Developing a vision for Natural Flood Management and ecosystem services in the R. Ock catchment

Jeremy Biggs

© Freshwater Habitats Trust
Oxford
2019

For further information please contact:
Freshwater Habitats Trust
Bury Knowle House
North Place
Headington
Oxford, OX3 9HY

This report should be cited as:

Biggs, J. 2019. Developing a vision for Natural Flood Management and ecosystem services in the R. Ock catchment. Freshwater Habitats Trust, Oxford.

Acknowledgements

We would like to thank Emily Williamson and Sally White for initiating and guiding the work described in this report. Advice and comments on the draft report from Adella Buckland, Caroline Drewett, Vivianna Levy and Jo Old were also much appreciated.

Summary

This report provides background environmental, historical and social data to set the scene for the development of an overall vision for a catchment-wide natural flood management (NFM) and ecosystem services delivery programme on the R. Ock.

The development of a catchment-wide NFM scheme forms part of currently preferred options for the reduction of flood risk in Abingdon. The main driver for funding an NFM scheme is through the financial benefits obtained from reducing the number of properties at risk of flooding. In the longer term there may also be additional economic benefits from enhanced ecosystem services which can support the further development of NFM approaches. In the present report the valuation of ecosystem services as a funding mechanisms is introduced but further investigations will be needed for this to become a source of funding. Discussions are currently planned (with Environment Agency, local authorities, local environmental funders TOE2 and others) to discuss this potential. Although considerable progress has been made by the Environment Agency in designing a conventional flood-storage scheme to reduce flood-risk in Abingdon, more detailed design work has indicated that substantially more funding than is currently available will be needed to progress this scheme.

The current scoping study has two broad sections: a brief introduction to the environmental and water-specific history of the catchment and a review of the major sources of information available for undertaking an appraisal of the ecosystem services in the catchment. It also provides an overview of the scope and benefits of NFM work which are currently the subject of detailed computer modelling studies. It brings together the information in themes that reflect the economic appraisal methods (ecosystems services appraisal/natural capital) that will later be applied to the various strategic options, following the advice and guidance of the Environment Agency's in-house economics team. The broader national context of specific ecosystem services has also been briefly reviewed.

The review also considers other issues which it is anticipated will also influence the future economic and financial viability of the NFM programme including:

- Water Framework Directive failures and opportunities for improvement, protection of the area's designated fens habitats, fish populations, priority freshwater and wetland habitats (e.g. chalk streams, priority ponds), critically endangered freshwater and wetland species and
- The ecosystem services of clean water, food production, climate regulation and carbon storage (especially in soils), tourism, sustainable development, health and recreation.

The Ock is both typical of the agricultural landscape of lowland England, with a long-history of modification of the water and wetland environment, and unusual in retaining freshwater habitats of special natural and cultural interest (internationally important fens, and endangered freshwater species, a rich and well-documented water and wetland history).

Knowledge of environmental change in the Upper Thames Valley is well-documented, particularly because of archaeological work associated with extraction of gravel. 11,500 years ago at the end of the last glaciation the Thames and its tributaries were braided rivers. The whole of the water environment was probably like that we now see only in the least impacted areas (what we would call 'High status' in Water Framework Directive terms). There were peaty backswamps behind natural channel levees along rivers but the modern alluvial floodplains were yet to be created. During the Mesolithic, from 9600-4000 Before Present, rivers and streams had the characteristics of clean, calcareous water, well-vegetated and wooded. There is little evidence of active channel migration: indeed the channels have been stable for millennia. The aquatic flora everywhere would have been not so different to that we see now in the cleanest water. Sensitive water beetles (which tell us a

lot about the ancient water environment because they are well-preserved in floodplain sediments) would have been widespread; now they are only found in the least damaged locations). Nutrient sensitive water plants like Whorled Water-milfoil and Long-stalked Pondweed would have been common; now they are only found in off-channel locations, or are extinct as a result of pollution.

Tree clearance began in the Neolithic, 4000-2500 Before Present creating a patchwork landscape of woodland, some parkland grazed by animals and a few cultivation plots. Major changes began from around 2500 BC – from this time the more modern open landscape began to appear. By 1500 BC the gravel terraces and floodplains had mostly been cleared of trees. The landscape was laid out around settlement, and hedged field often had pond-like waterholes.

Water levels rose during the period 1400 BC - 150 BC as a result of increased runoff but substantial erosion posted-dated this period with alluviation of the floodplains, creating the modern alluvial soils we see now, taking place from 150 BC to 400 AD.

Although we are often told that the countryside is constantly changing, in all likelihood, there was comparatively little change from around the late Roman period c400 AD until the industrialisation of agriculture, and particularly the all-pervasive and widespread pollution of freshwaters, from the 19th Century onwards. Although Salmon was a staple part of the Thames Valley diet in the Middle Ages, some argue that the loss of salmon throughout Europe was exacerbated by the increased damming of rivers in the mediaeval period – with many mills in the Ock catchment by the time of the Domesday book.

It the last 100 year the Ock catchment has undergone substantial change as grassland has been replaced by arable land. Woodland cover remains low, except in the sandy north-eastern part of the catchment around Tubney, Frilford and Boars Hill.

Land drainage has been occurring in the Ock catchment for probably 200 years. The first phase probably took place in the 19th century with the widespread use of tile drains. Following the Second World War drainage records place the Ock in a broad category with 25-50% of the land under-drained, a process that culminated in the river engineering of the 1970s and 1980s.

Water pollution monitoring has been taking place systematically since the 1950s although it is hard to say whether conditions have generally improved or declined in that time. In the 1970s the river boards regarded the Ock as largely ‘unpolluted’ or ‘recovered from pollution’. However, sensitive water plants and animals have certainly gone extinct subsequently, and levels of some pollutants (e.g. nitrogen, phosphorus, biocides, micro-organics) increased substantially. More positively, organic pollution is uncommon, and nutrient levels have stabilised or started to decline. Post-1990 invertebrate community evidence supports the idea of reduced organic pollution, but several rivers and streams in the catchment appear to be losing invertebrate diversity.

An initial summary of the increases to ecosystem services likely to be delivered by the proposed NFM work is made. The major impacts are likely to be in:

- Increased water retention in the catchment
- Improved water quality through nutrient and sediment loss reductions
- Carbon sequestration in soils
- Carbon sequestration in woodland and peatland restoration (although this is substantially less than in soils)
- Increased recreational use of the landscape

Areas of search for the implementation of Natural Flood Management measures are identified based on three search features which we recommend as the focus for landowner engagement:

- areas with the highest concentrations of potential Runoff Attenuation Features; there is a clear concentration of potential location in the central, clay-dominated areas of the Vale of White Horse
- areas with potential for floodplain reconnection, which potentially provide the most substantial flood water retention options
- areas where meander restoration could be undertaken based on historic evidence of channel straightening on the main R. Ock.

The main recommendations with respect to the Natural Flood Management measures are:

- all landowners covering the 1 km squares with ‘high to medium’ densities of Runoff Attenuation Features should be contacted, as far as is practically possible (except those in the Cow Common Brook and Portobello Ditch catchment which may be affected by plans for a new reservoir).

- in developing models of the NFM measures, potential river restoration options are included in the model to test the effect of different scenarios.

- for floodplain reconnection, it will be necessary (i) to assess the locations (are there interested landowners, would they consider additional reconnection works?) and (ii) assess whether the options have a significant impact on flood storage in the models.

- an evaluation is made of the effect of widespread reduction of land drainage (mole drains, tile drains) on heavier soils is undertaken as a modelling study. Does this provide flood risk benefits?

- NFM measures are targeted on grassland sites, as these are generally poorer grade agricultural land, and therefore less likely to be growing high value crops which are intolerant of flooding.

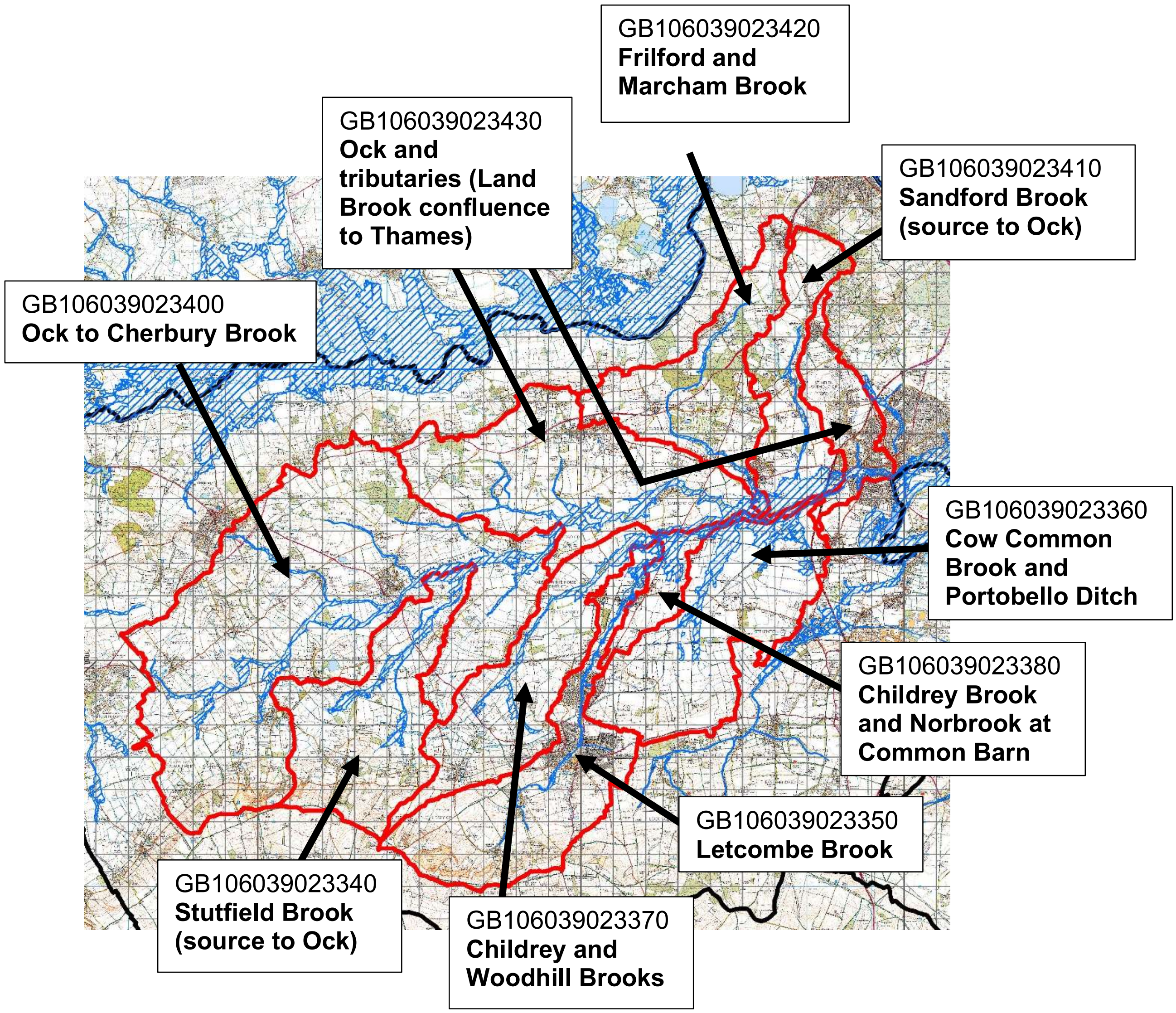


Figure 1. Water Framework Directive waterbodies and sub-catchments in the Ock catchment.

CONTENTS

1. Introduction

1.1 The R. Ock catchment

The River Ock catchment is both typical and unusual. It has a long history of modification, suffers from the typical lowland impacts affecting England's freshwaters, yet retains high quality freshwater habitats including an SAC wetland complex and rivers with WFD High status invertebrate assemblages. It is home to small populations of some of Britain's most vulnerable freshwater and wetland animals such as the Habitats Directive listed Southern Damselfly (*Coenagrion mercuriale*), Water Vole, which recent evidence suggests is still declining nationally[1], the increasingly endangered Curlew and the Natterjack Toad.

The Ock catchment is a productive farming landscape, generates floods which place the main settlement Abingdon at risk, and is the potential location for a new strategic reservoir for London.

Importantly, the Ock benefits from many different sources of practical and technical expertise: in the Environment Agency, in the NGO sector and in the research community. It also has keen and forward looking landowners and farmers.

Although most of the western Vale of White Horse is open grass and arable farming, the northern areas have a higher than average woodland density. Over most of the catchment, woodland covers just 2% - 4% of the land, but in the catchment of the Marcham, Frilford and Sandford Brooks in the north-eastern sandier parts of the catchment it reaches 15%.

Since the 1930s the landscape has changed from 48% grassland as shown by the 1930 Dudley Stamp Land Use survey to 30% grassland on Land Cover Map 2015 (Figures 2 and 3).

[1] http://www.wildlifetrusts.org/news/2018/02/26/new-report-points-30-decline-water-vole-distribution

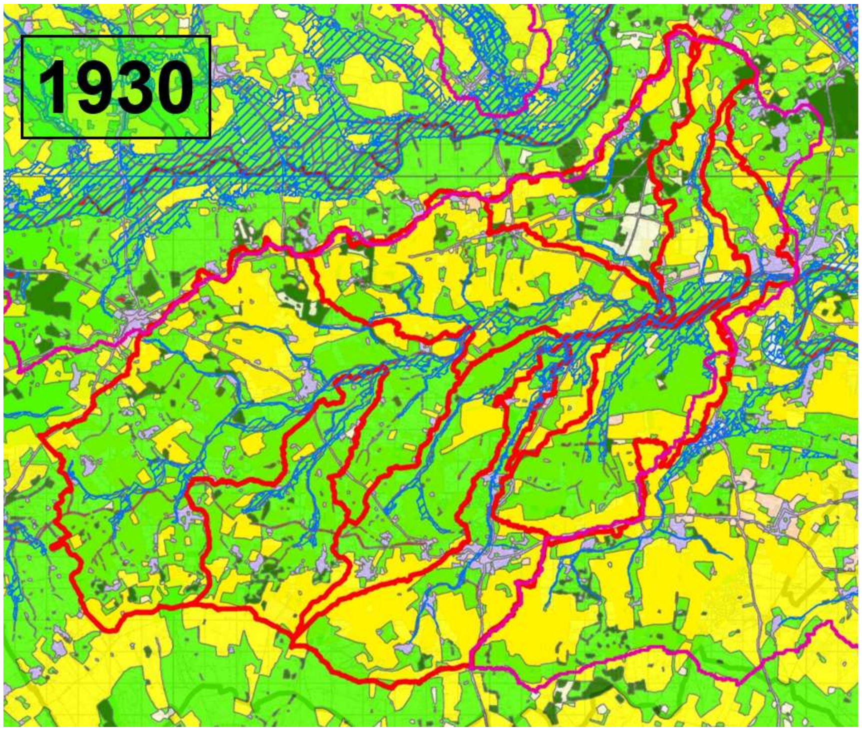


Figure 2. 1930s Dudley Stamp Land Use Survey for the Ock catchment.

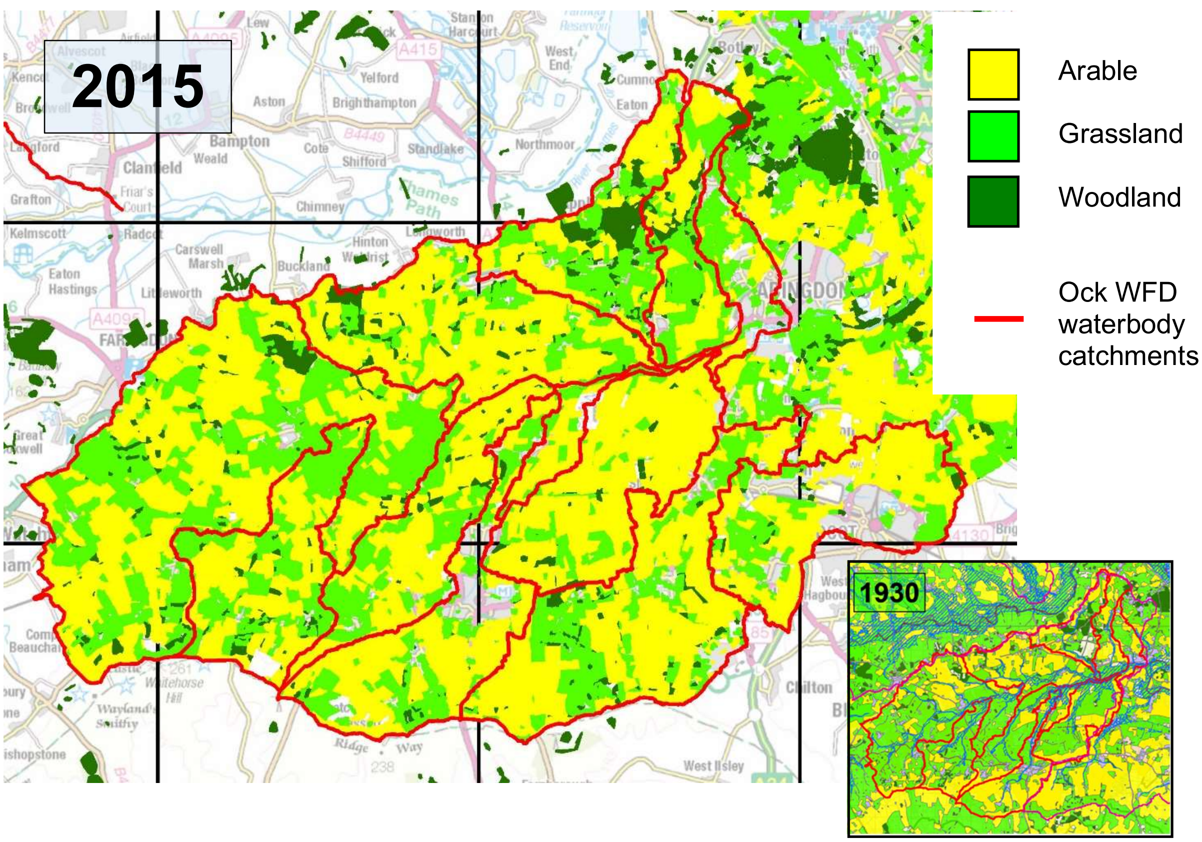


Figure 3. Arable land in the Ock catchment from the 2015 Land Cover Map. Inset shows extent of arable and grassland in 1930.

Investigations are currently being undertaken by the Environment Agency on the feasibility of implementing a large-scale Natural Flood Management project in the Ock catchment. If NFM methods are technically and practically feasible this could present an opportunity to put in place a catchment scale project that, as well as providing flood risk benefits, could also improve the water environment and generate a range of linked ecosystem services benefits. Building on the technical experience of partners working in the catchment work of this sort could also provide extensive scope for gathering evidence about the benefits of NFM work which can help others to learn and benefit from the Ock experience.

Potentially, the Ock catchment could provide the potential to implement one of the largest lowland natural flood management schemes, create a project of national significance as a demonstration site for 'multiple benefits' work, contribute to real flood protection for Abingdon, and perhaps smaller settlements, and bring together 25 years of practical experience in freshwater conservation work.

2. Aim of the scoping study

This scoping study brings together information from a range of sources to provide the overall vision and context for a catchment-wide natural flood management (NFM) programme in the catchment of the R. Ock. The aim of the work is to scope out the potential for water storage in the catchment to reduce flood risk. In this report the broad range of NFM opportunities are examined; the report should be read in conjunction with results of detailed catchment modelling which is being undertaken by JBA and Jacobs, scheduled for completion in Spring 2019.

The vision for the catchment overall takes account of the history of the landscape and river management, including: pre-historic (forest clearance), historic (e.g. milling, enclosures) and more recent changes (e.g. 1970s-80s land-drainage of the Ock), the modern hydrology of the catchment (based on current Jacobs information), the current water quality stresses and what needs to be done to alleviate them, the protection of catchment freshwater biodiversity, opportunities for landowner income diversification (e.g. the great crested newt District Level Licensing scheme, woodland planting) and the potential to enhance ecosystem services other than flood storage, including recreation opportunities.

Some of this work is already being done by the Catchment Partnership (see https://freshwaterhabitats.org.uk/wp-content/uploads/2017/03/Reformatted-The-Ock-Catchment-Water-Environment-Improvement-PlanJB.pdf)

The scoping study provides a data reference for the NFM programme and bring together the information in themes that reflect the economic appraisal methods (ecosystems services appraisal/natural capital) that will later be applied to the various strategic options, following the advice and guidance of the Environment Agency's economist.

The report is focussed particularly on the issues which have most influence on the economic and financial viability of the NFM programme, namely Water Framework Directive failures, protection of the area's SAC fens, fish populations, priority freshwater and wetland habitats (e.g. chalk streams, priority ponds), critically endangered freshwater and wetland species and the ecosystem services of clean water, flood prevention, food production, climate regulation, tourism, sustainable development, health and recreation. Add back in water storage.

The data sources that already exist regarding the key supporting, provisioning, regulating and cultural ecosystem services are reviewed to provide the basis for establishing the current baseline ecosystem service condition, and enable more detailed analysis by the project.

The report includes:

- The main features of the vision (e.g. ecosystem services opportunities, floodplain restoration, habitat creation, opportunity areas for freshwater biodiversity, principle areas for WFD improvement, improving fish passage, and enhancing recreation opportunities).
- The evidence base needed to describe the ecosystem services of the area, how they can be enhanced and an appraisal of the environmental economics of the area
- The main partners, and the approach that should be taken to partnership working and the role of the Ock Catchment Partnership in supporting long-term delivery.
- The approach to interacting with the land-owning community, and joint development of the vision with catchment partners.

3. The vision for natural flood management in the Ock catchment

3.1 The vision for the Ock catchment

The Ock Catchment Partnership Plan sets out a broad vision for the Ock catchment covering all aspects of the water environment (see Box 1).

In terms of the overall catchment vision, natural flood management work relates most specifically to the aim to ensure that 'Towns are protected from flooding'. A broad vision of the areas where NFM work can be implemented is given in Chapter 4. Specific details of the optimum locations for NFM will be established in the detailed hydrological and hydraulic models of the catchment.

In addition, NFM work may potentially contribute to virtually all of the other objectives of the vision. For example, creating leaky dams that push flood flows onto the floodplain might also reduce sediment losses, improving water quality; reconnecting floodplains to store could help stop and reverse the decline of freshwater wildlife; and engaging farmers in the practical implementation of NFM works may help maintain a thriving agriculture and forestry sector. More generally, restoring high quality wetland habitats which retain water may help to resist the anticipated negative impacts of global heating. If NFM projects are effectively monitored and evaluated, this will contribute to the Ock catchment being an area where we have good knowledge of the condition of the water environment.

Box 1. The vision for the R. Ock catchment set out in the R. Ock Catchment Partnership is:

- Achieve Water Framework Directive standards to achieve Good status or above in all waterbodies by 2027 i.e. in 10 year time.
- At least freshwater SSSIs and SACs are in good condition.
- We have stopped and reversed the decline of freshwater wildlife.
- Priority freshwater habitats and species are in favourable condition.
- We have good knowledge of the condition of the water environment so that we can tell whether it is getting better or worse in condition.
- There is enough water for public and business use.
- There is a thriving agricultural and forestry sector in the area contributing to the sustainability of the water environment.
- **Towns are protected from flooding.**
- We have helped the natural environment to resist the negative impacts of climate change.

To achieve the broader goals of the Ock catchment partnership, the Catchment Plan sets out the following priorities relating to three main coordinated actions within sub-catchments:

(i) Identify and protect the best

- Analyse existing datasets and collate information from published and unpublished sources.
- Collect additional information if the habitats we know to be important are not currently monitored e.g. ponds, small lakes, headwater streams.
- Monitor parameters we perceive to be causing a problem if they are not currently monitored.
- Identify smaller units than currently used by the Water Framework Directive, for example headwater streams achieving high status compared with downstream stretches of the same waterbody which are currently classified as Moderate under WFD criteria.

(ii) Build out from the best areas to strengthen important populations and encourage species dispersal, which is essential for biological recovery.

- Use a strategic coordinated approach in the management of river catchments rather than ad hoc work over a large area.
- Use both management / restoration of habitats and creation of new habitats to sustain and build populations of freshwater plants and animals

(iii) Recreate the scarcest of all resources – clean water

- Reduce pollution from pipe sources, such as Waste Water Treatment Works and diffuse pollution from agricultural and urban areas.
- Where it is not possible to reduce pollution below the levels needed for a healthy freshwater environment, create new clean water habitats to put back clean water in the landscape.

4. Implementing NFM

4.1 Selecting locations to investigate for NFM measures

As part of the Working With Natural Processes toolkit (see: https://www.gov.uk/government/publications/working-with-natural-processes-to-reduce-flood-risk) JBA created a national map of the location of potential Runoff Attenuation Features that would come into operation under different return period flood. We have used the density of 3.3% Annual Exceedance Period Runoff Attenuation Features map as an indicator to identify the areas most likely to be able to retain water in the catchment using NFM measures. A 3.3% AEP flood is a 1 in 30 year flood event.

The main concentration of potential Runoff Attenuation Features using those that have a 3% Annual Exceedance Probability (AEP) are shown in Figure 4. Woodland planting in riparian strips can be undertaken at many locations in the catchment (see Figure 40).

We recommend that all landowners covering the 'high to medium' (red, light brown, pale pink) 1 km squares in Figure 4 are contacted as far as possible except those in the Cow Common Brook and Portobello Ditch catchment which may be affected by plans for a new reservoir.

There are nine priority areas with high densities of Runoff Attenuation Features which should be evaluated although modelling will be needed to confirm the overall impact of features in these areas.

Likely costs of physical storage measures are shown in Table 1. The catchments with greatest potential for NFM measures are all located on the low-lying clay dominated parts of the catchment in the following catchments. They are:

- Ock to Cherbury Brook
- Stutfield Brook (source to Ock)
- Ock and tributaries (Land Brook confluence to Thames)
- Childrey and Woodhill Brooks
- Childrey Brook and Norbrook at Common Barn.

4.2 Where would different NFM options best be applied?

The different NFM options are best applied on different sizes of water bodies, although modelling should be used to confirm the effect of application in different areas. NFM measures can be broadly categorised as applicable to three different waterbody sizes: ditches, smaller streams and headwaters, larger channels (say greater than 10 m waterbody width). Options for the different sizes of waterbody are shown below. Note that, in addition to this simple size classification, account should also be taken of the site hydrology as many of the measures are most like to be more effective on the more flashy clay dominated catchments, with less, or no, significant, impact on groundwater fed chalk streams.

Of the measures listed below, on free-draining soils affecting more stable streams, soil management and potentially woodland planting are most likely to be the preferred options.

	Ditches	Headwaters, small to medium streams (up to 10 m wide)	Larger channels (greater than 10 m wide)
Online leaky dams	✓		
Dam extensions	✓	✓	
Bunded ditches	✓	✓	
Field corner bunds	✓	✓	
Offline storage ponds	✓	✓	
Interception ponds	✓	✓	
Flood storage bund		✓	✓
River restoration e.g paleo channel reinstatement		✓	✓
Floodplain reconnection		✓	✓
Floodplain bunds		✓	✓
Woodland planting	✓	✓	✓
Soil management	✓	✓	✓

4.3 Local design requirements of Natural Flood Management measures

The following notes highlight aspects of NFM measure design which should be taken account of in the practical implementation of the work.

- **How does locations affect type of bund applied?** Bunds on ditches (provided they have bottom pipes to prevent permanent water retention) give additional small scale storage. When applied in field corners on floodplains they are also mainly to increase storage, although in big floods there would be an element of 'roughening up' the flood plain. Predicting the effect of that roughening up would probably be fairly subjective as it is likely to rely on estimation of 'Mannings n'.
- Field corner bund 1 and field corner bund 2, Explain the difference between EA field corner bund (cores, expensive etc) and more simplified field corner bunds as this will impact cost.
- Bunded ditches – is this just blocking ditches?
- Include intent to have a discussion with landowner in terms of which type of FCB they would like.
- Does the field corner bund work like offline storage area?
- Interception ponds - good for sediment catcher but don't have much impact on holding flow as they fill so quickly. Great for habitat, not great for flood risk. Off line better than online
- Clarify flood plain bund, like beetle bank? Hedge lines also useful

4.4 River restoration

An initial assessment of the potential zone for river restoration has been made based on the distribution of 1970s flood drainage works (Figure 17) and using historic map data for the first 10 km of the R. Ock main channel, from the A34 to Charney Bassett (Figure 42).

The approaches which can potentially be adopted are all fairly conventional river restoration work, with the optimum outcome being re-creation of the natural profile and planform of the Ock. This would, in simple terms, be much shallower and narrower, and probably a complex of anastomosing channels. The extent to which this objective can be achieved largely depends on landowner interest and funding.

Figures 43 and 44 show the two main areas of obvious historic modification between Marcham Mill and the A34 and earlier (pre-1870 map) modification of the R. Ock between Charney Bassett and Garford.

In the Ock catchment it may be more acceptable to landowners to focus on re-wetting floodplain habitats than reshaping channels, although creating a demonstration site to get a foothold for restoration in the area would probably be beneficial.

We recommend that in developing models of the NFM measures, potential river restoration options are included in the model to test the effect of different options.

Details of the river restoration techniques potentially applicable are available in the River Restoration Centre (RRC) manual. As many of the methods included were originally developed in the context of the R. Cole at Coleshill (Oxfordshire) they will be applicable here. The RRC 'Manual of River Restoration Techniques' is accessible here: https://www.therrc.co.uk/manual-river-restoration-techniques.

