The Mayes Brook restoration in Mayesbrook Park, East London: an ecosystem services assessment

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Dissemination Status:
Publicly available

Keywords:
Ecosystem services, Mayesbrook, urban river, economic valuation, ecosystems approach, case study

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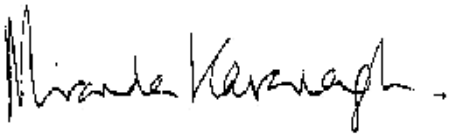

Miranda Kavanagh

Director of Evidence

Executive summary

Restoration of the Mayes Brook in Mayesbrook Park, in the London Borough of Barking and Dagenham, is an opportunity to create an ecological and community focal point within a broader environmental regeneration project. It is designed to produce the UK's first climate change adaptation public park. The restoration of an urban river within a barren park landscape is also a good example of an approach that combines flood storage, biodiversity enhancement and adaptation to climate change within a city environment. This study explores some of the key benefits of the planned river restoration and the wider park 'greenspace' improvements, in terms of their impact on ecosystem services. Ecosystem services are the many benefits delivered to individuals and society from the natural environment.

The urban setting means that restoration and improvements will contribute to 'regulatory services' (regulation of air and water quality, microclimate and flood risk) affecting the local community. Enhanced recreation and tourism (cultural services) are also likely to bring benefits, since many people in the borough lack gardens or ready access to other green spaces.

The benefits for 'supporting services', which are hard to quantify but important in maintaining ecosystem functions, are significant in terms of nutrient cycling and providing habitats for wildlife. This latter ensures there are animals and plants capable of colonising the wider landscape as the habitat improves. These improved habitats also serve as 'stepping stones' for wildlife to move across and between limited and fragmented suitable habitat in the urban landscape.

Due to the urban setting and lack of biodiversity in Mayesbrook Park and the Mayes Brook, restoring the river will not boost 'provisioning services' (things that can be taken from ecosystems to support human needs, such as fresh water, food, fibre and fuel, and so forth). This makes this assessment different to others in this series of reports, which have described the ecosystem services provided in the Tamar catchment, the Alkborough Flats, the River Glaven sea trout restoration and the development of a buffer zone on the upper Bristol Avon).

Many of the more important benefits of the Mayesbrook Park restoration can be seen in social and health aspects, enhancing the quality of life in the borough and the wellbeing of local communities. In fact, if the annual value of services to health, risk and culture are pooled, despite there remaining many unmeasured or possibly unquantifiable benefits, they will account for over 90% cent of the total annual ecosystem service benefits for the Mayesbrook Park restoration scheme.

The overall benefits are substantial relative to the planned investment. The lifetime value of restoring the site across the four ecosystem service categories (provisioning, regulatory, cultural and supporting) yields a grand total of calculated benefits of around £27 million, even if 'likely significant positive benefits' for the regulation of air quality and microclimate are excluded. This is

compared to the estimated costs of the whole Mayesbrook Park restoration scheme at £3.8 million including the river restoration works. This produces an excellent lifetime benefit-to-cost ratio of £7 of benefits for every £1 invested.

Urban river restoration would therefore be of major public value, fully justifying the planned investment and providing firm evidence that investment in urban 'green infrastructure' is highly favourable for the health and wellbeing of local people and the economic improvement of deprived wards. Restoring the vitality and function of the natural environment tends to enhance or maintain benefits across all ecosystem service categories. This contrasts with traditional single element solutions, which tend to maximise only the targeted services and often are associated with unintended consequences for other interconnected services. The case for the application of ecosystem-based solutions to environmental management problems is thus substantiated.

The study sets out a range of options for further enhancing public value from the restoration scheme, through new or redesigned initiatives or in management practices. These include:

- enhancing the hydrological function of the whole park landscape and infrastructure;
- using reedbed filtration to improve water quality in a bypassed reach of river and at lake inflows and outflows;
- improving climate regulation through energy-efficient building design, installation of renewable energy sources and reusing tree and other park trimmings as biomass fuel (or mulch) on site; and
- optimising park restoration design to provide health and educational resources to the local community.

Assessing the ecosystem service implications for all of these options, and others that may be identified in later phases of planning and research, would help to support the economic case for their implementation.

This case study provides evidence to help improve the current scheme design and the greater integration of social, economic and ecological benefits in future initiatives. The results of this assessment are valuable not only in the Mayesbrook Park restoration project but are also applicable to wider urban river and urban area restoration initiatives and will support future research in this field. It will also help in achieving 'good ecological potential' for the Seven Kings water body as part of the Water Framework Directive.

Acknowledgements

Many thanks for support with this work to Robert Oates (Thames Rivers Restoration Trust), Tony Chadwick (London Wildlife Trust), Alex Farris (London Borough of Barking and Dagenham), Dr Bella Davis (Wandle Trust), William Playle (Barking and Dagenham Canoe Club), Bill Watts (Principal Economist, Environment Agency), Anna Maria Giacomello (Principal Economist, Environment Agency) and various people in partner organisations including Natural England and the Greater London Authority.

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1. Introduction

This report evaluates the projected outcomes of a programme of work to restore the Mayes Brook and its associated floodplain in Mayesbrook Park, East London, in terms of the benefits this will bring to ecosystem services in the area. Ecosystem services are the benefits that individuals or society derive from the natural environment.

Restoration of the Mayes Brook within the wider regeneration of Mayesbrook Park is a flagship ecological project for the local community. The project will create an ecological and community focal point within a broader environmental regeneration project, which is designed to produce the UK's first climate change adaptation public park. Rehabilitation of three river reaches within a currently uniform and habitat-depleted park landscape will also be a good example of an approach that combines flood storage and biodiversity enhancement with adaptation to climate change within the confines of an urban environment. It will also help in achieving 'good ecological potential' for the Seven Kings water body as part of the Water Framework Directive.

The aim of this report is to explore the key benefits of restoring the river reaches, areas of floodplain and associated parkland, by assessing the many natural benefits that they may provide for the local community. Many of these valuations are based on broad assumptions necessary to derive rough estimates and identify the scale and direction of change. Although these are expressed in economic terms, these values are rounded so as to avoid spurious impressions of accuracy. The deduced values do not necessarily have absolute meaning, but are monetised approximately to indicate and compare the tendency (improvement or degradation) and strength of likely effects across ecosystem services.

Through this ecosystem services assessment, we hope this report will demonstrate the socio-economic benefits of such projects. The report offers a starting point for more detailed monetisation studies, for discussions on the assessment of ecosystem services from urban river restoration schemes, and as a basis for identifying research needs.

1.1 The Mayes Brook

The Mayes Brook is a tributary of the River Roding within the River Thames basin. The brook receives its surface water flow from a relatively small urban catchment of approximately 14 km^2, lying between its source north of Chadwell Heath and its confluence with the River Roding at Barking Creek (Jacobs, 2008). The exact source of the brook is difficult to determine as the reaches upstream of Mayesbrook Park are entirely culverted, with the exception of the ponds at Goodmayes Park (TQ4693886852). The Mayes Brook is roughly 7.4 km in length from its possible source at Chadwell Heath to the confluence at Barking Creek, where a flapped outfall and penstock operates to control saline intrusion and flood surges (Jacobs, 2008). However, approximately half of its length is fully culverted. Two tributary ditches drain into the brook in the lower

reaches, and a small tributary stream is indicated on some maps close to the estimated source (Environment Agency and Queen Mary, University of London, 2010).

Local geology within the Mayes Brook catchment consists of alluvial river terrace gravels over London Clay (LBBD, 2001). The catchment is urban in character and largely covered with residential housing in the upper catchment, and with an increasing density of road and rail transport infrastructure in the lower catchment along with several industrial estates. The catchment contains a number of public open spaces including Chadwell Heath, Goodmayes Park, Mayesbrook Park and Greatfields Park as well as the private playing fields of two secondary schools and Rippleside Cemetery, all of which are located close to or along the linear riparian corridor of the brook (Environment Agency and Queen Mary, University of London, 2010).

The Mayes Brook runs through the London Borough of Barking and Dagenham (LBBD), which has 17 wards of which 5 are ranked within the 10% most deprived wards in England and a total of 14 wards are ranked within the 20% most deprived (http://www.barkingdagenhampartnership.org.uk/boroughprofile, accessed 23rd March 2011). Socio-economic statistics indicate that the borough has a relatively high unemployment rate (5.4 per cent) and low household incomes compared to London-wide and national levels (http://www.barkingdagenhampartnership.org.uk/boroughprofile, accessed 23rd March 2011). Health deprivation in the borough is also linked to high rates for teenage pregnancy, cancer and heart disease and below national and London average life expectancy (ONS, 2008; LBBD, 2005 both cited in Environment Agency, 2008b).

Water quality is affected by several surface drains that discharge into the Mayes Brook, and by large quantities of litter which frequently accumulate on the screening grills covering the larger inlets. The brook also receives effluent from many misconnections (waste water that should go to foul sewer rather than surface water drains). Reported pollution incidents (mostly minor incidents) mostly occur in the northern lake, probably associated with storm drainage during high flow events. These incidents represent a significant pollutant load in addition to more general diffuse urban pollution. Thames Water, the local water services utility, has recently completed a two-year misconnection study (2008-2009), with further investment in misconnection identification included in their investment plans for 2010-2015.

1.2 Mayesbrook Park

Mayesbrook Park lies towards the middle section of the Mayes Brook catchment. It covers an area of around 45 hectares. The park land is owned by Barking and Dagenham Borough Council.

