A Catchment Plan for the River Wandle

Prepared by the Wandle Trust on behalf of the communities and stakeholders of the Wandle Catchment

Written by Theo Pike, Claire Bedford, Bella Davies and Dave Brown

THE RIVER WANDLE CATCHMENT PLAN
September 2014: v1

0.1 EXECUTIVE NON-TECHNICAL SUMMARY

The Wandle Catchment Plan has been compiled to provide a holistic strategy for restoring south London's River Wandle to its former glory as one of the world's most famous chalk streams.

The Wandle rises on the north slopes of the North Downs in Carshalton and Croydon, and flows 23.5km through the London boroughs of Croydon, Sutton and Merton to join the Thames at Wandsworth.

Chalk streams like the Wandle are a globally-rare and precious part of our cultural heritage, but many now suffer from human modification and other pressures including over-abstraction of water, sources of pollution including roads and sewage treatment works, and the spread of industry and urban areas.

In recognition of these pressures on the Wandle, a wide-ranging partnership including the Environment Agency, local councils, the Wandle Trust, London Wildlife Trust, local anglers and many residents and Wandle Valley stakeholders have come together to create this shared plan for the future of their river.

The first component of this Catchment Plan is the Vision, which was published in 2012, and the second component is this more technical document. This is designed to be an aspirational, 'living' Action Plan based on evidence and sound science, which will also be updated in light of new knowledge and emerging research.

As such, it fits into the EA's national Catchment Based Approach for river management planning, and will help the Wandle to reach a state of health known as 'Good Ecological Potential' for the purposes of fulfilling the UK's obligations under the European Water Framework Directive.

In the course of compiling this Catchment Plan, the following Aims have been identified for sustainably improving the health of the Wandle, and its value to local people:

- **Water**: the river's water should be plentiful and clean, and varied in its flow speeds, widths and depths
- **Habitat and wildlife**: the river should support a mosaic of habitats with high biodiversity
- **Good access**: local people should be able to access sympathetically managed pathways along the whole river
- **Engagement**: everyone in the catchment should be aware of the river, and knows how their actions can affect it, with councils, businesses, government agencies and the public working together to improve the river

In turn, these Aims have generated a suite of shared Objectives:

- **Water quantity**: water supply in all sections of the river should be sufficient to sustain a healthy population of native flora and fauna and is resilient to risk of drought or flood from extreme weather events or management for human use
- **Water quality**: quality of water flowing in the River Wandle should meet the standards required for Good Ecological Potential and is stable with no risk of deterioration
- **Dynamics of flow**: the river should have a re-naturalised varied profile that creates a diversity of flow speeds and water quantity to provide all the key habitat types required by the native flora and fauna associated with lowland chalk streams

- **Fish and fisheries**: thriving populations of native fish associated with chalk rivers should be present and able to move freely
- **Macrophytes, trees and the wider river habitat**: communities associated with chalk rivers should be abundant along the river, providing good habitat variety for wildlife and for people
- **Invertebrates**: the diverse communities associated with chalk rivers should be abundant along the river, playing important roles in ecosystem function and complexity, such as providing a food source for other wildlife
- **Phytobenthos**: good populations associated with chalk rivers should be present along the river

Under each Objective, a range of Targets and Actions has also been identified for the river's benefit, and to increase the environmental and cultural benefits (also known as ecosystem services) which it provides for local people.

These Actions are listed in tables at the end of each section of the Catchment Plan, with indicative costs. Future pressures and changes – including climate change, demand for water, population increase and other socio-economic pressures are also considered, and broad brush solutions are suggested where possible.

Supporting documentation such as the Environment Agency's Catchment Summary Sheets are incorporated into the Catchment Plan in the form of easily-updatable Appendices, and further reading and opportunities for research are identified wherever relevant.

By progressively implementing the measures identified in this Catchment Plan, all partners involved hope that the River Wandle can be restored to good health as a shining example of an urban chalk stream, enhancing the wellbeing of local communities, and resilient to present and future pressures.

0.2 CONTENTS

0.3 ACKNOWLEDGEMENTS

The Wandle Catchment Plan is the creation of a partnership project involving the following organisations:

The Wandle Trust (WT), Environment Agency (EA), Natural England (NE), WWF-UK, Thames Water (TW), Sutton & East Surrey Water (S&ESW), London Boroughs of Wandsworth (LBW), Merton (LBM), Sutton (LBS) and Croydon (LBC), London Wildlife Trust (LWT), National Trust (Morden Hall Park) (NT), Wandle Valley Regional Park Trust (WVRPT), Beddington Farmlands (BF), The Angling Trust (AT), The Rivers Trust (RT).

It would not have been possible to produce this document without the invaluable input and support of many people, and we extend our warmest thanks to all of them. They are:

The Steering Group:

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Dr Bella Davies, Dr Dave Brown, Theo Pike, Laurence Evans, Toby Hull, Tim Longstaff, Erica Evans, Claire Shahbazian Bedford

Fish Technical Advisory Group:

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The Wandle Catchment Plan was compiled and written by Claire Shahbazian Bedford and Theo Pike, with support from Dr Bella Davies and Dr Dave Brown.

0.4: TIMELINE

See separate document attached

SECTION 1: INTRODUCTION

1.1: The need for a Catchment Plan for the River Wandle

"We're glad to see lots of people and organisations already looking after the River Wandle, and we want even more joined up planning and projects to improve the river"

- from Ketso community and stakeholder workshops

Chalk streams like the River Wandle are a rare and precious part of our cultural and ecological heritage.

The image of a pristine chalk stream or river, with constant flows of clean, clear water, and iconic native species like trout and mayflies, is recognised all over the world. Around 85% of the world's chalk streams and rivers are located in southern and eastern England, and they still have the potential to provide a pristine environment for wildlife, as well as many benefits for people who live near them. Yet these globally-rare habitats face intense and mounting pressures, which have already forced many into a seriously degraded state.

The Wandle represents a microcosm of these pressures – from over-abstraction to pollution, urbanisation and invasion by non-native species. But these challenges also offer unique opportunities to restore and even recreate significant areas of habitat which have been described as England's equivalent of the Arctic ice-caps or the Brazilian rainforest.

Since the 1960s, when the Wandle was fishless and effectively functioning as south London's open sewer, the river's environmental status has already seen astonishing improvements – to the extent that it was singled out as one of the six British rivers with the highest rate of improvement in 1972 (Shew, 2012) and once again hailed by the Environment Agency as one of the UK's most improved rivers in 2011.

In 2007, after one of the most serious pollution incidents in the Wandle's history, local communities and the statutory authorities agreed that sustainable recovery needed to be based on robust scientific evidence, strong partnerships around the river, and a long-term Catchment Plan. This would also contribute to meeting the objectives of the European Water Framework Directive (WFD), which requires the river to reach Good Ecological Potential by 2015 (with alternative target dates of 2021 and 2027 under certain circumstances).

Since the need for a Wandle Catchment Plan was agreed by local stakeholders in the Wandle catchment, the Catchment Based Approach to river management and restoration has been formally adopted by government as the best framework for delivering river improvements nationwide. As a result, the Wandle Catchment Plan now forms part of a UK-wide suite of strategy documents, each tailored to the individual requirements of their river catchments.

The Wandle Catchment Plan consists of two parts – the Vision (published in 2012) and this more technical document.

It is designed to be a 'living' document, to be updated in light of new and ongoing work and research. It is also designed to be aspirational: using robust science to identify what is strategically necessary to restore the river, and make it resilient to future pressures, rather than responding to political pressures which may be subject to change over time (thus bringing different delivery priorities and tactical opportunities to the fore).

And it represents the outstanding commitment of local communities and the statutory authorities to restore the Wandle "to be a naturally functioning and self-sustaining chalk stream, rich in biodiversity and a haven for Londoners".

1.2: A shared Vision and Action Plan

The Wandle Catchment Plan has been developed by means of a rigorous partnership process of investigation, using a double-stranded approach of community consultation underpinned by expert scientific guidance, as depicted in the flow chart below.

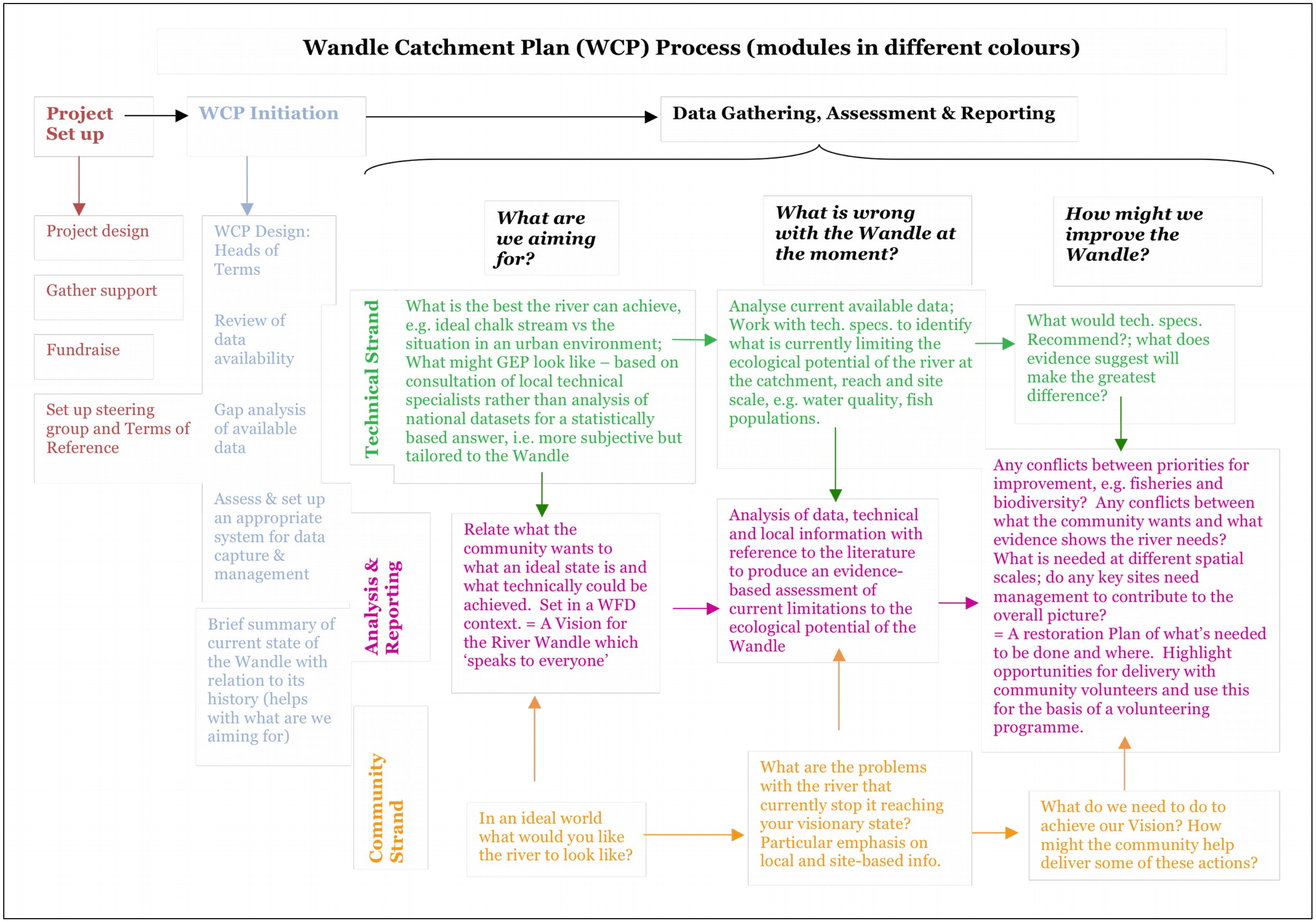
The creation and implementation of the Wandle Catchment Plan is a partnership project facilitated by the Wandle Trust, an environmental charity dedicated to restoring and maintaining the health of the River Wandle and its catchment. The Wandle Trust works closely with policy makers, land managers and statutory bodies in addition to engaging with the local community in outreach and education activities. This has made the charity a natural choice to lead the consultation on local people's Vision and Action Plan for their river, and develop and maintain the Wandle Catchment Plan in the future.

Strategic guidance has been provided by a Steering Group formed of representatives from local, regional and national organisations: the London Boroughs of Croydon, Sutton, Merton and Wandsworth, Environment Agency (EA), Natural England (NE), the National Trust (Morden Hall Park), Beddington Farmlands, Thames Water (TW), Sutton & East Surrey Water (S&ESW), Wandle Valley Regional Park Trust, WWF-UK, the Angling Trust, the Rivers Trust and London Wildlife Trust.

The Wandle Catchment Plan is composed of two parts:

- A shared Vision for the River Wandle outlining what the community (anyone with an interest in the Wandle) wants the river to look like in the future: this was published in October 2012

- An Action Plan of evidence-based Objectives, Targets, Actions and Projects to restore the river, maintain and enhance the ecosystem services it provides for people, and help it to achieve Good Ecological Potential under the European Water Framework Directive (WFD)


Wandle Catchment Plan (WCP) Process (modules in different colours)
Project Set up
WCP Initiation
Data Gathering, Assessment & Reporting
Project design
Gather support
Fundraise
Set up steering group and Terms of Reference
WCP Design: Heads of Terms
Review of data availability
Gap analysis of available data
Assess & set up an appropriate system for data capture & management
Brief summary of current state of the Wandle with relation to its history (helps with what are we aiming for)
What are we aiming for?
What is wrong with the Wandle at the moment?
How might we improve the Wandle?
Technical Strand
What is the best the river can achieve, e.g. ideal chalk stream vs the situation in an urban environment; What might GEP look like – based on consultation of local technical specialists rather than analysis of national datasets for a statistically based answer, i.e. more subjective but tailored to the Wandle
Analyse current available data; Work with tech. specs. to identify what is currently limiting the ecological potential of the river at the catchment, reach and site scale, e.g. water quality, fish populations.
What would tech. specs. Recommend?; what does evidence suggest will make the greatest difference?
Analysis & Reporting
Relate what the community wants to what an ideal state is and what technically could be achieved. Set in a WFD context. = A Vision for the River Wandle which 'speaks to everyone'
Analysis of data, technical and local information with reference to the literature to produce an evidence-based assessment of current limitations to the ecological potential of the Wandle
Any conflicts between priorities for improvement, e.g. fisheries and biodiversity? Any conflicts between what the community wants and what evidence shows the river needs? What is needed at different spatial scales; do any key sites need management to contribute to the overall picture? = A restoration Plan of what's needed to be done and where. Highlight opportunities for delivery with community volunteers and use this for the basis of a volunteering programme.
Community Strand
In an ideal world what would you like the river to look like?
What are the problems with the river that currently stop it reaching your visionary state? Particular emphasis on local and site-based info.
What do we need to do to achieve our Vision? How might the community help deliver some of these actions?

1.2.1: Community consultation

From the very first stages of creating the Wandle Catchment Plan, engagement with local stakeholders has been a key priority. The views of residents and other stakeholders have been at the heart of creating the shared Vision, and have guided the definition of Good Ecological Potential for this Action Plan.

By involving local communities in developing the first strand of the Catchment Plan, plans for future actions and projects have been designed to reflect their values and interests. As a result, it's hoped that these projects will be sustainably enhanced with long-term support from local people.

Four questions were posed during the consultation process, at group workshops and via a questionnaire (both in hard copy and electronically via the Wandle Trust website):

- What would they like the River Wandle to look like, in an ideal world? (vision)
- What is currently good about the River Wandle? (assets)
- What is currently bad about the River Wandle? (challenges and barriers)
- What could be done to help improve the River Wandle, and how could they be involved? (solutions)

Fifty-six different organisations and interest groups participated, involving approximately 500 people including councillors, residents' associations, local schools and angling clubs. Twenty-seven workshops took place across the London Boroughs of Croydon, Sutton, Merton and Wandsworth, and were run during the daytime, evenings and weekends to enable as many people as possible the opportunity to participate at a venue and time local and convenient to them. Questionnaires were handed out at local events (for instance, Morden May Fayre and Wandle Trust community river cleanups).

To enable everyone to have a say in a creative, hands-on format, a Ketso kit (www.ketso.com) was used as a consultative tool. This innovative tool is designed to encourage participation whilst preventing any one individual from dominating a workshop. Additionally, workshops were tailored to the groups' needs, for example creating a more discursive situation with people on hand to transcribe ideas if participants were less comfortable with writing. All participants were asked for feedback on the method used and content of the workshop and the results were overwhelmingly positive.

Participants were asked to provide contact details and their interest in volunteering to enhance the River Wandle. Options included desk-based and non-manual volunteering as well as physical activities such as planting native species, litter cleanups and surveying. This information has already increased the volunteer database within the catchment and fed into funding applications that encourage volunteer involvement.

1.2.2: A shared Vision

Participants' answers to the first question above ("What would you like the River Wandle to look like, in an ideal world?") were organised into themes. Several themes emerged as being important to local people, with four standing out in particular. All the comments made about these four themes were then examined again in full to create the wording of the shared Vision's final aims:

- Habitat and wildlife: the river supports a mosaic of habitats with high biodiversity
- Water: plentiful and clean, and varied in its flow speeds, widths and depths
- Good access: sympathetically managed pathways along the whole river

- Engagement: everyone in the catchment aware of the river and knowing how their actions can affect it. Councils, businesses, government agencies and the public working together for the river

Together, the participants' responses were used to create a shared Vision of:

"A naturally functioning and self-sustaining chalk river rich in biodiversity and a haven for Londoners"

The outputs from the workshops were then submitted for a second round of community consultation via the Wandle Trust website. In addition to ensuring transparency and checking for accuracy of interpretation, this was designed to demonstrate that the consultation responses were being used and kept the community informed and engaged with progress of the Catchment Plan.

The Vision is written in plain English for wide distribution throughout the catchment. It has been designed as an attractive, pocket-sized booklet, which is available both as a hard copy and to download in electronic (pdf) format. The Vision outlines the four aims that the local community identified as mattering most to them, and includes an illustrative map of the river, showing the main tributaries and associated stillwater bodies to set the river in the context of its wider landscape. It also describes the Wandle Catchment Plan mission to help the river attain Good Ecological Potential, and is a valuable promotional tool for the Wandle Catchment Plan.

1.2.3: Scientific guidance

In addition to strong local engagement, the robustness of the Wandle Catchment Plan rests on foundations of strong science. To this end, expert scientific evidence has been provided by Technical Advisory Groups (TAGs), with guidance based on scientific data analysis relating to the Wandle specifically, and drawing upon best practice experience of comparable scenarios elsewhere.

Academic researchers, practitioners and regulators discussed several topics: fish and fisheries, ground water and abstraction, the multi-stranded topic of surface water including flow, quality, ecotoxicology, flood risk management and storage, and how to define and measure Good Ecological Potential for the Wandle. Individuals with strong local knowledge and historic understanding of particular sites have also provided valuable input.

As the Wandle Catchment Plan is reviewed for the progress being made towards achieving GEP in the months and years to come, the TAGs will continue to play a vital role in expanding our knowledge and understanding, and ensuring that best practice principles and adaptive management techniques are adopted.

1.2.4: The Action Plan: its Objectives, Targets, Actions and Projects

A key outcome of the Wandle Catchment Plan is to detail clear means of delivering seven key Objectives which have been identified as central to achieving the Vision.

Two of the four Aims described in the Vision – Habitat and Wildlife, and Water – are clearly linked to WFD objectives (see Section 2).

Consequently, they form the focus of this initial stage of the Action Plan. The Action Plan Objectives describe the Targets and Actions that will help to restore the river, starting with those specifically aimed at achieving Good Ecological Potential, before moving onto wider ecological issues of importance. In this way it is hoped that the purpose of the Catchment Plan is clear: that of fulfilling WFD requirements whilst also addressing the wider issues that matter regarding the health of the river and the enjoyment people can gain from it. These Objectives are detailed in Objectives tables at the end of the relevant sections of this Catchment Plan, and are supplemented by Projects tables in Appendix E.

Aim 1 (Water): Water is plentiful and clean, and varied in its flow speeds, widths and depths	
Objective 1: water quantity	Water supply in all sections of the river is sufficient to sustain a healthy population of native flora and fauna and is resilient to risk of drought or flood from extreme weather events or management for human use
Objective 2: water quality	Quality of water flowing in the River Wandle meets the standards required for Good Ecological Potential and is stable with no risk of deterioration
Objective 3: dynamics of flow	The river has a re-naturalised varied profile that creates a diversity of flow speeds and water quantity to provide all the key habitat types required by the native flora and fauna associated with lowland chalk streams
Aim 2 (Habitat and Wildlife): The river supports a mosaic of habitats with high biodiversity	
Objective 4: fish and fisheries	Thriving populations of native fish associated with chalk rivers are present and able to move freely
Objective 5: macrophytes, trees and the wider river habitat	Communities associated with chalk rivers are abundant along the river, providing good habitat variety for wildlife and for people
Objective 6: invertebrates	The diverse communities associated with chalk rivers are abundant along the river, playing important roles in ecosystem function and complexity, such as providing a food source for other wildlife
Objective 7: phytobenthos	Good populations associated with chalk rivers are present along the river
Aim 3 (Good Access): Local people can access sympathetically managed pathways along the whole river	
Aim 4 (Engagement): Everyone in the catchment is aware of the river, and knows how their actions can affect it. Councils, businesses, government agencies and the public work together to improve the river	

The Vision's Aims relating to Access and Engagement demonstrate local people's enthusiasm for being able to see or get to the river, and interact with it for a wide range of recreational, educational and cultural purposes.

These Ecosystem Services provided for people by the river are extremely important, since they reveal how the restoration of ecological processes has far wider benefits for society. As a result, the values placed by local people on the Ecosystem Service benefits derived from the river and its associated landscape are integral to the definition of Good Ecological Potential for the Wandle, and will help to shape the way future project work is carried out.

The relationship between the Catchment Plan's Aims, Objectives, Targets, Actions and Projects are depicted below:

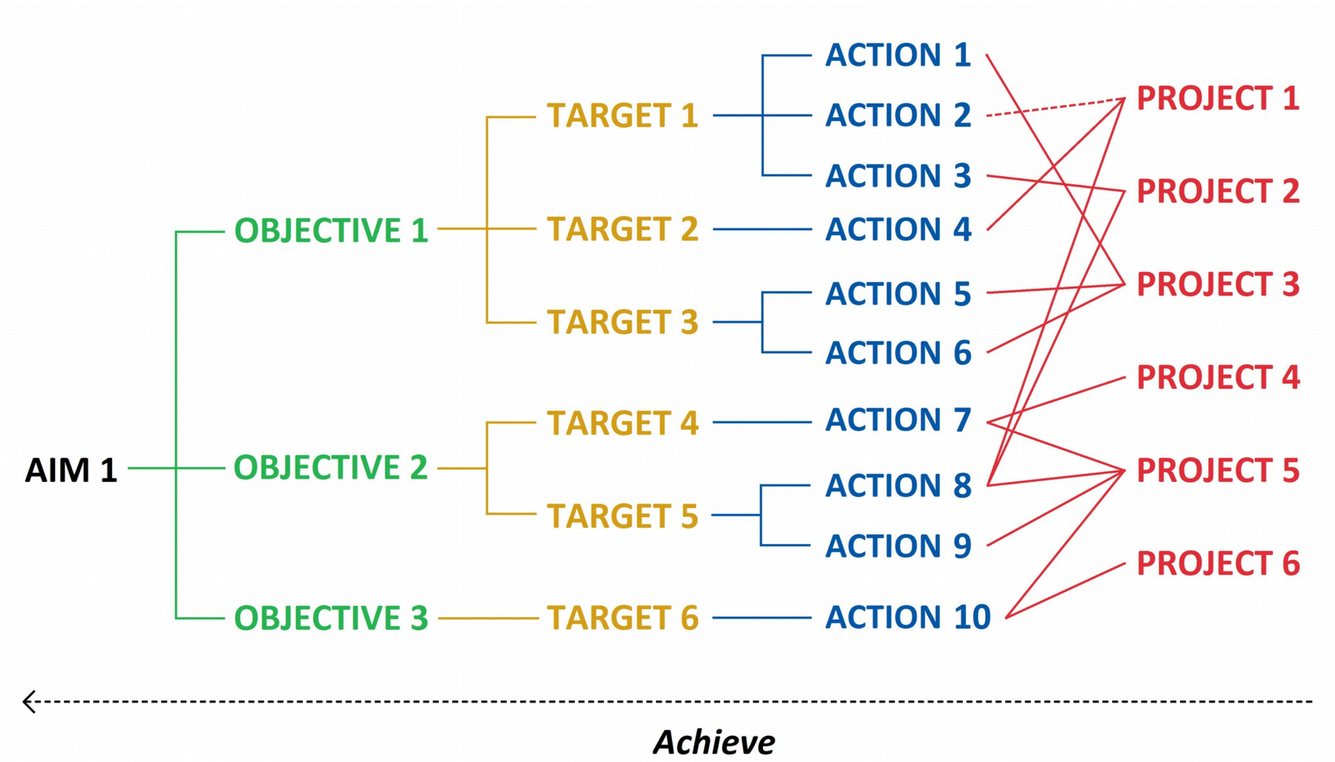


Fig 1a: The relationship between the Wandle Catchment Plan's Aims, Objectives, Targets, Actions and Projects. Each Project achieves multiple Actions.

It is important to note that the Wandle Catchment Plan is intended to focus on scientific issues directly relating to the river and its ecosystem, rather than wider socio-economic themes of access and engagement, which fall outside the direct scope of this Plan. It is anticipated that issues of access and engagement will be addressed by a separate process, for instance through the Wandle Forum's Access and Recreation Working Group, and the Wandle Valley Regional Park.

1.2.5: Existing and future projects

The final component of developing the Action Plan has been working with partners to identify projects that are already contributing to improving the ecological health of the river and its associated landscape now.

This information is presented in the Projects tables in Appendix E and demonstrates the significant levels of funding that are already being invested into improving the river. It also reveals the wide variety of projects being undertaken, and the effectiveness of partnership working on the Wandle, with many organisations already involved and benefiting from volunteer contributions along the full length of the river.

By drawing this information together and updating it regularly, existing partnerships can be strengthened, resources can be shared, and gap analysis can reveal priority areas for action where different groups could collaborate to achieve even greater success.

1.3: The Ecosystem Approach

The overall objective of the Wandle Catchment Plan is to present a holistic strategy for the river – not only to guide implementation of WFD requirements, but also to exceed these objectives with sound science and create a healthy river for people and wildlife. These societal values will play a direct role in how the Wandle is managed for future generations, and the Catchment Plan embraces this philosophy via the Ecosystem Approach.

The Ecosystem Approach, as adopted by the Convention on Biological Diversity in 2000, seeks to develop a strategy for integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way. Perhaps most significantly, it also recognises the importance of human choice in the management of natural resources.

In the Wandle catchment, the importance of community engagement has long been recognised as vital to the success of ecological enhancement works. Involving local stakeholders engenders deeper understanding of the natural environment and a sense of ownership, and from this understanding emerges a valuable interest in protecting it from destruction and degradation. Considerable community consultation, to identify societal values concerning the river, has been a feature of the Wandle Catchment Plan from the outset.

The Ecosystem Approach works holistically to maintain natural processes and look at likely outcomes of actions in the long-term and as a bigger picture, rather than focusing on the immediate and local scale. The Wandle Catchment Plan has looked at the many pressures and threats to the River Wandle, now and those that are likely in the future, and has identified the fundamental natural processes that should be prioritised for restoration if the river is to improve and attain Good Ecological Potential.

The Ecosystem Approach also helps to assess the best management approaches for the delivery of ecosystem services, which are further discussed in Section 9.

1.4: The Catchment Based Approach

The Catchment Based Approach (CaBA) to river management and restoration is an intuitive and scalable solution to the challenge of large-scale River Basin Management Planning which has arisen as a result of WFD.

Part of this approach includes WFD's requirement (under Article 14) to engage stakeholders through a more local focus, in order to develop a sense of common ownership of river catchment problems and solutions. Historic water and land management policies have tended to separate issues: CaBA considers water and land management holistically through the lens of ecosystem services (see Section 9) in order to achieve multiple environmental and social benefits (Catchment Change Network, 2014).

Between May 2011 and December 2012, a series of 25 Catchment Pilots were developed nationally to test this new approach. The Wandle was selected as one of an additional 38 catchments where seed funding was granted and lessons were learned, although full evaluation did not take place.

CaBA was launched in 2013, informed by lessons learned from the full range of catchments involved. This Catchment Plan is related to that process.

<u>Further reading:</u>

The Catchment Change Network's website: http://www.catchmentchange.net/pilot-catchments/

1.5: Cost Benefit Analysis

In early 2014 the EA undertook an extensive Cost Benefit Analysis (CBA) of all possible projects related to delivery of WFD on the Wandle, and the effect of these projects on ecosystem services provided by the river.

This analysis is designed to facilitate prioritisation of projects for completion before 2021, and it will also be incorporated into the next Thames River Basin Management Plan (RBMP). As such, the CBA will be available as part of the RBMP consultation process.

Further reading:

Environment Agency (2014) *Thames River Basin Management Plan (draft for consultation September 2014 – March 2015)*

1.6: Reference conditions, enhancement and restoration

Chalk streams and rivers present particular difficulties when it comes to deciding reference conditions for river restoration. As highly anthropogenically-modified systems, almost all chalk streams have been shaped by extensive re-engineering for water meadows, milling and other socio-economic functions, with abstraction and intensive urbanisation appearing as more recent factors.

Chalk stream headwaters are usually located some way down their topographic catchment, where the spring line breaks out of the aquifer. It is likely that the upper reaches of a natural chalk stream would be extensively braided in shifting channels through wet woodland, with heavy shading, and substantial inputs of woody debris creating constant diversions to flow (English Nature / Environment Agency, 2004)

Very few such reference conditions currently exist, except on the Bere Stream tributary of the Piddle, and a small stretch of the Wylye. Part of the upper Nar also supports similar habitat, with more formalised channel morphology due to relatively high hydraulic energy: this may be cognate to the steepness of the upper Wandle. No British examples of unmodified larger chalk rivers now survive (English Nature / Environment Agency, 2004).

As a result of massive urbanisation throughout its lower catchment, returning any part of the Wandle to such a primordial state is likely to be difficult. However, the task may be facilitated by concentrating on reactivating natural fluvial functions and processes rather than restoring actual physical structures.

In 2010 the EA's Rivers and Streams Habitat Action Plan Steering Group published the following definitions, drawing a clear distinction between 'enhancement' and 'restoration':

- **Enhancement** is defined as instream habitat enhancement, channel-narrowing, removal of weirs or barriers, establishment of buffer zones through riparian fencing or tree planting, and wetland creation within 10 metres of the channel. Also appropriate agreement and implementation of ongoing planned management activity. Enhancement projects include restoration work.

- **Restoration** is defined as measures that result in a significant increase in diversity of hydromorphological features and / or improved floodplain connectivity and the restoration of river function through essential physical or biological processes, including flooding, sediment transport and the facilitation of species movement.

Perhaps ironically, restoring the Wandle's natural ecological processes is likely to be more realistic in its modern post-industrial urban setting than attempting to revert the river to a Mesolithic-era wildwood reference condition.

Restoring natural processes will make the river more resilient to pressures such as pollution, invasive non-native species and severe weather events caused by climate change. It will also help the Wandle to support a wide range of flora and fauna, and improve provision of the many ecosystem service benefits which are important to local people, including access, recreational activities, aesthetic appeal and cultural heritage.

It should be noted that prior written consent from the EA is required for any works in, under, over or within 8 metres of the top of the bank, or within 16 metres of the landward toe of a tidal defence, under the terms of the Water Resources Act 1991 and Thames Region Land Drainage Byelaws 1981. Any proposed works must demonstrate no increase in flood risk to third party property or land.

1.7: Monitoring

Monitoring long-term changes, whether as a result of deliberate enhancement activities or any other influences, is a critically important part of the process of environmental management. Despite the potential for significant learnings, however, the importance of scientific monitoring is not widely recognised by funders, and sufficiently long-term funding of this nature is almost always difficult to obtain.

It is the view of all partners involved in this Catchment Plan that well-designed, long-term monitoring should be viewed as an essential component of any project undertaken to restore or enhance the River Wandle.

1.8: The focus of the Wandle Catchment Plan

"From local volunteers to councils and businesses, we want everyone to co-operate and make sustainable long-term commitments to improving the river"

- from Ketso community and stakeholder workshops

The Wandle Catchment Plan is designed to be an aspirational, 'living' document underpinned by scientific evidence, best practice and the values of the community.

Regular reviews and updates will enable it to remain relevant and useful to stakeholders, and to feed highly relevant and actionable information into the Thames River Basin Management Plan. It will also facilitate changes in approach whenever necessary: for example when new research identifies ways to address challenges that could not be tackled previously, or when new funding streams become available.

The overarching aims of the Catchment Plan are:

- To draw together data and knowledge on the Wandle catchment and evaluate it in light of current and future pressures to identify optimum solutions for improving the river
- To present a Vision for the River Wandle that has strong stakeholder (including community) buy-in
- To investigate and define Good Ecological Potential (GEP) for the River Wandle
- To investigate the Ecosystem Services offered by the River Wandle, and identify added benefits of attaining GEP
- To identify a suite of Objectives, Targets, Actions required to realise GEP
- To identify projects and measures required to realise GEP and, where possible, their associated costs

For the purposes of this Catchment Plan, the River Wandle system has been divided into eight reaches based on the local distinctiveness of their physico-chemical and morphological surface water character and fish populations. These divisions were agreed in discussion with the Fish and Surface Water TAGs. Distinguishing these reaches will enable rehabilitation measures to be targeted more effectively and will facilitate monitoring of progress towards attaining GEP. They are (see also Fig 1b):

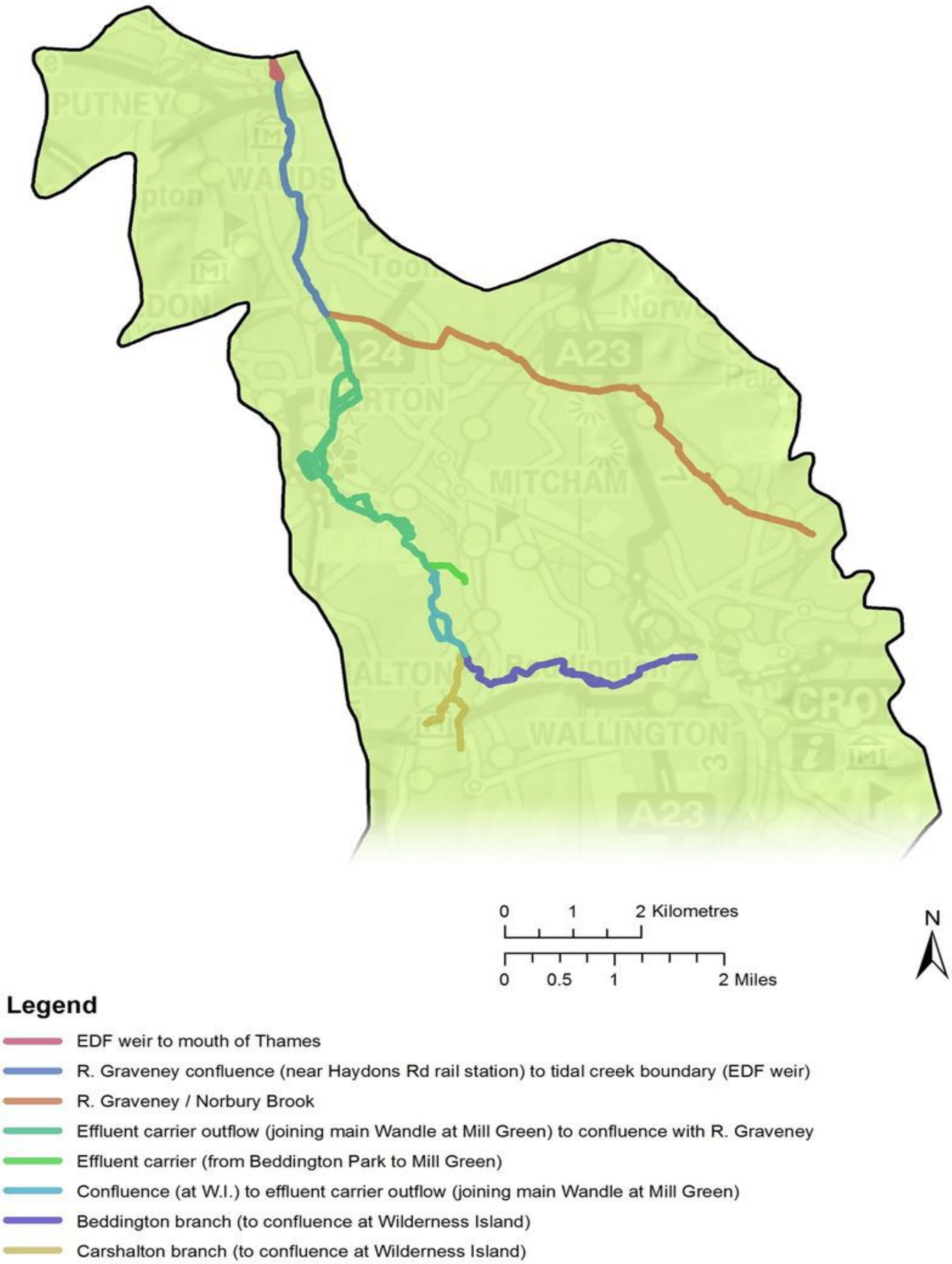
1. Carshalton water body (Carshalton Ponds source to confluence with Croydon branch at Wilderness Island)
2. Beddington reach (Croydon source to confluence with Carshalton branch at Wilderness Island)
3. Confluence to Beddington Sewage Treatment Works effluent carrier outflow at Mill Green
4. Effluent carrier (the outflow from Beddington STW at Mill Green)
5. Effluent carrier to confluence with River Graveney
6. River Graveney (including the Norbury Brook)
7. Confluence with River Graveney to tidal creek (EDF weir)
8. Tidal creek to mouth of the River Thames

In future, additional ephemeral reaches may be added: for instance, the Grotto arm of the river through Carshalton.

The River Graveney joins the Wandle at two points: by Connolly's Mill below Wandle Park in Merton, and adjacent to Waterside Way industrial estate via a culvert siphon under Tooting High Street. The main flow emerges from this latter, downstream point and is the most meaningful dividing point between functioning reaches on the Wandle.

Some experts in the Fish and Surface Water TAGs have noted that they are unable to identify distinct differences in the characteristics between some of these reaches: for example, with regard to water quality, because it is not currently possible to assess water quality separately for each of these proposed reaches, due to a lack of sufficient EA monitoring sites or other data. However, expert opinion within the TAGs suggests that there are likely to be different characteristics between these reaches, and that monitoring is likely to confirm this.

It is therefore strongly recommended that additional monitoring be adopted as soon as possible to fill gaps in current knowledge, and it has been agreed that river restoration efforts should initially be focused on reaches 1, 2, 3, 5 and 7 where the greatest opportunities for improvement may be found.


PUTNEY
A24
A23
MITCHAM
WALLINGTON
A23
0
1
2 Kilometres
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Legend
EDF weir to mouth of Thames
R. Graveney confluence (near Haydons Rd rail station) to tidal creek boundary (EDF weir)
R. Graveney / Norbury Brook
Effluent carrier outflow (joining main Wandle at Mill Green) to confluence with R. Graveney
Effluent carrier (from Beddington Park to Mill Green)
Confluence (at W.I.) to effluent carrier outflow (joining main Wandle at Mill Green)
Beddington branch (to confluence at Wilderness Island)
Carshalton branch (to confluence at Wilderness Island)

Fig 1b: The eight functioning reaches of the River Wandle identified for the purposes of the Wandle Catchment Plan.

1.9: Next steps: a living document

The Wandle Catchment Plan is not the first strategic document to address the health of the river and its surrounding landscapes.

Many strategies and local plans already address various site- or issue-specific challenges related to the ecological health of the river and the benefits it provides for local people. Examples include those written by local councils, the National Rivers Authority (NRA) and its successor the EA, and the water companies Thames Water and Sutton & East Surrey Water. Some of these plans pre-date the Water Framework Directive or do not address it directly. Many are difficult to access because they were published in non-digital formats, or were written primarily for internal use.

This first iteration of this aspirational Catchment Plan will facilitate a gap analysis for the River Wandle and its catchment – not only pertaining to Actions that currently have no projects to deliver them, or those that are being delivered incompletely and require further support - but also to identify where further research and liaison with partners are needed before projects can go ahead.

Once this has been achieved, priorities for action can be highlighted based on criteria including contribution to delivering GEP, timescales and status within the sequence of activities required, ecosystem service benefits, and social and political interest amongst others. It should also be possible to identify aspirational projects to work towards GEP and wider ecosystem benefits. This will enable partners to pool resources, develop joint strategies and make funding applications to carry out such projects.

The Wandle Catchment Plan aims to identify knowledge gaps, draw existing plans together and build on the wealth of experience they represent, in order to understand the whole catchment more fully.

Everyone involved hopes that it will encourage new research where gaps in our knowledge need to be filled, as well as many future projects where partnership working will produce better results and multiple benefits for the river and its communities. The Wandle Catchment Plan will also seek to establish regular monitoring of all WFD elements, using standard methods, to ensure there are no data gaps and that a robust baseline exists for measurement of future changes. To this end, and to facilitate targeting resources for restoring the river, a pilot Urban River Survey project is proposed to assess the characteristics of river reaches and facilitate the targeting of resources in rehabilitating the river.

Ongoing liaison with the Steering Group and TAGs will continue, in addition to knowledge exchanges with other chalk river and urban catchments undergoing restoration. This will make it easier to share information and build relations with further teams and individuals, such as the water companies' water resource teams and the EA's flood risk management staff, to achieve greater integrated working and success.

SECTION 2: THE WANDLE AND THE WATER FRAMEWORK DIRECTIVE

2.1: The Water Framework Directive (2000/60/EC)

The European Water Framework Directive (WFD) may be one of the most far-reaching pieces of legislation ever created for improving and protecting aquatic environments.

Based on the concept of river basin planning, it has the following major objectives (The Rivers Trust):

- To prevent further deterioration and protect and enhance the status of aquatic ecosystems and associated wetlands
- To promote the sustainable consumption of water; to reduce pollution of waters from priority substances
- To prevent the deterioration in the status and to progressively reduce pollution of ground waters
- To contribute to mitigating the effects of floods and droughts.

The WFD was passed by the European Union in 2000, covering all large freshwater bodies including rivers, canals, lakes (over 50 ha in area), ground water, estuaries and coastal water (but not marine environments). It requires all Member States of the European Union to ensure that their water bodies reach Good Ecological Status by 2015, with alternative target dates of 2021 and 2027 in certain circumstances, and a special alternative target of Good Ecological Potential (GEP) for waters which have been designated as Heavily Modified Water Bodies for flood defence, navigation and other purposes (if those purposes are still relevant).

The WFD was transposed into UK domestic law in 2003, and is now being implemented by the Environment Agency (EA) via a series of statutory River Basin Management Plans (RBMPs). Each river basin in the UK comprises a series of WFD management catchments, which may in turn cover one or more rivers and operational catchments (also known as sub-catchments). Under this system of classification, the Wandle falls within the remit of the Thames River Basin Management Plan, and is an operational catchment of the larger London WFD management catchment. At an even smaller scale, the river is split into two separate surface water bodies and two ground water bodies: its tidal limit at its confluence with the River Thames is included under the separate Middle Thames water body.

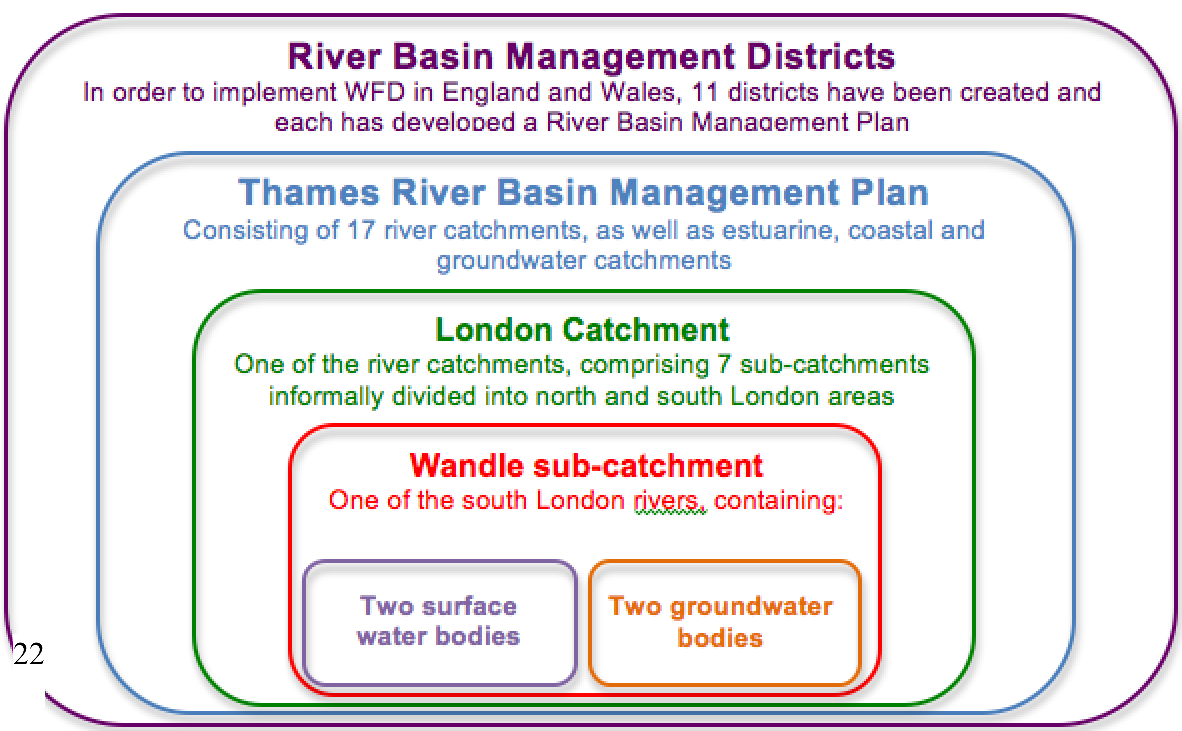

Fig 2a: The River Wandle and its water bodies within the WFD implementation hierarchy

Although Catchment Plans have not been made a statutory requirement, it is generally recognised that they form a very useful tool for translating local issues into regional and national policy and action. Significantly, they also provide a means of fulfilling WFD Article 14, which requires Member States "to encourage the active involvement of interested parties" in all aspects of the implementation of the WFD.

As such, the intention of the Wandle Catchment Plan is to inform the Thames RBMP, to represent the ambitions of local people for their river, and to secure a healthy future for the Wandle under European law.

2.2: WFD designation of the Wandle

For the purposes of the WFD, the Wandle has been subdivided into 2 fluvial surface water bodies:

- GB106039023460: Wandle (Croydon to Wandsworth) and the River Graveney: the mainstem of the river, rising in Croydon and flowing north to join the Thames at Wandsworth: the River Graveney tributary joins the Wandle at Haydon's Road in south Wimbledon

- GB106039017640: Wandle (Carshalton branch at Carshalton): a shorter chalk stream headwater which rises in Carshalton and joins the mainstem of the river at Wilderness Island in Hackbridge

Both Wandle fluvial water bodies have been designated as Heavily Modified Water Bodies: the Croydon-Wandsworth branch on morphological grounds of urbanisation and flood defence, and the Carshalton branch on morphological grounds of urbanisation. This designation recognises that they are unlikely to meet the reference conditions and Good Ecological Status expected of less modified water bodies, and sets the alternative target of Good Ecological Potential by 2015.

The Wandle catchment also includes 2 separate ground water bodies:

- The first (GB40601G602200: Epsom North Downs Chalk) is assessed as Poor for quantitative quality, and Good for chemical quality: the same classifications are predicted for 2015

- The second (GB40602G602300: Bromley Tertiaries) is similarly assessed as Poor for quantitative quality, and Good for chemical quality: the same classifications are predicted for 2015

These ground water bodies supply fluvial flow for the Wandle's surface water bodies, but are believed to be seriously depleted by abstraction from several boreholes (see Section 3.6)

The latest EA catchment information sheets, containing summaries of all material relating to the Wandle's WFD designations, can be found in Appendices A and B, and the EA's full method statement for the classification of surface water bodies is in Appendix C.

2.3: Defining and measuring Good Ecological Potential (GEP)

In the case of Heavily Modified Water Bodies like the Wandle, which are not considered capable of reaching Good Ecological Status (GES) on grounds of socio-economic modifications, the following process applies for measuring the alternative target of Good Ecological Potential (GEP) (Royal Haskoning: River Wandle NEP Investigation 2013):

- Identifying the impacts affecting the water body

- Identifying the Mitigation Measures necessary to ensure the hydromorphological characteristics of a water body are consistent with Good or Maximum Ecological Potential (see Appendix D)

- Assessing whether those measures have been taken. Where all applicable Mitigation Measures have already been taken or screened out, the water body can be classified as GEP or better. Where one or more Mitigation Measure(s) remains to be taken, the water body will be classified as Moderate Ecological Potential (MEP) or worse.

  This classification will then be combined with the outcomes from biological, physio-chemical and hydromorphological (not explicitly required, but taken into account in assessments to give an overall classification). The water body's overall ecological status is defined by its lowest score against all these assessments.

At the time of writing this Catchment Plan, both of the Wandle's surface water bodies are classified as Poor because not all the Mitigation Measures necessary to raise them to GEP are in place, and those that remain are judged to be disproportionately expensive to achieve GEP by 2015 (see Appendices A and B). As a result, an alternative target date of 2027 has been set for both water bodies.

A series of Mitigation Measures (such as removal of obsolete structures) for both surface water bodies were identified by the EA in 2012 (see Appendix D). Where possible, these will be implemented in order to move the Wandle's water bodies towards GEP: it is hoped that the Carshalton water body will reach Good Ecological Potential by 2015, on the basis of ongoing morphological and fish-related projects currently being undertaken by the Wandle Trust and its partners.

