane as a result of realigning the channel closer to these properties. Embanking could be used to mitigate this.	• At the time of the assessment it was considered that there would be a potential of increased flood risk to the properties over the right hand bank off of Cottonmill Lane as a result of realigning the channel closer to these properties. Embanking could be used to mitigate this.	• There is unlikely to be a significant flood risk impact as a result of this option.	• At the time of the assessment it was considered that there would be a potential of increased flood risk to the properties over the right hand bank off of Cottonmill Lane as a result of bank lowering work to encourage floodplain re-connection, however this is less likely than for options 1 and 2.
Hydromorphology	• The realignment works to connect this to the realigned Reach 4 Option, creation of a wet woodland zone and narrowing / further morphological improvements would improve the flow and habitat diversity. This should increase the hydraulic habitat diversity with a greater frequency of higher energy riffle units. The wet woodland zone would extend the existing wet woodland area.	• The realignment works, creation of a wet woodland zone and narrowing / further morphological improvements would improve the flow and habitat diversity. This should increase the hydraulic habitat diversity with a greater frequency of higher energy riffle units. The wet woodland zone would extend the existing wet woodland area	• The realignment works to re-direct the main channel through the existing wet woodland zone would further improve the wet habitat in this area and also create an improved morphology and the increase the diversity of the hydraulic habitat through this reach	• The in-channel features, creation of a wet woodland zone and floodplain reconnection works would improve the flow and habitat diversity as well as overall morphological functionality of this reach. This should increase the hydraulic habitat diversity with a greater frequency of higher energy riffle units. The wet woodland zone would extend the existing wet woodland area.
Connection with Reach 4	• This option would require a new structure through the road at the upstream end to reconnect with the realigned Reach 4 option. • Cost of around £250k quoted for culvert works on its own plus the cost of any utility diversions.	• Work would be required to allow reconnection to the Reach 4 options that relink to the existing main channel course.	• Work would be required to allow reconnection to the Reach 4 options that relink to the existing main channel course.	• Work would be required to allow reconnection to the Reach 4 options that relink to the existing main channel course.
Abstractions and other hydrological concerns	• There are no abstractions in this reach and so no effect of the scheme on these.	• There are no abstractions in this reach and so no effect of the scheme on these.	• There are no abstractions in this reach and so no effect of the scheme on these.	• There are no abstractions in this reach and so no effect of the scheme on these.
Groundwater connectivity	• The wet woodland creation within the identified high groundwater level zone would improve the groundwater connectivity to the fluvial system.	• The wet woodland creation within the identified high groundwater level zone would improve the groundwater connectivity to the fluvial system.	• The wet woodland creation within the identified high groundwater level zone would improve the groundwater connectivity to the fluvial system.	• The wet woodland creation within the identified high groundwater level zone would improve the groundwater connectivity to the fluvial system.
Environmental Permits / consented discharges	• There are no consented discharges in this reach and there would be no changes as a result of this option.	• There are no consented discharges in this reach and there would be no changes as a result of this option.	• There are no consented discharges in this reach and there would be no changes as a result of this option.	• There are no consented discharges in this reach and there would be no changes as a result of this option.
Heritage	• The option would result in the channel being closer to Sopwell Nunnery scheduled monument. The asset is of high heritage value and its surrounding landscape is of importance regarding its designation. The re-aligned river would also be brought closer to the potential site of an Old Roman Road. Given these, the works may result in significant heritage effects that would need to be mitigated and/ or accounted for which may be problematic.	• The option would result in the channel being slightly closer to Sopwell Nunnery scheduled monument. The asset is of high heritage value and its surrounding landscape is of importance regarding its designation. The re-aligned river would also be brought closer to the potential site of an Old Roman Road. Given these, the works may result in heritage effects that would need to be mitigated and/ or accounted for which may be problematic although the risk is considered to be relatively low.	• The option would result in works close to Sopwell Nunnery scheduled monument. The asset is of high heritage value and its surrounding landscape is of importance regarding its designation. No significant impacts on the monument are anticipated as a result of the option, however.	• The option would result in works close to Sopwell Nunnery scheduled monument. The asset is of high heritage value and its surrounding landscape is of importance regarding its designation. No significant impacts on the monument are anticipated as a result of the option, however.
Water Mains and Sewers (foul and surface water)	• There are Affinity Water mains that would likely be crossed at least once by the re-aligned channel. A trial hole may be required to establish depth. • There are foul water sewers under Cottonmill Lane that would need to be accounted for if a new culverted crossing at the upstream end of this reach was constructed. This would be expensive and potentially be	• There are two Thames foul water sewers that the re-aligned channel would cross. These are at depths of approximately 2.7m bgl. With the re-alignment through this reach these may potentially be impacted, requiring works 9such as bed protection) to mitigate this risk. • There are 3 surface water sewers in this reach which	• Affinity Water mains (depths to be confirmed through trial holes) and Thames Water foul sewers (depths approximately 2.7m bgl) would likely be crossed by plant and should be accounted for. No works are anticipated close to mains or sewers, however. • There are 3 surface water sewers in this reach	• Affinity Water mains (depths to be confirmed through trial holes) and Thames Water foul sewers (depths approximately 2.7m bgl) would likely be crossed by plant and should be accounted for. No works are anticipated close to mains or sewers, however. • There are 3 surface water sewers in this reach