To the southern (downstream) end of the park are two linked lakes, created as a result of sand and gravel extraction between 1919 and 1938 as London expanded. A decision was taken in the 1930s not to build on this area but to retain it as an urban park in amongst the sprawl of development. The development of the park was interrupted in 1939 by the start of the Second World War, and features such as the Italianate gardens were never completed.

The park is now surrounded by dense urban development, including many housing estates and associated infrastructure. Upney underground tube station, roughly a kilometre from the south west boundary of the park, provides a rail link to central London and eastwards to Upminster.

Around 1.6 km of the Mayes Brook runs through Mayesbrook Park, defining its border to the north and west. The brook is currently completely disconnected from the park. It is fenced off on the park side, and also largely invisible from the park as the channel is deeply sectioned. An embankment on the park side of the channel, resulting from an accumulation of spoil dredged from the brook and piled on the bank, further blocks the view and water flows between river and park. This potentially poses a flood risk to adjacent properties on the right bank which lie at a lower level than the park side embankment on the left bank. Furthermore, along the right bank top and face, several of the adjoining residential gardens have encroached onto the 2-3 metre right bank, which now includes areas of planting as well as dumping sites for garden waste.

Today, much of the park area comprises short mown grass, which provides poor habitat for wildlife and is not used intensively by the neighbouring community. Around the two lakes, large quantities of faeces produced by native and non-native birds (predominantly Canada geese) present a health risk.

The lakes have become heavily polluted as they have served as a sink for substances from the Mayes Brook storm water overflow entering via the connecting high flow inlet channel. Three metres of polluted sediment have now accumulated in the top lake. The top lake has an overflow to the bottom lake, and there is a further outflow from the bottom lake into the Mayes Brook immediately before the brook flows through the screened entrance to the culvert downstream of Mayesbrook Park. Fishing and boating were historically popular activities on the lakes. However, both have now been stopped due to pollution concerns, although kayaking continues when conditions permit; with regular sessions run by the Barking and Dagenham Canoe Club on the upper lake, despite pollution and interruptions caused by unsafe levels of blue-green algal blooms.

Figure 1.1: Kayaking at Mayesbrook Park
(http://www.flickr.com/photos/26600172@N05/show/, reproduced with kind permission of William Playle, Barking and Dagenham Canoe Club)

The park has received minimal investment over recent years. The lack of warden services is reported as contributing to fear of crime, and reduces use of the park (Shears, 2009). A survey by the Community Safety Strategic Partnership investigating crime issues found that two-thirds of people in the London Borough of Barking and Dagenham (LBBD) felt threatened by crime and antisocial behaviour, which was often associated with open park spaces (Environment Agency, 2008b). In the centre of the park, the main playground area is currently located a long way from other facilities and it is run down and uninviting.

1.3 Proposals to improve the park

A public consultation was carried out by LBBD in 2009 to provide an opportunity for local people to express ideas and opinions about the proposed park restoration project. The main concerns raised were primarily over security within the park followed by provision of play facilities and good park maintenance. Local park visitors would like the park as a whole to include a balance of sports, play and natural areas, plus toilets, seating and eating areas (LBBD, 2009b).

In its current state of under-investment, Mayesbrook Park provides minimal benefits to the community. The Mayes Brook, in particular, is separated from the public by the high palisade fencing barrier and makes no perceptible contribution to public wellbeing.

The Environment Agency owns a number of flood management assets on site (sluices, pumps and so on), many of which are reaching the end of their useful lives. This includes a large flood control sluice gate immediately downstream of the lake inlet channel which is controlled automatically at times when high tides and high flows coincide. Flood control mechanisms include telemetry, a pumping station and related infrastructure, which would cost millions of pounds to replace. This creates a further reason to explore other options for management of the Mayes Brook and Mayesbrook Park.

Notwithstanding the brook's many problems, fish surveys by the Environment Agency, carried out as part of the Mayes Brook Restoration Scheme ecological survey, have revealed some small chub, dace and roach in the brook in the stretch adjacent to the park (Environment Agency, 2008a). The park includes bat boxes fixed to poplar trees to the north-west.

Recent changes in the park maintenance regime associated with the forthcoming restoration include a relaxed mowing regime in the area of proposed floodplain restoration. This has created an area of meadow grassland with mown meandering pathways for park users.

2. The Mayesbrook Park restoration

The Mayes Brook restoration was initiated by a partnership of the Thames Rivers Restoration Trust (TRRT), the London Borough of Barking Dagenham (LBBD) and Environment Agency. The latter commissioned the River Restoration Centre (RRC) to look for the best urban centre to use as an exemplar of urban river restoration (RRC, 2007). Additional partners guiding the project include Natural England (NE), the Greater London Authority (GLA), Design for London (DfL), London Wildlife Trust (LWT) and World Wildlife Fund UK. The aspirations of all the organisations involved included the following plans which together initiated the project:

- London Borough of Barking Dagenham Strategy for parks and green spaces (LBBD, 2004).
- Environment Agency Strategy for Restoring Rivers in North London (Environment Agency, 2006).
- Greater London Authority (2008a): *Draft Climate Change Adaptation Strategy*.
- Greater London Authority (2008b): *Improving Londoners' Access to Nature*.
- Greater London Authority (2008c): *East London Green Grid Framework.*

The RRC (2007) feasibility study included an assessment of the ecological and socio-economic viability of several potential sites for restoration in the North Thames region, using a questionnaire and matrix to compare suitability for the works. The feasibility study identified the Mayes Brook at Mayesbrook Park as the most suitable for restoration, and this project is currently seen as a flagship for the London Rivers Action Plan (Environment Agency, 2009) as well as the Department for Environment, Food and Rural Affairs *England Biodiversity Strategy: Climate Change Adaptation Principles* (Defra, 2008).

The project to restore the brook fulfils the local and national Biodiversity Action Plan (BAP) goals to protect and enhance reedbeds and wetland habitats. Additional benefits to biodiversity will be to improve resilience to changing climate conditions by providing a greater range of habitats and cooling effects through new woodland areas. These effects will also benefit park users by providing cooler shaded areas as well as the air and water quality improvements.

2.1 The whole park plan

Plans for the restoration of Mayes Brook have been integrated into a whole-park restoration plan (LBBD, 2009a) with a projected spend of £5 million. The whole park restoration is intended to:

- Restore the physical, chemical and ecological condition of the river by:
  - re-naturalising the river;
  - improving water quality;
  - improving biodiversity of river, wetlands and conservation area;
  - improving the river corridor;
  - showing how EU Water Framework Directive goals can be met;
  - providing a demonstration for the London Rivers Action Plan; and
  - increasing fish populations in the brook.
- Restore the polluted lakes by:
  - increasing recreational activities on the lakes;
  - establishing native fisheries within the lakes; and
  - establishing an angling facility with associated coaching.
- Improve the whole park by:
  - improving landscape character of park;
  - improving biodiversity in the park;
  - planting trees (urban woodland) in the southern area;
  - contributing to the Mayor's London Biodiversity Targets;
  - contributing to the Mayor's targets for parks;
  - improving ecosystem services; and
  - reducing flood risk to properties adjacent to and downstream of the park.
- Socio-economic uplift by:
  - building a visitor centre, play area, café and similar facilities;
  - employing a warden to help improve security;
  - increasing the value of the park as an asset for public use;
  - promoting regeneration of the area;
  - improving safety, security and public perception;
  - providing environmental education for local schools and colleges and general public; and
  - increasing public understanding of climate change adaptation and river restoration.
- Increase the evidence base about:

- linking morphological changes to improved biodiversity through river restoration;
- demonstrating the benefits of adaptive management for ecology and economics; and
- demonstrating climate change adaptation and natural approach to flood management.

(Source: Unpublished list of aims from Mayesbrook Park project steering group meeting, 2008.)

The Mayesbrook project steering group estimates that around £0.5 million pounds of the overall plan cost will be needed for river restoration. A summary of the costs of the phased project schedule is provided in Section 2.8 below.

Proposed works include controlling the flow of polluted brook water into the lake, cleaning the lake, and improving the habitat of the brook and its floodplain and their accessibility to park visitors. A water balance study is planned to support the envisaged work on the lake.

Restoration is planned across three of the four reaches of the brook within the park, as illustrated in Figures 2.1 and 2.2 and described in the remaining sub-sections of this chapter based upon research published in the Mayes Brook Catchment Restoration Strategy (Environment Agency and Queen Mary, University of London, 2010).

