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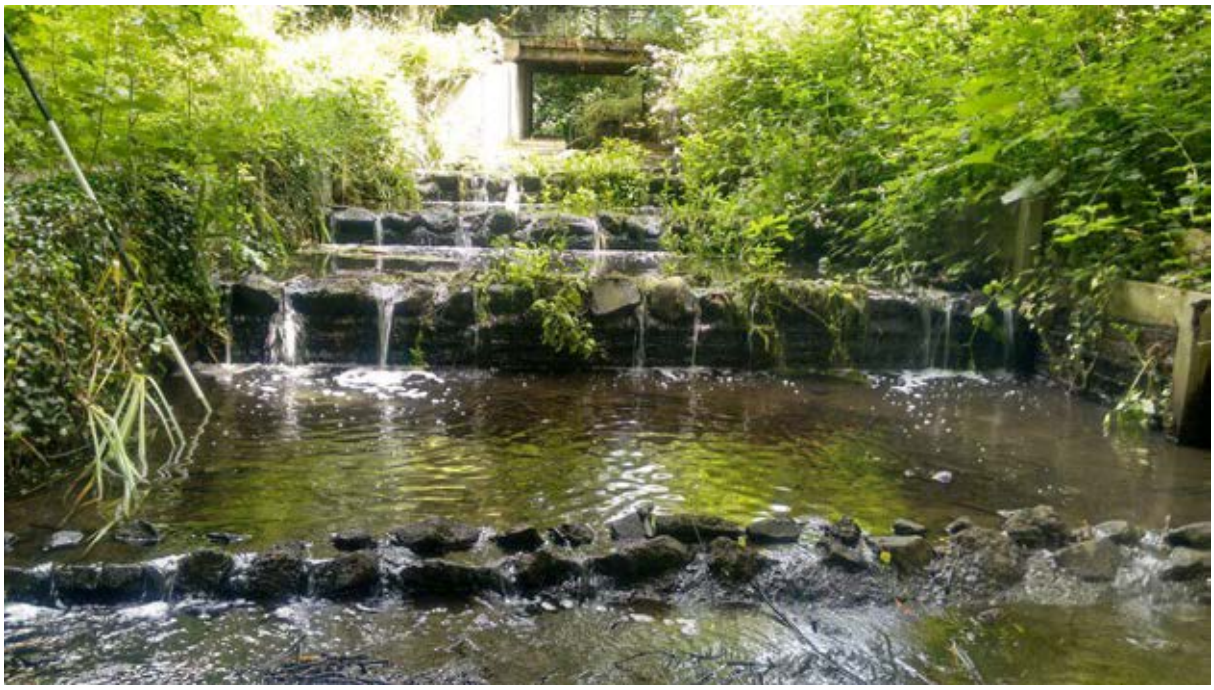
An Assessment of Barriers to Fish Passage in the Crane River Catchment

June 2016



Stepped Barrier at the Mill Stream ©Tom White

Client

Crane Valley Partnership

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Executive Summary

Obstructions within a river channel, such as weirs, millraces, and culverts have the potential to restrict the upstream and/or downstream movement of freshwater fish. The River Crane, in West London, is obstructed by 53 man-made structures which have the potential to negatively affect fish passage. This report provides a full physical assessment of all obstructions to upstream and downstream coarse fish and eel passage in the Crane Catchment. The report aims to prioritise barriers for removal in terms of their impact on the ingress of fish from the River Thames and their impact on habitat connectivity.

Barriers to fish passage were assessed using a methodology developed by The Scotland & Northern Ireland Forum for Environmental Research (SNIFFER). The methodology provides a means of assessing the physical attributes of obstructions within a river channel in relation to their impact on the swimming abilities of various fish species. For the purpose of this report barriers were assessed for their impact on the upstream passability of coarse fish and juvenile eels and for the downstream passability of coarse fish and adult eels. This was due to the fact that these species are present in the Crane Catchment.

53 obstructions were assessed in the Catchment on the Yeading Brook East, Yeading Brook West, Yeading Brook, Hounslow Mill Stream, River Crane and Lower Duke of Northumberland's River. A range options for consideration in regards to barrier easement are outlined for each barrier in the results section of this report.

43 out of the 53 obstructions present a complete barrier to the upstream migration of cyprinids. 19 obstructions presented a complete barrier to the upstream migration of juvenile eels. The most common reasons for the impassability of barriers were insufficient water depth, the size of the barriers hydraulic head and the availability of suitable climbing substrate for juvenile eels. 5 barriers for cyprinids and 2 barriers for juvenile eels were shown to be partially passable for upstream migrants, but still had a high impact on the number of fish able to ascend them. 2 barriers for cyprinids and 3 for juvenile eels were also shown to be partially passable, whilst having a low impact on the number of fish able to ascend them.

In terms of downstream passability for coarse fish, 33 barriers were found to be completely impassable. 1 barrier was partially passable whilst having a high impact and 4 barriers were found to be partially passable whilst having a low impact. In terms of downstream passability for adult eels, 27 barriers were found to be completely impassable, 2 barriers were partially passable whilst having a high impact and 3 barriers were partially passable whilst having a low impact. The most common reason for the impassability of barriers downstream was insufficient water depth.

The report highlights two possible options to allow for the ingress of fish to the catchment from the River Thames: 1. Improving fish passage via the Lower Duke of Northumberland's River; 2. Improving fish passage via the Lower Crane. Importantly, the Lower DNR has 12 fewer obstructions than the Lower Crane and is regarded to have notably better habitat for coarse fish and eels. In an ideal scenario, fish passage would be improved in both of these rivers in order to provide two connection points to the Thames. Currently it is advisable that barrier easement works are prioritized for the Lower Duke of Northumberland's River until major habitat restoration works are undertaken on the Lower Crane.

In terms of improving habitat connectivity for coarse fish and eels on the upper river, a number of barriers have been prioritized in order to link the River Crane to the Yeading Brook and Yeading Brook West. A number of other factors are acknowledged to be limiting to the movement of fish throughout this area of the catchment, such as habitat quality and water quality. Ten barriers in the catchment have been prioritized for removal. These are mapped and included in a table at the end of the report along with an estimated indication of cost and recommended easement technique.

Glossary of Terms Used:

Bankfull conditions: the level of flow in a channel where the water is just about to overtop the banks.

Climbing substrate: applicable to juvenile eels. Any wetted roughened substrate such as mosses, rough rock or vegetation that can be used by eels to climb up vertical or near vertical surfaces.

Current conditions: the water flow conditions at the time of the survey.

Downstream migration (DS): The passive movement downstream of fish dictated by flow conditions in the channel, as opposed to active swimming abilities.

Effective pool depth: the depth of the water at the location in the downstream pool from which ascending fish are considered most likely to launch from, if attempting to cross the obstacle.

Effective resting locations: areas in the downstream vicinity of the obstacle where reduced water velocity and low turbulence, combined with increased water depth, provide refuge for fish from the channel flow. This enables fish time to recover between passage attempts.

High flows: refers to a time when flows are elevated from the current conditions. Surveyors are required to estimate if the high flow situation would lead to an improvement or reduction in passability for fish species.

Hydraulic head: the difference in water level between the crest and the foot of the obstacle structure. Measured from water surface to water surface.

Inlet/crest of structure: the highest submerged point of a riverine obstacle where the majority of the water flow is focused. Often associated with a notch or localised area of increased water depth at man-made structures.

Lip: these are distinguishable additional features on an obstacle < 0.10m in height that clearly deflect water off the main surface of the structure. Lips are often placed at the crest or foot of a riverine obstacle that acts to divert water off a surface. Lips can cause difficulties for fish passage by dewatering sections of otherwise passable sloping surfaces.

Mid-point of structure: the position midway between the structure crest and foot, with measurements only applicable for structures that present a slope or steps.

Outlet/foot of structure: the downstream edge of the riverine structure, usually at the point immediately before the downstream pool begins. Where man-made structures are “perched” on bedrock, the point should be taken where bedrock enters the downstream pool. Measurements here are only applicable for structures that present a slope or steps.

Passive migration: movement conducted passively using the water flow to displace and transport in a downstream direction. Often considered to be the predominant mode of downstream migration for many riverine fish species.

Passability: the extent that fish passage is possible across the obstacle. Scored from 1.0 = no obstacle, partial low impact obstacle = 0.6, partial high impact obstacle = 0.3 and complete obstacle = 0.0.

Standing wave: a free-standing wave feature associated with the return of water to the surface after being forced down by increased flow or a height change. Waves can take many forms and sizes but all exhibit a noticeable localised increase in water surface height. Standing waves can create problems for fish passage by causing them to become disoriented and water velocities can exceed swimming capacity.

Transect: a straight line drawn perpendicular to the direction of water flow from water's edge to water's edge across a riverine obstacle structure, along which measurement of water velocity and depth are taken.

Transversal section: a portion of a riverine structure used in the assessment of passability at riverine obstacles. When viewed from downstream, a transversal section is distinguished as having water velocity and depth conditions remaining similar across its' width. A transversal section can consist of several features longitudinally (i.e. a vertical jump and then a swim feature for fish), but generally provides a possible direct route for fish passage across the structure.

Turbulence: entrained air and chaotic flows associated with high water velocities and plunging flows at riverine obstacles. Turbulence can create difficulties for fish due to disorientation and impeding swimming ability.

Upstream migration (US): the active movement upstream of fish moving against the direction of water flow.

1.0 Background

1.1 The Crane Catchment

The River Crane is a lowland river that flows through West London. Rising as the Yeading Brook West, from nine springs in the low hills of west Harrow, the river flows south before converging with its first tributary in North Hillingdon, the Yeading Brook East. The Yeading Brook continues through North Hillingdon and then briefly enters the London Borough of Ealing. The river then re-enters Hillingdon and, after passing Minet Country Park, becomes formally known as the River Crane. The Crane then flows through the London Borough of Hounslow, where it is joined by the Duke of Northumberland's River, a man-made river that flows from the River Colne. Finally the river flows through the London Borough of Richmond-upon-Thames, where the Duke of Northumberland's River branches away from the main river again before both arms reach their confluence with the River Thames in Isleworth.

The 63km of river channel that the catchment provides is responsible for draining an area of around 125km². Much of the river has been modified for industrial purposes over the past 300 years. Historically, the Crane was once a source of power for West London's numerous water mills. Today, the catchment's notable industrial sites include Heathrow Airport; and transport links such as the M4, M40 and mainline westbound rail services pass through large areas of urban and suburban development.

Prior to industrialisation, the river would have taken a much different shape. Once a meandering river of good depth and flow, the Crane now follows an artificially straightened course for parts of its duration with angular turns, lined and enforced banks and artificially widened sections, which prohibit the river from functioning naturally. The river channel is often obstructed by operational and redundant structures such as concrete culverts, weirs and mill races. Obstructions such as these prevent the free movement of fish throughout the catchment.

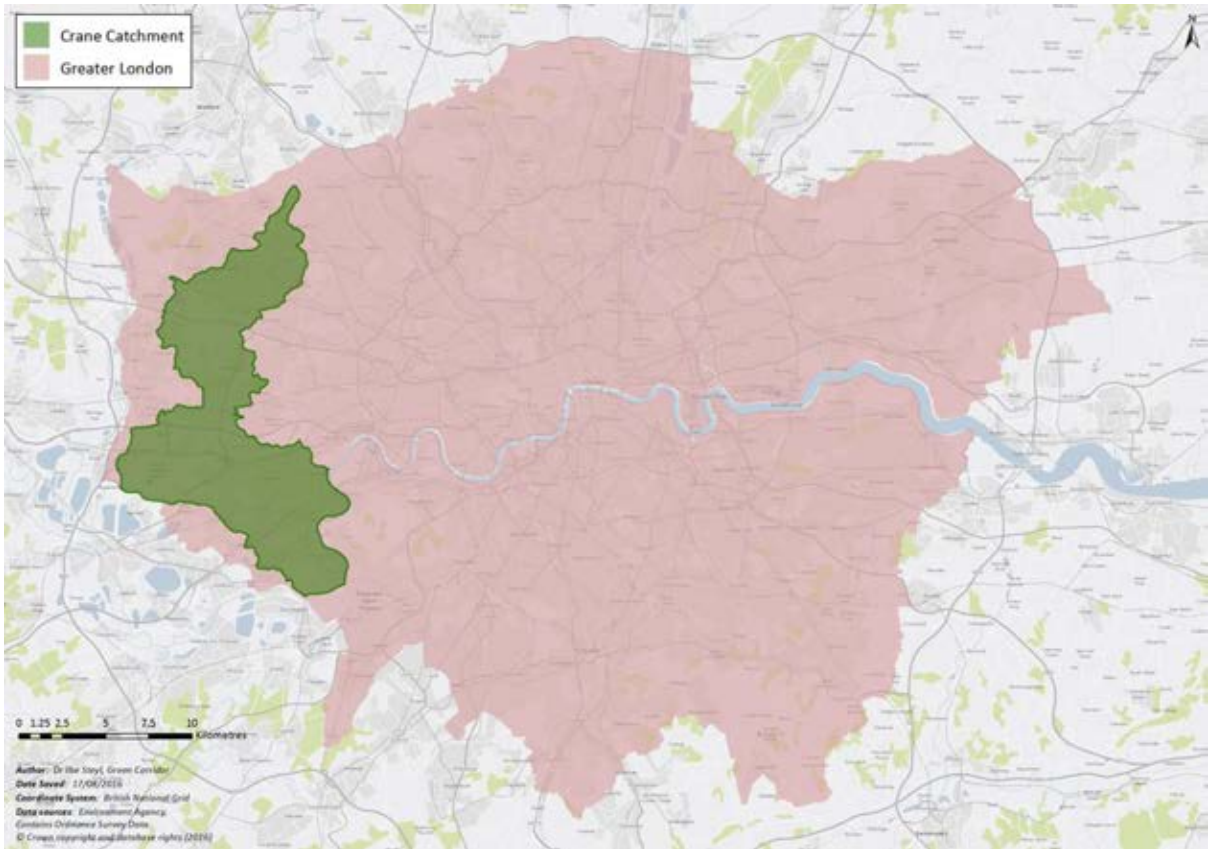

Figure 1.1a Study area map of the Crane Catchment

1.2 Fish Populations

The River Crane once held good populations of coarse fish between Cranford and Twickenham, with species including; chub, dace, roach, perch, pike, barbel, bream, gudgeon, bull head, minnow and stickleback. The River Crane was subject to major pollution incidents in 2011 and 2013, resulting in a complete loss of its fish populations from Cranford, Middlesex to the river's confluence with the Thames in Isleworth. Due to the number of barriers to fish migration in the catchment, fish are unable to ingress from the River Thames to repopulate the river. Some natural repopulation has occurred as a result of the minor species of fish found in the upper catchment migrating downstream.

A four year restocking programme has been implemented, funded by Thames Water as a result of the pollution incidents, with chub, barbel, dace, roach and bream being reintroduced to the river (Environment Agency, 2012). As a result of the stocking programme, fish populations appear to be recovering well. The stocking programme is regarded as a temporary measure, and efforts need to be made to ensure fish populations can recover naturally should a major pollution incident in the future. One method of achieving this is by ensuring the free passage of coarse fish and European eels from the River Thames, via the lower Crane or lower Duke of Northumberland's River.

Barriers on the Longford River, Upper Duke of Northumberland's River, Whitton Brook and Ickenham Stream were not included in this study. This decision was made due to the fact that, The Longford flows in separation to the River Crane; the Upper DNR connects with the River Colne; and the Whitton Brook and Ickenham Stream mostly flow underground in culverts.

1.3 Fish Passage

Migration is essential to the life cycle of many fish species that rely on free movement to utilise a variety of habitats for spawning, juvenile recruitment and sheltering. The European Eel (*Anguilla anguilla*) completes the growth stage of its life cycle in freshwater river systems after migrating to Europe from the Sargasso Sea (Aarestrup *et al.,* 2009). The species relies on free passage in order to ascend rivers to find suitable habitat to complete this life stage, and also to descend rivers in order to return to sea to spawn. Coarse fish species undertake a relatively modest migration in comparison to European eels, usually only a few kilometres. Chub have been known to migrate up to 13km for spawning migration and similarly dace have been shown to travel between 3.5km to 16km for the same purpose (Lucas *et al.*, 1998). This shows that free passage for coarse fish species is essential for their long term survival.

Structures such as weirs and sluices are known to have a negative impact on the ability of fish to migrate within a river system. The free passage of migratory fish is a key requirement of the Water Framework Directive, and is being used as an indicator for assessing whether water bodies are meeting Good Ecological Potential or Status. In order to achieve this, redundant structures should be removed or made passable via a variety of fish easement options such as barrier removals or fish pass installations.

There are 53 obstructions within the Yeading Brook East, the Yeading Brook West, the Yeading Brook, the River Crane and the Lower Duke of Northumberland's River that are potentially impassable by coarse fish and eels. Each obstruction will differ in terms of its impact on fish migration and the river's ability to recover from fish kills. Obstructions located on the Lower Crane and Lower DNR are seen as high priority for removal in light of their importance to ensuring the future viability of the catchment's fish stocks and resilience against pollution events. Barriers on the River Crane downstream of Cranford Park should also be prioritised, as the river is stocked with fish in two locations below this site and initial observations show that fish populations are recovering well.

1.4 Aims and Need

This report aims to provide a full physical assessment of all obstructions to upstream and downstream coarse fish and eel passage in the Crane Catchment. The report aims to prioritise barriers for removal in terms of their impact on the ingress of fish from the River Thames and their impact on habitat connectivity. The results and recommendations of this report will enable the Crane Valley Partnership to deduce which barriers are having the greatest impact on fish populations and which of these structures would be the most valuable to remove or ease.

The need for this report was established by The Crane Valley Partnership Fisheries Group, a sub group of the Crane Valley Partnership attended by London Wildlife Trust, The Environment Agency, Green Corridor, Zoological Society of London and The London Borough of Hounslow. The group met prior to the production of this report to establish the remit of the project and to decide on an appropriate methodology to follow.

The production of this report was funded by *The Thames Water Compensation Fund* via the agreement of the Crane Valley Partnership

2.0 Approach

2.1 Initial Desk Based Research

A list of structures to be included was agreed early in the conduct of this investigation; this included all structures known to the Environment Agency in the Crane Catchment. The purpose and function of some of these structures was included with this data, where this was not available surveyors estimated the purpose of structures via on site observations and local knowledge.

The river catchment was walked by surveyors in order to locate barriers which weren't included in the Environment Agency's records. The original list has been updated to contain all known structures in The Yeading Brook West, Yeading Brook East, The Yeading Brook, The River Crane and the lower Duke of Northumberland's River.

A GIS geodatabase was set-up, (using ArcGIS 10.4.1), into which all data recorded was uploaded. These data were used to generate field maps for surveyors; quality check field data records; and produce maps for reporting. A story map application was also developed using the data, which can be accessed via this link - http://arcg.is/2aJEJV3. More detailed data can be viewed using the link.

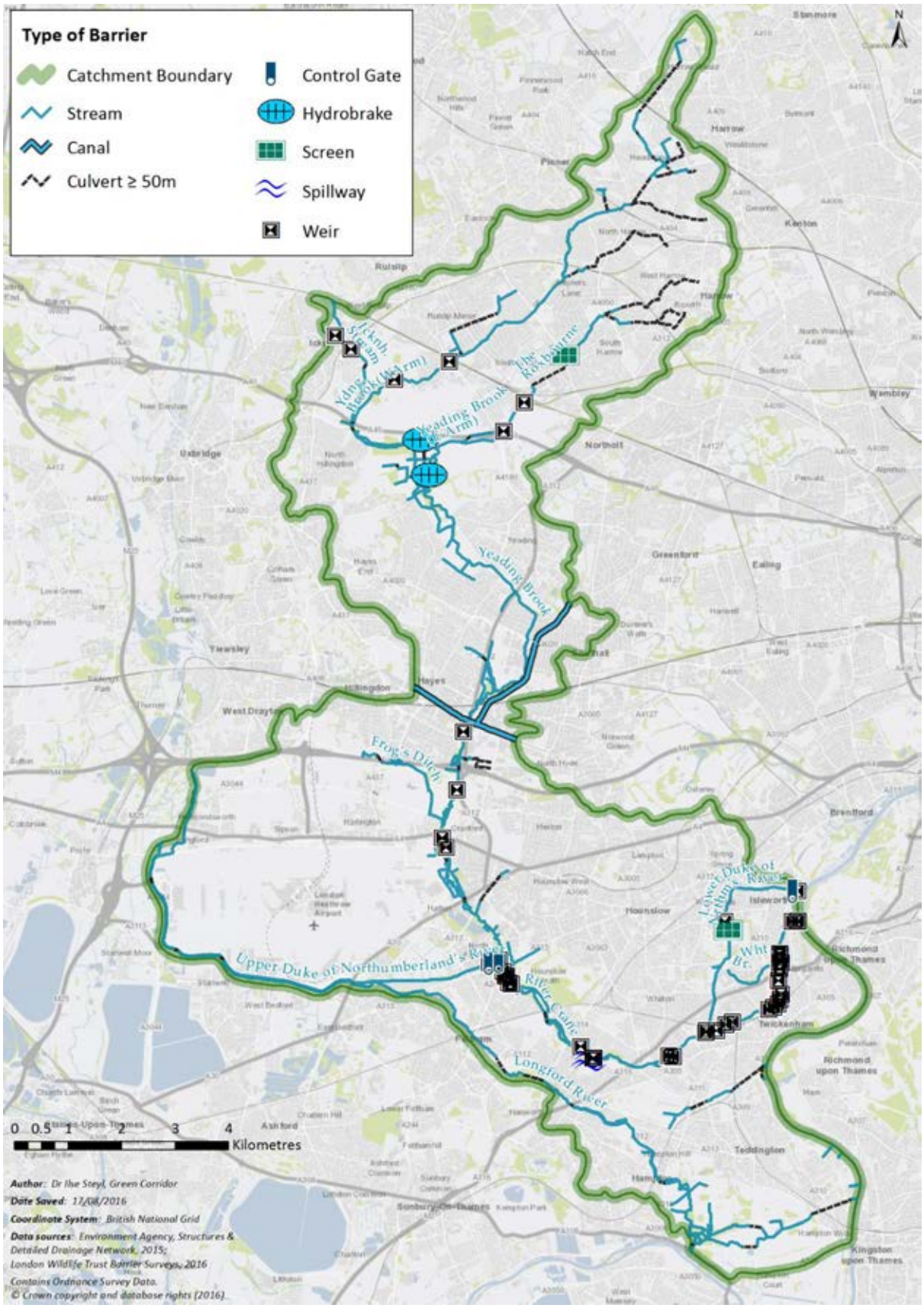

Figure 2.1a: All known structures in the River Crane Catchment

2.2 Methodology

The SNIFFER *Coarse Resolution Rapid-assessment Methodology* (Scotland & Northern Ireland Forum for Environmental Research, 2010) was used to assess all known barriers to fish passage on the River Crane, West London. The full methodology can be found on the Scotland & Northern Ireland Forum for Environmental Research website: http://www.sniffer.org.uk/knowledge-hubs/resilient-catchments/water-framework-directive-and-uktag-co-ordination/fish-obstacles-porosity/

2.3 Survey Conditions

All structures were visited between June and August 2016, in order to try to conduct survey work during summer low level flow conditions. Summer low levels mark the time when obstructions in a river are most limiting to fish migration due to reduced water depths and flows, and increased hydraulic head height. Flow and antecedent conditions were recorded at the start of every survey, along with the degree of estimation used to record the parameters taken. Each barrier was assessed for all known fish species in the catchment, three species/guilds (cyprinids, juvenile eels, adult eels).

2.4 Site Details and Structure of Concern

GPS coordinates were recorded for every barrier in order to confirm its location with existing records or to mark a previously unrecorded location. These were then checked using the GIS database and corrected where necessary. The general characteristics of each barrier were also recorded in order to inform future fish easement projects. This included, three photos of each barrier where possible (upstream, midpoint, downstream), the barrier type (vertical weirs including notched vertical weir; sloping weir including crump weirs, Flat-Vs and Flumes; stepped weirs; fords; bridge footings; natural barriers including waterfalls, rapids and debris dams; dams; culverts; sluices; abstraction offtakes) , construction material and access and ownership information. A field sketch of each barrier was also drawn to provide further detail.

2.5 Barrier Type and Physical Attributes

The SNIFFER *Coarse Resolution Rapid-assessment Methodology* gave surveyors a bespoke means of surveying a range of different barrier types:

1. **Barriers presenting a vertical drop**
   Weirs, culvert, ford or bridge footing outlets, overshot sluices, waterfalls and debris dams.

2. **Barriers presenting a slope**
   Weirs, culverts, fords, bridge footings, rapids, chutes and diversion channels

3. **Barriers presenting steps**
   Stepped weirs, box traverse type fishways and complex waterfalls

4. **Barriers with specific features e.g. gaps**
   Notched weirs, culverts, debris dams and undershot sluices

5. **Abstraction points**
   Abstraction points are included in the methodology but none were surveyed as part of this project. There are a number of abstraction points in the catchment but none were surveyed as they did not obstruct the river channel or pose an obstacle to fish migration.

Where applicable, the following parameters were recorded for each barrier in order to carry assess their passability for coarse fish, juvenile eels and adult eels:

1. **Barrier dimensions (m)**
   Width, length, slope, wetted width, step dimensions, gap dimensions

2. **The Number of transversal sections**
   A Transversal Section (TS) is a portion of a riverine structure used in the assessment of passability at riverine obstacles. When viewed from downstream, a transversal section is distinguished as having water velocity and depth conditions remaining similar across its width. A transversal section can consist of several features longitudinally (i.e. a vertical jump and then a swim feature for fish), but generally provides a possible direct route for fish passage across the structure. The maximum transversal sections per barrier recorded in this study is 3 and the minimum and most common is 1.

3. **Water depth (m)**
   Water depth was measured at five points along 1 transect (crest) for vertical transversal section and at five points along 3 transects (crest, midpoint, outlet) for sloping transversal sections.

4. **Velocity (m^3/s)**
   Velocity was measured at five points along 1 transect (crest) for vertical transversal section and at five points along 3 transects (crest, midpoint, outlet) for sloping transversal sections.

5. **Hydraulic Head (m)**
   The difference in water level between the crest and the foot of the obstacle structure. Measured from water surface to water surface.

6. **Effective pool depth (m)**
   Although effective pool depth was not used to calculate passability for coarse fish and eels, it was recorded in order to provide further detail for each barrier and for future salmonid passability assessments.

7. **Presence of resting locations**
   The presence of resting locations downstream of the outlet of each barrier was recorded. Resting locations are important for fish making numerous attempts to pass a barrier.

8. **Presence of limiting physical features (lip, debris blocking structure)**
   The presence of any obtrusive lips or debris blocking structures that may affect fish passage was recorded.

9. **Presence of limiting hydrological features**
   The presence of standing waves and levels of turbulence at each barrier were recorded.

10. **Presence of suitable climbing substrate for juvenile eels**
    The presence of suitable climbing substrate for juvenile eels was recorded. Surveyors examined each barrier for rough and wet areas, bypass channels, wet marginal vegetation and wet mosses or tree roots that provide a directly passible route for juvenile eels.

11. **The presence of features that may be damaging to downstream migrants.**
    Surveyors examined each barrier for features that may damage fish passing in a downstream direction e.g. tall vertical drops leading to shallow concrete aprons.

2.6 Passability Scores

The measurements taken for each of these parameters were cross referenced with a collation of published data (passability assessment guidance tables found in methodology) describing the swimming and leaping abilities of coarse fish, juvenile eels and adult eels. By comparing the measurements obtained for a barrier to the optimum conditions for passability, the surveyor is able to generate a passability score for each fish species/guild being examined.

The passability scores used in this methodology were adapted by SNIFFER adapted Kemp *et al.,* (2008).

Table 2.6a: Passability Scores

Score 0.0 = Impassable, complete obstacle to fish movement if that the target species/life-stage, or species guild can not pass the obstacle.
Score 0.3 = A partial high impact obstacle is assigned if the obstacle represents a significant impediment to the target species/life-stage, or species guild, but some of the population (e.g. < one-third) will pass eventually; or the obstacle is impassable for a significant proportion of the time (e.g. > two-thirds).
Score 0.6 = A partial low impact obstacle is assigned if that the obstacle represents a significant impediment to the target species/life-stage, or species guild, but most of the population (e.g. > two-thirds) will pass eventually; or the obstacle is impassable for a significant proportion of the time (e.g. < one-third). Culverts represent good examples of partial obstacles if they impede fish during periods of high or low flow.
Score 1.0 = No obstacle, passable if that the obstacle does not represent a significant impediment to the target species/life-stage, or species guild, and the majority of the population should be able to pass during the majority of the period of migration (movement). This does not mean that the obstacle poses no costs in terms of delay, e.g. increased energetics, or that all fish will be able to pass.

2.7 Passability Assessment Guidance Tables

Upstream Migration:

Table 2.7a: Cyprinids (Vertical Weirs, culverts, fords and bridge footings with outlet drop, waterfalls, dams and overshot sluices)

Criteria	Passability score			
	1.0	0.6	0.3	0.0
Hydraulic head For all structures: For debris dams with porous gap sizes > 0.2 m	≤ 0.10 m Any height	0.11 – 0.15 m Any height	0.16 – 0.24 m Any height	≥ 0.25 m Any height
Effective resting locations for fish downstream For all structures:	Present	-	Absent	-
Lip and/or standing wave present For all structures:	May be present but do not restrict fish passage	-	May be present and may locally restrict fish passage	-
Water turbulence associated with structure For all structures:	Low	-	Moderate	High
Debris/sediment blockage For all structures:	May be present but does not restrict fish passage	-	Present and may locally restrict fish passage	-
Gap width For notched weirs, culverts, waterfalls, debris dams and overshot sluices:	≥ 0.20 m	0.10 - 0.19 m	0.06 - 0.09 m	≤ 0.05 m

Table 2.7b: Juvenile Eels (Vertical weirs, culverts, fords and bridge footings with outlet drop, waterfalls, dams and overshot sluices)

Criteria	Passability score			
	1.0	0.6	0.3	0.0
Climbing substrate For all structures:	Present	-	-	-
Water turbulence associated with structure In absence of climbing substrate	Low	-	Moderate	High
Debris/sediment blockage For all structures:	May be present but does not restrict fish passage	Present and may locally restrict fish passage	-	-

Table 2.7c: Cyprinids (Sloping weirs, culverts, fords, bridge footings, rapids, undershot sluices and sloping fishways)

Criteria	Passability score			
	1.0	0.6	0.3	0.0
Effective length of structure For all structures	≤ 1 m	2 – 6 m	7 – 19 m	≥ 20 m
Slope of structure Structure effective length ≤ 1m Structures effective length 2-4m Structures effective length ≥ 5m	≤ 15% ≤10% ≤ 5%	16 – 25% 11 – 15% 6 – 10%	26 – 39% 16 – 19% 11 – 14%	≥ 40% ≥20% ≥ 15%
Effective resting locations for fish downstream For all structures:	Present	-	Absent	-
Lip and/or standing wave present For all structures:	May be present but do not restrict fish passage	-	May be present and may locally restrict fish passage	-
Water turbulence associated with structure For all structures:	Low	-	Moderate	High
Debris/sediment blockage For all structures:	May be present but does not restrict fish passage	-	Present and may locally restrict fish passage	-
Gap width For culverts, debris dams and undershot sluices:	≥ 0.20 m	0.10 - 0.19 m	0.06 - 0.09 m	≤ 0.05 m

Table 2.7d: Juvenile eels (Sloping weirs, culverts, fords, bridge footings, rapids, undershot sluices and sloping fishways)

Criteria	Passability score			
	1.0	0.6	0.3	0.0
Climbing substrate For all structures:	Present	-	-	-
Effective length of structure In absence of suitable climbing substrate:	≤ 3 m	4 – 6 m	7 – 29 m	≥ 30 m
Water turbulence associated with structure In absence of climbing substrate:	Low	-	Moderate	High
Debris/sediment blockage For all structures:	May be present but does not restrict fish passage	Present and may locally restrict fish passage	-	-

Table 2.7e: Cyprinids (Stepped weirs, stepped fish passes or complex natural features)

Criteria	Passability score			
	1.0	0.6	0.3	0.0
Individual step/box characteristics Maximum step hydraulic head Minimum water depth Minimum length of step/box	≤ 0.1 m ≥ 1.0 x step hydraulic head ≥ 1.0 m	0.11 – 0.15 m ≥ 0.6 x step hydraulic head 0.5 – 0.99 m	0.16 -0.24 m ≥ 0.4 - 0.5 x step hydraulic head 0.19 – 0.49 m	≥ 0.25 m ≤ 0.3 x step hydraulic head ≤ 0.2 m
Effective resting locations for fish downstream For all structures:	Present	-	Absent	-
Lip and/or standing wave present For all structures:	May be present but do not restrict fish passage	-	May be present and may locally restrict fish passage	-
Water turbulence associated with structure For all structures:	Low	-	Moderate	High
Debris/sediment blockage For all structures:	May be present but does not restrict fish passage	-	Present and may locally restrict fish passage	-

Table 2.7f: Juvenile eels (Stepped weirs, stepped fish passes or complex natural features)

Criteria	Passability score			
	1.0	0.6	0.3	0.0
Climbing substrate For all structures:	Present	-	-	-
Water turbulence associated with structure In absence of climbing substrate:	Low	-	Moderate	High
Debris/sediment blockage	May be present but does not restrict fish passage	Present and may locally restrict fish passage	-	-

Downstream Migration:

Table 2.7g: All species for all structures

Criteria		Passability score			
		1.0	0.6	0.3	0.0
Maximum DEPTH at crest					
	Adult salmon	> 0.15 m	0.11 – 0.15 m	0.07 – 0.10 m	< 0.07 m
	Adult trout	> 0.10 m	0.075 – 0.10 m	0.05 – 0.074 m	< 0.05 m
	Adult grayling	> 0.10 m	0.075 – 0.10 m	0.05 – 0.074 m	< 0.05 m
	Cyprinids	> 0.10 m	0.075 – 0.10 m	0.05 – 0.074 m	< 0.05 m
	Juvenile salmonids	> 0.08 m	0.06 – 0.08 m	0.03 – 0.059 m	< 0.03 m
	Juvenile Lamprey	>0.02m	0.01 – 0.02m	0.005 - 0.01m	<0.005m
	Adult Eel	> 0.08 m	0.06 – 0.08 m	0.03 – 0.059 m	< 0.03 m
Minimum Gap dimensions For Notched weirs, Culverts, Waterfalls, Debris dams and Overshot sluices:					
	Adult salmon	> 0.5 m	0.25 - 0.50 m	0.15 – 0.26 m	< 0.15 m
	Adult trout	> 0.3 m	0.20 – 0.30 m	0.10 – 0.19 m	< 0.10 m
	Adult grayling	> 0.3 m	0.20 – 0.30 m	0.10 – 0.19 m	< 0.10 m
	Cyprinids	> 0.3 m	0.20 – 0.30 m	0.10 – 0.19 m	< 0.10 m
	Juvenile salmonids	> 0.15 m	0.10 – 0.15 m	0.05 – 0.09 m	< 0.05 m
	Juvenile Lamprey	> 0.05 m	0.02 – 0.05 m	0.01 – 0.02 m	< 0.02 m
	Adult Eel	> 0.15 m	0.10 – 0.15 m	0.05 – 0.09 m	< 0.05 m
DAMAGING STRUCTURES For all species:structures that could damage fish moving downstream over obstacle		No damaging structures present	-	Damaging structures present	-
Debris blockage For all species:		May be present but does not present an obstacle for fish passage	May be present and could restrict fish passage	-	Present and prevents fish passage

2.8 Method for assessing culverts that do not obstruct the river channel

The physical attributes of some culvert structures do not obstruct the dimensions of the river channel and are best assessed using a different method. The impact of such culverts was assessed on the basis of water depth, water velocity, and length.

The SNIFFER *Coarse Resolution Rapid-assessment Methodology* states, for upstream migration, barriers are passable for cyprinids if water depth is greater than 10cm throughout and velocity is less than 1m/s. For juvenile eels and if no climbing substrate is present, water depth should be greater than 5cm throughout and velocity less than 0.3m/s. Therefore, if depth and flow was sufficient the culvert was scored 1 and if depth or flow was limiting (i.e. too shallow or too fast-flowing), the culvert was scored 0.

Although not explicitly referred to in the SNIFFER methodology, there is evidence that the length of culverts has a negative impact on upstream migration. Fish may be discouraged from swimming through culverts due to the absence of natural light and it has been suggested that the provision of natural light “chimneys” may be important for fish passage in culverts greater than 50m (Environment Agency, 2010). Therefore, where depth and flow were sufficient, it was also important to assess whether the length of the culvert may itself present a barrier. If length was greater than 50m, it was noted that it may present a barrier and was scored as a partial barrier/low impact (0.6) for upstream migration. If the culvert was less than 50m, the length was not considered limiting and culverts were scored solely on the basis of depth and flow. Culverts longer than 50m are depicted in the maps.

For downstream migration of cyprinids and adult eels, water depth is the only limiting factor and should be greater than 10cm and greater than 8cm throughout respectively. It was deemed that culvert length would not significantly limit downstream migration.

2.9 Prioritising barriers for action

Barriers were prioritised for action as:

1. High – Where action to mitigate barriers would vastly improve the ingress of fish from the Thames and/or open up large sections of habitat for fish upstream. These barriers are generally high-impact, being impassable for course fish and/or eels at current conditions and high flows.
2. Medium – Where action to mitigate barriers would have moderate impact on improving fish passage. Action may slightly improve ingress of fish from the Thames and/or open up small sections of habitat for fish upstream. However there also may be other confounding factors limiting the passage of fish upstream such as habitat and water quality.
3. Low – Where action to mitigate barriers would have little or no impact on improving fish passage. If a barrier is already passable, removal would have little impact on overall fish passage. Alternatively, the barrier could be high-impact but its location means mitigation would not enable the ingress of fish from the Thames to the catchment, nor would it open up significant habitat upstream. There are often other confounding factors limiting the passage of fish upstream such as habitat and water quality.