	prohibitive. • There are two Thames foul water sewers that the re-aligned channel would cross. These are at depths of approximately 2.7m bgl. With the re-alignment through this reach these may potentially be impacted, requiring works to mitigate this risk. • There are 3 surface water sewers in this reach which discharge into the existing channel via the northern/ left bank. The furthest downstream sewer enters once the channel has rejoined the main channel and so no impact upon the rivers ability to dilute this discharge is anticipated. However, the two other sewers enter at the upstream end of the reach where the river is re-aligned. Given that much of the flow would be re-routed this discharge would need to be re-routed too, or else it may have a significant impact upon on water quality in the relict channel that remains.	discharge into the existing channel via the northern/ left bank. The scheme would not result in significant changes to the hydrology through this reach and so no impact upon the rivers ability to dilute these discharges is anticipated. • It should be noted that there are assets under Cottonmill Lane that may be impacted, although any effect would likely depend on the Reach 4 option that is progressed with.	which discharge into the existing channel via the northern/ left bank. The scheme would not result in significant changes to the hydrology through this reach and so no impact upon the rivers ability to dilute these discharges is anticipated.	which discharge into the existing channel via the northern/ left bank. The scheme would not result in significant changes to the hydrology through this reach and so no impact upon the rivers ability to dilute these discharges is anticipated. • It should be noted that there are assets under Cottonmill Lane that may be impacted, although any effect would likely depend on the Reach 4 option that is progressed with.
Other Utilities	• There are a number of utilities at the top end of reach, under Cottonmill Lane. These would need to be accounted for if a new culverted crossing at the upstream end of this reach was constructed. This would be expensive and potentially be prohibitive.	• There are a number of utilities at the top end of reach, under Cottonmill Lane. These would need to be accounted for if culvert/ structural adjustment works are required (likely dependent on Reach 4 option that is progressed with).	• No impacts on other utilities are anticipated with this option.	• There are a number of utilities at the top end of reach, under Cottonmill Lane. These would need to be accounted for if culvert/ structural adjustment works are required.
Geo-environmental	• Re-alignment would occur through an area that was formerly allotments. This would provide a direct route for contaminants and nutrients to be introduced into the river and would have an impact upon water quality in the river for the short term at least. It is noted that there is currently a pathway for these to enter the river indirectly, via runoff.	• Re-alignment would occur through an area that was formerly allotments. This would provide a direct route for contaminants and nutrients to be introduced into the river and would have an impact upon water quality in the river for the short term at least. It is noted that there is currently a pathway for these to enter the river indirectly, via runoff.	• Increased floodplain connection would provide a direct route for contaminants and nutrients to be introduced into the river (if present in the floodplain sediments) and would have an impact upon water quality in the river for the short term at least. It is noted that there is currently a pathway for these to enter the river indirectly, via runoff.	• Increased floodplain connection would provide a direct route for contaminants and nutrients to be introduced into the river (if present in the floodplain sediments) and would have an impact upon water quality in the river for the short term at least. It is noted that there is currently a pathway for these to enter the river indirectly, via runoff.
Statutory and non-statutory sites conservation sites	• Inflows into the Watercress Wildlife Site may alter as a consequence of the design and would be assessed using hydraulic modelling. Design iteration may occur during the detailed design stage based on the outcomes of this exercise.	• Inflows into the Watercress Wildlife Site may alter as a consequence of the design and would be assessed using hydraulic modelling. Design iteration may occur during the detailed design stage based on the outcomes of this exercise.	• Inflows into the Watercress Wildlife Site would be affected by the design, effectively limiting any connection between the channel and the conservation site to overbank flows.	• Inflows into the Watercress Wildlife Site may alter as a consequence of the design and would be assessed using hydraulic modelling. Design iteration may occur at the detailed design stage based on the outcomes of this exercise.
Tree Protection Orders (TPO)	• There are a few TPOs in this reach although north of the river and these would not be impacted by the option or associated construction activities.	• There are a few TPOs in this reach although north of the river and these would not be impacted by the option or associated construction activities.	• There are a few TPOs in this reach although north of the river and these would not be impacted by the option or associated construction activities.	• There are a few TPOs in this reach although north of the river and these would not be impacted by the option or associated construction activities.
Public Rights of Way	• A public right of way extends throughout the route of the works proposed by this scenario and would need to be diverted for the duration of the works. The path is also boardwalk for much of the reach and this would need to be re-instated as part of any works, which would add additional expense.	• A public right of way extends throughout the route of the works proposed by this scenario and would need to be diverted for the duration of the works. The path is also boardwalk for much of the reach and this would need to be re-instated as part of any works, which would add additional expense.	• A public right of way extends throughout the route of the works proposed by this scenario and would need to be diverted for the duration of the works. The path is also boardwalk for much of the reach and this would need to be re-instated as part of any works, which would add additional expense.	• A public right of way extends throughout the route of the works proposed by this scenario and would need to be diverted for the duration of the works. The path is also boardwalk for much of the reach and this would need to be re-instated as part of any works, which would add additional expense.
Other Costs	• Traffic Management Order may be required if a new culvert is needed under the road, which would be disruptive. A new pedestrian crossing, even temporary, may also be required. • Scheme may necessitate footpath realignment works and new crossing points.	• May require footpath realignment works and new crossing points.	• May require footpath realignment works and new crossing points.	• May require footpath realignment works and new crossing points.
Landscape impact	• The option should result in an improved looking and more natural appearing river that is better connected to its flood plain.	• The option should result in an improved looking and more natural appearing river that is better connected to its flood plain.	• The option should result in a slightly improved looking and more natural appearing river that is better connected to its flood plain (though less so than the other options).	• The option should result in an improved looking and more natural appearing river that is better connected to its flood plain.
Recreation and amenity	• The scheme is likely to be publically well received as it should result in accessible wet woodland and more visually interesting river that would encourage visitors.	• The scheme is likely to be publically well received as it should result in accessible wet woodland and more visually interesting river that would encourage visitors.	• The option would result in a more accessible river which should be appealing for people to visit (though less so than the other options).	• The scheme is likely to be publically well received as it should result in accessible wet woodland and more visually interesting river that would encourage visitors

Riparian ownership issues	• No significant riparian ownership issues are anticipated although there are riparian landowners on the left bank who may not find the scheme acceptable.	• No significant riparian ownership issues are anticipated although there are riparian landowners on the left bank who may not find the scheme acceptable.	• There are riparian landowners on the left bank who would likely find the routing of the river away from their properties unacceptable.	• No significant riparian ownership issues are anticipated although there are riparian landowners on the left bank who may not find the scheme acceptable.

APPENDIX P – Determination of the Reach 6 Preferred Option

P.1 Overview

A summary of the derivation of the preferred option for Reach 6 (see Figure P.1) is presented within this Appendix. The included the following steps:

- Reach 6 Long List Appraisal.
- Reach 6 Short List Appraisal.

These results of the appraisals are outlined below.

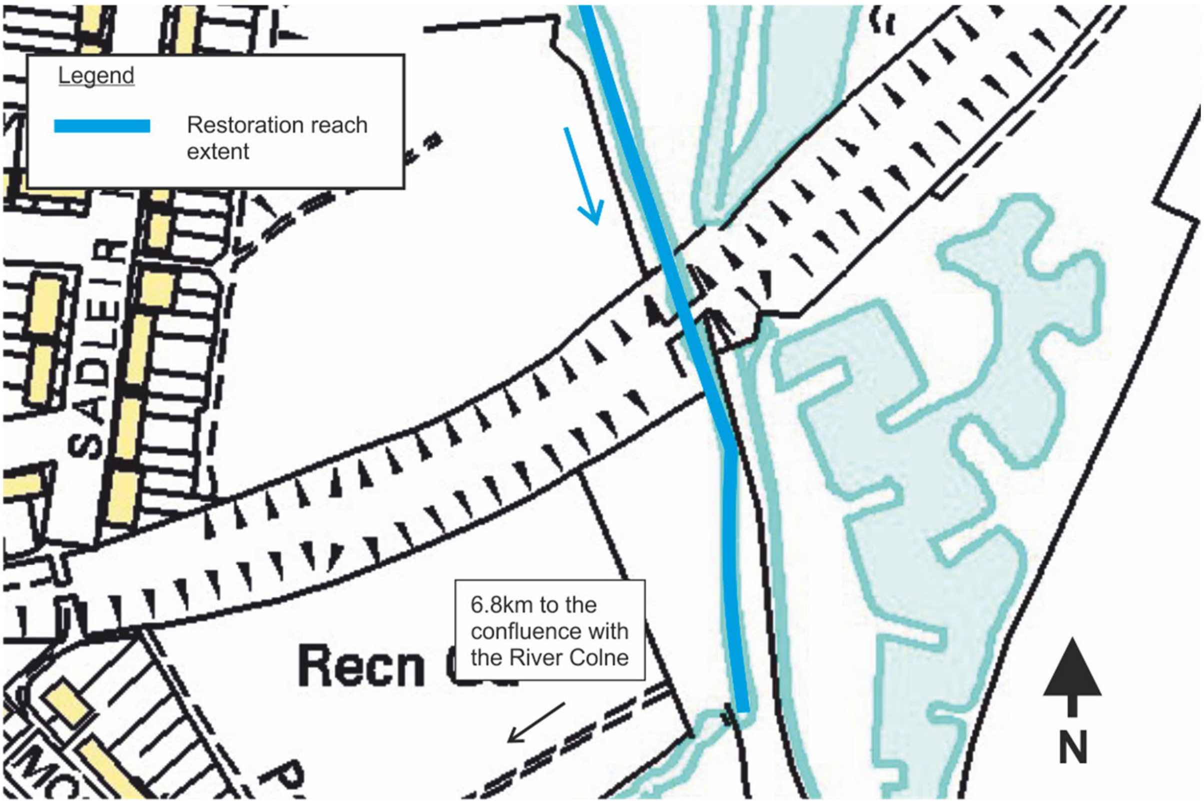


Figure P.1 Reach 6 of the study area (From the Watercress Wildlife Site to Sopwell Mill Farm)

P.2 Reach 6 Long List Appraisal

Options Identification

The long list of options for Reach 6 are outlined in Table P.1.

Table P.1 Long List Options Reach 6

Option	Description
1	Increased sinuosity of existing channel
2	Retain existing channel and improve

A schematic of these options is provided in Figures P.2 – P.3 below.

Long List Appraisal

A summary of the long list appraisal and scoring is provided in Table P.2 below. Individual options are appraised in subsequent sub-sections. The long list appraisal methodology was presented in Section 2.3 and Appendix B.

