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WHAT ARE THE ECOSYSTEM SERVICES BENEFITS OF ACHIEVING GOOD ECOLOGICAL POTENTIAL FOR THE RIVER WANDLE?

GGM122 RESEARCH PROJECT

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LIST OF ABBREVIATIONS

EA	Environment Agency
ES	Ecosystem Services
GEP	Good Ecological Potential
GES	Good Ecological Status
HMWB	Heavily Modified Water Bodies
MA	Millennium Ecosystem Assessment
RBMP	River Basin Management Plan
UK NEA	UK National Ecosystem Assessment
WFD	Water Framework Directive

ABSTRACT

This valuation study was designed to determine the existing ecosystem health of the River Wandle and its catchment, and examine the multiple ecosystem benefits arising from future improvements in the river's 'ecological potential', which is currently classed as poor under the Water Framework Directive. To deliver the target of 'good ecological potential' across the Wandle catchment over the next 15 years, it is vital to address sources of pollution, improve floodplain connectivity to minimise the impacts of high peak flows and downstream flooding, provide additional green spaces and ensure a more inclusive approach to river and land management. To examine the community aspect of 'good ecological potential', a non-monetary valuation of ecosystem services was carried out on the basis of current value judgements of local communities and stakeholder groups. The assessment revealed that the catchment is valued for a wide variety of reasons, however its most notable benefits arise from cultural services, which amount to over three quarters of all values placed on the river. The most important conclusion of this valuation study, derived from an ecosystem services framework, is that local communities perceive 'good ecological potential' as a set of multiple benefits delivered through improved water quality and fresh water provision, the restored functioning of key regulating services (primarily the regulation and purification of water and flood risk management) and the ongoing preservation of cultural services. Therefore, ecosystem enhancements designed to boost and maintain the functioning of regulating services will positively impact all cultural services and simultaneously improve the ecological status of the river. This study will also contribute to the creation of a sustainable Wandle Catchment Plan, designed to sustain ecosystem benefits to society in the long term.

CHAPTER 1: INTRODUCTION

The European Water Framework Directive (WFD) requires all water bodies to reach 'good ecological status' (GES), however in the case of heavily modified water bodies, such as the River Wandle, the target of 'good ecological potential' (GEP) is set to take into account changes to the river's hydromorphology necessary due to flood protection or urbanisation (EA, 2009). While much work has gone into defining the GES, the meaning of 'ecological potential' is still open to interpretation (Borja and Elliott, 2007). In addition, the societal benefits of the WFD outcomes are poorly understood and often undervalued by the public (Everard, 2012). This research project will therefore attempt to fill these knowledge gaps by answering the question: 'What are the ecosystem services benefits of achieving GEP for the River Wandle?' by assessing qualitative data collected during a six-month catchment-wide public consultation.

A strategic approach, based on ecosystem services (ES), has been selected to address the research question. As the river has been modified for people, it could be argued that local communities should be involved in identifying what is 'good' about the river. The Wandle Trust, in collaboration with the Environment Agency (EA) and other key stakeholders, are interested in exploring this as a concept, which will feed into the Wandle Catchment Plan project to give guidance on how the river can attain GEP not only through the traditional scientific route, but also via the application of this ES approach. Although the research will be carried out specifically with reference to the River Wandle, its potential to serve as an example for other urban water bodies is vast.

This project aims to assess the benefits of using the ES approach for the management of the Wandle to aid the implementation of the WFD and the development of a sustainable Wandle Catchment Plan, with a particular focus on stakeholder participation and integrated water resource management. Since the WFD is one of the primary drivers of river restoration projects across the EU, the application of this work will ensure that all future river restoration plans and projects consider ES and maximise multiple ES benefits.

The underlying aims of the project are:

- To carry out an audit of ES for the River Wandle and identify the current and future status of ecosystem health in order to ensure the long-term sustainability of the river and its catchment

- To analyse and provide guidance on the potential value of the ES approach to support the implementation of the WFD requirements at a local scale so that the Wandle can achieve the GEP status by 2027
- To examine the linkages between functioning ecosystems and effective water management practices by assessing the added values of the ES approach with the ultimate objective of fulfilling the present and future requirements of the local community for a high-quality environment, recreational activity or cultural heritage
- To contribute to the creation of the Wandle Catchment Plan with an ES framework that will inform and support the integrated management of the River Wandle and lead to a greater understanding of the WFD implementation at the catchment level

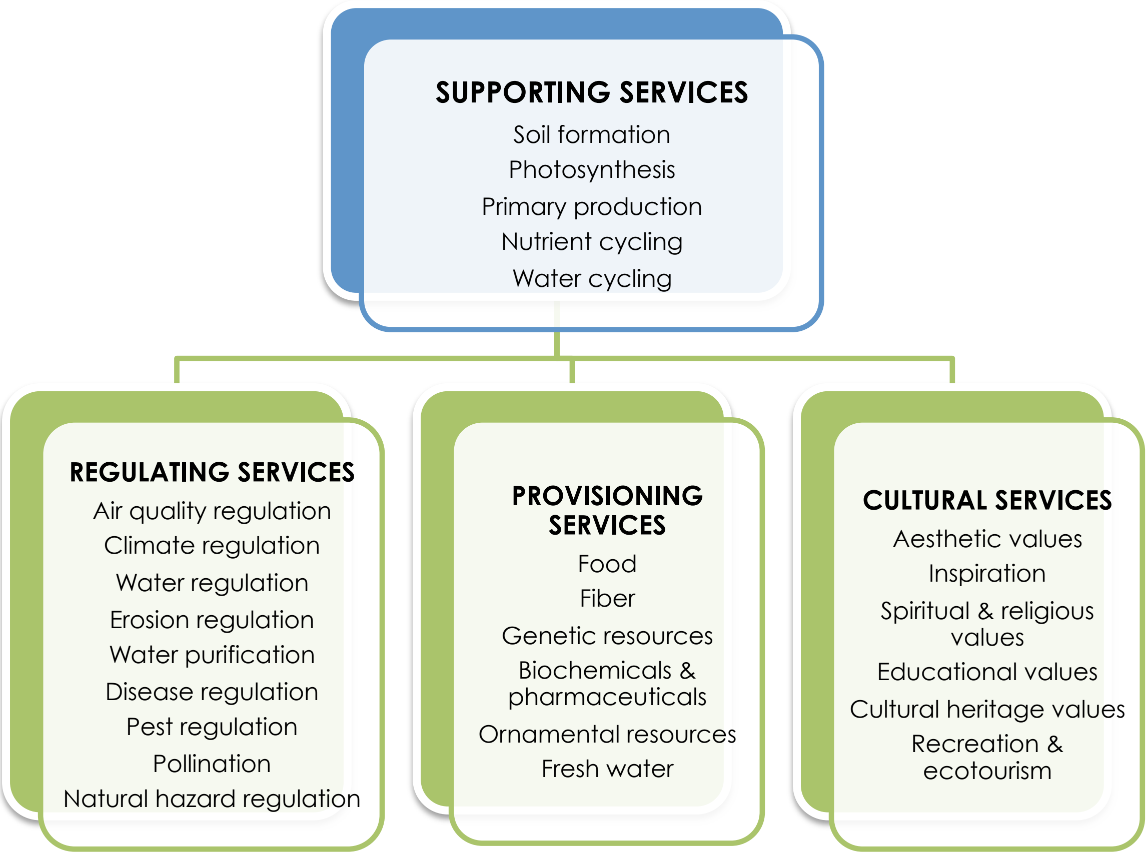
CHAPTER 2: ECOSYSTEM SERVICES

Since its emergence in the late 1980s, the concept of ecosystem services (ES) has gradually become a central guiding principle and an integral tool for the development and implementation of effective conservation policies, designed to uphold both human wellbeing and sustainable development (Everard, 2012). Additionally, the role of the ES approach has gained particular prominence in water management since the publication of international studies such as the Millennium Ecosystem Assessment in 2005 or The Economics of Ecosystems and Biodiversity in 2009 (PEER, 2011). At the same time, the societal benefits of the WFD outcomes are often poorly understood and therefore undervalued by a wide range of stakeholders and the public (Everard, 2012). Hence, the ES approach not only helps to justify the need for GES or GEP in terms of multiple ecosystem benefits, but it also strengthens public and stakeholder engagement and the discourse on environmental management solutions (ECRR, 2008; Everard, 2012).

2.1 The classification of ecosystem services

Whereas ecosystems represent the combined physical and biological components of an environment, ES (i.e. a term that incorporates ecosystem goods and services) refer to the conditions and processes provided by natural ecosystems (i.e. ecosystem functions) for the direct or indirect benefit of human populations (Daily, 1997; WRI, 2005). The relationship between ES and ecosystem functions is not necessarily analogous as some ES are generated by a combination of two or more ecosystem functions and conversely, some ecosystem functions are instrumental for the continuation of two or more ES (Constanza et al, 1997). ES range from the most tangible, such as fresh water, crops or fish, to those that are practically imperceptible to humans, such as water regulation, pest control or climate regulation. The most widely accepted classification system, formulated by the Millennium Ecosystem Assessment (MA), groups ES into four primary categories, namely supporting, regulating, provisioning and cultural services (Figure 1; WRI, 2005).

Figure 1: MA classification of ecosystem services (Source: adapted from WRI, 2005)



1. Despite having an indirect effect on human wellbeing, supporting services underpin the functioning of all other ES. They encompass some of the most vital ecological processes of terrestrial and aquatic ecosystems, such as soil formation, photosynthesis and the cycling of water and nutrients. Consequently, all supporting services are strongly interlinked and dependent on multiple biological, physical and chemical interactions. Their vulnerability to the effect of climate change, land use and nitrogen deposition, in particular, has been observed across UK habitats.
2. The regulating services of ecosystems are a highly diverse yet strongly interconnected ES category, consisting of pollination and the regulation of air quality, climate, pests and diseases, water, sediment, nutrients and pollutants. Many of these services, particularly those occurring in fluvial and riparian environments across the UK, have been significantly weakened by soil degradation, climate change and the associated changes in the patterns and magnitude of precipitation, often leading to increased flood risk and storm damage. In addition to a multitude of interdependencies between regulating services (e.g. water quality, which is determined by catchment processes, is linked to nutrient cycling and soil and air quality), there are also a number of trade-offs (e.g. reduced acidification in upland soils not only leads to an improved soil buffering of water quality, but it also intensifies the release of carbon stocks).

3. The supply of goods derived from ecosystems for the direct benefit of human populations, such as crops, livestock, fish, wild game, timber and water from surface water bodies and aquifers, is secured via provisioning services. Since the 1950s, production from heavily managed ecosystems, e.g. agriculture or dairy farming, has been on the increase in the UK, while production from natural and semi-natural ones, e.g. fresh water or fisheries, has been gradually declining. Due to their strong historical connection to human activities, provisioning services are closely associated with cultural services (WRI, 2005; Lundy and Wade, 2011; UK NEA, 2011a).
4. Cultural services arise from a number of environmental settings, i.e. places where humans interact with the natural world (e.g. national landscapes, green and blue spaces or domestic gardens). Apart from providing opportunities for outdoor learning and recreation, the benefits of cultural services also entail aesthetic satisfaction, improvements in physical and mental wellbeing and access to natural habitats (WRI, 2005; Lundy and Wade, 2011). The UK National Ecosystem Assessment (UK NEA) highlighted the need for more quantitative and qualitative research in order to fill in the knowledge gaps around the complex ways individuals and communities interact with their environmental settings and in order to better understand the non-monetary value of cultural benefits linked to ES (UK NEA, 2011a).

The publication of the MA in 2005 provided the first systematic insight into the relationship between ecosystem change and human wellbeing. The report was commissioned by the former UN Secretary-General, Kofi Annan in 2000 and involved the work of over 1,300 international scientists. The MA was structured to reflect a dynamic interaction between people and their surrounding ecosystems, emphasising the significant extent of ecosystem changes resulting from intensive human management. The report concluded that about 60 per cent (15 out of 24) of ES examined during the assessment (Figure 1) have been degraded or treated unsustainably in the last 50 years as a direct result of the intensification of agriculture, forestry, fisheries, industries and urbanisation (WRI, 2005).

A recent UNEP report (2011), incorporating the findings of a 20-year evaluation of the world's changing environment, also concluded that the unprecedented economic growth observed since the Rio Earth Summit in 1992 has been achieved at the cost of vastly depleted natural resources and extensive ecosystem degradation and loss. The demand for basic resources such as water, energy, food and land is constantly rising as a consequence of overpopulation, and such resources are further restricted by unforeseen changes in ecosystems and the impacts of climate change.

Similar to the MA and UNEP results, the first peer-reviewed analysis of the state of the UK's natural environment and ES, the UK NEA, deduced in 2011 that over 30 per cent of the services provided by eight of the most dominant aquatic and terrestrial habitat types in the UK have been experiencing a long-term decline since the 1940s (UK NEA, 2011a). For the purposes of this thesis, the technical reports produced for freshwaters and urban habitats provided a useful guidance for the identification of ES generated by the River Wandle and its catchment, and gave valuable insights on the future drivers of change that are likely to affect the functioning of these habitat types.

Both, human wellbeing and the global economy depend entirely on the continuation of ES. Their vulnerability to changing human activities is evident from their deteriorating status, as noted by the MA, UNEP and UK NEA reports. Along with population growth and climate change, urbanisation can also lead to spatial shifts in the supply of ES and the beneficiaries [of the services]. Based on a 16 per cent population increase by 2031, Eigenbrod et al (2011) modelled changes in UK's urban land cover for three ES – natural hazard regulation, food production and climate regulation. They found that land-use alterations, driven predominantly by urbanisation, are likely to have a significant impact on the distribution of ES before 2050. Moreover, the effects of climate change weaken the functioning and supply of goods and services generated by ecosystems (Thomas et al, 2008; Heyder et al, 2011), with Heyder et al (2011) suggesting that severe ecosystem changes will arise on each continent, with Europe experiencing the lowest risk and Africa the highest risk of ES change.

2.3 The ecosystem services approach

The recognition that the functioning aquatic and terrestrial services of freshwater ecosystems are in fact natural assets lies at the heart of the ES concept, which not only provides a basis for identifying and assessing the services and societal benefits of ecological systems, but also a mechanism for achieving sustainable environmental outcomes, i.e. the target of GES or GEP under the EU WFD. According to Everard (2012), ES offer a unifying language and framework for integrated river basin management by linking the products and processes of both natural and human-dominated ecosystems to societal benefits and by determining the impacts of human actions on the delivery of these services. However, the framework [of the ES approach], which enables the integration of ES into public and private decision-making, has long been a subject of contention, thus its practical application at the catchment level has not yet reached its full potential (Cowx and Portocarrero Aya, 2011).

By incorporating the ES component as the connecting link between ecosystems and human users, the ES approach refines the framework of the ecosystem approach, originally developed under the Convention on Biological Diversity (WRI, 2008). Fundamentally, both concepts recognize the importance of stakeholder engagement and public support for a sustainable management of natural resources at all spatial scales (Potschin et al, 2008). On the whole, the methods used for the implementation of the ES approach include valuations (both monetary and non-monetary), impact assessments, policies and scenarios at a catchment or regional level, which can identify important focus areas and trade-offs and often entail the projection (e.g. via modeling) of future impacts on selected ES.

The significance of maintaining the delivery of ecosystem goods and benefits, as well as ecosystem functioning for the purpose of recreation and leisure, waste management or flood mitigation can be articulated without a need for the monetary valuation of ES (Cowx and Portocarrero Aya, 2011). Hence, aquatic and associated terrestrial ecosystems can be managed effectively by linking the delivery of ES to the conservation of aquatic biodiversity.

Unlike the traditional discipline-specific management approaches to integrated water management, the ES approach enables the integration of data and research from both physical and social sciences on a range of biophysical status indicators, pressures and biological impacts that influence human health and wellbeing (Lundy and Wade, 2011). Through traversing multiple ecological, social, economic and political boundaries, the concept of ES is regarded as a holistic management and communication tool for decoding complex biophysical systems into a simpler language and for drawing attention to key ecological processes (Cowx and Portocarrero Aya, 2011; Lundy and Wade, 2011, Everard, 2012). Along with better-informed policymaking, the ES approach also leads to an improved public perception of the benefits of protecting environmental quality.

The restoration of Mayes Brook, a tributary of the River Roding within the Thames river basin, serves as a good example of an ES approach that marries flood control and biodiversity enhancement with climate change adaptation within the context of an urban environment. Completed in 2011, the project played a vital role in the wider regeneration of Mayesbrook Park in East London by demonstrating the socio-economic benefits of functioning ecosystems for the local community and also helping to achieve GEP for the Seven Kings Water, a further tributary of the River Roding. The assessment of potential benefits [of the Mayes Brook restoration] showed no change in provisioning services, however significant benefits were observed across other service categories, with benefits outweighing the cost of the regeneration scheme by sevenfold (Everard et al, 2011; Everard, 2012).

Quantitative and qualitative information on the contribution of urban water components to the delivery of ES is relatively scarce (Lundy and Wade, 2011). Therefore, further research and advice on the wide array of ecosystem functions and services of multiple activities extending across a number of spatial scales is still needed. Moreover, positive and negative effects also need to be taken into consideration during an ES assessment (Cowx and Portocarrero Aya, 2011).

CHAPTER 3: RIVER RESTORATION AND THE EUROPEAN WATER FRAMEWORK DIRECTIVE

For centuries, human populations have reengineered and thus profoundly modified the vast majority of the world's riverine systems for water supply, agriculture, hydropower generation, flood defence or recreation. According to recent estimates (Vörösmarty et al, 2010), anthropogenic influences on rivers currently pose a 'moderate to high' threat to 65 per cent of global river discharge, including the associated aquatic habitat. Channelisation, pollution, the removal of riparian vegetation, the loss of permeability in river catchments and river/floodplain disconnection (Vaughn et al, 2010) are amongst the most prevalent human-induced disturbances that expose the fluvial system to a series of negative hydrological, geomorphic or ecological consequences. Human modifications affect the overall river health by dissociating or impairing the natural linkages (Boulton, 1999), with potentially serious implications for riverine and/or riparian ecosystems (e.g. poor water quality from urban runoff).