Figure 2.1: Mayesbrook Project Phase 1 Landscape Masterplan
(reproduced with kind permission of LBBD)

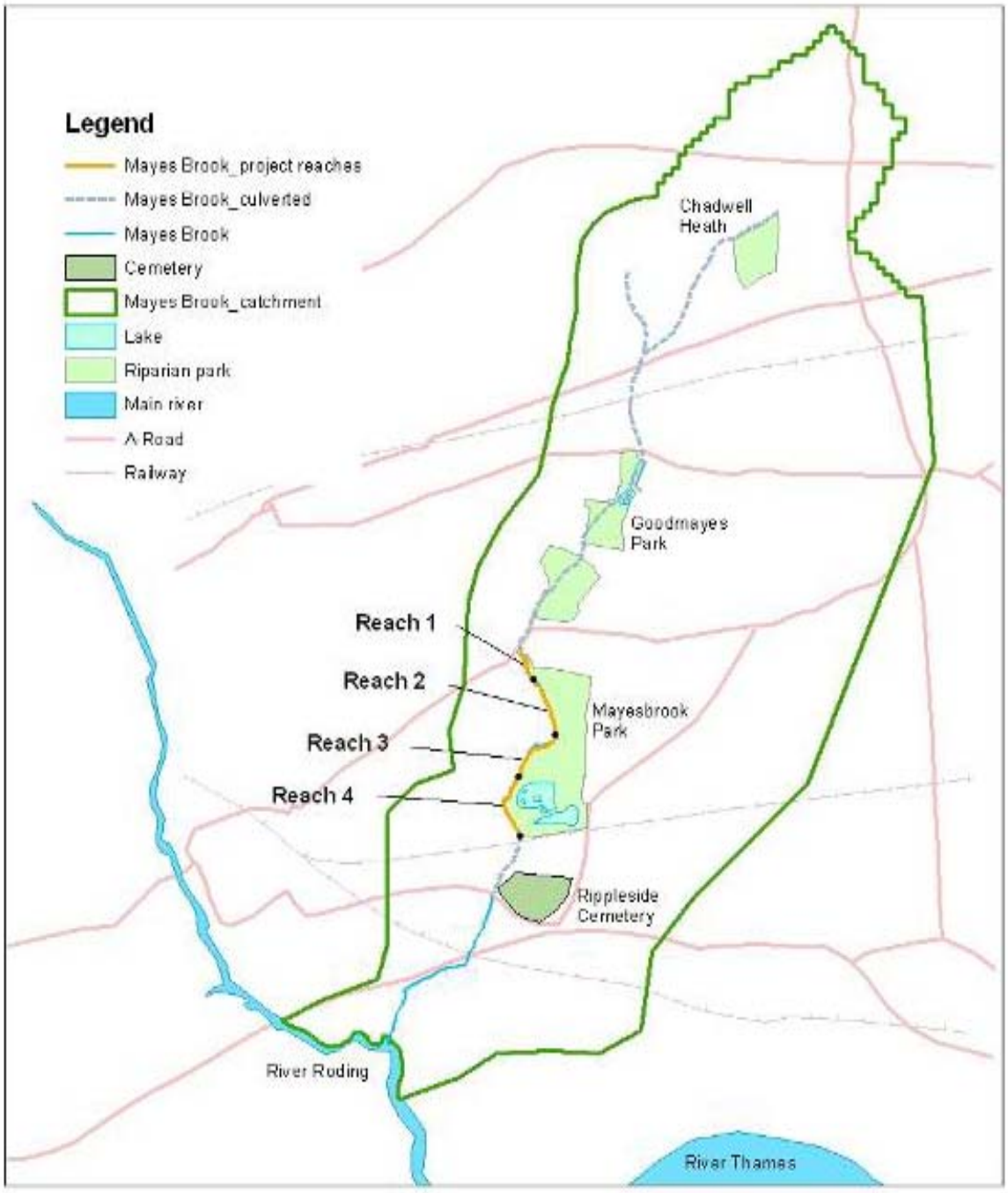

Figure 2.2: Map of Mayes Brook catchment showing position of Mayesbrook Park project reaches in relation to culverted and open reaches of Mayes Brook, riparian open spaces and local transport

2.2 Restoration of Reach 1

The Mayes Brook emerges from its fully culverted upper reaches south of the junction of the A124 and Waterside Close. The brook within Reach 1 runs through an enclosed area of amenity grassland for roughly 150 metres and then in a constrained corridor between the park and an adjacent housing estate access road. Together with a concrete post fence on its left bank, the brook provides a boundary to the Mayesbrook Park to the east. On the western side,

the grassed area provides an open but inaccessible green space for adjacent residential properties.

The trapezoidal channel is 300 metres long and fully reinforced along its length with brick tiles, although the brook is not completely straight. The channel is partially shaded by semi-continuous tree cover along the east bank. Inflows to the main channel include a large screened inlet immediately downstream of the emerging channel from the east. During site visits, this screen was heavily covered with litter. Two other smaller storm flow inlets were observed in this stretch, plus one additional land drain which is fully blocked with soil material.

Baseline Study (Environment Agency, 2008d)

[Photo: © Lucy Shuker 2009

Figures 2.3 and 2.4: Mayes Brook at Reach 1: view from north showing Mayesbrook park boundary to left of image and amenity grassland to right alongside a fully reinforced and shaded section.

Restoration plans for this reach are included in Phase 1. These include removal of channel reinforcement and creation of a short length of new sinuous channel, with space for reed colonisation and flood storage within the river margin.

2.3 Restoration of Reach 2

Reach 2 (400 m) runs between a high palisade fence on both bank tops, following a drop in level at the start of the reach which produces a small chute as the brook flows into this reach. This straightened section of the brook flows within a uniformly over-widened and deepened channel. The brook is entirely disconnected from the adjacent environment and community by the high steel palisade fencing that forms a harsh boundary between Mayesbrook Park to the east and the Leftley housing estate to the west.

Figure 2.5: Mayes brook at Reach 2 (Photo © Lucy Shuker, 2009)

The channel in Reach 2 has been re-sectioned to form an enlarged trapezoidal cross profile that is reinforced along the bottom of the bank and channel bed with concrete. However, these reinforcements are heavily overlain with sediments along much of the stretch to form a semi-continuous succession of sidebars dominated by emergent reeds and sedges including large stands of. Branched Bur-reed (*Sparganium erectum*). These depositional features within the resectioned channel confine a narrower gravel bed channel that divides and meanders around the vegetated bars.

As part of maintenance for flood management, the channel within Mayesbrook Park is cleaned annually with all in-channel and lower bankside vegetation trimmed back to ground levels to remove the superficial foliage and improve flood conveyance. This maintenance regime is illustrated in Figure 2.5.

There are no plans to realign Reach 2 due to the presence of subterranean electrical infrastructure owned by the utility company EDF, which supplies a large area of East London. However, some in-channel enhancement work may be carried out to improve the habitat.

2.4 Restoration of Reach 3

Within Reach 3 (500 m), the brook has also been straightened, overwidened, resectioned and reinforced. The steel palisade fence runs continuously along the eastern bank top while, to the west, the physical boundary between the brook and adjoining residential properties consists of a mix of garden fences and hedges. The character of the stretch is similar to that immediately upstream in Reach 2, but additional features include engineered bends, two large inlets and a small footbridge, which collectively create a range of different habitat structures within the channel and riparian zone. A large scour pool is also present immediately downstream of the largest inlet, as well as large quantities of litter much of which is believed to arrive from this confluence.

Figure 2.6: Mayes Brook at Reach 3 illustrating full summer foliage prior to trimming and potential for reed bed habitat (Photo © Lucy Shuker, 2009)

Restoration of Reach 3 comprises the most substantial element of the brook restoration. Works will include:

- relocating the fence to the bank opposite the park, adjacent to bordering properties;
- excavating a meandering course for the Mayes Brook within the park;
- excavating a one-hectare floodplain around this new winding channel, creating brook and riparian habitat and improving the resilience of the river to climate change;
- increasing the range of recreational opportunities;
- lowering the level of the flood bank, which is currently higher on the park side than the houses opposite due to historic dredging;
- creating new reed bed habitat within parts of the old channel as a backwater and pollution sink, which will also serve to provide 'wet fencing' security for waterside houses;
- reducing the mowing regime within the floodplain area;
- creating new wetland habitat within the new floodplain area; and
- moving around 40,000 cubic metres of spoil to create a new football pitch and a feature mound within the park landscape.

Work on Reach 3 is due to start within Phase 1 of the works (proceeding in 2011). This will begin with an excavation phase, followed by a planting phase.

2.5 Restoration of Reach 4

From the flood sluice downstream to the railway line, Reach 4 (500 m) forms the south western boundary between the park and the adjacent housing estate. The character of the brook is similar to upstream Reaches 2 and 3 with an over-enlarged re-sectioned cross profile. The steel palisade fence continues along the left bank top only with intermittent residential garden boundary fences along the right bank top. The channel engineering includes a footbridge at the south western entrance to the park and two road run-off drainage inlets. Visual signs

of poor water quality can be observed at the inlet locations, including plumes of opaque water discharging into the brook. The adjacent park area between the Mayes Brook and the Mayesbrook Park lakes includes a tree nursery and protective hedge cover. However, these are separated from the channel by the palisade fence.

At the most south-westerly point of the park, the Mayes Brook passes through a large screening grill and beneath the railway line into a culverted section. Just upstream of the culvert, there is an additional overflow inlet associated with the Mayesbrook Park lakes. A partial restoration of Reach 4 is planned within Phase 1 of the work. Issues of neighbour security will be addressed within the restoration works. The focus of works on Reach 4 is likely to include:

- forming a small section of new meandering channel adjacent to the restored woodland area (although not on the scale of Reach 3);
- re-grading of the brook banks to improve the visual amenity and water flows with the park;
- extensive tree planting to create two hectares of riparian woodland habitat;
- removal of the fence on the park bankside; and
- additional fencing on the residential bankside to ensure neighbour security where it is an issue.

2.6 The overall programme

The Mayesbrook Park programme is supported by: Barking and Dagenham Borough Council, Thames Rivers Restoration Trust (TRRT), Greater London Authority, Design for London, Environment Agency, Natural England (NE) and London Wildlife Trust (LWT). Funding sources including the Royal Sun Alliance (RSA) are administered by the TRRT.