Table P.2 Appraisal of Reach 6 Long List Options

Option	Fulfil Project WFD Objectives for WB?	No constraints that would make option unfeasible?	Acceptable from a H&S perspective?	Not result in significant detrimental or loss of characteristic features?	Hydromorphology & Naturalisation	Habitat	Water Quality	Flood Risk	Landscape/ Visual	Recreation & Amenity**	Heritage	Contaminated Land & Sediment	Fish Passage	Sustainability/ Ongoing Maintenance	Total Score
	Y/N	**Y/N**	**Y/N**	**Y/N**	**-2 to 2**	**-2 to 2**	**-2 to 2**	**-2 to 2**	**-2 to 2**	**-2 to 2**	**-2 to 2**	**-2 to 2**	**-2 to 2**	**-2 to 2**	
Do nothing/ Baseline															
0	N	Y	Y	Y	0	0	0	0	0	0	0	0	0	0	0
1	Y	Y	Y	Y	1*	1	1	1	1	-2	0	0	0	1	4
2	Y	Y	Y	Y	1*	1	1	1	1	-1	0	0	0	1	5

* The hydromorphology in this reach is currently considered to be acceptable and so gains in this reach would be minimal (hence hydromorphology gains for the different options are no greater than 1)

** key issues in this reach are potential losses to allotments and benefits regarding footpath (currently being undermined)

Reach 6 Option 1

This option is illustrated in Figure P.2 below. This option was considered to fulfil the necessary long listing criteria and was scored as part of the long listing appraisal. The option scored fairly (scoring 4 in total) and was thus not shortlisted for more detailed consideration.

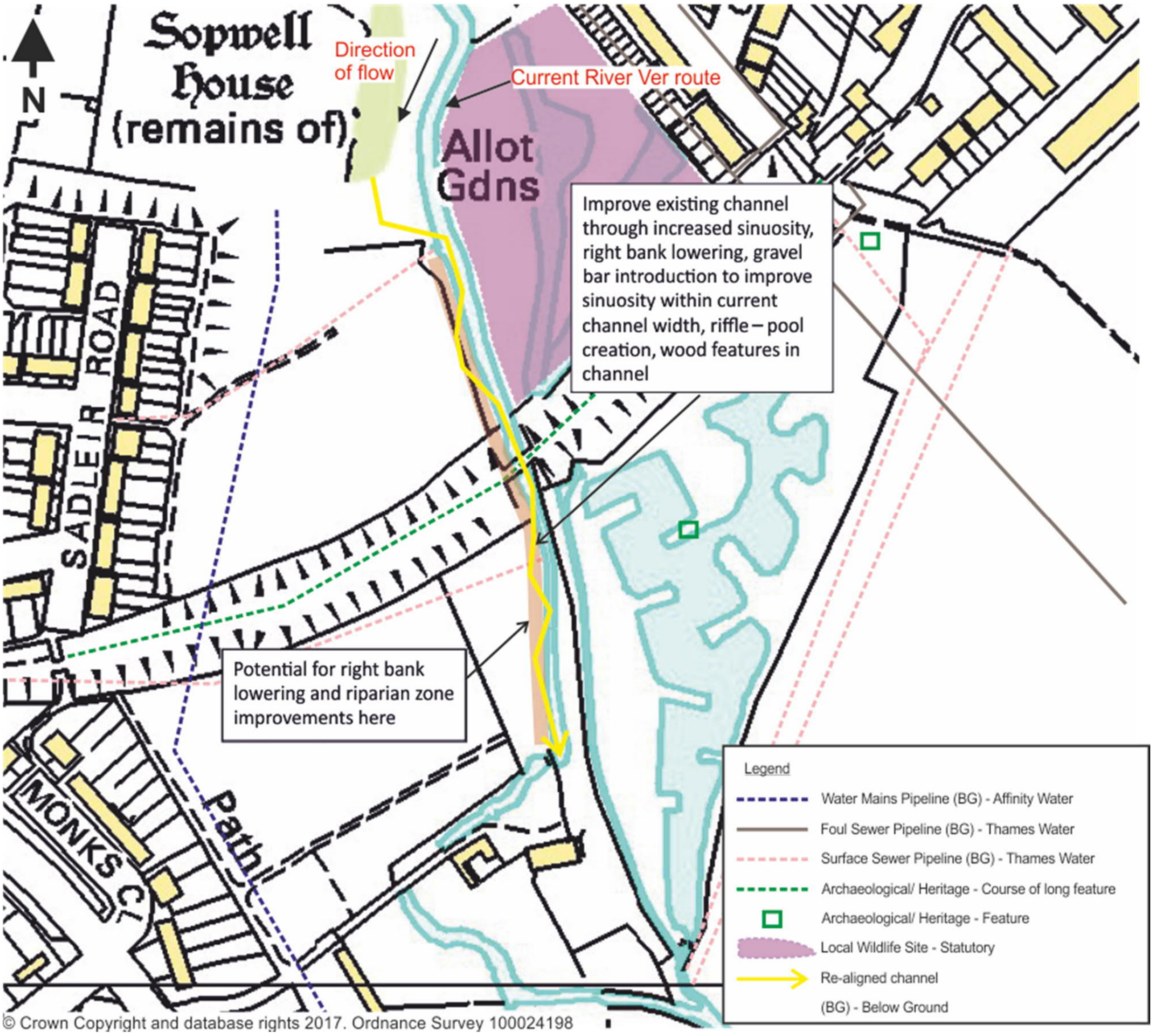


Figure P.2 Option 1 – Increased sinuosity of existing channel

Reach 6 Option 2

This option is illustrated in Figure P.3 below. This option was considered to fulfil the necessary long listing criteria and was scored as part of the long listing appraisal. The option scored well (scoring 5 in total) and was thus shortlisted for more detailed consideration.