Presently, over half the world's population resides in urban areas and this population shift from rural to urban environments is expected to rise to 60 per cent by 2030 (PRB, 2007). While urbanisation is seen as one of the major drivers of human-induced river landscape transformation (Chin, 2006; Paul and Meyer, 2001; Eigenbrod et al, 2011), the restoration potential of degraded urban water bodies is increasingly recognized and implemented to achieve improvements in habitat quality and heterogeneity (Andel and Aronson, 2006) as well as contribute to sustainable water management (Paul and Meyer, 2001; Everard, 2004). This chapter summarises two decades of research available on the topic of river restoration with particular reference to urban environments and the implementation of the European Water Framework Directive (WFD).

One of the goals of river restoration is to promote activities that help re-establish a multifunctional use of rivers to create sustainable river environments. Within the European context, river restoration projects facilitate the implementation of environmental directives, primarily the WFD and the Habitats Directive, and various national and regional water management policies (EA, 2011a). Research by Clark et al (2003), for instance, advocates a holistic and integrated approach to restoring European surface water bodies in order to meet the obligations of the WFD to reach 'good ecological status' (GES) by 2015. Research undertaken for this dissertation will link the holistic principles of the ES approach (Lundy and Wade, 2011) to the primary requirement of the WFD, i.e. to the target of 'good ecological potential' (GEP) for the River Wandle – firstly to provide guidance for the

Wandle Catchment Plan and inform the future design of effective river restoration schemes and secondly to fill the existing knowledge gaps (as identified in Chapter 2.3) on the contribution of functioning ecosystems to the realisation of various environmental outcomes at a local scale.

3.1 The main concepts of the Water Framework Directive

The WFD (2000/60/EC) is a groundbreaking piece of European legislation, which came into force in 2000 and was transposed into UK water policy in 2003. The Directive advocates a catchment-scale approach to river management and its objectives are implemented by means of river basin districts (Boon and Raven, 2012). Article 1 of the Directive defines a set of targets for the protection of surface and coastal water bodies and groundwater in order to prevent the degradation of aquatic ecosystems or to promote sustainable water use, for instance (OJEC, 2000). However, its primary objective for all Member States is to achieve GES for natural water bodies by 2015 or GEP for artificial and heavily modified water bodies (HMWB) by 2027, at the latest.

Under the WFD, the ecological quality of a water body is derived from the status of its biological (e.g. fish, invertebrates), physico-chemical (e.g. temperature, pH) and hydromorphological quality elements (OJEC, 2000). The assessment of 'ecological status' varies from that of 'ecological potential' in that the former is defined as a measured variation from a reference condition (Borja and Elliott, 2007), while the latter is much harder to define as water bodies that were designated as artificial or heavily modified are unable to achieve natural conditions (EA, 2009).

The River Wandle, whose 'ecological potential' has been studies during this project, is one of the 38 designated river water bodies in the Greater London area, which are to achieve GEP by 2027 (EA, 2012). It has received a HMWB designation in the Thames River Basin Management Plan (RBMP) because the hydromorhological modifications needed for it to achieve GES would jeopardise the wider environment, water regulation, flood protection or recreation. In addition, many of the benefits served by its modified characteristics cannot be substituted with more suitable environmental options due to technical feasibility or disproportionate costs (OJEC, 2000; EA, 2009).

In principle, 'ecological status' and 'ecological potential' are recorded on the scale of maximum, good, moderate, poor and bad. Additionally, as per the first cycle of the River Basin Management Planning, artificial water bodies and HMWB are classed as either a) those that have achieved GEP or better and b) those that have achieved 'moderate ecological potential' or worse (UKTAG, 2008). Currently, 278 urban river bodies in England

and Wales (34 per cent) fall into the latter classification (UK NEA, 2011b), which obliges their management to implement a series of mitigation measures in order to reach at least GEP by the stated deadline. In accordance with Annex V of the WFD, a HMWB can achieve GEP if the values of its biological quality elements are only marginally different from those of 'maximum ecological potential', and if the status of its physico-chemical elements is adequate to maintain the functioning of aquatic ecosystems (OJEC, 2000).

Another major requirement of the WFD is that each RBMP should be revised and updated every six years to account for the impacts of anthropogenic pressures on the water environment and incorporate a programme of measures to enhance the status of water bodies and restore their ecology to a close approximation of their natural conditions (Borja and Elliott, 2007). In the UK, the Environment Agency (EA) is currently developing the second round of RBMPs to be published in 2015.

Since the river catchment has long been recognized as the most effective unit for reducing human impacts (Boon and Raven, 2012), the UK government, in line with the WFD focus on catchment-scale management, is aiming to produce a framework for integrated water management across England by 2013, while encouraging stakeholder engagement in the decision-making process. In addition to the 25 existing catchment pilots led by the EA and other organisations, a further 41 initiatives are in development in other catchments (EA, 2012), one of which is the Wandle Catchment Plan hosted by The Wandle Trust (see Chapter 4).

3.2 Goals and objectives of river restoration

The goals driving river restoration projects can vary from improving water quality to attaining enhanced aesthetic or recreational benefits. As most European rivers and floodplains have been severely impacted by engineering-dominated practices over prolonged periods of time, any restoration work, based purely on historical evidence, should weigh up the existing ecological and socio-economic needs of the river environment before undertaking restoration to a former state (Mainstone and Holmes, 2010). In theory, river restoration should encourage a return to natural flow regimes, enhance fish passage through weir alteration or removal, and should aim to reinstate hydrological connectivity between the river system and the floodplains. A more radical restoration technique, typically used in urban areas, is the deculverting of 'lost' rivers, which involves uncovering buried watercourses and restoring them to more natural conditions (Wild et al, 2011), leading to a significant increase of the river's biodiversity value (Andel and Aronson, 2006).

While many restoration projects aim to rehabilitate to some extent the original morphology of the river or its particular sections, river management agencies are increasingly focusing on ecosystem restoration to enhance or re-establish specific ecosystem functions, such as the revegetation of riparian zones to minimise the risk of pollution from urban runoff (Wissmar and Beschta, 1998). The main objective of restoration activities, aimed specifically at habitat enhancement, is to improve functional habitats (also known as 'meso-habitats') in fragmented landscapes by creating or restoring ecosystem linkages (Kemp et al, 1999). According to research conducted by Ward and Tockner (2001), this could be achieved through the reconstitution of functional processes across the river corridors to increase habitat heterogeneity and concomitantly enhance the diversity of aquatic and riparian species. Their research concluded that a wider concept of biodiversity, including surface and subsurface waters, riparian systems and other ecosystem components, is needed for effective river conservation and management.

Within the literature, river restoration projects are frequently grouped into three mainstream categories (EA, 2011a):

1. *Multi-reach restoration* often involves the entire length of a water body and the connected on-line lakes.
2. *Floodplain restoration* aims to reduce areas of urban land take and rehabilitate natural processes to a riparian zone or floodplain.
3. *Catchment-scale approach*, however, has become the most advocated framework today (Harper et al, 1999; Clarke et al, 2003) as it takes into consideration a wide range of processes and constraints present within the wider catchment.

For the past 30 years, site-specific approaches have prevailed in the field of river restoration in Europe. On the whole, these traditional restoration methods have been applied to smaller-scale single-issue or species/habitat-driven projects. For example, the latter often attempted to recreate channel forms to benefit particular species or habitats yet by disregarding fundamental geomorphological processes, many of these schemes were ineffective without a continued management input, and therefore failed to create self-sustaining ecosystems. Clarke et al (2003) addressed this issue by proposing a multidisciplinary approach to sustainable river management, contingent on stakeholder collaboration and the monitoring of project outcomes. Moreover, the catchment-scale approach advocated by Clarke et al encourages the formation of a strategic and process-driven framework, which is capable of sustaining spatial and temporal heterogeneity – an underlying characteristics of fluvial systems. Such research is needed to address the current lack of evidence base and of practical tools available to support decision-making and the sustainable development of catchments (Everard, 2004).

3.3 Scientific concepts underpinning urban river restoration

The application of scientific research is instrumental in guiding river restoration practices and the transition towards an ecosystem approach to sustainable river management (Brierley, 2008). Despite that, the subject of ES in urban rivers and streams remains to be a largely understudied area (Paul and Meyer, 2001). Furthermore, Wohl et al (2005) emphasize the paucity of scientific context in numerous river restoration projects and consequently present two key concepts for restoration success. The first one claims that the restoration of aquatic ecosystem processes is more likely to succeed than a single-issue restoration due to the natural variability of river systems. The second concept involves the application of a catchment-scale approach to river restoration to account for the complex relationships between the various physical, chemical, and biological processes of a river system, which fits in with the abovementioned seminal research findings (Clarke et al, 2003).

The classification of urban rivers has been the focal point of a British research team led by Gurnell for almost a decade to address a shortfall in assessment methodologies specifically designed for urban or heavily engineered rivers. In 2004, they developed the Urban River Survey (URS), a reach-scale assessment technique, which forms the basis of urban river management across the UK (Davenport et al, 2004; Boitsidis et al, 2006). The initial stage of URS, which is built on the EA's River Habitat Survey, involves data collection on 500m stretches of urban rivers and their margins, selected according to engineering type. Indices developed from the URS data help assess the physical quality of individual surveyed stretches to identify river sections that require priority management across urban catchments. By applying cluster analysis to these indices, three classifications of urban stretches, namely Materials, Physical Habitat and Vegetation, are obtained – these can help enhance habitat quality, diversity and complexity of urban rivers. The ES approach carried out as part of this research project can be used to supplement quantitative data acquired via URS and other similar research to incorporate public perception into the decision-making process.

The impacts of urban development on hydrological processes, such as river flow or sediment transport, are widely known; they include increased flood peak discharge, changes in the dynamics of river sediment and significant river channel modifications (Chin and Gregory, 2005; Chin, 2006). With reference to the above-stated URS research, Gurnell et al (2011) assessed 180 urban river stretches of varying engineering type from four

European river basins. Importantly, their findings revealed 'statistically significant' associations between the degree of an engineering intervention and the characteristics of physical habitats (i.e. river condition), indicating that the engineering of urban river channels, particularly if carried out in a patchy and varied fashion, can be compatible with a diverse natural functioning of rivers, provided good water quality is maintained.

3.4 Restoration potential of urban water bodies

Although opportunities for river restoration in urban areas are in essence dependent on the availability of space, significant improvements can be achieved by a gradual elimination of some engineering structures and barriers to allow for a heterogeneous recovery of the river system (NERC, 2012). Recent developments in European legislation, primarily the WFD and the Habitats Directive, have prompted an upsurge in river restoration projects undertaken across the EU, creating numerous opportunities for the rehabilitation of ecosystem processes that support river ecology (Clarke et al, 2003).

Most of the problems relating to poor water quality have now been addressed in the majority of lowland UK rivers, despite that many are affected by ecological degradation from treated sewage effluent discharges and storm drainage runoff (Harper et al, 1999). As a result, improvements in habitat heterogeneity have now become the determining factor for river ecology. Past engineering interventions have significantly fragmented habitat continuity, so opportunities for ecologically based restoration of degraded river channels are numerous (Palmer et al, 2005). Restoration techniques that aim to deliver water quality, flood protection and conservation benefits have so far been applied unsystematically in relatively small-scale situations, therefore Harper et al (1999) draw attention to a need for an integrated approach at the planning stage to achieve the most favourable project outcomes.

Palmer et al (2010) recently challenged the biodiversity benefits of river restoration projects, despite their contribution towards species and habitat heterogeneity. They analysed habitat and invertebrate data collected from 78 self-regulating streams, and found a negative correlation between habitat heterogeneity and invertebrate diversity in most restored streams. These findings imply that the restoration of HMWB should not be driven solely by physical heterogeneity.

The removal of in-stream barriers (e.g. weirs) not only helps to reconnect the river, but most importantly it makes the river more resilient to pressures such as extreme flood events or pollution (White and Stromberg, 2011), providing a series of environmental and ecological benefits. Two significant modelling approaches have been developed on the subject of barrier removal. Firstly, O'Hanley (2011) designed an optimisation model to improve functional connectivity and the environmental status of a river system by maximising the potential of the largest stretches of unobstructed river network. Secondly, Mouton's integrated modelling approach (Mouton et al, 2007) went one step further to assess the ecological impacts of river engineering on a selected fish population. Here, an eco-hydraulic simulation tool was used to mimic the physical effects of weir removal on the bullhead (*Cottus gobio*) habitat, found typically in European rivers. Based on the simulation outcomes, the weir removal was predicted to bring about significant improvements in habitat suitability for bullhead populations.

In order to implement the objectives of the WFD, stream and river restoration projects of varying scales are currently in development in order to reach GES or GEP within the given time frame. The restoration of the Upper Main is not only a successful example of the largest river restoration in Germany, but also an exemplary accomplishment of multiple WFD targets. The project, which took 18 years to complete, entailed extensive channel restoration, the reconnection of historical oxbow lakes and the installation of vast riparian buffer zones on an 18-km stretch of the river. Using a multi-metric assessment system, Lüderitz et al (2011) set out to evaluate the restoration success of the Upper Main and found that, in contrast to the non-restored sections, the restored river stretches achieved a GES, based on a range of indicators such as hydromorphological condition and biological parameters (e.g. fish populations, macroinvertebrates and aquatic flora).

3.5 Public and stakeholder participation

Human populations derive a host of cultural and economic benefits from freshwater ecosystems, e.g. water purification and water supply, regulation of hydrological flows and the provision of recreational and aesthetic values (see Chapter 2). It is therefore unsurprising that Boulton (1999) underlined the significance of ecological as well as human values for river health assessments. Increasingly, the planning of river restoration projects involves catchment-scale stakeholder consultation and input to amalgamate multiple viewpoints and concerns, and to gain support for restoration efforts. Stakeholder consultations typically comprise representatives from the public and private sector (for instance policy makers, scientists and non-governmental organisations) and potentially affected user groups (Likens, 2010; EA, 2011a).

During the planning stage of most river restoration projects, ecological aspects are frequently prioritised over aesthetic considerations. To evaluate the public's visual appreciation and interpretation of river restoration outcomes, Junker and Buchecker (2008) carried out a Switzerland-wide study where aesthetic preference data (acquired through surveys using photographic simulations) was correlated to scientific assessments of ecological quality. The survey findings revealed unexpected positive associations between the public's visual perception of naturalness and the improved eco-morphological quality of restored rivers, suggesting that even small-scale ecological improvements to rivers can produce favourable aesthetic outcomes. A similar study conducted by Buijs (2009) in the Netherlands emphasized the integration of public perception into river restoration projects as a way of gaining public support and creating strategic relationships between project planners and local residents.

The Mersey Basin in the northwest of England represents a successful example of a collaborative partnership approach to urban river restoration in the UK. Nolan and Guthrie (1998) assessed the community aspect of restoration activities on the Whittle Brook and the River Alt in the Mersey Basin. Whittle Brook is a small but highly engineered watercourse; ecological and aesthetic improvements carried out on a section, which flows through an urban green space adjacent to a housing development, involved the restoration of physical structures and riparian zones. On the other hand, a culverted section of the River Alt was turned into an open river/habitat corridor and revegetated under a community-driven catchment initiative 'Alt 2000'. In accordance with the findings of Boulton (1999) and Junker and Buchecker (2008), Nolan and Guthrie (1998) also came to the conclusion that collaborative partnerships involving the local community are vital to river restoration success.

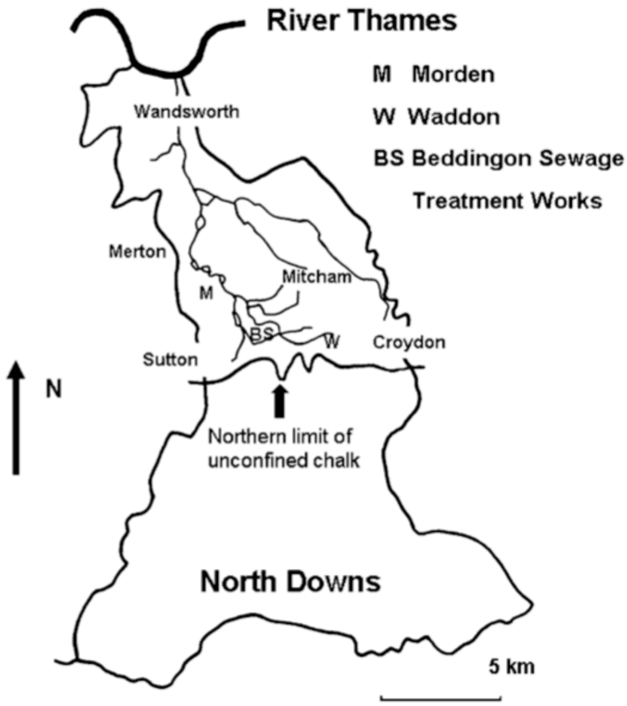
Increasingly, the rehabilitation of river systems in urban environments is recognized as an integral component of river management strategies at a local, regional and national scale. It is, however, evident from the reviewed studies and research findings that many river restoration activities still need to overcome a number of critical challenges, one of which is the prevailing public perception that ecological restoration is a scientific rather than a social effort. Since the success of urban restoration projects rests on the holistic integration of social, environmental and political factors, more emphasis needs to be placed on the assimilation of practical (i.e. science-based) project aims with those of the social sciences (Eden and Tunstall, 2006). Furthermore, local implementation of European and national legislation, especially the WFD, is vital for attaining a GEP for the vast majority of urban rivers (EA, 2011a), but improved understanding of ecological and economic benefits, the adoption of integrated catchment-scale approaches to ecosystem restoration and the need for collaborative stakeholder involvement (Nijland and Cals, 2001) are also key to achieving project success.

CHAPTER 4: THE RIVER WANDLE CATCHMENT

4.1 Catchment hydrology

The River Wandle is a relatively short tributary of the River Thames (15 km long), located in southwest London, England. Its catchment drains from the chalk ridge of the North Downs beyond the Greater London area in the south to its confluence with the Thames at Wandsworth (Baxter, 2011). Covering an area of roughly 200 km^2, the catchment incorporates the London boroughs of Wandsworth, Merton, Sutton and Croydon (Figure 2).

