Catchment Based Approach
Partnerships for Action

Natural England Pollution Risk Assessment

RIVER LAMBOURN CATCHMENT

FINAL DRAFT MAY 2017

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Westcountry Rivers Limited (the commercial arm of Westcountry Rivers Trust) are working with Natural England to develop a method for catchment-wide pollution risk and source apportionment assessment. The collaborative approach to developing these assessments will act to facilitate the sharing of data, knowledge and local information with catchment stakeholders and Catchment Based Approach (CaBA) Partnerships.

The Integrated Catchment Based Approach was developed as a framework by Defra in 2009 for improving the water environment at the catchment scale. After a successful pilot phase in 2011, actions were made for the wider adoption and national implementation of CaBA from 2013. As Rivers Trusts now represent catchments across a large part of England and Wales, with new ones continually forming, they are responsible partner hosts for the majority of local CaBA initiatives around the United Kingdom. Key objectives of CaBA are: to deliver positive and sustained outcomes for the water environment by promoting a better understanding of the environment at a local catchment scale;and to encourage local collaboration and more transparent decision-making when both planning and delivering activities to improve the water environment.

CaBA allows local communities, businesses, organisations and other stakeholders to come together to undertake actions or develop projects which incorporate local priorities such as compliance, flood risk management, fisheries and biodiversity.

CaBA will see issues being identified and tackled at a much more local level, giving key stakeholders and local communities the opportunity to get involved.

Westcountry Rivers Ltd is the commercial trading subsidiary of the Westcountry Rivers Trust (charity no. 1135007 company no 06545646). All profits generated through the consultancy are covenanted to the Trust to help secure the preservation, protection, development and improvement of the rivers, streams, watercourses, and water impoundments in the Westcountry and to advance the education of the public in the management of water.

Cover photo: River Lambourn leaving Lynch Wood © Flicker creative commons, 2009.

Written by:

Westcountry Rivers Ltd.
Rain Charm House, Kyl Cober Parc, Stoke Climsland, Callington, Cornwall, PL17 8PH.
Tel: 01579 372140; Email: info@wrt.org.uk; Web: www.wrt.org.uk

Document history:

Revision	Details of Revision	Prepared by	Checked by	Approved by	Date of Issue
Issue v1	1st draft for client comment	James Gilbert Angela Fells			
Issue v2	Final revisions	Angela Fells James Gilbert	Russell Smith		20.01.2017
Issue V3	Final revisions by NE	Helen Wake		Helen Wake	09.05.17

Contents

Abbreviations

CaBA – Catchment Based Approach

CSF – Catchment Sensitive Farming

CSM – Common Standards Monitoring

DWPP – Diffuse Water Pollution Plan

ES – Environmental Stewardship

EWGS - English Woodland Grant Scheme

HES – High Ecological Status

JNCC - Joint Nature Conservation Committee

LOD – Limit of detection

RBMP – River Basin Management Plans

SAC – Special Area of Conservation

SDD – Small Domestic Discharge

SRP – Soluble Reactive Phosphorus

SS – Suspended Solids

SSSI – Site of Special Scientific Interest

TP – Total Phosphorus

UWWTD – Urban Wastewater Treatment Directive

WFD – Water Framework Directive

WwTW –Wastewater Treatment Works

Executive Summary

This is one in a series of Natural England Catchment Risk Assessments which aim to provide evidence-led water quality risk assessments for identified Special Areas of Conservation (SACs), Special Protection Areas (SPAs) and Sites of Special Scientific Interest (SSSIs). These assessments have been developed in partnership with local stakeholders including local authorities, water companies, NGOs, and Catchment Based Approach (CaBA) partnerships. This collaborative working is achieved through two stakeholder workshops, the first to collate local data and evidence, whilst also ground-truthing national data, and a second to disseminate the findings of the report to stakeholders, to facilitate discussion and identify the key evidence from which conclusions are drawn. Through an improved and shared understanding of pollution risks and pressures these assessments enable better coordination and targeting of advice and mitigation measures. These assessments also form the basis for Natural England to update Diffuse Water Pollution Plans.

This report focuses on the River Lambourn, which is designated as a SSSI and SAC and has been identified as failing to meet its water quality targets due, to diffuse and point source pollution pressures. Phosphorus and to a lesser extent sediment have been identified as the main pollution pressures.

The following sections provide a summary, including bespoke targeting maps, to illustrate the key data (monitoring and modelling) from which the main conclusions are drawn for each pollutant pressure.

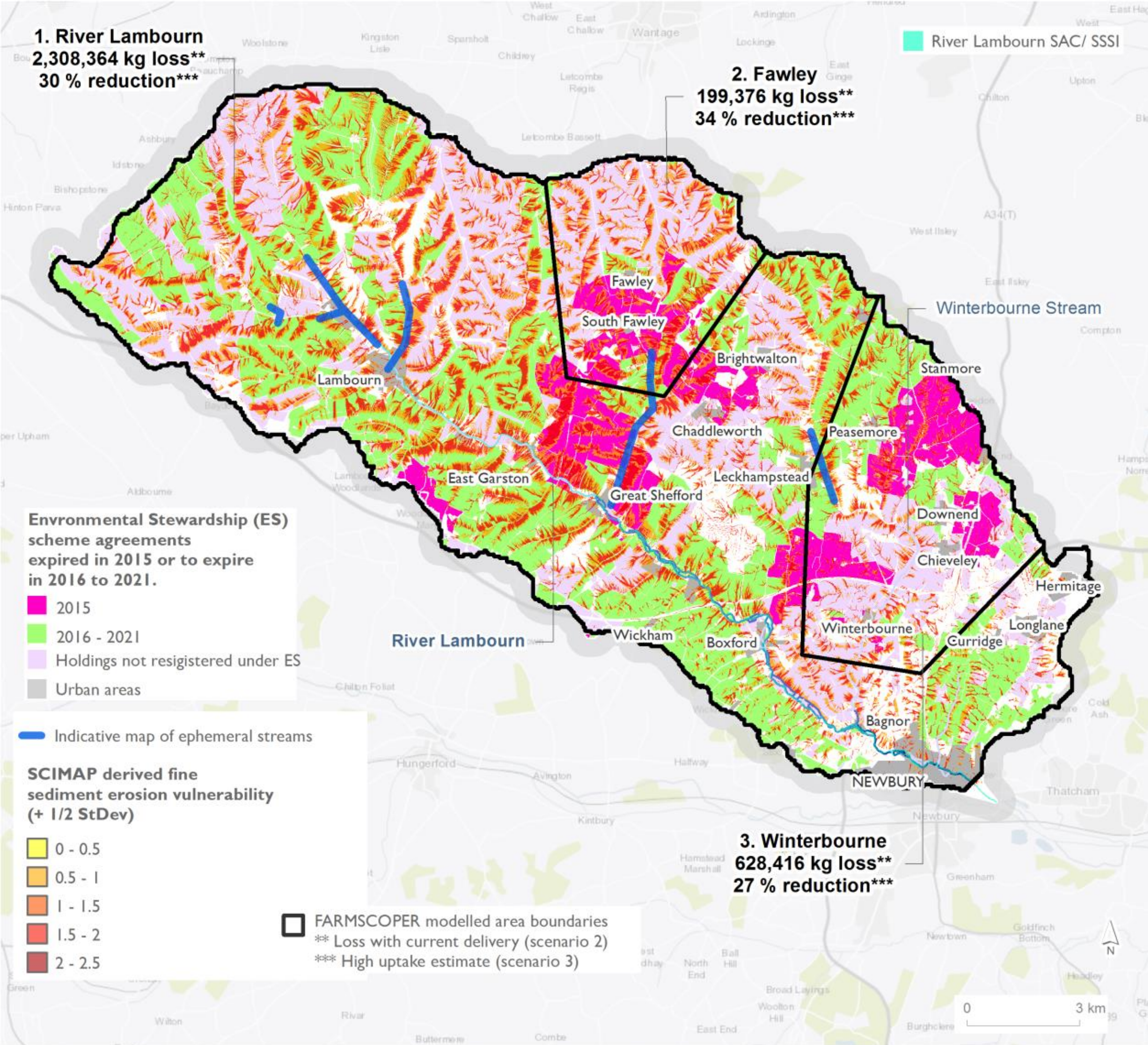
SEDIMENT

SSSI condition assessments do not include quantitative sediment targets. However, the SSSI Common Standard Monitoring (CSM) guidance for Rivers states that that there should be ‘no unnaturally high levels of siltation’, which should be assessed using field observations and site specific information. Erosion vulnerability modelling based on SCIMAP (Reaney, 2006) illustrates a relatively uniform erosion risk, as you would expect in a groundwater dominated catchment like the Lambourn. Marginally higher vulnerability is evident in the Lambourn Downs compared to lowland areas. Sediment delivery is therefore more likely to be associated with high risk activities in riparian areas or those well connected to the river via impermeable features that form preferential pathways for surface runoff (i.e. roads and tracks).

Based on FARMSCOPER most agricultural losses are primarily derived from cereal cropping, general farms, and lowland grazing and to a lesser extent mixed, dairy, poultry and indoor pig farms. Modelling based estimates, again based on FARMSCOPER, of the reductions in sediment losses that could be achieved ranged from 27% to 34% across the catchment. Although the hydrological component of the model is not able to represent the ephemeral nature of some subcatchments, particularly Fawley which can remain dry for several years. Mitigation measures with the potential to produce large reductions in sediment losses from cereal, and general farm types were identified as ‘Undersown spring cereals’ and ‘Early harvesting and establishment of crops in the autumn’ respectively.

The key evidence for sediment described above are summarised in Figure 1 below.

Figure 1: *Targeting map showing relative sediment erosion vulnerability in the Lambourn catchment using the SCIMAP modelling framework. 'High uptake' management measure reductions (scenario 3) and sediment losses from agricultural sources based on current delivery (scenario 2) from FARMSCOPER are shown for each sub-catchment modelled in FARMSCOPER. Holdings with Environmental Stewardship (ES) scheme agreements which have expired or are soon to expire (to 2021) are shown along with holdings not registered under ES.*



PHOSPHORUS

SSSI condition assessments include quantitative phosphorus targets for rivers as Soluble Reactive Phosphorus (SRP). The River Lambourn SSSI is divided into three units with different targets:

- The Upper River Lambourn (Unit 1) has the most stringent CSM target of 0.02 mg SRP/l, but has no monitoring data against which compliance can be directly assessed.
- The Middle River Lambourn (Unit 2). The CSM target is 0.03 mg SRP/l and monitoring data is available against which compliance can be assessed.
- The Lower River Lambourn (Unit 3) has a CSM target of 0.03 mg SRP/l but no monitoring data against which to directly assess compliance.

Modelling (SAGIS) can be used as the basis for assessing compliance where monitoring is not available and to estimate the relative contribution from different sector sources. Over half of the phosphorus loss is attributed to agriculture particularly arable areas, with the contribution from waste water treatment works also important locally and in combination in the lower reaches. Based on the key evidence available (see Figure 2) the following conclusions can be drawn for each unit.

SSSI Unit 1 – Upper River Lambourn

- Unit 1 is non- compliant with the CSM SRP target (0.02 mg/l) based on SAGIS modelling.
- SAGIS indicates agriculture as the dominant source of SRP (arable - 41%, livestock - 22% apportioned).
- Concentrations increase in the mid-reaches of the unit downstream of Fawley WwTWs.
- Based on 'high uptake' FARMSCOPER reductions (scenario 3) losses from agricultural in the order of 27 % are achievable. These alone would not achieve compliance with the CSM target.
- Reductions in livestock intensity, slurry spreading management and landuse change, not included in the FARMSCOPER assessment, could also lead to further reduce losses from agriculture.

SSSI Unit 2 – Mid River Lambourn

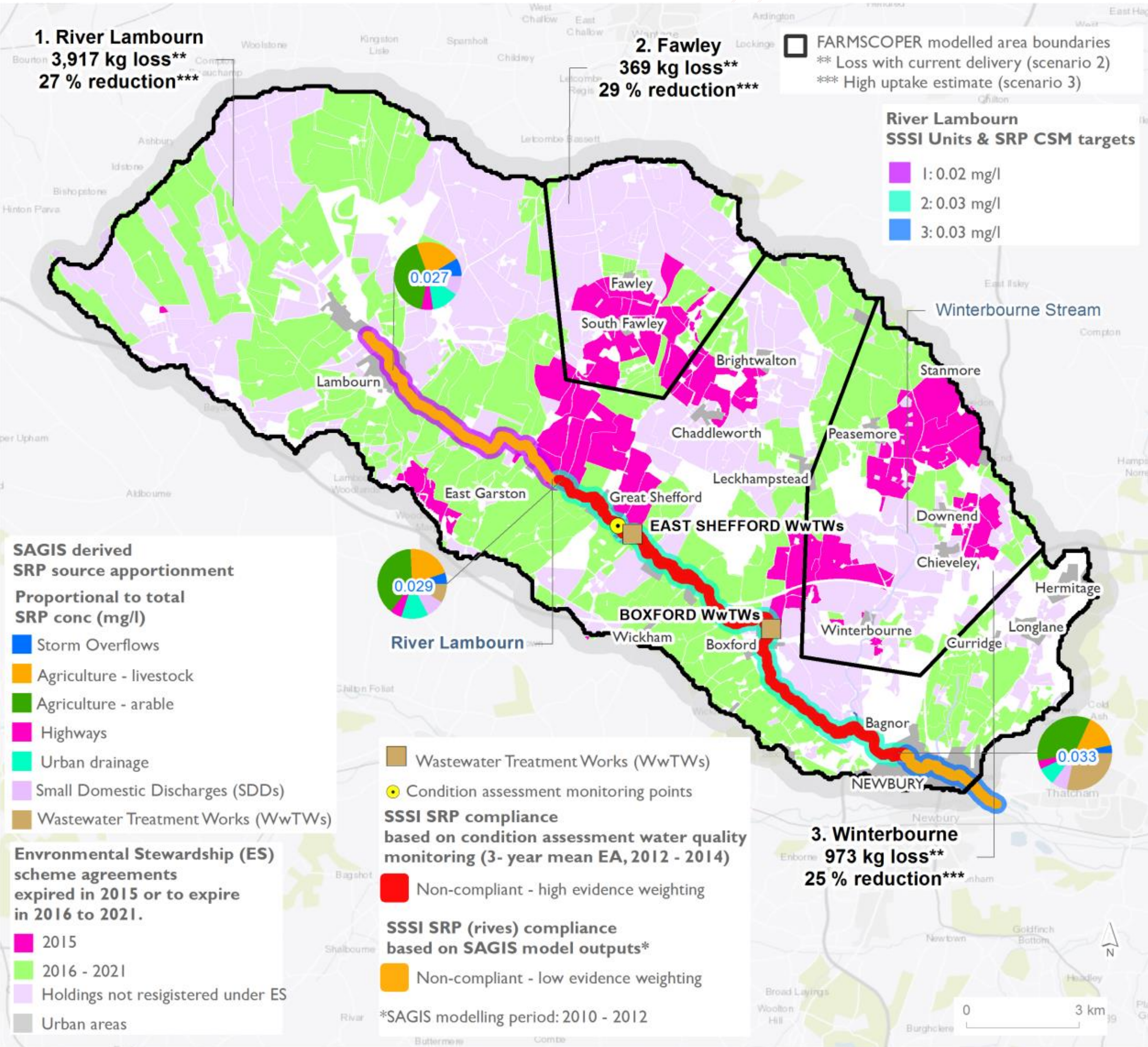
- Based on the 2012 – 2014 mean SRP concentrations were 0.01 mg/l above the CSM target for SRP (0.03 mg/l), largely as a result of elevated concentrations over winter months.
- Based on SAGIS, arable (39%) and livestock (21%) are dominant sources of SRP. However, East Shefford WwTWs is just downstream of the condition assessment monitoring point where it becomes the dominant source. In the lower reaches of SSSI Unit 2, Boxford WwTWs also makes a significant source.
- Based on 'high uptake' FARMSCOPER scenario 3 reductions of 27 % for the River Lambourn and 29% for Fawley sub catchments, the modelled catchment management options would not bring SRP concentrations within the target and wider measures not considered would need to be employed. However, it should be noted that measures such as spreading imported slurry, land-use change and livestock reduction that could further reduce losses from agriculture, are not included in the FARMSCOPER modelling.
- A combination of mitigation measures at WwTWs, along with reductions in agricultural sources from the upper River Lambourn catchment are likely to be needed to meet the CSM target within SSSI Unit 2.

SSSI Unit 3 – Lower River Lambourn

- Based on the SAGIS, Unit 3 is marginally non- compliant with the CSM SRP target (0.03 mg/l) by around 0.001 to 0.003 mg/l.
- SAGIS phosphorus apportionment indicates that arable (35%), WwTWs (28%) and livestock (15%) are dominant sources of SRP.
- Based on 'high uptake' FARMSCOPER scenario 3 reductions in the order of 27% for Lambourn, 29% for Fawley and 25% for the Winterbourne sub catchment, are achievable from agricultural sources. This would allow compliance at the very bottom end of the Lambourn below the Winterbourne.

Similar to sediment, mitigation measures with the potential to produce large reductions in phosphorus losses from cereal, and general farm types were identified as 'Undersown spring cereals' and 'Early harvesting and establishment of crops in the autumn' respectively. Additionally, 'Establish cover crops in the autumn' was highlighted as potentially producing large reductions in phosphorus losses in lowland grazing farm types.

Figure 2: *Targeting map showing compliance in the River Lambourn SAC/ SSSI. SAGIS source apportionment pie charts are shown upstream of non-compliant SSSI units. 'High uptake' management measure reductions (scenario 3) (adjusted to represent reductions from agricultural sources based on SAGIS source apportionment) and phosphorus losses from agricultural sources based on current delivery (scenario 2) from FARMSCOPER. Holdings with Environmental Stewardship (ES) scheme agreements which have expired or are soon to expire (to 2021) are shown along with holdings not registered under ES.*



1 Introduction

RIVER LAMBOURN SAC/ SSSI

Sites of Special Scientific Interest (SSSIs) are defined as an area identified as having flora, fauna, or geological features of nationally special interest, which are legally protected under the Wildlife and Countryside Act 1981. Legislation covering SSSIs gives Natural England powers to ensure better protection and safeguard them for future generations. Special Areas of Conservation (SACs) and SPAs (Special Protection Areas notified for birds) are collectively known as Natura 2000 sites and are protected under EU Habitats Directive for their habitats and/ or species of European importance. Under the Water Framework Directive, water dependent Natura 2000 sites are classed as Protected Areas and are required to meet their objectives (WFD or Natura 2000 whichever is most stringent) by the timescales set out in the River Basin Management Plan (i.e. 2021 or 2027).

The Improvement Programme for England's Natura 2000 Sites (IPENS) has identified where Diffuse Water Pollution Plans (DWPPs) are needed on a site by site basis, based on where they are failing to meet their objectives due to diffuse water pollution. DWPPs are also identified as a remedy for SSSIs in unfavourable condition due to diffuse sources. To effectively inform targeted delivery and drive implementation, DWPPs need to be evidence-led and regularly updated. They may also help to identify where further action is needed to address point sources.

This report focuses on the River Lambourn SSSI and its wider catchment area. In the upper reaches, the River Lambourn is a lowland chalk river and the SSSI is notified as a base rich, low energy, lowland river and for its high quality and diverse habitats, which support a wide range of protected aquatic vegetation, invertebrates, bird, and fish species. The River Lambourn is also designated as an SAC for the following interest features: 'river habitat characterised by the water crowfoot and starwort vegetation community', bullhead and brook lamprey.

The condition of the River Lambourn SAC/ SSSI is unfavourable as it fails to meet its water quality targets due, to diffuse and point source water pollution pressures associated with phosphorus and sediment. This report provides an evidence-led spatial analysis of phosphorus and sediment sources and risks within the Lambourn catchment, and provides a bespoke targeted intervention strategy for improving water quality in the identified sites. The report provides a basis to inform and update the DWPP for the River Lambourn SAC/ SSSI.

Note on terminology: within this report Soluble Reactive Phosphorus (SRP) is used to represent dissolved phosphorus which predominantly consists of ortho-phosphate.

1.1 Key Contacts

Organisation	Role	Contact
Natural England	River Lambourn SSSI Officer	Des Sussex
	Lead Advisor	Rebecca Tibbetts
	Former Catchment Sensitive Farming Officer (CSFO)	Andrew Russell
	Catchment Sensitive Farming Officer (CSFO)	Karen Davies
	Environmental specialist (coastal ecologist)	Vicki Howden
Environment Agency	Conservation Technical Specialist – West Thames	Graham Scholey
	Catchment Coordinator	Alison Love
	Technical Officer - Groundwater Quality & Contaminated Land	Gillian Davies
Thames Water	Abstraction Manager	Steve Tuck
	Stakeholder Engagement Officer	Laura Beardsworth
	Drinking Water Strategy Manager	Graham Welland
Centre for Ecology and Hydrology	Researcher	Collin Roberts
	Researcher	Gareth Old
Kennet Catchment Partnership	Director of Rivers Trust "Action for the River Kennett"	Charlotte Hitchmore
West Berkshire Council	Principal Engineer	Stuart Clark

1.2 Purpose Statement

The identified site covered in the report is the River Lambourn SSSI. There are three SSSI Units with associated water quality targets, these are: Unit 1 to 3 inclusive, all of which are covered in this report. This report is focused on improving the condition of the identified sites, where diffuse pollution is preventing favourable condition, and specifically, to:

- Identify causes of unfavourable condition in relation to water quality.
- Collate the evidence and identify the sources / risks associated with the identified water quality impacts.
- Identify any further evidence or monitoring investigations that would enhance the existing data available.
- Produce an intervention strategy to identify the most effective measures and locations for deployment of measures.
- Engage local contacts, including Catchment Based Approach (CaBA) hosts to capture their data and knowledge and work within the catchment and encourage long-term engagement to help, through collaboration, deliver the actions identified in the plans.
- Through engagement raise awareness and understanding of the issues and information that can be used to enable effective targeting of advice and mitigation.

In partnership with other regulatory and local stakeholders, Natural England will seek to ensure implementation of the necessary measures in the catchment to achieve compliance with water quality targets and favourable condition where feasible and where mechanisms exist.

2 Methodology

The risk assessment here is tailored to the Lambourn catchment taking into consideration its size, existing evidence, and water quality pressures. Evidence from national datasets and outputs from modelling tools describing catchment characteristics, potential pollutant sources and risks provide a starting point. Where available local / catchment specific data are then used to refine and ground-truth these assessments. Recent water quality monitoring data is used as the basis for assessing compliance against Common Standard Monitoring (CSM) targets and to indicate the scale of the required improvements. The Water Framework Directive (WFD) Good ecological Status (GES) classifications are also used to provide contextual information on pollution pressures and challenges.

2.1.1 Pollution Risk Assessment & Source Apportionment

Existing evidence is used to provide an integrated spatial assessment of pollution risks at the catchment scale. The outputs can then aid with diagnosing possible causes for any degradation or failure to meet conservation targets within the identified site.

A variety of approaches are available to model land use and other human-derived pollution risks and estimate pollutant loads at the catchment scale. The main modelling outputs used here include; SCIMAP a fine sediment erosion tool and SAGIS a phosphorus source apportionment model used to estimate the contribution of consented and un-consented sewage discharges, along with inputs from diffuse sources. PSYCHIC and NEAP-N outputs are also used to estimate Total Phosphorus (TP) loads delivered to receiving waters.

Where possible, the outputs from these risk assessment tools and models are combined with local spatial evidence to identify potentially high risk areas and validate modelled outputs.

2.1.2 Assessment of Current Mitigation Measures in the Catchment

Before a full catchment management plan can be developed, it is necessary to have a clear understanding of what mitigation measures have already been put in place or are in the process of being implemented. The measures assessed include the presence of naturally occurring mitigation in the landscape, the protection of the landscape through the designation of protected areas, the uptake of Environmental Stewardship (ES) schemes, Catchment Sensitive Farming (CSF), English Woodland Grant Schemes (EWGS), and any other relevant environmental management initiatives.

2.1.3 Assessment of Potential Outcomes

It is vital that sufficient evidence is collected to provide an objective and scientifically robust estimate of the effectiveness of any intervention strategy. The assessment of potential outcomes demonstrates the type of pollutant reductions which could be achievable. The FARMSCOPER decision support tool is used here as a guide for agricultural pollutant load reductions which might be possible under different catchment management scenarios, along with secondary environmental benefits. The FARMSCOPER version 3 'upscale' model (ADAS, 2016) is used for the analysis in this report. In the 'upscale' FARMSCOPER model farm practices have already been entered from agricultural census data and divided into individual farm types for management catchments nationally. In this report, the outputs for the Kennet and Pang management catchment are scaled to modelled areas for the Lambourn catchment and based on the number of farms of each farm type within these areas.

2.1.4 Targeting Delivery in the Catchment

The assessment adopts a weight of evidence approach, with monitoring data and locally derived evidence afforded a higher weighting compared to national data and modelling outputs. The bespoke targeting maps (Figure 8.1 and 8.2) draw together the key evidence from which the main conclusions are drawn. The maps combine modelling and monitoring data to non-compliant areas and spatial source risk or vulnerability for the key pollutants. Holdings with ES agreements which have expired or are expiring between 2015 and 2021 are also shown as these present a risk that best management practices not being continued as grants, advice and incentives are withdrawn.

3 Catchment overview

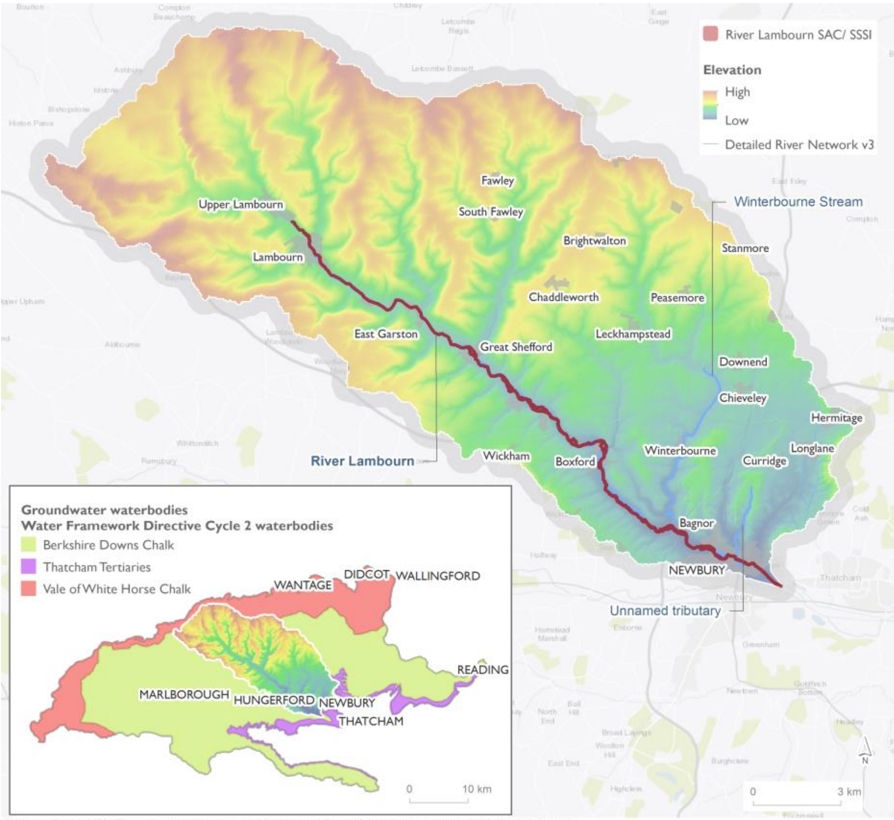
3.1 Morphology & Hydrology

The River Lambourn is one of the largest tributaries of the River Kennet. Rising near the village of Lambourn in Berkshire it flows south-east for around 30 km through the Kennet Valley to its confluence with the main River Kennet near the town of Newbury. The catchment is characterised by well drained hill sides in the upper reaches situated within the Lambourn Downs (part of the Berkshire Downs). South-east of Great Shefford the catchment flattens out towards the town of Newbury, with elevations in catchment ranging between 260 m in the upper reaches to 96 m in the south-east of the catchment (Figure 3.1).

The hydrology of the Lambourn catchment is dominated by groundwater. The catchment transects three groundwater waterbodies; Vale of the White Horse Chalk, Berkshire Downs Chalk, and Thatcham Tertiaries. With a high baseflow index (0.98 BFI) the river is characterised by stable flows and temperatures, responding slowly to rainfall events. The upper reaches are also ephemeral flowing only when the water table is sufficiently high, generally between late autumn through to May/June or later, although this varies from year to year.

Between Great Shefford and Bagnor, the system meanders through disused water meadow systems and wet pastures. The main channel bifurcates in places, with secondary channels previously associated with disused meadows and mills. It should be noted that these channels have retained the character of the main system. The main tributary to the River Lambourn is Winterbourne Stream, which flows into the Lambourn at Bagnor. Additional groundwater flows enter the Lambourn from a series of springs along the Great Shefford Dry Valley. In some reaches, macrophyte stands strongly influence instream heterogeneity, which in turn effect flow and sediment dynamics.

Figure 3.1: *Morphology and hydrology of the River Lambourn catchment showing key hydrological features.*



GROUNDWATER SAFEGUARD ZONES

Safeguard Zones are areas where activities can impact adversely on the quality of water abstracted. Action to address pollution is targeted in Groundwater Safeguard Zones (GSgZs) in order to reduce extra treatment costs. Safeguard Zones are a non-statutory, joint initiative between the Environment Agency and water companies. Safeguard Zones are one of the main tools for delivering the drinking water protection objectives of the Water Framework Directive (WFD).

GSgZs within the catchment are generally associated with the extent of Source Protection Zone 3 boundaries, which reflect the whole groundwater catchments of abstraction boreholes (Figure 3.2). Larger GSgZs within the catchment include those associated with Ashdown Park, Fognam Down and Leckhampstead abstraction boreholes. There is also, outside of the surface water catchment, a small pesticide related GSgZ located near Great Bedwyn. In the stakeholder workshop, it was noted that the shape of the SgZ for Leckhampstead is incorrect. Therefore, it is a recommendation for the map to be updated once the updated layer is available from the Environment Agency.

SOURCE PROTECTION ZONES (SPZ)

Groundwater SPZs are designated where local groundwater is used for public drinking water supply and it is therefore essential to protect it from contamination originating from activities that might cause pollution in the area; the closer the activity to the actual borehole the greater the risk.

The SPZ in the River Lambourn catchment contains the following zones:

SPZ1 – Inner zone (red)

Defined as the 50-day travel time from any point below the water table to the source: designed to protect against the effects of human activity, which might have an immediate effect upon the source.

SPZ2 - Outer zone (green)

Defined by a 400-day travel time from a point below the water table or at least 25% of the recharge catchment or 250 m: designed to provide protection against slowly degrading pollutants.

SPZ3 – Total Catchment (blue)

Defined as the area around a source within which all groundwater recharge is presumed to be discharged at the source. This may be displaced from the source in confined aquifers and may include the entire recharge area for heavily exploited aquifers.

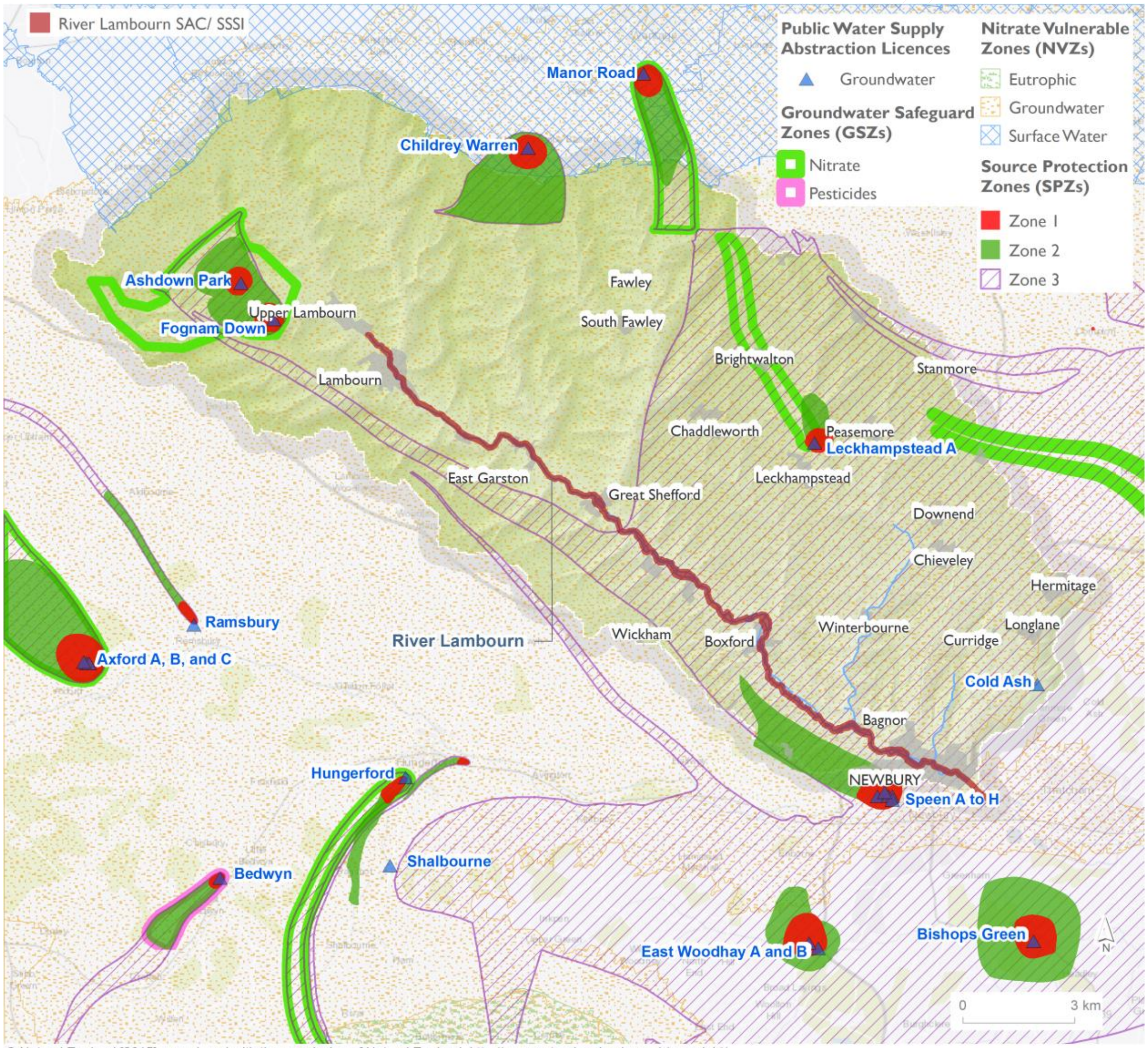
There are six SPZs which overlap the surface water catchment of the River Lambourn. The zones are mostly confined to the immediate surroundings of the designated source, however, there is an extensive SPZ 3 in the south-eastern half of the catchment (Figure 3.2).

