River Wye SAC
Nutrient Management Plan
Evidence base and options appraisal

Environment Agency & Natural England

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Plan Design Enable

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Executive Summary

The River Wye and River Lugg are areas of special importance for nature conservation, with both rivers being designated as Sites of Specific Scientific Interest (SSSIs) and the lower stretches of the River Lugg, along with the River Wye, are also a part of the River Wye Special Area of Conservation (SAC) designated under the European Community (EC) Habitats Directive. Natural England's current phosphate compliance assessments have determined that parts of the River Wye SAC are currently not meeting the required phosphate targets (set at 0.03 mg/l in the upper River Wye sub-catchment and 0.05 mg/l in both the River Lugg and lower River Wye sub-catchments).

As part of the Environment Agency's Review of Consents (RoC) process in 2010, it was agreed that a plan is needed for the River Wye SAC in order to reduce current phosphate concentrations in the river to comply with conservation objectives. To this end, in 2013 the Environment Agency and Natural England issued a joint Statement of Intent to prepare a Nutrient Management Plan (NMP) for the River Wye SAC, which would also address predicted growth within the catchment. In this way, the Environment Agency and Natural England are also working together to support Herefordshire Council to develop a framework for determining planning applications which are constrained by their Habitats Assessment process. The proposals will also inform Herefordshire Council's Core Strategy and other relevant development plans.

The farming community plays a crucial role in the River Wye SAC catchment. Alongside population growth, the agricultural sector will change in the future and the NFU vision is to achieve this development together with environmental improvement. This NMP provides some of the technical understanding necessary to support this approach.

Objectives and scope

An NMP is typically divided into three parts:

- **Part 1 - Evidence and supporting information -** containing the background and evidence base for action;
- **Part 2 - Options Appraisal** – setting out the balance of options that could be implemented to achieve the required outcomes; and
- **Part 3 - the "Action Plan" -** containing the measures that could be implemented in order to help achieve favourable condition within the River Wye SAC, including action owners and timings.

The scope of this project covered parts 1 and 2, setting out the evidence base for action and the options that could form the basis of a long term action plan. The next step is for Natural England, the Environment Agency and Defra to consider the findings of this study and further consult with the key stakeholders within the catchment, including Herefordshire County Council, Welsh Water, land managers and land owners. These regulators and delivery partners will need to work collaboratively to agree how best to integrate the findings of this study within local catchment management initiatives in order to form and agree an action plan for implementation.

Approach

For this assessment, the River Wye SAC has been divided up into three reaches:

- The upper River Wye sub-catchment (the River Wye upstream of the confluence with the River Lugg);
- The River Lugg sub-catchment (upstream of its confluence with the River Wye); and
- The Lower River Wye sub-catchment (downstream of the confluence with the River Lugg).

The focus of this study has been on the upper River Wye and the River Lugg sub-catchments, with the rationale that if these sections achieve their respective phosphate targets then the lower River Wye sub-catchment will achieve its own targets by default. This of course is contingent on the current situation of discharges in the lower River Wye SAC remaining constant over the period of this NMP, and also on the assumption that a discharge concentration of 0.1mg/l is technically achievable as suggested in this study for the upstream works.

Atkins has undertaken a source apportionment exercise for the River Wye and River Lugg catchments to understand current phosphate contributions from the main point and diffuse sectors. Alongside this, the potential contributions of phosphate from various agricultural farm types characteristic of the catchment were also assessed using the Defra tool FARMSCOPER. From this, an options appraisal process was undertaken to understand how different measures could be applied in the wastewater and agricultural sectors in order to achieve the target phosphate levels required.

Source apportionment

A source apportionment model has been used to examine the current pressures acting on these two main reaches of the River Wye SAC. The Source Apportionment Geographical Information System (SAGIS) tool, developed by Atkins jointly on behalf of the Environment Agency and the water industry, can be used to evaluate both the overall water quality along any given river reach (in this case, phosphorus), but also the source apportionment of chemicals (that is what portion of the overall concentration of phosphorus comes from different contributing sectors acting in the catchment).