The plan for the five-year programme was publicly launched in July 2010, with work on the ground scheduled to start in early 2011 on Reaches 1, 3 and 4. The phased costs of the programme are estimated to include:

Phase 1

Funding for Phase 1 is largely secured from a range of sources including public and private sector sponsors. The estimated total of £1 million is broken down into:

River restoration	410,000
Cosmetic grading to river/mound	35,000
Landscape work to conical mound	30,000
General refurbishment (entrances, furniture and so on)	150,000
Path improvements	37,000
Fencing to housing boundary	60,000
Tree planting	22,000
Meadow/grassland/marginals (85,000 m^2)	67,000
Tree management	25,000
Playbuilder (a central government play promotion initiative)	100,000

design and build	
Adizone (outdoor gym area sponsored by Adidas)	150,000

Phase 2

The estimated total of £2 million is broken down into:

Visitor centre and ranger base (adapt existing buildings)	350,000
Lakes restoration (desilting/planting to improve water quality)	400,000
Watersports facilities	350,000
Sports centre refurbishment	500,000
Teenage recreation facilities	100,000
Habitat improvements (including use of volunteers)	50,000
Tree-lined streets	50,000
Professional fees	100,000
Contingency	80,000

Phase 3

The estimated total is £300,000.

Cycle connections to Goodmayes and Barking Riverside (to be funded by Transport for London and Sustrans)	300,000

Revenue project

The estimated total of £180,000 covers:

Ranger service (three years funded by Access to Nature)	160,000
Volunteer activities (funded by Access to Nature)	20,000

Improvements to the sports grounds to the north and east of Mayesbrook Park and along the spine path will not contribute notably to ecological benefits. However, the whole park will benefit from the screening and greening effects of over 5,000 trees planted for biodiversity, aesthetics and cooling.

The grand total (Phases 1-3 plus three years of funding for revenue) is £3,840,000.

3. Ecosystem service assessment of the Mayes Brook restoration

The methods used in this ecosystem services assessment of the Mayes Brook restoration are based largely on those derived for the *Ecosystem services case studies* on the Tamar catchment and Alkborough Flats managed realignment scheme by (Everard 2009a) and on related ecosystem service case studies on the River Glaven (Everard, 2010) and upper Bristol Avon (Everard and Jevons, 2010). Evidence presented in these related reviews is used to inform this ecosystem services assessment of the Mayesbrook Park restoration.

3.1 About ecosystem services

Ecosystem services describe the multiple beneficial services derived by society from ecosystems. These services are many and substantial, supporting basic human health and survival as well as economic activities, the fulfilment of human potential and enjoyment of life. The essence of the 'ecosystems approach' – management of whole ecosystems and their benefits – is to establish multiple, simultaneous benefits, so that one benefit is not achieved through the inadvertent degradation of other benefits with net harm to other beneficiaries (including future generations).

The history of industrial development has largely overlooked or disregarded many of these ecosystem services, skewing environmental management to the maximisation of commercially-valued outputs (food, fibre and so on) whilst degrading other ecosystem services which are not factored into thinking or traditional cost-benefit analyses (habitat for wildlife, water yield from landscape, air quality regulation and so on.

Modern conceptions of ecosystem services represent the convergence of diverse strands of resource protection science and practice that have emerged since the 1980s. The UN Millennium Ecosystem Assessment (MA, 2005) introduced a consistent typology of 'ecosystem services' as a basis for assessing the status of global ecosystems and their capacity to support human wellbeing. The MA grouped ecosystem services into four main categories: provisioning, regulatory, cultural and supporting services.

- Provisioning services are those things that can be taken from ecosystems to support human needs, including such tangible assets as fresh water, food, fibre and fuel.
- Regulatory services include processes regulating the natural environment, including the regulation of air quality, climate, water flows, erosion and pests.
- Cultural services include diverse aspects of aesthetic, spiritual, recreational and other cultural values.

- Supporting services do not necessarily have direct economic worth but include processes essential to the maintenance of the integrity, resilience and functioning of nature (photosynthesis, nutrient cycling, soil formation and so on) and so support the other ecosystem services.

The complete MA classification of ecosystem services is listed in Table 3.1.

Table 3.1 MA classification of ecosystem services

Provisioning services
Fresh water
Food (crops, fruit, fish etc.)
Fibre and fuel (timber, wool etc.)
Genetic resources (used for crop/stock breeding and biotechnology)
Biochemicals, natural medicines, pharmaceuticals
Ornamental resources (shells, flowers etc.)
Regulatory services
Air quality regulation
Climate regulation (local temperature/rainfall, greenhouse gas sequestration etc.)
Water regulation (timing and scale of run-off, flooding etc.)
Natural hazard regulation (storm protection)
Pest regulation
Disease regulation
Erosion regulation
Water purification and waste treatment
Pollination
Cultural services
Cultural heritage
Recreation and tourism
Aesthetic value
Spiritual and religious value
Inspiration of art, folklore, architecture and so on
Social relations (such as fishing, grazing or cropping communities)
Supporting services
Soil formation
Primary production
Nutrient cycling
Water recycling
Photosynthesis (production of atmospheric oxygen)
Provision of habitat

The MA typology provides a broadly inter-comparable set of services across bioregions and ecosystem types. It also exposes the complexity of interactions between social and natural systems, the knowledge gaps about how all ecosystem services are produced, and the need for methods to monitor them.

3.2 Valuation of ecosystem services

Defra (2007a) states that: "*An ecosystems approach to valuation provides a framework for looking at whole ecosystems in decision making, and for valuing*

the ecosystem services they provide, to ensure that we can maintain a healthy and resilient natural environment now and for future generations".

There is a broad consensus that economic values derived from this type of assessment have no absolute meaning, sensitive as they are to a broad spectrum of factors including what is omitted or included, explicit and implicit assumptions, valuation methods and the scale of evaluation (Costanza *et al*., 1997; Defra, 2007a). However, the determination of marginal values, reflecting changes in ecosystem services, derived by comparing a baseline condition to an altered state, provide insights into the tendency (positive or negative) and scale of changes and are helpful in analysis and decision-making.

In this study, the baseline is taken as the state of services prior to restoration interventions. The economic benefits of most ecosystem services are calculated on the basis of a range of stated assumptions linked to real market values, surrogate market prices or values transferred from related studies. Transferred values for this study are drawn from previous studies and standard databases (for example EVRI^{TM}, Woodward and Wui, 2001), as well as directly related ecosystem service studies (Everard, 2009a and 2010; Everard and Kataria, 2010; Everard *et al*., 2009; Everard and Jevons, 2010). Methods, assumptions and transferred values for each ecosystem service are described in Annex 1.

The UK government's *Green Book* (HM Treasury, 2003) is used as a reference for methods to assess the total economic value of the benefits and costs entailed in public development projects). The *Green Book* does not specify a design life for schemes, but does specify discount rates for the asset lifetimes. A lifetime of 25 years (with a discount of 3.5 per cent) was used in other studies in this series – Alkborough Flats and the Rivers Tamar, Glaven and Bristol Avon – river channel modification, wetland creation, tree planting, flood defences and wider landscaping of parkland at Mayesbrook Park are expected to have a longer asset lifetime of at least 40 years For this reason, lifetime benefits are assessed over 40 years (with a discount rate of 3.5 per cent for the first 30 years declining to three per cent for years 31-40), which is still highly conservative given the maturation rate of forestry and the longevity of river and park assets.

The formula under which Net Present Value (NPV) is calculated is the sum of per annum (*dt*) values where:

$$dt = 1/(1+r)^{t}$$

…in which r is the discount rate and t is the year at which discounted.

This simplified approach, using a uniform asset life, was adopted for three reasons:

- Avoiding a spurious sense of accuracy. A more technically precise approach might include identifying different design lives and discount rates for each element of the infrastructure but, since most valuation is based on assumptions and inferences about value transfer, there is a great deal of subjectivity in all derived annual values.

- The principle of parsimony. This relates to not undertaking too exacting an analysis relative to the scale of the project or the levels or uncertainty within it. Too elaborate a method, particularly one that does not reflect uncertainties in the derivation of underpinning annual values, may inhibit understanding and hinder use.
- Conservative values. We do not want to risk overstating values, and so this method is conservative to reveal a 'worst case' outcome, in particular a pessimistic view of the benefits that may be achieved.

This pragmatic approach results in a simpler and more useful method, although some long-lived benefits may be undervalued. This may risk undervaluing the often enduring benefits of environmental schemes. However, the method better represents the level of assessment normally possible where there is rarely time or budget to make a bespoke or more detailed assessment. Derived lifetime values are more readily communicated, and the conservative nature of derived values can underline the positive case for proceeding with schemes.

Some authors argue that only final services, such as fresh water extracted and not ecosystem processes that store and purify it, should be valued (for example Turner *et al*., 2008). Others going beyond this to argue that only tradable 'goods' deriving from these final services should be monetised (for example Bateman *et al*., in press). This is to avoid double-counting. However, the authors of this assessment follow Everard (2009a and 2010), Everard *et al*. (2009), Everard and Jevons (2010) and Everard and Kataria (2010) in seeking to value all services, whilst explaining how double-counting has been avoided.

3.3 Paying for ecosystem services (PES)

The concept of paying for ecosystem services (PES) is introduced here as it may prove useful in suggesting markets (payments by service beneficiaries re-circulated to those affecting service production) for ecosystem services resulting from opportunities for further improvements to the Mayesbrook Park restoration. Beneficial services highlighted in this study that may not traditionally have been considered as 'environment outcomes', from which investment may be drawn for public benefit, include health, amenity and other societal benefits.