NITRATE VULNERABLE ZONES

Nitrate Vulnerable Zones (NVZs) focus primarily on management of diffuse agricultural nitrate pollution, and are designated where land drains and contributes to the nitrate found in 'polluted' waters. Polluted waters include: (1) surface or ground waters that contain 50 mg/l or more of nitrate; (2) surface or ground waters that are likely to contain 50 mg/l or more nitrate in the future if no action is taken; and (3) waters which are eutrophic, or are likely to become eutrophic if no action is taken.

Almost the entire Lambourn catchment is situated within a Nitrate NVZ, except for a small area stretching from the north east of Newbury and east of Longlane (Figure 3.2). There is also Surface Water NVZ bordering the northern edge of the River Lambourn catchment.

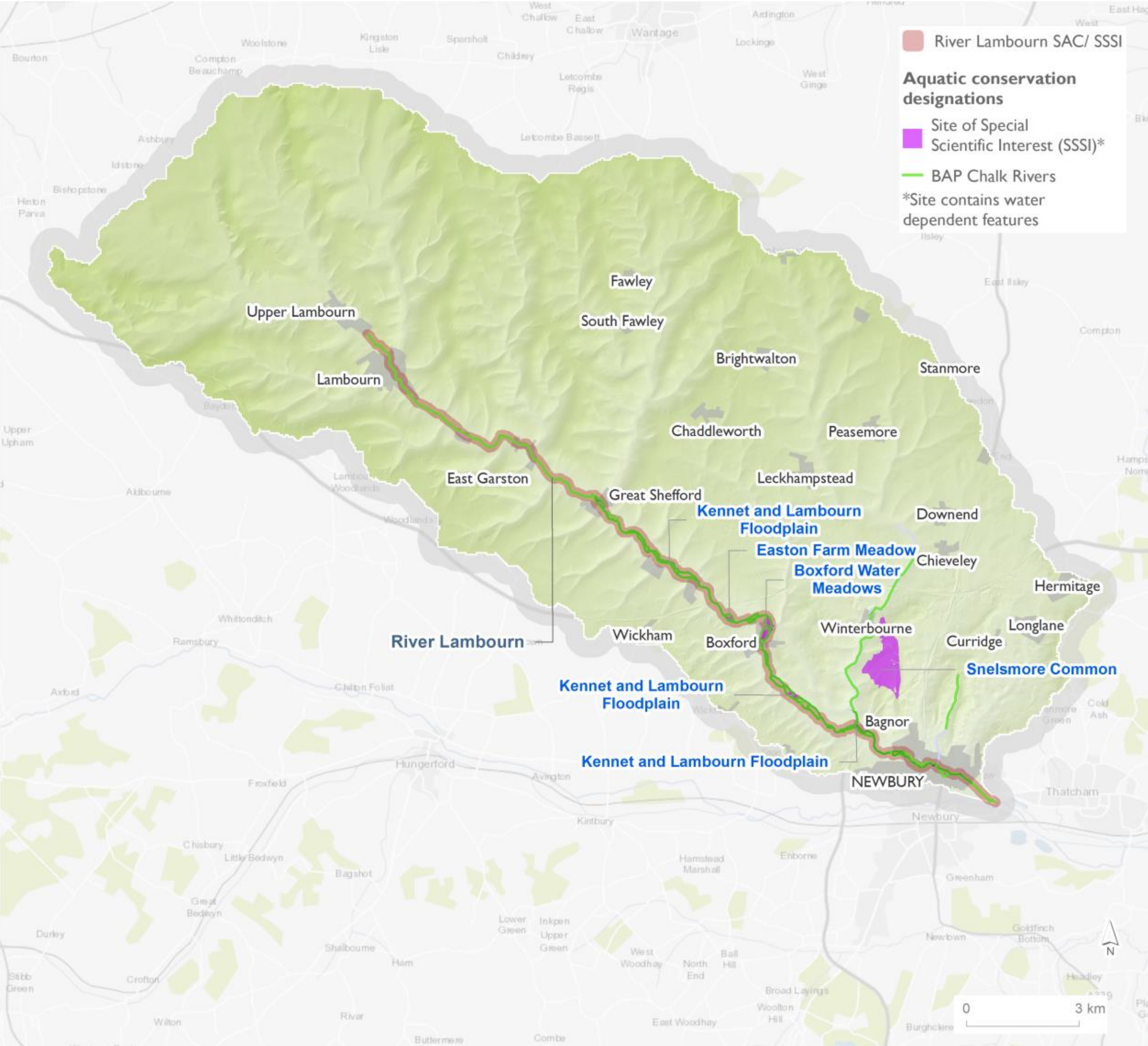
Figure 3.2: *Water supply and management designations relating to the River Lambourn catchment.*



N.B.: The shape of the Safeguard Zone for Leckhampstead was highlighted as incorrect during the stakeholder workshop – this is not amended within the figure.

Figure 3.3 shows conservation designations for sites which include water dependant features in the River Lambourn catchment. Snelsmore Common is the largest SSSI (104 ha) within the catchment and features mires amongst other notified features. Other SSSIs include the Kennet and Lambourn Floodplain, featuring the nationally rare and declining Desmoulin's whorl snail (Vertigo moulinsiana) and communities associated with poorly drained permanent pastures, and two additional designated meadows.

Figure 3.3: *Conservation designations relating to sites which include aquatic features in the River Lambourn catchment.*

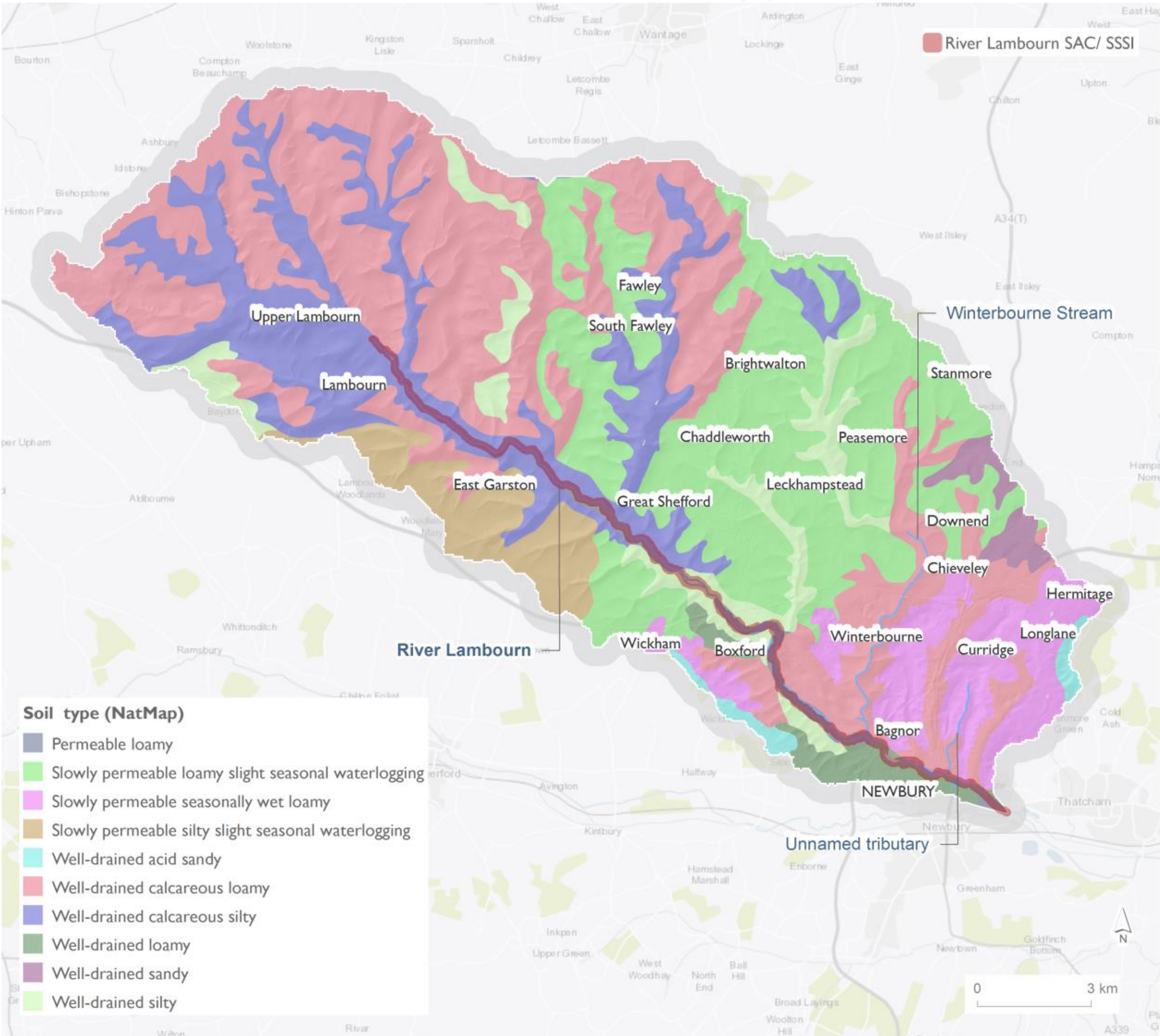


The bedrock geology in the catchment is predominantly comprised of Chalk, covering a large proportion of the catchment (23769 ha, 90 %, Figure 3.4). The south-east of the catchment is overlain by clay and minor pockets of sand geology. Superficial geology in the catchment is predominantly comprised of clay with flints, with an extensive deposit east of Great Shefford and the hill valley system of the upper reaches of the catchment. The north-west of the catchment also features pockets of clay with flint and some alluvium deposits, whilst in the far south-east, sand and gravel deposits can be found. Alluvium deposits follow the southern bank of the main channel extending past its headwaters to the north west.

Figure 3.4: *Dominant bedrock geology and superficial geology types in the River Lambourn catchment.*

The two main soil types in the Lambourn catchment are 'well drained calcareous loamy soils' and 'slowly permeable loamy soils' prone to slight seasonal waterlogging (Figure 3.5). Well-drained soil types are predominantly found in the upper reaches and along the main river channel. These soils tend to have a slower rainfall run-off response compared to slowly-permeable soils but they have a higher erosion risk, leading to potential gullying. Less well drained soils are more predominant east of Great Shefford and south east of East Garston. These lower-permeability, clay-rich soils are highly cohesive and with a low erosion risk. However, low porosity leads to waterlogging and higher run-off rates. In addition, high flow periods can lead to bank scouring and bank erosion where large sections of compact clay-rich soils can fall into the channel network.

Figure 3.5: *Dominant soil types and their dominant hydrological function, in the Lambourn catchment (NSRI).*



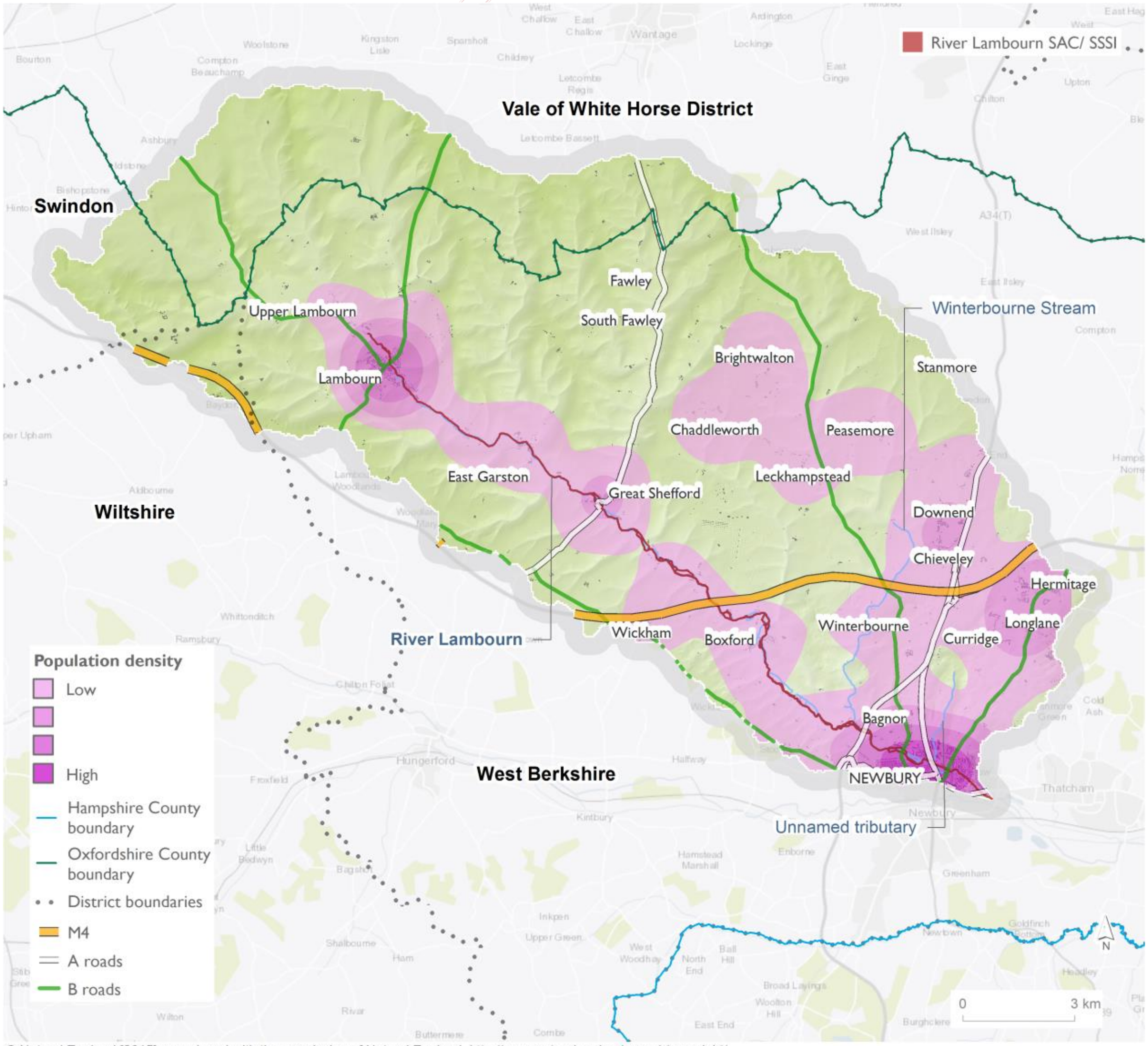
3.2 Social & Economic

The Lambourn catchment is located predominantly within Berkshire, extending into Oxfordshire in the north of the catchment. It is divided between the districts of Vale of the White Horse, Swindon, Wiltshire, and West Berkshire.

The main population, estimated using address layer (2015) postcode densities, is dispersed across a few villages and Newbury, the principal town in west Berkshire (Figure 3.6). Larger villages include Lambourn and Great Shefford, with Newbury (population ~ 31,331) and Lambourn (population ~ 4,103) displaying areas of greatest population density within the catchment. The population of Newbury and Lambourn parishes increased between 2001 and 2011, growing by 10 % and 2 % respectively (ONS Census, 2011).

The M4 transects the River Lambourn catchment east to west a few kilometres north of Newbury and clips the catchment boundary west of Lambourn village. A number of A and B roads also cross the river system, predominantly east of Great Shefford and increasingly towards Newbury. The road network can act as both a source and a conduit for pollutants entering the river system.

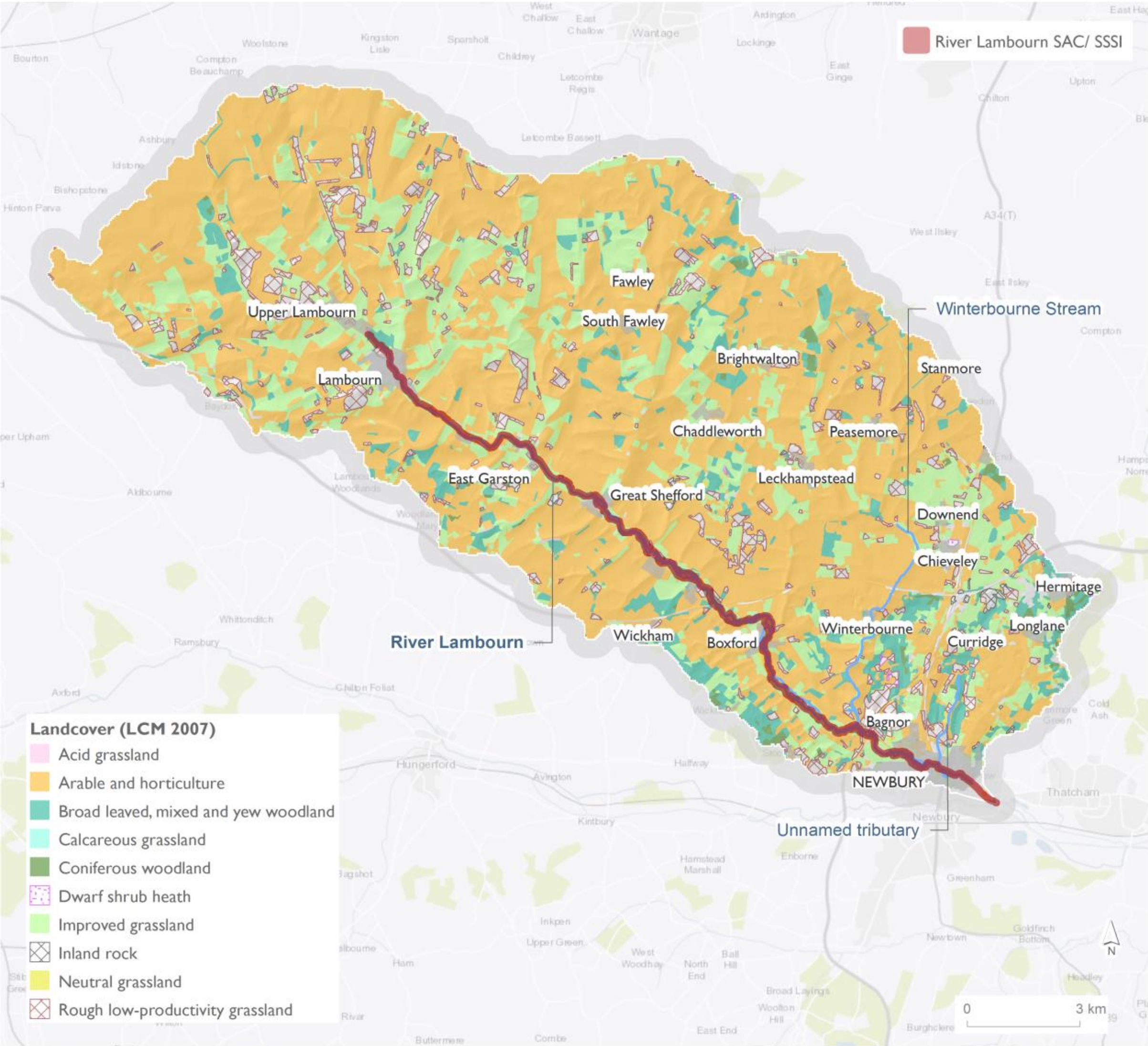
Figure 3.6: *Population density hotspots, key infrastructure, and administrative boundaries in the River Lambourn catchment.*



3.3 Farming & Land Use

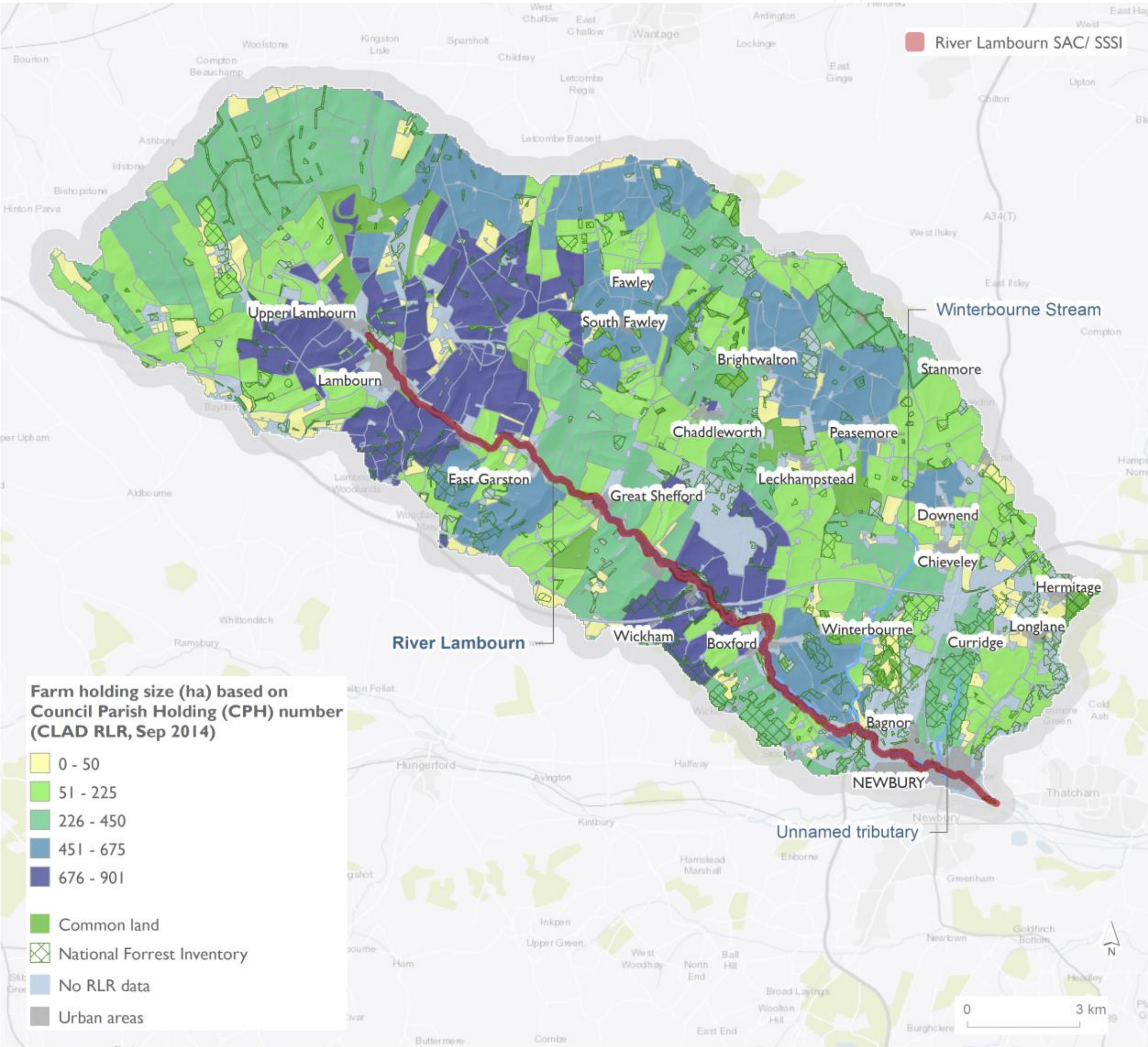
Based on the 2007 Landcover Map (CEH), 80 % of the catchment (total area: 26369 ha) is classified as 'arable and horticulture' (16,479 ha, ~ 62 %) and 'improved grassland' (5,530 ha, ~ 21 %) Figure 3.7.

Figure 3.7: *Landcover classifications in the River Lambourn (CEH, 2007).*



Larger farm areas offer potential benefits for management as fewer resources are likely be required to gain walkover permissions and carryout farm visits. However, larger farms also tend to have resources to invest in infrastructure and implement the advice, which in some cases smaller holdings will not. The RLR data indicates that there were around 62 farms covering over 100 Ha (Figure 3.8). The largest farm areas in the catchment are focused around the upper ephemeral reaches of the Lambourn, with some larger holdings also situated around Wickham and Boxford.

Figure 3.8: *Farm sizes and common land in the River Lambourn (CLAD Rural Land Registry, September 2014).*



Agricultural Census returns data from the years 2000 and 2010 provide a comparison of the relative intensity of selected land use practices and livestock numbers (Figure 3.9). Selected categories represented here are those which are considered to have the greatest potential impact upon phosphorus and sediment pollution supply and transfer. A limitation of the AgCensus data is that seasonal variability is not taken account, except where spring and winter cropping types are separated in the data. It should be noted that sheep numbers are registered based on grazing areas and therefore provide only an indication of the total number of sheep within the catchment.

The data indicates that temporary grassland decreased by around 16 % between 2000 and 2010. This reflects the 39 % and 36% decrease in cattle and sheep respectively over the same period.

Temporary grassland areas in the western extreme of the catchment and around East Garston are coincident with cattle and/or sheep in 2000, but not in 2010.

The number of dairy cattle shows a decreasing trend throughout the United Kingdom in recent years largely driven by economics and a reduction in cattle, both beef and dairy, is evident in the Lambourn catchment.

Maize cropping, a high risk landuse prone to soil erosion, was observed between 2000 and 2010. Although more maize cropping was recorded in central areas e.g. around Lambourn and East Garston and a pocket in the north-western extreme of the catchment in 2010.

During the stakeholder workshop, it was highlighted that there are large numbers of horses within the catchment. Land with intensive equestrian use is under particular risk for sediment loss from poaching. However, horses are not currently included in the AgCensus data. The spatial precision and static nature of the AgCensus data should also be considered when drawing conclusions from this data.

Figure 3.9: *Relative intensity of selected agricultural land use practices and stocking densities in the River Lambourn in the years 2000 and 2010. Source 2km AgCensus data.*

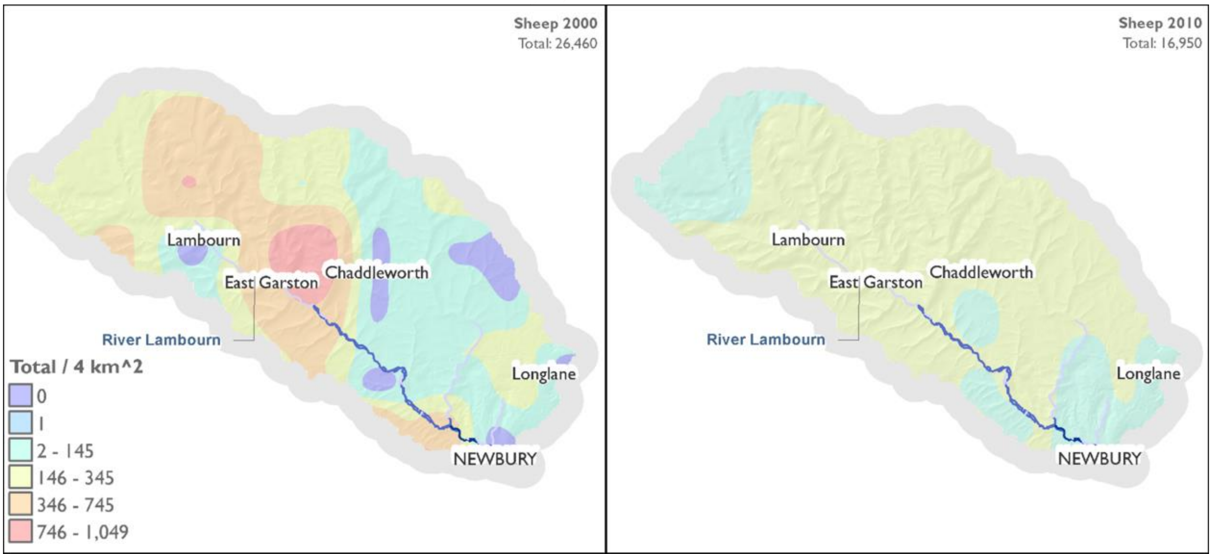
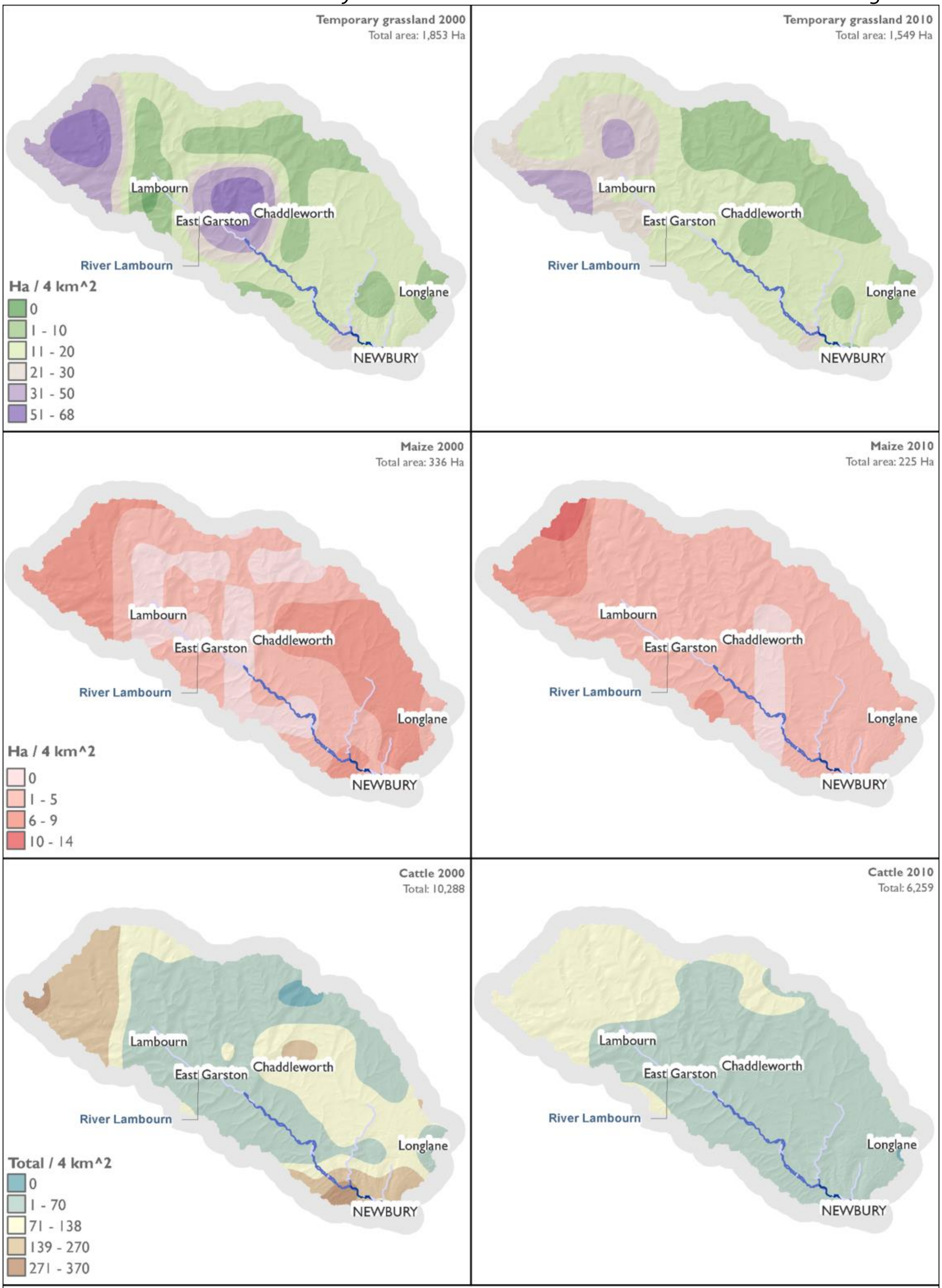


Figure 3.9: *...Continued. Relative intensity of selected agricultural land use practices and stocking densities in the River Lambourn in the years 2000 and 2010. Source 2km AgCensus data.*



4 Catchment Classifications & Pressures

Two status classifications relate to pollution pressures in the River Lambourn catchment, SSSI condition assessments and Water Framework Directive (WFD) status. Natural England are responsible for assessing SSSI and SAC conditions and the Environment Agency carry-out water quality monitoring for statutory and water management purposes. Brief descriptions of SSSI and WFD evaluation methods and targets are provided in this section. In addition, the compliance of SSSI Units in the River Lambourn and status of Cycle 2 WFD river waterbodies within the River Lambourn catchment are presented.

4.1 Sediment Pressures

SSSI condition assessments and WFD objectives do not include quantitative sediment targets because natural sediment loads vary widely within and across river systems. However, the SSSI Common Standard Monitoring (CSM) guidance for rivers does include an objective for siltation, which states that there should be 'no unnaturally high levels of siltation', which should be assessed using field observations and site specific information, this can be derived from River Habitat Surveys (RHS).

There has not been a comprehensive evaluation of sediment pressures at the catchment scale for the River Lambourn. A River Habitat Survey (RHS) was carried-out in 2016, however the results were not available to include within this report. A catchment scale modelling effort, assessing the vulnerability of land to potentially generate sediment losses is provided here, in order to identify any potentially high vulnerability areas. This should support current and future work to investigate and mitigate sediment losses within the catchment.

4.2 SSSI Condition Assessment

Favourable condition targets must be met in order for SSSI units to be classed as being in 'Favourable condition'.

'Favourable condition' means that: *'the designated feature(s) within a unit are being adequately conserved and the results from monitoring demonstrate that the feature(s) in the unit are meeting all the mandatory site specific monitoring targets set out in the Favourable Condition Target (FCT). The FCT sets the minimum standard for favourable condition for the designated features and there may be scope for the further (voluntary) enhancement of the features / unit. A unit can only be considered favourable when all the component designated features are favourable* (JNCC, 2015)'.

Methods for assessing SSSI units include River Habitat Surveys (RHS), water quality monitoring, and calculation of biological indexes. Environment Agency monitoring data covering the three most recent consecutive years where data is available are used to evaluate compliance with water quality FCTs for the SSSI (JNCC, 2015).

There are 3 units included in the River Lambourn SSSI: Units 1 to 3 all of which feature 'Rivers and Streams' as their main habitat (Figure 4.1). It should be noted that there are two water-dependant SSSIs along the River Lambourn SSSI, namely Boxford Meadows SSSI and Easton Farm Meadow SSSI, though these do not form the main focus of this report.

Table 4.1 details the descriptive statistics and targets which were used in the water quality condition assessment. The water quality condition assessment was performed using statutory Environment Agency monthly monitoring data from 2012 – 2014. All parameters were evaluated as set out in the CSM Guidance for Rivers (2014). For SRP, an additional calculation was made to assess the seasonal 3-year mean for March to September inclusive. In this report, annual means are also calculated for

SRP to enable evaluation of changes in trends and to show compliance where data was not available for all years. It should be noted that values below the Limit of Detection (0.02 mg/l for SRP) were halved as set out within the CSM guidance, this equated to 5 out of 36 samples.

The condition assessment (Figure 4.1) highlights SRP as the main water quality driver for the River Lambourn SSSI during 2012 - 2014. SRP concentrations were found to be non-compliant at monitoring site 1 in Unit 2 of the SSSI in all years, the 3-year mean and the seasonal mean. The water quality monitoring from 2012 to 2014 indicates that a reduction of 25 % or 0.01 mg/l is required to meet the CSM target for SRP in SSSI Unit 2.

Un-ionised ammonia and ammonia (Total as N), were found to be compliant with their CSM targets. Dissolved Oxygen (DO) was non-compliant with the CSM target. There is no water quality data for Unit 1 or 3 to enable a compliance assessment.