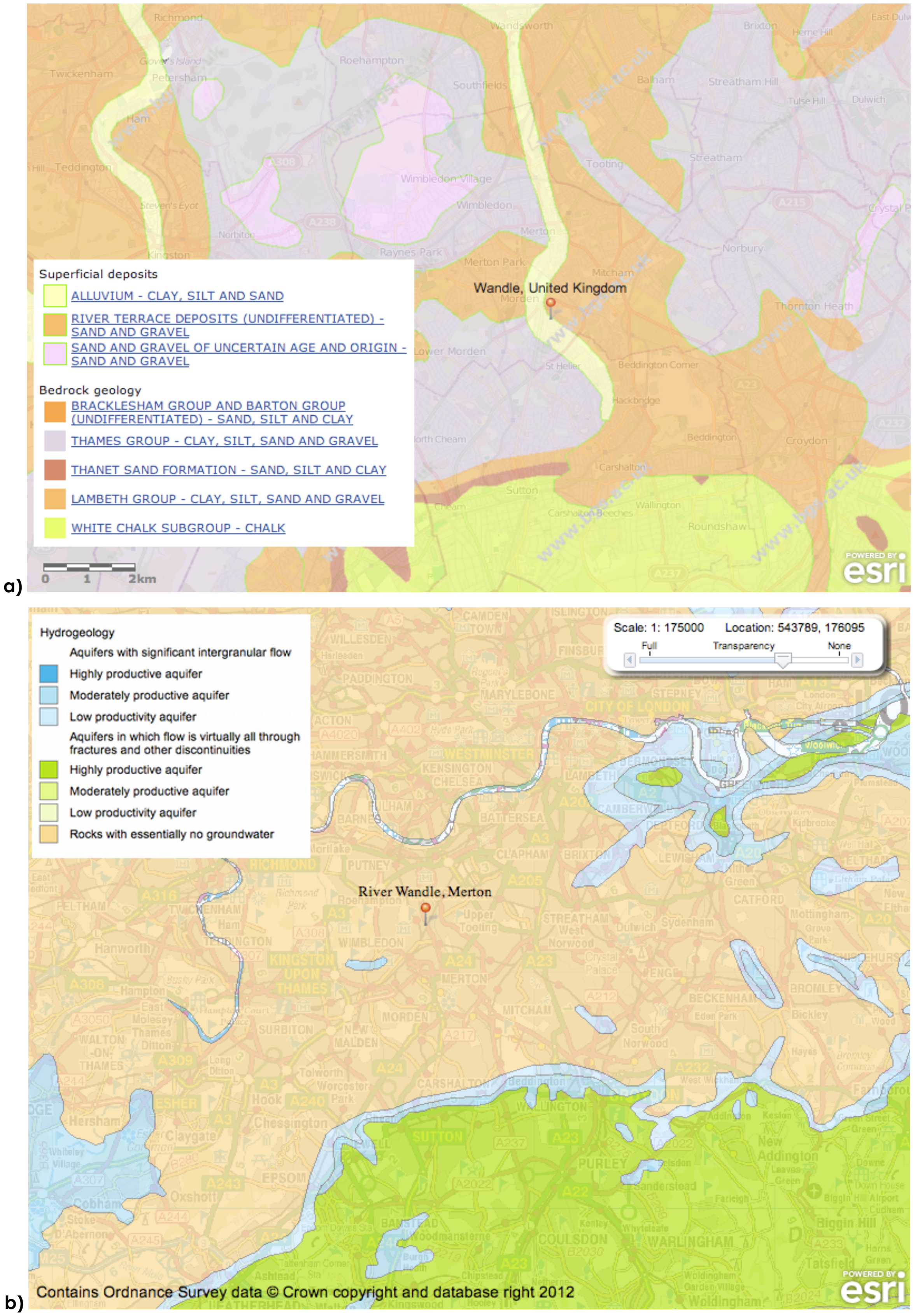
Figure 2: The Wandle catchment boundaries and stream network (Source: Cook, 2008)



The origin of the river is from rainwater percolating the North Downs, giving rise to springs at the junction between the chalk and the overlying drift cover (i.e. clays and gravels) in Carshalton and Croydon (Figure 3a). Another source of the river is the seasonal stream, known as the Bourne, which runs through the Downs (i.e. Caterham and Coulsdon valleys) and only surfaces during wet winters. In its upper catchment, the Wandle's base flow relies on groundwater capture from the chalk aquifer; therefore water abstractions (within the aquifer) impact on the quantity of river flow (Figure 3b; Baxter, 2011).

The Carshalton and Waddon branches of the river combine at Hackbridge and flow through Mitcham. There, a short tributary called the Beddington Corner branch, which carries discharge from Beddington Sewage Treatment Works (STW), merges with the main channel (Figure 2).

Figure 3: River Wandle 1:625 000 scale maps of a) geology b) hydrogeology (Source: BGS, 2012)



Compared with a predominantly rural upper catchment, the lower catchment lies in a densely urbanised setting. The bedrock here is formed of London Clay, with alluvium and gravel deposits along the river valley (Figure 3a; Baxter, 2011). The Wandle has two tributaries: the River Graveney and the Caterham Bourne. The former rises from springs near Croydon whereas the latter is an ephemeral chalk stream in the upper catchment, which drains into the Wandle at Waddon.

4.2 History of human management

The Wandle's water power had been of prime industrial importance for many centuries (Smith, 2001). The 1086 Domesday survey recorded at least 13 watermills along its length, but by the beginning of the 18th century, there were 42 mill sites, producing everything from leather, cloth and dyes through copper, timber, paper, oil and flour to beer and snuff (Cook, 2008). However, these were small-scale enterprises and the river remained unpolluted and remarkably productive as a fishery until the mid-1800s. In fact, the Wandle became renowned for its crystal-clear waters and the quality of its trout (Pugh, 1808; Cook, 2008). Up until the 1850s, native trout of two and three pounds were commonplace and abundant catches of brace were also recorded on the river.

By the 19th century, however, the once rural landscape of the Wandle catchment had been transformed through industrial development and urbanisation (Cook, 2008). The river drove an increasing number of mills and flowed through the parks and gardens of several grand houses of industrial entrepreneurs (Nagle, 1999). Many of these riverside open spaces became the bleaching and drying fields for the mills, such as the grounds adjacent to the river at Merton and Mitcham where the bleaching and printing of calico took place (Pugh, 1808). In 1885, Arthur Liberty, of the Regent Street Store, acquired Merton Abbey Mills' calico factory for the dyeing of silks (Smith, 2001).

Driven by the booming manufacture of paper, leather, snuff, gunpowder and textiles, the Wandle eventually came to be known as one of the most heavily industrialised rivers for its size in the world, with 90 mills lining its banks by the late 18th century (White, 1984). To fulfil the demands of the extensive milling industry, the Surrey Iron Railway, Britain's first public railway, was founded along the Wandle Valley by the civil engineer William Jessop in 1803 (Smith, 2001). To further support the industrial growth along its banks and increase its efficiency as a storm drain, sections of the river were heavily reengineered in the 18th and 19th centuries (Smith, 2001). For instance, channelisation and millrace construction altered the entire length of the Wandle in the Merton area during the 18th century. In fact, a small tributary stream, known as the Pickle Ditch, now remains the only surviving section of its original course in Merton (Baxter, 2011). Nevertheless, the Wandle has preserved far more of its natural features than many other London rivers (e.g. the subterranean River Fleet) thanks to its early value to fishing, farming and light industry and the attractiveness of its valley, and still maintains its course to the River Thames without too many physical obstructions (Nagle, 1999).

The continually rising rate of industrialisation and floodplain urbanisation eventually resulted in conflicts over water quality and supply, causing competition between different industrial processes (Cook, 2008). Many legal arguments ensued over the loss of water supply, with arbitrators suggesting the use of waterwheels on a rota basis, but by the 1860s industrial-scale milling on the Wandle was rapidly dying. Many of the mill sites converted to producing paints, solvents and chemicals, all of which eventually found their way into the river. In the coming years, the Wandle became heavily contaminated with industrial effluents and sewage (White, 1984). In addition, outbreaks of waterborne disease were recorded in Croydon in the early 19th century (Cook, 2008), which led to the opening of the sewage works in 1860 to improve sewage treatment and reduce the levels of wastewater pollution.

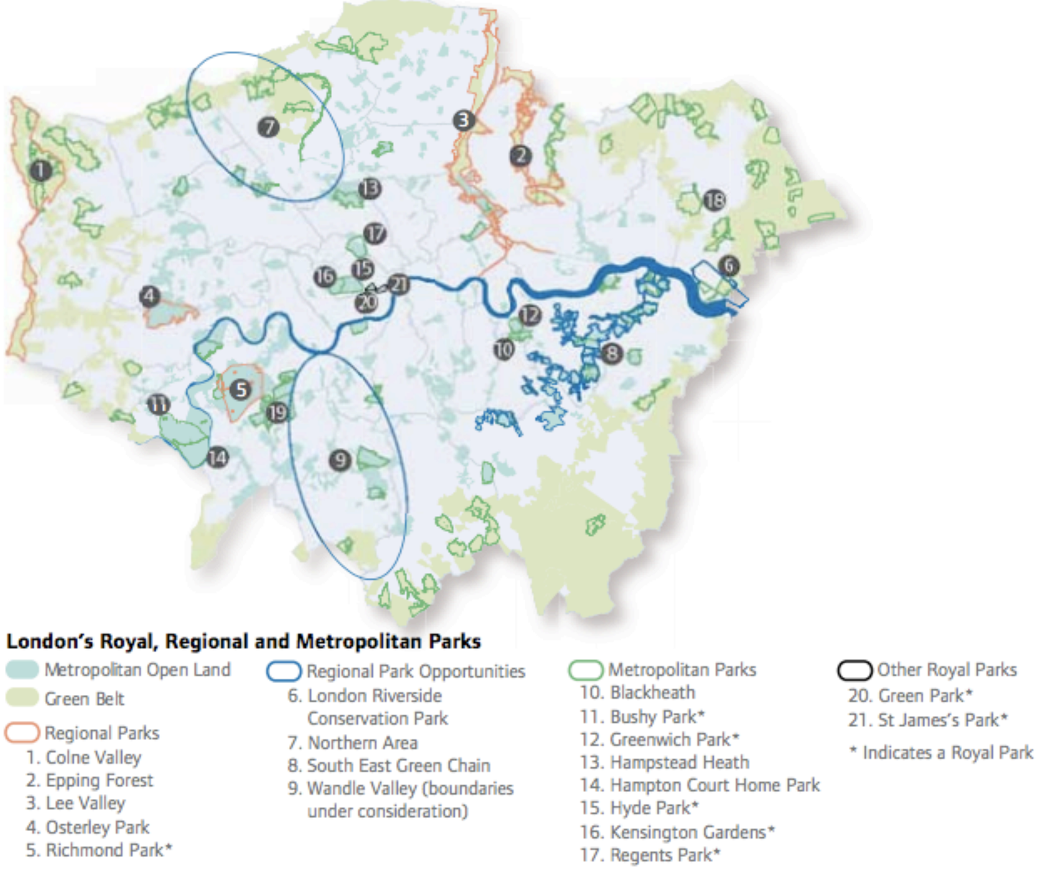
By the mid-1930s, the water quality deteriorated even further due to population increase and heavy groundwater abstraction. Eventually, a report published by the Ministry of Housing Committee in 1961 stated that the Wandle was so heavily polluted that "if a sample of it had been submitted for test as a sewage effluent, it would have failed to satisfy the Royal Commission Standard" (New Scientist, 1961). In the 1970s, the Wandle often ran red, pink or blue with dye used in local tanneries. The most recent pollution incident occurred in September 2007 when sodium hydrochloride was accidentally released during cleaning of the tertiary treatment plant at Beddington STW. The pollution spread downstream for nearly 5 km, decimating the majority of the fish, fly life and in-stream vegetation (i.e. *Ranunculus*). To its credit, Thames Water admitted responsibility and provided financial compensation for the damage (Cook, 2008).

A successful river restoration programme has been implemented on the Wandle since 1990 to gradually reinstate the lost ecological and aesthetic properties of this recovering urban river (Cook, 2008). The programme also involved the restocking of fish populations. Subsequent cleanups have led to a significant improvement in water quality and the return of the river's once famous brown trout as well as of other fish varieties, such as dace, chub, roach and perch (Baxter, 2011). In 2010, the Wandle was voted the fifth best river in the Our Rivers campaign thanks to the ecological and physical improvements carried out in recent years (Our Rivers, 2011).

4.2 Current management strategy

To a large extent, the River Wandle exemplifies many urban rivers since it has to contend with multiple development pressures (Nagle, 1999), which severely restrict its natural functioning. Despite its lack of natural river processes and habitat diversity (EA, 2011b), the Wandle catchment provides a valuable green corridor through heavily urbanised areas. Additionally, it links existing open spaces and sites of conservation interests, such as the Wilderness Island, Watermeads Nature Reserve or the Upper River Wandle, which is a designated Site of Metropolitan Importance for Nature Conservation (Baxter, 2011). In 2011, the Mayor's London Plan selected the Wandle Valley to become a Regional Park (Figure 4) to enhance the existing network of open spaces and wildlife sites along the River Wandle and provide new and accessible recreational opportunities in South London (GLA, 2011). The application of an ES approach to the Wandle will therefore help highlight the range of recreational, cultural and other benefits associated with the river corridor, emphasising the value of its aquatic and riparian ecosystems for human wellbeing and sustainable development.

Figure 4: London's strategic open space network, including the proposed Wandle Valley Regional Park (Source: GLA, 2011)



As specified in the Thames RBMP, the Wandle is designated as a heavily modified water body (HMWB) since over 75 per cent of its surface water network is urbanised, and a complete restoration of former ecosystems would not only compromise existing urban development but it would essentially become disproportionately costly and technically unfeasible due to the scope and prolonged history of human interventions (EA, 2009).

The current 'ecological potential' of the river is classed as poor under the WFD (Table 1; EA, 2009). The Wandle has not met the GEP target primarily because of the absence of fish populations, which act as one of the most accurate bioindicators of river health (Cowx and Portocarrero Aya, 2011; EA, 2011b). River modifications, i.e. flood engineering structures, culverts and weirs led to a significant loss of habitat diversity for the majority of fish species, especially the migratory varieties (e.g. trout and eel). While many of these culverts and in-stream structures are essential for flood protection, some of the obsolete barriers are now being removed or installed with ladders to allow fish passage upstream, for instance the planned Shepley Mill fish pass or the Merton Abbey Mills eel pass (RRC, 2009). Furthermore, water quality varies significantly throughout the catchment and is affected by pollution pressures through storm sewage misconnections and overflows, increased urban run-off and the effluent from the Beddington STW, which equates to a maximum consented discharge of 234,000 m^3 per day and accounts for 80 to 90 per cent of the Wandle's river flow (EA, 2011b).

Table 1: Classification of ecological potential – River Wandle (Croydon to Wandsworth) (Source: EA, 2009)

QUALITY	ELEMENT	CURRENT STATUS	PREDICTED STATUS BY 2015
BIOLOGICAL QUALITY	**Fish**	Poor	Poor
	Invertebrates	Moderate	Moderate
	Macrophytes	Moderate	Moderate
	Phytobenthos	Poor	Poor
PHYSICO-CHEMICAL QUALITY	**Ammonia**	Good	Good
	Dissolved Oxygen	High	High
	pH	High	High
	Phosphate	Bad	Bad
HYDROMORPHOLOGICAL QUALITY	**Quantity & dynamics of flow**	Supports good	Supports good

The WFD requires the Wandle to achieve GEP by 2027 (EA, 2009) by implementing a series of mitigation measures on the river channel to enhance water chemistry and ecology as well as habitat diversity. Consequently, the catchment is the focus for a number of initiatives, which feature river restoration and improvement. The London Rivers Action Plan, which *inter alia* supports the delivery of the Thames RBMP under the WFD, acts as a primary river restoration stimulus across the Greater London area, identifying remedial opportunities along the non-tidal freshwater tributaries of the River Thames. Within the Wandle catchment, 18 sites have been earmarked for future restoration, ranging from bank naturalisation of the river channel at Mill Green and Ravensbury Park to the modification of redundant flood defence structures at the mouth of the river and the deculverting of Wandle Park in Croydon (RRC, 2009).

To achieve the WFD target, the management of the Wandle catchment will need to identify and balance the conflicting needs of many interests (Cook, 2008), i.e. flood storage, pollution control, conservation and recreation, and active organisations (Figure 5), including two active Rivers Trusts, namely the Wandle Trust and the Thames Rivers Restoration Trust. The former was founded in 2000 as an environmental charity devoted to restoring and maintaining the health of the River Wandle and its catchment through educational work (e.g. the award-winning 'Trout in the Classroom' project), monthly community river cleanups, fish restocking, restoration projects and environmental monitoring. The Trust is currently creating the Wandle Catchment Plan, in close collaboration with local communities and stakeholder organisations, to ensure the integrated planning and development of the river so that it can reach its full environmental potential and the GEP status by 2027.