Investigations into both the Carshalton water body and the upper Croydon – Wandsworth water body are currently being carried out under the EA's National Environment Programme (NEP):

- Carshalton water body: Royal Haskoning for Sutton & East Surrey Water
- Upper Croydon – Wandsworth water body: AMEC for Thames Water

The formal end point for these investigations is 31st March 2015: however conclusions may be available before this date.

2.4: Defining GEP on the Wandle

The Water Framework Directive (WFD) has set targets, based on a series of biological, physico-chemical and hydromorphological elements, for Heavily Modified Water Bodies (HMWBs) like the Wandle to achieve GEP. However, whereas GES for relatively unmodified rivers is tightly defined with well-understood reference conditions, GEP lacks specific definition under WFD.

No reference conditions exist for HMWBs because each has been subjected to a unique set of socio-economic modifications, sometimes over the course of many centuries. As a result, GEP is loosely understood to be the best condition that a given HMWB can be expected to achieve in view of those historic modifications (see also Section 2.3 above).

The Wandle is subject to many pressures, including those formally assigned in a WFD context (flood protection and urbanisation), which are linked to the ecosystem services expected by the catchment's human population of approximately 800,000 Londoners. If GEP on the Wandle is understood to be the highest achievable ecological state, it is reasonable to suggest that developing a more detailed definition will draw on both the natural and social sciences, to create a framework for restoring natural processes and the benefits these processes can provide for people across south London.

As described above, workable definition and delivery of GEP for the Wandle hinges on implementing a range of Mitigating Measures (see Appendix D), and measuring their effectiveness, qualitatively or quantitatively.

This implies the following five additional components to achieving and maintaining GEP:

- A robust measuring methodology
- An iterative management approach
- Stakeholder engagement from the outset
- Tangible delivery on the ground
- An ongoing monitoring regime which informs management and delivery

To measure the Wandle's achievement of GEP, it has been agreed that quantitative criteria should be applied wherever possible. Where this is not possible, the definition of specific GEP elements may be essentially descriptive and qualitative, accompanied by a rationale.

In time, these definitions should be subject to re-evaluation and refinement as more information becomes available and this Catchment Plan is reviewed (for instance, in the context of the next cycle of River Basin Management Planning to 2021). The latest results of these measurements – for fish, macrophytes, invertebrates and phytobenthos - are presented in Section 7.

2.4.1: Defining GEP on the Carshalton water body

Targeted implementation of a suite of Mitigation Measures are intended to result in the Carshalton water body achieving GEP in 2015.

Because GEP has not previously been defined for HMWBs, this provides an opportunity to pioneer a process for determining GEP – which can then be rolled out to the Croydon-Wandsworth water body, and possibly other HMWBs across the UK.

The following methodology has been agreed for determining GEP for the Carshalton water body:

- Provide definition of GEP via the following tasks:
    - Desk study: review definitions of GEP from relevant sources including WFD, Thames RBMP and UK TAG
- Define GEP for the Carshalton water body via the following tasks:
    - Provide descriptive summary of the water body
    - Describe GES and justification for lower objective
    - Describe measures identified within TRBMP to reach GEP
    - Describe measures identified within Wandle Catchment Plan
    - Describe wider ecosystem services objectives

  - Describe outputs from the Cost Benefit Analysis

- Describe actions undertaken to achieve GEP via the following tasks:

  - Describe outputs from relevant investigations
  - Describe reasons for failure
  - Describe Measures implemented

- Describe changes in ecological / hydromorphological elements and ecosystem services via the following tasks:

  - Describe changes in status / condition since 2009
  - Describe current status / condition
  - Describe predicted short term / long term changes
  - Describe improvements in ecosystem services

- Identify “no deterioration” measures via the following tasks:

  - Review Thames RBMP and Wandle Catchment Plan

- Verification process via the following tasks:

  - Review conclusions of assessment with EA National Team
  - Review findings with Wandle Catchment Plan Steering Group

2.5: Assessing progress towards GEP on the Wandle

On the basis that GEP for the Wandle will be defined as this HMWB’s highest achievable ecological state, it is foreseen that a multi-strand approach may be taken to measuring GEP, comprising physical, chemical, biological and social assessments:

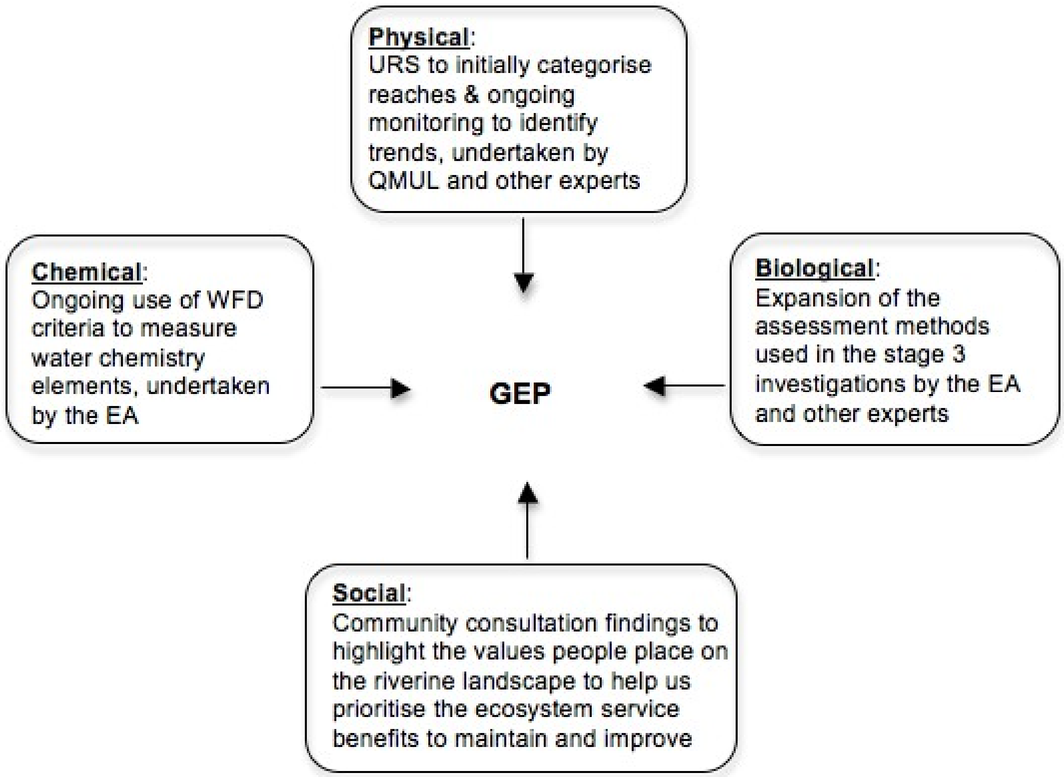

Fig 2b: The four themes to be assessed in measuring progress towards Good Ecological Potential on the River Wandle

Physical assessment

In order to achieve a robust scientific assessment of the Wandle's physical habitats, the Urban River Survey (URS) has been suggested as a useful tool. URS is based on the EA's River Habitat Survey, which was adapted to assess urban water bodies which are often designated as Heavily Modified.

To help identify and deliver future projects linked to the Wandle Catchment Plan, a pilot is proposed to test the ability of URS to identify:

- Ecologically functioning reaches of the river, and connecting reaches between them
- Important habitat and recruitment areas for all life stages of different fish species
- How effectively URS can link to other Ecosystem Services definitions, such as access and aesthetics

Appendix F includes details of the URS indices for habitat supporting GEP. The potential of the URS to inform the Wandle Catchment Plan and GEP assessment is outlined below.

Chemical and biological assessment

To augment the assessment of the physical characteristics of the river provided by URS, ongoing chemical and biological monitoring should be carried out, using the standard methods already employed by the EA for WFD, and in particular the Stage 3 investigations undertaken in 2012.

Particular scores to attain GEP are described in the objectives for each element where appropriate, and monitoring should be expanded to the eight distinct functional reaches as outlined in Section 1.8.

Other habitat assessments, such as the habitat suitability survey devised for water voles, may help indicate wider ecosystem quality for other important groups such as birds and bats, and will provide further valuable information to guide project work and management decisions.

Social assessment

As outlined above, significant numbers of local stakeholders were actively engaged from the outset of the Catchment Plan's development. The four overall aims in the shared Vision reflect issues identified by local people, and they are also an integral part of this Action Plan.

It is anticipated that consultation and engagement will continue in the long term, to enable evaluation of any changes in the values placed by people upon the river and its landscape, and their accommodation within the definition of GEP as part of the Ecosystem Services approach (see Section 9). Inclusion of social value assessment will also continue the benefit of gaining experience from local knowledge, to demonstrate how targets are being achieved and to help build a sustainable management legacy for the Wandle.

Further discussion of GEP definitions, relating to specific WFD components can be found in relevant chapters throughout this Catchment Plan.

SECTION 3: CATCHMENT CHARACTERISTICS OF THE WANDLE: AN OVERVIEW

3.1: Location and landscape

"We love the Wandle because it's a London river that hasn't been covered and built over – it's a peaceful green haven in an urban environment"

- from Ketso community and stakeholder workshops

The Wandle is a lowland chalkstream which rises from a line of springs on the dip slope of the North Downs and flows 17.5km (11 miles) north to join the tidal Thames at Wandsworth. Due to the meandering course of the river, the total length of its main stem increases to 23.5km, and additional milling leats and other channels may add as much as another 6.4km: a total of almost 30km of perennial river.

The Wandle catchment falls at an average gradient of 1:75 from a peak of around 200m AOD (Above Ordnance Datum) on the Downs to below 50m AOD at the Thames floodplain. The Wandle's perennial headwaters in Carshalton and Croydon are at 33.5m and 35.6m AOD respectively, and the River Thames is at 5m AOD.

Over the course of many centuries, the Wandle has been extensively straightened and modified for industrial, ornamental, sewage disposal and flood risk management purposes: as a result, much of its channel is hardened with concrete, steel piling and wooden toe-boards, and very few reaches are now likely to follow their original course.

In 1999 the EA's Local Environment Agency Plan (LEAP) for the Wandle assessed the catchment as follows:

- Urban: 46.1%
- Semi-natural grassland: 25.6%
- Woodland: 9.3%
- Managed grassland: 8.9%
- Tilled land: 8.4%
- Heathland: 0.8%
- Bare ground: 0.8%
- Inland water: 0.1%

The northern, fluvial area of the catchment is almost entirely urbanised, contributing most of its total population of at least 800,000 people. However, this very high population density in close proximity to the river means that the Wandle offers a uniquely valuable blue green space for recreation and contact with nature, often in areas which are noticeably lacking in such opportunities and classified as Areas of Multiple Deprivation. Thanks to the Wandle Trail and many riverside parks and other public open spaces, access is notably better than many comparable urban rivers.

South of the Croydon – Carshalton spring line (which continues west to give rise to the headwaters of the Hogsmill at Ewell) the Wandle's catchment extends as far as the M25, covering an area of approximately 200km^2 (77 square miles). Annual average rainfall in the catchment varies, with the upper catchment on the North Downs typically receiving more (760mm) than the lower catchment around the river itself (630mm). The 2006 Environment Agency Catchment Abstraction Management Strategy (CAMS) noted that this was considerably less than the national annual average rainfall of 897mm. After losses to evaporation and transpiration, these rainfall figures reduce to 320mm in the upper catchment and 160mm in the lower catchment.

The permeable Chalk geology of the upper catchment enables rainfall to enter the ground and percolate slowly into the aquifer, but in the areas around the river the urban character of the landscape (featuring an abundance of impermeable surfaces coupled with clay-based soil) results in the majority of rainfall running off the surface and entering the river system. Below Goat Bridge, the river's natural hydrograph and chalkstream characteristics are further masked by the high proportion of additional flow which is contributed by effluent from the Beddington sewage treatment works.

Further reading:

British Geological Survey (2008) *The Chalk Aquifer of the North Downs*

Environment Agency (1999) *Local Environment Agency Plan: Wandle, Beverley Brook and Hogsmill*

English Nature / Environment Agency (1999) *Chalk Rivers: Conservation and Management*

3.2: History and culture

"The Wandle Valley is full of important landmarks and reminders of the river's history, mills and people. We want to use plaques, information boards, maps and websites to make sure the Wandle's heritage and culture are never forgotten"

- from Ketso community and stakeholder workshops

As one of the closest chalkstreams to London, the Wandle's ecosystem services and their economic and cultural influence have extended far beyond the geographical confines of the river's own catchment. Global aspects of industry, religion, art and fishing have all been influenced by the Wandle, and have left their own marks upon it up to the present day.

Industry

The Wandle has frequently been described as "the hardest worked river for its size in the world" (Malcolm, 1805 cited by Twilley and Wilks, 1974) and "London's engine room" (Steel and Coleman, 2012), offering both the benefits of a steep gradient, which proved ideal for hydropower, and proximity to the markets of the capital.

Domesday Book recorded 13 mills on the Wandle: at the height of London's industrial revolution in the 19th century, it is generally estimated that at least 90 mills were working on the river. This concentration of mills attracted investment by entrepreneurs and industrialists from all over Britain and Europe, including Huguenot weavers and printers as well as later textile specialists like William Morris and Arthur Lazenby Liberty. From the 18th century a wide variety of herbs and plants were cultivated in the Wandle valley, including lavender, opium, watercress and osiers, and both the river and its surrounding landscapes were managed with increasing intensity.

Most milling sites were retooled many times in their history, and the river powered a wide variety of industries according to market forces. Sectors known to have operated on the Wandle include textile printing, weaving and dyeing, brewing and medical distillation, oil, leather, paper, snuff, gunpowder, cannon boring and machine tooling (Shew, 2012). Despite at least one attempt to modify the Wandle for navigation, the river's mill-owners put up effective resistance to this idea, and the river remained uncanalised to that extent. However, repeated re-engineering for milling purposes has still left the river highly modified, which continues to mask many of its natural characteristics.

Fortunes were made in the course of this industrial boom, and many mill owners invested their wealth in large houses, formal gardens and riverside estates adjacent to their mills. Several of these grounds still survive as public parks, and offer levels of public access to the river (along the Wandle Trail) which compare very favourably with many other urban waterways.

Religion

Merton Priory was founded in 1115 on a site straddling the old Roman Stane Street, adjacent to its ancient crossing point over the Wandle. The priory and church fell victim to Henry VIII's dissolution of the monasteries, but not before the Statute of Merton was passed in 1236 during what can be seen as the world's first recognisable sitting of Parliament.

Today, much of the Merton Priory site is buried beneath the Sainsbury's Savacentre car park: only the foundations of the former Chapter House are visible under the adjacent Merantun Way flyover, together with a stretch of perimeter wall. However the Merton Priory Trust's plans to revitalise this historic space are now well underway, thanks to belated Section 106 funding and incorporation into the Wandle Valley's successful Heritage Lottery Fund urban landscape bid.

Art

Together with the smaller River Hogsmill, the Wandle was the cradle of the Arts & Crafts movement.

William Morris' decision to relocate his manufacturing (fabric printing and weaving) base to Merton Abbey in 1881 attracted other members of this aesthetic, philosophical and cultural movement including Philip Webb, Edward Burne-Jones, and William de Morgan whose premises were located on Byegrove Road. Morris' own "river prints" series of floral designs includes a design named "Wandle" in order "to honour the helpful stream" (Morris cited by Parry, 1983).

From around 1877, Liberty's department store sourced most of its fabric printing from Littler's block-printing works in the old Merton Abbey precinct, and took over the factory's entire production in 1904. The company maintained a design studio on the Merton Road until c2000.

Fishing

As early as 1606 the quality of fieldsports offered by the Wandle was recognised by designation as a royal hunting and fishing preserve. The river's reputation as a trout stream lasted for the next 300 years at least, with huge catches of trout recorded in 18th and 19th century accounts, and no guarantee of permission to fish, even for the most prestigious Victorian fishing writers.

A reference to Wandle trout "with marked spots like a tortoise" appears in a footnote to the 1833 and 1835 editions of Izaak Walton's *Compleat Angler* (Merton Historical Society, 2009), and Nelson is popularly supposed to have fished the Wandle before his death at Trafalgar, although research shows that Sir William Hamilton, husband of Lord Nelson's lover Emma Hamilton, was by far the keener angler (pers comm.Theo Pike, 2010).

The Wandle made a permanent impression on the global cultural development of fly-fishing c1868 when the young Frederic Halford learned the "Carshalton Dodge" from local anglers: a technique designed to deceive wary, clear-water trout by casting a dry fly upstream from behind their tails rather than standing in full view to swinging a wet fly downstream towards them. As pollution gradually destroyed the Wandle as a fishery, Halford started searching further afield for his sport, and introduced the dry-fly technique to the Test, Itchen and Kennet. From these rivers, it has spread internationally as a practical and aesthetic sporting code.

To maintain this level of sport, the river was experimentally stocked with several different species of trout including French sea trout and char (Smee, 1872), and a group of concerned local fishery owners formed the Wandle Fisheries Association c1880 with the objective of reversing the river's decline. Despite establishing a trout hatchery in Watermeads, with a bailiff living in one of the Fisheries Cottages at Mitcham Bridge, their efforts proved a losing battle (Montague, 2005). The upper river's fishery seems to have survived until 1914, when Charles Dingwall ascribed the death of most of his trout to tar laid on the roads (Wilks and Rookledge, 2002), although tradition suggests that the last old Wandle trout was caught by a coarse angler in 1934.

From the 1980s onwards the river was stocked with roach, dace, chub and barbel by successive water authorities as an amenity cyprinid fishery, developing a very strong local culture of freely-available inner city angling which research has shown to confer many social and environmental benefits (Substance, 2012).

Early stockings of trout and grayling as proxy tests for water quality did not survive, but as polluting factories closed and water quality improved incrementally, trout have been reintroduced to the river by the Wandle Trust's Trout in the Classroom programme, and were confirmed to be spawning successfully in 2012. This community-driven initiative has inspired the Wild Trout Trust to develop a national network of Trout in the Town projects, using trout as an iconic indicator species to promote the restoration of other post-industrial streams.

Although many species of fish are still not completing their life cycles in the Wandle with full success, it is hoped that as a result of this Catchment Plan a wide variety of limiting factors can be addressed to fulfil WFD targets, and restore the river to its former glory as a self-sustaining fishery.

<u>Further reading:</u>

Braithwaite (1861) *On the Rise and Fall of the River Wandle: Its springs, tributaries and pollution*

Hayter (2002) *FM Halford and the Dry-Fly Revolution*

Parry (1983) *William Morris Textiles*

Steel and Coleman (2012) *River Wandle Companion and Wandle Trail Guide*

3.3: Local designations

"We enjoy the many wonderful parks along the Wandle Trail, which provide places for both people and wildlife in the city"

- from Ketso community and stakeholder workshops

Although the River Wandle has no statutory designations, it is a Site of Metropolitan Importance for Nature Conservation (SINC).

The Local Environment Agency Plan (LEAP) for the Wandle, Beverley Brook and Hogsmill (1999) ascribes this designation largely to the river's aquatic plant life, particularly in the upper reaches, being typical of a chalk-fed river. As such, the upper river is also identified as a Site of Metropolitan Importance for Nature Conservation.

However, the river's catchment encompasses a wide range of nature reserves and other sites of ecological significance.

Sites of Importance for Nature Conservation (SINC)

Beddington Farmlands, a large area of sewage treatment sludge lagoons to the north of Croydon, is one of the best sites for birds in London, and is now in the process of being restored as a nature reserve.

Habitats include marsh/swamp, pond/lake, ruderal, running water, wet ditches, wet grassland and wet woodland/carr, providing feeding, resting and breeding areas for many species of waders and other wetland birds. A detailed discussion of Beddington Farmlands can be found in Section 3.8.

Sites of Metropolitan Importance for Nature Conservation (SMI)

There are several Sites of Metropolitan Importance within the Wandle catchment, some of which are associated with the riparian landscape, while others are good examples of chalk habitat:

- Addington Hills
- Bell Lane Creek
- Bennetts Hole
- Croham Hurst
- Farthing Downs and Happy Valley
- Kenley Common
- Mitcham Common
- Morden Hall Park
- Riddlesdown
- Roundshaw Downs
- Spencer Road Wetland
- Therapia Lane Rough
- Wilderness Island
- Woodcote Park Golf Course.

Sites of Special Scientific Interest (SSSI)

The Wandle's wider catchment includes 5 SSSIs:

- Chipstead Downs: chalk grassland with associated scrub and secondary woodland, as well as large areas of ancient woodland
- Croham Hurst: ancient woodland
- Farthing Downs and Happy Valley: extensive expanses of species rich chalk and neutral grassland, and an area of ancient woodland
- Riddlesdown Common: the largest single expanse of long-established chalk scrub and herb-rich chalk grassland
- Woldingham and Oxted Downs: rich chalk grassland, scrub and mature and secondary woodland

Local Nature Reserves (LNR)

There are 9 LNRs along the banks of the river, including:

- Spencer Road Wetland: a 1.04 ha site on the eastern bank of the river at Goat Bridge, developed as the primary site for London Wildlife Trust's water vole reintroduction project

- Watermeads
- Bennetts Hole
- Wilderness Island: a 2.72 ha wetland area at the junction of the Croydon and Carshalton branches of the river, with a variety of habitats including a mosaic of ponds, sedge bed and damp hollows, supporting 30 species of birds and 70 kinds of wildflower
- Wandle Meadow Nature Park
- Wandle Valley Wetland: a 0.62 ha site near the river at Goat Bridge that includes open water, marginal vegetation and seasonal pools supporting invertebrates such as dragonflies and damsel flies
- Sutton Ecology Centre

Across the wider catchment, the following nature reserves also offer important havens for wildlife and local people:

- Roundshaw Downs
- The Spinney, Carshalton
- Ruffet and Bigwood
- Myrna Close

<u>Further reading:</u>

Green Environmental Consultants (1996): *River Wandle Catchment Summary*

3.4: Geology and geomorphology

"Chalk streams like the Wandle are a unique kind of habitat, and it's even rarer to find one in a city. We're glad that some improvements are already underway, but we want to see the river full of fresh, clean water, and less of the banks covered up by concrete and other infrastructure"

- from Ketso community and stakeholder workshops

Cretaceous chalk is a soft and highly porous form of limestone, 98% pure calcium carbonate, formed from the compressed shells of millions of coccoliths (calcite plates of marine algae) laid down in a warm marine environment between 70 and 88 million years ago (Toghill).

Subsequent millennia of climatic cooling and erosion have now lifted and exposed these calcium beds high above sea level, forming extensive areas of chalk hills which dominate many areas of southern and eastern England.

Winter rain falling on chalk geology infiltrates easily, recharging vast underground aquifers which later discharge via springs where the chalk meets less permeable rock. Water is also thought to move within chalk aquifers via fissures and veins of flint. This slow process of percolation provides a filtering effect, giving the water a high mineral content (typically calcium and magnesium ions) and a consistent temperature of around 10°C at the point of discharge. Based on seasonally abundant rainfall, this annual cycle of recharge and discharge typically gives chalk rivers a highly predictable (and comparatively unvarying) flow regime, which combined with the high mineral content of the water can support an exceptionally productive ecosystem.

In the case of the River Wandle, some theories suggest that it once rose on the Wealden Dome and may have responsible for much of the erosion of its height, through the now-dry valleys in the Chipstead area, before falling victim to headwater capture by the River Mole (Hobson, 1914). The very intermittent appearance of winterbournes in the Caterham and Coulsdon valleys, approximately once every 7 – 10 years is a reminder that the fluvial river system also includes these valleys as a result of the Wandle's geomorphological history.

Today, the perennial Wandle rises from a distinct line of Cretaceous Chalk springs in Croydon, Beddington and Carshalton on the northern dip slope of the North Downs. (This spring line also extends west to Ewell, supplying the headwaters of the Hogsmill River). The Wandle then runs rapidly onto Bromley Tertiary deposits of Thanet Sand: a sandy layer interspersed with outcrops of chalk which connect to the deeper chalk bedrock and may supply additional fluvial flow. North of the Thanet Sands and the Lambeth Group, from a point marked by "the Cut" at Wilderness Island, the river's course passes out over impermeable London clay, which isolates the river from any further interaction with the underlying chalk. However, the London basin also contains extensive deposits of glacial moraine: flint gravels which hold water in the river's hyporheic zone and may also provide some direct contribution to fluvial flow. Geologically-younger fluvial deposits of sand lenses also hold water and have been exploited as aquifers during the urbanisation of the London area.

As urbanisation of the northern Wandle catchment has increased, the river's hydrology and hydrograph have become less natural and more 'flashy' (water levels rising quickly in response to rainfall events). The proliferation of hard urban surfaces has reduced infiltration into the London basin gravels, and increased direct runoff into the river: indeed the Wandle has been deliberately maintained as a flood channel to remove rain falling on south London as rapidly as possible to the Thames.

In light of these complex factors of hydrology and geomorphology, some experts believe that it may not be possible to regard the Wandle as a true chalk river for its entire length, preferring the term "chalk fed" instead (pers comm. Steve Barrow, 2012).

Based on geology, the EA's National Chalk Stream Working Group recognises the following extent of chalk stream habitat on the Wandle (pers comm. Dave Webb, 2014):

- The Carshalton water body
- The Grotto arm (ephemeral at present)
- The Croydon arm from a point near the top of Beddington Park to its confluence with the Carshalton water body at Wilderness Island
- A stretch of the Wandle's original course through Beddington Farmlands, now used for flood risk management in conjunction with the Beddington Park flume
- The main river from Shepley Mill downstream to Goat Bridge

The EA's map of the chalk stream reaches of the Wandle in this area is contained in Appendix H.

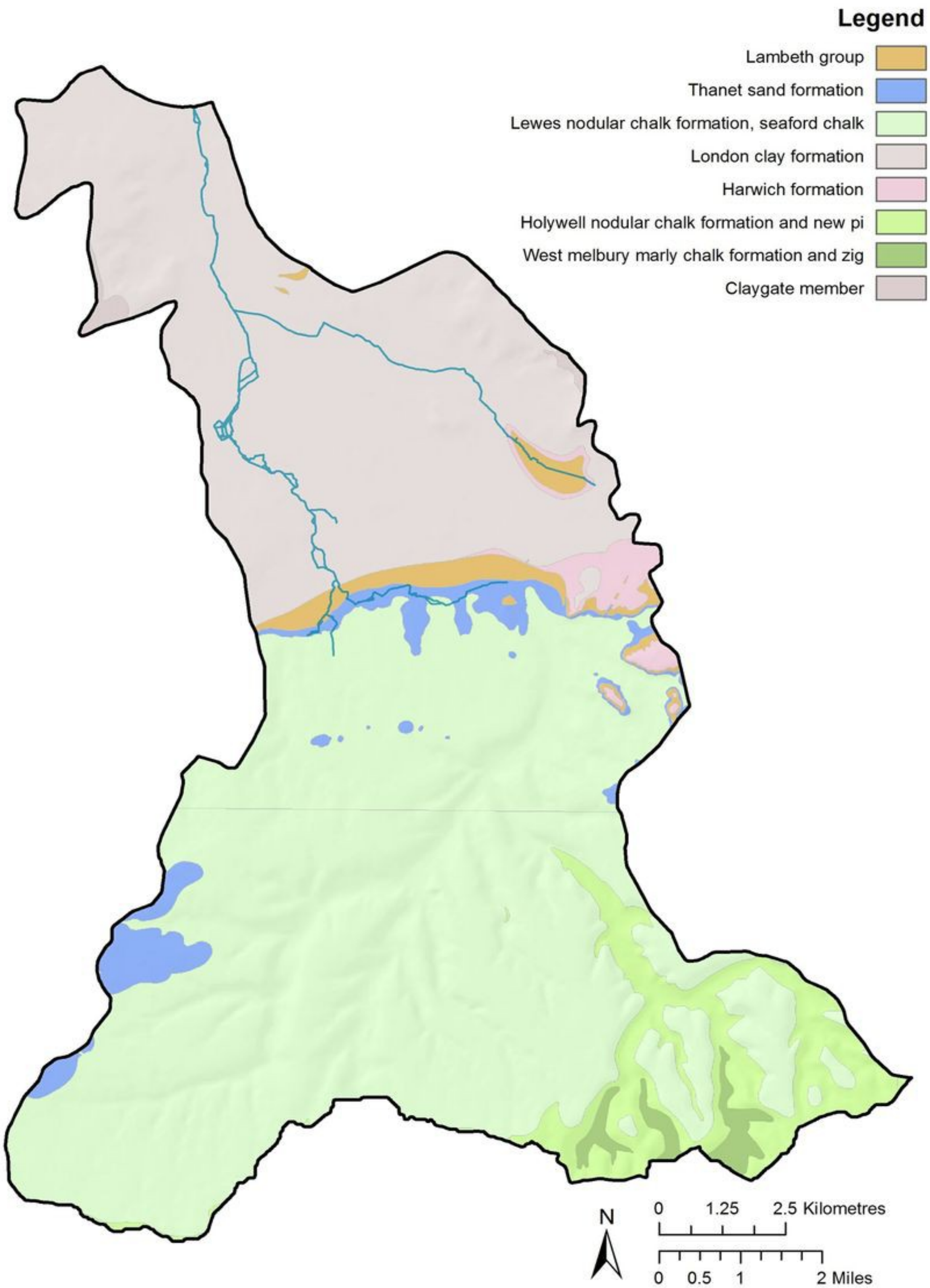

Fig 3a: Bedrock geology of the Wandle catchment

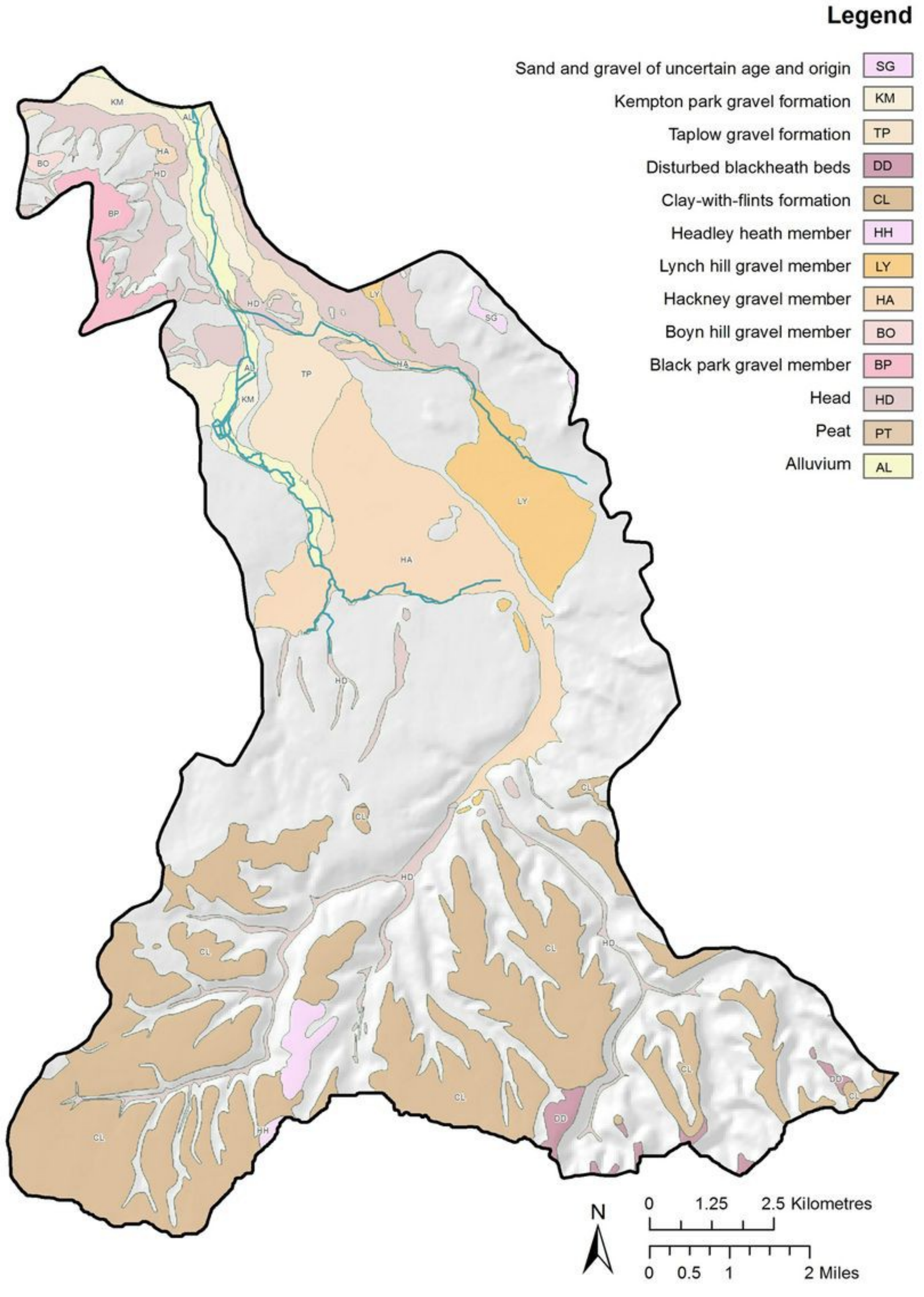

Fig 3b: Superficial deposits in the Wandle catchment

3.5: Ground water and aquifers

The Wandle catchment includes two ground water bodies: the Epsom North Downs Chalk (GB40601G602200) and the Bromley Tertiaries (GB40602G602300).

For the purposes of the WFD, both of these water bodies are classified as Poor for quantitative quality and Good for chemical quality: the same classifications are predicted for 2015.

Ground water quality is monitored by the water companies to ensure that water used for potable supply is of high quality, but changes are difficult to detect due to the slow rate of ground water movement, so that impacts are often slow to manifest themselves. The Chalk of the North Downs is threatened by pollution by nitrates and pesticides because of the high permeability of its soils and geology: indeed high nitrate levels have already been detected in many parts of the Epsom North Downs Chalk ground water body, which are eventually likely to have an impact on surface water systems such as the Wandle. The terrace gravels that overlay the London Clays are also vulnerable ground water resources and have been subject to widespread local contamination from past industrial activities.

The EA aims to protect ground water quality via a series of non-statutory policies outlined in the *Groundwater Protection: Principles and Practice* (3PG) document. Topics include landfill activity, current and former industrial sites, use of soakaways (including road and rail drainage), effluent discharges and agricultural activity. Ground water vulnerability maps indicate areas vulnerable to pollution infiltration from the land surface and depends on the nature of the overlying soils, the underlying geology and the depth to the water table. Safeguard Zone Action Plans for future work are developed around any boreholes or wells where monitoring shows that the ground water quality is poor or deteriorating, and can be made available to facilitate understanding of the catchment.

Although the Wandle Catchment Plan is primarily concerned with enhancing the Wandle's two surface water bodies, the condition of the aquifers providing the river's natural flow is inseparable from the condition of the river itself.

As such, the WFD classification of both ground water bodies, due to their potential effects on the catchment's surface water bodies, should be an ongoing cause for concern. At the time of writing, investigations into both the Carshalton water body and the upper Croydon – Wandsworth water body are being carried out under the EA's National Environment Programme (NEP):

- Carshalton water body: Royal Haskoning for Sutton & East Surrey Water
- Upper Croydon – Wandsworth water body: AMEC for Thames Water

The formal end point for these investigations is 31st March 2015: however conclusions may be available before this date (see Section 3.6 below).

3.6: Abstraction and licensing

"Not enough people know how their actions can directly affect the Wandle, including how much water they use. If necessary, agreements with water companies should also be changed to help the river"

- from Ketso community and stakeholder workshops

The Wandle's aquifers are an important source of public water supply, but they have a long reputation for sensitivity to varying levels of recharge and modern pressures of abstraction.

Historic flows were jealously guarded by mill owners whose businesses relied on the power of the river, and periodic schemes to abstract water directly from the Wandle to supply London and its expanding suburbs met with fierce resistance. In 1610 a proposal to pipe 10% of the flow from the springs at Waddon directly to the City of London was abandoned. But in a test case in 1859 (Chasemore vs the Croydon Local Board of Health) the House of Lords ruled that "no right could be acquired to subterranean water flowing or percolating in indefinite channels, and that the rules of law applicable to surface waters do not apply to subterranean streams." (Smee, 1872). The precedent established by this case survived for more than 100 years until regulatory abstraction licensing was instituted in the 1960s.

In 1881, a railway engineer estimated that the dewatering effect of the Oxted railway tunnel had effectively transferred two square miles of the Wandle's catchment area to the Eden (Latham, 1904 cited by Bourne Society, 2012). Further impacts became evident in 1906 when a railway borehole sunk at Carshalton reduced the springs to half flow and caused a drop of a foot in the general level of the river after only two days of test pumping. By the 1920s the springs at Carshalton were failing on a regular basis: in 1921-22, 1934-35, 1944-45 and more regularly and frequently during the 1950s and early 1960s (Twilley and Wilks, 1974). In addition to boreholes for public water supply, private businesses also abstracted large volumes of water: Payne's confectionery business sank its own borehole in 1921 and continued to operate it until the factory closed in 2002, while even deeper wells were opened after the Second World War to supply Croydon B power station with water for cooling (Shew, 2012).

By the 1960s, public amenities like Carshalton Ponds and Wandle Park boating lake in Croydon had almost permanently dried up. In 1964 the Wandle Park lake was filled in, with any intermittent baseflow culverted over (Shew, 2012), while water levels in Carshalton Ponds were maintained for amenity purposes by lining them with concrete and recirculating a sweetening flow from the Wandle at Goat Bridge (however, this system was not designed to maintain the ecology of the Carshalton branch of the river).

The right to abstract up to 20,000 litres a day without a licence is enshrined in law, based on the amount of water that could reasonably sustain one small farm, its workers and livestock. Today, this right is rarely exploited in south London, and is virtually unheard of in the inner boroughs. The EA is unaware of any from or near the Wandle, although such abstractions might only be discovered if such an abstraction were specifically reported, or if routine EA monitoring revealed a site-specific and otherwise inexplicable drop in water level (pers comm. Steve Barrow, 2012).

Current abstraction licences permit the following abstractions from the Wandle aquifers which may influence fluvial flow in the river's headwaters:

- Licence reference 28/39/41/69 (The Oaks) permits Sutton & East Surrey Water (SESW) to abstract a total 19,638 m3/d from the 3 boreholes associated with the Oaks Park pumping station

- Licence reference 28/39/40/8 (The Cheam Group) permits SESW to abstract 2,273 m3/d from Langley Park which may also influence fluvial flow in the upper Wandle

- Licence reference 28/39/41/12 permits Thames Water to abstract 15,502 m3/d at Waddon pumping station

  Average abstraction from Waddon is 7,580 m3/d, peaking at 15,500 m3/d: this abstraction has some impact on Waddon Ponds and the River Wandle, but it effect varies according to prevailing groundwater levels, and requires further investigation in conjunction with SESW's abstractions (pers comm. Thames Water 2014)

- Licence reference 28/39/41/86 permits Thames Water to abstract 17,950 m3/d at Brantwood Road pumping station, and 15.911 m3/d at Surrey Street (currently disused and aggregated with Brantwood Road)

  The Brantwood Road pumping station has very little impact on the River Wandle (pers comm. Thames Water 2014)

- Three other minor permits have also been issued for ground water abstraction: two are currently defunct (at the theatre on Carshalton High Street and at a site north of Waddon Ponds), while a third at a car showroom in Beddington operates solely as a ground source heat exchange system, with no net loss to total ground water

Under the EA's London Catchment Abstraction Management Strategy (2006), these abstractions contribute to placing the Water Resource Management Unit which covers the Wandle (WMRU1) in the No Water Available category for increased consumptive abstraction licensing. This assessment was confirmed by the EA's most recent London Abstraction Management Strategy, which states that the unconfined Chalk in the upper reaches of the Wandle is subject to unsustainable ground water abstractions impacting spring flow. In order to protect the Thames, which is already heavily impacted by abstractions, WRMU1 is heavily restricted for licensing. No further consumptive abstraction will be available during low flows, and abstractions will only be allowed at times of higher flow with a flow constraint to protect the river environment.

Current abstraction regimes are also under scrutiny as part of the EA's Natural Environment Programme (NEP) and Restoring Sustainable Abstraction (RSA) programme, which suggests a possible deficit of almost 90% of total annual rainfall across the Wandle's catchment area (Sutton & East Surrey Water, NEP phase 1 report). It is suspected that in addition to the impact of individual abstraction boreholes, the river may be suffering from adverse flow conditions arising from the cumulative effect of several boreholes acting together, and the EA would encourage a water company to relocate an abstraction borehole if good evidence were found to support this hypothesis.

On the Carshalton arm, the EA has identified the possibility of ground water abstractions from Oaks Park and Langley Park causing or contributing to failure of Good Ecological Potential (GEP), based on the following assessment (SESW, NEP phase 1 report):

- Poor status assessment of fish biological quality under WFD
- A calculated flow deficit in this branch of the river based on gauged river flows at Carshalton Mill
- A very high proportion of SESW's recent ground water abstraction estimated to be contributing to the calculated flow deficit in the River Wandle

The aims of the investigation, which started in 2010 and will conclude in 2015, are to:

- Determine if SESW's ground water abstraction is causing or contributing to the failure of GEP
- Quantify the impact that this water company licence is having on the Carshalton water body
- Identify if a change to any of SESW's ground water abstraction licenses or operations is required in order to achieve and maintain GEP

On the Croydon arm of the Croydon-Wandsworth water body, Thames Water's investigation into the impact of Waddon pumping station on Waddon Ponds and the River Wandle has not been definite in its conclusions. The EA has requested completion of an options paper in conjunction with SESW, including investigation of impacts of both Thames Water's and SESW's groundwater abstractions. This is planned for the next AMP (2015 – 2020), Further information required:

Final results and analysis of NEP investigations into abstraction and low flows on the Carshalton and Croydon arms of the river: the formal end date for these investigations is 31st March 2015, however conclusions may appear sooner.

Results and options appraisal of joint Thames Water / SESW's investigation into impacts of their abstraction points in combination, due to be undertaken during AMP6 (2015 – 2020)

Further investigation and finalisation of water balance calculations across the Wandle's catchment

Further reading:

Environment Agency (2006) *London Catchment Abstraction Management Strategy*

Environment Agency (2013) *London Abstraction Licensing Strategy*

Sutton & East Surrey Water PLC (2011) *River Wandle National Environment Programme (NEP) Investigation (Phase 1 report)*

Thames Water *River Wandle National Environment Programme (NEP) Investigation (references needed)*

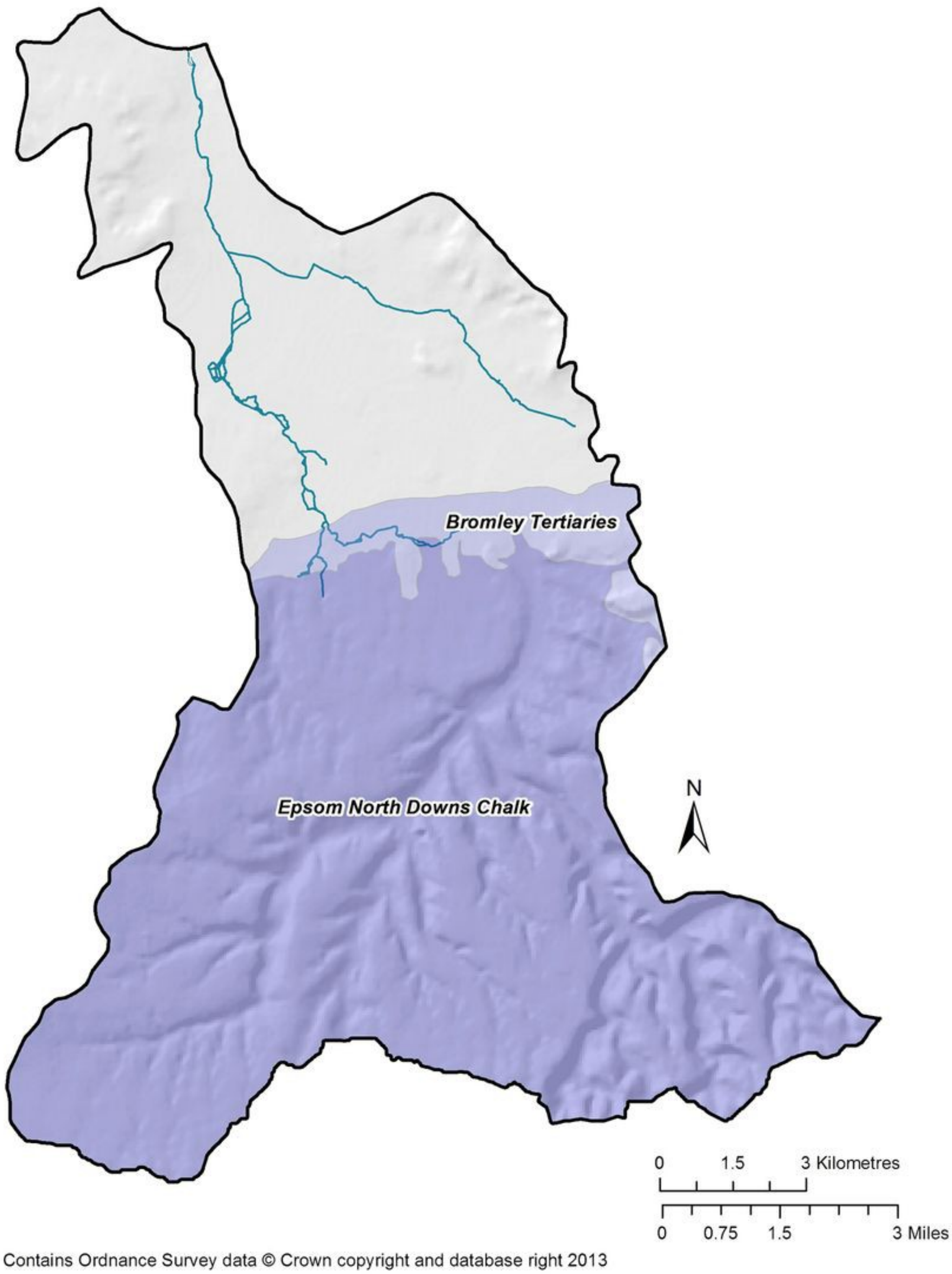

Fig 3c: Ground water bodies in the Wandle catchment

3.7: Hyporheic connectivity

A river's hyporheic zone is the saturated layer of gravels between its surface channel and its catchment's ground water, with hyporheic water deriving either from the river itself or via infiltration through the surrounding landscape.

Hyporheic flow can often be equal in volume to visible fluvial flow, and the interactions in the hyporheic zone play an important role in improving water quality, removing nutrients from the fluvial river, and regulating extremes of river temperature. Research into low-gradient rain-fed rivers in North America's Olympic Peninsula has revealed hyporheic zones more than 600 metres deep, with lateral reaches of 3 – 5 kilometres, containing more than 95% of the river's total biomass, including migratory fish fry and macroinvertebrates (Rose, 2003). In rivers with good connectivity to their hyporheic zone, subterranean parafluvial flow occurs at sharp bends where the flow bypasses the bend and flows in a straight line: this flow can exist up to 2km from the actual river in large systems like the Danube, and is likely to occur along the reach of any river which still has connectivity with a porous aquifer (eg chalk) underneath (pers comm. Lee Knight, 2014).

Historic records strongly suggest that the fluvial Wandle once had extensive hydraulic interaction with its hyporheic zone, even in the river's lower reaches (see Section 4.1, below: Braithwaite citation). However, this lateral connectivity has now been severely compromised, both by hard engineering which has physically isolated the river from its ground water (eg the concrete channels through Earlsfield and Wandsworth), and by two distinct programmes of abstraction:

- Historic and current general abstraction for domestic and industrial use (see Section 3.6)
- Strategic abstraction to control ground water levels in the London basin.

London's confined chalk aquifer is complex in structure, with ground water apparently existing in different volumes and various degrees of quality in different locations. Between the early 1800s and around 1940, ground water abstraction in the London basin rose from c9 million cumecs/year to 83 million cumecs/year. This led to a decline in ground water levels from 35m below ground level in 1845 to 90m below ground level by 1960. From this date onwards, however, as ground water-dependent industries such as breweries and paper mills began to move away from London, ground water levels began to recover until studies considered that they threatened the structural integrity of many buildings, as well as infrastructure like the London Underground system.

In 1992, the General Aquifer Research Development & Investigation Team (GARDIT) was formed by Thames Water, the EA and London Underground with support from other organisations including the Association of British Insurers, with a remit to "control ground water levels in the chalk aquifer under central London in order to maintain the integrity of underground structures and foundations in the London Clay" (EA, 2007). GARDIT re-opened old boreholes and constructed new ones to increase abstraction levels by up to 70,000m3/day. By 1994 a cone of depression more than 40m below sea level had been created under central London. By 2000, ground water levels had stabilised, and abstraction was capped at a total 50,000m3/day, with two boreholes near the Wandle in Wandsworth and Lambeth.

In view of this ongoing programme of abstraction to protect London's infrastructure, it is unlikely that the Wandle's historic connectivity to its hyporheic zone, except perhaps in the river's upper reaches, can ever be restored. This supposition is reinforced by a study in 2011 in which several springheads were surveyed for hypogean (subterranean) fauna. During the survey process most of the springheads were found to be clogged with silt, indicating a lack of flow exchange with ground water. Indeed, in a survey of four springs, only one individual subterranean shrimp was found – although the detection of hypogean crustacea in one spring suggests that some connectivity still exists between the benthos and hyporheos (Knight, 2011 and pers comm. 2014)

The Wandle Catchment Plan's Fish TAG has warned that this lack of hyporheic connectivity may have far-reaching consequences for the river's ecology. In particular, lack of upwelling ground water may result in fluvial water temperatures rising above upper avoidance limits for species which might otherwise thrive in the Wandle (eg grayling), and other species may also suffer negative effects.