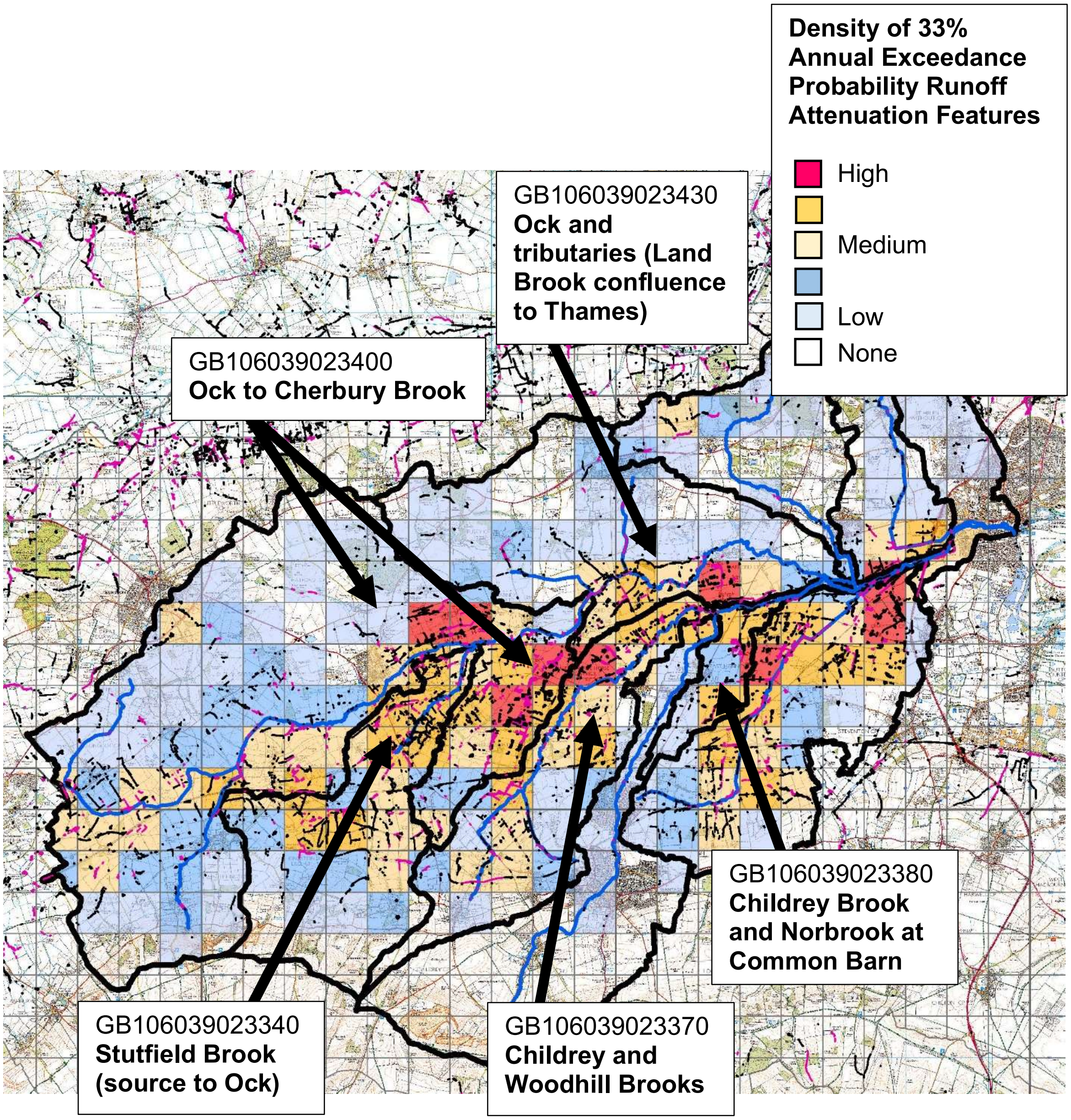


Figure 4. Areas with high densities of Runoff Attenuation Features which could be prioritised as areas of search for implementation of NFM measures.

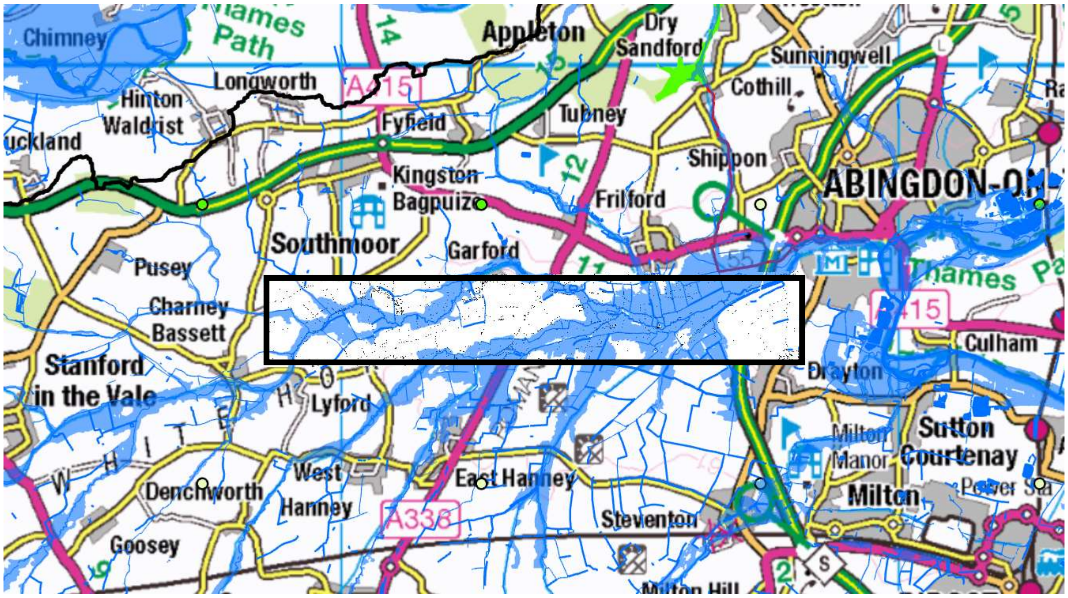


Figure 5. Initial area of search for analysis of historic channel modification based on OS 1:2500 map data

4.5 Floodplain reconnection

JBA mapping in the Working With Natural Processes toolkit has identified, using national level datasets, where floodplain areas currently appear to be isolated from the river channel, mainly as a result of embankments or other artificial constraints on flooding. These areas provide potentially substantial opportunities for further natural flood storage. In theory, to reconnect them to the floodplain, fairly straightforward and relatively inexpensive, bank removal would be needed.

The floodplain reconnection areas are identified by matching up river- and stream-side locations which do not flood, according to Environment Agency flood risk mapping, but are low-lying enough to be in the original natural floodplain.

The zones where floodplain reconnection could be prioritised are shown in Figure 6 (below) overlaid on focus areas for Runoff Attenuation Features. There are three main areas for potential floodplain reconnection: Charney Bassett area, Lyford to Garford and south-west of Marcham. The large floodplain reconnection opportunities in the south and east parts of the catchment are excluded as these are in the Cow Common Brook and Portobello Ditch catchment which is substantially constrained by the potential construction of a new reservoir

These are all areas where there is potential without substantial channel restoration (i.e. bed-raising and narrowing) to increase flows onto the floodplain. These areas could provide significant extra storage. To assess their value they should be included in the modelling work for the catchment. This will allow us to asses how important the contribution that could be made by these area will be.

The main recommendations for floodplain reconnection are (i) to assess the locations (are there interested landowners, would they consider additional reconnection works) and (ii) do they have a significant impact on flood storage in the models.

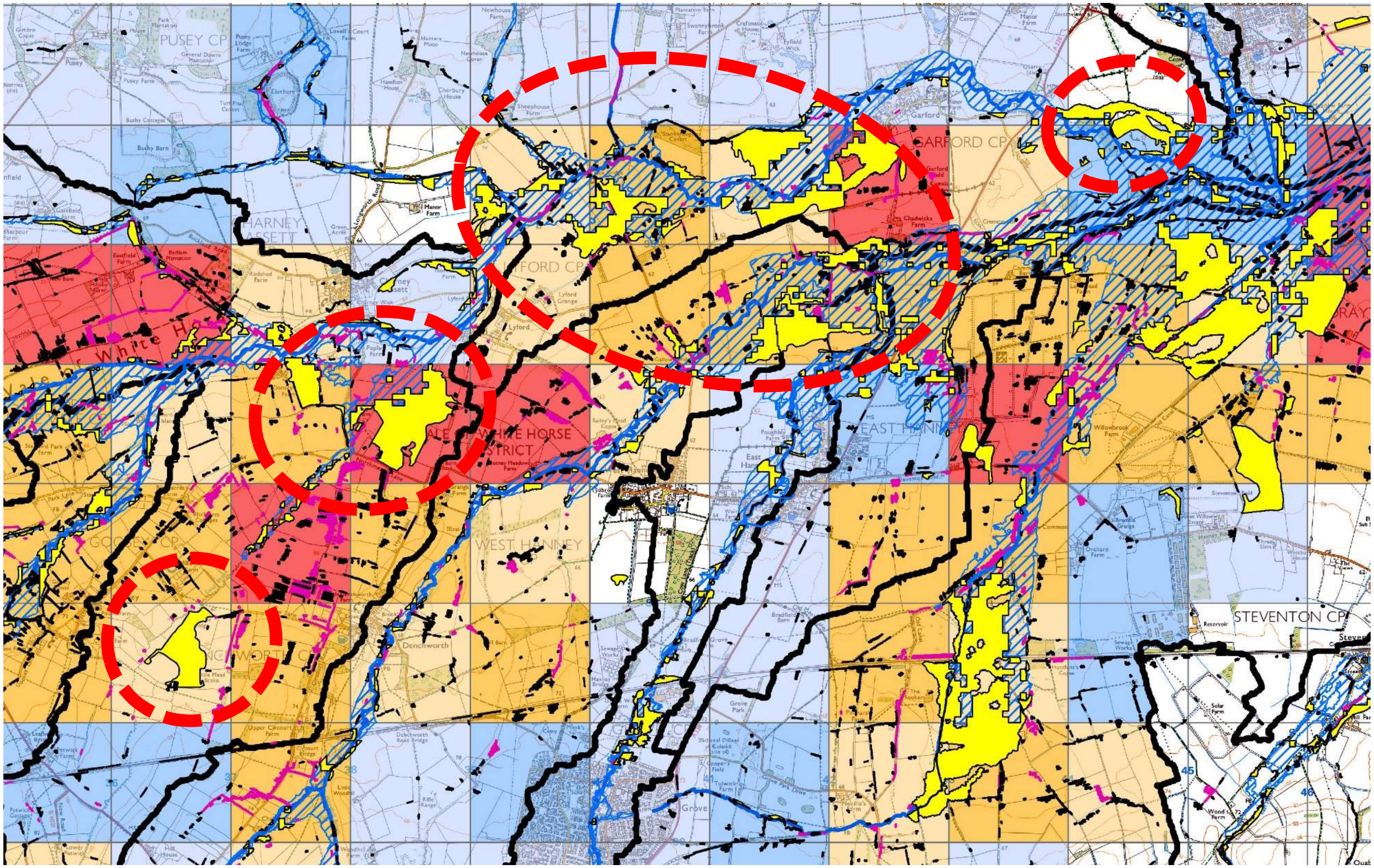


Figure 6. Main areas of search for floodplain reconnection. There are three main areas of search: Charney Bassett area, Lyford to Garford and south-west of Marcham. The large floodplain reconnection opportunities in the south and east parts of the catchment are excluded as these are in the Cow Common Brook and Portobello Ditch catchment which is substantially constrained by the potential construction of a new reservoir.

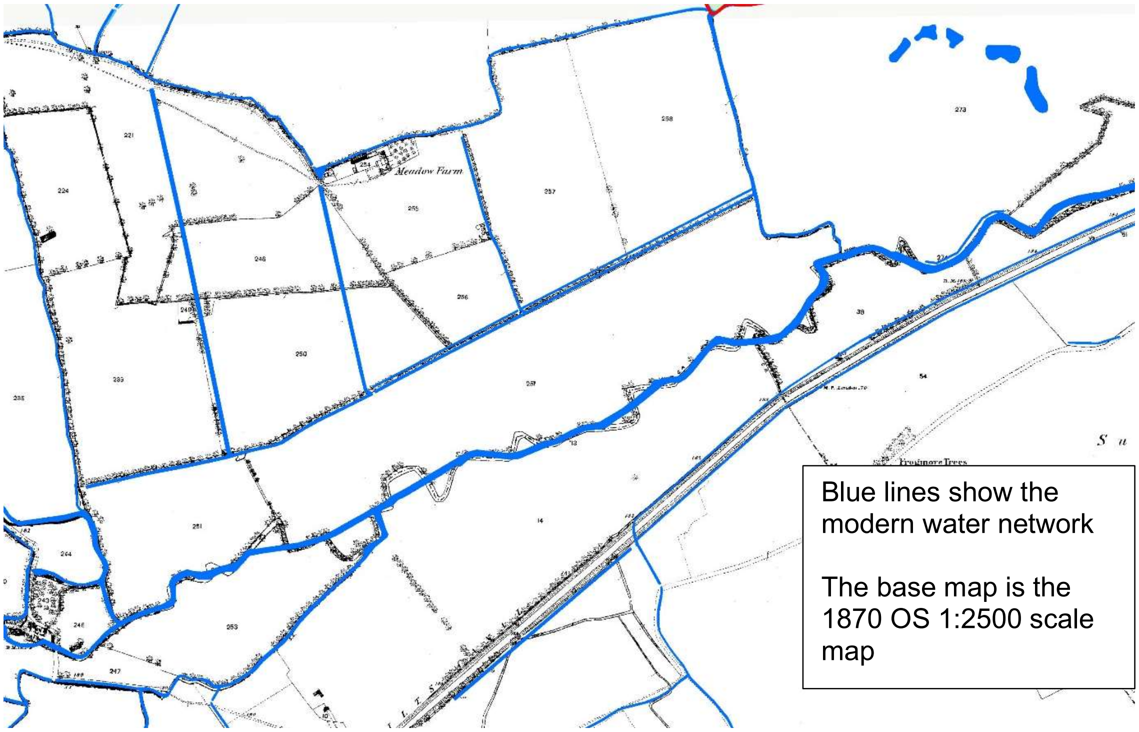


Figure 7. In this section, straightening of the main stretch of the R. Ock took place in the 1970s.

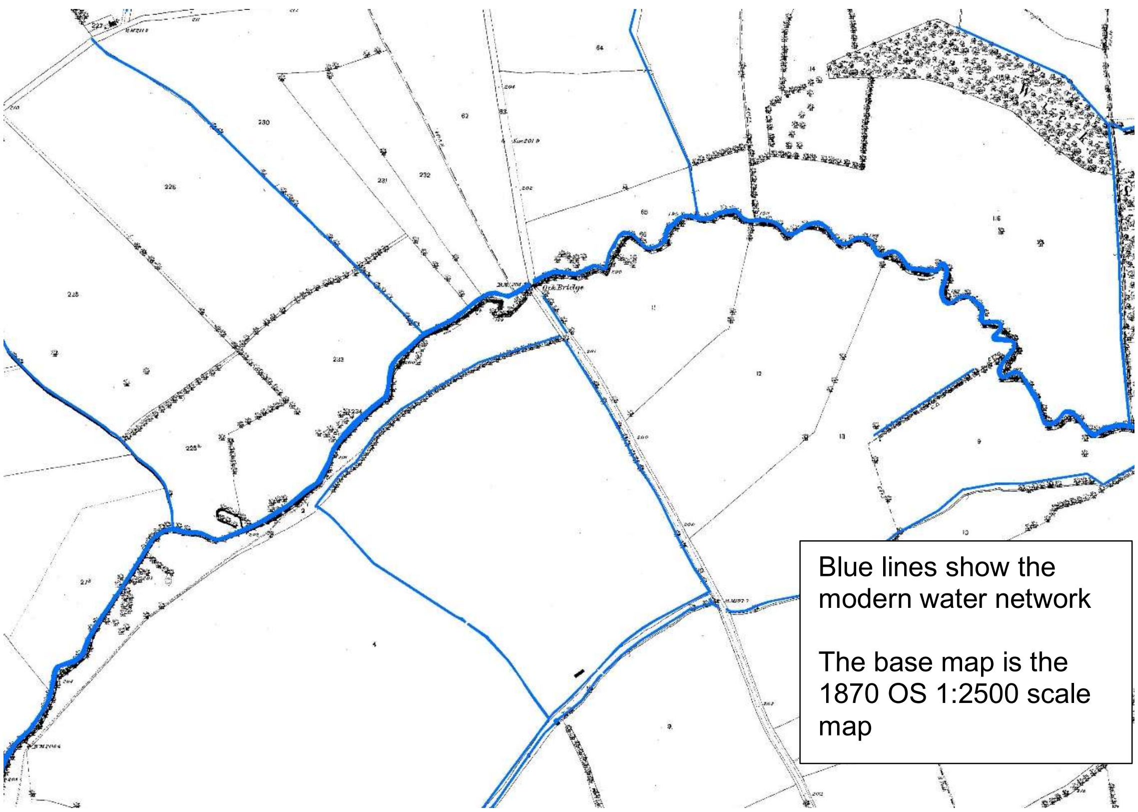


Figure 8. In this section, straightening of the river took place before the creation of the earliest OS 1:2500 1870 map. Evidence of previous meanders, still tree-lined, is clearly visible at this time.

4.6 Areas of search for floodplain reconnection

The areas of search for floodplain reconnection as shown in Figure 6. Figure 9 shows the reconnection areas in relation to areas of previous channel works for land drainage. The main areas of opportunity appear to be on the Ock from Charney Bassett down to the Marcham area.

There was apparently less channel engineering for land drainage on the southern, spring-fed, part of the catchment.

If there are opportunities with sympathetic landowners it would make practical sense to combined river channel restoration work with locations where there were significant opportunities for floodplain reconnection.

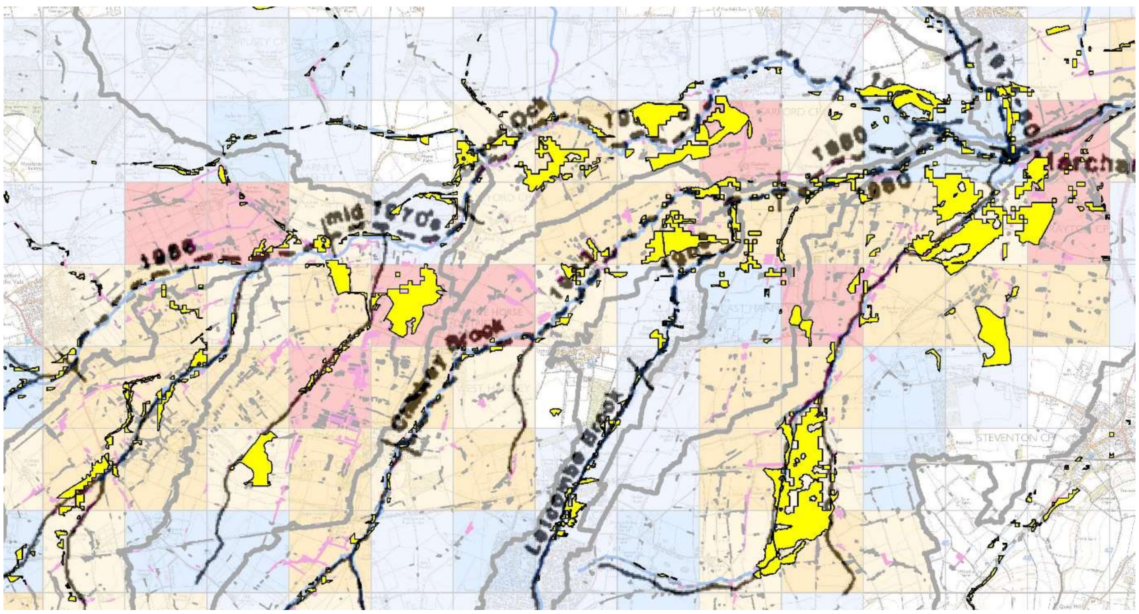


Figure 9. Location of potential floodplain reconnection area in relation to the areas where 1970s and 1980s land drainage work was undertaken in the Ock catchment. Note that locations of land drainage work are taken from a simple sketch of the main catchment in Robinson, 1990.

4.7 Costs

Costs of alternative methods for retaining water in the catchment are summarised in Table 1. In generating a first set of estimates of costs we have used Freshwater Habitats Trust previous experience of installing measures, costing information created by JBA, and information from River Restoration Centre.

Table 1. Natural Flood Management pilot – indicative costings – ADD SOMETHING ABOUT THE NFM / WFD BENEFIT.

Measure	**NFM category**	**Purpose/description**	**Details / Cost per cubic metre where possible or cost of measure**	**Notes on costings**	**Priority**	**Wider benefits**	**References**
Online leaky dams	Temporary storage (in channel)	Store relatively small volumes of water temporarily (up to c.2000 m^3 per dam) within the main river channel. Dams are created to allow low flows to pass, yet built high enough to hold back flood flows. Generally these are constructed using timber felled locally.	Materials £2000 Digger: £8000 c.£555 per dam c. £1-2/m^3 water stored. 18 dams, retaining 5000-10000m^3. Water Friendly Farming average per dam =500m^3	Costs derived from Water Friendly Farming project, 2016/2017 which assumes timber is felled on site or bought in locally. We have no experience of management or maintenance costs yet as dams only 1-2 years old.	**High** In smaller channels, FHT evidence shows that holding water within the stream/river channel is the most cost effective way of influencing the hydrograph and reducing peak flows d/s	The effects (positive or negative) of the online leaky dams are being evaluated in the Water Friendly Farming Project. The EA evidence review shows water quality, habitat and climate regulation benefits (Working with natural processes: evidence directory: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/681411/Working_with_natural_processes_evidence_directory.pdf).	Water Friendly Farming project report: https://freshwaterhabitats.org.uk/wp-content/uploads/2016/11/Water-Friendly-Farming-update-2016.pdf Also EA Working With Natural Process Evidence Summary at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/654440/Working_with_natural_processes_one_page_summaries.pdf
Lateral extensions of dams onto floodplain	Temporary storage (in channel and on floodplain)	Wing walls created from timber, designed to push more water onto floodplain, resulting in additional temporary water storage on floodplain and grater hydraulic connectivity	Additional £500/dam to extend onto floodplain Additional £5/m^3 for earth floodplain bunds depending on location of source material	Costs of timber dams will vary depending on source of material used for construction	**High** Additional capacity results when connecting floodplain	Increased hydraulic connectivity with floodplain. See National Trust Holnicote example where combined with floodplain low bunds – see Case Study 20 of the EA WWNP Evidence Base at https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/651917/Case_Studies_1_to_23_Rivers_and_Floodplains.zip.	Water Friendly Farming project report: https://freshwaterhabitats.org.uk/wp-content/uploads/2016/11/Water-Friendly-Farming-update-2016.pdf

Bunded ditches	Temporary storage in ditch network	By creating earth bunds within ditch network flood water can be held back within the catchment. A pipe ensures low flows are not impeded.	c. £5/m3 to shift material + small cost for pipe. Approx. volume of earth required to form bund is modest - 5-10m^3 maximum. Storage capacity is modest, in the range 5-30m^3.		**High** Provided clay can be sourced locally, costs are minimal. This approach may require multiple earth structures to create required capacity	As small features, generally have modest water retention capability. Retention of sediments which may improve downstream water quality, and creates additional water-logged habitat which produces abundant flying insects (mainly Diptera) (see http://randd.defra.gov.uk/Document.aspx?Document=BD1323_6873_FRP.doc). A disadvantage is that this can also create small nutrient point sources which are released by later erosion.	Water Friendly Farming project report: https://freshwaterhabitats.org.uk/wp-content/uploads/2016/11/Water-Friendly-Farming-update-2016.pdf
Flood storage bund	Temporary storage (floodplain)	Store moderate volumes of water temporarily, up to reservoir volume (10,000 m^3)	Construction of a bund 0.7 m high Option 4A = c.100 m = £350 Option 4B = c.250 m = £875	Costs based on £5/m2 assuming material to form bund is sourced locally	**High** Ability to temporarily store large volumes of water at relatively little cost	Holding water for longer periods on floodplains, through the creation of flood storage bunds, could bring ecological benefits for breeding water and wetland birds and perhaps fish, although monitoring data for this type of approach are not yet available. The extent of benefits will normally depend on the extent to which new habitats (temporary ponds, permanent ponds, other wetland vegetation types) are created.	The National Trust Holnicote Estate work is the most developed example of this type of work. This has been the subject of detailed hydrological/flood monitoring but less information is available about ecological outcomes where benefits are currently presumed but not formally verified. See: http://randd.defra.gov.uk/Document.aspx?Document=13230_HolnicotePESFinalReportSeptember2015.pdf.

River restoration e.g Paleo channel reinstatement	River restoration	Roughens floodplain to slow overland flow, and/or creates additional channel capacity	c.£200/m £50,000 for 250m of paleo channel reinstatement	Costs derived from EU River Restoration guide which we assume includes project management costs: https://www.ecologic.eu/sites/files/publication/2014/inventory-of-restoration-costs-and-benefits.pdf EA costs for construction of new meanders £50-250/m	**Med** Although substantial additional storage capacity can be created, overall this is a costly approach	WFD benefits: creating additional channel habitat which is likely to improve the quality of fish habitat, add additional channel length and moderate additional channel capacity. Note that without water quality improvements ecological benefits following physical habitat restoration likely to be fairly modest.	There are surprisingly few detailed appraisals of river restoration as a NFM measure, although it probably always adds some storage capacity. Water quality improvements are generally negligable. RRC case study: http://www.therrc.co.uk/MOT/Final_Versions_(Secure)/1.7_Little_Ouse.pdf
Field corner bunds	Temporary storage	Small scale temporary in-field storage which may be applied catchment wide	Creation of 0.7 m bund £3.50/m^2	Based on £5/m3	**Medium** Large scale change required to make a difference	May result in minor reduction in soil loss which if applied widely could be beneficial for river.	Primarily intended for water retention and able to produce measurable effects, depending on location. Local evidence available from Evenlode project. See Belford Case Study 16 in https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/651917/Case_Studies_1_to_23_Rivers_and_Floodplains.zip) which provides general evidence of this approach.

Offline storage ponds	Temporary storage	Increased capacity if engineered to retain more water in flood conditions e.g. excavated earth used to create bund surrounding pond	Excavation, on site disposal may be as little as £2.50/m2 Excavation, off site removal (e.g. floodplain) c.£5/m2	-	**Medium** If this approach is to be viable, ponds must be engineered to retain more water in flood conditions than at 'normal' times	Ponds will beneficial to catchment biodiversity if designed to receive clean water e.g. cited in upper reaches of catchment/on higher land in otherwise clean, low intensity, catchments.	Mainly provides NFM benefits. Limited evidence of catchment scale water quality improvement, although outflow pollutant levels often lower than inflows, indicating some treatment potential. Can also be pollutant source, especially of captured phosphorus. https://freshwaterhabitats.org.uk/wp-content/uploads/2016/11/Water-Friendly-Farming-update-2016.pdf.
Interception ponds	Temporary storage	Field drain interception ponds, may provide moderate attenuation but wider benefits in mitigating soil loss to rivers	Excavation, on site disposal may be as little as £2.50/m2 Excavation, off site removal (e.g. floodplain) c.£5/m2	-	**Medium**	WFD benefits: minor reduction of soil loss from field, interception ponds will require management/desilting if they are to remain functional in the long term.	Provides modest NFM benefits and some water quality improvement. Limited biodiversity value as quickly become polluted. https://freshwaterhabitats.org.uk/wp-content/uploads/2016/11/Water-Friendly-Farming-update-2016.pdf
Off-floodplain bunds	Run-off management	Intercepting Fast Flow Pathways. Breaking up flow pathways, slowing the flow, delaying peak. Off-floodplain bunds are usually created on flow pathways on slopes, to reduce runoff rates.	Bund creation from £5/m3	-	**Low** Scale of change required to make a difference is too great to be feasible in this project	WFD benefits: may help to reduce soil loss into rivers if created on a large enough scale. Few lowland floodplain examples for this approach so far implemented.	Primarily intended to provide NFM benefits. May have minor sediment and nutrient reduction benefits. No specific references.

Woodland planting	Woodland management	Roughens floodplain, may increase permeability of soil/land. These measures may include: catchment woodlands; floodplain woodlands; riparian woodlands; cross-slope woodlands.	EA cost for floodplain woodland establishment = £2,000-6,000/ha + management at £75/ha per year Leck catchment is approx. 10km2 = 1000ha So afforestation across the entire catchment Low = £2m High = £6m Cost of individual trees c.£1.40/tree. Based on FC data Cost of fencing river banks (encouraging natural regeneration of bankside veg/trees) c. £10/m length of stock netting and fence posts.	Complete afforestation of the catchment is implausible as an NFM measure. Fencing large sections of watercourses and allowing trees to grow may adversely impact on the watercourse so is also implausible as an NFM option, although partial tree-planting may be more desirable. Targeted tree planting on the floodplain may help to slow flood flows by increasing channel roughness (precise impacts would require modelling).	**Low** Mixed evidence with regards to tree planting to reduce flooding. Modelling suggests that in order to achieve difference to the hydrograph, the entire catchment would need planting which is technically infeasible in the Leck.	There are potentially benefits of woodland establishment for catchment wide biodiversity – planting trees is likely to be good for bats, birds, carbon storage etc. A more evidence-based perspective on woodland planting benefits for woodland insects, which is perhaps more representative of woodland planting benefits for biodiversity, is available at: https://besjournals.onlinelibrary.wiley.com/doi/abs/10.1111/1365-2664.13035.	At a large scale, may alter regional hydrology enough to reduce flooding. See examples in the EA WWNP Evidence Base. Several case studies deal with woodland planting located at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/651919/Case_Studies_24_to_30_Woodlands.zip.