CHAPTER 5: MATERIALS AND METHODS

5.1 Data collection methods

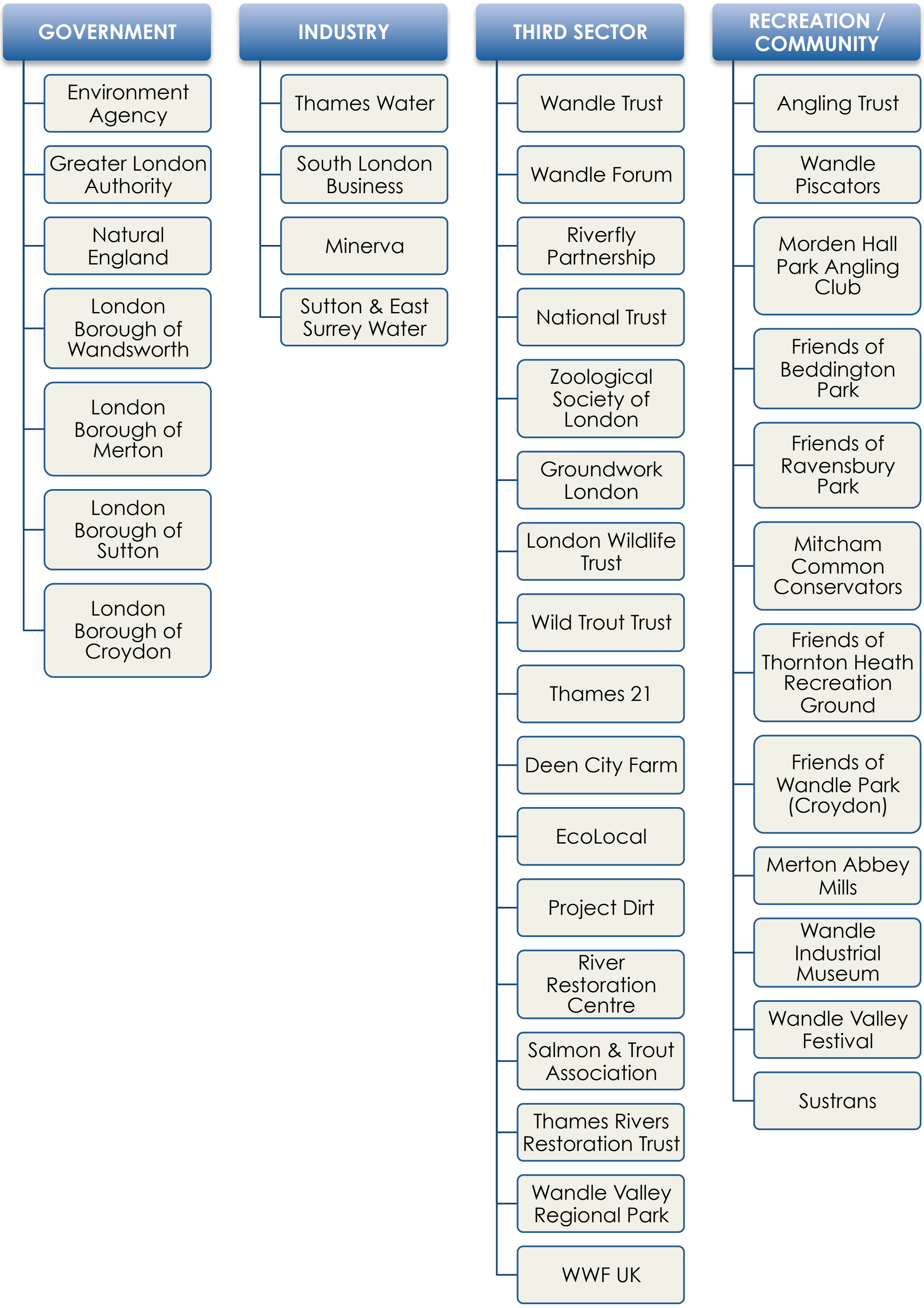
Qualitative data from a series of public consultation workshops and an online questionnaire have provided a direct resource for evaluating the significance of ES within the River Wandle catchment. From January to June 2012, the Wandle Trust ran a series of 27 public workshops along the entire catchment to engage the views and suggestions of local organisations and community representatives in the creation of a Wandle Catchment Plan. People from close to 30 different organisations and interest groups have participated, including charities, 'Friends of' groups and social clubs as well as landowners and managers (Figure 5). The workshops played a key part in identifying long-term solutions for securing the river's healthy future so that it can not only achieve GEP under the WFD, but also benefit people. In addition, an online questionnaire-type survey was made available (via www.surveymonkey.com) to wider audiences and for those who were unable to attend the local workshops (see Appendix A).

Raw workshop data and online questionnaire responses formed the basis of this qualitative data analysis. Given that the Wandle Trust had collected the materials prior to the commencement of this research project, I had no direct influence on the workshop format or the data collection methods used. Incidentally, all workshop data was amassed without a pre-formed coding scheme. The format of the online survey differed from that of the workshop, as respondents were able to choose from a predetermined set of multiple answers available for each question. The use of secondary data was deemed suitable for the purposes of this project, primarily because of the large sample size and because further data collection would have duplicated pre-existing information.

5.2 Data analysis

In order to review the collected data in a systematic manner, a qualitative analysis was undertaken, which primarily involved the scaling down of the sheer volume of raw data, the identification of significant patterns and relationships, and the development of a two-stage coding schema to categorise data into themes (Table 2; Patton, 2002; Gibson and Brown, 2009) and subsequently into ES. The ES coding methodology (Table 3) enabled me to develop a list of aquatic and associated terrestrial ecosystem values provided by the River Wandle by conducting an inventory of ecosystem functions to identify individual ES components.

Figure 5: Stakeholder groups of the River Wandle catchment by organisation type



At first instance, I decoded the content into broad thematic categories and identified primary patterns in the data (Table 2; Patton, 2002). Each category emerged during analysis and addressed larger theoretical issues identified in the literature review. This approach to analysis is typically referred to as thematic analysis, because the themes become apparent gradually without the application of a predetermined coding scheme and therefore the number of themes is not fixed. In order to compare and contrast results from various workshop groups, I used the method of comparative analysis, which worked well in combination with thematic analysis (Dawson, 2002). The comparative technique was not only useful for pinpointing, for instance, a particularly favourable asset of the River Wandle identified by several workshop groups, but it also enabled me to measure public workshop results against those of the online survey.

Table 2: Coding scheme of identified categories and keywords

THEMATIC CATEGORY	SUB-THEMES
ACCESS	Recreation; Fishing; Walking; Cycling; Wandle Trail; Banks; Transport; Safety
BUILT ENVIRONMENT	Facilities (e.g. cafés, bins); Concrete; Space and layout; Specific sites
EDUCATION AND INFORMATION	Communication; Education; Press and publicity; Awareness; Information points; Heritage; Fishing; Trout in the Classroom
FLORA AND FAUNA	Flora; Fauna: Birds, Fish, Invertebrates; Mammals; Non-native Invasive Species (NNISp); Predator/Prey relationship; Habitat; Biodiversity
HERITAGE	Information; History and story; Specific sites
HYDROMORPHOLOGY	Flow speed; Concrete; Features and connectivity; Quantity; Chalk stream; Enhancement
LANDSCAPE	Banks; Open spaces; Protected areas; Rural haven; Specific sites
MANAGEMENT AND PLANNING	Collaboration; Politics; Maintenance; EA; Boroughs; Staffing; Management plan; River restoration
PEOPLE AND PLACE	Engagement; Respect and care; Sense of place; Rural haven
RECREATION AND ACTIVITIES	Cycling; Walking; Fishing; Swimming and paddling; Picnics; Cleanups; Volunteering; Navigation (e.g. boating, canoeing); Wildlife watching
WATER QUALITY	Pollution; Sediment; Runoff; Rubbish and litter; Quality

The next stage involved the coding of both sets of data for ES, using a combination of the Millennium Ecosystem Assessment (MA) and the UK National Ecosystem Assessment (UK NEA) as a guideline (Table 3). The UK NEA, published in June 2011, adapted the theoretical framework of the groundbreaking MA to incorporate more recent developments in ES theory and practice with specific reference to eight broad UK habitat types (UK NEA, 2011a). I tested both ES classification systems separately, however I found that the UK NEA's in-depth assessment of freshwater and urban habitats (UK NEA, 2011b), when combined with the broader MA assessment, enabled me to produce a more accurate (i.e. habitat-specific) categorisation of ES for the Wandle catchment. Since this qualitative study was based on the public's perception of the river, supporting services were excluded from the analysis due to their indirect human effects (WRI, 2005; Lundy and Wade, 2011).

Once all ES were identified, I was then able to develop a (non-market) valuation methodology of the river's ecosystems (based on people's perceptions) by measuring the relative as well as the ranked importance of each ES contribution. Relative importance represents the overall strength of feeling, whereas ranked importance is derived from the rank order of a particular theme as indicated by each participant (or groups of participants). For instance, the local community may not regard the presence of riparian vegetation as a highly ranked feature of the river, but its contribution to flood protection and control, which may cause direct and indirect economic losses in the catchment, is likely to be valued very highly.

Table 3: Ecosystem services associated with urban water bodies (Source: adapted from MA, 2005 and UK NEA, 2011b)

CATEGORIES	ECOSYSTEM SERVICE	ECOSYSTEM FUNCTION	MAIN GOODS AND BENEFITS
PROVISIONING SERVICES	FOOD	Gross primary production extractable as food	Production of crops, fish, game, honey etc.
	FRESH WATER	Storage and retention of water	Potable and industrial use of water Energy generation
REGULATING SERVICES	AIR QUALITY REGULATION	Regulation of atmospheric chemical composition	Clean air
	CLIMATE REGULATION	Regulation of climatic process at global/local levels	Reduced urban temperatures Carbon sequestration
	WATER REGULATION	Regulation of hydrological flows	Reduced runoff volume and velocity
	PEST REGULATION	Regulation of pests, diseases, and populations of invasive species	Predator control of prey species Non-native invasive species control
	NOISE REGULATION	Regulation of environmental noise	Noise reduction
	HAZARD REGULATION	Retention of soil with an ecosystem	Stabilisation of sediments Erosion and flood protection

	WATER PURIFICATION	Recovery of mobile nutrients and removal/breakdown of excess nutrients and compounds	Removal of pollutants Waste treatment
CULTURAL SERVICES	**CULTURAL HERITAGE VALUES**	Providing opportunities for non-commercial uses	Aesthetic, artistic and spiritual values of ecosystems
	EDUCATION VALUES	Providing opportunities for education uses	Increased environmental awareness Educational values of ecosystems
	SOCIAL RELATIONS	Providing opportunities for social interaction	Neighbourhood development Social and environmental citizenship
	RECREATION & TOURISM	Providing opportunities for recreational activities	Physical and mental wellbeing Tourism, sport fishing etc.

5.3 Statistical techniques

Both, the workshop and online questionnaire data were decoded numerically for the purposes of statistical analysis. The statistical software package, PASW (Predictive Analytics Software) Statistics proved particularly useful for the management and organisation of the large list of workshop values. In order to describe the main features of the samples, I initially performed a basic univariate analysis for each variable (or groups of variables), commonly referred to as frequency distributions in qualitative analysis, which allowed me to present the perceptions of workshop and survey participants effectively and highlight any significant findings numerically (i.e. according to relative importance). Frequency distributions were followed by the analysis of bivariate relations via contingency tables (or cross tabulations) in order to identify statistically significant relationships between variables (Dawson, 2002). These two forms of descriptive statistics were sufficient for attaining the results necessary for the development of the final ES framework (Table 14). The majority of visual analysis (e.g. charts, diagrams and tables) was produced in Microsoft Excel to attain a consistent appearance in graphics throughout the entire report.

CHAPTER 6: RESULTS AND DISCUSSION

6.1 Workshop results

The overall results indicate that the public rates the use values of the Wandle catchment, i.e. cultural services, higher that its non-use values, i.e. regulating services, which is in line with the findings of previous monetary and non-monetary valuations of freshwater ecosystem goods and services in urban settings (Green and Tunstall, 1992; West et al, 2009; Everard et al, 2011; Everard, 2012). Even though 77 per cent of total workshop values describe cultural services (Figure 9), further analysis revealed that the public are aware of the role of non-use ecosystem components for the sustainable management and conservation of the catchment, of which water purification, water regulation and hazard regulation were regarded as highly significant for reaching the GEP target (Table 14).

Figure 6 indicates the overall relative importance of the main components of the river catchment, as perceived by specific stakeholder groups. Numbers of participants per workshop varied (Table 4), with an average of 19 responses per participant. There are relatively small differences between the groups in terms of the importance of components (i.e. themes), except for the Wandle Management Board and Working Groups' emphasis on the management and planning aspect and the Friends of Ravensbury Park's focus on the biodiversity and landscape features (Figure 6).

Workshop participants identified the existing positive and negative aspects of the river catchment in terms of water quality, river channel, riparian appeal, ease of access or recreational uses (Table 6), producing a comprehensive list of river features that helped define the current status of the catchment. Figure 7 shows that the river's recreational use, heritage value, and its landscape and biodiversity features are currently the highest valued assets, while the extent of human impact on water quality (i.e. litter, pollution and urban runoff) represents a serious concern, together with a lack of education and policy concerning the management of the river catchment.

In terms of future needs, workshop participants highlighted the importance of ongoing biodiversity and landscape enhancements and of improved access to the river, however better community policy and education as well as improvements in water quality featured prominently among priority goals and improvements (Table 7), which corresponds to the perceived positive and negative river aspects outlined above. Clearly, the public regard good water quality and an integrated approach to river management vital for maintaining healthy ecosystem functioning across the catchment and for reaching the

WFD objective by the stated deadline. To pinpoint the areas most in need of improvement and ensure a cost-effective management of the Wandle catchment (Boon and Raven, 2012), a map of spatial hotspots has been created [http://bit.ly/WandleHotspots; Appendix B], based on site-specific workshop values.

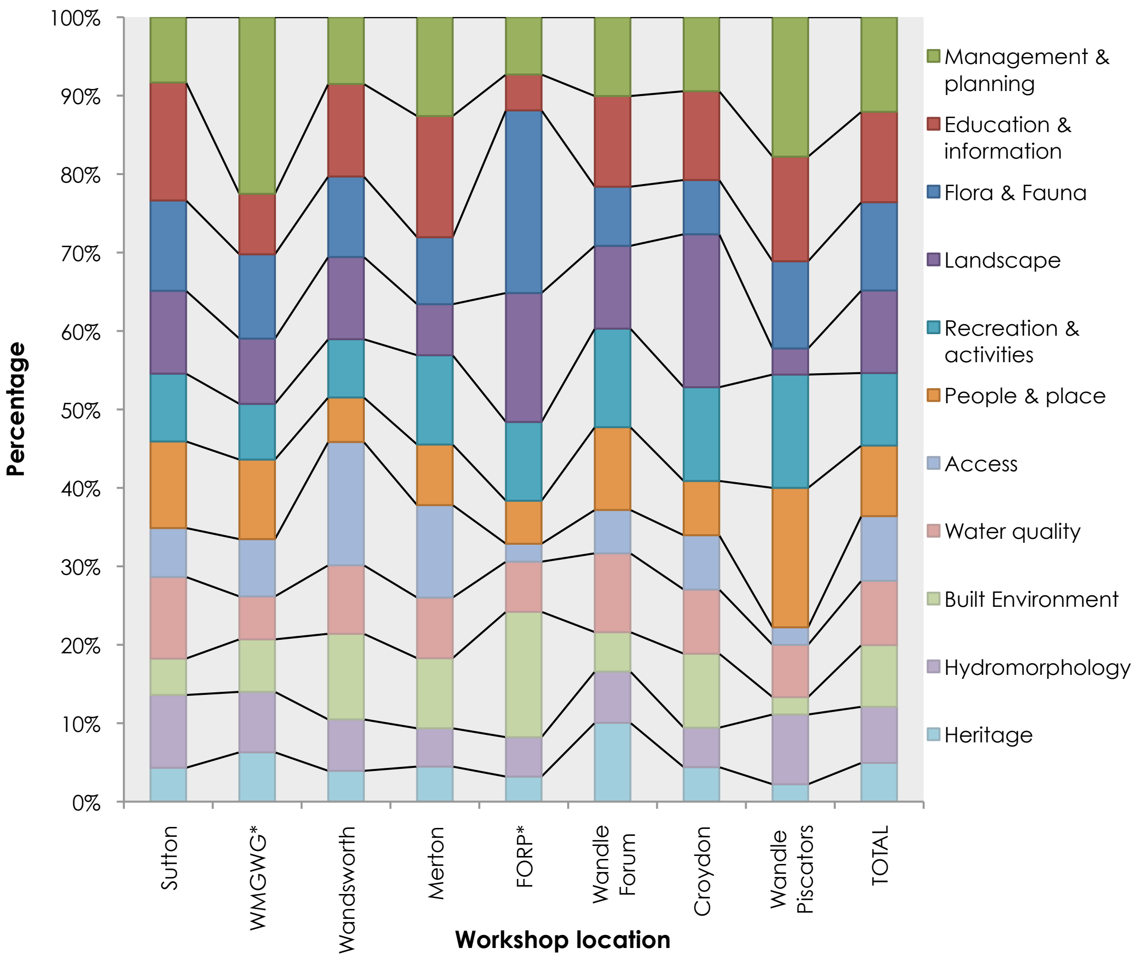
Table 4: Breakdown of workshop data by participants and individual responses

WORKSHOP	SUTTON	WMGWG	WANDSWORTH	MERTON	FORP	WANDLE FORUM	CROYDON	WANDLE PISCATORS	TOTAL
Participants (n)	25	24	23	13	11	7	6	3	112
Total number of individual responses per workshop	555	467	411	230	198	167	130	78	2,236
Total number of responses (% of total)	24.8	20.9	18.4	10.3	8.9	7.5	5.8	3.5	100%
Average number of responses per participant	22.2	19.46	17.87	17.69	18	23.86	21.67	26	19.96

Table 5: Relative importance of thematic categories by workshop locations

THEMATIC CATEGORY	SUTTON	WMGWG	WANDSWORTH	MERTON	FORP	WANDLE FORUM	CROYDON	WANDLE PISCATORS	TOTAL
Management & planning	52	111	39	31	16	20	15	16	300
Education & information	94	38	54	38	10	23	18	12	287
Flora & Fauna	72	53	47	21	51	15	11	10	280
Landscape	66	41	48	16	36	21	31	3	262
Recreation & activities	54	35	34	28	22	25	19	13	230
People & place	69	50	26	19	12	21	11	16	224
Access	39	36	72	29	5	11	11	2	205
Water quality	65	27	40	19	14	20	13	6	204
Built Environment	29	33	50	22	35	10	15	2	196
Hydromorphology	58	38	30	12	11	13	8	8	178
Heritage	27	31	18	11	7	20	7	2	123

Figure 6: Overall perception of the River Wandle by locations and themes



**WMGWG: Wandle Management Board and Working Groups*
**FORP: Friends of Ravensbury Park*

Table 6: Current status of the River Wandle by themes, including relative and ranked importance