Further information required:

Investigation of the Wandle's hyporheic zone throughout an appropriate length of the river (initially by desk study or walk over to identify areas of upwelling and downwelling flow in the river, as indications of connectivity with the hyporheic zone)

Investigation of ground water inputs into the Wandle in order to help define a good baseline flow

Further reading:

Braithwaite (1861) *On the Rise and Fall of the River Wandle: Its springs, tributaries and pollution*

Johns (2011) *The Groundwater Animals Project*: downloadable from **http://hcrs.freshwaterlife.org/sites/172.16.0.99.hcrs.local/files/GWAnimalsProjectReport.pdf**

Hyporheic Network: **http://www.hyporheic.net/**

Rose (2003) *The Color of Winter: Steelhead Fly Fishing on the Olympic Peninsula* (probably referencing Naiman, Cantor and Bilby (eds) (2001) *River Ecology and Management: Lessons from the Pacific Coastal Ecoregion*)

3.8: Wetlands

Although the Wandle's lateral connectivity with its floodplain and original surrounding wetlands has been severely compromised by the pressures of urbanisation, a number of wetlands still survive or have been created as nature reserves along the river's corridor.

These include Wilderness Island, Spencer Road Wetland, Wandle Valley Wetland, Bennetts Hole, Watermeads and parts of Morden Hall Park - several of which have been identified as potential release sites for London Wildlife Trust's water vole reintroduction project (see also Section 3.3).

Additionally, the Wandle's catchment encompasses Beddington Farmlands: a large area of sludge lagoons and gravel pits which is already one of the best sites for birds in London, and is now being progressively restored as a SINC-designated nature reserve with a mixture of habitats, including marsh/swamp, pond/lake, ruderal, running water, wet ditches, wet grassland and wet woodland/carr.

Beddington Farmlands already supports important populations of breeding, wintering and passage species. The sludge drying beds present a range of early successional habitats, initially providing mud and bare ground for feeding waders, seasonally succeeded by seed-rich weed stands which attract finches. Breeding waders include lapwing, little ringed plover and redshank, while large numbers of teal, shoveler and snipe overwinter. Waterfowl including egret, osprey and avocet have been seen on the lake, and a wide range of migrating species are recorded on passage, including one or two national rarities in most years.

The site is also important to feeding bats, and is one of very few places in London where the serotine is regularly recorded.

Until relatively recently, Beddington Farmlands supported up to 100 pairs of tree sparrows, which was by far the largest colony in London of this nationally declining, UK BAP priority species. However, this colony's population has fallen precipitously in recent years, maybe as low as one single breeding pair in 2014 (pers comm. Derek Coleman, 2014).

SECTION 4: WATER QUANTITY AND FLOW

"Our Vision is a river full of water that is plentiful and clean, and varied in its flow speeds, widths and depths"

Wandle Catchment Plan Objective 1: Water supply in all sections of the river is sufficient to sustain a healthy population of native flora and fauna, and is resilient to risk of drought or flood from extreme weather events or management for human use

4.1: Overview and historic flow records

Chalk rivers like the Wandle rely on abundant autumn and winter rainfall (when evaporation and transpiration by trees and plants is reduced) to recharge their ground water aquifers, scour silt away from gravels during high winter flows, and then maintain flows at adequate levels for the rest of the year (English Nature and Environment Agency, 2004).

When flows are reduced by abstraction and other pressures such as climate change, the duration of flow in winterbournes is shortened or lost altogether, perennial habitat for fish and other animals is lost, river gravels are choked by algae as a result of increased nutrient concentrations, and pollution events become more damaging because dilution is reduced.

Most chalk rivers are located in south eastern England, where population densities are high (and growing) and rainfall is relatively low. In some river catchments, including the Wandle, ground water aquifers have historically been relied upon as a source of clean water for public supply: as a result, today's flows in the Wandle are considerably reduced from their historic highs.

By some estimates, increased abstraction has meant that natural baseflows in the river today are a mere sixth of their historic value in the early 19th century (Shew, 2012). Old descriptions of Croydon refer to the Bishop's Palace being "surrounded by a large moat and fish ponds, fed by the limpid streams of the Wandle" (*Local History Reprints: Bygone Surrey – Mediaeval Croydon*). In a description of his youth near Croydon in the 1820s, John Ruskin remembered "the cress-set rivulets in which the sand danced and minnows darted above the Springs of Wandel". Even at the time of Braithwaite's detailed survey of the full length of the Wandle in 1861, pointedly titled *On the Rise and Fall of the River Wandle: Its springs, tributaries and pollution*, flow from the Croydon springs alone totalled more than 19,000,000 imperial gallons (0.99 cumecs) every 24 hours, even before this flow was augmented by 1,200,000 gallons (0.06 cumecs) per day from Waddon Ponds. Today, flow in the newly-deculverted river channel through Wandle Park in Croydon is barely visually perceptible unless increased by rainfall and urban runoff from Croydon's modern hard surfaces, while Waddon Ponds provide most of the Croydon arm's spring flow at an average 0.07 cumecs.

Further down the river, Braithwaite noted that the gravelly soil of Mitcham Common was "generally well charged with water, so that there would be considerable difficulty in cutting a trench, or making a sewer, on account of the water which would flow in, or filter through the joints of the works". Conversely, "during dry seasons… the gravelly district not only refuses to part with its water, but even robs the river of water, which flows down from a district less influenced by evaporation". This suggests significant interaction between the Wandle and an extended hyporheic zone, which has now been damaged by general abstraction and isolation of the river by means of fully concreted channels through Earlsfield and Wandsworth.

At Garrett's oil mills in Wandsworth, Braithwaite also recorded a flow of 4.36 cumecs: more than twice the average 1.7 cumecs recorded by the EA's gauging station at Connolly's Mill, not far upstream, between the 1960s and 2010 (by which time flows in the lower river had also been considerably boosted by the addition of treated effluent from Beddington sewage treatment works).

For the purposes of public water supply, the Wandle catchment's water resources are managed by Thames Water (sewerage and supply) and Sutton & East Surrey Water (supply only). Their management systems are not mapped precisely to the river's hydrological catchment: fresh water supply is influenced by the Thames Water Ring Main, which transports water from several different catchments and reservoirs in west London. At the other end of the process, most sewage goes to Beddington STW and is thus returned to the Wandle. However, much of the sewage from the northern end of the surface water catchment is pumped "out of catchment" for treatment at Crossness.

In summary, there is no doubt that quantity (and hence the quality) of the Wandle's water supply has been severely impacted by anthropogenic activities. The question remains: how can the effects of those activities be mitigated to match this Catchment Plan's Vision?

<u>Further information required:</u>

Investigation of the actual proportion of locally-sourced water used for domestic purposes within the Wandle catchment, in order to forecast the real effectiveness of wise water use campaigns

<u>Further reading:</u>

Braithwaite (1861) *On the Rise and Fall of the River Wandle: Its springs, tributaries and pollution*

English Nature and the Environment Agency (2004) *The State of England's Chalk Rivers: A report by the UK Biodiversity Action Plan Steering Group for Chalk Rivers*

4.2: Recent and contemporary flow and water quantity assessment

River flow (also known as discharge, symbolised by the letter Q) is generally expressed as the volume of water passing over any point over a period of time, and is measured in cubic metres per second (cumecs).

In any river it is important to understand both high and low flows: high flows shape the channel profile and control sediment transport, while low flows through the river's *thalweg* represent more likely day to day conditions. High flow conditions are typically expressed as Q10 (Q represents the discharge and 10 represents the flow quantity that exceeds normal discharge volumes only 10% of the time). Low flow conditions are expressed as Q95 (discharge exceeds this amount 95% of the time). For the purposes of maintaining sustainable levels of abstraction, the EA often requires abstraction to stop when fluvial flow is at Q90.

As such it is also important to recognise that the Wandle's Q figures have changed significantly over time, and that baseflow volumes have been much reduced by pressures such as recharge deficits, abstraction for public supply and even policy-driven control of ground water levels to maintain integrity of underground structures in the London clay (although it is noted that this is unlikely to affect baseflow in the chalk-fed reaches of the Wandle).

Chalk streams are typically characterised as stable, predictable systems: however, pinched between general catchment hardening by urban development on one hand, and abstraction for industry and urban communities' consumption on the other, the Wandle's hydrograph is now almost entirely anthropogenically controlled.

High flows

Through much of the 20th century the Wandle was progressively re-engineered as a highly efficient flood relief channel for rainfall flashing off the urban surfaces of south London. As such, high flows are controlled by the following measures:

- Tilting weirs: installed as an integrated system to manage the time-response of the river to rainfall in different parts of the catchment.

- A flood flume in Beddington Park: designed to divert high flows away from the Wallington and Hackbridge area via the Beddington Mitcham Area of Opportunity (BMAO)

- Flood storage capacity in the BMAO: made available by long-term gravel extraction in this area

- An array of 8 storm tanks at Beddington STW: designed to capture over-capacity flow, often resulting from rainfall entering the surface water drainage system. These usually take 4 - 6 hours to fill, although particularly heavy rainfall could fill them in as little as 2 hours.

- When high groundwater levels trigger the appearance of the Caterham Bourne rises, flood storage capacity is provided by a bund in Bourne View allotments, and a balancing pond at Purley Oaks depot. Overpumping into the surface water drainage system is also possible (and indeed took place in early 2014).

Low flows

As a result of abstraction for public water supply, the Wandle's chalk aquifer can be rapidly depleted in periods of low recharge. The following measures go some way to mitigating the effects of massive depletion to the river's natural baseflow:

- Under the terms of Sutton & East Surrey Water's abstraction licence for the 3 boreholes associated with the Oaks Park pumping station, a minimum average daily flow of 4.5Ml/d must be maintained over the gauging weir below Carshalton Ponds. This is achieved by abstracting river water at Goat Bridge and recirculating it back upstream via an unusual augmentation system (see Section 4.6).

- Below Goat Bridge, the river's flow is dominated by treated sewage effluent. Beddington STW adds 234,000 m3 of treated sewage effluent to the Wandle every day (2.708 cumecs), a volume which contributes an estimated 60% - 90% to the seasonal flow of the river. Over the 24 period, this average flow shows clear diurnal fluctuation corresponding to peaks and troughs of human activity within the STW's catchment.

The variable and combined effects of these influences on the river's natural hydrograph makes any study of flow data exceptionally complex, unless in extreme detail and with great specificity as to location.

However, it is the Wandle Catchment Plan's partners' view that any steps taken to renaturalise the river's hydrograph, and reduce anthropogenic control of the river's processes for long-term sustainability, would be welcomed in the future.

4.3: Springs

"We love it when the springs around Carshalton are flowing, filling up the dried-out sections and washing away all that smelly black mud in the Ponds"

- from Ketso community and stakeholder workshops

The natural sources of chalk rivers often migrate considerable distances up and down their catchments according to the height of the ground water within their aquifers. These ephemeral reaches above the perennial headwaters are known as winterbournes, which can often harbour complex and highly adapted ecosystems in their subsurface hyporheic zones, but are often very vulnerable to fluctuations in rainfall and anthropogenic influences including abstraction.

Today, the sources of the perennial Wandle appear fixed: however this appearance is often illusory as a result of the impact of long-term abstraction, and hard engineering solutions such as the Goat Bridge – Carshalton augmentation system installed in the 1960s to mitigate the aesthetic impacts of severely depleted aquifers.

Several headwater reaches of the Wandle which once flowed perennially have been reduced to very occasional winterbourne status: almost within living memory the Grotto arm of the river flowed constantly from an ornamental grotto in Carshalton Park to power two large mills year round, but it now rises only in response to unusually heavy and prolonged aquifer recharge (most recently in the winter of 2013-14). Similar conditions apply to Carshalton Park's Hogpit Pond, which once supplied power for a small mill near the south western corner of Carshalton Ponds. At a slightly lower elevation, springs appear more frequently in Margaret's Pool and the lake at St Philomena's School in response to aquifer recharge, and also flow into Carshalton Ponds.

On the Croydon branch of the river, the combined effects of abstraction and the gradient on the dip slope of the North Downs (which is relatively sharp compared to the gradient of the groundwater surface) mean that most of the Wandle's springs now appear within a short distance of the main river channel, whose Croydon branch flows east to west from Waddon to Wallington along the line of the Bromley beds.

Several springs, historically formalised and ornamented to greater or lesser degrees, appear in the Beddington Park area, and converge at the London Road bridge before flowing down to the confluence with the Carshalton water body at Wilderness Island. Despite being culverted, some of these springs appear to flow consistently year round, and it has been suggested that simple deculverting may be sufficient to restore important reaches of new chalk stream headwaters for the benefit of trout and other species (pers comm. Dave Brown, 2013).

4.4: Bournes

In addition to the spring sources described in Section 4.2 above, the Wandle catchment features several winterbournes which rise very intermittently in the chalk valleys above Croydon.

Historically they acquired a reputation as "woe waters", portending national disasters including plague in London in 1665 and the revolution of 1688 (Bourne Society, 2002: Aubrey, 1723). Much more likely is the explanation that the rising of the bournes indicated high levels of aquifer recharge, which resulted in higher than average ground and surface water levels in the Croydon area and led to outbreaks of illness linked to poor sanitation.

Although unpredictable, the Caterham Bourne appears to flow most frequently, approximately once every seven to ten years. It generally rises in the area of the Woldingham viaduct, sometimes flooding areas of Whyteleafe and Kenley, before becoming fully culverted at Purley.

The Coulsdon Bourne is less easy to trace on the ground for significant distances: however a short length appears at Coulsdon South railway station and later joins the course of the Caterham bourne at Purley. At these points a low but possibly perennial flow seems apparent, which may be due to a relatively impermeable layer of surface geology maintaining surface flow.

Recent winterbourne-related flooding has occurred in the 1960s, in 1995 and through the winter of 2000-2001 when homes and roads in Kenley and Whyteleafe were submerged for several weeks (Bourne Society, 2012). Continuous aquifer recharge during 2012 and 2013 also resulted in strong winterbourne flows from January 2014.

Local geology may be complex and not fully understood: the EA's LEAP of 1999 suggests that some surface flows may sink below ground level again and continue deeper underground to join the confined London aquifer, rather than feeding into the Wandle directly via culverts under Croydon. Some water may also re-emerge as springs along the dip line. However, lack of flow in the Wandle's winterbournes can now be considered typical, even in winter, and their primary function appears to be as surface water drains for road runoff.

Further reading:

The Bourne Society (2002) *A Celebration of the Bourne*

4.5: Beddington Sewage Treatment Works

"We've been outraged by many years of pollution incidents from Beddington sewage treatment works. Now we believe everyone needs to work together to protect the Wandle from damage by future pollutions"

- from Ketso community and stakeholder workshops

Clean water supply and sewage disposal are binary issues which have long affected many urban rivers and their surrounding human populations, and the Wandle has been no exception to this rule.

Today, the catchment's main sewage treatment works (STW) at Beddington serves a population of 350,000 across 28 square miles of south London, with sewage from four sewerage systems as shown in Fig 4.1 below:

- Central and Southern Croydon Gravity Sewer
- Sewage from Carshalton received via Buckhurst Avenue pumping station
- Mitcham Gravity Sewer
- Roundshaw housing estate

According to figures released by Thames Water in November 2012, the STW discharges 234,000 m3 of treated sewage effluent into the Wandle every day (2.708 cumecs), a volume which contributes an estimated 60% - 90% to the seasonal flow of the river below the effluent channel's confluence point at Goat Bridge.

Over a 24 hour period, flows through the STW show a clear diurnal pattern in response to human activities: falling to their lowest around 4am, before rising sharply just before 8am and remaining high throughout the day apart from a dip in the mid afternoon. Volumes and patterns are roughly stable throughout the year (pers comm. Thames Water), and are sometimes thought to provide ecologically beneficial flows in drought conditions when the river's baseflow is severely depleted.

Specific water quality issues relating to Beddington STW, together with details of the sewage treatment process, are further discussed in Section 5.7.

Storm tanks

Storm tanks are commonly used at STWs to capture (and temporarily store) over-capacity flow which arrives as a result of precipitation runoff into the combined drainage system.

At Beddington STW, if the volume of sewage entering the works is greater than 2.3 m3/s, it backs up behind the inflow penstock and overflows over a weir into a channel which diverts it to an array of 8 storm tanks with a cumulative capacity of 25,900 m3. These tanks perform a function similar to primary treatment: stored sewage has the chance to settle so that solids fall to the bottom. If the tanks fill beyond capacity, the stored effluent is then released into the river. If they don't fill beyond capacity, the sewage is recirculated for treatment.

On average, Beddington STW's storm tanks take four to six hours to fill, although particularly heavy rainfall could fill them in as little as two hours. This capacity far exceeds the maximum flow to treatment retention time for most Thames Water STWs, which are designed to have only 2.67 hours' capacity before raw sewage is released. As a result, this capacity is considered to be very good.

Any overflow into the Wandle is likely to consist mainly of the watery sewage components as a result of settling in the tanks. In the course of normal operation, Beddington STW's storm tanks overflow no more than six times a year, at times when dilution is likely be maximised as a result of heavy rain throughout the catchment. Raw sewage would not be released into the Wandle for any other predictable reason.

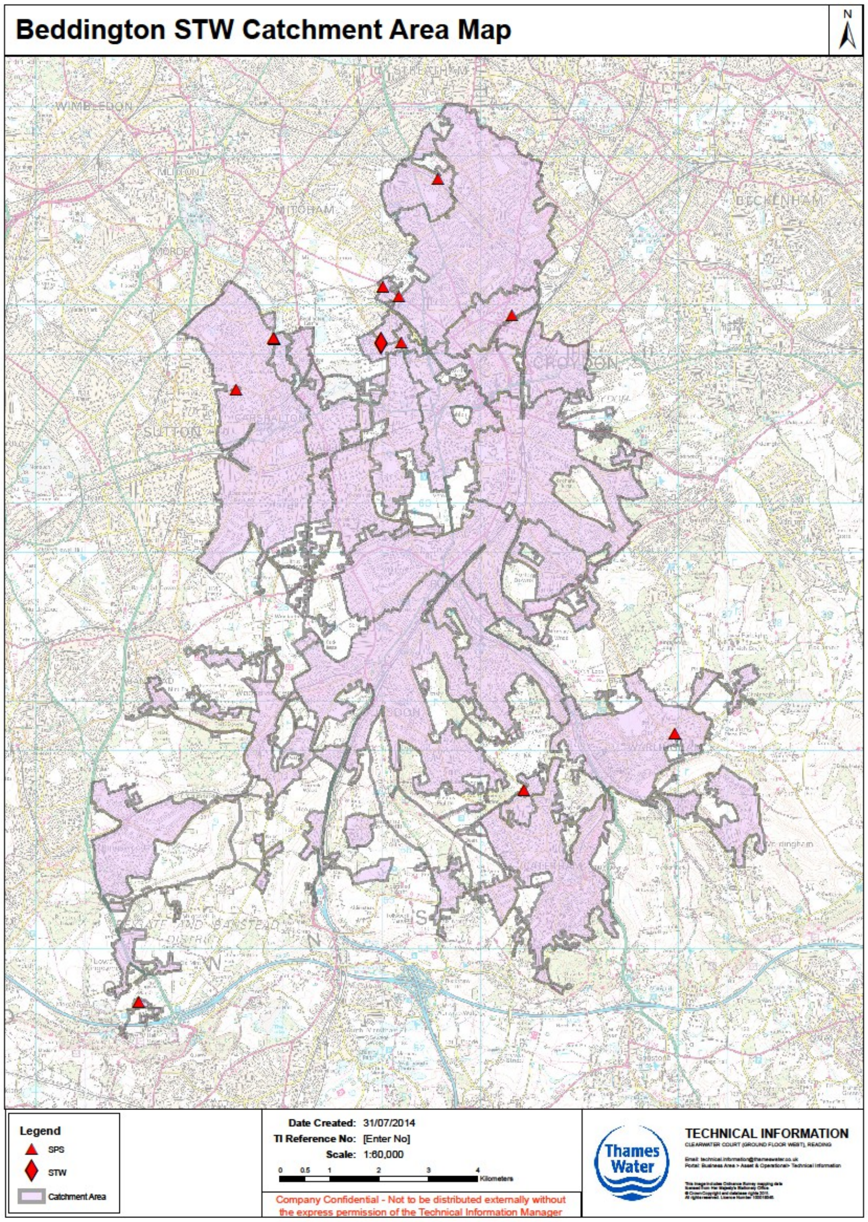

Fig 4a: The catchment area of Beddington STW

4.6: Carshalton branch augmentation system

"We're glad that the artificial recirculation system has kept the upper river flowing for so long, but we want a more natural and sustainable solution in the long term"

- from Ketso community and stakeholder workshops

In the late 1960s, when the effects of abstraction had begun to register permanent effects on the Wandle's headwater spring flow, the then Sutton District Water Company and Thames Water Authority agreed to maintain amenity water levels in Carshalton Ponds by concreting the base of the Ponds and recirculating water back upstream from the Wandle at Goat Bridge (Shew, 2012).

Under the terms of SESW's abstraction licence for the three boreholes associated with the Oaks Park pumping station, no ground water can be abstracted unless the rate of flow in the Wandle, measured at the Carshalton Ponds gauging station, is greater than 4.546 megalitres per day (SESW).

This is achieved by abstracting water from the river at Goat Bridge (a few metres above the upper river's confluence effluent channel from Beddington Park STW), passing it through sand filtration tanks, and pumping it upstream via a steel pipe under the river and adjacent roads to the upper corner of Carshalton Ponds adjacent to Honeywood House (pers comm. SESW). The sand filtration process may help to remove metal loading, since metals are associated with particles of a size range which would get caught by the sand, as well as reducing Biological Oxygen Demand (pers comm. Dave Brown, 2012). Introducing water from the Croydon arm into the Carshalton water body may also have implications for GEP.

From the time that the pumping system is triggered, water takes approximately half an hour to travel from Goat Bridge to Carshalton Ponds, and c3 hours to work its way through the Ponds to raise the river level noticeably. Likewise, there is a c3 hour lag between switching the pumps off and the river level falling

During periods of low flow, this augmentation pumping maintains a minimum average daily flow of 4.5Ml/d as measured at Carshalton Ponds gauging station. The rules for the Goat Bridge abstraction are governed by two abstraction licenses and the following key parameters (pers comm. SESW):

- Abstraction from the Wandle at Goat Bridge is limited to a maximum of 6.819 Ml/d (i.5 Mg/d)
- Abstraction from the Oaks boreholes is limited to periods when there is at least 4.546 Ml/d passing over the weir below Carshalton Ponds (measured at Carshalton Ponds gauging station)
- The output of the Goat Bridge works is increased or lowered as necessary to ensure the minimum flow requirement at Carshalton

This flow augmentation system is believed to have been unique at the time of installation, and can be fully credited with maintaining perennial flow in the Carshalton water body (and hence the possibility of achieving GEP) while comparable reaches of the Wandle's headwaters in Carshalton (such as Margaret's Pool, St Philomena's lake, the Grotto arm and the former Grove Mill channel) have been reduced to very intermittent and ephemeral appearance, usually after periods of exceptional rainfall and recharge.

However, the terms of the abstraction licence do not apply if SESW is prevented from discharging water into Carshalton Ponds due to frost, mechanical breakdown etc, and experience shows that the augmentation system has not always been entirely reliable.

In 2005, local community action was required to alert SESW to repeated mechanical and warning system failures during low flow conditions, which resulted in fluvial flow in the upper Wandle being reduced to almost nothing (Wandle Trust). It is understood that mechanical upgrades (including leaf screens on the Goat Bridge abstraction intake) have now been put in place, but this threat to the Carshalton branch should not be underestimated, especially in view of the subsequent removal of impounding structures which previously retained minimal volumes of water in the river's steep *thalweg* during these periods of flow augmentation failure.

The augmentation system has also been inadvertently affected by members of the public piling up ornamental rocks against the downstream face of the Carshalton Ponds gauging weir (thus impounding more water over the weir sill). Additional questions remain over the calibration of the gauging pipes, which may at times become blocked by debris, and the long-term sustainability and carbon footprint of such an augmentation scheme.

<u>Further information required:</u>

Results of NEP investigations

Confirmation of reliability of Carshalton Ponds gauging station (gauging pipes etc)

Investigation of sand filtration process used (rapid or slow filtration will produce different levels of treatment)

<u>Further reading:</u>

Sutton & East Surrey Water PLC (2011) *River Wandle National Environment Programme (NEP) Investigation (Phase 1 report)*

4.7: Other tributaries

"Don't forget about the Wandle's smaller tributaries – it's important to recognise their importance too"

- from Ketso community and stakeholder workshops

River Graveney

General dewatering of the Wandle catchment has resulted in many former tributaries having disappeared or being culverted into pipes from which they now emerge flow only intermittently, often carrying large volumes of urban runoff. One of the best examples of the re-engineering of the catchment is the River Graveney, which historical records suggest was once a significant water body in its own right, and certainly the Wandle's largest tributary.

Also known as the Norbury Brook in its upper reaches, which rise just to the east of Selhurst railway depot, the Graveney springs from an area of acid geology consisting of a perched layer of gravels over London clay. As such, it has no interaction with the underlying chalk, and is not a chalk stream.

In 1861 Braithwaite described the Graveney as "a considerable tributary, with a dirty appearance when the Wandle is comparatively clear". During a period of significant aquifer recharge when "the river, its bed and the adjacent soil had been saturated with heavy rains" the resulting spate "took 7 days to discharge the flood and restore the Collier Brook, or River Graveney, to its usual level". Further records from 1852 - 1853 show the Graveney adding 0.3 – 1.2 cumecs to the main flow of the Wandle.

Today, the whole of the Graveney sub-catchment has been heavily armoured for flood defence purposes, including the addition of a siphon under Tooting High Street which redirects excess runoff via an open channel alongside Lambeth Cemetery, to a lower confluence with the Wandle adjacent to the Waterside Way industrial estate. This bypass channel has been tentatively dated to the 1930s, and was designed to divert higher flows from the short culvert under the railway line, at the time when the area was being developed for housing.

The Graveney suffers from large-scale modification, lack of natural habitat, and diffuse pollution including misconnections (although possibly not as many as might be expected in an urban setting) plus runoff from the Selhurst railway depot and reported CSOs under Tooting High Street. As a result, it contributes large volumes of urban runoff to the main River Wandle, and can present a flood risk: the EA conducted a major rubbish removal exercise from the bypass channel culverts around 2002 (Wandle Trust). Apart from riverfly monitoring by the Wandle Piscators angling club at the Graveney's confluence with the Wandle, no monitoring currently takes place on this tributary, and addressing many of these problems is considered Technically Infeasible or Disproportionately Expensive at present.

As such, continuing to include the Graveney in the main Wandle water body (GB106039023460) can only bring the Wandle's overall WFD classification down, under the "one out, all out" principle. The Wandle Catchment Plan partnership therefore recommends that the Graveney should be removed from the main Wandle water body for purposes of WFD classification, and treated as its own water body with a specific set of pressures to address.

Wimbledon Brook

The Wimbledon Brook rises from several points on a spring line at the edge of the permeable terrace gravels and Claygate beds of Wimbledon Common, and joins the Wandle in Earlsfield. It is now heavily modified throughout its length, including impoundment to form Wimbledon Park Lake as a result of 18th century landscaping works by Capability Brown. The brook is not designated as a separate water body under WFD.

Pickle Ditch and Bunces Ditch

These two minor waterways epitomise the extensive re-engineering to which the Wandle has been subjected over many centuries.

The route of the Pickle Ditch may represent the historic course of the main River Wandle before it was diverted into its current course for milling purposes alongside Merton Abbey Mills and Merton High Street. Meanwhile, Bunces Ditch rises on the west bank of the Wandle, is culverted under the river's new main channel, and joins the Pickle Ditch to the south of the Merton Abbey Mills housing developments. The Pickle Ditch's name is thought to derive either from "pike and eel hole", perhaps referring to early monastic fishing habits, or from the Old English "pightle", meaning a piece of land (Montague cited by Steel and Coleman, 2012).

Both water courses are under ongoing investigation for historic misconnections: the Pickle Ditch also suffers from road runoff from the A236. A fish passage study in 2010 suggested that the Pickle Ditch could be considered as a bypass channel for the tilting weir at Merton Abbey Mills (Solomon, 2010). However, water quality issues may act as a chemical barrier to fish, while flood risk management concerns are likely to limit the attractant flow that can be diverted down this channel (very small compared to the main Wandle), and the significant height of the offtake weir would be likely to require a technical fish pass.

Neither the Pickle Ditch nor Bunces Ditch are designated as separate water bodies under WFD.

<u>Further reading:</u>

Braithwaite (1861) *On the Rise and Fall of the River Wandle: Its springs, tributaries and pollution*

Solomon (2010) *Fish Passage on the River Wandle*

4.8: Transitional water

"The Wandle Delta is hard for people to get to, and what should be great intertidal habitat is full of silt behind the half-tide weir. We'd like to see the whole area improved."

- from Ketso community and stakeholder workshops

The tidal area where the Wandle meets the Thames has been subject to many centuries of modification – most recently the installation of a half-tide weir during the 1990s in an attempt to make a boating marina. This enterprise was unsuccessful, but it has left a legacy of large quantities of potentially contaminated silt behind the remains of an obsolete structure.

For WFD purposes, this transitional tidal stretch of the Wandle is included in the Tidal Thames Upper Thames water body, which extends from Teddington to Cremorne Gardens in Chelsea, due to its shared characteristics. As a HMWB, it is only assessed only for chemical status and ecological potential.

Setting immediate targets for enhancement or restoration of this area will best be achieved through liaison with the Tidal Thames Catchment Plan partnership.

However, it is the desire of the Wandle Catchment Plan partnership to include it as part of the Croydon-Wandsworth Wandle water body, both because it forms part of the physical and ecological River Wandle and because the modifications maintaining this area in its current unfavourable condition are likely to change as a result of restoration works.

In order to improve the intertidal habitat in this area, tidal terraces and wooden wall boxes have been installed on the vertical riparian pilings of the Delta.

<u>Further reading:</u>

Tidal Thames Catchment Partnership (2012) *Tidal Thames Catchment Based Pilot Project*

4.9: Water quantity action tables

The information in these tables has been assembled from suggestions made in community consultations, TAG meetings and specific stakeholder input to develop a series of Objectives, Targets and Actions. Information on existing projects has been collated and used to identify gaps, and where additional projects may need to be developed to fulfil Actions, Targets and Objectives.

Actions to achieve the Catchment Plan's overall aim for aim for water: Water is plentiful and clean, and varied in its flow speeds, widths and depths

Objective 1: ***Water quantity:*** **water supply in all sections of the river is sufficient to sustain a healthy population of native flora and fauna and is resilient to risk of drought or flood from extreme weather events or management for human use**				
Specific Actions to attain GEP				
Target	**Actions**	**Project**	**MM**	**Indicative cost to deliver these Actions**
1.1: Groundwater abstraction is managed in a way that is considered 'acceptable' (eg availability and demand are balanced) Carshalton WB by 2015 Croydon-Wandsworth WB by 2027	1.1.1 – Identify whether abstraction activities are responsible for over-abstraction of groundwater and resultant low flows in both perennial headwaters of the Wandle. Use the NEP investigations on both Wandle water bodies for guidance, including whether abstraction activities have been responsible for the 'Grotto' headwater drying out in Carshalton Park.	NEP Investigations		These Actions are being fulfilled in part by the EA's ongoing NEP investigations on both sources of the Wandle. Thames Water, which operates the largest and closest groundwater abstraction borehole to the Croydon / Beddington branch, reported early findings in 2013. Sutton & East Surrey Water operates boreholes near to the Carshalton branch and is due to report its findings in 2015. The Environment Agency's new London Catchment Abstraction Management Strategy (CAMS) was published in 2013 and will also inform these Actions. Liaison, additional financial outlay for further investigations, monitoring and future recommendations for good practices to maintain
	1.1.2 – Define an 'acceptable' quantity of water abstraction for the River Wandle (with reference to the findings of the two NEP investigations) and draw up measures to ensure any organisation wishing to abstract water is doing so responsibly and in keeping with this 'acceptable' definition for the river (eg demand does not outstrip availability).	Tbc		

	1.1.3 – Ensure organisations currently abstracting water, or likely to do so in the future, are acting responsibly and in an acceptable manner.	Tbc	10	required flow and quality will be led by the EA, the water companies and Ofwat.
1.2: Flood risk management within the catchment is effective and has adopted water sensitive urban design as a contributing tool Carshalton WB by 2015 Croydon-Wandsworth WB by 2027	1.2.1 – Identify the main causes and locations of flooding (both fluvial and surface runoff) on the Wandle and compare to historic scenarios to highlight particular pressure points.	A9, A10	9	These Actions are being fulfilled, at least in part, by various EA and Local Authority strategies, including the Thames Catchment Flood Management Plan and the Strategic Flood Risk Assessment for LB Wandsworth, Merton, Sutton and Croydon as well as their Surface Water Management Plans. Liaison, additional financial outlay for further investigations and future recommendations for good practice working to identify and reduce flood risk will be led by the EA and the local authorities. Independent hydraulic modelling to support identification of opportunities and constraints for river improvement works in relation to flood risk management is **estimated to cost between £40,000 - £80,000**. Independent analysis of Water Sensitive Urban Design techniques for the whole catchment, including the suitability and cost-implications of various SuDS measures to help replicate natural drainage patterns is **estimated to cost £100,000**. Independent work to re-align in-stream flows at a reach-scale as a flood risk management tool (including modelling, in situ silt retention, re-profiling channel with new gravels) is **estimated to cost £250 / linear metre**.
	1.2.2 – Identify measures for attaining natural flow regimes (or a reasonable alternative) without increasing flood risk – possibly by means of a Water Sensitive Urban Design (WSUD) study that assesses suitability and cost-implications of various SuDS measures to help replicate natural drainage patterns.	A10, B12	9	
	1.2.3 – Develop and maintain surface water management plans in each borough to address flood risk effectively.	A9, A10	9	
	1.2.4 – Work closely in partnership to promote WSUD and any other measures that can contribute towards effective flood risk management, plus any added benefits including wise water use, water quality enhancement etc.	A10, B12	9	
	1.2.5 – Instigate an ongoing programme of monitoring to evaluate whether implemented measures to reduce / mitigate against flood risk are effective.	None	9	

	1.2.6 – If monitoring reveals implemented measures are not effective at reducing / mitigating flood risk, identify and obtain funding sources for researching alternative measures – and then implementing them – within the catchment as necessary.	None	N/A	Independent work to design and implement restoration of river-floodplain connectivity with local flood storage options, such as the creation of a small wetland area, is **estimated to cost £20/m^2** depending on the location and accessibility of the site and other complementary work that may also take place (such as narrowing the river channel and creating a berm).

Wider Actions to improve the ecological functioning of the river				
Target	**Actions**	**Project**	**MM**	**Indicative cost to deliver these Actions**
1.3: The natural and modified catchments and pathways of water movement into the Wandle are understood	1.3.1 – Identify where the natural catchment boundary for the different elements of the river/groundwater system actually is.	None		These Actions are being fulfilled by the EA's ongoing National Environment Programme (NEP) investigations on both sources of the Wandle. Thames Water, which operates the largest and closest groundwater abstraction borehole to the Croydon / Beddington branch reported early findings in 2013. Sutton & East Surrey Water operates boreholes near to the Carshalton branch and is due to report its findings in 2015. Liaison, additional financial outlay for further investigations and future recommendations for good practice working that maintain required flow and quality will be led by the Environment Agency, the water companies and Ofwat. Independent surveys and research to identify the original source of the Wandle is **estimated to cost £25,000**. Independent work to collate and compare the different natural and artificial catchment boundaries that exist and the implications for such differences depends largely on the findings of the two NEP investigations. **Financial estimates of other elements to be added in due course**.
	1.3.2 – Improve understanding of how groundwater behaves within the catchment and what factors affect its movement, quantity and quality (consider modelling to help).	None		
	1.3.3 – Identify whether changes to the current situation are likely, and whether these may cause conflicts or new pressures on the catchment. For example, due to changes in how the water cycle is managed by water companies, the EA or local authorities, or as a result of climate change.	None		
	1.3.4 – Identify all artificial inputs to groundwater and surface water within the Wandle catchment.	None		
	1.3.5 – Identify modifications to the natural catchment boundary which may result from these artificial interventions (eg create maps to illustrate different catchments and sub-catchments) and identify what the potential consequences might be of these differences.	None		

1.4: The Carshalton augmentation system is managed to maximise both ecological benefits and ecosystem service benefits for people	1.4.1 - Understand the role of the augmentation system* in altering fluvial flow rates and how it is managed, including any maintenance, monitoring and cleaning regimes. ** This abstracts river water at Goat Bridge and pumps it back up to Carshalton Ponds to maintain fluvial flow.*	None		These Actions are being fulfilled by the EA's ongoing National Environment Programme (NEP) investigation led by Sutton & East Surrey Water which is due to report its findings in 2015. Liaison, additional financial outlay for further investigations and future recommendations for good practice working that maintain required flow and quality will be led by the Environment Agency, the water company and Ofwat. Independent analysis of Water Sensitive Urban Design techniques for the whole catchment, including the suitability and cost-implications of various SuDS measures to help replicate natural drainage patterns is **estimated to cost £100,000**. Independent work to reduce silt volume in Carshalton Ponds by introducing activated chalk to break it down (including monitoring of chemical presence to advise on repeat applications as necessary) is **estimated to cost £3,000 for a one-off application, with repeat applications in**
	1.4.2 – Identify the benefits provided by the augmentation system for the ecological health of the river (such as diluting road runoff pollution and preventing the Ponds from becoming highly eutrophic and potentially dominated by algal blooms that could be hazardous to the health of wildlife and people).	None		
	1.4.3 – Identify the wider ecosystem service provided by the augmentation system for people (such as aesthetic/cultural value by maintaining the water levels in the Ponds and recreational/cultural value afforded by the presence of waterfowl).	None		

	1.4.4 – Identify ways in which any negative impacts of the augmentation system can be removed or compensated for. (Negative impacts may include organic nutrient and chemical pollutant dispersal downstream, elevation of water temperature. Mitigation may include re-direction of water via the maintenance pipe downstream of Carshalton Ponds to avoid organic nutrient dispersal downstream).	None		**future years as necessary, dependent on monitoring outcomes**.
1.5: Groundwater abstraction practices are amended to restore perennial flow to the headwater reach on the Carshalton water body	1.5.1 – Confirm whether the headwater of the Carshalton arm in Carshalton Park, LB Sutton (which today is predominantly dry) is the southernmost spring line of the perennial chalk headwaters on the Carshalton water body (as believed and indicated by its classification as Main River). If so, restoring flow and this habitat would rehabilitate approximately 1.5 km of rare and ecologically important lowland chalk stream habitat. It would also help to reinstate ecological flows which support the Wandle, reconnecting the Carshalton arm with more of its headwaters, and would, therefore, be a priority consideration.	None		These Actions are being fulfilled in part by the EA's ongoing NEP investigations on both sources of the Wandle. Thames Water operates the largest and closest groundwater abstraction borehole to the Croydon / Beddington arm reported early findings in 2013. Sutton & East Surrey Water operates boreholes near the Carshalton branch and is due to report in 2015. Independent work to undertake surveys and research to identify the original source of the Wandle is **estimated to cost £25,000 (as above)**. The EA's new London Catchment Abstraction Management Strategy (CAMS), published in 2013, will also inform these Actions.

	1.5.2 – Research the potential wider benefits of restoring the perennial flow at source of the Carshalton arm, eg it will a) benefit a priority habitat type b) possibly increase flow to Carshalton Ponds, thus reducing or removing the need for the augmentation system that is currently in operation between Goat Bridge and Carshalton Ponds c) improve water quality in the Carshalton arm by increasing spring fed base flow input.	None		Liaison, additional financial outlay for further investigations, monitoring and future recommendations for good practice working to maintain flow and quality will be led by the EA, the water companies and Ofwat.
	1.5.3 – Investigate likely measures and associated costs with restoring flow to the Carshalton arm source and whether these are deemed technically feasible and not disproportionately expensive, taking into account any potential wider benefits.	None		
1.6: Water consumption (per capita and total) within the catchment is reduced across all sectors (individuals, businesses etc) and water efficiency	1.6.1 – Identify the population of the catchment now and projected increases in the next 15-20 years. Then use this to calculate estimated *per capita* consumption levels and use examples from other initiatives to calculate realistic consumption reduction targets within this timeframe.	None		Use information from existing wise water use campaigns. Costs will relate to staff time and may include some budget for the provision of water saving devices, but these are often offered by water companies at no cost.

measures are implemented, including water saving appliances and metering	1.6.2 – Design and implement an education and awareness raising programme for the public, local businesses etc within the catchment to explain why reductions in water consumption are desirable, reasonable and essential to their ongoing well-being and the ecological health of the river. To help persuade people, show how the maintenance of ecosystem function underpins the cultural, regulating and provisioning ecosystem service benefits that they value.	None		
	1.6.3 – In tandem with the education and awareness raising programme, identify a suite of water-saving measures suitable for use in the Wandle catchment and promote these by making them readily available and attractive to consumers (eg free or low-cost to install, with speedy payback) .	None		
	1.6.4 – Instigate an ongoing programme of monitoring to evaluate whether implemented measures to achieve the target reduced water consumption rates (set in Action 1.7.1) are effective and, if not, amend measures accordingly.	None		
1.7: Water losses within the distribution network are addressed	1.7.1 – To complement water saving activities by consumers, the main causes of water wastage within the supply system are identified and mitigation measures are implemented where possible. Regular reviews of these causes and mitigation measures will help to maintain efficiencies.	None	N/A	This Target will need to be led by the water companies and Ofwat working with the EA and local authorities.

SECTION 5: WATER QUALITY

"Our Vision is a river full of water that is plentiful and clean, and varied in its flow speeds, widths and depths"

Wandle Catchment Plan Objective 2: The quality of water flowing in the River Wandle meets the standards required for Good Ecological Potential and is stable with no risk of deterioration

5.1: Overview and historic water quality records

Despite extensive exploitation for public and industrial supply and waste disposal, the River Wandle enjoyed a long historic reputation for the unusual clarity and quality of its chalkstream water. Although not scientifically detailed, water quality can be inferred from multiple descriptions of the river's natural purity, clarity and suitability for pollution-sensitive organisms like trout – and conversely from accounts of the catastrophic levels of pollution to which the river was later subjected.

Numerous early writers eulogised the river as "the best and clearest stream near London" (Davy, 1828) and "one of the most celebrated trout streams in England… the chalkiest of chalk streams (Dewar, 1899). Around 1870, Halford recollected, the upper Wandle in Carshalton "was a beautifully clear stream in which every stone could be seen in four or five feet of water" (Halford, 1903).

Even in 1881, more than a generation after Braithwaite had recorded astonishing levels of aquatic pollution further down the river in the 1850s, general water quality still seems to have been good enough to persuade William Morris to move his printing works to Merton Abbey. His printing processes required a particularly pure quality of water for madder dyeing, and Morris's decision to relocate to the Merton Abbey area of Wandle, over several other contenders including the Colne and Cray (Parry, 1983), almost certainly indicates the dilutive effect of strong baseflows which had not yet been damagingly reduced by abstraction.

This hypothesis is supported by simultaneous developments on the Croydon branch of the river. As industrialisation intensified, and the population of Croydon increased from 5,7423 in 1801 to 134,037 in 1901, these pressures so far exceeded the local councils' ability to provide adequate waste disposal that this stretch devolved progressively into an open sewer and probably contributed to epidemics of cholera and typhoid in the late 1840s and 1875 (Shew, 2012).

The Wallington-based horticulturalist Alfred Smee noted how "the Board of Health of Croydon carried all the sewage of the town into the river which passed through Beddington Park to my garden. The effluvium was noxious; the fish died; and foul mud was deposited on the bottom of the river. It became a question whether I should abandon my garden; but I determined otherwise, and commenced an agitation to stop the pollution of rivers" (Smee, 1872). His landmark court case (Smee v Croydon Board of Health) eventually forced the creation of a purpose-built sewage irrigation farm on the former Carew Manor deer park in Beddington, though not before "a committal (had to be) signed to commit the members of the Board to prison" (Smee, 1872).

But the river's downward spiral now has the all the appearance of inevitability. "By 1905 a newspaper reported that 'Wandsworth knows the Wandle as a sickly stream, sage green and sluggish, soiled by a dozen factories, often smelling vilely'" (Courtney Williams, 1945). In 1899, Dewar had already written, "As for the poor Wandle in Merton, it is a shocking sight and colour: you might as well indeed fly-fish at Wandsworth as at Merton to-day."

New sewage treatment works were eventually built in the 1930s, and the current works were commissioned in December 1960, leading to slow improvement in water quality. Continued investment in sewage treatment technology has now resulted in a river which can sustain healthy populations of stocked fish, including trout which are only able to survive in clean, well-oxygenated water.

However, Beddington STW remains a continuous source of nutrients and chemicals not removed by sewage treatment processes, and an occasionally catastrophic threat to water quality. Abstraction and general urbanisation of the catchment also continue to place considerable pressure on the Wandle's water quality.

<u>Further reading</u>

Braithwaite (1861) *On the Rise and Fall of the River Wandle: Its springs, tributaries and pollution*

Courtney Williams (1945) *Angling Diversions*

Halford (1903) *An Angler's Autobiography*

Smee (1872) *My Garden: Its plan and culture*

5.2: Modern water quality assessment

Under the supporting elements categories for WFD assessment, surface water quality is reported and managed by the Environment Agency under two schemes: General Quality Assessment (GQA) and River Quality Objectives (RQO).

GQA makes regular assessments to monitor trends over time and compare rivers in different areas, with 3 classification components:

- General chemistry: 6 grades A (highest) – F (lowest) for dissolved oxygen, biochemical oxygen demand (BOD) and Total Ammonia. (NB chemical content of water samples can be influenced by the time of day at which they were taken: eg the relationship between dissolved oxygen levels and the rate of the photosynthesis-respiration cycle and by the nature of discharges into the watercourse)

- Biology: a proxy measurement based on benthic macroinvertebrate monitoring. Aquatic invertebrates are continuously exposed to changes in water quality, and respond to intermittent and low level pollutants that may not be detected by standard chemical monitoring methods.

- Aesthetics: very labour-intensive, therefore only used in reaches where information is required for a particular reason (eg to monitor storm outfall improvements).

RQO establishes surface water quality targets based on the uses of the watercourse, in order to provide a commonly agreed planning framework for the regulatory bodies and dischargers, with one main component based on the river's ability to support various fish populations:

- River ecosystem (RE): 5 classes RE1 (best - very good water quality suitable for all fish species) - RE5 (worst - water of poor quality likely to limit coarse fish populations)

Under these water quality assessment schemes, the Wandle's Carshalton water body is designated as Good (ie in line to achieve GEP for water quality) while the Croydon-Wandsworth waterbody is failing on phosphate only.

This assessment implies that the Croydon-Wandsworth water body is eutrophic and requires immediate protection and improvement measures to prevent deterioration. As a result, the Wandle has been designated a Phosphate Sensitive Area under the Urban Waste Water Treatment Directive, and Thames Water will be required to install phosphate stripping equipment at Beddington STW during AMP6, with completion due by November 2018 (pers comm. Angela Gorman, EA, 2014).

Statutory water quality monitoring on the Wandle is also supported by two voluntary schemes:

- **Riverfly monitoring**: monthly invertebrate monitoring has been carried out by the Wandle Piscators' fishing club at 11 key sites on the river since 2008. Diversity and abundance of key aquatic invertebrates are noted by trained volunteers as proxy measurements for water quality: if scores fall below pre-defined trigger levels (typically 50% of the running average over six months of the riverfly monitoring score for the site) an EA investigation is launched.

- **Pollution Assessment Volunteers**: a network of volunteers works with the EA and the Wandle Trust to assess Category 3 (minor) pollution incidents, and identify misconnections and other point source pollutions.

In 2013 the EA and Thames Water undertook a very successful pollution prevention project in Croydon town centre, identifying and resolving a large number of regular point sources of pollution. The EA continues to raise awareness of pollution issues and is involved with assessing certain crucial pollution sources, including the Deer Park Road Industrial Area (Merton) and Willow Lane Industrial Estate (Mitcham).

Additionally, through the Surface Water Outfall Programme, pollution hotspots are identified and listed by the EA, and project managed by Thames Water. In February 2014, work started on the Morden Hall Road outfall: cleaning sewer lines, unblocking manholes, identifying misconnections and persistent polluters, and dealing with these through negotiation or legal notices.

Further pollution pathways into the Wandle are discussed in Section 5.8.

5.3: Temperature

The Wandle's chalk stream sources emerge from a spring line on the dip slope of the North Downs at a constant temperature of c11°C: a typical temperature for chalk springs. This water becomes progressively warmer as it flows north to the Thames at Wandsworth, with thermal loading occurring at several points, particularly as a result of the inflow of treated sewage effluent from Beddington STW (see Section 5.8.8) which adds an average c2.6°C to water temperatures.

Between January 1998 and April 2009, the EA took regular water samples at six monitoring points on the river for water quality testing. Water temperatures were recorded, and a summary is presented below:

Beddington Park Lake	**Average recorded temp °C**	**11.7**
(gauging station)	Max record	18.3
	Min record	0.4

Butter Hill	**Average recorded temp °C**	**11.2**
	Max record	18.3
	Min record	3.7
Goat Bridge	**Average recorded temp °C**	**11.4**
	Max record	17.4
	Min record	5
Watermeads	**Average recorded temp °C**	**14**
(Mitcham)	Max record	20.7
	Min record	8.6
	Average °C added by STW	**2.6**
	Av max variation	2.8
Plough Lane	**Average recorded temp °C**	13.7
	Max record	21.5
	Min record	7.2
Wandsworth	**Average recorded temp °C**	13.4
(Causeway)	Max record	20.3
	Min record	6.3

Fig 5a: Comparative water temperatures at six sites on the Wandle between January 1998 and April 2009: this data illustrates the year-round thermal impact of Beddington STW on the river's temperature regime (data source: EA / Wandle Trust)

All temperatures were recorded between 8.30am and 1pm. Because these records were generated as part of a general methodology for collecting water samples for chemical analysis, it should be noted that the sampling points and timings were not targeted for maximum information on the thermal range which the Wandle may experience. As a result they may not reflect maximum solar-thermal loading when water has been resident in online impoundments for several hours on a sunny summer afternoon, with associated implications for dissolved oxygen levels (fully saturated water contains 14ppm of oxygen at 1°C, 11ppm at 11°C, and 9ppm at 20°C) (Watson, 1993).