Soil manage-ment	Soil and land manage-ment	Changes to land management e.g. changing to minimum or zero tillage which is thought to increase water retention properties of soil.	Unknown	Unknown	**Low** Limited evidence unless on a large scale	Evidence of the benefits of changing soil management regimes is still relatively undeveloped and is a major focus of current research. Evidence that stream invertebrate fauna better in minimum-tilled catchments compared to traditional ploughed catchments	Currently, largely unproven as an NFM technique, although expected to provide benefits. Some evidence of stream quality improvement, presumably due to reduced durface runoff. Can create pollution by increasing groundwater nutrient levels. See research summary in the EA WWNP literature review at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/654443/Working_with_natural_processes_evidence_directory_appendix_2_literature_review.pdf. Freshwater Habitats Trust unpublished results of the EU-LIFE Soil and Water Protection (SOWAP) project.

4.8 Conclusion

The Ock catchment is suitable for a range of standard NFM measures with ditches and small streams potentially suitable locations for bunded ditches, leaky dams (including those which push water into the riparian and floodplain zones) and, on larger water courses such as the main R. Ock, river restoration methods. Changes to cultivation practice are a rather higher risk, experimental, option as the effects/benefits in terms of flood management are still poorly understood, and changing tillage practice is a major change for a farmer.

Potential locations for measures have been identified at a range of sites across the catchment in the course of project funded by WEIF grants in 2017 and 2018 which, with suitable follow up negotiations with land-owners, could be put in place.

Modelling is needed to understand the likely effect on flood risk of installing NFM measures. Landowners and managers are primed to put measures in place, and are ready for a practical projects as funding opportunities become available.

Reports from the two farm diffuse pollution projects, following farm visits by FHT (undertaken by Iain Naimsmith, Jeremy Biggs and Hanna Jenkins, the latter working closely with Adella Buckland, provide the basis for following-up opportunities to put measures in place.

5. An introduction to the R. Ock catchment

The name 'Ock' probably derives from a pre-Saxon word for a young salmon"[2]. Salmon have not, however, been seen in the Ock since the Industrial Revolution and it is unlikely that they could survive (or more particularly, their young survive and grow) in the present-day river.

The Ock has also famously lost its native crayfish which could be collected in the 1970s by the rucksac full[3]. In a survey carried out in 1992, native crayfish (*Austropotomobius pallipes*) were recorded at two sites on the River Ock. However subsequent surveys carried out in 1993 failed to locate any crayfish along the Ock. This probably represented the point at which the animal became extinct in the river.

Sometime in the twentieth century it lost one of its most famous natural sites: Cherbury Camp. Cherbury Camp was listed by George Druce as a site which should be protected as a nature reserve in the first ever list of potential nature reserve sites, prepared by the embryonic wildlife trust movement in the 1900s. Although the camp still exists as a monument, its biological interest seems to have been largely destroyed.

Catchment data about the Ock first started to be summarised over 20 years ago (Figure 10). Then, Oxford had a population of approximately 127,000, Abingdon 31,000 and Didcot 16,000 (1991 figures). Now their populations are Oxford: 154,600 (ONS 2017), Abingdon 34,000 in mid-2016; Didcot 30,000 in 2016.

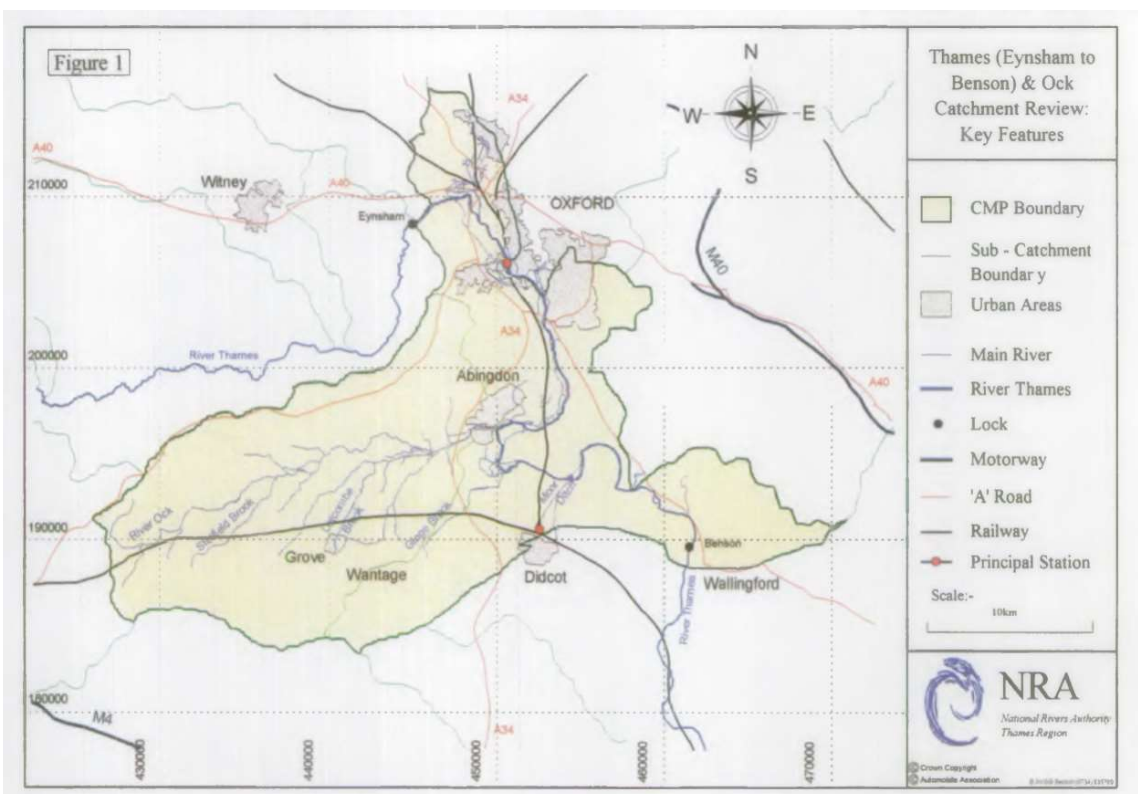


Figure 10. Extract from the first National Rivers Authority catchment management plan produced in 1994.

[2]Gelling, Margaret (1972). *Place-Names of Berkshire. p15.* ISBN978-0904889451.
[3]Bob Eeles, personal communication

During the early 1960s major land drainage works were carried out on the Ock for agricultural purposes. The works, largely involving dredging, aimed to contain a 1 in 10 year flood event within the channel. In the mid-1970s to early 1980s flood alleviation works were also carried out to protect urban property adjacent to the River Ock in Abingdon. The scheme was designed to give flood relief for an up to 1 in 25 year flood.

5.1 Water pollution monitoring in the Ock catchment

Serious water pollution monitoring began in the 1960s and 1970s. In 1972 the Department of the Environment produced the first national report on the extent of water pollution, following a survey in 1970. An 'unofficial and unpublished' survey had been undertaken in 1958 but this survey was described as 'less exact and less thorough' than the 1970 survey

At the time it was declared that 'three quarters of the length of river are free from pollution' although in these early days of invertebrate and fish monitoring what counted as polluted was very different to what we call polluted now (Figure 11).

Rivers were divided into four classes:

- Class 1 - River unpolluted or recovered from pollution
- Class 2 - Rivers of doubtful quality and needing improvement
- Class 3 - Rivers of poor quality requiring improvement as a matter of urgency
- Class 4 - Grossly polluted rivers.

All the rivers in the Ock and adjacent part of Oxfordshire fell into Class 1 at that time except for the Northfield Brook, which fell into Class 2 and the Ladygrove Ditch which was Class 3/4.

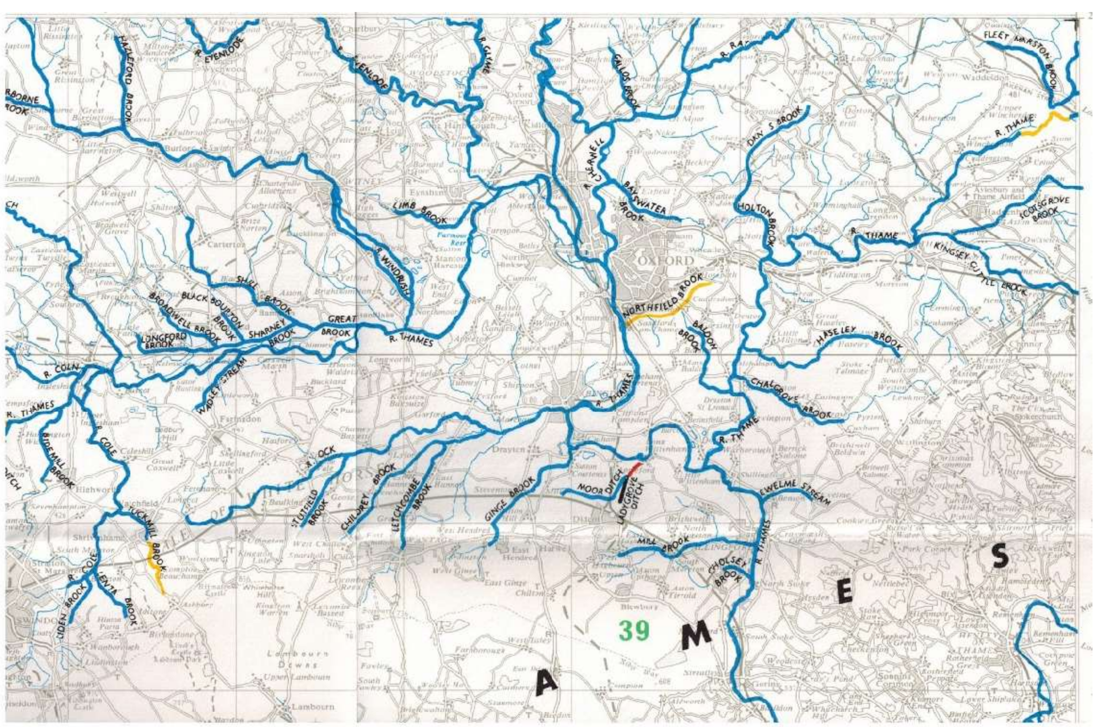


Figure 11. Water pollution status of the Ock watercourse in the 1970s

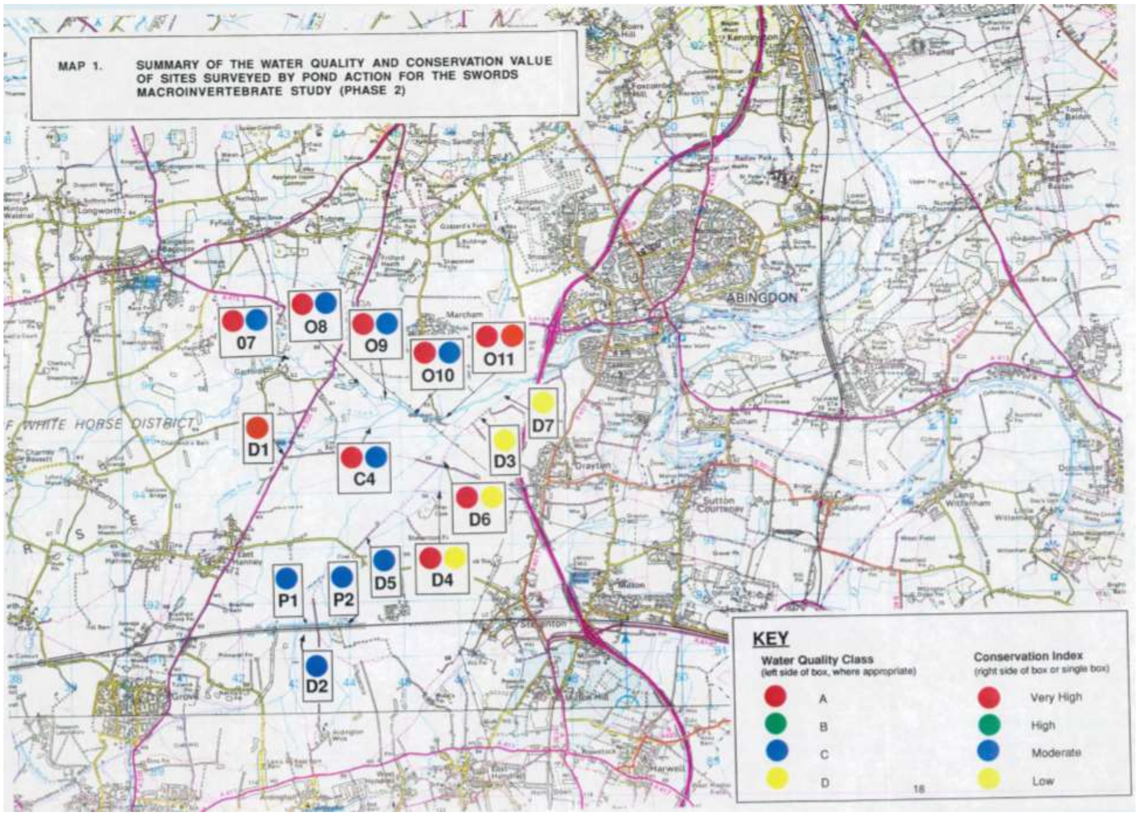


Figure 12. Freshwater Habitats Trust has been working on behalf of the Environment Agency and Thames Water in the Ock catchment for many years. The map above shows the results of early assessments of the conservation value of the R. Ock and various ponds and smaller ditches in the area proposed for the 'new' reservoir.

6. History of the Ock catchment

6.1 Prehistory: 11,500 BC – AD 50

The Thames Valley is a well-documented area archaeologically, much of this referring to the results of gravel excavation which has provided a well-rounded picture of landscape change over the last 14,000 years, since the end of the last Ice Age. Although there is limited detailed data from the Vale of the White Horse - most evidence being associated with the Thames corridor - a vivid picture of the last 10,000 years landscape history can be created. Some data provide information on even earlier times

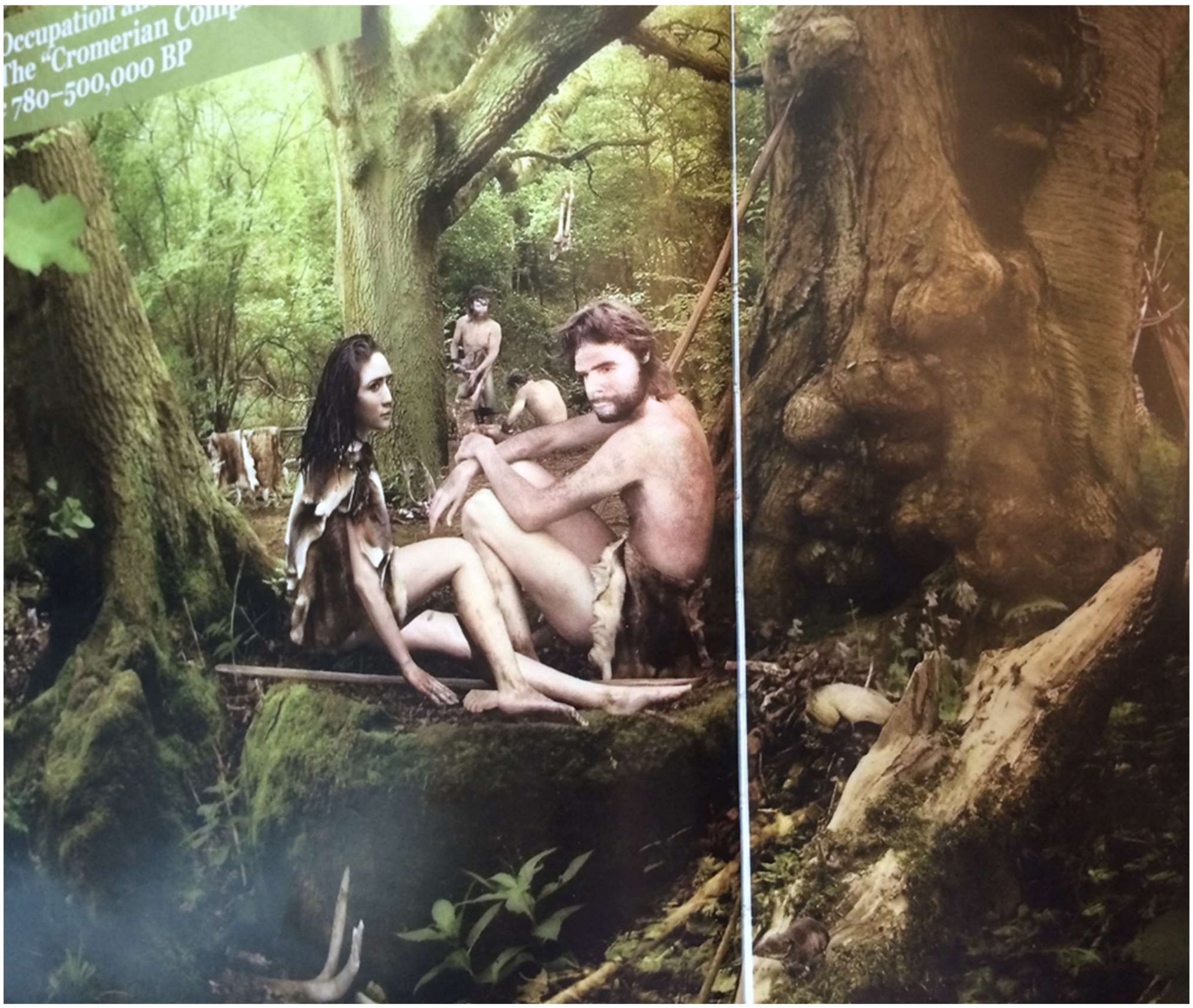


Figure 13. Life in Abingdon has barely changed in 500,000 years. Here a group of hunter gatherers are imagined from archaeological evidence at Sugworth near Abingdon. This is a group of *Homo heidlebergensis* people who left behind remains of early flint tools.

Table 2. A summary of pre-historic change in the Thames Valley with reference to the Ock catchment. Source: Dodd et al. 2011.

Period	Key features of the aquatic environment
The Late Devensian to Holocene transition 11,500 BP – 9500 BC	The Thames, and presumably many tributaries, was a braided system of many migrating channels. At the end of the Late Devensian there is evidence of the transition from braided channels to a system of broad incised multiple channels at the end of the Late Devensian at the time the climate was warming from the end of the last Ice Age. In the Upper Thames there is no evidence of alluvial floodplains at this time. Glacial species are present in sediments from this time like *Helophorus glacialis* a water beetle of snow meltwater pools now extinct in Britain.
Mesolithic 9600-4000 BP	There was little channel migration but peaty backswamps probably existed behind levees on the margins of the river channels. The rivers and streams had the characteristics of unmanaged, well-vegetated rivers and with clean calcareous water with mesotrophic water i.e. natural and low nutrient levels. The aquatic flora was not so different to now – except that in the modern river most of the nutrient sensitive plants are now restricted to isolated off-line areas. These included Whorled Water-milfoil, an uncommon plant now but still scattered (for example at Otmoor, Kennington and the River of Life site) as well as various pondweeds (*Potamogeton* species), many of which are sensitive to nutrients. Riffle beetles from this time – such as the now rare *Stenelmis canaliculata* – are now restricted to the Wye. The Thames Ram's-horn, found in Neolithic sediments, still occasionally occurs, and is restricted to the Thames and rarely reported.
Neolithic 4000-2500 BP	Archaeological evidence suggests limited channel migration and no alluvial floodplain in the modern sense, although there is evidence of occasional large floods. There is significant tree clearance during this time. Some have suggested that trees were mainly killed by ring-barking, and then burnt after falling. There were permanently open areas at this time, either used for cultivating cereal crops or grassland, although woodland also regenerated. Overall, the landscape of the Upper and Middle Thames was a patchwork of relatively undisturbed woodland with alder on ther wettest areas of the floodplain, open parkland where animals were grazed and a few cultivation plots. The landscape can be characterised as one of cycles of woodland clearance and regeneration.
The early Bronze Age: 2500-1500 BC	During the Bronze Age there is the first evidence of a rising water table on floodplains and the start of the transition to modern conditions. The early Bronze Age was a period of larger-scale clearances which were perhaps more permanent on the main river valley terraces. Clearance resulted in a landscape of lightly grazed grassland and thorn scrub. The open landscape of today was beginning.
Middle Bronze Age: 1500 BC onwards	Around this time major changes occurred to the landscape. Most of the gravel terraces and floodplain had been cleared of trees and some fields were now evident. Before this time, the landscape was related to earlier ceremonial sites; after this date it became more related to agriculture with small probably hedged field laid out around settlements. Many had pond-like waterholes, with the field mainly used for pasture but other crops also cultivated.

6.2 Tree clearance in the Thames Valley

A fundamental shift in lifestyle and settlement – which can perhaps be seen as the beginning of modern life – began around 4000-3500 BC as agricultural communities began to appear. This is the transition from hunter-gatherer lifestyles to settled agriculture.

A key component of this change was the gradual clearance of trees. In the Thames Valley this appears to have a number of stage in which trees are rather gradually killed and then supressed by grazing animals.

The process is:

- Some trees killed by ring barking in old high woodland
- Grass begins to grow on woodland floor but grazing prevents trees regenerating
- Any remaining trees are felled
- Thorn scrub invades the pasture (it would usually be supressed in woodland)
- Woodland trees become established in thorn scrub, where protected from grazing
- Woodland regenerates and stock are moved to a new area.

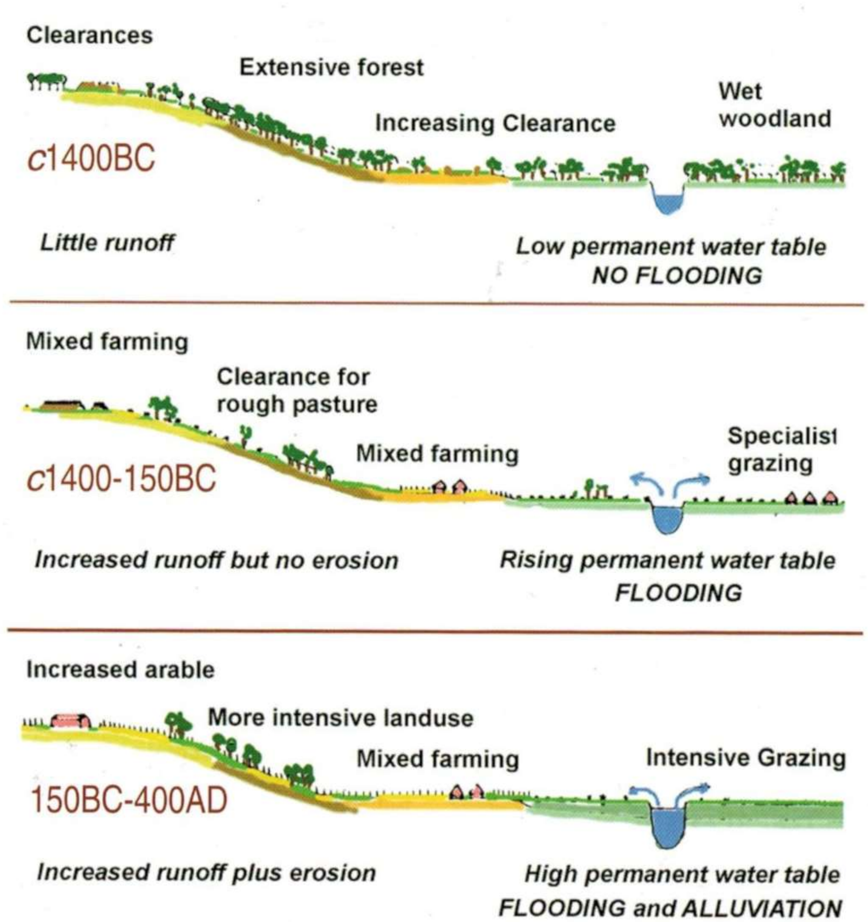


Figure 17. Increased clearance and cultivation from 1400 BC to 400 AD led to alluvial floodplain development in the Thames Valley.

6.3 The early historical period: AD 1 – 1000

6.3.1 Late Iron Age and Early Roman Period: AD 1-250

By the start of the Roman period the landscape of the Upper Thames, and by implication that of the Ock valley, was a productive agricultural landscape, particularly on the gravel terraces. Scrub with rough grazing and 'waste' was probably restricted to the tributary valley and clay slopes. The floodplains were grassland, and the lower areas experienced seasonal flooding.

Meadowland resembling the modern MG4 or MG5 communities was present at this time, evidence for its very long history in the region. Although most has now been lost to intensification the floodplain grassland remaining provide substantial opportunities for recreating high freshwater biodiversity systems.

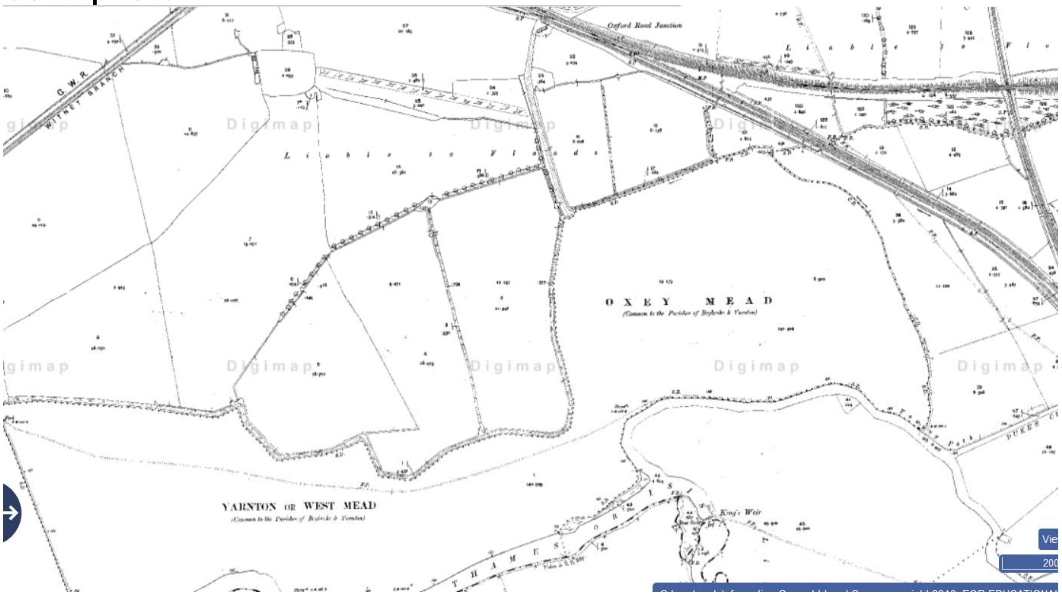
6.3.2 Late Roman Period: AD 250-410

At this time seasonal flooding and alluviation probably extended over the whole of the floodplain. There is evidence of pasture land, based on the types of molluscs and beetles found in excavated sediments. There was little or no woodland on the gravel terraces.

6.3.3 Early Saxon Period AD 410-650

The overall impression of the Early Saxon period is little abandonment of floodplain land but the land was being exploited less intensively. Woodland regeneration did occur beyond the river valleys (for example in the Cotswolds). A palaeochannel on Oxey Mead, on the Thames floodplain just north of Oxford radiocarbon dated to AD 650-850, provides evidence of transition from pasture to hay meadow at this time, based on dung beetle and clover/vetch feeding weevils. This management persisted until the mid-20th century on the site, only ending in the 1930s when the grassland was destroyed by roadbuilding and agricultural intensification, later becoming a gravel pit.

OS map 1910



OS Map 1930

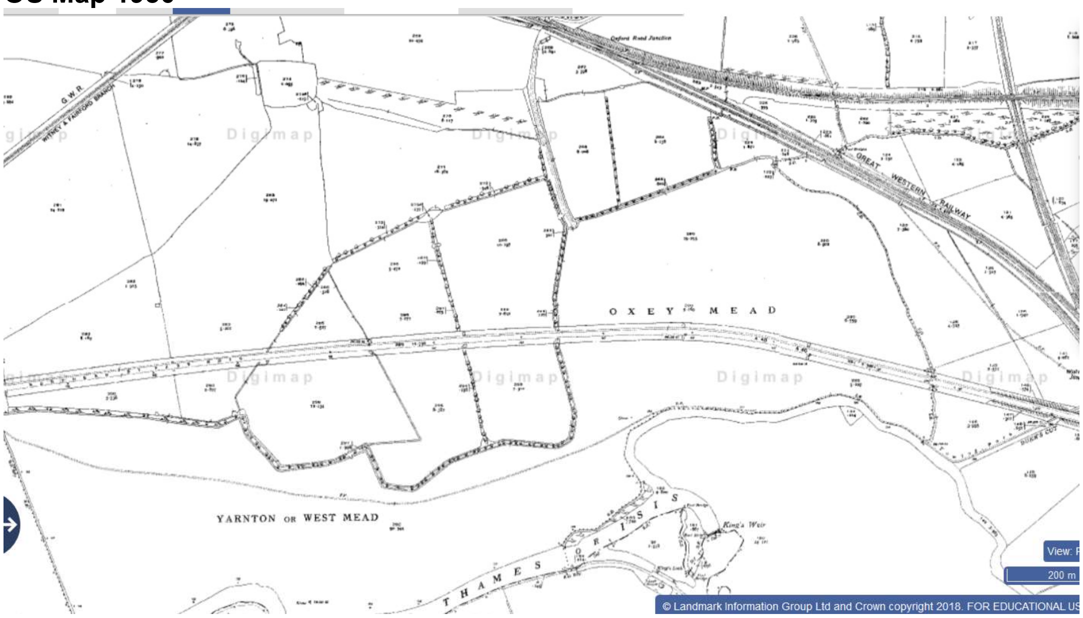


Figure 18. A palaeochannel on Oxey Mead, now destroyed by road building and gravel excavation, provides important evidence of the origin of Thames floodplain meadows with the now rare MG4 and MG5 type hay meadows appearing to exist in the Mid-Late Saxon Period AD 650-850.

6.3.4 Mid to Late Saxon Period

At the end of the Saxon period some indication of the environment of the Thames Valley and associated tributaries, amongst many other sources of evidence, is provided by the range of wild mammal, bird and fish bones recorded further down the catchment at Wraysbury.