3.0 Results

3.1 Lower Crane: Tidal Reach

3.1.1 Crane-Thames Barrier (ID 990001)

3.1.1.1 Location:

- *GPS:* 51.465398, -0.32161249
- *Distance from Thames confluence:* 0m
- *Distance to next structure downstream:* 0m
- *Number of structures downstream (direct route to Thames confluence):* 0
- *Distance from next structure upstream:* 105m

3.1.1.2 Brief description:

Stepped weir made of pre-cast concrete at the mouth of the Crane. This barrier is completely submerged at high tide.

3.1.1.3 Photos:

Figure 3.1.1.3a (left): At high tide, the Crane-Thames Barrier is submerged. This shows the barrier's location viewed from upstream at the left bank

Figure 3.1.1.3b (right): The location of the Crane-Thames Barrier at the mouth of the River Crane, viewed from upstream at left bank. The barrier is completely submerged at high tide.

3.1.1.4 Plan of site:

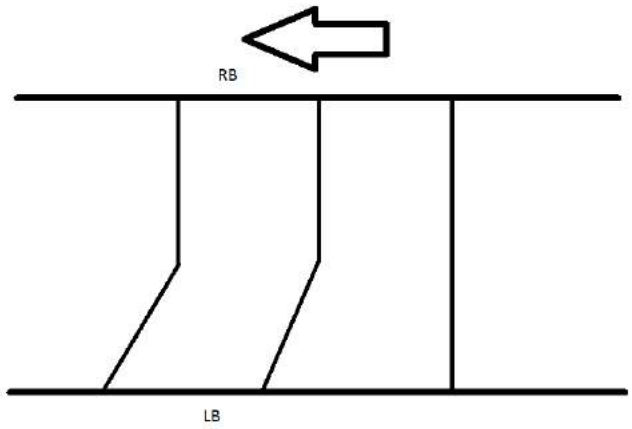

Figure 3.1.1.4a: Site plan for Crane-Thames Barrier

3.1.1.5 Structure dimensions:

Channel width	8.1m
Barrier width at crest	8.1m
Wetted width	2.8m
Transversal sections	1
Effective length	8.6m
Number of steps	2
Height of step (limiting)	0.4m
Length of step (limiting)	1.1m

3.1.1.6 Impact of the structure on habitat:

Large concreted area unable to support marginal plant life

3.1.1.7 Ownership and function:

- *Landowner and operator:* The London Borough of Richmond-upon-Thames. Access via Isleworth Sea Scout hut.
- *Original purpose of structure:* Unknown; possibly to control the rise of the tide
- *Current uses and value of structure:* Unknown; possibly to control the rise of the tide

3.1.1.8 Survey Conditions:

- *Antecedent conditions:* Light rain/drizzle within past two to three days
- *Flow Conditions:* Low tide
- *Was the structure submerged or dry?* No
- *Degree of estimation:* All measurements undertaken

3.1.1.9 Upstream fish passage assessment

	Flow conditions	**Passability score**	**Reason/s**
Coarse fish	Low	0	Water depth; Step water depth; Height of step
	High	1	Barrier submerged at high tide but not at high flows.
Juvenile eels	Low	0	No substrate present; Water depth
	High	1	Barrier submerged at high tide

3.1.1.10 Downstream fish passage assessment

	Flow conditions	**Passability score**	**Reason/s**
Coarse fish	Low	0	Water depth, height of barrier and number of steps may be damaging to downstream migrants.
	High	1	Barrier submerged at high tide
Adult eels	Low	0.3	Water depth, height of barrier and number of steps may be damaging to downstream migrants.
	High	1	Barrier submerged at high tide

3.1.1.11 Options for fish passage improvement

- *Priority for action:* Low
  This barrier is passable at high tide and the Duke of Northumberland's River has the potential to provide a more suitable route for fish migration (see Discussion).

- *Consideration of options*:
  Due to low flow conditions in summer months, easement options are limited. A maximum water depth of 4cm was taken at the crest of the structure. Technical fish passes such as larinier fish passes require a minimum depth of 10-15cm for large coarse fish, with the head of water running above the baffles of the pass not exceeding 0.5m (EA, 2010). A larinier fish pass may also be prone to blocking with debris due to the cross current of the Thames at high tide. Other options such as rock ramps also require certain depths of water to allow fish to ascend them. The provision of a 2 staged channel above this barrier may lead to improved water depths and flows at low tide. Rock ramps are prone to erosion however and may be damaged by to the cross current of the Thames at high tide.

  Passage for juvenile eels could be improved at this obstruction via the provision of an open type eel pass (see section 4.1.4). Ideally an eel pass would be attached to the side walls of the structure, but this option is not possible due to the fact that only 2.8m of the 8.1m channel is wetted, meaning that the eel pass would be dry at low tide. A closed type eel pass with the provision of a pump could be used to overcome this problem, but due to the location of this barrier, the facility would be difficult to access and maintain. Eel passage to the middle reaches of the Crane has already been achieved via the provision of 2 eel passes on the Lower Duke of Northumberland's River.

3.1.2 Tidal Crane Barrier 1 (ID 990002)

3.1.2.1 Location:

- *GPS:* 51.465384, -0.32312466
- *Distance from Thames confluence*: 105m
- *Distance to next structure downstream*: 105m
- *Number of structures downstream (direct route to Thames confluence)*: 1
- *Distance from next structure upstream*: 5m

3.1.2.2 Brief description:

Footing for a tide gate structure. Vertical barrier that has two transversal sections in a V-shape. The barrier is made from pre-cast concrete with a steel lip. The barrier is submerged at high tide. There are large tide gates at either side of the barrier which close at very high tides.

3.1.2.3 Photos:

Figure 1.2.3a (left): Tidal Crane Barrier 1 from viewed from downstream

Figure 1.2.3b (right): Tidal Crane Barrier 1 from viewed from upstream

3.1.2.4 Plan of site:

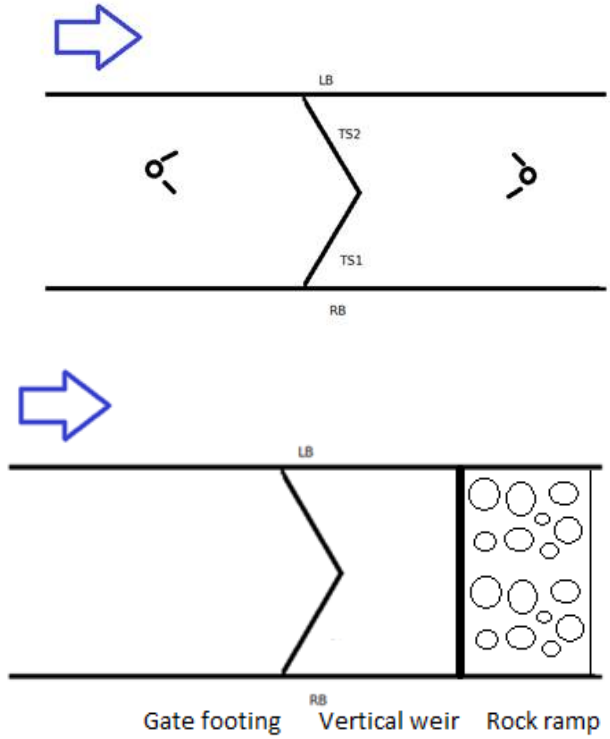

Figure 3.1.2.4a (above): Site plan for Tidal Crane Barrier 1

Figure 3.1.2.4b (below): Site plan with additional information

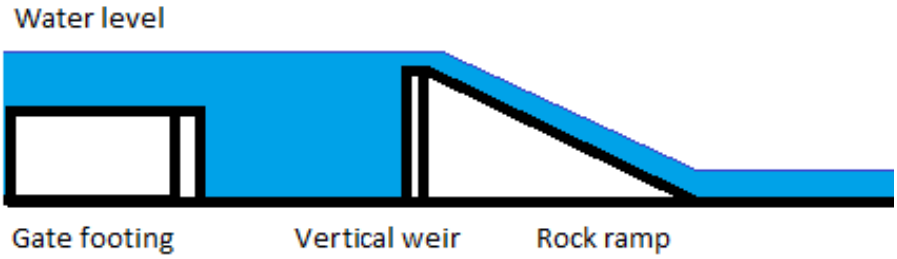

Figure 3.1.2.4c: Longitudinal site plan of Tidal Crane Barrier 1

3.1.2.5. Structure dimensions:

Channel width	5.5m
Barrier width at crest	6.4m
Wetted width	6.4m
Transversal sections	1
Hydraulic head	0.35m

3.1.2.6 Impact of the structure on habitat:

Large concreted area unable to support marginal plant life

3.1.2.7 Ownership and function:

- *Landowner and operator:* Environment Agency

- *Original purpose of structure:* To control the rise of the tide into the lower Crane. The tide gates would close at very high tides to prevent flooding.
- *Current uses and value of structure:* To control the rise of the tide into the lower Crane. The tide gates would close at very high tides to prevent flooding.

3.1.2.8 Survey Conditions:

- *Antecedent conditions:* No rain within past week
- *Flow Conditions:* Low tide
- *Was the structure submerged or dry?* No
- *Degree of estimation:* All measurements undertaken

3.1.2.9 Upstream fish passage assessment

	Flow conditions	**Passability score**	**Reason/s**
Coarse fish	Low	0	Water depth; Hydraulic head
	High	1	Barrier submerged at high tide
Juvenile eels	Low	1	No substrate present but sufficient depth of water to pass
	High	1	Barrier submerged at high tide

3.1.2.10 Downstream fish passage assessment

	Flow conditions	**Passability score**	**Reason/s**
Coarse fish	Low	0	Water depth
	High	1	Barrier submerged at high tide
Adult eels	Low	0.3	Water depth
	High	1	Barrier submerged at high tide

3.1.2.11 Options for fish passage improvement

- *Priority for action:* Low
  This barrier is passable at high tide and the Duke of Northumberland's River has the potential to provide a more suitable route for fish migration (see Discussion).

- *Consideration of options:*
  There are limited options available for easement due to the function of the structure. One available option is to place a small vertical weir with the provision of a rock ramp downstream of the structure in order to retain an increased head of water upstream and submerge the tide gate footings.

3.1.3 Tidal Crane Barrier 2 (ID 990003)

3.1.3.1 Location:

- *GPS*: 51.465376 -0.32319693
- *Distance from Thames confluence*: 110m
- *Distance to next structure downstream*: 5m
- *Number of structures downstream (direct route to Thames confluence)*: 2
- *Distance from next structure upstream*: 699m

3.1.3.2 Brief description:

Wooden planks across the channel present a vertical barrier at low tide. There are four thin metal pieces along the crest of the structure. There is a ~10cm gap at the left bank resulting in lower hydraulic head and faster flows over/through the structure. The barrier is submerged at high tides.

3.1.3.3 Photos:

Figure 3.1.3.3a (left): Tidal Crane Barrier 2 in the background viewed from downstream

Figure 3.1.3.3b (right): Tidal Crane Barrier 2 viewed from upstream

Figure 3.1.3.3c: Tidal Crane Barrier 2 viewed along crest from left bank

3.1.3.4 Site:

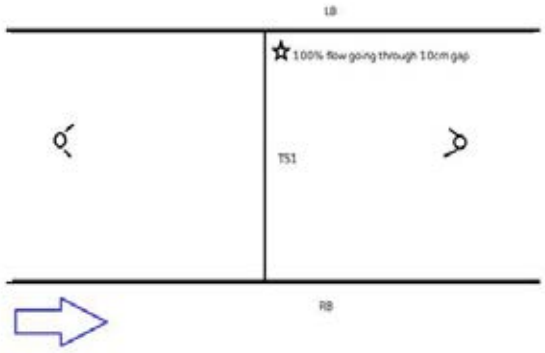

Figure 3.1.3.4a: Site Plan for Tidal Crane Barrier 2

3.1.3.5 Structure dimensions:

Channel width	5.55m
Barrier width at crest	5.55m
Wetted width	0.1m
Transversal sections	1
Hydraulic head	0.28m

3.1.3.6 Impact of the structure on habitat:

Prevents sediments from migrating downstream.

3.1.3.7 Ownership and function:

- *Landowner and operator:* Environment Agency
- *Original purpose of structure:* Lip of the tidal gate structure to reduce chances of sediment and debris accumulation to allow proper function of the tidal gate structure.
- *Current uses and value of structure:* Lip of the tidal gate structure to reduce chances of sediment and debris accumulation to allow proper function of the tidal gate

3.1.3.8 Survey conditions:

- *Antecedent conditions:* No rain within past week
- *Flow Conditions:* Low tide
- *Was the structure submerged or dry?* The crest of the structure is dry except for the gap at the left bank
- *Degree of estimation:* All measurements undertaken

3.1.3.9 Upstream fish passage assessment

	Flow conditions	**Passability score**	**Reason/s**
Coarse fish	Low	0	Hydraulic head
	High	1	Barrier submerged at high tide
Juvenile eels	Low	0	No substrate present; water flowing through gap is too fast
	High	1	Barrier submerged at high tide

3.1.3.10 Downstream fish passage assessment

	Flow conditions	Passability score	Reason/s
Coarse fish	Low	1	Sufficient depth through gap
	High	1	Barrier submerged at high tide
Adult eels	Low	1	Sufficient depth through gap
	High	1	Barrier submerged at high tide

3.1.3.11 Options for fish passage improvement

- *Priority for action:* Medium.
  This barrier is passable at high tide and the Duke of Northumberland's River has the potential to provide a more suitable route for fish migration (see Discussion).

- *Consideration of options:*
  There are limited options for easement due to purpose of structure. It is essential for preventing sediments blocking the tide gates should they need to operate. The method of easement listed for the previous barrier (tidal crane 2) would have the same effect on this obstruction as it is part of the same tide gate structure.

3.1.4 Tidal Crane Barrier 3 (ID 990004)

3.1.4.1 Location:

- *GPS*: 51.460049, -0.32676056
- *Distance from Thames confluence*: 809m
- *Distance to next structure downstream*: 699m
- *Number of structures downstream (direct route to Thames confluence)*: 3
- *Distance from next structure upstream*: 68m

3.1.4.2 Brief Description:

Small vertical weir made from pre-cast concrete that is fully submerged at high tides.

3.1.4.3 Photos:

Figure 3.1.4.3a (left): Tidal Crane Barrier 3 viewed from downstream

Figure 3.1.4.3b (right): Tidal Crane Barrier 3 viewed from upstream

Figure 3.1.4.3c: Tidal Crane Barrier 3 viewed along crest from mid-channel

3.1.4.4 Plan of site:

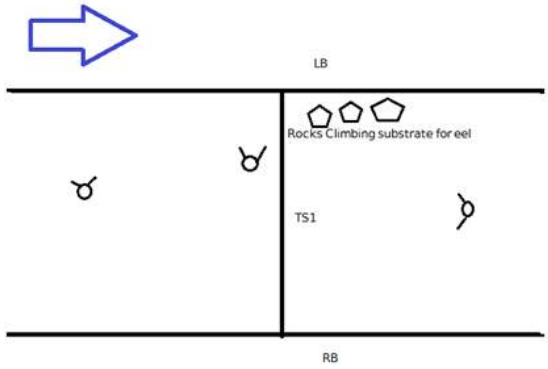

Figure 3.1.4.4a: Site plan for Tidal Crane Barrier 3

3.1.4.5 Structure dimensions

Channel width	8m
Barrier width at crest	8m
Wetted width	8m
Transversal sections	1
Hydraulic head	0.08m

3.1.4.6 Impact of the structure on habitat:

There is minimal impact of this structure on the habitat. It is designed to hold back flow resulting in areas of the river drying up downstream.

3.1.4.7 Ownership and function:

- *Landowner and operator:* London Borough of Richmond-upon-Thames, Environment Agency. Accessible from Coal Park Allotments.
- *Original purpose of structure:* Water level management
- *Current uses and value of structure:* Water level management

3.1.4.8 Survey conditions:

- *Antecedent conditions:* No rain within past week
- *Flow Conditions:* Low tide
- *Was the structure submerged or dry?* No
- *Degree of estimation:* All measurements undertaken

3.1.4.9 Upstream fish passage assessment

	Flow conditions	**Passability score**	**Reason/s**
Coarse fish	Low	0	Water depth
	High	1	Barrier submerged at high tide
Juvenile eels	Low	1	Climbing substrate present
	High	1	Barrier submerged at high tide

3.1.4.10 Downstream fish passage assessment

	Flow conditions	Passability score	Reason/s
Coarse fish	Low	0	Water depth
	High	1	Barrier submerged at high tide
Adult eels	Low	0	Water depth
	High	1	Barrier submerged at high tide

3.1.4.11 Options for fish passage improvement

- *Priority for action:* Medium.
  This barrier is passable at high tide and the Duke of Northumberland's River has the potential to provide a more suitable route for fish migration (see Discussion).

- *Consideration of options:*
  There is very little water passing over this barrier at low tide, with the maximum depth recorded at the crest of the structure being 1 cm. The river channel is also very wide in this location (8m) and has little flow. The provision of a two staged channel up and downstream of this barrier coupled with breaching the barrier along the middle of its crest would ensure the correct depths and flows to allow fish passage. Alternatively, if flows were increased down the river via the Mereway tilting weir, the barrier would most likely be passible.

3.1.5 Tidal Crane Barrier 4 (ID 283179)

3.1.5.1 Location:

- *GPS*: 51.459875, -0.326551
- *Distance from Thames confluence*: 836m
- *Distance to next structure downstream*: 726m
- *Number of structures downstream (direct route to Thames confluence)*: 4
- *Distance from next structure upstream*: 596m

3.1.5.2 Brief description:

Large vertical weir made from pre-cast concrete. It can be submerged at very high tides. Note that this barrier is on a backstream near Cole Park Allotments and is by-passable by the main river channel.

3.1.5.3 Photos:

Figure 3.1.5.3a: Tidal Crane Barrier 4 viewed from downstream at right bank

3.1.5.4 Plan of site:

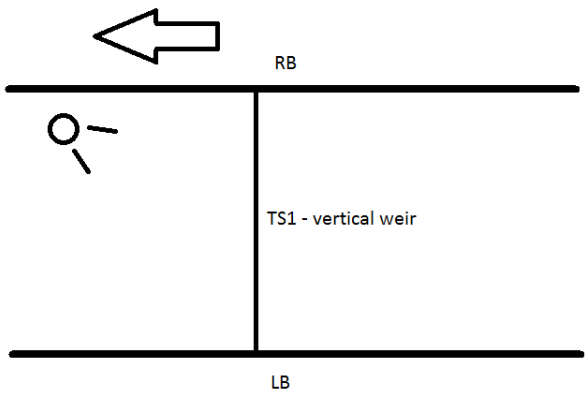

Figure 3.1.5.4a:: Site plan for Tidal Crane Barrier 4

3.1.5.5 Structure dimensions:

Channel width	5.7m
Barrier width at crest	5.7m
Wetted width	3.3m
Transversal sections	1
Hydraulic head	0.55m

3.1.5.6 Impact of the structure on habitat:

Holds back flow resulting in areas of river drying up downstream and excessive siltation upstream in the backstream at Cole Park Allotments.

3.1.5.7 Ownership and function:

- *Landowner and operator:* London Borough of Richmond-upon-Thames
- *Original purpose of structure:* To control the rise of the tide into the lower Crane and prevent flooding.
- *Current uses and value of structure:* To control the rise of the tide into the lower Crane and prevent flooding.

3.1.5.8 Survey Conditions:

- *Antecedent conditions:* No rain within past week
- *Flow Conditions:* Low tide
- *Was the structure submerged or dry?* No
- *Degree of estimation:* All measurements undertaken

3.1.5.9 Upstream fish passage assessment:

	Flow conditions	**Passability score**	**Reason/s**
Coarse fish	Low	0	Water depth; Hydraulic head
	High	1	Barrier submerged at high tide
Juvenile eels	Low	1	Climbing substrate present
	High	1	Barrier submerged at high tide

3.1.5.10 Downstream fish passage assessment:

	Flow conditions	**Passability score**	**Reason/s**
Coarse fish	Low	0	Water depth
	High	1	Barrier submerged at high tide
Adult eels	Low	0	Water depth
	High	1	Barrier submerged at high tide

3.1.5.11 Options for fish passage improvement:

- *Priority for action:* Low.

This barrier is passable at high tides and is located on a backchannel of the river at Cole Park Island. The Duke of Northumberland's River has the potential to provide a more suitable route for fish migration (see Discussion).

- *Consideration of options:*
  At low tide the barrier works to retain a head of water in the backchannel at Cole Park Island. The back channel is deeper than the main river at low tides, and has good marginal habitat and riparian cover. This area will serve as an important refuge for aquatic wildlife at low tide. Unless flow conditions are dramatically improved along the entirety of the Tidal Crane, the barrier's removal would result in the loss of this habitat. The aquatic refuge and good riparian cover also serve as a visual amenity for local residents.

3.1.6 Tidal Crane Barrier 5 (ID 990005)

3.1.6.1 Location:

- *GPS*: 51.459438, -0.32676853
- *Distance from Thames confluence*: 877m
- *Distance to next structure downstream*: 68m
- *Number of structures downstream (direct route to Thames confluence)*: 4
- *Distance from next structure upstream*: 112m

3.1.6.2 Brief Description:

Small vertical weir made from pre-cast concrete that is fully submerged at high tide.

3.1.6.3 Photos:

Figure 3.1.6.3a (left): Tidal Crane Barrier 5 viewed from downstream at left bank

Figure 3.1.6.3b (right): Tidal Crane Barrier 5 viewed from upstream at left bank

3.1.6.4 Plan of site:

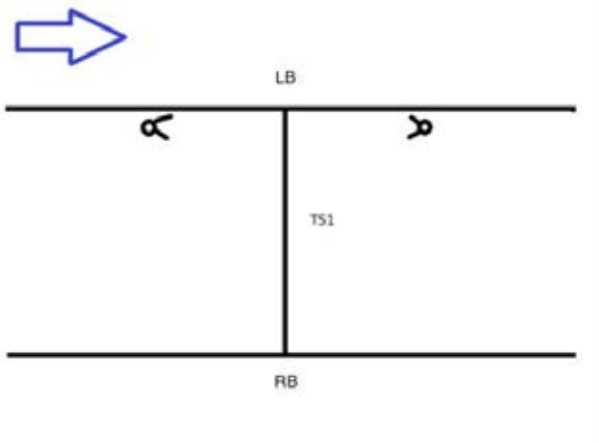

Figure 3.1.6.4a:: Site plan for Tidal Crane Barrier 5

3.1.6.5 Structure dimensions:

Channel width	8.5m
Barrier width at crest	8.5m
Wetted width	8.5m
Transversal sections	1
Hydraulic head	0.13m

3.1.6.6. Impact of the structure on habitat:

Minimal; holds back flow resulting in areas of river drying up downstream.

3.1.6.7 Ownership and function:

- *Landowner and operator:* London Borough of Richmond-upon-Thames, Environment Agency. Access via Cole Park Allotments
- *Original purpose of structure:* Water level management, Tide Control.
- *Current uses and value of structure:* Water level management, Tide Control.

3.1.6.8 Survey Conditions:

- *Antecedent conditions:* No rain within past week
- *Flow Conditions:* Low tide
- *Was the structure submerged or dry?* No
- *Degree of estimation:* All measurements undertaken

3.1.6.9 Upstream fish passage assessment

	Flow conditions	**Passability score**	**Reason/s**
Coarse fish	Low	0.6	Hydraulic head
	High	1	Barrier submerged at high tide
Juvenile eels	Low	1	Climbing substrate present
	High	1	Barrier submerged at high tide

3.1.6.10 Downstream fish passage assessment

	Flow conditions	**Passability score**	**Reason/s**
Coarse fish	Low	1	Sufficient depth
	High	1	Barrier submerged at high tide
Adult eels	Low	1	Sufficient depth
	High	1	Barrier submerged at high tide

3.1.6.11 Options for fish passage improvement:

- *Priority for action:* Low.

This barrier is partially passable at low flows and fully passably at at high tide and the Duke of Northumberland's River has the potential to provide a more suitable route for fish migration (see Discussion).

- *Consideration of options:*

There is very little water passing over this barrier at low tide, with the maximum depth recorded at the crest of the structure being 1 cm. The river channel is also very wide in this location (8.5m) and has little flow. The provision of a two staged channel up and downstream of this barrier coupled with breaching the barrier along the middle of its crest would ensure the correct depths and flows to allow fish passage. Alternatively, if flows were increased down the river via the Mereway tilting weir, the barrier would most likely be passible.

3.1.7 Tidal Crane Barrier 6 (ID 281215)

3.1.7.1 Location:

- *GPS*: 51.458461, -0.32640119
- *Distance from Thames confluence*: 989m
- *Distance to next structure downstream*: 112m
- *Number of structures downstream (direct route to Thames confluence)*: 5
- *Distance from next structure upstream*: 110m

3.1.7.2 Brief description:

Small vertical weir made from pre-cast concrete that is fully submerged at high tides.

3.1.7.3 Photos:

Figure 3.1.7.3a (left): Tidal Crane Barrier 6 viewed from downstream

Figure 3.1.7.3b (right): Tidal Crane Barrier 6 viewed from upstream

3.1.7.4 Plan of site:

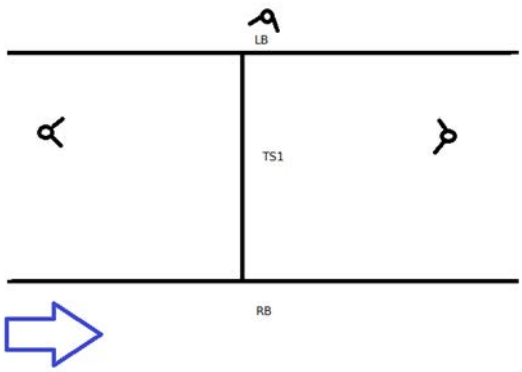

Figure 3.1.7.4a: Site plan for Tidal Crane Barrier 6

3.1.7.5 Structure dimensions:

Channel width	8.5m
Barrier width at crest	8.5m
Wetted width	8.5m

Transversal sections	1
Hydraulic head	0.22m

3.1.7.6 Impact of the structure on habitat:

Minimal; holds back flow resulting in areas of river drying up downstream.

3.1.7.7 Ownership and function:

- *Landowner and operator:* London Borough of Richmond-upon-Thames, Environment Agency. Access via Cole Park Allotments.
- *Original purpose of structure:* To control the rise of the tide into the lower Crane.
- *Current uses and value of structure:* To control the rise of the tide into the lower Crane.

3.1.7.8 Survey Conditions:

- *Antecedent conditions:* No rain within past week
- *Flow Conditions:* Low tide
- *Was the structure submerged or dry?* No
- *Degree of estimation:* All measurements undertaken

3.1.7.9 Upstream fish passage assessment

	Flow conditions	**Passability score**	**Reason/s**
Coarse fish	Low	0	Water depth
	High	1	Barrier submerged at high tide
Juvenile eels	Low	1	Climbing substrate present
	High	1	Barrier submerged at high tide

3.1.7.10 Downstream fish passage assessment

	Flow conditions	**Passability score**	**Reason/s**
Coarse fish	Low	0	Water depth
	High	1	Barrier submerged at high tide
Adult eels	Low	0	Water depth
	High	1	Barrier submerged at high tide

3.1.7.11 Options for fish passage improvement

- *Priority for action:* Medium. This barrier is passable at high tide and the Duke of Northumberland's River has the potential to provide a more suitable route for fish migration (see Discussion).

- *Consideration of options:*
  There is very little water passing over this barrier at low tide, with the maximum depth recorded at the crest of the structure being 2 cm. The river channel is also very wide in this location (8.5m) and has little flow. The provision of a two staged channel up and downstream of this barrier coupled with breaching the barrier along the middle

of its crest would ensure the correct depths and flows to allow fish passage. Alternatively, if flows were increased down the river via the Mereway tilting weir, the barrier would most likely be passible.

3.1.8 Tidal Crane Barrier 7 (ID 281217)

3.1.8.1 Location:

- *GPS*: 51.457514,-0.32681008
- *Distance from Thames confluence*: 1098m
- *Distance to next structure downstream*: 110m
- *Number of structures downstream (direct route to Thames confluence)*: 6
- *Distance from next structure upstream*: 229m

3.1.8.2 Brief description:

Large vertical weir made from pre-cast concrete with a slight curve along the crest. It is submerged at high tides.

3.1.8.3 Photos:

Figure 3.1.8.3a (left): Tidal Crane Barrier 7 viewed from downstream at left bank

Figure 3.1.8.3b (right): Tidal Crane Barrier 7 viewed from upstream at left bank

Figure 3.1.8.3c: Potential eel climbing substrate at Tidal Crane Barrier 7

3.1.8.4 Plan of site:

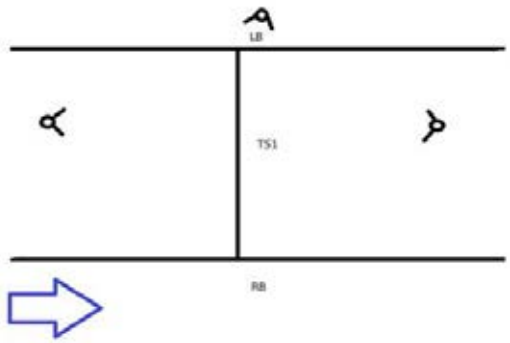

Figure 3.1.8.4a: Site plan of Tidal Crane Barrier 7

3.1.8.5 Structure dimensions:

Channel width	8.3
Barrier width at crest	8.5
Wetted width	8.3
Transversal sections	1
Hydraulic head	0.63m

3.1.8.6 Impact of the structure on habitat:

Holds back flow resulting in areas of river drying up downstream and excessive siltation/minimal flow upstream.

3.1.8.7 Ownership and function:

- *Landowner and operator:* London Borough of Richmond-upon-Thames, Environment Agency. Access via Coal Park Allotments.
- *Original purpose of structure:* Water level management. Tide Control.
- *Current uses and value of structure:* Water level management. Tide Control.

3.1.8.8 Survey Conditions:

- *Antecedent conditions:* No rain within past week
- *Flow Conditions:* Low tide
- *Was the structure submerged or dry?* No
- *Degree of estimation:* All measurements undertaken

3.1.8.9 Upstream fish passage assessment

	Flow conditions	**Passability score**	**Reason/s**
Coarse fish	Low	0.3	Water depth; Hydraulic head
	High	1	Barrier submerged at high tide
Juvenile eels	Low	1	Climbing substrate present
	High	1	Barrier submerged at high tide

3.1.8.10 Downstream fish passage assessment

	Flow conditions	Passability score	Reason/s
Coarse fish	Low	0	Water depth
	High	1	Barrier submerged at high tide
Adult eels	Low	0	Water depth
	High	1	Barrier submerged at high tide

3.1.8.11 Options for fish passage improvement

- *Priority for action:* Medium.

  This barrier is passable at high tide and the Duke of Northumberland's River has the potential to provide a more suitable route for fish migration (see Discussion).

- *Consideration of options:*

  There is very little water passing over this barrier at low tide, with the maximum depth recorded at the crest of the structure being 0.8cm. The river channel is also very wide in this location (8.3m) and has little flow. The provision of a two staged channel up and downstream of this barrier coupled with breaching the barrier along the middle of its crest would ensure the correct depths and flows to allow fish passage. Alternatively, if flows were increased down the river via the Mereway tilting weir, the barrier would most likely be passible with the provision of a rock ramp. This also could be implemented with the two staged channel design.

3.1.9 Tidal Crane Barrier 8 (ID 192561)

3.1.9.1 Location:

- *GPS*: 51.455487, -0.32718646
- *Distance from Thames confluence*: 1327m
- *Distance to next structure downstream*: 229m
- *Number of structures downstream (direct route to Thames confluence)*: 7
- *Distance from next structure upstream*: 304m

3.1.9.2 Brief description:

Sloping weir made from pre-cast concrete.

3.1.9.3 Photos:

Figure 3.1.9.3a: Tidal Crane Barrier 8 viewed from right bank (Archive picture, not taken at time of survey)

3.1.9.4 Plan of site:

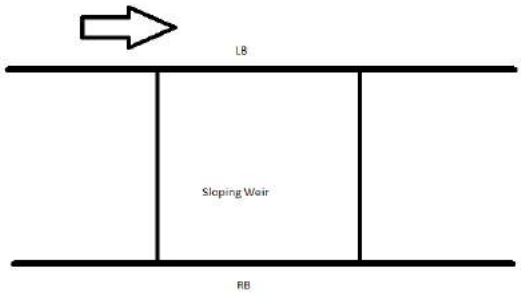

Figure 3.1.9.4a: Site plan for Tidal Crane Barrier 8

3.1.9.5 Structure dimensions:

Channel width	9m
Barrier width at crest	9m
Wetted width	9m
Transversal sections	1

Hydraulic head	1m
Effective length	2m
Gradient	50%

3.1.9.6 Impact of the structure on habitat:

Holds back flow resulting in areas of river drying up downstream. Results in siltation and minimal flow upstream.

3.1.9.7 Ownership and function:

- *Landowner and operator:* London Borough of Richmond-upon-Thames, Environment Agency. Limited access. Requires permission from resident to access via back garden.
- *Original purpose of structure:* Unknown
- *Current uses and value of structure:* Unknown

3.1.9.8 Survey Conditions:

- *Antecedent conditions:* N/A – data were estimated from a photo
- *Flow Conditions:* Low tide
- *Was the structure submerged or dry?* No
- *Degree of estimation:* All measurements estimated from a photo – we were unable to access this barrier

3.1.9.9 Upstream fish passage assessment

	Flow conditions	**Passability score**	**Reason/s**
Coarse fish	Low	0	Water depth
	High	0	Gradient of slope; potential for high flows & turbulence
Juvenile eels	Low	0	No climbing substrate; water depth
	High	0	Gradient of slope; potential for high flows & turbulence

3.1.9.10 Downstream fish passage assessment

	Flow conditions	**Passability score**	**Reason/s**
Coarse fish	Low	0	Water depth
	High	1	Should have sufficient water depth
Juvenile eels	Low	0	Water depth
	High	1	Should have sufficient water depth

3.1.9.11 Options for fish passage improvement

- *Priority for action:* Medium.
  The Duke of Northumberland's River has the potential to provide a more suitable route for fish migration (see Discussion).

- *Consideration of options:*

Currently we believe this barrier to be impassable at low flows due to its hydraulic head and insufficient water depth. At high flows the barrier may be impassable due to high velocities and the presence of a standing wave at the outlet. This barrier marks the upper tidal limit of the Crane and at high tide, during low flow conditions, may be partially passible due to the reduction in hydraulic head. The provision of a rock ramp may be suitable here if flows were improved on the Lower Crane via the Mereway Weir at Kneller Gardens, Twickenham.

Lower Crane (Non-tidal)

3.1.10 Twickenham Barrier 1 (ID 990009)

3.1.10.1 Location:

- *GPS*: 51.453176, -0.32656568
- *Distance from Thames confluence*: 1631m
- *Distance to next structure downstream*: 304m
- *Number of structures downstream (direct route to Thames confluence)*: 8
- *Distance from next structure upstream*: 101m

3.1.10.2 Brief description:

Small vertical weir made from pre-cast concrete

3.1.10.3 Photos:

Figure 3.1.10.3a (left): Twickenham Barrier 1 viewed from downstream

Figure 3.1.10.3b (right): Twickenham Barrier 1 viewed from upstream

Figure 1.10.3c: Twickenham Barrier 1 viewed along the crest from right bank

3.1.10.4 Plan of site:

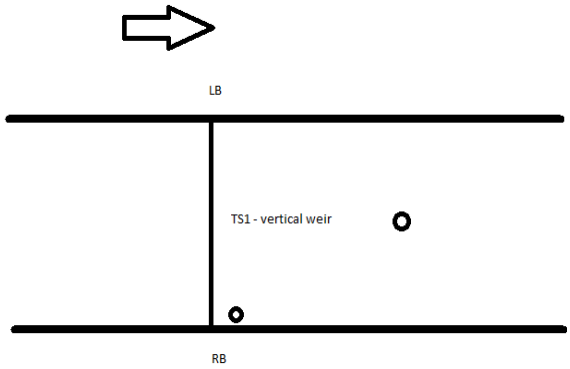

Figure 1.10.4a: Site plan for Twickenham Barrier 1

3.1.10.5 Structure dimensions:

Channel width	7.6m
Barrier width at crest	7.6m
Wetted width	7.6m
Transversal sections	1
Hydraulic head	0.3m

3.1.10.6 Impact of the structure on habitat:

Holds back flow resulting in areas of river drying up downstream and excessive siltation/minimal flow upstream.

3.1.10.7 Ownership and function:

- *Landowner and operator:* London Borough of Richmond-upon-Thames, Environment Agency. Access from Heatham House Community Centre, Twickenham.
- *Original purpose of structure:* Water level management
- *Current uses and value of structure:* Water level management

3.1.10.8 Survey Conditions:

- *Antecedent conditions:* Light rain/drizzle within past two to three days
- *Flow Conditions:* Summer low flows
- *Was the structure submerged or dry?* Dry
- *Degree of estimation:* All measurements undertaken

3.1.10.9 Upstream fish passage assessment:

	Flow conditions	**Passability score**	**Reason/s**
Coarse fish	Low	0	Water depth; Hydraulic head
	High	0.6	Hydraulic head
Juvenile eels	Low	1	Climbing substrate present
	High	1	Climbing substrate present

3.1.10.10 Downstream fish passage assessment:

	Flow conditions	Passability score	Reason/s
Coarse fish	Low	0	Water depth
	High	1	Should be sufficient water
Adult eels	Low	0	Water depth
	High	1	Should be sufficient water

3.1.10.11 Options for fish passage improvement

- *Priority for action:* Medium.
  The Duke of Northumberland's River has the potential to provide a more suitable route for fish migration (see Discussion).