On the other hand, these records provide a long-term data set which allows tentative conclusions to be reached. For example, despite impacts of impoundments, most of the river appears to be well within the comfortable optimum temperature ranges for trout growth (7- 9°C and 16-19°C) (Solbé, 1997), a hypothesis which is confirmed by the observed ability of trout to survive and grow to large sizes in the Carshalton water body, as well as the Croydon-Wandsworth water body above Goat Bridge.

Further downstream, below the influence of Beddington STW, temperatures are also tolerable for salmonids, but become better suited to a wide range of cyprinids. (However, dace and perch are also able to spawn in colder water, at or below 12°C: see Section 7.2.2).

5.4: General water chemistry

The effluent carrier channel from Beddington STW significantly increases the flow of the main River Wandle below Goat Bridge by c234,000 m3 (2.708 cumecs) of treated sewage effluent per day.

On 9 July 2009 an investigation into general water chemistry was carried out by representatives from the EA, Wandle Trust and Thames Water, with the objective of providing an understanding of "normal" conditions for the river.

This investigation has also provided an assessment of the direct impact of Beddington STW on the Wandle's water chemistry. The comparative data resulting from this investigation is tabulated below (Fig 5b):

Component Name	Units	U/strm of BSTW	D/strm of BSTW
DO	%	95.6	86.1
DO	mgl	9.84	8.85
Cond	µS	625.9	747.8
TDS	ppm	338.6	487.5
NaCl	ppm	555.4	684.3
Water Temp	°C	14.4	14.9
pH		7.06	7.43
$P0_4$	ppm	0.25	>4
$N0_3$	ppm	7	11
BOD (5 Day using ATU)	mg/l	<1.0	1.1
COD	mg/l	<10.0	19.5
Solids Suspended 105C	mg/l	<2.00	5.50
Ammoniacal Nitrogen	mg/l	<0.04	<0.04
Sulphate as SO_4	mg/l	24.3	41.5
P SOL Reactive	mg/l	<0.03	2.67
Neat E. coli 2000	MPN/100ml	1203	>2420
Neat coliform 2000	MPN/100ml	>2420	>2420
1/1000 E. coli 2000	MPN/100ml	1	1
1/1000 Coliform 2000	N	20	26

Fig 5b: Results of an investigation into the Wandle's water chemistry in 2009

This investigation concluded that the STW's impact on the general water chemistry of the river was moderate. However, the following direct impacts have been noted:

- Phosphate and sulphate levels increase dramatically below Beddington STW: there are currently no limits on the discharge of phosphate and sulphate from the STW (but see below). At the time of this study, the increases were deemed acceptable at a proportional level
- COD and turbidity levels also increase below the STW, although these increases are within the current discharge limits set by the EA (see Section 5.7)
- *E.coli* levels in the river double below the STW
- No increase in ammonia was detected

In 2013 the Wandle was designated as a Phosphate Sensitive Area. Under the Urban Waste Water Treatment Directive, Beddington STW is now on the EA's National Environment Programme (NEP) in AMP6, to have phosphate stripping installed to remove phosphate to a permit of 1mg/l. This scheme is due to be completed by 14 November 2018 (pers comm. Angela Gorman, EA, 2014).

<u>Further information required:</u>

Further detailed interpretation of general water chemistry data

5.5: Ecotoxicology

Ecotoxicology is defined as the study of the effects of toxic chemicals on biological organisms, especially at the population, community, and ecosystem level.

Ecotoxicology is a multidisciplinary field, which integrates toxicology and ecology. It differs from environmental toxicology in that it integrates the effects of stressors across all levels of biological organisation from the molecular to whole communities and ecosystems, whereas environmental toxicology focuses upon effects at the level of the individual and below.

The end objective of ecotoxicology is to be able to predict the effects of pollution, including interactions between pollutants, so that the most efficient and effective action to prevent or mitigate any detrimental effects can be identified. In ecosystems which have already impacted by pollution, ecotox studies can suggest the best courses of action to restore ecosystem services and functions efficiently and effectively (Wikipedia, accessed Jan 2014). This approach can be seen in the recommendations relating to sediments, heavy metals and PAHs (see Section 5.8.6 above).

Fish and invertebrates can be affected by pollution in a variety of ways:

- Acute pollution: the effects of short "spikes" of pollution passing down a river can vary widely, depending on factors including concentration, how long the spike persists, and its distribution through water column (sometimes influenced by the mixing effect of weirs etc). Larger fish are more likely to survive pollution incidents, especially if they can find refuge from a short spike, but their food sources may be seriously depleted if the pollution has damaged invertebrate communities as well as small fish

- Chronic pollution: generally related to existing pollutants (often deposited by historic former industries and bound up in sediment deposits) which become remobilised into the water column by high flows, foraging or spawning fish, or other disturbance.

Further information required

Further investigation into pollutants, their interactions and their effects on the Wandle

Further reading:

Brierley (2013) *The characterisation and quality appraisal of riverbed and road runoff sediments within the Carshalton arm of the River Wandle, London, UK*

5.6: Historic pollution records

As London's industrial revolution gathered momentum through the 18th century, much of the energy for this revolution was provided by the Wandle, leading to the frequently-quoted assertion that it was "one of the hardest-worked rivers for its size in the world".

In addition to sewage pollution from Croydon's booming population on the headwaters, many industries used river water for their manufacturing processes before discharging it again, or simply exploited the Wandle as a conduit for flushing away waste. From early use as corn mills, most milling sites changed their industrial focus several times according to market forces and other economic pressures.

The textile trade evolved from relatively low-impact sun-bleaching, felting and organic dyeing to widespread use of chemicals, while heavier and more seriously polluting industries included copper, iron (including cannon boring and machine tooling), oil, leather, paper, snuff and gunpowder works, as well as brewing and medical distillation (Shew, 2012; Steel and Coleman, 2012). In the late 18th century, Carshalton became a centre of national importance for paper making, largely due to the expertise of the industrialist Christopher Patch, who from 1789 was one of the first paper makers to use chlorine to bleach the rags for his paper (Steel and Coleman, 2012).

Braithwaite's survey of 1861 provides a vivid picture of the variety of pollutants entering the Wandle, ranging from "pieces of skin" and "flocculent matters" from the tanyards at Goat Bridge, to "sulphuric acid, alum, muriate of tin, chloride of lime, prussiate of potash, nitrate of iron, sulphate of copper and oxallic acid" discharged by silk works at several points along the river. From 1881 onwards, at Merton Abbey Mills, Arthur Lazenby Liberty reportedly gloated that "we send all our dirty water down to Morris".

Heat pollution from quenching processes in forges and foundries would have compounded the effects of these pollutants, and it is still possible to find fig trees growing in the margins of the river: mill workers ate the figs, whose seeds passed out into the river in sewage, and successfully germinated and grew in the heated conditions (a phenomenon also observed on many post-industrial northern mill streams).

In time, as steam power outcompeted water, the industrial focus moved towards light industry and chemical works, many of which would also have polluted the river. Then as now, casual fly-tipping and disposal of household waste were recorded in Ruskin's eulogy for the Wandle in 1870: "Just where the welling of stainless water, trembling and pure like a body of light, enters the pool of Carshalton … the human wretches of the place cast their street and house foulness: heaps of dust and slime, and broken shreds of old metal, and rags of putrid clothes, which having neither energy to cart away, nor decency enough to dig into the ground, they thus shed into the stream to diffuse what venom of it will float and melt far away in all places where God meant those waters to bring joy and health…" (Ruskin, 1870).

Local landowner Charles Dingwall attributed the final decline of the upper Wandle's trout fishery to tar laid on local roads in 1914 (Wilks and Rookledge, 2002): a problem separately identified by Arthur Ransome in the Lake District.

By 1929 the ecological situation was severe enough for a committee of local anglers to draw up a report describing the state of the river: "No fish could survive in the Wandle nowadays; they would immediately die from the poisoning. The once clean, swiftly-moving waters are now black and muddy, cluttered with evil-smelling, putrescent flotsam, and rendered foul and malignant by the outpourings of industrialism. The river has not merely been neglected; it has been deliberately, wantonly, turned into a kind of open sewer. The bottom is littered with old tin cans, scraps of iron, broken bottles, and miscellaneous rubbish of all kinds." (Courtney Williams, 1945).

Even during the modern era of improving sewage treatment, non-biodegradable foaming agents in synthetic detergents were able to pass through Beddington STW, resulting in "masses of floating foam" (Montague, 2005) covering the river from Poulters Park downstream and sometimes blowing across Merton High Street in the late 1960s.

Heat pollution also continued into the 1970s, when cooling water entering the river from Croydon's power stations was measured at 75°C, while damaging discharges of cyanide were recorded from Beddington in 1973 and diesel from Croydon in 1974 (Montague, 2005). Cyanide entering the drainage system was responsible for the failure of Beddington STW in 1995, causing a week-long discharge of untreated sewage, and an accidental spillage of sodium hypochlorite from the STW in 2007 bleached up to 5km of river channel and killed at least c7,000 fish of all species. A month earlier, an untraced pollution episode, possibly containing oil and heavy metals, also killed large numbers of fish in the Mill Green area.

<u>Further reading</u>

Braithwaite (1861) *On the Rise and Fall of the River Wandle: Its springs, tributaries and pollution*

Montague (Merton Historical Society) (2005) *Mitcham Histories 6: Mitcham Bridge, the Watermeads and the Wandle mills*

Steel and Coleman (2012) *River Wandle Companion and Wandle Trail Guide*

5.7: Beddington Sewage Treatment Works

As discussed in Section 4.5, Beddington sewage treatment works (STW) provides a significant proportion of flow in the Wandle below Goat Bridge. Since the 1960s, when several other STWs were also operating on the lower Wandle, and the river was officially classified as a public open sewer, centralisation of the STW function at Beddington, and investment in treatment processes, have resulted in great improvements to general water quality.

Today, Beddington STW is operated by Thames Water, and probably still represents the single greatest point source influence on the Wandle's water quality, both generally and in relation to major pollution incidents.

Influent monitoring

According to Thames Water, the major threat to the proper functioning of Beddington STW is a soluble chemical entering the STW and impairing the biological processes. This is what happened when cyanide entered the STW via the drainage network in October 1995.

Inflowing sewage is monitored for BOD, COD, SS and NH_4, so many chemicals are still undetectable at this point, unless they affect these parameters. However, once a damaging chemical has entered the STW system, the microbes on which the STW relies to work will be killed, and continuously monitored dissolved oxygen (DO) levels will start to rise, since the microbes are no longer using this oxygen for respiration. The chemical in question can then be detected, and Thames Water's Trade Effluent Team may be able to work out its source by a process of elimination against consents for discharging this chemical.

Alert levels are assigned percentages depending on severity (since the system also flags up DO levels etc which form part of the STW's regular processes), with levels over c80% flagged as red, and alarms sounded. If the controller has not responded on the computer system within 30 minutes, for instance due to being occupied with another alert, the control centre in Reading is automatically alerted.

Effluent monitoring and discharge consents

Effluent leaving Beddington STW is constantly analysed by two on-site monitors: one measuring turbidity and NH_3, the other measuring NH_3, Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD) and suspended solids (SS) in real time via probes installed c2008 in all Thames Water's larger STWs. Turbidity and NH_4 are tested daily on site to check the monitoring equipment, and additional samples are taken each week for lab testing

Discharge consent limits for BOD, NH_3 as N and SS are tight, and are set as follows by the EA in line with the Urban Waste Water Treatment Directive, with a 95% compliance limit:

SS-95%ile (mg/l):	15	SS-Upper Tier (mg/l):	none
BOD-95%ile (mg/l):	10	BOD-Upper Tier (mg/l):	50
AmmN-95%ile (NH_3 as N): (mg/l)	2.5	AmmN-Upper Tier (mg/l):	20
Cadmium (ug/l):		P (UWWTD) (mg/l):	
Copper (ug/l):		Beryllium (ug/l):	
Zinc (ug/l):		Iron (ug/l):	
Chromium (ug/l):		HCH (ug/l):	
Nickel (ug/l):		Chloroform (ug/l):	
Lead (mg/l):		Boron (ug/l):	
Mercury (ug/l):		Cyanide (mg/l):	
Metal/Other Indicator:	Y	Oil & grease (mg/l):	

Fig 5c: Discharge consent limits for Beddington STW

If the upper tier limits are exceeded, the STW fails its consent. Since the introduction of self-regulation, Thames Water are required to take 12 samples per year: if more than one sample fails, the STW will lose its Overall Performance Assessment (OPA) points and Thames Water may have its funding from OFWAT cut by £10 million (a circular problem, since this funding may be needed to stop failures).

In 2013 the Wandle was designated as a Phosphate Sensitive Area. Under the Urban Waste Water Treatment Directive, Beddington STW is now on the EA's National Environment Programme (NEP) in AMP6, to have phosphate stripping installed with the objective of removing phospate to a permitted limit of 1mg/l. This scheme is due to be completed by 14 November 2018 (pers comm. Angela Gorman, EA, 2014).

Sewage treatment process

Raw sewage reaches Beddington STW via pipes, draining under gravity from the Croydon area, and being pumped from the Carshalton side of the STW catchment using a rising main and pumping station at Buckhurst Avenue.

Influent sewage is monitored for BOD, COD, SS and NH_3. The sewage flows into uncovered outdoor tanks at the start of the process before entering the treatment process.

- **Preliminary treatment** removes 70 – 75% of coarse solids and other large materials found in waste water. The sewage passes through 6mm band screens to strain off solids: these are transferred to a separate area for compaction and storage as rags, before being transferred to landfill. Grit also drops out of the flowing sewage at a velocity of <0.3 m/s: this is captured and could be reused on road surfaces (where it usually originates as road runoff in any case)

  Before the band screens were installed c1999, much coarser bar screens were used, which enabled much coarser waste to pass through. The band screens have "made a big difference to the river" (pers comm. Thames Water, 2012).

- **Primary treatment** removes settleable solids by sedimentation and skimming off scum. Beddington STW has eight circular primary sedimentation tanks: sewage is piped into the middle of these tanks from underneath, entering the tank through the centre and moving towards the edge. Residence time is around two hours, enabling finer solids to settle out. A bridge slowly rotates, scrapers scrape solids off the walls and bottom, and the conical base of the tank funnels solids down to a hopper in the middle.

  Raw sludge then goes to the sludge digestion process (an anaerobic process taking 15 to 20 days at 35 - 40ºC. The majority of organic material is broken down into biogas and the black secondary sludge is sent to the lagoons for dewatering after which it is spread on to land). At this point, with sludge removed, the effluent's BOD has been lowered by 40 – 50%.

- **Secondary treatment** deals with primary treated effluent, removing residual organics and sewage sludge. This part of the process decreases BOD and nitrate content in line with requirements to reduce BOD from 100 to 10 mg/l and ammonia from 30 to 2.5 mg/l.) At this stage 98% of the BOD requirement and ammonia are removed.

  Mixed with bacterially activated sludge, sewage enters 16 activated sludge settlement tanks (arrayed in four groups of four). Air is blown in through aeration blowers (installed c2007 to improve surface aeration) consisting of 52,000 bubble domes which last 8-10 years. This is the most expensive part of the treatment process, using around 60% of the STW's total energy requirement.

  For maximum microbial activity, solids levels are measured each day and kept constant. Approximately 5% of the solids are removed and pumped back to the beginning of the process, to be mixed with the incoming sewage. The activated sludge is settled out and pumped back in at the start of the secondary process to reseed sewage with bacteria. Denitrification takes place during the anoxic stage of this process: sewage enters at c30 mg/l ammonia as N, and N is reduced to c10-12mg/l.

  The final stage of secondary treatment is secondary settlement in circular tanks, similar to primary settlement but with a more conical shape optimised for settling sludge. The resulting effluent can be discharged without tertiary treatment as it meets all necessary standards and in the past was discharged at this stage. Currently, however, 50% goes on to tertiary treatment.

- **Tertiary treatment** is designed as a final screening process for 50% of the flow from the STW. The remaining 50% (or less if flow is reduced) goes straight out to the Wandle. Effluent is piped into the middle of a drum containing fine disc filters, which remove particles down to a few microns in size. Any solids are washed off the filters and returned to the primary settlement tanks, while the filtered effluent is piped out into the river.

- **Digested sludge** from secondary treatment is transferred to lagoons (3 at present) where the solids settle out leaving supernatant liquor on top. This liquor contains high levels of ammonia, and is returned to the front of the works for treatment. A sludge thickener was installed c2009 to reduce volumes of sludge by up to 50%. The sludge is pumped out of the lagoons and applied to the land in a leased area, or made into sludge cake in a clam press and dried on land.

  The lagoons are scheduled for decommissioning and replacement by a dewatering plant: the resulting sludge cakes will be used as farming fertiliser, with additional treatment to reduce pathogens to regulation levels.

- **Biogas** produced by the sludge digestion process (c65% methane) is used to fuel the plant. The digestion process can produce 10-12,000 m3 of gas per day for this purpose, which was historically converted to electricity via turbines in the control centre building

Control and monitoring

Until 21 August 2012, Beddington STW was run from the original 1960s control centre, which had been updated as necessary with equipment including a Scada control system. In 2012, the control centre was burned to the ground by a fire, resulting in the release of a large volume of partly treated sewage including the sludge caps from the secondary treatment tanks.

During construction of a new control centre, Beddington STW has been remotely controlled and monitored from Thames Water's Hogsmill STW.

Major pollution incidents

Despite improvements in general sewage treatment, Beddington STW has been the source of several very serious pollution incidents during the last four decades:

- **Summer 1969**: a discharge of partially digested sludge, which led to children's boating being banned in Ravensbury Park (Montague, 2005)

- **October 1995**: an extended discharge of untreated sewage, caused by cyanide illegally dumped into a factory drain, which entered the STW and disabled its biological processes for up to a week. As a result, the Wandle suffered a major fish kill.

- **September 2007**: a discharge of 1,600 litres of sodium hypochlorite bleach into the Wandle as a result of contractor's error at the end of a cleaning process on the STW's tertiary treatment disc filters. Up to 5km of the river were heavily affected, and at least c7,000 fish of all species were killed. (NB during the previous month, a still-untraced pollution incident had already killed large numbers of fish in the Mill Green area). An alternative cleaning procedure has been developed to prevent any such incident from recurring.

- **August 2012**: a discharge of partly treated sewage sludge resulting from a catastrophic fire in the STW's control centre. Despite emergency deployment of aeration equipment, several thousand fish of 11 species were killed.

- **January 2014 onwards**: as a result of high ground water entering the combined sewage system, the STW ran at storm capacity for several weeks, with all inflowing effluent being discharged untreated into the river. Due to high dilution and low temperatures, no fish kills were reported, but sewage fungus was noted in several areas, and invertebrates may have been adversely affected.

At least one additional pollution incident has also been narrowly averted:

- **February 2009**: during cold winter weather, the screw mechanism on the inlet penstock jammed it shut so that raw sewage was diverted into the storm tanks. Without the use of heavy machinery to lift the penstock by force, sewage would have started overflowing into the Wandle within hours. The penstock has now been refurbished with a constraints system and different materials, with frequent inspections to check proper functioning.

Mitigation measures

Given the domination of treated effluent below Beddington STW and the history of pollution incidents arising from the STW, total elimination of accidental pollution from this site is probably unrealistic.

However, in light of the damage which such incidents can inflict on this recovering river (including failure of WFD metrics), it would seem prudent to implement mitigation measures for the river. These could include:

- Installing an interceptor pipe linking Beddington STW to an existing main sewer to Crossness STW

- Investigating the feasibility of introducing large lagoons or wetland areas for effluent to traverse before entering the main channel of the Wandle

- Increasing the Wandle's resilience to catastrophic pollution incidents by means of river restoration, including creation of refugia for fish.

  In particular, it has been noted that basic river renaturalisation along the effluent channel at Mill Green would probably not slow down pollution appreciably, due to the velocity of treated effluent in this area. However, large online and back channel fish refugia may be beneficial where possible.

- Ensuring that the STW has a backup power supply controlled from a remote location.

5.8: Pollution sources and pathways

The urban nature of the Wandle's surrounding landscapes means that the river is at risk of pollution from a wide variety of sources.

Diffuse urban pollution has sometimes been described as "lots of point source pollutions", and it will eventually be necessary to identify, prioritise and tackle each of these individually. On the other hand, it is recognised that the Wandle's urban environment means that the river may always be subject to such pressures. It is therefore the Wandle Catchment Plan's overarching objective to make the river as resilient as possible when inevitable pollution incidents do occur, as well as identifying particular threats and working with all appropriate partners to mitigate them.

The following broad pollution types and pathways have been identified:

Type of pollution	Specific pollutant	Vector of transmission into the river	Sources & pathways
Nutrients	P	Treated sewage effluent	Beddington STW
		Untreated sewage, detergent, oil, fat etc	Misconnections into surface water drainage
		Animal waste	Ducks, geese, dumped dog waste
	N	Garden and park fertiliser	Runoff into surface water drainage

		Grass clippings / garden waste	Dumped into river or onto banks
		Bread	Duck feeding
		Animal waste	Ducks, geese, dumped dog waste
Urban runoff	Heavy metals		Road runoff into surface water drainage
	PAHs	Oil	Road runoff into surface water drainage
		Petrol / diesel	Road runoff into surface water drainage
		Tyre fragments	Road runoff into surface water drainage
	Winter road treatments	Sand	Road runoff into surface water drainage
		Salt	Road runoff into surface water drainage
		Sugar	Road runoff into surface water drainage
Point source specific	Untreated / semi-treated / raw sewage		Beddington STW
			Misconnections into surface water drainage
			Overflow from blocked sewer pipes
			Cracked sewer pipes near river
			CSOs
	Endocrine disrupters		Beddington STW
			Misconnections, sewage overflows, cracked pipes and CSOs
	Chemicals (incl industrial waste)	Various	Beddington STW
		Various	Factory spillages

		Various	Road accident spillages
		Various	Illegal dumping (gully pots or direct into river)
		Various	Leachate from contaminated land or landfill
		Various	Domestic disposal via misconnections
		Pesticides / herbicides	Used on riverside land
		Permethrin	Pet flea treatments (dogs in river)
	Petrol / diesel		Breached pipes or storage into surface water drainage
			Road accident spillages
			Vehicles illegally dumped into river
	Fire fighting water and foam		Runoff into urface water drainage
	Silt and sediments		Eroded from banks or mobilised within water column
			Building site washoff (surface water drainage or direct into river)
	Plastic microbeads (from eg exfoliating face and body washes)		Beddington STW
			Misconnections into surface water drainage
Fly tipped rubbish			Illegal dumping direct into river or onto banks
			Light litter (esp plastic bags) blown into river
Sediments	Heavy metals		Already in river
	PAHs		Already in river
	P		Already in river

	N		Already in river
Heat			Beddington STW
			Urban runoff
			Solar heat taken up during water residency in impoundments

Fig 5d: Pollution types and pathways impacting the River Wandle

Further information required

Full investigation into receptors and impacts of all types of pollution entering the River Wandle

5.8.1: Phosphorus

"We don't like the way the river sometimes smells of detergent, especially below the sewage works."

- from Ketso community and stakeholder workshops

Elemental phosphorus is extremely toxic to aquatic life, but phosphate (the most commonly appearing form) is generally damaging only at concentrations of parts per million or higher, for instance as a result of STW discharges. As such they exert a primarily indirect effect, for example by causing eutrophication with features including algal blooms.

When nutrients reach eutrophic levels in rivers, filamentous algae proliferates, blocking essential light from macrophytes like *Ranunculus*, which may also be outcompeted by *Potamogeton* (Spink, below).

Algae also increase dissolved oxygen (DO) levels by photosynthesising during daylight, while reversing this process at night, potentially reducing DO below fatal levels for fish. Toxins produced by specific algae are some of the most toxic known (Solbé, 1997).

For many years the EA has routinely taken monthly water samples on the Wandle at Beddington Park (Beddington branch) and Butter Hill (Carshalton branch) for nutrient analysis. Results of these samples are shown below (graphs supplied by the EA):

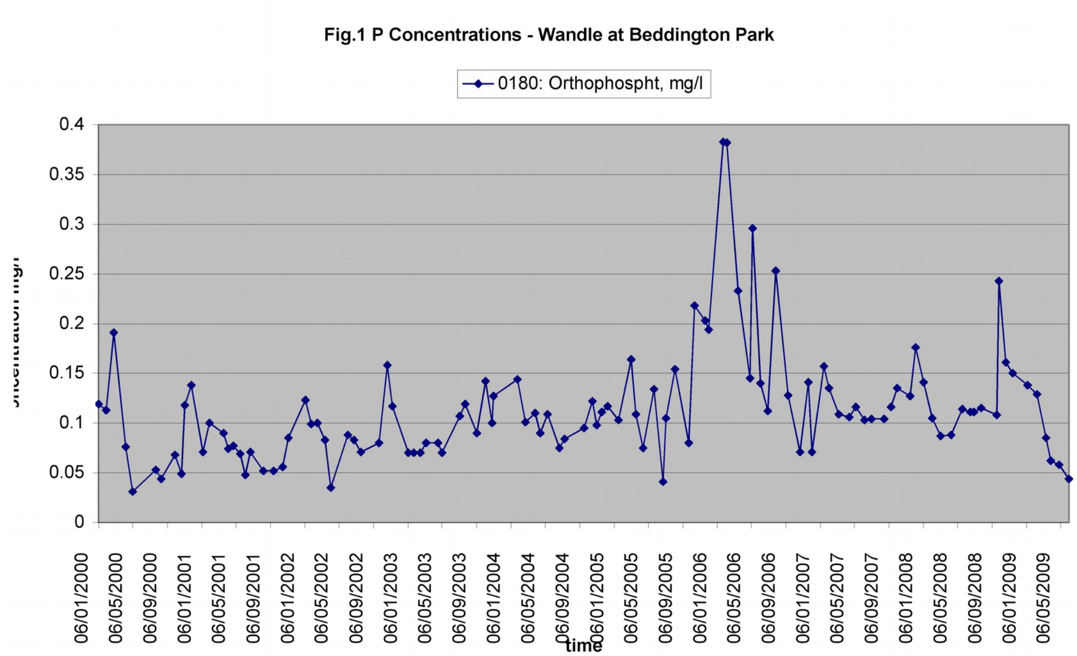

Fig 5f: Long-term results of P sampling on the Wandle at Beddington Park (Croydon arm) (source: EA)

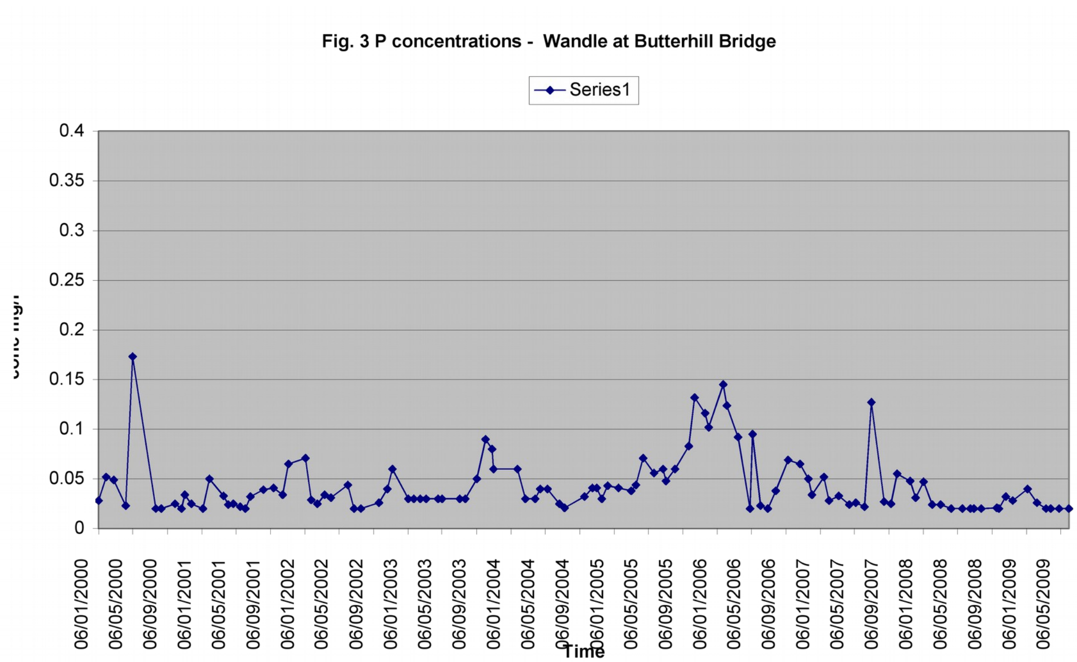

Fig 5g: Long-term results of P sampling on the Wandle at Butter Hill (Carshalton arm) (source: EA)

These graphs show a close correlation between the results from each of the Wandle's upper branches. This suggests either the same source of P over a wide area (eg shown in patterns of runoff) or higher concentrations of P in the Croydon arm which are mirrored but muted on the Carshalton arm, possibly as a result of recirculation through the low flow augmentation system.

P levels in the Wandle increase dramatically below Goat Bridge as a result of the input of treated effluent from Beddington STW. The Wandle is now included in the EA's calibrated SAGIS model, which confirms that approximately 91% of the P load at the bottom of the Wandle derives from Beddington STW (pers comm. Robert Kenway, EA, 2014). The Wandle has been designated a Phosphate Sensitive Area under the Urban Waste Water Treatment Directive, and Thames Water will be required to install phosphate stripping equipment at Beddington STW during AMP6, with completion due by November 2018 (pers comm. Angela Gorman, EA, 2014).

Expert observational experience has found that c1mg/l is often a tipping point between systems supporting *Ranunculus* and *Cladophora* filamentous algae, with algae preferring the higher concentration, leading to *Ranunculus* being replaced. The presence of *Cladophora* is indicative of elevated nutrient concentrations, and CB communities can be compromised by poor water quality, depleted flows and other effects of urbanisation.

P stripping at Beddington STW may not be the only solution to reducing P levels in the Wandle. To enable P stripping benefits to be realised, naturalisation of the river and its hydromorphology will help to restore natural processes, moving P-laden silt out of the system.

In order to achieve Good status for WFD purposes, P is required to be <0.1mg/l (equivalent to chalkstream reference conditions). P levels have not been defined for GEP on HMWBs like the Wandle: however in expert discussion with the EA, it has been suggested that if P levels can be reduced to 1mg/l, and the river's hydromorphology is improved to help CB communities and flush sediment-bound P out of the system, this could represent a definition of GEP for an urban chalkstream.

<u>Further information required</u>

Further investigation to establish sources of P in the upper Wandle

<u>Further reading:</u>

Spink, *Effects of Eutrophication on Ranunculus and Potamogeton*:
http://www.andrewspink.nl/ranunculus/wrec.htm

5.8.2: Nitrogen

"Too many people feed whole loaves of bread to the ducks, which just sinks to the bottom and rots. Others let their dogs mess on the banks and don't clear it up. These things aren't good for the river."

- from Ketso community and stakeholder workshops

Like phosphorus, nitrogen in nitrate form can contribute to eutrophication, but has no measurable toxicity per se at any realistic concentrations that are likely on the Wandle. In alkaline chalk stream waters, however, nitrate (NO_3) can reduce to nitrite (NO_4): this induces anaemia in fish, and is therefore highly toxic to all fish species. Sources of nitrite can also include ammonia (NH_3) from STWs, which is oxidised first to NO_2 by the bacterium *Nitrosomonas* and finally to NO_3 by *Nitrobacter* (Solbé, 1997).

Routine monthly water sampling by the EA has provided the following nutrient analysis for nitrates in the Wandle. As for phosphates (above) these graphs have been supplied by the EA:

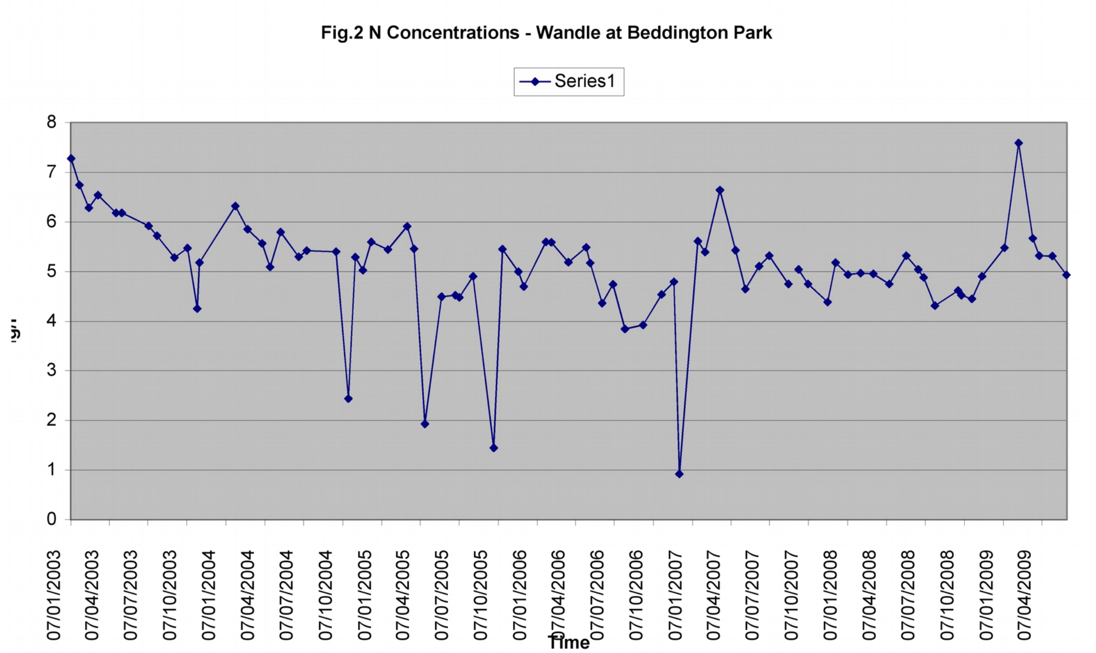

Fig 5h: Long-term results of N sampling on the Wandle at Beddington Park (Croydon arm) (source: EA)

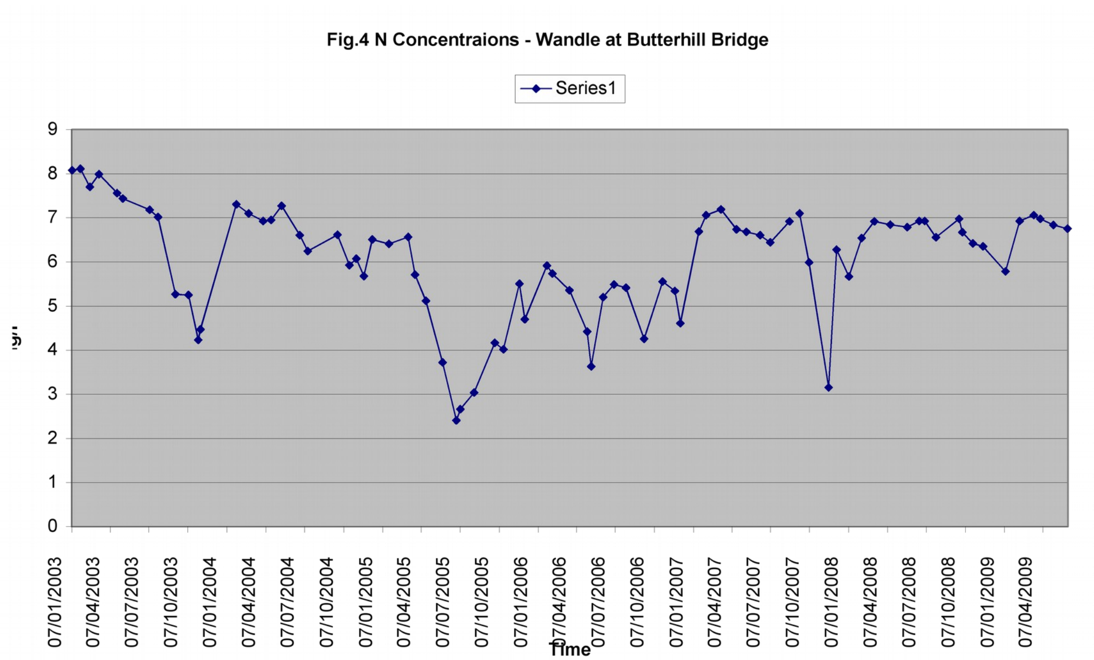

Fig 5i: Long-term results of N sampling on the Wandle at Butter Hill (Carshalton arm) (source: EA)

Assessment of these results suggests clear seasonality in terms of N, with particularly dramatic variations on the Croydon arm of the upper river. Lower N in October on the Carshalton arm may suggest the effects of the augmentation system.

Further information required

Further investigation to establish sources of N in the upper Wandle

5.8.3: Urban runoff

"The Wandle shouldn't turn black every time it rains in Croydon. We want to see more measures to stop dirty water getting into the river in the first place."

- from Ketso community and stakeholder workshops

The highly urbanised nature of the Wandle's catchment, especially in the vicinity of its surface waters, means that the river is at permanent risk of pollution by urban runoff: a cocktail of pollutants including heavy metals, polycyclic aromatic hydrocarbons (PAHs: oil, petrol and tyre fragments) and winter road treatments.

Polluted water can also enter the river from the sewer network, either from overflows during periods of high rainfall, or at source, where misconnections occur due to the foul water system being mistakenly connected to surface water drainage.

Modern urban planning now champions source control as the most sustainable route to mitigating urban runoff, ideally by identifying pollution sources and addressing runoff as close as possible to the point of precipitation – for instance, by installing SuDS (see Section 6.2). As such, this is also a means of minimising flood risk, which is often elevated in urban areas.

Depending on rainfall, road runoff into the Wandle during winter months is likely to contain high concentrations of salt, which together with sand makes up the components of de-icing road grit. High levels of chloride discharged into freshwater bodies may be harmful to fish and other aquatic organisms which are not adapted to living in saline environments. Nutrient levels (and hence de-oxygenation due to BOD) may also be increased by novel de-icing techniques such as adding molasses to road grit in order to prolong its adhesion to the road surface.

Further discussion of heavy metals and other contaminants in urban runoff, and thus in sediments, appears below.

5.8.4: Point source specific pollution

The almost entirely urbanised nature of the fluvial Wandle's landscape means that most of its course is vulnerable to occasional or one-off point source pollution.

Some point sources of pollution have already been identified as major (if intermittent) risks to the river's health: for instance Beddington STW and unmapped misconnections into the River Graveney, which in turn flows into the Wandle near Plough Lane. Point source pollutions resulting from misconnections are being progressively identified by organisations like the Wandle Trust, and addressed via liaison with Thames Water and the EA.

Since 2013 the Wandle Trust has also been running a Pollution Assessment Volunteers' scheme in partnership with the EA. This scheme enables trained local volunteers to assess Category 3 minor pollution incidents reported to the EA, enabling faster and more efficient response, and potentially more effective follow-up by EA pollution prevention teams. The network of volunteers will also enable efficient monitoring of more serious incidents (Wandle Trust, 2014).

5.8.5: Fly tipped rubbish

"We don't like seeing the river being used as a rubbish dump. We want to see the Wandle Trust's community cleanups continue, with more bins near the river, and campaigns asking people to take their rubbish home with them."

- from Ketso community and stakeholder workshops

Fly-tipping has long been recognised as a blight of urban rivers like the Wandle, and Ruskin specifically recorded domestic fly-tipping on the Carshalton water body in 1870 (see Section 5.6).

Although urban litter is highly unsightly and contributes to general public perception that the river is polluted and even lifeless, an ongoing loophole in the law means that this rubbish is no-one's responsibility to remove unless it threatens to cause a flood risk. In this case, it falls within the responsibility of the EA's FRM teams: in all other cases the usual interpretation of the law is that rubbish removal is left to community groups.

In 1982 the Beddington Society instigated annual Wandle cleanup days, which appear to have lapsed within a few years (Shew, 2012). Since the start of the 21st century, monthly community river cleanups, rotating through the Boroughs of Sutton, Merton and Wandsworth, and supported by each council, have been organised by the Wandle Trust.

These cleanups engage up to c70 local volunteers every month, providing them with the necessary equipment, confidence and health and safety support to increase their engagement with their local environment. Each cleanup removes c5.6m^3 of assorted rubbish from the river: notable items include motorbikes (many leaking oil and petrol), shopping trolleys, bicycles, traffic cones, car tyres and other parts including discarded batteries, domestic furniture and appliances, demolition and builders' waste, plastic bags, drinks cans and bottles, and even handguns (pers comm. Wandle Trust, 2014).

Blackspots for rubbish dumping appear to be bridges and other locations where road access to the river is easy but secluded: from these points the rubbish is swept downstream by peak flows, collecting in pools or at pinch points, and accumulating other debris and silt around it. As plastic drinks bottles and other items break down, they release toxins, so removing this litter promotes water and substrate quality for beneficial macrophytes such as *Ranunculus*, which in turn will improve habitat for all species.

Particularly in the highly engineered channels of the middle and lower Wandle, it has been noted that fish use heavy rubbish as shelter and habitat, and there are concerns that removing this rubbish results in loss of habitat in otherwise featureless areas. Current consensus is that removing heavy rubbish and the lighter litter that collects around it should be prioritised in order to improve public perception of the river, thus reducing fly-tipping and pollution in the long term (pers comm. Wandle Trust, 2014: cf Broken Windows Theory). However, the Wandle Trust has noted the urgent need to devise some means of replacing c67m3 per annum of unconsented rubbish with consented, well-designed and properly–secured habitat structures to help fish of all species to survive in highly channelised reaches of the Wandle (pers comm. Wandle Trust, 2014).

<u>Further information required:</u>

Research into habitat structures to provide fish habitat in highly channelised urban river reaches

Further reading:

Gallay (2013) *A Broken Windows Theory for Environmentalism*:
http://www.huffingtonpost.com/paul-gallay/a-broken-windows-theory-f_b_4497904.html

Wilson and Kelling, *Broken Windows*: http://www.manhattan-institute.org/pdf/_atlantic_monthly-broken_windows.pdf

Wandle Trust: monthly community river cleanup blog reports at www.wandletrust.org

5.8.6: Sediments: metals

"Twenty years ago you could wade across the river to Wilderness Island on clean gravel. Now you'd be waist deep in silt with a metallic, chemical smell."

- from Ketso community and stakeholder workshops

A notable impact of urbanisation on many rivers is the accumulation of fine-particulate sediment (sometimes termed "road dust") deposited in the river channel by urban runoff. Highly modified urban rivers like the Wandle can act as sediment sinks, collecting contaminated sediment in very large volumes behind impounding structures like weirs where normal sediment transport is inhibited.

Apart from the smothering effect that even clean sediments can have on river gravels (pers comm. Paul Gaskell, 2014) road dust contains elevated concentrations of sediment-bound contaminants including heavy metals and polycyclic aromatic hydrocarbons (PAHs) which may have serious impacts on fish and macroinvertebrates. Stormwater flushes fine grain sizes from road surfaces more efficiently than coarser grain sizes (Droppo et al., 1998 cited by Brierley, 2013) which tend to be left on the road. These easily-transported fine sediments (<63µm) contain higher trace metal and PAH concentrations (Horowitz, 1991 cited by Brierley, 2013), which may then remain in urban rivers for prolonged periods of time, leading to almost indefinite water quality problems.

In 2013 an MSc study investigated fine grain sediments and contaminant sources on the Carshalton water body, which has provided an excellent baseline analysis for further research (Brierley, Wandle Trust, 2013: *The characterisation and quality appraisal of riverbed and road runoff sediments within the Carshalton arm of the River Wandle, London, UK*). A summary of the paper's findings on heavy metals appears below:

Metal	Lowest Effect Level (LEL)	Severe Effect Level (SEL)	Butter Hill	Mill Lane	Denmark Road	Upstream
Cd	0.6	10	0.94	0.76	0.46	0.89
Cu	16	110	126.59	84.52	76.83	73.23
K	N/a	N/a	2040.14	1830.14	1803.21	1587.77
Mg	N/a	N/a	3154.39	2728.43	2194.27	1736.05

Mn	460	1100	152.91	131.00	163.51	81.40
Na	N/a	N/a	804.55	646.42	742.12	706.92
Ni	16	75	20.25	16.70	16.17	18.81
Pb	31	250	144.32	106.47	134.39	101.57
Sr	N/a	N/a	96.02	78.03	134.39	78.48
Zn	120	820	285.33	247.10	196.08	158.55

Fig 5j: Mean metal concentrations in river sediments (mg/kg) in each sub reach of the Carshalton water body compared to the Canadian Provincial Sediment Quality Guidelines (PSQGs) for Lowest Effect Level and Severe Effect Levels of trace metals on freshwater biota. Metal concentrations exceeding Lowest Effect Level are highlighted in yellow, and those exceeding Severe Effect Levels are highlighted in red (Brierley, 2013)

Metal	Min	Max	STD	%CV
Cd	0.12	2.15	0.41	58.02
Cu	20.5	388.68	60.51	64.52
K	614.88	4879.87	739.05	39.42
Mg	771.71	9741.46	1413.13	54.23
Mn	53.37	791.84	99.68	66.64
Na	207.93	2879.9	440.37	59.68
Ni	8.54	50.27	6.62	37.52
Pb	5.23	461.91	74.65	57.41
Sr	32.01	206.16	26.4	32.09
Zn	66.26	920.76	141.29	60.41

Fig 5k: Minimum and maximum mg/kg concentrations within the entire study site on the Carshalton water body as well as standard deviation (SD) and CV (%) values. Metal concentrations exceeding Lowest Effect Level are highlighted in yellow, and those exceeding Severe Effect Levels are highlighted in red (Brierley, 2013)

Sources and effects of heavy metals include:

- Pb: until the 1970s, petrol was a primary source of lead pollution. Today, petrol rarely contains lead, but it is still commonly found in paper, plastics and ceramics (Callander and Rice, 2000 cited by Brierley 2013). In sediment, Pb and Cd concentrations can be transformed into organo-metallic compounds, which enhances their bioavailability and toxicity even at low levels (Sutherland, 2000; Nicolau et al., 2006; Wong et al., 2006 cited by Brierley, 2013).

- Zn: environmental concentrations of Zn are greater than Pb within urban catchments, because Zn is used in a wide range of metal works, including tyre manufacture and steel galvanization (Callander and Rice, 2000 cited by Brierley, 2013). Although Zn is a biologically essential element, it may cause toxic effects at elevated levels.

- Ni, Sr, Cr and Mn are commonly derived from automobile parts. They often accumulate on roads and car parks, and are flushed into rivers by rainfall.

Because of the impact of heavy metals on water quality and fish, the study also notes a variety of surface water implications for WFD purposes. Al and Fe have been designated as specific pollutants in England and Wales, and Surface water Environmental Quality Standards (EQS) have been set forward for both to meet the requirements of the WFD:

- Fe: in 2007 new EQSs were proposed by the UK Technical Advisory Board (TAB) on the WFD for Fe from the current dissolved Fe EQS from 1 mg/l to 0.016 mg/l (EA, 2007). However, a UK TAG report for further EQS for specific pollutants in April 2012 has yet to accept the proposed Fe EQS from 2007. The EA still refers to the previously existing Fe EQS of 1 mg/l as its current guideline for dissolved Fe (EA, 2012). This may have implications for the Carshalton water body's ability to reach GEP by 2015 or 2027. If the proposed UK TAG EQS is accepted for iron, it will have a significant impact on the Carshalton water body's ability to maintain Fe levels under the new EQS.

- Al: concentrations recorded in sediments in the Carshalton water body are one order of magnitude above the proposed UK TAG EQS of 0.005 mg/l. However, the UK TAG has not accepted any EQS proposals for Al, suggesting that more data is needed (EA, 2012). Currently there is still no surface water environmental quality standard for Al.

The presence of heavy metals may also have implications for the Wandle's WFD status in relation to fish:

- Fe: concentrations of Fe may be the most significant threat to fish in the Carshalton water body, since formations of Fe on biological surfaces can effect survival, reproduction, and behaviour of aquatic animals. At a neutral pH, ferric hydroxide can have toxic effects on fish eggs, as well as gills, where it impedes respiratory and immune functions (Vuori, 1995 cited by Brierley, 2013). Other studies show that even at low concentrations, Fe can have significant effects on hatching, fry and growth. The maximum Fe concentrations collected in surface water samples from the Wandle were taken at relatively high flows, and were still recorded at 0.12 mg/l, a level which has been found to negatively impact brown trout. If surface water samples had been collected during base flow conditions, it is likely that both Fe concentrations would have been higher (Brierley, 2013)

- Al: due to the high pH of the chalk-derived water in the Carshalton branch, which ranges from 7.68 to 7.81, Al toxicity is not thought to pose a significant threat to fish health.

Throughout the study site on the Carshalton water body, mean concentrations of Cd, Cu, Ni, Pb and Zn all exceeded the PSQGs lowest effect level. This means that the actual ecotoxicological effects become present, as the sediment exceeding LEL is considered marginally polluted (OME, 2008):

- Maximum concentrations of Cu, Pb and Zn all exceeded PSQG severe effect levels, indicating heavily contaminated sediments that could potentially eliminate most of the benthic organisms present (OME, 2008 cited by Brierley, 2013). This may limit the ability of the Carshalton water body to meet WFD ecological guidelines.

- Trout interact with riverbed sediment through the construction of redds, removing fine sediments in order to create an area of loose gravels which permits oxygen transfer to eggs. Egg survival within redds can be affected by oxygen-consuming metals like Cd and Pb, which were recorded above LEL in the Carshalton water body, as well as by deposition of fine sediments blocking egg pores.