THEMATIC CATEGORY	CURRENT BENEFITS	CURRENT BARRIERS	PRIORITY BARRIERS
Management & planning	36	85	14
Education & information	24	51	13
Flora & fauna	82	34	4
Landscape	96	26	4
Recreation & activities	79	20	3
People & place	71	54	8
Access	34	38	5
Water quality	14	83	18
Built Environment	32	62	7
Hydromorphology	33	50	7
Heritage	68	15	2
TOTAL	**569**	**518**	**85**

Figure 7: Current status of the River Wandle by themes

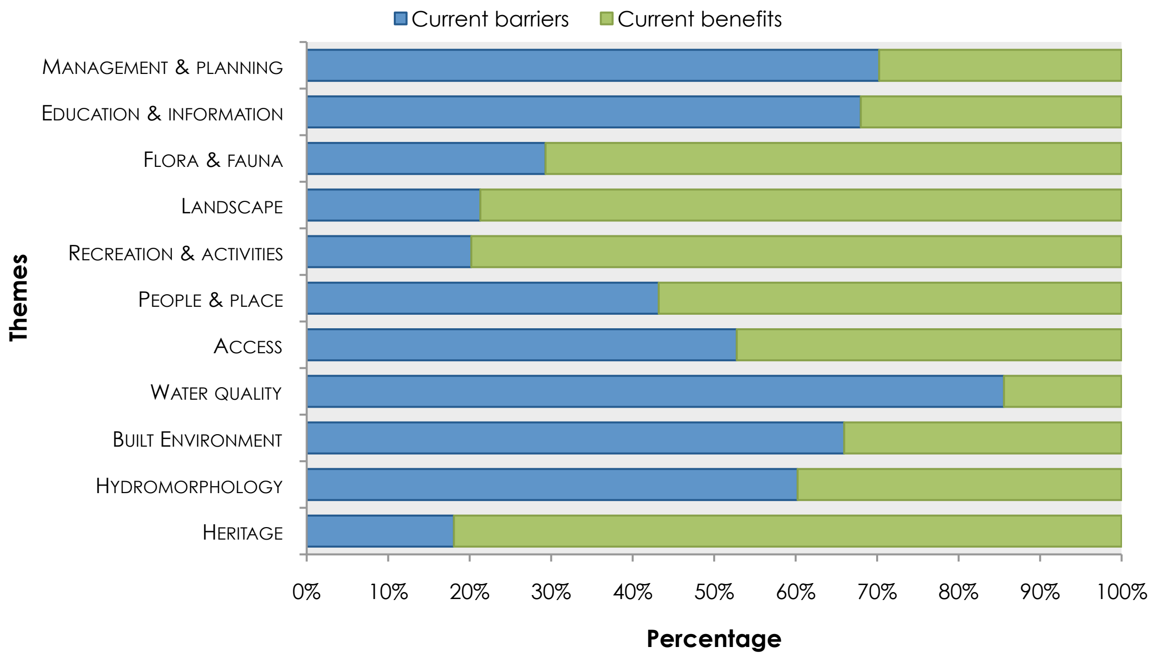
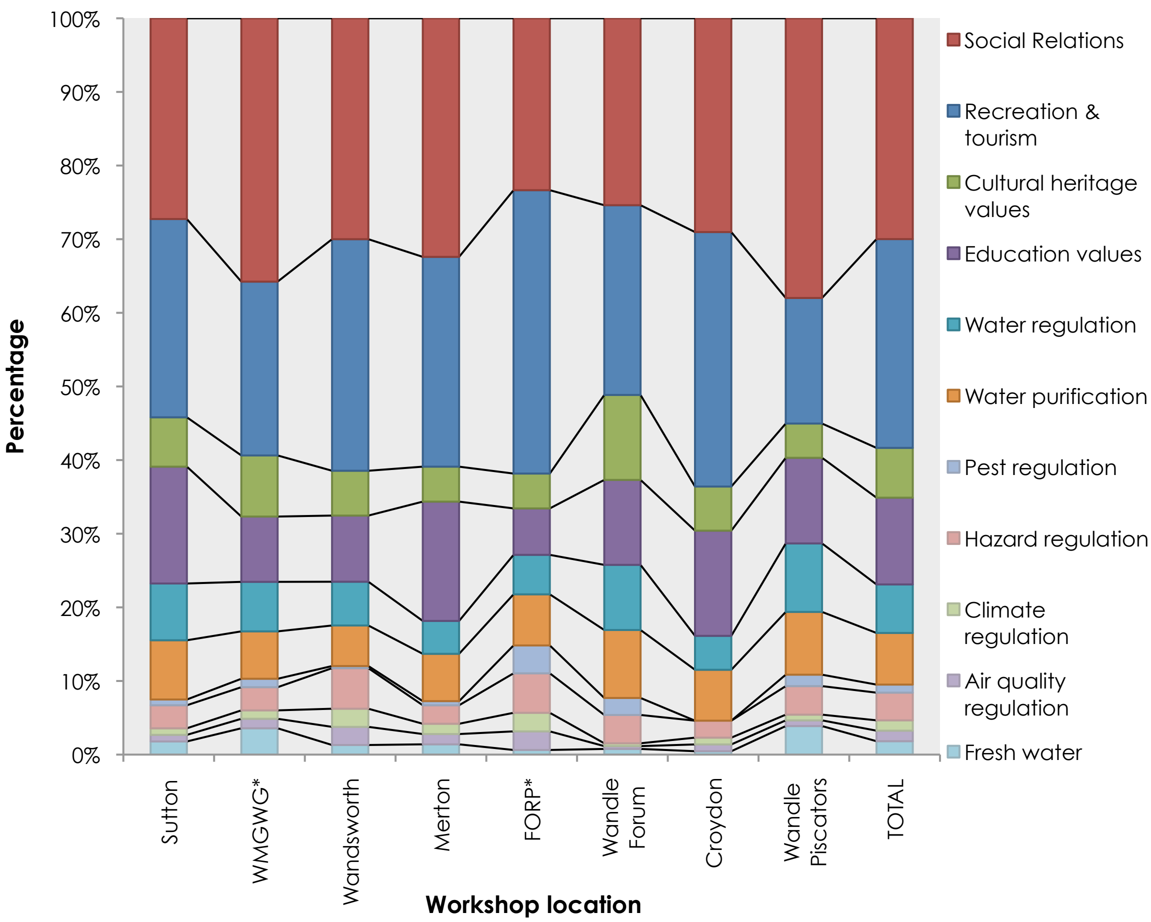


Table 7: Future status of the River Wandle by themes, including relative and ranked importance

THEMATIC CATEGORY	POTENTIAL GOALS	DESIRED IMPROVEMENTS	PRIORITY GOALS
Management & planning	44	135	24
Education & information	92	120	18
Flora & fauna	136	28	18
Landscape	105	35	16
Recreation & activities	97	34	3
People & place	44	55	14
Access	108	25	17
Water quality	78	29	20
Built Environment	64	38	4
Hydromorphology	66	29	4
Heritage	24	16	3
TOTAL	**858**	**544**	**141**

Figure 8: Ecosystem services by workshop location



**WMGWG: Wandle Management Board and Working Groups*
**FORP: Friends of Ravensbury Park*

Due to a higher rate of human consumption than production and the widespread distribution of impermeable surfaces, urban ecosystems produce significantly lower outputs of goods and services than their rural counterparts (TEEB, 2011). The contribution of green spaces, parks and urban water bodies to the overall supply of urban ES (i.e. air quality and microclimate regulation, noise reduction, water regulation and purification, pest regulation or cultural and recreational values) is paramount (WRI, 2008).

Overview of provisioning services in the Wandle catchment

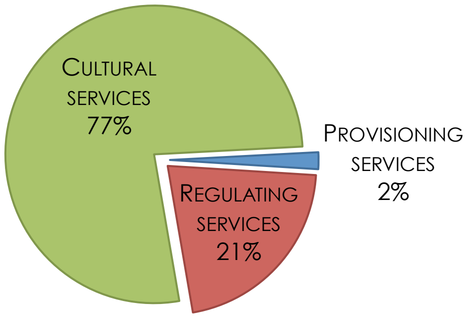
Amounting to a mere two per cent of all workshop values, the majority of sub-habitats along the Wandle catchment supply limited provisioning services, such as food, timber or ornamental plants (Table 8; Figure 9). When compared to most cultural and regulating services, the current significance of fresh water provision is low (Table 9; Figure 10), despite being strongly linked to water regulation and the delivery of several recreational and cultural activities. Table 10 shows that the future value of this ES is likely to remain unchanged. Indeed, as discussed in Chapter 4.2, the current 'ecological potential' of the

Wandle is classed as poor under the WFD (EA, 2009). Water quality is affected by a number of industrial processes, i.e. the treated sewage effluent discharged from the Beddington STW, which accounts for up to 90 per cent of the river flow. In addition, the assessment of the Wandle's surface water by the London Catchment Abstraction Management System (CAMS) found 'no water available' for abstraction (EA, 2011b), making it unsuitable for the supply of domestic or irrigation water in the Greater London area. Nevertheless, it is a WFD requirement to ameliorate water quality and resource levels in the catchment, therefore the potential for improving the function and resilience of fresh water provision for other services (e.g. water purification, pest regulation and cultural services) needs to be explored as a priority.

Table 8: Ecosystem services by workshop location

CATEGORY	ECOSYSTEM SERVICE	SUTTON	WMGWG	WANDSWORTH	MERTON	FORP	WANDLE FORUM	CROYDON	WANDLE PISCATORS	TOTAL
PROVISIONING SERVICES	FRESH WATER	16	25	9	5	2	2	1	5	**65**
REGULATING SERVICES	AIR QUALITY REGULATION	8	9	17	5	8	1	2	1	**51**
	CLIMATE REGULATION	8	8	17	5	8	1	2	1	**50**
	HAZARD REGULATION	28	22	38	9	17	10	5	5	**134**
	PEST REGULATION	7	8	2	2	12	6	0	2	**39**
	WATER PURIFICATION	72	45	38	23	22	24	15	11	**250**
	WATER REGULATION	69	47	41	16	17	23	10	12	**235**
CULTURAL SERVICES	EDUCATION VALUES	142	62	62	58	20	30	31	15	**420**
	CULTURAL HERITAGE VALUES	60	58	42	17	15	30	13	6	**241**
	RECREATION & TOURISM	241	165	217	102	122	67	75	22	**1011**
	SOCIAL RELATIONS	244	250	207	116	74	66	63	49	**1069**

Figure 9: Relative importance of ecosystem services categories



Overview of regulating services in the Wandle catchment

At present, the Wandle catchment provides a range of regulating services, however many of these ES are not functioning at their full potential (Figure 10). Together with water regulation, water purification is valued highly by the workshop participants, however it is also the most degraded regulating service and the one that shows great potential for future improvement (Table 10). Of all regulating services, water regulation is viewed as the most positive asset of the catchment, and its future significance is expected to double. On the other hand, the public consider the regulation of air quality, climate and pests relatively negligible, and their future potential is likely to increase only marginally.

Since there are strong interdependencies between most regulating services, the deterioration of one ES can inhibit the functioning of another. The regulation of water quality, for instance, is essential for preserving in-stream and associated riparian habitats for a variety of flora and fauna and is also linked to the provision of fresh water and climate regulation (PEER, 2011; UK NEA, 2011b). In addition, poor water quality (inc. odour) can have a detrimental impact on cultural services by reducing recreational and aesthetic opportunities. The entire Wandle catchment relies on the healthy functioning of water purification for good water quality, yet this ES is heavily compromised by a multitude of polluted inputs from treated sewage effluents, urban and road runoff and misconnections from municipal to storm sewers (UK NEA, 2011b; Losco et al, 2012). In addition, urbanisation in the lower catchment has reduced the river's natural capacity to immobilise or remove nutrient pollutants (e.g. nitrogen) from runoff water. As demonstrated by recent multi-scale biophysical models (PEER, 2011), total nitrogen retention provided by natural and semi-natural surface water bodies typically amounts to the combined input of all point sources (domestic and industrial) discharged to the river network, therefore there is a need to carry out a detailed assessment of this ES along the catchment and devise a set of mitigation measures that will enhance and sustain its future functioning.

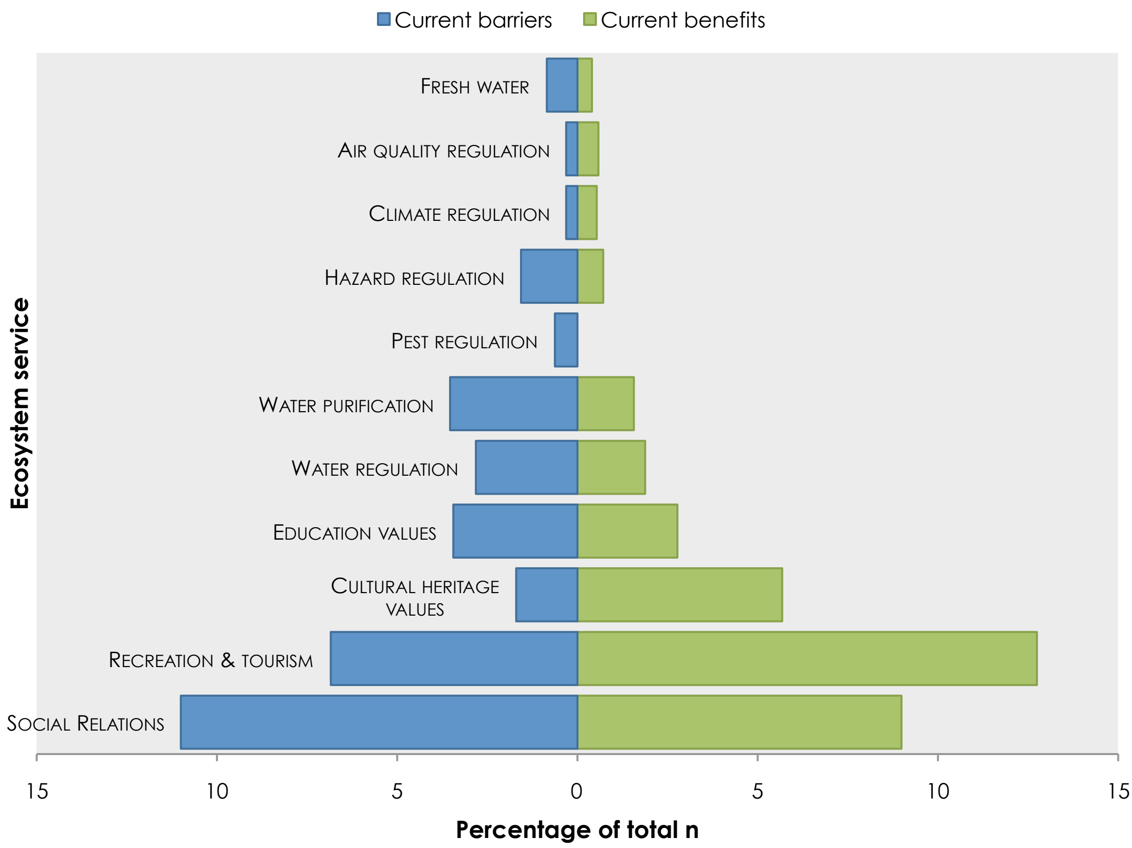
Workshop participants have rated floodplain connectivity negatively, which means that many open spaces and riparian areas that are vital for the buffering of storm water runoff are currently unable to carry out their natural flood risk management function (PEER, 2011). Due to its heavily urbanised lower catchment, the Wandle (especially between the areas of Beddington and Wandsworth) has shown a fast response to high intensity rainfall, producing significantly higher peak flows than a naturally functioning system and thus increasing the risk of downstream flooding. Improvements in hazard and water regulation could be achieved through the restoration of channelised stretches, the modification or removal of obsolete structures and the application of sustainable urban drainage systems (SuDS) where possible (Lundy and Wade, 2011). Such measures would not only enhance flood storage capacity, but also reduce the occurrence of local floods in areas, which are at high risk of fluvial flooding (e.g. up to 5 per cent of all properties in the Borough of Sutton).

Table 9: Current status of the River Wandle by ecosystem services, including relative and ranked importance

ECOSYSTEM SERVICE	CURRENT BENEFITS	CURRENT BARRIERS	PRIORITY BARRIERS
FRESH WATER	9	19	2
AIR QUALITY REGULATION	13	7	0
CLIMATE REGULATION	12	7	0
HAZARD REGULATION	16	35	4
PEST REGULATION	0	14	1
WATER PURIFICATION	35	79	17
WATER REGULATION	42	63	9
EDUCATION VALUES	62	77	17
CULTURAL HERITAGE VALUES	127	38	4
RECREATION & TOURISM	285	153	20
SOCIAL RELATIONS	201	246	36

There is growing evidence to suggest that a number of urban sub-habitats, such as open spaces, parks or vegetated riparian zones, coincide with improved air quality and climate regulation as well as noise and light reduction (UK NEA, 2011b). Based on workshop findings (Table 9), the semi-natural areas and green infrastructure present along the Wandle catchment are contributing only marginally to local climate regulation (e.g. the moderation of urban heat island effects and the buffering of wind speeds). Nevertheless, there is significant potential for a more effective use of green infrastructure and the planting of trees and other vegetation to strategically regulate microclimates and air quality in the catchment.

Figure 10: Current status of the River Wandle by ecosystem services



Overview of cultural services in the Wandle catchment

84 per cent of total current benefits are attributed to cultural services (Figure 10) with 'recreation and tourism' being the highest valued service, accounting for 36 per cent of total assets. The comparison of the catchment's current and future status reveals that the importance of its recreational values is likely to double in the future (Table 9 and 10). Conversely, 'social relations', although highly significant, is perceived as the most degraded ES of the river catchment today and also accounts for 42 per cent of all suggested future improvements (Table 10). Workshop participants have rated walking and fishing as the most important recreational river assets, followed by family-friendly activities and volunteering opportunities (including river cleanups).