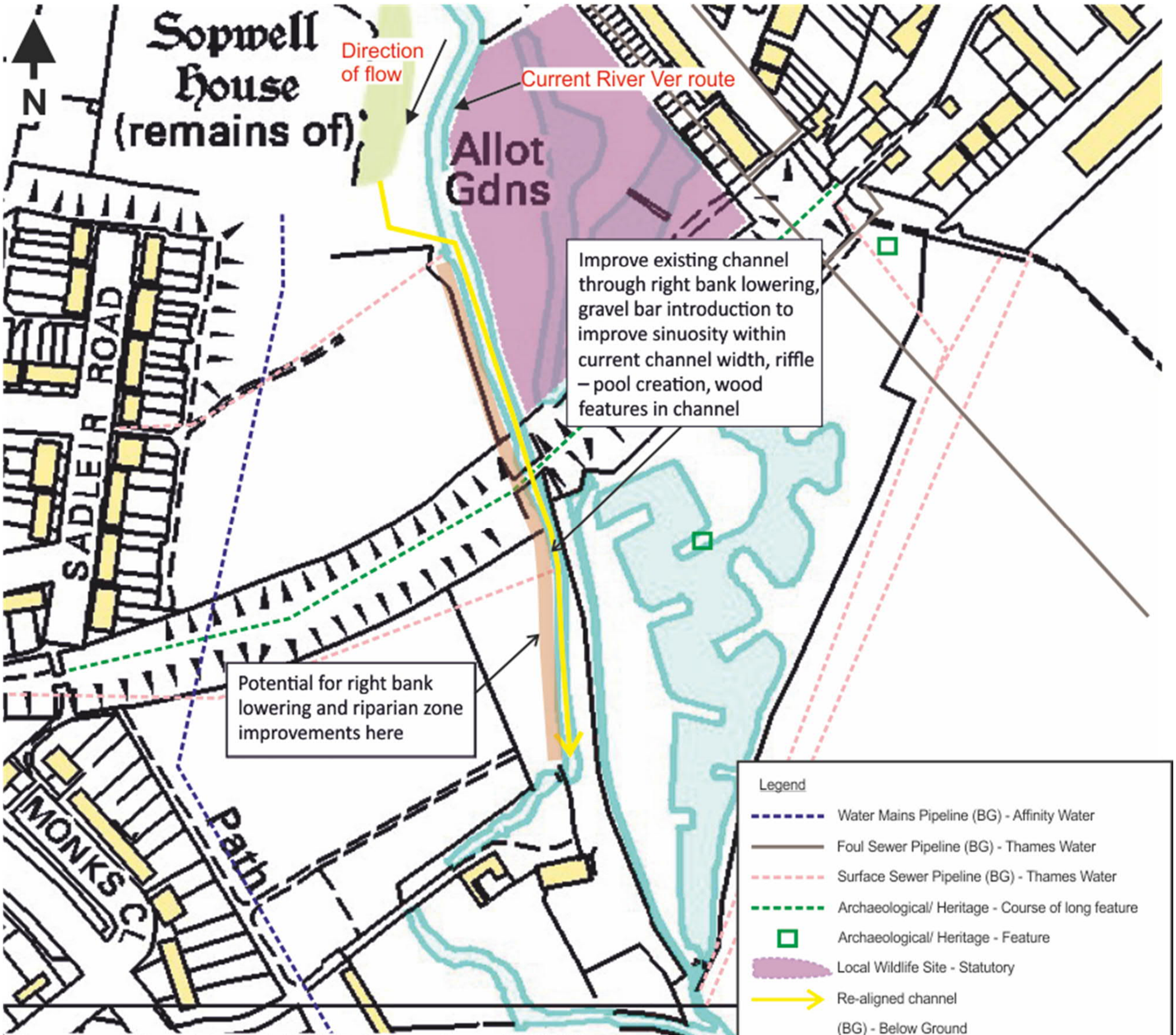


Figure P.3 Option 2 – Retain existing channel and improve

Reach 6 Longlisting Summary

As a result of the long list appraisal process, Reach 6 Option 1 was selected for shortlisting.

P.3 Reach 6 Short-listing Appraisal

Reach 6 Option Overview

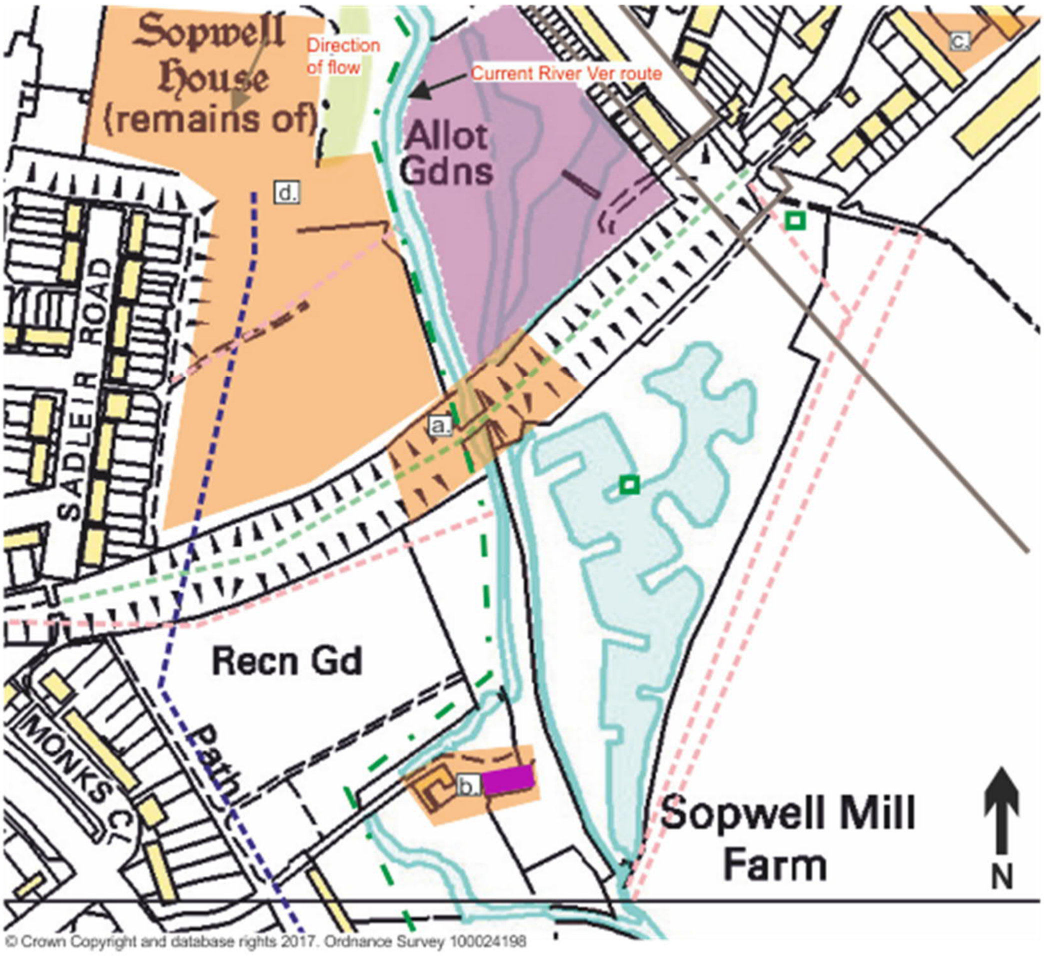
The options outlined in Table P.3 were derived from the long listing appraisal and have been reviewed as part of the Short-listing appraisal.

Table P.3 Reach 5Short Listed Options following Long List Appraisal

Option	Description
Reach 6	
2	Retain existing channel and improve

Review of Constraints and Opportunities

A plan of potential constraints for Reach 6 is provided in Figure P.4.



Legend

- Water Mains Pipeline (BG) - Affinity Water
- Foul Sewer Pipeline (BG) - Thames Water
- Surface Sewer Pipeline (BG) - Thames Water
- Archaeological/ Heritage - Course of long feature
- Local Wildlife Site - Statutory
- Archaeological/ Heritage - Feature
- Land Use - Past & present extent of notable land use (See codes a-d)
- Ver Valley Trail
- Consented Discharge - British Gas Fuel Installations
- Listed Building

Land Use Description

a. Vehicle servicing, testing, repair
b. Former mill and farm
c. Embankments could be made ground along course of former railway line
d. Present allotment site

Pollution Incidents

Seven minor WQ pollution incidents (category 3 - minor impact) recorded throughout the course of the reach

(BG) - Below Ground

Note: Reach 6 upstream of the Alban Way falls within Conservation Area No 11 (St Albans)

Figure P.4 Reach 6 Option 2 constraints plan

Reach 6 Option 2

Option Description and Restoration Plan

This option would involve retaining existing channel and improving features in it.

In this option the existing channel course would be maintained, with right bank lowering upstream of the bridge to encourage floodplain connection, causing one row of the Nunnery allotments to be lost. Right bank lowering also enables the Ver Valley Trail to be set back and stabilised given the current path has many erosion points. Inset floodplain and riparian zones would be created on the right bank immediately downstream of the Alban Way crossing over the river.

This section of the channel would also be subject to in-channel re-profiling and incorporation of a suitable morphology including a riffle-pool regime and berm features (as illustrated in Figure P.5, which also includes the features included within the modelling).

Figure P.5 Feature plans for Reach 6 Option 2

The effects of constraints on the feasibility of this option are described in Table P.4 below, along with potential advantages/ opportunities. Within this the discussion of each constraint/ opportunity for each option has been coloured accordingly:

- Green – Desired improvements and project objectives achieved. No constraints identified in relation to the category in question.
- Yellow - Desired improvements and project objectives achieved. Low or moderate mitigation costs and/ or constraints identified in relation to the category in question.
- Orange - Desired improvements and project objectives achieved. Moderate or high mitigation costs and/ or constraints identified in relation to the category in question.
- Red – Desired improvements and project objectives may not be achieved and/ or high mitigation costs and/ or major constraints identified in relation to the category in question that may be difficult or expensive to overcome.