- Fish of all species also disturb and re-suspend sediments and their contaminants through foraging activity, allowing contaminants to be absorbed and stored in tissue (Gao, 2001 cited by Brierley, 2013). Metal concentrations typically enter the food chain through uptake by invertebrates, which are then consumed by fish (Brierley, 2013). Heavy metal concentrations within sediment are likely to result in high concentrations in fish tissue, with heavy metal concentrations within fish tissue at higher levels than those found in the general water column (Yi et al, 2008 cited by Brierley, 2013).

On the other hand, this study found lower concentrations of dissolved metals, such as Cu, Pb, Cd and Zn, within surface water samples compared to water samples analysed in 1995 when the BP site on Mill Lane was being decommissioned. This may indicate that water quality in the Carshalton branch has improved since 1995: a position also suggested by the EA River Basin Management Plan (2009) in which Cu and Zn received 'High' statuses due to the concentrations measured.

As a result of this study, the following recommendations were made:

- Hydrodynamic vortex silt traps should be installed on 3 key stormwater outflows on the Carshalton arm, and monitored to determine whether contaminants are being successfully intercepted. These silt traps were installed by the Wandle Trust in summer 2013.

- Continued monitoring of the health and abundance of invertebrates will also assist ongoing understanding of the impact of metals on the Carshalton water body

- Continued river restoration including channel narrowing, introduction of new gravels, and planting marginal vegetation, will increase water depth, flow diversity and velocity, promoting scour and removal of fine sediments.

- A programme of street sweeping within the Carshalton water body's surface water catchment would reduce the amount of transportable sediments being flushed into the river. Research has shown that brush street sweepers remove a larger amount of coarser grained sediment, while vacuum street cleaners are most efficient at removing the fine grained fractions which generally have the highest loading of contaminants (Pitt and Clark, 2003; Brinkmann and Tobin, 2003 cited by Brierley, 2013).

It has been noted that large online impoundments like Carshalton Ponds and Beddington Park Lake may act as sediment traps – to the benefit of lower reaches of the river. If such online impoundments are taken offline, consideration should be given to alternative means of trapping contaminated sediments on their downstream journey.

<u>Further information required</u>

Extend investigation into metals from the Carshalton water body to the Croydon-Wandsworth water body

<u>Further reading:</u>

Brierley (2013) *The characterisation and quality appraisal of riverbed and road runoff sediments within the Carshalton arm of the River Wandle, London, UK*

Solbé (1997) *Water Quality for Salmon and Trout*

5.8.7: Sediments: PAHs

Polycyclic aromatic hydrocarbons (PAHs) are produced by incomplete combustion of fossil fuels like petrol, diesel and coal.

Due to high concentrations and widespread availability within the environment, as well as their carcinogenic and mutagenic properties, PAHs have become a major concern in the context of restoring urban rivers. In the course of the investigation into heavy metals in the Carshalton water body (Brierley, 2013) described above, PAHs were also studied.

Like metals, PAHs bind easily to fine sediments, and are known to have adverse effects on biological organisms in fresh water. PAHs are non-volatile, hydrophobic and bind easily with bed sediment, thus removing themselves from the water column: as a result, they are readily absorbed by fish and invertebrates as a result of exposure to contaminated food and sediments. They become toxic at high concentrations, and have the potential to impact fish reproduction and egg development (Tuvikene, 1995 cited by Brierley, 2013). By physical interactions with cells, they can also lead to mutations, teratogenesis and cancer. To varying extents, however, fish are able to mitigate dangerous bioaccumulation within tissue by metabolising PAHs.

The 2013 study showed that the Carshalton water body's substrate is severely contaminated by PAHs:

	Lowest Effect Level	Severe Effect Level	Butter Hill	Mill Lane	Denmark Road	Upstream
Acenaphthene	6.71	88.9	227.81	446.35	211.12	138.07
Acenaphthylene	5.87	128.2	140.76	272.45	127.7	114.03
Anthracene	46.9	245	681.4	1368	720.82	518.67
Benzo(a)anthracene	31.7	385	3310.9	6852.5	3480	2910
Benzo(a)pyrene	31.9	782	3793.4	6852.5	4064	3360
Benzo(b)fluoranthene		N/A	5688	9382.5	5005	4586.67
Benzo(ghi)perylene	240^	13400^	2891	4907.5	2757.1	2260
Benzo(k)fluoranthene	170^	3200^	2008.9	3601.88	2208.5	1568.33
Chrysene	57.1	862	3542.2	6763.75	4115	2950
Coronene		N/A	717.5	1013.38	476.74	579
Dibenzo(ah)anthracene	6.22	135	773.8	1310.13	626.7	662
Fluoranthene	111	2355	7498	14832.5	8006	6500
Fluorene	21.2	144	257	595.13	270.3	189.33
Indeno(1,2, 3-cd)pyrene N/A	3669	6750		3547.4	3330	
Naphthalene	34.6	391	208.17	405.25	334.7	268.33
Phenanthrene	41.9	515	3014.2	6370	3182	2405.33
Pyrene	53	875	6109.45	12416.25	6659	5333.33

Fig 5l: Mean PAH concentrations in river sediments (µg/kg) in each zone WRS compared to the Canadian Sediment Quality Guidelines (CSQGs) and Ontario Sediment Guidelines (^) for Lowest Effect Levels and Severe Effect Levels of PAHs on freshwater biota. PAH concentrations exceeding Lowest Effect Level are highlighted in yellow, and those exceeding Severe Effect Levels are highlighted in red.

PAH	Mean	Min	Max	STD	%CV
Acenaphthene	275.73	61.2	1220*	218.7	79.32
Acenaphthylene	169.35	35.3	541	111.23	65.68
Anthracene	851.34	144	3450*	625.36	73.46
Benzo(a)anthracene	4122.78	609	9910*	2344.51	56.87
Benzo(a)pyrene	4662.31	724	11600*	2589.53	55.54
Benzo(b)fluoranthene	6335	1050	17700	3735.58	58.97
Benzo(ghi)perylene	3337.53	610	8910	1935.61	58
Benzo(k)fluoranthene	2479.19	419	6790	1454.16	58.65
Chrysene	4516.63	672	11100**	2547.98	56.41
Coronene	693.01	90.4	2170	497.74	71.82
Dibenzo(ah)anthracene	853.13	168	2300*	545.12	63.9
Fluoranthene	9487.5	1450	24000*	5456.51	57.51
Fluorene	345.34	88	1850*	311.51	90.2
Indeno(1,2,3-cd)pyrene	4402.63	690	10900	2758.51	62.66
Naphthalene	307.37	45.6	718	175.96	57.25
Phenanthrene	3892.75	562	14400**	2790.23	71.68
Pyrene	7871.08	74.5	20500**	4682.09	59.48

Fig 5m: Table showing minimum and maximum ug/kg concentrations within the entire study site, as well as standard deviation (SD) and CV (%) values. PAH concentrations exceeding Lowest Effect Level are highlighted in yellow, and those exceeding Severe Effect Levels are highlighted in red.

**Indicates the order of magnitude above Severe Effect Level*

These results confirm that the Carshalton water body is heavily contaminated with PAHs, probably largely derived from combustion, and deposited through road runoff. The study's recommendations for mitigating PAHs are the same as for silt: hydrodynamic vortex silt traps, continued invertebrate monitoring and river restoration, and street sweeping across the Carshalton water body's surface water catchment.

<u>Further information required</u>

Investigation into PAHs on the Croydon-Wandsworth water body

<u>Further reading:</u>

Brierley (2013) *The characterisation and quality appraisal of riverbed and road runoff sediments within the Carshalton arm of the River Wandle, London, UK*

Solbé (1997) *Water Quality for Salmon and Trout*

5.8.8: Thermal impacts

As discussed in Section 5.3, the Wandle's naturally constant (and relatively low) spring-fed water temperature is subject to thermal loading from several sources.

Now that Croydon's power stations are no longer discharging heated cooling water into the Wandle via channels across Beddington farmlands, the most significant thermal input is probably Beddington STW, which adds an average 2.6°C to the temperature of the river between Goat Bridge and Watermeads. Thermal loading is also likely to take place in slow-flowing water which is exposed to the sun for long periods, for instance when ponded behind weirs and other obstructions in summer low flow conditions. On the Wandle, several impoundments retain large volumes of water over substrates dominated by silt and road dust particulates (which are dark and therefore likely to absorb solar heat more readily) at Carshalton Ponds, Beddington Park Lake, Goat Bridge, Watermeads, Ravensbury Park and Morden Hall Park.

Intermittent flushes of thermally-loaded water may also be caused by summer storms, when high volumes of precipitation fall on sun-heated surfaces and flash off into the river. Such runoff typically has very low dissolved oxygen content and may result in fish kills.

In urban conurbations, the urban heat island effect often results in air temperatures several degrees warmer than surrounding rural areas. Although the Wandle is likely to provide local mitigation of London's heat island local people, the river will also be subject to its influence, since surface water temperatures reflect air temperatures.

With regard to the biotic impact of heat loading, different organisms have different thermal preferences and optimal ranges, and the Wandle may experience subtle ecological shifts due to these preferences. Higher temperatures can cause pollutants to have greater effects, in particular increasing the toxicity of metals and ammonia.

Although some experts recommend reducing shading on many reaches of the Wandle in order to promote growth of valuable aquatic macrophytes like *Ranunculus*, this recommendation probably needs to be balanced against the shading benefits offered by riparian trees, which is likely to help mitigate solar heating in summer months. Considerable investigation by the river restoration community is still required to define the effects of shading on small river channels – and particularly with regard to chalk streams where aquatic plants form an important component of the total ecosystem. However at this stage it is thought likely that the generally-accepted optimum 60:40% light:shade ratio will offer the widest range of benefits.

<u>Further information required:</u>

Research to confirm water temperatures and impacts of impoundments etc year round on the full length of the river

<u>Further reading:</u>

Solbé (1997) *Water Quality for Salmon and Trout*

5.8.9: Light

"We'd like to see better lighting to make some parts of the Wandle Trail feel safer at night, but it shouldn't disturb the bats and other wildlife."

- from Ketso community and stakeholder workshops

Light pollution, which is defined as brightening of the night sky caused by anthropogenic artificial light, has increased dramatically over the last century. This artificial light derives from floodlights and building illumination, security lamps, advertising and display lighting, car headlamps, and reflection from roads, pavements and buildings. However, the single largest source of light pollution is street lighting (Royal Commission on Environmental Pollution, 2009).

Light pollution has been noted to cause ecological disruption: bird migrations can be affected, and insects are attracted to light. Changes to plant life history, including flowering and leaf fall, have also been observed. These effects are most noticeable in urban environments, where artificial light sources are concentrated, and it is thought that they may be particularly pronounced in London.

Different street lights have different spectral compositions. The most numerous low-pressure sodium lamps emit light that is concentrated in the longer wavelengths of the visible spectrum, appearing yellow or orange to the eye. Millions of these are now scheduled for replacement with a new generation of shorter wavelength lamps, which shed a brighter, whiter light across a fuller spectrum, and could precipitate significant changes in impact on natural systems (Rich and Longcore, 2006).

Recent research shows that white light pollution can severely affect fish behaviour. Synchronous emergence and dispersal of swim-up salmonid fry from gravel, and downstream migrations of smolts, occur at night. These timings are generally accepted to be predator avoidance strategies, so any alteration or disruption to these processes may increase rates of predation and affect recruitment (pers comm. CEFAS, 2012).

Preliminary results from a CEFAS study based on the River Itchen in 2012 showed that:

- Without light pollution from street lighting, mean fry dispersal took place around 4.17 hours after dusk, with less than 2% dispersing in hours of daylight

- When street lighting was present, mean fry dispersal was delayed by at least 2 hours, to 6.38 hours after dusk, with 32% of fry now dispersing in daylight hours

- In incubators exposed to street lighting, fry emergence was delayed until 2.8 days later, while these fry were smaller than those in control conditions without light pollution

These results suggest that salmonids can be severely affected by the presence of white light pollution at a critical stage of population recruitment. It has also been noted that although modern street lamp designs are often deliberately angled to limit the levels of light cast upwards into the night sky, and are instead angled downwards to illuminate footpaths, car parks and other areas, this may often result in brighter light pollution sources shining directly into adjacent urban rivers Artificially enhanced light levels are also likely to facilitate heavier predation on fish of all species at other life stages (pers comm. Wandle Trust, 2014).

Further information required

Research to determine the effect of different wavelengths of artificial light on all life stages of all fish species

5.8.10: Water quality action tables

The information in these tables has been assembled from suggestions made in community consultations, TAG meetings and specific stakeholder input to develop a series of Objectives, Targets and Actions. Information on existing projects has been collated and used to identify gaps, and where additional projects may need to be developed to fulfil Actions, Targets and Objectives.

Actions to achieve the Catchment Plan's overall aim for water: Water is plentiful and clean, and varied in its flow speeds, widths and depths

Objective 2: *Water quality:* quality of water flowing in the River Wandle meets the standards required for Good Ecological Potential and is stable with no risk of deterioration				
Specific Actions to attain GEP				
Target	**Actions**	**Project**	**MM**	**Indicative cost to deliver these Actions**
2.1: Identify the current chemistry of the River Wandle and a set of parameters to achieve as an 'ideal' for GEP Carshalton WB by 2015 Croydon-Wandsworth WB by 2027	2.1.1 – Draw together existing monitoring data to understand the current 'supporting elements' (physico-chemical) classifications more fully.	None	N/A	The TAG is fulfilling this Target, with input from the Steering Group as appropriate. Both the Steering Group and TAG have demonstrated a commitment to remain constituted and complete the implementation of these Actions. Costs will be incurred in undertaking this research, even if it largely desk-based.
	2.1.2 – Identify the certainty of each 'supporting element' classification, the methodology used to ascribe each classification and whether this is a robust approach.	None	N/A	
	2.1.3 – Identify suitable response measures for any chemical parameters that may fail WFD in the future and the associated costs of implementing such measures.	None	N/A	
	2.1.4 – Set up a monitoring programme to assess chemical status for GEP and whether measures implemented to improve and maintain good quality are successful.	(A1 – support this Action but does not wholly deliver the Action)	N/A	Time and expertise will be required. Training partners to help with monitoring will also incur an expense.

2.2: The impact of diffuse pollution entering the river from urban surface runoff is minimised Carshalton WB by 2015 Croydon-Wandsworth WB by 2027	2.2.1 – Identify existing pollutant pathways and threats to surface water quality.	A2, B3, B12	N/A	The TAG is fulfilling this Target, with input from the Steering Group as appropriate. Both the Steering Group and TAG have demonstrated a commitment to remain constituted and complete the implementation of these Actions. Independent work to undertake walkover surveys and associated investigations, eg dye tracing, mapping and consultations is **estimated to cost £35,000**.
	2.2.2 – Surface water flooding is also associated with diffuse pollution from urban runoff. Therefore, identify the main pollutants involved (such as heavy metals and particulates from vehicle exhausts and tyre wear) and which water sensitive urban designs might best prevent them from being washed into the river in heavy rainfall conditions, including silt traps at surface water outfalls.	B12, C1, C2	9	Independent analysis of Water Sensitive Urban Design techniques for the whole catchment, including the suitability and cost-implications of various SuDS measures to help replicate natural drainage patterns is **estimated to cost £100,000**. The cost for installing SuDS and other measures to help replicate natural flow patterns varies considerably, depending on the location, ease of access, flood risk implications, ease of installation and maintenance, and whether such work can be incorporated into new developments or has to be retro-fitted. For example, **porous and permeable paving can cost between £100 per 20m^2 driveway** (to purchase and install gravel) and **£2000** to purchase and install Concrete Block Permeable Paving for the same area.

	2.2.3 – Identify and obtain funding sources for installation of pollutant interception measures	C1	9, 10	The cost of installing micro-wetlands is highly dependent on a number of factors, notably land prices. An **indicative cost, based on a location in Hackbridge, LB Sutton, is estimated at £20,000 per acre to install, plus monthly management costs and health and safety considerations such as fencing** Estimations of cost for the whole river would be dependent on walkover surveys and detailed feasibility studies drawing on the local authorities Surface Water Management Plans. Design and installation of silt traps being retrofitted in an urban environment is **estimated to cost £40,000** (small), **£50,000** (medium) and **£60,000** (large).
2.3: Domestic and industrial plumbing do not cause pollution in the river Carshalton WB by 2015	2.3.1 – Survey for sewage fungus at outfalls into river (as an indicator of misconnected plumbing)	A2	10	These Actions are likely to be fulfilled by Thames Water, the EA and Wandle Pollution Assessment Volunteers. This could be delivered by maintaining and extending the existing Wandle Pollution Assessment Volunteer project. It would need support from landowners and managers (eg for access to land). **Estimated cost to run approx £8,000/pa**.
	2.3.2 – Inform and educate the local community including businesses within the catchment to identify pollution hotspots and behaviour which may lead to pollution.	A2	10	

Croydon-Wandsworth WB by 2027	2.3.3 – Using examples from elsewhere in the UK and overseas, undertake a programme of education and awareness-raising to promote correct installation of domestic and industrial plumbing (eg the 'Yellow Fish' campaign initiated in Canada and replicated around the world which raises awareness of drains flowing to rivers and not putting potentially polluting substances down them; engaging local centres that run plumbing courses to show correct installations and retro-fitting, and appropriate disposal of toxic substances).	None	10	Thames Water and the EA will fulfil this Action in part at least. This Action could be assisted via an MSc student desk-based research project into applying best practice in the Wandle catchment, which would inform a funding bid or an awareness raising campaign. Voluntary co-operation campaigns have been shown to be effective eg in Stockholm with mercury interception from dentists, and cadmium from paint.
2.4: Phosphate stripping is in place at Beddington STW to meet requirements for the Urban Waste Water Treatment Directive Carshalton WB N/A Croydon-Wandsworth WB by 2027	2.4.1 – Thames Water to submit plans to Ofwat as part of their AMP6 and business planning procedures in 2014, which would then make implementation likely between years 3 and 5 (2018-2020).	None	N/A	This Target and Action are being fulfilled by Thames Water's ongoing preparation of their AMP6 Business Plan for submission to Ofwat in 2014. Liaison, additional financial outlay for further investigations and future recommendations for good practice working that maintain required treated effluent discharge quality will be led by Thames Water, the EA and Ofwat.

Wider Actions to improve the ecological functioning of the river				
Target	**Actions**	**Project**	**MM**	**Indicative cost to deliver these Actions**
2.5: The Wandle is free from fly-tipping and other rubbish, both in-stream and on the banks Carshalton WB by 2015 Croydon-Wandsworth WB by 2027	2.5.1 – An awareness-raising campaign is designed and undertaken throughout the catchment to explain the dangers and consequences of rubbish, and to deter this anti-social and ecologically damaging activity.	None	10	These Actions are being fulfilled by several organisations within the Wandle catchment, in particular the Wandle Trust in partnership with the local authorities. A monthly site-specific cleanup event, involving approximately 45 local volunteers each time, is **estimated to cost £1500 per event**. As well as enhancing water quality, this provides several added benefits of local community engagement, building social capital and sense of community empowerment, educating local stakeholders in key ecological issues, and engendering stewardship of the river. All these added benefits are likely to help prevent anti-social behaviour (such as fly-tipping and damage to natural habitats) in the future. Extended benefits could be generated via the ongoing partnership work already taking place in the catchment, such as the Wandle Forum and Wandle Valley Regional Park Trust.
	2.5.2 – Existing river cleanup volunteer workdays are maintained and expanded through secure funding streams, designated staff support and strengthened relationships with local authorities and community groups.	A4	10	
	2.5.3 – Develop and maintain relationships with a broad range of sectors within the Wandle catchment to identify future opportunities for developing initiatives to discourage fly-tipping and reward responsible waste disposal.	A4	10	
2.6: Groundwater inputs are protected from contamination	2.6.1 – Understand how groundwater behaves within the catchment and what factors affect its movement, quantity and quality (consider modelling to help).	None		These Actions are being fulfilled by the EA's ongoing National Environment Programme (NEP) investigations on both sources of the Wandle. Thames Water, which operates the largest and closest groundwater abstraction borehole to the Croydon / Beddington branch, reported early findings in 2013. Sutton & East Surrey Water operates boreholes near the Carshalton branch and is due to report its findings in 2015. Liaison, additional financial outlay for further investigations

	2.6.2 – Existing pollution pathways and threats to groundwater quality are identified, including the perceived severity of those threats and priorities for action.	None		and future recommendations for good practice working that maintain required flow and quality will be led by the EA, the water companies and Ofwat. The cost of installing micro-wetlands is highly dependent on a number of factors, notably land prices. An **indicative cost, based on a location in Hackbridge, LB Sutton, is estimated at £20,000 per acre to install, plus monthly management costs and health and safety considerations such as fencing.** Estimations of cost for the whole river would be dependent on walkover surveys and detailed feasibility studies drawing on the local authorities' Surface Water Management Plans.
	2.6.3 – Embark on an awareness-raising programme targeted at those groups identified as most likely to be posing a risk to groundwater contamination (probably commercial enterprises), educating them on the pressures and risks to groundwater quality, the impacts these can have on the ecological health of the river, and on ecosystem service benefits for people.	None		

	2.6.4 – Identify, and obtain funding for, measures to reduce pollutants entering groundwater systems (eg installing SuDS to help filter out pollution using natural processes).	None	9, 10	
	2.6.5 – Implement measures to reduce pollutants entering groundwater systems.	None	9, 10	
	2.6.6 – Instigate a monitoring programme to assess groundwater quality and whether measures implemented to improve and maintain good quality are successful.	None	N/A	
2.7: The contamination of surface water runoff is minimised.	2.7.1 – Embark on an awareness-raising programme regarding the pressures and risks to surface water quality (eg encouraging households not to use artificial fertilisers and pesticides in their gardens), educating them on the impacts these can have for the ecological health of the river and the ecosystem service benefits for people.	None	9, 10	These Actions are likely to be fulfilled by Thames Water and the EA in part at least, with support from the TAG and Steering Group as appropriate. Independent work to undertake walkover surveys and associated investigations, eg dye tracing, mapping and consultations is **estimated to cost £35,000**. Independent analysis of Water Sensitive Urban Design techniques for the whole catchment, including the suitability and cost-implications of various SuDS measures to help replicate natural drainage patterns is **estimated to cost £100,000**. The cost for installing SuDS and other measures to help replicate natural flow patterns varies considerably, depending on the location, ease of access, flood risk implications, ease of installation
	2.7.2 – Effective interception of contaminants may require addressing pollutants and their specific pathways into the river on an individual basis. Research measures that have been implemented successfully in other countries, and adopt / adapt these as appropriate.	None	9, 10	
	2.7.3 – Identify and obtain funding sources for installation of pollutant interception measures.	None	9, 10	

	2.7.4 – Investigate the impact of salt (for winter road gritting) on the osmoregulation of plants and animals.	None	9, 10	and maintenance, and whether such work can be incorporated into new developments or has to be retro-fitted. For example, **porous and permeable paving can cost between £100 per 20m^2 driveway** (to purchase and install gravel) and **£2000** to purchase and install Concrete Block Permeable Paving for the same area. The cost of installing micro-wetlands is highly dependent on a number of factors, notably land prices. An **indicative cost, based on a location in Hackbridge, LB Sutton, is estimated at £20,000 per acre to install, plus monthly management costs and health and safety considerations such as fencing.** Estimations of cost for the whole river would be dependent on walkover surveys and detailed feasibility studies drawing on the local authorities' Surface Water Management Plans. Design and installation of silt traps being retrofitted in an urban environment is **estimated to cost £40,000** (small), **£50,000** (medium) and **£60,000** (large).
2.8: Effluent outflow from Beddington STW is effectively managed and regulated to ensure no accidental discharges cause pollution incidents on the river	2.8.1 – Explore the possibilities of increased storm tank storage.	None	N/A	This Target will need to be led by the water companies and Ofwat working with the EA.
	2.8.2 – Investigate the possibility of diverting effluent to Crossness in times of emergency.	None	N/A	
	2.8.3 – Ensure there is always a backup power supply controlled from a separate location.	None	N/A	

SECTION 6: DYNAMICS OF FLOW AND HYDROMORPHOLOGY

"Our Vision is a river full of water that is plentiful and clean, and varied in its flow speeds, widths and depths"

Wandle Catchment Plan Objective 3: The river has a re-naturalised varied profile that creates a diversity of flow speeds and water quantity to provide all the key habitat types required by the native flora and fauna associated with lowland chalk streams"

6.1: Flood risk management

"Even in the 1980s the river bed was literally being flattened with bulldozers every winter for flood defence. Now we want to see the natural shape of the river restored, with riffles, bends, shallow bits and deep bits – which will actually help stop so much water rushing downstream to flood Earlsfield and Wandsworth!"

- from Ketso community and stakeholder workshops

Reducing the likelihood and incidence of floods, and their effects on local people, is an important aspect of catchment management. Climate change research suggests that the UK's winters may become wetter, and all weather events may become more intense. This suggests that the highly urbanised Wandle valley will need to find new solutions, including Sustainable Urban Drainage Schemes (SUDS), to mitigate the future effects of urbanisation and climate change.

Like most rivers across the Thames basin, the natural chalkstream hydrograph of the Wandle has been heavily modified over many years – not just for industrial purposes, but also for flood risk management (FRM) in an urban environment where infiltration is extensively compromised by roads, roofs and impermeably paved gardens.

Today, the river's remaining channels have all been radically simplified, often for the purposes of conveying the maximum volume of flood water to the Thames Tideway as rapidly as possible. Over the course of the catchment's evolution from rural to urban, most of the modifications made to the Wandle had industrial functions. As the mills declined, these structures were adapted or replaced by others, ostensibly for FRM purposes: a reduction in industry along the river has not been matched by a decline in hydromorphological modifications. Scientific understanding of the causes of flood risk has also improved. Consequently, many of the features once installed for FRM may now only be serving a redundant historical function which conflicts with robust modern science and the priorities of WFD catchment management, and may even be increasing the risk of flooding.

FRM has historically been seen by local people and authorities alike as an important ecosystem service provided by the river. In the context of climate change and the likelihood of more extreme weather events, the importance of FRM is only likely to increase: however it may also provide valuable opportunities to restore natural catchment processes including flood storage and infiltration.

Flood risk has two components:

- The chance (probability) of a particular flood
- The impact (consequence) of a flood if it happened: ie a product of the geographical extent and duration of the flood

Flood risk is often expressed in terms of the return period: for instance, a one-in-ten year flood would on average be expected to occur once in every ten years.

Flood risk is calculated on the likelihood of a flood of a given size occurring within a one year period: a 1% flood has a 1% chance or 0.01 probability of occurring in any one year.

In the Wandle catchment, flood risk may arise from the following separate but partially interconnected factors:

- Ground water: rising water in the river's aquifer and hyporheic zone (which also forms the river's natural baseflow)
- Surface water: including fluvial flooding and runoff from rainfall, exacerbated by hard surfaces across the catchment, causing flash flooding in vulnerable areas
- Combined urban drainage systems: if capacity is overwhelmed by heavy rainfall

In the Thames region, c135,000 properties currently have a more than 1% chance of flooding in any one year from rivers. London and the Lower Thames have the greatest number of people and property at risk.

According to the EA's Thames Catchment Flood Management Plan (CFMP), Merton has the highest flood risk of the four local authorities within the River Wandle's influence, with a 1% annual probability fluvial flood putting more than 5,000 properties at risk. Wandsworth, Sutton and Croydon have slightly lower risk levels, with between 2,000 and 5,000 properties each at risk (EA, 2009).

To tackle flood risk, the EA have divided the Thames CFMP region into 43 sub-areas, and applied one of six policy options for flood risk management in each sub-area, depending on the perceived level of flood risk. The River Wandle falls into sub-area 8 ("heavily populated floodplain") under policy number 5: "an area of moderate to high flood risk where (the EA) can generally take further action to reduce flood risk".

Under Section 21 of the Flood and Water Management Act 2010, lead local flood authorities are required to maintain a register of structures and features which are likely to have a significant effect on flood risk in their area.

The EA's current FRM regime for the Wandle focuses on risks from fluvial flooding since only limited data is available for flooding from other sources in the region. As such, the EA now requires that any surface water runoff from new development and re-development, especially within the floodplain, does not impact on flooding by increasing fluvial flood risk. Modern urban planning champions source control as the most sustainable route to mitigating urban runoff, ideally by identifying pollution sources and addressing runoff as close as possible to the point of precipitation – for instance, by installing SUDS (see Section 6.2). As such, this is also a means of minimising flood risk, which is often elevated in urban areas.

In addition to clearing rubbish screens (installed to prevent blockage of box culverts), part of the routine work of the EA also involves creation of flood storage schemes, sometimes incorporating existing permanent water bodies. One such opportunity exists in the Beddington Mitcham Area of Opportunity (BMAO) adjacent to Beddington STW, where additional flood storage is already provided via the flume installed on the Wandle at Beddington Park.

Alluvial gravels are currently being extracted in the BMAO, with permission for extraction originally granted by the GLC in 1985 on condition that rehabilitation plans eventually included re-landscaping for conservation, recreation and large-scale flood storage purposes. The Beddington flume already considerably reduces flood risk, resulting from precipitation and runoff from Croydon, in the Hackbridge area. The EA is working with Thames Water, LB Sutton and other interested parties to realise the potential of this site in the long term.

In addition to the Beddington Park flume, river levels on the Wandle are extensively controlled by tilting weirs at Beddington Park lake, Goat Bridge, Watermeads, Ravensbury Park and Merton Abbey Mills. These were installed in order to maintain historic water levels and manage the time-response of the river to heavy rainfall in different parts of the catchment, but may now be questioned on WFD grounds.

Future flood risk will be influenced by a range of factors, most notably changes in land use from urban growth, as well as climate change which is likely to increase both chance and impact of flooding. Using broad scale modelling, the EA have estimated that the number of properties at a 1% risk of flooding from rivers in the Thames CFMP area will increase by approximately 20% as a result of climate change. Milder, wetter winters resulting in increases in peak river flows will mean flooding will occur more often and large-scale flooding is more likely. More frequent, short duration, intense storms in summer will be likely to cause more widespread and regular surface water “flash flooding” from overwhelmed drainage systems, and in some cases rivers.

Fluvial flood risk in catchments like the Wandle is typically of short duration, with rapid rise and fall of river levels. The depth of the floodwater, speed and duration are not likely to be great but the lag period between the rainfall and a flood will be relatively short. This can mean that a flood can still be disruptive, depending on the time of occurrence.

Where removal of weirs on the Wandle is contemplated, detailed modelling will be the first step towards establishing impacts. Increasing evidence from practitioners engaged in catchment-scale restoration on other rivers now shows that increasing upstream flood storage, as well as restoring channel roughness and morphology throughout a river system, may also provide significant FRM benefits by delaying the arrival of peak fluvial flood flows at vulnerable pinch points like urban bridges. In turn, this approach implies major opportunities for restoring natural river processes whilst also obviating hard engineering solutions like tilting weirs and reducing catchment flood risk.

<u>Further information required</u>

Further investigation into feasibility of removing redundant structures

<u>Further reading:</u>

Environment Agency (2009) *Thames Catchment Flood Management Plan*

Local Councils’ Strategic Flood Risk Assessments

6.2: Sustainable Urban Drainage Schemes (SUDS)

“We want to see more imaginative solutions to droughts and floods in the Wandle Valley, including green roofs, grey water recycling, swales and rain gardens.”

- from Ketso community and stakeholder workshops

Sustainable urban drainage systems (SUDS) are drainage solutions that are designed to provide an alternative to channelling surface water directly into the nearest watercourse via pipes and sewers. By attempting to recreate natural ‘rainscapes’, SUDS aim to increase infiltration and flood storage capacity, reduce surface water flooding and urban runoff into nearby rivers, and enhance the environment for people and wildlife.

Provision for SUDS and the national standards required for their design, construction, maintenance and operation is included in the Flood and Water Management Act 2010.

The EA is generally supportive of installing SUDS to mitigate flood risk, subject to certain caveats. For instance, experience has indicated that many SUDS proposed by developers are effectively soakaways sited in very vulnerable and sensitive locations, such as where ground water is particularly shallow or close to water supply boreholes. As a result, the EA advises developers to refer to best practice SUDS guidance provided by CIRIA, and enter into discussions with the EA at the earliest possible opportunity.

Under the Flood and Water Management Act 2010, local drainage approving bodies (SABs) will be designated to take responsibility for approving SUDS within new developments. In most cases these SABs will be local councils, which will assess applications for SUDS under national standards set by Defra. The assessment process will involve consulting statutory consultees, including sewerage companies, highways authorities and the EA.

As a highly urbanised catchment subject to significant flood risk, the Wandle offers clear opportunities for management of surface water via SUDS: either by incorporating them into new developments *ab initio* or by retrofitting them into existing urban landscapes.

In 2012 a study summarising the potential for SUDS in Hackbridge found that local geology, depth to ground water and possibly contaminated land could affect the feasibility of direct infiltration systems. The likely predominance of clay soil could result in an infiltration system being largely ineffective, and the probability of contamination from previous industrial uses would make infiltration unsuitable (Wandle Trust, 2012).

As a result, this study recommended installing source control measures, with storage areas outside zones of main flood risk to attenuate runoff, to reduce the risk of flooding on site and slow the rate of runoff into the river:

- A number of 3m wide grass swales, and a generously-sized rain garden, would allow large volumes of water to be held on site (c5000m^3). These areas would also be used for amenity and provide opportunities for environmental gain

- Investigate potential measures, including large communal rainwater harvesting tanks, to provide capacity for reducing water consumption and providing additional surface water storage

- As a last resort, the SUDS would be linked into the main flood drainage paths to discharge water into the river after exceptionally heavy downpours

To maximise the impact of SUDS installation, opportunities were also identified for local communities' involvement in wise water use campaigns and helping to monitor the long-term effectiveness of the SUDS.

Further reading:

CIRIA SUDS Guidelines: available via http://www.susdrain.org/resources/ciria-guidance.html

The London Plan: available via http://www.london.gov.uk/priorities/planning/londonplan

Wandle Trust (2012) *Sensitive Water Management in Hackbridge, London*

6.3: Dynamics of flow action tables

The information in these tables has been assembled from suggestions made in community consultations, TAG meetings and specific stakeholder input to develop a series of Objectives, Targets and Actions. Information on existing projects has been collated and used to identify gaps, and where additional projects may need to be developed to fulfil Actions, Targets and Objectives.

Actions to achieve the Catchment Plan's overall aim for water: Water is plentiful and clean, and varied in its flow speeds, widths and depths

Objective 3: *Dynamics of flow*: the river has a re-naturalised varied profile that creates a diversity of flow speeds and water quantity to provide all the key habitat types required by the native flora and fauna associated with lowland chalk streams				
Specific Actions to attain GEP				
Target	**Actions**	**Project**	**MM**	**Indicative cost to deliver these Actions**
3.1 Volume and timing of surface water input rates, including transitional water, reflect natural regimes Carshalton WB by 2015 Croydon-Wandsworth WB by 2027	3.1.1 – Undertake research to identify a suitable proxy for natural patterns of volume and timing for the Wandle (eg historic, pre-industrial data; surface water runoff reduced from current approx. 55% for an urban area to 10% to reflect natural drainage).	None	9	This Target has been fulfilled to a large extent by the EA's existing analytical reports and by previous independently funded work.
	3.1.2 – Identify causes of any changes in discharge rates from historical natural flows; via investigation for patterns that might be due to natural seasonal variation, pumping systems, industry etc.	None	9	
	3.1.4 – Identify and obtain funding sources for measures, such as Sustainable Urban Drainage Systems (SUDS), to reflect / restore natural input patterns within the catchment.	None	9	The cost for installing SUDS and other measures to help replicate natural flow patterns varies considerably, depending on location, ease of access, flood risk implications, ease of installation and maintenance. For example, **porous and**

	3.1.5 – Implement measures such as SUDS to replicate natural patterns without increasing flood risk.	None	9	**permeable paving for a 20m^2 driveway can cost between £100 and £2000** (to purchase and install gravel or Concrete Block Permeable Paving respectively). The cost of installing micro-wetlands is highly dependent on a number of factors, notably land prices. An **indicative cost, based on a location in Hackbridge, LB Sutton, is estimated at £20,000 per acre to install, plus monthly management costs and health and safety considerations such as fencing.** Estimations of cost for the whole river would be dependent on walkover surveys and detailed feasibility studies drawing on the local authorities' Surface Water Management Plans.
	3.1.6 – Develop an infrastructure to enable monitoring (ie recruiting volunteers and obtaining monitoring equipment / funds, plus monitoring and analysing results).	None	9	Independent monitoring to measure the success of measures aiming to restore natural processes of surface water input (eg by measuring discharge rates for stability of flow patterns and emulation of chalk stream characteristics) could be run with volunteers at minimal cost once monitoring equipment and analysis capabilities were obtained (such as data-analytical computer software). **Estimated cost for start up and maintenance for 10 years £65,000**.
	3.1.7 – Instigate an ongoing programme of monitoring to measure success. Agree terms with partners – perhaps defining success as ensuring surface water discharge rates are stable, sustainable or replicating natural patterns. Measures to be amended as needed if they are not demonstrating success.	None	9	
3.2: Channel profile is enhanced to restore natural functioning and impact on flow speeds and	3.2.1 – Identify stretches of the river that require restoration work to achieve a varied and naturally functioning channel profile, including removing weirs and other barriers to water flow or wildlife movement.	A4, B1, B3, B10/C9, B13, B14, B17, B18	1, 2, 3, 4, 5,	<u>Actions 3.2.2 and 3.2.3</u> Independent work to undertake feasibility studies to restore natural functioning at a key reach on the Wandle has been **estimated as costing £15,000 to £25,000**.

directions with minimised impact of barriers on water flow or wildlife movement Carshalton WB by 2015 Croydon-Wandsworth WB by 2027	3.2.2 – Identify and obtain sources of funding to undertake feasibility studies to identify the best remedial measures to remove barriers to water flow or wildlife movement. Draw upon latest scientific recommendations and best practice techniques for sound ecological grounding and robustness of approach: consider using modelling	B19, B20, B21, B28, B30, B31, B33, C1, C4, C5, C6	6, 7, 8, 9, 10	3.2.4 As with other Actions relating to underpinning habitat enhancement works and restoring chalk stream fluvial processes, it is difficult to estimate cost without reach-specific or structure-specific evaluation. However, comparable projects involving hydraulic modelling, weir removal, creation of fish bypass channels, introduction of woody debris and other habitat enhancements important to all fish life stages suggest **such work would cost some millions, with indicative costs accruing as follows:** Modelling the feasibility of removing or modifying weirs which are causing a barrier to fish migration and identifying flood risk implications is **estimated to cost £100,000 to £200,000**. Physical removal of impoundments such as weirs is very heavily dependent on the complexities of the structure. Comparatively simple structures are **estimated to cost £30,000 per weir to remove** though this may be reduced to £20,000 if removing multiple weirs facilitates economies of
	3.2.3 – Identify and obtain funding for carrying out restoration work within the catchment identified through the feasibility studies (and monitor success afterwards).			
	3.2.4 – In partnership with relevant landowners, managers and statutory agencies, implement measures to re-naturalise the channel profile and restore natural functioning (ie incorporating pools, riffles, meanders, backwaters, in-stream deflectors and islands).			
	3.2.5 – Review existing remedial work to check whether expected improvements have been realised. Address any shortcomings with revised plans and implement works as necessary.	None	1, 2, 3, 4, 5,	

	3.2.6 – Collate evidence and techniques used to create a 'best practice' manual for urban river restoration that can be applied as a template to other urban projects.	None	6, 7, 8, 9, 10	scale. A proportion of this cost may be required for modelling. Conversely, to remove a large, heavily engineered weir and make good afterwards could cost as much as **£250,000. Costs may be higher where weirs are keyed into river walls.** In-stream and bank enhancement works are estimated to cost **between £150 and £350 per linear metre**, depending on the particular characteristics of a reach, such as accessibility for machinery and the level of channel reinforcement.
Wider Actions to improve the ecological functioning of the river				
Target	**Actions**	**Project**	**MM**	**Indicative cost to achieve these Actions**
3.3: Urban development optimises the visibility of the river at all times (eg no culverting)	3.3.1 – Using examples from elsewhere in the UK and overseas, create an awareness-raising campaign aimed at local authorities, developers, landowners and managers (and also the general public) to promote positive results from incorporating Water Sensitive Urban Design (WSUD) into new development plans. Show how WSUD can create aesthetic regeneration as well as provide vital flood management and water quality control services.	None		This could be delivered via an MSc student desk-based research project to inform an awareness-raising campaign funding bid incorporating best practice techniques and experiences.

	3.3.2 – Research deculverting the river at all remaining feasible points, including those that are currently considered Technically Infeasible or Disproportionately Expensive (eg Southside shopping centre in Wandsworth) so that opportunities can be seized whenever they arise in the future.	None		This Action will need to be led by the EA in partnership with the water companies and local authorities. Formalising existing liaison channels, to establish a local authority led system to flag up opportunities as and when they arise, could be a valuable asset supporting this work.
3.4 Water Sensitive Urban Design (WSUD) is implemented throughout catchment	3.4.1 – Identify all sites within the catchment likely to be redeveloped or prime for such work, to develop good relations and encourage partnership working to instigate WSUD from the outset, and seek opportunities for fundraising.	None		Ongoing dialogue with councils and integration of the WSUD approach through their SUDS approving body function.

SECTION 7: ECOLOGY RELATED TO WFD

7.1: Ecological components of WFD

The Wandle Catchment Plan recognises the importance of WFD in prioritising work to restore the Wandle's natural processes.

For the purposes of assessing GEP, WFD classification focuses on fish and fisheries, macrophytes, invertebrates and phytobenthos as key indicators of ecosystem health.

7.2: Fish and fisheries

Our Vision is a river that supports a mosaic of habitats with high biodiversity

Wandle Catchment Plan Objective 4: Thriving populations of native fish associated with chalk rivers are present and able to move freely

"We like seeing responsible fishing on the river – it's part of the Wandle's history, and a great way for kids and adults to relax and reconnect to the environment."

- from Ketso community and stakeholder workshops

As indicators of the health of the entire aquatic ecosystem, fish and the fisheries they provide are key metrics for any assessment of the productivity and resilience of streams, rivers and lakes.

For the purposes of WFD, fish stocks are scored with the Fish Classification System (version 2) (FCS2) tool: a Baysian statistical model which classifies the fish quality of rivers based on observed fish catch against the "expected catch" of an undisturbed site. It is also possible for technical experts to make site-specific recommendations that depart from the FCS2 model, or add to the expected species list, particularly if there is historical evidence for any particular species' presence.

Fish status on the Carshalton water body is classified as Poor, on a basis of a single sampling site at Butter Hill. Fish on the Croydon – Wandsworth water body were classified as Poor in the 2009 Thames River Basin Management Plan, but this status has now been raised to Moderate on a basis of surveys in 2010, 2011 and 2012. Both water bodies are thought to be failing Good status due to deficiencies in water quality, habitat, flow and barriers to fish migration: PO_4 has also been noted as a constraint on the Croydon – Wandsworth water body.

For the purposes of the Wandle Catchment Plan, as discussed in Section 1.8, the Wandle's two water bodies have been further subdivided into functioning reaches which the Fish and Surface Water TAGs consider distinct for fish. Together with consideration of fish guild structure, this analysis should allow river restoration measures to be targeted most effectively, and will also facilitate monitoring progress towards GEP:

1: Carshalton water body (Carshalton Ponds source to confluence with Croydon branch at Wilderness Island)
2: Beddington reach (Croydon source to confluence with Carshalton branch at Wilderness Island)
3: Confluence to Beddington Sewage Treatment Works effluent carrier outflow at Mill Green
4: Effluent carrier (the outflow from Beddington STW at Mill Green)
5: Effluent carrier to confluence with River Graveney
6: River Graveney (including the Norbury Brook)
7: Confluence with River Graveney to tidal creek (EDF weir)
8: Tidal creek to mouth of the River Thames

By a process of combining the FCS2 predictions with expert knowledge, the Fish TAG has agreed that the following species are expected for these reaches after appropriate river restoration measures:

	Reaches				
	1	**2**	**3**	**4**	**5 & 7**
	Carshalton reach	**Beddington reach**	**Confluence to effluent carrier**	**Effluent carrier**	**Effluent carrier to Tidal Creek**
Eel	✔	✔	✔	✔	✔
Brown trout	✔	✔	✔	✔	✔
Bullhead	✔	✔	✔	✔	#
Chub			✔	✔	✔
Dace	#	#	✔	✔	✔
Roach			#	✔	✔
Barbel				✔	✔
Grayling	=	=	=	=	=
Stoneloach	★	#	#	#	#
Minnow			#	#	#
Gudgeon				#	#
Perch				#	#
Pike				#	#
3-spined stickleback	#	#	#	#	#

Legend	
✔	*GEP species*
#	*Possibly present, particularly depending on outcome of habitat restoration, but not a GEP indicator*
=	*Possibly present if reintroduced*

Fig 7a: Fish species agreed by the Fish TAG, using FCS2 outputs combined with expert knowledge, for each reach of the Wandle following appropriate restoration works, which could be used as GEP indicators. (NB Reach 6 (Graveney) is heavily culverted and polluted, and Reach 8 (Tidal Creek) is not currently part of the Croydon-Wandsworth water body under WFD, so these reaches have not been included in this analysis).

The Wandle is currently designated as a cyprinid fishery, and FCS2 expects a mixed population of coarse and salmonid species. Accordingly, the Wandle Catchment Plan's Fish TAG suggests defining GEP on a basis of thriving fish populations, with ecosystem function demonstrated by sustainable recruitment.

General priorities for achieving GEP for fish are outlined below and in the tables at the end of this Section. These have been addressed as Actions for water (Objectives 1-3), macrophytes and wider habitat features (Objective 5) as well as fish (Objective 4).

- Balancing use of the groundwater system so that characteristic chalk stream inputs and the associated chemical and thermal conditions are restored and maintained.

- Re-naturalising the river's hydrograph. This will require detailed assessment of current abstraction practices and augmentation system, as well as deeper understanding of how the surrounding landscape interacts with the river, and ongoing consideration of effective flood risk management. By restoring a wide diversity of microhabitats, including backwater refugia, pool and riffle hydromorphology and channel sinuosity, colonisation and survival by fish and many other species will be greatly enhanced.

- Restoring connectivity for both up- and downstream migration. The removal or reduction of impounding structures will also turn reduce sedimentation of gravel substrates which are vital to successful spawning for many fish species. Restoring the river's natural gradient will also assist scouring of silt and sediment transport.

  To facilitate fish passage for all species, weirs have been removed or reduced at Mill Lane (Carshalton) (2010), Three Arch Bridge (2011), Poulter Park (2012), Ravensbury Park back channel (2012), Culvers Island (2014) and Butter Hill (2014).

- Reducing the impact of contaminants: both acute pollution spill events and chronic degradation of water quality resulting from misconnected pipes and from road runoff containing heavy metals, hydrocarbons and other pollutants in solution and associated with sediments. This will require deeper understanding of the bioavailability of pollutants and how contaminants may bioaccumulate within the Wandle. Monitoring the intensity and duration of pollution incidents will enable more accurate predictions about severity and effectiveness of any remedial action taken.

As work is undertaken to restore ecological processes and reverse the degradation of the Wandle's natural chalk river characteristics, existing fish distribution, populations and biomass are likely to change. Although both Wandle water bodies are currently failing GEP, it will still be important to demonstrate no deterioration from the current situation. Trout, salmon and bullhead are also designated as UK BAP species.

Restocking has taken place since the pollution incident of 2007, but the EA's regular amenity stocking of coarse fish ceased in 2010. Even after fish kills resulting from pollution incidents, the EA no longer restocks fish automatically, preferring to invest any funds in habitat enhancements and multi-species fish passage improvements, to improve the river's underlying resilience and enable natural recolonisation.

Angling is a highly popular recreational activity offered by the Wandle, and the enthusiasm of the local angling community has driven many recent habitat improvements on the river. For instance, the Wandle Piscators fishing club co-ordinates monthly riverfly monitoring throughout the catchment: an ongoing, award-winning project which has set national standards for full-catchment coverage, and has contributed to several investigations including designation of the Wandle as a nutrient-sensitive area. Such angling interest is a valuable ecosystem service in an inner-city area, and should be taken into account when setting a course for the Wandle's future fish populations, including the possibility of boosting population levels of some species (eg barbel) via targeted maintenance stocking. It has also been noted that coarse fish tend to live longer and grow more slowly than trout, so amenity stocking of juvenile fish may take several years to show satisfactory results for anglers.

Fig 7b (below) shows fish population density and biomass estimates from 12 EA survey sites along the Wandle in 2011: a snapshot of the river's fish populations at the time of compiling this Catchment Plan. Although many species of fish are still not completing their life cycles in the Wandle with full success, it is hoped that as a result of this Catchment Plan a wide variety of limiting factors can be identified and projects developed to fulfil WFD targets, in order to restore the river to its former glory as a self-sustaining fishery.