- *Consideration of options:*
  There was no water passing over this structure during the time of survey. Upstream large areas of the river had dried out, showing that the structure is essential for retaining water during times of low flow. Barrier removal or breaching may have a negative impact on water level management upstream.

  The provision of a two staged channel up and downstream of this barrier coupled with improving flows via the Mereway tilting weir at Kneller Gardens could reverse this issue, thus allowing the barrier to be breached along the middle of its crest. A rock ramp would also be a suitable method of easement should the structure still be imperative to maintaining water levels upstream.

3.1.11 Twickenham Barrier 2 (ID 192557)

3.1.11.1 Location:

- *GPS*: 51.45229, -0.32685715
- *Distance from Thames confluence*: 1732m
- *Distance to next structure downstream*: 101m
- *Number of structures downstream (direct route to Thames confluence)*: 9
- *Distance from next structure upstream*: 97m

3.1.11.2 Brief description:

Small vertical weir made from pre-cast concrete

3.1.11.3 Photos:

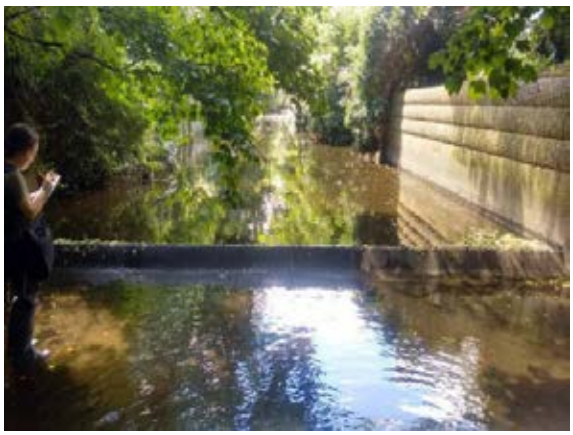

Figure 3.1.11.3a (left): Twickenham Barrier 2 viewed from downstream

Figure 3.1.11.3b (right): Twickenham Barrier 2 viewed from upstream

Figure 3.1.11.3c: Twickenham Barrier 2 viewed along the crest from right bank

3.1.11.4 Plan of site:

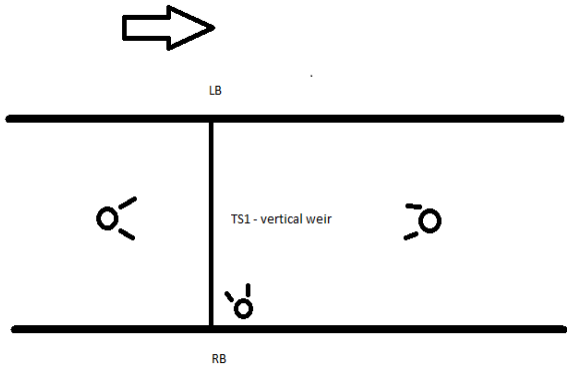

Figure 3.1.11.4a: Site plan for Twickenham Barrier 2

3.1.11.5 Structure dimensions:

Channel width	8.1m
Barrier width at crest	8.1m
Wetted width	4.6m
Transversal sections	1
Hydraulic head	0.32m

3.1.11.6 Impact of the structure on habitat:

Holds back flow resulting in areas of river drying up downstream and excessive siltation/minimal flow upstream.

3.1.11.7 Ownership and function:

- *Landowner and operator:* London Borough of Richmond-upon-Thames
- *Original purpose of structure:* Water level management
- *Current uses and value of structure:* Water level management

3.1.11.8 Survey Conditions:

- *Antecedent conditions:* Light rain/drizzle within past two to three days
- *Flow Conditions:* Summer low flows
- *Was the structure submerged or dry?* No
- *Degree of estimation:* All measurements undertaken

3.1.11.9 Upstream fish passage assessment

	Flow conditions	**Passability score**	**Reason/s**
Coarse fish	Low	0	Water depth; Hydraulic head
	High	0.6	Hydraulic head
Juvenile eels	Low	1	Climbing substrate present
	High	1	Climbing substrate present

3.1.11.10 Downstream fish passage assessment:

	Flow conditions	Passability score	Reason/s
Coarse fish	Low	0	Water depth
	High	1	Should be sufficient water
Adult eels	Low	0	Water depth
	High	1	Should be sufficient water

3.1.11.11 Options for fish passage improvement

- *Priority for action:* Medium.
  The Duke of Northumberland's River has the potential to provide a more suitable route for fish migration (see Discussion).

- *Consideration of options:*
  There was no water passing over this structure during the time of survey. Upstream large areas of the river had dried out, showing that the structure is essential for retaining water during times of low flow. Barrier removal or breaching may have a negative impact on water level management upstream.

  The provision of a two staged channel up and downstream of this barrier coupled with improving flows via the Mereway tilting weir at Kneller Gardens could reverse this issue, thus allowing the barrier to be breached along the middle of its crest. A rock ramp would also be a suitable method of easement should the structure still be imperative to maintaining water levels upstream.

3.1.12 Twickenham Barrier 3 (ID 192558)

3.1.12.1 Location

- *GPS*: 51.451534, -0.32741731
- *Distance from Thames confluence*: 1828m
- *Distance to next structure downstream*: 97m
- *Number of structures downstream (direct route to Thames confluence)*: 10
- *Distance from next structure upstream*: 101m

3.1.12.2 Brief description:

Small vertical weir made from pre-cast concrete

3.1.12.3 Photos*:*

Figure 3.1.12.3a (left): Twickenham Barrier 3 viewed from downstream

Figure 3.1.12.3b (right): Twickenham Barrier 3 viewed from upstream

Figure 1.12.3c: Twickenham Barrier 3 viewed along the crest from right bank

3.1.12.4 Plan of site:

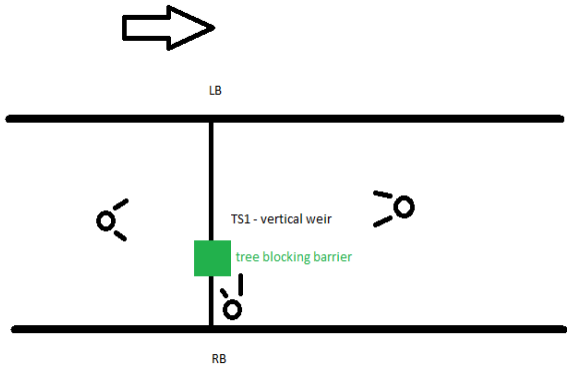

Figure 3.1.12.4a: Site plan for Twickenham Barrier 3

3.1.12.5 Structure dimensions*:*

Channel width	8.3m
Barrier width at crest	8.3m
Wetted width	4.7m
Transversal sections	1
Hydraulic head	0.32m

3.1.12.6 Impact of the structure on habitat:

Holds back flow resulting in areas of river drying up downstream with still or stagnant water upstream. The structure is essential for retaining water and providing a space for aquatic organisms to persist.

3.1.12.7 Ownership and function:

- *Landowner and operator:* London Borough of Richmond-upon-Thames, Environment Agency. Access via Heatham House Community Centre.
- *Original purpose of structure:* Water level management
- *Current uses and value of structure:* Water level management

3.1.12.8 Survey Conditions:

- *Antecedent conditions:* Light rain/drizzle within past two to three days
- *Flow Conditions:* Summer low flows
- *Was the structure submerged or dry?* Dry
- *Degree of estimation:* All measurements undertaken

3.1.12.9 Upstream fish passage assessment

	Flow conditions	**Passability score**	**Reason/s**
Coarse fish	Low	0	Water depth; Hydraulic head
	High	0.6	Hydraulic head
Juvenile eels	Low	1	Climbing substrate present
	High	1	Climbing substrate present

3.1.12.10 Downstream fish passage assessment

	Flow conditions	Passability score	Reason/s
Coarse fish	Low	0	Water depth
	High	1	Should be sufficient water
Adult eels	Low	0	Water depth
	High	1	Should be sufficient water

3.1.12.11 Options for fish passage improvement

- *Priority for action:* Medium.
  The Duke of Northumberland's River has the potential to provide a more suitable route for fish migration (see Discussion).

- *Consideration of options:*
  There was no water passing over this structure during the time of survey. Upstream large areas of the river had dried out, showing that the structure is essential for retaining water during times of low flow. Barrier removal or breaching may have a negative impact on water level management upstream.

  The provision of a two staged channel up and downstream of this barrier coupled with improving flows via the Mereway tilting weir at Kneller Gardens could reverse this issue, thus allowing the barrier to be breached along the middle of its crest. A rock ramp would also be a suitable method of easement should the structure still be imperative to maintaining water levels upstream.

3.1.13 Twickenham Barrier 4 (ID 192559)

3.1.13.1 Location:

- *GPS*: 51.451038, 0.32862995
- *Distance from Thames confluence*: 1930m
- *Distance to next structure downstream*: 101m
- *Number of structures downstream (direct route to Thames confluence)*: 11
- *Distance from next structure upstream*: 101m

3.1.13.2 Brief description:

Small vertical weir made from pre-cast concrete

3.1.13.3 Photos:

Figure 3.1.13.3a (left): Twickenham Barrier 4 viewed from downstream

Figure 3.1.13.3b (right): Twickenham Barrier 4 viewed from upstream

Figure 3.1.13.3c: Twickenham Barrier 4 viewed along the crest from right bank

3.1.13.4 Plan of site:

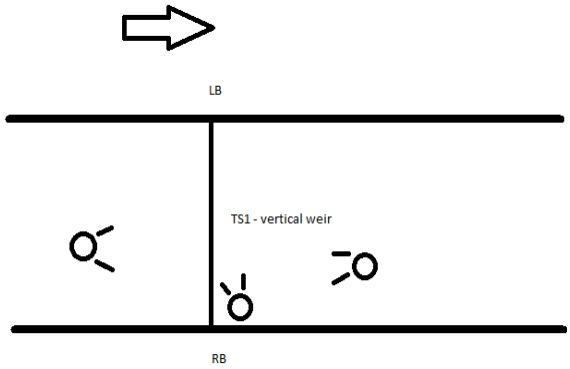

Figure 3.1.13.4a: Site plan for Twickenham Barrier 4

3.1.13.5 Structure dimensions:

Channel width	8.15m
Barrier width at crest	8.15m
Wetted width	1.4m
Transversal sections	1
Hydraulic head	0.4m

3.1.13.6 Impact of the structure on habitat:

Holds back flow resulting in areas of river drying up downstream and excessive siltation/minimal flow upstream.

3.1.13.7 Ownership and function

- *Landowner and operator:* London Borough of Richmond-upon-Thames, The Environment Agency. Access via Heatham House Community Centre.
- *Original purpose of structure:* Water level management
- *Current uses and value of structure:* Water level management

3.1.13.8 Survey Conditions

- *Antecedent conditions:* Light rain/drizzle within past two to three days
- *Flow Conditions:* Summer low flows
- *Was the structure submerged or dry?* Dry
- *Degree of estimation:* All measurements undertaken

3.1.13.9 Upstream fish passage assessment

	Flow conditions	**Passability score**	**Reason/s**
Coarse fish	Low	0	Water depth; Hydraulic head
	High	0.6	Hydraulic head
Juvenile eels	Low	1	Climbing substrate present
	High	1	Climbing substrate present

3.1.13.10 Downstream fish passage assessment

	Flow conditions	Passability score	Reason/s
Coarse fish	Low	0	Water depth
	High	1	Should be sufficient water
Adult eels	Low	0	Water depth
	High	1	Should be sufficient water

3.1.13.2 Options for fish passage improvement

- *Priority for action:* Medium.
  The Duke of Northumberland's River has the potential to provide a more suitable route for fish migration (see Discussion).

- *Consideration of options:*
  There was no water passing over this structure during the time of survey. Upstream large areas of the river had dried out, showing that the structure is essential for retaining water during times of low flow. Barrier removal or breaching may have a negative impact on water level management upstream.

  The provision of a two staged channel up and downstream of this barrier coupled with improving flows via the Mereway tilting weir at Kneller Gardens could reverse this issue, thus allowing the barrier to be breached along the middle of its crest. Should breaching the barrier have a negative effect on water level management, a rock ramp would also be a suitable method of easement coupled with a two stage channel.

3.1.14 Twickenham Barrier 5 (ID 192560)

3.1.14.1 Location:

- *GPS*: 51.450689, -0.32998117
- *Distance from Thames confluence*: 2031m
- *Distance to next structure downstream*: 101m
- *Number of structures downstream (direct route to Thames confluence)*: 12
- *Distance from next structure upstream*: 754m

3.1.14.2 Brief description:

Small vertical weir made from pre-cast concrete. On the right bank, there is a broken section of the weir that has been repaired.

3.1.14.3 Photos:

Figure 3.1.14.3a (left): Twickenham Barrier 5 viewed from downstream

Figure 3.1.14.3b (right): Twickenham Barrier 5 viewed from upstream

Figure 3.1.14.3c: Twickenham Barrier 5 viewed along the crest from right bank

3.1.14.4 Plan of site:

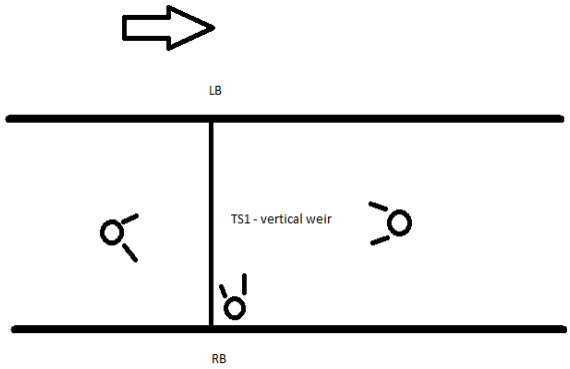

Figure 3.1.14.4a: Site plan for Twickenham Barrier 5

3.1.14.5 Structure dimensions:

Channel width	8.3m
Barrier width at crest	8.3m
Wetted width	0m
Transversal sections	1
Hydraulic head	0.3m

3.1.14.6 Impact of the structure on habitat:

Holds back flow resulting in areas of river drying up downstream and excessive siltation/minimal flow upstream. Because no water is flowing over the crest of the barrier, there is a back-up of pollution upstream.

3.1.14.7 Ownership and function:

- *Landowner and operator:* London Borough of Richmond-upon-Thames, Environment Agency. Access via Heatham House Community Centre.
- *Original purpose of structure:* Water level management
- *Current uses and value of structure:* Water level management

3.1.14.8 Survey Conditions:

- *Antecedent conditions:* Light rain/drizzle within past two to three days
- *Flow Conditions:* Summer low flows
- *Was the structure submerged or dry?* Dry
- *Degree of estimation:* All measurements undertaken

3.1.14.9 Upstream fish passage assessment

	Flow conditions	**Passability score**	**Reason/s**
Coarse fish	Low	0	Water depth; Hydraulic head
	High	0.6	Hydraulic head
Juvenile eels	Low	1	Climbing substrate present
	High	1	Climbing substrate present

3.1.14.10 Downstream fish passage assessment

	Flow conditions	Passability score	Reason/s
Coarse fish	Low	0	Water depth
	High	1	Should be sufficient water
Adult eels	Low	0	Water depth
	High	1	Should be sufficient water

3.1.14.11 Options for fish passage improvement

- *Priority for action:* Medium.
  The Duke of Northumberland's River has the potential to provide a more suitable route for fish migration (see Discussion).

- *Consideration of options:*
  There was no water passing over this structure during the time of survey. Upstream large areas of the river had dried out, showing that the structure is essential for retaining water during times of low flow. Barrier removal or breaching may have a negative impact on water level management upstream.

  The provision of a two staged channel up and downstream of this barrier coupled with improving flows via the Mereway tilting weir at Kneller Gardens could reverse this issue, thus allowing the barrier to be breached along the middle of its crest. A rock ramp would also be a suitable method of easement should the structure still be imperative to maintaining water levels upstream.

3.1.15 Mereway Barrier 1 (ID 192274)

3.1.15.1 Location:

- *GPS*: 51.448698, -0.33983994
- *Distance from Thames confluence*: 2785m
- *Distance to next structure downstream*: 754m
- *Number of structures downstream (direct route to Thames confluence)*: 13
- *Distance from next structure upstream*: 130m

3.1.15.2 Brief description:

Sloping weir made from concrete (poured on site)

3.1.15.3 Photos:

Figure 3.1.15.3a (left): Mereway Barrier 1 viewed from upstream at left bank

Figure 3.1.15.3b (right): Mereway Barrier 1 viewed along the crest from left bank

3.1.15.4 Plan of site:

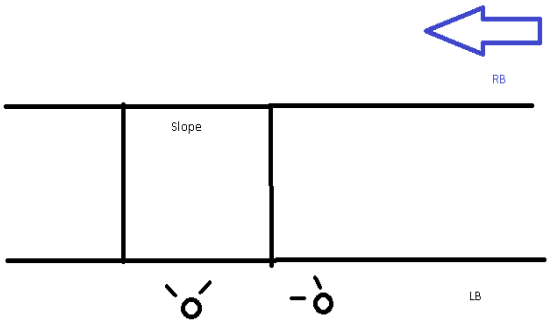

Figure 3.1.15.4a: Site plan for Mereway Barrier 1

3.1.15.5 Structure dimensions:

Channel width	7m
Barrier width at crest	7m
Wetted width	1.5m
Transversal sections	1
Hydraulic head	0.3m
Effective length	2.1m
Gradient	19%

3.1.15.6 Impact of the structure on habitat:

The structure holds back flow resulting in areas of river drying up downstream and areas of water stagnating upstream. This said, it is essential for retaining water in this reach of river and ensures the river channel continues to offer aquatic habitat to wildlife.

3.1.15.7 Ownership and function

- *Landowner and operator:* London Borough of Richmond-upon-Thames, Environment Agency. Access via Heatham House Community Centre.
- *Original purpose of structure:* Water level management
- *Current uses and value of structure:* Water level management

3.1.15.8 Survey Conditions

- *Antecedent conditions:* Light rain/drizzle within past two to three days
- *Flow Conditions:* Summer low flows
- *Was the structure submerged or dry?* No
- *Degree of estimation:* All measurements estimated from left bank – we were unable to access this barrier

3.1.15.9 Upstream fish passage assessment

	Flow conditions	**Passability score**	**Reason/s**
Coarse fish	Low	0	Water depth across slope; Gradient
	High	0.3	Gradient
Juvenile eels	Low	1	Climbing substrate present
	High	1	Climbing substrate present

3.1.15.10 Downstream fish passage assessment

	Flow conditions	**Passability score**	**Reason/s**
Coarse fish	Low	0	Water depth
	High	1	Should be sufficient water
Adult eels	Low	0	Water depth
	High	1	Should be sufficient water

3.1.15.11 Options for fish passage improvement

- *Priority for action:* Medium. The Duke of Northumberland's River has the potential to provide a more suitable route for fish migration (see Discussion).

- *Consideration of options:*
  Although there was a small amount of water passing over one side of the structure, providing a wet area for eels to climb, it was otherwise dry. Downstream from this structure, large areas of the river had dried out or contained stagnating water. Upstream the river had little flow, and was shallow in depth with excessive amounts blanket weed. This shows that the structure is essential for retaining water during times of low flow but also has an impact on fish passage downstream due to low water levels. Barrier removal or breaching may have a negative impact on water level management upstream and extend the area of dry riverbed found downstream.

  The provision of a two staged channel up and downstream of this barrier coupled with improving flows via the Mereway tilting weir at Kneller Gardens could reverse this issue, thus allowing the barrier to be removed. A rock ramp would also be a suitable method of easement should the structure still be imperative to maintaining water levels upstream.

3.1.16 Mereway Barrier 2 (ID 192275)

3.1.16.1 Location:

- *GPS*: 51.448309, -0.34160976
- *Distance from Thames confluence*: 2915m
- *Distance to next structure downstream*: 130m
- *Number of structures downstream (direct route to Thames confluence)*: 14
- *Distance from next structure upstream*: 227m

3.1.16.2 Brief description:

Small vertical weir made from pre-cast concrete. There was a notch in the centre of the weir but the missing section has been replaced.

3.1.16.3 Photos:

Figure 3.1.16.3a: Mereway Barrier 2 viewed from downstream

Figure 3.1.16.3b: Mereway Barrier 2 viewed from upstream at left bank

3.1.16.4 Plan of site:

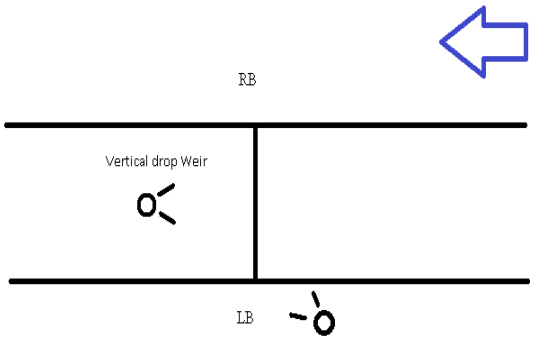

Figure 3.1.16.4a:: Site plan for Mereway Barrier 2

3.1.16.5 Structure dimensions:

Channel width	7m
Barrier width at crest	7m
Wetted width	0m
Transversal sections	1
Hydraulic head	0.25m

3.1.16.6 Impact of the structure on habitat:

The structure holds back flow resulting in areas of river drying up downstream and areas of water stagnating upstream. This said, it is essential for retaining water in this reach of river and ensures the river channel continues to offer aquatic habitat to wildlife.

3.1.16.7 Ownership and function:

- *Landowner and operator:* London Borough of Richmond-upon-Thames, Environment Agency. Access via Heatham House Community Centre.
- *Original purpose of structure:* Water level management
- *Current uses and value of structure:* Water level management

3.1.16.8 Survey Conditions:

- *Antecedent conditions:* Light rain/drizzle within past two to three days
- *Flow Conditions:* Summer low flows
- *Was the structure submerged or dry?* Dry
- *Degree of estimation:* All measurements undertaken

3.1.16.9 Upstream fish passage assessment

	Flow conditions	**Passability score**	**Reason/s**
Coarse fish	Low	0	Water depth at inlet; Hydraulic head
	High	0.6	Hydraulic head
Juvenile eels	Low	0	No climbing substrate; Water depth at inlet
	High	1	Should be sufficient water

3.1.16.10 Downstream fish passage assessment

	Flow conditions	**Passability score**	**Reason/s**
Coarse fish	Low	0	Water depth
	High	1	Should be sufficient water
Adult eels	Low	0	Water depth
	High	1	Should be sufficient water

3.1.16.11 Options for fish passage improvement

- *Priority for action:* Medium.

- The Duke of Northumberland's River has the potential to provide a more suitable route for fish migration (see Discussion).

- *Consideration of options:*
  There was no water passing over this structure during the time of survey. Areas of the river had dried out, upstream and downstream or contained stagnating water, showing that the structure is essential for retaining water during times of low flow. Barrier removal or breaching may have a negative impact on water level management upstream.

  The provision of a two staged channel up and downstream of this barrier coupled with improving flows via the Mereway tilting weir at Kneller Gardens could reverse this issue, thus allowing the barrier to be breached along the middle of its crest. A rock ramp would also be a suitable method of easement should the structure still be imperative to maintaining water levels upstream.

3.1.17 Mereway Barrier 3 (ID 192277)

3.1.17.1 Location:

- *GPS*: 51.447348, -0.34419179
- *Distance from Thames confluence*: 3143m
- *Distance to next structure downstream*: 227m
- *Number of structures downstream (direct route to Thames confluence)*: 15
- *Distance from next structure upstream*: 208m

3.1.17.2 Brief description:

Small vertical weir made from pre-cast concrete. There was a notch in the centre of the weir but the notch has been blocked with two cement bags. There is some water flowing underneath the cement bags.

3.1.17.3 Photos:

Figure 3.1.17.3a (left): Mereway Barrier 3 viewed from downstream

Figure 3.1.17.3b (right): Mereway Barrier 3 viewed from upstream

Figure 3.1.17.3c: Mereway Barrier 3 viewed along the crest from left bank

3.1.17.4 Plan of site:

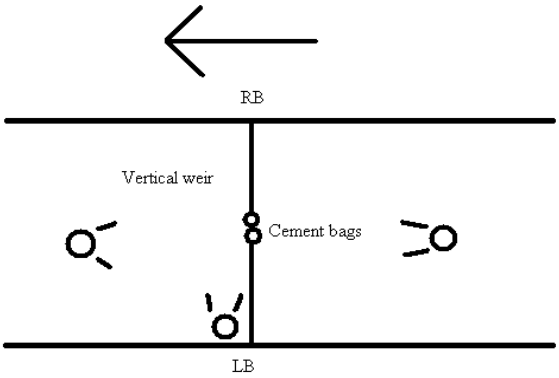

Figure 3.1.17.4a: Site plan for Mereway Barrier 3

3.1.17.5 Structure dimensions:

Channel width	8m
Barrier width at crest	8m
Wetted width	0.63m
Transversal sections	3
Hydraulic head	0.1m

3.1.17.6 Impact of the structure on habitat:

The structure holds back flow resulting in areas of river drying up downstream and areas of water stagnating upstream. This said, it is essential for retaining water in this reach of river and ensures the river channel continues to offer aquatic habitat to wildlife.

3.1.17.7 Ownership and function

- *Landowner and operator:* London Borough of Richmond-upon-Thames, Environment Agency. Access via Heatham House Community Centre.
- *Original purpose of structure:* Water level management
- *Current uses and value of structure:* Water level management

3.1.17.8 Survey Conditions

- *Antecedent conditions:* Light rain/drizzle within past two to three days
- *Flow Conditions:* Summer low flows
- *Was the structure submerged or dry?* The crest of the original weir is dry but there is water flowing over and under the cement bags at the centre
- *Degree of estimation:* All measurements undertaken

3.1.17.9 Upstream fish passage assessment

	Flow conditions	**Passability score**	**Reason/s**
Coarse fish	Low	0	Water depth at inlet; Hydraulic head
	High	1	Should be sufficient water and reduced hydraulic head

Juvenile eels	Low	1	Climbing substrate present
	High	1	Climbing substrate present

3.1.17.10 Downstream fish passage assessment

	Flow conditions	Passability score	Reason/s
Coarse fish	Low	0	Water depth
	High	1	Should be sufficient water
Adult eels	Low	0	Water depth
	High	1	Should be sufficient water

3.1.17.11 Options for fish passage improvement

- *Priority for action:* Medium.
  The Duke of Northumberland's River has the potential to provide a more suitable route for fish migration (see Discussion).

- *Consideration of options:*
  There was no water passing over this structure during the time of survey. The structure had been breached but then repaired at a later date with cement bags as this clearly had a negative effect on water level management during times of low flow.

  Areas of the river had dried out, upstream and downstream or contained stagnating water, showing that the structure is essential for retaining water during times of low flow. Barrier removal or breaching may have a negative impact on water level management upstream.

  The provision of a two staged channel up and downstream of this barrier coupled with improving flows via the Mereway tilting weir at Kneller Gardens could reverse this issue, thus allowing the barrier to be breached along the middle of its crest. A rock ramp would also be a suitable method of easement should the structure still be imperative to maintaining water levels upstream.

3.1.18 Mereway Barrier 4 (ID 192278)

3.1.18.1 Location:

- *GPS*: 51.446956, -0.34702656
- *Distance from Thames confluence*: 3351m
- *Distance to next structure downstream*: 208m
- *Number of structures downstream (direct route to Thames confluence)*: 16
- *Distance from next structure upstream*: 2423m

3.1.18.2 Brief description:

Large vertical tilting weir made from pre-cast concrete and metal. The structure is responsible for the flow split between the Lower Crane and Duke of Northumberland's River. Currently most of the Crane's flow is diverted down the DNR and it is this factor that is responsible for the areas of dry river bed and stagnating water found downstream on the lower Crane.

3.1.18.3 Photos:

Figure 3.1.18.3a (left): Mereway Barrier 4 viewed from downstream

Figure 3.1.18.3b (right): Mereway Barrier 4 viewed from upstream at right bank

Figure 3.1.18.3c: Mereway Barrier 4 viewed along the crest from right bank

3.1.18.4 Plan of site:

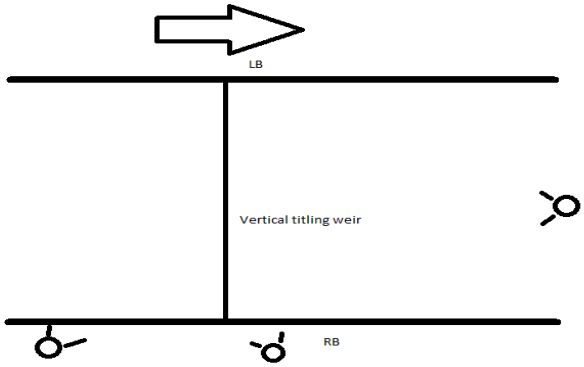

Figure 3.1.18.4a: Site plan for Mereway Barrier 4

3.1.18.5 Structure dimensions:

Channel width	9m
Barrier width at crest	9m
Wetted width	0m
Transversal sections	1
Hydraulic head	2m

3.1.18.6 Impact of the structure on habitat:

This barrier has a profound impact on habitat. It holds back flow resulting in areas of river drying up downstream and excessive siltation and decreased flows upstream. At low flows, there is little to no water flowing over the barrier into the lower Crane which results in a partially dry river channel for several kilometres until the tidal zone.

3.1.18.7 Ownership and function:

- *Landowner and operator:* London Borough of Richmond-upon-Thames, Environment Agency. Access via Kneller Gardens, Twickenham.
- *Original purpose of structure:* Water level management. The tilting weir will open at times of high flow, allowing water into the lower Crane and utilising it as a flood relief channel.
- *Current uses and value of structure:* Water level management. The tilting weir will open at times of high flow, allowing water into the lower Crane and utilising it as a flood relief channel.

3.1.18.8 Survey Conditions:

- *Antecedent conditions:* Light rain/drizzle within past two to three days
- *Flow Conditions:* Summer low flows
- *Was the structure submerged or dry?* Dry
- *Degree of estimation:* All measurements estimated from right bank – we were unable to access this barrier from the river channel.

3.1.18.9 Upstream fish passage assessment

	Flow conditions	Passability score	Reason/s
Coarse fish	Low	0	Water depth at inlet; Hydraulic head
	High	0	Hydraulic head
Juvenile eels	Low	0	No climbing substrate present; Water depth at inlet; Hydraulic head
	High	0	Hydraulic head

3.1.18.10 Downstream fish passage assessment

	Flow conditions	Passability score	Reason/s
Coarse fish	Low	0	Water depth
	High	0.3	Damaging to DS migrants
Adult eels	Low	0	Water depth
	High	0.3	Damaging to DS migrants

3.1.18.11 Options for fish passage improvement

- *Priority for action:* Medium.
  The Duke of Northumberland's River has the potential to provide a more suitable route for fish migration (see Discussion).

- *Consideration of options:*
  The tilting weir will not allow fish passage regardless of whether or not it is open and permitting flow to the river Crane. The provision of a larinier fish pass would be unsuitable due to the variable hydraulic head of the structure and low water levels observed downstream. Complete removal of the structure would impact on water level management and lead to the lower Duke of Northumberland's River drying out.

  The only option available is to replace the structure with one that still permits the regulation of flows, yet does not have a variable hydraulic head. If this was possible, and if the new structure allowed a greater volume of water to be diverted down the Lower Crane, a lariner fish pass could be installed to allow fish passage from the lower Crane to the middle reaches of the river.

3.2 Lower Duke of Northumberland's River

3.2.1 Duke of Northumberland –Thames Barrier (ID 990006)

3.2.1.1 Location:

- *GPS*: 51.470459, -0.32151315
- *Distance from Thames confluence*: 0m
- *Distance to next structure downstream*:0m
- *Number of structures downstream (direct route to Thames confluence)*: 0
- *Distance from next structure upstream*: 90m

3.2.1.2 Brief description:

Concrete stepped weir consisting of 2/3 steps of poured concrete at the Duke of Northumberland/Thames confluence. This barrier is completely submerged at high tide.

3.2.1.3 Photos:

Figure 3.2.1.3a (left): Looking upstream from Thames at the stepped barrier

Figure 3.2.1.3b (right): Birds eye view at the barrier

Figure 3.2.1.3c: View from right bank of the stpped barrier

3.2.1.4 Plan of site:

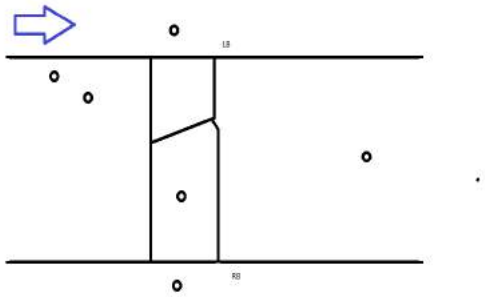

Figure 3.2.1.4.a: Site plan for Duke of Northumberland's – Thames Barrier

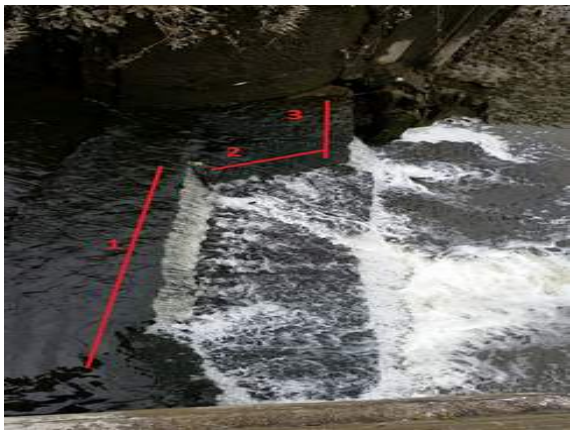

Figure 3.2.1.4b: Illustration of the 3 transversal sections assessed in Duke of Northumberland's – Thames Barrier

3.2.1.5 Structure dimensions:

Channel width	8.0m
Barrier width at crest	8.0m
Wetted width	8.0m
Transversal sections	3
Hydraulic head	1.0M
Effective length	1.0m
Number of steps	2
Height of step (limiting)	0.3m
Length of step (limiting)	1.0m

3.2.1.6 Impact of the structure on habitat:

Large concrete structure unable to support aquatic plant life. The large concrete beds either side of the channel does not support riparian habitat.

3.2.1.7 Ownership and function

- *Landowner and operator:* The London Borough of Hounslow/Environment Agency. Access via the footpath opposite Isleworth Ait Nature Reserve, near the London Apprentice Pub.
- *Original purpose of structure:* Water level management.

- *Current uses and value of structure:* Water level management.

3.2.1.8 Survey Conditions

- *Antecedent conditions:* Light rain/drizzle within past two or three days
- *Flow Conditions:* Low tide
- *Was the structure submerged or dry?* No
- *Degree of estimation:* All measurements undertaken.

3.2.1.9 Upstream fish passage assessment

	Flow conditions	**Passability score**	**Reason/s**
Coarse fish	Low	0	Depth of water at the inlet, step water depth and height of step.
	High	1	Barrier submerged at high tide
Juvenile eels	Low	1	Climbing substrate present
	High	1	Barrier submerged at high tide

3.2.1.10 Downstream fish passage assessment

	Flow conditions	**Passability score**	**Reason/s**
Coarse fish	Low	0.6	Water velocity
	High	1	Barrier submerged at high tide
Adult eels	Low	0.6	Depth of water
	High	1	Barrier submerged at high tide

3.2.1.11 Options for fish passage improvement

- *Priority for action:* High.
  This barrier is submerged at high tides.

- *Consideration of options:*
  A larinier fish pass could be installed to overcome the limiting attributes of the structure (Depth of water at the inlet, step water depth and height of step). There is sufficient water depth and flow in the channel upstream and downstream at low tide to allow for a larinier fish pass to work efficiently. A larinier fish pass may be prone to blocking with debris as a result of the cross current of the river Thames as tides rise and fall. Due to the location of the barrier this would be difficult to maintain and would require regular checks.

  A rock ramp may be a more efficient way of easing this structure. There is suitable space below the structure to ensure the correct length and gradient for this type of fish pass. The morphology of the Thames in this location would offer the rock ramp protection from erosion. Flows from the DNR have scoured out a pool beneath the barrier and the area is sheltered by large gravel banks which are fully exposed at low tide.

3.2.2 Duke of Northumberland Barrier 1 (193108)

3.2.2.1 Location:

- *GPS:* 51.470504, -0.32276415
- *Distance from Thames confluence*: 90m
- *Distance to next structure downstream*: 90m
- *Number of structures downstream (direct route to Thames confluence)*: 1
- *Distance from next structure upstream*: 0m

3.2.2.2 Brief description:

Stepped weir located directly after the Kids Mill Sluice. The structure is located within a small runnel and appears to be made from pre-cast concrete. There is an eel pass on the left bank of the structure which allows the passage of juvenile eels.

3.2.2.3 Photos:

Figure 3.2.2.3a (left): Stepped barrier at low tide. Eel pass is visible at the left bank.

Figure 3.2.2.3b (right). Stepped barrier completely submerged at high tide.

3.2.2.4 Plan of site:

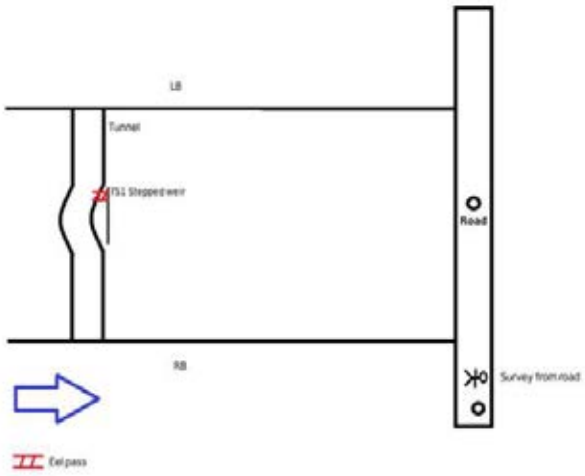

Figure 3.2.2.4a: Site plan for Duke of Northumberland's Barrier 1

3.2.2.5 Structure dimensions:

Channel width	5m
Barrier width at crest	5m
Wetted width	5m
Transversal sections	1
Hydraulic head	1m
Effective length	1m
Number of steps	2
Height of step (limiting)	0.5m
Length of step (limiting)	0.6m

3.2.2.6 Impact of the structure on habitat:

No marginal vegetation due to concrete bed and shading from the tunnel it is directly under.