Table P.4 Review of constraints and opportunities for Reach 6 Option 2

Topic	Potential Issues	Assessment of the Effect or Potential Effect of the Option
Access	Access may be difficult and even prohibitively expensive under certain circumstances	• Access for works should be relatively straightforward and likely be from the west/ south west.
Flood Risk	As a result of re-alignment or floodplain works, flood risk from the River may decrease or increase in areas	• There is unlikely to be any significant flood risk impact associated to the modifications to the existing channel for this option.
Hydro-morphology	Does the scheme improve the hydromorphological functioning of the reach?	• The proposed morphological improvements to the existing channel for this option would help to reduce the tendency for fine sediment deposition and create a more diverse hydraulic habitat through the reach. This would include a higher proportion of higher energy riffled units. Local riparian zone improvements would be created as a result of the proposed right bank works.
Abstractions and other hydrological concerns	Consideration as to whether the scheme may result in other adverse or beneficial hydrological effects. For example re-routing of the river may impact upon distributaries as well as the main river.	• There are no abstractions in this reach and so no effect of the scheme on these.
Groundwater connectivity	Does the scheme affect connectivity between surface water and groundwater?	• There are unlikely to be any significant improvements to groundwater connectivity through this reach as the existing channel alignment is being retained.
Environmental Permits / consented discharges	Significant re-routing of the system may result in less flow being in the river at the point where a consented discharges enters and less dilution of that discharge.	• There are no active consented discharges in this reach and there would be no changes as a result of this option.
Heritage	Scenario has the potential to impact upon Scheduled Monument or other archaeological feature	• The option is unlikely to have a significant effect of features of archaeological importance.
Water Mains and Sewers (foul and surface water)	Under certain scenarios, construction may be routed close to other water mains and sewers. If so, these may have substantive effects on the cost of the scheme, its feasibility and duration of its construction.	• There is a Thames Water surface water sewers that enters the river towards the top end of Reach 6. This enters at the right bank where works are proposed. The works would need to account for this and depth of the structure should be confirmed to determine how this is accounted for. • The scheme would not result in significant changes to the hydrology through this reach and so no impact upon the rivers ability to dilute the associated discharge is anticipated.
Other Utilities	Under certain scenarios, construction may be routed close to other utilities, such as BT or gas mains. If so, these may have substantive effects on the cost of the scheme, its feasibility and duration of its construction.	• No impacts on other utilities are anticipated with this option.
Geo-environmental	Consideration as to whether scheme could result in pathways for contaminants to enter the water environment.	• Increased floodplain connection would provide a direct route for contaminants and nutrients to be introduced into the river (if present in the floodplain sediments) and would have an impact upon water quality in the river for the short term at least. It is noted that there is currently a pathway for these to enter the river indirectly, via runoff.
Wildlife Sites	Wildlife sites lie throughout the study area and could potentially be impacted by the scenarios	• Sopwell Meadows Local Wildlife Site lies downstream of Reach 6, and the fishery lies alongside the left bank. Inflows into the fishery may alter as a consequence of the design and would be assessed using hydraulic modelling. Design iteration may occur at the detailed design stage based on the outcomes of this exercise.
Tree Protection Orders (TPO)	Consideration of the effect of Tree Protection Orders on the option	• There are no TPOs in this reach and so no effect on the scheme.
Public Rights of Way	Public Rights of Way may need to be diverted if works are would occur over their route	• A public right of way extends throughout the route of the works proposed by this scenario and would need to be diverted for the duration of the works.
Other Costs	Identification of potentially significant costs or aspects that are comparably low cost	• The works are downstream of a large river bridge. The works should not impact upon the stability of this structure or on its function, although this should be accounted for during the works. • There may be a small cost associated to realignment of the footpath as a result of the proposed riparian works.
Landscape impact	Review whether option would have a significant visual impact	• The option should result in a slightly improved looking and more natural appearing river that is better connected to its flood plain.
Recreation and amenity	Review whether option would have significant impacts upon recreation and amenity	• The option would result in a more accessible river which should be appealing for people to visit. Works would not extend in the recreational area and so no loss of playing grounds is anticipated.
Riparian ownership issues	Consideration as to whether option may require re-routing through lands that are privately owned or result in riparian changes that may be unacceptable.	• St Albans City and District Council have advised that they own all the area that would be affected by this option and so riparian ownership issues are anticipated.

APPENDIX Q – Reach 1 Lake Long-Listing Appraisal

Lake Options Verulamium Lake - Long Listing Appraisal

1. Introduction

This note presents and assesses the pros and cons of a number of lake only options for the furthest upstream reach (Reach 1) of the “Feasibility Study, Options Appraisal and Outline Designs for the River Ver Through St Albans”. Combined lake and river options have been assessed separately. It is intended that this note will enable lake only options to be selected which allow for the lake improvements to be delivered as a standalone project if desired. This will ensure that the issues with the lake can be addressed as a matter of urgency and aren’t tied to the wider works which may take longer to secure permission and funding.

2. Verulamium Lake

Lake Overview

The Verulamium Lake is situated within Verulamium Park to the south west of St Albans (see Figure 1). The park and lake were created in 1930 from agricultural land. The lake is composed of two areas:

i) The small circular upper (northern) lake with an area of around 4,300 m^2 and referred to locally as the ‘boating lake’ as it is commonly used for model boating, and

ii) The lower (southern) lake with an area of around 33,600 m^2.

Figure 1 Aerial view of Verulamium Lake © Microsoft 2017

The lower lake contains two wooded islands, one of which supports a heronry. The lakes are surrounded by amenity grass and/or surfaced footpath. The marginal or semiaquatic vegetation is limited to the northern end of the large lake and was artificially installed.

Lake Hydrology

A small flow of water intermittently enters the upper lake from the adjacent River Ver (permitted through an Environment Agency abstraction license). This enters via sluice gates and gravity flow arrangements. A further weir separates the upper and lower lake. There is also an abstraction from the River Ver at the north eastern corner of the lower lake although it has been reported that this does not work. Water flows back to the River Ver through an outlet at the southeast extent of the lower lake. Flow into, through and out of the lakes is considered to be low though amounts have not been determined (it is anticipated that amounts are low). A hydraulic model of the area has recently been constructed by JBA although it has not yet been provided. It is assumed that this model will be suitable to determine flows into and out of the lake under various flows conditions (e.g. during low, moderate and high flows). This would help inform lake options that may be taken forward.

A previous study[1] in 2012 found water depths of only 16-40 cm in the upper lake and 13-59 cm in the lower lake. This order of sediment depths were observed during lake sampling undertaken as part of this study (sampling discussed further below).

Lake Water Quality and Sediment Quality

A review of water and sediment quality in the lake has been undertaken as part of the wider study. Based on the limited data available, it appeared that the water quality of the shallow upper lake site is poorer and potentially more polluted and nutrient enriched than the lower lake. This may be due in part to the inflow from the adjacent River Ver combined with the shallow site conditions causing a greater concentration of pollutants and nutrients in this area. Recreational activities (model boating) may also be an important local source of some of the contaminants present. Once the water has passed over the weir into the lower lake it is expected that it is diluted by a greater volume of water with deeper cycling of nutrients and metals, and consequently the high concentrations observed in the upper lake were no longer apparent. As noted above, these conclusions are based on limited water quality data that provide only a 'snapshot' in time and should be used with some caution.

On the back of the findings above, the Environment Agency are undertaking further water quality sampling that should help inform the wider study.

There is considerable public concern about the condition of Verulamium Lake, particularly given an episode of avian botulism in 2015[2]. Botulism bacterial spores are naturally occurring and can survive for years. However, the bacteria only produce toxins under particular environmental conditions, which are generally believed to include warm temperatures, anoxic conditions and an organic nutrient source[3]. As such, if affected sediment was to be excavated from the site, then allowed to dry and warm up then this *may* inadvertently cause the bacteria to reactivate and potentially produce the toxin that causes botulism. Further investigation is recommended to better understand the risk to human health.

Under certain conditions there may also be the risk of algal blooms affecting the lake. Algae are natural components of a healthy fresh water lake system. However, during favourable conditions they can multiply rapidly causing blooms. When blooms are formed, the risk of toxin contamination of surface waters increases, especially for some species of blue green algae with the ability to produce toxins and other noxious chemicals .