Figure 4.1: *Water quality condition assessment for the River Lambourn SAC/ SSSI. Figure relates to Table 4.1.*

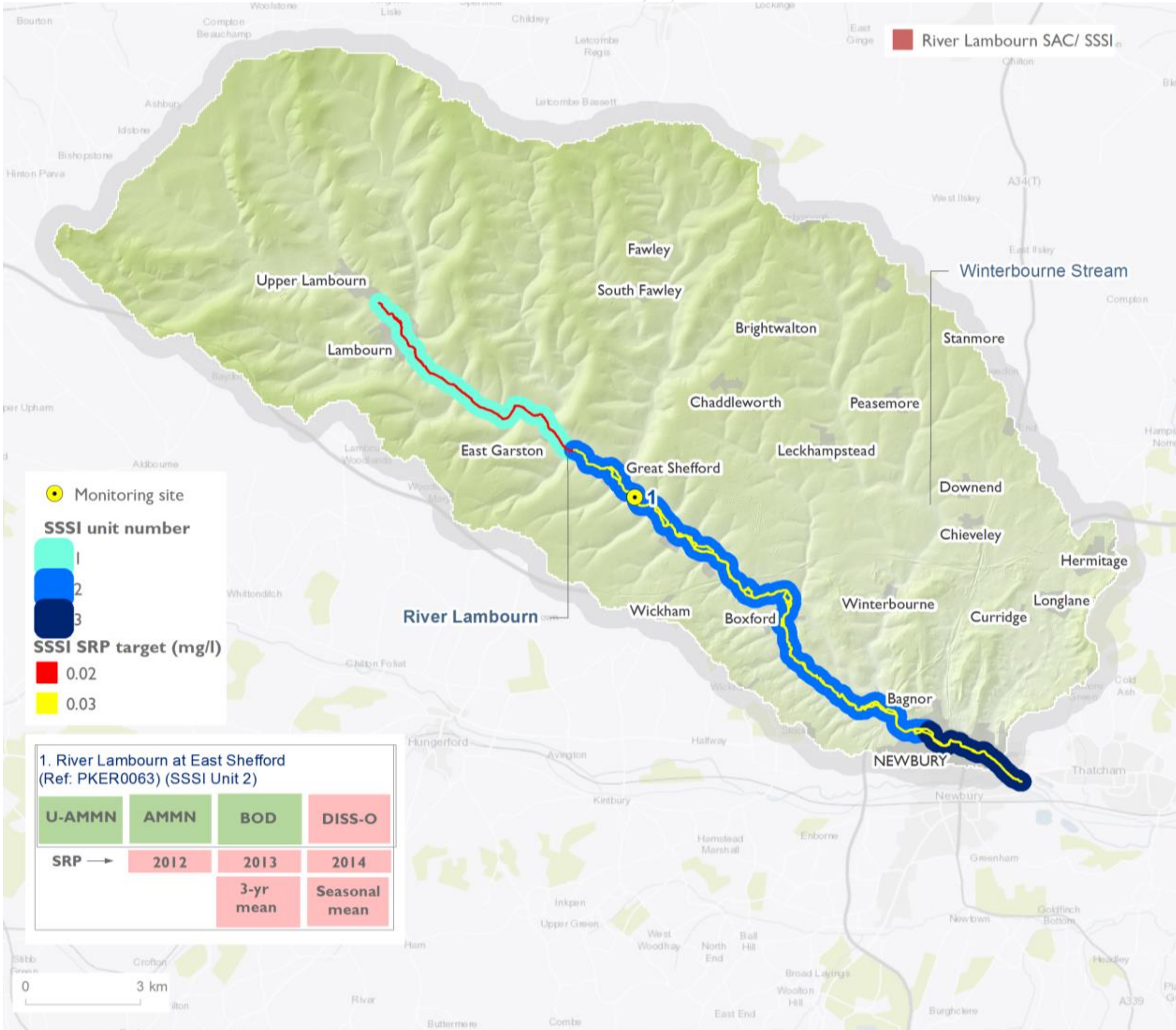


Table 4.1: *River sites descriptive statistics and environmental quality standard targets for the River Lambourn condition assessment. Values highlighted in green were compliant with the target; those highlighted in red were non-compliant. Table relates to Figure 4.1.*

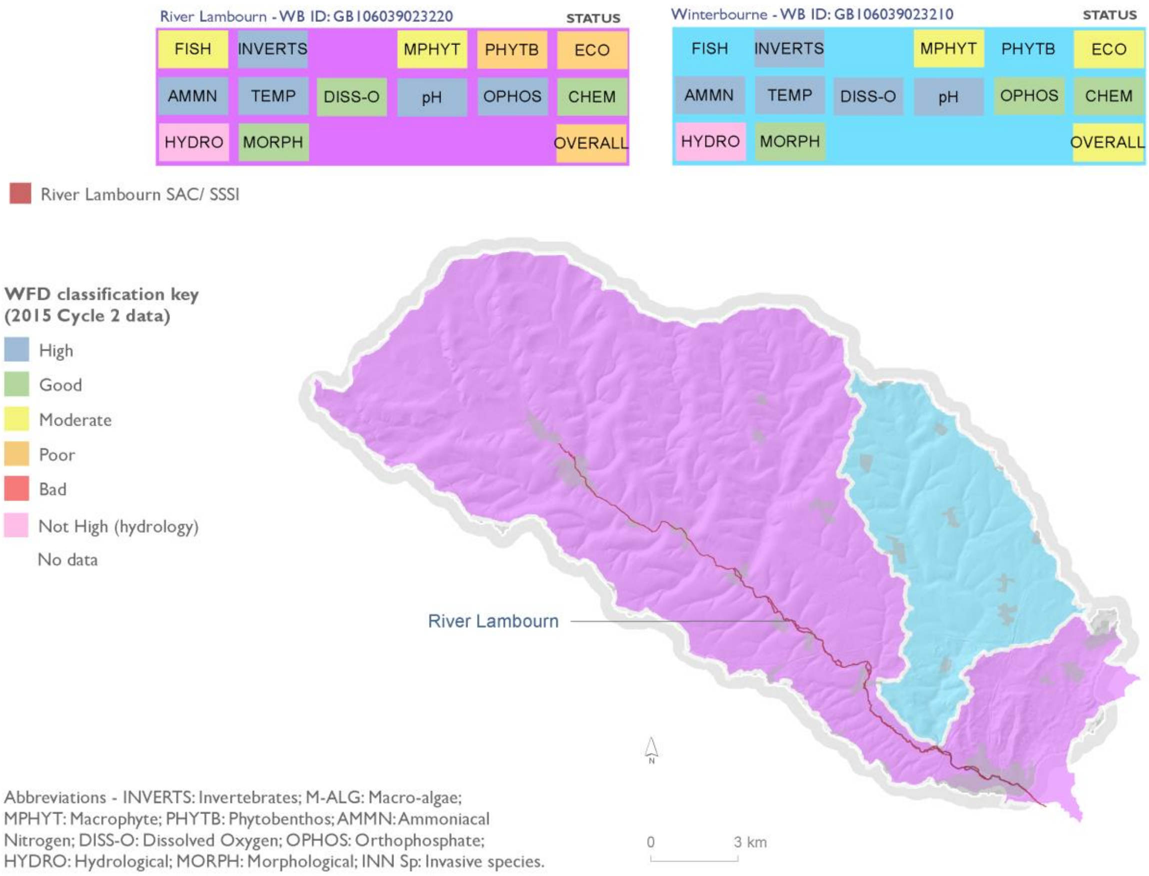
		SSSI Unit number	**1**	**2**	**3**
		Monitoring site number	**n/a**	**1**	**n/a**
Water Quality Parameter	**Statistic**	**CSM Target**			
Un-ionised Ammonia (mg/l)	95^{th} percentile	0.021	-	0.0005	-
Total Ammonia (mg/l)	90^{th} percentile	0.25	-	0.03	-
Dissolved Oxygen (DO) (% saturation)	10^{th} percentile	>85	-	76.5	-
Biological Oxygen Demand (BOD) (mg/l)	Mean	1.5	-	-	-
Soluble Reactive Phosphorus (SRP) (mg/l)	Annual mean year	2012	-	0.030	-
		2013	-	0.046	-
		2014	-	0.043	-
	3-year mean (2012 – 2014)		-	0.040	-
	3 year growing-season mean (Mar - Sep inclusive 2012 - 2014		-	0.031	-
		Long term SRP target	**0.02**	**0.03**	
		% reduction required for non-complaint sites to reach compliance 3-year SRP mean	-	**25**	-
		Concentration reduction required for non-complaint sites to reach compliance 3-year SRP mean	-	**0.01**	-

4.3 WFD Status Classifications

The status of Water Framework Directive (WFD) Cycle 2 waterbodies within the Lambourn catchment provides information relating to the issues of physical, chemical, and biological pressures in meeting 'Good Ecological Status (GES)'. It should be noted however that, whilst WFD waterbody monitoring data and classifications can provide some insight into pollution issues, the low sampling resolution rarely allows for identification of high risk areas to target advice and interventions. For instance, many waterbodies only have one monitoring location, which may not be representative of the waterbody. In addition, water quality targets for WFD GES can differ and in many cases, can be less stringent than the targets for the Natura 2000 Protected Areas and/or SSSIs, therefore the WFD GES classifications (Figure 4.2) are presented as contextual information only.

In contrast to the SSSI condition assessment (Figure 4.1) the 'WFD health report card' (Figure 4.2) does not highlight SRP as a significant pressure or reason for failure across all sites. The discrepancy is likely to be due to differences in assessment methods, missing data, and less stringent targets for SRP to achieve WFD GES at the time of classification. The failing elements at each site (fish and macrophytes) relate to ecological status but a nutrient pressure. The interim WFD targets are less stringent compared with the SSSI condition assessment targets and within the River Lambourn are currently being met.

***Figure 4.2:** Water Framework Directive (WFD) 'health report card' showing 2015 surface water classification for Cycle 2 River Waterbodies. Classification are colour coded to the waterbody they relate.*



5 Pollution Risk Assessment & Source Apportionment

This section provides an integrated assessment of both observed (monitored) and derived (modelled) data to identify potential sources of sediment and phosphorus to the River Lambourn SAC/ SSSI. The pollution risk assessment is undertaken in accordance with the 'source-pathway-receptor' principle (Figure 5.1).

Figure 5.1: *Pollution source, pathway receptor principle which has been used to assess pollution risk in the River Lambourn catchment.*

SOURCE		PATHWAY	RECEPTOR
Pollutant Availability	+ Mobilisation	+ Connectivity	= Pollution risk

5.1 Sediment

Several methods have been developed to identify the sources of sediment and the dynamics of sediment transport in rivers. Overall sediment source studies reveal that sediment load in rivers is primarily derived from point or diffuse sources in three principal locations, these are: (1) material from the river channel and banks; (2) soil and other organic material from the surface of surrounding land; and (3) particulate material from anthropogenic sources such as roads, industry, and urban areas.

5.1.1 Fine sediment risk analysis

In addition to the mobilisation of sediment and other suspended material from within the riparian corridor, fine sediment can be mobilised from land-surface sources by overland flow. Potential sources can be identified through field surveys, but to get an initial catchment-wide assessment of risk, a modelling approach can be used to assess the fine sediment erosion and mobilisation risk across the catchment.

The SCIMAP fine sediment erosion model, developed through a collaborative project between Durham and Lancaster Universities (Reaney, 2006) was used here to carry-out a catchment scale assessment of erosion risk or vulnerability. The development of SCIMAP was supported by the UK Natural Environment Research Council, the Eden Rivers Trust, and the Department of the Environment, Food and Rural Affairs and the Environment Agency.

The SCIMAP model uses elevation, landuse and rainfall data to identify areas which are vulnerable to sediment mobilisation from land and likely delivery to a watercourse from that area of land. However, in this report, the SCIMAP analysis was altered to include only elevation and rainfall data to produce a sediment erosion **vulnerability** map based on slope and hydrological connectivity. Landcover data was omitted due to inaccuracies in the 2007 CEH landcover data, as identified in the stakeholder workshop. Where an area is vulnerable to sediment erosion, risky land use practices should be avoided or at least managed with best practices to mitigate against risk.

SCIMAP has been shown to be effective in the identification of local areas with a high potential for sediment erosion risk, or vulnerable areas of land where risky land use practices could lead to increased sediment erosion. However, it is important that limitations are considered and that SCIMAP derived outputs are validated with local data and evidence.

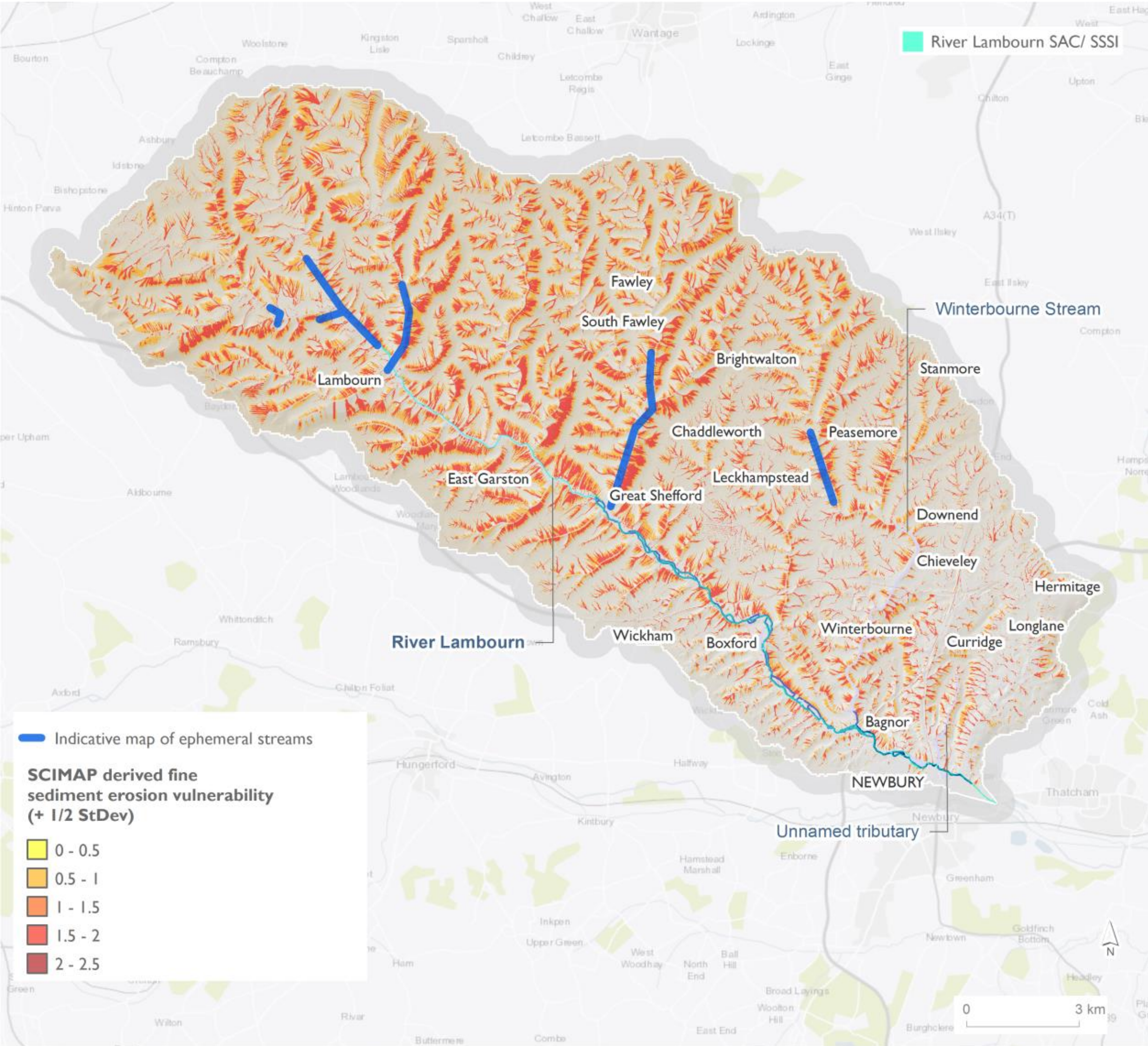
LIMITATIONS AND ASSUMPTIONS

1. The erosion vulnerability map provides an indication of the potential underlying vulnerability based on slope and hydrological connectivity only.
2. SCIMAP does not take account of management measures and practices.
3. In practice, on the ground, the vulnerability or risk can be increased or lessened by factors such as soil type and the way the land is being managed. For example, a presence of a buffer strip in a vulnerable location may reduce connectivity and therefore mitigate against at least part of the sediment erosion vulnerability or risk.
4. When using a Digital Surface Model (DSM) rather than at Digital Terrain Model (DTM) vegetation and buffer strips can be included if they fall within the resolution constraints of the data. However, sediment transport through woodlands may not be shown as they can be classed as a barrier to connectivity.
5. Soils data are not included in the sediment erosion analysis.
6. In the Lambourn catchment, sediment transport is driven partly by groundwater levels as there is not always connectivity between ephemeral streams in the catchment and the River Lambourn.

SCIMAP outputs for the Lambourn catchment (Figure 5.2) highlight fairly evenly spread vulnerability for fine sediment erosion across the catchment – however, areas within the upper reaches of the catchment, located within the Lambourn Downs hill valley system, display marginally higher erosion vulnerability compared to lowland areas.

As a low energy chalk stream with relatively stable flows, overbank flows are infrequent and unlikely to generate large amounts of sediment. Surface runoff is also rare due to the high permeability of the underlying geology. However, episodic events on land adjacent to the river may erode and transfer sediment to the water course. Areas highlighted of most concern by stakeholders, include the upper Lambourn, and runoff from the road that runs parallel to the river.

Figure 5.2: *Relative fine sediment erosion vulnerability derived using the SCIMAP modelling approach for the Lambourn catchment. An indicative map provided by the Environment Agency, indicates areas with ephemeral streams.*



In addition to the catchment scale maps of erosion vulnerability, in small targeted areas of the catchment, the use of fine-scale Light Detection And Ranging (LiDAR) data and aerial photography data can aid with validation of the SCIMAP outputs and provide information about land use and management practices. The fine scale SCIMAP outputs were used to identify the relative sediment vulnerability within Rural Land Registry (RLR) (2015) County Parish Holdings (CPH) parcels. Fine-scale SCIMAP targeting maps can be a useful tool for communication with land owners.

Two metre resolution Digital Surface Model (DSM) LiDAR (+/- 1 m vertical accuracy) data was used for the analysis and the SCIMAP outputs are shown over the most recently available aerial photography to enable comparison with land use type and on-the-ground features. Commons land has been included in the analysis.

Fine-scale SCIMAP vulnerability outputs for areas in the Lambourn catchment which have relatively high erosion vulnerability and / or areas identified by stakeholders to support existing or planned work or to investigate areas where relatively little is known about sediment erosion vulnerability are shown in Figures 5.3 to 5.5.

Land parcels with the greatest vulnerability for fine sediment erosion were focused within the western upper and lower extremes of the 'Winterbourne' waterbody (Figures 5.3 and 5.4). Additionally, two specific parts of the 'Lambourn from Source to Newbury' Waterbody were highlighted as containing land parcels with high vulnerability for fine sediment erosion (Figures 5.5). Firstly, in the north eastern extreme, north of Upper Lambourn and secondly a larger area ranging between Fawley southwards through South Fawley, East Garston and Great Shefford.

Figure 5.3: *Fine sediment erosion vulnerability derived using the SCIMAP modelling approach for the upper-reaches of the Winterbourne sub-catchment. The fine sediment erosion vulnerability maps are symbolised to show above average erosion vulnerability derived for each modelled catchment area. Aerial photography is shown from the year 2009/10. The average relative SCIMAP derived vulnerability of sediment transport from land to watercourses was used to identify vulnerable areas based on Rural Land Registry (RLR) (2014) County Parish Holdings (CPH) parcels.*

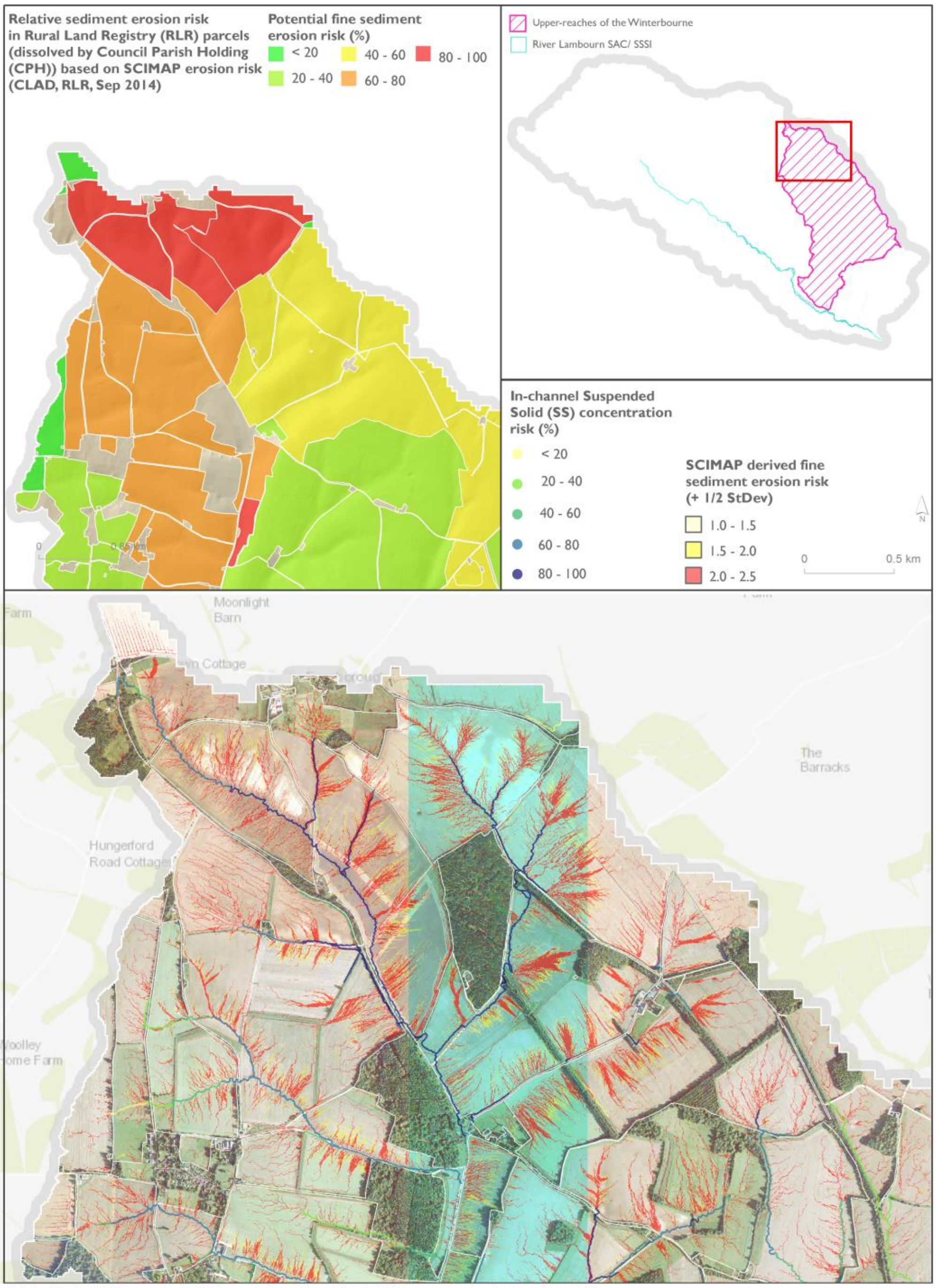


Figure 5.4: *Fine sediment erosion vulnerability derived using the SCIMAP modelling approach for the lower-reaches of the Winterbourne sub-catchment. The fine sediment erosion vulnerability maps are symbolised to show above average erosion vulnerability derived for each modelled catchment area. Aerial photography is shown from the year 2009/10. The average relative SCIMAP derived vulnerability of sediment transport from land to watercourses was used to identify vulnerable areas based on Rural Land Registry (RLR) (2014) County Parish Holdings (CPH) parcels.*

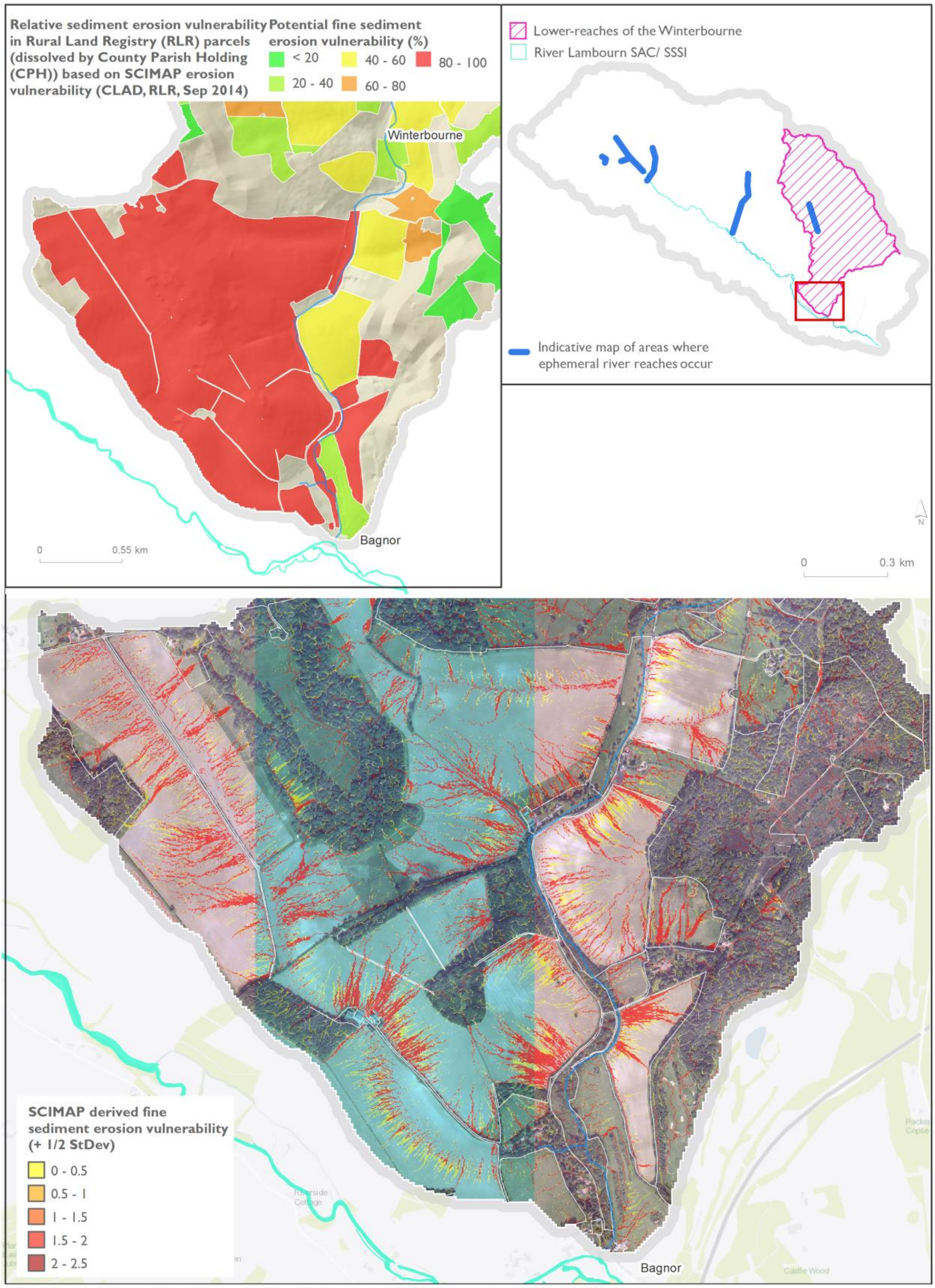
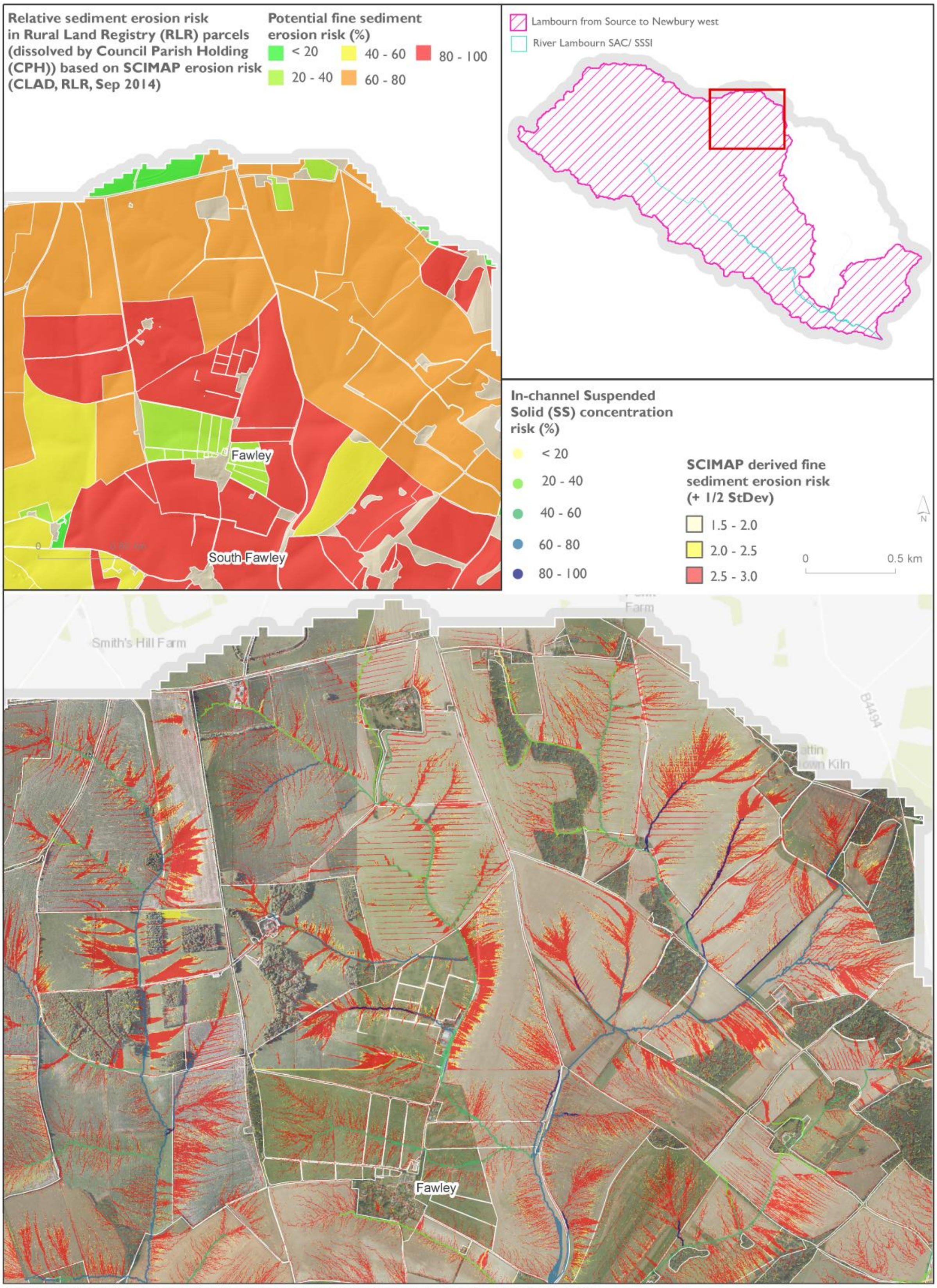


Figure 5.5: *Fine sediment erosion vulnerability derived using the SCIMAP modelling approach for the Lambourn from Source to Newbury north-east. The fine sediment erosion vulnerability maps are symbolised to show above average erosion vulnerability derived for each modelled catchment area. Aerial photography is shown from the year 2009/10. The average relative SCIMAP derived vulnerability of sediment transport from land to watercourses was used to identify vulnerable areas based on Rural Land Registry (RLR) (2014) County Parish Holdings (CPH) parcels.*



5.1.2 Sediment source apportionment

Outputs from the **SE**ctor **P**ollutant **A**ppo**R**tionment for the **A**qua**T**ic **E**nvironment (**SEPARATE**) model are presented here to assess sediment source apportionment for the Lambourn catchment. SEPARATE was developed as part of a field tool kit for ecological targeting of agricultural diffuse pollution mitigation as part of Defra project WQ0223 and developed through North Wyke Rothamsted Research, ADAS and the Centre for Ecology and Hydrology (CEH) (Defra, 2013)

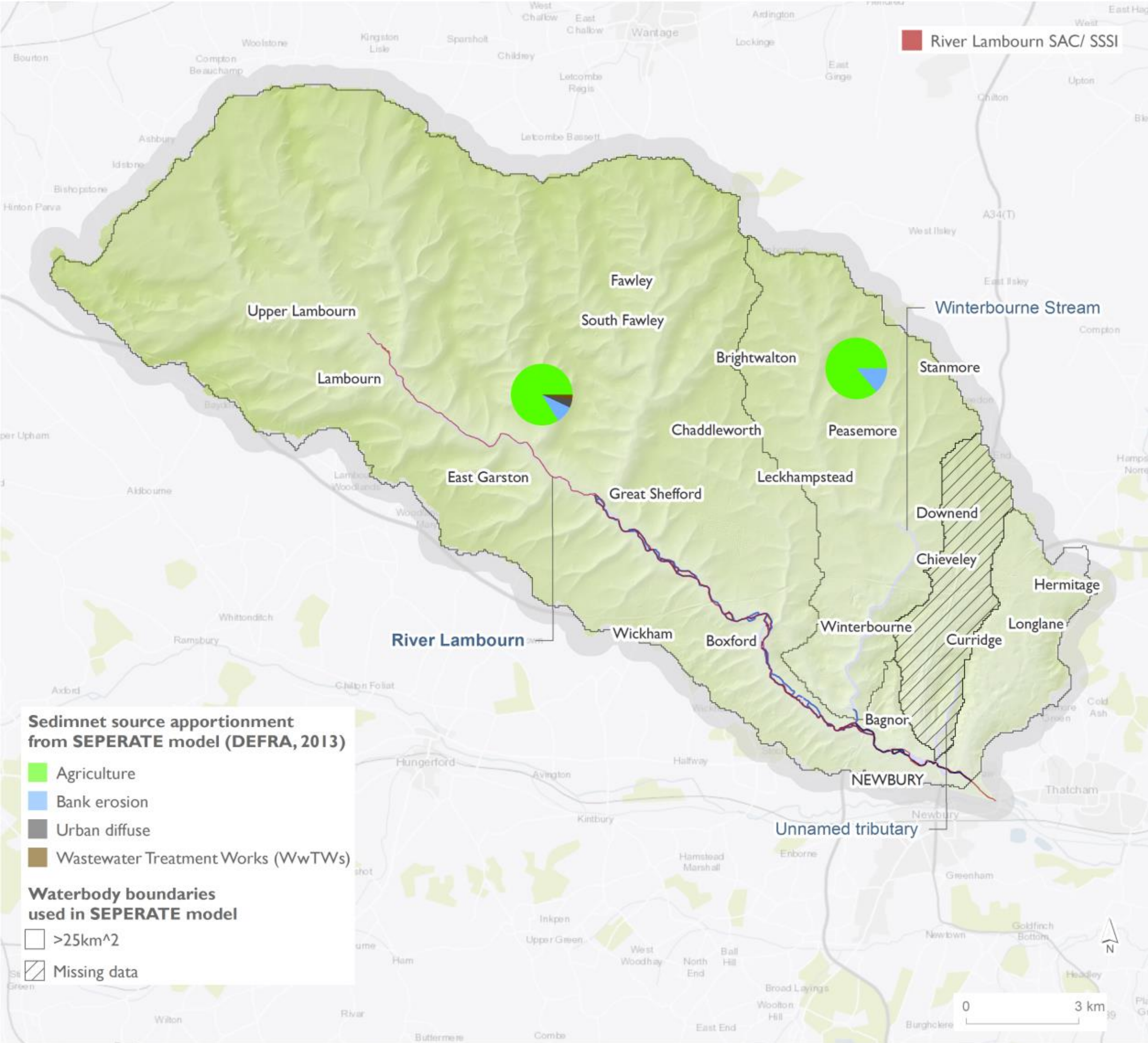
The outputs of SEPARATE are summarised by WFD cycle 2 waterbodies, however, the results for individual waterbodies with areas <25 km^2 should be treated with caution. As with the other modelling tools the resolution of regionally averaged data, particularly landuse, leads to uncertainty at smaller spatial scales. The pollutant emissions from the agricultural sector represent a baseline with no prior implementation of mitigation methods.