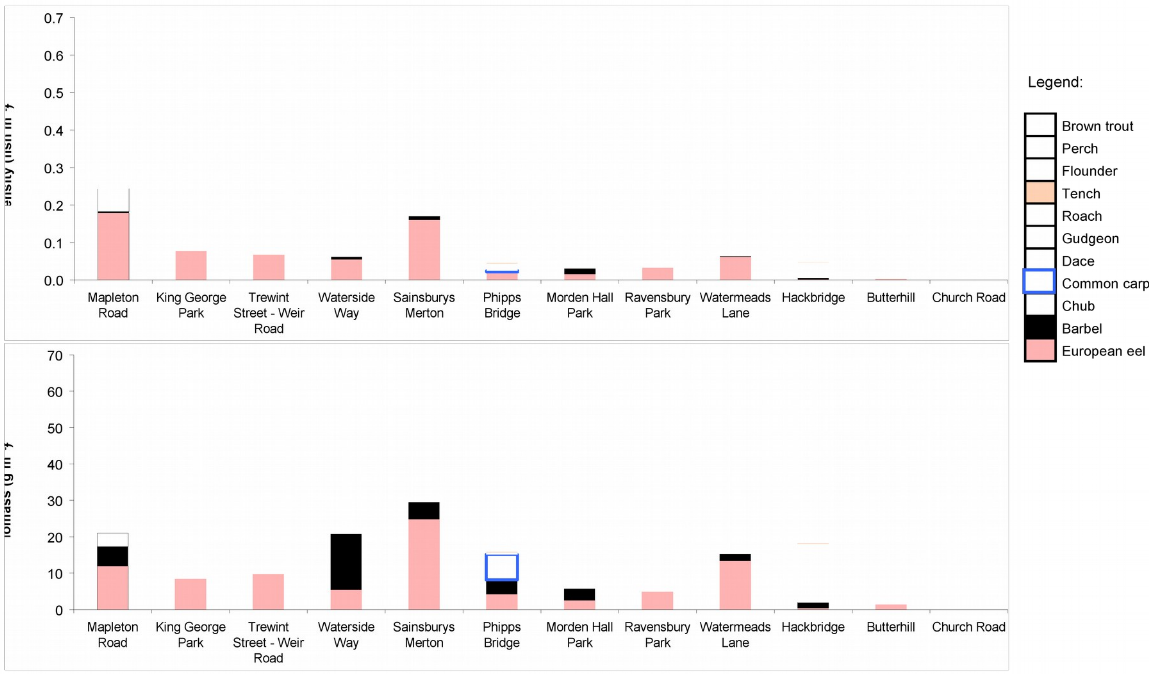

Fig 7b: Fish population density (top) and biomass (bottom) estimates from the River Wandle survey sites 2011 (source: EA, 2011)

7.2.1: Trout, salmon and grayling

As discussed in Section 3.2, the Wandle enjoyed a national reputation for the quality of its trout fishing from the medieval until the late Victorian era.

The much-quoted footnote to the 1833 and 1835 editions of Izaak Walton's *Compleat Angler* refers to Wandle trout "with marked spots like a tortoise", while Gilliat Hatfeild's unpublished *Fly Fishing in the Wandle* records that "the Wandle trout are of a very peculiar sort all covered with tortoiseshell and red spots" (c1840). Alfred Smee identified two separate strains of Wandle trout, one with red and one with white flesh (Smee, 1872): he also noted that Wandle trout tended to spawn late, "about the third week of January… till the end of February or the first few days of March", a statement corroborated by Francis Francis in his *Practical Management of Fisheries* (1883).

The Wandle's natural trout population was supplemented by extensive stocking, including French sea trout procured from Huningue by Smee himself before 1870, and trout from a hatchery at Watermeads operated by the Wandle Fisheries Association c1895 (Montague, 2005) but it is no longer known to what extent the native strains were affected by genetic introgression. The last old Wandle trout is popularly supposed to have survived until 1934 (Courtney Williams, 1945), but a very sparsely-spotted strain of trout in sections of the Sussex Ouse catchment may represent a surviving remnant of the original Wandle phenotype (pers comm. Dave Brown, 2013).

Between 1978 and 1991, the water authorities periodically stocked adult trout into the Carshalton and Hackbridge area, either for angling amenity or as a proxy test for water quality. The Wandle Trust's Trout in the Classroom environmental education programme began introducing Itchen-strain trout fry to the upper river from 2003. With water quality improvements in the Butter Hill and Hackbridge areas, these have survived and thrived: early spawning attempts by adult trout were first noted in winter 2007-2008, and the first confirmed wild-spawned trout fry was found during riverfly monitoring at Hackbridge in early 2010 (pers comm. Theo Pike, 2014). Anecdotal evidence also suggests that the Wandle Trust's stocking of Trout in the Classroom fry at Richmond Green on the Croydon arm of the river in 2008 survived until they were killed a year later by a red diesel pollution incident.

In partnership with the Environment Agency and the Wild Trout Trust, the Wandle Trust is now developing a strategy to restore a sustainable population of "urban-adapted" wild trout to the upper river. Research carried out by Exeter University on the River Hayle in Cornwall has identified a healthy population of trout which has adapted to levels of Pb and Cu normally considered lethal to salmonids (Uren Webster, 2013). Applying this principle to the Wandle will involve sourcing trout parr from similar urban rivers like the Buckinghamshire Wye and Dover Dour, which have already adapted to high levels of urban runoff including metals and PAHs, and allowing the resulting genetic palette to self-select further according to prevailing conditions in the restored upper Wandle. By ensuring a healthy trout population in the upper river, this project is designed to deliver Good WFD status for fish in the Carshalton water body.

In order to complete their lifecycle successfully, wild brown trout require the following range of habitats:

Trout	**Water depth**	**Mean water velocity**	**Substrate**	**Other**
Spawning and alevin	25-60cm	25-75cm/sec	Loose, well-sorted gravel with little fine sediment	Nearby cover for spawning adults: deeper water, undercut bank, boulders, weed
Fry	5-40cm	0-30cm/sec	Cobbles, gravel, woody debris or gravel with rooted plants	Abundant bankside and / or instream cover
Parr	10-60cm	5-50cm/sec	Cobbles, gravel, woody debris or gravel with rooted plants	Abundant bankside and / or instream cover
Adult	>30cm	10-60cm/sec	Wide range: gravel and weed to boulders and large woody debris	Abundant bankside and / or instream cover

Fig 7c: Habitat requirements of all life stages of wild trout (The Wild Trout Trust, 2012)

On the Carshalton branch of the river, the following measures are being put in place, in the hope that they will maximise the habitat potential for wild trout and improve the water body's status to Good for fish by 2015:

- Water quality: reduction of urban runoff, including sediment, heavy metals, PAHs and other pollutants, is likely to increase spawning success as well as survival of vulnerable juvenile fish. (Fine entrained sediment smothers fish eggs, depriving them of oxygen, while metals and PAHs bind easily to fats which form a high proportion of eggs)

- Water temperature: the average range of temperatures in the upper Wandle is well within the tolerances of trout, whose comfortable optimum ranges for growth are 7- 9°C and 16-19°C (Solbé, 1997). However, reduction of impoundments will help to reduce unnecessary solar heat loading

- Connectivity: numerous historic and flood risk management structures still fragment the connectivity of the Wandle and restrict the ability of fish to migrate between reaches to complete different stages of their lifecycle. These have also prevented recolonisation of the Wandle by sea trout from the River Thames. Future work to remove or bypass obsolete structures, particularly at Beddington Park, Shepley Mill, Goat Bridge, Watermeads and Merton Abbey Mills will be an important component of restoring sustainable trout populations to the Wandle.

- Channel morphology: centuries of anthropogenic modifications have left the Wandle's channel highly simplified. Ongoing habitat works, which include reconstructing pool and riffle sequences, and introducing large woody debris, will improve hydromorphological diversity and habitats for all life stages. Consideration should also be given to creating deep pool habitat, currently provided by large impoundments such as Shepley Mill and Goat Bridge weirs, as deep-water refugia during natural low flow conditions.

Apart from trout, research does not reveal significant contributions to the historic Wandle fishery from any other salmonids. This may have resulted from very early industrialisation in the Wandsworth area, where mills are known to have been operating (and obstructing fish passage for salmon and sea trout) from 1371 (Steel and Coleman, 2012). Decreasing water quality on the upper river may have led to the failure of Smee's attempt to introduce grayling from Derbyshire to the Beddington area, which survived and spawned for many years, but never recruited successfully (Smee, 1872).

In the modern era, 150 salmon fry were released in Carshalton as a precursor to the Trout in the Classroom project, and occasional adult salmon have reportedly been caught by anglers on the lower Wandle since around 2005 (pers comm. Wandle Piscators, 2014). Grayling were stocked annually on the upper river 1978-1981, and seem to have survived until a serious pollution incident in 1983: one or more were reported from the Mill Green area before the September 2007 pollution incident, and similarly lower down the river (pers comm. Wandle Piscators, 2014). The EA would prefer to re-establish a sustainable trout population in the upper river before addressing grayling: however the Fish TAG has noted research from Scandinavia which suggests that grayling thrive better than trout in highly simplified channels (pers comm. Dave Brown, 2012). This implies that grayling could thrive in the upper Wandle, above the heat loading effect from Beddington STW, if other water quality and habitat objectives are met.

7.2.2: Coarse fish

Since the late 1980s, a variety of coarse fish species have provided excellent angling for local people.

Historically the Wandle was predominantly noted for trout and eels (see above and below), but other species were also found in the middle river. In LB Merton, Nelson's downstream neighbour James Perry fished for pike c1805, probably at what is now Connolly's Mill, while Gilliat Hatfeild caught perch up to ¾lb below Ravensbury Mill in 1841, and recorded that roach and dace were plentiful in Merton (Hatfeild, c1840). William Morris stocked perch from the upper Thames at Merton Abbey in 1882, and lamprey, bullhead and dace were recorded during the 1870s in Mitcham and Beddington (Smee, 1872). In 1894, Alfred Jardine wrote in the *Fishing Gazette* that roach were multiplying and that jack pike had also increased in numbers.

The Wandle's coarse fishery suffered the same fate as its more celebrated trout interests through the mid 20th century, but was revived almost as soon as sewage treatment technology permitted. The first modern stocking record dates from 1978, when chub, dace, gudgeon, perch and roach were stocked by the water authorities between Hackbridge and Goat Bridge. Roach in particular were stocked through the 1980s, with more chub and dace in the 1990s. Barbel were introduced at Morden Hall Park in 1996.

In fulfilment of its statutory duty to maintain, improve and develop fisheries, the EA stocked barbel, dace, chub and roach at several points on the Wandle (as well as the Hogsmill and Beverley Brook) annually between 2006 and 2010. At this point, when electrofishing records showed that very few coarse fish were completing their lifecycles successfully, EA fisheries staff took the decision to suspend stocking until factors limiting recruitment were identified and addressed.

To assess the lifecycle habitat requirements of coarse fish, it is usual to classify species according to the concept of "spawning guilds" (Barcellos, 1997):

- Lithophilic species (barbel, chub and dace) deposit their eggs on clean gravel in flowing water. These requirements tend to limit the distribution of these species, and make them susceptible to environmental changes.
- Psammophilic species (bullhead, gudgeon and stone loach) scatter their eggs on sand or under rocks, principally in flowing water
- Phytophilic species (carp and tench) spawn on aquatic or flooded vegetation
- Phytolithophilic species (bream and roach) have very flexible spawning requirements, and are known to spawn on moss, willow roots, *Phragmites* and gravel

A summary of these species' lifecycle habitat requirements (as relevant to the Wandle) appears below:

Species and spawning guild	**Life stage**	**Water temp**	**Life stage preferred habitats**
Barbel	Spawning	>14°C	Over clean gravel among open weed beds
Barbus barbus	Fry habitat and diet		Riparian cover and reed beds: floodplain connectivity may also be important
Lithophilic	Adult		Lowland river reaches with clean water, clean gravels and weed beds. Fast water by bridges and weirs is favoured
Chub	Spawning	>12°C	Over weed beds: eggs stick to weeds, stones and gravel
Leuciscus cephalus	Fry habitat and diet		Hatched fry drift to shallow, slow flowing water. Diet: initially minute invertebrates, then plant material and larger invertebrates
Lithophilic	Adult		Middle and lower river reaches with mixed habitat where riffles alternate with slower pools with weed and silt
Dace	Spawning	12-15°C	Shallow sections of riffle, over gravel or stony substrate with some weed. Egg survival may be poor in areas of high silt and low gravel content
Leuciscus leuciscus	Fry habitat and diet		Diet: diatoms, then larger invertebrates and terrestrial insects
Lithophilic	Adult		Middle reaches of clean, fast-flowing streams and rivers, mainly in lowland areas: not small streams

Perch	Spawning	10-15°C	Shallow water over submerged macrophytes or woody debris
	Fry habitat and diet		Survival is affected by temperature, with long warm summers best: Diet: invertebrates from aquatic plants
Phytolithophilic	Adult		Slow flowing rivers
Roach	Spawning	>12°C	A wide variety of substrates, with eggs deposited just below the surface. As a result they may be vulnerable to dessication after any sudden fall in water level.
Rutilus rutilus	Fry habitat and diet		Young fry remain attached to weed or other spawning substrate, feeding on invertebrates and vegetable matter
Phytolithophilic	Adult		Very adaptable to still or slow flowing waters including canals and lakes: tolerant of some pollution, able to feed on detritus as well as algae, molluscs and invertebrates
Bullhead	Spawning		Males excavate nests under large stones for females to deposit eggs. In areas without suitable stones, woody debris may also be used
Cottus gobio	Fry habitat and diet		Shallow stony riffles. Diet: small crustaceans
Psammophilic	Adult		Moderate or fast-flowing water with coarse substrates, more than 5cm deep
Gudgeon	Spawning	>14°C	Shallow water among plants and gravel
Gobio gobio	Fry habitat and diet		Weed and gravel. Diet: small crustaceans
Psammophilic	Adult		Fast flowing water with sand / gravel substrate, plus weed beds for cover

Fig 7d: Lifecycle requirements of the Wandle's key species of coarse fish

A combination of regular stocking and downstream drift of all fish species have tended to mask the dynamics of the Wandle coarse fishery. However, some information can be gleaned from a variety of studies to show that limited recruitment has been taking place in certain areas:

- Phytolithophilic wild-spawned roach were found in large numbers at Wilderness Island, and in smaller numbers in King George's Park, in 1997. Small numbers of phytolithophilic perch were also found in these areas (Barcellos, 1997)
- Wild-spawned roach were found at Morden Hall Park in 2009 and 2011. In 2011 they were also found at Trewint Street and King George's Park (EA, 2011)
- Lithophilic wild-spawned chub were found at Ravensbury Park and Trewint Street in 2011 (EA, 2011)
- Lithophilic wild-spawned dace were found at Trewint Street in 2011 (EA, 2011)

- The first lithophilic wild-spawned barbel on the Wandle was recorded at King George's Park in 2011 (EA, 2011)

- Psammophilic stone loach and gudgeon have been recorded as recruiting naturally in several areas (Barcellos, 1997). Incidental records from riverfly monitoring on the upper river show bullhead recruiting strongly on the Carshalton water body, as well as on the Croydon-Wandsworth water body at Hackbridge and Goat Bridge (Wandle Piscators, 2014).

Overall, while the post-industrial Wandle may have seemed suitable from a water quality point of view for maintenance stocking as an amenity coarse fishery, the river's highly simplified hydromorphology appears to militate against sustainable recruitment by most coarse species. Barcellos noted that the only recruitment areas for highly-adaptable phytolithophilic roach and perch were characterised by excellent marginal macrophyte cover, offering protection from current and predators (Barcellos, 1997): this is likely to apply to all species.

Growth rates of most coarse fish species in the Wandle appear to be slightly below average compared to the growth of species in "southern" rivers. In 2011, Percentage Standard Growth (PSG) of barbel was 97%, chub was 93%, roach was 86%, while dace was 111%, indicating that conditions in the Wandle suit this species if enough suitable habitat for spawning and development is available (EA, 2011).

Although traditional fisheries management often draws strong distinctions between the requirements of trout and coarse species, many lifecycle requirements are startlingly similar, including the need to migrate to different parts of the river system at different times of the year. On the Wandle, habitat improvements of almost any kind are likely to have far-reaching benefits for many species:

- Water quality: ongoing improvements to water quality, and sediment reduction as a result of rubbish removal, are probably already contributing to more successful recruitment by lithophilic species. In areas with less fine sediment, coarse fish eggs will be less exposed to heavy metals and PAHs.

- Water temperature: throughout most of the river, average water temperatures during the usual coarse fish spawning season (ostensibly mid-March to mid-June) are well within the trigger range for spawning activity. However, the Carshalton arm may only reach temperatures above 12°C towards the end of June, potentially limiting recruitment opportunities for some species.

- Water flow: Barcellos notes that roach eggs deposited just below the water's surface, on weed beds or tree roots, may be very vulnerable to sudden decreases of water level as a result of weed cutting or operation of locks and sluices (Barcellos, 1997). Due to the diurnal effluent release pattern from Beddington STW, water levels below Goat Bridge commonly rise and fall by many centimetres, sometimes several times over 24 hours. This factor may be contributing significantly to roach recruitment failures on the middle and lower Wandle.

  Except at Merton Abbey Mills, little weed cutting currently takes place on the Wandle. However, if *Ranunculus* and other macrophytes become more widely established, consideration may need to be given to cutting regimes that do not adversely impact fry survival. Low flows at migration times may also exacerbate fish passage issues.

- Connectivity: traditional fisheries management has not adequately recognised the significant migratory needs of many coarse fish species. A study of barbel on the River Nidd has showed that weirs delay or prevent upstream migration to key spawning areas, while chub studied on the River Spree in Germany prefer to return to spawn on the "imprinted" gravels where they themselves hatched (Ashby, 2012: Fredrich et al, 2003). On the Wandle, weirs at Beddington Park, Shepley Mill, Goat Bridge, Watermeads, Ravensbury Park, Merton Abbey Mills and Connolly's Mill are likely to be hindering migrations of many species. It is hoped that fish passage improvements such as the Wandle Trust's rock ramp fish pass in Ravensbury Park will help to reconnect significant longitudinal reaches of the river to enable fish of all species to fulfil their migratory instincts.

Much of the middle and lower Wandle is currently disconnected from its floodplain by hard engineering. However, for juveniles of many species including barbel, latitudinal river-to-floodplain connectivity may also be important, enabling them to take refuge from high fluvial flows and forage in nutrient-rich and warmer shallow-water environments.

- Channel morphology: centuries of anthropogenic modifications have left the Wandle's channel highly simplified. Together with the exaggerated flashiness of the river's urbanised hydrograph, this is almost certainly resulting in fish of all age classes being progressively washed downstream over weirs and other structures which they cannot re-ascend - including very vulnerable fry which emerge at the time of the "European monsoon" in June (Wandle Piscators, 2014).

  As discussed in Section 5.8.5, fish of all species may also be relying on large pieces of fly-tipped rubbish as habitat, including shopping trolleys in the absence of more natural features, in the highly-engineered middle and lower Wandle (Barcellos, 1997). The Wandle Trust has noted an urgent need to improve the hydromorphological diversity of such channelised reaches, by introducing well-designed habitat structures which do not collect silt and other debris, or increase flood risk (Wandle Trust, 2014).

  A programme of fish passage works, backwaters and other refugia will be essential for establishing sustainable coarse fish populations in the Wandle. Even in the less hardened upper reaches of the river, ongoing projects to improve morphological diversity (including weir removal, pool and riffle reconstruction, and introducing large woody debris) will improve habitats for all life stages. Consideration should also be given to creating deep pool habitat, currently provided by large impoundments such as Goat Bridge weir, as deep-water refugia during natural low flow conditions.

7.2.3: Eels

The River Wandle's historic reputation as an eel fishery appears to have been second only to its fame as a trout stream. Even on the upper river, more than 8 miles from the Thames, Smee wrote that "next to the trout, the eel is our most important fish" and recorded major migrations of elvers (May – July) and adult eels (July – September) through his garden at Beddington en route to and from the river's headwaters in Croydon (Smee, 1872).

For most of the Wandle's history it is likely that eels have made up the dominant fish biomass: however, the river's population has probably reflected the global decline of this species by approximately 90% since the 1980s. Nevertheless, EA surveys in 2009 and 2011 showed that eels made up 42% and 38% of the total fish biomass captured in the course of these surveys (EA, 2011).

European eels are classified as a UK BAP species. They are catadromous fish which spend most of their lifecycle in fresh water before migrating to the area of the Sargasso sea to breed. The fry drift on ocean currents for several years, reaching the shores of western Europe as "glass eels" or elvers, and migrating up rivers during summer months when temperatures have exceeded 15°C. This migration is driven by population density, with high mortality noted where high density exists, so impassable structures can be detrimental to eel populations. European eels are sexually dimorphic: fish over 450mm in length are considered female, while those below this length are male, with any below 300mm indeterminate (Houston, 2010). Sexual development tends to be density-related, with low densities of predominantly female eels in east coast UK rivers, and high densites of predominantly males on the west coast (Knight et al, 2001).

Despite severely reduced numbers, the Wandle is still regarded as a key stronghold for European eels in the Thames Basin, and EA monitoring results from 2009 and 2011 show no decline between these years, nor any change in the rate of decline with increasing distance upstream (Fig 7e, below).

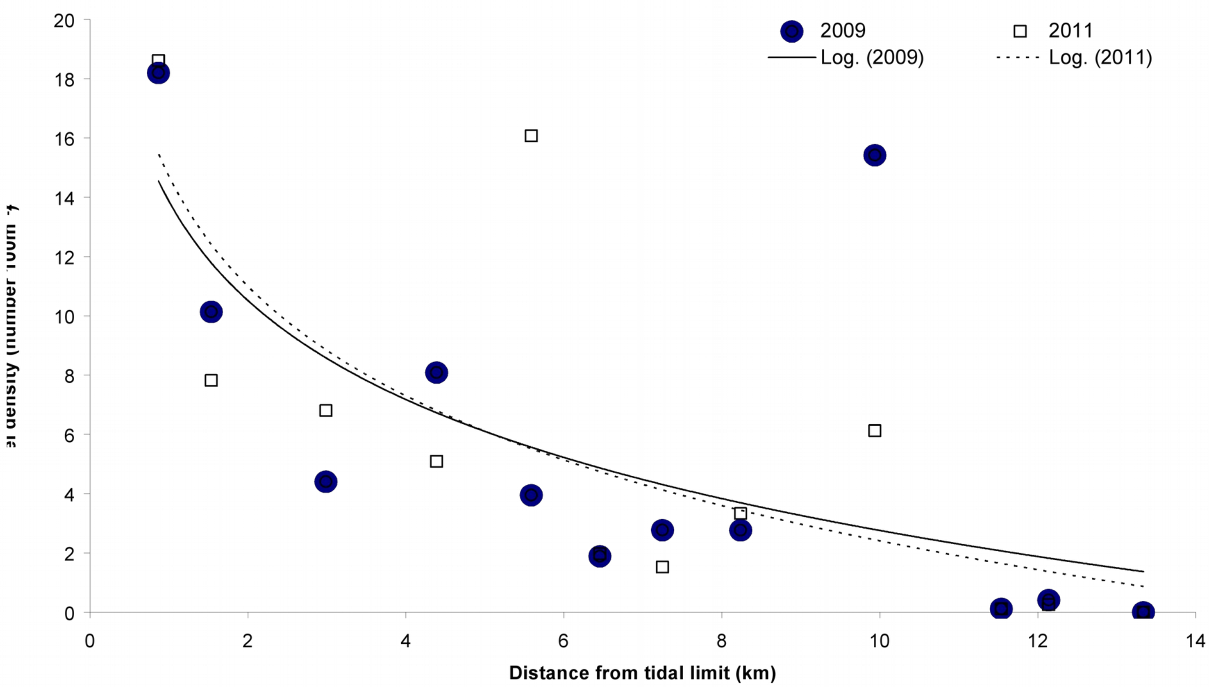

Fig 7e: Density of eels across 12 monitoring sites surveyed in 2009 and 2011 (source: EA, 2011)

The following observations and recommendations may be made with regard to eel populations in the Wandle:

- Water quality, temperature and flow are all likely to be within the normal toleration range for European eels, with the exception of very severe pollution events such as the 2007 pollution incident from Beddington STW.

- Connectivity: upstream-migrating elvers are hindered by weirs and other obstructions, which can even cause density-related mortality as noted above.

  An IFM diploma study in 2010 identified at least 2 “break points” on the river where fish passage obstructions appeared to be blocking upstream migration of elvers (Houston, 2010). Population densities dropped sharply between survey sites at Sainsbury’s Merton and Phipps Bridge, indicating a fish passage problem at the Merton Abbey Mills tilting weir. A second break point occurred above Watermead Lane, where the tilting weir at Goat Bridge also appears to present an almost impassable obstacle. (By extrapolation against very low figures, it is likely that the culverts and weirs at Shepley Mill present similar difficulties).

To address eel passage problems, eel passes have been installed at Watermeads, Ravensbury Park (lake weir and tilting weir), Merton Abbey Mills, and the weirs behind Topps Tiles in Wandsworth. Monitoring suggests that these measures have proved successful in moving elvers upstream. A dedicated eel pass has also been installed as part of the multi-species fish pass which forms part of the National Trust's hydropower installation at Morden Hall Park.

To facilitate fish passage for eels and other fish species, weirs have been removed or reduced at Mill Lane (Carshalton) (2010), Three Arch Bridge (2011), Poulter Park (2012), Ravensbury Park back channel (2012), Culvers Island (2014) and Butter Hill (2014).

- Channel morphology: European eels are photosensitive, preferring slow flowing areas with silt and crevices for refuge during daylight hours. The highly-engineered River Wandle provides comparatively few of these refugia except in heavy complex rubbish: volunteers at Wandle Trust community river cleanups have noted the likelihood of finding several eels hiding within the structure of motorbikes removed from the lower and middle river. As above, the Wandle Trust recommends increasing habitat for eels by means of well-designed habitat structures which do not collect silt and other debris, or increase flood risk (pers comm. Wandle Trust, 2014).

Further information required:

Further monitoring of the designated reaches

Further investigation of limiting factors for all fish species in the River Wandle, including endocrine disruption

Further reading:

Appendix A: Environment Agency (2014) WFD summary sheets

Ashby (2012) *Restoration of coarse fish populations in the River Wandle* (MSc dissertation)

Barcellos (1997) *Investigation into the current status of coarse fish recruitment in the River Wandle* (MSc dissertation)

Environment Agency (2004) *Fisheries Survey Sites on the River Wandle 2004*

Environment Agency (2011) *River Wandle Fish Population Survey 2011*

Environment Agency (2011) *Summary of European eel surveys on the River Wandle*

Thames Water (1988) *River Wandle Fisheries Survey 1988*

Uren Webster, Bury, van Aerle and Santos (2013) *Global Transcriptome Profiling Reveals Molecular Mechanisms of Metal Tolerance in a Chronically Exposed Wild Population of Brown Trout*

Wild Trout Trust (2012) *The Wild Trout Survival Guide (third edition)*

Zoological Society of London (Gollock, Pryor, Godsall and Debney) (2012) *River Thames catchment European eel Anguilla anguilla (L.) monitoring report 2008*

7.2.4: Fish and fisheries action tables

The information in these tables has been assembled from suggestions made in community consultations, TAG meetings and specific stakeholder input to develop a series of Objectives, Targets and Actions. Information on existing projects has been collated and used to identify gaps, and where additional projects may need to be developed to fulfil Actions, Targets and Objectives.

Actions to achieve the Catchment Plan's overall aim for habitat and wildlife: the river supports a mosaic of habitats with high biodiversity

Objective 4: Fish and fisheries : thriving populations of native fish associated with chalk rivers are present and able to move freely

Specific Actions to attain GEP

Target	Actions	Project	MM	Indicative cost to deliver these Actions
4.1: Fish can move freely through the entire length of the Wandle Carshalton WB by 2015 Croydon-Wandsworth WB by 2027	4.1.1 – Understand all possible barriers to fish movement (eg physical, chemical, thermal, flow speed) in different river conditions (eg high flow, low flow).	A1, B3, B14, B22, B23, B24, B25, B26, B27, B28	5	Action 4.4.1 has been fulfilled to a large extent by the EA's existing analytical reports and by previous independently funded work. As with other Actions relating to underpinning habitat enhancement works and restoring chalk stream fluvial processes, it is difficult to estimate cost without reach-specific or structure-specific evaluation. However, comparable projects involving hydraulic modelling, weir removal, creation of fish bypass channels, insertion of woody debris and other habitat enhancements important to all fish life stages suggest **such work would cost some millions, with indicative costs accruing as follows:**
	4.1.2 – Identify all obstructions that can be physically removed (eg weirs) and seek opportunities to maximise multiple benefits (eg deliver habitat work at the same time or support future habitat work).	B14, B21, B22, B23, B24, B25, B26, B29, B30, C4, C5,	1, 5	
	4.1.3 – For obstructions that cannot be removed, perhaps because they provide flood control measures, identify mitigations to enable fish passage (including technical solutions and bypass channels).		5	

	4.1.4 – Raise funds / work with others to implement options.		5	Modelling the feasibility of removing or modifying weirs which are causing a barrier to fish migration and identifying flood risk implications is **estimated to cost £100,000 to £200,000**. Physical removal of impoundments such as weirs is very heavily dependent on the complexities of the structure. Comparatively simple structures are **estimated to cost £30,000 per weir to remove** though this may be reduced to £20,000 if removing multiple weirs facilitates economies of scale. A proportion of this cost may be required for modelling. Conversely, to remove a large, heavily engineered weir and make good afterwards could cost as much as **£250,000. Costs may be higher where weirs are keyed into river walls.** There are limited opportunities for implementing bypass channels for fish passage on the Wandle, including habitat enhancements for different fish lifecycle stages because of the highly urbanised landscape. Most opportunities exist only in parkland and conditions vary greatly. Thus an **estimated cost range is between £50,000 - £250,000**.

Target	Actions	Project	MM	Indicative cost to deliver these Actions
4.2: The fish population is self-sustaining (including successful reproduction and growth with sufficient habitat to support all life stage of fish) Carshalton WB by 2015 Croydon-Wandsworth WB by 2027	4.2.1 – Agree on a definition for 'self-sustaining population' (eg survives without need for stocking, demonstrable recruitment occurs at accepted levels) and how it relates to GEP.	None	N/A	The TAG is fulfilling this Target, with input from the Steering Group as appropriate. Both the Steering Group and TAG have demonstrated a commitment to remain constituted and complete the implementation of these Actions.
	4.2.2 – Develop a programme to move away from stocking to that of a naturally occurring population without deterioration under WFD.	C3	N/A	Independent work to improve habitat quantity and complexity suitable for all fish life stages as per Actions 4.2.4 is **estimated to cost between £150 and £350 per linear metre**, depending on the particular characteristics of a reach, such as accessibility for machinery and the level of channel reinforcement needing attention. Work would typically include introducing in-stream woody debris, sculpted gravel substrates, bank re-profiling, planting marginal vegetation, channel narrowing to increase flow velocity, and creating meanders and pool and riffle systems. Please note: costs for longer reaches may be less per linear metre than for shorter ones, due to economies of scale with equipment, materials and labour. The TAG is fulfilling this Target, with input from the Steering Group as appropriate. Both the Steering Group and TAG have demonstrated a commitment to remain constituted and complete the implementation of these Actions.
	4.2.3 – Define the different requirements of the various life stages of the species/populations, including water quality, quantity and dynamics of flow, food sources, habitats for spawning, nursery and refuge from pollution incidents or flush out during spate conditions etc. Identify and quantify the areas of these habitats in the river to assess possible bottlenecks and guide restoration priorities.	None	N/A	
	4.2.4 – Create a work programme and secure funding to improve habitat quantity and complexity as per Action 4.2.3 including winter refuges and spawning and nursery habitat.	B1, B10/C9, B11/C10, B13, B14, B20, B21, B22, B30, B31, B33, C1, C4, C5, C6	2, 3, 4, 6, 8	
4.3 The river contains refuges for fish to escape unfavourable	4.3.1 – Restoration work is undertaken which includes online backwater refuges from predation, pollution incidents and flush out during extreme weather events.	B1, B10/C9, B11/C10, B13, B14,	2, 3, 6, 8	A prime location to consider for these measures is the effluent channel at Mill Green, LB Sutton. Estimation of cost for this work is difficult without undertaking a site assessment first; particularly as

conditions (eg high flows, low flows and pollution)		B20, B21, B22, B30, B31, B33, C1, C4, C5, C6		it features constant large volumes of high velocity water, and consequently large quantities of concrete reinforcement and other engineering structures. Accessibility of machinery is anticipated to be easy, however. Work to re-naturalise banks and create fish refuges is anticipated to cost **between £150 and £350 per linear metre** for less engineered sites. For engineered sites, such as Mill Green, the cost is likely to be in excess of this. Thames Water, the owners of the effluent channel, may consider supporting these costs. Work would typically include introducing in-stream woody debris, re-profiled gravel substrate, bank re-profiling, planting marginal vegetation, channel narrowing and creating meanders and pool and riffle systems. Please note: costs for longer reaches may be less per linear metre than for shorter ones due to economies of scale.

Wider Actions to improve the ecological functioning of the river				
Target	**Actions**	**Project**	**MM**	**Indicative cost to deliver these Actions**
4.4: The fish population reflects that of a healthy chalk river	4.4.1 – Define the composition of a healthy chalk river fish population in terms of species presence and relative abundance, in each of the distinct functioning ecological reaches of the Wandle.	C3		The TAG is fulfilling this Target, with input from the Steering Group as appropriate. Both the Steering Group and TAG have demonstrated a

	4.4.2 – Compare the current species community composition to the ideal species community composition, and identify what changes would need to be made to the river's habitat and environmental conditions to enable a natural transition from current species to ideal species.	C3		commitment to remain constituted and complete the implementation of these Actions.
	4.4.3 – Create a work programme and secure funding to enable a shift from current species community composition to ideal species community composition as identified in 4.4.2.	B1, B10/C9, B11/C10, B13, B14, B20, B21, B22, B30, B31, B33, C1, C4, C5, C6		
	4.4.4 – Identify whether any desired fish species are missing from current fish populations, and evaluate whether a strategy for re-introduction is necessary: if so, develop this strategy and secure funding to carry out the re-introduction.	C3		

4.5: Self-sustaining populations of brown trout are present in the River Wandle	4.5.1 – Use the survey outputs (from 4.4) and analysis on habitat bottlenecks (Action 4.2.3) to guide the development of a restoration plan that will support all life stages of brown trout. Ensure sufficient overhead winter cover and cover at fish passes is included.	C1, C3, C6		Independent work to identify and obtain a genetically appropriate urban-adapted donor population of brown trout is underway: **estimated to cost between £5,000 and £10,000** Independent work to enhance habitat and water characteristics, including connectivity through removal of impoundments, and interception of road runoff and silt, is difficult to estimate without reach-specific or structure-specific evaluation. However, in-stream and bank enhancement works are estimated to cost **between £150 and £350 per linear metre**, depending on the particular characteristics of a reach, such as
	4.5.2 – Obtain funding and implement the action plan to achieve the requisite conditions to support a population of brown trout.	C3		
	4.5.3 – Trout are likely to require reintroduction: locate and source a genetically appropriate donor population of brown trout parr.	C3		

	4.5.4 – Develop and implement a monitoring programme to record and evaluate translocation and recruitment success, and to enable any necessary amendments to the action plan to support a self-sustaining population of brown trout in the Wandle.	C3		accessibility for machinery and the level of channel reinforcement needing attention. Physical removal of impoundments such as weirs is very heavily dependent on the complexities of the structure. Comparatively simple structures are **estimated to cost £30,000 per weir to remove** though this may be reduced to £20,000 if removing multiple weirs facilitates economies of scale. A proportion of this cost may be required for modelling. Conversely, to remove a large, heavily engineered weir and make good afterwards could cost as much as **£250,000. Costs may be higher where weirs are keyed into river walls.** The Environment Agency is expected to undertake annual monitoring, including electrofishing. Support for this activity could be provided independently with volunteers counting trout redds at minimal cost once equipment was purchased and training was undertaken. **Estimated start up and annual maintenance cost over 5 years £3,000 plus a recommendation to continue monitoring beyond this period**.
4.6: Any fishing on the Wandle is sustainable and contributes to local engagement with and knowledge of the river	4.6.1 – Undertake education and awareness-raising amongst anglers to promote catch and release for all species.	None		This Target falls within the remit of the EA, working with the local authorities and local fishing clubs and other interest groups.
	4.6.2 – Devise and implement a responsible angling scheme that anglers can sign up to.	None		
	4.6.3 – Devise and implement a data collection programme whereby anglers collect data that can inform river management work (eg catch return information).	None		

4.7: The potential impacts of contaminants on fish populations is understood, including how ‘urban adapted species’ may evolve, and the effects are mitigated where possible	4.7.1 – Investigate existing fish populations to see if they display any signs of pressure from pollutants, eg lack of survival at a particular life stage.	None		This Target is best fulfilled via research undertaken by ecotoxicologists and independent fisheries experts, working with the Environment Agency. Design and installation of silt traps being retro-fitted in an urban environment is **estimated to cost £40,000** (small), **£50,000** (medium) and **£60,000** (large). The cost of installing micro-wetlands is highly dependent on a number of factors, notably land prices. An **indicative cost, based on a location in Hackbridge, LB Sutton, is estimated at £20,000 per acre to install, plus monthly management costs and health and safety considerations such as fencing** Estimations of cost for the whole river would be dependent on walkover surveys and detailed feasibility studies drawing on the local authorities’ Surface Water Management Plans.
	4.7.2 – Identify any particular pollutants, or combination of pollutants, that might compromise fish population health. Connected to actions within Target 2.2 - Identify likely pollution pathways and investigate options for interception.	None		
	4.7.3 – Research other examples of freshwater fish populations that are known to survive in polluted rivers and seek to learn from their examples (eg Cornish streams containing levels of metals that laboratory analysis identified as lethal to fish yet fish are surviving and recruitment is occurring).	None		

7.3: Macrophytes, trees and the wider river habitat

Our Vision is a river that supports a mosaic of habitats with high biodiversity

Wandle Catchment Plan Objective 5: Plant communities associated with chalk rivers are abundant along the river, providing good habitat for wildlife and for people

"We like having lots of varied flora along the river banks and in the water, with rushes, wild flower areas and overhanging willow trees."

- from Ketso community and stakeholder workshops

The term "macrophytes" is commonly used to describe larger plants that are seen easily with the naked eye. For the purposes of WFD, the UKTAG has defined it to refer to aquatic species, including all vascular plants (those that bear seeds), bryophytes (mosses and liverworts), stoneworts (*Characeae*) and macro-algal growths.

Macrophytes play a vital role in chalk rivers, helping to bind sediments, stabilise banks and riverbeds and absorb nutrients. They increase habitat complexity by interacting with fluvial flow to create a variety of flow speeds and directions, and can buffer the river from extremes of light, wind disturbance and diffuse pollution. They also provide habitat for many species of wildlife.

Because of their luxuriant growth in chalk rivers, macrophytes can produced immediate effects on water quality, together with pronounced diurnal fluctuations in DO levels. These fluctuations result from photosynthetic activity during daylight hours, when plants are giving off oxygen (sometimes even leading to DO supersaturation): by contrast, DO levels can fall very low at night when plants are respiring and taking up oxygen instead.

The multitude of roles played by aquatic macrophytes makes them good indicators of ecosystem health: they cannot move and so the species that are present at a given site may reveal important information about the amount of water available, its flow regime, nutrient status, and other physico-chemical factors such as exposure to sunlight, pollutants, disturbance, soil and underlying geology.

Chalk rivers characteristically support communities of *Callitricho-Batrachion* vegetation (commonly known as CB communities). These submerged plant types are priority communities in the UK Biodiversity Action Plan and comprise water crowfoot (*Ranunculus*) and water-starwort (*Callitriche*) species. Three main sub-types of CB community have been defined, based on geology and river type, and it is possible for rivers to show a transition to one sub-type from another, as substrate type changes from chalk to clay. The River Wandle does just this, despite its urban setting and modified nature, and supports some good examples characteristic of both sub-types 1 and 2 such as stream water crowfoot (*Ranunculus penicillatus sp. Pseudofluitans*), blunt-fruited water starwort (*Callitriche obtusangula*), lesser water parsnip (*Berula erecta*) and other water crowfoots and water starworts identified only to Family level.

For the purposes of WFD, macrophytes are scored under the 5 indices of the River LEAFPACS system:

- Nutrient concentrations
- Hydromorphology (flow)
- Number of aquatic species
- Number and presence of different growth forms
- Extent of filamentous algae

These scores are compared to those expected for undisturbed reference conditions to generate a final Ecological Quality Ratio (EQR). EQR score ranges from 0 (for highly degraded sites) to 1 (for un-impacted or natural sites). WFD utilises 5 such bands of EQR score, corresponding to High, Good, Moderate, Poor and Bad.

Macrophytes on the River Wandle are currently classified as Moderate (Quite Certain) for both River Wandle water bodies. This classification fails Good status on grounds of elevated phosphate concentrations and poor hydromorphological conditions, with modified channel structure reducing habitat opportunities. Although sampling has only taken place on the Croydon-Wandsworth water body, the EA considers that the historic sampling site at Goat Bridge (ie upstream of the major nutrient input from Beddington STW) should be also be representative of the Carshalton water body for macrophytes. However, this assumption may require confirmation.

Orthophosphate concentrations emerging from Beddington STW are <1mg/l as required by the Urban Waste Water Treatment Directive (UWWTD). Expert observational experience has found that c1mg/l is often a tipping point between systems supporting *Ranunculus* and *Cladophora* filamentous algae, with algae preferring the higher concentration, leading to *Ranunculus* being replaced. The presence of *Cladophora* is indicative of elevated nutrient concentrations, and CB communities can be compromised by poor water quality, depleted flows and the effects of urbanisation.

Despite Moderate classification under LEAFPACS for WFD, however, aquatic macrophyte species richness and diversity of plant types currently recorded on the Wandle exceeds expected scores for GEP. Many species characteristic of chalk rivers, such as watercress (*Rorippa nasturtium-aquaticum*), fool's watercress (*Apium nodiflorum*), water forget-me-not (*Myosotis scorpioides*), water mint (*Mentha aquatica*), great willowherb (*Epilobium hirsutum*) water figwort (*Scrophularia auriculata*), bittersweet (*Solanum dulcamara*), brooklime (*Veronica beccabunga*), flag iris (*Iris pseudacorus*) and branched bur-reed (*Sparganium erectum*) are found on the River Wandle alongside several species of water starwort (*Callitriche sp*.), water crowfoot (*Ranunculus sp.*), moss, sedge (*Carex sp.)* and willow (*Salix sp*.). Management practices should therefore aim to ensure no deterioration of these indices whilst seeking to improve the failing targets.

The following expert advice has been received from the Wandle Catchment Plan TAG:

- Nutrient concentrations should be reduced sufficiently to enable macrophyte communities with a River Macrophyte Nutrient Index (RMNI) score of 5.8 or lower to thrive. This will be assisted by phosphate stripping at Beddington STW within AMP6, but is unlikely to reduce the orthophosphate level sufficiently to pass the WFD standard of 0.12mg/l for Good status. Indeed the WFD standard is likely to change to an even lower value in the next RMBP, which would make achieving the standard even more challenging in future

- Hydromorphological conditions should be improved such that flow supports macrophyte communities with a River Macrophyte Hydraulic Index (RMHI) score of 6.4 or below

- The number of functional macrophyte groups (NFG) should maintain the higher than expected NFG index score of 4.1, and ideally remain higher than the lowest 2012 score of 7 (to demonstrate no deterioration)

- The number of truly aquatic species richness (NTAXA) maintains the higher than expected NTAXA index score of 5.3, 5.6 and ideally remains higher than the lowest 2012 score of 8 (to demonstrate no deterioration)

- CB communities should be present in all reaches except the River Graveney (reach 6), with an ongoing and ideally increasing presence over the long term. The viable level to be assessed by expert judgement. *Ranunculus* beds are characteristic aesthetic chalkstream features and should also be maintained as an ecosystem service benefit to local people

As suggested above, attaining Good classification for macrophytes overall will depend largely upon reducing nutrient concentrations and increasing flow.

These issues are addressed in Objective 5 (below) and associated water Actions in Objectives 1, 2 and 3. Improvements to the macrophyte community will in turn greatly benefit fish (Objective 4) as well as the wider ecology of the river. For example, restoring baseflows, sediment transport and channel roughness will help plants to grow, which in turn will create highly valuable micro-habitats for fish at all life stages as they seek food and shelter from predators.

The more complex the habitat created by plants, the more fish can be accommodated within a given area. This contributes to successful and sustainable recruitment, as it enables fish energy to be conserved for growth rather than risk being expended in territorial conflict or simply holding against peak flows in a featureless channel.

<u>Further information required:</u>

Extend macrophyte assessment to the Carshalton water body as soon as possible to confirm Moderate (Quite Certain) or better classification for WFD. The Croydon arm of the Croydon-Wandsworth water body above Beddington STW should also be assessed.

Monitoring and further research should be undertaken for *Cladophora* and CB communities' cover and density with a view to establishing a clear understanding of what can be termed an 'acceptable' quantity for ideal nutrient concentrations and flow dynamics to achieve Good status.

There is also strong anecdotal evidence that CB communities on the Wandle, in particular *Ranunculus*, are being replaced by *Elodea canadensis* or *E. nuttallii* (to be confirmed - most likely as a consequence of increased nutrient concentrations and reduced flow). Further evidence is needed to confirm this, with targets that are specific to the conditions on the Wandle (eg what percentage of the riverbed should be covered by the CB community?)

<u>Further information required:</u>

Extend macrophyte sampling to the Carshalton water body and the Croydon arm of the Croydon-Wandsworth water body above Beddington STW

Confirm replacement of CB communities on the Wandle with *Elodea canadensis* or *E. nuttallii*

<u>Further reading:</u>

Appendix A: Environment Agency (2014) WFD summary sheet

7.3.1: Macrophytes action tables

The information in these tables has been assembled from suggestions made in community consultations, TAG meetings and specific stakeholder input to develop a series of Objectives, Targets and Actions. Information on existing projects has been collated and used to identify gaps, and where additional projects may need to be developed to fulfil Actions, Targets and Objectives.

Actions to achieve the Catchment Plan's overall aim for habitat and wildlife: the river supports a mosaic of habitats with high biodiversity

Objective 5: Macrophytes†, trees and the wider river habitat: communities associated with chalk rivers are abundant along the river, providing good habitat variety for wildlife and for people *† The UKTAG defines Macrophytes as larger plants of fresh water which are easily seen with the naked eye, including all vascular plants (plants that bear seeds), bryophytes (mosses and liverworts), stoneworts (Characeae) and macro-algal growths.*				
Specific Actions to attain GEP				
Target	**Action**	**Project**	**MM**	**Indicative cost to deliver these Actions**
5.1: Nutrient concentrations in the river, particularly phosphate, are sufficiently low to sustain the expected communities of macrophytes associated with healthy chalk rivers and filamentous algae cover in-stream is low Carshalton WB by 2015 Croydon-Wandsworth WB by 2027	5.1.1 – As part of their statutory requirement to reduce orthophosphate concentrations emerging from Beddington STW to <1mg/l under the Urban Waste Water Treatment Directive, Thames Water have included orthophosphate stripping in their AMP6 Business Plan and work towards obtaining Ofwat's agreement (due in 2014) for it to be implemented at the earliest possible opportunity and no later than Year 5 of AMP6 (2020).	None	N/A	This Action is being fulfilled by Thames Water's ongoing preparation of their AMP6 Business Plan for submission to Ofwat in 2014. Liaison, additional financial outlay for further investigations and future recommendations for good practice working that maintain required treated effluent discharge quality will be led by the EA, Thames Water and Ofwat.
	5.1.2 – Address and reduce diffuse sources of pollution, such as misconnected pipes and urban surface runoff, sufficiently to enable macrophyte communities with a GEP RMNI index score of 5.8 or lower to thrive.	A2, A4, B12, C1, C2, B34	3, 6, 9	These Actions are likely to be fulfilled by Thames Water and the EA in part at least, with additional expert input from the TAG as appropriate.

	5.1.3 – Projects relating to EA Mitigation Measure 10 (educate landowners on sensitive management practices – urbanisation). are undertaken in all locations identified as relevant as soon as possible and ongoing	None	10	Independent walkover surveys and associated investigations, eg dye tracing, mapping and consultations is **estimated to cost £35,000**. Independent monitoring could be run with volunteers at minimal cost once monitoring equipment and analysis capabilities were obtained (such as data-analytical computer software). It is also dependent on ongoing support from local authorities and other landowners and managers. **Estimated cost for start up and maintenance for 10 years £15,000**.
	5.1.4 – Agreement to be reached as to what an 'acceptable' percentage of in-channel cover by filamentous algae might be for GEP classification in each distinct functional reach. (Filamentous algae is indicative of elevated nutrient concentrations).	None	N/A	

	5.1.5 – Monitoring of nutrient concentrations is not currently undertaken consistently along all distinct functional reaches* of both Wandle water bodies. It is therefore necessary to expand the current monitoring programme to determine orthophosphate concentrations and those of other nutrients in all distinct functional reaches identified in both water bodies (safe physical access permitting) on an ongoing basis.	A1	N/A	Independent analysis of WSUD techniques for the whole catchment, including the suitability and cost-implications of various SUDS measures to help replicate natural drainage patterns is **estimated to cost £100,000**. The cost for installing SUDS and other measures to help replicate natural flow patterns varies considerably, depending on the location, ease of access, flood risk implications, ease of installation and maintenance, and whether such work can be incorporated into new developments or has to be retro-fitted. For example, **porous and permeable paving can cost between £100 per 20m^2 driveway** (to purchase and install gravel) and **£2000** to purchase and install Concrete Block Permeable Paving for the same area. The cost of installing micro-wetlands is highly dependent on a number of factors, notably land prices. An **indicative cost, based on a location in Hackbridge, LB Sutton, is estimated at £20,000 per acre to install, plus monthly management costs and health and safety considerations such as fencing.** Estimations of cost for the whole river would be dependent on walkover surveys and detailed feasibility studies drawing on the local authorities' Surface Water Management Plans. Design and installation of silt traps being retro-fitted in an urban environment is **estimated to cost £40,000** (small), **£50,000** (medium) and **£60,000** (large).