Verulamium Lake is home to a large population of waterfowl, most notably *Branta Canadensis* (Canada Geese) and cyprinid fish population (predominantly carp). Faecal wastes from waterfowl (and fish) combined with food given to them by the public represents a significant nutrient source that may be enriching the lake. This is further exacerbated by a limited flow through the lake (leading to limited flushing of the lake), a high surface area to volume ratio (which makes the lake more susceptible to warming by incident sunlight), bioturbation of soft bed sediments by fish (resulting in increased turbidity and releasing stored nutrients), or the release of sediment-bound phosphorus when anoxic conditions form at the bed-water interface. The combination of these factors, together with suitable calm climatic conditions, provide the favourable conditions for algal blooms to occur (i.e. when there is a significant nutrient supply that is retained within the

[1] Symbio, Verulamium Lake, Survey and Analysis 2012
[2] St Albans City and District Council website, Information about the condition of the Lakes, 2016.
[3] USGS, National Wildlife Health Center, Disease Fact Sheets, Avian Botulism.

system and not absorbed by aquatic vegetation). There is also a notable absence of macrophytes in both lakes. Poor oxygen levels, high turbidity and a lack of suitable substrate also restrict opportunities for macrophytes and encourage a disturbed turbid, phytoplankton dominated lake system.

The base and sheer sides of the lake are entirely concrete lined. Pedestrian paths surround the lake margin on all sides and grass is present up to the lake edge. The western margin is characterised by short grass (kept short by grazing geese) while the eastern edge has overhanging deciduous trees, the fallen leaves from which are an allochthonous source of organic matter into the lake each autumn (noting that the prevailing wind is from the west and so leaf litter from the eastern edge might be blown the other way[4]). Two small islands in the lower lake are also colonised by deciduous trees.

Sediment depths in the same study were found to be in the region of 49 cm at the northernmost extent of the lower lake and 41 cm toward the outlet area. Strategic removal of sediment has previously been carried out, for instance the upper lake was drained and sediment removed in 2008 and taken to a contaminated waste landfill due to heavy metals. Further sediment removal has been undertaken in 2016, notably towards the lake outlet and below the weir into the lower lake[5]. It is not possible to determine the areas of greatest sediment accumulation from aerial imagery that is available online.

A site survey and analysis of the lake was also undertaken in 1991[6], and the lake was subsequently subject to a bioremediation treatment and biomanipulation programme (discussed further below under the *Lake Maintenance* sub-section).

Based on limited available data collected as part of the wider study, the results from bulk sediment samples suggested that lake sediments are ‘potentially hazardous’, with the upper lake being the most contaminated. This has consequences in terms of sediment re-use, and further sampling to determine the full extent of fuel pollution (potentially relating to model boating) in this area is recommended. However, leachate analysis suggested that lake sediments would be suitable for inert landfill. There were, however, a number of failures of the leachate data with WFD standards, which mainly affected the sample nearest the outflow of the lower lake. Leachate tests typically overestimate the risk in the natural environment and dilution, dispersion and duration factors would need to be considered, but this suggests that significant mobilisation of sediments could potentially have an impact on the lake ecosystem and potentially the River Ver downstream. This risk should be assessed in more detail before any works that affect lake sediments are undertaken. Regardless of the contamination risk, such works would need to be carefully planned and implemented using appropriate techniques and mitigation to minimise this risk.

On the back of the findings above, the Environment Agency and St Albans District Council are undertaking further sediment quality sampling that should help inform the wider study.

Lake Maintenance

Following the 1991 study outlined, under the *Lake Bed and Sediment* sub-section, a bioremediation treatment and biomanipulation programme has been undertaken. This has included removal of approximately 8 tonnes of roach with the aim of reducing direct pollution inputs, reducing silt disturbance from bioturbation and predatory pressure on zooplankton that are important for controlling phytoplankton populations. Further fish removal was performed in later years. Remedial biological sachets have been used sporadically at the site since 2003.

St Albans District Council is working others to stop the sale of bird food (for feeding the water fowl) to the public and a PR campaign has been put in place to deter people from feeding of the birds.

3. Summary of Lake Issues and what Lake Only Option would need to Deliver

The preferred option should be designed to help remediate water quality issues in the lake that have led to avian botulism. It should take account of, and potentially improve, the intricate hydrology in and out of the lake. If the concrete bed of the lake is removed the design should also account for groundwater recharge

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[4] Pers. comm from Daniel Flitton (St Albans District Council) 24 March 2017
[5] St Albans City and District Council website, Information about the condition of the Lakes, 2016.
[6] Symbio, Verulamium Lake, Site Survey and Analysis 1991

(rise in groundwater levels) in the area that are expected due to reductions in nearby Affinity Water abstractions.

4. Lake Only Options

A range of potential measures are available that could help improve the situation in the lake. These are outlined in Table 1 overleaf. This summarises their main characteritsics and whether they are suitable for inclusion within a preferred scheme.

Table 1 Lake only sub-options, descriptions of them and their appropriateness for inclusion within a preferred scheme

Sub-option		Option description and Rationale	Ruled in or out and why	Complimentary sub-options
A	Complete lake infilling	Lake would be infilled with soil, then grassed and landscaped. Would remove the risk of algal blooms and associated avian botulism.	This option would result in an important characteristic feature of the area with amenity and recreational benefits. It is hence rule out.	n/a
B	Partial infilling/ narrowing	Lake could be partially infilled. This would increase the rate of throughflow the system which would help flush out the system.	On its own this would need to be significant to make a difference to nutrient levels and algal blooms. This would not be considered appropriate given value of the lakes. More limited narrowing may be complimenary to other options.	C1, C2, D, E, F, G, H, I, K, O
C1	Full removal of the concrete bed removal and reprofiling	Concrete bed removal (full or partial) would help create a more natural feature through reprofiling and deepening of parts. Varying depths could potentially help improve circulatory patterns in the system which in turn would help improve water quality/ dissolved oxygen levels through increased mixing. Option would also improve the substrate and make it more suitable for macrophytes to root.	Ruled in. In addition to potential water quality and naturalisation benefits, the option may result in lake becoming groundwater fed and self sustaining hydrologically. This would be considered a positive (assuming not that sediments are removed if they are found to be hazardous and if groundwater levels are high enough to feed the lake following anticipated groundwater recharge in the area) and would also mean that river improvements could be greater as more flow would be retained in that system. Removal of concrete bed may result in contamination of groundwater unless potentially hazardous sediment is removed or remediated.	B, D, E, F, G, H, I, K, O
C2	Partial removal of the concrete bed removal and reprofiling			
D	Wetland creation/ planting of marginal, submergent and floating plants	A variety of macrophytes could be introduced into the lake. These would be marginal (e.g. phragmites), floating (e.g. white water lilies) or submerged. Introduction of these should help improve water quality in the lake as these would absorb nutrients in the lake.	Ruled in. Introduction of vegetation would not on its own improve the situation but could be part of a package of restoration measures. Vegetation should be selected that is not desired by Canada Geese for grazing, for example they do not like to graze of established phragmites. There is a risk of non natives being introduced when introducing vegetation. Potential stockists should be screened carefully so that this does not occur. Avoiding shallow marginal areas which support water plants will also restrict the food supply for the geese, but this may adversely affect other waterfowl and/or damage the rest of the aquatic habitat.	B, C1, C2, E, F, G, H, I, K, O
E	Disconnecting lake and river	This would involve closing off abstractions into the lake and/ or the discharge from the lake. This could improve water quality in the river (as water of poorer water quality from the lake would not enter it).	Tentatively ruled in warranting further investigation. Would result in potential improvements to the River Ver by providing more flow to that system and lowering the risk of water of poorer water entering the river from the lake. Not an ideal sub-option for the lake though (reduced flow through the lake would result in it becoming more eutrophic over time) and so this sub-option should only be considered in combination with other sub-options (e.g. if the lake became groundwater fed as a result of sub-option C).	B, C1, C2, D, H, I, K, O