WwTW emissions are based on monitored data and so reflect the tightening of discharge permits and the gradual introduction of nutrient stripping (currently at or planned to be at ~600 works by 2015 in conjunction with the Urban Wastewater Treatment or Habitats Directives). Nonetheless, there are significant uncertainties associated with the flow and effluent concentrations emanating from the smaller WwTWs (< 250 population equivalent). In this instance default estimates are used based on a national relationship between actual and consented discharges for the period 2010-2012 combined with regional average effluent concentrations. Input data used to derive estimates for the individual sectors or sources are also not for the same time-period, 1991-2010 for agriculture, 2010-2012 for WwTWs.

The estimates of channel bank erosion do not account for channel margin protection works. SEPARATE represents pollution delivery to and not retention in the watercourse and does not include biogeochemical cycling. Therefore, as for all models there are limitations associated with how processes are represented and the data underpinning the model and therefore output are inherently uncertain and should be treated with caution.

The SEPERATE sediment source apportionment (Figure 5.6) indicates that agriculture is the dominant source of sediment supplied to watercourses in the catchment, with bank erosion and urban sources making a much smaller contribution.

Figure 5.6: *Sediment source apportionment outputs from the SEPARATE model for the River Lambourn catchment (Defra, 2013). Pie-charts are placed in the middle of waterbodies for presentation purposes.*

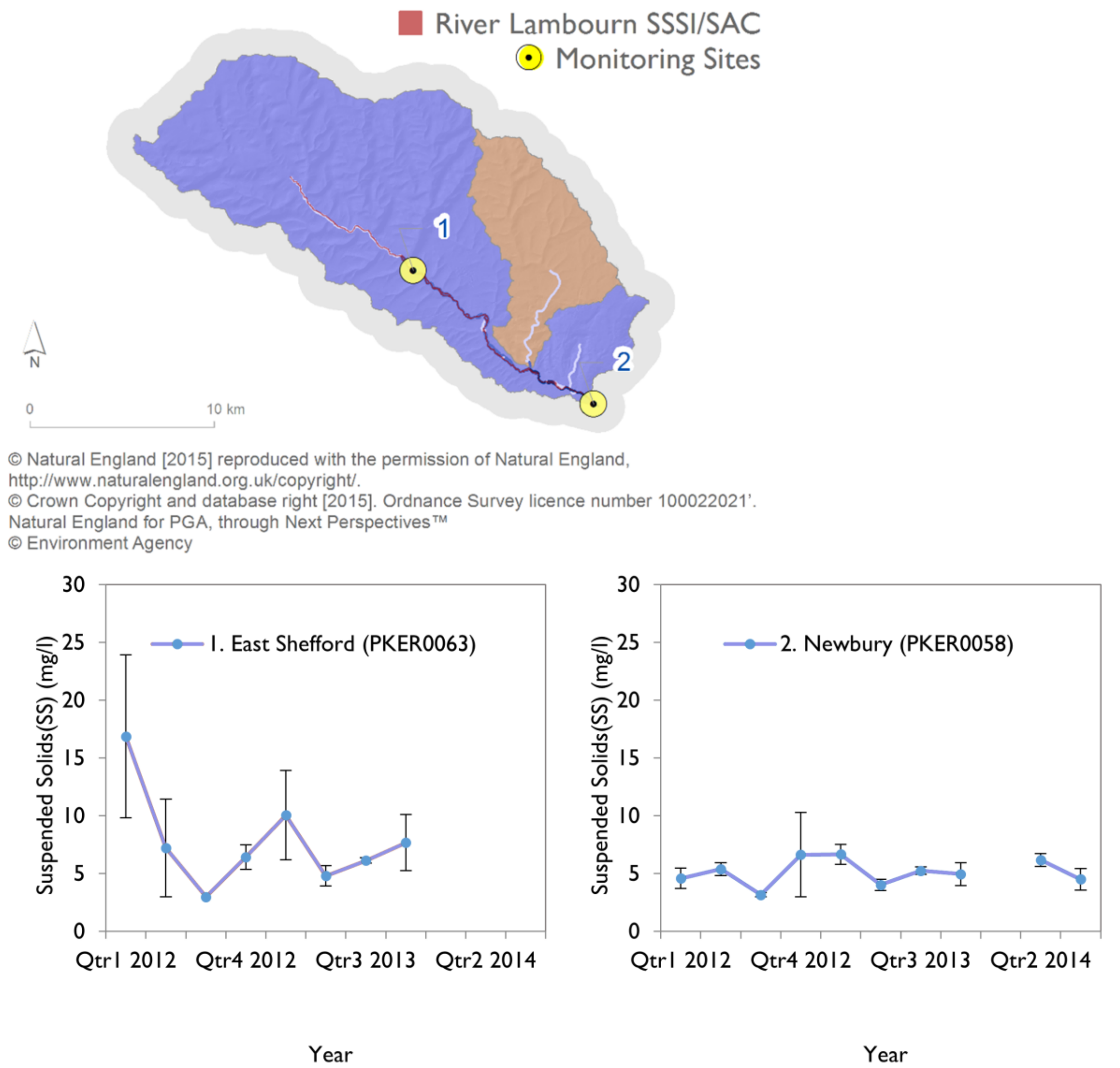


5.1.3 Water Quality Analysis - Suspended Solids

Water quality monitoring data can be used to identify areas contributing the greatest amount of in-stream Suspended Solids (SSs). However, the spatial and temporal resolution of the data available in the Lambourn catchment was insufficient to do this. Data was available for two EA monitoring sites with SS concentrations sampled on a quarterly basis between 2012 and 2014. This data can help to validate/challenge SCIMAP derived relative erosion vulnerability maps and indicate which sub-catchments may be acting as significant source of sediment.

Monitoring site 1, East Shefford, situated in the headwaters of the river, displays the greatest SS concentration and range as it will be influenced by localised inputs. Monitoring site 2 displays a marginally lower average and range reflecting the contribution from a wider source area.

Figure 5.7: *Time-series plots showing quarterly averages of Suspended Solid (SS) concentrations (mg/l) within the Lambourn catchment; using statutory Water Framework Directive (WFD) monitoring data, where available, from 2012 – 2014 (source: Environment Agency). Standard error bars are shown. Sample numbers and locations and sub-catchments (WFD Cycle 2, surface water) are shown in the inset map. Values at the LOD (3 mg/l) were not removed from the analysis.*



5.2 Phosphorus

There are two principal measures of phosphorus in water: SRP (known as soluble reactive phosphorus, which is largely the same as and has historically been used inter-changeably with ortho-phosphate by the Environment Agency) and Total Phosphorus (TP). The soluble reactive form (SRP) is regarded as being biologically available and is usually the nutrient limiting the growth of algae in freshwaters. The insoluble fraction of TP is often associated with sediment in the water and is often ignored, but it can rapidly become biologically active through decomposition or solubilisation and as such TP is the better or more complete measure of phosphorus load in rivers.

There are five principal sources of phosphorus: (1) agricultural sources (diffuse and point); (2) consented point sources (e.g. WwTWs); (3) other diffuse anthropogenic sources (e.g. septic tanks, urban run-off etc.); (4) SRP release from historic build-up in sediments; and (5) groundwater sources. The potential for phosphorus sources to generate nutrient pollution in the Lambourn catchment are described in the following sections.

5.2.1 Phosphorus Risk Analysis

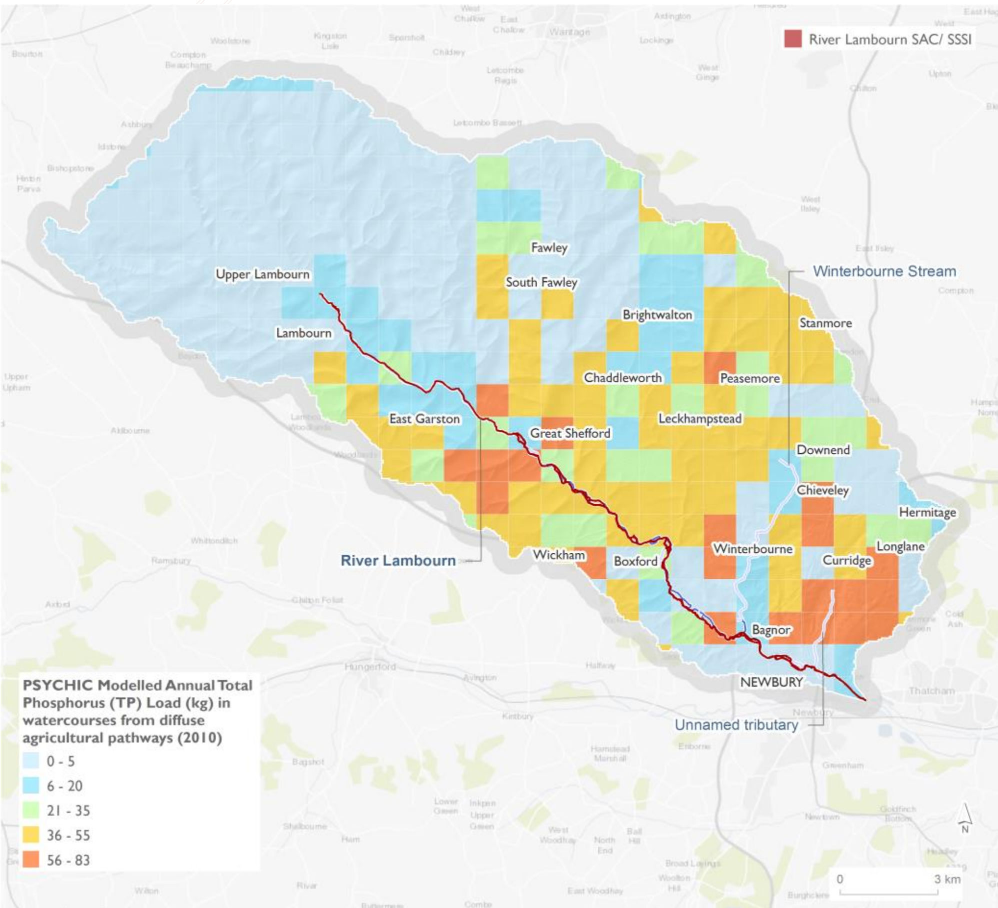
The **P**hosphorus and **S**ediment **Y**ield **CH**aracterisation **I**n **C**atchments (**PSYCHIC**) model can be used to assess the distribution of phosphorus pollution risk from runoff. PSYCHIC was developed by a consortium of academic and government organisations led by ADAS (Davison et al., 2008).

PSYCHIC is a process-based model of phosphorus and suspended sediment mobilisation and subsequent delivery to watercourses. Modelled transfer pathways include release of desirable soil phosphorus, detachment of sediment and associated particulate phosphorus, incidental losses from manure and fertiliser applications, losses from hard standings, the transport of all the above to watercourses in under-drainage (where present) and via surface pathways.

The PSYCHIC model can be used at two spatial scales: the catchment scale, where it uses available national scale datasets to infer all necessary input data, and at the field scale, where the user is required to supply all necessary data. The catchment-scale model, output which is used here, is designed to provide the first tier of a catchment characterisation study, and is intended to be used as a screening tool to identify areas within the catchment which may be at elevated risk of phosphorus loss. The model is sensitive to crop and animal husbandry decisions, as well as to environmental factors such as soil type and field slope angle.

Total Phosphorus (TP) loads were greatest on the low permeability soils in mid to lower reaches of the catchment (Figure 5.8). Predicted phosphorus hotspots may also correlate with high risk sources (e.g. intensive livestock) or pathways (e.g. farm tracks etc.).

Figure 5.8: *Total Phosphorus (TP) baseline load risk for the Lambourn catchment, derived using PSYCHIC (2010).*



5.2.2 Consented & Unconsented Discharges

Treated sewage effluent presents a significant source of bioavailable phosphorus delivered directly to the receiving water via an end-of-pipe discharge. The principal sources of SRP in sewage are human faeces, urine, food waste, detergents and industrial effluent which enter the sewer system and are conveyed to WwTWs.

Typical water company WwTWs remove 15-40% of the phosphorus compounds present in raw sewage. Advanced/ tertiary treatment, usually in the form of chemical dosing with a precipitant (e.g. Iron or Aluminium Sulphate), can remove up to 95% of phosphorus compounds. In rural areas with a relatively small and dispersed population there are many smaller less efficient private sewage discharges (Package Treatment Plants (PTPs) or SDDs). Both in isolation and combined, these can make a significant contribution to in river phosphorus loads and concentrations, both locally and to the overall catchment budget. As sewage discharges are continuous, the relative contribution from these sources tends to increase during base/ low flow periods, as a result of a lower dilution ratio, though as stated above flows are relatively stable in groundwater fed rivers such as the Lambourn.

Discharge consents to surface waters and ground water active in 2015, are shown in Figures 5.9 and 5.10, respectively. There were 83 consented discharges to surface watercourses in the catchment, of which 59 were private sewage discharges and 21 were water company operated. Of the 25 consented discharges to groundwater, 23 were private sewage discharges, whilst a water company treated sewage discharge and private trade contributed to a further 2 discharges.

Figure 5.9: A*ctive discharge consents to surface waters within the Lambourn catchment (source: Environment Agency, 2015).*

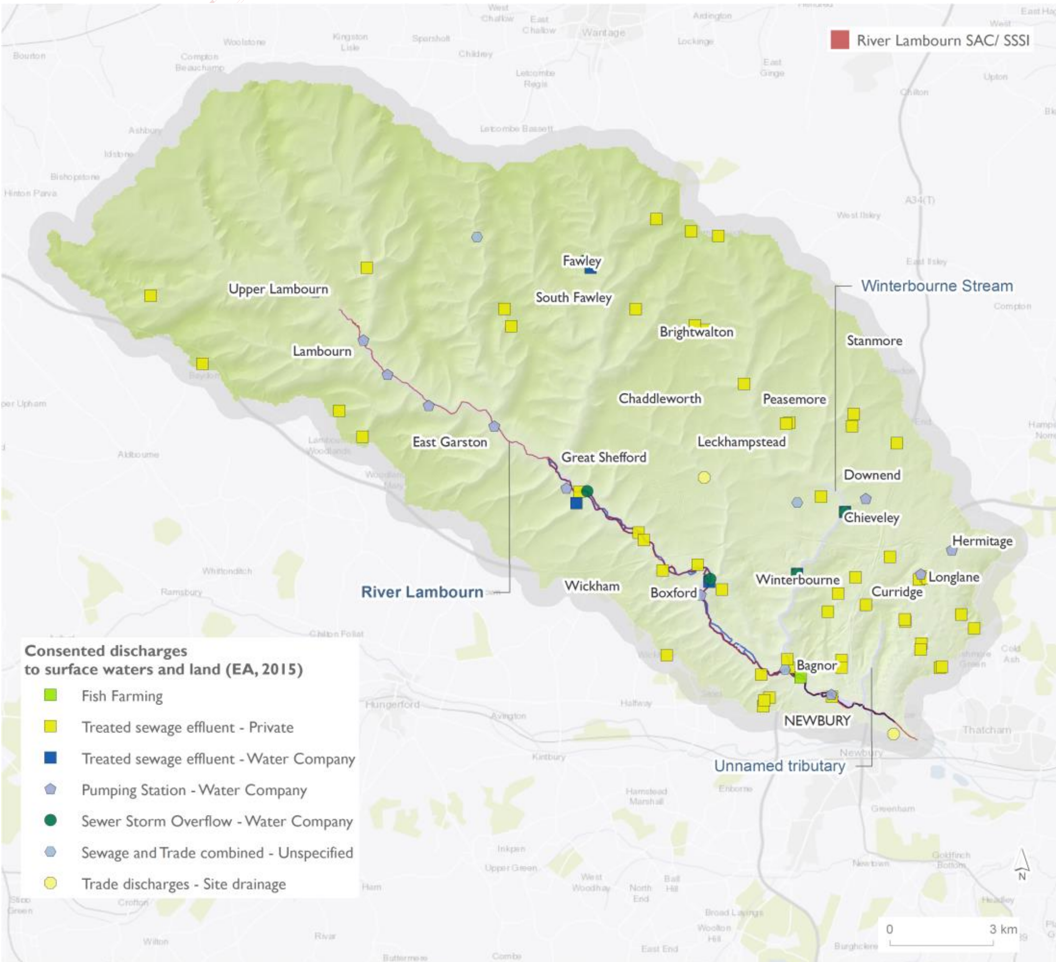


Figure 5.10: ***A****ctive discharge consents to ground waters within the Lambourn catchment (source: Environment Agency, 2015).*

While consented sewage discharges have an environmental permit or discharge consent associated with them, there are still many small private PTPs and SDDs which are not registered or consented and therefore do not have a numerical discharge limit.

SDDs, which include septic tanks and package treatment plans (PTPs), have been highlighted as potential sources of nutrients which can cause water quality problems; although often it is not known how significant they are (May and Woods, 2015 - NECR 179). In theory, septic tank systems should pose little threat to the environment, because much of the phosphorus discharged from the holding tank is removed from the effluent as it percolates through the soil in the drainage field or soakaway. However, based on available, albeit limited, information, it seems that many septic tank systems do not function properly because they are incorrectly sited and/or improperly maintained. Studies in Ireland have indicated that more than 80% of septic systems are probably not working efficiently. Anecdotal information indicates that the situation in England may be similar, though this has yet to be firmly established (May et al., 2015 - NECR170).

The literature review conducted as part of the NECR170 report revealed cases where septic tank discharges have had a significant impact on downstream phosphorus concentrations, causing increases of up to 700% in some cases. This has the potential to cause considerable ecological damage at the local scale, especially in sensitive areas where internationally important conservation sites may be threatened.

In terms of seasonality, it is likely that septic tank effluents have the potential to increase the phosphorus concentrations of receiving waters all year-round, depending on the local circumstances (May et al., 2015 - NECR170).

In a 2015 (May and Woods NECR179) review of the effectiveness of different on-site wastewater treatment systems (OSWwTS) and their management to reduce phosphorus pollution, it was concluded that the most effective options for reducing the levels of phosphorus discharged from OSWwTS to the environment are as follows:

1) Reducing phosphorus inputs to the tank (e.g. using phosphorus free detergents).
2) Using chemical precipitation to retain phosphorus within the tank and incorporate it into the sludge.
3) In areas where the water table is high, i.e. <1.5 m below soil surface, impacts on nearby watercourses can probably be reduced by installing mounded soakaway systems.

It should be noted that the use of phosphorus free detergents is becoming increasingly common due to the introduction of recent European legislation (European Union, 2012). Whilst chemical precipitation is an effective method of retaining phosphorus within tanks, due to issues of personal and environmental safety it is not currently considered appropriate for widespread use.

In addition to the above, many other approaches to tank management have the potential to effectively reduce phosphorus discharges from these systems. However, at present, there is insufficient data and information available for their level of efficacy to be determined. Other options that are often recommended include frequent de-sludging or replacing traditional septic tanks with PTPs. It is unclear how and to what extent these other options are effective at reducing the phosphorus concentration in tank effluent or whether, in practice, these approaches could be making the situation even worse in some situations (May and Woods, 2015 – NECR179).

In January 2015, a set of binding rules came into place, as part of the Environment Agencies 'reform of the regulatory system to control SDDs and PTPs in England'. The reform sets out to simplify existing regulation within less sensitive areas and providing a more risk based approach to permitting in more sensitive areas.

More information on the reform can be found here:

https://www.gov.uk/government/consultations/small-sewage-discharges-new-approach-to-how-we-regulate-in-england

CEH recently carried-out a desk study for Natural England (NE, 2014) with the aim of developing a general methodology that could be used to estimate the number and location SDDs discharging to ground within the catchment of freshwater SSSIs and assess their relative likelihood (low, moderate, high) of causing phosphorus pollution. Level of risk was based on literature based value ranges: (1) distance to watercourse; (2) winter water table height; and (3) slope.

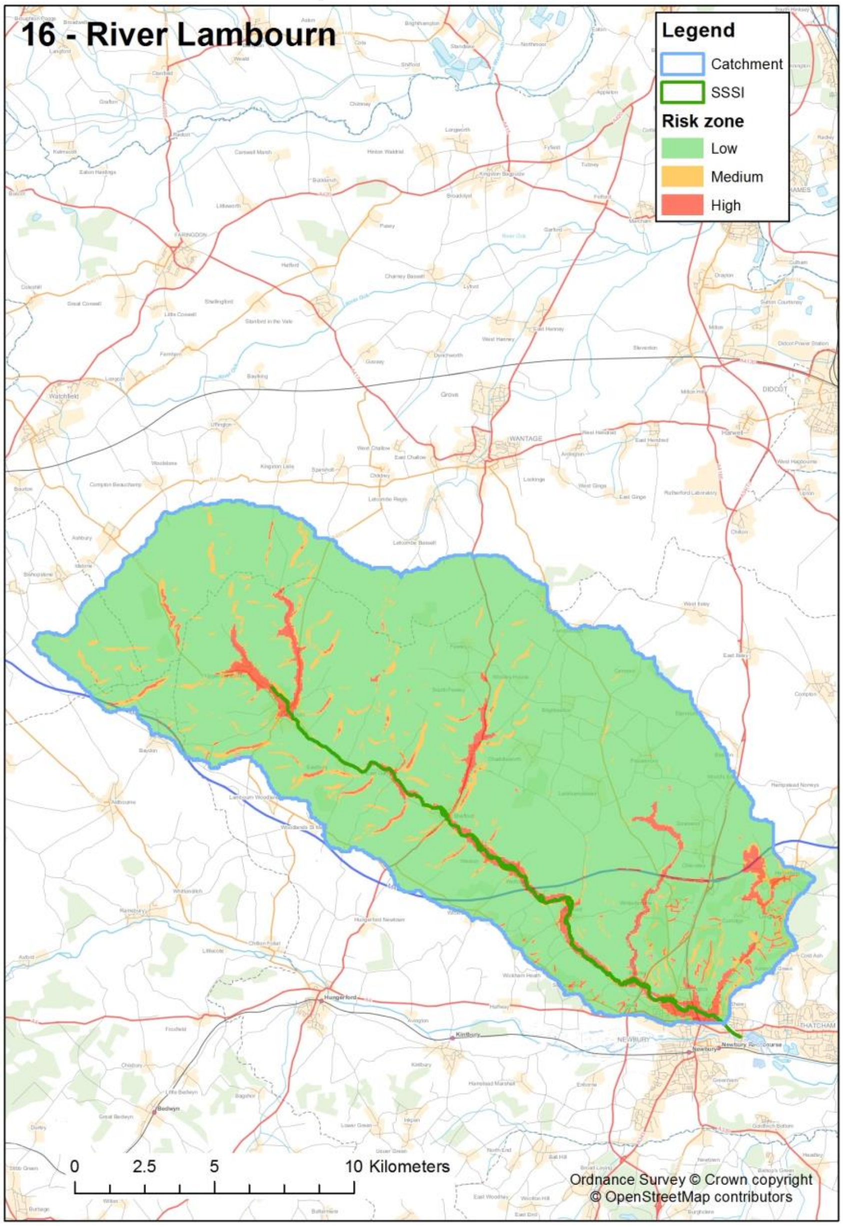
The method for assessing the relative likelihood of SDDs causing phosphorus pollution was derived from May et al., (2015 - NERC171).

While evidence exists for the potential for phosphorus to travel at least 30 m from the septic tank, in general it has shown that this part of the soil soakaway has the capacity to remove most of the phosphorus from SDD effluent before it enters a waterbody that is at a greater distance. However, it should be noted that this capacity will be reduced if the functioning of this system is compromised by enhanced hydrological connectivity, such as that caused by direct discharge to a waterbody, the installation of local drainage channels and/or a high-water table. In addition, a reduction in phosphorus retention capacity may also occur if soils become temporarily waterlogged for any reason, such as during local flooding or hydraulic failure of the soakaway caused by the incorrect repair and maintenance of the system.

The Lambourn catchment was included in the NE, 2014 study of the relative likelihood of SDDs discharging to ground causing phosphorus pollution in SSSIs and outputs are shown in Figure 5.11.

Most, 89 %, of the catchment was considered low risk in terms of the location of SDDs, 6 % was found to be moderate risk and 5 % was found to be high risk. Of the ~9,584 properties estimated to be in the catchment, 6,916 appeared to be connected to the main sewer. Of the remaining unsewered properties 355 were in high risk areas, with a high risk of contaminating watercourses, 140 were at moderate risk and 2,173 at low risk.

Figure 5.11: *Natural England small domestic discharges (SDD) risk map (NE, 2014), showing (1) high, moderate, and low risk zones for locating SDDs to ground.*



5.2.3 Phosphorus Source Apportionment

There are many catchment scale models available that can be used to estimate the relative contribution to in river phosphorus loads and concentrations from different sources/ sectors, and are thus useful for targeting. In many cases a combination of measures across multiple sources and sectors will be required to meet conservation objectives.

The National Source Apportionment GIS (SAGIS) model is used in this report to estimate the relative contribution of different sectors and areas to instream phosphorus concentrations and loads and, where water quality monitoring was not available, assess compliance.

SAGIS was developed through UK Water Industry Research (UKWIR) and represents the most consistent modelling framework and has been adopted by both the Environment Agency and water industry for catchment planning purposes. SAGIS has predominantly been used for strategic planning, for example to inform policy decisions or run scenarios at the National or regional scale.

The detailed SAGIS outputs used in this report are based on a regional calibration produced for the UKWIR funded project (WW02B207), which was supported by Natural England. The automated calibration methodology adjusts diffuse inputs to fit observed instream monitoring data on a regional basis. The model was calibrated against data between 2010 – 2012. The same UKWIR project also led to some improvements to SAGIS including: (1) better representation of headwater defaults; (2) improved application of regionally defined default values for effluent quality in the absence of observed data; (3) updated point source and AgCensus data; and (4) the application of non-parametric files to better define the relationship between catchment inputs of chemicals and river flow.
It is important to note that local quality assurance / calibration of the model inputs / outputs was not undertaken. Experience in using SAGIS in other areas has shown there can be significant local features that require altering (characterisation /addition / removal) to gain confidence in the source apportionment estimates and thus forecasting the effectiveness of suitable measures. However, SAGIS still represents the best available, and certainly most consistent, outputs though they should be treated with caution providing only an indication of the relative contribution rather than absolutes. Adopting a weight of evidence approach observed data and local knowledge should be afforded a higher weighting than SAGIS model outputs.

The detailed outputs from the national model provided are based on the following principles:

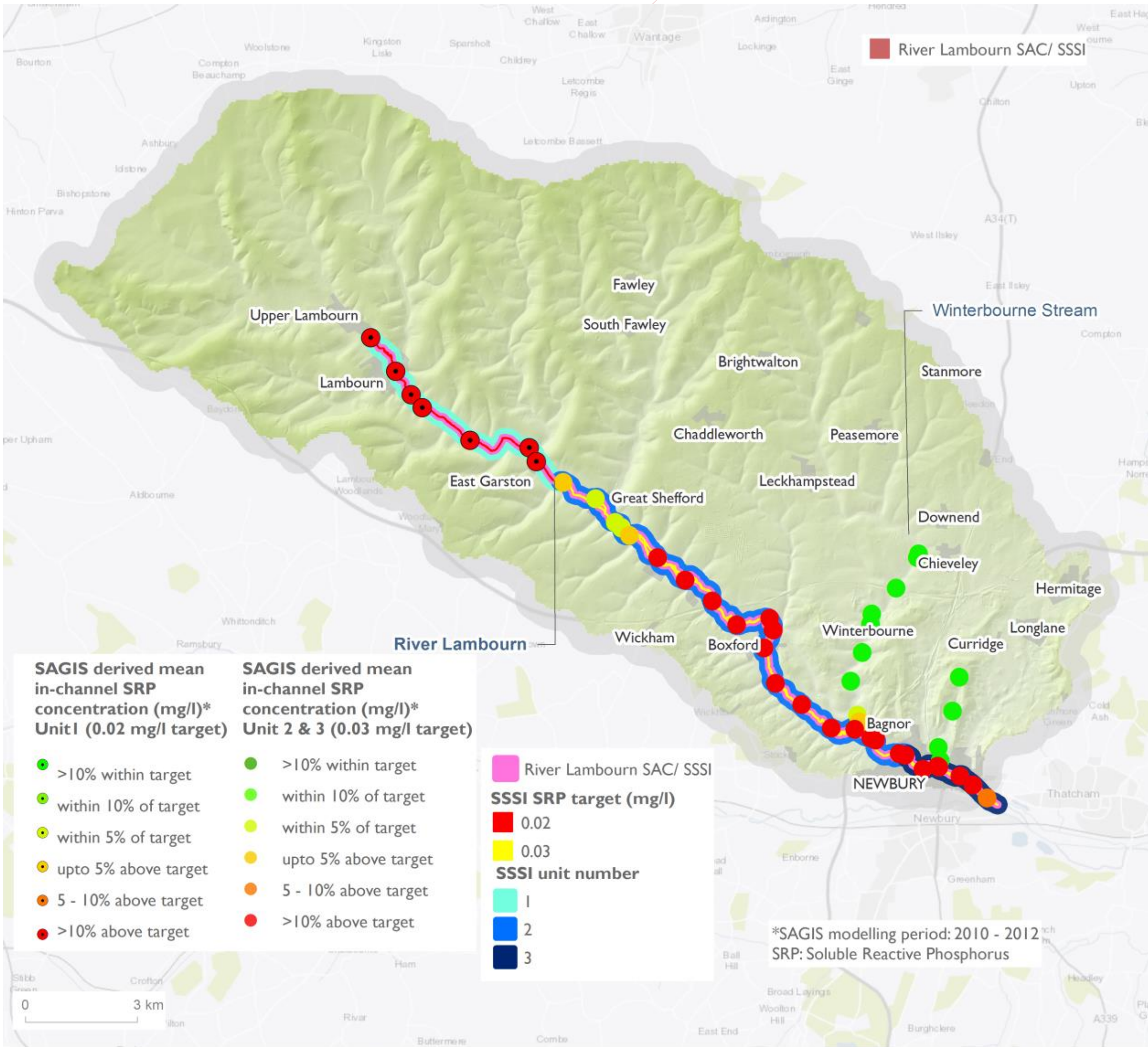
1) Sector contributions to river concentrations are provided for all locations.
    - For each location SAGIS estimates the contribution of each individual upstream point source (i.e. all WwTWs, industrial discharges, mines, and intermittent discharges).
    - For each location, SAGIS models the contribution of the upstream waterbody(s) to the relevant diffuse source sector.
2) The relationship between the scale of the input and the consequent downstream concentration is assumed linear; for example, if an input from a point or diffuse source is halved the associated component of the downstream concentration will also be halved.

Based on these principles, at any point in the river, concentrations can be separated into their individual component sector sources. Component sectors can then be modified, based on a change in an individual point source or a diffuse source within a specific waterbody, and instream concentrations recalculated. The recalculation exercise provides the basis for assessing the impact of catchment management measures or changes to point source discharges/ consents on downstream concentrations and loads. Additional information on the sectors covered in SAGIS can be found in Appendix 1.

The SAGIS model outputs were reviewed by water company representatives in the stakeholder workshop, and no upgrades have been made at the WwTWs in the catchment since 2012.

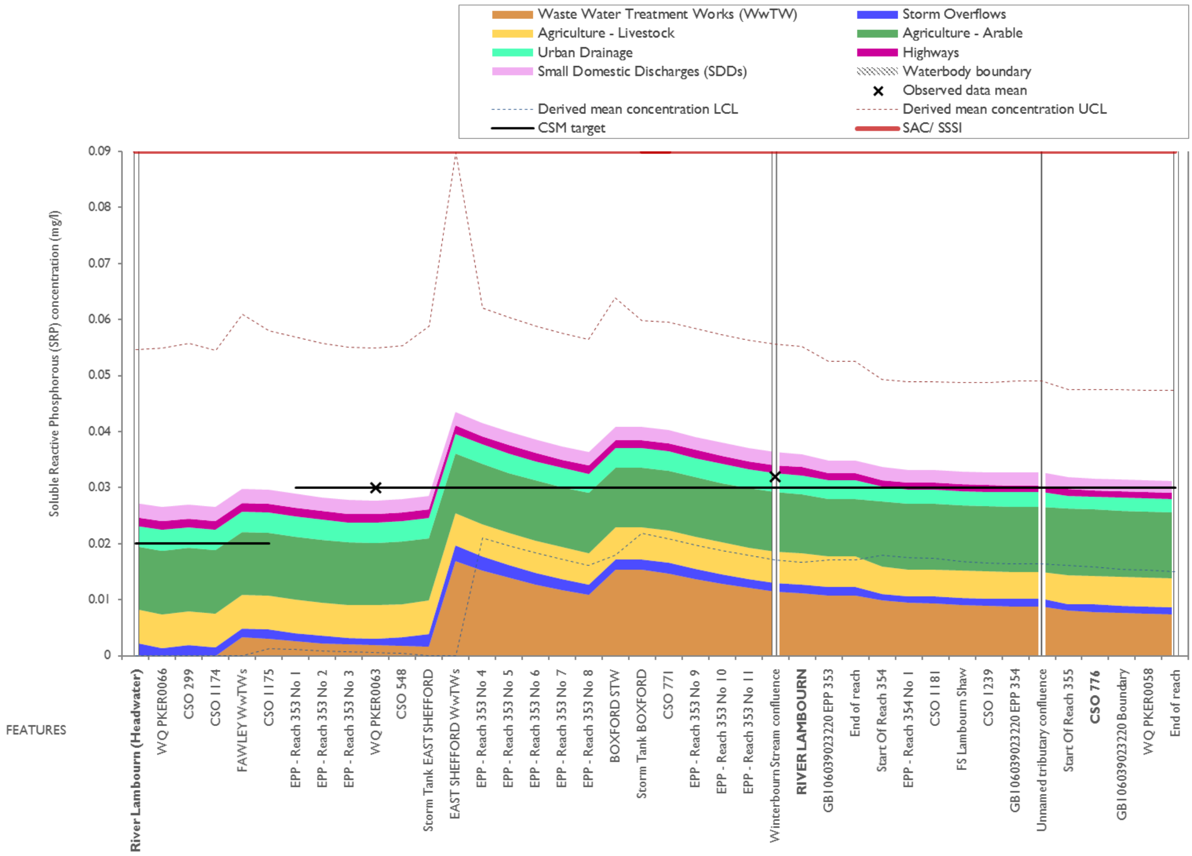
The SAGIS baseline shows the entire River Lambourn SAC/SSSI as being non-complaint with CSM targets for SRP, except for a small stretch in the upper-reaches of Unit 2, to East Shefford (Figure 5.12). The same stretch is non-compliant based on available monitoring.