Mammals and fish are particularly interesting with the Burbot and the Beaver, the former still extinct in Britain but the latter beginning a comeback

Table 3. Mammal, bird and fish bones recovered at Wraysbury from a late Saxon settlement (AD 650-1000). Source: Booth *et al*., 2007

Beaver	Mallard	European Eel
Water Vole	Corncrake	Herring-type
Mole	Woodcock	Brown Trout
Common Shrew	Golden Plover	Salmon
Red Deer	Lapwing	Pike
Roe Deer	Buzzard	Chubb
Field/Wood Mouse	Goshawk	Rudd or Bleak
Harvest Mouse	Partridge	Cf. Bream
House Mouse	Wood Pigeon	Barbel
Black Rate	Dove or domestic pigeon	Gudgeon
	Crow or Rook	Burbot
	Robin	Perch
	Blackbird	Flat fish
	Thrush-type	
	House Sparrow	
	Wren	

6.4 Documented history

Documented history in the Ock catchment begins around 1000 AD.

Here we have picked out three documentary sources that are important for understanding the catchment:

- Maps
- Milling
- The history of land drainage.

There are many interesting projects which could be developed to understand the landscape better, perhaps helping to stimulate the ecosystem services associated with cultural heritage.

6.5 Maps

6.5.1 Introduction

Maps and associated documentary sources provide us with an overview of post-17th century landscape development in the Vale of White Horse. Maps start about 250 years ago with the Roque 1761 map of Berkshire (which covers the Vale of White Horse), and later with the early OS mapping (e.g. Figure 18).

They play an important part in the description of the historic landscape and have been summarised in the Oxfordshire Historic Landscape Characterisation project which maps current and past land use across Oxfordshire (Figure 19).

Large-scale maps of Oxfordshire, produced by the project, showing the current landscape and what Oxfordshire looked like at the end of the 18th and 19th centuries, and the mid-16th century.

6.5.2 Important parts of the landscape

The main historic landscape types in the Ock

The Oxfordshire Historic Landscape Characterisation project identifies four main historic landscape types in the Ock catchment, and three dominant modern landscapes.

- Historic landscape types

Ancient Enclosure: Areas of land enclosed prior to the 18th century. These fields can be co-axial or irregular. Co-axial field systems have a sinuous pattern of small, elongated fields. Irregular field systems consist of piecemeal enclosures of various sizes and shapes. N.B. This HLC type has been used variously throughout the project. It is described as pre-18th century fields, but, at times, it has also been used to indicate fields shown on the mid-late 18th century Roque and Davis Maps. It is possible, therefore, that earlier 18th century fields have been characterised as Ancient.

Planned Enclosure: Fields with a predominantly straight boundary morphology giving a geometric and regular appearance. Normally laid out by surveyors these field patterns are often the result of enclosure during the 18th and 19th centuries. This type of field system often overrides earlier systems.

Piecemeal enclosures: Field systems that have been created out of the medieval open fields by informal agreement. They appear to have been established on a field by field basis and often are small and irregular fields with at least two boundaries of a reverse 'S' curve or 'dog-leg’. Includes enclosed furlongs and enclosed strips.

Parkland: Areas of land designated as Parkland or part of a designed landscape associated with a 'great house', and deer parks for the keeping of deer. Identified using English Heritage's Historic Parks and Gardens Register and from OS mapping.

- Modern landscape types

Prairie / Amalgamated enclosure: Patterns of large fields (in excess of 10 hectares), some with boundaries over 1km long. Often resulting from post WW2 combination of holdings and the removal of earlier boundaries creating land units convenient for highly mechanised arable, or for extensive livestock raising.

Paddocks and Stables: Small and generally regular fields used for horses and associated structures.

Parks and golf courses: modern amenity sites.

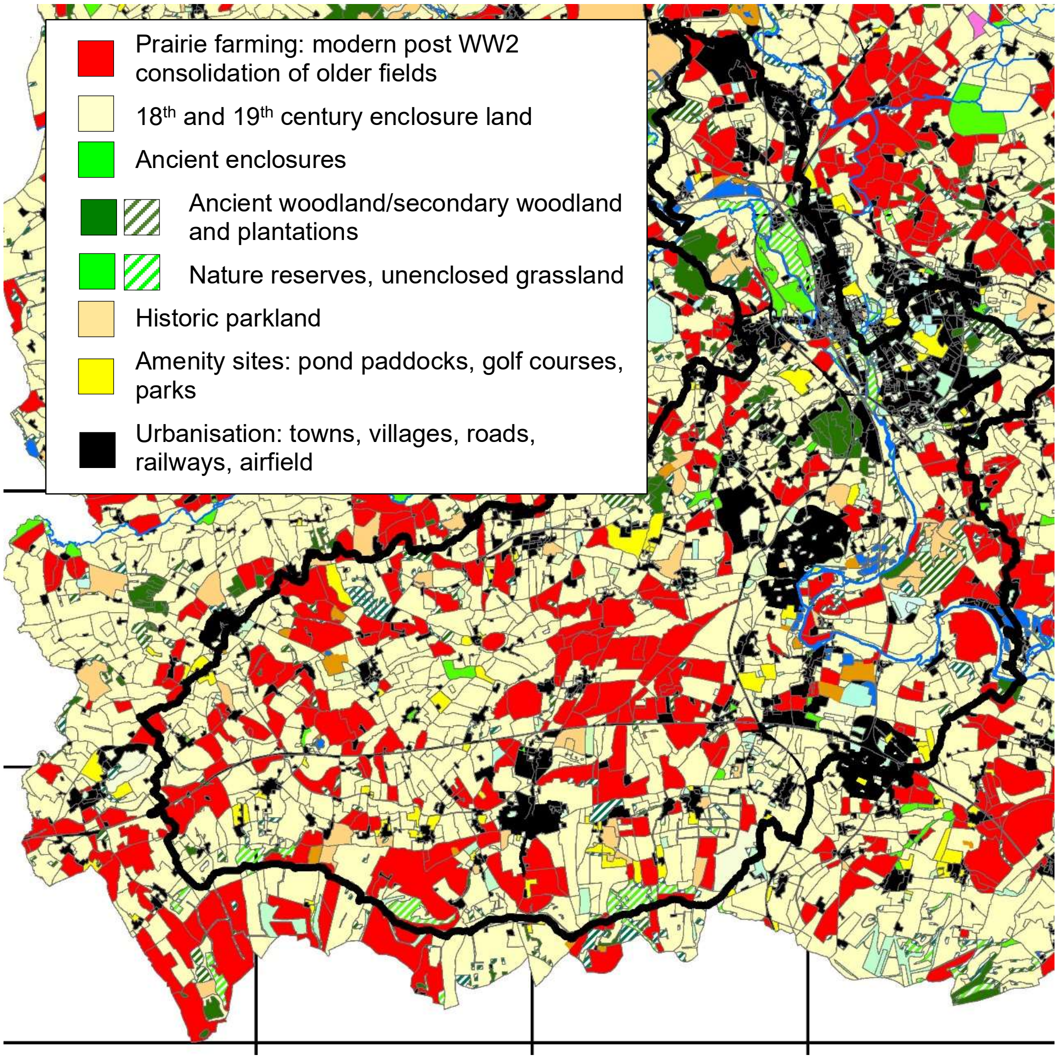


Figure 19. Overview of historic landscape change in the Ock operational catchment: redrawn from Oxfordshire Historic Landscape Characterisation.

For reference the full range of land use types captured by the Oxfordshire Historic Landscape Characterisation project are shown in Figure 20.

Figure 20. Full range of landuse types described in the Oxfordshire Historic Landscape Characterisation project

6.6 Local sources of information

'Charney Manor' was a grange, built by Abingdon Abbey, to house the steward or bailiff appointed to look after the Abbey's lands around Charney. Charney had to provide the Abbey with a specified number of bushels of grain and barrels of fish every year and it was the bailiff's job to see that these were delivered. The fish was principally salmon from the Ock. Salmon was a staple part of the diet in the Thames Valley in the Middle Ages. The Ock also provided crayfish which were on sale in Oxford until c1900.

Figure 21. William Stanley 1811 map of part of the Vale of White Horse

Figure 22. William Stanley 1811 map of part of the Vale of White Horse: enlargement showing Marcham and Abingdon

6.7 Milling

The Domesday Book contains the result of a census completed in 1086 and commissioned by William the Conqueror. It gives details of the number of watermills existing in 11th century England. By this time, watermills were already numerous with estimated numbers ranging from 5,600 to more than 6,000.

Figure 23. Sketch map showing approximate distribution of mills in the Domesday Book (from Hodgen 1935).

Mills have had a profound influence in the river network. Mills were present on the river and stream network 1000 years ago and have led to the modification of the structure of most of the Ock catchment's river and stream network. Figure 23 shows the general distribution of mills in England, with Figure 24 showing a closer view of the Ock catchment.

It has recently been suggested that by Lenders *et al*. (2016) that Atlantic Salmon that populations declined by up to 90% during the transitional period between the Early Middle Ages (c. 450–900 AD) and Early Modern Times (c. 1600 AD), coinciding with improvements in watermill technology and the geographical expansion of mills across Europe.

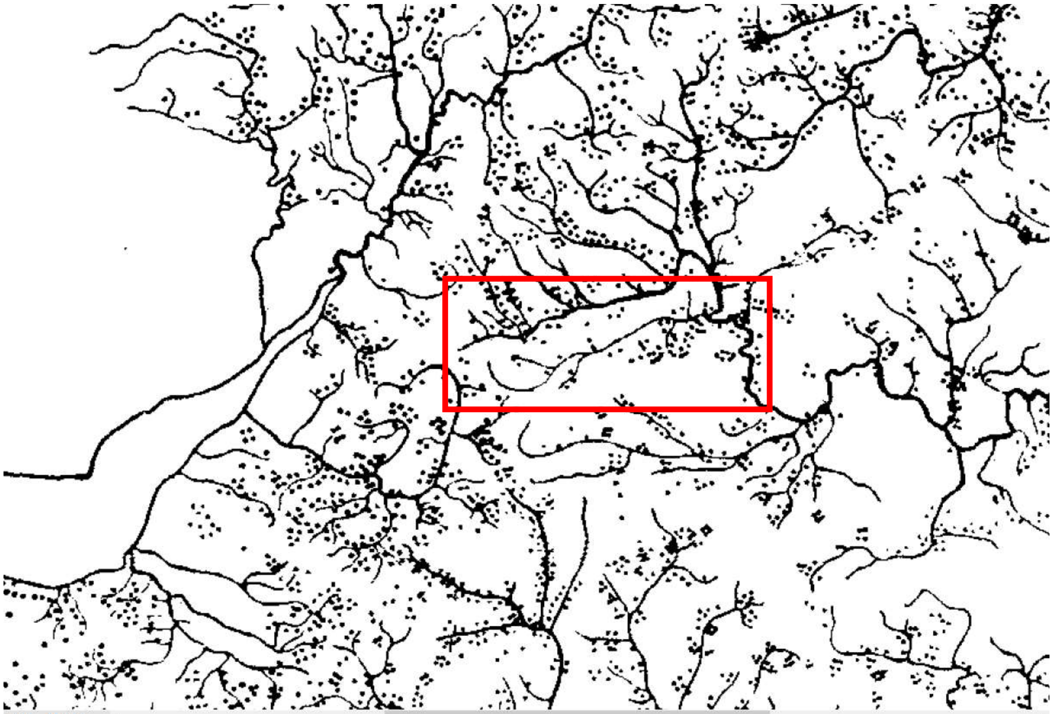


Figure 24. Sketch map showing approximate distribution of mills in the Domesday Book – enlarged to emphasise Ock catchment (from Hodgen 1935).

A gazetteer of the Ock mills was published by the Wantage Industrial Archaeology Group in 1978 (see https://millsarchive.org/explore/library/entry/25445/mills_of_the_ock#.W3lUGLgnZPY).

More details of mills in the Ock catchment are available on the Mills Archive at https://millsarchive.org/.

6.8 The history of land drainage.

Land drainage at both small and large scale has been taking place since at least Roman times but it is only in the last 200 years that significant amounts have been carried out (Robinson 1986[4]).

Before the 20th century intensification of land drainage it is estimated that 57,000 km^2 (14 million acres) was drained with old drains, which represents 52 per cent of the agricultural land in England and Wales (Figure 25).

Following the Second World War with mechanisation and extensive government grants drainage became widespread. The provision of grant-aid by the Ministry of Agriculture, Fisheries and Food (MAFF) for drainage schemes and the need for farm visits by ADAS Drainage and Water Supply Officers (DWSO) for prior-approval created a system of centralised technical information on drainage schemes that could be used to generate reliable statistics, since the majority of schemes would have received government grants.

Prior to 1971 records were only collated at the MAFF Division level. During the 1970s detailed records were collected at the parish level and held on computer. Subsets of these data have been published (Green, 1973; Armstrong, 1981). This was a time of great agricultural prosperity, with an estimated drainage rate in England and Wales of over 100,000 ha per year for much of the 1970s. Subsequently the rate of drainage declined in the 1980s to almost negligible levels by 1989 as the most suitable areas requiring drainage for effective farming had been drained and concerns were growing about excess agricultural production and reforms of the EU Common Agricultural Policy led to the reductions in support to farmers. The requirement for prior approval was abolished from May 1980 and detailed records became increasingly less complete (Robinson 1986).

The first major phase of drainage probably occurred on the Ock in the mid-18th century when tile drains came into widespread use although this has not been documented in detail in the Ock catchment. A second phase of drainage occurred in the second half of the 20th century.

In the second half of the 20th century secondary documentary source material describing land drainage activities in the Ock specifically is available and some examples of the impact of these activities is shown in Figures 26-28.

It remains uncertain whether blocking drains (or allowing them to fall into disrepair), effectively reversing land drainage schemes, increases water storage. The Ock was an area where the work of Robinson (1990) made an assessment of the effect of land drainage on flooding. The conclusion was that there was some evidence of increased downstream floods, after land drainage, but the quality of the available hydrological data made this uncertain.

An initial evaluation of the effects of reducing land drainage widely could be undertaken as a modelling study. Locally, it is more likely that land drainage impacts on the catchment could be reversed to increase local storage, especially on the floodplain, by narrowing channels and raising beds. **We recommend that, if possible, such an assessment is included in the catchment modelling study.**

This is most likely to be acceptable to landowners who enter agri-environment schemes which encourage grassland or semi-natural vegetation on the floodplain.

---

[4]Robinson M (1986) The extent of farm underdrainage in England and Wales, prior to 1939. Agricultural History Review, 34, 79-85.

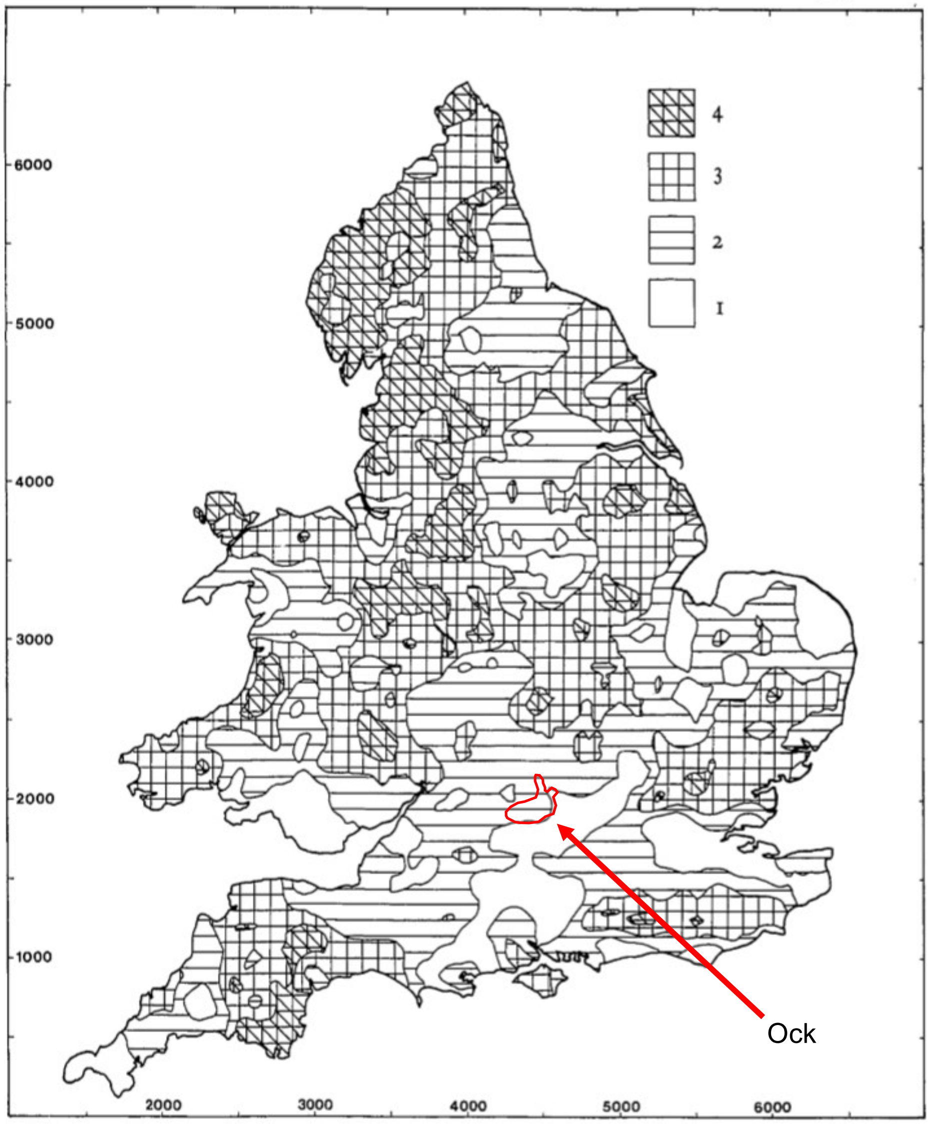


Figure 25. Intensity of land drainage in England and Wales showing approximate location of the Ock catchment. The catchment lies in the area with 25-50 underdrainage. Level of drainage intensity: 1 = under 25 per cent, 2 = 25 to 50 per cent, 3 = 50 to 75 per cent and 4 = over 75 per cent

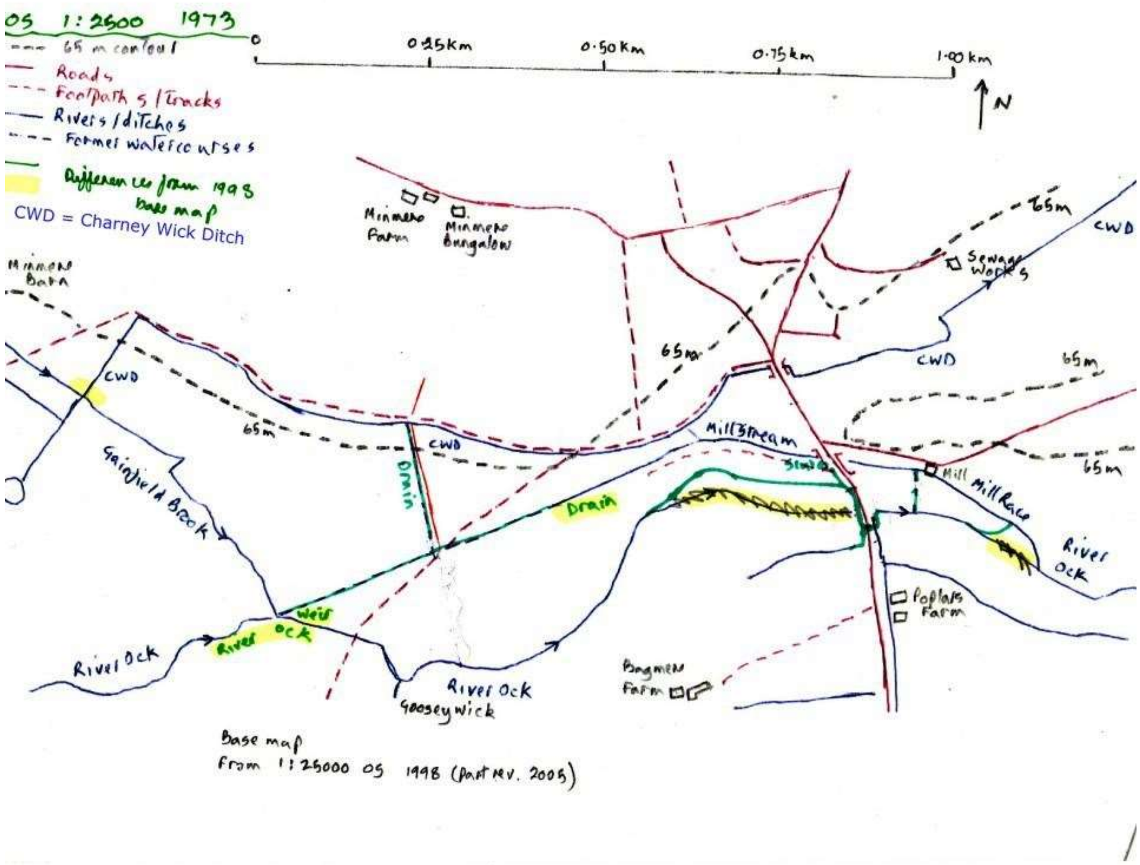
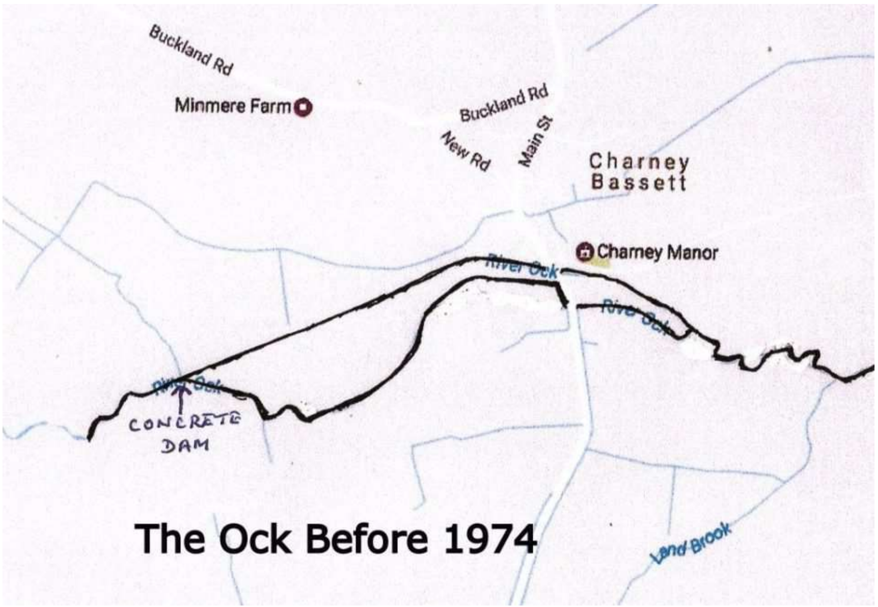


Figure 26. Channel modifications associated with land drainage around Charney Bassett in 1974.



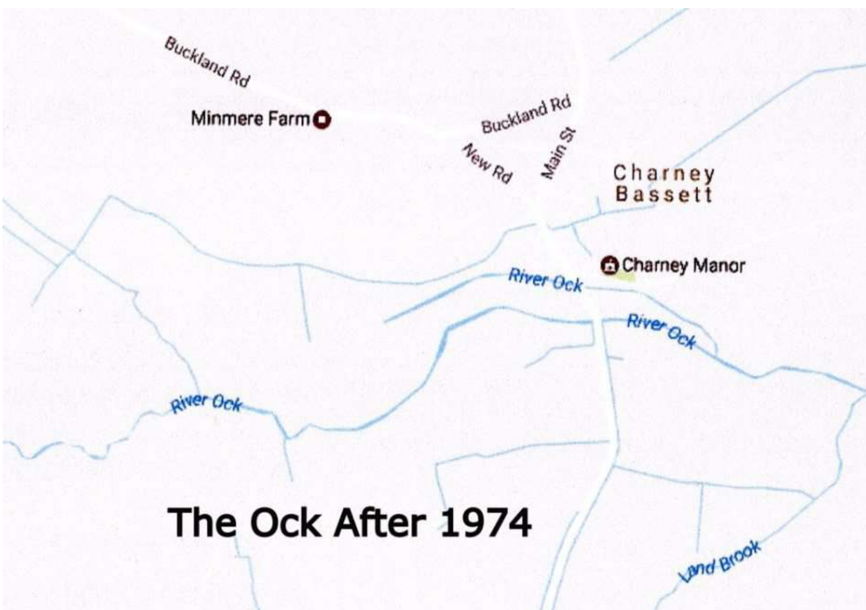


Figure 27. Modification to the route of the Ock at Charney Basset resulting from 1970s land drainage scheme. At Charney Bassett the former mill leat was cut off from the main river.

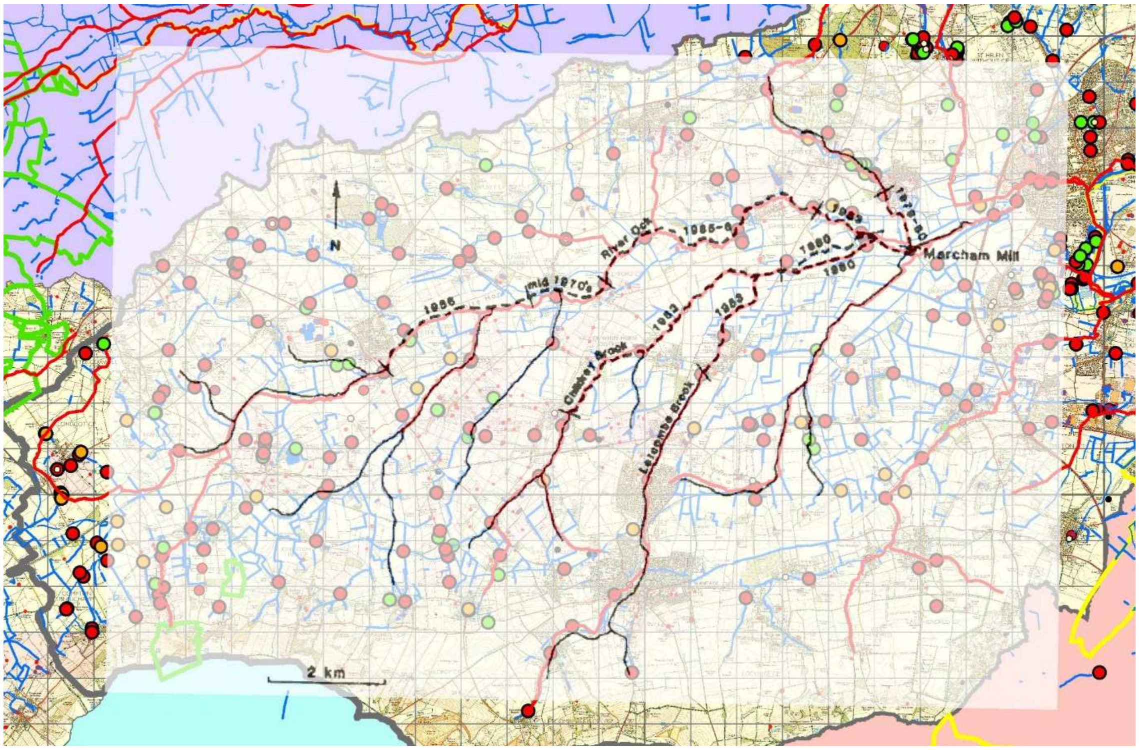


Figure 28. Summary of land drainage work overlaid on current GIS mapped network. Source of sketch map is Robinson 1990[5].

Figure 28 shows the areas of the Ock catchment where land drainage works were undertaken in the 1970s and 1980s. Work was mainly concentrated on the lower Ock and the lower Letcombe Brook.

[5]Robinson, M. 1990. Impact of improved land drainage on river flows. Institute of Hydrology Report 113, Wallingford, 226pp. (www.ceh.ac.uk/products/publications).

7. Freshwaters in the Ock catchment

7.1 What are freshwaters?

In this report we use the following definitions of waterbodies, most of which were first developed by Brown *et al*. (2006):

Ponds	Waterbodies between 25 m^2 and 2 ha in area which may be permanent or seasonal (Collinson *et al*., 1995). Includes both man-made and natural waterbodies.
Lakes	A body of water >2 ha in area (Moss *et al*., 1996). Includes reservoirs and gravel pit lakes.
Streams	Small lotic waterbodies created mainly by natural processes. Marked as a single blue line on 1:25,000 Ordnance Survey (OS) maps and defined at this map scale by OS as being less than 8.25 m in width. Streams differ from ditches by: (i) usually having a sinuous planform; (ii) not following field boundaries, or if they do, pre-dating boundary creation; (iii) showing a relationship with natural landscape contours, e.g. running down valleys.
Rivers	Larger lotic waterbodies, created mainly by natural processes. Marked as a double blue line on 1:25,000 OS maps and defined by the OS as greater than 8.25 m in width at this map scale.
Ditches	Man-made channels created primarily for agricultural purposes, and which usually: (i) have a linear planform; (ii) follow linear field boundaries, often turning at right angles; (iii) showing little relationship with natural landscape contours.
Springs	Locations where groundwater emerges for at least some part of the year to make a surface water flow (Biggs *et al*., 2016).
Flushes	Areas where the flow of ground water onto the surface is more diffuse, either below a spring or where water flows widely over the surface of saturated ground rather than in a well-defined channel. Flushes can be areas of open, stony ground with only a sparse plant cover or have a complete and often dense cover of flowering plants, usually sedges or rushes, with the bryophytes forming a ground layer under this canopy (Plantlife, 2009).

For other wetlands, standard definition are used (e.g. fen, bog, marsh).

7.2 The Office for National Statistics definition of freshwaters and wetlands

To ensure that the Ock ecosystem services analysis relates to national standard approaches, definitions and approaches used by the Office for National Statistics in producing environmental accounts are briefly described, as necessary.