Sub-option		Option description and Rationale	Ruled in or out and why	Complimentary sub-options
G	Varying abstraction regime from the River Ver	This would involve the river only providing flows at times of high flow.	The current arrangements of flow into the lake are yet to be established (hydraulic model not yet provided). The current inflow(s) are gravity fed and so flows from the river only occur at higher flows. Option not discounted and could potentially form part of a larger in-combination option.	B, C1, C2, D, H, I, K, O
H	Removing fish from the lake	Remove carp from the lake. This would increase the zooplankton population, that graze on algae and reduce the amount of lake bed sediment disturbance helping to maintain a clear lake water environment.	Fish removal and relocation would likely be required for in lake works and so this option would likely be included within the preferred option.	B, C1, C2, D, E, F, G, I, K, O
I	Physical aeration or oxygenation of the lake	Would occur through air or oxygen injection (e.g. via an injection system or boat based bubblers) or via a fountain (pump driven).	Potential to help improve oxygen levels in the system. Current and proposed depths in the lake may be insufficient for a number of aerator or mixing systems to be installed. Boat based system may be preferred unless lay out of the lakes changes substantially. Benefits would be maximised in combination with a number of other sub-options.	B, C1, C2, D, E, F, G, H, K, O
J	Chemical Oxygenation of the lake	Dosing of the system with chemicals that would generate oxygen once released into the lake.	Could include dosing of chemicals such as hydrogen peroxide or Ozone dosing. Ruled out- the chemicals are expensive, potentially hazardous and chemical dosing is not considered sustainable.	n/a
K	Physical mixing of the lake	Mechanical measures (such as surface or floating agitators and paddlewheels) could be introduced that would oxygenate the water. Some potential physical aeration/ oxygenation measures would help physically mix the system too.	Sub-option has the potential to improve Current and proposed depths in the lake may be insufficient for a number of mixing systems to be installed. Similary current layout may make it difficult for fixed point systems to be effective. Thus a boat based system may be preferred unless lay out of the lakes changes substantially.	B, C1, C2, D, E, F, G, H, I, O
L	Use of algicidal chemicals	Algicidal chemicals, such as copper or aluminium sulphate, could be spread into the lakes to supress algal growth (through inactivating phosphorous which is an essential nutrient for algal growth). This option is currently undertaken by the Council and is not sufficient to remediate the water quality problems. It is not considered sustainable and so is ruled out.	Use of algicidal chemicals, such as copper or aluminium sulphate, to supress algal growth (e.g. through inactivating phosphorous, and essential nutrient for algal growth); Would require repeat application, e.g. annually. Some dosing of the system currently occurs and has not solved the issue. Not a sustainable solution.	n/a
M	Physical measures to discourage Canadian Geese	Measures, such as lake edge planting and fencing areas off, may physically discourafe Canada Geese from in and around the lakes.	Physical measures may play a part in the final scheme though not considered ideal, so tentatively ruled out. Fencing areas off or steepening banks to make access more difficult for Canada Geese to access the land or water, may just shift the problem elsewhere. Fencing may also look visually unappealing. Canada Geese prefer to breed on islands and so removal of the islands could have been a potential sub-option. However, the islands in the lake are considered important habitat and so this is not considered appropriate.	n/a

	Sub-option	Option description and Rationale	Ruled in or out and why	Complimentary sub-options
N	Other measures to discourage Canadian Geese	This could include visual or acoustic scaring measures. Could include population controls, such as culling or egg control. St Albans District Council previously implemented an egg control programme called "Mother Goose" where eggs were removed and rehomed elsewhere[7].	The Canada Goose is protected under the EC Wild Birds Directive implemented in the United Kingdom through the Wildlife and Countryside Act (1981). This makes it an offence to capture, kill or injure Canada Geese, to damage their nests or eggs, or to disturb them on a breeding site. Any control technique which involves breaking the protected status of the Geese requires a licence from the appropriate government authority. Could also include increased signage for people to not feed the birds. Some measures that would discourage Canada Geese may form part of a final preferred option though these are tenatively ruled out at this stage.	n/a
O	Dredging of all sediments within the lake	Would remove a significant source of nutrients from the lake and on its own, reduce the likelihood of algal blooms occurring in the short term.	This sediment in the lakes is is potentially hazardous and may need to be disposed of offsite (e.g. in a landfill) at significant cost given the large volume of material. Otherwise it may be included in features on site or to enlarge the islands. On its own dredging is expensive and not a sustainable option. In order for a scheme to operate to work it is likely sediment dradging would be needed and so this sub-option is ruled in and should be undertaken in combination with other options	B, C1, C2, D, E, F, G, H, I, O
P	Island enlargement	Extending the size of these through soft engineering techniques and backfilling of the enlarged areas (potentially with dredged material).	Has the potential to increase ecological value and aesthetic appearance of the lake. Would also help achieve some of the potential benefits outlined for sub-option B.	B, C1, C2, D, E, F, G, H, I, O

[7] Pers. comm from Daniel Flitton (St Albans District Council) 24 March 2017. Programme implemented approximately 10 years ago.

It is evident that a number of sub-options may be suitable. In general these could be complimentary to one another. Figures 2 and 3 below present some potential cumulative plans of what two alternate combined schemes may look like. Note that the plans are indicative.

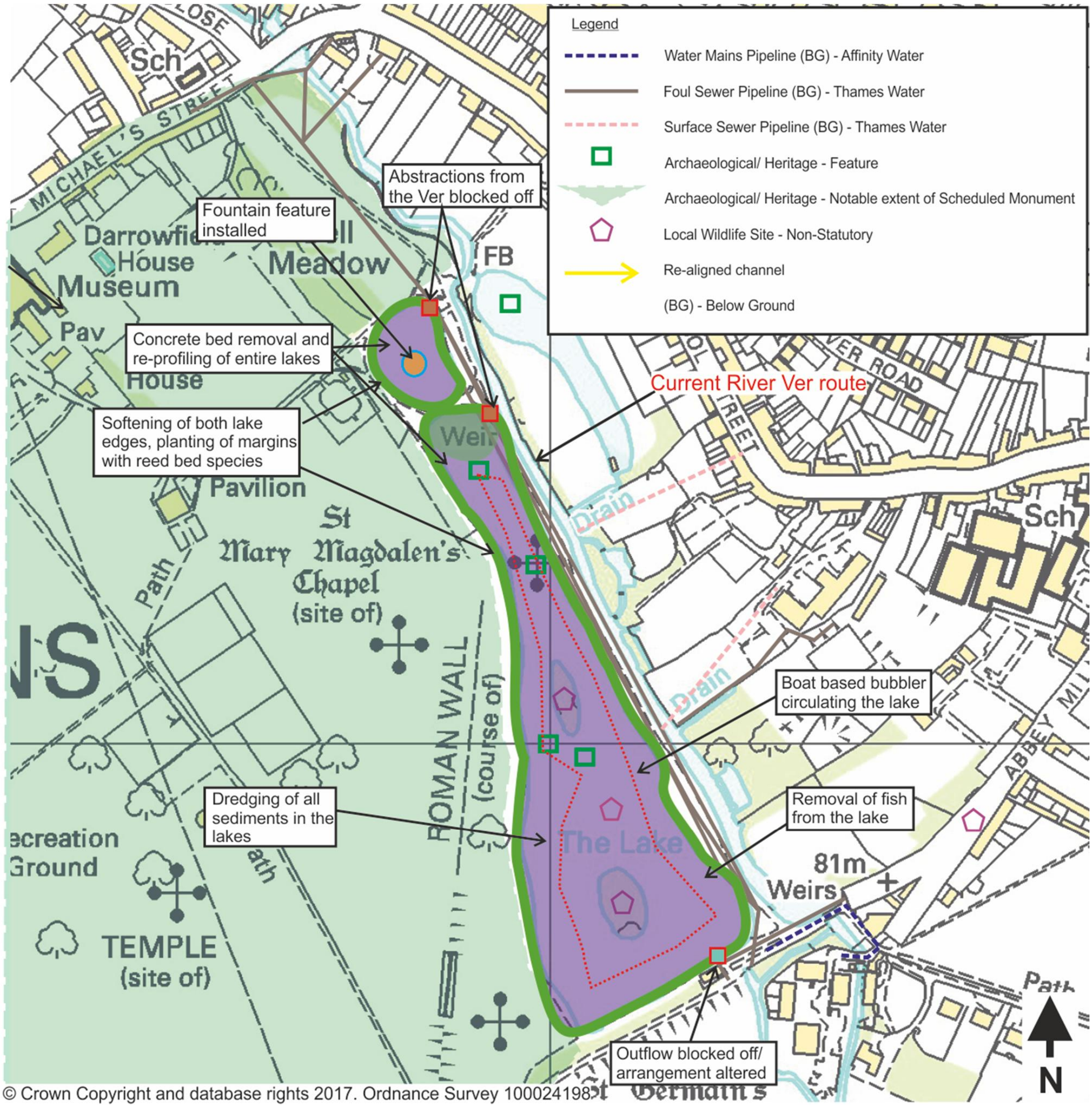

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Figure 2 Lake Only Combined Scheme 1