Figure 5.12: *SAGIS derived mean in-channel Soluble Reactive Phosphorus (SRP) concentrations for the Lambourn catchment. Most recent (2015) Common Standards Monitoring (CSM) targets for SRP are shown. Reaches not in the SSSI that do not have targets are assessed against the target of the reach they flow into. The target used is delineated by symbol (circles with or without dots) and compliance with the target is illustrated by colour.*



Agriculture, particularly arable sources, make a significant contribution to instream SRP concentrations along the length of the Lambourn (Figure 5.13). An increase in concentration downstream of East Shefford is attributable to WwTW discharges, and a marginal increase is also evident downstream of Boxford WwTWs. WwTW contributions do decline further downstream as due to instream processes and further dilution from inflows, particularly groundwater.

Figure 5.13: *Chainage plot showing SAGIS derived Soluble Reactive Phosphorus (SRP) (mg/l) downstream along the River Lambourn with sector apportionment. The observed SRP concentrations and simulated mean confidence limits are shown. Feature names are shown in the x axis. The most recent (2015) Common Standards Monitoring (CSM) SRP targets for the River Lambourn SAC/SSSI are shown.*

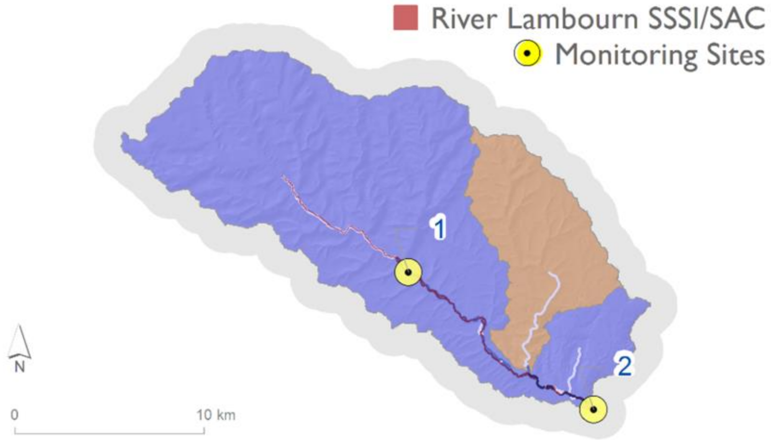


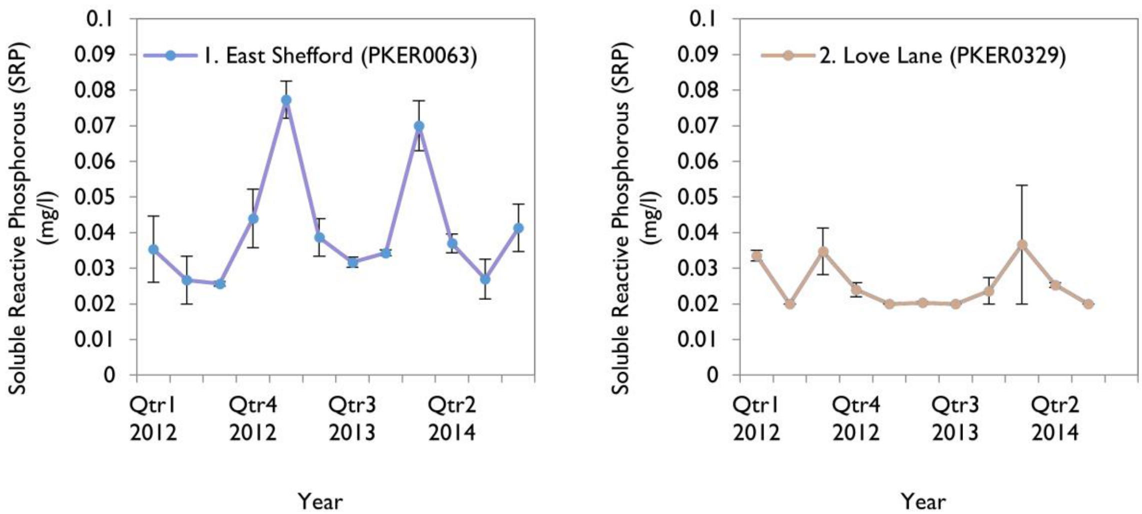
Abbreviations: EPP – Extra plot point; FS – Flow monitoring station; WQ – Water quality monitoring point; CSO – Combined Sewage Overflow; ST – Storm Tank; WwTW – Wastewater Treatment Works; UCL – Upper Confidence Limit; and LCL – Lower Confidence Limit

5.2.4 *Surface Water Quality Monitoring Analysis – Phosphorus*

Average SRP concentrations consistently exceeded the CSM target at site 1 (East Shefford), in many cases by some margin. The CSM target was also exceeded at site 2 (Love Lane) though only marginally and with more consistent average concentrations (Figure 5.14) but it should be noted that this point was excluded from the condition assessment in section 4.2 due to insufficient data at this point.

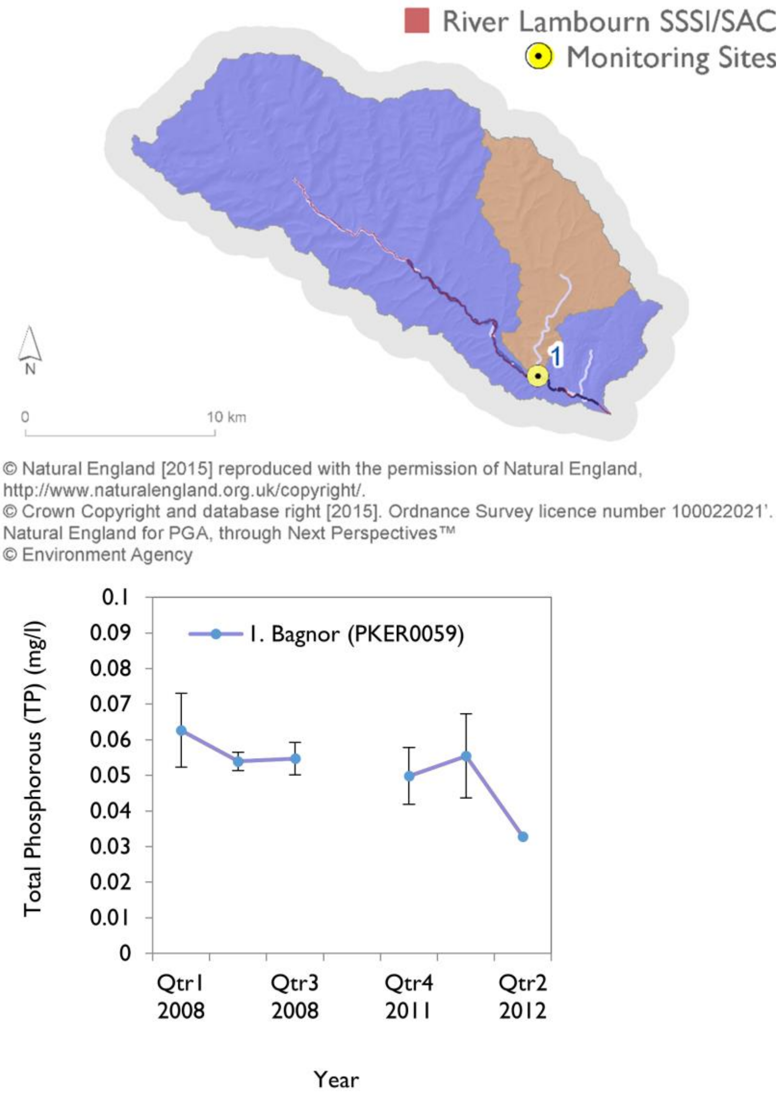
Figure 5.14: *Quarterly averages of Soluble Reactive Phosphorus (SRP) concentrations (mg/l) within the Lambourn catchment; using statutory Water Framework Directive (WFD) monitoring data, where available, from 2012 – 2014 (source: Environment Agency). Standard error bars are shown. Monitoring locations are shown in the inset map. Values at the LOD (0.02 mg/l) were not removed from the analysis.*





There is only limited data for TP in the catchment, with one monitoring site: 'Bagnor'. Here concentrations are marginally higher (~30-50%, see Figure 5.15) than SRP concentrations observed downstream at Love Lane.

Figure 5.15: *Quarterly averages of Total Phosphorus (TP) concentrations (mg/l) within the Lambourn catchment; using statutory Water Framework Directive (WFD) monitoring data, where available, from 2012 – 2014 (source: Environment Agency). Standard error bars are shown. Sample location is shown in the inset map. It should be noted that values at the LOD were not removed from the analysis.*



5.3 Nitrate

Nitrate has been included in this assessment for general information purposes as it is not considered to contribute to the unfavourable condition in the SAC/SSSI. However, the wider effects of nitrate contamination within a groundwater aquifer warrant some consideration. The main risk associated with nitrate in the environment, is that it is highly soluble, and is easily transported as leachate or run-off and can build-up in groundwater aquifers, with limited scope for remediation. There are three principal sources of nitrate pollution in a river catchment: (1) agricultural sources (point and diffuse), (2) consented WwTWs, and (3) other anthropogenic sources, such as landfills and waste sites (leachate). The potential for these sources to generate pollution in the Lambourn catchment are described in the following sections.

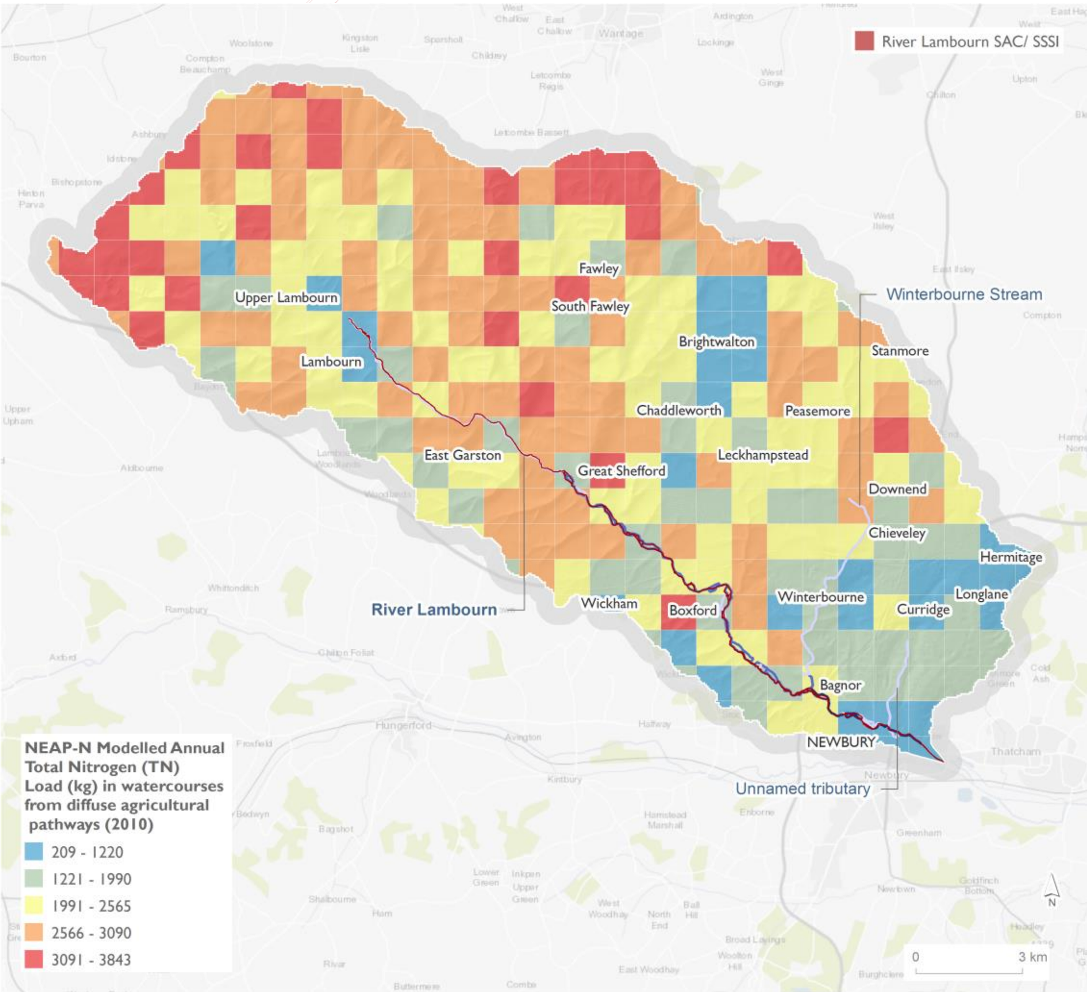
5.3.1 Nitrate Risk Analysis

The National Environment and Agricultural Pollution Nitrate (NEAP-N) model (Lord & Anthony, 2000) was used to assess the distribution of nitrate pollution risk across the River Lambourn catchment.

NEAP-N is a national scale tool for predicting annual average soil drainage, total nitrate load, and average and peak concentrations of nitrate in leachate from agricultural land. The predictions of nitrate leaching are sensitive to crop and animal type, soil type and climate. The model has been applied extensively to develop catchment and national scale predictions of nitrate losses to support catchment characterisation and pollutant source apportionment for UK government policy development.

NEAP-N has been shown to give a good representation of the variation in nitrate loss across the country. Each land use and livestock type is assigned a potential nitrate loss, which is then modified according to the local climate and soil type. The nitrate risk map in Figure 5.16 shows values as annual TN loads from agricultural sources in watercourses and was taken from the 2010 national NEAP-N model. The relatively low to moderate modelled losses of nitrate shown in Figure 5.16 are predominantly found to be associated with slowly permeable soil types, whilst free draining soil types are associated with a higher leaching potential and thus nitrate loss.

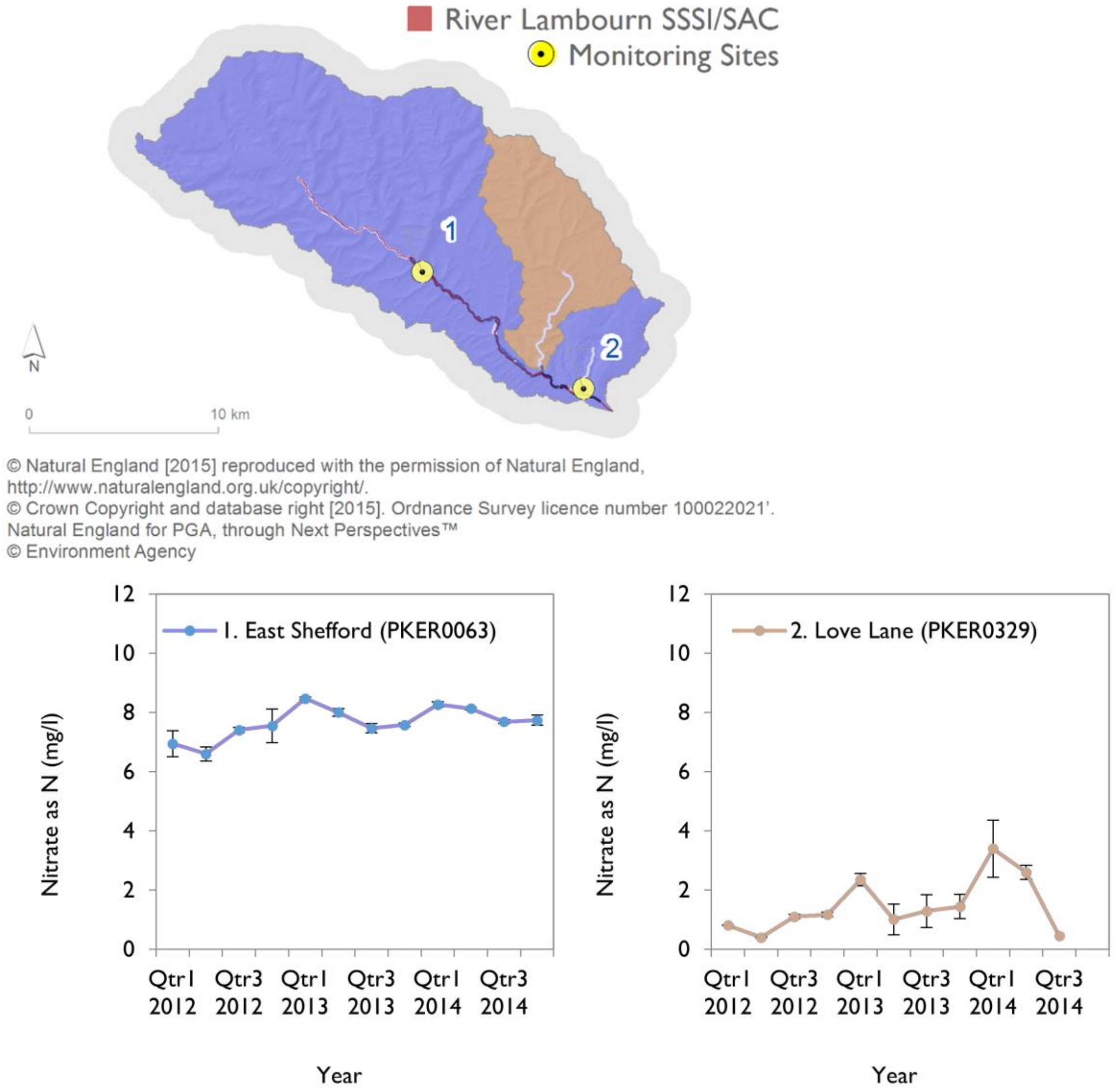
Figure 5.16: *NEAP-N derived annual surface water nitrate load risk map for the River Lambourn Catchment, 2010.*



5.3.2 Surface Water Quality Nitrate Analysis

Quarterly averaged nitrate concentrations varied significantly between the two observed sites both monitored monthly by the EA between 2012 and 2014. Site 3 'Love Lane' displays much lower average nitrate as N concentration (1.6 mg/l) compared with East Shefford (7.7 mg/l). It is likely that river concentrations reflect the localised groundwater quality.

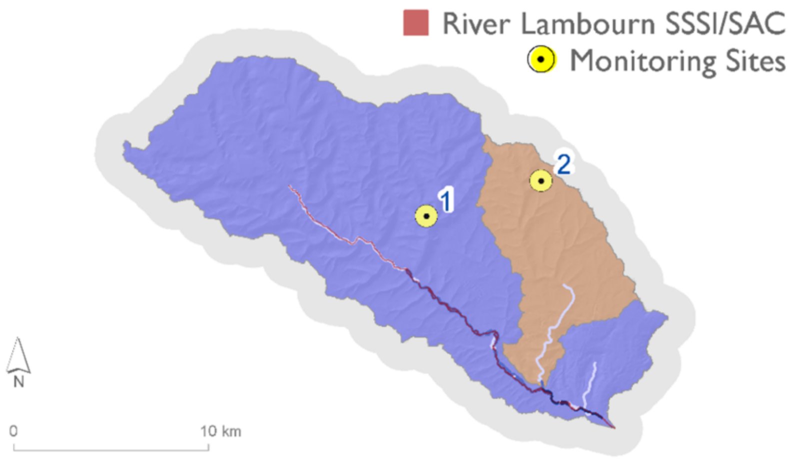
Figure 5.17: *Quarterly averages of nitrate expressed as nitrogen concentrations (mg/l) within the Lambourn catchment; using statutory Water Framework Directive (WFD) monitoring data, where available, from 2012 – 2014 (source: Environment Agency). Standard error bars are shown. Sample locations and sub-catchments (WFD Cycle 2, surface water) are shown in the inset map. It should be noted that values at the LOD were not removed from the analysis.*

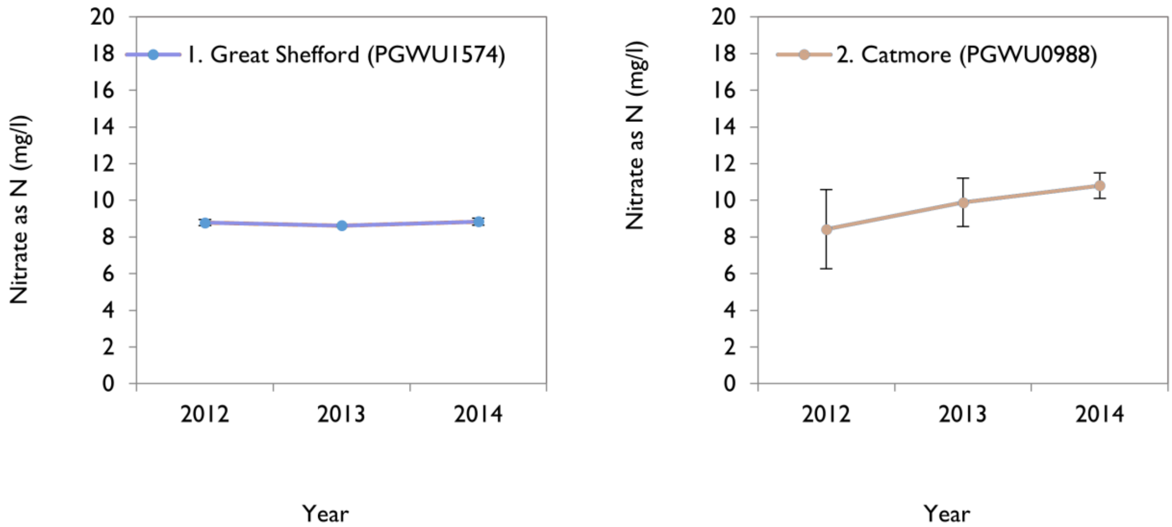


5.3.3 Groundwater Quality Nitrate Analysis

Annual average nitrate concentrations in groundwater (Figure 5.18) are stable but significantly higher than in river concentrations. This is almost certainly due to the historic impact of high nitrate applications in the 1970s and 80s which may still be working their way through the groundwater system. Longer term monitoring data would be required to establish if there was an upward or downward trend in groundwater concentrations.

Figure 5.18: *Average annual of nitrate concentrations (mg/l) within the groundwater based on statutory Water Framework Directive (WFD) monitoring data, where available, from 2012 – 2014 (source: Environment Agency). Standard error bars are shown. Sample locations are shown in the inset map.*





5.4 Additional Pollution Risks & Pressures

5.4.1 Pollution Incidents

Pollution incidents can be very diverse, ranging from large fires and chemical spills to farm slurry spills, odours from waste sites and faulty sewerage systems. They may be caused by severe weather, accidents, deliberate acts, but all have the potential to damage the environment. Chemical spills and effluent pollution incidents can have devastating impacts on ecosystems and wildlife. For instance, pesticide and fungicide spillages from crop sprayers can result in fish deaths and impacts on other wildlife, as well as domestic pets and potentially humans.

In this section, the available information on incidents in the Lambourn catchment, between Jan 2001 and Sept 2014, as recorded by the EA are summarised (Figures 5.19 and 5.20). Category descriptions used by the EA are as follows:

Category 1: most serious and damaging

Category 2: significant damage and impact

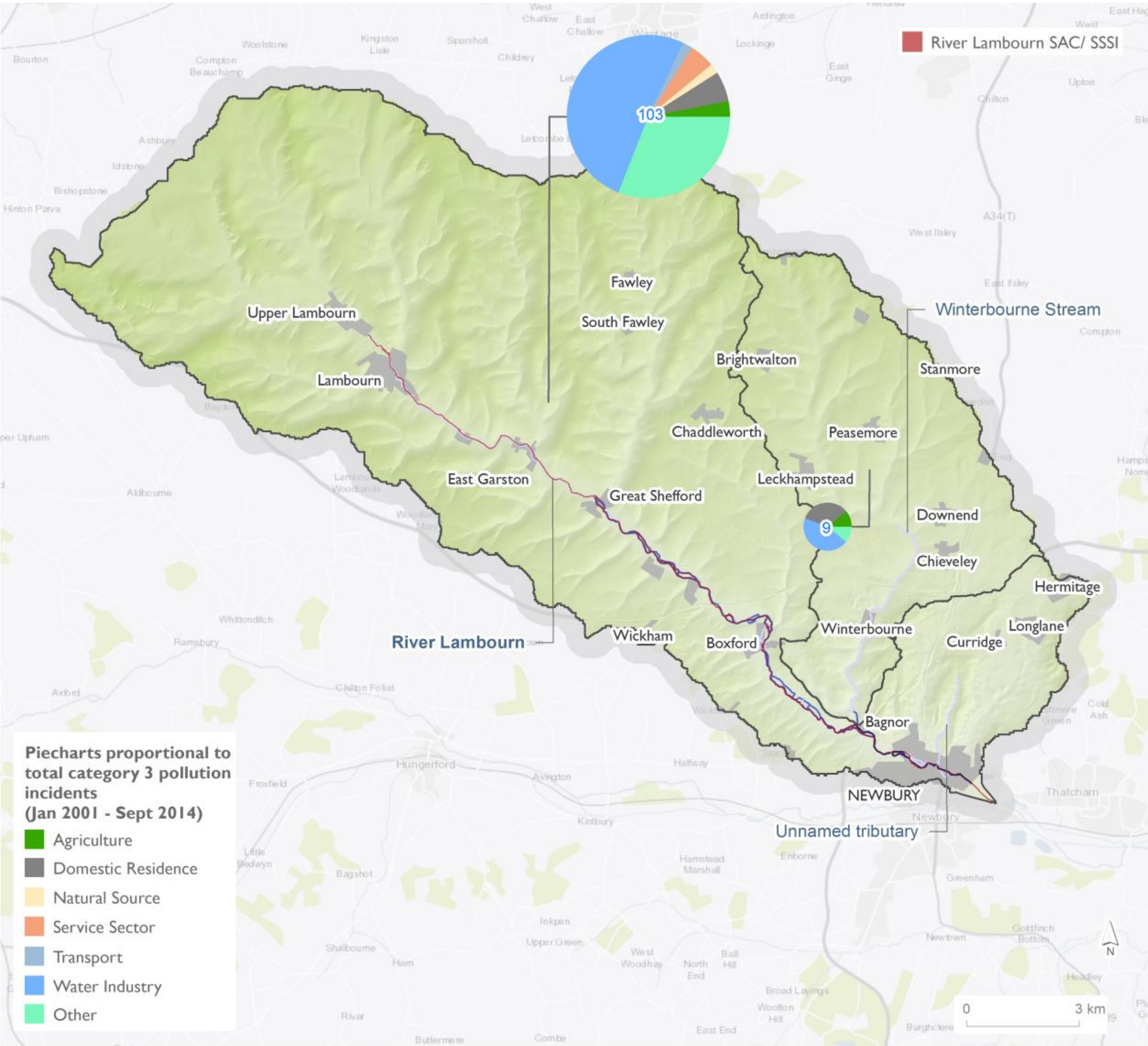
Category 3: pollution confirmed – local impact

Category 4: event reported but no damage can be confirmed

Records indicate one Category 1 and one Category 2 pollution incident within the Lambourn catchment. These were 'Organic Chemical/ Product' and 'Oils and Fuel' related, however not included in Figure 5.19 owing to the sensitivity of the information.

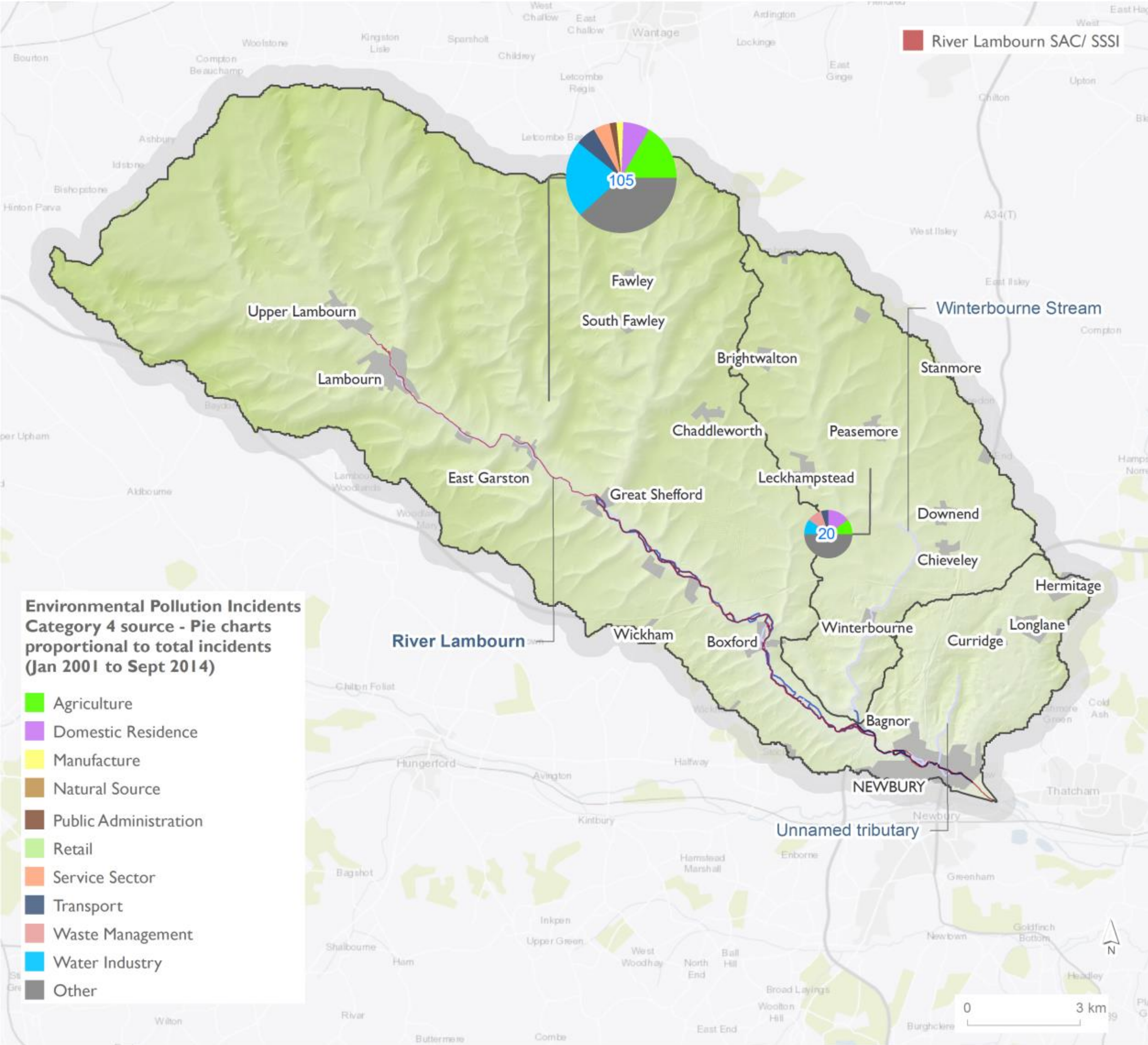
The water industry accounts for around half of Category 3 pollution incidents across the catchment (Figure 5.19). There were fewer incidents recorded in the Winterbourne Stream, though of those recorded domestic residents formed around a third.

Figure 5.19: *Category 3 pollution incidents by sector, between Jan 2001 and Sept 2014 (Environment Agency, 2014). Pie charts are shown in the middle of each waterbody and are proportional to the total number of pollution incidents (as labelled within the pie charts).*



The source of the majority of Category 4 pollution incidents in the Lambourn catchment are classed as other, though both water industry and agriculture also make a significant contribution of those recorded (Figure 5.20)

Figure 5.20: *Category 4 pollution incidents by sector, between Jan 2001 and Sept 2014 (Environment Agency, 2014). Pie charts are shown in the middle of each waterbody and are proportional to the total number of pollution incidents (as labelled within the pie charts).*



6 Intervention Strategy Development

To develop a catchment management programme to mitigate against sediment and phosphorus pollution risks to the River Lambourn SAC/ SSSI, evidence of what plans are already in place and what interventions have been delivered is needed.

6.1.1 Natural Habitats & Designated Sites

Natural habitats play a key structural and functional role in the ability of ecosystems to provide the services on which we all depend; including the protection of clean, fresh water in our rivers and streams, the mitigation of flood risk and the prevention of erosion.

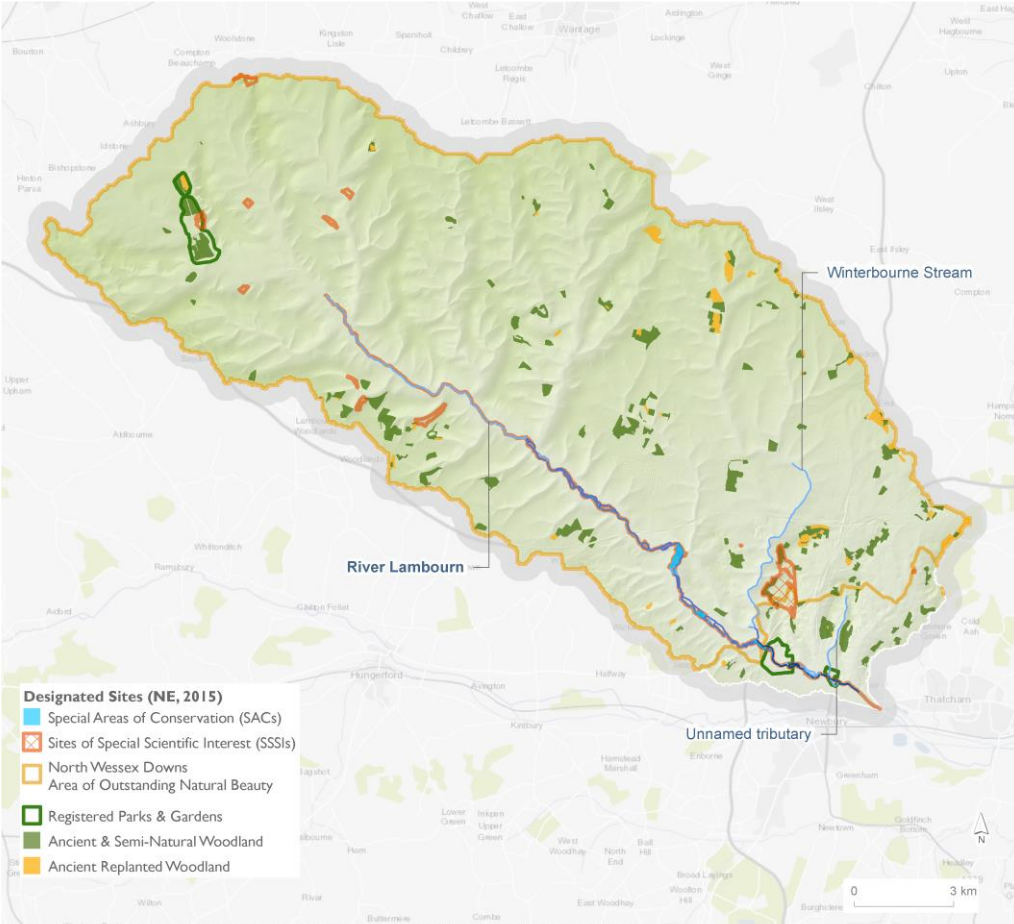
Extending and increasing the connectivity of existing natural habitats across catchments, in addition to the creation of new riparian buffers and wetlands to disconnect hydrological pollution pathways, are some of the key methods used in catchment management and natural resource protection.