3.2.2.7 Ownership and function

- *Landowner and operator:* Environment Agency. No direct access.
- *Original purpose of structure:* Historical structure associated with the Kids Mill Sluice and former watermill.
- *Current uses and value of structure:* Unknown.

3.2.2.8 Survey Conditions

- *Antecedent conditions:* No rain within the past week
- *Flow Conditions:* Low tide
- *Was the structure submerged or dry?* No
- *Degree of estimation:* All measurements estimated.

3.2.2.9 Upstream fish passage assessment

	Flow conditions	**Passability score**	**Reason/s**
Coarse fish	Low	0	Hydraulic head
	High	1	Barrier submerged at high tide
Juvenile eels	Low	1	Presence of eel pass
	High	1	Presence of eel pass

3.2.2.10 Downstream fish passage assessment

	Flow conditions	**Passability score**	**Reason/s**
Coarse fish	Low	0.3	Damaging to downstream migrants
	High	1	Barrier submerged at high tide
Adult eels	Low	0.3	Damaging to downstream migrants
	High	1	Barrier submerged at high tide

3.2.2.11 Options for fish passage improvement

- *Priority for action*: High.

This barrier is submerged at high tide but does not allow fish passage at low tides. Easing this barrier I essential for allowing the ingress of fish to the Crane Catchment from the Thames.

- *Consideration of options:*
  A larinier fish pass could be installed to overcome the limiting attribute of the structure (hydraulic head). There is sufficient water depth and flow in the channel upstream and downstream at low tide to allow for a larinier fish pass to work efficiently. A larinier fish pass may be prone to blocking with debris as tides rise and fall. Due to the location of the barrier this would be difficult to maintain and would require regular checks. There is also an alternative option to installing a larinier specifically to bypass this structure. It is possible to bypass this structure and the next upstream with the provision of a lariner pass from the Kids Mill Sluice (discussed in next section).

  This structure could also be bypassed with a rock ramp. There is suitable space below the structure to ensure the correct length and gradient for this type of fish pass and sufficient flow from upstream to allow it to function efficiently.

3.2.3 Kids Mill Sluice (ID 193108)

3.2.3.1 Location

- *GPS*: 51.470504, -0.32276415
- *Distance from Thames confluence*: 90m
- *Distance to next structure downstream*: 0m
- *Number of structures downstream (direct route to Thames confluence)*: 2
- *Distance from next structure upstream*: 1818m

3.2.3.2 Brief description:

Steep vertical weir with a large hydraulic head made from pre-cast concrete and steel. The adjacent undershot sluice was not assessed as it was currently closed and does not present a potential pathway for fish migration. At high tide the water level rises by approximately 3m.

3.2.3.3 Photos:

Figure 3.2.3.3a (left): Kids Mill Sluice front view from downstream. The undershot sluice not assessed is on the left bank

Figure 3.2.3.3b (right): Looking upstream at left bank from Kids Mill Sluice which is directly under the metal bridge as seen in the photo.

Figure 3.2.3.3c (left): The assessed vertical weir for Kids Mill Sluice viewed along the crest at right bank.

Figure 3.2.3.3d (right): A currently unused (dry) sluice that could present a potential site for creation of a fish pass

3.2.3.4 Plan of site:

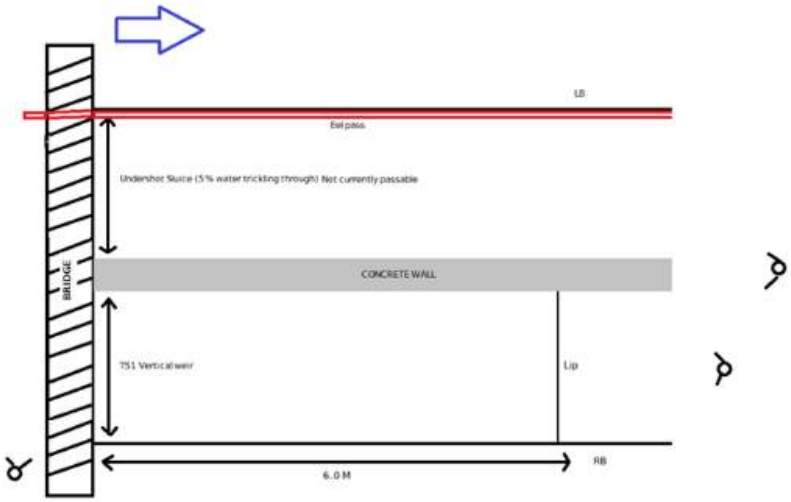

Figure 3.2.3.4a: Site plan for Kids Mill Sluice

3.2.3.4 Structure dimensions:

Channel width	5.2m
Barrier width at crest	1.45m
Wetted width	1.45m
Transversal sections	1
Hydraulic head	4.0m

3.2.3.5 Impact of the structure on habitat:

The structure retains an area of open water upstream. The mill pool is relatively still and provides a diverse array of marginal plant life. The pool provides good habitat for a range of fish species and year classes. It will also make a suitable home for a range of aquatic invertebrates including those normally associated with still water habitats such as dragonflies. King fisher banks are scheduled to be installed at the site.

3.2.3.6 Ownership and function:

- *Landowner and operator:* Environment Agency. Access via Kids Mill Compound.
- *Original purpose of structure:* Historic Mill Race.
- *Current uses and value of structure:* The structure is used to regulate the DNR's flows and prevent the ingress of the tide upstream.

3.2.3.7 Survey Conditions:

- *Antecedent conditions:* Light rain/drizzle for past week.
- *Flow Conditions:* Low tide and
- *Was the structure submerged or dry?* No
- *Degree of estimation:* All measurements undertaken.

3.2.3.9 Upstream fish passage assessment

	Flow conditions	Passability score	Reason/s
Coarse fish	Low	0	Hydraulic head
	High	0	Hydraulic head
Juvenile eels	Low	1	Presence of eel pass
	High	1	Presence of eel pass

3.2.3.10 Downstream fish passage assessment

	Flow conditions	Passability score	Reason/s
Coarse fish	Low	0.3	Damaging to downstream migrants
	High	0.3	Damaging to downstream migrants
Adult eels	Low	0.3	Damaging to downstream migrants
	High	0.3	Damaging to downstream migrants

3.2.3.11 Options for fish passage improvement

- *Priority for action*: High.
  It is imperative this barrier is made passable to ensure the ingress of coarse fish from the River Thames.

- *Consideration of options:*
  An unused channel is present at the right bank of the structure (Fig 3.2.3.3d). Water is retained at the head of this channel by a sluice that is rarely used (Environment Agency, pers coms, 2016). The channel is able to bypass the Kids Mill sluice and the stepped structure located 1m downstream. Due to the head of water retained by the sluice, the correct flows and water depth could be provided for a larinier fish pass. Larinier fish passes can be used to accommodate a head difference of up to 1.5m per flight (sloped section), with flights being 8-10m long (EA, 2010). The combined head difference of both barriers at low tide is approximately 5m. A larinier pass would have to provide a minimum of three resting locations and three flights with a maximum gradient of 15% in order to make this barrier passable.

  Alternatively a shorter lariner fish pass could be installed to operate at high tide. Due to the decreased head difference, less flights and resting locations would need to be provided to ensure fish passage. The pass would only operate for a few hours a day however.

3.2.4 Mogden Sewage Works Barrier 1 (ID 990007)

3.2.4.1 Location:

- *GPS*: 51.465597, -0.34129983
- *Distance from Thames confluence*: 1908m
- *Distance to next structure downstream*: 1818m
- *Number of structures downstream (direct route to Thames confluence)*: 3
- *Distance from next structure upstream*: 97m

3.2.4.2 Brief description:

Small vertical weir made from steel which is under a small foot bridge. It divides into two channels due to the presence of a concrete wall under the footbridge.

3.2.4.3 Photos:

Figure 3.2.4.3a (left): Small vertical weir directly under the footbridge from right bank.

Figure 3.2.4.3b (right): Steel vertical weir under footbridge from right bank.

Figure 3.2.4.3c: Photo taken at right bank looking upstream. The concrete wall under the footbridge separated this barrier to be assessed in two transversal sections.

3.2.4.4 Plan of site:

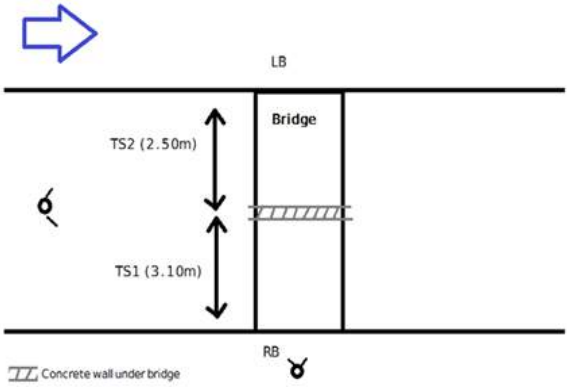

Figure 3.2.4.4a: Site Plan of Mogden Sewage Works Barrier 1

3.2.4.5 Structure dimensions:

Channel width	6m
Barrier width at crest	6m
Wetted width	6m
Transversal sections	2
Hydraulic head	0.09m

3.2.4.6 Impact of the structure on habitat:

No obvious impact of structure to habitat. Slight increase in siltation upstream as a result of the weir holding back flows.

3.2.4.7 Ownership and function:

- *Landowner and operator:* Thames Water and London Borough of Hounslow
- *Original purpose of structure:* Water level management
- *Current uses and value of structure:* Water level management

3.2.4.8 Survey Conditions

- *Antecedent conditions:* No rain within past week.
- *Flow Conditions:* Summer low level
- *Was the structure submerged or dry?* No
- *Degree of estimation:* All measurements undertaken

3.2.4.9 Upstream fish passage assessment

	Flow conditions	**Passability score**	**Reason/s**
Coarse fish	Low	1	Sufficient depth of water
	High	1	Sufficient depth of water
Juvenile eels	Low	1	Climbing substrate present
	High	1	Climbing substrate present

3.2.4.10 Downstream fish passage assessment

	Flow conditions	Passability score	Reason/s
Coarse fish	Low	1	Sufficient depth of water
	High	1	Sufficient depth of water
Juvenile eels	Low	1	Sufficient depth of water
	High	1	Sufficient depth of water

3.2.4.11 Options for fish passage improvement

- *Priority for action*: Low.
  This barrier is passable.

- *Consideration of options:*
  None.

3.2.5 Mogden Sewage Works Culvert 1 (ID 990008)

3.2.5.1 Location:

- *GPS*: 51.464733, -0.34124478
- *Distance from Thames confluence*: 2005m
- *Distance to next structure downstream*: 97m
- *Number of structures downstream (direct route to Thames confluence)*: 4
- *Distance from next structure upstream*: 140m

3.2.5..2 Brief description:

Culvert of approximately 135m in length located in Mogden Sewage Works site. The depth of water flowing through culvert is estimated at >10cm and flow of water is estimated at less than 1m/s.

3.2.5.3 Photos:

Figure 3.2.5.3a (left): Entrance of Modgen Sewage Works culvert from upstream

Figure 3.2.5.3b (right): Length of culvert at Mogden Sewage Treament Works

3.2.5.4 Plan of site:

No site plan available

3.2.5.5 Structure dimensions:

Channel width	4m
Barrier width at crest	4m
Wetted width	4m
Transversal sections	1

3.2.5.6 Impact of the structure on habitat:

Straightened underground channel with poor morphology unable to support complex aquatic habitats.

3.2.5.7 Ownership and function

- *Landowner and operator:* Thames Water

- *Original purpose of structure:* Culvert to allow vehicular and pedestrian traffic to cross over the waterway to Mogden Sewage Treatment Works.
- *Current uses and value of structure:* As above.

3.2.5.8 Survey Conditions

- *Antecedent conditions:* Light rain drizzle within past two to three days
- *Flow Conditions:* Summer low level
- *Was the structure submerged or dry?* No
- *Degree of estimation:* All measurements estimated with gridreferencefinder.com

3.2.5.9 Upstream fish passage assessment

	Flow conditions	**Passability score**	**Reason/s**
Coarse fish	Low	0.6	Length of culvert may present a barrier
	High	0.6	Length of culvert may present a barrier
Juvenile eels	Low	0.6	Length of culvert may present a barrier
	High	0.6	Length of culvert may present a barrier

3.3.2.5..10 Downstream fish passage assessment

	Flow conditions	**Passability score**	**Reason/s**
Coarse fish	Low	1	Sufficient depth of water
	High	1	Sufficient depth of water
Adult eels	Low	1	Sufficient depth of water
	High	1	Sufficient depth of water

3.2.5.11 Options for fish passage improvement

- *Priority for action*: Low

- *Consideration of options:*
  The provision of artificial lighting to the tunnel could ensure darkness does not deter fish passage.

3.2.6 Mogden Sewage Works Barrier 3 (ID 262984)

3.2.6.1 Location:

- *GPS*: 51.463991, -0.34024958
- *Distance from Thames confluence*: 2145m
- *Distance to next structure downstream*: 140m
- *Number of structures downstream (direct route to Thames confluence)*: 5
- *Distance from next structure upstream*: 5672m

3.2.6.2 Brief description: Sloping weir made from poured concrete and steel at the Mogden Treatment Sewage Works. Used as Environment Agency Telemetry Station.

3.2.6.3 Photos:

Figure 3.2.6.3a (left): Mogden Sewage Works Barrier 3 viewed from downstream at right bank

Figure 3.2.6.3b (right): Mogden Sewage Works Barrier 3 viewed from upstream at right bank

Figure 3.2.6.3.c: Mogden Sewage Works Barrier 3 viewed along the crest at right bank

3.2.6.4 Plan of site:

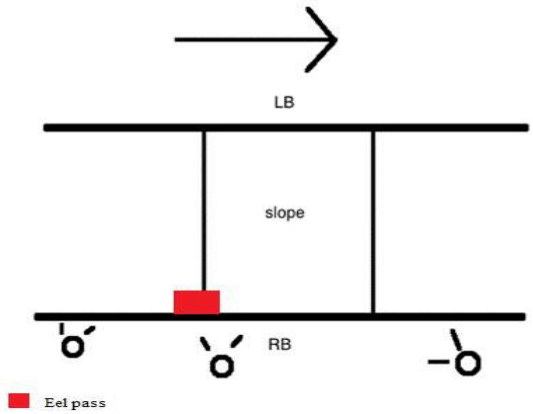

Figure 3.2.6.4a: Site plan for Mogden Sewage Works Barrier 3

3.2.6.5 Structure dimensions:

Channel width	7m
Barrier width at crest	7m
Wetted width	7m
Transversal sections	1
Effective length	0.6m
Gradient	18%

3.2.6.6 Impact of the structure on habitat:

The structure causes excessive siltation upstream and prevents the migration of sediments.

3.2.6.7 Ownership and function

- *Landowner and operator:* Thames Water
- *Original purpose of structure:* To maintain water levels to guarantee supply to a gravity-fed abstraction point for Mogden Sewage Works
- *Current uses and value of structure:* To maintain water levels to guarantee supply to a gravity-fed abstraction point for Mogden Sewage Works. This site also site also provides flow gauging data for Environment Agency.

3.2.6.8 Survey Conditions

- *Antecedent conditions:* Light rain/drizzle within past 2/3 days.
- *Flow Conditions:* Summer low level
- *Was the structure submerged or dry?* No
- *Degree of estimation:* Measurements partially undertaken

3.2.6.9 Upstream fish passage assessment

	Flow conditions	Passability score	Reason/s
Coarse fish	Low	0	Water depth; Turbulence; Standing wave; Gradient of slope
	High	0.3	Aforementioned would decrease
Juvenile eels	Low	1	Eel pass present
	High	1	Eel pass present

3.2.6.10 Downstream fish passage assessment

	Flow conditions	Passability score	Reason/s
Coarse fish	Low	1	Sufficient water depth
	High	1	Sufficient water depth
Adult eels	Low	1	Sufficient water depth
	High	1	Sufficient water depth

3.2.6.11 Options for fish passage improvement

- *Priority for action*: High.
  Removal of this barrier would open up a large section of the river as the next impassable barrier upstream is at Brazil Mill Woods, Feltham.

- *Consideration of options:*
  A Larinier fish pass would be best suited to ease fish passage at the sloping weir. Due to the hydraulic head of the structure (0.4m) a single flight could be provided with no resting locations. The short length of this fish pass would make it cost effective and easy to install.

  The current function of this structure may affect mitigation options. Any easement method proposed should be evaluated by the Environment Agency as it has the potential to affect telemetry data recorded in this location.

3.3 River Crane (Middle and Upper Reach)

3.3.1 Mill Road Barrier 1 (ID 193349)

3.3.1.1. Location:

- *GPS*: 51.443099, -0.35602979
- *Distance from Thames confluence*: 4187m
- *Distance to next structure downstream*: 837m
- *Number of structures downstream (direct route to Thames confluence)*: 17 (via River Crane) or 6 (via lower Duke of Northumberland's River)
- *Distance from next structure upstream*: 2882m

3.3.1.2 Brief description:

Vertical weir made from pre-cast concrete with a large hydraulic head and a small lip at the foot of the structure. There is a long concrete bed in the run-up to this barrier and a small lip further downstream. Note that this barrier is by-passable by the main river therefore in practice is completely passable.

3.3.1.3 Photos*:*

Figure 3.3.1.3a (left): Mill Road barrier viewed from downstream at left bank.

Figure 3.3.1.3b (right): Mill Road barrier viewed along the crest at left bank. This vertical barrier has a small lip at the foot of the structure.

Figure 3.3.1.3.c: Small lip downstream from structure as viewed from left bank.

3.3.1.4 Plan of site:

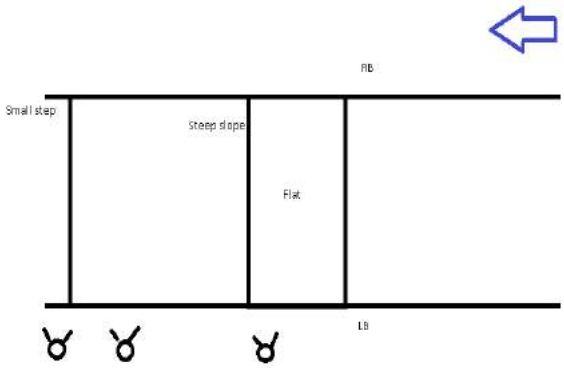

Figure 3.3.1.4a: Site plan for Mill Road Barrier 1

3.3.1.5 Structure dimensions:

Channel width	3.5m
Barrier width at crest	3.5m
Wetted width	3.5m
Transversal sections	1
Hydraulic head	2m

3.3.1.6 Impact of the structure on habitat:

The river bed is concreated for 10m downstream of the structure and is unable to support marginal plant life or complex aquatic invertebrate communities. The river is also very shallow in this location. Upstream of the barrier the river slow and sluggish in nature. Excessive siltation in this location shows that the weir is preventing sediment transport. The back channel at Mill Road

3.3.1.7 Ownership and function:

- *Landowner and operator:* London Borough of Richmond-upon-Thames, Access via Mill Road Island, Twickenham.

- *Original purpose of structure:* Historical structure to drive mill machinery and hold back large volume of water.
- *Current uses and value of structure:* Historical value; holds back large volume of water

3.3.1.8 Survey Conditions:

- *Antecedent conditions:* Light rain/drizzle within past two to three days.
- *Flow Conditions:* Summer low level
- *Was the structure submerged or dry?* No
- *Degree of estimation:* All measurements estimated

3.3.1.9 Upstream fish passage assessment

	Flow conditions	**Passability score**	**Reason/s**
Coarse fish	Low	1	Main river channel bypasses structure
	High	1	Main river channel bypasses structure
Juvenile eels	Low	1	Main river channel bypasses structure
	High	1	Main river channel bypasses structure

3.3.1.10 Downstream fish passage assessment

	Flow conditions	**Passability score**	**Reason/s**
Coarse fish	Low	1	Main river channel bypasses structure
	High	1	Main river channel bypasses structure
Adult eels	Low	1	Main river channel bypasses structure
	High	1	Main river channel bypasses structure

3.3.1.11 Options for fish passage improvement:

- *Priority for action*: Low.
  This barrier is completely by-passable via the main river.

- *Consideration of options:*
  Removal of entire structure as it is no longer serving a purpose. This would also restore some natural features to the river and the riparian habitat.

3.3.2 Hanworth Culvert (ID 990010)

3.3.2.1 Location:

- *GPS*: 51.449239, -0.38958604
- *Plan of site*: No site plan available
- *Distance from Thames confluence*: 5773m
- *Distance to next structure downstream*: 3541m
- *Number of structures downstream (direct route to Thames confluence)*: 17 (via River Crane) or 6 (via lower Duke of Northumberland's River)
- *Distance from next structure upstream*: 1229m

3.3.2.3 Brief description:

Culvert of 235m in length under the train line at Hanworth. Although the river is culverted, the depth, flow and width of the channel is unchanged.

3.3.2.3 Photos:

No photos available

3.3.2.4 Plan of site:

Figure 3.3.2.4a: Map of Hanworth Culvert flowing under the train tracks from the Green Circle to Red Circle.

3.3.2.5. Structure dimensions:

Channel width	5m
Barrier width at crest	5m
Wetted width	5m
Transversal sections	1
Effective length	235m

3.3.2.6 Impact of the structure on habitat:

As a result of no natural light inside the culvert, there would be no plant growth in the river and fortified river banks.

3.3.2.7 Ownership and function:

- *Landowner and operator:* Network Rail
- *Original purpose of structure:* To divert the river under the railway line
- *Current uses and value of structure:* To divert the river under the railway line

3.3.2.8 Survey Conditions:

- *Antecedent conditions:* Light rain/drizzle within past two to three days
- *Flow Conditions:* Summer low flows
- *Was the structure submerged or dry?* No
- *Degree of estimation:* All measurements estimated from gridreferencefinder.com

3.3.2.9 Upstream fish passage assessment

	Flow conditions	**Passability score**	**Reason/s**
Coarse fish	Low	0.6	Length of culvert may present a barrier
	High	0.6	Length of culvert may present a barrier
Juvenile eels	Low	0.6	Length of culvert may present a barrier
	High	0.6	Length of culvert may present a barrier

3.3.2.10 Downstream fish passage assessment

	Flow conditions	**Passability score**	**Reason/s**
Coarse fish	Low	1	
	High	1	
Adult eels	Low	1	
	High	1	

3.3.2.11 Options for fish passage improvement

- *Priority for action*: Medium

- *Consideration of options:*
  There are limited options available to modify this structure due to its purpose and function. The provision of artificial lighting could be made in order to ensure that low light levels do not deter fish passage.

  There is electric lighting in the pedestrian tunnel adjacent to the river so this could potentially be viable.

3.3 Brazil Mill Woods Barrier 1 (ID 990011)

3.3.3.1 Location:

- *GPS*: 51.456141, -0.39983608
- *Distance from Thames confluence*: 7003m
- *Distance to next structure downstream*: 1229m
- *Number of structures downstream (direct route to Thames confluence)*: 18 (via River Crane) or 7 (via lower Duke of Northumberland's River)
- *Distance from next structure upstream*: 135m

3.3.3.2 Brief description:

This barrier is in two sections: (1) ~10m culvert in a semi-circular shape made from brick, followed by (2) a vertical overshot sluice made from brick, wood and metal. The river channel is narrowed upstream of the barrier making the water over the sluice especially fast flowing and turbid.

3.3.3.3 Photos:

Figure 3.3.3.3a (left): Brazil Mill Woods Barrier 1 viewed from downstream. The culvert entrance to the barrier is visible at the right bank.

Figure 3.3.3.3b (right): Brazil Mill Woods Barrier 1 viewed from upstream at left bank, showing the water flowing over the vertical overshot sluice

3.3.3.4 Plan of site:

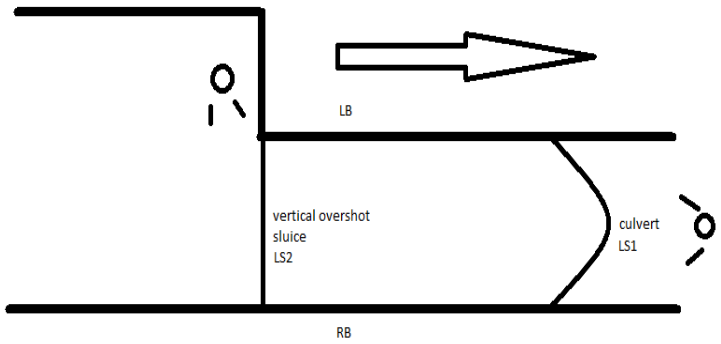

Figure 3.3.3.4a: Site plan for Brazil Mill Woods Barrier 1

3.3.3.5 Structure dimensions:

Channel width	5.05m
Barrier width at crest	1.6m
Wetted width	1.6m
Transversal sections	1
Longitudinal sections	2
Hydraulic head	1.05m

3.3.3.6 Impact of the structure on habitat:

The structure forces the river over a narrow sluice gate. Upstream of the sluice gate excessive siltation has occurred. Downstream of the structure is a large weir pool that offers good habitat to coarse fish and adult eels. The pool provides a deeper area for fish to seek refuge during extreme low flows. The pool also provides good recruitment habitat for juvenile coarse fish.

3.3.3.7 Ownership and function

- *Landowner and operator:* London Borough of Hounslow
- *Original purpose of structure:* Mill race used to house water wheel.
- *Current uses and value of structure:* No current use. Holds value as a historical asset.

3.3.3.8 Survey Conditions

- *Antecedent conditions:* Heavy rainfall within past two to three days
- *Flow Conditions:* Elevated
- *Was the structure submerged or dry?* No
- *Degree of estimation:* Measurements partially undertaken – outlet of the sluice could not be accessed.

3.3.3.9 Upstream fish passage assessment

	Flow conditions	**Passability score**	**Reason/s**
Coarse fish	Low	0	Hydraulic head; High flow; Turbulence
	High	0	Hydraulic head; High flow;

			Turbulence
Juvenile eels	Low	0	Hydraulic head; High flow; Turbulence
	High	0	Hydraulic head; High flow; Turbulence

3.3.3.10 Downstream fish passage assessment

	Flow conditions	Passability score	Reason/s
Coarse fish	Low	1	
	High	1	
Adult eels	Low	1	
	High	1	

3.3.3.11 Options for fish pass passage

- *Priority for action:* High

- *Consideration of options*
  Total removal of this obstruction is probably not a viable option due to the historic value of the structure. The mill race is a remnant of one of the historic watermills at Brazil Mill Woods.

  The structure could be made passable with minimal alteration however. The river is forced over the mill race via a series of stop logs that retain water upstream. The stop logs could be modified or replaced to house a larinier fish pass without having to alter the structure of the millrace itself. It could be ensured that the same level of water is retained upstream, in order to ensure that the modification did not have a negative effect on water level management.

  The larinier fish pass would have to overcome a hydraulic head difference of 1.05m. This would be easily achievable with a one flight larinier pass. The weir pool preceding the barrier is deep enough to provide the depth required for the outlet of the pass. The head of water retained upstream of the obstruction should be able to provide sufficient flows and depths for the pass to function efficiently.

  In addition to the larinier fish pass, a closed type eel pass could be provided for juvenile eels. Currently there is no suitable climbing substrate for eels in this location. Water velocities in the tunnel preceding the mill race may also be too high for juvenile eels during times of high flow. A closed type eel pass could bypass this tunnel, providing fish passage from the slower flows of the weir pool downstream.

3.3.4 Brazil Mill Woods Barrier 2 (ID 278508)

3.3.4.1 Location

- *GPS*: 51.457232, -0.40067598
- *Distance from Thames confluence*: 7137m
- *Distance to next structure downstream*: 135m
- *Number of structures downstream (direct route to Thames confluence)*: 19 (via River Crane) or 8 (via lower Duke of Northumberland's River)
- *Distance from next structure upstream*: 102m

3.3.4.2 ***Brief description*:**

Vertical barrier made from pre-cast concrete and timber in a V-shape with three transversal sections – there are two wooden planks at the left and right banks, with a notch in the centre. The entire barrier is drowned at the time of survey.

3.3.4.3 Photos*:*

Figure 3.3.4.3a (left): Brazil Mill Woods Barrier 2 viewed from downstream

Figure 3.3.4.3b (right): Brazil Mill Woods Barrier 2 viewed from upstream

Figure 3.3.4.3c: Brazil Mill Woods Barrier 2 viewed along the crest from right bank

3.3.4.4 Plan of site:

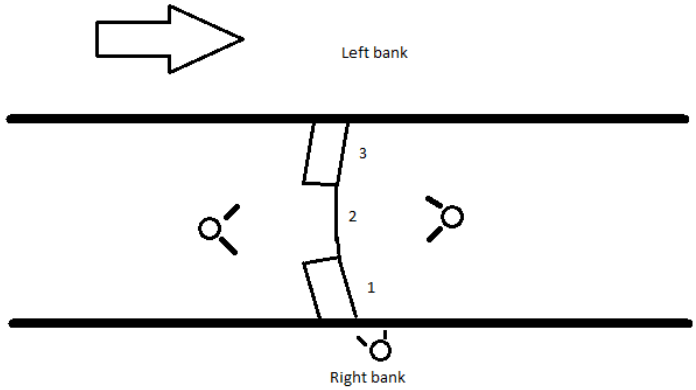

Figure 3.3.4.5a: Site plan for Brazil Mill Woods Barrier 2

3.3.4.5 Structure dimensions:

Channel width	9m
Barrier width at crest	9.2m
Wetted width	9.2m
Transversal sections	3
Hydraulic head	0m

3.3.4.6 Impact of the structure on habitat:

Minimal. At lower flows, the wooden planks may increase water velocity through the centre of the barrier. This is effect is expected to be positive due to the deeper area it will provide during times of low flow.

3.3.4.7 Ownership and function:

- *Landowner and operator:* London Borough of Hounslow. Access via Brazil Mill Woods footpath.
- *Original purpose of structure:* Water level management in relation to historic watermills at Brazil Mill Wood.
- *Current uses and value of structure:* Water level management in relation to the flow split between the River Crane and Brazil Mill Woods Mill Stream.

3.3.4.8 Survey Conditions:

- *Antecedent conditions:* Heavy rainfall within past two to three days
- *Flow Conditions:* Elevated
- *Was the structure submerged or dry?* Drowned
- *Degree of estimation:* All measurements undertaken

3.3.4.9 Upstream fish passage assessment

	Flow conditions	**Passability score**	**Reason/s**
Coarse fish	Low	1	
	High	1	

Juvenile eels	Low	1	
	High	1	

3.3.4.10 Downstream fish passage assessment

	Flow conditions	Passability score	Reason/s
Coarse fish	Low	1	
	High	1	
Adult eels	Low	1	
	High	1	

3.3.5.11 Options for fish passage improvement

Priority for action: Low. This barrier is passable.

Consideration of options: None

3.3.5 Brazil Mill Woods Barrier 3 (ID 278499)

3.3.5.1 Location:

- *GPS*: 51.458059, -0.40130921
- *Distance from Thames confluence*: 7239m
- *Distance to next structure downstream*: 102m
- *Number of structures downstream (direct route to Thames confluence)*: 20 (via River Crane) or 9 (via lower Duke of Northumberland's River)
- *Distance from next structure upstream*: 3080m

3.3.5.2 Brief description:

Vertical weir made from pre-cast concrete in a rough V-shape with three transversal sections.

3.3.5.3 Photos:

Figure 3.3.5.3a (left): Brazil Mill Woods Barrier 3 viewed from downstream.

Figure 3.3.5.3b (right): Brazil Mill Woods Barrier 3 viewed from upstream at right bank

Figure 3.3.5.3c: Brazil Mill Woods Barrier 3 viewed along the crest from right bank

3.3.5.4 Plan of site:

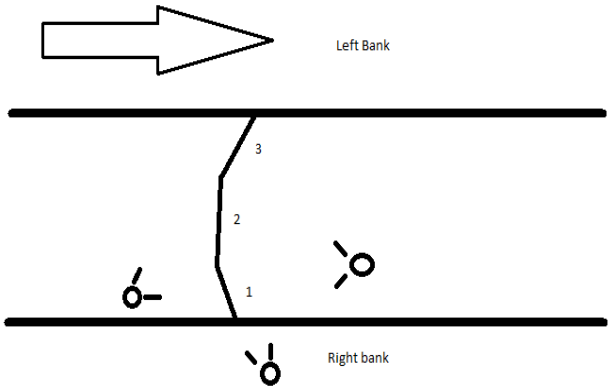

Figure 3.3.5.4a: Site plan for Brazil Mill Woods Barrier 3

3.3.5.5 Structure dimensions:

Channel width	14.8m
Barrier width at crest	15.4m
Wetted width	15.4m
Transversal sections	3
Hydraulic head	0.25m

3.3.5.6 Impact of the structure on habitat:

Holds back water upstream; creates a small weir pool downstream, providing a range of depths and flows for different age classes and species of coarse fish.

3.3.5.7 Ownership and function:

- *Landowner and operator:* London Borough of Hounslow. Access via Brazil Mill Wood footpath.
- *Original purpose of structure:* Water level management
- *Current uses and value of structure:* Water level management

3.3.5.8 Survey Conditions:

- *Antecedent conditions:* Heavy rainfall within past two to three days
- *Flow Conditions:* Elevated
- *Was the structure submerged or dry?* No
- *Degree of estimation:* All measurements undertaken

3.3.5.9 Upstream fish passage assessment

	Flow conditions	**Passability score**	**Reason/s**
Coarse fish	Low	0.3	Hydraulic head
	High	0.6	Hydraulic head
Juvenile eels	Low	1	Climbing substrate present
	High	1	Climbing substrate present

3.3.5.10 Downstream fish passage assessment

	Flow conditions	Passability score	Reason/s
Coarse fish	Low	1	
	High	1	
Adult eels	Low	1	
	High	1	

3.3.5.11 Options for fish passage improvement

- *Priority for action*: High.
  This would open up a large stretch of river to Cranford.

- *Consideration of options*
  The obstruction is partially passible but has a high impact on upstream migration, with only one third of fish being able to ascend it. The most suitable option for easement would be to breach the centre of the weir in order to reduce its hydraulic head, which is the main factor that is preventing fish passage. There are sufficient volumes of gravel impounded behind the barrier to wash through this breached area to improve the gradient of the river bed.

  Ensuring fish passage in this location would provide unimpeded access to the next barrier 3km upstream. This reach of river provides high quality habitat including important recruitment areas for juvenile coarse fish and semi online still water habitats for adult eels.

3.3.6 Crane Bank Barrier 1 (ID 193617)

3.3.6.1 Location:

- *GPS*: 51.48075, -0.41684702
- *Distance from Thames confluence*: 10319m
- *Distance to next structure downstream*: 3080m
- *Number of structures downstream (direct route to Thames confluence)*: 21 (via River Crane) or 10 (via lower Duke of Northumberland's River)
- *Distance from next structure upstream*: 1079m

3.3.6.2 Brief description:

Sloping weir made from pre-cast concrete and small boulders, giving the water flowing down the weir a rough rather than smooth trajectory.

3.3.6.3 Photos:

Figure 3.3.6.3a (left): Crane Bank Barrier 1 viewed from downstream at right bank

Figure 3.3.6.3b (right): Crane Bank Barrier 1 viewed from upstream

Figure 3.3.6.3c: Crane Bank Barrier 1 viewed along the crest from left bank

3.3.6.4 Plan of site:

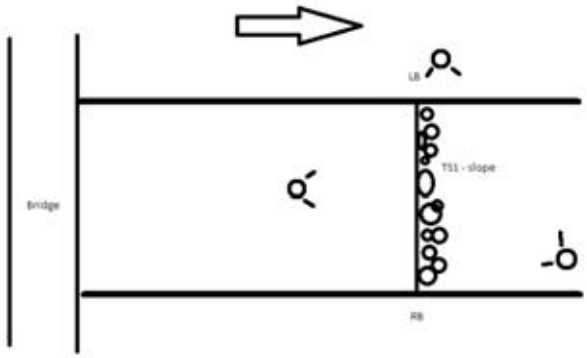

Figure 3.3.6.4a: Site plan for Crane Bank Barrier 1

3.3.6.5 Structure dimensions:

Channel width	11.7m
Barrier width at crest	11.7m
Wetted width	9.7m
Transversal sections	1
Hydraulic head	0.38m
Effective length	1.85m
Gradient	21%

3.3.6.6 Impact of the structure on habitat:

Holds back water upstream resulting in minor siltation. The sloped weir has created a pool at its outlet that offers deeper, slower flowing habitat with good riparian cover. The pool provides good recruitment habitat to juvenile fish and a deeper area for aquatic wildlife to persist during times of low flow.