According to Office for National Statistics, open waters include standing and flowing waters. Standing waters consist of natural bodies such as lakes, meres and pools, as well as manmade features such as reservoirs, canals, ponds and gravel pits. Flowing waters include rivers and streams that flow into the sea or a lake.

Wetlands are defined as areas of land covered by shallow water at or near the surface level including fens, marshes, swamps and bogs.

Office for National Statistics categories are therefore compatible with the definitions first developed in Brown et al. 2006, which have become widely adopted (see for example, Biggs et al 2017).

Note that Office for National Statistics environmental accounts do not include floodplains as a wetland habitat (presumably other than when floodplains are occupied by one of the recognised wetland habitat types).

The total area of freshwater and wetland habitat in the UK is shown in Appendix Table 1.

Table 4. Length / number of waterbodies in the Ock operational catchment, monitored and unmonitored as part of the WFD

Waterbody type	Number or length in km	Monitored (length, km or number)	Unmonitored (length, km or number)
WFD Rivers and streams (lengths derived from EA mapping)	209 km	209 km	0
Non-WFD linear water courses (includes rivers, streams and ditches)[1]	1227 km	0	1227 km
Ponds	943	2	941
Lakes	48	0	48

[1]Linear waterbodies are the combined OS waterline and water surface area layers. The surface area segments treated as rivers, streams or ditches were 5000 m or longer and those having area/length ratios of less than or equal to 5.

7.3 Waterbodies in the Ock operational catchment

The Ock has around 1250 km of linear waterbodies (rivers, streams, ditches) and about 1000 ponds and lakes (Table 4).

7.3.1 River, streams and ditches

Of the linear watercourses, the ecological quality of just over 200 km of the total length of watercourses is classified under the Water Framework Directive. There are about 1250 km of unmonitored watercourses as shown by Ordnance Survey mapping. The ratio of unmonitored compared to monitored linear watercourses (roughly 20% monitored, 80% unmonitored) is normal for the British landscape.

In this analysis, for simplicity we did not separate linear waterbodies into rivers, streams and ditches. Classification of waterbodies into these three categories would require more detailed GIS work than was possible within the time constraints of the present project.

7.3.2 Ponds and lakes

Ordnance Survey mapping shows c.950 ponds in the Ock catchment. Very few of these ponds are regularly monitored with a small number included in existing Freshwater Habitats Trust surveys and other monitoring programmes (e.g. Flagship sites such as Little Wittenham Upper Pond, Kennington Pit).

Ordnance Survey mapping shows 30 lakes (standing waters of 2 ha or more in area) in the Ock catchment. As far as we are aware none of these waterbodies are subject to regular monitoring (Figure 30). The broad distribution of all lakes on in the Ock catchment is shown in Figure 30.

We have not included springs and flushes as water layer information that is publicly accessible does not contain information on these features.

The broad distribution of the rivers and streams classified under the Water Framework Directive is shown in Figure 29. The distribution of ponds in the Ock catchment is shown in Figure 31.

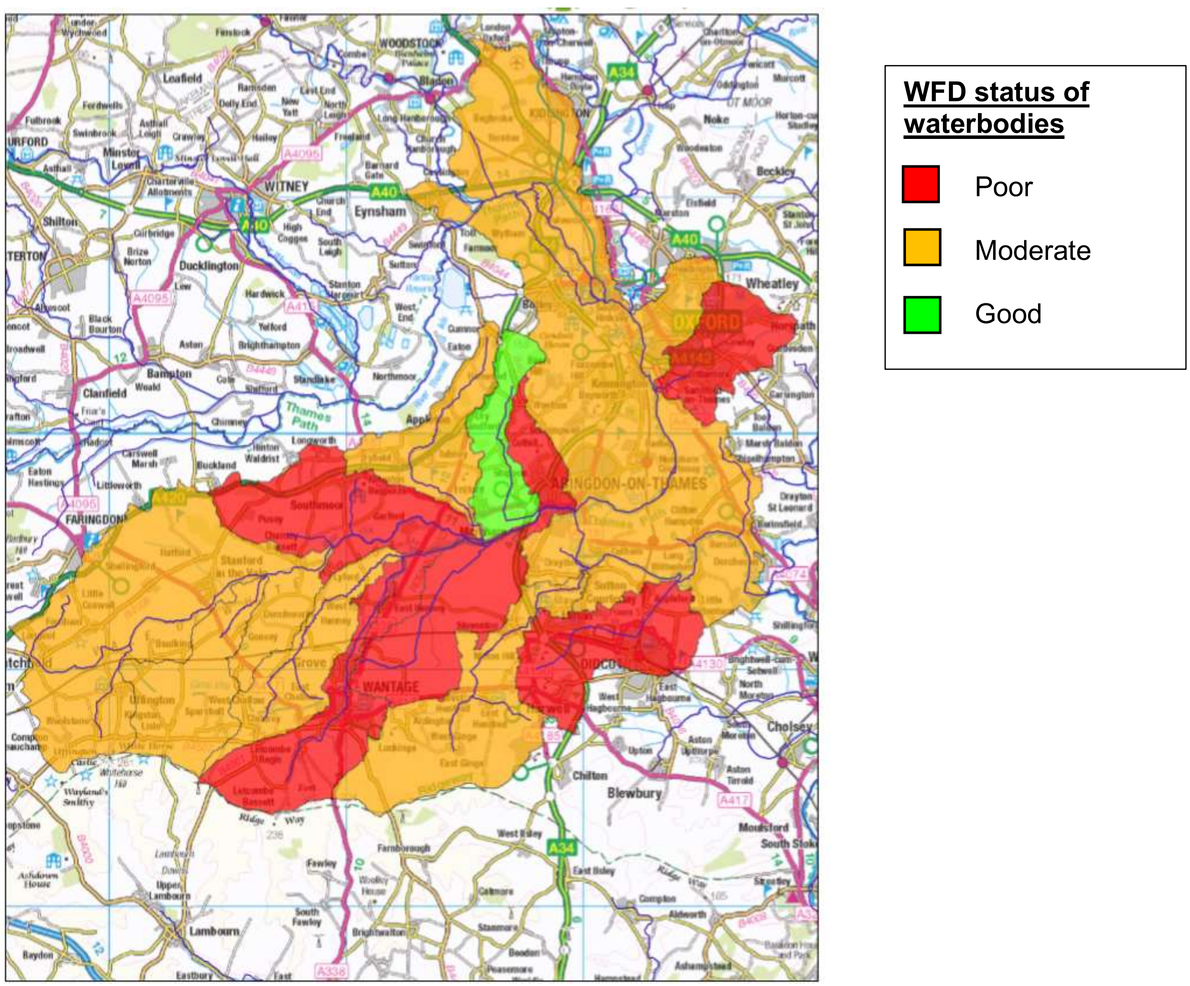


Figure 29. Broad distribution of Water Framework Directive (WFD) classified waterbodies in the Ock operational catchment. Colours show the WFD status of waterbodies.

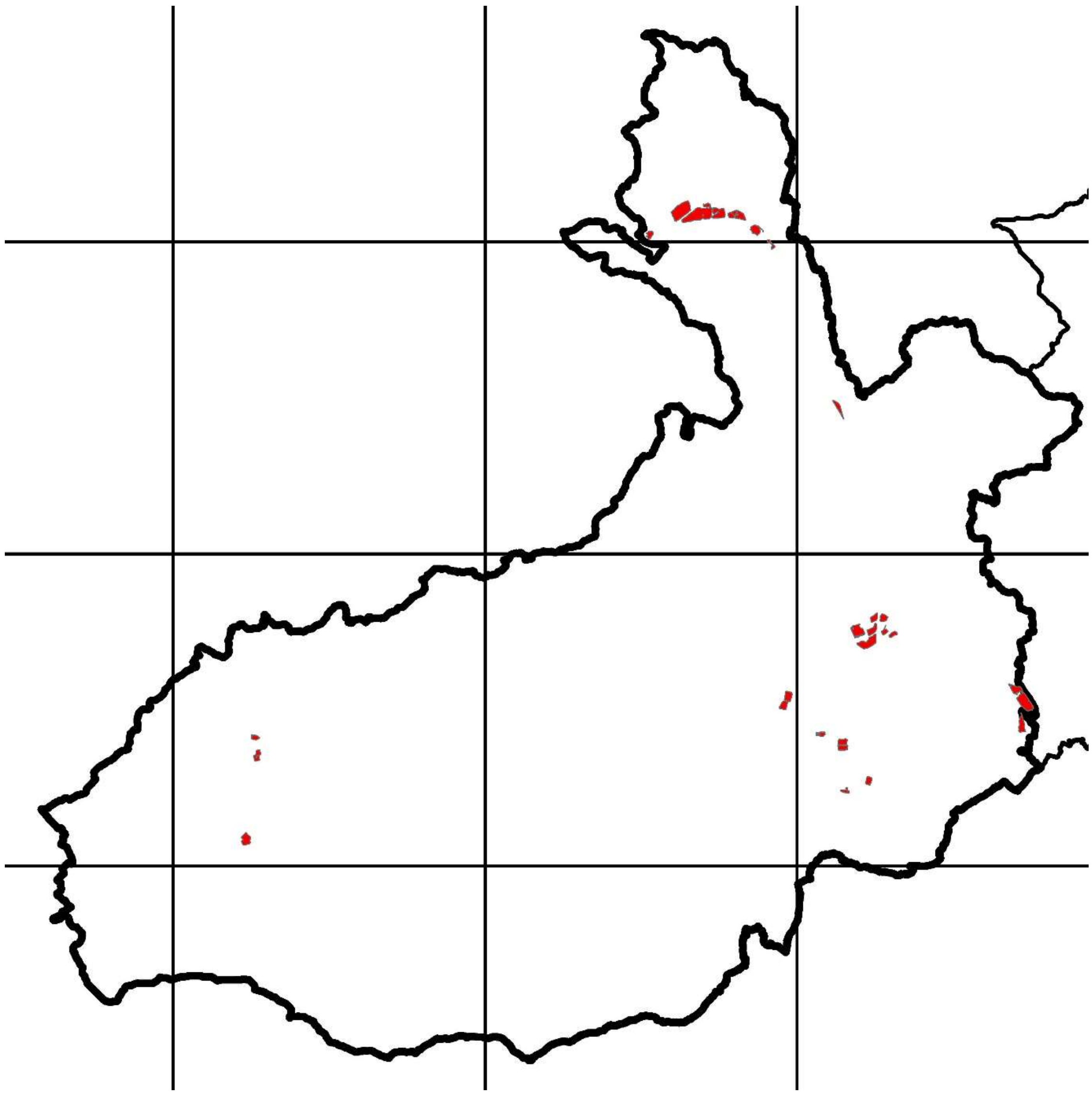


Figure 30. Lakes in the Ock operational catchment

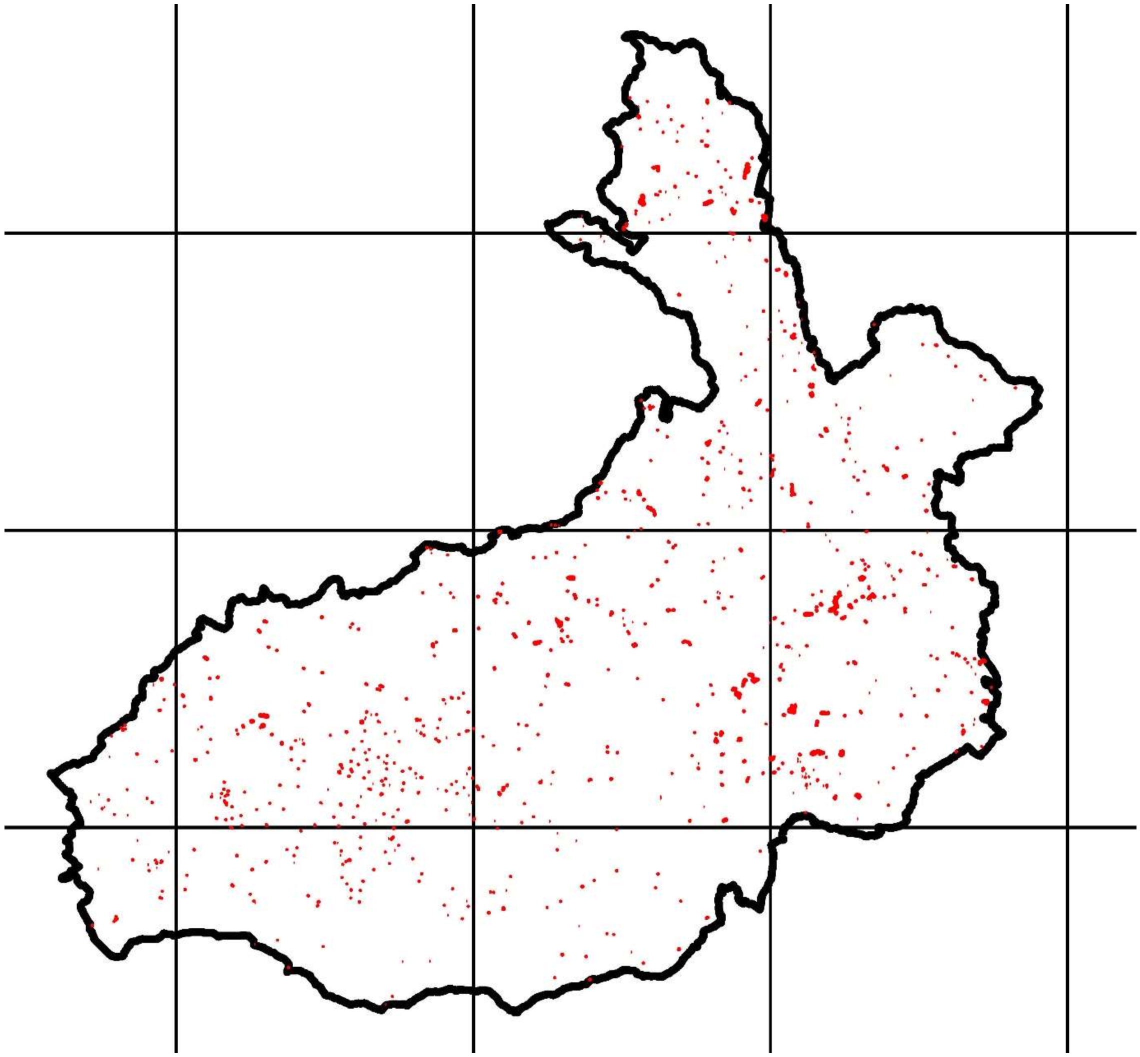


Figure 31. Ponds in the Ock operational catchment

8. Ecosystem services in the Ock catchment

8.1 Introduction

In this part of the report the main types of context of ecosystem services delivery in the Ock is established with reference to national environmental accounts, and the status of stock and flows of services from ecosystems delivered.

As biodiversity is omitted from most ecosystem service accounting some extra comments on approaches to restoring freshwater biodiversity are included. This reflect the fact that the Ock is national pilot and potential demonstration catchment for the management and recovery of freshwater biodiversity.

National environmental accounts produced by the Office for National Statistics provide a broad context for evaluating change in ecosystems services in the UK and therefore help set the context for the Ock catchment. They also indicate the services for which there is reasonable likelihood of measuring change.

8.2 National Environmental accounts 2016 - Office for National Statistics

8.2.1 Introduction

This section briefly describes the national context of ecosystem services accounting used by the Office for National Statistics. It is based on data from the most recent statistical release in July 2017 "UK natural capital: ecosystem accounts for freshwater, farmland and woodland"[6]. The ONS noted that as the primary findings of this statistical release that:

- Conditions of freshwater habitats in recent years have generally deteriorated, whilst the condition of woodland has improved.
- Woodland removed more harmful pollution and carbon dioxide from the atmosphere than any other habitat, valued at £1.8 billion in 2015.
- Between 2009 and 2015 the amount of time spent visiting woodlands in the UK was estimated to have increased from 245 million hours to 350 million hours.
- Farmland habitats are producing more energy from solar power, with 600 times more solar energy being produced in 2015 than in 2007.

Table 6 reproduces the measures used by Office for National Statistics to describe freshwaters as 'generally deteriorating'. In the next section the condition of freshwater ecosystem services at national level are briefly described to set the context of the Ock work.

The overall value of the freshwater services so far quantified are summarised in Table 5. These show that the greatest value is in water supply, followed by recreation.

[6] https://www.ons.gov.uk/economy/environmentalaccounts/bulletins/uknaturalcapital/landandhabitatecosystemaccounts

Table 5: UK freshwater condition indicators, 2008 and 2012

Type	Indicator	Indicator signalling improvement or deterioration in condition between 2008 and 2015
Chemical	Ammonium Levels	Improvement
	Biomedical Oxygen Demand	Improvement
River Flow	Exceptionally high annual flow	No Trend
	Exceptionally low flow	Little/no change
Biodiversity	Water and Wetland Birds index	Deterioration
WFD status for rivers and canals	Percentage of rivers and canals in good or excellent condition	Little/no change
	Percentage of rivers and canals in poor or bad condition	Deterioration
WFD status for lakes	Percentage of lakes in good or excellent condition	Deterioration
	Percentage of lakes in poor or Bad Condition	Deterioration

Source: European Environment Agency, Joint Nature Conservation Committee, Natural Environment Research Council and Defra

Table 6: UK freshwater annual monetary flow value by service, 2007 to 2015

						£ million				
Type of Service	**Ecosystem Service**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
Provisioning services	Water abstraction	1,001	1,213	643.7	575.4	917.7	1,223.8	1,289	1,019	-
	Peat extraction	2.3	1.4	2.6	1.4	2.9	3.4	8.4	5.4	-
	Fish capture	1.4	1.3	1.4	1.8	1.3	1.2	1.0	-	-
Regulating services	Pollution removed	25.0	23.9	22.8	21.6	20.5	19.3	18.1	16.9	15.7
Cultural services	Time spent at habitat			530.1	410.9	493.1	456.2	456.3	321.8	303.0

Source: Office for National Statistics

The total annual value of the services provided by freshwater is shown in Table 6. The financial value of water is dominated by two services: water supply and recreation.

This suggests that the greatest monetary benefit from ecosystem services will be those that allow the storage of more water in the catchment, and increased visiting to water and wetland sites.

8.2.2 Freshwaters status in the Ock

With respect to the status of freshwater environment, the national picture is echoed in the Ock. The overall status of freshwaters in the Ock monitored as part of the Water Framework Directive has become slightly worse since the introduction of the Directive (Figure 34). This is probably because more of the four main biological quality elements (macrophytes, algae, macroinvertebrates, fish) are now included in the assessment so the results look worse, although it is possible that there is some actual worsening.

However, when the individual biological and physico-chemical elements of WFD status are broken down, there are both positive and negative trends (see Section 6.5.1 below). For example, considering invertebrates, which have the longest biological record, ASPT values are better now than 25 years ago, whereas NTAXA values are often worse in the Ock catchment than they were 25 years ago. ASPT is the average score per taxon which responds mainly to organic pollution and NTAXA is the number of invertebrate taxa which is usually interpreted as a measure of habitat quality – the more diverse and natural the habitat, the wider the variety of taxa (though water quality can play a role as well in this metric).

8.3 Payment for ecosystem services

Payments for ecosystem services provide a mechanism by which the benefits of an ecosystem services approach can be practically funded. An introduction to Payments for Ecosystem Services schemes is provided by Smith et al. 2015. Payments for Ecosystem Services schemes involve payments to the managers of land or other natural resources in exchange for the provision of specified ecosystem services (or actions anticipated to deliver these services) over-and-above what would otherwise be provided in the absence of payment.

Payments are made by the beneficiaries of the services in question, for example, individuals, communities, businesses or governments acting on behalf of various parties. Beneficiaries and land or resource managers enter into PES agreements on a voluntary basis and are in no way obligated to do so.

Ecosystem services, simply defined, are the benefits we derive from the natural environment. These include, for example, the provision of food, water, timber and fibre; the regulation of air quality, climate and flood risk; opportunities for recreation, tourism and cultural development; and underlying functions such as soil formation and nutrient cycling. Maintaining and enhancing ecosystem services – and restoring them where they have been lost or degraded – is increasingly recognised as essential for sustainable economic growth, prosperous communities and promoting peoples' wellbeing.

Payments for freshwater related ecosystem services currently made in the Ock catchment include (see Figure 32):

- Water supply – paid for by charges to water consumers
- Water quality regulation – mainly funded through agri-environment scheme payments, and charges to water consumers (although this is perhaps more like a 'polluter pays' scheme)
- Navigation – made by payments from boat owners, and by grant-in-aid funding from the public purse. This service only refers to the main River Thames, there being no navigation right in the Ock catchment.
- Cultural heritage: payments are made for maintenance of cultural heritage for wetland nature reserves through a combination of public, agri-environment and private funds

(e.g. donations to environmental charities), although it is widely assumed that these payments are too small to maintain the service

- Water regulation (i.e. flood defence) - at present uses traditional engineering approaches funded by beneficiaries and the public purse, but could become an ecosystem service provided by a natural flood management scheme.

At present, most other ecosystem services potentially associated with the water environment (e.g. local climate regulation, genetic resources, species diversity, pollination) are not specifically measured, paid for or delivered as an ecosystem service. Rather they are delivered incidentally in the course of other activities.

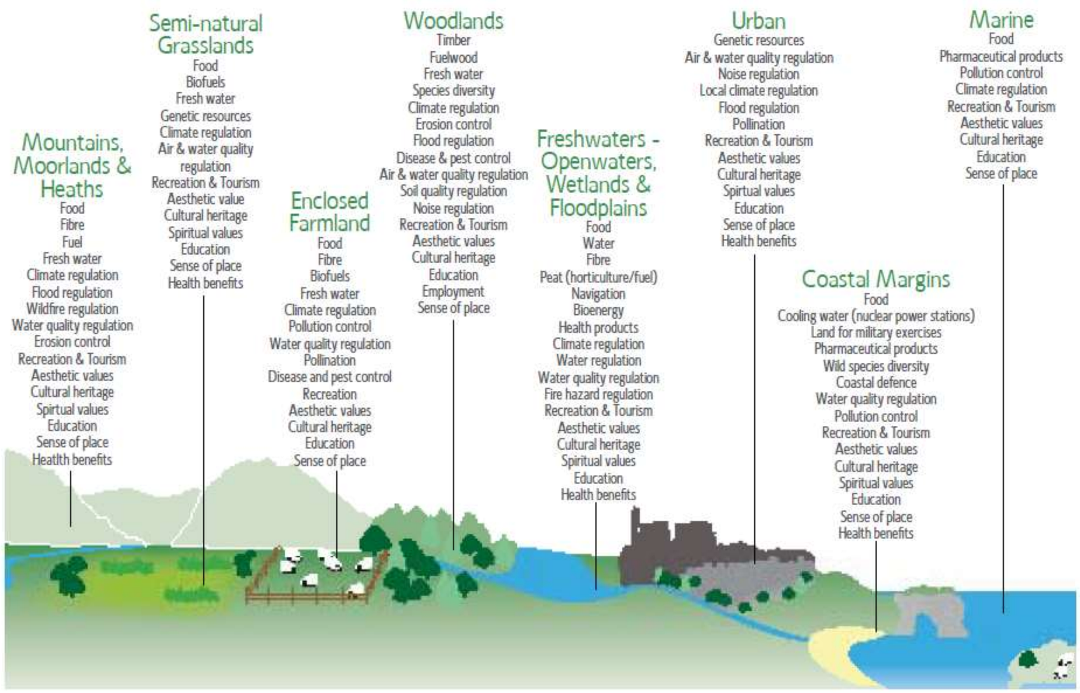


Figure 32. Examples of the ecosystem services derived from the eight Broad Habitat types in the UK National Ecosystem Assessment[7].

[7]Smith, S., Rowcroft, P., Everard, M., Couldrick, L., Reed, M., Rogers, H., Quick, T., Eves, C. and White, C. (2015). Payments for Ecosystem Services: A Best Practice Guide. Updated edition. Defra, London.

Box 1: Biodiversity offsetting

While construction of domestic houses, warehouses, railways, roads may incorporate biodiversity considerations within their design, they may still result in some biodiversity loss. The Natural Choice, the Government's Natural Environment white paper emphasises that one way to compensate for this loss is through biodiversity offsetting whereby the project developer secures compensatory habitat elsewhere. The Natural Choice defines biodiversity offsets as "conservation activities designed to deliver biodiversity benefits in compensation for losses in a measurable way". A market-based approach to biodiversity offsetting involves landowners registering their wildlife sites so as to provide conservation or offset 'credits' which can then be purchased by project developers to offset their biodiversity impacts. Offsets can involve habitat expansion (creation) or restoration and offset providers must provide additional benefits: offsets cannot be designed simply to maintain current habitat extent or condition.

PES differs somewhat from biodiversity offsetting. PES can be distinguished by a particular focus on the 'beneficiary pays principle', whereby the beneficiaries of ecosystem services provide payment to the providers of ecosystem services. Conversely, biodiversity offsetting incorporates an element of the 'polluter pays principle', since developers pay for the provision of compensatory habitat expansion or restoration elsewhere.

8.4 Biodiversity offsetting

A pilot scheme paying for habitat protection and creation for a protected species, the Great Crested Newts, has been established by NatureSpace Partnership and local authorities in the project area, implementing a form of offsetting (Box 1). Note that offsetting differs from Payment for Ecosystem services, being more analogous to the 'polluter pays' principle of damage mitigation.

8.5 Current status of the Ock natural environment ecosystem services

8.5.1 Introduction

This section briefly summarises the status of the water environment in the Ock catchment as far as is known. For brevity, the main focus is on Water Framework Directive data which summarises the monitoring programme conducted by the Environment Agency on the principal river and stream water bodies. As is normal for most of the rest of the UK landscape, the ecological quality of other surface freshwaters (ponds, lakes, headwater streams and ditch networks) is not routinely monitored although there is evidence of habitat quality from a range of sources not discussed here.

Environment Agency water chemistry monitoring data is not discussed in detail as to a substantial extent this is captured in the Water Framework Directive headline summaries. The citizen science nutrient pollution monitoring programme piloted in the Ock catchment by Freshwater Habitats Trust is reviewed as it provides a perspective on the whole of the water environment which is not readily available in other sources. Although this is so far a one-off pilot, and the rapid test kits used do not provide the same level of precision as laboratory analysed water samples, technically credible data, which is of sufficient quality to be published in peer-reviewed scientific papers, can be obtained this method (e.g. McGoff et al, 2016, and see Appendix.

8.5.2 Status of Ock waterbodies

All waterbodies in the Ock catchment, except for the Good status Sandford Brook, are classified as Moderate or Poor. The classifications have generally got slightly worse over time as more biological quality elements have been added. This is probably because all sites initially had invertebrate data, which generally provide the most optimistic picture of waterbody condition, and as more water plant, diatoms and fish data have become available a less optimistic picture has generally emerged.

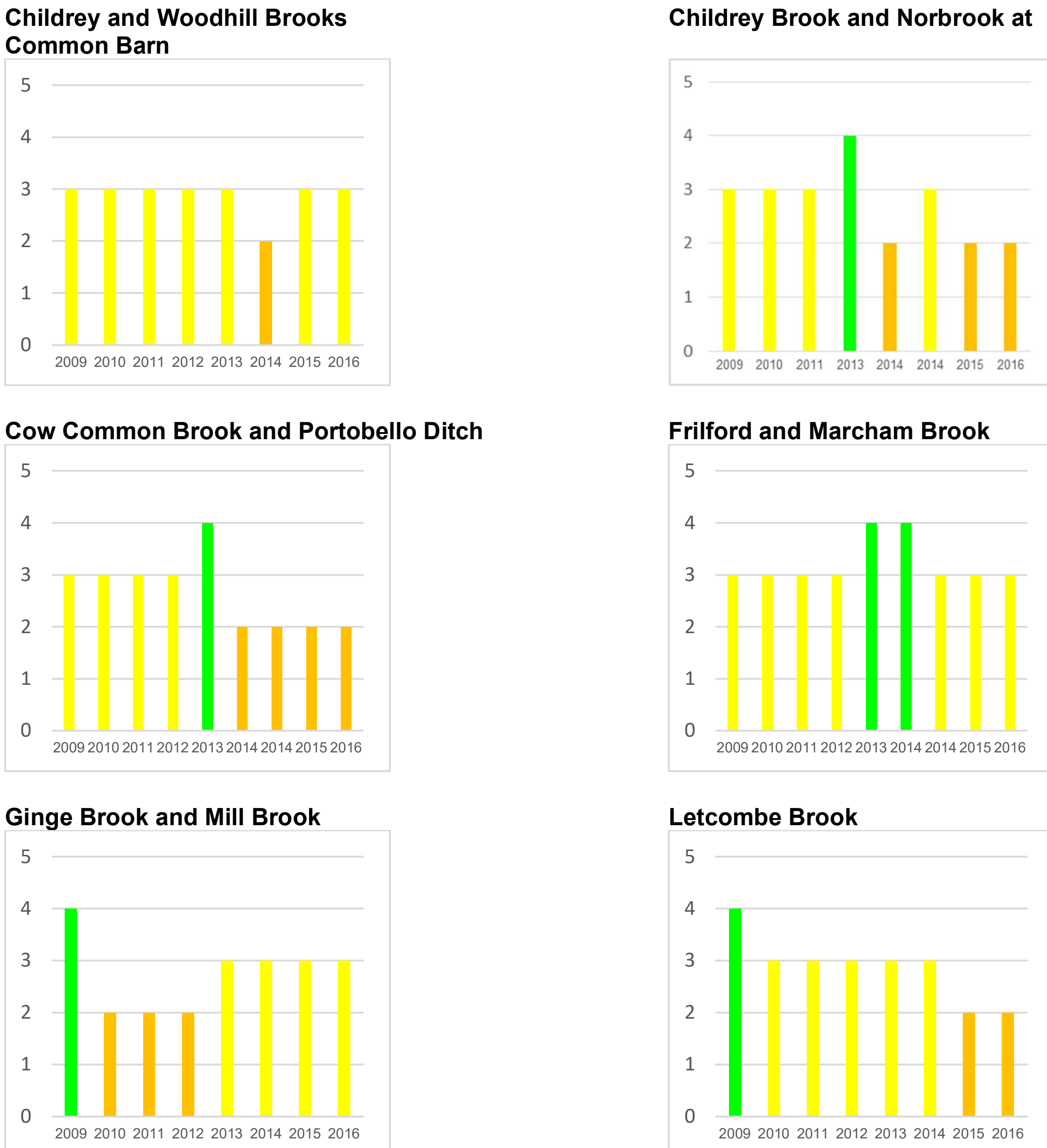
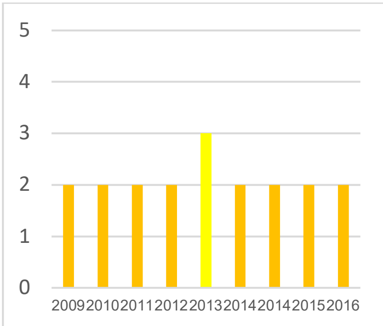
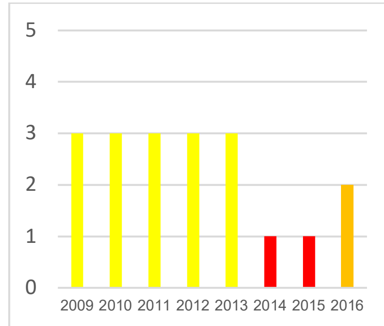


Figure 33. WFD status changes with time in the R. Ock catchment. Note that year to year variation is a combination of the increasing number of metrics included in the analysis combined with actual positive or negative quality changes.