The capacity of urban ecosystems to provide cultural services is positively correlated to the presence of biodiversity (i.e. a range of flora and fauna) and multifunctional landscapes (i.e. open spaces, parks and protected areas) and to their degree of naturalness (e.g. an urban haven). The delivery of cultural goods and services is also influenced by the condition, accessibility and the neighbouring infrastructure of these urban sub-habitats (PEER, 2011). Figure 16 indicates the vast contribution of green and blue spaces along the River Wandle to the physical and mental wellbeing of the local population, however the provision of recreational opportunities is distributed unequally depending on the level of urbanisation. The larger cultural landscapes of the catchment, such as Beddington Park, Morden Hall Park or Mitcham Common, are often considered as semi-natural and almost rural in character, due to a combination of relatively moderate ecological management and the screening of suburban features with trees. Moreover, the Wandle Valley is designated to become London's second regional park (Figure 4). The project, approved by the Greater London Authority and currently in its planning stage, is aiming to enhance the existing network of open spaces and wildlife sites along the River Wandle and drive the future regeneration of the South London region (GLA, 2011).

The ES, which is of primary concern to the local community, i.e. social relations, is also highly dependent on accessible, high quality open spaces that can foster better community cohesion and social inclusion (UK NEA, 2011b). Clearly, local communities want to participate in planning decisions that may result in unfavourable land use changes in their neighbourhood, therefore more emphasis needs to be placed on promoting social and environmental citizenship via the use of a participatory approach to environmental decision-making.

Table 10: Future status of the River Wandle by ecosystem services, including relative and ranked importance

ECOSYSTEM SERVICE	POTENTIAL GOALS	DESIRED IMPROVEMENTS	PRIORITY GOALS
FRESH WATER	19	18	4
AIR QUALITY REGULATION	26	5	0
CLIMATE REGULATION	26	5	0
HAZARD REGULATION	60	23	6
PEST REGULATION	15	10	3
WATER PURIFICATION	107	29	20
WATER REGULATION	88	42	7
EDUCATION VALUES	128	153	22
CULTURAL HERITAGE VALUES	58	18	7
RECREATION & TOURISM	420	153	44
SOCIAL RELATIONS	290	332	66

Presently, the River Wandle and its catchment serve as a valuable resource for wildlife and cultural heritage education. The Wandle Trust, for instance, runs the 'Trout in the

Classroom' initiative, which breeds young trout for release. In terms of its future significance, the service of educational values, which is contingent on the preservation of ecological knowledge (e.g. wildlife conservation and environmental education), is likely to double (Table 10). As seen in Chapter 4.2, which outlines the historical value of the river, the entire catchment of the Wandle boasts a rich cultural heritage and a distinctive sense of place, including the deer parks from the Tudor period at Beddington and Morden Hall and the remains of numerous historic mills. Hence the value of cultural heritage is rated as the third most favourable asset of the river, amounting to 16 per cent of total benefits (Table 9).

6.2 Online survey results

On the whole, the comparative analysis revealed a correlation between the workshop and online survey findings. 63 per cent of all survey values referred to cultural services, while regulating services were the subject of 32 per cent of all responses and the remaining 5 per cent referred to provisioning services (Figure 11).

Table 11: Basic demographic information of survey respondents

Gender	Male	Female
n	40	32
%	55.6	44.4

Age	18-29	30-49	50-64	Over 65
n	9	25	24	13
%	12.7	35.2	33.8	18.3

Length of residence	Less than 4 years	4-9 years	10-20 years	Over 20 years	Entire life
n	18	9	21	19	2
%	24.3	12.2	28.4	25.7	2.7

There were no significant variations between the genders (Table 11), as both gave an almost equal prominence to the highest rated catchment assets, i.e. recreational and cultural heritage values (Figure 12). In addition, cultural services were rated most favourable by the 30-49 and 50-64 age groups; these age groups were the most representative of the total survey sample. In terms of location, survey respondents came from 17 different postcode areas, representing a cross section of the local community. Wimbledon Park, Wandsworth, Carshalton and Croydon provided over a third of all responses. 85 per cent of respondents (63) have participated in outdoor activities along the Wandle in the last 12 months, and a further 53 per cent (39) have been involved with at least one stakeholder organisation (Figure 5) either as a volunteer or a member during the same time period.

Figure 11: Breakdown of ecosystem services by areas

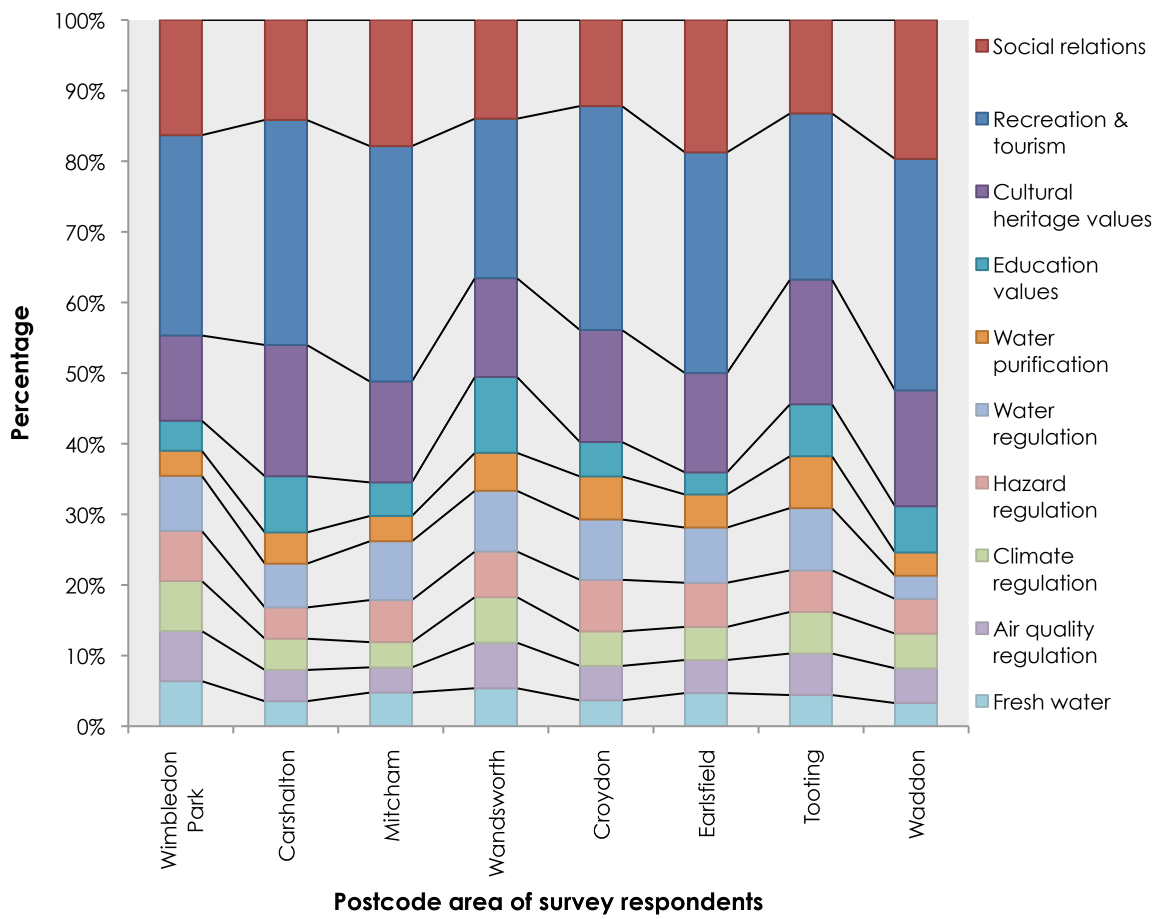


Table 12: Current status of the River Wandle by ecosystem services, including relative and ranked importance

ECOSYSTEM SERVICE	CURRENT BENEFITS	CURRENT BARRIERS	PRIORITY BARRIERS
FRESH WATER	58	69	12
AIR QUALITY REGULATION	67	0	0
CLIMATE REGULATION	67	0	0
HAZARD REGULATION	79	140	28
PEST REGULATION	0	66	11
WATER PURIFICATION	60	136	40
WATER REGULATION	99	278	54
EDUCATION VALUES	89	204	29
CULTURAL HERITAGE VALUES	209	0	0
RECREATION & TOURISM	384	487	73
SOCIAL RELATIONS	200	553	79

Figure 12: Current status of the River Wandle by ecosystem services

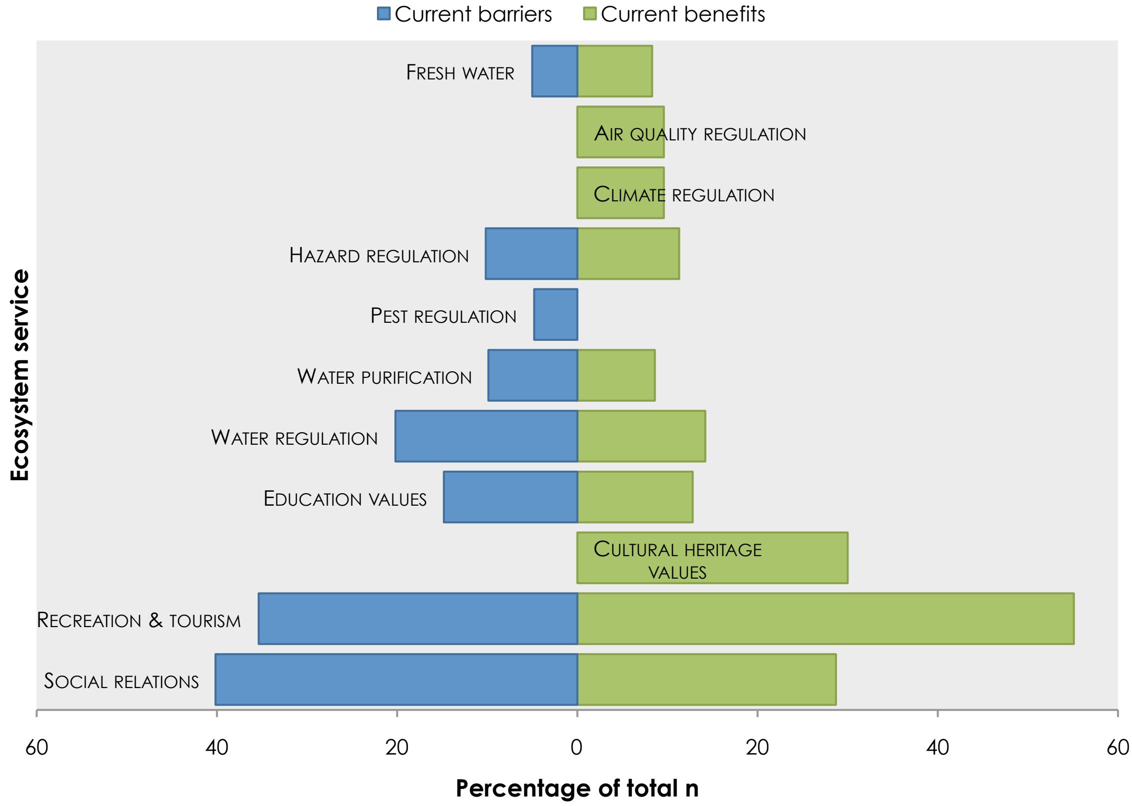
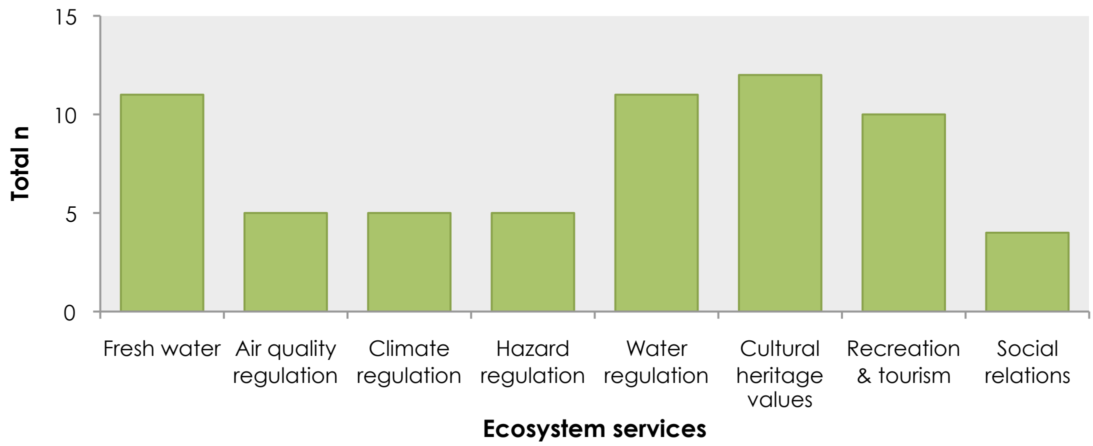


Figure 13: Current benefits of the River Wandle by ranked importance



Survey respondents perceive 'recreation and tourism' as the most desirable ES provided by the catchment (55 per cent of total benefits), followed by cultural heritage values and social relations (Figure 12). However, when asked to rank various river components in order of importance, water regulation and the provision of fresh water outranked most cultural services (Figure 13) – this suggests that people appreciate the quantity and dynamics of the Wandle's river flow.

Figure 14: Current barriers of the River Wandle by ranked importance

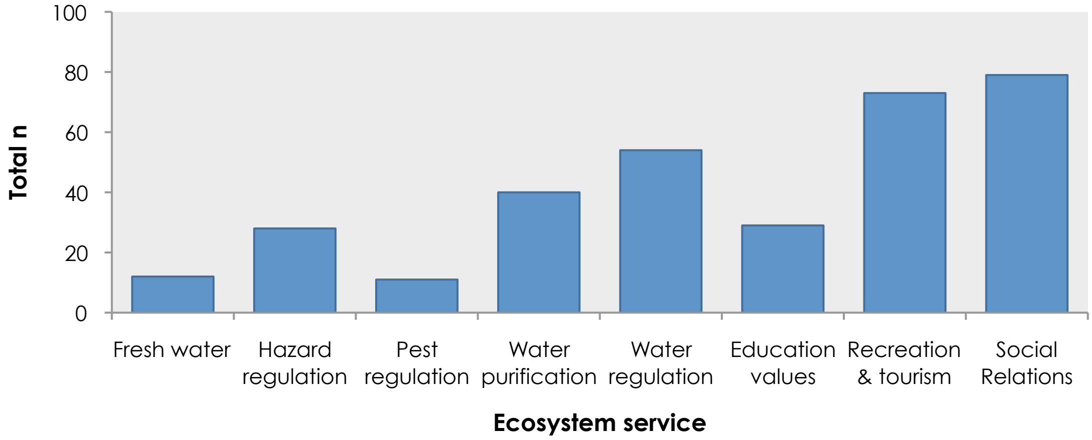
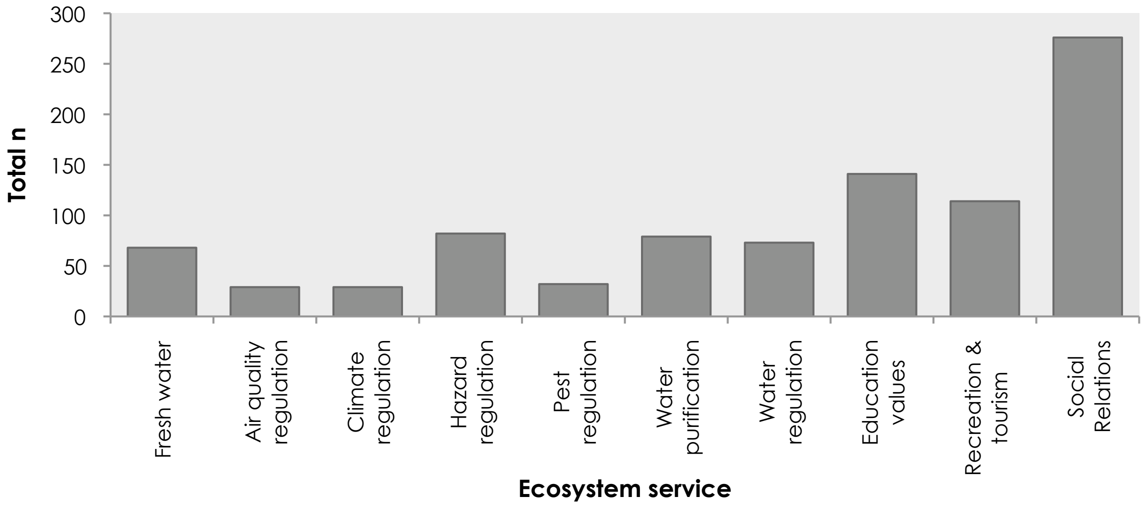


Figure 12 and 14 indicate that respondents consider 'social relations' as the most negative aspect of the river catchment, constituting 40 per cent of all barriers. Social relations are dependent on high quality multifunctional landscapes, which facilitate community cohesion and foster environmental citizenship (UK NEA, 2011b). The degradation of this ES has been attributed to litter and fly tipping, vandalism and lack of accessibility (to the river and adjacent green spaces). As a result of low physical habitat diversity, water regulation is also of primary concern, accounting for 20 per cent of all negative river components. Survey respondents associate the poor functioning of this service with the presence of hard bank reinforcement (e.g. concrete) and various in-stream structures that prevent fish movement.

Table 13: Future status of the River Wandle by ecosystem services, including relative and ranked importance

ECOSYSTEM SERVICE	DESIRED IMPROVEMENTS	PRIORITY IMPROVEMENTS
FRESH WATER	133	68
AIR QUALITY REGULATION	63	29
CLIMATE REGULATION	63	29
HAZARD REGULATION	189	82
PEST REGULATION	64	32
WATER PURIFICATION	136	79
WATER REGULATION	181	73
EDUCATION VALUES	272	141
CULTURAL HERITAGE VALUES	0	0
RECREATION & TOURISM	254	114
SOCIAL RELATIONS	605	276

Figure 15: Desired improvements by ranked importance



Improvements in the functioning of cultural services are the most highly desired (Table 13; Figure 15), with 'social relations' accounting for 31 per cent of all improvements. Some of the solutions proposed for the enhancement of this ecosystem category include more environmentally sensitive building development plans, measures to deter anti-social behaviour and improved safety along the catchment.