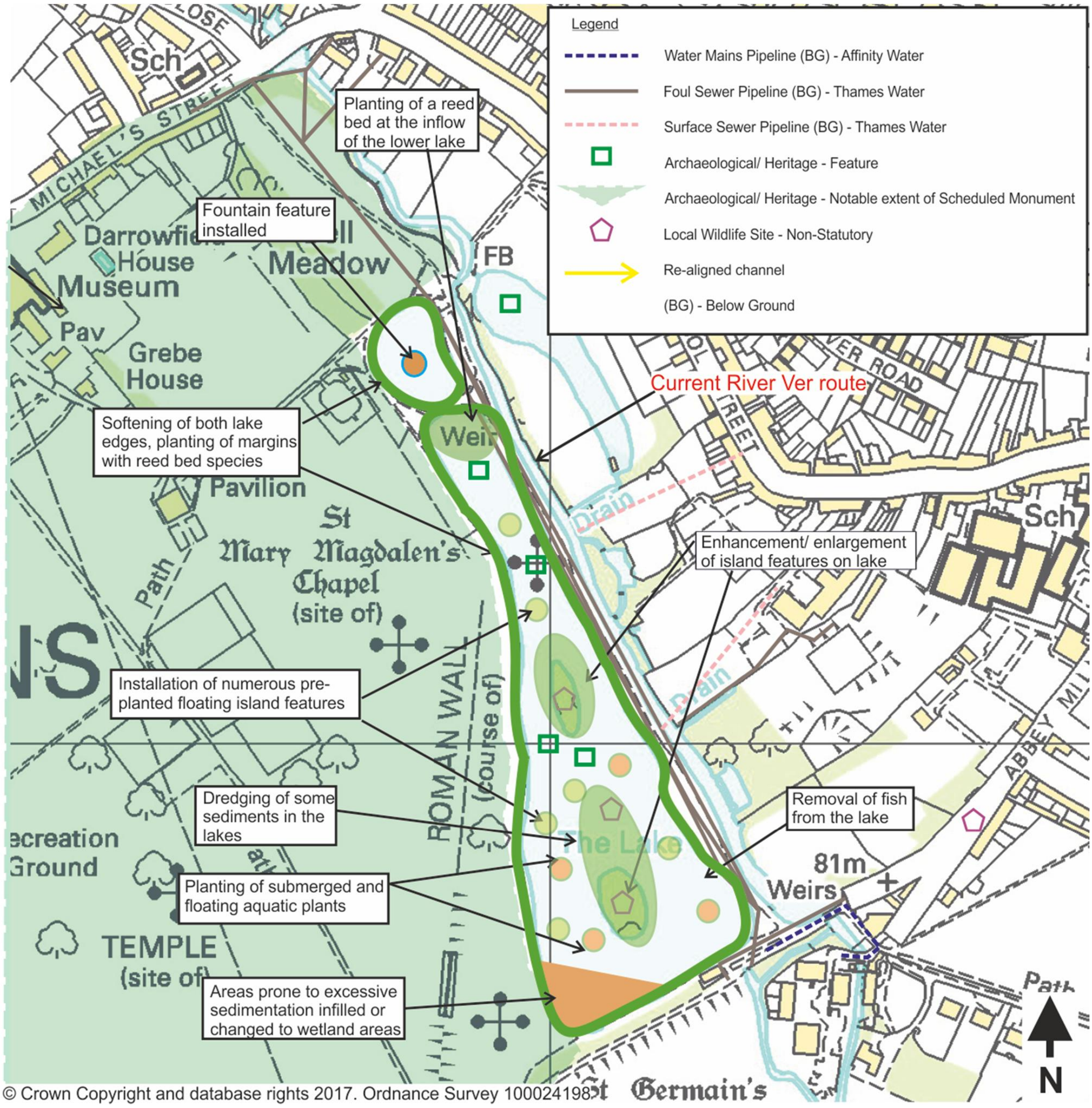

Figure 3 Lake Only Combined Scheme 2

5. Further work and ongoing studies that should help inform the selection of a lake only restoration option

The following are currently not known though should be determined during works already underway:

- A bathymetry survey of the lake.
- Further sampling and studies to inform the nutrient levels within the lake.
- The size of the abstraction into the lakes, which are gravity fed. It is considered that information on this could be available from the JBA/Environment Agency ISIS-TuFlow hydraulic model although this has not yet been provided to check;
- Long term and seasonal trends in water quality. Additional water quality and sediment sampling is being undertaken by the Environment Agency and St Albans District Council. This may extend through to the autumn; and
- Groundwater recharge study is currently being undertaken by AECOM and would help inform the appraisal.

APPENDIX R – EIA Screening Process

The aim of Environmental Impact Assessment (EIA) is to protect the environment by ensuring that a local planning authority when deciding whether to grant planning permission for a project, which is likely to have significant effects on the environment, does so in the full knowledge of the likely significant effects, and takes this into account in the decision making process[1].

The proposed restoration options for the River Ver study area were screened by an EIA consultant to determine whether they are likely to have any significant effects on the environment, and if the project is of a type listed in Schedule 1 or Schedule 2 of the Town and Country Planning (Environmental Impact Assessment) Regulations 2011 as amended.

Schedule 1 of the EIA Regulations lists types of development for which EIA is mandatory. Schedule 2 lists types of development for which EIA may be required if certain criteria apply. If a development is of a type listed in Schedule 2, and it is located within or partly within a 'sensitive area' then EIA is required. The Regulations define a 'sensitive area' as being:

- A Site of Special Scientific Interest (SSSI);
- A National Park;
- An Area of Outstanding Natural Beauty (AONB);
- A World Heritage site;
- A Scheduled Monument; or
- A European site within the meaning of regulation 8 of the Conservation of Habitats and Species Regulations 2010(6).

If the development is not within or partly within a 'sensitive area' but it exceeds relevant applicable thresholds and criteria set out in that Schedule, it is referred to as 'Schedule 2 Development'. 'Schedule 2 Development' requires EIA to be undertaken if it is likely to have significant effects on the environment by virtue of its nature, size or location; it is then referred to as 'EIA development'. An applicant can request that a Local Planning Authority (LPA) provide a screening opinion to determine whether a development is EIA Development, though some level of information is obviously needed to inform this opinion.

The proposed restoration options are not of a type of development that is listed in Schedule 1 of the Regulations. This type of development is also not specifically listed under Schedule 2 of the Regulations. However the EIA regulations are generally interpreted as having a 'wide scope and broad purpose' and as such, although this type of development is not specifically mentioned, it is likely to be classified as an 'infrastructure project' (paragraph 10), and in terms of sub category, it is typically paragraph 10(h) 'Inland-waterway construction not included in Schedule 1, canalisation and flood-relief works'. The indicative threshold for paragraph 10(h) projects is 1 ha.

If it is likely that the total area of the preferred options 'development site' including all permanent and temporary land take, will cover an area in excess of 1 ha; further consideration under Schedule 3 as to whether it is likely to have significant effects on the environment by virtue of its nature, size or location is required to determine if it will be EIA development. A screening opinion from the Local Authority would be requested in order to confirm whether or not, in their view, the proposed option constitutes EIA Development.

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