Priority Habitats (NE, 2015) and areas in the National Forest Inventory (FC, 2014) are shown in Figure 6.1. Coverage of priority habitats within the catchment is dispersed relatively uniformly across the catchment, except for a corridor along the northern bank of the River Lambourn. Deciduous woodland (covering 1735 ha, 6.6 % of catchment area) is the main habitat classification. There are also many areas designated as 'no main habitat but additional habitats' where there are a variety of habitat types (accounting for 2 % of catchment area). Woodland is largely fragmented across the catchment, with some larger / better connected areas around Newbury.

Figure 6.1*: Important natural habitats in the Lambourn catchment.*

The Lambourn is located within the North Wessex Downs AONB and features a variety of international and national designations, including ~ 965 ha of ancient woodland. These designations are fragmented and spread across the catchment (Figure 6.2).

Figure 6.2: *Designated sites in the Lambourn catchment.*



6.1.2 Prior Interventions

Agri-environment schemes provide funding to farmers and land managers to farm in a way that supports biodiversity, enhances the landscape, and improves the quality of water, air, and soil. The following sections provide an overview of key agri-environment schemes in the Lambourn catchment.

ENVIRONMENTAL STEWARDSHIP SCHEMES

The Environmental Stewardship (ES) Scheme (2006 – 2015), incorporates the Entry Level Scheme (ELS), Organic Entry Level Scheme (OELS), and Higher Level Schemes (HLS) which provided payments to farmers to undertake specific management practices or capital works that protect and enhance the environment and wildlife.

ES was offered to farmers on a voluntary basis and was promoted as a multi-objective scheme covering a range of biodiversity, heritage, and natural resource protection objectives, including soil and water protection. ELS and OELS were non-competitive schemes open to all farmers whilst, the HLS was a competitive scheme within which farmers effectively bid for a share of a limited budget. As of early 2015, ES now falls under the new Countryside Stewardship Scheme, which has a greater focus on water and reducing water quality issues to meet WFD objectives. Payments will still be made for ongoing HLS and ELS agreements but will not be renewed once they have expired.

Countryside Stewardship has three main elements:

1. Higher-tier (can include capital grants)
2. Mid-tier (can include capital grants)
3. Stand-alone capital grants

Countryside Stewardship gives access to funding and/or capital grants for an agreed range of environmental management actions ('options'). A potential limitation of Countryside Stewardship is that HLS will continue until the end of the agreement date, and many ELS agreements won't be going into Countryside Stewardship. Therefore, there is a possibility of losing many options that have been reducing diffuse water pollution. Therefore, there will be less Countryside Stewardship agreements and subsequently less spatial coverage than in the previous ES scheme. But there are opportunities to acquire more schemes for water protection on Countryside Stewardship agreements that do go forward.

There were 495 holdings in ELS agreements in the Lambourn catchment (Figure 6.3), 228 in ELS only schemes and a similar amount in both ELS and HLS. Within the western half of the catchment, there are 10 holdings in entry level Organic Stewardship and 29 holdings in Organic Entry Level and HLS to the west of South Fawley.

Holdings with ES schemes which ended in 2015 are mostly located within the centre of the catchment and near Peasemore (Figure 6.4). Most ES schemes will be ending in 2016 and 2017 – 144 and 78 schemes respectively.

Figure 6.3: *Distribution of holdings signed up to Environmental Stewardship (ES) schemes (2015) along with historic Higher Level Stewardship (HLS) target areas.*

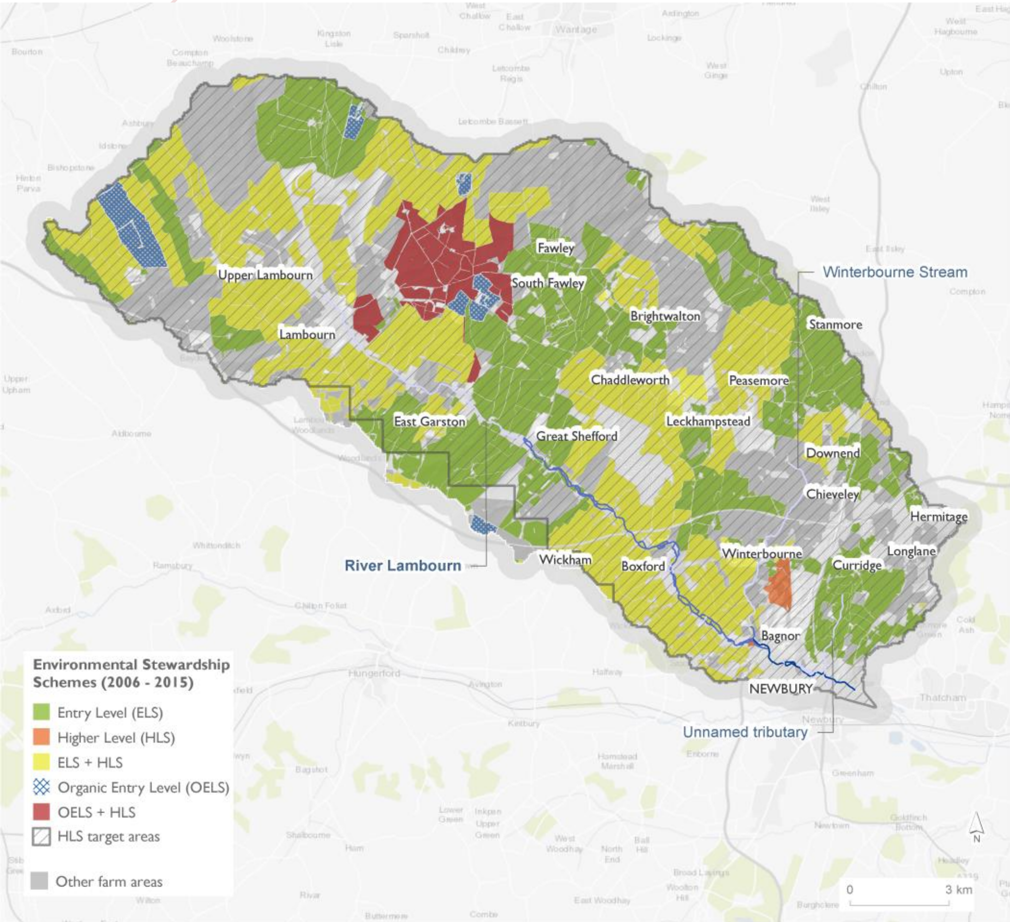
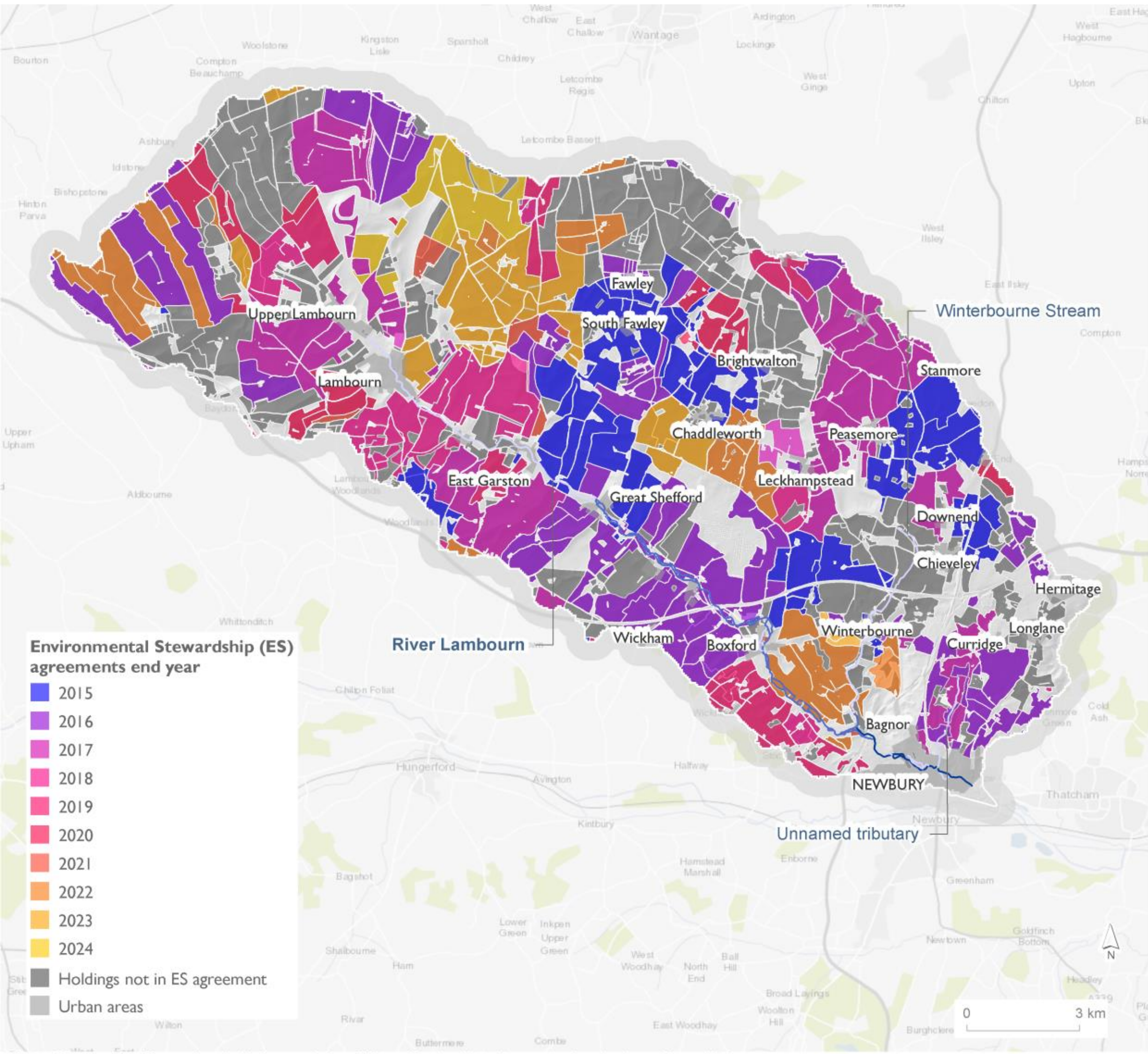


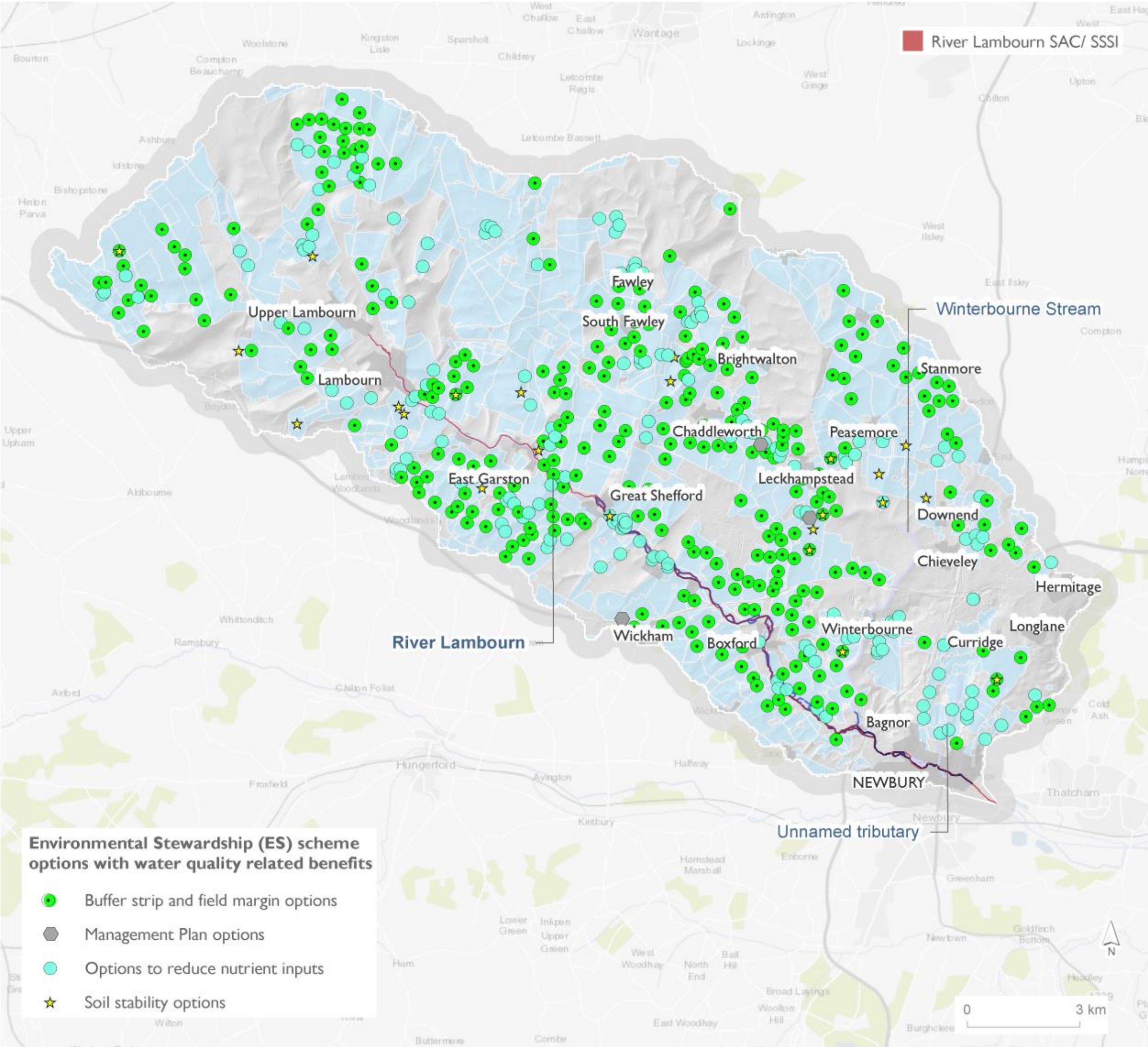
Figure 6.4: *Environmental Stewardship (ES) scheme agreement end dates.*



There are many other ES scheme options which have the potential to improve water quality if used at the optimal location and time, although often this is not the case. A full list of the ES options and codes included in each category in Figure 6.5 can be found in Appendix 2.

The most frequently applied ES options with significant direct water quality benefits in the Lambourn catchment were buffer strip and field margin options (381), followed by options to reduce nutrient inputs (220) (see Figure 6.5).

Figure 6.5: *Distribution of Environmental Stewardship (ES) schemes options with significant water quality benefits in the Lambourn catchment between 2006 and 2015.*



CATCHMENT SENSITIVE FARMING

Catchment Sensitive Farming (CSF) is a scheme run by Natural England in partnership with the Environment Agency and The Department for Environment, Food, and Rural Affairs. It raises awareness of diffuse water pollution from agriculture by giving free training and advice to farmers in selected areas in England, called 'priority catchments'. The aim of CSF is to improve the environmental performance of farms through provision of grants and advice and it has been in place in England since 2006. Since 2015, CSF has been part of Countryside Stewardship, through which water grants are funded. In the Lambourn catchment CSF started in 2007, with delivery starting in 2008.

Some form of advice was delivered on 54% of the area covered by rural land registry parcels within the catchment, with most of the delivery advice focused on farm holdings in the mid-section of the catchment and on land immediately surrounding the main river channel (Figure 6.6). The main type of advice given pertained to soil management (37 %), fertiliser management (35 %) and farm infrastructure (34 %). Figure 6.7 shows CSF capital grant scheme option delivery between 2007 and 2014 in the Lambourn catchment.

Figure 6.6: *Continued next page. Catchment Sensitive Farming (CSF) advice delivered between 2007 and 2015 in the Lambourn catchment by advice type. The numbers of visits on each holding are also shown.*

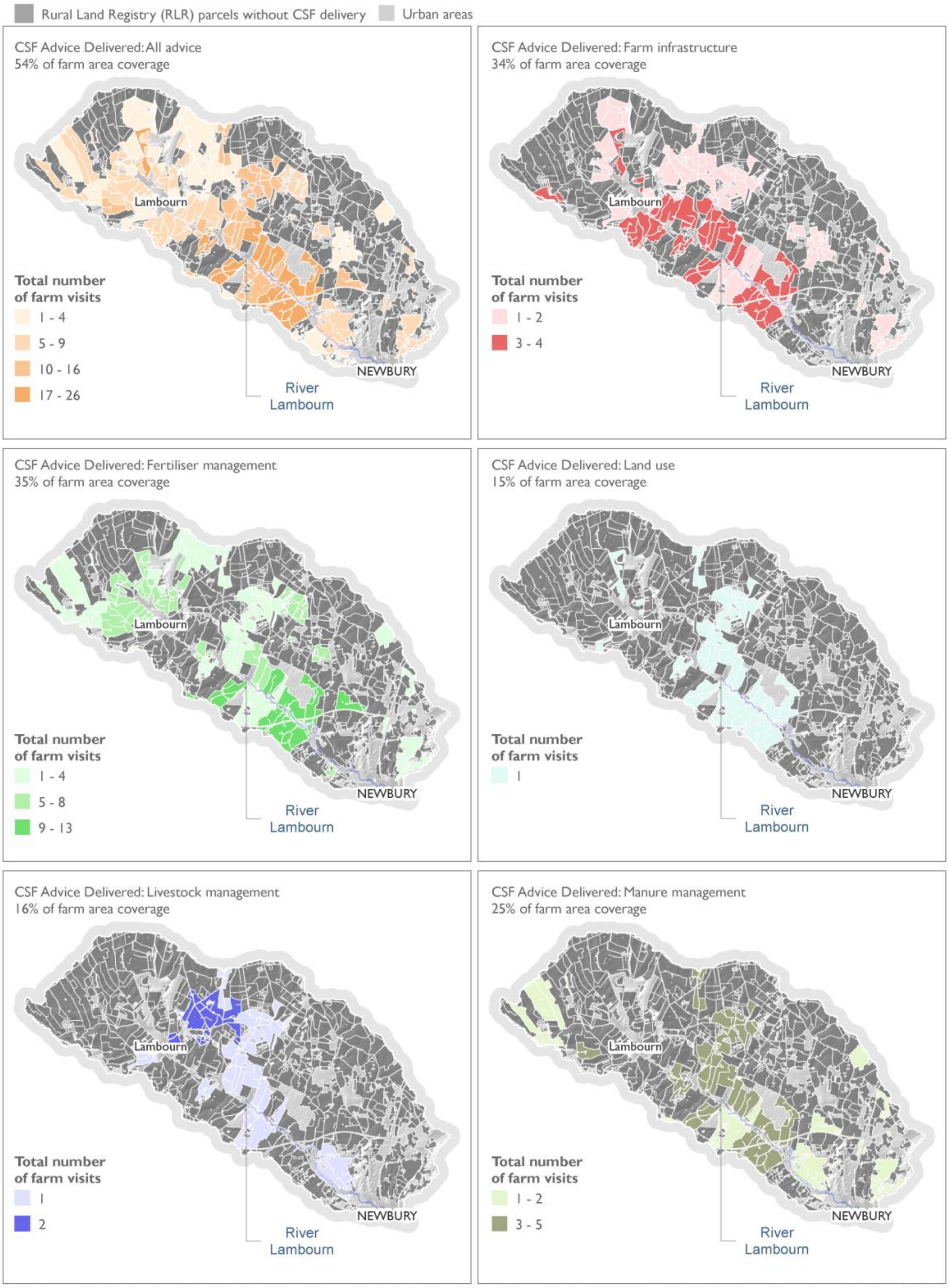


Figure 6.6: *Continued. Catchment Sensitive Farming (CSF) advice delivered between 2007 and 2015 in the Lambourn catchment by advice type. The numbers of visits on each holding are also shown.*

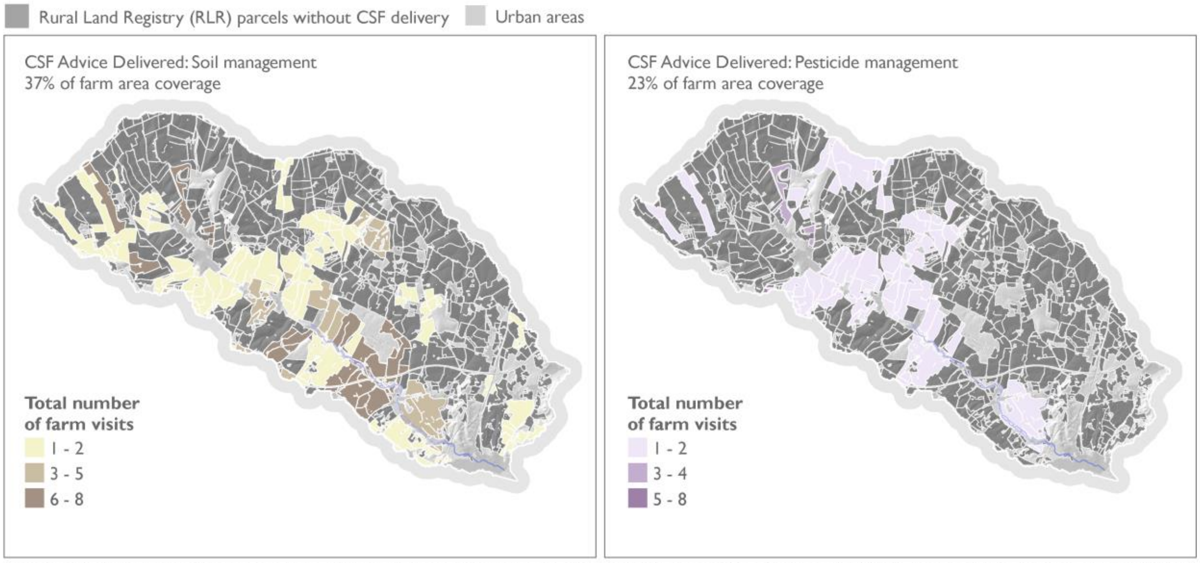
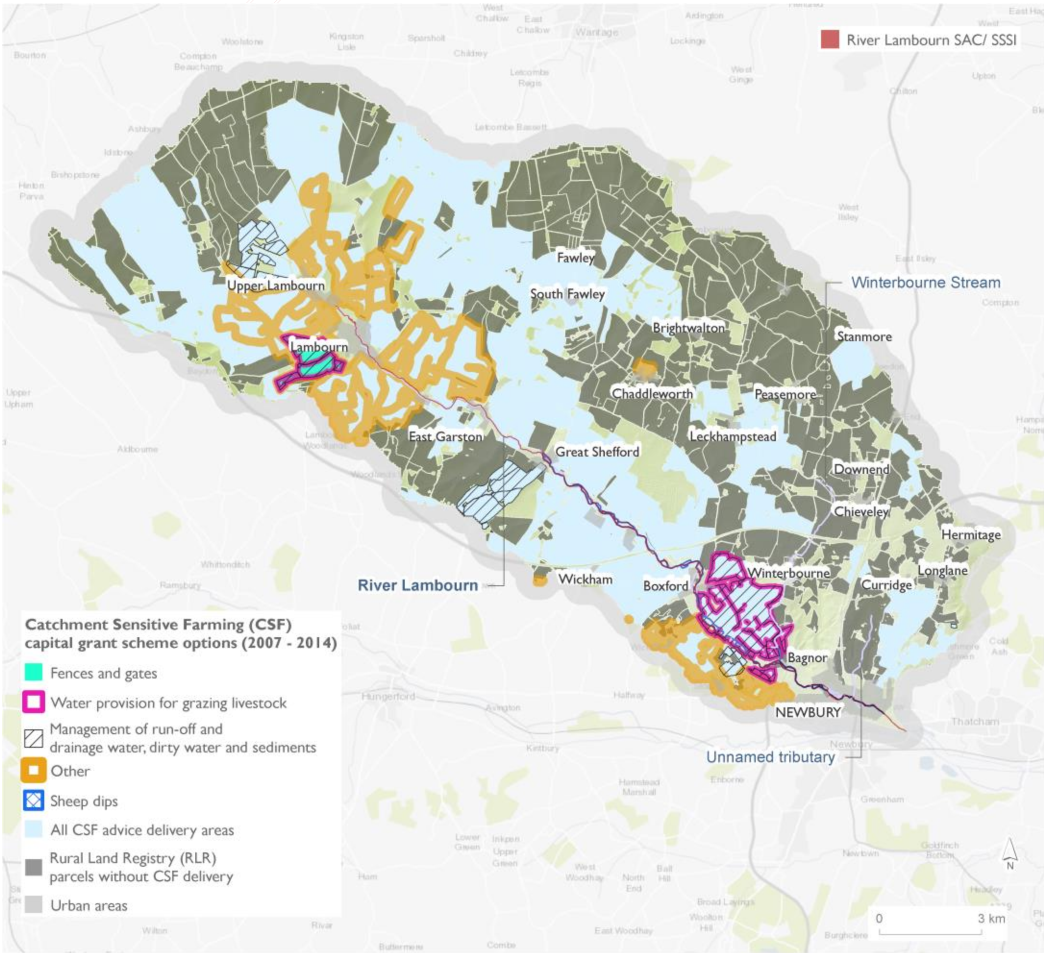


Figure 6.7: *Map showing Catchment Sensitive Farming (CSF) capital grant scheme options delivered between 2008 and 2014 in the Lambourn catchment.*



ENGLISH WOODLAND GRANT SCHEME

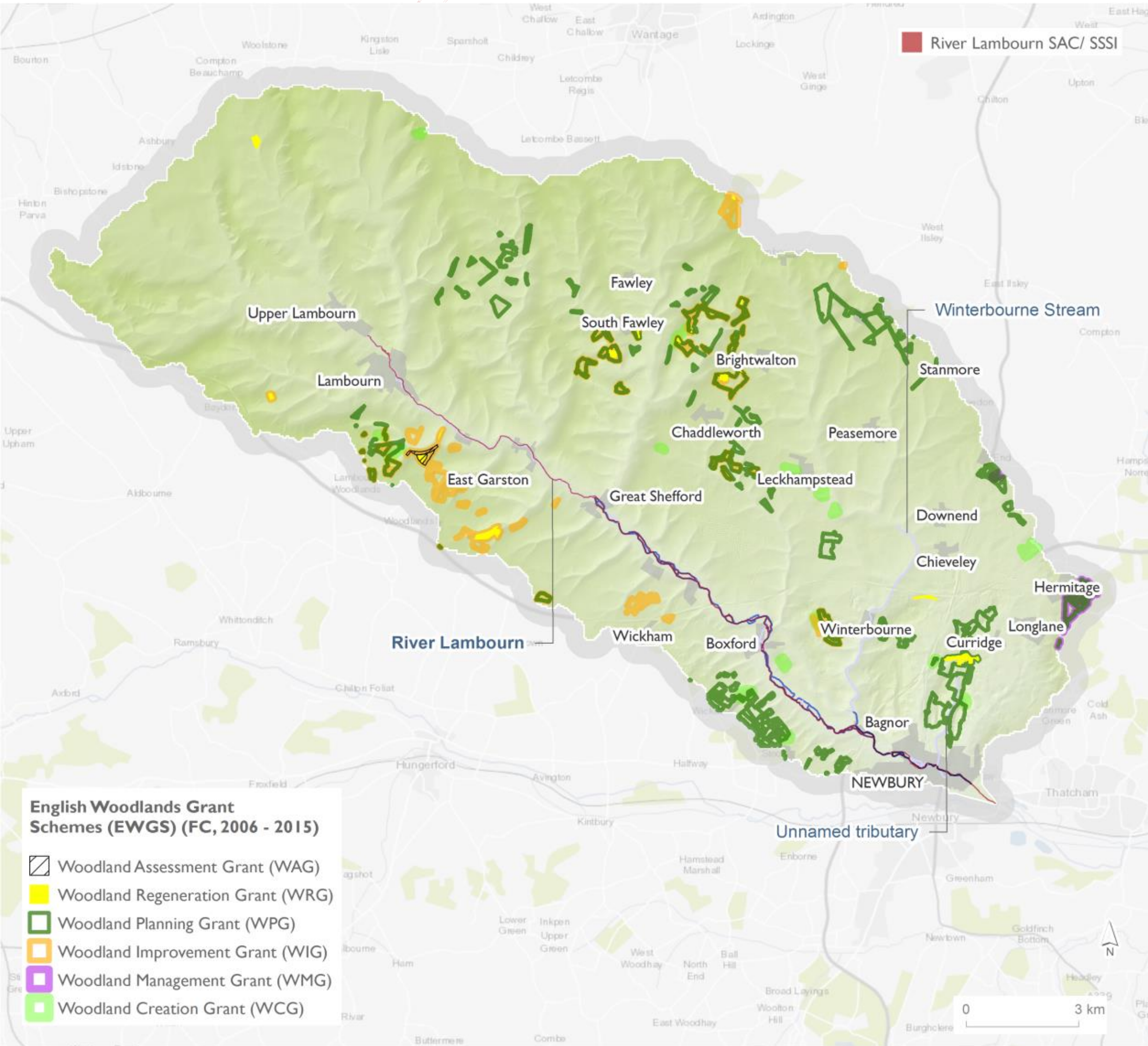
The English Woodland Grant Scheme (EWGS) was operated by The Forestry Commission under the Rural Development Programme for England (RDPE). The purpose of the scheme was to develop the co-ordinated delivery of public benefits from woodlands. The grant scheme had a national framework but funding was allocated and grants targeted at a regional level.

The overarching objectives for EWGS were:

1. To sustain and increase the public benefits derived from existing woodlands in England.
2. To invest in the creation of new woodlands in England of a size, type and location that most effectively deliver public benefits.

The component grant types of EWGS had their own objectives. Some grants were focused regionally to meet the priorities of the Regional Forestry Framework action plans, and the objectives were specified more closely to suit specific areas. In 2015, EWGS was incorporated into the Countryside Stewardship Scheme. Areas signed up to EWGS between 2006 and 2015 in the Lambourn catchment are shown in Figure 6.8.

Figure 6.8: *Areas signed up to the Forestry Commission (FC) English Woodland Grant Scheme (EWGS) in the Lambourn catchment between 2006 and 2015.*



KENNETT CATCHMENT PARTNERSHIP – ACTION FOR THE RIVER KENNETT

Action for the River Kennett (ARK) host the catchment based approach (CaBA) for the Kennett Catchment Partnership. The Kennet Catchment stretches from the upper reaches of the Winterbournes above Avebury west of Marlborough in Wiltshire, to Reading in Berkshire where the Kennet flows into the Thames, and includes the River Lambourn. Through CaBA and other initiatives ARK have been working to improve water quality and biodiversity in rivers within the Kennett catchment. A key project relating to water quality in the SAC/ SSSI is work carried-out by ARK to educate residents about septic tanks using data from Thames Water to target properties not on the sewer network.

7 Assessment of outcomes

7.1 FARMSCOPER Analysis

FARMSCOPER MODELLED AREAS

There are many water quality models that can predict the cumulative effects of implementing on-farm Best Farming Practice (BFP) at a catchment or sub catchment scale. In this section, the results of the FARM Scale Optimisation of Pollutant Emission Reductions (FARMSCOPER3) (ADAS, 2016) model, are used to assess potential nutrient and sediment reduction scenarios from agricultural sources.

FARMSCOPER is a decision support tool which can be used to assess diffuse agricultural pollutant loads on a farm and quantify the impacts of farm pollutant control options (Zhang et al., 2012). FARMSCOPER allows for the creation of unique farming systems, based on combinations of livestock, cropping and manure management practices. FARMSCOPER uses input farm data and representative farm types to provide a baseline for diffuse agricultural pollutant emissions. FARMSCOPER gives a baseline load for agricultural pollutants (nitrate, phosphorus, ammonia, sediment, methane, and nitrous oxide) and units or scores for secondary impacts (pesticides, soil carbon, soil quality, faecal indicator organisms (FIOs) biodiversity, water use and energy use). The effects of selected interventions are then set against these baseline loads, characterised as a percentage reduction. The effectiveness of different mitigation measures is based on a number of existing literature reviews, field data and expert judgement, and are allowed to take negative values, which represent 'pollutant swapping', where a reduction in one pollutant is associated with an increase in another.

METHOD

The FARMSCOPER 3 model 'Upscale' tool, released in 2016, is used here. The FARMSCOPER Upscale workbook is pre-populated with National AgCensus 2010 data for individual management catchments. Instead of running the catchment area as one farm, in-built weightings are used to apportion the total census data between the different farm types.

The apportionment is carried out using the following formula:

$$A_T = \frac{A_C}{H_T} \cdot \frac{N_T . H_T}{\sum_{1}^{T} N_T \cdot H_T}$$

Where: AT is area of a crop type or number of livestock on farm type T within the catchment, AC is the total area of a crop type or number of livestock in the catchment, NT is the typical crop area or livestock count on farm type T and HT is count of farm type T in the catchment (ADAS, 2016).

FARMSCOPER calculates baseline and reductions for each farm type represented in the catchment area under different management scenarios, and these are multiplied by the number of farms for each type. Values for all farm types are then added to estimate the overall baseline or reduction value for the area being modelled.

The methodology used is as follows:

1. Agricultural Census data from 2010 is used to represent farming practices across the Kennett and Pang management catchment to build catchment specific farm types for each of the modelled areas.
2. Rural Land Registry (RLR) County Parish Holdings (CPH) farm holding data is used to estimate the number of farms within each modelled area. The total number of farm types within the management catchment (derived from FARMSCOPER) is scaled down to derive a total number of farm types within the individual modelled areas.
3. NSRI NatMap soil mapping data and Met Office rainfall data are used as the basis for defining the soil type and rainfall band, are used along with NVZ coverage to apportion Agricultural Census data to the appropriate categories used within FARMSCOPER.
4. A quantification of current delivery of catchment interventions based on Environmental Stewardship and Catchment Sensitive Farming capital grant delivery.

The following three scenarios were assessed:

Scenario 1: Quantifying baseline pollutant losses for modelled areas (sum of baseline loss for all farm types in each modelled area). The baseline value does not include any mitigation or compliance measures.

Scenario 2: An estimate of the reductions achieved by the current uptake of agri-environment schemes, including ES agreements and CSF capital grants delivered, based on national data. The uptake values used in this scenario can be found in Appendix 4.

Scenario 3: This 'high uptake scenario' provides an estimate of the reduction from implementation of all relevant FARMSCOPER on farm management measures, based on 80% uptake of methods. An 80% uptake rate was selected to provide an idea of what could be achieved by a large scale uptake of the management measures. All appropriate mitigation methods for phosphorus, nitrate and sediment management were selected for the analysis in scenario 3, but it does not consider management measures not included in FARMSCOPER, land use change or changes to livestock numbers.