The emerging practice of 'paying for ecosystem services' (PES) schemes connects 'sellers' of ecosystem services, produced by improved environmental management or restoration, with 'buyers' benefiting from those services. PES is defined by Wunder (2005) as "*a voluntary, conditional agreement between at least one 'seller' and one 'buyer' over a well defined environmental service - or a land use presumed to produce that service*". PES schemes are being developed around the world by creating markets to link those who influence production of services with those that benefit from them (for example as reviewed by Mander and Everard, 2008). Water supply has often constituted an important medium for such markets, including for example safeguarding the quality of the Vittel bottled springwater source in France (Perrot-Maître, 2006) and of the New York City public water supply (reviewed by Everard, 2009b) both of which are enacted through a partnership with the managers of rural land.

As noted above, there may be opportunities for PES creation to support restoration of Mayesbrook Park in recognition of the many potential beneficiaries of improved ecosystem services.

4. Results of ecosystem service assessment of the Mayes Brook restoration

Table 4.1 below contains a summary of results abstracted from the detailed assessment of likely ecosystem service impacts, positive and negative, resulting from the Mayes Brook restoration. The detailed analysis, documenting working assumptions, is recorded in Annex 1.

Table 4.1: Summary results from changes in ecosystem services arising from the Mayes Brook restoration

Ecosystem service	Annual benefit assessed Research gap/note
Gross annual provisioning service benefits	**There is no increase to provisioning services**. This contrasts markedly with related rural case studies (Everard, 2009a and 2010; Everard *et al*., 2009; Everard and Jevons, 2010; Everard and Kataria, 2010), where impacts on farm profits significantly affect this service category. Some development options (reuse of trimmings for 'fibre and fuel') may potentially produce provisioning service benefits.
Gross annual regulatory service benefits	**Gross annual regulatory service benefits are approximately £28,000** (calculated total = £28,087) comprising climate regulation @ £13,000 + flood risk @ £10,000 + erosion @ £5,000. However, there will also be **'likely significant positive benefits'** for the regulation of air quality and microclimate. All of these benefits relate almost entirely to public health and risk management, showing the potential role of Mayesbrook Park to enhance the wellbeing of the neighbourhood.
Gross annual cultural service benefits	**Gross annual cultural service benefits are approximately £820,000** (calculated total = £820,169) comprising recreation and tourism @ £815,000 + educational value @ £5,000. However, the net uplift (via 'social relations') to **regional regeneration is assessed with a lifetime (100 year) benefit of @ £7,800,00** which will be factored into the final NPV calculation.
Gross annual supporting service benefits	**Gross annual supporting service benefits are approximately £31,000** (calculated total = £30,573) comprising nutrient cycling @ £21.,000 + habitat for wildlife @ £10,000.
Total annual ecosystem services uplift across the four categories	**Gross annual ecosystem service benefits are approximately £880,000** (total = £878, 829 based on summing calculated values to avoid rounding errors) but there are also **'likely significant positive benefits'** for the regulation of air quality and microclimate as well as a (100-year) contribution to **regional regeneration of £7,800,000.**

When annual benefits are assessed over 40 years (discount rate of 3.5 per cent initially with three per cent applied for years 31-40), this equates to a gross lifetime benefit of nearly £19 million (calculated total is £18,848,830). However, to this we have to add the calculated 100-year uplift to neighbouring properties (£7,800,000), which yields a grand total of around £27 million (calculated total is £26,661,329). Note this excludes the 'likely positive benefits' for the regulation of air quality and microclimate.

The gross costs of the Mayesbrook Park restoration scheme (Phases 1-3 plus three years of funding for revenue) is estimated in Section 2 as £3,840,000.

On the basis of the suite of ecosystem services values in this case study, which includes likely benefits from the regulation of air quality and microclimate, the Mayesbrook Park restoration yields a lifetime benefit-to-cost ratio of roughly 7:1 (the calculated ration is 6.94:1), or £7 of benefits for every £1 invested.

5. Discussion and learning points

This section explores the learning points and research needs highlighted by our assessment of the planned restoration in Reaches 1, 3 and 4 (three of the four reaches of the Mayes Brook) within Mayesbrook Park.

5.1 Key outcomes of the Mayes Brook restoration

The most notable benefits of the Mayesbrook Park restoration are from cultural services, which account for around 93 per cent of total benefits (40-year NPV of annual benefits + 100-year property uplift). Overall benefits are substantial relative to investment, representing a lifetime benefit-to-cost ratio of around 7:1.

The urban setting and impoverished biodiversity of Mayesbrook Park and the stretch of the Mayes Brook that runs through it means that restoration will bring no further benefits from provisioning services. This is a different outcome to other assessments in this series of Environment Agency case studies of interventions in the aquatic environment, all of which have addressed rural areas (Tamar catchment, Alkborough Flats, River Glaven sea trout restoration, and buffer zone installation on the upper Bristol Avon).

In contrast, the urban setting means that ecosystem enhancements can make major contributions to regulatory services (regulation of air and water quality, microclimate and flood risk) affecting the local community. The same is true for cultural services (recreation and tourism, social cohesion and educational opportunities), particularly since many people in the borough lack gardens or ready access to other green spaces.

Supporting services, which are hard to quantify but essential for maintaining ecosystem functions underpinning more directly-used services, are significant in terms of nutrient cycling and provision of habitat for wildlife. This habitat improvement helps ensure there are animals and plants capable of colonising the wider landscape as the habitat improves, also serving as a ‘stepping stone’ for wildlife to move across and between limited and fragmented suitable habitat in the urban landscape.

This suggests that much public value will accrue from urban river and parkland restoration, fully justifying the planned investment and providing firm evidence that investment in urban ‘green infrastructure’ is highly favourable to the health and wellbeing of local people and economic uplift of deprived wards. This scheme is a cost-effective means of improving wellbeing and quality of life of urban communities.

This study is in agreement with the four rural case studies in this series, in that, by restoring natural vitality and function, beneficial services are boosted or maintained across all ecosystem service categories (provisioning, regulatory, cultural and supporting). This also contrasts with traditional, single-element solutions, which tend to maximise only the targeted services and often are associated with unintended consequences for other interconnected services. The case for the application of ecosystem-based solutions to environmental management problems is thus substantiated.

5.2 Consideration of the market

Unlike many traditional provisioning services, e.g. water, fuel, fibre, food, the value of less tangible services has been overlooked in the past. We need to think in broader terms about the 'missing markets' for these services, recognising that health budgets ring-fenced to traditional treatment of illness may miss substantial and potentially cost-effective opportunities for improvements of general health. The approach could apply to social inclusion activities, which, if they provide green and safe environments for shared recreation, participation and communal activities, may help to rebuild social cohesion.

These missing markets represent opportunities for more integrated thinking about how social and economic benefits can flow from protection and improvements of shared environmental resources that may have been radically undervalued in the past. They also represent opportunities for paying for ecosystem services (PES) markets in which, potentially, interests in public health, flood risk management, urban biodiversity and other sectors might be induced to invest in the green infrastructure delivering these benefits. This is an area of further exploration and development in extending the Mayesbrook Park restoration beyond Reaches 1, 3 and 4 and in other urban areas.

5.3 Evidence gaps

There were many instances of services that could not be quantified and/or monetised due to gaps in knowledge and tools. This was especially the case for all regulatory services, with the exception of flood risk. Expert judgement highlighted positive likely benefits for the regulation of air quality and microclimate, which could have boosted quantified benefits. More research is needed to quantify pathways of benefit from regulation of air quality, climate and microclimate, linking these to health and potential climate change impacts and their associated costs.

This opens up the possibility of better urban engineering, including use of green spaces and river/stream corridors tailored to improving the health of residents. Cultural services, such as the aesthetic and spiritual value of natural spaces within an urban environment, are more difficult to quantify but nevertheless have value in terms of both physical and mental health benefits and quality of life. Urban green spaces may also act as socio-ecological treatment systems to improve the urban environment, its enjoyment and public health.

There is also the opportunity to explore paying for ecosystem services (PES) schemes around ecosystem restoration and positive management for the benefit of many cultural, regulatory and supporting service beneficiaries.

Overall, this assessment shows that there are many complex and interrelated aspects of ecological, social and economic gain which, at present, are difficult to quantify. However, there is currently much research on such methods of evaluation (including a Natural England (2007) study of the value of green open space to mental health and wellbeing as well as further significant

interdisciplinary research in the United States e.g. Institute of Medicine, 2007; and Europe e.g. Maas et al, 2006, Tzoulas et al, 2007) which should feed into future urban environmental assessments.

5.4 Efficacy of the ecosystems approach

Ecosystem services assessment of likely outcomes of the Mayesbrook Park restoration provides a broad vision not merely of environmental impacts, but also their implications for a wide range of community groups. These impacts have associated economic implications, helping to connect thinking across traditional policy areas and guiding more sustainable thinking.