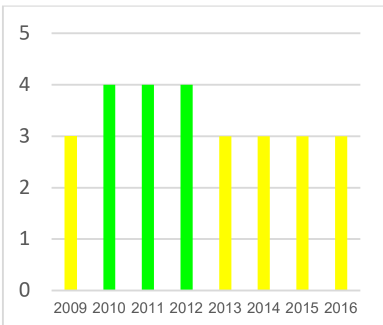
Moor Ditch and Ladygrove Ditch



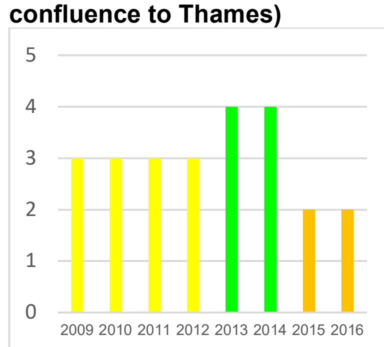
Northfield Brook (Source to Thames) at Sandford



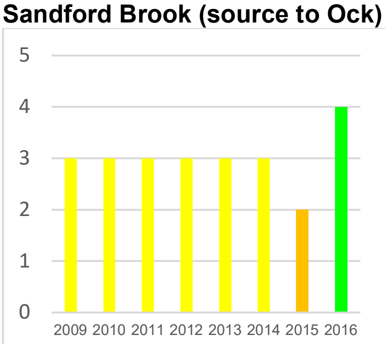
Ock (to Cherbury Brook)



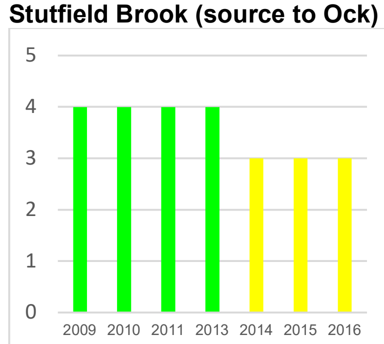
Ock and tributaries (Land Brook confluence to Thames)



Sandford Brook (source to Ock)



Stutfield Brook (source to Ock)



Thames (Evenlode to Thame)

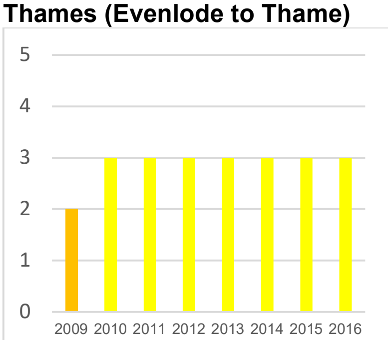


Figure 33 (continued). WFD status changes with time in the R. Ock catchment. Note that year to year variation is a combination of the increasing number of metrics included in the analysis combined with actual positive or negative quality changes.

8.6 Ock water quality at landscape level

Detailed data on water quality are available for water bodies included in Environment Agency monitoring programmes. However, many smaller waters and wetlands are not monitored although they collectively make a significant contribution to the water environment in the catchment. The pilot Clean Water for Wildlife survey run by Freshwater Habitats Trust in 2016 provided an initial overview of broad patterns of nutrient pollution in the catchment.

The R. Ock catchment is typical of much of lowland England in that clean water is largely confined to ponds and lakes, within high quality fens (SACs and SSSIs), some ditches and some headwater streams in woodland. An important use of the test kits is to indicate the extent of clean water in landscapes where their distribution was not previously identified, and to provide a rapid overview of the water quality of the whole catchment.

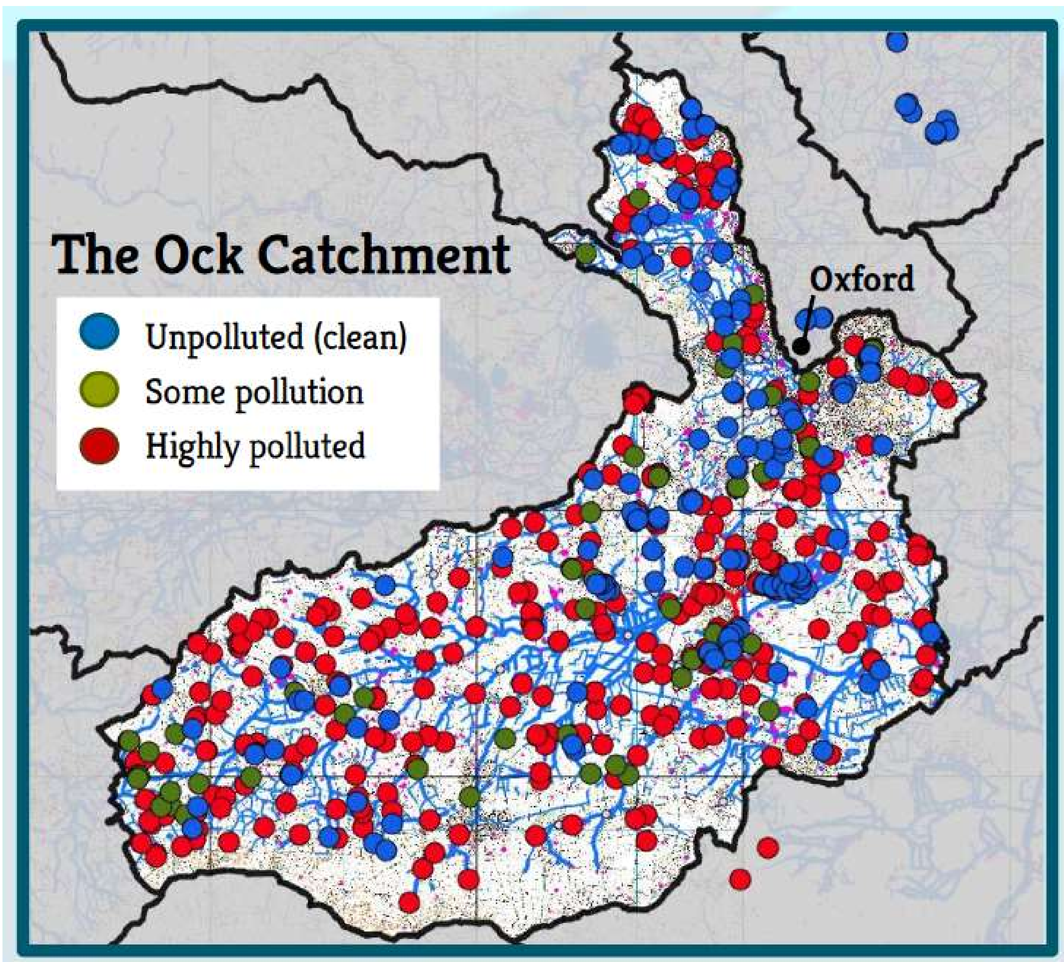


Figure 34. Clean Water for Wildlife case study: the R. Ock catchment, Oxfordshire. Waterbodies surveyed include a representative mixture of rivers, streams, ponds, lakes, ditches and canals. The number of locations with of clean water in this catchment contrasts substantially with more semi-natural landscape, like the New Forest (Appendix Figure 2).

The Clean Water for Wildlife data are publically accessible on the project website at: https://www.waternet.org.uk/explore-data/clean-water-wildlife/. Data can be uploaded at this location. Landscape level views of the results are also accessible (Figure 27).

Figure 35. A landscape view of a small part of the Ock catchment near Baulking showing water quality differences between streams, ditches, ponds and a lake.

The relatively simple data of the Clean Water for Wildlife data can be used to give broad overviews of water quality at catchment and landscape level.

Such maps can give a broad indication of landscape which are 'clean' in terms of phosphorus. In the Ock catchment there are a surprising number of such locations although most of these areas are also affected by high levels of nitrogen pollution (Figure 36)

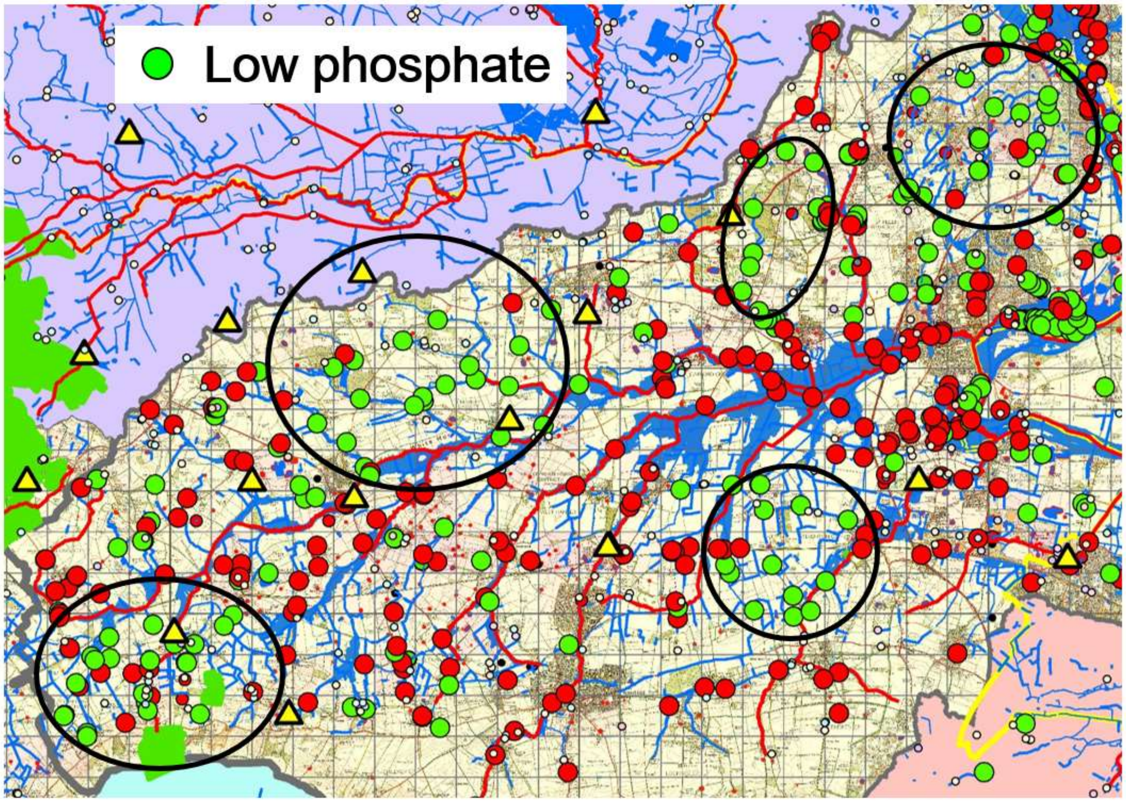


Figure 36. Concentrations of high and low phosphate waterbodies in the Ock catchment. Sites which are coloured green are locations with low non-biologically damaging nutrient levels (see Biggs et al. 2017[8]). Sites in red are those with moderately or highly polluting phosphate levels. Concentrations at green sites are broadly equivalent to High or Good status under WFD. Yellow triangles show the location of sewage treatment works.

[8]Clean Water for Wildlife Technical Manual available at: https://freshwaterhabitats.org.uk/wp-content/uploads/2015/10/CWfWTechnicalDocumentFINAL.pdf.

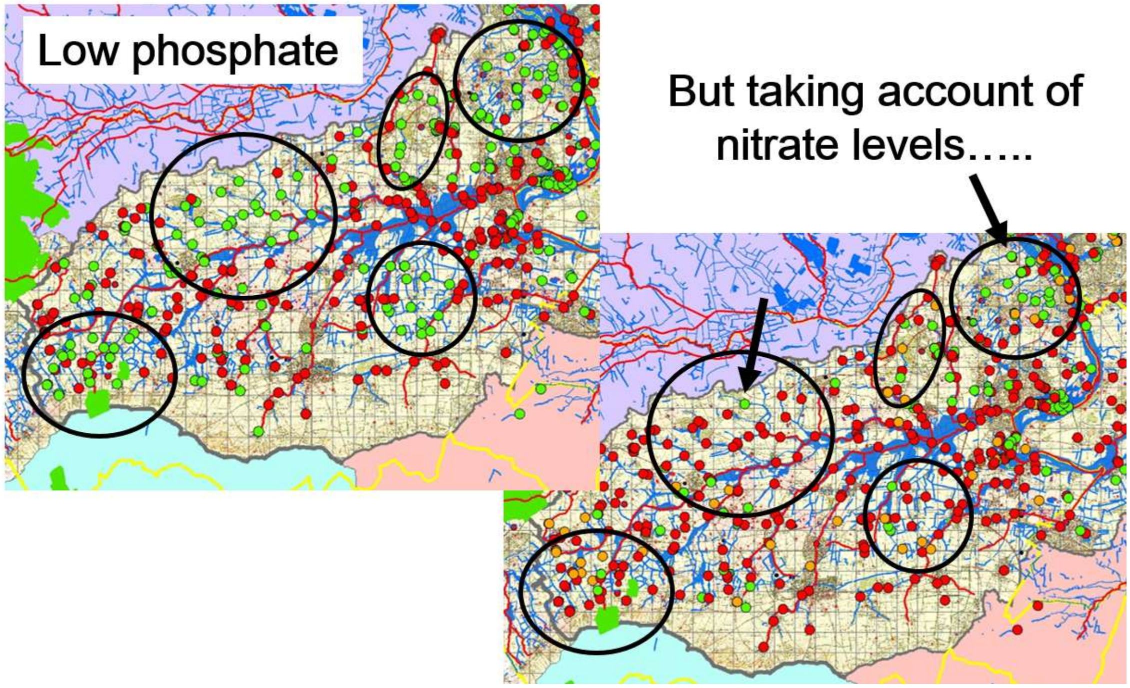


Figure 37. Site which have both low levels of phosphate and nitrate (bottom right picture). This shows that in the Ock catchment water free from nutrient pollution is largely restricted to woodland headwaters, ponds, lakes and some fens.

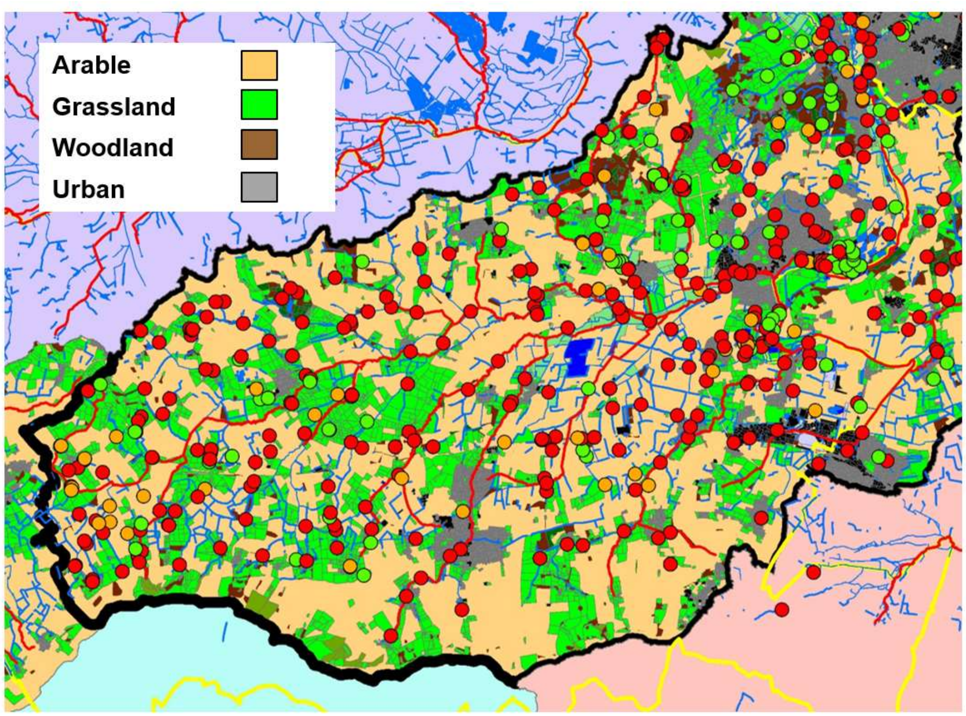


Figure 38. Relationship between landuse and the occurrence of clean water in the Ock catchment. Circles show water free from nutrient pollution (green) or polluted by either nitrate or phosphate, assessed using the 2016 Ock Clean Water for Wildlife pilot dataset.

8.7 Invertebrate assemblages in the R. Ock catchment: long-term trends

Evaluation of the condition of the Ock catchment watercourse using WFD data provides one perspective on the state of the water environment. Useful additional detail can be derived by looking further into these datasets. One example of this approach is to consider in more detail the longest running of the biological datasets, that provided by monitoring of freshwater invertebrates. Results shown here are derived from the publically accessible archive of invertebrate monitoring data at https://ea.sharefile.com/share/view/s9a5d086dee7425d8.

Most watercourses in the R. Ock catchment have shown stable or increasing ASPT values over the last 25 years. ASPT (Average Score per Taxon) broadly reflects the impact of organic pollution and suggests that efforts to reduce organic pollution have led to positive change in stream invertebrate communities (Table 9, Figure 39). ASPT is an index – it uses invertebrates to provide an indication of how near-to-natural the fauna of streams and rivers is. It is not in itself a measure of diversity, but more a reflection of the proportion of the fauna represented by animals needing high levels of oxygen. It is broadly reflective of diversity – higher ASPT values will be found at sites with the widest variety of invertebrates.

Interestingly, the measure of biodiversity – NTAXA, the number of invertebrate families present shows a surprisingly contrasting trend to that of ASPT. Here, slightly over half of the monitored sites in the Ock catchment have shown a downward trend in number of invertebrate families. Even at sites where ASPT has increased, there is usually no concomitant increase in the number of invertebrate families, which is what would be expected. Even as water has been getting cleaner, the variety of invertebrates present has not changed, or has gone down. The causes of these changes are not known although it is possible that non-organic pollution, loss of habitat diversity and predation by non-native crayfish could all be involved.

Table 9. Summary of ASPT and NTAXA changes in the R. Ock catchment from 1990 to 2016/17

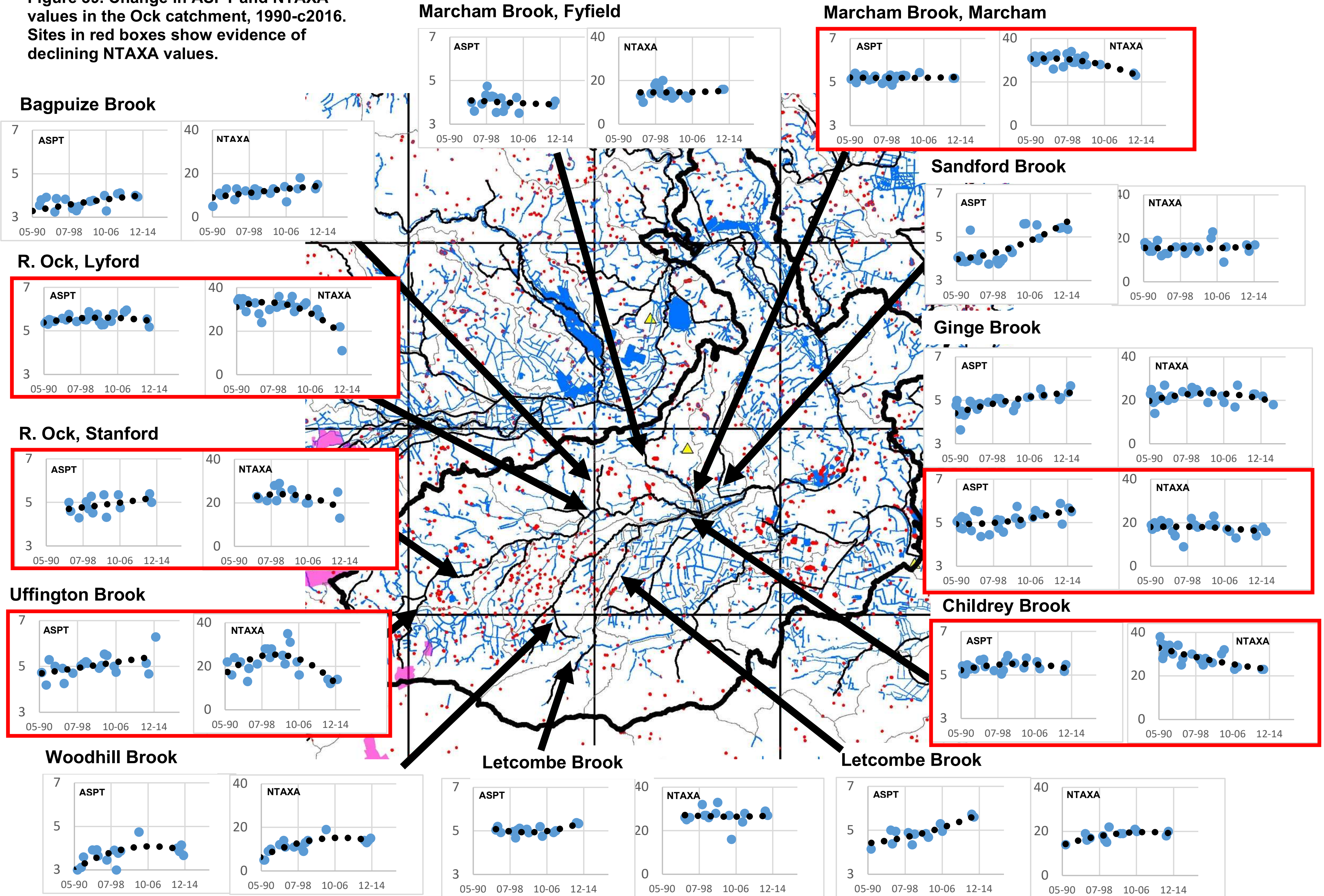
ASPT values: change from 1990-2016/17	**No. of waterbodies in Ock catchment**	**WFD invertebrate assemblage status**				
		Bad	Poor	Moderate	Good	High
Increased	8	-	-	1	2	3
Stable	5	-	-	-	3	2
Decreased	-	-	-	-	-	-

NTAXA values: : change from 1990-2016/17	**No. of waterbodies in Ock catchment**	**WFD invertebrate assemblage status**				
		Bad	Poor	Moderate	Good	High
Increased	3	-	-	1l	-	1
Stable	4	-	-	-	2	2
Decreased	6	-	-	-	3	2

Habitat managed for NFM may help to reverse the trends seen in invertebrate diversity, if implemented on a sufficiently large scale. The most likely intervention to achieve this is widespread addition of wood into the streams and rivers. There is some recent evidence that this is a technique which can increase the abundance and possibly diversity of invertebrates in streams.

It should be noted that adding wood to streams has to overcome the cultural hurdle, long and deeply ingrained, of removing anything from rivers and streams that appears to be blocking or slowing the flow.

Figure 39. Change in ASPT and NTAXA values in the Ock catchment, 1990-c2016. Sites in red boxes show evidence of declining NTAXA values.



8.8 Ecosystem services potentially provided by the Ock catchment

The following sections summarise the main ecosystem services which could be provided by the landscape of the R. Ock. Table 11 shows the broad list of services identified in the UK Millennium Ecosystem Assessment. Table 12 is the more detailed list of services included in the Environment Agency Appraisal Summary Table for capturing impacts on Ecosystem Services (provided by Viviana Levy).

Table 12 shows the ecosystem services for which data are known to be, or are likely to be available, for the Ock catchment. Those highlighted in green are discussed in more detail in this version of the report. Those highlighted in red have yet to be obtained. Those not marked are unlikely to be assessable with currently available data.

Table 11. The Millennium Ecosystem Assessment classification of ecosystem services

Provisioning

- Fresh water
- Food (e.g. crops, fruit, fish, etc.)
- Fibre and fuel (e.g. timber, wool, etc.)
- Genetic resources (used for crop/stock breeding and
- Biochemicals, natural medicines, pharmaceuticals
- Ornamental resources (e.g. shells, flowers, etc.)

Regulatory services

- Air quality regulation
- Climate regulation (local temperature/precipitation, greenhouse
- Water regulation (timing and scale of run-off, flooding, etc.)
- Natural hazard regulation (i.e. 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, etc.
- Social relations (e.g. fishing, grazing or cropping communities)

Supporting services

- Soil formation
- Primary production
- Nutrient cycling
- Water recycling
- Photosynthesis (production of atmospheric oxygen)
- Provision of habitat

Table 12. Summary of ecosystem services being evaluated. Boxes highlighted in green indicate services for which data are available and have been initially reviewed. Boxes in red indicate services for which data are available but have not been included in this report.

Ecosystem Service	Description of the Ecosystem Service	Guidance on what to include in the baseline description in the AST	Data sources which could be used to assess the service in the Ock catchment, and brief comments on service
Fresh water	The storage and retention of water for domestic, industrial and agricultural use by current and future generations. This water will help meet economic and societal needs of communities. This ecosystem service also covers water and waste treatment which in turn leads to improvement in the fresh water available.	How significant is water use/abstraction from these water bodies? Consider reliance (alternative sources?) and number of users as well as future trends. Avoid double counting with 'Food' services. What is the baseline water quality? What are the baseline waste treatment facilities in the catchment? How would the measures change the quality or quantity of freshwater available for use by, for example, domestic users? Under this ecosystem service, measures such as for point source pollution, dealing with misconnections and abstractions might apply, and diffuse pollution measures such as the use of wetlands to remove phosphate and sediment which would lead to an improvement in the freshwater available for users.	**Water use and abstraction** • Water not available for licensing (CAMS strategy). **Reliance on water** • Need is generally increasing in the Ock catchment. **Baseline water quality** • Assess with monitoring data • Assess unmonitored waters with additional information from citizen surveys **How would the measures change the quality or quantity of freshwater available for use by, for example, domestic users**? • Reduced nitrogen losses: would make water more useable for drinking water abstraction. • Reduced minor toxicants: would make water more useable for drinking water abstraction. • STW improvements: would contribute to, but not on its own, achieving Good/High status under WFD.
Food (e.g. crops, fruit, fish etc.)	Floodplains are naturally fertilised and therefore are amenable to seasonal grazing by livestock and arable production. Waterbodies also support commercially significant	What is the make up of agricultural land in the area - e.g. Quality/Grade and type of food produced. What is the relationship with water (e.g. mainly rain-fed pasture or crops which are reliant on irrigation abstracted from water bodies)? Are there fisheries (commercial or otherwise) which	**Agricultural land** • Agricultural land is mainly Grade 3 and 4. **Agricultural relationship with water** • Agriculture mainly rain-fed. There are some area of horticultural cropping in the Frilford area.

	fisheries (salmon, trout, crayfish, etc). Other harvested crops may include: fruit, berries, fungi and nuts	provide a food resource? (Avoid double counting with more recreational-based angling i.e. coarse fishing or catch and release). Are shellfish harvested in the area?	**Fisheries as food resource** • None.
Fibre and fuel (e.g. timber, wool, etc.)	Fibre may include skins, wool, reeds, leather, cotton and straw. Fuel sources may include timber (willow, popular, etc), firewood, turf and biomass.	Is there substantial water-dependent fibre and fuel production locally? Examples might include commercial forestry or coppiced forest products or peat mining for horticulture. Consider production of raw material rather than industrial process which would fall under 'Fresh Water'. Also consider whether it is a primary material or more of a by-product (leather, wool) to avoid double counting e.g. where it is a by-product of food production this should be considered under the food production service.	**Water-dependent fibre and fuel production** • None **Wool** • Sheep are farmed but wool has almost no market value at present. **Commercial forestry** • Yes
Biochemicals, natural medicines, pharmaceuticals	Includes natural medicines and pharmaceuticals. These may be from known valuable agents such as salicylic acid (willow bark), fungal extracts, and local herbal remedies.	Is there a major production of raw material for the biochemical/pharmaceutical industry? Could this be affected by our plans for the water environment?	**Biochemicals, natural medicines, pharmaceuticals** • None
Ornamental resources (e.g. shells, flowers, etc.)	The provision of pebbles, gravel, cobbles and sand. Also Includes insectivorous (carnivorous) plants,	Assume that ornamental refers to the final use and doesn't include aggregate industry for construction for example. Is there a major source or a particularly valued area of extraction	**Ornamental resources (e.g. shells, flowers, etc.)** • None

	bulrushes and other plants of decorative interest. Also includes fossils.	(e.g. fossil hunting on the Jurrasic coast) which could be affected by our plans for the water environment?	
Water for non-consumptive use	The provision of water that is used for energy generation (hydroelectric, cooling for thermoelectric such as fossil fuel and nuclear plants), Navigation and Transport which may help sustain economic and population growth.	Are there major energy generation facilities reliant on the waterbody? Consider future uses such as fracking. Are the rivers, lakes, harbours and ports used for navigation. Avoid double counting with recreational effects such as pleasure boating and canoeing.	**Energy generation facilities with consumptive water use** • None
Air Quality regulation	Waterbodies may assist in the settlement of aerial particulates (including dirt, dust and soot) and the metabolism of pollutants (such as SOX, NOX and Ozone). Climatic improvements (suppressed wind speeds) may occur on some sites depending on the nature of the site.	Note that the effects of the plan on Air Quality have been scoped out of the SEA as not likely to have significant effects. However, it is possible that some large-scale catchment measures could have a positive effect and therefore should be considered in the AST. Are there known air quality issues associated with car use, industry, etc, for example, are any Air Quality Management Areas present? Likely to be an issue in larger urban areas and industrial zones. What is the relationship between the river corridor (vegetation in particular) and local air quality?	**Air quality** • Farming derived ammonia and other nitrogen pollution sources.