6.3 The ecosystem services framework

Evidently, in addition to recreational and aesthetic preoccupations, the perspectives and values of the local community are also influenced by environmental principles and moral responsibility (Green and Tunstall, 1992). On the basis of the findings outlined in Chapters 6.1 and 6.2, it is clear that the existing public perception of the Wandle catchment complements the ecological evidence in the Thames RBMP, which currently classifies the River Wandle as having 'poor ecological potential' on account of failing a number of biological and physico-chemical quality elements (EA, 2009). The integration of diverse information from the physical and social sciences is, in fact, one of the key advantages of using the ES approach (Lundy and Wade, 2011), which was applied in this research for the assessment of wider societal benefits derived from reaching the GEP status.

The results of this valuation study suggest that ES are an effective communication tool for linking ecosystem health to societal goals, so that the values of achieving the GEP target can be conveyed in terms of environmental benefits rather than merely technical standards (Everard, 2012). An ES framework, formulated by using a ratio comparison of the four value elements (i.e. benefits, barriers, goals and desired improvements) to define service significance and ranked importance to define the trend in ecosystem health, helped determine the current and potential value of the Wandle catchment in terms of ecosystem benefits (Table 14). The framework shows that under the business as usual scenario, the significance of most provisioning and regulating services to the river environment is moderate to low, while all cultural services are valued highly. This represents the current level of service provision against which all future improvements in 'ecological potential' can be measured. Furthermore, local communities perceive GEP as a set of multiple benefits delivered through improved water quality and fresh water provision, the restored functioning of key regulating services and the ongoing preservation of cultural services (Table 14). The GEP scenario is essentially a baseline ecological quality for non-deterioration of the aquatic and associated terrestrial environment once the GEP target has been reached (Figure 17).

Figure 16: Synergies between the components and services of ecosystems of the Wandle catchment

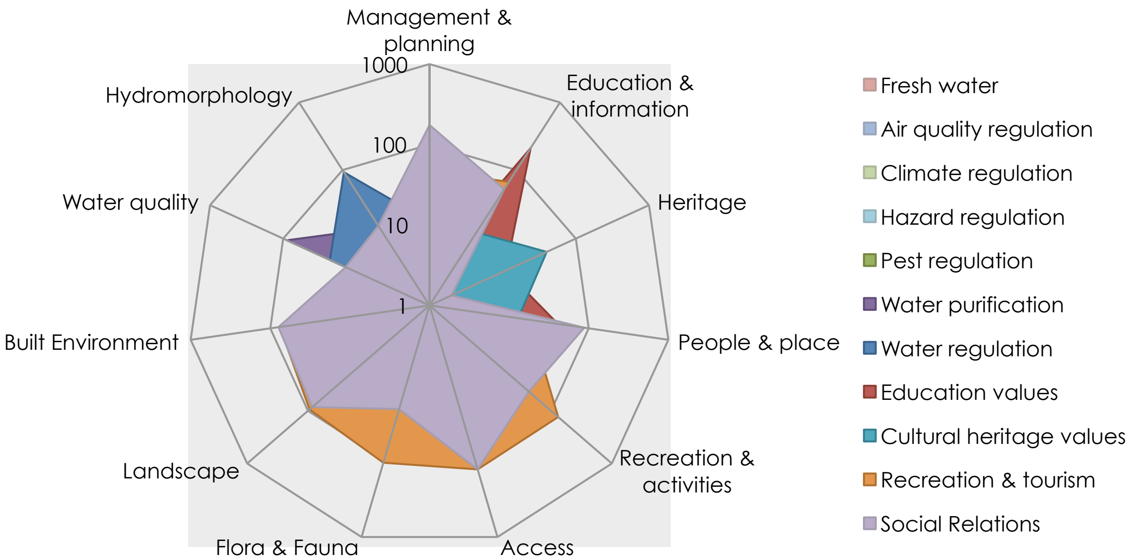


Figure 16 illustrates the various components of the catchment ecosystem and their contribution to the delivery of mostly regulating and cultural ES categories. The diagram also reveals that the restoration of natural functions is contingent on a number of significant ES interdependencies, which are vital for sustaining overall ecosystem health. Hence, ecosystem enhancements designed to boost and maintain the functioning of regulating services (primarily the regulation of flood risk, water and pest and water purification), for instance, will positively impact all cultural services and simultaneously improve the ecological status of the River Wandle. This suggests that the strategic restoration of the river and adjoining green spaces is highly favourable to the health and wellbeing of the local community and for achieving the WFD objective of GEP by 2027.

Table 14: Ecosystem services framework

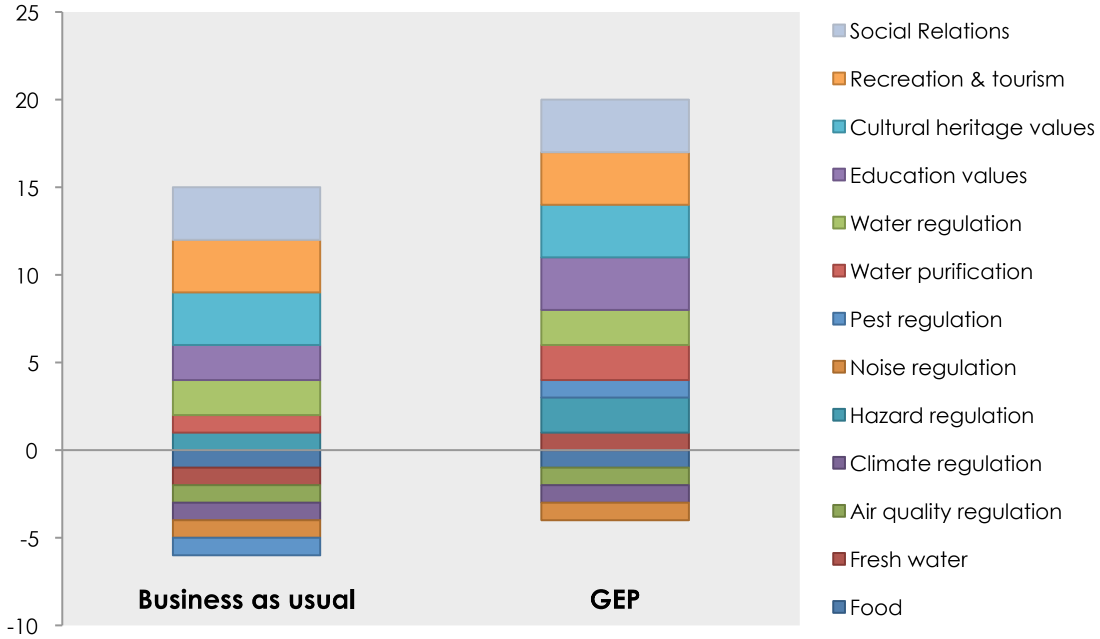
CATEGORY	ECOSYSTEM SERVICE	BUSINESS AS USUAL	GOOD ECOLOGICAL POTENTIAL BY 2027
PROVISIONING SERVICE	FOOD	→	
	FRESH WATER	↘	
REGULATING SERVICE	AIR QUALITY REGULATION	→	
	CLIMATE REGULATION	→	
	HAZARD REGULATION	↘	
	NOISE REGULATION	→	
	PEST REGULATION	↘	
	WATER PURIFICATION	↘	
	WATER REGULATION	↘	
CULTURAL SERVICE	EDUCATION VALUES	↘	
	CULTURAL HERITAGE VALUES	↑	
	RECREATION & TOURISM	→	
	SOCIAL RELATIONS	↘	

KEY

Service significance to River Wandle	Score
Low	-1
Moderate	1
High	2
Very High	3

Trend in ecosystem health	
↘	Decreasing
→	Continuing
↗	Increasing
↑	Very rapid increase

Figure 17: Linking the ecosystem services framework to the target of 'good ecological potential'

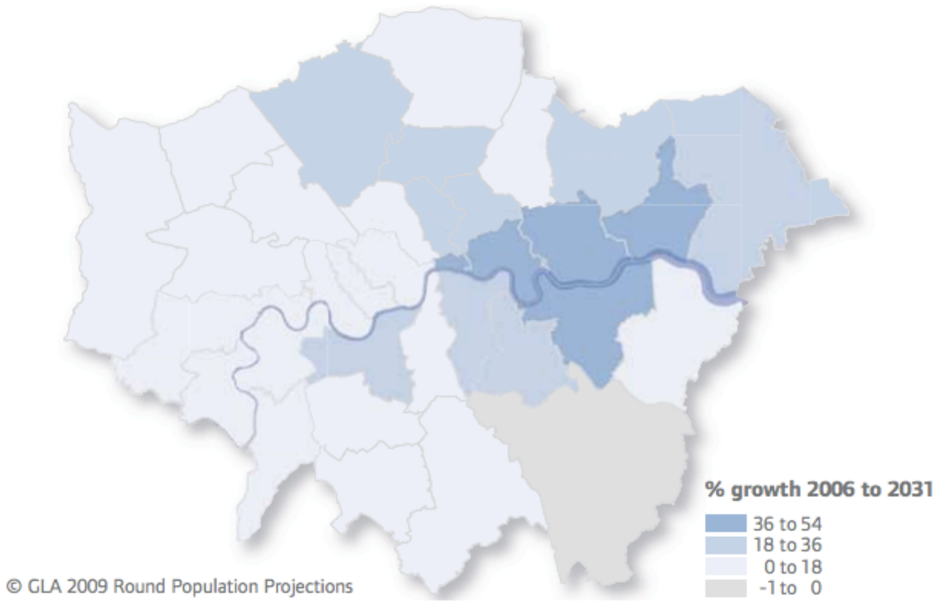


Future drivers of ecosystem change

In order to make the catchment ecology more resilient in the face of future ecosystem change, it is important to assess the ability of ecosystems to adapt to new conditions, i.e. those imposed by climate change, population growth or by changes in local land use and the economy (WRI, 2008). In the context of an average 18 per cent increase in demographic change in the South London region over the next 20 years, the development of the Wandle Valley Regional Park and the associated extreme events of climate change, the distribution of ES and the beneficiaries of these services is likely to alter over the next two decades, presenting the management of the River Wandle with a significant WFD challenge of preventing the deterioration of aquatic ecosystems under these pressures.

In view of a 14 per cent projected population increase over the next decade, London is one of the fastest-growing regions in England (ONS, 2012). By 2031, for instance, the Wandle's semi-rural upper catchment could see an increase in population of up to 18 per cent, whereas an 18 to 36 per cent growth is expected in its densely urbanised lower catchment (GLA, 2011; Figure 18). Population growth, coupled with economic change (i.e. the establishment of the Wandle Valley Regional Park, which will stimulate regeneration and tourism across southwest London), will no doubt heighten the demand for fresh water provision, hazard regulation and recreation and tourism.

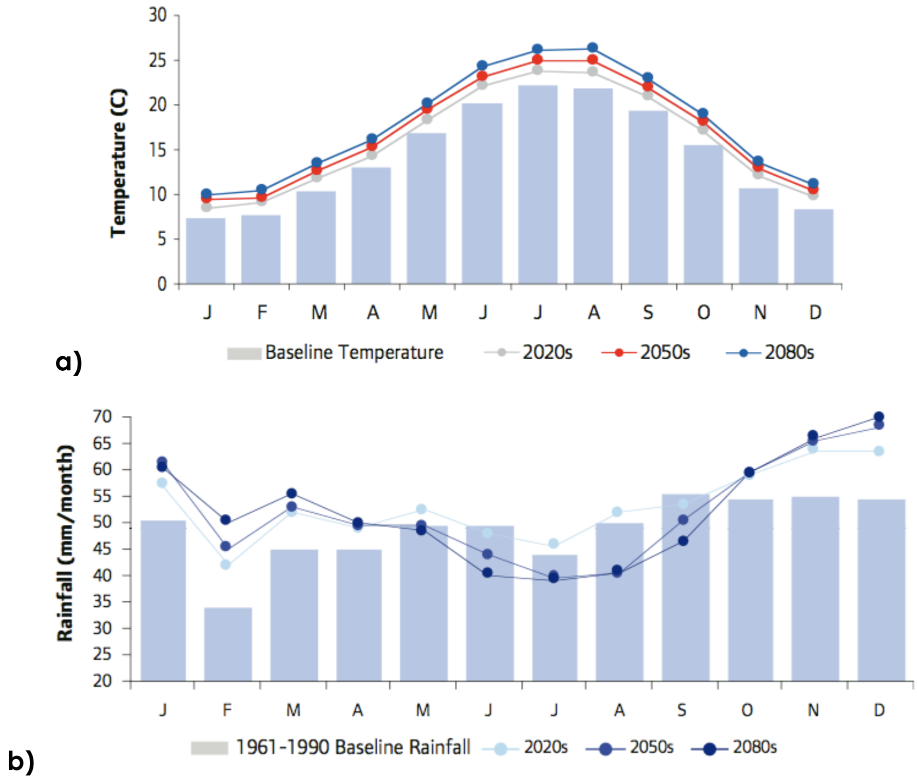
Figure 18: Distribution of population growth in Greater London between 2006 and 2031 (Source: GLA, 2011)



According to the latest UK Climate Change Projections (GLA, 2010; Figure 19), London may experience an up to 2.7-degree increase in summer temperatures, a 15 per cent rise in mean winter rainfall and an 18 per cent drop in mean summer rainfall by the 2050s (when compared to a 1961–1990 baseline). Consequently, climate change has the capacity to significantly modify the quantity, quality and timing of ES within an urban environment (WRI, 2008). Along with more frequent heat waves and droughts, which will affect water availability by reducing river flows and groundwater recharge, there will also be an increased likelihood of fluvial and surface water flooding due to the prevalence of impervious urban cover and significantly higher winter rainfall volume and intensity (GLA, 2010).

At present, the floodplains of the Thames and its tributaries accommodate 1.5 million people and 480,000 properties (LCCP, 2012), which amounts to 15 per cent of London's surface area. The extent of floodplain occupancy is likely to intensify with an 18 per cent projected rate of urbanisation by 2031. Eigenbrod et al (2011) used hydrological models to explore the impact of land use change on the service of hazard regulation under two different urbanisation patterns, namely the densification and sprawl scenario. They found that the spread of suburban (i.e. low-density) development has a less detrimental effect on flood mitigation services than the proliferation of dense urban housing, since the latter can lead to a threefold increase in peak flows and downstream flooding as a result of greater reductions in subsurface water storage. Therefore, to maximise the potential of urban and fresh water ecosystems along the Wandle catchment to provide services, the consideration of ES needs to become an integral component of future land use planning (UK NEA, 2011a).

Figure 19: a) Average monthly maximum temperatures and b) average monthly rainfall in London over the century, under a medium emissions scenario, compared to baseline period (Source: GLA, 2010)



Ecosystem changes in the catchment will not only affect the economy but also the direct and indirect beneficiaries (i.e. stakeholders and members of the local community) of particular services, therefore ensuring future ecosystem health is crucial for reducing climate change impacts. For example, ES such as the regulation of water, hazards and pests are instrumental in buffering communities from increased floods, droughts and pest outbreaks (WRI, 2008). As discussed in Chapter 6.1, urban green spaces provide multiple ecosystem benefits (e.g. flood risk, noise and air pollution reduction, the offsetting of urban heat islands or the provision of recreational opportunities), safeguarding the future ecosystem health of the catchment.

It was beyond the scope of this project to carry out a detailed assessment of ecosystem change for the River Wandle and its catchment. The future status of ES, as described in Table 14 and Figure 17, is based entirely on public perception, therefore an additional assessment should be carried out using physical data to model the response(s) of specific ES to direct or indirect drivers of change.

CONCLUSIONS AND RECOMMENDATIONS

Scientific evidence, presented in Chapter 2, shows that the integration of the ES approach into environmental decision-making is extremely beneficial for the cost-effective management of natural resources, which ultimately leads to improvements in the quality of human health and wellbeing (TEEB, 2011). This valuation study identified a full range of aquatic and associate terrestrial ES provided by the Wandle catchment through participatory ranking and scoring to define the condition and trends of ES (WRI, 2008). As the main beneficiaries of ES, stakeholder groups and local communities acted as key players in this assessment, adding new values and perspectives and offering a valuable set of local knowledge that typically does not feature in scientific literature.

The principal goal of the study was to assess the multiple ecosystem values of the River Wandle and its catchment with specific reference to the WFD target of GEP and identify synergies between different ES, while recognizing potential trade-offs between short-term use and medium to long-term capacity (UK NEA, 2011a). For instance, the removal of hard bank reinforcement (where possible) and subsequent habitat restoration to more natural conditions can lead to improved long-term flood storage capacity, reduced occurrence of downstream flooding and enhanced ecological value of the riparian zone (Eigenbrod et al, 2011), providing a cost-effective (i.e. multifunctional) alternative to traditional hard engineering solutions whose goals may be only effective in the short-term.

The WFD advocates the implementation of the ecosystem approach for the integrated management of land and water across the entire catchment (UK NEA, 2011a). In order to avert further deterioration of aquatic ecosystems in the Wandle catchment, the objective of ‘good ecological potential’ must be reached by 2027, involving the implementation of several hydromorphological (referring to the hydrological regime and river continuity) and physicochemical mitigation measures to protect and enhance the river’s overall ecosystem health (OJEC, 2000; EA, 2009). Future management will also need to ensure the resilience of catchment-wide ecosystems to potential changes in climate, demographics, land use and water demand to maximise their long-term capacity to provide essential ES.

This study demonstrates that data acquired through stakeholder engagement can contribute to an improved understanding of the status and vulnerability of ES, to the mapping of the distribution of human benefits derived from ecosystems and to the development of response options that include local knowledge (WRI, 2005). Over three quarters of all values placed on the river fall into the cultural services category, namely recreational, educational and cultural heritage uses, and social relations. The most significant cultural component of the catchment is recreation and tourism, which currently amounts to 36 per cent of total river benefits and its importance is expected to double in the future. On the contrary, the service of social relations, which is highly dependent on accessible green spaces, is perceived as the most degraded ES of the river catchment. Clearly, more emphasis needs to be placed on promoting social and environmental citizenship via the use of a participatory approach to environmental decision-making.