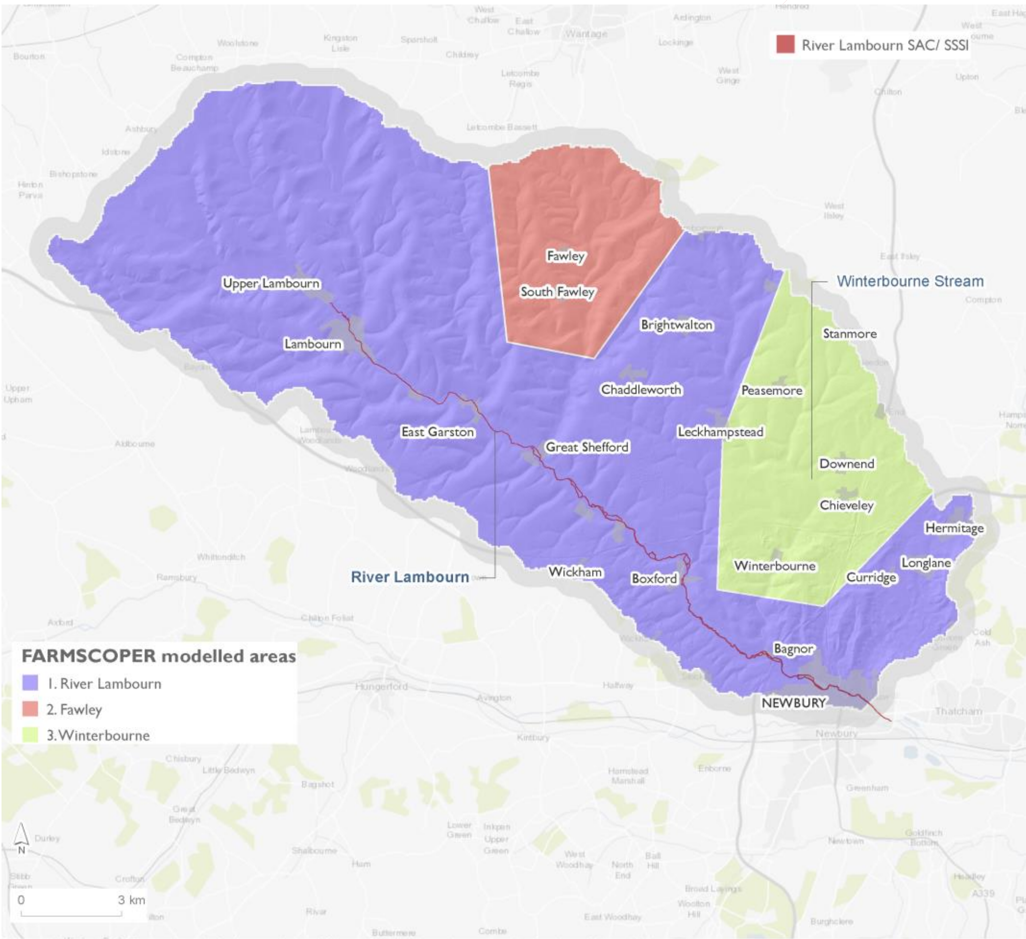
KEY LIMITATIONS AND ASSUMPTIONS IN THE FARMSCOPER ANALYSIS ARE SUMMARISED BELOW:

- FARMSCOPER 3 uses AgCensus data from 2010 for the larger Kennett and Pang catchment scaled to the Lambourn sub-catchments and it is assumed that this data represents a true reflection of current landuse practices.
- AgCensus data is provided at an averaged 2 km resolution, thus farm scale land-use variability cannot be reliably assessed.
- The level of prior implementation of mitigation methods used in scenario 2 has been estimated from current interventions (ES, CSF capital grants and NVZ areas) presented in this report. Furthermore, any additional voluntary uptake of the methods not funded through specific schemes/grants, may not be accounted for - therefore reductions achieved by this scenario may be conservative.
- Compliance in ES agreement areas is assumed in the current delivery estimate. Therefore, in the instance of non-compliance reductions from current delivery will be overestimated.

FARMSCOPER MODELLED AREAS

Results for the farm of each type in each of the areas (see Figure 7.1) are added to determine the overall loss. It should be noted that the Fawley sub-catchment often has no connectivity with surface waters in the catchment, which can be the case for multiple years at a time and in itself represents a very effective "natural" mitigation.

***Figure 7.1:** Map showing sub-catchment areas modelled in FARMSCOPER for the Lambourn catchment.*



Built-in FARMSCOPER summary graphs show the apportionment (kg) and footprints (kg/ ha) for different farm types and modelled areas (Figures 7.2 to 7.4).

The majority of nitrate loss was apportioned to cereal farms in all subcatchments. However, the high footprints are associated with poultry and indoor pig farms and could therefore be locally important (Figure 7.2)

Cereals, general and mixed farms, and lowland grazing make a significant contribution to phosphorus losses (Figure 7.3). To a lesser extent dairy, poultry and indoor pig farms are also important, especially locally due to high footprints.

Most sediment loss was apportioned to cereal, general farms, and lowland grazing, whilst mixed, dairy, poultry, and indoor pig were highlighted as having potentially high local impacts due to high footprint (Figure 7.4).

Figure 7.2: *Built-in FARMSCOPER summary graphs or nitrate losses, derived from farm types for each area modelled. The graphs show the apportionment (kg) and footprints (kg/ ha) for farm types for modelled areas.*

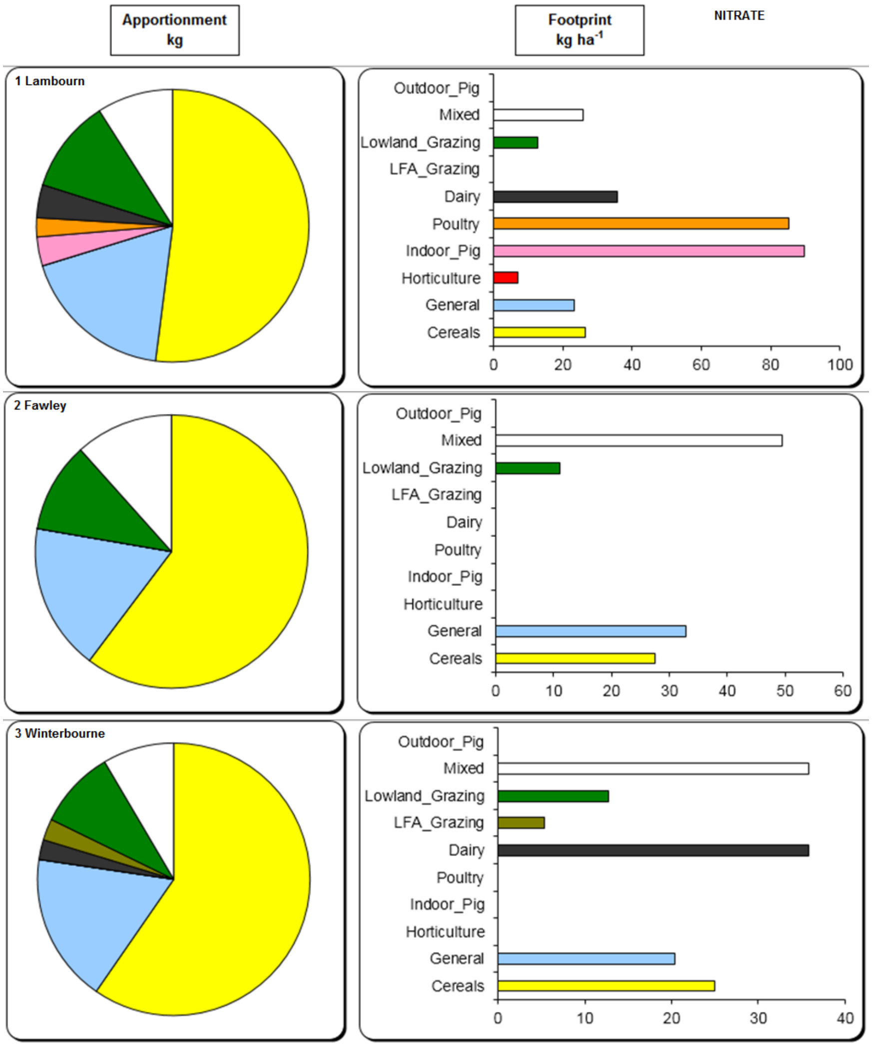


Figure 7.3: *Built-in FARMSCOPER summary graphs for phosphorus losses, derived from farm types for each area modelled. The graphs show the apportionment (kg) and footprints (kg/ ha) for farm types for modelled areas.*

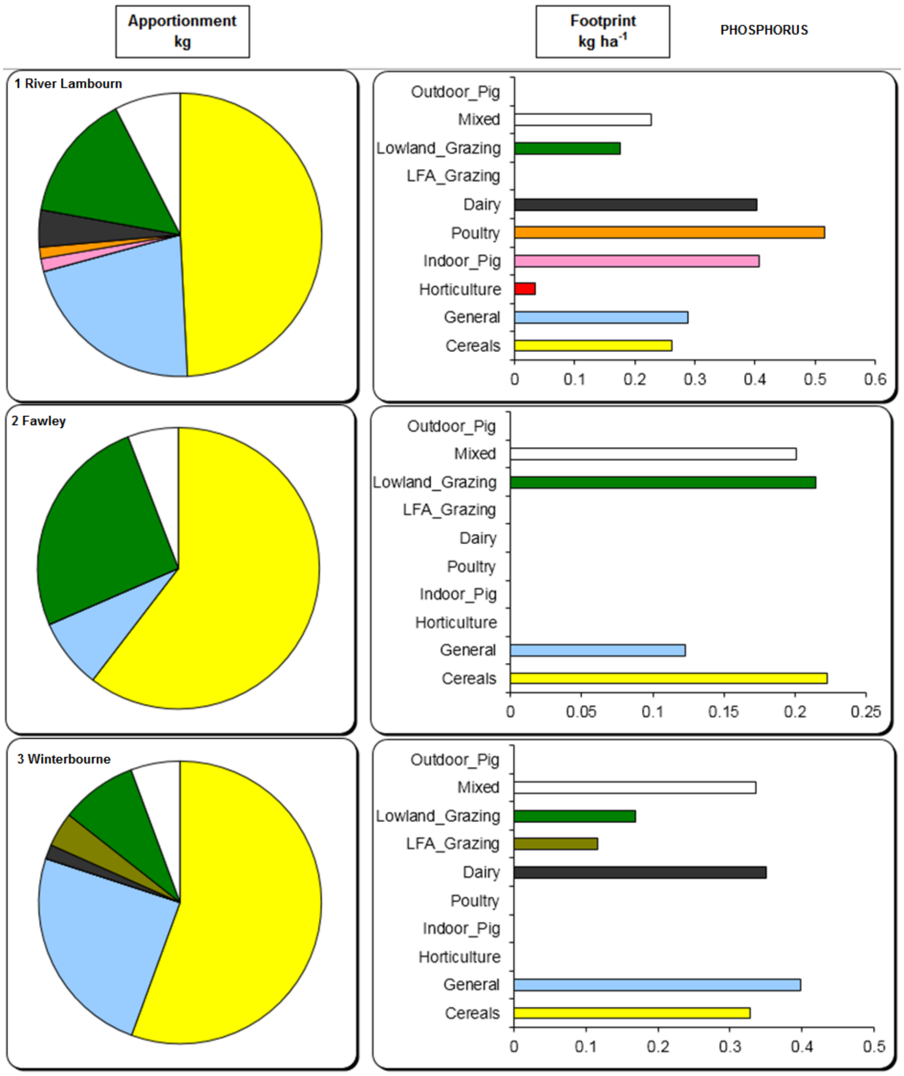
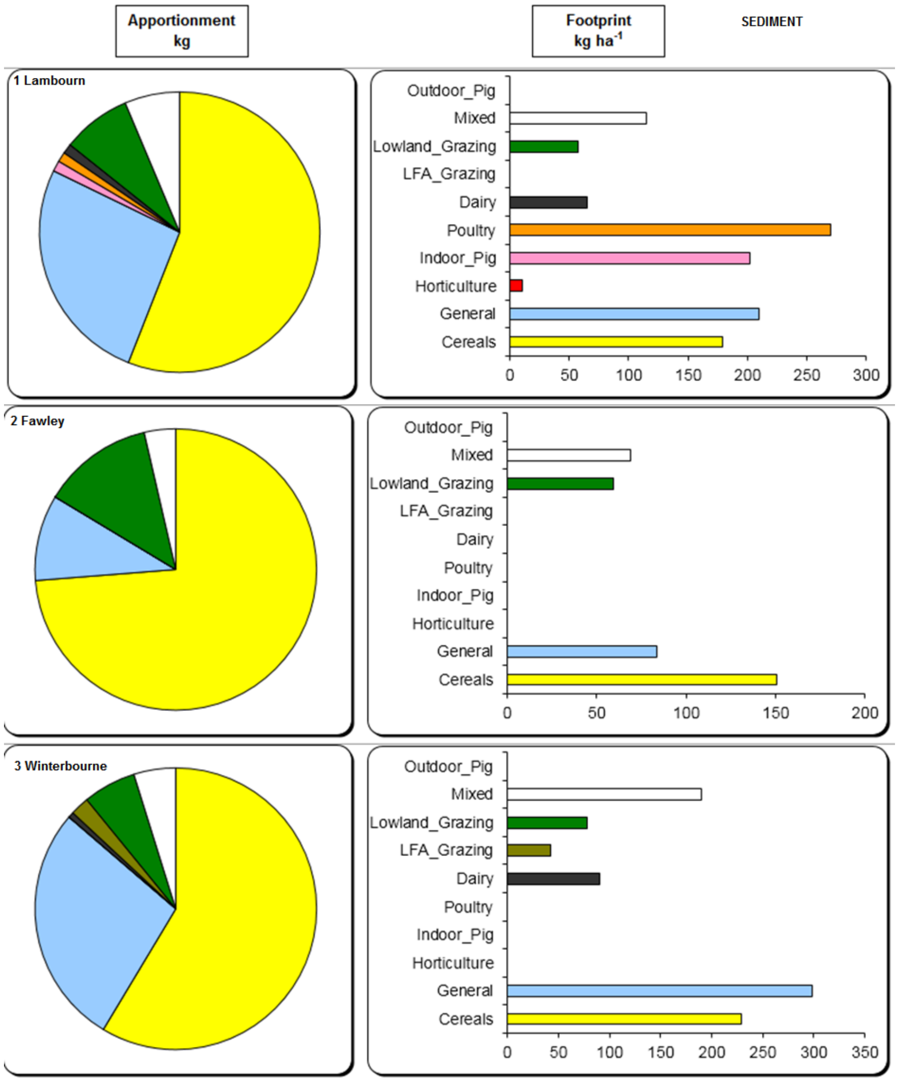


Figure 7.4: *Built-in FARMSCOPER summary graphs for sediment losses, derived from farm types for each area modelled. The graphs show the apportionment (kg) and footprints (kg/ ha) for farm types for modelled areas.*



RESULTS

SCENARIO 1: BASELINE POLLUTANT LOSSES

Scenario 1 presents baseline losses (kg/ yr) in nitrate, phosphorus, and sediment in each modelled area (Table 7.1). Assessing losses per unit area, to highlight areas presenting the highest risk, the main River Lambourn sub-catchment has the highest nitrate loss at 27 kg/ ha/ yr, with loss rates slightly lower in the other subcatchments. The Winterbourne sub-catchment has significantly higher loss rates for both phosphorus (0.35 kg/ ha / yr) and sediment (229 kg/ ha/ yr) compared to the other subcatchments. It should be reiterated that, due to the hydrology of the Winterbourne sub-catchment, sources from here may be disconnected from the receiving waters.

Table 7.1: *FARMSCOPER modelled baseline nitrate, phosphorus, and sediment losses from agriculture (kg/ yr and kg/ha/yr)).*

Catchment	Farm holding area (ha)	Loss kg/yr (in brackets kg/ha/yr)		
		Nitrate	Phosphorus	Sediment
1. River Lambourn	15,602	426,945 (27.34)	4,290 (0.27)	2,567,751 (164.58)
2. Fawley	2,411	50,575 (20.97)	409 (0.17)	226,801 (94.07)
3. Winterbourne	3,043	74,565 (24.50)	1,053 (0.35)	697,095 (229.08)

SCENARIO 2: POLLUTANT LOSSES BASED ON CURRENT DELIVERY

Scenario 2 takes current delivery into account based on agri-environment schemes (ES agreements and CSF capital grants) from 2006 to 2015 inclusive and assumes compliance within NVZ designations (Table 7.2). The application of Environmental Stewardship is evenly distributed throughout the catchment, as illustrated by comparable percentage reductions between the modelled subcatchments. Again, the main stem of the River Lambourn has the greatest nitrate loss per unit area (25 kg/ ha/ yr) and the Winterbourne subcatchment the highest for both phosphorus (0.32 kg/ ha/ yr) and sediment (207 kg/ ha/ yr). Nitrate losses are only marginally lower compared to scenario 1, despite most of the Lambourn catchment falling within NVZ designation.

Table 7.2: *FARMSCOPER derived reductions for nitrate, phosphorus, and sediment losses from agriculture (%) based on current delivery estimates. Values shown are kg/yr and kg/ha/yr in brackets loss for target areas, representing pollutant loss estimates based on the current level of mitigation delivery through agri-environment schemes (ES agreements and CSF capital grants) from 2006 to 2015 inclusive and NVZ compliance within NVZ designations.*

Catchment	Nitrate		Phosphorus		Sediment	
	Loss kg/ yr (kg/ha/yr)	% reduction	Loss kg/ yr (kg/ha/yr)	% reduction	Loss kg/ yr (kg/ha/yr)	% reduction
1. River Lambourn	394,678 (25.3)	8	3,917 (0.25)	9	2,308,364 (147.95)	10
2. Fawley	46,812 (19.41)	7	369 (0.15)	10	199,376 (82.69)	12
3. Winterbourne	68,721 (22.58)	8	973 (0.32)	8	628,416 (206.51)	10

SCENARIO 3: 'HIGH UPTAKE' POTENTIAL REDUCTIONS ESTIMATE

Scenario 3 presents potential reductions for the 'high uptake' of all relevant FARMSCOPER measures for agricultural nitrate, phosphorus, and sediment pollution, based on an 80% uptake (Table 7.3). Reductions are based on scenario 2, to take account of current delivery. Estimates of the 'high uptake' reduction were consistent across subcatchments ranging from 9 – 11% for nitrate, 25 – 27% for phosphorus and 27 -30% for sediment. The highest reductions were returned for the Fawley subcatchment which has the lowest estimated total losses and may therefore have limited benefit on downstream concentrations /loads.

Table 7.3: *FARMSCOPER derived 'High uptake' potential reductions for nitrate, phosphorus loads and sediment losses (%) from agriculture based on an 80% uptake of all applicable mitigation methods. Percentage reductions represent the reduction in pollutant losses from current delivery (Table 7.2).*

Catchment	Nitrate		Phosphorus		Sediment	
	Loss kg/ yr (kg/ha/yr)	% reduction	Loss kg/ yr (kg/ha/yr)	% reduction	Loss kg/ yr (kg/ha/yr)	% reduction
1. River Lambourn	357,427 (22.90)	9	2,848 (0.18)	27	1,622,704 (104.00)	30
2. Fawley	42,491 (17.62)	9	262 (0.12)	29	131,182 (54.41)	34
3. Winterbourne	61,107 (20.08)	11	726 (0.24)	25	459,377 (150.96)	27

The most effective mitigation measures for reducing phosphorus and sediment losses from the modelled farm types are summarised in Table 7.4 below. It should be noted, that horticultural farm types were excluded from this summary table as only minor losses were predicted to be associated with these farm types. These outputs should be considered in conjunction with the relevant pollutant loss apportionment (kg) and footprints (kg/ ha) for farm types in the modelled areas. Cereal farm types were apportioned the largest share of nutrient and sediment losses across all modelled areas, and the mitigation method of 'Undersown spring cereals' is identified as potentially producing large reductions in these farm types. Furthermore, 'Early harvesting and establishment of crops in the autumn' is identified as producing one of the highest potential reductions across lowland, and general farm types, which were also apportioned large proportions of pollutant losses. Additionally, 'Fence off rivers and streams from livestock' is highlighted as reducing losses from dairy farm types (with high losses and small footprints), and therefore may be important locally.

Table 7.4: *Mitigation measures, identified by FARMSCOPER, with the potential to reduce phosphorus and / or sediment losses for common farm types within the Lambourn catchment. Farm types producing the majority of losses of phosphorus and sediment are highlighted in blue and farm types identified as potentially producing significant local contributions are highlighted in green.*

			Phosphorus losses							
			Sediment losses							
Method ID	**Method description**	**Phosphorus impact (%)**	**Sediment impact (%)**	**Lowland**	**General**	**Mixed**	**Cereal**	**Dairy**	**Pig**	**Poultry**
4	Establish cover crops in the autumn	95	95	X						
76	Fence off rivers and streams from livestock	95						X		
113	Undersown spring cereals	95	95				X		X	X
5	Early harvesting and establishment of crops in the autumn	80	80	X	X	X				
14	Establish riparian buffer strips	80	80				X			X
61	Store solid manure heaps on an impermeable base and collect effluent	80		X				X		
103	Management of in-field ponds	80	80		X	X				
8	Cultivate compacted tillage soils	50	50	X			X	X	X	X
9	Cultivate and drill across the slope*	50	50	X	X			X		
11	Manage over-winter tramlines	50	50	X	X	X		X	X	
13	Establish in-field grass buffer strips	50	50	X	X		X	X		X
15	Loosen compacted soil layers in grassland fields	50	50	X				X		
25	Do not apply manufactured fertiliser to high-risk areas	50				X		X		X
32	Do not apply P fertilisers to high P index soils	50		X	X	X	X	X	X	X
35	Reduce the length of the grazing day/grazing season	50	50	X				X		
64	Use poultry litter additives	50				X				
69	Do not spread slurry or poultry manure at high-risk times	50						X		X
72	Do not spread FYM to fields at high-risk times	50				X				
106	Plant areas of farm with wild bird seed / nectar flower mixtures	50	50		X					
26	Avoid spreading manufactured fertiliser to fields at high-risk times	25		X						
36	Extend the grazing season for cattle	25				X				
38	Move feeders at regular intervals	25	25	X				X		
39	Construct troughs with concrete base	25	25	X		X		X		
62	Cover solid manure stores with sheeting	25				X			X	
78	Re-site gateways away from high-risk areas	25	25			X				X
80	Establish new hedges	25	25			X				
105	Management of arable field corners	25	25	X		X		X		
117	Use correctly-inflated low ground pressure tyres on machinery	25	25	X	X	X	X		X	X
23	Integrate fertiliser and manure nutrient supply	18		X	X	X		X	X	X
10	Leave autumn seedbeds rough	10	10	X				X		
19	Make use of improved genetic resources in livestock	10		X		X		X		
27	Use manufactured fertiliser placement technologies	10		X	X	X	X			X
63	Use liquid/solid manure separation techniques	10		X						
79	Farm track management	10	10			X				
108	Uncropped cultivated margins	10	10			X			X	

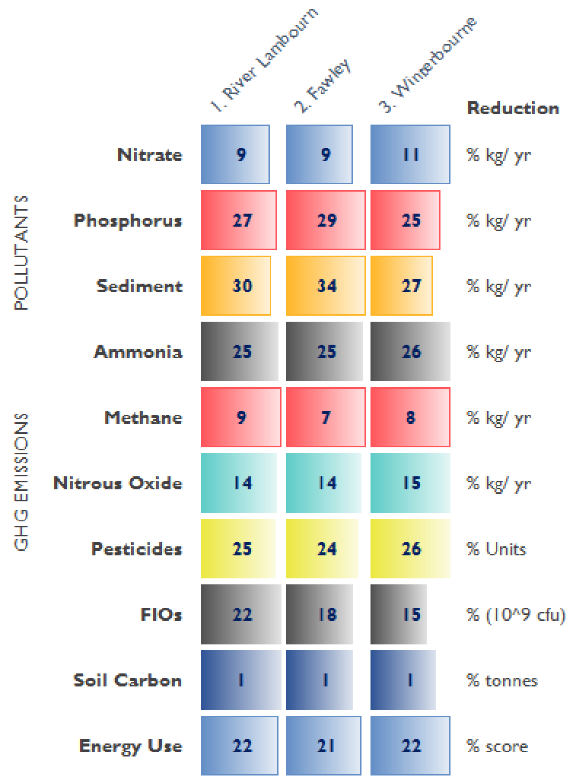
Table 7.4: *… Continued.*

			Phosphorus losses							
			Sediment losses							
Method ID	Method description	Phosphorus impact (%)	Sediment impact (%)	Lowland	General	Mixed	Cereal	Dairy	Pig	Poultry
114	Management of grassland field corners	10	10							
118	Locate out-wintered stock away from watercourses	10	10	X		X				
123	Use efficient irrigation techniques (boom trickle, self-closing nozzles)	10	10		X					X

SECONDARY BENEFITS

Alongside nitrate, phosphorus, and sediment reductions, catchment mitigation has the potential to deliver additional benefits. Particularly notable are the potential reductions in ammonia, pesticides, Faecal Indicator Organisms, and energy usage (Figure 7.5).

Figure 7.5: *Infographic summarising potential secondary benefits associated with optimised 'high uptake' nitrate, phosphorus, and sediment reductions. Values show % reductions; bars in each cell represent the level of reduction.*

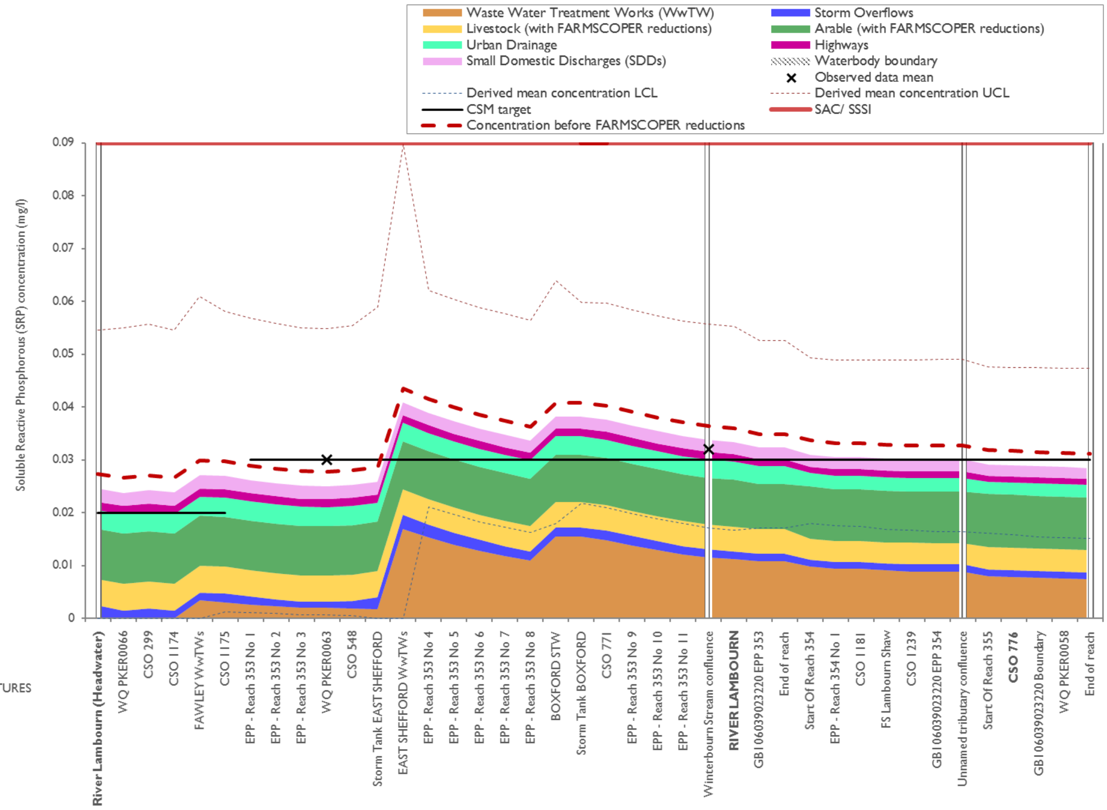


PHOSPHORUS REDUCTION SCENARIO TESTING

Detailed outputs from SAGIS were adjusted to reflect the 'high uptake' potential phosphorus reductions shown in Table 7.3 to determine the impact on in-stream concentrations. Mitigation methods were split into arable or livestock sectors based on the assumptions for these categories used in PSYCHIC, which also underpins SAGIS.

This modelling indicates that catchment management would only marginally bring SRP within the CSM target in the downstream reaches below the Winterbourne and illustrates the need for further reductions across all sectors, and in particular WwTW, in order to meet the CSM target and reduce the risk of non-compliance.

Figure 7.6: *Chainage plot showing SAGIS derived Soluble Reactive Phosphorus (SRP) (mg/l) along the River Lambourn with sector apportionment, based on % reductions for agricultural phosphorus sources modelled in 'high uptake' scenario 3 in FARMSCOPER. Features are shown in the x axis. Septic tanks include small domestic discharges (SDDs) and package treatment plans (PTPs), which includes discharges to ground and surface water.*



Abbreviations: EPP – Extra plot point; FS – Flow monitoring station; WQ – Water quality monitoring point; ST: Storm Tank: WwTWs: Wastewater Treatment Works; and CSO – Combined Sewage Overflow.

8 Conclusions - Targeting Delivery

The conclusions have been drawn based on a weight of evidence approach with the key evidence of current condition or risk are combined spatially in bespoke maps for each pollutant, along with the potential reductions that could be achieved through catchment measures focused on agricultural sources. To facilitate targeting delivery, holdings with ES agreements which have expired or are expiring between 2015 and 2021 are also shown.

The main conclusions and targeting maps for the key polluting pressures, sediment, and phosphorus pollution, are presented here. Nitrate is not currently a driver for non-compliance in the River Lambourn SAC/ SSSI, so is not discussed further here though, for completeness as this is a groundwater dominated catchment in which nitrate leaching may become an important pressure, evidence relating to sources and risks are included in Chapter 5 of this report.

SEDIMENT

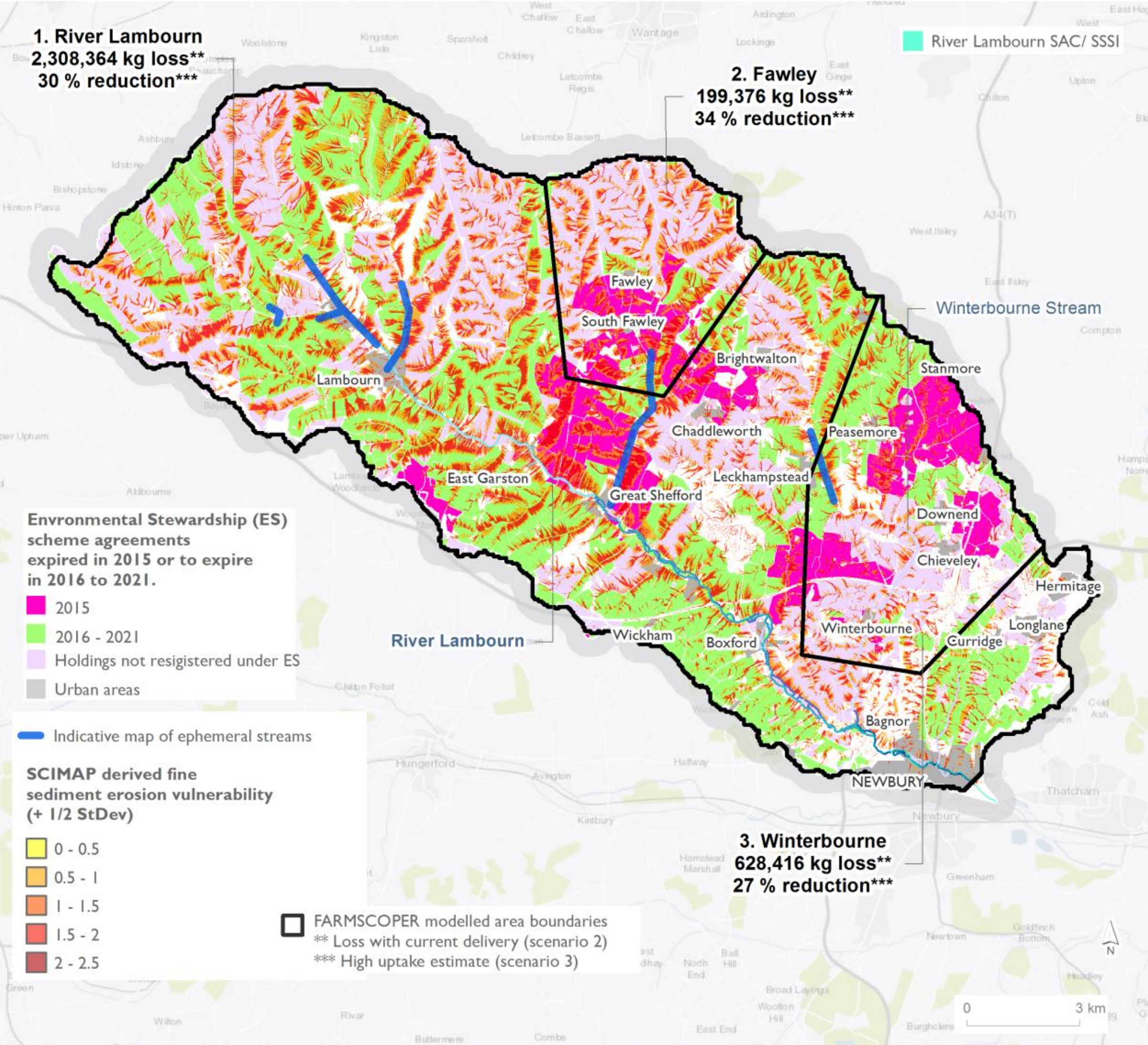
SSSI condition assessments do not include quantitative sediment targets. However, the SSSI Common Standard Monitoring (CSM) guidance for Rivers states that that there should be 'no unnaturally high levels of siltation', which should be assessed using field observations and site specific information.

Figure 8.1 shows relative sediment risk for the modelled areas in the Lambourn catchment along with 'high uptake' reductions (scenario 3) and sediment losses based on current delivery (scenario 2) from FARMSCOPER.

SCIMAP outputs highlight evenly spread erosion vulnerability (Figure 8.1) – to be expected in a groundwater dominated catchment such as the Lambourn. With a very high baseflow index of 0.98 activities or features within the riparian corridor itself represent the main sources and risks associated with sediment loss. For example, the road that runs adjacent to the river much of the way down the valley was highlighted by stakeholders as a source and potential pathways hydrologically connecting a wider source area to the river.

Agriculture is highlighted as the most important source, along with bank erosion, based on the SEPERATE model. Whilst, FARMSCOPER apportioned losses to cereal, general farms, and lowland grazing and to a lesser extent mixed, dairy, poultry and indoor pig farms (Figure 7.4). The scenario 3 modelling predicted potential reductions in sediment losses in the order of 27% to 34% across the catchment. Although the model does not account for the ephemeral nature of the catchment and particularly the Fawley sub-catchment that could during sustained dry periods effectively disconnect sources from the hydrological network.

Figure 8.1: *Targeting map showing relative sediment erosion vulnerability in the Lambourn catchment using the SCIMAP modelling framework. 'High uptake' management measure reductions (scenario 3) and sediment losses from agricultural sources based on current delivery (scenario 2) from FARMSCOPER are shown for each sub-catchment modelled in FARMSCOPER. Holdings with Environmental Stewardship (ES) scheme agreements which have expired or are soon to expire (to 2021) are shown along with holdings not registered under ES.*



PHOSPHORUS

SSSI condition assessments include quantitative targets for Soluble Reactive Phosphorus (SRP) against which compliance can be assessed using the best available evidence. A weight of evidence approach has been adopted to highlight potential sources and risks of phosphorus pollution across the catchment to help target measures effectively. Based on the evidence, the majority of phosphorus loss from agriculture was apportioned to cereal cropping, general and lowland grazing farms.