3.3.6.7 Ownership and function

- *Landowner and operator:* London Borough of Hounslow. Access via Crane Bank in winter or Berkeley Park, Hillingdon during summer (giant hog weed present at Crane Bank during summer)
- *Original purpose of structure:* Water level management
- *Current uses and value of structure:* Water level management

3.3.6.8 Survey Conditions

- *Antecedent conditions:* Light rain/drizzle within past two to three days
- *Flow Conditions:* Summer low level
- *Was the structure submerged or dry?* No
- *Degree of estimation:* All measurements undertaken

3.3.6.9 Upstream fish passage assessment

	Flow conditions	**Passability score**	**Reason/s**
Coarse fish	Low	0	Depth of water across slope
	High	0.6	Effective length and gradient of slope

Juvenile eels	Low	1	Climbing substrate present
	High	1	Climbing substrate present

3.3.6.10 Downstream fish passage assessment

	Flow conditions	Passability score	Reason/s
Coarse fish	Low	0	Depth of water across slope
	High	1	Should be sufficient water depth
Adult eels	Low	0.3	Depth of water across slope
	High	1	Should be sufficient water depth

3.3.6.11 Options for fish passage improvement

- *Priority for action*: Medium

- *Consideration of options:*
  The hydraulic head retained by the barrier appears to be essential to maintaining water levels upstream. Dropping water levels at this point would result in a very shallow area of river around the Bath Road (A4) road bridge (Cranford bridge), which may impede fish migration.

  The most suitable option to ensure fish passage at this barrier is the provision of a rock ramp. There is sufficient space downstream of the sloped weir to ensure that the rock ramp has the correct gradient in order to permit fish passage. Due to low water levels upstream of the barrier two baffles could be fitted to either side of the crest of the weir in order to increase water depth over the rock ramp and ensure that it functions efficiently. A rock ramp would have a low visual impact in this location and integrate well with the natural aesthetics of the river in this location.

3.3.7 Cranford Park Barrier 1 (ID 265972)

3.3.7.1 Location:

- *GPS*: 51.488714, -0.41259576
- *Distance from Thames confluence*: 11398m
- *Distance to next structure downstream*: 1079m
- *Number of structures downstream (direct route to Thames confluence)*: 22 (via River Crane) or 11 (via lower Duke of Northumberland's River)
- *Distance from next structure upstream*: 371m

3.3.7.2 Brief description:

Sloping weir made from pre-cast concrete in two longitudinal sloping sections with varied gradient.

3.3.7.3 Photos:

Figure 3.3.7.3a (left): Cranford Park Barrier 1 viewed from downstream at left bank

Figure 3.3.7.3b (right): Cranford Park Barrier 1 viewed from upstream

Figure 3.3.7.3c: Cranford Park Barrier 1 viewed along the crest from left bank

3.3.7.4 Plan of site:

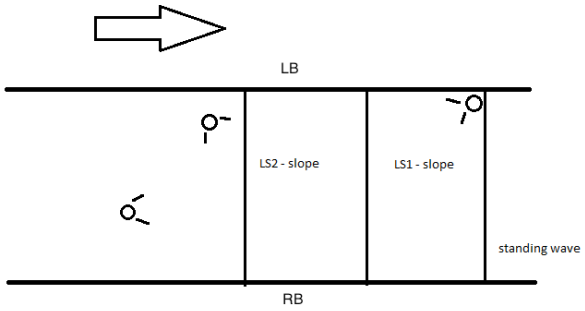

Figure 3.3.7.4a: Site plan for Cranford Park Barrier 1

3.3.7.5 Structure dimensions:

Channel width	9m
Barrier width at crest	5.9m
Wetted width	5.9m
Transversal sections	1
Longitudinal sections	2
Hydraulic head (limiting)	0.13m
Effective length (total)	9.81m
Gradient (limiting)	5.8%

3.3.7.6 Impact of the structure on habitat:

Holds back water upstream resulting in excessive siltation; long and shallow concreted channel provides no suitable area for marginal plants to establish.

3.3.7.7 Ownership and function:

- *Landowner and operator:* London Borough of Hillingdon/Hounslow. Environment Agency. Access via Avenue Park, Hounslow or Cranford Park, Hillingdon.
- *Original purpose of structure:* Telemetry station.
- *Current uses and value of structure:* Telemetry station.

3.3.7.8 Survey Conditions

- *Antecedent conditions:* Heavy rain within past two to three days
- *Flow Conditions:* Elevated
- *Was the structure submerged or dry?* No
- *Degree of estimation:* All measurements undertaken

3.3.7.9 Upstream fish passage assessment

	Flow conditions	**Passability score**	**Reason/s**
Coarse fish	Low	0	Depth of water across slope; high velocity
	High	0.6	Effective length of slope

Juvenile eels	Low	0	No climbing substrate; depth of water across slope; high velocity
	High	0	No climbing substrate; high velocity

3.3.7.10 Downstream fish passage assessment

	Flow conditions	Passability score	Reason/s
Coarse fish	Low	0.3	Depth of water across slope
	High	1	Should be sufficient water depth
Adult eels	Low	0.6	Depth of water across slope
	High	1	Should be sufficient water depth

3.3.7.11 Options for fish passage improvement

- *Priority for action*: High

- *Consideration of options*
  The telemetry station at Cranford Park serves an important purpose and any modification should be sympathetic to its current function.

  A baffle type fishway would be suitable to ease this obstruction but is likely to disrupt telemetry readings. The provision of chevron baffles could be made to one side of the sloped weir providing that the telemetry station could be recalibrated to function affectively. Breaching or complete removal would have an even more profound affect, but would be a good option if the Environment Agency were prepared to reconsider the location of their asset.

  Alternatively a larinier fish pass could be installed, with its inlet upstream and outlet downstream of the weir, in order to provide fish passage without any major alterations to the structure itself. Further research is required to evaluate whether such a pass would function efficiently in this location and if it would have an impact on the current function of the structure.

3.3.8 Cranford Park Culvert (ID 990013)

3.3.8.1 Location:

- *GPS*: 51.492014, -0.41194815
- *Distance from Thames confluence*: 11769m
- *Distance to next structure downstream*: 371m
- *Number of structures downstream (direct route to Thames confluence)*: 23 (via River Crane) or 12 (via lower Duke of Northumberland's River)
- *Distance from next structure upstream*: 741m

3.3.8.2 Brief description:

Culvert of 105m in length under M4 at Cranford. Depth and flow is unaffected but the river is in a concrete channel underground for this entire length.

3.3.8.3 Photos:

No photos available

3.3.8.4 Plan of site:

No site plan available

3.3.8.5 Structure dimensions:

Channel width	12m
Barrier width at crest	12m
Wetted width	12m
Transversal sections	1
Effective length	105m

3.3.8.6 Impact of the structure on habitat:

As a result of no natural light inside the culvert, there would be no plant growth in the river; concreted and fortified river banks

3.3.8.7 Ownership and function:

- *Landowner and operator:* London Borough of Hounslow
- *Original purpose of structure:* Divert the river under the M4
- *Current uses and value of structure:* Divert the river under the M4

3.3.8.8 Survey Conditions:

- *Antecedent conditions:* Light rain/drizzle within past two to three days
- *Flow Conditions:* Summer low flows
- *Was the structure submerged or dry?* No
- *Degree of estimation:* All measurements estimated from gridreferencefinder.com

3.3.8.9 Upstream fish passage assessment

	Flow conditions	Passability score	Reason/s
Coarse fish	Low	0.6	Length of culvert may present a barrier
	High	0.6	Length of culvert may present a barrier
Juvenile eels	Low	0.6	Length of culvert may present a barrier
	High	0.6	Length of culvert may present a barrier

3.3.8.10 Downstream fish passage assessment

	Flow conditions	Passability score	Reason/s
Coarse fish	Low	1	Sufficient depth and flow
	High	1	Sufficient depth and flow
Adult eels	Low	1	Sufficient depth and flow
	High	1	Sufficient depth and flow

3.3.8.11 Options for fish passage improvement

- *Priority for action*: Low.
  The structure does not obstruct the river channel however length (i.e. low light levels) may impact fish migration.

- *Consideration of options:*
  There are limited options available to modify this structure due to its purpose and function. The provision of artificial lighting could be made in order to ensure that low light levels do not deter fish passage.

3.3.9 Hillingdon Barrier 1 (ID 265978)

3.3.9.1 Location:

- *GPS*: 51.498478, -0.41048452
- *Distance from Thames confluence*: 12510m
- *Distance to next structure downstream*: 741m
- *Number of structures downstream (direct route to Thames confluence)*: 24 (via River Crane) or 13 (via lower Duke of Northumberland's River)
- *Distance from next structure upstream*: 7207m

3.3.9.2 Brief description:

Vertical weir made from concrete poured-on-site. The barrier is notched at right bank.

3.3.9.3 Photos:

Figure 3.3.9.3.a (left): Hillingdon Barrier 1 viewed from downstream.

Figure 3.3.9.3b (right): Hillingdon Barrier 1 viewed from upstream

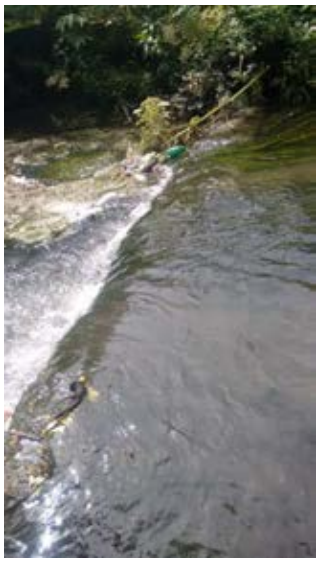

Figure 3.3.9.3c: Hillingdon Barrier 1 viewed along the crest from left bank

3.3.9.4 Plan of site:

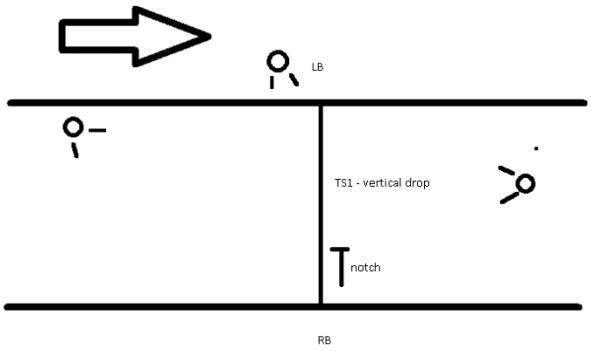

Figure 3.9.4a: Site plan for Hillingdon Barrier 1

3.3.9.5 Structure dimensions:

Channel width	6.7m
Barrier width at crest	6.7m
Wetted width	4.7m
Transversal sections	1
Hydraulic head	0.15m

3.3.9.6 Impact of the structure on habitat:

Holds back water upstream resulting in low levels of siltation.

3.3.9.7 Ownership and function:

- *Landowner and operator:* London Borough of Hillingdon. Access via footpath downstream of road bridge providing no giant hogweed is present.
- *Original purpose of structure:* Water level management
- *Current uses and value of structure:* Water level management

3.3.9.8 Survey Conditions:

- *Antecedent conditions:* No rain within past two to three days
- *Flow Conditions:* Summer low level
- *Was the structure submerged or dry?* No
- *Degree of estimation:* All measurements undertaken

3.3.9.9 Upstream fish passage assessment

	Flow conditions	**Passability score**	**Reason/s**
Coarse fish	Low	0.6	Water depth; hydraulic head
	High	1	Should be sufficient depth and hydraulic head would reduce
Juvenile eels	Low	1	Climbing substrate present
	High	1	Climbing substrate present

3.3.9.10 Downstream fish passage assessment

	Flow conditions	Passability score	Reason/s
Coarse fish	Low	1	
	High	1	
Adult eels	Low	1	
	High	1	

3.3.9.11 Options for fish passage improvement

- *Priority for action*: Low.
  This barrier is partially passable.

- *Consideration of options:*
  The weir is lightly notched close to the right bank of the river. This notch could be widened or the weir could be completely removed in order to move the barrier's passability score from a 0.6 to a 1.0.

3.4 Hounslow Mill Stream

3.4.1 Mill Stream Barrier 1 (ID 283927)

3.4.1.1 Location

- *GPS*: 51.445187, -0.38072033
- *Distance from Thames confluence*: 6124m
- *Distance to next structure downstream*: 2773m
- *Number of structures downstream (direct route to Thames confluence)*: 17 (via River Crane) or 6 (via lower Duke of Northumberland's River)
- *Distance from next structure upstream*: 2244m

3.4.1.2 Brief description:

Weir consisting of a three longitudinal sections: two sloping concrete sections followed by steps made from poured concrete and masonry. The sloping section was covered under a footbridge and was narrow with a shallow depth of water running over.

3.4.1.3 Photos:

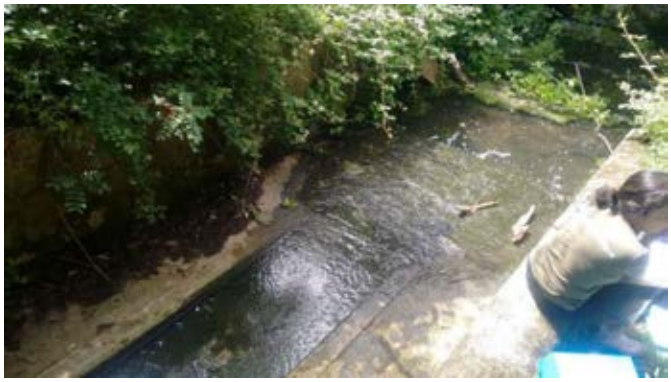

Figure 3.4.1.3a (left): Sloping concrete section of the weir viewed from upstream at right bank.

Figure 3.4.1.3b. (right): Sloping section of the weir viewed at mid channel from downstream.

Figure 3.4.1.3c (left): Steps made from poured concrete and masonry. Photo taken at right bank from downstream.

Figure 3.4.1.3d (right): Stepped part of the weir viewed along the crest at right bank.

3.4.1.4 Plan of site:

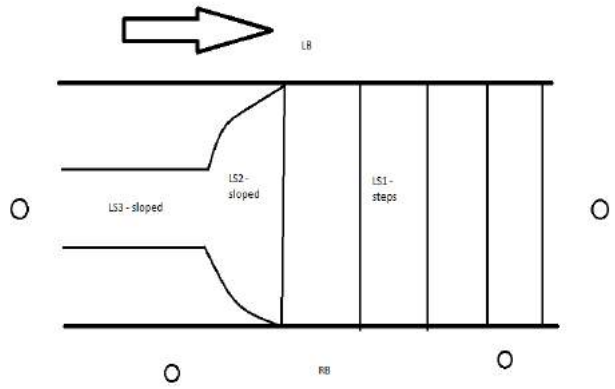

Figure 3.4.1.4a: Site plan for Mill Stream Barrier 1

3.4.1.5 Structure dimensions:

Channel width	4.7m
Barrier width at crest	3.37m
Wetted width	3.37m
Transversal sections	1
Longitudinal sections	3
Hydraulic head	1.1m
Effective length	10.7m
Gradient	1%
Number of steps	5
Height of step (limiting)	0.55m
Length of step (limiting)	3.2.63m

3.4.1.6 Impact of the structure on habitat:

The sloping chute at the head of the structure is concreted and does not support aquatic flora or fauna. The steps preceding the chute offered more complex habitat due to increased depth and ability to support marginal plant life. The structure does not seem to impact habitat up or downstream. The millstream is narrow in comparison to the main river and provides a complex array of riparian cover and submerged aquatic plant life.

3.4.1.7 Ownership and function:

- *Landowner and operator:* London Borough of Richmond. Access via Crane Park.
- *Original purpose of structure:* Water level management in relation to historic watermills.
- *Current uses and value of structure:* Retains a head of water in the Hounslow Millstream.

3.4.1.8 Survey Conditions

- *Antecedent conditions:* Heavy rainfall within past two or three days
- *Flow Conditions:* Summer low level
- *Was the structure submerged or dry?* No
- *Degree of estimation:* All measurements undertaken

3.4.1.9 Upstream fish passage assessment

	Flow conditions	Passability score	Reason/s
Coarse fish	Low	0	Low water depth at longitudinal sections
	High	0	Maximum step height is too high.
Juvenile eels	Low	1	Climbing substrate present
	High	1	Climbing substrate present

3.4.1.10 Downstream fish passage assessment

	Flow conditions	Passability score	Reason/s
Coarse fish	Low	0	Low water depth at longitudinal sections
	High	1	High flow of water reducing damaging structures to downstream migrants.
Adult eels	Low	0	Low water depth at longitudinal sections
	High	1	High flow of water reducing damaging structures to downstream migrants.

3.4.1.11 Options for fish passage improvement

- *Priority for action*: Low.
  The main river offers an alternative route for fish migration and a larger area of good quality habitat.

- *Consideration of options:*
  Due to the mill stream's limited flow and depth, there are few options to make this obstruction passable. A report conducted by the Wild Trout Trust recommended making the chute at the inlet of the structure passable via bolting two baffles to the concrete apron in order to increase depth of the channel upstream. The report also recommended that stones were removed from the stepped structure to create narrow notches in order to reduce hydraulic head and make each step passable (Fig 3.4.1.11a) (The Wild Trout Trust, 2012).

  At the time of survey there was very little water passing through the structure, so it is uncertain whether these measures would be effective for improving fish passage at low flows. Notching each step could potentially lower the water depth of each step or cause them to dry out completely. Such an improvement may improve fish passage at high flows however.

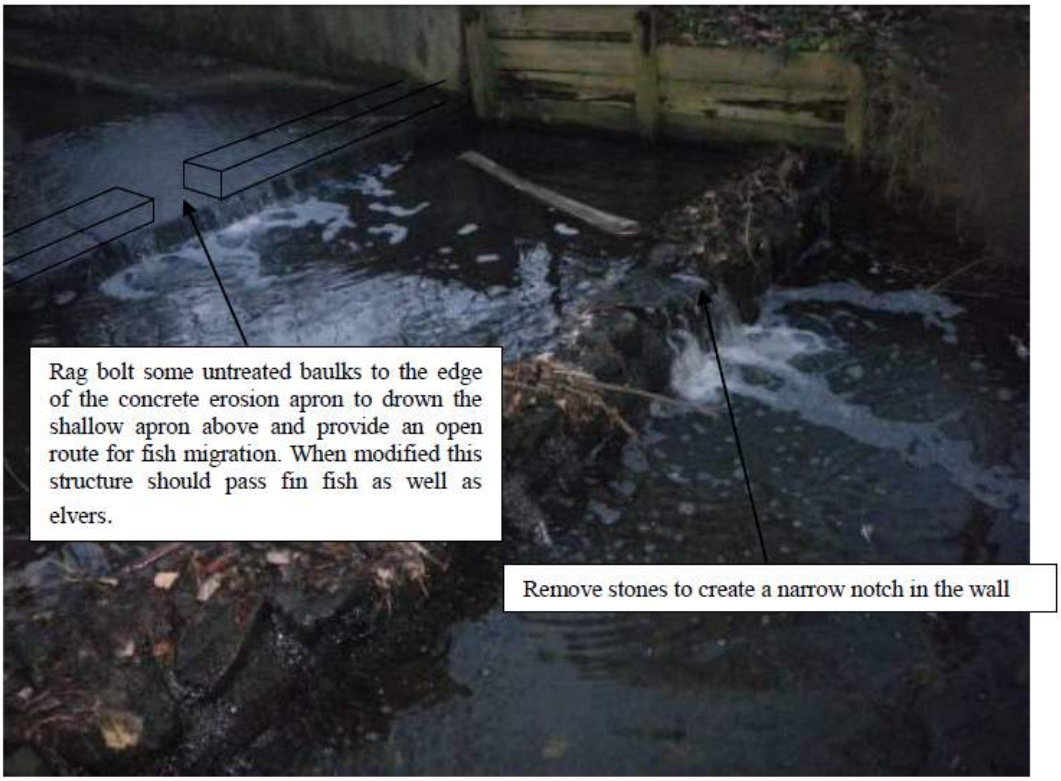

Figure 3.4.1.11a: Recommendation for barrier easement provided by the Wild Trout Trust

3.4.2 Mill Stream Barrier 2 (ID 990012)

3.4.2.1 Location:

- *GPS*: 51.456141, -0.39983608
- *Distance from Thames confluence*: 7003m
- *Distance to next structure downstream*: 1229m
- *Number of structures downstream (direct route to Thames confluence)*: 18 (via River Crane) or 7 (via lower Duke of Northumberland's River)
- *Distance from next structure upstream*: 177m

3.4.2.2 Brief description:

Weir in three longitudinal sections: (1) a chute on the left bank with abstracting water from the Mill Stream (2) a vertical concrete structure where the river takes a sharp 90° angle and (3) a culvert which diverts water from the millstream into the River Crane.

3.4.2.3 Photos:

Figure 3.4.2.3a (left): Viewed from upstream, the chute on the left directs the flow of water to vertical drop where it gets culverted and opens up downstream

Figure 3.4.2.3b (right): Viewed from downstream at right bank, the water directed from the culvert opens up into the river.

Figure 3.4.2.3c: The chute on the left bank just before the vertical drop where the course of the river changes.

3.4.2.4 Plan of site:

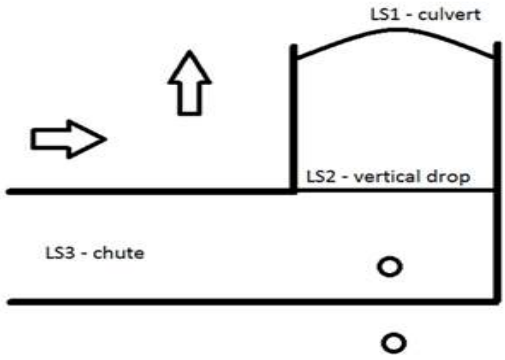

Figure 3.4.2.4a: Site plan for Mill Stream Barrier 2

3.4.2.5 Structure dimensions:

Channel width	2m
Barrier width at crest	2m
Wetted width	2m
Transversal sections	1
Longitudinal sections	3
Hydraulic head	0.5m

3.4.2.6 Impact of the structure on habitat:

The chute and culvert have a concrete bed and do not support aquatic flora. The tunnel culvert is straightened, narrow and darkened. Downstream of the structure, in the River Crane, is a large weir pool that offers good habitat to coarse fish and adult eels. The pool provides a deeper area for fish to seek refuge during extreme low flows. The pool also provides good recruitment habitat for juvenile coarse fish.

3.4.2.7 Ownership and function

- *Landowner and operator:* London Borough of Hounslow
- *Original purpose of structure:* Historical structure consisting of a millrace.
- *Current uses and value of structure:* Historical structure consisting of a millrace.

3.4.2.8 Survey Conditions

- *Antecedent conditions:* Heavy rainfall within the past two or three days
- *Flow Conditions:* Elevated
- *Was the structure submerged or dry?* No
- *Degree of estimation:* All measurements undertaken

3.4.2.9 Upstream fish passage assessment

	Flow conditions	**Passability score**	**Reason/s**
Coarse fish	Low	0	Large hydraulic head at the vertical drop

	High	0	Large hydraulic head at the vertical drop
Juvenile eels	Low	1	Climbing substrate present
	High	1	Climbing substrate present

3.4.2.10 Downstream fish passage assessment

	Flow conditions	**Passability score**	**Reason/s**
Coarse fish	Low	1	Sufficient water depth
	High	1	Sufficient water depth
Adult eels	Low	1	Sufficient water depth
	High	1	Sufficient water depth

3.4.2.11 Options for fish passage improvement

- *Priority for action*: Low. This would provide upstream passage into the Mill Stream from the Crane so this does not ease fish passage on the Crane.

- *Consideration of options*
  None recommended. Easing fish passage is not advantageous in this location as it would provide access to the millstream from the River Crane. The upper millstream is impeded by another obstruction that requires easing in order to provide access back to the main river.

3.4.3 Mill Stream Barrier 3 (ID 278496)

3.4.3.1 Location

- *GPS*: 51.455934, -0.39910928
- *Distance from Thames confluence*: 6964m
- *Distance to next structure downstream*: 1192m
- *Number of structures downstream (direct route to Thames confluence)*: 19 (via River Crane) or 8 (via lower Duke of Northumberland's River)
- *Distance from next structure upstream*: 200m

3.4.3.2 Brief description:

A sloping weir in the middle of an obstruction made of pre-cast concrete and stone masonry. The large breezeblock structures either side and behind the sloping weir, forces the river through a narrow gap, leading to high water velocities and high turbidity.

3.4.3.3 Photos:

Figure 3.4.3.3a (left): Mill Stream Barrier 3 viewed from downstream

Figure 3.4.3.3b (right): Mill Stream Barrier 3 viewed along the crest from right bank showing the large breezeblock structures on either side of the weir.

Figure 3.4.3.3c (left): Photo of the breeze blocks behind the barrier shown from left bank

Figure 3.4.3.3d (right): Mill Stream Barrier 3 viewed from upstream at left bank. The strong velocity associated with the sloping part of the weir can be seen at the foot of the slope.

3.4.3.4 Plan of site:

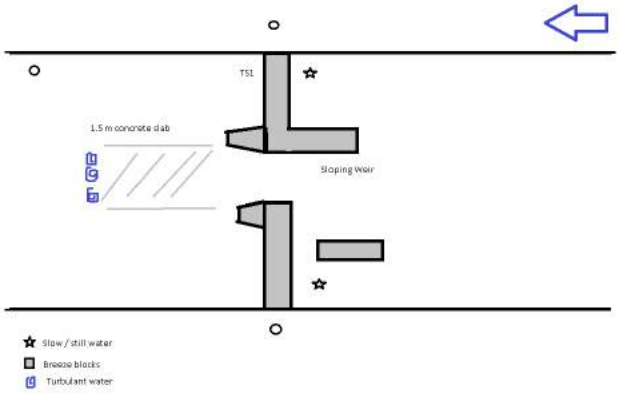

Figure 3.4.3.4a: Site plan of Mill Stream Barrier 3

3.4.3.5 Structure dimensions:

Channel width	7.5m
Barrier width at crest	1.5m
Wetted width	1.5m
Transversal sections	1m
Effective length	3.75m
Gradient	29%

3.4.3.6 Impact of the structure on habitat:

The structure obstructs a large part of the river channel, which has led to excessive siltation and the accumulation of debris upstream. The concrete slope stretches >10m and the high velocities of water passing over this has led to a pool being scoured downstream. The pool provides good habitat for coarse fish and adult eels and offers a deeper area for fish to seek refuge during extreme low flows. The pool also provides good recruitment habitat for juvenile coarse fish.

3.4.3.7 Ownership and function

- *Landowner and operator:* London Borough of Hounslow, Access via Brazil Mill Wood island.
- *Original purpose of structure:* Historic water level management. The structure was used to retain a head of water in order to provide sufficient flows to the mill race located nearby on the main river.
- *Current uses and value of structure:* Redundant structure serving no current purpose.

3.4.3.8 Survey Conditions

- *Antecedent conditions:* Light rain/drizzle within past two or three days
- *Flow Conditions:* Elevated
- *Was the structure submerged or dry?* No
- *Degree of estimation:* All measurements undertaken (apart from hydraulic head)

3.4.3.9 Upstream fish passage assessment

	Flow conditions	Passability score	Reason/s
Coarse fish	Low	0	Velocity of water and gradient
	High	0	Velocity of water would increase
Juvenile eels	Low	0	No climbing substrate
	High	0	No climbing substrate

3.4.3.10 Downstream fish passage assessment

	Flow conditions	Passability score	Reason/s
Coarse fish	Low	0	Gradient of slope
	High	0	Gradient of slope
Adult eels	Low	1	Sufficient water depth
	High	1	Sufficient water depth

3.4.3.11 Options for fish passage improvement

- *Priority for action*: Low

- *Consideration of options:*
  The obstruction could be removed in its entirety to ensure fish passage. Removing this structure would have a positive effect on the morphology of the mill stream as it would aid sediment transport and reduce siltation upstream.

3.4.4 Mill Stream Barrier 4 (ID 278497)

3.4.4.1 Location

- *GPS:* 51.457272, -0.40031473
- *Distance from Thames confluence*: 7165m
- *Distance to next structure downstream*: 200m
- *Number of structures downstream (direct route to Thames confluence)*: 20 (via River Crane) or 9 (via lower Duke of Northumberland's River)
- *Distance from next structure upstream*: 1192m

3.4.4.2 Brief description:

Vertical weir barrier in the middle of the river channel. Made from timber and pre-cast concrete. 100% of channel flow is going through the centre of the barrier.

3.4.4.3 Photos*:*

Figure 3.4.4.3a (left): Mill Stream Barrier 4 viewed along the crest from left bank

Figure 3.4.4.3b (right): Mill Stream Barrier 4 viewed from downstream at left bank

Figure 3.4.4.3c: Mill Stream Barrier 4 viewed from upstream

3.4.4.4 Plan of site:

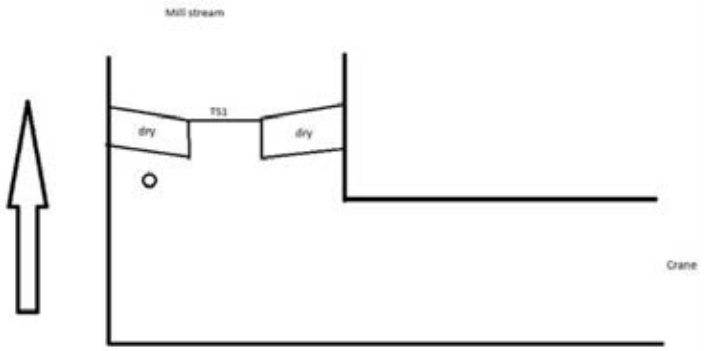

Figure 3.4.4.4a: Site plan for Mill Stream Barrier 4

3.4.4.5 Structure dimensions:

Channel width	8.3m
Barrier width at crest	8.9m
Wetted width	3.5m
Transversal sections	1
Hydraulic head	0.08m

3.4.4.6 Impact of the structure on habitat:

Increased siltation upstream as a result of water being held back behind the barrier.

3.4.4.7 Ownership and function

- *Landowner and operator:* London Borough of Hounslow
- *Original purpose of structure:* Unknown, water level management.
- *Current uses and value of structure:* Unknown, water level management.

3.4.4.8 Survey Conditions

- *Antecedent conditions:* Heavy rainfall within past two or three days.
- *Flow Conditions:* Elevated
- *Was the structure submerged or dry?* No
- *Degree of estimation:* All measurements undertaken

3.4.4.9 Upstream fish passage assessment

	Flow conditions	**Passability score**	**Reason/s**
Coarse fish	Low	0.3	Medium level turbulence and standing wave
	High	1	Medium level turbulence and standing wave would lessen under high flows
Juvenile eels	Low	1	Climbing substrate present
	High	1	Climbing substrate present

3.4.4.10 Downstream fish passage assessment

	Flow conditions	Passability score	Reason/s
Coarse fish	Low	1	Sufficient water depth
	High	1	Sufficient water depth
Adult eels	Low	1	Sufficient water depth
	High	1	Sufficient water depth

3.4.4.10 Options for fish passage improvement

- *Priority for action*: Low

- *Consideration of options:*
  This barrier is partially passable but still has a high impact on fish passage. The barrier could easily be breached at its centre to make it fully passable. The work could be undertaken with hand tools and completed within a day.

  Breaching this barrier may have disadvantages to water level management. The barrier is located at the head of the millstream, where it branches off from the main river. Reducing the hydraulic head of this barrier may reduce flows on the main river downstream of this point. Reducing the flow of the main river may have a negative effect on fish passage or limit easement options for barriers located downstream due to decreased flow and depth.

3.5 Yeading Brook

3.5.1 Ten Acre Woods Barrier 1 (ID 194186)

3.5.1.1 Location

- *GPS*: 51.541798, -0.41816157
- *Distance from Thames confluence*: 19717m
- *Distance to next structure downstream*: 7207m
- *Number of structures downstream (direct route to Thames confluence)*: 25 (via River Crane) or 14 (via lower Duke of Northumberland's River)
- *Distance from next structure upstream*: 1201m

3.5.1.2 Brief description:

Hydrobrake made from cast-in-place concrete. The hydrobrake is short in length but narrows the river channel, thus increasing water velocities at the centre of the structure.

3.5.1.3 Photos:

Figure 3.5.1.3a (left): Ten Acre Woods Barrier 1 viewed from downstream.

Figure 3.5.1.3b (right): Ten Acre Woods Barrier 1 viewed from upstream through the centre of the hydrobrake

3.5.1.4 Plan of site:

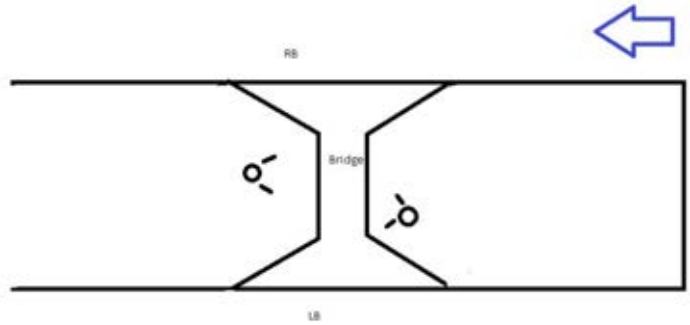

Figure 3.5.1.4a: Site plan for Ten Acre Woods Barrier 1

3.5.1.5 Structure dimensions:

Channel width	4.88m
Barrier width at crest	4.88m
Wetted width	4.88m
Transversal sections	1
Gap width	1.75m
Length of narrowed section	3.70m

3.5.1.6 Impact of the structure on habitat:

Straightened section of the river, bricked banks and concrete base does not allow for complex aquatic habitats and marginal plant life. There is potential for high velocity of water.

3.5.1.7 Ownership and function:

- *Landowner and operator:* Environment Agency
- *Original purpose of structure:* Hydrobrake used to control the flow of water to prevent flooding upstream and downstream.
- *Current uses and value of structure:* Hydrobrake used to control the flow of water to prevent flooding upstream and downstream.

3.5.1.8 Survey Conditions

- *Antecedent conditions:* Light rain/drizzle within past two to three days
- *Flow Conditions:* Summer low level
- *Was the structure submerged or dry?* No
- *Degree of estimation:* All measurements undertaken

3.5.1.9 Upstream fish passage assessment

	Flow conditions	**Passability score**	**Reason/s**
Coarse fish	Low	1	
	High	0.6	Potential for high turbulence
Juvenile eels	Low	1	
	High	0.6	Potential for high turbulence

3.5.1.10 Downstream fish passage assessment

	Flow conditions	**Passability score**	**Reason/s**
Coarse fish	Low	1	
	High	1	
Adult eels	Low	1	
	High	1	

3.5.1.11 Options for fish passage improvement

- *Priority for action*: Low. This barrier is passable.

- *Consideration of options*
  None

3.6 Yeading Brook West

3.6.1 Gutteridge Woods Barrier 1 (ID 453385)

3.6.1.1 Location

- *GPS*: 51.547725, -0.42023478
- *Distance from Thames confluence*: 20711m
- *Distance to next structure downstream*: 994m
- *Number of structures downstream (direct route to Thames confluence)*: 26 (via River Crane) or 15 (via lower Duke of Northumberland's River)
- *Distance from next structure upstream*: 1408m

3.6.1.2 Brief description:

Hydrobrake made from cast-in-place concrete which, although short in length it narrows the river from the wider channel.

3.6.1.3 Photos:

Figure 3.6.1.3a (left): Gutteridge Woods Barrier 1 viewed from upstream showing the hydrobrake narrowing the river channel

Figure 3.6.1.3b (right): Gutteridge Woods Barrier 1 viewed from downstream

3.6.1.4 Plan of site:

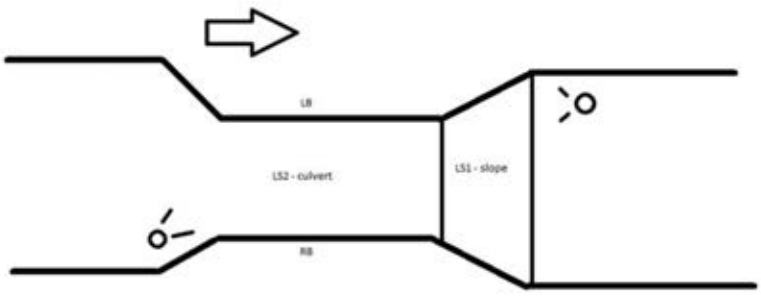

Figure 3.6.1.4a Site plan for Gutteridge Woods Barrier 1

3.6.1.5 Structure dimensions:

Channel width	2.2m
Barrier width at crest	1.75m
Wetted width	1.75m
Longitudinal sections	2
Effective length	4.1m
Gradient	1.2m

3.6.1.6 Impact of the structure on habitat:

Straightened section of the river, bricked banks and concrete base does not allow for complex aquatic habitats and marginal plant life.

3.6.1.7 Ownership and function:

- *Landowner and operator:* Environment Agency
- *Original purpose of structure:* Hydrobrake used to control the flow of water to prevent flooding upstream and downstream.
- *Current uses and value of structure:* Hydrobrake used to control the flow of water to prevent flooding upstream and downstream.

3.6.1.8 Survey Conditions:

- *Antecedent conditions:* Light rain/drizzle within past two to three days
- *Flow Conditions:* Summer low level
- *Was the structure submerged or dry?* No
- *Degree of estimation:* All measurements partially undertaken

3.6.1.9 Upstream fish passage assessment

	Flow conditions	**Passability score**	**Reason/s**
Coarse fish	Low	0	Shallow water depth
	High	0.6	Sufficient water depth but velocity may be higher + length of slope is limiting
Juvenile eels	Low	0.3	No substrate but can potentially pass as water is not turbid and shallow depth of water
	High	0.6	The water depth would lessen

3.6.1.10 Downstream fish passage assessment

	Flow conditions	**Passability score**	**Reason/s**
Coarse fish	Low	0	Shallow water depth
	High	1	Sufficient water depth
Adult eels	Low	0	Shallow water depth
	High	1	Water depth not limiting

3.6.1.11 Options for fish passage improvement

- *Priority for action*: Medium

- *Consideration of options:*
  This structure functions as a hydro brake and is designed to decrease flow conveyance. It is believed to have been installed as part of the 10 Acre Wood flood storage area. It is important that any alterations to this structure maintain its current function.

  The low water depth on the sloped part of this structure is responsible for preventing fish passage. A baffle-type fish way would be a suitable option for increasing water depth and providing resting locations for fish to ascend this structure. The work could be completed within a day and simply involves bolting baffles to the concrete structure to increase water depths.