5.2: Hydromorphological conditions in the river enable fluvial flows and macrophyte habitats characteristic of healthy chalk rivers to exist Carshalton WB by 2015 Croydon-Wandsworth WB by 2027	5.2.1 – Undertake channel re-naturalisation and enhancement projects (including EA Mitigation Measures 1, 2, 3, 6 and 8) to increase flow, reduce detrimental siltation and increase the number of microhabitats (such as bars, islands, pool and riffle systems, meanders etc) so that it is sufficient to support macrophyte communities with a GEP RMHI index score of 6.4 or lower.	A4, A6, A7, A8, B4, B6, B1, B2, B5, B10/C9, B15, B16, B28, B30, B31, B33, B34, B11/C10, B14, B19, B20, B21, C1, C4, C5, C6	1, 2, 3, 6, 8	Work to improve habitat quantity and complexity is **estimated to cost between £150 and £350 per linear metre**, depending on the particular characteristics of a reach, such as accessibility for machinery and the level of channel reinforcement needing attention. Work would typically include introducing in-stream woody debris, sculpted gravel substrates, bank re-profiling, planting marginal vegetation, channel narrowing to increase flow velocity, and creating meanders and pool and riffle systems. Please note: costs for longer reaches may be less per linear metre than for shorter ones, due to economies of scale with equipment, materials and labour.
	5.2.2 – Urban River Survey monitoring is carried out along the full length of both water bodies (safe physical access permitting) and results aggregated to obtain scores for each distinct functional reach*. Repeated surveys will enable evaluation of project success and indicate whether any adjustments are necessary so that the system is always improving and there is 'no deterioration').	None	N/A	

5.3: Riverbed and bank substrate materials and condition are appropriate to support the expected macrophyte communities of a healthy chalk river Carshalton WB by 2015 Croydon-Wandsworth WB by 2027	5.3.1 – Undertake work to ensure substrate materials are appropriate (eg gravels dominate the bed rather than debris such as brick rubble) and their condition is good (eg gravels and sands are of an appropriate size for the river, and are not silted or impacted). Likewise, bank materials and condition are good (eg not reinforced or reveted wherever possible, taking into account urbanisation and flood protection requirements). Project work to conserve and enhance substrate should include EA Mitigation Measures 2, 3, 4, 6 and 8.	B1, B2, B14, B20, B21, B30, B33, C1, C4, C5, C6	2, 3, 4, 6, 8	As 5.2 above
	5.3.2 – Include substrate monitoring as part of the wider management monitoring for both water bodies to maintain condition and avoid deterioration over time.	None	N/A	
5.4: Macrophyte communities present are abundant, highly diverse and include good numbers of characteristic chalk river species. Carshalton WB by 2015 Croydon-Wandsworth WB by 2027	5.4.1 – Monitoring of macrophyte communities is not currently undertaken consistently along all distinct functional reaches of both Wandle water bodies (indeed the Carshalton water body is not currently assessed for macrophytes). It is therefore a priority to commence macrophyte community monitoring, using the River LEAFPACS methodology, annually along the full length of both water bodies (safe physical access permitting) and for the results to be shared so that projects to attain GEP can be evaluated and amended as necessary.	None	N/A	As 5.2 above

	5.4.2 – Projects to conserve and enhance the ecological value of in-stream, marginal, bankside and riparian habitat (including EA Mitigation Measures 1, 2, 3, 6, 8, and 10, and works to reduce or eliminate siltation, overshading, presence of INNS, filamentous algae dominance etc) are undertaken. These projects will cumulatively produce the following priority outcomes: Firstly, that the number of functional macrophyte groups continues to surpass its GEP N FG index score of 4.1 and remains higher than the lowest score recorded in 2012 of 7 in order to demonstrate 'no deterioration'. Secondly, that the number of truly aquatic species richness continues to surpass its GEP NTAXA index score of 5.3 and remains higher than the lowest score recorded in 2012 of 8 in order to demonstrate 'no deterioration'.	A6, A7, A8, B4, B5, B6, B10/C9, B15, B16, B28, B31, B32, B33 B11/C10, B14, B19, B20, B21, C1, C4, C5, C6	1, 2, 3, 6, 8, 10	

Wider Actions to improve the ecological functioning of the river				
Target	**Action**	**Project**	**MM**	**Indicative cost to deliver these Actions**
5.5: Macrophyte, shrub and tree communities present are those characteristic of high quality chalk rivers	5.5.1 – Work is undertaken to conserve and enhance the extent of macrophyte and tree species composition in each of the distinct functional reaches so that it reflects the most appropriate of the five standard categories of chalk watercourse (R1 = winterbournes, R2 = perennial headwaters, R3 = classic chalk streams, R4a = classic chalk rivers, R4b = mixed geology chalk rivers (Mainstone, 1999).	A4, A6, A7, B4, B5, B6, B10, B11, B12, B13, B14, B19, B20, B21, B28, B30, B31, B32, B33, C1, C4, C5, C6,	1, 2, 3, 6, 7, 8, 9, 10	Independent work to improve habitat quantity and complexity is **estimated to cost between £150 and £350 per linear metre**, depending on the particular characteristics of a reach, such as accessibility for machinery and the level of channel reinforcement needing attention. Work would typically include introducing in-stream woody debris, sculpted gravel substrates, bank re-profiling, planting marginal vegetation, channel narrowing to increase flow velocity, and creating meanders and pool and riffle systems. Please note: costs for longer reaches may be less per linear metre than for shorter ones, due to economies of scale with equipment, materials and labour

	5.5.2 – Work is undertaken to conserve and enhance the presence of *Ranunculus-Callitriche* species communities present on the Wandle, in recognition of their importance as UK Biodiversity Action Plan priority habitat types. These are formally defined as 'Rivers with *Ranunculion fluitantis* and *Callitricho-Batrachion* vegetation' (CB communities) and are characterised by the abundance of water-crowfoots (*Ranunculus* spp.). Many variants of this habitat type exist, depending on geology and river type. They are associated with different assemblages of aquatic plants including water cress, water-starworts, water parsnips, water-milfoils and water forget-me-not: the cover of these may exceed that of *Ranunculus* species. Three main habitat sub-types have been defined according to substrate type, and a few southern rivers (including the Wandle) show a transition from one sub-type to another, as geology changes from chalk to clay.	A4, A6, A7, B4, B5, B6, B10, B11, B12, B13, B14, B19, B20, B21, B28, B30, B31, B32, B33, C1, C4, C5, C6,	1, 2, 3, 6, 7, 8, 9, 10	5.5.3 This Action could be assisted via an MSc student desk-based research project

	5.5.3 – Research is carried out to identify whether the localised replacement of *Ranunculus* species by *Elodea* species has wider implications for chalk river ecosystem function, beyond the loss of important UK Biodiversity Action plan priority habitat type, or whether it provides the same ecological function (such as modifying flow, promoting fine sediment deposition and providing shelter and food for fish and invertebrates).	None	N/A	
5.6: The Wandle supports a mosaic of macrophyte habitats and rich biodiversity suitable for a wide range of aquatic and riparian faunal species	5.6.1 – Management of the riparian landscape is such that macrophytes, trees and shrubs provide important variety of habitat with structural complexity (such as standing dead wood, large woody debris, nesting and roosting sites, exposed tree roots, dappled shade, channel braiding etc) without dominating the landscape and resulting in lowered biodiversity or reduced human access. (The riparian landscape is important for ecological functioning including reducing sediment and nutrient input to the river. It also facilitates connectivity between terrestrial and aquatic communities. Interactions between land and water are to be encouraged wherever possible, taking into account flood protection requirements and health and safety).	A4, A6, A7, B4, B5, B6, B10, B11, B12, B13, B14, B19, B20, B21, B28, B30, B31, B32, B33, C1, C4, C5, C6	2, 6, 8, 10	This Target and Actions are likely to be lead by local authorities and other landowners and managers, with guidance from the EA and environmental NGOs. Independent work to improve habitat quantity and complexity is **estimated to cost between £150 and £350 per linear metre**, depending on the particular characteristics of a reach, such as accessibility for machinery and the level of channel reinforcement needing attention. Work would typically include introducing in-stream woody debris, sculpted gravel substrates, bank re-profiling, planting marginal vegetation, channel narrowing to increase flow velocity, and creating meanders and pool and riffle systems. Please note: costs for longer reaches may be less per linear metre than for shorter ones, due to

	5.6.2 – Management of amenity green spaces is sensitive to the needs of wildlife and is clearly communicated to visitors as a benefit for engagement, education and public enjoyment. (Examples include relaxation of mowing regimes, particularly in proximity to banksides; creation and / or maintenance of 'wild refuge' areas where wildlife can remain undisturbed, particularly during key lifecycle stages such as nesting; installation of bird and bat boxes to compensate for any lacking natural sites).	None	10	economies of scale with equipment, materials and labour.
	5.6.3 – Invasive non-native species (INNS) are controlled or eradicated according to the Wandle Invasive Species Action Plan.	A7, A8, B4, B5, B6, B10, C9,	1, 3, 6, 8, 10	

	5.6.4 – As part of the Biodiversity Action Plan aim to re-introduce water vole to the River Wandle, regular surveying (perhaps using the water vole Habitat Suitability Index) should be undertaken along the full length of both water bodies, with particular attention paid to the upper Wandle planned re-introduction zone – between Wandle Park, Croydon and Morden Hall Park, Merton – to monitor suitability. Such monitoring will also provide broader assessment of the flora and wider landscape than can be surmised from the River LEAFPACS survey. Habitats that are suitable for water vole are also suitable for a wide range of other faunal species such as birds and bats, and thus may provide a helpful proxy of wider ecosystem quality. The H.S.I. survey can also highlight wider enhancement opportunities such as bank softening	B27, B28	N/A	
5.7: Effluent channel from Beddington STW incorporates refuges for wildlife in the event of an accidental harmful discharge from the STW	5.7.1 – Canalised effluent channel on Mill Green is modified (preferably to enable the establishment of natural processes), to provide wildlife refuges from any pollution incidents.	None	9	Estimation of cost for this work is difficult without undertaking a site assessment first; particularly as it features constant high flow velocity and large volumes of water and consequently large quantities of concrete reinforcement and other engineering structures. Accessibility of machinery is anticipated to be easy however. Independent work to re-naturalise banks and create refuges for fish and other wildlife at this site is **could potentially cost in excess of the anticipated cost of between £150 and £350 per linear metre** at sites with less engineering on

				the River Wandle but it is expected that Thames Water would fund this in part at least. Work would typically include introducing in-stream woody debris, sculpted gravel substrates, bank re-profiling, planting marginal vegetation, channel narrowing and creating meanders and pool and riffle systems. Please note: costs for longer reaches may be less per linear metre than for shorter ones, due to economies of scale with equipment, materials and labour.

7.4: Macroinvertebrates

Our Vision is a river that supports a mosaic of habitats with high biodiversity

Wandle Catchment Plan Objective 6: The diverse invertebrate communities associated with chalk rivers are abundant along the river, playing important roles in ecosystem function and complexity, such as providing a food source for other wildlife

"It's important to have a wide range of aquatic insects, but there are too many midges in some places – we should encourage the birds and bats to eat them, and get the river flowing faster in these areas."

- from Ketso community and stakeholder workshops

Aquatic invertebrates are a key biological element group under WFD. Like macrophytes and phytobenthos, invertebrates can be good indicators of water quality, particularly the impacts of pollution. The group is very diverse and includes families such as mayflies and stoneflies (which can be very sensitive to pollution) to worms and midges (which are very pollution-tolerant).

Since they are constantly exposed to any variations in aquatic water quality, as well as being relatively easy to sample and identify to group level with the naked eye, sampling aquatic invertebrates can be used as a method which allows rapid and accurate water quality assessments according to the sensitivity of the families which are found.

Aquatic invertebrates are monitored for WFD using RICT (the UKTAG's River Invertebrate Classification Tool) and are classified using 4 different indices:

- ASPT (Average Score Per Taxon): organic pollution index
- No Taxa (Number of Taxa): diversity index
- LIFE (Lotic Invertebrate Flow Evaluation): flow sensitivity index
- PSI (Percentage Sediment Index) : sedimentation index

As with macrophytes, these observed scores are then compared to expected scores for natural, undisturbed reference sites to produce a final Ecological Quality Ratio (EQR) score. Again, the EQR scores are divided into 5 bands for WFD purposes: High, Good, Moderate, Poor and Bad.

Invertebrates on the River Wandle are currently classified as Good on the Carshalton water body, whilst the Croydon-Wandsworth water body is classified as Moderate. As a consequence of this failing score, sampling for WFD assessment since 2009 has taken place only on the Croydon-Wandsworth water body. However, invertebrate monitoring is carried out on the Carshalton arm under other drivers: a drought monitoring site at Three Arch Bridge has been sampled twice yearly since 2013, with the same methodology as sampling for WFD. As a result, this data can be used to confirm Good WFD classification in the future. (River habitat data will also be collected at this site in 2014, and every six years subsequently).

Current WFD failure for invertebrates on the Croydon-Wandsworth water body is due to a combination of water quality and habitat issues: phosphate levels are too high, leading to indirect effects including algal growth smothering substrates, and data from 2009-10 indicates diurnal fluctuations in dissolved oxygen and spikes of ammonium.

In many areas the river also suffers from excessive sedimentation and lack of suitable habitat due to its heavily urbanised, modified channel and absence of macrophytes, causing stress to the invertebrate community in a number of ways:

- Increased hard and impermeable surfaces across the river's catchment can quickly lead to greater quantities of contaminated urban surface runoff entering the river in times of heavy rainfall. This can render the water turbid from re-suspension of riverbed sediments or toxins, as well as particulates flushed in from roads and storm drains.

- Nutrient enrichment from Beddington STW, misconnected pipes and other diffuse pollution sources can cause both acute and chronic stress to invertebrates in the form of short-term toxic spikes and ongoing degradation of water quality. Larger pollution incidents from Beddington STW are probably also responsible for keeping populations of more sensitive invertebrates suppressed and unable to re-establish.

- Modification of the river channel including weirs and over-widening causes impoundment of water and degrades natural flow and sediment transport regimes. This leads to excessive fine sedimentation which can affect invertebrates by smothering gravels and reducing habitat suitability for many macrophytes which invertebrates need.

- Culverting, straightening and deepening many areas of the river's channel has reduced naturally complex substrates to smooth, bare concrete or clay which are difficult for invertebrates to cling onto, or otherwise escape high flows.

Following the EA's Stage 3 investigation for WFD failure in December 2012, this expert advice has been received:

- The invertebrate community is likely to be stressed by a range of pressures, including pollution, flow, sedimentation and lack of macrophytes.

- These factors, and possibly more that are currently unidentified, interact with one another in ways that make it difficult to isolate any particular actions that would be sure to improve invertebrate EQR score.

- General improvements to riverine conditions, such as those designed more specifically to benefit fish and macrophytes, would also be likely to benefit invertebrates: in particular, identifying and reducing misconnections, and preventing and remediating runoff from the urban environment.

- Instead of focusing on setting specific targets for invertebrates at this stage, expert opinion is that long-term monitoring of the individual scores for each index should be undertaken. These can then be analysed to identify any trends that show a response to river process restoration which might suggest what is achievable for invertebrates on the Wandle.

- After some initial improvement, invertebrate response may plateau despite any continuing habitat enhancement work, and this level may represent GEP for the Wandle.

An overall EQR score of 0.71 or above is the threshold for achieving 'Good' status for invertebrate communities. As above, this overall EQR is calculated using 4 biotic indices (ASPT, No Taxa, LIFE and PSI), which are also recommended for long-term monitoring to establish a realistic GEP score for invertebrates on the Wandle.

It should be noted that all the classifications above have been derived using existing classification tools: once new classification tools (eg WHPT rather than BMWP) are introduced, some classifications may alter as an artefact of this new process.

The Actions in Objective 6 (at the end of this chapter) are designed to address current pressures upon invertebrates in the River Wandle.

They complement the underlying priority aims for the river of improving water quality and restoring naturalised hydromorphological functioning (Objectives 1-3). Actions to improve habitat quality (Objective 5) will in turn benefit invertebrates in providing refuge from flood conditions or pollution incidents, influencing flow dynamics and binding nutrient-rich sediments.

In addition to targets for attaining GEP, efforts should be made to conserve the nationally uncommon populations of *Bdellocephala punctata* that have been recorded on both Wandle water bodies. *Bdellocephala punctata* is the largest of Britain's flatworm species. It is geographically wide-ranging in Britain across a number of distinct distribution types, but is often scarce in the habitats where it does exist. Actions to enhance habitat in adjoining areas (Objective 5) may help encourage an expansion of areas currently colonised at Goat Bridge in LB Sutton (confirmed by EA sampling in spring 2014), Morden Hall Park in LB Merton and on the Carshalton water body.

Reintroduction of species should be considered on a case by case basis, if they were present historically and can be shown to cope with enhanced prevailing conditions. For biosecurity reasons, reintroductions should be carefully controlled, especially in relation to the source of any reintroduction specimens.

<u>Further information required:</u>

Further detailed interpretation of current and historic invertebrate data

On the Carshalton arm, use invertebrate data gathered for drought monitoring purposes to confirm Good classification for WFD.

Long-term monitoring is recommended to establish a realistic GEP score for invertebrates on the Wandle.

Monitoring and further research should be undertaken for the nationally uncommon flatworm *Bdellocephala punctata* populations currently extant, to ensure they remain and, if possible, expand.

<u>Further reading:</u>

Appendix A: Environment Agency (2014) WFD summary sheet

Knight, L. (2011) *The River Wandle (Carshalton branch): a baseline ecological survey prior to habitat restoration works (September 2010)*

7.4.1: Macroinvertebrates action tables

The information in these tables has been assembled from suggestions made in community consultations, TAG meetings and specific stakeholder input to develop a series of Objectives, Targets and Actions. Information on existing projects has been collated and used to identify gaps, and where additional projects may need to be developed to fulfil Actions, Targets and Objectives.

Actions to achieve the Catchment Plan's overall aim for for habitat and wildlife: the river supports a mosaic of habitats with high biodiversity

Objective 6: Invertebrates: the diverse communities associated with chalk rivers are abundant along the river, playing important roles in ecosystem function and complexity, such as providing a food source for other wildlife				
Specific Actions to attain GEP				
Target	**Actions**	**Project**	**MM**	**Indicative cost to deliver these Actions**
6.1: Water quality in the river is improved sufficiently to enable the expected invertebrate communities associated with healthy chalk rivers to be sustained. Carshalton WB by 2015	6.1.1 – As part of their statutory requirement to reduce orthophosphate concentrations emerging from Beddington STW to <1mg/l under the Urban Waste Water Treatment Directive, Thames Water are to put orthophosphate stripping into their AMP6 Business Plan and work towards obtaining Ofwat's agreement (due in 2014) for it to be implemented at the earliest possible opportunity and no later than Year 5 of AMP6 (2020).	None	N/A	This Action is being fulfilled by Thames Water's ongoing preparation of their AMP6 Business Plan for submission to Ofwat in 2014. Liaison, additional financial outlay for further investigations and future recommendations for good practice working that maintain required treated effluent discharge quality will be led by the EA, Thames Water and Ofwat.

Croydon-Wandsworth WB by 2027	6.1.2 – Address and reduce diffuse sources of pollution, such as misconnected pipes and urban surface runoff, sufficiently to enable invertebrate communities with an overall EQR (Ecological Quality Ratio) score of 0.71* or above to thrive. Particular attention should be paid to making progress towards Good / High scores for ASPT (organic pollution index) and Number of Taxa (diversity index). ** 0.71 is the threshold for achieving Good status.*	A2, A4, B12, C1, C2, B34	3, 6, 9, 10	These Actions are likely to be fulfilled by Thames Water and the EA in part at least. Independent work to undertake walkover surveys and associated investigations, eg dye tracing, mapping and consultations is **estimated to cost £35,000**. Independent monitoring to assist this could be run with volunteers at minimal cost once monitoring equipment and analysis capabilities were obtained (such as data-analytical computer software). It is also dependent on ongoing support from local authorities and other landowners and managers. **Estimated cost for start up and maintenance for 10 years £15,000**.
	6.1.3 – Projects relating to EA Mitigation Measure 10 (educate landowners on sensitive management practices – urbanisation) are undertaken in all locations identified as relevant as soon as possible and ongoing	None	10	

	6.1.4 – Monitoring of nutrient concentrations is not currently undertaken consistently along all distinct functional reaches of both Wandle water bodies. It is therefore necessary to expand the current monitoring programme to determine orthophosphate concentrations and other key chemical parameters (particularly dissolved oxygen and ammonia) in all distinct functional reaches (safe physical access permitting) on an ongoing basis. Real-time monitoring (for periods of one month at least) is recommended as it will reveal evidence of spikes and diurnal variations that are important to invertebrates but may not be detected using spot sampling alone.	A1	N/A	Independent analysis of Water Sensitive Urban Design techniques for the whole catchment, including the suitability and cost-implications of various SUDS measures to help replicate natural drainage patterns is **estimated to cost £100,000**. The cost for installing SUDS and other measures to help attenuate surface runoff and replicate natural flow patterns varies considerably, depending on the location, ease of access, flood risk implications, ease of installation and maintenance, and whether such work can be incorporated into new developments or has to be retro-fitted. For example, **porous and permeable paving can cost between £100 per 20m^2 driveway** (to purchase and install gravel) and **£2000** to purchase and install Concrete Block Permeable Paving for the same area. The cost of installing Micro-wetlands is highly dependent on a number of factors, notably land prices. An **indicative cost, based on a location in Hackbridge, LB Sutton, is estimated at £20,000 per acre to install, plus monthly management costs and health and safety considerations such as fencing.** Estimations of cost for the whole river would be dependent on walkover surveys and detailed feasibility studies drawing on the local authorities' Surface Water Management Plans. Design and installation of silt traps being retro-fitted in an urban environment is **estimated to cost £40,000** (small), **£50,000** (medium) and **£60,000** (large).

6.2: Hydromorphological conditions in the river are characteristic of healthy chalk rivers and support good numbers of expected invertebrate communities Carshalton WB by 2015 Croydon-Wandsworth WB by 2027	6.2.1 – Undertake channel re-naturalisation and enhancement projects (including EA Mitigation Measures 1, 2, 3, 6 and 8) to create an appropriate flow regime that removes detrimental silt and increases the number of microhabitats (such as bars, islands, pool and riffle systems, meanders etc) without flushing away gravels or invertebrate refuge habitat. Progress towards achieving GEP can be measured by working towards enabling invertebrate communities with an overall EQR (Ecological Quality Ratio) score of 0.71* or above to thrive. Particular attention should be paid to making progress towards Good / High scores for LIFE (flow sensitivity index) and PSI (sedimentation index). * *0.71 is the threshold for achieving Good status.*	A4, A6, A7, A8, B4, B6, B1, B2, B5, B10/C9, B15, B16, B28, B30, B31, B33, B34, B11/C10, B14, B19, B20, B21, C1, C4, C5, C6	1, 2, 3, 6, 8	Independent work to improve habitat quantity and complexity is **estimated to cost between £150 and £350 per linear metre**, depending on the particular characteristics of a reach, such as accessibility for machinery and the level of channel reinforcement needing attention. Work would typically include introducing in-stream woody debris, sculpted gravel substrates, bank re-profiling, planting marginal vegetation, channel narrowing to increase flow velocity, and creating meanders and pool and riffle systems. Please note: costs for longer reaches may be less per linear metre than for shorter ones, due to economies of scale with equipment, materials and labour. As with other Actions relating to underpinning habitat enhancement works and restoration of chalk stream fluvial processes, it is difficult to estimate cost without reach-specific or structure-

	6.2.2 – Annual Urban River Survey monitoring is carried out along the full length of both water bodies (safe physical access permitting) and results aggregated to obtain scores for each distinct functional reach on an ongoing basis. (This will enable evaluation of project success and for any necessary adjustments to be made so that the system is always improving and there is 'no deterioration'.)	None	N/A	specific evaluation. However, comparable projects involving hydraulic modelling, weir removal, creating fish bypass channels, introducing woody debris and other habitat enhancements important to all fish life stages suggest **such work would cost some millions. Here are some examples of how the costs might accrue:** Modelling the feasibility of removing or modifying any weirs which are causing a barrier to fish migration and identify flood risk implications is **estimated to cost £100,000 to £200,000**. Physical removal of impoundments such as weirs is very heavily dependent upon the type of engineering that is involved in the structure. Comparatively simple structures are **estimated to cost £30,000 to remove per weir** though this may be reduced to £20,000 with removal of multiple weirs facilitating economies of scale. Conversely, to remove a large, heavily engineered weir and make good afterwards could cost as much as **£250,000 each costs may be higher where weirs are tied into river walls.** There are limited opportunities for the design and creation of a bypass channel for fish passage, including habitat enhancement important to fish life stages on the Wandle because of the highly urbanised landscape. Most opportunities exist only in parkland and conditions vary greatly. Thus an **estimated cost range is between £50,000 - £250,000**.

Wider Actions to improve the ecological functioning of the river

Target	Actions	Project	MM	Indicative cost to deliver this Action
6.3 Nationally uncommon species are conserved	6.3.1 – Populations of *Bdellocephala punctata* are conserved and where possible encouraged to expand through the enhancement of adjoining habitat. (*B. punctata* is the largest of Britain's flatworm species. It is geographically wide-ranging in a number of distinct distribution types, though it is often scarce in the habitats where it is found). On the River Wandle it has been recorded on the Carshalton water body and at Goat Bridge, Beddington Park and Morden Hall Park on the Croydon-Wandsworth water body.	None	N/A	N/A

7.5: Phytobenthos

Our Vision is a river that supports a mosaic of habitats with high biodiversity

Wandle Catchment Plan Objective 7: Good populations of phytobenthos associated with chalk rivers are present along the river

Also known as diatoms, phytobenthos are microscopic plants, typically algae, which live in or near the bottom of rivers and other freshwater systems. They form slippery brownish coverings known as 'biofilm' over larger plants and stones. Various species have different habitat preferences, including nutrient concentrations: as a result, the species present in a river, and their relative abundance, can say much about the water quality. Diatoms are the main phytobenthic groups that are used for such assessments: with distinctive silica shells, often intricately patterned, they are easy to identify under a microscope.

Diatoms are assessed using the standard DARES methodology (Diatom Assessment for River Ecological Status) to measure the River Trophic Diatom Index. This methodology involves counting the number of species present, assessing the proportion of each species in all the samples gathered, and comparing these observed figures to what might be expected in undisturbed reference conditions to produce an Ecological Quality Ratio (EQR) score.

WFD classifies EQR scores into 5 bands for Good Ecological Status: High, Good, Moderate, Poor and Bad. Failure to achieve a Good or High score for diatoms under WFD is most likely to be caused by nutrient concentrations (typically phosphate) being too high. However, no status criteria for GEP on HMWBs like the Wandle have yet been defined.

Water chemistry assessments on the Croydon-Wandsworth water body have already identified that phosphate concentrations in the mid to lower reaches of the river far exceed the standard required under both the Urban Waste Water Treatment Directive (<1mg/l) and the Water Framework Directive itself (0.12mg/l for Good status): mean concentration for the Wandsworth sampling site in 2011 was 2.87mg/l.

Unsurprisingly, therefore, the Croydon-Wandsworth water body has a Poor classification for phytobenthos, predominantly due to elevated phosphate concentrations and general nutrient enrichment from diffuse pollution, which exert a direct effect on populations of phytobenthos a situation which is unlikely to change until phosphate and other nutrient concentrations are lowered substantially. The main cause of these eutrophic conditions is the effluent from Beddington STW, which provides the majority of flow from the approximate midpoint of Croydon-Wandsworth water body. Even when phosphate stripping equipment is installed at Beddington STW in AMP6, phosphate may remain bound in the river's sediments for many years, releasing intermittently in high fluvial flows or other disturbance. Removing this bound-up source of eutrophication presents a serious challenge, but should nevertheless be a long-term Action.

By contrast, water chemistry on the Carshalton branch of the river already attains GEP, so phytobenthos on this water body is inferred to be Good, with a focus on ensuring no deterioration. However, more information is needed to help inform management practices for the future.

So far, phytobenthos sampling has taken place at only one site on the River Wandle, at Trewint Street in Wandsworth. Phytobenthos monitoring has not been carried out on the Carshalton water body due to the high alkalinity of the water: in areas of high alkalinity, the EA generally considers macrophytes to be the only tool which can provide a realistic measure of nutrient impact. This is due to the nature of the diatom classification tool, in which the taxa resulting in 'Good' status classifications tend to be those present in acidic waters.

Following the Environment Agency's stage 3 investigation for WFD failure in December 2012, expert advice confirms that the full suite of reasons for phytobenthos failure is currently unclear and likely to be complex:

- Nutrient concentrations on the Wandle generally are considered to be too high and likely to be causing stress to phytobenthos populations

- Efforts to reduce nutrients generally will be beneficial, but to what extent improvements can be expected in the phytobenthos EQR score, or how long it might take to achieve, is unknown

In view of this advice, the only specific quantifiable target that can reasonably be set for phytobenthos GEP at this stage is:

- Orthophosphate concentrations emerging from Beddington Sewage Treatment Works are <1mg/l (as required by the UWWTD).

As per the EA's advice for invertebrates (above) monitoring should be continued, and any changes observed after river restoration work analysed for trends that might reasonably suggest what is achievable for phytobenthos on the Wandle. This score can then be set as the Wandle's own GEP standard for phytobenthos.

Actions for Phytobenthos (Objective 7 at the end of this chapter) aim to address the issues set out above, building on the fundamental aims to improve water quality in the Wandle (Objective 2). Additionally, because of their close association with higher plants and gravel and stone substrates, diatoms will benefit from complementary Actions to enhance macrophytes and substrate (Objective 5) and channel morphology (Objective 3).

<u>Further information required:</u>

Long-term monitoring is recommended to establish a realistic GEP score for phytobenthos on the Wandle.

<u>Further reading:</u>

Appendix A: Environment Agency (2014) WFD summary sheet

7.5.1: Phytobenthos action tables

The information in these tables has been assembled from suggestions made in community consultations, TAG meetings and specific stakeholder input to develop a series of Objectives, Targets and Actions. Information on existing projects has been collated and used to identify gaps, and where additional projects may need to be developed to fulfil Actions, Targets and Objectives.

Actions to achieve the Catchment Plan's overall aim for habitat and wildlife: the river supports a mosaic of habitats with high biodiversity

Objective 7: Phytobenthos † – good populations associated with chalk rivers are present along the river

† Aquatic flora, typically algae, that live at or near the bottom of rivers and form slippery brownish coverings over larger plants and stones. An important group are diatoms, which are unicellular algae encased in silicate capsules that assume a wide variety of intricately patterned designs.

Specific Actions to attain GEP

Target	Actions	Project	MM	Indicative cost to deliver these Actions
7.1: Nutrient concentrations in the river, particularly phosphate, are sufficiently low to sustain good communities of diatoms associated with healthy chalk rivers. Carshalton WB by 2015 Croydon-Wandsworth WB by 2027	7.1.1 – Undertake further research for full understanding of the diatom communities most commonly associated with healthy chalk rivers, including their habitat preferences and relative abundance, so that SMART target projects can be carried out to encourage their colonisation of the river and conservation.	None	N/A	This Action is likely to be led by the TAG in liaison with the EA, Thames Water and Sutton & East Surrey Water companies.
	7.1.2 – Instigate a programme of annual monitoring using the standard DARES methodology (Diatom Assessment for River Ecological Status), employed by the EA, to create a robust baseline against which annual scores can be compared and longer term trends can be identified to infer the progress being made to attain GEP for phytobenthos.	None	N/A	This target is likely to be fulfilled by the EA with support from other experts.

	7.1.3 – As part of their statutory requirement to reduce orthophosphate concentrations emerging from Beddington STW to <1mg/l under the Urban Waste Water Treatment Directive, Thames Water are to put orthophosphate stripping into their AMP6 Business Plan and work towards obtaining Ofwat's agreement (due in 2014) for it to be implemented at the earliest possible opportunity and no later than Year 5 of AMP6 (2020).	None	N/A	This Action is being fulfilled by Thames Water's ongoing preparation of their AMP6 Business Plan for submission to Ofwat in 2014. Liaison, additional financial outlay for further investigations and future recommendations for good practice working that maintain required treated effluent discharge quality will be led by the EA, Thames Water and Ofwat.
	7.1.4 – Address and reduce diffuse sources of pollution, such as misconnected pipes and urban surface runoff, with particular reference to reducing phosphate concentrations.	A2, A4, B12, C1, C2, B34	3, 6, 9, 10	This Action is likely to be fulfilled by Thames Water and the EA in part at least. Independent walkover surveys and associated investigations, eg dye tracing, mapping and consultations is **estimated to cost £35,000**. Independent monitoring could be run with volunteers at minimal cost once monitoring equipment and analysis capabilities were obtained (such as data-analytical computer software). It is also dependent on ongoing support from local authorities and other landowners and managers. **Estimated cost for start up and maintenance for 10 years £15,000**. Independent analysis of WSUD techniques for the whole catchment, including the suitability and cost-implications of various SUDS measures to help replicate natural drainage patterns is **estimated at £100,000**. The cost for installing SUDS and other measures to help replicate natural flow patterns

				varies considerably, depending on the location, ease of access, flood risk implications, ease of installation and maintenance, and whether such work can be incorporated into new developments or has to be retro-fitted. For example, **porous and permeable paving can cost between £100 per 20m^2 driveway** (to purchase and install gravel) and **£2000** to purchase and install Concrete Block Permeable Paving for the same area. The cost of installing micro-wetlands is highly dependent on a number of factors, notably land prices. An **indicative cost, based on a location in Hackbridge, LB Sutton, is estimated at £20,000 per acre to install, plus monthly management costs and health and safety considerations such as fencing.** Estimations of cost for the whole river would be dependent on walkover surveys and detailed feasibility studies drawing on the local authorities' Surface Water Management Plans. Design and installation of silt traps being retro-fitted in an urban environment is **estimated to cost £40,000** (small), **£50,000** (medium) and **£60,000** (large).
	7.1.5 – Seek additional ways of reducing phosphate concentrations in the river (eg promoting domestic use of phosphate-free washing powder). The orthophosphate concentration standard for Good status under WFD is 0.12mg/l: phosphate stripping at Beddington STW alone is unlikely to achieve this downstream of the effluent channel at Mill Green, LB Sutton.	None	N/A	This Action is likely to be led by the TAG in liaison with the EA, Thames Water and Sutton & East Surrey Water companies.

SECTION 8: WIDER ECOLOGY, BIOLOGY AND BIODIVERSITY

Rivers and their associated ecological corridors are widely recognised as hotspots for biodiversity. Even in its modified state, the Wandle supports a range of wildlife and is an important part of the wider landscape. This wildlife is also an important attraction for local people who enjoy bird watching, fishing, photography and the opportunity to connect with the natural world.

Plant species may be naturally established, translocated by the wind or movement of animals or birds, deliberately introduced by river enhancement schemes, or accidentally spread by people (for instance by emptying garden ponds into wetlands or the Wandle itself). Similarly, animals may be either naturally established, deliberately reintroduced (eg water voles) or released as invasive non-native species (eg terrapins).

8.1: UK BAP Species

"We like it that water voles, eels and trout are being encouraged to return to the Wandle."

- from Ketso community and stakeholder workshops

The UK Biodiversity Action Plan (UK BAP) was published in 1994, as the UK Government's response to the Rio de Janeiro Convention on Biological Diversity (CBD) of 1992.

The UK was the first country to produce a national biodiversity action plan to identify the priority species and habitats which were the most threatened and in need of conservation action. The original species lists in the UK Biodiversity Action Plan (UK BAP) were updated in 2007, and have now been succeeded by the UK Post-2010 Biodiversity Framework, published in July 2012. However, the UK BAP lists of priority species and habitats remain important focal points for conservation management, and have been used to draw up country-level statutory lists of priority species for England, Scotland, Wales and Northern Ireland (JNCC).

At the time of writing this Catchment Plan, the Wandle provides habitat for several UK Biodiversity Action Plan (BAP) species. The Catchment Plan partners hope that future river restoration and other improvements will permit natural or anthropogenic reintroduction of several more. A current assessment of the Wandle's BAP species is presented below:

Current species	**Measures for improvement**
European eel *(Anguilla anguilla)*	Habitat and fish passage improvements
Trout *(Salmo trutta)* (both migratory and non-migratory life forms)	Habitat and fish passage improvements
Potential future species	**Measures to improve potential for natural recolonisation**
Otter *(Lutra lutra)*	Fish population improvements
Salmon *(Salmo salar)*	Sporadic individuals have been reported. Widespread fish passage improvements would be needed to enable free migration from the Thames throughout the Wandle
Sea trout *(Salmo trutta)*	Removal or modification of weirs and other obstructions to enable free migration from the Thames throughout the Wandle
Potential future species	**Measures for improvement to enable reintroduction**

Water vole *(Arvicola terrestris)*	Last reliably reported on the Wandle at Wilderness Island in the 1980s (Steel and Coleman, 2012). Widespread habitat and connectivity improvements are needed: work is being undertaken to create backwaters and soft river margins, and remove large weirs and culverts, enabling establishment of interconnected meta-populations for long-term sustainability. Water vole reintroduction may also be threatened by predation from brown rats in the river corridor
White-clawed crayfish *(Austropotamobius pallipes)*	None present: Smee records absence from the upper Wandle in the 1870s, and his attempts at introduction were unsuccessful (Smee, 1872). Habitat and water quality improvements would be required before any further introductions

Fig 8a: A summary of the Wandle's BAP species

<u>Further reading:</u>

London Wildlife Trust (2009) *A Water Vole Reintroduction Feasibility Study for the River Wandle*

8.2: Other species of interest

"We like watching herons, grey wagtails, egrets and moorhens, and especially kingfishers flashing past. Viewing hides along the river would help more people to appreciate the wildlife without disturbing it."

- from Ketso community and stakeholder workshops

The River Wandle provides habitat for several rare species which are not listed under UK BAP but are still considered to be of conservation interest:

- Bullhead *(Cottus gobio)* is listed in Annex II of the EC Habitats Directive as a species of European conservation interest from a conservation point of view. Bullhead are abundant in the upper Wandle, particularly in the Carshalton water body.

- The flatworm *Bdellocephala punctata* is the largest of Britain's flatworm species. It is geographically wide-ranging in Britain across a number of distinct distribution types, but is nationally uncommon and often scarce in the habitats it does inhabit. *Bdellocephala punctata* has been recorded at Goat Bridge in LB Sutton, Morden Hall Park in LB Merton and on the Carshalton water body.

- Little egret (*Egretta garzetta garzetta)* disappeared from Britain until the 16th century, and only began to recolonise from France and the Netherlands in the late 1980s. Individuals are frequently sighted on both Wandle water bodies, and may start breeding (Steel and Coleman, 2012).

Further species of interest include:

- Aquatic plants: the river reflects a typical progression of macrophytes, from communities which favour smaller, faster flowing watercourses in the headwaters, to those associated with slower-flowing and more nutrient rich environments in its lower reaches. Notable species include classic CB communities in the Carshalton headwaters (including brook water crowfoot and water cress) and hemlock water dropwort at Spencer Road Wetlands.

- Birds: iconic species including kingfishers (*Alcedo atthis*) and grey and yellow wagtails are present on the Wandle: until recently, Beddington Farmlands also hosted a nationally important population of tree sparrows (*Passer montanus*). Reed warblers and reed buntings have also been recorded breeding along the river (Steel and Coleman, 2012). In exceptionally cold weather, birds may migrate from Beddington Farmlands to the warmer microclimate provided by the Wandle at Watermeads.

- Bats: a number of species are associated with the Wandle, including Daubenton's and pipistrelles. Beddington Farmlands is also one of the best sites in London for bats, including noctules, Leisler's and Nathusius' (Steel and Coleman, 2012).

In addition to the BAP species listed in Section 8.1, the following species is currently being introduced:

- Mayfly *(Ephemera danica)* is present on almost all chalkstreams, but has rarely been recorded on the Wandle, and is believed to have become locally extinct during the Industrial Revolution.

  With appropriate biosecurity measures and consent from Natural England, approximately 7 million *danica* eggs were harvested from the Hampshire Avon at West Amesbury in June 2014. After incubation and monitoring up to the penultimate stage of development, these were introduced to the Culvers Island area of the Wandle c3 weeks later: monitoring will be undertaken by the Wandle Piscators' Riverfly monitoring project (pers comms. Cyril Bennett and William Tall, 2014).

8.3: Invasive non-native species (INNS)

"We don't like seeing the river being taken over by Himalayan balsam and floating pennywort. We need to know more about invasive species and how to control them."

- from Ketso community and stakeholder workshops

Invasive non-native species (INNS) are usually defined as plants or animals which cause unacceptable damage after being spread by humans, deliberately or unintentionally, beyond the areas where they naturally evolved.

In their new habitats, which they have often reached via anthropogenic trade, transport, travel or tourism, INNS thrive where the natural environment has already been unbalanced by urban development and other human activities. Free from their co-evolved enemies, competitors and parasites, they multiply and spread rapidly along landscape features such as roads, railway lines, footpaths and rivers, outcompeting native species and sometimes re-engineering whole landscapes and ecosystems (Pike, 2014).

Although not specifically assessed for WFD purposes, INNS already present a wide range of very real threats to the ecology of rivers like the Wandle. As such they may contribute to, or even cause, WFD deterioration or failure and are considered within mitigation measures by the EA. A current assessment of river-related INNS and their potential threats to the Wandle's WFD status is presented below:

INNS	Carshalton water body	Croydon - Wandsworth water body	Specific location(s)	Threat to WFD status	Control measures

Aquatic, emergent or riparian plants					
Canadian pondweed *(Elodea canadensis)*		Present	Throughout	WFD: Macrophytes	Clear by hand
Floating pennywort *(Hydrocotyle ranuculoides)*	Present	Present	Wilderness Island downstream	WFD: Macrophytes	Spray with glyphosate or hand clear
Himalayan balsam *(Impatiens glandulifera)*	Formerly present, now cleared	Present	Almost cleared above Beddington Park; pervasive downstream	WFD: Fish (siltation)	Clear by hand
Giant hogweed *(Heracleum mantegazzianum)*	Present	Present	Intermittently throughout	WFD: Fish (siltation) plus human health	Dig up (cut tap root) or spray with glyphosate
Japanese knotweed *(Fallopia japonica)*		Present	Intermittently throughout	WFD: Macrophytes	Inject with glyphosate
Nuttall's waterweed *(Elodea nuttallii)*		Present		WFD: Macrophytes	Clear by hand
Parrot's feather *(Myriophyllum aquaticum)*		Present	Spring pond in Beddington Park (plus Mapleton Rd, Wandsworth?)	WFD: Macrophytes	Shade out
Water fern *(Azolla filiculoides)*		Present	Morden Hall Park garden centre channel	WFD: Macrophytes	Clear by hand or introduce *Stenopelmus rufinasus* weevil
Birds and insects					
Canada goose *(Branta canadensis)*	Present	Present	Intermittently throughout	Water quality: eutrophication	Trap or prick / oil eggs
Chinese mitten crab *(Eriocheir sinensis)*		Present	Merton Abbey Mills downstream	WFD: Fish / Invertebrates	No known control
Imminent threats					
American signal crayfish *(Pacifastacus leniusculus)*	Not yet recorded	Not yet recorded		WFD: Fish / Invertebrates	Stringent biosecurity: no known control
Australian swamp stonecrop (New Zealand pygmyweed) *(Crassula helmsii)*	Not yet recorded	Not yet recorded		WFD: Macrophytes	Shade out

Mink *(Neovison vison)*	Not yet recorded	Not yet recorded in 1-year monitoring programme c2008	Potential spread from from Barnes wetland via Thames	WFD: Fish	Monitoring and trapping
Ponto-Caspian shrimp *(Dikerogammarus villosus, Dikerogammarus haemobaphes)*	Not yet recorded	Not yet recorded		WFD: Fish / Invertebrates	Stringent biosecurity: no known control
Topmouth gudgeon *(Pseudorasbora parva)*	Not yet recorded	Not yet recorded		WFD: Fish / Invertebrates	Stringent biosecurity: rotenone poisoning
Quagga mussel *(Dreissena bugensis rostriformis)*	Not yet recorded	Not yet recorded		WFD: Fish / Invertebrates	Stringent biosecurity: no known control except physical clearance
Zebra mussel *(Dreissena polymorpha)*	Not yet recorded	Not yet recorded		WFD: Fish / Invertebrates	Stringent biosecurity: no known control except physical clearance

Fig 8b: INNS which may threaten the Wandle's WFD status

From a point of view of potential WFD status deterioration on the Wandle, the following may be worth noting:

- INNS generally: comparison of current information to the *Wandle Catchment RCS Survey* (Green, 1996) suggests that many INNS have spread significantly through the Wandle catchment in recent years, and new INNS have arrived. Some control measures have been implemented by the EA and volunteers, but these efforts need to be maintained and extended to avert likely progressive deterioration.

  The Wandle Catchment Plan's Fish TAG regards Chinese mitten crabs (CMC) and American signal crayfish (ASC) as the greatest potential threats to the Wandle's fish populations. CMC are already present on the river and can migrate upstream via eel passes: control may be possible at distinct times of migration, but these are also likely to coincide with downstream eel migration (September – November) and upstream movement by elvers (April – May). ASC would be unable to reach the Wandle independently but there is a serious risk of deliberate anthropogenic introduction. Other crayfish species are known to exist in Greater London (eg Louisiana red swamp crayfish *Procambus clarkii*).

- Himalayan balsam (HB): a recent study suggests that HB infestation may promote significant soil loss in riparian areas. HB overshades native vegetation before dying back in the winter, leaving soil exposed to erosion by precipitation and fluvial flow: as a result, for every HB-infested kilometer of river bank up to 10 tonnes of nutrient-rich sediment may be deposited in rivers every year (Greenwood and Kuhn, 2013).

Volunteers have already cleared HB from the Carshalton water body and are now addressing the Croydon-Wandsworth water body, working downstream year on year.

- Canadian pondweed: there is strong anecdotal evidence that CB communities on the Wandle, particularly *Ranunculus*, are being replaced by *Elodea canadensis*, most likely as a consequence of increased nutrient concentrations and reduced flow. Further evidence is needed to confirm this. Canadian pondweed was recorded around Carshalton Ponds and the Grove in 1974 (Twilley and Wilks, 1974), and may have been present before this time.

  Floating pennywort (FP): since its probable first appearance at Wilderness Island (Carshalton) c1999 (Derek Coleman, 2014) FP has spread very rapidly to colonise all downstream reaches of the Wandle. At least £150,000 has already been spent by the EA on emergency clearance of FP for flood risk management purposes, while voluntary organisations like the Wandle Trust, London Wildlife Trust (Wilderness Island group) and Morden Hall Park Angling Club are struggling to keep backwater fish refugia clear of this rapidly-spreading INNS.

In order to protect the Wandle from the spread of existing INNS and incursions by new species, biosecurity guidelines should be heavily promoted to all river users: in particular, GBNNSS's Check-Clean-Dry and Be Plant Wise campaigns.

<u>Further information required:</u>

Further research into the impact of *Elodea canadensis* on CB communities (especially *Ranunculus*)

<u>Further reading:</u>

Environment Agency and Wandle Trust: *Invasive Non-Native Species Action Plan*

Francis, ed (2012) *A Handbook of Global Freshwater Invasive Species*

Green (1996) *Wandle Catchment RCS Survey*

Greenwood and Kuhn (2013) *Does the invasive plant, Impatiens glandulifera, promote soil erosion along the riparian zone? An investigation on a small watercourse in northwest Switzerland*

Pike (2014) *A Pocket Guide to Balsam Bashing and How to Tackle Other Invasive Non-Native Species*

Wandle Forum Landscape and Biodiversity Group (2010) *Wandle Invasive Non-Native Species Plan*

SECTION 9: ECOSYSTEM SERVICES

The concept of ecosystem services (ES) emerged in the late 1980s as a structure for defining the direct or indirect benefits provided for people by naturally-functioning ecosystems (Everard, 2012).

The most widely accepted classification system, formulated by the Millennium Ecosystem Assessment (MA) of 2005, groups ES into four primary categories: Supporting, Provisioning, Regulating and Cultural. Their interactions are displayed in Fig 9a below:

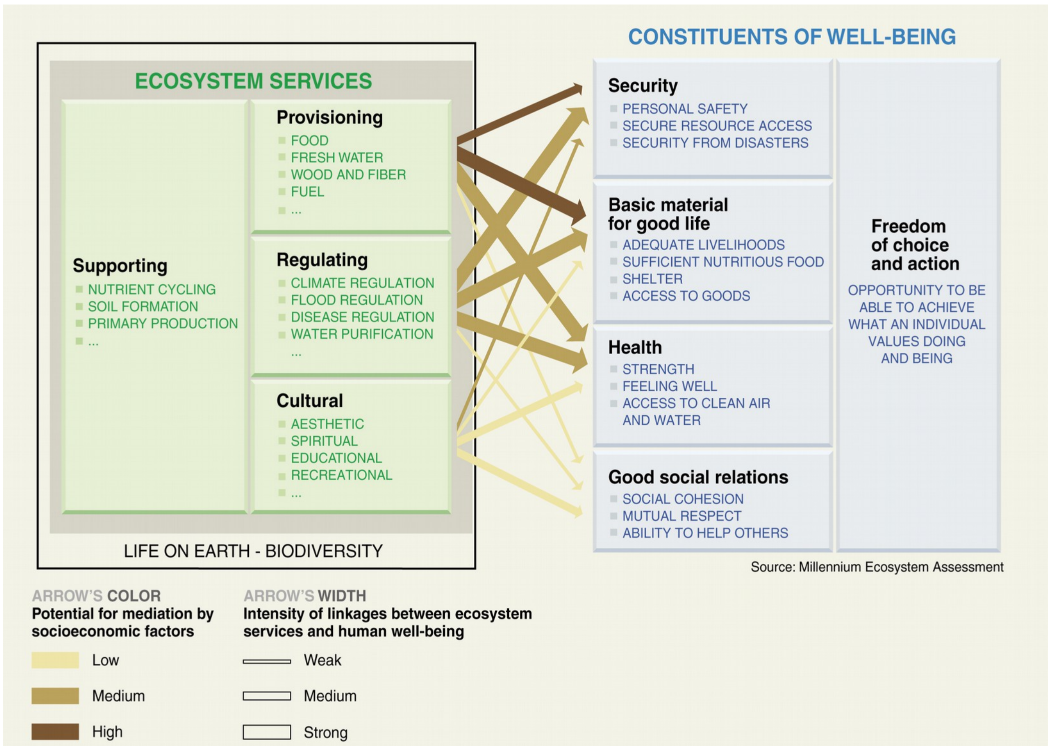

Fig 9a: Ecosystem service benefits as described by the Millennium Ecosystem Assessment (MEA), 2005

Ecosystem service benefits to people can be measured without ascribing a monetary value to them. This is helpful because it is not yet possible to describe all benefits in financial terms, and the methods by which this might be attempted are not yet fully developed (although studies like the UK's National Ecosystem Assessment in 2011 ascribed a wide range of economic values including £1.5bn per year for clean water produced by the UK's inland wetlands, and £300 per person per year in health benefits from living near green space like the Wandle corridor).