5.5 Recommendations for improved sustainability and public value

All ecosystem services represent benefits to people, and hence can be optimised to enhance the public value of scheme design and operation. Ecosystem service considerations can also be applied in consideration of further phases of development to improve sustainability and broader public benefits. Further options for improvement considered for the next phase of this scheme include:

- Enhanced hydrological function of the whole park landscape and infrastructure, including:
  - building sustainable drainage systems (SuDs) into all buildings, car parks, paths and playing field areas particularly to enhance the 'water regulation' service;
  - putting green roofs on new buildings; and
  - consideration of installing greywater recycling systems on new buildings, following an evaluation of the overall sustainability of any such project
- Improving water quality, supporting healthier ecosystems and protecting the freshwater resource, throughout the scheme by:
  - managing the cut-off (current) channel bypassed by stream meandering in Reach 3 so that it acts as a reedbed filtration system improving habitat and cleansing water;
  - building semi-natural wetland treatment systems into the inflows and outflows of the two currently polluted lakes; and
  - if polluted sediment washing into the park remains a problem, design into these inlets and outlets areas that can be regularly dredged to trap and remove pollutants before they can disperse into the wider park ecosystem.
- Improved climate regulation through:
  - energy-efficient design of buildings;

    - making use of embedded renewable energy generation including solar panels and micro wind power generation; and
    - potential reuse of tree and other park trimmings as fuel for biomass boilers in park buildings or adjacent properties (such as the neighbouring schools).
- Optimisation of design of park restoration so that it is managed as a health and educational resource (green gyms, outdoor classes etc.) which will enhance the cultural services provided by the park.
- Some of these enhancements may bring direct as well as indirect economic gains, including exploitation of tree trimmings and hay cut from the recreated floodplain and less intensively-mowed areas which may offset costs (when used as replacements fuels) or generate revenue from sale. Planting herbs and vegetables for the community café (following the lead of the Capital Growth project: www.capitalgrowth.org/) may also be beneficial to the community. These measures would enhance the provisioning service benefits of the scheme, also reducing waste and the amount of food imported onto the site.

Assessment of ecosystem service implications for all of these options, and others identified in later phases of planning, can further bolster the economic case for their implementation not only for Mayesbrook Park but also other future park works.

5.6 Learning beyond the Mayes Brook restoration

All of this learning is relevant not only to the Mayesbrook Park restoration but to other urban river and urban area restoration initiatives.

Notwithstanding the assumptions underpinning some aspects of this ecosystem services assessment, this case study provides evidence for improved scheme design and greater integration of social, economic and ecological benefits in future initiatives.

Annex 1: Detailed results of ecosystem services assessment of the Mayesbrook Park restoration

Tables A1.1 to A1.4 below document the ecosystem services assessments of the benefits arising from the Mayesbrook Park restoration respectively for provisioning, regulatory, cultural and supporting services, using methods explained in the body of this document.

Table A1.1: Assessment of changes in provisioning services from the Mayes Brook restoration

Provisioning services and the methods and assumptions used for their evaluation	
Fresh water	There is no abstraction from the Mayes Brook catchment today, and the brook also discharges into the saline Barking Creek which is not abstracted for public supply. Therefore any contribution to water quality and resource availability is not used for abstraction. **Annual value = £0**
Food (such as crops, fruit, fish)	There is no food production on site or any river-dependent farming downstream in this urban area. There is believed to be informal abstraction by bucket for private gardens, but the small scale of this is likely to make the benefit negligible. There are fish in the Mayes Brook but none that are suitable for food. **Annual value = £0**
Fibre and fuel (such as timber, wool)	There is a potential for hay harvesting on the new one-hectare floodplain habitat. A reduced bi-annual mowing regime could yield benefits in terms of the use of hay cuttings for mulch or compost within the park site. Pruning of other vegetation, including the extensive tree planting, would be a resource (wood chip biofuel and so on) rather than a net disposal cost. These resources may be most valuable if they can be processed (chipped/shredded) and used on site as compost or mulching material, reducing transport costs. Installing a biofuel facility would entail initial capital and maintenance costs which would need to be offset against the longer term gains. These are highlighted as potential development options and are not part of current plans, so are assessed as zero value for the current assessment. **Total monetary value = £0**

Genetic resources (used for crop/stock breeding and biotechnology)	Restoration of more natural river and floodplain habitat can protect or restore biodiversity with its associated genetic resources. This is likely to improve resilience of biodiversity, creating an 'island' within this heavily impacted urban environment. However, there appear to be no markets of informal uses of this genetic resource which is therefore ascribed a zero value. **Annual value = £0**
Biochemicals, natural medicines, pharmaceuticals	This mirrors the observations for genetic resources above, for which a zero value is ascribed despite the likely overall contribution to ecosystem diversity and resilience (which are accounted for as cultural and supporting services). Maintaining viable populations of native flora and fauna in an urban setting is a valuable insurance for a future when the biochemical value of these resources may be recognised and required. **Annual value = £0**
Ornamental resources (such as shells, flowers)	We can expect local people to enjoy flowers on the restored and accessible floodplain, but this will be included as a cultural value as it has no substantial provisioning benefits. **Annual value = £0**
Gross annual provisioning service benefits	**There is no uplift to provisioning services**. Some options (reuse of trimmings for 'fibre and fuel') may bring provisioning service benefits.

Table A1.2: Assessment of changes in regulatory services from the Mayes Brook restoration

Regulatory services and the methods and assumptions used for their evaluation	
Air quality regulation	Increase of vegetation diversity, including tall herbs and grasses in the floodplain and less intensively mown areas as well as tree plantings, could make a substantial difference to air quality. This happens through particulate fallout, adsorption of metals and metabolism of nitrous oxides, ozone and other pollutant gases (see for example Nowak *et al*., 1998 and 2002). Given the high urban population densities around the park, there are many potential beneficiaries, and the scheme could be considered and optimised as a 'green lung' for the city. The Defra (2007b) *Air Quality Strategy for England, Scotland, Wales and Northern Ireland* July 2007 estimates that the costs of the health impact of man-made particulate air pollution in the UK in 2005 was between £8.5 billion and £20 billion a year, which the UK Government's Environmental Audit Committee report on air quality (House of Commons, 2010) considers an underestimate. Pollution is most intense in urban areas, largely related to traffic which is the biggest source in the UK. We therefore conservatively estimate that 8,000 people (0.00013 of the UK population) living within 0.5 km of the park boundary suffer £1.1 million of health impact from fine airborne particulates (based on Defra estimate and summary statistics for adjacent wards from the UK Census 2001, http://neighbourhood.statistics.gov.uk/dissemination/). However, quantification of air clean-up and its knock-on

	implications for urban health are both highly uncertain, despite expert judgement that there is a likelihood of substantial health-related benefits, particularly given the high density population around Mayesbrook Park. For this reason, this service is not quantified, but the likely positive benefits (we can not yet imply they are 'significant' due to uncertainties) and need for further research are noted. **Annual value = 'Likely positive benefit'**
Climate regulation (local temperature/ precipitation, greenhouse gas sequestration, and so on)	We can expect a marginal difference in carbon sequestration as a result of tree growth, less intensive mowing, and potential organic matter accumulation in floodplains. Quantification of these components includes the following five aspects. 1) Sequestration in trees. SWIMMER (2007) reviews scientific literature on soil organic content and standing crop, noting that riparian rewetting can increase soil carbon from 20,324 C t ha^{-1} (g m^{-2}), recorded for floodplain permanent grassland, to soil carbon of 26,064 C t ha^{-1} for floodplain woodland. The difference of 5,740 C t ha^{-1} resulting from tree planting and growth for three extra hectares of trees yields a total additional soil carbon sequestration of 172 t C ha^{-1} a^{-1} over 100 years. To this is added the standing crop of trees (SWIMMER, 2007 calculated that alder forest has a 100-year annual average carbon storage of 65 t C ha^{-1} a^{-1}) which accounts for further sequestration of 195 t C ha^{-1} a^{-1}. Multiplying the sum of annual woodland soil (172 t C ha^{-1} a^{-1}) and above-soil (65 t C ha^{-1} a^{-1}) sequestration by the current £55 per tonne non-traded price of carbon (HM Treasury and DECC, 2010) yields a forestry-related annual carbon sequestration benefit of @£13,000. This method of calculation is conservative, and is likely to underestimate actual sequestration over the first 40 years (the timeline used for NPV calculation) of forest growth which is greater during rapid initial growth. 2) Sequestration in reedbeds and wetland habitat is uncertain, since natural and constructed freshwater wetlands can be both sources and sinks of carbon, depending on factors such as their environmental setting and age (Kayranli *et al*., 2010). Therefore, we attribute zero to their valuation in this assessment 3) Sequestration in floodplain soils. Zehetner *et al*. (2009) found rapid carbon accumulation during the initial 100 years of floodplain soil formation, with rates exceeding 100 g m^{-2} a^{-1} (= 1 t C ha^{-1} a^{-1}). Applying this value to the one hectare of created floodplain yields a total carbon sequestration rate of 1 t C a^{-1} equating to an annual value (@ £52 per tonne) of £52. 4) Mowing regime. It is uncertain how quickly or permanently a change in mowing regime will affect soil carbon, so this potential benefit is not quantified in this study. 5) Net carbon sequestration value. The sum of the above three annual benefits is £13,087. These annual values will yield a conservative lifetime value as: (1) the non-traded price of carbon should in theory rise over time, but this compounding has not been applied here to simplify the process and avert any overstatement of the certainties in