  It is also worth noting that the flood storage area at 10 Acre Wood is due to be decommissioned. Whether or not this structure will still be essential to water level management after this occurs, this should be assessed by the Environment Agency. If it is no longer required the structure could be removed.

3.6.2 Gutteridge Woods Culvert (ID 990014)

3.6.2.1 Location:

- *GPS*: 51.549475, -0.43813079
- *Distance from Thames confluence*: 22119m
- *Distance to next structure downstream*: 1408m
- *Number of structures downstream (direct route to Thames confluence)*: 27 (via River Crane) or 16 (via lower Duke of Northumberland's River)
- *Distance from next structure upstream*: 1399m

3.6.2.2 Brief description:

Long slightly sloping culvert of 186m made from pre-cast concrete, followed by a small vertical drop. The vertical drop spans the channel at an angle, thus increasing the length of its crest, spreading flows over a wider area than the width of the river channel.

3.6.2.3 Photos:

Figure 3.6.2.3a (left): Gutteridge Woods Culvert viewed from downstream. There is a vertical drop at the outlet of the culvert.

Figure 3.6.2.3b (right): Gutteridge Woods Culvert viewed from upstream.

3.6.2.4 Plan of site:

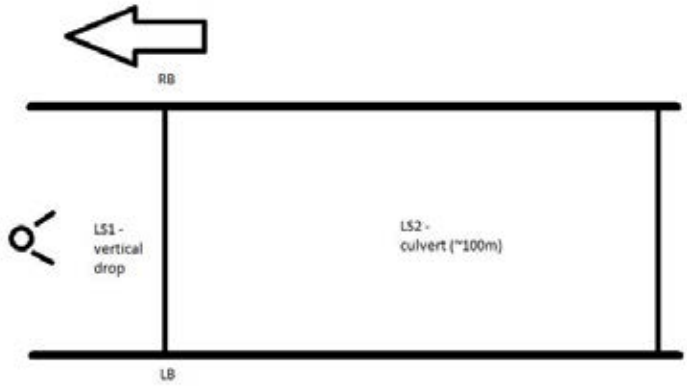

Figure 3.6.2.4a: Site plan of Gutteridge Woods Culvert

3.6.2.5. Structure dimensions:

Channel width	6m
Barrier width at crest	6m
Wetted width	6m
Transversal sections	1
Longitudinal sections	2
Hydraulic head	0.3m (for the vertical drop)
Effective length	186m (for the culvert)

3.6.2.6 Impact of the structure on habitat:

Large concrete sloping weir under culvert. Shaded straightened and widened. Does not support complex aquatic habitat, poor morphology and no marginal plant life. Shallow depth of water flowing through the culvert.

3.6.2.7 Ownership and function:

- *Landowner and operator:* London Borough of Hillingdon
- *Original purpose of structure:* Culvert designed to allow pedestrian and vehicle traffic to cross over the waterway.
- *Current uses and value of structure:* Culvert designed to allow pedestrian and vehicle traffic to cross over the waterway.

3.6.2.8 Survey Conditions:

- *Antecedent conditions:* Light rain/drizzle within past two to three days
- *Flow Conditions:* Summer low level
- *Was the structure submerged or dry?* No
- *Degree of estimation:* Measurements partially undertaken.

3.6.2.9 Upstream fish passage assessment

	Flow conditions	Passability score	Reason/s
Coarse fish	Low	0	Shallow depth, hydraulic head at vertical drop and length of culvert
	High	0	Shallow depth, hydraulic head at vertical drop and length of culvert
Juvenile eels	Low	0	No climbing substrate, length of culvert
	High	0	Shallow depth, hydraulic head at vertical drop and length of culvert

3.6.2.10 Downstream fish passage assessment

	Flow conditions	Passability score	Reason/s
Coarse fish	Low	0	Shallow depth
	High	1	Shallow depth may be passable at high flows
Adult eels	Low	0.3	Structures damaging to downstream migrant
	High	0.6	Structures damaging to downstream migrant (lessened by higher flow of water)

3.6.2.11 Options for fish passage improvement

- *Priority for action*: Medium

- *Consideration of options:*
  The barrier is impassable due to the shallow depth of water present within the culvert. A series of baffles could be attached to the inside of the culvert on each bank to increase water depth in the centre of the culvert.

  In order to make the vertical drop passable, a small rock ramp could be constructed at the outlet of the structure. Alternatively a series of baffles could be installed downstream to raise river levels upstream and drown the vertical drop of the culvert.

  The provision of artificial lighting, or chimneys in the roof of the culvert, to increase light levels may also have a beneficial effect on fish passage.

3.6.3 Stafford Road Barrier 1 (ID 261323)

3.6.3.1 Location

- *GPS*: 51.557878, -0.42700931
- *Distance from Thames confluence*: 23519m
- *Distance to next structure downstream*: 1399m
- *Number of structures downstream (direct route to Thames confluence)*: 28 (via River Crane) or 17 (via lower Duke of Northumberland's River)
- *Distance from next structure upstream*: 1214m

3.6.3.2 Brief description:

Small vertical weir made from pre-cast concrete with a small concrete sill.

3.6.3.3 Photos:

Figure 3.6.3.3a (left): Stafford Road Barrier 1 viewed from upstream

Figure 3.6.3.3b (right): Stafford Road Barrier 1 viewed along the crest from right bank

Figure 3.6.3.3c (left): Mossy, rocky and muddy ground sloping into the river at the right bank provides good climbing substrate for juvenile eels

Figure 3.6.3.3d (right): Stafford Road Barrier 1 viewed from downstream at right bank

3.6.3.4 Plan of site:

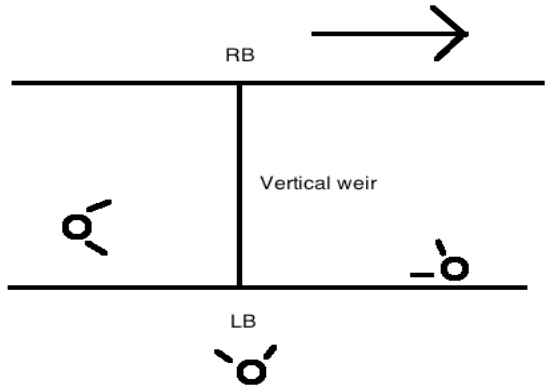

Figure 3.6.3.4a: Site plan for Stafford Road Barrier 1

3.6.3.5 Structure dimensions:

Channel width	5.2m
Barrier width at crest	5.2m
Wetted width	5.2m
Transversal sections	1
Hydraulic head	0.26m

3.6.3.6 Impact of the structure on habitat:

Little impact as the vertical weir is small however it causes increased siltation upstream as a result of holding back water and sediment.

3.6.3.7 Ownership and function:

- *Landowner and operator:* Unknown private landowner (right bank), Northolt Airport (left bank). Access via Stafford Rd Open Space, Ruislip Gardens.
- *Original purpose of structure:* Unknown / water level management
- *Current uses and value of structure:* Unknown/ water level management

3.6.3.8 Survey Conditions:

- *Antecedent conditions:* Light rain/drizzle within past two to three days
- *Flow Conditions:* Elevated
- *Was the structure submerged or dry?* No
- *Degree of estimation:* All measurements undertaken

3.6.3.9 Upstream fish passage assessment

	Flow conditions	**Passability score**	**Reason/s**
Coarse fish	Low	0	Hydraulic head
	High	0.3	At higher flows it is likely that the hydraulic head would decrease and water depth at the inlet increase

Juvenile eels	Low	1	Climbing substrate present
	High	1	Climbing substrate present

3.6.3.10 Downstream fish passage assessment

	Flow conditions	Passability score	Reason/s
Coarse fish	Low	0.3	Depth of water at inlet
	High	1	Depth of water at inlet would likely increase across the width of the small channel.
Adult eels	Low	0.6	Depth of water at the inlet
	High	1	Depth would likely increase at high flows.

3.6.3.11 Options for fish passage improvement

- *Priority for action*: Medium.
  Easing this barrier would provide unimpeded access upstream to Ruislip Gardens Underground Station (1.2km). The reach of river offers medium quality habitat for aquatic wildlife and has good potential for river restoration works (backwater creation, meander connections).

- *Consideration of options:*
  The original purpose of this barrier is unclear and it does not appear to be essential for retaining water levels upstream. The barrier could be completely removed or breached at the centre of the structure in order to ease fish passage.

  The London Borough of Hillingdon has informed us that they are unaware who the land owner is for this particular area of the river. The left bank of the river is owned by Northolt Airport and the right bank of the river is owned by an unknown private landlord. This may delay removal of the obstruction, as permission to work must be obtained from the landlord.

3.6.4 Stafford Road Barrier 2 (ID 261327)

3.6.4.1 Location:

- *GPS*: 51.56046, -0.4123495
- *Distance from Thames confluence*: 24732m
- *Distance to next structure downstream*: 1214m
- *Number of structures downstream (direct route to Thames confluence)*: 29 (via River Crane) or 18 (via lower Duke of Northumberland's River)
- *Distance from next structure upstream*: 51m

3.6.4.2 Brief description:

Large stepped weir consisting of 3 steps spanning the entire length of the channel in a curved in a semi-circular shape. The barrier is made from pre-cast concrete. Upstream from the barrier consists of a concreted bed before the channel splits into two and gets culverted. The depth of water over the concrete channel is very shallow.

3.6.4.3 Photos:

Figure 3.6.4.3a (left): Stafford Road Barrier 2 viewed along the crest at right bank

Figure 3.6.4.3b (right): Stafford Road Barrier 2 viewed from upstream

Figure 6.4.3c: Stafford Road Barrier 2 viewed from downstream

3.6.4.4 Plan of site:

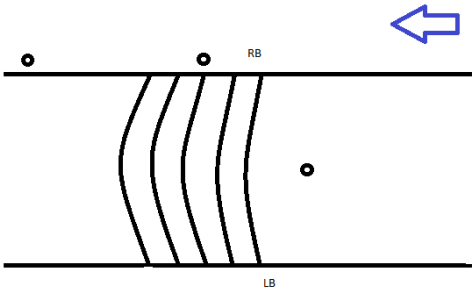

Figure 6.4.5a: Site plan for Stafford Road Barrier 2

3.6.4.5 Structure dimensions:

Channel width	5.3m
Barrier width at crest	5.5m
Wetted width	5.5m
Transversal sections	1
Hydraulic head	0.54m
Number of steps	3
Height of step (limiting)	0.26m
Length of step (limiting)	0.65m

3.6.4.6 Impact of the structure on habitat:

Upstream river levels are extremely low and the bed of the river is lined with concrete, thus limiting its potential for colonisation by aquatic flora and fauna. Downstream of the structure is a weir pool that provides deeper habitat for aquatic wildlife to shelter.

3.6.4.7 Ownership and function

- *Landowner and operator:* London Borough of Hillingdon
- *Original purpose of structure:* Water level management in relation to Ruislip Gardens Underground Station.
- *Current uses and value of structure:* Water level management in relation to Ruislip Gardens Underground Station.

3.6.4.8 Survey Conditions:

- *Antecedent conditions:* Heavy rainfall within past two or three days
- *Flow Conditions :* Summer low level
- *Was the structure submerged or dry?* No
- *Degree of estimation:* All measurements undertaken

3.6.4.9 Upstream fish passage assessment

	Flow conditions	**Passability score**	**Reason/s**
Coarse fish	Low	0	Height of step, step water depth
	High	0	Height of step, step water depth

Juvenile eels	Low	0.3	Medium level of water turbulence
	High	0.3	Medium level of water turbulence

3.6.4.10 Downstream fish passage assessment

	Flow conditions	**Passability score**	**Reason/s**
Coarse fish	Low	0	Depth of water at inlet
	High	1	Depth of water at inlet sufficient in high flows
Adult eels	Low	0.3	Depth of water at inlet
	High	1	Depth of water at inlet sufficient in high flows

3.6.4.11 Options for fish passage improvement

- *Priority for action*: Low. Closely upstream to this barrier is the Ruislip Gardens culvert which is impassable therefore removing this barrier would have little impact on fish passage upstream overall.

- *Consideration of options:*
  No action is recommended due to the proximity of this obstruction to Ruislip Gardens Underground Station. A barrier is present at the train station that cannot be removed so there is little advantage in undertaking easement works in this location.

3.6.5 Stafford Road Culvert (ID 990015)

3.6.5.1 Location

- *GPS*: 51.560767, -0.41181943
- *Distance from Thames confluence*: 24783m
- *Distance to next structure downstream*: 51m
- *Number of structures downstream (direct route to Thames confluence)*: 30 (via River Crane) or 19 (via lower Duke of Northumberland's River)
- *Distance from next structure upstream*: 2545m

3.6.5.2 Brief description:

71m Culvert located underneath Ruislip Gardens underground station. The river is split between 3 separate culverts in order to prevent flooding upstream of the railway line. This has led to extremely poor flows (less than 1m/s) and water depths (less than 10cm) in this area.

3.6.5.3 Photos:

Figure 3.6.5.6a (left): Viewed from downstream, the culvert splits into two separate paths separated by a concrete wall.

Figure 3.6.5.3b (right): Viewed from downstream, the right channel is further diverted into two pipes

Figure 3.6.5.3c (left): Viewed from upstream, the left channel continues and opens up on the other side of the bridge/road.

Figure 3.6.5.3d (right): Viewed from upstream, the right channel diverted into pipes opens up on the other side of the bridge/road as single pathways (1st pipe view)

Figure 3.6.5.3e (left): Viewed from upstream, the right channel diverted into pipes opens up on the other side of the bridge/road as single pathways (2nd pipe view)

Figure 3.6.5.3f (right): Viewed from upstream, the left channel emerges on the other side of the bridge/road.

3.6.5.4 Plan of site:

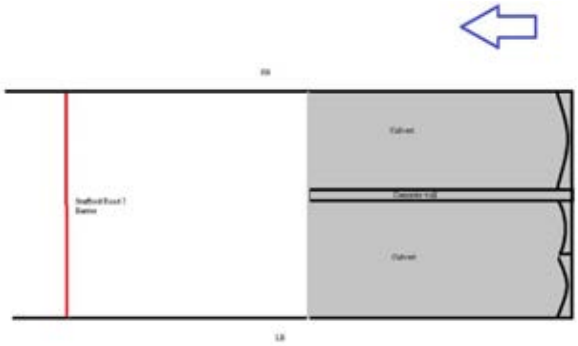

Figure 6.6.4a: Field sketch of culvert. The two paths are shown with two further opening from the split at left bank.

3.6.5.5 Structure dimensions:

Channel width	4.5m
Barrier width at crest	4.5m
Wetted width	4.5m
Transversal sections	3
Effective length	71m

3.6.5.6 Impact of the structure on habitat:

The structure splits the river over a series of channels and pipes, therefore effectively widening the channel and resulting in very shallow water flowing through each of the culverts. The absence of natural light and concreted bottom of the channel prevent suitable habitat from being present.

3.6.5.7 Ownership and function:

- *Landowner and operator:* London Borough of Hillingdon/TFL. Access via Stafford Rd Open Space and Spider Park, Ruislip Gardens.
- *Original purpose of structure:* To facilitate transport infrastructure (railway and road) and to prevent the flooding of these assets.
- *Current uses and value of structure*: To facilitate transport infrastructure (railway and road) and to prevent the flooding of these assets.

3.6.5.8 Survey Conditions:

- *Antecedent conditions:* Light rain/drizzle within past two to three days
- *Flow Conditions:* Summer low level
- *Was the structure submerged or dry?* No
- *Degree of estimation:* All measurements estimated

3.6.5.9 Upstream fish passage assessment

	Flow conditions	Passability score	Reason/s
Coarse fish	Low	0	Depth of water and length of culvert
	High	0.6	Length of culvert may present a barrier
Juvenile eels	Low	0	Depth of water and length of culvert
	High	0.6	Length of culvert may present a barrier

3.6.5.10 Downstream fish passage assessment

	Flow conditions	Passability score	Reason/s
Coarse fish	Low	0	Depth of water and length of culvert
	High	1	Potentially would swim downstream if flows are high enough
Adult eels	Low	0	Depth of water and length of culvert
	High	1	Potentially would swim downstream if flows are high enough

3.6.5.11 Options for fish passage improvement

- *Priority for action*: Low

- *Consideration of options:*
  Limited options are available to ease this barrier due to its current function. The river is split between three pipes and channelled underground in order to reduce the river's energy and reduce flooding in the vicinity of Ruislip Gardens underground station.

  As a result of the river being split between three pipes, water levels are too low to permit fish passage. It would be difficult to increase water depth in this location due to the fact that the river is spread over such a wide area. The provision of baffles within the culverts would have little effect on increasing water depth due to the lack of energy the river has in this location. Baffles may also lead to the pipes blocking during times of high flow, causing flooding upstream of Ruislip Gardens station.

3.6.6 Roxbourne Park Culvert 1 (ID 990016)

3.6.6.1 Location:

- *GPS*: 51.572763, -0.38350741
- *Distance from Thames confluence*: 27328m
- *Distance to next structure downstream*: 2545m
- *Number of structures downstream (direct route to Thames confluence)*: 31 (via River Crane) or 20 (via lower Duke of Northumberland's River)
- *Distance from next structure upstream*: 549m

3.6.6.2 Brief description:

Small culvert made from pre-cast concrete in Roxbourne Park associated with a small pedestrian footbridge. The culvert splits into two pipes separated by a concrete wall. There is a large amount of debris blocking the pipe at the right bank of the river.

3.6.6.3 Photos:

Figure 3.6.6.3a (left): Viewed from downstream, the culvert splits into two tunnels

Figure 3.6.6.3b (right): Viewed from upstream, the tunnel at the right bank is blocked with a large amount of debris

3.6.6.4 Plan of site:

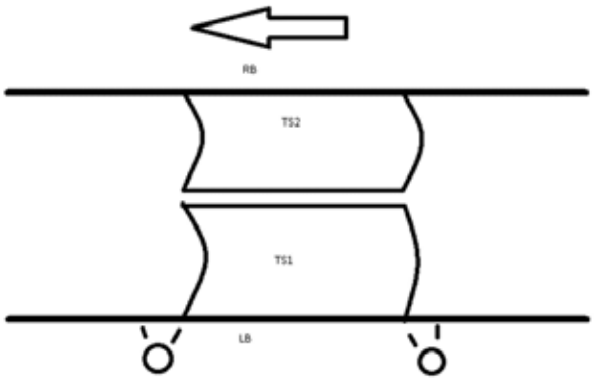

Figure 3.6.6.4a Site plan of Roxbourne Park Culvert 1

3.6.6.5 Structure dimensions:

Channel width	3m

Barrier width at crest	3m
Wetted width	3m
Transversal sections	2
Effective length	16m

3.6.6.6 Impact of the structure on habitat:

The culvert has a minimal impact on habitat but may be prone to causing siltation upstream as a result of the structure blocking with debris.

3.6.6.7 Ownership and function:

- *Landowner and operator*: The London Borough of Harrow
- *Original purpose of structure:* To allow pedestrian access over the waterway at Roxbourne Park.
- *Current uses and value of structure:* To allow pedestrian access over the waterway at Roxbourne Park.

3.6.6.8 Survey Conditions:

- *Antecedent conditions:* Heavy rainfall within past two to three days;
- *Flow Conditions:* Elevated
- *Was the structure submerged or dry?* No
- *Degree of estimation:* Measurements partially undertaken.

3.6.6.9 Upstream fish passage assessment

	Flow conditions	**Passability score**	**Reason/s**
Coarse fish	Low	1	Sufficient water depth
	High	1	Sufficient water depth
Juvenile eels	Low	1	Climbing substrate present
	High	1	Climbing substrate present

3.6.6.10 Downstream fish passage assessment

	Flow conditions	**Passability score**	**Reason/s**
Coarse fish	Low	1	Sufficient water depth
	High	1	Sufficient water depth
Adult eels	Low	1	Sufficient water depth
	High	1	Sufficient water depth

3.6.6.11 Options for fish passage improvement

- *Priority for action*: Low

- *Consideration of options:*
  No action is required but it would be advantageous to unblock the right hand pipe of the culvert to reduce velocities at this pinch point in the river channel.

3.6.7 Roxbourne Park Culvert 2 (ID 990017)

3.6.7.1 Location:

- *GPS*: 51.576445, -0.37991319
- *Distance from Thames confluence*: 27877m
- *Distance to next structure downstream*: 549m
- *Number of structures downstream (direct route to Thames confluence)*: 32 (via River Crane) or 21 (via lower Duke of Northumberland's River)
- *Distance from next structure upstream*: 1887m

3.6.7.2 Brief description:

A culvert made from masonry with a small vertical drop at the entrance.

3.6.7.3 Photos*:*

Figure 3.6.7.3a (left): Viewed from downstream at right bank, Roxbourne Park Culvert 2 has a small vertical drop at the entrance

Figure 3.6.7.3b (right): Viewed from upstream, the culvert emerges the other side of the road

Figure 3.6.7.3c (left): Roxbourne Park Culvert 2 viewed from the inside

3.6.7.4 Plan of site:

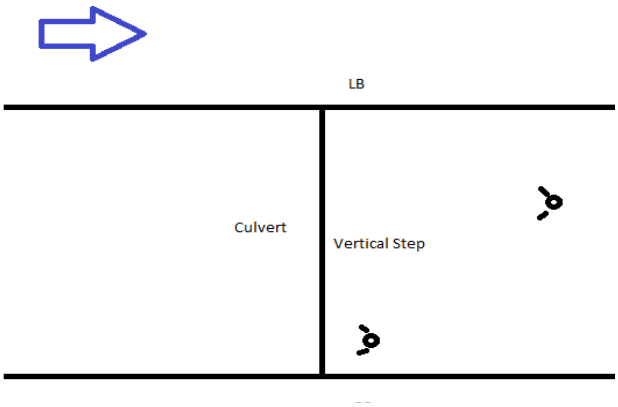

Figure 3.6.7.4a: Site plan for Roxbourne Park Culvert 2

3.6.7.5 Structure dimensions:

Channel width	2m
Barrier width at crest	2m
Wetted width	1m
Transversal sections	1
Longitudinal sections	2
Hydraulic head	0.1m (for the vertical drop)
Effective length	20m (for the culvert)

3.6.7.6 Impact of the structure on habitat:

The narrow and dark culvert is unable to support aquatic plant life. It has a brick bed which is unable to provide suitable substrate for aquatic invertebrates. There is a small pool at the outlet of the structure which provides a deeper area for aquatic organisms to persist during times of low flow.

3.6.7.7 Ownership and function:

- *Landowner and operator:* London Borough of Harrow.
- *Original purpose of structure:* The river is culverted due to the presence of the railway line leading to Rayners Lane Railway Station.
- *Current uses and value of structure:* The river is culverted due to the presence of the railway line leading to Rayners Lane Railway Station.

3.6.7.8 Survey Conditions:

- *Antecedent conditions:* Light rain/drizzle within past two to three days
- *Flow Conditions:* Summer low level
- *Was the structure submerged or dry?* No
- *Degree of estimation:* All measurements undertaken

3.6.7.9 Upstream fish passage assessment

	Flow conditions	Passability score	Reason/s
Coarse fish	Low	0	Depth of water
	High	1	Depth of water would be sufficient
Juvenile eels	Low	0	No climbing substrate
	High	1	Depth of water would be sufficient

3.6.7.10 Downstream fish passage assessment

	Flow conditions	Passability score	Reason/s
Coarse fish	Low	0	Depth of water at inlet
	High	1	Depth of water would be sufficient
Adult eels	Low	0	Depth of water at inlet
	High	1	Depth of water would be sufficient

3.6.7.11 Options for fish passage improvement

- *Priority for action*: Low

- *Consideration of options*:
  The structure is impassable for coarse fish and eels in both upstream and downstream directions due to insufficient water depth. The provision of two baffles either side of the outlet of the culvert could increase water depth along the length of the structure and ensure that it is passable.

  The provision of an open type eel pass, attached to the brick bed of the culvert could ensure free passage for juvenile eels.

3.6.8 North Harrow Culvert (ID 990018)

3.6.8.1 Location:

- *GPS*: 51.585617, -0.3650081
- *Distance from Thames confluence*: 29764m
- *Distance to next structure downstream*: 1887m
- *Number of structures downstream (direct route to Thames confluence)*: 33 (via River Crane) or 22 (via lower Duke of Northumberland's River)
- *Distance from next structure upstream*: N/A – this is the final barrier

3.6.8.2 Brief description:

The culvert is approximately 3000m long, running between Northumberland Road, Harrow and Northwick Park Underground Station. The water depth is estimated at less than 10 cm and flow is estimated at less than 1m/s throughout. Due to the length of the culvert light levels are expected to deter fish migration.

3.6.8.3 Photos:

No photos available

3.6.8.4 Plan of site:

Figure 3.6.8.4a: Map showing the North Harrow culvert which flows from Greenhill (green circle) to North Harrow tube station (red circle).

3.6.8.5 Structure dimensions:

Channel width	5m
Barrier width at crest	5m
Wetted width	5m
Transversal sections	1
Effective length	3000m

3.6.8.6 Impact of the structure on habitat:

The structure darkens the river channel for 3.2km leading to a complete loss of aquatic life throughout its reach.

3.6.8.7 Ownership and function:

- *Landowner and operator*: London Borough of Harrow
- *Original purpose of structure:* To divert the river underground to make room for urban development and infrastructure.
- *Current uses and value of structure:* To divert the river underground to make room for urban development and infrastructure.

3.6.8.8 Survey Conditions:

- *Antecedent conditions:* Light rain/drizzle within past two to three days
- *Flow Conditions:* Summer low level
- *Was the structure submerged or dry?* No
- *Degree of estimation:* All measurements estimated

3.6.8.9 Upstream fish passage assessment

	Flow conditions	**Passability score**	**Reason/s**
Coarse fish	Low	0	Water depth; Length of culvert
	High	0	Length of culvert
Juvenile eels	Low	0	Water depth; Length of culvert
	High	0	Length of culvert

3.6.8.10 Downstream fish passage assessment

	Flow conditions	**Passability score**	**Reason/s**
Coarse fish	Low	0	Length of culvert
	High	0	Length of culvert
Adult eels	Low	0	Length of culvert
	High	0	Length of culvert

3.6.8.11 Options for fish passage improvement

- *Priority for action:* Low.
  This is due to the length and purpose of culvert.

- *Consideration of options:*
  There are no easement options available for this structure due to the length of the culvert and the importance of the infrastructure and urban areas overhead.

3.7 Yeading Brook East

3.7.1 Polish War Memorial Culvert 1 (ID 990019)

3.7.1.1 Location:

- *GPS*: 51.547646, -0.40773326
- *Distance from Thames confluence*: 20918m
- *Distance to next structure downstream*: 1201m
- *Number of structures downstream (direct route to Thames confluence)*: 26 (via River Crane) or 15 (via lower Duke of Northumberland's River)
- *Distance from next structure upstream*: 713m

3.7.1.2 Brief description:

This culvert is 559m in length. It consists of an underground section that passes beneath the A40, an open section that flows adjacent to the A40 and an underground section that flows past the Polish War Memorial in the London Borough of Hillingdon. The river in this location is extremely shallow due to the widened nature of the culvert.

3.7.1.3 Photos:

Figure 3.7.1.3a (left): Polish War Memorial Culvert 1 viewed from downstream

Figure 3.7.1.3b (right): Polish War Memorial Culvert 1 viewed from upstream

Figure 3.7.1.3c: Downstream of the underground culvert is a long, straight, concreted section of the river

3.7.1.4 Plan of site:

No field sketch available

3.7.1.5 Structure dimensions:

Channel width	4.2m
Barrier width at crest	4.2m
Wetted width	4.2m
Transversal sections	1
Effective length	569m

3.7.1.6 Impact of the structure on habitat:

The culvert offers little in the way of aquatic habitat although there is a small (10m) vegetated sediment bar in the open section.

3.7.1.7 Ownership and function:

- *Landowner and operator:* London Borough of Hillingdon
- *Original purpose of structure:* Culverted under the A40 motorway, allowing for vehicular traffic to pass over the river.
- *Current uses and value of structure:* Culverted under the A40 motorway, allowing for vehicular traffic to pass over the river.

3.7.1.8 Survey Conditions:

- *Antecedent conditions:* Light rain/drizzle within past two to three days
- *Flow Conditions:* Summer low level
- *Was the structure submerged or dry?* No
- *Degree of estimation:* All measurements estimated

3.7.1.9 Upstream fish passage assessment

	Flow conditions	**Passability score**	**Reason/s**
Coarse fish	Low	0	Water depth; Length of culvert may present a barrier
	High	0.6	Length of culvert may present a barrier
Juvenile eels	Low	0	Water depth; Length of culvert may present a barrier
	High	0.6	Length of culvert may present a barrier

3.7.1.10 Downstream fish passage assessment

	Flow conditions	**Passability score**	**Reason/s**
Coarse fish	Low	0	Water depth
	High	1	Sufficient water depth
Adult eels	Low	0	Water depth
	High	1	Sufficient water depth

3.7.1.11 Options for fish passage improvement

- *Priority for action:* Low

- *Consideration of options:*
  Currently water quality is extremely poor in the Yeading Brook East and encouraging fish passage to this part of the catchment is not recommended. If water quality improves in future years, the culvert could be made passable via a two staged channel. A two staged channel would increase the depth of water at the centre of the river and provide areas for marginal habitat to establish.

3.7.2 Polish War Memorial Barrier 2 (ID 268618)

3.7.2.1 Location:

- *GPS*: 51.548789, -0.39785702
- *Plan of site*: No field sketch available
- *Distance from Thames confluence*: 21631m
- *Distance to next structure downstream*: 713m
- *Number of structures downstream (direct route to Thames confluence)*: 27 (via River Crane) or 16 (via lower Duke of Northumberland's River)
- *Distance from next structure upstream*: 1084m

3.7.2.2 Brief description:

Sloping weir made of pre-cast concrete. Note that we were unable to access this barrier as it is located on private property.

3.7.2.3 Photos*:*

Figure 3.7.2.3a (left): Polish War Memorial Barrier 2 viewed from the road at left bank (unable to see barrier)

Figure 3.7.2.4b (right): Polish War Memorial Barrier 2 viewed from downstream

3.7.2.4 Plan of site:

No plan of site available

3.7.2.5 Structure dimensions:

Channel width	3m
Barrier width at crest	3m
Wetted width	3m
Transversal sections	1
Hydraulic head	0.5m
Effective length	1.5m
Gradient	33%

3.7.2.6 Impact of the structure on habitat:

The river channel has enforced concrete banks with a with concrete bed and is unable to support any type of complex aquatic habitat

3.7.2.7 Ownership and function

- *Landowner and operator:* Unknown
- *Original purpose of structure:* Water level management
- *Current uses and value of structure:* Water level management

3.7.2.8 Survey Conditions:

- *Antecedent conditions:* Light rain/drizzle within past two or three days
- *Flow Conditions:* Summer low level
- *Was the structure submerged or dry?* No
- *Degree of estimation:* All measurements estimated

3.7.2.9 Upstream fish passage assessment

	Flow conditions	**Passability score**	**Reason/s**
Coarse fish	Low	0	Depth of water at inlet and gradient of slope
	High	0.3	Gradient of slope
Juvenile eels	Low	0	Depth of water at inlet
	High	1	Sufficient depth of water at inlet

3.7.2.10 Downstream fish passage assessment

	Flow conditions	**Passability score**	**Reason/s**
Coarse fish	Low	0	Depth of water at inlet
	High	1	Sufficient depth of water at inlet
Adult eels	Low	0	Depth of water at inlet
	High	1	Sufficient depth of water at inlet

3.7.2.11 Options for fish passage improvement

- *Priority for action:* Low.
  Water quality and habitat is especially poor in the Yeading Brook East and fish passage should not be encouraged until these factors are addressed.

- *Consideration of options:*
  Due to the heavily modified nature of the river channel in this location, there are few options to ease fish passage for this barrier. Fish are currently unable to reach this barrier via the river channel downstream, as it is culverted, lined with concrete and suffers from extreme low flows. Water quality is also especially poor in the Yeading Brook East and is expected to be unsuitable for sustaining a complex aquatic ecosystem.

3.7.3 Civic Way Culvert (ID 990020)

3.7.3.1 Location:

- *GPS*: 51.556277, -0.38986198
- *Distance from Thames confluence*: 22715m
- *Distance to next structure downstream*: 1084m
- *Number of structures downstream (direct route to Thames confluence)*: 28 (via River Crane) or 17 (via lower Duke of Northumberland's River)
- *Distance from next structure upstream*: 949m

3.7.3.2 Brief description:

Culverted section of river at Civic Way Road. The length of the culvert is 949m with water depth estimated at less than 10cm and flow less than1m/s throughout. The culvert runs underneath Victoria Road.

3.7.3.3 Photos:

No photos available

3.7.3.4 Plan of site:

Figure 3.7.3.4a: The culverted section of river that is flows from Field End Road (green circle) to Civic Way Road (red circle).

3.7.3.5 Structure dimensions:

Channel width	3.3m
Barrier width at crest	3.3m
Wetted width	3.3m
Transversal sections	1
Effective length	949m

3.7.3.6 Impact of the structure on habitat:

Loss of natural aquatic flora and fauna due to loss of sunlight

3.7.3.7 Ownership and function:

- *Landowner and operator:* The London Borough of Harrow
- *Original purpose of structure:* Culvert, designed to allow vehicular traffic to pass over the river.
- *Current uses and value of structure:* Culvert, designed to allow vehicular traffic to pass over the river on Victoria Road.

3.7.3.8 Survey Conditions:

- *Antecedent conditions:* Light rain/drizzle within past two or three days
- *Flow Conditions:* Summer low level
- *Was the structure submerged or dry?* No
- *Degree of estimation:* All measurements estimated

3.7.3.9 Upstream fish passage assessment

	Flow conditions	**Passability score**	**Reason/s**
Coarse fish	Low	0	Water depth; Length of culvert may present a barrier
	High	0.6	Length of culvert may present a barrier
Juvenile eels	Low	0	Water depth; Length of culvert may present a barrier
	High	0.6	Length of culvert may present a barrier

3.7.3.10 Downstream fish passage assessment

	Flow conditions	**Passability score**	**Reason/s**
Coarse fish	Low	0	Water depth
	High	1	Sufficient water depth
Adult eels	Low	0	Water depth
	High	1	Sufficient water depth

3.7.3.11 Options for fish passage improvement

- *Priority for action: Low*

- *Consideration of options:*
  None

3.7.4 Field End Screen (ID 193110)

3.7.4.1 Location:

- *GPS*: 51.561342, -0.38082506
- *Distance from Thames confluence*: 23664m
- *Distance to next structure downstream*: 949m
- *Number of structures downstream (direct route to Thames confluence)*: 29 (via River Crane) or 18 (via lower Duke of Northumberland's River)
- *Distance from next structure upstream*: 554m

3.7.4.2 Brief description:

Field End Screen, assessed as vertical weir made from pre-cast concrete. Primarily used to collect debris and placed immediately before a culvert.

3.7.4.3 Photos:

Figure 3.7.4.3a (left): Field End Screen viewed from right bank. The screen has a two-stage screen arrangement.

Figure 3.7.4.3.b (right): Notice board at Field End Screen

Figure 3.7.4.3c: The vertical weir at Field End Screen viewed from downstream

3.7.4.4 Plan of site:

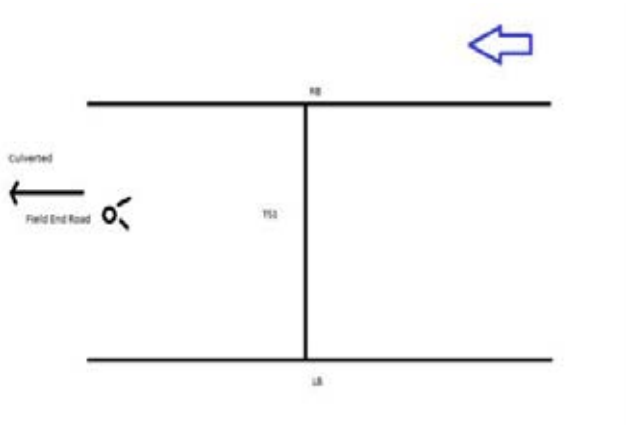

Figure 3.7.4.4.a: Site plan of Field End Screen

3.7.4.5 Structure dimensions:

Channel width	3m
Barrier width at crest	3m
Wetted width	3m
Transversal sections	1
Hydraulic head	0.1m

3.7.4.6 Impact of the structure on habitat:

Narrow straightened channel with poor morphology. No riparian or aquatic plant life.

3.7.4.7 Ownership and function:

- *Landowner and operator:* Environment Agency
- *Original purpose of structure:* Trash screen used to collect debris on the Yeading Brook East watercourse and to protect the natural river habitat and culverts.
- *Current uses and value of structure:* Trash screen used to collect debris on the Yeading Brook East watercourse. Reduces risk of blockage at the culvert and unauthorised access.

3.7.4.8 Survey Conditions:

- *Antecedent conditions:* Light rain and drizzle within past two or three days
- *Flow Conditions:* Summer low level
- *Was the structure submerged or dry?* No
- *Degree of estimation:* All measurements estimated

3.7.4.9 Upstream fish passage assessment

	Flow conditions	**Passability score**	**Reason/s**
Coarse fish	Low	0	Depth of water at inlet
	High	1	Depth of water would be sufficient at high flows
Juvenile eels	Low	1	Climbing substrate present
	High	1	Climbing substrate present

3.7.4.10 Downstream fish passage assessment

	Flow conditions	Passability score	Reason/s
Coarse fish	Low	0	Depth of water at inlet
	High	1	Depth of water would be sufficient at high flows
Adult eels	Low	0	Depth of water at inlet
	High	1	Depth of water would be sufficient at high flows

3.7.4.11 Options for fish passage improvement:

- *Priority for action:* Low

- *Consideration of options:*
  None recommended. Limited options available.