Climate regulation (local temperature/ precipitation, greenhouse gas sequestration)	Decisions we make in the RBMP could have implications for climate regulation. Individually these are likely to be relatively minor, but cumulatively they will be more significant. Consider the use of fossil fuels associated with pumping and mechanical cleaning of water for example. Also, certain habitats (e.g. forests, peat bogs, lake sediments) can be a net store of carbon which can also be if these habitats deteriorate; or provide additional storage if they are restored or added to. In addition, plants play an important part in local temperature and humidity regulation (in particular riparian shading).	Are there any major peat deposits or large lakes and are these capturing carbon or releasing it? Peat bogs release carbon as they dry out/decompose. Do waterbodies (such as large lakes, wetland areas) have an effect on the local microclimate? Is there riparian shading that is having an effect on the local temperature along a water body? Could these be influenced by decisions we take for the water environment? Consider the long-term use of fossil fuels (e.g. pumping) in any decisions.	**Note that in this section some data have been obtained (peat land extent, riparian shading) but others are not yet available.** **Peat land** • The catchment has small areas of peatland, although some known minor deposits are not yet mapped. **Current water environment emissions** • Emissions can be estimated but data not yet obtained. **Large waterbodies** • Emissions can be estimated but data not yet obtained. **Riparian shading** • Most of the rivers are unshaded, as indicated by the JBA WWNP processes maps of opportunities for tree planting.

Water regulation (timing and scale of run-off, flooding, etc.)	This may be defined as the influence the ecosystem has on the timing and magnitude of water runoff, flooding, and aquifer recharge, particularly in terms of the water storage potential of the ecosystem or landscape.	Run-off is high in urban and built-up areas. Land use and different agricultural practices have an influence on run-off and groundwater recharge which in turn can influence flood risk. Agricultural soils are often drained to avoid water logging. Consider the current and future land use and how this impacts on run-off and flood risk.	**Storage of water in the catchment** • Changing landuse to reduce runoff is a core objective of the NFM project. • Using the datasets currently available further evaluation by modelling will be needed to assess effects of landuse change on water regulation.
Natural hazard regulation (i.e. storm protection)	Natural hazards are assumed to mainly include storms and gales. Other natural hazards such as earthquakes are not frequent enough to be considered in the assessment. To avoid double-counting, more general flooding is captured under 'Water Regulation'.	Do any existing environmental features provide protection from natural hazards (e.g. Sand Dunes and salt marshes?).	n/a
Erosion regulation	The regulation or prevention of negative effects of erosion (such as impoverishing of soil and increased sedimentation of water bodies) by promoting sediment stabilisation and soil retention.	Is soil erosion an issue in the catchment? e.g. peat erosion in some upland areas. Is sedimentation of rivers/lakes an issue? It is worth remembering that erosion is also a natural feature for example on rivers and the coast and provides important habitat for some species.	**Sedimentation** • Typical soil erosion processes occur in the Ock catchment. Data on sediment loads are not readily available. It may be possible to derive estimates of background sediment losses from modelling.

Water purification and waste treatment	Freshwater systems can dilute, store and detoxify waste products and pollutants. This ecosystem service is about the the ability for the ecosystem to self purify.	What is the baseline water quality? Are there natural systems such as reedbeds and salt marshes that perform a water purification function? This ecosystem service could include measures such as wetland and reedbed creation, buffer strips, etc. The measures that lead to a change in this ecosystems service will tend to involve more natural treatment methods for dealing with diffuse pollution.	**Baseline water quality** • Data are available, and summarised in WFD and landscape information. **Self-purification mechanisms** • Evaluation of self-purification mechanisms requires detailed modelling. This analysis would be a major part of developing and assessing the benefits of an NFM scheme.
Cultural heritage	Includes sites of historical significance such as Scheduled Ancient Monuments, Listed Buildings, Heritage Coasts, World Heritage Sites, Battlefields and territorial boundaries. Data can be found on Easimap (EA Staff) or English Heritage's Online Mapping (Public) http://list.english-heritage.org.uk/	All catchments will contain cultural heritage features. It is important to identify those features which could be influenced by proposed measures to improve the water environment. These could be for example visible historical features such as weirs and structures adjacent to water bodies which may be affected by measures to improve status, or areas of preserved deposits, the conservation of which could be influenced by water-level management measures.	**Historic river structures** • Mills: data obtained. **Historic landscapes** • Oxford Historic Landscape Characterisation project data obtained.
Recreation and tourism	Includes recreational fisheries, iconic species (rare birds, flowers or amphibians), swimming, boating, kayaking, etc.	All catchments contain recreation assets. Therefore focus on assets which could be affected by measures to improve the water environment. Consider the relative value/use of the resource compared to other assets elsewhere.	**Boating** Data not yet obtained. Ock catchment has a small proportion of the income associated with the Thames boating business.

Aesthetic value	Includes designated landscapes such as National Parks and Areas of Outstanding Natural Beauty (AONB). Also covers waterscapes, landscapes and other areas valued for their beauty or distinctiveness and the visual amenity they provide to people.	Consider the presence of designated landscapes (National Parks, Heritage Coasts, AONBs), cityscapes and areas of high visual amenity.	**AONBs** • North Wessex Downs map data available. **National Parks** • None
Spiritual and religious value	Freshwaters may be sites of historical baptisms and religious festivals.	Are water bodies in the catchment used for religious or spiritual festivals? Are they any sites which are highly valued by a religious or spiritual group? Consider documenting in baseline if measures to improve the water environment could affect these features?	**Spiritual and religious value** • None in the Ock catchment for traditional religions.
Intellectual and scientific, educational	Lake, floodplain and mire sediment sequences contain palaeo-environmental archives and human (pre)history, artefacts that may be lost if disturbed or desiccated. Freshwater and Marine ecosystems are important outdoor laboratories. Consider visitor centres, research facilities.	Applies particularly to highly-valued habitats (such as designations) where there is likely to be most research (bird counting on SPAs etc) but also habitats that are close to urban areas or have research facilities nearby and tend to be used by educational establishments. Sites owned by RSPB, WFWT often have a lot of educational facilities.	**Intellectual and scientific, educational** Water related education at the following centres: • Earth Trust • Sutton Courtney Education Centre • Wytham Woods (ponds part of education/science interest) • Oxford University including Field Station • Archaeology of floodplain gravels: important resource • Freshwater Habitats Trust

Inspiration of art, folklore, architecture, etc	Water bodies have been focal points in the landscape for societies for hundreds of years due to their importance in trade, travel and food etc and have and continue to be inspiration in all forms of art.	Is there a prominent artistic community for which landscape (including the water environment) is a significant inspiration.	**Inspiration of art, folklore, architecture** • Not assessed.
Existence Values	The value that individuals place on knowing that a resource exists, even if they never use that resource.	Are there designated habitats or species that are valued by society even where they don't necessarily provide a great deal of other services? It might be that they are not that visible or accessible to people. Examples might include Arctic Char, fresh water pearl mussels, or a rare mountain plant community.	**Designated sites and species** Data area available: • SSSIs • SACs • LNRs • Private sites • Undesignated sites • Mapping by Freshwater Habitats Trust has characterised the presence of valuable freshwater species across the landscape.
Social relations (e.g. fishing, grazing or cropping communities)	Ecosystems influence the types of social relations that are established in particular cultures. Fishing societies, for example, differ in many respects in their social relations from urban or agricultural societies.	Is there a particular community which is centred on/reliant on water? Examples might include fen-based communities in East Anglia or fishing communities on the coast.	**Social relations** • There is a social community associated with navigation and boating, mainly associated with the Thames. No data have been obtained on this ecosystem service.

Soil formation	Soil forms through a slow process of weathering rock through physical and chemical action and the incorporation of organic material from decaying plants and animals. Land use (e.g. agriculture, forestry) influences soil formation. The action of water (e.g. erosion, leaching, river/coastal silt deposition, etc) is also an important part of soil formation.	Are there active soil formation process evident in the catchment? Is their degradation of the existing soil resource associated with e.g. agricultural practices.	**Soil formation** • Soil formation occurs in all landscapes. However it is probably outweighed by degrading processes associated with agriculture at present. Data are not yet available.
Primary production (in river)	Primary production in river refers to the growth of plants and algae (primary producers). In-river is assumed to include marginal and bank side vegetation.	Does the river and habitats associated with it contribute to primary production? Consider any proposed changes in the catchment when describing the baseline.	**Primary production** • The water environment contributes to primary production but this contribution has not yet been assessed. • Data specific to the catchment are available for the R. Thames but not for other parts of the catchment.
Nutrient cycling	Flow of nutrients (e.g., nitrogen, sulphur, phosphorus, carbon) through ecosystems.	Water is a fundamental component in the cycling of nutrients. How much of a role do the waterbodies play in the cycling of nutrients?	**Nutrient cycling** • Not yet assessed though data may be available.
Water recycling	Flow of water through ecosystems in its solid, liquid, or gaseous forms.	Evaporation/transpiration by plants is a key component in the water cycle. What are the current strategic influences on the water cycle. Consider any proposed changes in in the catchment when describing the baseline.	**Water recycling** • Holding back water in the catchment will lead to increased evaporation/transpiration. • Not yet assessed.

Photosynthesis (production of atmospheric oxygen)	Process by which carbon dioxide, water, and sunlight combine to form sugar and oxygen. The rate of photosynthesis will be dependent on the extent of vegetation and their ability to use available sunlight which will be limited by other factors including water, temperature and CO2 concentration.	Describe the type and extent of vegetation present. Consider any proposed changes in in the catchment when describing the baseline.	**Photosynthesis (production of atmospheric oxygen)** • Not yet evauated.
Provision of habitat	Includes designated habitats such as National Nature Reserves (NNR), Sites of Specific Scientific Interest (SSSI), Local Nature Reserves (LNR). These designation can be viewed on mapping at Easimap (internal EA) or www.magic.gov.uk (Public). Also BAP Priority Habitats (see http://jncc.defra.gov.uk/page-5706). Includes habitat connectivity and green infrastructure.	Describe the diversity of habitats and species in the catchment. Are there valued wetland habitats such as saltmarsh, raised bogs, fens, reedbeds, river corridors? Consider any proposed changes in in the catchment when describing the baseline.	**Provision of habitat** • Mapped in the Ock catchment Important Freshwater Areas project.

8.9 Hydrogeology and agriculture

The Ock catchment is dominated by four main agricultural landscape classes (Figure 40 and Table 13):

- Landscape 6: Pre-Quaternary Clay landscapes
- Landscape 7: Chalk and Limestone plateaux and coombe valleys
- Landscape 1: River floodplains and low terraces
- Landscape 3: Sandlands.

Addtionally there is a smaller area of pre-Quaternary loam landscape. These landscape are characterised in terms of main soil types, the dominant waterbody types, the depth to groundwater and the dominant flow direction (i.e. horizontal or vertical) (see Table 13 and Brown et al. 2006):

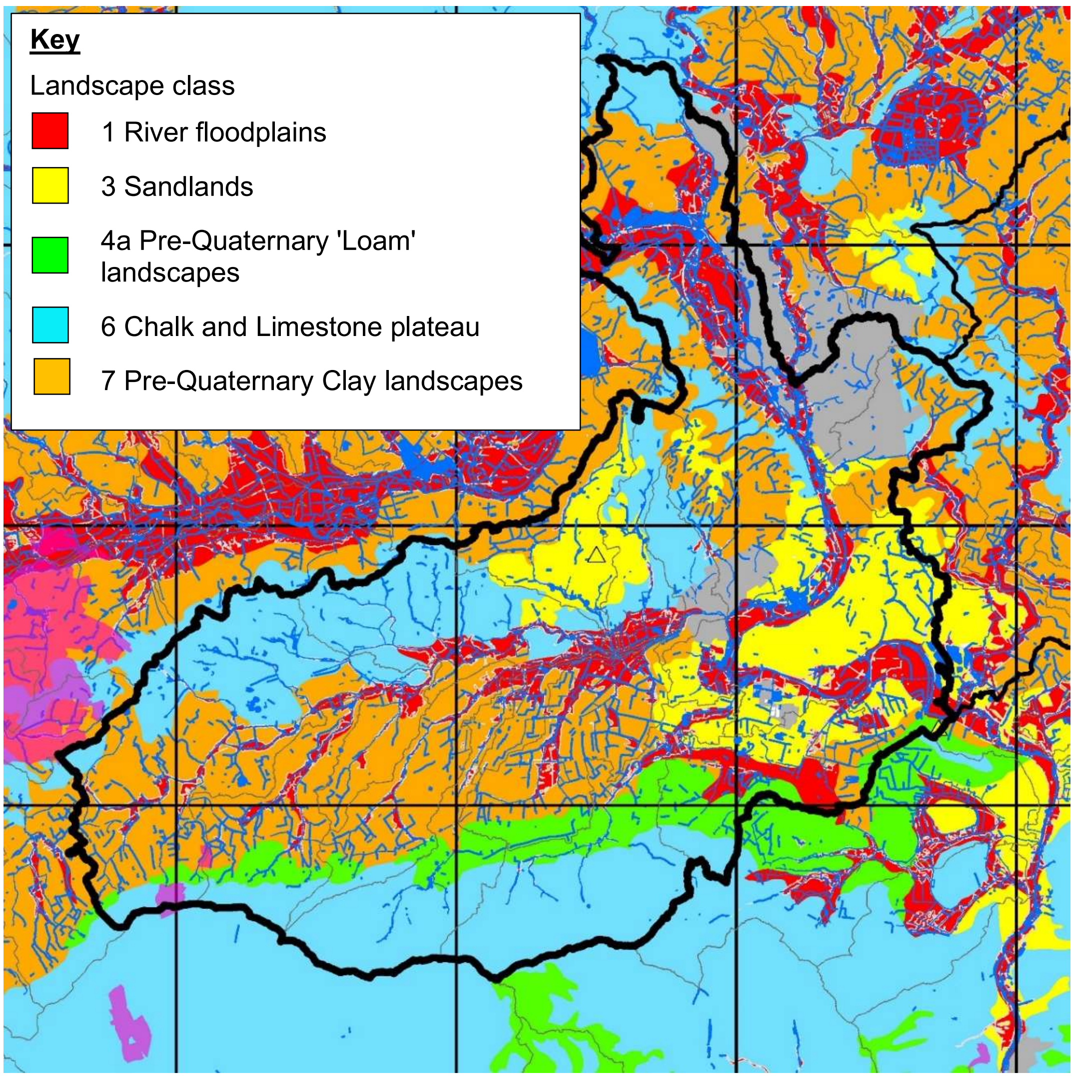


Figure 40. Agricultural landscape classes of the Ock catchment. For key see

Physical characterisation of British landscape classes

No.	Landscape	Description	Total area (km^2)	Dominant waterbodies	Groundwater	Dominant water flow
1	River floodplains and low terraces	Level to very gently sloping river floodplains and low terraces	7781	Rivers, streams, ponds and some ditches	Normally present at <2 m depth	Vertical
2	Warplands, fenlands and associated low terraces	Level, broad 'flats' with alluvial very fine sands, silts, clays and peat	9017	Ditches and rivers	Normally present at <2 m depth	Vertical or saturated lateral
3	Sandlands	Level to moderately sloping, rolling hills and broad terraces. Sands and light loams	10871	Rivers (and some ponds and streams) in low lying areas	Normally present at >2 m depth	Vertical
4	Till landscapes (eutrophic)	Level to gently sloping glacial till plains. Medium loams, clays and chalky clays, with high base status (eutrophic). Some lighter textured soils on outwash	22151	Ditches, streams, ponds and rivers	Generally none present	Predominantly saturated lateral
5	Till landscapes (oligotrophic)	Level to gently sloping glacial till plains. Medium loams and clays with low base status (oligotrophic). Some lighter textured soils on outwash	15449	Ditches, streams, ponds and rivers	Generally none present	Predominantly saturated lateral
6	Pre-quaternary clay landscapes	Level to gently sloping vales. Slowly permeable, clays (often calcareous) and heavy loams. High base status (eutrophic)	19706	Ditches, streams, ponds and rivers	None present	Saturated lateral
7	Chalk and limestone plateaux and coombe valleys	Rolling 'wolds' and plateaux with 'dry' valleys. Shallow to moderately deep loams over chalk and limestone	14197	Rivers, and possibly seasonal streams	Present at >2 m depth	Vertical
8	Pre-quaternary loam landscapes	Gently to moderately sloping ridges and vales and plateaux. Deep, free-draining and moderately permeable silts and loams	10072	Streams, ponds and rivers; possibly some ditches locally	None present	Saturated lateral
9	Mixed, hard, fissured rock and clay landscapes	Gently to moderately sloping hills, ridges and vales. Moderately deep free-draining loams mixed with heavy loams and clays in vales	12259	Streams and rivers with ponds in clay areas	Either none or present at >2 m	Saturated lateral; some vertical over groundwater
10	Hard rock landscapes	Gently to moderately sloping hills and valleys. Moderately deep free-raining loams over hard rocks. Some slowly permeable heavy loams on lower slopes and valleys	23342	Streams and rivers	None	Lateral along rock boundaries
11	*Scotland only*: moundy morainic and fluvioglacial deposits	Gently and moderately sloping mounds, some terraces. Free-raining morains, gravels and sands on mounds, poorly draining gleys in hollows	2270	Streams and rivers	Variable	Vertical over groundwater; some saturated lateral
12	*Scotland only*: footslopes with loamy drift	Concave slopes or depressional sites, often with springlines	1081	Streams and rivers, occasional ditches		
13	Non-agricultural	All areas not cultivated with arable (including orchards, soft fruit and horticultural) or maintained grassland	79690	Ditches, streams, ponds and rivers	Variable	Variable

Table 13. Physical characteristics of British agricultural landscape classes (from Brown et al, 2006[9]). PUT INTO AN APPENDIX.

[9]Brown, C. D., N. Turner, J. Hollis, P. Bellamy, J. Biggs, P. Williams, D. Arnold, T. Pepper & S. Maund, 2006. Morphological and physico-chemical properties of British aquatic habitats potentially exposed to pesticides. Agriculture, Ecosystems and Environment 113: 307–319.

8.10 Agricultural land quality

Agricultural land is mainly Land Classes 3 and 4, with higher quality Land Class 2 on the chalk and limestone soils of the fringes of the catchment (Figure 41).

The categories are:

- Grade 1 - excellent quality agricultural land. Land with no or very minor limitations to agricultural use. A very wide range of agricultural and horticultural crops can be grown and commonly includes top fruit, soft fruit, salad crops and winter harvested vegetables. Yields are high and less variable than on land of lower quality.

- Grade 2 - very good quality agricultural land. Land with minor limitations which affect crop yield, cultivations or harvesting. A wide range of agricultural and horticultural crops can usually be grown but on some land in the grade there may be reduced flexibility due to difficulties with the production of the more demanding crops such as winter harvested vegetables and arable root crops. The level of yield is generally high but may be lower or more variable than Grade 1.

- Grade 3 - good to moderate quality agricultural land. Land with moderate limitations which affect the choice of crops, timing and type of cultivation, harvesting or the level of yield. Where more demanding crops are grown yields are generally lower or more variable than on land in Grades 1 and 2.

  Subgrade 3a - good quality agricultural land. Land capable of consistently producing moderate to high yields of a narrow range of arable crops, especially cereals, or moderate yields of a wide range of crops including cereals, grass, oilseed rape, potatoes, sugar beet and the less demanding horticultural crops.

  Subgrade 3b - moderate quality agricultural land. Land capable of producing moderate yields of a narrow range of crops, principally cereals and grass or lower yields of a wider range of crops or high yields of grass which can be grazed or harvested over most of the year.

- Grade 4 - poor quality agricultural land. Land with severe limitations which significantly restrict the range of crops and/or level of yields. It is mainly suited to grass with occasional arable crops (e.g. cereals and forage crops) the yields of which are variable. In moist climates, yields of grass may be moderate to high but there may be difficulties in utilisation. The grade also includes very droughty arable land.

- Grade 5 - very poor quality agricultural land. Land with very severe limitations which restrict use to permanent pasture or rough grazing, except for occasional pioneer forage crops.

More information on the Agricultural land classification is available at: http://publications.naturalengland.org.uk/file/5526580165083136.

We recommend that NFM measures are targeted on grassland sites as these are generally poorer grade agricultural land, and therefore less likely to be growing high value crops which are intolerant of flooding.

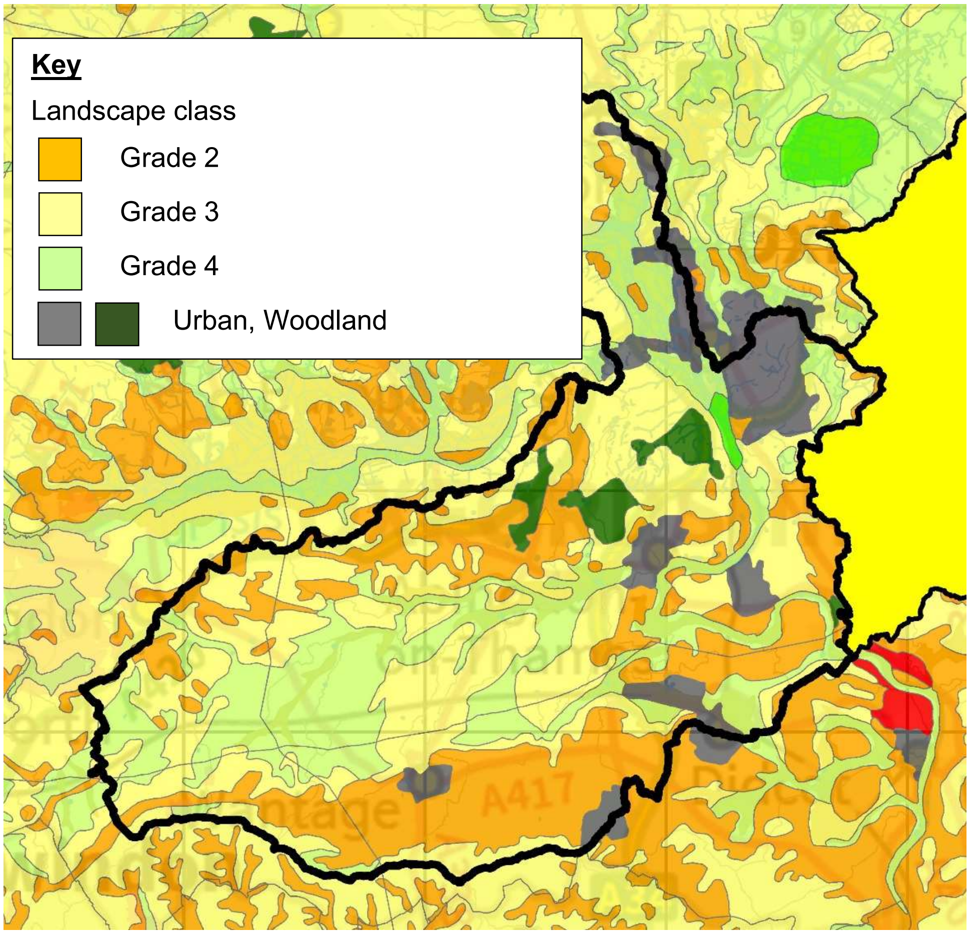


Figure 41. Agricultural landscape classes of the Ock catchment.

8.11 Soils and soil carbon

8.11.1 Soils

Soils data has currently only been accessed from the publically available Soilscapes mapping portal at the University of Cranfield which provides a low resolution version of the National Soils Map (Figure 42).

The predominant soil types in the area are:

- Soilscape 20: Loamy and clayey floodplain soils with naturally high groundwater
- Soilscape 18: Slowly permeable seasonally wet slightly acid but base-rich loamy and clayey soils
- Soilscape 5: Freely draining slightly acid loam rich soils
- Soilscape 3: Shallow lime-rich soils over chalk or limestone

More detailed data may be accessible under license to the Environment Agency, and are available commercially.

It would be valuable to explore the availability of this more detailed soil data as part of the engagement with farmers and to understand soil / water relations better.

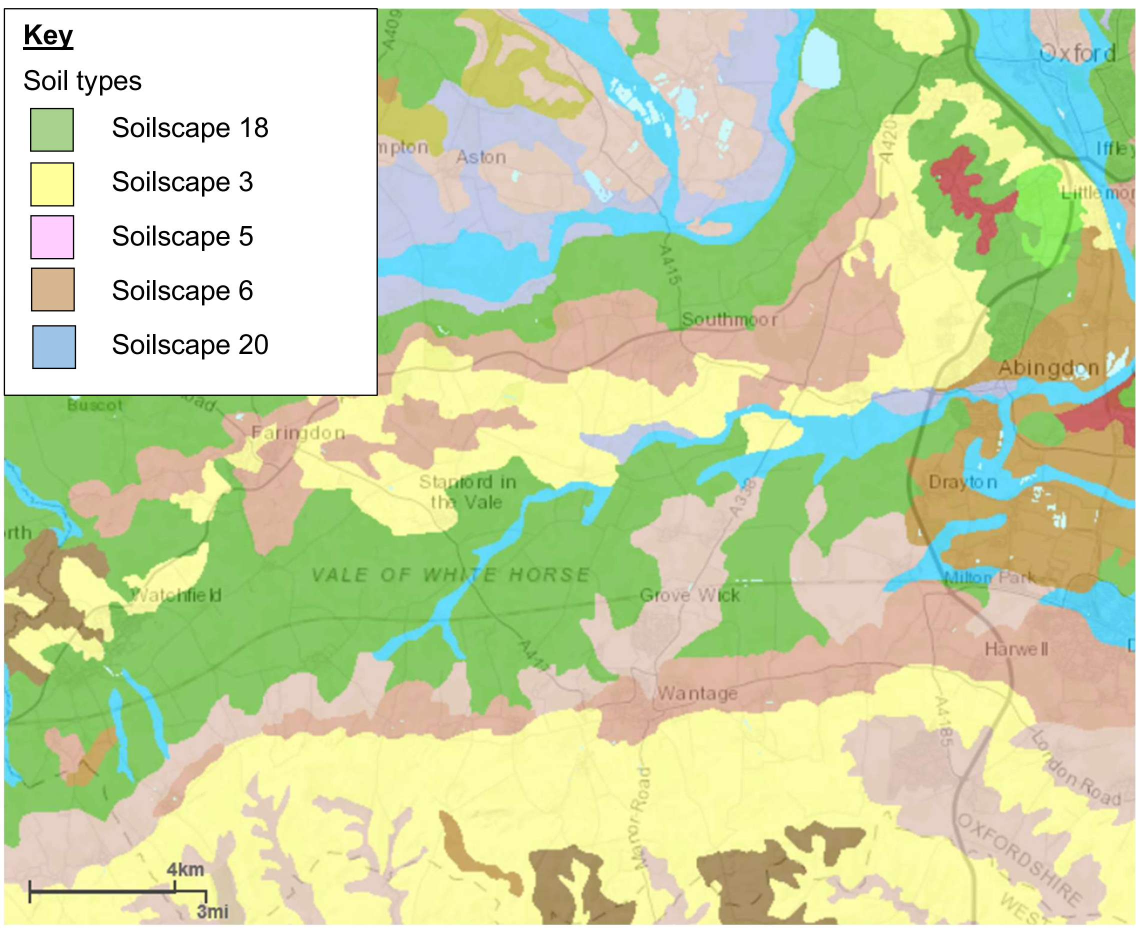


Figure 42. Soil types in the Ock catchment.

8.11.2 Soil carbon

Soil carbon represents a very large proportion of UK carbon stores although most of this is in peat based wetlands (Figure 43).

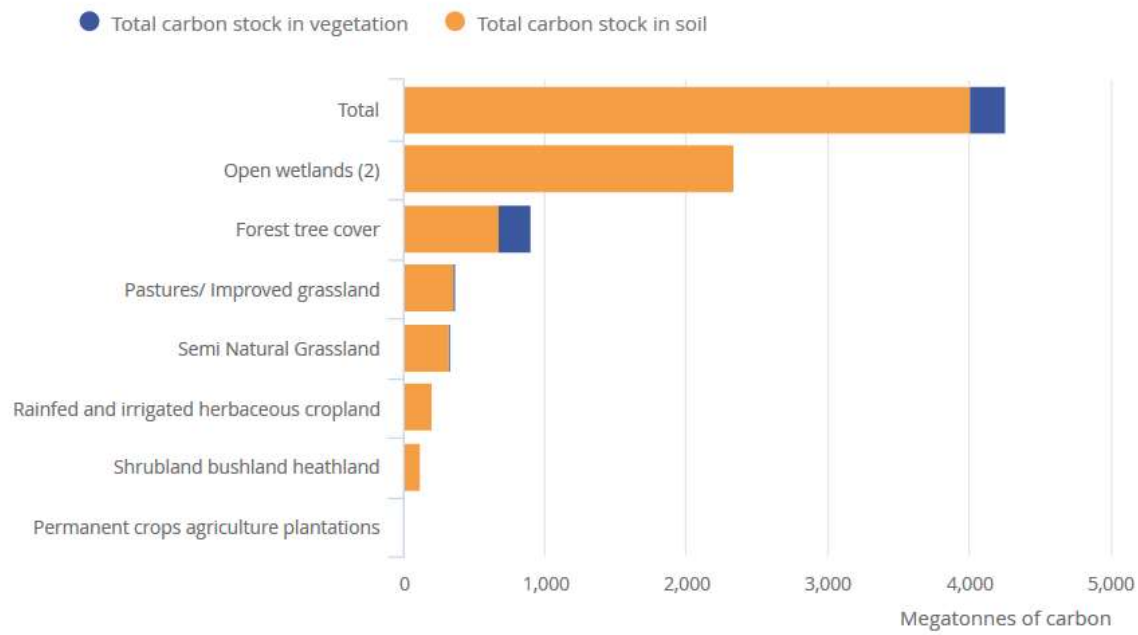


Figure 43. UK biocarbon stock estimates (MtC), by SEEA-EEA habitat class, 2007. Source: Office for National Statistics.