As part of the Ecosystem Approach, outlined in Section 1.3, the Wandle Catchment Plan assessed the current ecosystem services provided by the River Wandle and its catchment in order to identify:

- The values people place on the ecosystem service benefits which they derive from the riverine landscape. This has helped to define GEP for the Wandle: a river that has been heavily modified for societal benefit needs to keep societal interests and priorities integrated with any ecologically driven management approach.

- How ecosystem service benefits may be affected by the achievement of GEP. This will help to guide river restoration activities, in order to achieve the best results with multiple benefits wherever possible.

In order to meet these objectives, an MSc research project (Moore, 2012) was undertaken in summer 2012 at the same time as the Wandle Catchment Plan's community consultations. This research incorporated data from the consultation and a previous unpublished assessment of existing ecosystem services derived from the Wandle, which was undertaken by the EA and the Wandle Trust in 2011 (Everard et al., unpublished data). The MSc research project made several observations and recommendations which have been incorporated into the development of this Catchment Plan. The information will also be shared with other relevant strategies and plans in the Wandle area, and is appended to this Catchment Plan in Appendix G.

The values of ES can be based on qualitative information, such as public opinion: this was the approach used during this Catchment Plan's community consultations. It is important to note that such values may change through time with varying circumstances, eg increased publicity for a particular issue, or demographic changes in a local community.

Comments made during the community consultations were coded according to the 4 ecosystem service themes described in Figure 9a above. Local people currently value the river and its catchment for a variety of reasons. However the majority of values, accounting for more than 75% of all the responses, could be ascribed to cultural services such as recreational, educational, cultural heritage and aesthetic values (Figure 9b below).

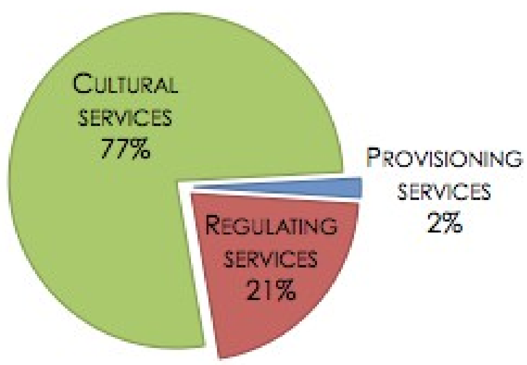

Fig 9b: Relative importance of ecosystem service categories as expressed by stakeholders in the Wandle Catchment Plan community consultations (Moore, 2012)

The absence of supporting services (such as nutrient cycling and soil formation) being noted by the local community is likely to be due to the fact that these are less noticeable services: thus they are less likely to be cited by people, unless they have a strong ecological background. The unpublished ecosystem services assessment on the Wandle identifies that the current provision of supporting services is severely depleted due to pollution and urbanisation but also that, with the right restoration, there is the potential to restore some of these services. Additionally, participants in the community consultation did recognise that the cultural services they valued so highly are dependent on provisioning and regulating services, and that restoring and maintaining these will also enhance cultural services.

Of the values relating to cultural services, recreation (including angling) and tourism are currently the most highly valued benefits in the catchment, and are expected to increase notably in importance in the future. Likewise, social relations (which help foster social and environmental stewardship and community cohesion) are seen as a great benefit at present. Yet this service is also perceived to be the most degraded and was cited as a priority for improvement. This could be achieved through the creation of high quality, multi-functional landscapes, which can encourage positive neighbourhood interaction and an interest in and ownership of the local environment.

The Wandle has a strong industrial and cultural heritage, which is reflected in its status as the third most highly valued cultural service benefit. Cultural heritage engenders a strong sense of place. Education about the heritage of the Wandle is valued highly by local people, and this value is expected to increase in the future. However, stakeholders recognise that this will be achievable only if existing knowledge about local history and ecology is nurtured and passed on.

Overall, the greatest values local people place upon the provisioning and regulating services that the river and its landscape provide are for flood risk management, water purification and regulation, landscape and biodiversity features. Stakeholders recognise that ecological processes and environmental health underpin many of the other benefits they enjoy. Concerns centre on the extent of negative human impact on water quality (from pollution, litter and road runoff), the lack of education and awareness about these and other issues, and the lack of cohesive policy concerning management of the catchment. For the future, stakeholders' priorities focused on maintaining ongoing work to enhance biodiversity and landscape, improving access to the river, championing better education and policy, and, crucially, improving water quality.

Notably, the Catchment Plan's community consultation results (social science analysis) complement the ecological evidence (natural science analysis) that the River Wandle currently fails GEP on a number of biological and physico-chemical quality elements. This demonstrates three important points:

- Far wider benefits can be derived from rehabilitation of the natural riverine environment
- The concept of ecosystem services can be an effective communication tool for linking ecosystem health to societal goals
- Achieving GEP for the River Wandle can be made more meaningful for local people by discussing it in terms of the added benefits they will gain, rather than sticking to traditional technical terms

People in the Wandle catchment perceive GEP to be delivered through a multi-strand approach. Provisioning, regulating and cultural services must all be rehabilitated and enhanced and supporting services restored. Likewise, management needs to take into account societal values and interests so that more sustainable policy can be realised now, and for the long term.

These pieces of research align strongly with work carried out by other analysts, most notably in the fields of access to blue green spaces such as those provided by the Wandle (Alcock, 2014) and the social and community benefits of angling (Substance, 2012).

9.1: Wider benefits of ecosystem services

Ecosystem services provided by the Wandle are closely interrelated to many themes in this Catchment Plan.

These relationships are summarised in the sequence of tables below, which are intended to demonstrate the multiple benefits of delivering the Catchment Plan's objectives – including how these objectives will contribute to fulfilling many other strategic plans.

9.2: Water quantity

Objective	**1: Water Quantity**
Projects contributing to delivery of this objective	A3, B12, B14, B17, C2
Mitigation Measures being addressed	9, 10, 7
Numbers of volunteers involved	To be calculated, but volunteers are already identified as participating in 1 project delivering this Objective.
Skills: number of people trained and themes	Numbers of people to be calculated but themes include: native species planting and wetland creation.

Catchment Plan objectives overlap with a broad range of other strategies and plans under the following themes (including, but not limited to, the examples given below)	
WFD Statutory Legislation (eg River Basin Management Planning)	✓
Biodiversity (eg Biodiversity 2020, Mayor's London Plan)	✓
Water abstraction and resource management (eg Environment Agency's Catchment Abstraction Management Strategy, Local Authorities' Surface Water Management Plans, Water Companies' Water Resource Management Plans)	✓
Health and Wellbeing (eg Mayor's London Plan, LB Wandsworth's Health & Wellbeing Board)	✓
Planning and Green Infrastructure (eg All London Green Grid, Local Authorities' Local Plans – formerly LDFs)	✓
Economic Growth (eg Mayor's London Plan)	✓

9.3: Water quality

Objective	**2: Water Quality**
Projects contributing to delivery of this objective	A1, A2, A4, B3, B12, C1, C2
Mitigation Measures being addressed	9, 10

Numbers of volunteers involved	To be calculated, but volunteers are already identified as participating in 3 projects delivering this Objective.
Skills: number of people trained and themes	Numbers of people to be calculated but themes include: pollution monitoring and reporting, and riverfly assessments.

Service Category	Ecosystem Service	Examples of the benefits provided for people
Regulating Services	• Water purification • Hazard regulation • Water regulation • Pest regulation • Climate regulation • Air quality regulation	• Removal of pollutants, waste treatment • Soil retention helping sediment stabilisation and erosion protection • Reduced surface runoff volume / speed helping flood risk management: increased flood storage capacity, decrease in localised flood events • Control of invasive non-native species, pests and disease, • Reduced urban temperatures • Clean air
Provisioning Services	• Provision of fresh water	• Domestic and industrial use • Energy generation
Cultural Services	• Cultural heritage • Education opportunities • Social relations • Recreational activities	• Aesthetic appeal, artistic and spiritual value • Increased awareness of the natural environment and social factors such as industrial heritage and buildings • Neighbourhood cohesion and environmental stewardship • Physical and mental well-being, tourism, sport (fishing, paddling, wildlife watching etc)

Catchment Plan objectives overlap with a broad range of other strategies and plans under the following themes (including, but not limited to, the examples given below)	
WFD Statutory Legislation (eg River Basin Management Planning)	✓
Biodiversity (eg Biodiversity 2020, Mayor's London Plan)	✓
Water abstraction and resource management (eg Environment Agency's Catchment Abstraction Management Strategy, Local Authorities' Surface Water Management Plans, Water Companies' Water Resource Management Plans)	✓
Health and Wellbeing (eg Mayor's London Plan, LB Wandsworth's Health & Wellbeing Board)	✓
Planning and Green Infrastructure (eg All London Green Grid, Local Authorities' Local Plans – formerly LDFs)	✓
Economic Growth (eg Mayor's London Plan)	✓

9.4: Dynamics of flow

Objective	**3: Dynamics of flow**
Projects contributing to delivery of this objective	A4, B1, B3, B10/C9, B13, B14, B17, B18, B19, B20, B21, B28, B30, B31, B33, C1, C4, C5, C6
Mitigation Measures being addressed	1, 2, 3, 4, 5, 6, 7, 8, 9, 10
Numbers of volunteers involved	To be calculated, but volunteers are already identified as participating in 13 projects delivering this Objective.
Skills: number of people trained and themes	Numbers of people to be calculated but themes include: habitat suitability assessments, mink monitoring, riparian habitat management, scrub clearance and tree pruning, native species planting and wetland creation, and installation of flow deflectors.

Service Category	**Ecosystem Service**	**Examples of the benefits provided for people**
Regulating Services	• Water purification • Hazard regulation • Water regulation • Pest regulation • Climate regulation • Air quality regulation	• Removal of pollutants, waste treatment • Soil retention helping sediment stabilisation and erosion protection • Reduced surface runoff volume / speed helping flood risk management: increased flood storage capacity, decrease in localised flood events • Control of invasive non-native species, pests and disease, • Reduced urban temperatures • Clean air
Provisioning Services	• Provision of fresh water	• Domestic and industrial use • Energy generation
Cultural Services	• Cultural heritage • Education opportunities • Social relations • Recreational activities	• Aesthetic appeal, artistic and spiritual value • Increased awareness of the natural environment and social factors such as industrial heritage and buildings • Neighbourhood cohesion and environmental stewardship • Physical and mental well-being, tourism, sport (fishing, paddling, wildlife watching etc)

Catchment Plan objectives overlap with a broad range of other strategies and plans under the following themes (including, but not limited to, the examples given below)	
WFD Statutory Legislation (eg River Basin Management Planning)	✓
Biodiversity (eg Biodiversity 2020, Mayor's London Plan)	✓
Water abstraction and resource management	✓

(eg Environment Agency's Catchment Abstraction Management Strategy, Local Authorities' Surface Water Management Plans, Water Companies' Water Resource Management Plans)	
Health and Wellbeing (eg Mayor's London Plan, LB Wandsworth's Health & Wellbeing Board)	✓
Planning and Green Infrastructure (eg All London Green Grid, Local Authorities' Local Plans – formerly LDFs)	✓
Economic Growth (eg Mayor's London Plan)	✓

9.5: Fish and fisheries

Objective	**4: Fish and fisheries**
Projects contributing to delivery of this objective	A1, B1, B3, B10/C9, B11/C10, B13, B14, B20, B21, B22, B23, B24, B25, B26, B27, B28, B29, B30, B31, B33, C1, C3, C4, C5, C6
Mitigation Measures being addressed	1, 2, 3, 4, 5, 6, 8
Numbers of volunteers involved	To be calculated, but volunteers are already identified as participating in 19 projects delivering this Objective.
Skills: number of people trained and themes	Numbers of people to be calculated but themes include: invasive non-native species management, riparian habitat management, wetland creation and native species planting, scrub clearance and tree pruning, habitat suitability surveying, mink monitoring, riverfly assessment, basic weir notching and removal, eel pass and easement installation and monitoring, installation of flow deflectors.

Service Category	**Ecosystem Service**	**Examples of the benefits provided for people**
Regulating Services	• Water purification • Hazard regulation • Water regulation • Pest regulation • Climate regulation • Air quality regulation	• Removal of pollutants, waste treatment • Soil retention helping sediment stabilisation and erosion protection • Reduced surface runoff volume / speed helping flood risk management: increased flood storage capacity, decrease in localised flood events • Control of invasive non-native species, pests and disease, • Reduced urban temperatures • Clean air
Provisioning Services	• Provision of fresh water	• Domestic and industrial use • Energy generation

Cultural Services	• Cultural heritage • Education opportunities • Social relations • Recreational activities	• Aesthetic appeal, artistic and spiritual value • Increased awareness of the natural environment and social factors such as industrial heritage and buildings • Neighbourhood cohesion and environmental stewardship • Physical and mental well-being, tourism, sport (fishing, paddling, wildlife watching etc)

Catchment Plan objectives overlap with a broad range of other strategies and plans under the following themes (including, but not limited to, the examples given below)	
WFD Statutory Legislation (eg River Basin Management Planning)	✓
Biodiversity (eg Biodiversity 2020, Mayor's London Plan)	✓
Water abstraction and resource management (eg Environment Agency's Catchment Abstraction Management Strategy, Local Authorities' Surface Water Management Plans, Water Companies' Water Resource Management Plans)	✓
Health and Wellbeing (eg Mayor's London Plan, LB Wandsworth's Health & Wellbeing Board)	✓
Planning and Green Infrastructure (eg All London Green Grid, Local Authorities' Local Plans – formerly LDFs)	✓
Economic Growth (eg Mayor's London Plan)	✓

9.6: Macrophytes

Objective	**5: Macrophytes, trees and wider river habitat**
Projects contributing to delivery of this objective	A1, A2, A4, A6, A7, A8, B1, B2, B4, B5, B6, B10/C9, B11/C10, B12, B14, B15, B16, B19, B20, B21, B28, B30, B31, B32, B33, B34, C1, C2, C4, C5, C6
Mitigation Measures being addressed	1, 2, 3, 4, 6, 8, 9, 10
Numbers of volunteers involved	To be calculated, but volunteers are already identified as participating in 35 projects delivering this Objective.
Skills: number of people trained and themes	Numbers of people to be calculated but themes include: invasive non-native species management, riparian habitat management, wetland creation and native species planting, scrub clearance and tree pruning, eel pass installation and monitoring, habitat suitability surveying, mink monitoring, basic weir notching and removal.

Service Category	**Ecosystem Service**	**Examples of the benefits provided for people**

Regulating Services	• Water purification • Hazard regulation • Water regulation • Pest regulation • Climate regulation • Air quality regulation	• Removal of pollutants, waste treatment • Soil retention helping sediment stabilisation and erosion protection • Reduced surface runoff volume / speed helping flood risk management: increased flood storage capacity, decrease in localised flood events • Control of invasive non-native species, pests and disease, • Reduced urban temperatures • Clean air
Provisioning Services	• Provision of fresh water	• Domestic and industrial use • Energy generation
Cultural Services	• Cultural heritage • Education opportunities • Social relations • Recreational activities	• Aesthetic appeal, artistic and spiritual value • Increased awareness of the natural environment and social factors such as industrial heritage and buildings • Neighbourhood cohesion and environmental stewardship • Physical and mental well-being, tourism, sport (fishing, paddling, wildlife watching etc)

Catchment Plan objectives overlap with a broad range of other strategies and plans under the following themes (including, but not limited to, the examples given below)	
WFD Statutory Legislation (eg River Basin Management Planning)	✓
Biodiversity (eg Biodiversity 2020, Mayor's London Plan)	✓
Water abstraction and resource management (eg Environment Agency's Catchment Abstraction Management Strategy, Local Authorities' Surface Water Management Plans, Water Companies' Water Resource Management Plans)	✓
Health and Wellbeing (eg Mayor's London Plan, LB Wandsworth's Health & Wellbeing Board)	✓
Planning and Green Infrastructure (eg All London Green Grid, Local Authorities' Local Plans – formerly LDFs)	✓
Economic Growth (eg Mayor's London Plan)	✓

9.7: Macroinvertebrates

Objective	**6: Invertebrates**

Projects contributing to delivery of this objective	A1, A2, A4, A6, A7, A8, B1, B2, B4, B5, B6, B10/C9, B11/C10, B12, B14, B15, B16, B19, B20, B21, B28, B30, B31, B33, B34, C1, C2, C4, C5, C6
Mitigation Measures being addressed	1, 2, 3, 6, 8, 9, 10
Numbers of volunteers involved	To be calculated, but volunteers are already identified as participating in 25 projects delivering this Objective.
Skills: number of people trained and themes	Numbers of people to be calculated but themes include: invasive non-native species management, riparian habitat management, wetland creation and native species planting, scrub clearance and tree pruning, habitat suitability surveying, mink monitoring, riverfly assessment, basic weir notching and removal.

Service Category	**Ecosystem Service**	**Examples of the benefits provided for people**
Regulating Services	• Water purification • Hazard regulation • Water regulation • Pest regulation • Climate regulation • Air quality regulation	• Removal of pollutants, waste treatment • Soil retention helping sediment stabilisation and erosion protection • Reduced surface runoff volume / speed helping flood risk management: increased flood storage capacity, decrease in localised flood events • Control of invasive non-native species, pests and disease, • Reduced urban temperatures • Clean air
Provisioning Services	• Provision of fresh water	• Domestic and industrial use • Energy generation
Cultural Services	• Cultural heritage • Education opportunities • Social relations • Recreational activities	• Aesthetic appeal, artistic and spiritual value • Increased awareness of the natural environment and social factors such as industrial heritage and buildings • Neighbourhood cohesion and environmental stewardship • Physical and mental well-being, tourism, sport (fishing, paddling, wildlife watching etc)

Catchment Plan objectives overlap with a broad range of other strategies and plans under the following themes (including, but not limited to, the examples given below)	
WFD Statutory Legislation (eg River Basin Management Planning)	✓
Biodiversity (eg Biodiversity 2020, Mayor’s London Plan)	✓
Water abstraction and resource management (eg Environment Agency’s Catchment Abstraction Management Strategy, Local Authorities’ Surface Water Management Plans, Water Companies’ Water Resource	✓

Management Plans)	
Health and Wellbeing (eg Mayor's London Plan, LB Wandsworth's Health & Wellbeing Board)	✓
Planning and Green Infrastructure (eg All London Green Grid, Local Authorities' Local Plans – formerly LDFs)	✓
Economic Growth (eg Mayor's London Plan)	✓

9.8: Phytobenthos

Objective	**7: Phytobenthos**
Projects contributing to delivery of this objective	A2, A4, B12, B34, C1, C2
Mitigation Measures being addressed	3, 6, 9
Numbers of volunteers involved	To be calculated, but volunteers are already identified as participating in 4 projects delivering this Objective.
Skills: number of people trained and themes	Numbers of people to be calculated but themes include: invasive non-native species management, riparian habitat management and native species planting and pollution monitoring and reporting

Service Category	**Ecosystem Service**	**Examples of the benefits provided for people**
Regulating Services	• Water purification • Hazard regulation • Water regulation • Pest regulation • Climate regulation • Air quality regulation	• Removal of pollutants, waste treatment • Soil retention helping sediment stabilisation and erosion protection • Reduced surface runoff volume / speed helping flood risk management: increased flood storage capacity, decrease in localised flood events • Control of invasive non-native species, pests and disease, • Reduced urban temperatures • Clean air
Provisioning Services	• Provision of fresh water	• Domestic and industrial use • Energy generation

Cultural Services	• Cultural heritage • Education opportunities • Social relations • Recreational activities	• Aesthetic appeal, artistic and spiritual value • Increased awareness of the natural environment and social factors such as industrial heritage and buildings • Neighbourhood cohesion and environmental stewardship • Physical and mental well-being, tourism, sport (fishing, paddling, wildlife watching etc)

Catchment Plan objectives overlap with a broad range of other strategies and plans under the following themes (including, but not limited to, the examples given below)	
WFD Statutory Legislation (eg River Basin Management Planning)	✓
Biodiversity (eg Biodiversity 2020, Mayor's London Plan)	✓
Water abstraction and resource management (eg Environment Agency's Catchment Abstraction Management Strategy, Local Authorities' Surface Water Management Plans, Water Companies' Water Resource Management Plans)	✓
Health and Wellbeing (eg Mayor's London Plan, LB Wandsworth's Health & Wellbeing Board)	✓
Planning and Green Infrastructure (eg All London Green Grid, Local Authorities' Local Plans – formerly LDFs)	✓
Economic Growth (eg Mayor's London Plan)	✓

Further reading:

Appendix G

Alcock (2014*) Longitudinal Effects on Mental Health of Moving to Greener and Less Green Urban Areas*

Substance (2012) *Fishing for Answers: The Final Report of the Social and Community Benefits of Angling Project*

Moore (2012) *What are the ecosystem service benefits of achieving Good Ecological Potential for the River Wandle?*

SECTION 10: FUTURE PRESSURES AND CHANGES

10.1: Climate change

The next few decades are likely to see a wide range of natural and anthropogenic pressures brought to bear on the River Wandle. An ongoing challenge to be factored into future iterations of this Catchment Plan lies in predicting their effects and devising ways to mitigate them.

Rivers in general are considered to be highly sensitive to the effects of climate change, since they rely on the larger water cycle for their flow, and are unable to regulate their own temperature. Chalkstreams like the Wandle are often cited as being better buffered than rain-fed rivers, both in terms of flow and temperature, because the majority of their flows derive from deep chalk aquifers rather than direct runoff of precipitation. However, recent research reveals that this buffering effect may not be as great as originally believed (Durance and Ormerod, 2007; 2009).

Within the London area, climate change is already high on the political agenda. The Mayor's London Plan outlines London's response to climate change, highlighting that the key impacts on London will be overheating, flooding and drought.

Under a medium emissions scenario (UKCP09), average summer temperatures in London are likely to increase by 1.6°C in the 2020s, by 2.7°C in the 2050s and by 3.9°C in the 2080s. However, maximum daytime temperatures could increase by up to 10°C, and the urban heat island effect will continue to affect the river even in hours of darkness: London is already an average 9°C warmer than its surrounding green belt on a summer night. Long term water temperature trends may also threaten the viability of fish populations in some areas of the Wandle unless shade is increased by encouraging aquatic weed and riparian tree planting schemes.

Summer rain is forecast to decrease by 7% in the 2020s, by 19% in the 2050s and by 23% in the 2080s whilst winter rainfall is set to increase by 6% in the 2020s, 14% in the 2050s and by 19% in the 2080s (under the same medium emissions scenario). Reduced summer rainfall and less water in the river mean that the impacts of higher in-stream temperatures are likely to be intensified. Water quality may be reduced, with less dilutory capacity and increased concentrations of pollutants. Increased winter rainfall could result in more flooding (both pluvial and fluvial), risks to urban drainage, disruption to transport and damage to infrastructure.

Climate change is also likely to increase the frequency and intensity of extreme weather events, including both droughts and storms, with impacts on the Wandle and its species including heat stress and wash-out in high water. At the same time, ecosystem services offered by the river may become increasingly valuable to people living within the river's catchment: for instance as its blue-green spaces offer areas of cool refuge for recreation in times of drought and heat.

10.2: Demand for water

According to recent EA figures, London already has less water per capita than Sudan or Syria (EA, 2013).

Population growth and climate change predictions suggest that this demand is only likely to increase: a view confirmed by Sutton & East Surrey Water's latest plans which forecast overall demand to increase by around 1% from 2015 to 2020. Importantly, this is likely to be as a result of population growth rather than increased per capita consumption, which is actually predicted to decrease from 157 to 152 litres per person per day over this period (pers comm. Alison Murphy, Sutton & East Surrey Water, 2014).

Government policies encouraging redevelopment of brownfield sites, including former industrial and residential areas throughout the Wandle catchment, is already resulting in residential intensification and increased water use.

With no investment in constructing significant new reservoirs in the London area over the last 40 years, the vast majority of London's domestic water consumption is still abstracted from aquifers, and those supplying the Wandle headwaters are particularly vulnerable. Towards the centre of London, in the northern part of the river's catchment, domestic water supply is sourced from the Thames and Lea, with water being transferred between areas of London. However, in the southern part of the Wandle catchment, water is provided by abstraction from the chalk aquifer. Any increase in abstraction in the Wandle's headwater and winterbourne areas will put even more pressure on the river's headwaters. In turn, this will place increasingly unsustainable reliance on Sutton & East Surrey Water's augmentation system to keep the Carshalton water body flowing, exacerbating risks associated with recirculating water originating from different locations, and contributing to climate change due to the energy requirements of the system.

As part of its statutory remit, the EA has a duty to conserve, redistribute and augment water resources, and to secure their proper use – including managing supply and demand in light of economic and environmental considerations. To this end, the EA has asked water companies to produce water resource plans. These should be robust and follow a twin track approach to managing future water resources, based on active measures to manage the demand for water and achieve tough leakage targets to avert or delay the need to develop new water resource schemes. The resulting plans involve a range of measures to achieve sustainable management of water resources, including:

- Encouraging more efficient use of water by the public, including changes in public attitude to water usage
- Encouraging use of water meters and tariffs that distinguish between essential and non-essential use of water
- Encouraging water conservation in old buildings through retrofitting schemes supported by grants
- Encouraging water conservation in new buildings by influencing developers and the planning process
- Promoting development and sale of low-water usage domestic appliances
- Requiring leakage to be reduced before investment in new resources is considered

To reduce water loss through leaking mains pipes, which peaked in 2002 – 2003 at 738,000 m3 per day, Thames Water have replaced 2,250km of Victorian water mains pipes. Since 2006, leakage has been reduced by around a quarter (Thames Water, 2013).

National domestic water metering trials carried out in the 1990s suggested that on average a home with a meter will use 10 – 15% less water than a home without, with up to 30% reduction at peak summer times. These findings have been reinforced by studies undertaken by Southern Water (which currently has 40% of customers on meters, and plans to increase this to 92% by 2015) and South West Water (WWF, 2011).

Extreme weather events, such as catastrophic drought, may cause the Wandle to become subject to emergency water resource measures. In a state of national emergency, the usual processes and plans are dispensed with: in very prolonged drought, the emergency Cobra committee can decide where water comes from, with provision for the public considered more important than wildlife or the health of a river, and it is likely that any remaining water in the Wandle would be directly abstracted to supply the needs of people in the Wandle valley.

Even without this level of national crisis, however, local demand for water may put the Wandle under considerable stress. Informal local abstractions for car washing, watering gardens and other uses are already known to occur, and Wandle Trust staff observed multiple drums of water being filled and removed from the river during the 2012 drought and hosepipe ban.

Further reading:

Environment Agency (2013) *London Abstraction Licensing Strategy*

WWF (2011) *Fairness on Tap: Making the Case for Water Metering*

10.3: Population increase

South east England, and London in particular, has seen a large population increase in recent years and this is set to continue. There are targets to build more housing and associated infrastructure and the Wandle valley has been identified as an economic growth area in the Mayor's London Plan. As the Wandle Valley Regional Park becomes established, more people will be encouraged to visit the Wandle in their leisure time, and may result in more permanent residents moving into the area.

Increasing local population will put pressure on the Wandle in several ways:

- More demand for water (see Section 10.2)

- More demand for development which is likely to result in infilling and general conversion of permeable surfaces to impermeable roofs, concrete and tarmac. Without implementation of large-scale SUDS, negative consequences will include reduced infiltration to replenish ground water supplies, increased flood risk as additional surface water enters the river, and reduced river water quality as this surface water carries urban runoff particulates and other pollutants into the river.

- More pressure on Beddington STW, with more treated effluent entering the river during normal operation. Increased influent to the works also implies decreased time-capacity for filling the existing storm tanks (currently 3-4 hours' capacity), hence more frequent discharges of untreated sewage into the Wandle.

10.4: Socio-demographic risks and pressures

As the population of the Wandle catchment increases, the demographics of that population may also change, putting the river under new cultural and other pressures.

Different cultures may have different or conflicting views of the value and purpose of landscape features such as the Wandle, and they may use water and the river differently. For instance:

- High water consumption: increasing economic affluence is likely to mean more usage of domestic appliances such as power showers, which may already have contributed to an upward shift in London's water use. On average, Londoners already use more water (161 litres per person per day) than the national average (150 litres per person per day) (GLA, 2014).

- Heavier use of the Wandle Trail and the surrounding Wandle Valley Regional Park for leisure purposes. Higher footfall may disturb wildlife by reducing refugia and quieter areas. Management regime(s) for the Trail itself may also impact the river, and additional safety lighting may affect some species (see Section 5.8.9).

- Use of the river for religious purposes: most Wandle community river cleanups involve removing at least one coconut and assorted Hindu and other religious artefacts from the river, into which they have been thrown in the course of ceremonial observances.

- Damage to fish and fisheries: recovery, abundance and diversity of fish populations in the Wandle may be impacted by subsistence anglers from cultures which do not share the 'catch and release' sporting traditions commonly practised by UK anglers.

- Foraging and public health: research from North America's Columbia River suggests that subsistence fishing in post-industrial rivers may have implications for public health, with levels of carcinogenic PCBs bioaccumulated in resident fish at levels 27,000% above limits recommended by the EPA (Columbia Riverkeeper blog, accessed Jan 2014). During 2013, Wandle Trust staff observed watercress being harvested, possibly by restaurant owners, in areas of the Carshalton water body known to contain contaminated sediments and less than 100m downstream of positively identified sewer misconnections. Such urban foraging may raise the risk of heavy metals as well as *E. Coli* and other pathogens being consumed by members of the public.

10.5: Ecological shifts caused by climate change

Climate change also implies shifts in species and ecological communities in and around the Wandle.

As discussed in Section 10.1, even chalk streams are likely to be highly sensitive to the effects of climate change. Warmer average air and water temperatures are predicted to put pressure on native fish and invertebrates: in 2009 the EA calculated that invertebrate numbers in upland streams will fall by 20% for every 1°C rise in water temperature.

By contrast, many invasive non-native species may find a warming climate positively beneficial in terms of extended breeding, growing and dispersal seasons. Warmer temperatures may also help new non-native species to emerge as damaging and invasive threats, with effects cascading unpredictably through the Wandle catchment's ecosystem. Some of these future invasive species may already be present in the catchment's seed bank, awaiting suitable conditions to emerge and proliferate.

11: GLOSSARY

(with thanks to the EA LEAP)

Above Ordnance Datum (AOD): land levels are measured relative to the average sea level at Newlyn in Cornwall. This average level is referred to as 'Ordnance Datum'. Contours on Ordnance Survey maps of the UK show heights in metres above Ordnance Datum.

Abstraction: the process of taking water from any source, either temporarily or permanently.

Alluvial: referring to materials eroded, transported and deposited by the action of river flow.

Ammonia: a chemical found in water, often as a result of discharge of sewage effluent. High levels of ammonia affect fisheries and abstractions for drinking water supply.

Asset Management Plan (AMP): a programme of water companies' environmental improvement schemes (known as AMP schemes), linked to Ofwat's five-yearly Final Determination of Water Company Prices. This is enforced by the EA under the National Environmental Programme, which states what improvements each company must make. For instance, improvements to sewage treatment works will usually be stated as the new discharge permit limits.

Aquifer: a layer of porous rock able to hold or transmit water.

Backwater: a ponded side channel connected to the main river that holds still or slow-flowing water. These can act as nursery sites for fish and as refuges for wildlife from high flow conditions or pollution incidents.

Baseflow: the flow in a river derived from groundwater sources.

Biodiversity: the variety of life on earth.

Biomass: a quantitative measure of animal and / or plant matter.

By-pass channel: a channel built to divert water from a main channel. These may be used to enable fish passage upstream or down stream in areas where the main channel is effectively barricaded by a weir or other structure such as a culvert or trash screen.

Catchment: the area of land around a water body (such as a river or lake) that provides its water supply. A catchment boundary is known as its watershed.

Coarse fish: a common term for cyprinid fish (eg roach, bream, carp and chub) and other commonly associated species of angling importance such as pike, perch and eels. The term is not usually used in reference to minor species such as bullhead, stone loach, minnow and stickleback.

Combined Sewer Overflow (CSO): an overflow structure that permits a discharge from the sewerage system during wet weather.

Confluence: the point at which two rivers meet.

Culvert: a watercourse that has been piped or covered to carry water underground, usually under a road, canal, embankment etc.

Cyprinid fish: fish of the Family Cyprinidae (eg roach, bream, carp and chub). Commonly also known as **coarse fish**.

Diffuse pollution: pollution without a single point source (eg urban runoff, pesticides, acid rain).

Dissolved oxygen (DO): the amount of oxygen dissolved in water. Oxygen is vital for life so this measurement is an important, but highly variable, indicator of the 'health' of a water body. DO is used to classify waters.

Ecosystem: a biological community of interacting organisms and the physical environment that they inhabit and rely on.

Ecosystem Approach: the management of natural resources at the landscape scale that balances both their use and conservation fairly.

Ecosystem Services: the benefits people obtain from ecosystems.

Eutrophication: the enrichment of water by nutrients, such as compounds of nitrogen and phosphorus. It causes accelerated growth of algae and other, higher, plants and can have negative consequences for ecosystem 'health' if allowed to reach too high a level.

Fauna: animals.

Flash flood: sudden high flows shortly after rainfall.

Floodplain: the parts of river valleys or coastal plains which are inundated during floods. It includes areas protected by flood defences.

Fry: a baby fish that has hatched and absorbed its egg yolk and is only a few centimetres long

Groundwater: water that is contained in the spaces in pervious rocks and also within the soil.

Hydrogeology: the branch of geology concerned with water within the earth's crust.

Hydrograph: a graph showing water height (known as stage) or discharge (rate of flow) plotted against time.

Hydrology: the study of water and its dynamics of flow.

Impoundment: a structure that impedes the flow of water (eg a weir) which often causes water to back up into a pool.

Local Nature Reserve (LNR): a nature reserve established and usually managed by a Local Authority. The remit of Local Authorities to designate such sites falls under the National Parks and Access to the Countryside Act 1949.

Meander: a winding curve or bend in a river.

Morphology: the science of the form and structure of features, such as a river channel.

Naturally functioning: processes such as nutrient cycling and flow regulation that would normally be associated with a particular ecosystem.

Outfall: a point where a pipe discharges, for example into a river.

pH: a measure of the concentration of hydrogen ions in solution. Water with pH less than 7 is acid, 7 itself is neutral and more than 7 is alkaline or base.

Parr: a young trout or salmon less than 1 year old and distinguished by a series of dark “finger print” markings along its body.

Potable water: water suitable for human consumption.

Reach: a stretch of river.

Riffle: a shallow, stony or gravelly part of a riverbed where the water surface is broken in low flows.

Riffle-pool: a natural sequence of broken water flow and deeper areas characteristic of rivers with gravel beds.

Riparian zone: the land adjoining a river or stream.

River terrace: a lateral bench between a river channel and its valley sides.

Runoff: commonly used term to mean rainwater flowing across land (also known as overland flow). In urban areas, where impervious surfaces may be abundant, the amount of runoff is likely to be higher than in rural areas where rainwater can enter the ground where it falls more easily.

Salmonid fish: fish of the Family Salmonidae (eg trout and salmon).

Self-sustaining: populations or ecosystems that are able to maintain themselves without external assistance.

Surface water: a general term to describe all visible water features such as rivers and ponds.

Sustainable development: development that meets present needs without compromising the abilitis of future generations to meet their own requirements.

Sustainable Urban Drainage Systems (SUDS): a collective term used to describe the management of runoff at or near the point where rainfall meets the ground and before it enters either the piped drainage systems of urban areas or watercourses. The aim is to attenuate surface water flow quantity and speed and in so doing reduce flood risk and potential pollution impacts by using natural processes to filter out contaminants. Examples of SUDS include reedbeds, rain gardens, swales and balancing ponds.

Tributary: a stream or river which feeds into a larger one.

Watercourse: a stream, river or canal along which water flows.

Water table: the level below which the soil / rock is permanently saturated with water.

Weir: a low dam across a river.

Winterbourne: a seasonal stream, typically in the headwaters of a chalk or limestone river system, which flows only after prolonged rainfall has recharged the underlying aquifer

12: BIBLIOGRAPHY

Adams, B. (ed.) (2008) The Chalk aquifer of the North Downs, British Geological Survey Research Report, RR/08/02, Nottingham: NERC.

Alcock, I. (2014*)* *Longitudinal Effects on Mental Health of Moving to Greener and Less Green Urban Areas*, *Environmental Science and Technology* / University of Exeter.

Armstrong, J.D., P.S. Kemp, G.J.A. Kennedy, M. Ladle and N.J. Milner (2003) *Habitat requirements of Atlantic salmon and brown trout in rivers and streams*, Fisheries Research, 62, 143-170.

Ashby, C.L. (2012) *Restoration of coarse fish populations in the River Wandle*, unpublished MSC thesis, Sheffield Hallam University.

Barcellos, M. (1997) *Investigation into the current status of coarse fish recruitment in the River Wandle*, unpublished MSc thesis, University of London.

Braithwaite, F. (1861) *On the rise and fall of the River Wandle: Its springs, tributaries and pollution.*

Brierley, M. (2013) *The characterisation and quality appraisal of riverbed and road runoff sediments within the Carshalton arm of the River Wandle, London, UK*, unpublished MSc thesis

British Geological Survey (2008) *The Chalk Aquifer of the North Downs.*

Bywater, J. (2012) *Macroinvertebrate surveys of enhancement works in the River Wandle at Carshalton – Summer 2012 interim report*, Bywater Ecology.

Cluett, D. and J. Phillips (eds.) (1997), *The Wandle Guide*

Cook, H. (2008) *A Tale of Two Catchments: Water Management and Quality in the Wandle and Tillingbourne, 1600–1990* in A. Spicer (Hon. Ed.) and M. Hicks (Hon. Review Ed.) Southern History: a review of the history of southern England, 30, Bristol: Southern History Society.

Courtney Williams, A. (1945) *Angling Diversions*, Herbert Jenkins

Coward, B., P. Ehmann and B. Davies (2009) *Investigation into the water quality of the River Wandle*, unpublished report for the Wandle Trust, Thames Water and Environment Agency.

Cowx, I.G. and M. Portocarrero Aya (2011) *Paradigm shifts in fish conservation: moving to the ecosystem services approach*, Journal of Fish Biology, 79, 1663-1680.

Cowx, I.G., R.A. Noble, D. Nunn, J. Bolland and S. Walton (2012) *Flow requirements of non-salmonids*, Fisheries Management and Ecology, 19, 548-556.

Davies, B. (2010) unpublished notes summarising a visit to Beddington Sewage Treatment Works, Wandle Trust.

Davy, Sir H (1828) *Salmonia*.

Edwards, K., T. Russell and D. Bright (no date) *Fisheries walkover survey manual*, West Country Rivers Trust.

English Nature and Environment Agency (1999) *Chalk Rivers: Conservation and Management*

Environment Agency (1999) *Local Environment Agency Plan: Wandle, Beverley Brook and Hogsmill*

Environment Agency (2004) *Fisheries survey sites on the Wandle.*

Environment Agency (2006) *The London Catchment Abstraction Management Strategy (CAMS).*

Environment Agency (2007) Wandle fish stocking data.

Environment Agency (2009) *Managing flood risk: Thames Catchment flood management plan*, summary report.

Environment Agency (2009) *Nutrient concentrations in River Wandle.*

Environment Agency (2011) *Summary of European eel surveys on the River Wandle.*

Environment Agency (2011) Wandle eel survey data 2009-2011.

Environment Agency (2011) *River Wandle Fish Population Survey 2011.*

Environment Agency (2012) *Management of the London Basin Chalk Aquifer*, status report.

Environment Agency (2012) *Water for people and the environment: Water resources strategy*, regional strategy actions for South East Region.

Environment Agency (2013) *London Abstraction Licensing Strategy / London CAMS.*

Environment Agency and Wandle Trust (c2012) *Invasive Non-Native Species Action Plan*

Everard, M. (2010?) *River Wandle ecosystem services case study*, unpublished report for the Environment Agency.

Everard, M. (2011) *Dace: The Prince of the Stream*, mPress (Media) Ltd.

Francis, F. (1883) *Practical Management of Fisheries*.

Francis, R (ed) (2012) *A Handbook of Global Freshwater Invasive Species*

Gallay, P (2013) *A Broken Windows Theory for Environmentalism*, Huffington Post.

Gaskell, P. (2012) *Is habitat restoration effective?,* Wild Trout Trust.

Gerhold, D. (1998) *Wandsworth Past*, London: Historical Publications.

Giles, N. (2002) *The Nature of Barbel*, Perca Press.

Giles, N. (2005) *The Nature of Trout*, Perca Press.

Goodman, J. (2009) *The Wandle Trout Spotted*, Bulletin 170, Merton Historical Society

Gollock, M., A. Pryor, B. Godsall and A. Debney (2008) *River Thames catchment European eel (Anguilla Anguilla (L.) monitoring report*, Zoological Society of London and Environment Agency.

Green, J. (1996) *River Wandle catchment: Catchment summary part one*, report produced for the Environment Agency Thames Region.

Greenwood, P. and Kuhn, N. (2013) *Does the invasive plant, Impatiens glandulifera, promote soil erosion along the riparian zone? An investigation on a small watercourse in northwest Switzerland, Journal of Soils and Sediments* DOI 10.1007/s11368-013-0825-9.

Gurnell, A.M. and L. Shuker (2011) *Classification of urban river stretches using URS indices*, Queen Mary University London & ESRC-NERC.

Gurnell, A.M. and L. Shuker (2011) *Urban River Survey Manual*, Queen Mary University London & ESRC-NERC.

Gurnell, A.M. and L. Shuker (2011) *Index Calculations – aggregate stretch indices derived from URS data to describe the characteristics of the surveyed urban river channels and their margins*, Queen Mary University London & ESRC-NERC.

Harrison, S. (2011) *An investigation of the chalk spring sources of the River Wandle*, Wandle Trust.

Halford, F. (1903) *An Angler's Autobiography*

Hatfeild, G. (c1840) *Fly fishing in the Wandle*, unpublished manuscript and fishing diaries.

Hatton-Ellis, T.W. and N. Grieve (2003) *Ecology of watercourses characterised by Ranunclion fluitantis and Callitricho-Batrachion vegetation*, Conserving Natura 2000 Rivers Ecology Series No. 11, EC Life Project.

Hayter, T. (2002) *FM Halford and the Dry-Fly Revolution*, Robert Hale

Hobson, J. (1914) *The Book of the Wandle*.

Houston, T. (2010) *A review of the status of the eel population in the River Wandle with reference to obstructions to migration*, report produced for Institute of Fisheries Management Diploma.

Jardine, A. (1894) *Wanderings on the Wandle Twenty Years Ago*, Fishing Gazette.

Johns, A. (2012) *Water scarcity and rising groundwater levels in London*, unpublished MSc thesis, University College London.

Joint Nature Conservation Committee (2012) *SACs – 3260: Water courses of plain to montane levels with the Ranunculion fluitantis and Callitricho-Batrachion vegetation*, (WWW) http://jncc.defra.gov.uk/ProtectedSites/SACselection/habitat.asp?FeatureIntCode=H3260 accessed January 2013)

Jones, J. (2012) *Stage 1 Phosphate investigation: Wandle Croydon to Wandsworth water body*, Environment Agency.

Knight, L. (2011) *The River Wandle (Carshalton branch): a baseline ecological survey prior to habitat restoration works (September 2010)*, report prepared for the Wandle Trust.

Lewis, V. (2005) *Overview of habitat enhancement opportunities on the River Wandle, London*, report produced for the Wandle Trust, Windrush AEC Ltd.

Longstaff, T. (2010) *The rehabilitation of the River Wandle*, MSc thesis, Kings College London.

Lundy, L., J.B. Ellis and D.M. Revitt (2012) *Risk prioritisation of stormwater pollutant sources*, Water Research, 46, 20, 6589-6600.

Mainstone, C.P. (1999) *Chalk rivers: nature conservation and management*, Peterborough: English Nature and Environment Agency.

Moore, V. (2012) *What are the ecosystem service benefits of achieving Good Ecological Potential for the River Wandle?,* unpublished MSc thesis, Kingston University London.

Montague, E. (2005) *Mitcham Histories 6: Mitcham Bridge, the Watermeads and the Wandle mills*, Merton Historical Society.

Parry, L. (1983) *William Morris Textiles*, Crescent Books.

Peer Egerton (2012) Heavy metal and PAH research data (Beddington Park Lake)

Pennell, R. (1992) *The River Wandle*, National Rivers Authority Thames Region.

Pieris, M. (2012) *Wandle NEP monitoring update: River Wandle (Carshalton branch) hydrogeological monitoring project set-up*, unpublished report by Royal Haskoning for the Sutton & East Surrey Water Company.

Pike, T. (2014) *The Pocket Guide to Balsam Bashing – and how to tackle other invasive non-native species*, due for publication by Merlin Unwin Books.

Reader's Digest (1984) *Field Guide to the water life of Britain*, London: Reader's Digest Association Ltd.

Rose, D. (2003) *The Color of Winter: Steelhead Fly Fishing on the Olympic Peninsula*, Frank Amato Publications Inc.

Ruskin, J. (1870) *A Crown of Wild Olive*

Shahbazian, C., Kowalik, R. and Woodcock, S (2009) *A Water Vole Reintroduction Feasibility Study for the River Wandle*, London Wildlife Trust.

Shew, B. (2012) *Times remembered, times past: A history of Beddington and Bandon*, Carshalton and District History and Archaeology Society.

Smee, A. (1872) *My Garden – Its plan and culture*, Bell and Daldy.

Smith, S., M-H. Chen, R.G. Bailey, and W.P. Williams (1996) *Concentration and distribution of copper and cadmium in water, sediments, detritus, plants and animals in a hardwater lowland river*, *Hydrobiologia*, 341, 71-80.

Solbé, J. (1997, 2nd edn) *Water Quality for Salmon and Trout.*

Solomon, D. (2010) *Fish passage on the River Wandle*, draft 2.4 report produced for the Environment Agency Thames Region.

Solomon, J.F. and I. Thomson (2009) *Satanic Mills? An illustration of Victorian external environmental accounting*, *Accounting Forum*, 33, 74-87.

Steel, B. and D. Coleman (2012) *River Wandle Companion and Wandle Trail guide*, Lavenham: Culverhouse Books.

Stubbs, D. (1989) *Wandle catchment ecological survey*, report by the London Wildlife Trust for National Rivers Authority Thames Region.

Substance (2012) *Fishing for Answers: The Final Report of the Social and Community Benefits of Angling Project*

Sutton & East Surrey Water (2011) *River Wandle National Environment Programme (NEP) Investigation Phase 1 Report.*

Taeed, E. (2012) *Sensitive Water Management in Hackbridge, London*, unpublished report prepared for the London Borough of Sutton: Wandle Trust.

Thames Water (1988) River Wandle Fisheries Survey.

The Bourne Society (2000) *A Celebration of the Bourne*.

Tidal Thames Catchment Partnership (2012) *Tidal Thames Catchment Based Pilot Project.*

Twilley, R. and Wilks, M. (eds.) (1974) *The River Wandle: A Guide and Handbook*, London Borough of Sutton Public Libraries, The Wandle Group.

UK Biodiversity Action Plan Steering Group for Chalk Rivers (2004) *The State of England's Chalk Rivers*, Bristol: Environment Agency and English Nature.

UK Biodiversity Action Plan (2011) *UK BAP Priority Habitat Descriptions – Rivers*, updated version of the BRIG 2008 document edited by A. Maddock (WWW) (http://jncc.defra.gov.uk/page-5706 accessed January 2013).

Uren Webster, Bury, van Aerle and Santos (2013) *Global Transcriptome Profiling Reveals Molecular Mechanisms of Metal Tolerance in a Chronically Exposed Wild Population of Brown Trout*

Vermonden, K., R.S.E.W. Leuven, G. van der Velde, M.M. van Katwijk, J.G.M. Roelofs and A.J. Hendriks (2009) *Urban drainage systems: An undervalued habitat for aquatic macroinvertebrates*, Biological Conservation, 142, 5, 1105-1115.

Walton, I. (1833, 1835) *The Compleat Angler*.

Watson, R. (1993) *The Trout: A Fisherman's Natural History*, Swan Hill Press.

Webb, D. (2011) *River Wandle catchment action plan v1.14: First Thames River Basin Management Plan*, draft report produced for the Environment Agency.

Wentworth, J., (2011) *Natural Flood Management*, Postnote, 377, December 2011, London: Parliamentary Office of Science and Technology.

WFD UK TAG (no date) *Biological Status Methods: rivers – Phytobenthos*, Environment Agency, Northern Ireland Environment Agency and Scottish Environment Protection Agency.

WFD UK TAG (2008) *UKTAG Rivers Assessment Methods: Fish Fauna – Fisheries Classification Scheme 2*, Edinburgh: WFD UK TAG.
Wentworth, J., (2011) 'The Ecosystem Approach', Postnote, 377, May 2011, London: Parliamentary Office of Science and Technology.

WWF (2011) *Fairness on Tap: Making the Case for Water Metering*

Wild Trout Trust, (2012, 3rd edn) *The Wild Trout Survival Guide: Habitat and fishery management guidelines produced by the Wild Trout Trust.*

Wilks, S. and Rookledge, G (eds.) (2002) *The Book of Carshalton: At the Source of the Wandle*, Halsgrove.

Wilson, J and Kelling, G (undated) *Broken Windows*, http://www.manhattan-institute.org/pdf/_atlantic_monthly-broken_windows.pdf

Wood, P.J. and P.D. Armitage (1997) *Biological effects of fine sediment in the lotic environment*, *Environmental Management*, 21, 2, 203-217.

Personal communications:

Dr Lucy Shuker
Prof Angela Gurnell
Steve Barrow
Prof Ian Cowx
Darryl Clifton-Dey
Dave Bartlett
Paul Stewart
Dave Brown
Dr Bella Davies
Theo Pike