	quantification methods; and (2) values derived by annualising a 100-year sequestration rate will subsequently (see Section 3) be compounded into a lifetime value over only 25 years. Urban green spaces may help alleviate urban heat stress (World Health Organisation, 2004). Around 8,000 people live within a half-a-kilometre of Mayesbrook Park's boundaries (UK Census 2001 summary statistics for wards adjacent to Mayesbrook Park: http://neighbourhood.statistics.gov.uk/dissemination/). It is thus possible to extrapolate excess deaths reported during the major heat wave of western Europe in summer 2003, biased towards London compared to other English regions (Haines *et al*., 2006) and accounting for the vulnerability of elderly and deprived people (Kovats, 2008) and to assess likely health-related benefits from habitat improvement. It is possible to assess the degree to which floodplain and associated tree planting can moderate ambient temperatures for park users and provide cool refuges for aquatic species by buffering diurnal stream temperatures (Rutherford *et al*., 2004; Broadmeadow *et al*., 2010). However, in practice, reliable quantitative evidence linking these data are not available, and for this reasons the benefits are not quantified. Expert opinion nevertheless suggests a likely positive contribution to microclimate regulation, and the need for further research in this area is noted. **Combined annual value = £13,087 + 'likelihood of positive benefits' for microclimate regulation**
Water regulation (timing and scale of run-off, flooding and so on)	Mayesbrook Park lies within 'Zone 3b Functional Floodplain' of the *London Borough of Barking & Dagenham: Strategic Flood Risk Assessment (SFRA) Level 1* (Jacobs, 2008). Dagenham and Barking has a dense population (4,560 people per km^2 based on mid-2004 population estimate by www.barking-dagenham.gov.uk). A run-off curve method used by the United States Department of Agriculture (USDA) (Marek, 2009) allows comparison of percentage run-off from different land uses and soil types. Assuming that the soil supports a moderate infiltration rate and is currently under poor condition trampled mown grass, run-off is estimated at 79 per cent: • One hectare will be converted to floodplain which is equivalent to the USDA 'meadow' cover (58 per cent run-off due to better infiltration, saving 21 per cent). • Three ha will be converted to more woodland across the whole park (60 per cent run-off for intermediate condition woodland, which is the likely condition given the likely heavy use, saving 19 per cent of run-off). • Mowing can be expected to change run-off characteristics, possibly to intermediate between 'poor' and 'good' condition grassland (60 per cent saving 19 per cent run-off) over a conservative area of 20 ha. • A mean annual precipitation of 584 millimetres (http://www.bbc.co.uk/weather/world/city_guides/results.shtml). This yields a conservative saving of 26,729 m^3 of rapid run-off

	averted per year which, although some infiltrating water may enter the Mayes Brook as baseflow, will suppress flood peaks. This may be significant for climate change scenarios in which more intense rainfall and wetter winters are anticipated in London. Residential and industrial areas next to Mayes Brook downstream of the park are potential beneficiaries of this restoration, as are those adjacent to Barking Creek, although this is indirect and not assessed. Assuming that risks to 500 properties at damage estimates of £20,000 per property are reduced by 0.1 per cent (one year in a thousand risk reduction on an annual basis), this yields an annual damage estimate of £10,000. There are further opportunities for the Mayesbrook restoration including taking a wider ecosystem-based approach to park hydrology using innovations like green roofs, porous paving, sustainable urban drainage schemes and detention basins in park infrastructure and landscaping. These potential hydrological benefits are not quantified in this study as they do not (yet) feature in the design. **Annual value = £10,000**
Natural hazard regulation (storm protection)	This will mirror observations for microclimate resulting from roughness created by trees, floodplain and reduced mowing regime, all of which will absorb storm energy which is likely to increase under climate change scenarios. The authors could not find any studies helpful in quantifying this effect, so it is therefore not assessed in this study. **Annual value = £0**
Pest regulation	Restoration of habitat can restore stocks of natural crop pest predators in lowlands. However, there are few crops to suffer damage in this vicinity beyond those in gardens. Uncertainties about this service, and how to value it, mean that a neutral value is assigned. **Annual value = £0**
Disease regulation	Disease regulation is contentious. On the one hand, improved river and riparian habitat can eliminate waterborne pathogenic microbes (Nuttall *et al*., 1997). However, there is a perceived risk of malaria spreading under climate change forecasts, emphasising the value of the microclimate benefits (which will not be valued here in order to avoid double counting). Given the uncertainties, this service is not valued. **Annual value = £0**
Erosion regulation	The current (reinforced pre-restoration) condition of the Mayes Brook means that erosion is not a major issue on the riparian zone. However, there is deposition of fine silt and organic particulates on the stream bed which requires periodic dredging, largely as part of emergent vegetation removal. Following restoration, the floodplain can be expected to settle silt. Data on actual maintenance costs could not be broken down from overall area maintenance budgets. Dredging/trimming costs (fines

	and vegetation management of overhanging branches and emergent plants in the channel) are therefore estimated at £1,000 per 100 metres per year. For the restored Reaches 1, 3 and 4, with a combined length of one km, this yields a total of £10,000. Assuming that this management will conservatively decline by 50 per cent, the saving will be £5,000 per annum. Depending on the details of stream design, if there is sufficient energy in the brook channel post-restoration this may move fine particulates out of the channel and result in erosion of coarse sediment from banks which is dumped into channel to build habitat. All river energy absorbed in the park may contribute to averting erosion downstream. **Annual value = £5,000**
Water purification and waste treatment	The improved river and floodplain habitat, in addition to pollutants detained or transformed by attenuated run-off and the reedbed treatment system that may arise if the abandoned brook course (flood relief channel) is allowed to vegetate up and if reedbed systems are installed at lake inlets, will undoubtedly contribute to the physico-chemical purification of water and waste substances. This does not affect abstracted water as none is removed from the brook downstream. However, it is possible to view the restored brook habitat through Mayesbrook Park as green infrastructure that serves to clean up the environment including the catchment. If this opportunity is seized in brook corridor/backwater design, benefits will accrue to habitat for wildlife. Since there are risks of double-counting with fresh water, nutrient cycling and habitat for wildlife (for the last two see supporting services below) services, this service is not assigned a value here. **Annual value = £0**
Pollination	Restoration of habitat, particularly restored floodplain, can restore stocks of natural pollinators which may be beneficial for the high local population who may become more interested in cultivation. Currently, there is no market for this service, and uncertainties about future markets mean that this service is not yet valued. **Annual value = £0**
Gross annual regulatory service benefits	**Gross annual regulatory service benefits are approximately £28,000** (calculated total = £28,087) comprising climate regulation @ £13,087 + flood risk @ £10,000 + erosion @ £5,000. However, there will also be **'likely positive benefits'** for the regulation of air quality and microclimate. All of these benefits relate almost entirely to public health and risk management, showing the potential role of Mayesbrook Park in enhancing the wellbeing of the neighbourhood.

Table A1.3: Assessment of changes in cultural services from the Mayes Brook restoration

Cultural services and the methods and assumptions used for their evaluation	
Cultural heritage	There is little of historic significance on site, the whole unit only being established in the 1930s. However the unfinished Italianate gardens represent the history of changing priorities associated with the onset of war in 1939. The lakes are also relics of this era, dug for sand and gravel extraction for the sprawl of urban development. **Annual value = £0**
Recreation and tourism	There are many potential local visitors to the park. Currently, lack of amenity and fear of crime means that recreational use of the park is relatively low, beyond dog walking, sports clubs use of the football, and cricket fields and the canoe (kayaking) club at the lakes. The park is also used as a through route across the east-west pathway. Lake restoration will also boost frequency and safety of kayaking which is currently inhibited by blue-green algal blooms. as well as enabling the resumption of angling. Outdoor gyms and linkage of the park to cycle-ways will enhance use, as will construction of the visitor centre/café and particularly employment of a warden. (A 3 year post has now been successfully secured through the 'Access to Nature' scheme.) This is anticipated to increase local use significantly. A park user survey carried out over 28 days between January and June 2009 (Shears, 2009) revealed an average of 262 visitors per day, ranging from 59 to 1,103 visitors on a Saturday in May 2009. These data indicate that the majority of park users are families or groups (27%) followed by dog walkers (16%) and walkers (12%). Just under eight per cent of park users were unaccompanied children. This is likely to be associated with the close proximity of the secondary school to the park and sports facilities (Shears, 2009). The increase in use of the Ladywell Fields park (Lewisham Council, South London) was over 250 per cent in the year following restoration of the parkland and the River Ravensbourne that traversed it (RRC, 2008). When applied to the Mayesbrook Park, this would result in a post-project daily average visitor number of 656 persons. O'Gorman *et al*. (2009) record a value loss of £16.90 per person-day where closure of a waterway deters visitors. However, as this figure is a 'willingness to accept' value and it does not reflect the generally low-income population living in this area (compared for example to a weekly job seekers allowance of £65.45), this study uses half of O'Gorman's value (£8.45 per person per day). The approach taken to derive an annual value here was to assume a more pessimistic outcome than at Ladywell Fields park, merely doubling the visitor numbers (an extra 262 people in Mayesbrook Park). Multiplying the conservative per-person value (£8.45) by the conservative uplift in visitors and number of days in the year, this yields a projected uplift in annual value of £808,074. Though