3.7.5 Leamington Crescent Culvert 1 (ID 990021)

3.7.5.1 Location:

- *GPS*: 51.564497, -0.37494183
- *Distance from Thames confluence*: 24218m
- *Distance to next structure downstream*: 554m
- *Number of structures downstream (direct route to Thames confluence)*: 30 (via River Crane) or 19 (via lower Duke of Northumberland's River)
- *Distance from next structure upstream*: 170m

3.7.5.2 Brief description:

Culverted section of river at Leamington Crescent. The length of the culvert is 21m with water depth estimated at less than 10cm and flows less than 1m/s throughout.

3.7.5.3 Photos:

No photos available

3.7.5.4 Plan of site:

Figure 3.7.5.4a: Leamington Crescent culverts 1 and 2. Both are in close proximity to one another with residential gardens on either side.

3.7.5.5 Structure dimensions:

Channel width	1m
Barrier width at crest	1m
Wetted width	1m
Transversal sections	1
Effective length	21m

3.7.5.6 Impact of the structure on habitat:

Loss of natural aquatic flora and fauna due to loss of sunlight.

3.7.5.7 Ownership and function:

- *Landowner and operator:* London Borough of Harrow
- *Original purpose of structure:* Unknown
- *Current uses and value of structure:* Culverts usually provide access for vehicular or pedestrian traffic to pass over the watercourse. On this occasion however, the culvert runs longitudinally alongside the back of residential houses on either side.

3.7.5.8 Survey Conditions:

- *Antecedent conditions:* Light rain and drizzle within the past two or three days
- *Flow Conditions:* Summer low level
- *Was the structure submerged or dry?* No
- *Degree of estimation:* All measurements estimated

3.7.5.9 Upstream fish passage assessment

	Flow conditions	**Passability score**	**Reason/s**
Coarse fish	Low	0	Water depth maybe limiting
	High	1	Potentially sufficient water depth
Juvenile eels	Low	0	Water depth maybe limiting
	High	1	Potentially sufficient water depth

3.7.5.10 Downstream fish passage assessment

	Flow conditions	**Passability score**	**Reason/s**
Coarse fish	Low	0	Water depth maybe limiting
	High	1	Potentially sufficient water depth
Adult eels	Low	0	Water depth maybe limiting
	High	1	Potentially sufficient water depth

3.7.5.11 Options for fish passage improvement

- *Priority for action: Low*

- *Consideration of options:*
  None recommended

3.7.6 Leamington Crescent Culvert 2 (ID 990022)

3.7.6.1 Location*:*

- *GPS*: 51.565747, -0.37359875
- *Distance from Thames confluence*: 24387m
- *Distance to next structure downstream*: 170m
- *Number of structures downstream (direct route to Thames confluence)*: 31 (via River Crane) or 20 (via lower Duke of Northumberland's River)
- *Distance from next structure upstream*: 435m

3.7.6.2 Brief description:

Culverted section of river at Leamington Crescent. The length of the culvert is 20m with water depth estimated at less than 10cm and flow less than 1m/s throughout.

3.7.6.3 Photos*:*

No photos available

3.7.6.4 Plan of site:

Figure 3.7.6.4a: Leamington Crescent culverts 1 and 2. Both are in close proximity to one another with residential gardens on either side.

3.7.6.5 Structure dimensions:

Channel width	1m
Barrier width at crest	1m
Wetted width	1m
Transversal sections	1
Effective length	20m

3.7.6.6 Impact of the structure on habitat:

Loss of natural aquatic flora and fauna due to direct loss of daylight.

3.7.6.7 Ownership and function:

- *Landowner and operator:* London Borough of Harrow
- *Original purpose of structure:* Unknown. *Current uses and value of structure:* Culverts usually provide access for vehicular or pedestrian traffic to pass over the watercourse. On this occasion however, the culvert runs longitudinally alongside the back of residential houses on either side.

3.7.6.8 Survey Conditions:

- *Antecedent conditions:* Light rain and drizzle within the past two or three days
- *Flow Conditions:* Summer low level
- *Was the structure submerged or dry?* No
- *Degree of estimation:* All measurements estimated

3.7.6.9 Upstream fish passage assessment

	Flow conditions	**Passability score**	**Reason/s**
Coarse fish	Low	0	Water depth maybe limiting
	High	1	Potentially sufficient water depth
Juvenile eels	Low	0	Water depth maybe limiting
	High	1	Potentially sufficient water depth

3.7.6.10 Downstream fish passage assessment

	Flow conditions	**Passability score**	**Reason/s**
Coarse fish	Low	0	Water depth maybe limiting
	High	1	Potentially sufficient water depth
Adult eels	Low	0	Water depth maybe limiting
	High	1	Potentially sufficient water depth

3.7.6.11 Options for fish passage improvement

- *Priority for action:* Low

- *Consideration of option:*
  None recommended.

3.7.7 Alexandra Avenue Culvert (ID 990023)

3.7.7.1 Location:

- *GPS*: 51.568132, -0.36986311
- *Distance from Thames confluence*: 24822m
- *Distance to next structure downstream*: 435m
- *Number of structures downstream (direct route to Thames confluence)*: 32 (via River Crane) or 21 (via lower Duke of Northumberland's River)
- *Distance from next structure upstream*: N/A – this is the final barrier

3.7.7.2 Brief description:

Culvert at the Newton Farm Ecology Park under the A4090 Road. The length of the culvert is 116m with water depth estimated at <10cm and flow estimated at <1m/s throughout.

3.7.7.3 Photos:

No photos available

3.7.7.4 Plan of site:

Figure 3.7.7.4a: Alexandra Avenue Culvert under A4090 road

3.7.7.5 Structure dimensions:

Channel width	1m
Barrier width at crest	1m
Wetted width	1m
Transversal sections	1
Effective length	116m

3.7.7.6 Impact of the structure on habitat:

Loss of aquatic flora and fauna due to the loss of sunlight.

3.7.7.7 Ownership and function:

- *Landowner and operator:* London Borough of Harrow
- *Original purpose of structure:* Culverted to allow vehicular and pedestrian traffic to pass over the watercourse.
- *Current uses and value of structure:* Culverted under the A4090 road.

3.7.7.8 Survey Conditions:

- *Antecedent conditions:* Light rain and drizzle within past two and three days
- *Flow Conditions:* Summer low level
- *Was the structure submerged or dry?* No
- *Degree of estimation:* All measurements estimated

3.7.7.9 Upstream fish passage assessment

	Flow conditions	**Passability score**	**Reason/s**
Coarse fish	Low	0	Water depth maybe limiting
	High	0.6	Length of culvert may present a barrier
Juvenile eels	Low	0	Water depth maybe limiting
	High	0.6	Length of culvert may present a barrier

3.7.7.10 Downstream fish passage assessment

	Flow conditions	**Passability score**	**Reason/s**
Coarse fish	Low	0	Water depth maybe limiting
	High	1	Potentially sufficient water depth
Adult eels	Low	0	Water depth maybe limiting
	High	1	Potentially sufficient water depth

3.7.7.11 Options for fish passage improvement

- *Priority for action:* Low

- *Consideration of options:*
  None recommended. Limited options would be available.

3.8 Cyprinid Upstream Passability: current conditions (low flows) vs high flows

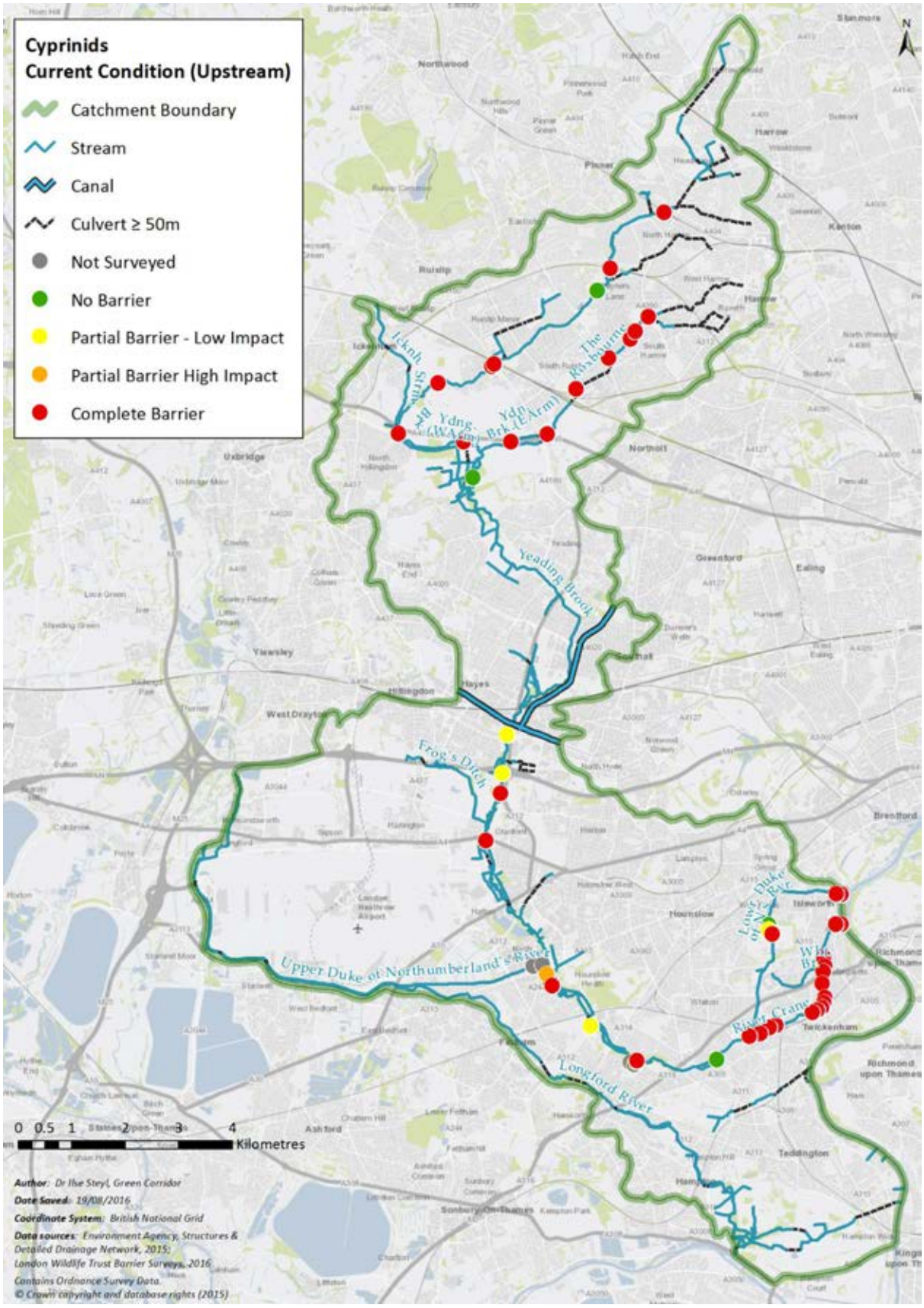

Figure 3.8a: Cyprinid upstream passability at low flows (current conditions)

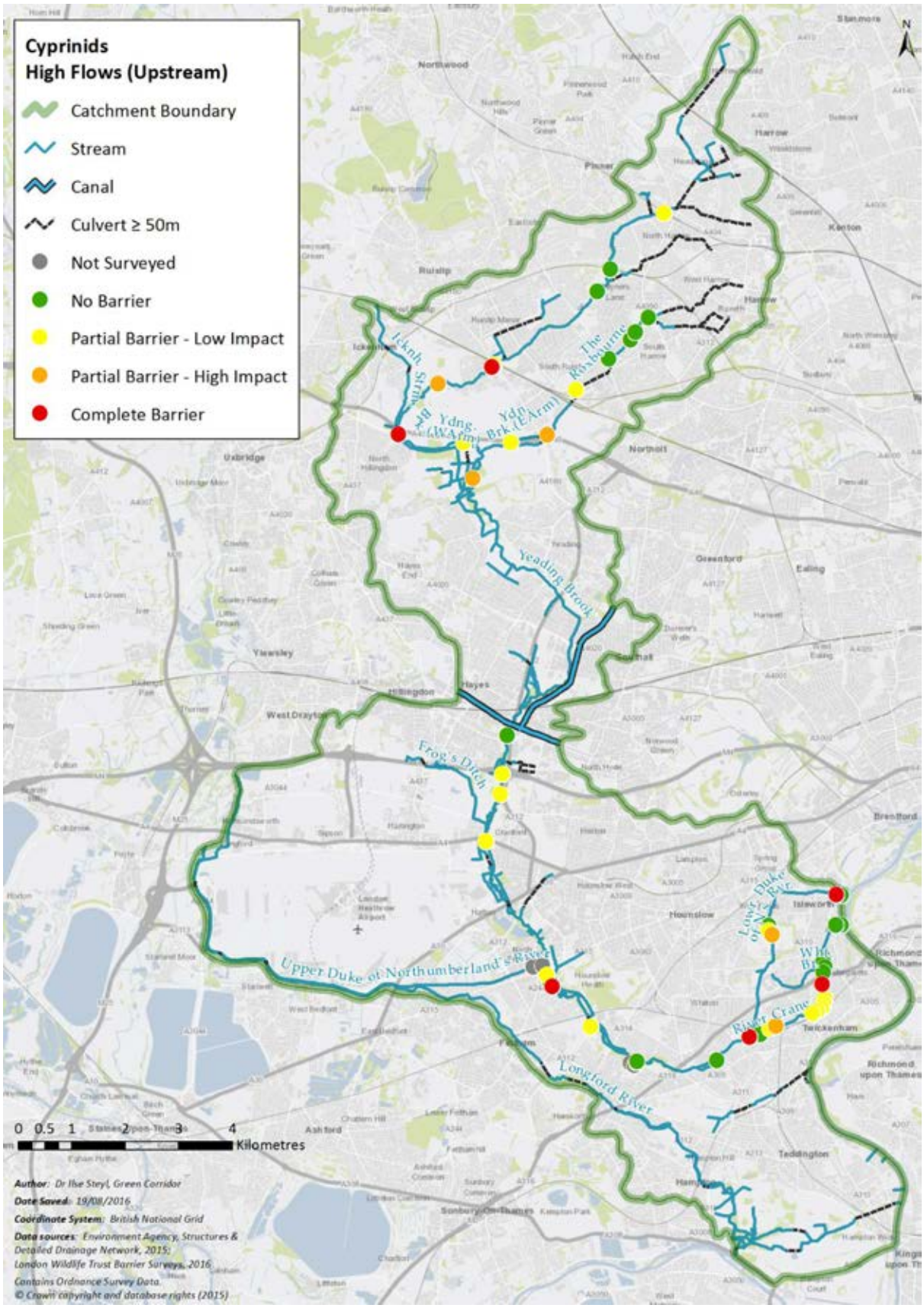

Figure 3.8b: Cyprinid upstream passability at high flows

3.9 Juvenile Eels Upstream Passability: current conditions (low flows) vs high flows

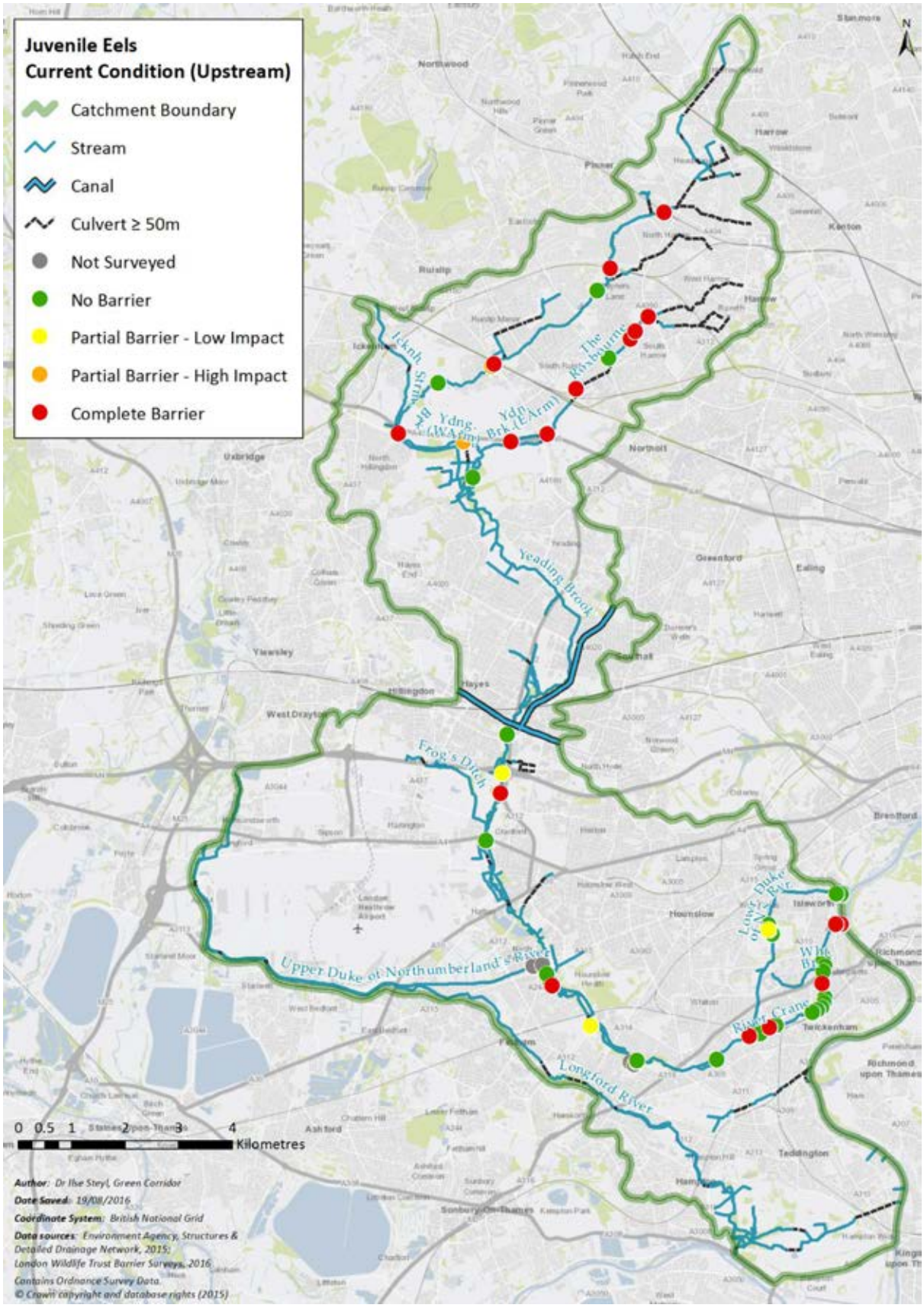

Figure 3.9a: Juvenile eel upstream passability at low flows (current conditions)

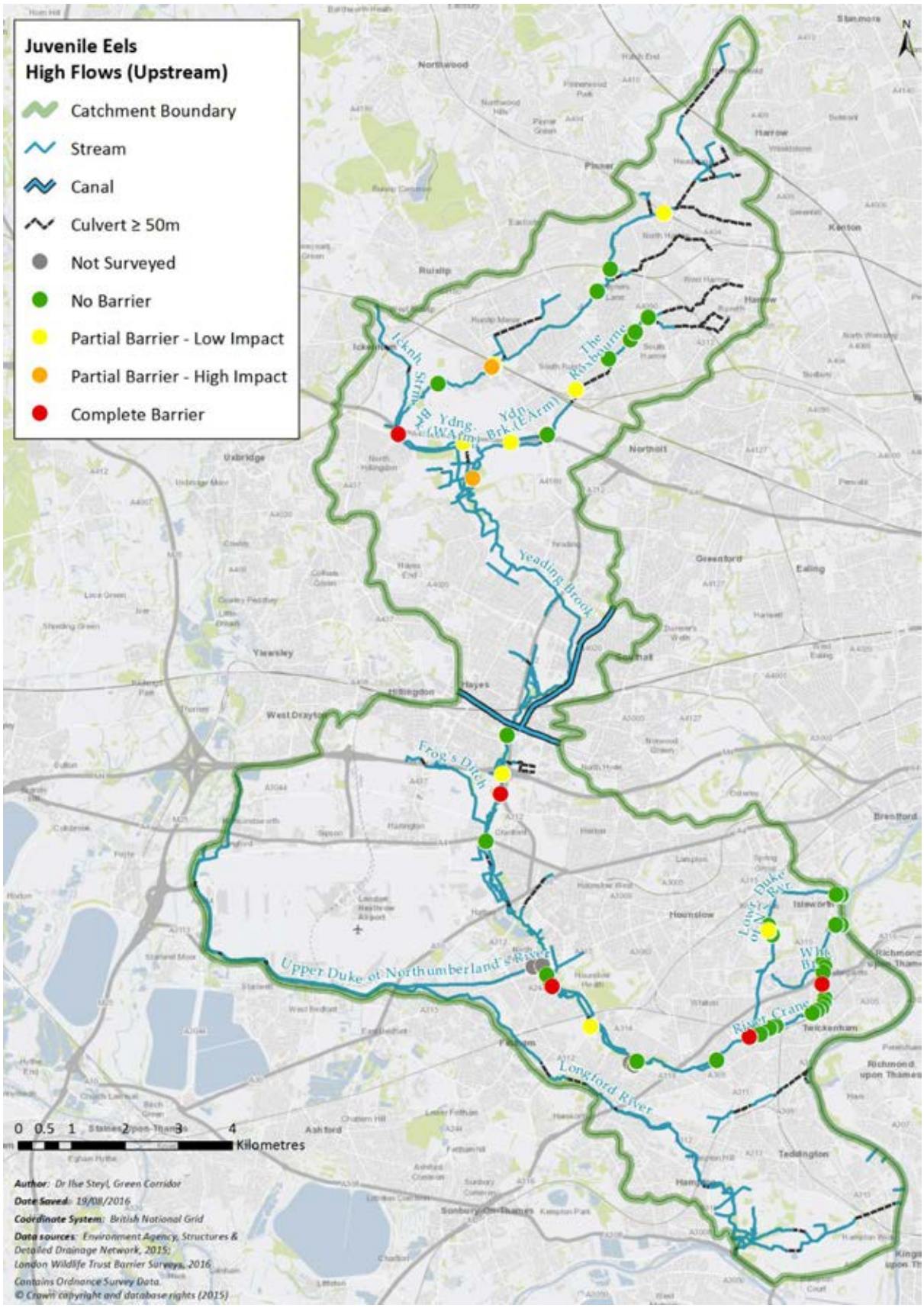

Figure 3.9b: Juvenile eel upstream passability at high flows

4.0 Conclusions and Recommendations

4.1 General notes on the removal of obstructions

One of the most cost effective methods of carrying out fish easement works to obstructions in river channels is to remove them completely. Alternatively structures can be breached or significantly lowered in order to achieve a similar result. These fish easement methods can also improve upstream and downstream passage for a variety of other wildlife, e.g. water voles, invertebrates, amphibians. The removal of structures can also have additional positive effects on the morphology and in channel habitat of a reach of river. Such benefits include; a reduction in siltation, improved sediment transport, the rehabilitation of a river's natural gradient, improved flow dynamics and a higher abundance of beneficial plant species such as *Ranunculus fluitans.*

Useful case studies already exist in the Crane Catchment where barrier removal projects have been completed. One such example is the former Mill Road Weir, located in Crane Park, Twickenham (TQ 14264 72867). The structure once played an essential role in retaining water upstream in order to power a watermill that has long since disappeared from the local landscape. The head retaining structure has now been removed and the result is an attractive, fast-flowing reach of river.

Before

After

Depending on the site in question, there may be strong arguments for and against removing an obstruction. It is important that each case is considered on its merits. In some circumstances decommissioning of a weir may result in loss of amenity, ecological value, heritage, or recreational use. Lowering water levels can reduce the hydraulic support to a river's banks resulting in bank failure. Removal of multiple weirs on straightened and shortened river reaches may lead to flow conveyance being increased to adverse levels. A weir may also be beneficial to the ecology of the river, with few if any other negative impacts. The Environment Agency Good Practice Guide for River Weirs (Rickard *et al.,* 2003) should be used as a guide for future practitioners to assess the suitability of decommissioning weirs in the Crane Catchment.

4.1.1 General notes on Larinier fish passes

Larinier fish passes are a popular method for enhancing fish migration. They are installed on or near slopes and weirs around a migratory obstacle, and they work by slowing down river flows via a series of baffles in order to enable fish passage. This type of pass is suitable for a range of species including salmon, sea trout, sea lamprey, trout, grayling and coarse fish, however they are not suitable for European eels. Their main disadvantage is their efficiency during times of increased head level and that they can be prone to blocking with debris being washed downstream.

For coarse fish species, they can be used to accommodate head differences up to a maximum of 1.3-1.5m; a maximum length of 8-10m per fight (sloped section); and a maximum gradient of 15%. Passes should have a minimum depth of 10-15cm for large coarse fish, with the head of water running above the baffles of the pass not exceeding 0.5m. Passes are not normally less than 0.6m wide, but smaller options might be considered where available flows and head ranges are very low. Once installed, passes should discharge at a range between 0.15-0.65m^3/s and have a mean velocity between 1.0-1.5m/s in order to be passable by coarse fish (Armstrong *et al.,* 2003).

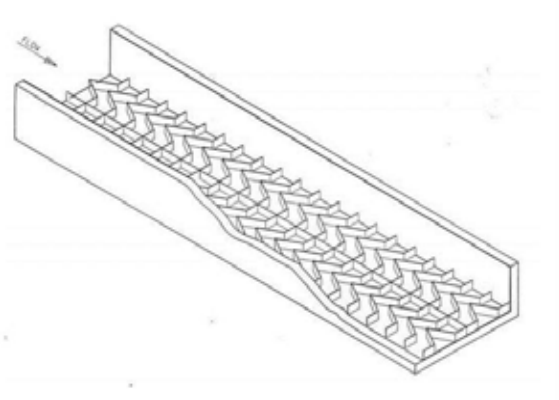

Figure 4.1.1a: Diagram of a Larinier fish pass

4.1.2 General notes on rock ramps

Rock ramps are integrated directly into weirs and extend across the entire width of a structure. They are designed to overcome head difference by creating a low gradient to the crest of a structure and a complex variety of velocities suitable for fish swimming and resting.

Rock ramps are a tried and tested means of improving fish passage at obstructions of a modest height. They are most suited to bypassing vertical fixed weirs and can overcome a head difference of ≤1m or up to 2m with the provision of resting locations (Armstrong *et al.,* 2003). They can be used to ease passage for a wide range of species and sizes. They are easy and cost effective to install and require low maintenance.

Rock ramps are only suitable for weirs where upstream water levels do not need to be tightly controlled and a flow control system is not required e.g. old weir structures, weirs used for channel stabilisation or those simply used to maintain headwater level. They must also be

robustly installed otherwise they can be prone to disintegrating in high flows

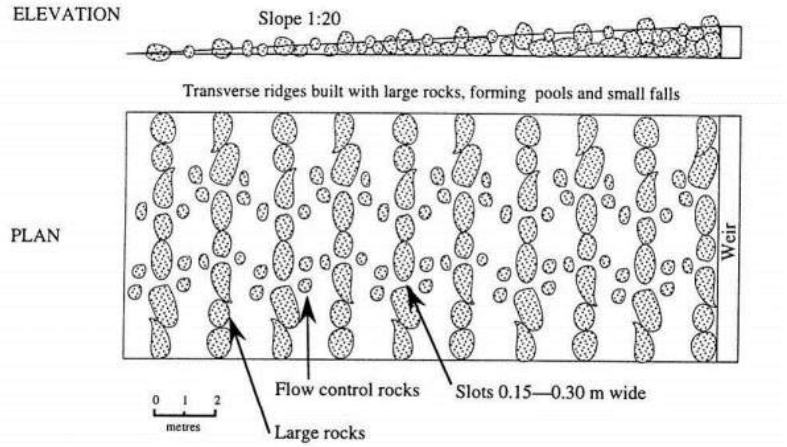

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Figure 4.1.2a: Example of a rock ramp design

4.1.3 General Notes on Baffle Type Fish Passes

Baffle type fish passes consist of geometrically-shaped deflectors fitted onto a straight, sloping channel. Baffle type fish passes function in reducing water velocity down a slope by developing helical currents, and they are able to effectively and continuously dissipate energy along a slope's entire length. Therefore, baffle type fish passes could assist fish passage on sloping weirs where high velocities currently limit upstream migration. Baffles are recommended for 1:2 slopes although they can be appropriate for slopes as shallow as 1:20. There is also the potential to include resting locations in passes with multiple flights (Armstrong *et al.,* 2003).

Different types of baffle fish passes exist where the baffles are placed on the sides of the channel, on the bottom of the channel, or both. Baffles are normally constructed from 10-12mm galvanised mild steel however stainless steel may be preferable to increase the design life past 60 years and in a salt-water environment (i.e. the Lower Crane where water is brackish). Disadvantages may occur if baffles are not constructed carefully; e.g. thinner baffles that create vibrations could dissuade fish from entering the pass and be abrasive. Also, there is potential to cause injury to fish if baffles are not fully rounded at their edges.

The length of a sloped barrier suitable for baffle type fish passes is limited to 6-8m for cyprinids (1.2-1.5m of drop) and 10-12m for other species (1.8-2.4m) of drop. The mean water velocity for any upstream exit channel should be 0.3-0.5m/s for course fish (Armstrong *et al.,* 2003). Providing a slope that is contiguous with the river bed would make baffle type fish passes more effective for benthic species such as Barbel. In general, baffles are a cost-effective means of reducing water velocity and easy to install.

4.1.4 General Notes on Eel Passes

Closed Type Eel Passes

Closed type eel passes typically consist of a pipe or trough of 10-25cm diameter, with a medium through which eels can climb (mesh, bottle-brushes) fastened to the base of the interior. The pass is fastened to the side of a weir and a small volume of water is drawn through the pipe from upstream. It is important to ensure that the medium is extended to the upstream and downstream river bed, and that it remains wetted throughout its entire length. The entrance of the pass is generally placed tight against the foot of an obstruction and extends close to the bed of the river. A pass can be fixed at angles up to 90° but shallower angles of 15-30° are most suitable for eel climbing. For particularly high passes, resting areas are recommended every 2-3m to ease an eel's climb over a barrier (Armstrong *et al.,* 2003).

Closed eel passes have been tried and tested in many locations with high success rates. They are also relatively cheap to construct and have the additional benefit of keeping fish safe from predation. A major difficulty with closed type eel passes is that they are easily clogged with debris and are very difficult to access for maintenance.

Open Type Eel Passes

Open type eel passes consist of a ramp covered in a medium, such as tufts of bristles, that is attached to the side of an obstacle to ease fish passage. Bristle type substrates consist of tufts of bristles that are spaced apart at distances suitable to meet the size of migrant expected (14mm apart for elvers and ≥21mm for adult eels). Open type eel passes can be used to overcome a head difference of around 2-3m before a resting location must be provided. The ideal width for these passes is 0.2-1.0m and their gradient should be between 5-45% (typically 20-30%). Water velocities should not exceed 0.2m/s in the area of passage (Armstrong *et al.,* 2003).

Open type eel passes are a tried and tested fish pass that are relatively cheap to construct and easy to install. They are available in standardised retro-fit units that can easily be attached to a structure. They can work efficiently in a range of flows and may also ease passage for some minor species including, bullhead, stone loach and brook lamprey. They do however require regular maintenance to stop the substrate from blocking with debris being washed down from upstream.

4.2 Prioritisation for Action

4.2.1 Ensuring the ingress of fish from the River Thames

There are two possible routes for fish to ingress to the Crane from the River Thames: The Lower Crane and The Lower Duke of Northumberland's River. The two rivers differ dramatically in terms of the number of obstructions to fish migration they contain, the quality of the habitat they offer to aquatic wildlife and their hydro morphology.

The Lower Crane (Twickenham to Isleworth)

The Lower Crane flows between Kneller Gardens, Twickenham and the River's confluence with the Thames in Isleworth. It contains 17 obstructions in total, 16 of which are impassable for coarse fish and 5 of which are impassable for juvenile eels.

The Lower Crane is tidal for around half of its reach, between Chertsey Road and it's confluence with the Thames. In its current condition, the river offers extremely low quality habitat to aquatic wildlife. The river has been contained within a heavily engineered channel with vertical concrete banks between 1.5-3m tall and a concrete bed offering little in the way of natural substrate.

In addition to the poor habitat, sections of this reach of river are prone to completely drying out in summer months. At the time of survey (July 2016), none of the weirs on the lower river were being overtopped with water, they were simply retaining a head of still or stagnant water upstream. The gradient of the river bed is clearly uneven in some places and some vertical weirs that are essential for water level management have become damaged over time. Fish were also observed to be stranded in occasional deeper pools that provided some refuge in an otherwise dry reach of river.

The flow problems on the Lower Crane arise from the DNR/Lower Crane flow split at Kneller Gardens. The River Crane forks into two arms in this location; The Lower DNR and Lower Crane. Currently the lower DNR takes most of the river's water, with the Lower Crane acting as a high flow channel that is utilised during times of heavy rainfall via the Mereway tilting weir. The Environment Agency has plans to address the flow split in this location in order to allow more water in to the lower Crane (Amanda Maclean, Brent & Crane Catchment Coordinator, pers coms, 2016). It must be noted that unless barrier mitigation is coupled with major habitat improvement works, such as the introduction of a low flow channel with appropriate marginal habitat, it will have little effect on improving fish passage in this reach of river. Each obstruction on the lower Crane would need to be reassessed in terms of fish passage after the flow split is adjusted.

The majority of barriers on the Lower Crane are regarded to be 'medium' priority despite their close proximity to the Thames Confluence. This is due to the environmental constraints of this reach of river, noted above, and information arising from our results which suggests that it would be easier to improve fish passage on the lower Duke of Northumberland's River in order to provide connectivity with the Thames.

In an ideal scenario, fish passage could be improved on both the Lower Crane and Lower DNR. The Crane Valley Partnership aspires to address the issues on the Lower Crane via *The Lower Crane Project*. A visioning document is being produced to outline the types of improvement that could be made to the river in this location and to catalyse future project work. This process is expected to be time consuming and until a route to delivery is established, improving fish passage on the DNR should be prioritised.

The Lower Duke of Northumberland's River (Twickenham to Isleworth)

The Lower DNR is a manmade river that was constructed in AD1605 to supply power to the area's watermills and water to the Duke of Northumberland's Estate at Syon Park, Isleworth. It flows from Kneller Gardens, Twickenham to its confluence with the Thames, opposite Isleworth Ait Nature Reserve. It contains 6 obstructions in total, 4 of which are impassable obstructions for coarse fish and 0 for juvenile eels. There are 12 fewer impassable barriers for course fish in The Lower DNR when compared to the Lower Crane.

The DNR is a flow regulated river, so it is not prone to the same summer low flow conditions as the Lower Crane. The flow split at Kneller Gardens ensures that the river maintains relatively uniform flows throughout the year. This in itself is beneficial to fish passage, as the variables recorded for each obstruction will remain relatively constant throughout the year. This entails that fish passes installed on these structures will operate at an equal efficiency regardless of time of year or antecedent conditions. This factor should be taken into account when considering options to address the Crane/DNR flow split. Reducing the DNR's flows may alter the passability scores assigned to each barrier in this report. The impact of the recalibrated flow split on fish passage should be fully assessed before any decisions are finalised.

The Lower DNR provides higher quality habitat for aquatic wildlife than the Lower Crane. Between Kneller Gardens and Twickenham Rugby Stadium, the river has low profile banks with a diverse array of marginal habitat. The river bed comprises of a clean gravel substrate, with water crowfoot (*Ranunculus fluitans*) visible in faster flowing sections. The habitat downstream of Mogden STW varies between straight sections of channel with enforced banks and natural substrate, to areas that are relatively 'natural' in appearance with low earth banks, complex riparian habitat and in-channel morphological features.

Ensuring fish passage from the River Thames to the middle reaches of the River Crane, hinges on easing four barriers on the Lower DNR. Two of these barriers (Asset IDs: 990006 and 193108) are already passable at high tide. The Kids Mill Sluice should be regarded as the highest priority as it prevents fish migrating upstream past the tidal limit of the DNR. As discussed in the results section (Section 3.2.3), a larinier fish pass could be installed in this location to provide coarse fish passage over the Kids Mill Sluice and the stepped barrier located shortly downstream of its outlet. An eel pass is already installed on this barrier so no action is required for this species. The barrier at the DNR's confluence with the Thames (990006) should also be prioritised to ensure that fish can enter the river at low tide. This barrier is currently impassable for coarse fish and eels and low tide.

The only barrier on the DNR upstream of those previously mentioned, which requires easement, is a small sloped weir located at Mogden Sewage Treatment Works. This barrier could be made passable via a small larinier or baffle type fish pass. Ensuring fish passage in this location, would provide fish with and unrestricted passage to Brazil Mill Woods, Feltham (approx. 10 km).