Conclusions from the data shown in Figure 8.2 are summarised next:

SSSI Unit 1 – Upper River Lambourn

- Based on outputs from the National SAGIS model, Unit 1 is non- compliant with the CSM SRP target (0.02 mg/l) by around 30-50%. Although SAGIS has not yet been calibrated locally and therefore outputs should be treated with caution, it still presents the best available evidence in the absence of any monitoring data.
- Based on SAGIS; arable (41 %) and livestock (22 %) are the dominant sources of SRP, although there is a clear increase in concentrations downstream of Fawley.
- Other sector sources are less significant at the subcatchment scale urban drainage (13 %), small domestic discharges (SDDs) (9 %), storm overflows (9 %) and highways (6 %). Though these sources may exert a greater impact locally,

SSSI Unit 2 – Mid River Lambourn

- Based on recent monitoring (2012 – 2014) Unit 2 was non-complaint, with mean concentrations 30% (0.01 mg/l) above the CSM target for SRP (0.03 mg/l). A comparison between summer and winter mean concentrations suggests this exceedance is largely a result of elevated concentrations during winter months.
- Below the sampling point, at which compliance is assessed and SAGIS calibrated, East Shefford WwTWs becomes the most significant source of SRP almost doubling the predicted instream concentration. Further downstream, at Boxford WwTWs, an increase in SRP concentrations (~0.005 mg/l) is also evident.
- Based on SAGIS; arable (39%) and livestock (21%) are dominant sources of SRP at the catchment scale although the relative apportionment along this stretch of river is highly variable, with WwTW making a significant contribution locally.
- To comply with the CSM target a combination of measures will be needed to address both WwTW and diffuse sources across the upper River Lambourn catchment.

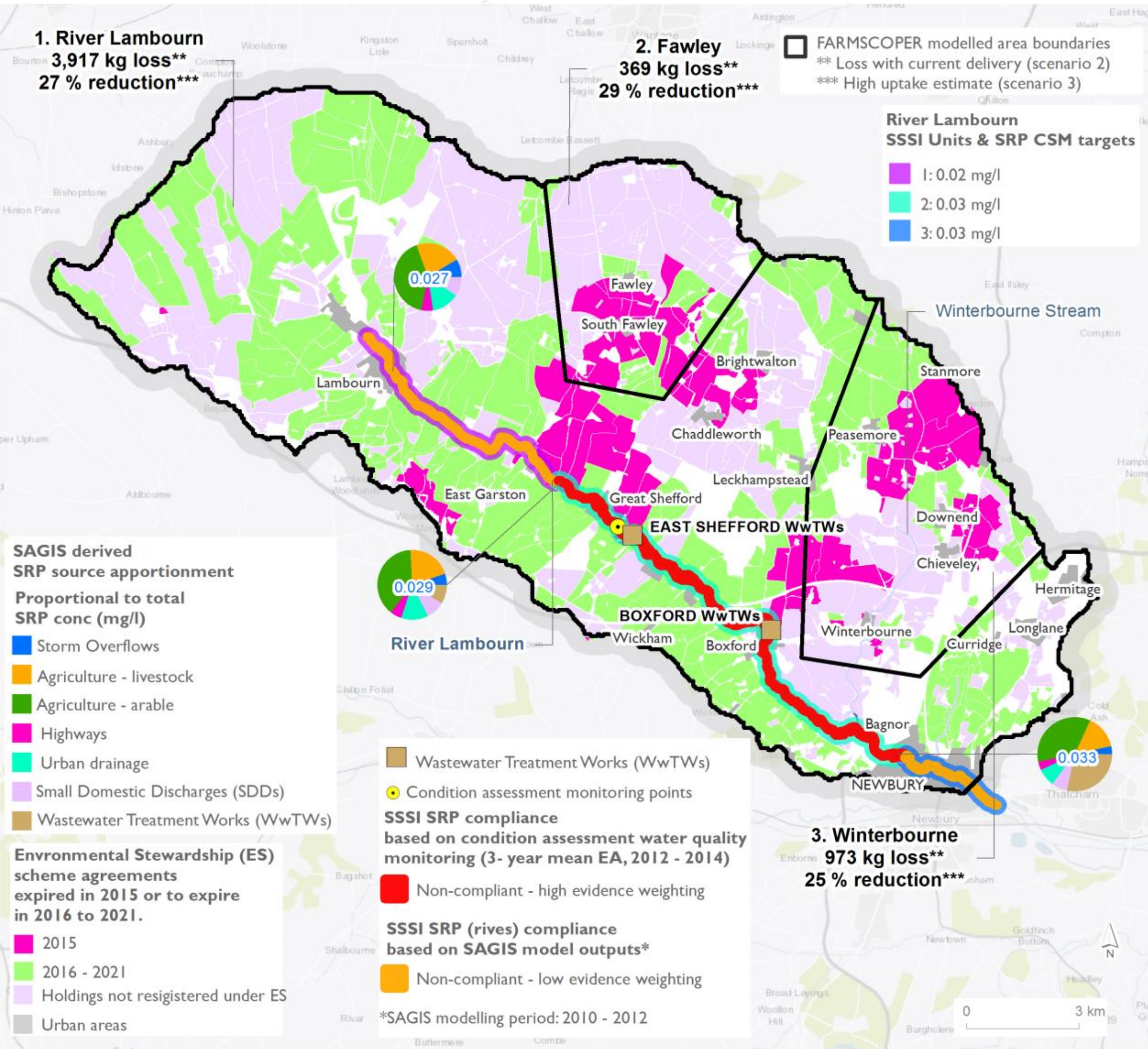
SSSI Unit 3 – Lower River Lambourn

- Based on outputs from the national SAGIS model, SSSI Unit 3 is marginally non- compliant with the CSM SRP target (0.03 mg/l) by up to 10%. There is no monitoring data against which to assess compliance.
- SAGIS modelling indicates arable (35%), WwTWs (28%) and livestock (15%) are dominant sources of SRP. Other sources are less significant at the catchment scale though they may be important locally, urban drainage (8%), SDDs (7%), highways (4%) and storm overflows (3%).

- Measures targeted in the upstream catchment to address diffuse agricultural sources should be able to achieve the reduction required to meet the CSM target below the Winterbourne, but other sources will need to be addressed to achieve the CSM target throughout the site.

FARMSCOPER estimates achievable reductions in P losses from agriculture from the 'high uptake' scenario 3 across the catchment ranging between 25 and 29%, indicating a combination of measures would likely be needed to achieve compliance – particularly in Units 1 and 2. However, it should be noted that measures such as spreading imported slurry, land-use change and livestock reduction that could further reduce losses from agriculture, are not included in the FARMSCOPER modelling.

Figure 8.2: *Targeting map showing compliance in the River Lambourn SAC/ SSSI. Compliance using water quality monitoring was assessed using CSM guidance methodologies, i.e. most recent three-year average concentrations of Soluble Reactive Phosphorus (SRP). SAGIS source apportionment pie charts are shown upstream of non-compliant SSSI units. High uptake' management measure reductions (scenario 3) (adjusted to represent reductions from agricultural sources based on SAGIS source apportionment) and phosphorus losses from agricultural sources based on current delivery (scenario 2) from FARMSCOPER. Holdings with Environmental Stewardship (ES) scheme agreements which have expired or are soon to expire (to 2021) are shown along with holdings not registered under ES.*



Recommendations on evidence

Analysis highlighted where further research would help to provide further validation and ensure decisions are underpinned by sufficient evidence, these are summarised below:

- Water quality monitoring in SSSI Unit 1 and 3 would enable a direct assessment of compliance.
- Analysis of high resolution CEH monitoring data around Boxford, including suspended solids, that was not made available for this study, alongside ecological survey data would support an assessment of the impact of sediment on the condition of the SSSI.
- Areas prone to groundwater flooding and highlighted as vulnerable of fine sediment erosion through SCIMAP modelling would benefit from ground-truthing through targeted wet weather walkovers.
- The landcover map (2007) and agricultural census data (2010) displayed in this report are out of date. To aid with further targeting within the catchment local knowledge and any newly available datasets should ideally be used to underpin modelling and identify areas with high risk land uses.
- Sufficiently robust fine resolution current landuse data would allow the verification and greater interpretation of FARMSCOPER outputs.
- SAGIS outputs are based on the national model and where / when the model has been refined and calibrated locally through water company and / or EA initiatives these should be adopted.
- Stakeholders highlighted large numbers of horses within the catchment which can present a pollution risk for sediment, and associated nutrient, loss from poaching. Horses are not currently included in the AgCensus data and therefore are not considered in the source apportionment or in assessing the effectiveness of potential mitigation measures.
- Slurry imported from outside the catchment also represents an important source of phosphorus and is not included in the modelling based assessment. Further information on manure / slurry management and soil testing to ensure best practice would help to quantify and mitigate this risk.
- With the hydrology of the catchment dominated by groundwater, any further information on preferential flow pathways that could link source areas with the river network would benefit the targeting of measures designed to address potential nitrate and phosphorus pollution

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Further Information & Contacts

Dr Russell Smith, Consultancy Director, BSc. MSc. PhD.

Russell is a Chartered Scientist and Environmentalist and Consultancy Director for Westcountry Rivers Ltd. Russell has over 12 years' experience in catchment management/planning and environmental monitoring working in the public and private sector and has considerable experience in directing and managing diverse multi-discipline projects. Russell has been involved in the application and development of farm, catchment to national scale models and decision support tools since the late 1990's in both research and consultancy. His experience in integrated catchment modelling is complemented by his experience in monitoring and his detailed understanding of the relationship between temporally and spatially variable catchment processes.

Email: russell@wrt.org.uk

Dr Nick Paling, Head of GIS, Evidence and Communications, BSc. MSc. PhD.

Nick is an applied ecologist and conservation biologist with 8 years of experience using spatial techniques to inform conservation strategy development and catchment management. He provides data, mapping & modelling support for all Trust projects and coordinates and manages a number of large-scale monitoring programmes currently being undertaken by the Trust.

Email: nick@wrt.org.uk

Appendix 1: Additional details of sectors included in the SAGIS source apportionment model.

SAGIS allows estimation, based on available data, of the relative sector contribution of phosphorus to receiving waterbodies in England and Wales. Developments have been made in the SAGIS modelling included in this report to better include relative contributions from SDDs, WwTWs and agriculture, and better incorporate real data (UKWIR, 2013).

THE TABLE BELOW OUTLINES THE DATA SOURCES FOR SAGIS

Data set	Methodology	Period	Source
River water quality	Processing of WIMS data to produce summary statistics – annual mean, standard deviation, and number of samples. Outliers removed using standard automated procedure.	2010-2012	Environment Agency
Lake water quality	Processing of WIMS data to produce summary statistics – annual and monthly mean, standard deviation, and number of samples. Outliers removed using standard automated procedure.	2010-2012	
Estuary water quality	Processing of WIMS data to produce summary statistics – annual and monthly mean, standard deviation, and number of samples. Outliers removed using standard automated procedure.	2010-2012	
Effluent quality from water company sewage works	Processing of WIMS data to produce summary statistics – annual mean, standard deviation, and number of samples. Outliers removed using standard automated procedure. In absence of data; if good data in the older SAGIS model (2006 to 2009) was available this was used. Otherwise, a default value was used. The default value was based on analysis of those sites with WIMS data on a national basis but for some substances (i.e. organic chemicals) data from the Chemical Investigation Programme (CIP) was used. For phosphorus, default values vary between the regional models, based on values proposed by the Environment Agency.	2010-2012 2006 to 2009	Environment Agency Environment Agency CIP
Effluent flow from water company sewage works	MCERTS data collected by the water companies and compiled nationally by the Environment Agency. For smaller works with no MCERTS data, the mean flow was assumed to be 1.3 x the permitted flow	2010-2012	Environment Agency (water companies)
Observed River flow	Flow data collected at Environment Agency flow gauges. This data is based on the period 2001 to 2004. In some cases, this has been updated more recently by the Environment Agency (2010 to 2012 data).	2001-2004 or 2010-2012	Environment Agency
Chemical loads from combined sewer overflows	CSO flows are based on rainfall data and an estimated value for the split between the proportion of rainfall in urban areas that passes into the sewer system and the proportion that drains to the rivers naturally or via the surface drainage system. A spill threshold was based on	2011	Atkins CIP

Data set	Methodology	Period	Source
	the flow to full treatment as 5 x Dry Weather Flow. The calculations were carried out at the waterbody scale and spills were allocated evenly between all CSOs within each waterbody. Concentrations in the spills, based on data from the Chemicals Investigation Programme were combined with this flows to create non-parametric files for discharged loads.		
Chemical loads from storm tanks	CSO flows are based on rainfall data and an estimated value for the split between the proportion of rainfall in urban areas that passes into the sewer system and the proportion that drains to the rivers naturally or via the surface drainage system. A spill threshold was based on the flow to full treatment as 3 x Dry Weather Flow + storm tank capacity. The calculation was carried out at the waterbody scale and spills were allocated evenly between all CSOs within a waterbody. Concentrations in the spills, based on data from the Chemicals Investigation Programme were combined with this flows to create non-parametric file for discharged loads.	2011	Atkins CIP
Diffuse inflows	This data drives the simulated naturalised river flows and was based on output from the LOWFLOWS 2000 model that is managed by Wallingford Hydro-Solutions. The data is based on long terms hydrological data for the period 1970 to 2000	1970-2000	WHS
River abstraction flows (mean flow and hands off flow)	These values have been unchanged from the original national SIMCAT models	2001-2004	Environment Agency
River network	Derived from the Environment Agency's detailed river network as released via Geostore. Some editing of the network was required to remove unnecessary small bifurcations and make polylines align with the SIMCAT connectivity rules	N/A	Environment Agency
River catchments (WFD waterbodies)	Environment Agency's WFD waterbody catchments, as released via Geostore (2015)	2015	Environment Agency
Lake waterbodies	Environment Agency's WFD waterbodies, released via Geostore (2015)	2015	
Estuary and coastal waterbodies	Environment Agency's WFD waterbodies, released via Geostore (2015)	2015	
Coastal catchments	Current Environment Agency waterbody catchments do not include areas around the coast. To retain functionality in SAGIS to estimate catchment inputs of flow and	N/A	Atkins

Data set	Methodology	Period	Source
	chemicals to estuaries and coastal waters, it was necessary to create catchments in these areas. These were allocated IDs based on the WFD for the adjacent estuary or coastal water. These are specific to SAGIS and are not intended to be used more widely.		
Catchment chemical loads from arable farming	Outputs from the ADAS model, PSYCHIC for phosphorus loads from agriculture (monthly loads) were processed to derive loads associated with arable farming. Likewise, outputs from the ADAS model, NEAP N were processed for nitrogen to derived arable farming loads. For other chemicals, export from the catchment are included in the natural background sector.	2010 agriculture data processed in PSYCHIC and NEAP N	ADAS
Catchment chemical loads from livestock farming	Outputs from the ADAS model, PSYCHIC for phosphorus loads from agriculture (monthly loads) were processed to derive loads associated with livestock farming. Likewise, outputs from the ADAS model, NEAP N were processed for nitrogen to derived stock farming loads. For other chemicals, export from the catchment are included in the natural background sector.	2010 agriculture data processed in PSYCHIC and NEAP N	ADAS
Catchment chemical loads from on-site treatment works (including septic tanks)	Outputs from an Environment Agency study 2011 were used to estimate the population associated with on-site treatment works within each waterbody. Per capita wastewater flows were combined with data on water quality in raw sewage from the literature and CIP to convert these input loads. Loss factors were then applied based on soil type and distance from the river network (taken from an earlier WRc study) to estimate the loads reaching the rivers.	2011	Environment Agency CIP
Catchment chemical loads from highways	Outputs from the WRc's HAWRAT model for motorways and trunk roads in England were used as inputs (converted to a 1km grid). The HAWRAT calculations are based on the impermeable surface area of the roads and rainfall data which is used to estimate runoff, combined with substance concentrations from Highways Agency monitoring to derived loads	2011	WRc
Catchment chemical loads from natural background	Outputs from the ADAS model PSYCHIC for catchment loads of sediment were combined with data on soils concentrations of chemicals (from FOREGS and other literature) to estimate loads.	2011	Atkins
Catchment chemical loads from atmospheric sources	Monitoring data for chemicals concentrations in rainfall were combined with rainfall volume data and estimated surface areas for rivers, lakes, and estuaries to estimate loads directly to these waterbodies (rainfall onto the catchment is assumed to be included in natural background inputs)	2006-2009	Various (complied by Atkins)
Chemical	Regional data on the numbers and size of boats from the	2013	Various

Data set	Methodology	Period	Source
loads to lakes and estuaries from boats	British Marine federation (BMF) were combined with wetted surface area from the boat design manual and literature on leaching rates of chemicals from hulls to estimate loads to waterbodies		(compiled by Atkins)
Chemical loads to lakes from wildfowl	Estimated wildfowl numbers for lakes were derived from RSPB regional wildfowl population data (distributed spatially based on lake area). This was combined with literature values for excretion rates from different species for N and P to derived loads (no inputs were derived for other chemicals).	2013	Various (compiled by Atkins)
Chemical loads to lakes from anglers	Estimated numbers of anglers were derived from EA road licence data that were distributed spatially based on lake area. This was combined with estimated numbers of visits, amount of bait used per visit and chemical content of bait to estimate loads.	2013	Various (compiled by Atkins)

A more detailed description of the methodologies described below are provided in the UWKIR reports: UKWIR WW02: CHEMICAL SOURCE APPORTIONMENT UNDER THE WFD – MODEL - APPENDIX A and WFD REQUIREMENTS FOR LAKES, TRANSITIONAL AND COASTAL WATERS, SOURCE APPORTIONMENT FOR NUTRIENTS AND PRIORITY CHEMICALS, APPENDIX B

APPORTIONING OUTPUTS TO THE BROAD 'ARABLE' AND 'LIVESTOCK' SECTORS

Agricultural exports were calculated for two broad sectors, 'arable' and 'livestock'. Within PSYCHIC, calculations are carried out and output generated separately for each land use in each 1km grid cell and each agricultural element (livestock type and crop type). These are then aggregated to produce summary results for all land in each 1km grid cell.

Based on PSYCHIC land cover data, an estimate was made of the area in each 1km grid cell which is under arable cropping and that which is under grassland (either managed or rough grazing). The "livestock" area was then calculated as the sum of these last two categories.

$$A_{Ar} = ARABLE$$

$$A_{LS} = GRASS + ROUGH$$

The fraction of the agricultural area was assigned to the arable sector (F_{Ar}) and the livestock sector (F_{LS}) as follows:

$$F_{Ar} = \frac{A_{Ar}}{A_{Ar} + A_{LS}}$$

$$F_{LS} = \frac{A_{LS}}{A_{Ar} + A_{LS}}$$

Monthly outputs are provided from PSYCHIC so these have been made available for input to the SAGIS tool.

Manure applications are split equally between arable and grasslands. Although this is unlikely in the absence of more detailed national data to support a more intelligent approach SAGIS adopts an equal split but includes the functionality to amend this where supported by local knowledge or data.

INTERMITTENT DISCHARGES AT WWTWS

The methodology applied to estimate intermittent discharge that occurs from discharges at WwTWs (e.g. storm tank overflows) was similar to that applied to estimate CSO discharge. The first step in estimating discharge volumes was to calculate a rainfall intensity threshold at which on-site storage would be exceeded. This was calculated as follows:

$$\mathrm{RIT_{WwTW}} = \frac{(\mathrm{SC} \times \mathrm{TDWF}) + (\mathrm{PE} \times \mathrm{STC})}{\mathrm{TISA}}$$

Where:

- RITWwTW is a national scale rainfall intensity threshold at which the on-site storage capacity will be exceeded (mm).
- SC is the sewer capacity as a multiple of dry weather flow (DWF) (in litres). This value reflects the flow retention capacity of the sewer.
- TDWF is an estimate of the national scale DWF (i.e. the sum of DWF for all WwTWs in England and Wales) in litres. The default DWF factor applied for this calculation was 3.5.
- PE is the population equivalent sewage treatment capacity.
- STC is the on-site storage capacity (68 litres per p.e.).
- TISA is an estimate of the total (national scale) impermeable surface area (in m2).
- Values for TISA were as previously described.

$$WwTW_i => (RIT_i \times ISA_i) - CSO_i$$

Where:

- WwTWi represents the total discharge from WwTWs in catchment *i.*
- RIT*i* represents the total rainfall amount (in mm) that occurs in catchment *i* which is in excess of the RIT.
- ISA*i* is the total (weighted) impermeable surface area in catchment *i*.
- CSO*i* represents the volume discharged from CSOs within catchment *i* (ensures that flow volumes are not double counted).

The subsequent total discharge volume within each catchment was assigned to each WwTW that occurred within the catchment on the basis of the works %age contribution to the catchment sewage treatment capacity. The substance loads were calculated on the basis of the flow discharge estimates and the (dilution adjusted) substance concentrations expected to occur in surface water run-off and raw sewage effluent.

INDUSTRIAL INPUTS

Data on inputs for 8 substances from 113 industrial sources was obtained from the Pollution Industry database and included in the export coefficient database. The correlation of the input load with river flows (i.e. a measure of the extent by which the input load correlates with river flow – required for the SIMCAT simulation) was 0. The coefficient of variation (i.e. a measure of the uncertainty in the input load value – required for the SIMCAT simulation) was 1.0.

URBAN SECTOR

Urban sector inputs represent surface water runoff from urban areas (i.e. roads, carparks and other impermeable areas. The surface water run-off, "Urban", load is a function of rainfall (R), impermeable surface area (ISA), % direct to surface water (%SW), concentration in the run-off (RC).

Where:

- Rainfall 'zones' determined from Met Office data (intensity and frequency profile).
- Surface permeability a function of land use type (surface type run-off coefficient).
- Concentrations in runoff are derived empirically from surface water drainage data collected as part of UKWIR's chemical investigation programme.

Urban Load = [Rainfall] x [%SW] x [ISA] x [Run-off Coeff.] x [RC]

Run-off Coeff is the percentage of rainfall that runs off impermeable areas. A default value of 49% is used which echoes a similar assumptions for runoff coefficients used for the Strategic Road network in HAWRAT. The remaining 51% is assumed to enter the sewer and is therefore captured within the CSO / Storm tank sector.

SCENARIO TESTER

The scenario tester collates detailed outputs from SAGIS that tracks the relative contribution from every sector source from individual points and each waterbody as they move downstream. By tracking individual each sector sources the scenario tester spreadsheet is able to assess the downstream impact of amended point source loads and or percentage reductions in diffuse loads from each waterbody or other defined spatial area. This simple spreadsheet based approach has been validated and tested against scenarios generated by rerunning SAGIS itself, both return the same outputs (Daldorph, pers comm 2016).

The SAGIS apportionment adjusted 'high uptake' potential FARMSCOPER reductions in phosphorus shown were used to further reduce contributions from livestock and arable sources in order to translate the FARMSCOPER estimated reductions in phosphorus, in the modelled sub-catchments, into in-stream concentrations. Mitigation methods were split into arable or livestock based on assumptions for these categories used in PSYCHIC, which also underpins SAGIS. Reductions applicable to individual FARMSCOPER methods for arable or livestock were then added to find the overall reduction in the arable and livestock contributions for each waterbody to amend the detailed outputs from SAGIS. FARMSCOPER was run to calculate reductions for the whole catchment and these reductions were applied to each waterbody in SAGIS which was within the FARMSCOPER sub-catchment.

Appendix 2: List of Environmental Stewardship (ES) Scheme options with significant water quality benefits included in each category.

Note that there are many other ES scheme options which have the potential to improve water quality if used in the location and time. However, as ES options which do not directly target water quality are often not specifically applied for improving water quality benefits, they are likely to have no or very little water quality benefit in most cases so have not been included in this list. Option codes are shown in parentheses.

Buffer strip and field margin options

12 m buffer strips for watercourses on cultivated land (EJ9, HJ9, OJ9)
12 m buffer strips for watercourses on rotational land (OHJ9)
6 m buffer strips on cultivated land next to a watercourse (EE9)
6 m buffer strips on intensive grassland next to a watercourse (EE10)
6 m buffer strips on organic grassland next to a watercourse (OE10)
6 m buffer strips on rotational land next to a watercourse (OE9)

Creation and/ or maintenance of fencing

Post and wire fencing along watercourses (UJ3, UOJ3)

Creation, reversion, restoration or regeneration of natural/ semi-natural land

Creation of lowland heathland from arable or improved grassland (HO4)
Creation of woodland (HC10, HC9)

Livestock management

Seasonal livestock removal from intensively managed grassland (HJ7)
Winter livestock removal next to streams, rivers and lakes (UJ12, UOJ12)

Management Plan options

Manure management plan (pre-RDPE) (EM3, HM3, OHM3, OM3)
Nutrient management plan (pre-RDPE) (EM2, HM2, OHM2, OM2)
Soil management plan (pre-RDPE) (EM1, HM1, OHM1, OM1)

Options to reduce nutrient inputs

Nil fertiliser supplement (HJ8)
Reversion to low input grassland to prevent erosion/run-off (HJ4)
Reversion to unfertilised grassland to prevent erosion/run-off (HJ3)

Soil stability options

Cropping restrictions on high erosion risk fields (HJ1)
Enhanced management of maize crops to reduce erosion and run-off (EJ10, HJ10)
Extended overwintered stubbles (EF22)
In-field grass areas to prevent erosion and run-off (EJ5, HJ5, OHJ5, OJ5)
Management of high erosion risk cultivated land (EJ1, OJ1)
Management of maize crops to reduce soil erosion (EJ2, HJ2)
Preventing erosion or run-off from intensively managed grassland (HJ6)
Winter cover crops (EJ13, HJ13, OHJ13, OJ13)

Appendix 3: Summary of input Agricultural Census 2010 data for FARMSCOPER analysis.

	1. Lambourn	2.Fawley	3.Winterbourne
Dairy Cows and Heifers	304	22	36
Dairy Heifers in Calf (2 years +)	571	37	34
Dairy Heifers in Calf (< 2 years)	184	13	21
Bulls (2 years +)	86	10	8
Beef Cows and Heifers	442	46	51
Beef Heifers in Calf (2 years +)	499	60	63
Beef Heifers in Calf (< 2 years)	285	30	33
Other Cattle (2 years +)	0	0	0
Other Cattle (1 - 2 years)	275	36	38
Other Cattle (< 1 year) & Calves	385	43	47
Sheep	9390	998	1530
Lambs (< 1 year)	4697	500	786
Sows in Pig & Other Sows	368	55	47
Gilts in Pig & Barren Sows	117	18	15
Gilts Not Yet in Pig	196	30	25
Boars	12	2	2
Other Pigs (> 110kg)	33	5	4
Other Pigs (80 - 110kg)	233	35	30
Other Pigs (50 - 80kg)	599	90	77
Other Pigs (20 - 50kg)	932	140	119
Other Pigs (< 20kg)	1199	180	153
Sows in Pig & Other Sows	3283	219	1393
Gilts in Pig & Barren Sows	3283	219	1393
Gilts Not Yet in Pig	6565	438	2786
Boars	21685	1497	26
Other Pigs (> 110kg)	165	123	15
Other Pigs (80 - 110kg)	1575	124	451
Other Pigs (50 - 80kg)	358	121	104
Other Pigs (20 - 50kg)	2470	272	407
Other Pigs (< 20kg)	872	38	106
Layers (Caged)	2974	303	572
Layers (Uncaged)	4507	572	837
Pullet	790	39	237
Broilers	919	83	194
Turkeys	1434	206	270
Breeding Birds	102	5	17
Another Poultry	15	1	0
Permanent Pasture (ha)	0	0	0
Rotational Grassland (ha)	220	14	15
Rough Grazing (ha)	499	93	98
Winter Wheat (Feed) (ha)	31	1	0
Winter Wheat (Milling) (ha)	135	26	31
Winter Barley (Malting) (ha)	2	0	0
Winter Barley (Feed) (ha)	2	0	0
Spring Barley (ha)	5	3	0
Winter OSR (ha)	1	1	0
Maize (ha)	838	61	257
Potatoes (ha)			
Sugar Beet (ha)	0	0	0
Peas (ha)	2042	260	518
Beans (ha)	304	22	36
Fodder Crops (ha)	571	37	34
Other Crops (ha)	184	13	21
Vegetables (Brassica) (ha)	86	10	8
Vegetables (Other) (ha)	442	46	51
Orchards (ha)	499	60	63
Soft Fruit (ha)	285	30	33
Bare Fallow (ha)	0	0	0
Set Aside (ha)	275	36	38
Woodland (ha)	385	43	47

Appendix 4: FARMSCOPER mitigation method options (Scenario 2).

Continued next page…

Method Name	ID	Sub-catchment		
		1	2	3
Establish cover crops in the autumn	4	36	45	47
Early harvesting and establishment of crops in the autumn	5	0	0	0
Cultivate land for crops in spring rather than autumn	6	3	2	2
Adopt reduced cultivation systems	7	25	25	25
Cultivate compacted tillage soils	8	10	10	10
Cultivate and drill across the slope	9	10	10	10
Leave autumn seedbeds rough	10	10	10	10
Manage over-winter tramlines	11	2	2	2
Establish in-field grass buffer strips	13	36	45	47
Establish riparian buffer strips	14	44	53	55
Loosen compacted soil layers in grassland fields	15	10	10	10
Allow grassland field drainage systems to deteriorate	16	2	2	2
Ditch management on arable land	180	25	25	25
Ditch management on grassland	181	25	25	25
Make use of improved genetic resources in livestock	19	0	0	0
Use plants with improved nitrogen use efficiency	20	0	0	0
Fertiliser spreader calibration	21	2	2	2
Use a fertiliser recommendation system	22	80	80	80
Integrate fertiliser and manure nutrient supply	23	80	80	80
Do not apply manufactured fertiliser to high-risk areas	25	80	80	80
Avoid spreading manufactured fertiliser to fields at high-risk times	26	80	80	80
Use manufactured fertiliser placement technologies	27	11	10	10
Use nitrification inhibitors	28	0	0	0
Replace urea fertiliser to grassland with another form	290	0	0	0
Replace urea fertiliser to arable land with another form	291	0	0	0
Incorporate a urease inhibitor into urea fertilisers for grassland	300	0	0	0
Incorporate a urease inhibitor into urea fertilisers for arable land	301	0	0	0
Use clover in place of fertiliser nitrogen	31	0	0	0
Do not apply P fertilisers to high P index soils	32	10	10	10
Reduce dietary N and P intakes: Dairy	331	80	80	80
Reduce dietary N and P intakes: Pigs	332	80	80	80
Reduce dietary N and P intakes: Poultry	333	0	0	0
Adopt phase feeding of livestock	34	80	80	80
Reduce the length of the grazing day/grazing season	35	2	2	2
Extend the grazing season for cattle	36	2	2	2
Reduce field stocking rates when soils are wet	37	10	10	10
Move feeders at regular intervals	38	11	10	10
Construct troughs with concrete base	39	2	2	2
Increase scraping frequency in dairy cow cubicle housing	42	0	0	0
Additional targeted bedding for straw-bedded cattle housing	43	0	0	0
Washing down of dairy cow collecting yards	44	80	80	80
Frequent removal of slurry from beneath-slat storage in pig housing	46	0	0	0
Install air-scrubbers or bio trickling filters in mechanically ventilated pig housing	48	0	0	0
More frequent manure removal from laying hen housing with manure belt systems	50	0	0	0
In-house poultry manure drying	51	10	10	10
Increase the capacity of farm slurry stores to improve timing of slurry applications	52	11	10	10
Adopt batch storage of slurry	53	0	0	0
Install covers to slurry stores	54	10	10	10
Allow cattle slurry stores to develop a natural crust	55	80	80	80
Anaerobic digestion of livestock manures	56	0	0	0
Minimise the volume of dirty water produced (sent to dirty water store)	570	11	10	10
Minimise the volume of dirty water produced (sent to slurry store)	571	11	10	10
Compost solid manure	59	2	2	2
Site solid manure heaps away from watercourses/field drains	60	50	50	50
Store solid manure heaps on an impermeable base and collect effluent	61	80	80	80
Cover solid manure stores with sheeting	62	2	2	2
Use liquid/solid manure separation techniques	63	2	2	2
Use poultry litter additives	64	0	0	0
Manure Spreader Calibration	67	2	2	2
Do not apply manure to high-risk areas	68	80	80	80
Do not spread slurry or poultry manure at high-risk times	69	80	80	80
Use slurry band spreading application techniques	70	2	2	2
Use slurry injection application techniques	71	2	2	2
Do not spread FYM to fields at high-risk times	72	80	80	80
Incorporate manure into the soil	73	25	25	25

Built-in FARMSCOPER mitigation method options.

...Continued

Method Name	ID	Sub-catchment		
		1	2	3
Fence off rivers and streams from livestock	76	59	68	70
Construct bridges for livestock crossing rivers/streams	77	2	2	2
Re-site gateways away from high-risk areas	78	1	0	0
Farm track management	79	1	0	0
Establish new hedges	80	2	2	2
Establish and maintain artificial wetlands - steading runoff	81	0	0	0
Irrigate crops to achieve maximum yield	82	50	50	50
Establish tree shelter belts around livestock housing	83	0	0	0
Calibration of sprayer	90	80	80	80
Fill/Mix/Clean sprayer in field	91	10	10	10
Avoid PPP application at high risk timings	92	80	80	80
Drift reduction methods	94	50	50	50
PPP substitution	95	2	2	2
Construct bunded impermeable PPP filling/mixing/cleaning area	96	2	2	2
Treatment of PPP washings through disposal, activated carbon or biobeds	97	2	2	2
Protection of in-field trees	101	44	53	55
Management of woodland edges	102	36	45	47
Management of in-field ponds	103	36	45	47
Management of arable field corners	105	44	53	55
Plant areas of farm with wild bird seed / nectar flower mixtures	106	44	53	55
Beetle banks	107	36	45	47
Uncropped cultivated margins	108	36	45	47
Skylark plots	109	36	45	47
Uncropped cultivated areas	110	34	43	45
Unfertilised cereal headlands	111	34	43	45
Unharvested cereal headlands	112	34	43	45
Undersown spring cereals	113	34	43	45
Management of grassland field corners	114	36	45	47
Leave over winter stubbles	115	10	10	10
Leave residual levels of non-aggressive weeds in crops	116	0	0	0
Use correctly-inflated low ground pressure tyres on machinery	117	2	2	2
Locate out-wintered stock away from watercourses	118	3	2	2
Use dry-cleaning techniques to remove solid waste from yards prior to cleaning	119	50	50	50
Capture of dirty water in a dirty water store	120	0	0	0
Irrigation/water supply equipment is maintained and leaks repaired	121	25	25	25
Avoid irrigating at high risk times	122	25	25	25
Use efficient irrigation techniques (boom trickle, self-closing nozzles)	123	10	10	10
Use high sugar grasses	124	10	10	10
Monitor and amend soil pH status for grassland	125	0	0	0
Increased use of maize silage	126	0	0	0

Sub-Catchment
1. Lambourn
2. Fawley
4. Winterbourne