	substantial, this uplift is derived from conservative assumptions. Further health benefits can be expected from access to green space (viewing, walking, connection with nature, relaxation and so on, some of which is reviewed by Pretty, 2002). These values are not, however, calculated here as many may be included in visitor numbers, though this valuation will be inherently conservative acknowledging some cultural wider benefits not captured. The creation of employment through the cafe and visitor centre, in terms of catering and cleaning services, also represents a benefit to local employees financially and in terms of quality of life and health gains. If the equivalent of one full-time post is created, a value might be ascribed in the resulting non-payment of job seekers allowance (currently £65.45 per week for a single person aged over 25 years www.direct.gov.uk/). An annual cost saving could be estimated as £65.45 x 52 = £3,403.40. If the value of housing benefit is included at the local housing allowance rate for Barking and Dagenham of £71 per week for a one-bed shared rental (https://lha-direct.voa.gov.uk/) this would represent an additional annual cost saving of £3,692. The combined saving in benefits gives an annual total figure for each full time job created of £7,095. This restoration includes creation of 1.5 x conservation warden posts (valued at 1.5 x £25,000, including National Insurance contributions, giving a total benefit of £37,500). The benefits of warden patrols will manifest in terms of other ecosystem services. Their employment is therefore an investment that is included in the overall costs of the restoration scheme. **Annual benefit = £815,169**
Aesthetic value	Increasing this value is a key target of the Mayes Brook restoration, including the increase in facilities, habitat and so on. These aspects are highlighted in the results of the 2009 public consultation which reflected the desires of the community for aesthetic improvements. However, these benefits have been picked up in other services and are not double-counted here. **Annual value = £0**
Spiritual and religious value	These values are not known, but are not considered significant. **Annual value = £0**
Inspiration of art, folklore, architecture, and so on	Schools use the park for artistic projects (funded by Natural England) at present, and this is anticipated to increase as the aesthetics and biodiversity of the park increases. Monetising this is not straightforward so no value is assigned at this stage. **Annual value = £0**
Social relations (such as fishing, grazing or cropping communities)	This is believed to be substantial as the park is underused, but use will rise as a result of improvements under the restoration plan. The restored brook, wetland, lakes and naturalised park areas will be a focus for clubs (fishing, boating, bird-watching and so on) and

	for informal use by children and parents, dog-walkers and others. Several areas designed for Natural Play are included within the Mayesbrook Landscape Masterplan (LBBD, 2009). These will be enhanced by passive supervision of young park visitors. Woodland and wetland trails as well as fitness stations located around the park will also encourage park visitors to interact with the landscape and each other whilst building common interest relationships with each other within the natural environment. Furthermore, the restoration provides opportunities for the creation of local interest and 'Friends of' groups which have been found to increase social cohesion in other examples of river restoration, such as the River Brent at Tockyngton Park (Mbeke, 2008). The value of volunteer work within the park also offers a per capita evaluation potential in terms of the value of maintenance or services to the landscape/community. Studies on other restoration schemes (such as on the River Glaven (Everard, 2010) and project work on London's River Wandle www.wandletrust.org) use estimates of the value of volunteer days to this social capital. The increased involvement of local young people in the park and environmental activities (angling, kayaking and so on) would lead to a greater sense of ownership of the space leading to a reduction in crime and vandalism. These values associated with park use are not, however, captured here in order to avoid double-counting with 'recreation and tourism' values derived above. The likely impact on adjacent property prices will capture, or at least act as a market surrogate, for these diverse values. CABE (2009) note uplift in adjacent property values as a significant effect of proximity to urban parks, and Petts *et al*. (2002) provide case studies highlighting the impact of proximity to good quality or restored urban rivers on property prices. CABE (2005) show a five to 34 per cent (average seven per cent) uplift in property value from park renovation, though figures vary widely from a range of factors. The area to the south of Mayesbrook Park is assumed not to be affected as it is separated by a railway line. However, average house prices were explored in residential areas to the west (£240,000) and east (£135,000) of the park, noting that these were probably affected by proximity to the primary and secondary schools, transport connections and other factors. Based on the average seven per cent rise cited by CABE (2005), the average uplift for properties would be £16,800 to the west and £9,450 to the east (mean value = £13,125). Taking a conservative assessment that this will affect properties within 0.25 km of the Mayesbrook Park boundary (approximately two streets), accounting for 596 houses, this produces a gross uplift of £7,822,500. Rather than artificially annualising this uplift value and then underestimating the contribution to NPV by considering only the first 40 years, the full lifetime value will be recognised in the final NPV calculation in Section 3. (This approach of assessing some benefits over a longer timescale was applied when considering

	flood risk outcomes in the Alkborough Flats study: Everard, 2009). There is an equity issue associated with 'gentrification' of formerly deprived wards, which may result in more affluent people moving in whilst poorer people move out. Beyond noting this as a potential equity issue, this is not considered in greater detail in this report. **Lifetime value (100 years) = £7,822,500**
Education resources	The habitats, sporting and amenity opportunities in the restored park will provide a diversity of educational benefit ('mini-beast', wetland and woodland trails, environmental chemistry, climate change studies, and other subjects on the Natural Curriculum). There is both a large secondary and a primary school immediately adjacent to the park. Evidence from the Trout in the Town project organised by the Wild Trout Trust (www.wildtrout.org) on the River Wandle has shown that roughly 9,000 children have been involved in the rearing and release of trout fry in that catchment (Wandle Trust, 2010). While the Mayes Brook may not yet represent a suitable location for this type of project, it shows the far-reaching benefits of locally accessible natural environments for ecological education. In the absence of resources for detailed social surveys, an averted cost method is used. Access to these facilities at the park will avert travel costs for access to alternative facilities, which may also act as a surrogate for the value of missed opportunities where schools elect not to transport students to other sites. We assume that the averted cost will total ten coaches per year @ (conservatively) £500 each, yielding a value of £5,000. In considering this benefit, further investment in, or modification of plan designs for, facilities such as an outdoor classroom (as put in place in the restoration of the River Quaggy in Sutcliffe Park) could further increase this value. Training of volunteers involved in tree planting also confers a hidden value to the community in terms of enhancing skills and employability for participants. The value of training varies by the nature of work performed and is therefore identified as an area for further research but this service is not yet valued within this report. **Annual value = £5,000**
Gross annual cultural service benefits	**Gross annual cultural service benefits are approximately £820,000** (calculated total = £820,169) comprising recreation and tourism @ 815,169 + educational value @ £5,000. However, the net uplift (via 'social relations') to **regional regeneration is assessed with a lifetime (100 year) benefit of £7.8 million (calculated £7,822,500)** which will be factored into the final NVP calculation.

Table A1.4: Assessment of changes in supporting services from the Mayes Brook intervention

Supporting services	
Soil formation	Soil accretion will be enhanced by improved and diversified habitat. However, to avoid double-counting with carbon sequestration and erosion regulation, this service is not quantified here. **Annual value = £0**
Primary production	Primary production will be enhanced by improved and diversified habitat. However, to avoid double-counting with services such as provisioning uses of hay and tree trimmings (fibre and fuel), this service is not quantified here. **Annual value = £0**
Nutrient cycling	Enhanced habitat will contribute to nutrient spiralling and transformation (for example via vegetative uptake, nitrification, denitrification and related ecosystem processes) based on 24 ha (20 hectares of the park scheduled for relaxed mowing regime, three ha of new woodland and one ha of created floodplain) and: • using pessimistic data drawn from a literature review (McInnes *et al*., 2008) that total N removed by storage and export is 170 kg N ha^{-1} a^{-1} (on flat land) and total P removed by storage and export is 25 kg P ha^{-1} a^{-1}; • applying market values of £8.32 kg^{-1} ha^{-1} a^{-1} for N removal costs and £12.00 kg^{-1} ha^{-1} a^{-1} for P removal (also McInnes *et al*., 2008); • assuming that degraded grassland (short mown and disconnected from watercourses) may have operated at 50 per cent nutrient cycling efficiency; This yields a total annual value for nutrient cycling (based on nutrient removal costs averted) in restored habitat of £20,573. Note: there is no market for this economic benefit, though averted costs of eutrophication of downstream reaches of the Mayes Brook and Barking Creek and impacts on those using these watercourses could be considered amongst actual benefits. **Annual value = £20,573**
Water recycling	Habitat restoration/creation can be expected to enhance water recycling via processes such as floodplain storage, groundwater exchange and recycling of evaporation in more complex vegetation structure including trees. However, to avoid double-counting with benefits valued under 'water regulation' and 'climate regulation' (microclimate) services, these are not quantified or monetised. **Annual value = £0**
Photosynthesis (production of atmospheric oxygen)	Photosynthetic oxygen generation will be enhanced by improved and diversified habitat. However, to avoid double-counting with services such as provisioning uses of hay and tree trimmings (fibre and fuel), this service is not quantified here.

	Annual value = £0
Provision of habitat	One of the major purposes of restoration of this urban watercourse and park is the improvement of habitat for wildlife. Whilst values such as the contribution of habitat and species to aesthetics, education and wider appreciation of nature and landscape are already captured as cultural services, and therefore not double-counted here, there are dimensions of habitat enhancement that have overlapping value. Restoration of habitat and biodiversity in Mayesbrook Park will also serve as: • a reserve of wildlife to colonise the river system (including fish, macrophyte and invertebrate species revealed in an Environment Agency (2008, unpublished) survey) and wider terrestrial habitats as and when they are regenerated; • an island or 'stepping stone' for wildlife to migrate across the otherwise inhospitable urban landscape; • a site into which wildlife may migrate and colonise, including for example the water vole populations remaining in the Mayesbrook downstream of the culvert to the south of the park); • suitable habitat for the seed bank to recolonise, noting that seed banks have been found to remain intact in urban river corridors and to germinate and spread under restoration conditions (Gurnell *et al*., 2006). A further benefit is that, if the restoration is designed so that the brook channel remains dynamic, this will suppress dominance by weedy vegetation species. Valuation of this benefit is necessarily complex, but can be done by assessing averted costs for bespoke nature conservation goals which, conservatively, may be estimated at £1,000 per 100 metres of river length (using assumptions from the River Glaven study (Everard, 2010) related to the costs of man/digger days + haulage costs to clean habitat or run bespoke conservation projects). The restored one km of combined Reaches 1, 3 and 4 of the Mayes Brook yields a value of £10,000. **Annual value = £10,000**
Gross annual supporting service benefits	**Gross annual supporting service benefits are approximately £31,000** (calculated total = £30,573) comprising nutrient cycling @ £20,573 + habitat for wildlife @ £10,000.

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