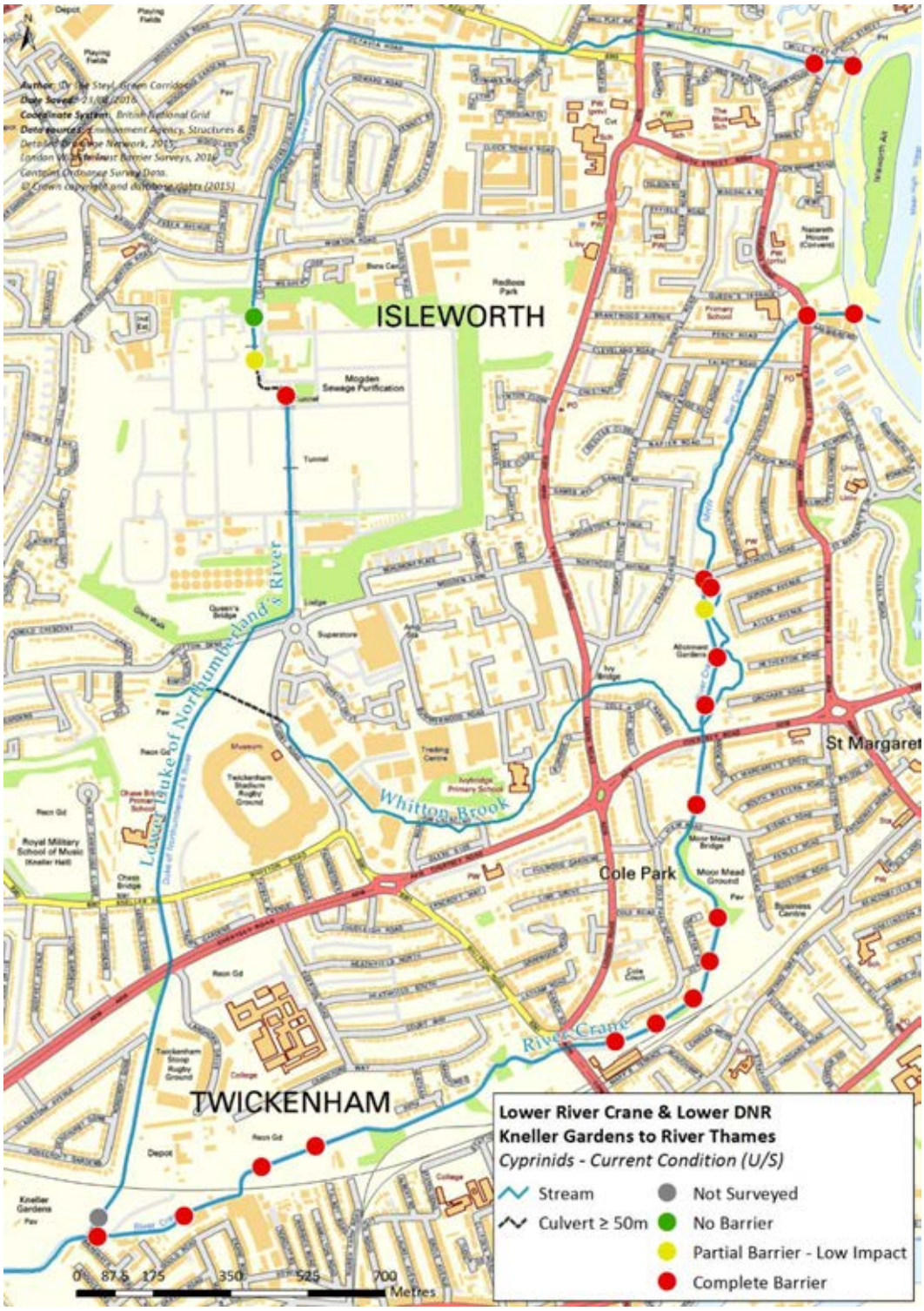

Figure 4.2.1a: Obstructions on the Lower Crane and Lower Duke of Northumberland's River for Cyprinids migrating upstream at low flow conditions.

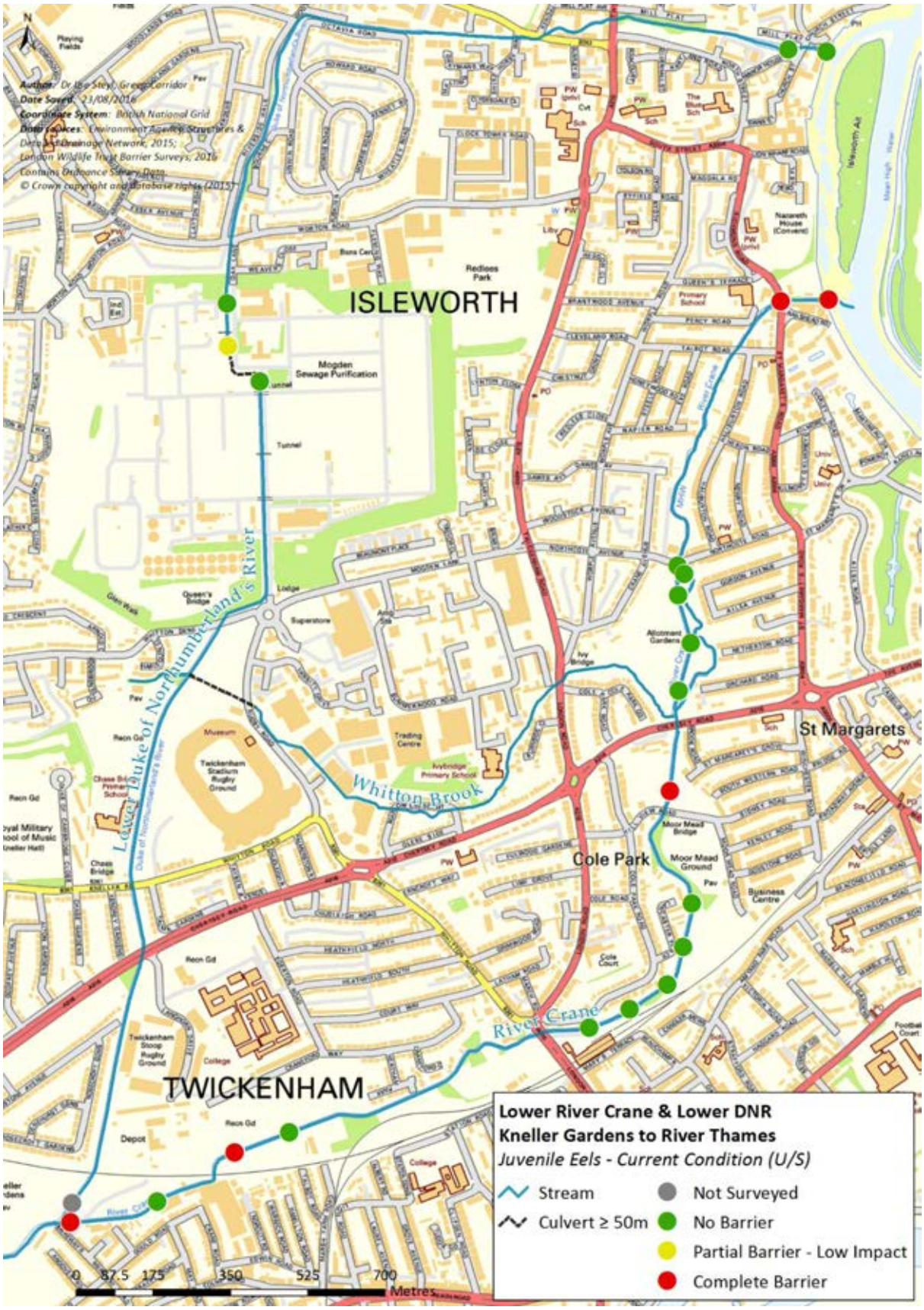

Figure 4.2.1a: Obstructions on the Lower Crane and Lower Duke of Northumberland's River for Juvenile Eels migrating upstream at low flow conditions.

4.2.2 Ensuring the connectivity of the middle and upper river

Once connectivity is improved between the Crane Catchment and the River Thames via barrier easement on the Lower DNR or barrier easement and major habitat improvement works on the Lower Crane, obstructions elsewhere in the catchment should be addressed in terms of their impact on habitat connectivity.

The River Crane (Middle and Upper Reaches)

The upper and middle reaches of the Crane flow between Minet Country Park, Hillingdon and Kneller Gardens, Twickenham. It contains 9 barriers in total, 4 of which are impassable for coarse fish, 3 for juvenile eels. The reach contains some of the best quality habitat in the catchment, including reconnected natural meanders, backwaters, complex riparian habitats and a diverse array of in-channel plant life. The reach also holds the most complete fish populations in the catchment, as a result of the River's restocking programme, which was implemented following major fish kills in 2011 and 2013.

Water quality between Donkey Wood, Feltham and Kneller Gardens is known to be the best in the catchment. The *Citizen Crane* Citizen Science Network has shown that water quality is dramatically improved downstream of where the upper (western) section of the DNR converges with the Crane (Crane Valley Partnership, 2015). The DNR brings a much needed source of freshwater from the River Colne, which helps to supplement the Crane's flows and dilutes polluted water. Above this point, between Donkey Wood and Minet Country Park, water quality deteriorates. Historical evidence shows that this reach still has the potential to support populations of coarse fish. Before the 2011 and 2013 fish kills, perch, gudgeon, roach, dace and chub were recorded in Environment Agency fisheries surveys at Cranford Park (Environment Agency, 2010). It is expected that water quality will improve in this area of the catchment as there are a number of active projects working to identify and resolve water quality issues in the catchment.

It is important that obstructions are made passable on this reach of river in order to ensure fish can migrate upstream to access the range of habitats required to complete their life cycles and to repopulate the Yeading Brook. Currently many barriers may be passable for downstream migrants but not for upstream migrants. These barriers should be eased to ensure that fish populations are not depleted in the upper reaches of the Crane as a result of downstream migration.

Ensuring fish passage from The River Crane to The Yeading Brook involves easing four obstructions. The most important of which is the historic mill race at Brazil Mill Wood, Feltham (Asset ID: 990011), discussed in the results section (Section 3.3.3), and the semi passable weir at Brazil Mill Wood located shortly upstream of this (Asset ID: 278508). Ensuring that these barriers are passable for coarse fish and eels will open up an area of river of 3km, with the next barrier upstream located in Cranford, Middlesex. As mentioned previously, this area of river offers some of the best coarse fish spawning and recruitment habitat in the catchment and a range of semi online habitats for adult eels to complete the growth phase of their life cycle. The mill race could be made passable via the provision of a

larnier fish pass and open or closed eel pass. The weir upstream could be breached at its centre, to reduce its hydraulic head and restore the natural gradient of the river.

In order to provide connectivity from The Crane to The Yeading Brook, two obstructions must be eased in Cranford (193617 and 265972; see sections 3.3.6 and 3.3.7). The first barrier (193617), located at Crane Bank could be made passable via the provision of a rock ramp and baffles attached to the crest of the structure. It is expected that implementing this design would be relatively simple in this location. Access is available from Crane Bank Meadows or can be arranged from the Bath Road (A4) with permission from The London Borough of Hounslow. The barrier upstream of this (265972), located at Cranford Park, is more difficult to address due to its current function as an Environment Agency telemetry station. Making this barrier passable would provide coarse fish an eels with unhindered access from Cranford Park to The Yeading Brook West, opening up an area of 7.3Km of river. Design options should be considered for a new telemetry station that has less of an impact on fish passage. Alternatively a larinier fish pass, baffle type fish pass or open eel pass could be fitted to one side of the structure if they could be installed in a way which did not affect telemetry data.

The Hounslow Mill Stream

The Hounslow Mill Stream splits off from the Crane at Brazil Mill Woods and re-joins the river at Crane Park in Whitton. The stream contains 4 barriers in total, 3 of which are impassable for coarse fish, and 1 for Juvenile eels. The mill stream suffers from low flows but offers high quality in-channel habitat in terms of submerged and emergent aquatic plant life. The channel is straight in its form throughout most of its length and is prone to siltation and blockages. The stream could be used as a bypass channel to provide an alternative to upstream migration via the River Crane. This would enable fish to pass two barriers in Brazil Mill Woods (990010 and 278508).

Much of the mill stream was inaccessible to surveyors during the production of this report. As a result we are unable to comment on its suitability as a bypass channel for coarse fish. It is unlikely that the millstream will provide a better alternative to the main river due to its manmade morphology, poor substrate, low flows and tendency to block. It may however be a suitable route of passage for juvenile eels, seeking more sheltered conditions to ascend the river during times of high flow.

The stepped barrier at the Mill Streams confluence with the Crane at Crane Park (283977; see section 3.4.1) may not be suitable for easement. At the time of survey, there was a very small amount of water passing over the barrier which may limit its suitability for easement techniques. Options for consideration are discussed in the results section.

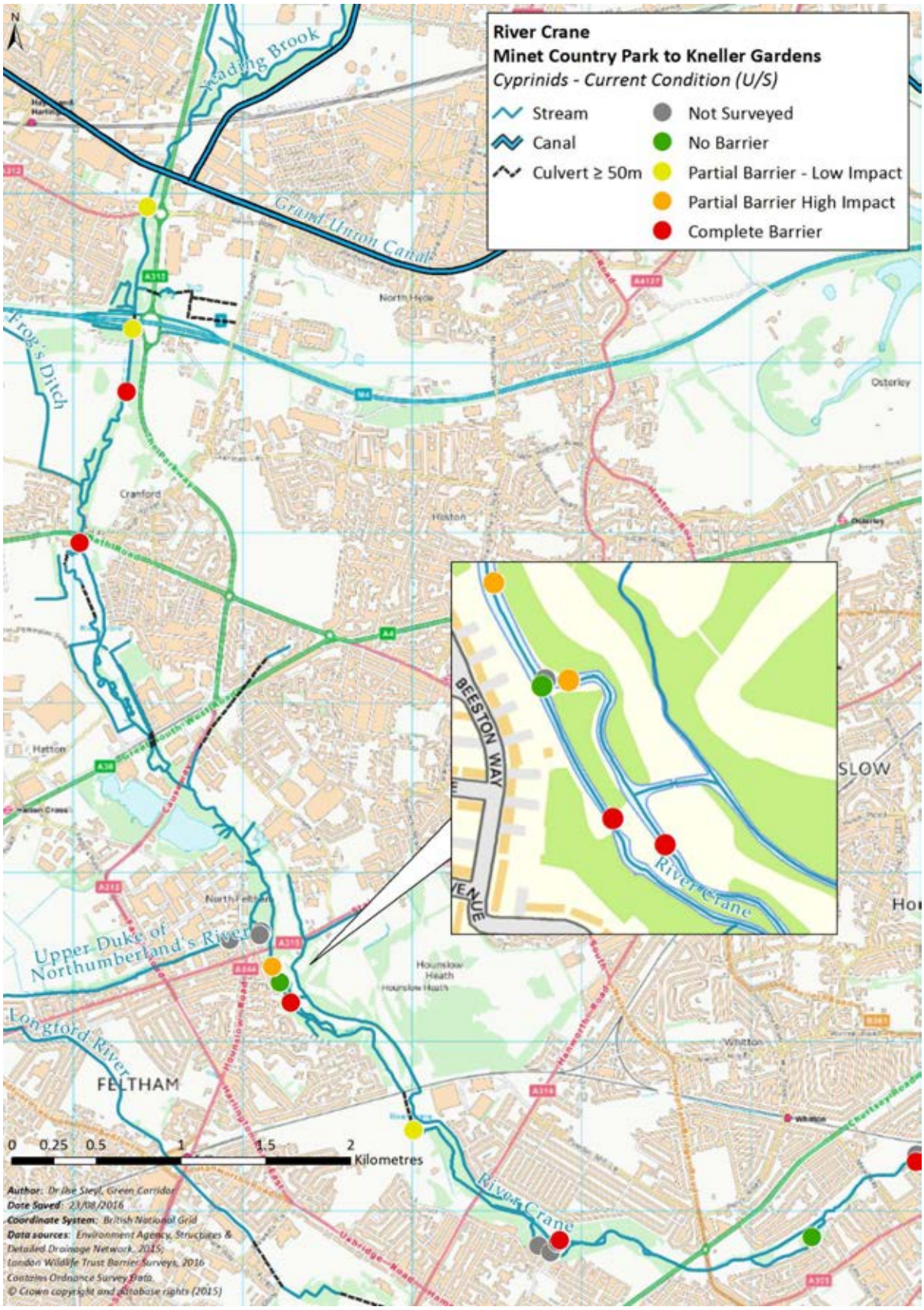

Figure 4.2.2a: Obstructions on the River Crane (middle and upper reaches) and Hounslow Mill Stream for Cyprinids migrating upstream at low flow conditions.

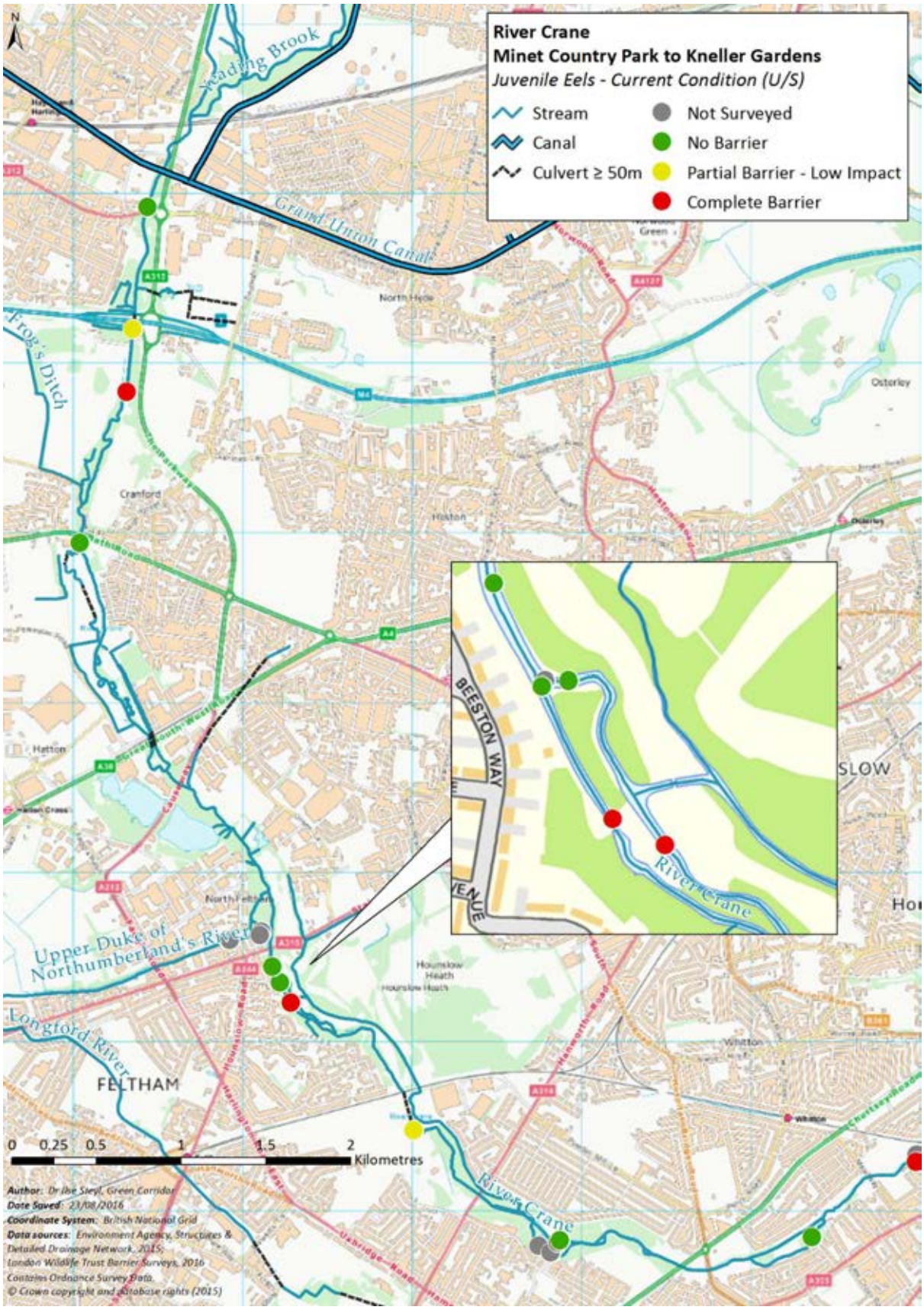

Figure 4.2.2b: Obstructions on the River Crane (middle and upper reaches) and Hounslow Mill Stream for Juvenile Eels migrating upstream at low flow conditions.

The Yeading Brook

The Yeading Brook flows between 10 Acre Woods Nature Reserve, Hayes to Minet Country Park, Hayes. It contains 1 obstruction in total that is passable by both coarse fish and juvenile eels. The Yeading Brook's aquatic habitat and hydro morphology is of poorer quality than that of the Crane. The river has been artificially straightened and widened throughout most of its length and in many areas has steep earth banks comprising of materials arising from historic dredging activity. The river passes through urban areas, public parks and nature reserves and has high potential for restoration. During the time of surveying, stoneloach, stickleback, minnows and chub were observed in this reach of river.

Water quality in the Yeading Brook is poorer than that of the Crane. The *Citizen Crane* citizen science network has shown that water quality is particularly poor at Minet Country Park, but improves upstream at Yeading Brook Meadows, Hayes. The brook contains numerous outfalls, many of which have been shown to pollute the river on an intermittent basis. Habitat and water quality should be improved in this part of the catchment in order to provide an area where fish and aquatic wildlife can flourish. This in itself will improve connectivity the upper reaches of the river, such as The Yeading Brook West.

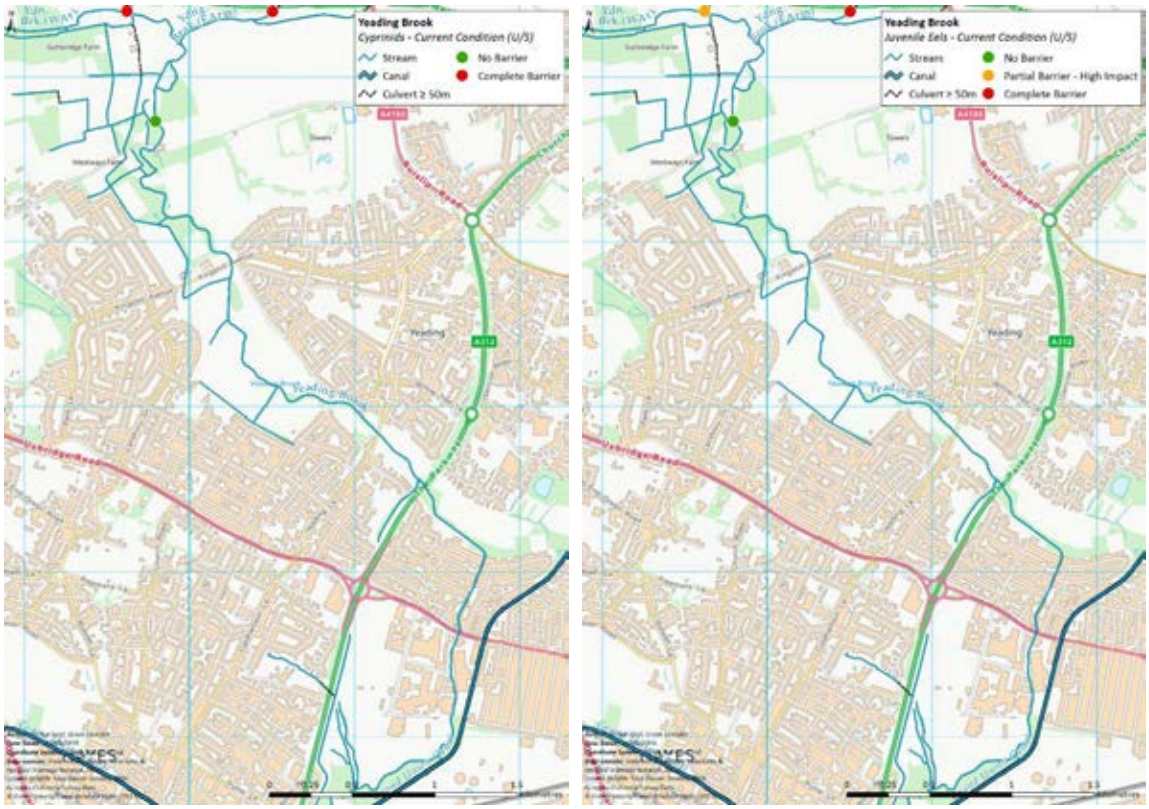

Figure 4.2.2c (left): Obstructions on the Yeading Brook for Cyprinids migrating upstream at low flow conditions.

Figure 4.2.2d (right): Obstructions on the Yeading Brook for Juvenile Eels migrating upstream at low flow conditions.

The Yeading Brook West

The Yeading Brook West flows between 10 Acre Wood Nature Reserve and Headstone Manor, Harrow. It contains 8 obstructions in total, 7 of which are impassable for cyprinids, 4 for juvenile eels. The morphology of the brook varies between artificially straightened and widened sections, such as Spider Park in Ruislip Gardens, to more natural and sinuous reaches, such as Ickenham Marsh, Ickenham. Large areas of the upper Yeading Brook have been culverted to make way for urban development. The substrate of the river is generally good quality and suitable for fish spawning. During the time of surveying, sticklebacks and minnows were observed in this reach of river.

The *Citizen Crane* citizen science network has shown that The Yeading Brook West's water quality is comparable to that of the Yeading Brook, with some areas, such as Spider Park scoring particularly poorly (Crane Valley Partnership, 2015). The brook contains numerous outfalls, many of which have been shown to pollute the river on an intermittent basis. This may have an effect on fish spawning as poor water quality can affect the viability of fish eggs.

The highest priority barriers for easement are located in Gutteridge Woods Nature Reserve, Hillingdon. These consist of a hydro break with sloped apron (453385) and a large box culvert with vertical step (990014). Easement options for consideration are listed in the results section (sections 3.6.1 and 3.6.2). The next barrier upstream from Gutteridge Wood (261323) is located 1.4km upstream at Stafford Road Open Space, Ruislip Gardens. The reach of river in between these barriers flows through Ickenham Marsh Nature Reserve. The river corridor in this location offers good habitat quality in comparison to other areas of the Yeading Brook, with areas of river being sinuous in nature with good light levels and diverse aquatic flora. Making this barrier passable would ensure fish passage through Stafford Road Open Space to Ruislip Gardens Underground Station.

Ruislip Gardens Underground station is considered to be the upper limit of fish passage on the Yeading Brook West. This is due to a large stepped weir (261327) and a complex culvert system (990015) that runs underneath the station itself and is integral to dissipating the river's energy during high flows to prevent flooding.

The Yeading Brook East

The Yeading Brook East flows between 10 Acre Wood Nature Reserve and Headstone Mannor, Harrow. It contains 7 barriers in total, 7 of which are impassable for coarse fish, 6 for juvenile eels. The river is heavily urbanised with large areas of its length being forced into concrete culverts and channels. Where the river does flow through greenspace, it is generally contained in straightened and over shaded channels, hidden from public view.

During the time of surveying, water quality was observed to be especially poor, with visible signs of pollution on the bed of the river. The *Citizen Crane* citizen science network has shown that water quality at Newton Park (West), at the head of the brook, is particularly poor given its close proximity to the river's source.

The obstructions recorded in this report are not the only features preventing fish passage in the Yeading Brook East. In many locations where the river flows through concrete channels, water depths were observed to be insufficient to allow fish passage. One such location is the Polish War Memorial culvert (990019), located just upstream of the river's confluence with the Yeading Brook, and running adjacent to the A40. The river is placed in an open culvert that does not provide the depths of water required for fish passage. Similar reaches of river can be found throughout the Yeading Brook East and as a result of this, coupled with poor water quality, it is not recommended that fish passage is encouraged to this part of the catchment.

A sensible option would be to improve biological water filtration at the lower end of the river. The Polish War Memorial culvert could be planted with reeds or turned into a sustainable urban drainage scheme in order to treat polluted water in before it reaches The Yeading Brook. This would also have an impact on river levels, possibly increasing them to an extent where fish passage would be possible. Extensive habitat improvement works throughout the Yeading Brook East are required to make it a suitable home for coarse fish and eel populations.

Figure 4.2.2e: Obstructions on the Yeading Brook East and Yeading Brook West for Cyprinids migrating upstream at low flow conditions.

Figure 4.2.2f: Obstructions on the Yeading Brook East and Yeading Brook West for Juvenile Eels migrating upstream at low flow conditions.

4.2.3 List of Top Ten Priority Structures

A table showing a list of the top ten priority barriers in the Crane Catchment with easement options and relative cost.

Priority	**Barrier**	**River and Location**	**Type of Easement**	**Estimated Cost** *(high, med, low)*
1	Kids Mill Sluice and stepped barrier 193108	DNR, Isleworth	Larinier fish pass	High
2	Mogden Barrier 3 Sloped Weir 262984	DNR, Isleworth	Larinier or baffle type fish pass	Medium
3	DNR/Thames Barrier Stepped Barrier 990006	DNR, Isleworth	Rock ramp or larinier fish pass.	Medium
4	Brazil Mill Wood Barrier 1 Mill Race 990011	Crane, Feltham	Larinier fish pass	Medium
5	Brazil Mill Wood Barrier 3 Vertical Weir 278508	Crane, Feltham	Breaching	Low
6	Crane Bank 1 Sloped Barrier 193617	Crane, Cranford	Rock ramp	Medium
7	Cranford Park 1 Telemetry Station 265972	Crane, Cranford	Uncertain	Uncertain
8	Gutteridge Wood 1 Hydro brake 453385	Yeading Brook West, Uxbridge	Baffle type fishway	Low
9	Gutteridge Wood 2 Box Culvert 990014	Yeading Brook West, Uxbridge	Rock ramp and baffle type fish way. Provision of lighting.	Medium/High
10	Stafford Road Vertical weir 261323	Yeading Brook West, Ruislip	Removal or breaching.	Low

Table 4.2.3a: List of the top ten barriers to prioritise action in the Crane Catchment

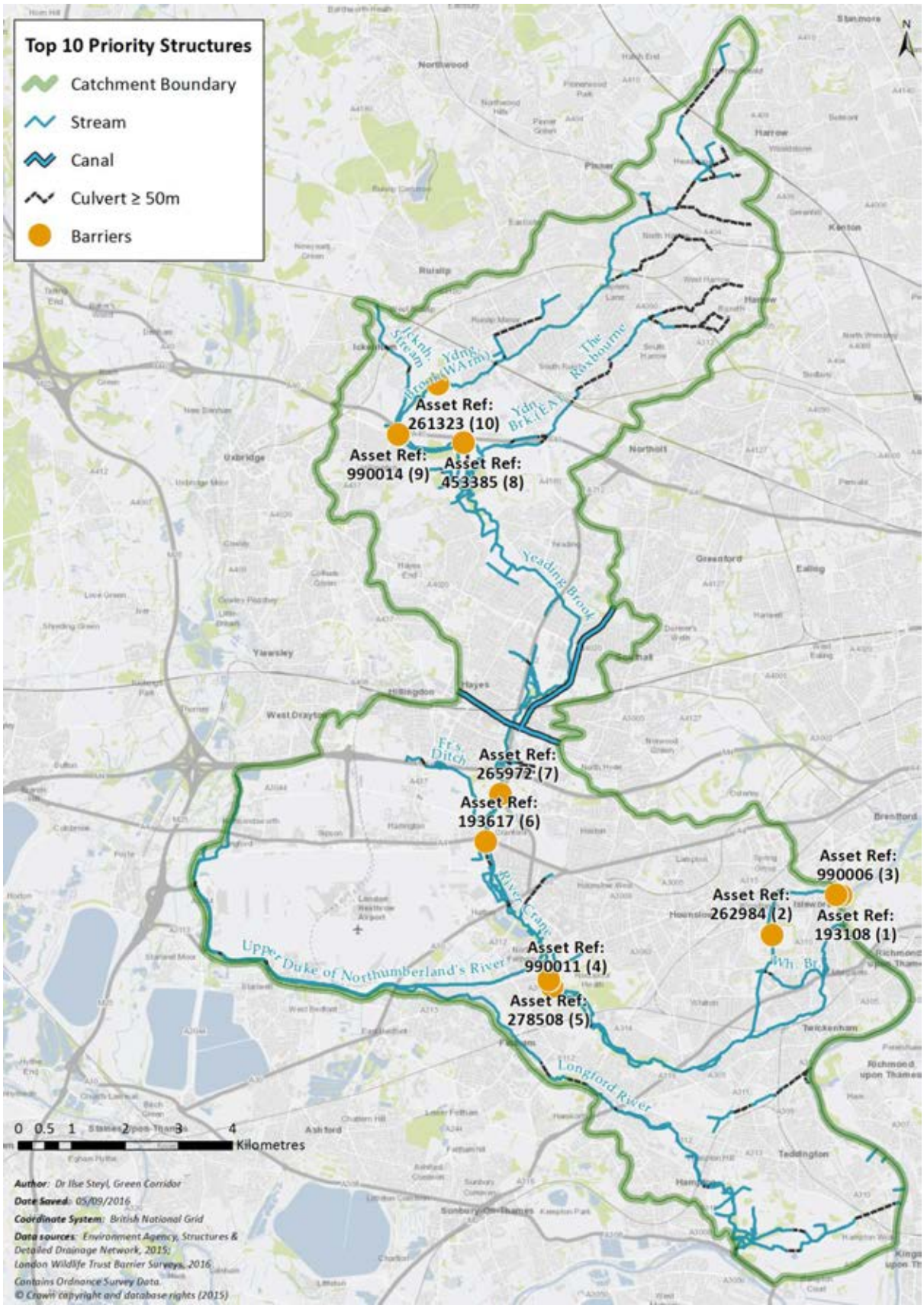

Figure 4.2.3a: Top 10 priority structures in The Crane Catchment

4.3 Limitations

The SNIFFER *Coarse Resolution Rapid-assessment Methodology* is an extensive and detailed methodology that takes into account a large number of parameters to generate passability scores separately for cyprinids and European eels both upstream and downstream. However, there are several limitations to this methodology when applied to the context of the Crane Catchment regarding the monitoring of culverts, accuracy of estimated data, and assessments of habitat and water quality.

Firstly, many culverts in the Crane Catchment (e.g. culverts at Mogden Sewage Works and Hanworth) do not obstruct the river channel, however the SNIFFER methodology does not explicitly account for cases such as these. As well as factors already accounted for in the methodology including depth and flow, there is also evidence that the length of culverts has a negative impact on upstream migration due to the fact that fish may be discouraged from swimming through culverts due to the absence of natural light (Environment Agency, 2010). In this report, length of culverts was taken into account in addition to the SNIFFER methodology (see Section 2.8). In future, a more detailed and evidence-informed methodology for assessing culverts would be welcomed.

In some cases, it was necessary to estimate measurements for barriers that were inaccessible, and therefore passability scores for these barriers should be considered less accurate than those where all measurements were undertaken. Similarly, in generating passability scores at high flows, surveyors estimated how higher water flows would impact the barrier, e.g. whether the barrier would have sufficient water flowing over it, whether high flows would increase water velocity, or whether the hydraulic head of a barrier might be reduced. The surveyors also consulted with local residents to discuss how barriers present at high flows.

When prioritising barriers for action, there were many more considerations than passability scores alone. Importantly, the location of the barrier influences how much habitat would be available to fish should a barrier be removed (i.e. distance to next impassable barrier upstream). The surveyors also made observations about habitat and water quality to consider the quality of habitat that would be available to fish in a particular reach of river. While the SNIFFER methodology generates passability scores for each barrier, it does not provide a method for translating these scores into action, nor does it recognise the potential of other confounding factors such as those discussed above.

The SNIFFER methodology is also not completely applicable to the range of species found in tidal reaches of river, such as the Lower Crane. Estuarine fish species, which use tidal transport to migrate upstream, would ascend barriers in a different way to rheophillic cyprinid species or juvenile eels. The methodology does not provide a means of calculating passability scores for such species, thus they are not accounted for in this report.

Acknowledgements

We are very grateful to the following people and organisations that contributed to this study:

Lydia Blake, Nature Reserve Warden, Thames Water

Martin Day, Tidal Crane Association

Paul Evans, Environment Agency

Heatham House Youth Centre, Twickenham

Rosalind Warwick-Haller

Additionally, we would like to acknowledge all those that commented on drafts of this report.

References

Aarestrup, K., Okland, F., Hansen, M., Righton, D., Gargan, P., Castonguay, M., Bernatchez, L., Howey, P., Sparholt, H., Pedersen, M. and McKinley, R., (2009). Oceanic Spawning Migration of the European Eel (Anguilla anguilla). *Science*, 325(5948), pp.1660-1660.

Armstrong G, Aprahamian M, Fewings A, Gough P, Reader N and Varallo P., (2004). Guidance notes on the legislation, selection and approval of fish passes in England and Wales. Published as CD entitled "Environment Agency Fish Pass Manual V1.1 24-02-2004" Environment Agency, Bristol.

Crane Valley Partnership, (2015). *The Citizen Crane Project Year One Interim Report*. [ONLINE] Available at: http://www.cranevalley.org.uk/documents/CitizenCraneReport_August2015.pdf [Accessed 24 Aug. 2016].

Environment Agency, (2010). *Brent and Crane Report. Water quality, ecology and fishery data 1999 - 2010*. Hatfield: Environment Agency.

Environment Agency, (2010). *Structural modification of culverts*. [ONLINE] Available at: http://evidence.environment-agency.gov.uk/FCERM/en/SC060065/MeasuresList/M7/M7T1.aspx?pagenum=2. [Accessed 22 August 2016]

Environment Agency, (2012). *Fish restocking strategy for the River Crane and Duke of Northumberland's River*.

Environment Agency, (2003). *River Weirs – Good Practice Guide Guide - Section A*. Bristol: Environment Agency.

Lucas, M.C., Thom, T.J., Duncan, A & Slavik, O., (1998). Fish Migration: Occurrence, Causes and Implications. Research and Development Technical Report W 152. Environment Agency, UK.

Kemp, P. S., Russon, I. J., Waterson, B., O'Hanley, J. & Pess, G. P., (2008). Recommendations for a Coarse Resolution Rapid Assessment Methodology to Assess Barriers to Fish Migration, and Associated Prioritisation Tools. International Centre for Ecohydraulic Research Report.

Scotland & Northern Ireland Forum for Environmental Research, (2010). *WFD111 (2a) Coarse resolution rapid-assessment methodology to assess obstacles to fish migration*.

The Wild Trout Trust, (2012). *The River Crane – an advisory visit carried out by the Wild Trout Trust*. [ONLINE] Available at: http://www.wildtrout.org/system/files/private/River%20Crane%20Advisory%20Visit.pdf [Accessed 24 Aug. 2016].