The most important conclusion of this valuation study is that local communities perceive GEP as a set of multiple benefits delivered through improved water quality and fresh water provision, the restored functioning of key regulating services (primarily the regulation and purification of water and flood risk management) and the ongoing preservation of cultural services. Therefore, ecosystem enhancements designed to boost and maintain the functioning of regulating services will positively impact all cultural services and simultaneously improve the ecological status of the River Wandle.

The study also emphasises the adequacy of non-monetary valuation for demonstrating the multifunctional value of the Wandle catchment as perceived by various stakeholders. However, future monetary valuation may be required to make the value of regulating services clear to all stakeholders (Everard et al, 2011). The ES framework, presented in Chapter 6.3, is relevant not only to the Wandle, but also to other urban rivers as it enables the integration of data from the physical and social sciences for the assessment of wider societal benefits derived from reaching the GEP status. The Wandle Trust, along with the EA and other key stakeholders, can use this framework to help determine how to manage the catchment so that it can provide an optimal mix of benefits to the local community and to help design a sustainable catchment plan that sustains ecosystem benefits to society in the long term. The application of this work will ensure that future river restoration projects consider ES and maximise multiple benefits for a cost-effective management of ecosystems.

Overall, the study highlights the difficulty of quantifying regulating services via a non-monetary valuation approach. Further data and research are needed to strengthen the evidence base on regulating services, predominantly air quality, climate, noise and light regulation, and to support their integration into local planning policy and climate change adaptation (UK NEA, 2011a). Consistent (quantitative and qualitative) data collection and the monitoring of the quality and use of various urban sub-habitats (and their ES delivery) within the catchment are also needed to gain further knowledge regarding the interactions between human needs and ES.

In line with the conclusions of this study, a series of recommendations are put forward for further research and sustainable catchment management.

1. Incorporate the findings of this study with ecological data and research on a range of biophysical status indicators, pressures and biological impacts, and carry out similar ES valuation studies in the future to review changes in the values and perspectives of stakeholder groups
2. Consider monetary valuation for all regulating services to help communicate their value to the public
3. Carry out a biophysical assessment of key ES at local resolution to map their production (on the basis of land use, climate and environmental variations) and model the changes in service provision over time (PEER, 2011)
4. Review site-specific workshop and survey values to feed into future river restoration planning (Appendix B)
5. Enhance degraded ecosystem processes and functions as identified in the Thames RBMP and this ES framework to restore multifunctionality across the catchment (Table 15)

Table 15: Suggested ecosystem enhancements

WATER REGULATION, HAZARD REGULATION AND PROVISION OF HABITAT	WATER PURIFICATION	ALL CULTURAL SERVICES, CLIMATE REGULATION, AIR QUALITY REGULATION AND NOISE REGULATION
- Remove hard bank protection and replace with soft engineering solutions (where appropriate) - Reinstate the floodplain to improve flood storage capacity (where appropriate) - Restore natural river channels with gravel bed and earth banks and reopen existing culverts (where appropriate) - Preserve and enhance the ecological value of marginal aquatic and riparian habitats	- Recreate a range of terrestrial and aquatic habitats, including wetland, lakes and ponds - Enhance hydrological function throughout the catchment, including building sustainable drainage systems into all buildings, paths and playing field areas	- Provide accessible green spaces, traffic-free cycle routes and footpaths - Improve natural environments in the densely urbanised lower catchment and the overall visual appearance of the river corridor

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APPENDIX A: ONLINE SURVEY FORMAT

The River Wandle Catchment Plan aims to create and maintain a natural river that functions well and that provides ecosystem services that benefit people.

We want to hear your thoughts about your local stretch of the river – what you like about it, what you don't like, what would help you love it more, and finally what you can suggest be done to help improve it.

Please help us by filling in this questionnaire, so together we can make the entire length of the River Wandle a nice place for both people and wildlife!

1. Where (roughly) is your local stretch of the river, or the main area that you visit?

____

2. How would you describe your local stretch of river? ***Please circle one number on each line:***

a.	Rural	1 2 3 4 5	Urban
b.	Natural	1 2 3 4 5	Built up
c.	Attractive	1 2 3 4 5	Unattractive
d.	Rich in wildlife	1 2 3 4 5	Poor in wildlife
e.	The river is easy to see	1 2 3 4 5	The river is hidden from public view
f.	Accessing the water's edge is easy	1 2 3 4 5	The water's edge is not accessible
g.	A nice place to be	1 2 3 4 5	An uncomfortable place to be
h.	Economically prosperous	1 2 3 4 5	Economically poor
i.	Safe	1 2 3 4 5	Does not feel safe
j.	Clean and well looked after	1 2 3 4 5	Signs of anti-social behaviour are present (e.g. litter, graffiti, vandalism)
k.	People are aware of the river and interested in it	1 2 3 4 5	People are not aware or interested in the river
l.	Local people are actively involved in looking after the river	1 2 3 4 5	Local people do not seem to be doing anything to look after the river
m.	Organisations are actively involved in looking after the river	1 2 3 4 5	No organisations seem to be actively involved in looking after the river

Any other comments:

____

Wandle Catchment Plan *Wandle Trust c/o Environmental Sustainability, L.B. Sutton, 24 Denmark Rd, Carshalton SM5 2JG* 1

3. What do you think are the good things about **your local stretch of river** at the moment?

Please tick all the boxes that apply:

a. There are trees and plants ☐ ______
b. There is little or no concrete or other manmade structures ☐ ______
c. You can see birds and waterfowl ☐ ______
d. You can see fish ☐ ______
e. You can see all different sort of wildlife ☐ ______
f. It looks natural, like a rural landscape ☐ ______
g. There is good access ☐ ______
h. You can go fishing ☐ ______
i. Children can enjoy the water ☐ ______
j. It has some great history ☐ ______
k. There are some interesting buildings ☐ ______
l. There are signs of its industrial past (water wheels etc) ☐ ______
m. There is little or no pollution ☐ ______
n. There are pleasant greenspaces nearby ☐ ______
o. There are cycle paths beside the river ☐ ______
p. There are footpaths beside the river ☐ ______
q. The local community is involved with the river ☐ ______
r. It is peaceful and attractive ☐ ______
s. There is little or no rubbish ☐ ______
t. There is always flowing water (the riverbed is never dry) ☐ ______
u. It is a haven from urban life ☐ ______
v. Other, please specify ________________________________ ☐ ______

4. Using the lines on the right-hand side of the page, ***please now rank the items you have ticked in order of importance. Start with 1 as the most important.***

5. What do you think are the problems or challenges associated with **your local stretch of river** at the moment?

Please tick all the boxes that apply:

a. There is a lot of concrete or other manmade structures ☐ ______
b. There are weirs and barriers to fish movement ☐ ______
c. There is too much urban development close to the river ☐ ______
d. There are times water levels are very low ☐ ______
e. There are times when the river floods or flows very fast ☐ ______
f. The river doesn't look natural ☐ ______
g. You can't access the river easily ☐ ______
h. You can't see the river easily ☐ ______
i. The river is polluted / occasionally polluted ☐ ______
j. Invasive species are present ☐ ______
k. The local community isn't involved with the river ☐ ______
l. Nobody seems to care about the river ☐ ______
m. Different organisations are operating with conflicting agendas ☐ ______
n. There is litter or fly tipping ☐ ______
o. There is graffiti or other types of vandalism ☐ ______
p. People fish illegally or in an irresponsible manner ☐ ______
q. There are too few bins ☐ ______
r. You can't cycle by it easily, there's no cycle path ☐ ______
s. You can't walk by it easily, there's no footpath ☐ ______
t. There is dog poo ☐ ______
u. Other, please specify ________________________________ ☐ ______

6. Using the lines on the right-hand side of the page, ***please now rank the items you have ticked in order of importance. Start with 1 as the most important.***

7. How do you think these problems could be overcome – what solutions might work to improve the health of **your local stretch of the river**?

Please tick all the boxes that apply:

a. Remove the concrete and other manmade features ☐ ______
b. Remove weirs to improve water flow and fish movement ☐ ______
c. Re-landscape riverside habitat by planting flowers, shrubs & trees ☐ ______
d. Raise awareness of how water from the river is used and managed ☐ ______
e. Remove invasive species ☐ ______
f. Tackle misconnected pipes to reduce pollution ☐ ______
g. Introduce more effective regulation of fishing activity ☐ ______
h. Work with industry to reduce their impact on the river ☐ ______
i. Raise public awareness about saving water and using it wisely ☐ ______
j. Increase partnership working to reduce political conflicts ☐ ______
k. Increase partnership working to achieve better project delivery ☐ ______
l. Have more practical community activities working on the river ☐ ______
m. Have more education and outreach activities to engage people ☐ ______
n. Add new cycle paths or improve existing ones by the river ☐ ______
o. Add new footpaths or improve existing ones by the river ☐ ______
p. Introduce more effective measures to reduce dog fouling ☐ ______
q. Make building development plans more environmentally-sensitive ☐ ______
r. Increase permeable surfaces to absorb rainwater & reduce runoff ☐ ______
s. Introduce new measures to deter littering and encourage recycling ☐ ______
t. Find ways to deter anti-social behaviour and make areas feel safer ☐ ______
u. Improve access to the river: make it more visible & easier to reach ☐ ______

8. What other solutions can you suggest that might help improve the health of the River Wandle?

____ ______
____ ______

9. Using the lines on the right-hand side of the page, ***please now rank the items you have ticked in order of importance. Start with 1 as the most important. Include any suggestions you made in Q8.***

10. Please look at the following list of outdoor activities:
Angling
Canoeing
Cycling
Walking
Bird watching
Bat surveys

Have you participated in any of these activities **along the River Wandle** in the past 12 months?

a. No, I do not participate in any of these activities anywhere ☐ ***please continue to Q11***
b. No, I do them **somewhere else** ☐
Please specify. Then continue to Q13

Activity_____________________________________ location ____________________

c. Yes ☐
Please tick all those that apply, and say how long you have been doing them. Then continue to Q13:

i. Angling ☐ length of time ___________
ii. Canoeing ☐ length of time ___________
iii. Cycling ☐ length of time ___________
iv. Walking ☐ length of time ___________
v. Bird watching ☐ length of time ___________
vi. Bat surveys ☐ length of time ___________

11. Have you participated in any of the listed activities **along the River Wandle** in the past?

a. No ☐ ***please continue to Q13***
b. Yes ☐
Please tick all those that apply, and say how long you did them.
Then continue to Q14:
i. Angling ☐ length of time ___________
ii. Canoeing ☐ length of time ___________
iii. Cycling ☐ length of time ___________
iv. Walking ☐ length of time ___________
v. Bird watching ☐ length of time ___________
vi. Bat surveys ☐ length of time ___________

12. What was your reason for stopping? ____

13. Please look at the following list of organizations that all have connections to the River Wandle:
National Trust (e.g. Morden Hall Park)
London Wildlife Trust (e.g. Spencer Road Wetlands, Wilderness Island)
Wandle Trust
Groundwork London
BTCV
Wandle Industrial Museum
Friends of Beddington Park
Friends of Ravensbury Park
Mitcham Common Conservators
Wandle Piscators
Morden Hall Park (MHP) Angling Club
Wandle Forum / Wandle working sub-groups

Have you been involved with any of them in the past 12 months, for example as a member or a volunteer?

a. No, I am not involved with any organisations connected to the River Wandle ☐
Please continue to Q15
b. Yes ☐
Please tick all those that apply, and say for how long you have been involved.
Then continue to Q14:
i. National Trust (Morden Hall Park) ☐ length of time ___________
ii. London Wildlife Trust ☐ length of time ___________
iii. Wandle Trust ☐ length of time ___________
iv. Groundwork London ☐ length of time ___________
v. BTCV ☐ length of time ___________
vi. Wandle Industrial Museum ☐ length of time ___________
vii. Friends of Beddington Park ☐ length of time ___________
viii. Friends of Ravensbury Park ☐ length of time ___________
ix. Mitcham Common Conservators ☐ length of time ___________
x. Wandle Piscators ☐ length of time ___________
xi. Morden Hall Park Angling Club ☐ length of time ___________
xii. Wandle Forum / working groups ☐ length of time ___________

c. I am involved with another organisation connected to the River Wandle. ☐
Please specify. Then continue to Q14:

Name of organization _________________________________ length of time ______

14. Do you take part in any activities for the enjoyment of nature or wildlife conservation with that organisation?
    a. Yes ☐ ***please specify*** ____
    b. No ☐

15. Would you be interested in volunteering to do practical work to help improve the river?
Please tick all that apply:
    a. River clean-ups ☐
    b. Keeping an eye out for pollution and reporting it ☐
    c. Invasive plant removal ☐
    d. Planting native plants ☐
    e. Habitat improvements, such as putting woody debris in-stream ☐
    f. Surveying and monitoring ☐

16. Would you be interested in volunteering to help in some other way?
Please tick all that apply:
    a. Raising awareness by delivering leaflets and putting up posters ☐
    b. Generating support via petitions, writing letters, talking to people ☐
    c. Assisting with refreshments at events and meetings ☐
    d. Assisting with transport or carrying equipment to events ☐

17. Age ***Please tick:***
    a. Under 18 ☐
    b. 18-29 ☐
    c. 30-49 ☐
    d. 50-64 ☐
    e. Over 65 ☐

18. Gender ***Please tick:***
    a. Male ☐
    b. Female ☐

19. Postcode _________________

20. Area (e.g. Carshalton or Wallington) ___________________________________

21. How long have you lived at your present address. ***Please tick:***
    a. All my life ☐
    b. More than 20 years ☐
    c. 10-20 years ☐
    d. 4-9 years ☐
    e. Less than 4 years ☐ Was your previous address within 2 km (1 ¼ miles) of the Wandle? ***Please tick:***
        a. Yes ☐
        b. No ☐
        c. Don't know ☐

If you answered Yes to volunteering in some way in response to Q15 or Q16, please provide contact details below so we can get in touch at a future date:

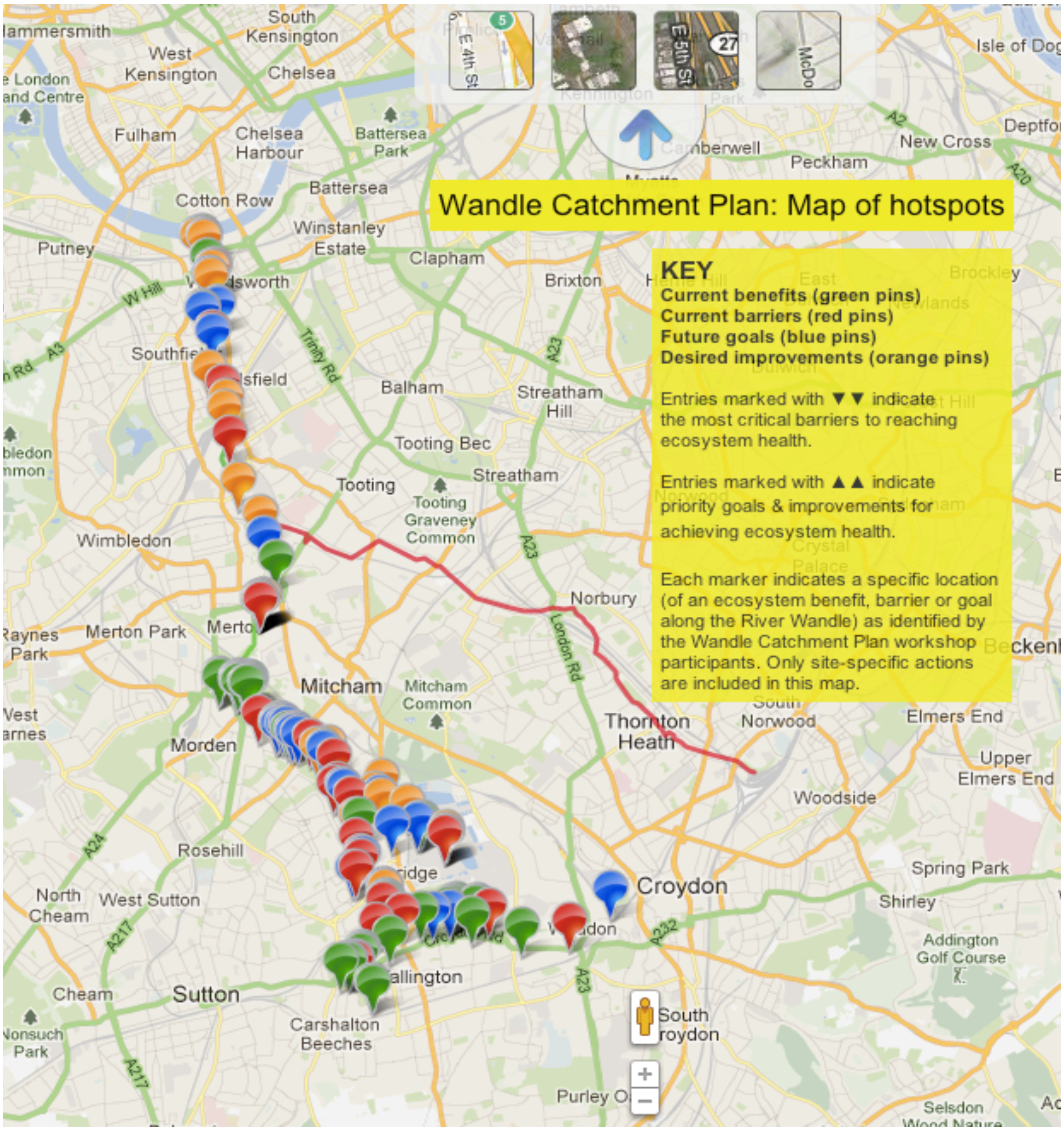
Title: ______________ First Name: ______________________________ Surname (Family name):________________

Address: ____

Email: ____ Phone number:____________________

Thank-you for your time and for helping us with the Wandle Catchment Plan

APPENDIX B: MAP OF SPATIAL HOTSPOTS



Map URL: http://bit.ly/WandleHotspots