For this reason modifications to soil carbon levels has the potential to generate substantial ecosystem service value, particularly the creation of saturated soils that led to peat generation. Grassland and cropped land in contrast have a relatively low 'carbon density' so make large contributions mainly because of their extent.

A recent meta-analysis of the effects conversion from conventional tillage to low till systems (Haddaway et al. 2017) indicates that the change-over increased soil organic carbon stocks by 4.6 tonnes / hectare.

Estimates of soil carbon stocks in the Ock catchment can be derived from the Countryside Survey. Figure 37 shows the distribution of the two lowland Environmental Zones of the Countryside Survey in the Ock catchment, and mean carbon stocks have been calculated for these landscapes.

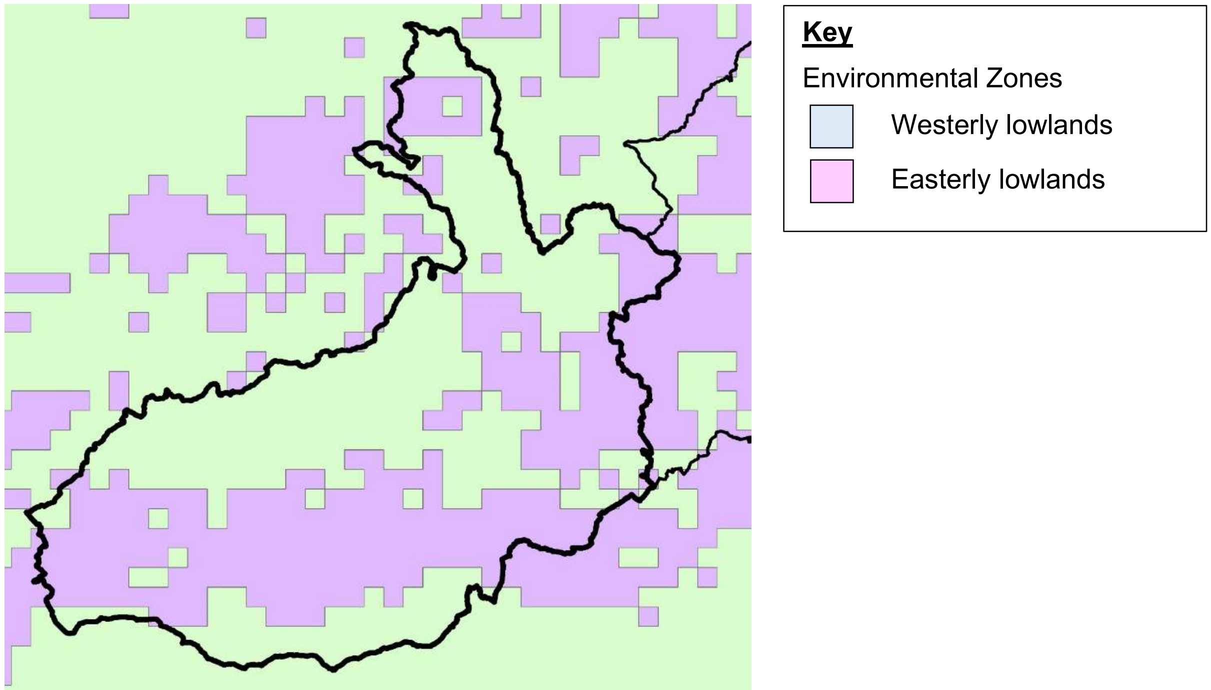


Figure 44. Environmental Zones of the Countryside Survey 2007. Field measured soil carbon estimates are available for these landscape zones.

8.12 Peatland carbon stores

Peatlands are a major store of carbon. Peat is present in the Ock catchment, but in small quantities (too small to be seen easily on a national scale map!) (Figure 45).

We have retained this map because lowland peat is a major concern for Defra: there will be a huge loss of carbon caused by the further degradation of lowland peat, especially in the Fens, which may place a greater premium on peat restoration in other landscape.

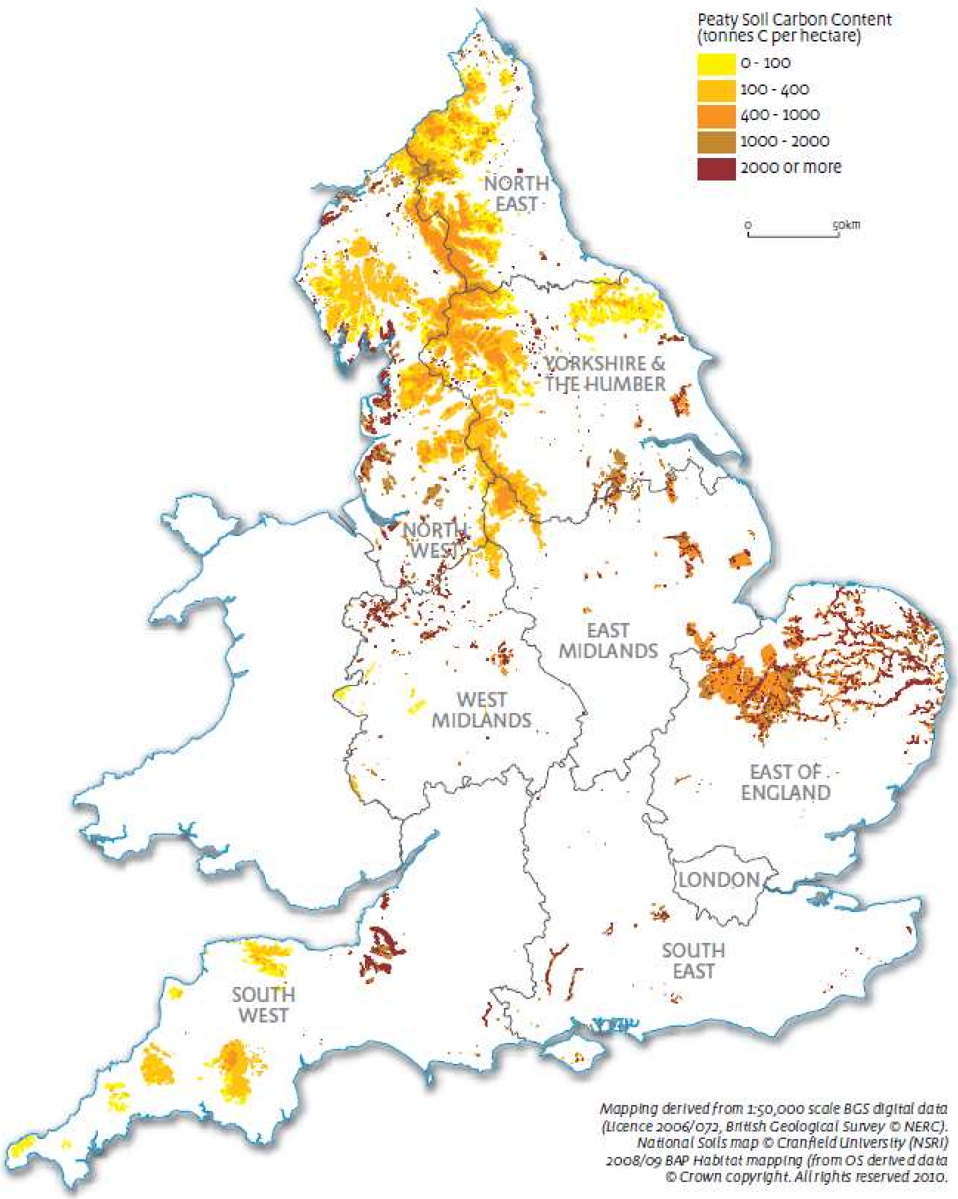


Figure 45. Peatland carbon stores in England. Note that lowland peatland generally has a higher carbon content than most upland blanket peat areas.

8.13 Woodland and trees

The Ock catchment has modest tree cover (Figure 46), most of it in the north-east sandy and acid part of the catchment.

Given the potential for tree planting in the riparian corridor, identified as part of the Environment Agency Working With Natural Processes project (Figure 47), there is potential to considerably increase tree density in the catchment.

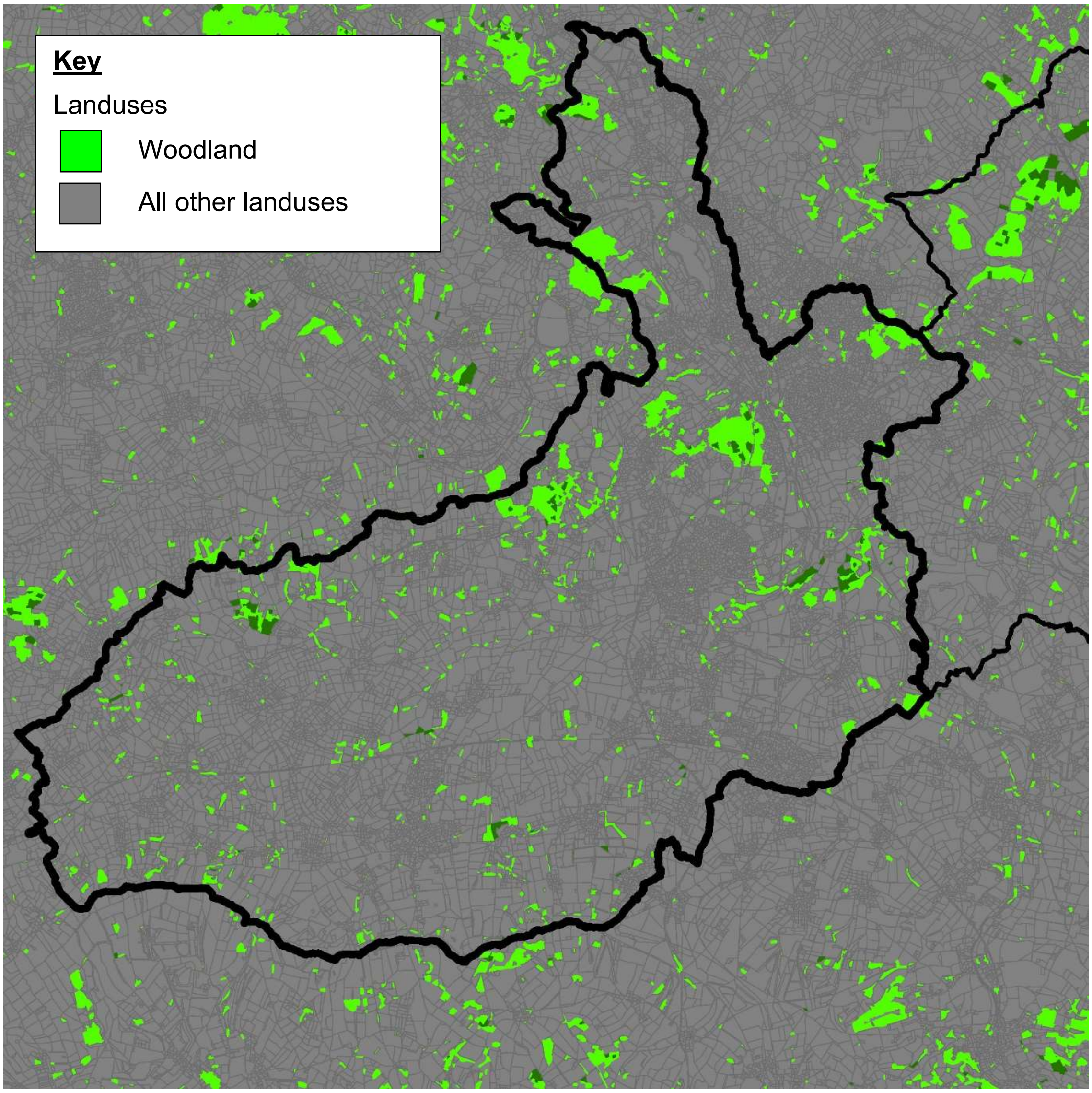


Figure 46. Woodland cover in the Ock catchment. ADD THE KEY

8.13.1 The best types of woodlands for NFM

Woodlands of all types are potentially suiatbale for the application of NFM measures. Woodland as a whole has the potential to reduce runoff simply by intercepting water and, in if large enough areas are present, substantially restore the natural hydrology of whole districts. At smaller scales, woodlands are most likely to provide locations where small-scale meaures can by implemented (woody and leaky dams, floodplain storage, river restoration measures) which may contribute usefully to landscape wide reduction of flood risk.

Woodlands are also important locations for clean water, especially where the whole catchment of a waterbody is contained within the wood.

8.13.2 Value of woodland carbon

The average global price of woodland carbon in January 2014 was £6/tCO_2, although there was wide variation around this figure, depending on the nature of the project. $7.8/tonne (tCO2e) in 2013 according to http://www.forestcarbonportal.com/resource/ahead-of-the-curve-state-of-the-voluntary-carbon-markets-2015.

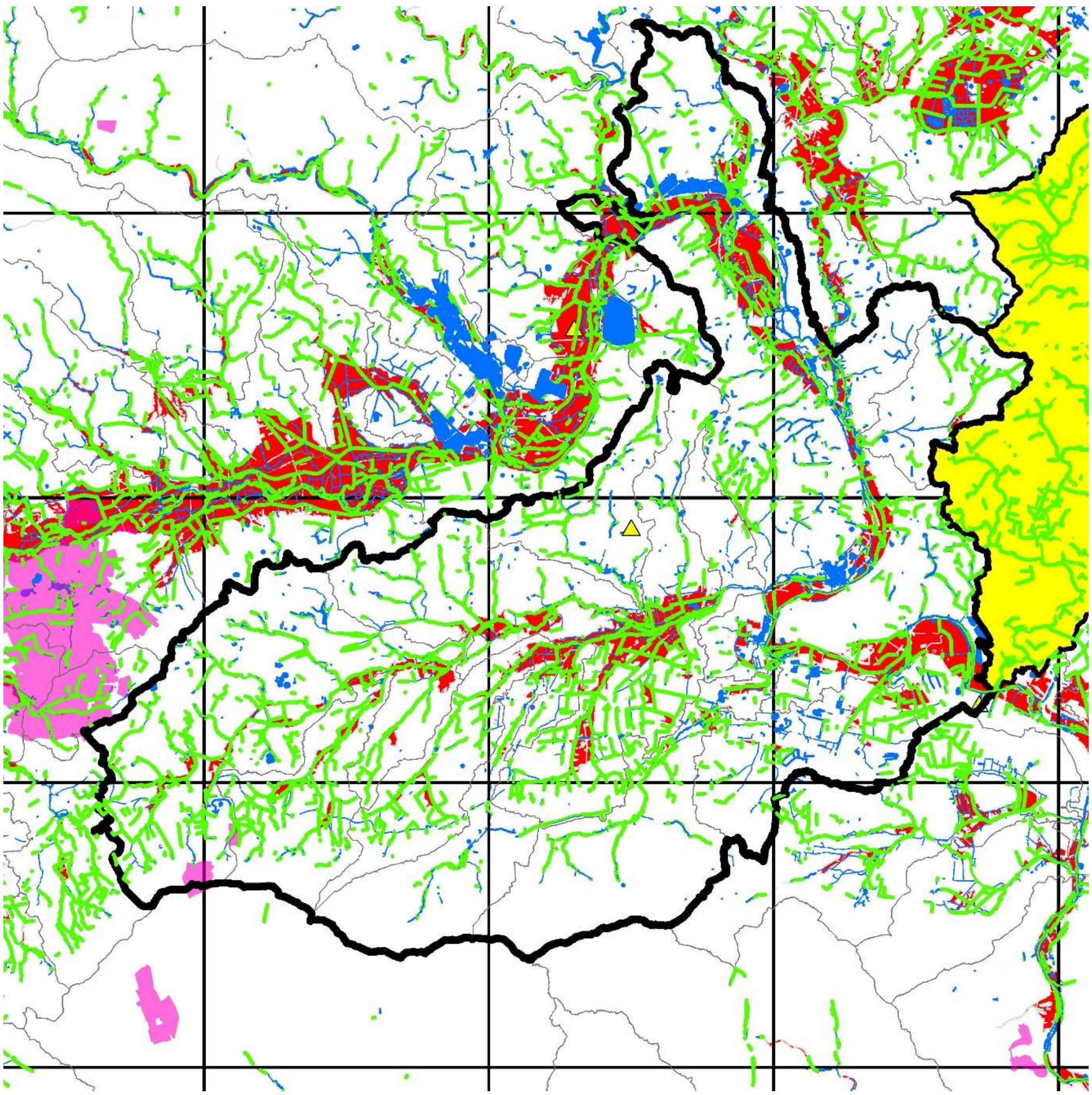


Figure 47. Potential riparian (green) and floodplain (red) planting zones in the Ock catchment as shown in the Working With Natural Processes mapping project.

8.14 Pollination

No data are currently available on pollination services in the R. Ock catchment.

8.15 Recreation

8.15.1 Fishing licenses

Data are currently being sought within the Environment Agency to assess this ecosystem service.

8.15.2 MENE survey.

Data on the number of visits to inland wetlands in England are from the Monitoring of Engagement with the Natural Environment (MENE) survey. This survey is conducted by Natural England on an annual basis. The MENE survey began in 2009 and therefore the data for annual visit are not available for 2008. To estimate the values for 2008, average values for 2009 to 2013 are used. As the visitor data relates to England only, they are scaled up to the UK level using population alone. This is required as there are not comparable data available for 7 England, Northern Ireland, Scotland and Wales. Hence, data for England are used as they would have the largest weighting and the required data were available.
Data on the number of visits to UK open waters are from various sources. The data for England for 2012 are from the MENE survey and, as discussed above, to estimate the values for 2008, average values for 2009 to 2013 are used. The data for Scotland are from the Scottish Recreation Survey and the data for Wales are from the Welsh Outdoor Recreation Survey. Data for Northern Ireland are not available

8.16 Other ecosystem services awaiting detailed review

We have not yet reviewed the following ecosystem services in the Ock catchment.

- Noise regulation
- Food production
- Local climate regulation
- Tranquillity
- Air purification
- Accessible nature
- Green travel.

9. References

Haddaway, N.R., Hedlund, K., Jackson, L.E., Kätterer, T., Lugato, E., Thomsen, I.K., Jørgensen, H.B., Isberg, P.-E., 2017. How does tillage intensity affect soil organic carbon? A systematic review. Environ. Evid. 6, 2–48.

McGoff E, Dunn F, Cachazo LM, Williams P, Biggs J, Nicolet P, et al. Finding clean water habitats in urban landscapes: professional researcher vs citizen science approaches. Sci Total Environ. 2017;581: 105–116.

10. Appendices

10.1 Land cover in the UK

Appendix Table 1: SEEA-EEA Land Cover Account, UK showing the extent of water and wetland habitats in the UK in 1998 and 3007. Values are hectares.

	Opening stock 1998	Additions to stock	Reductions to stock	Net change	Closing stock 2007
Urban and associated developed areas	2,753	175	-104	71	2,825
Rainfed herbaceous crops	4,779	376	-879	-503**	4,275
Permanent crops	114	26	-88	-62*	52
Pastures	5,069	963	-669	295**	5,363
Semi-natural grassland	4,002	670	-515	155*	4,157
Broadleaved, mixed and yew woodland	1,367	137	-43	94**	1,461
Coniferous woodland	1,500	48	-125	-77	1,423
Shrubland, bushland, heathland	1,293	110	-91	19	1,312
Barren land/Sparsely vegetated areas	92	13	-8	5	97
Open wetlands	**2,812**	**211**	**-223**	**-12**	**2,800**
Inland water bodies	**307**	**9**	**-2**	**7***	**314**
Coastal margins	150	7	-4	3	153
Unknown	183	-6	7	2	185
Total	24,419	2,739	-2,742	-3	24,417
Territorial Sea	11,717	-	-	-	11,717
Economic Exclusive Zone (Excluding Territorial waters)	56,624	-	-	-	56,624

Source:
https://www.ons.gov.uk/economy/environmentalaccounts/articles/uknaturalcapitallandcoverintheuk/2015-03-17#land-cover-accounts

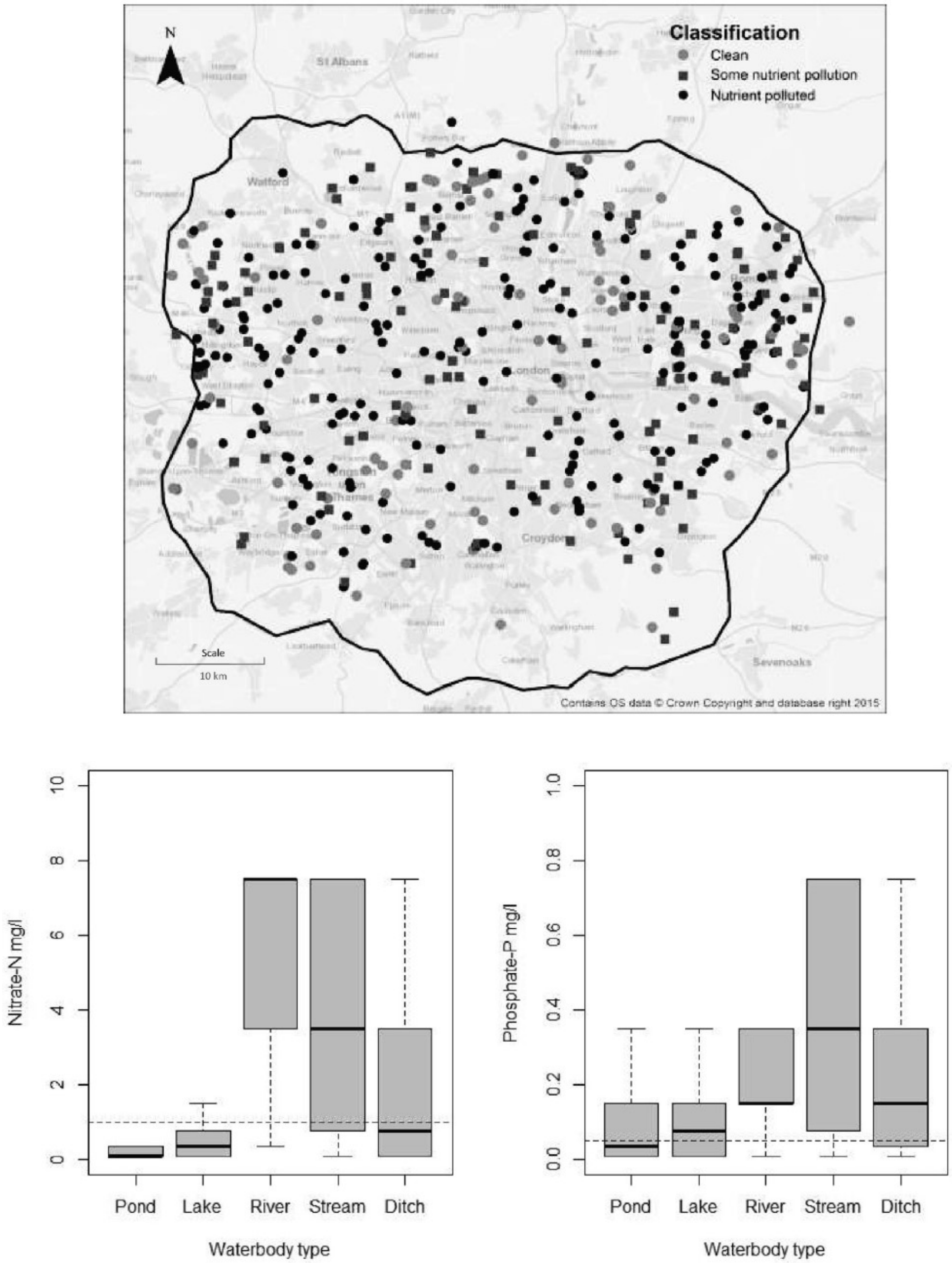
Appendix Table 2: SEEA-EEA Land Cover Account, UK

	Opening stock 1998	Additions to stock	Reductions to stock	Net change	Closing stock 2007
Urban and associated developed areas	2,753	175	-104	71	2,825
Rainfed herbaceous crops	4,779	376	-879	-503**	4,275
Permanent crops	114	26	-88	-62*	52
Pastures	5,069	963	-669	295**	5,363
Semi-natural grassland	4,002	670	-515	155*	4,157
Broadleaved, mixed and yew woodland	1,367	137	-43	94**	1,461
Coniferous woodland	1,500	48	-125	-77	1,423
Shrubland, bushland, heathland	1,293	110	-91	19	1,312
Barren land/Sparsely vegetated areas	92	13	-8	5	97
Open wetlands	**2,812**	**211**	**-223**	**-12**	**2,800**
Inland water bodies	**307**	**9**	**-2**	**7***	**314**
Coastal margins	150	7	-4	3	153
Unknown	183	-6	7	2	185
Total	24,419	2,739	-2,742	-3	24,417
Territorial Sea	11,717	-	-	-	11,717
Economic Exclusive Zone (Excluding Territorial waters)	56,624	-	-	-	56,624

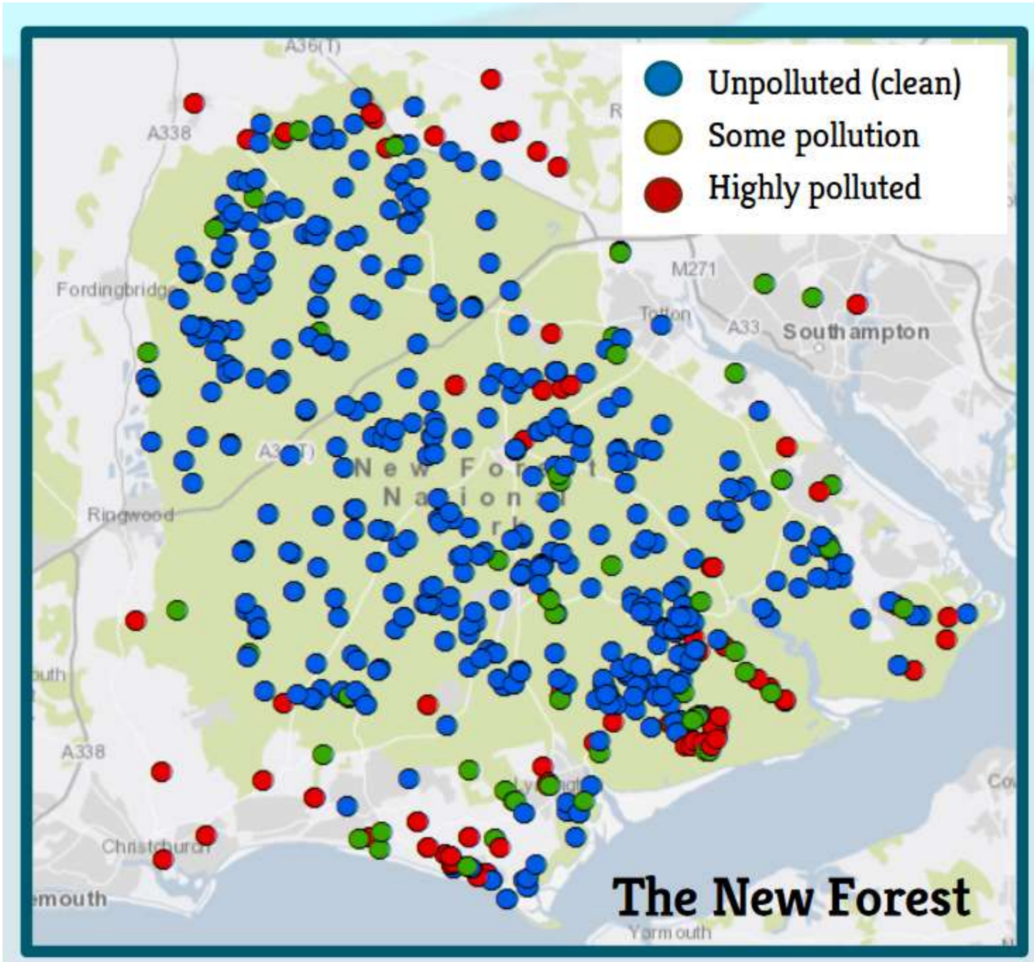
Source:
https://www.ons.gov.uk/economy/environmentalaccounts/articles/uknaturalcapitallandcoverintheuk/2015-03-17#land-cover-accounts

10.2 Citizen science water quality testing in London

In Greater London area inside the M25, McGoff et al. 2016 showed that, although running waters were substantially impacted by nutrient pollution there were still many areas of less polluted water in smaller standing waters, even in this highly managed landscape (Appendix Figure 1).



Appendix Figure 1. (a) Distribution of waterbodies with clean, some nutrient pollution and nutrient polluted water in Greater London; (b) the concentration of nitrate-N and phosphate-P in different waterbody types in Greater London (McGoff et al., 2016).



Appendix Figure 2. Clean Water for Wildlife case study: the New Forest, spring 2016. Waterbodies surveyed include a representative mixture of rivers, streams, ponds, lakes, ditches and canals.