A baseline modelling exercise was initially carried out to understand the current levels of phosphate within the river reaches, and the likely main contributing sources. This study relied on existing datasets within SAGIS, no new data was collected. A calibration process was undertaken in order to improve the model representation of reality and to identify the elements of uncertainty that might influence the agreement between simulated and observed concentration; this calibration showed good confidence in the model prediction.

Following the calibration exercise, the model was run for three baseline scenarios:

	Description
S1	Simulate the in-river phosphate concentration (immediately upstream of the confluence of the River Wye and Lugg) under current discharge conditions
S2	Simulate the in-river phosphate concentration (immediately upstream of the confluence of the River Wye and Lugg) under permitted discharge conditions (discharge flow and quality)
S3	Simulate the in-river phosphate concentration (immediately upstream of the confluence of the River Wye and Lugg) under permitted discharge quality conditions using the actual discharge flow (permitted discharge flow conditions often incorporate a significant amount of ‘headroom’ to accommodate future increases in discharge flows arising from an increase in in-flows due to population growth).

On the basis of the current discharge flows and quality scenario (S1), the baseline source apportionment has reflected the already known situation of non-compliance with conservation targets in the River Lugg sub-catchment; it has also shown that the phosphate levels in the upper River Wye sub-catchment are currently compliant but are near to the phosphate conservation target. When considering the fully licensed discharge flows and quality scenarios (S2 and S3) what is clear is that if water companies were discharging to their fully consented levels, the conservation targets would be exceeded in the upper River Wye sub-catchment and the existing situation of non-compliance in the Lugg would worsen.

The source apportionment exercise then considered the relative contributions from: sewage treatment works; agriculture (livestock and arable sectors); and “other” inputs including urban pressures and septic tanks. The baseline source apportionment has shown that the main pressures contributing to overall phosphate loading in the rivers are sewage treatment works discharges and diffuse phosphate pollution from agriculture. Furthermore, the source apportionment has shown that the two sub-catchments display quite a different balance of main contributing pressures, with phosphates from sewage treatment works dominating in the upper River Wye SAC sub-catchment, and agricultural inputs becoming comparatively more dominant in the River Lugg sub-catchment. This trait is not surprising when considering the sub-catchment characters; the upper River Wye sub-catchment contains several large towns alongside the typical rural Herefordshire setting, whereas the River Lugg is less densely populated and is dominated by rural activities.

Growth impact assessment for point source pressures

Following the baseline assessment, an impact assessment was then undertaken, taking into account the potential effect of growth on phosphate inputs.

To understand the effects of growth on the in-river phosphate concentrations, the predicted growth pattern and magnitude has been used to scale up the wastewater loads at different WwTW (and therefore the additional input loads to the river reaches). Within Herefordshire, the effect of population growth has been calculated by matching WwTWs to the regions they occur within and uplifting the discharge flows in accordance with the Herefordshire County Council population growth estimate. For example, the population of Hereford has been predicted to grow by 15% and consequently the discharge flows for sewage treatment works within the Hereford region have been increased by 15% from their current actual. Discharge quality has been assumed to be unchanged from the permitted quality conditions since it is anticipated that any additional influent volume would be treated to same degree of quality as at present. The population growth scenario (S4) is set out as follows:

	Description
S4	Simulate the in-river phosphate concentration (immediately upstream of the confluence of the River Wye and Lugg) under permitted discharge quality conditions with discharge flows uplifted to reflect population growth impacts (uplifted in line with County Council population increase projections).

The SAGIS modelling of the new population growth scenario indicates that, in the absence of further phosphate-reduction measures, the additional wastewater burden could put the current situation of compliance in the upper River Wye at further risk, with likely increase in non-compliance in the Lugg. This study further considered various combinations of mitigation options that could help address these impacts; these are summarised below.

Mitigation of point sources

In order to assess potential mitigation options in the point source sector, an optimisation exercise has been undertaken to assess where measures could be applied to reduce phosphate inputs to the rivers. In consultation with the project partners, a number of rules were agreed as the basis of this optimisation exercise, including for example:

- Only sewage treatment works that contribute more than 2% of the total contribution from point source inputs have been selected as candidates for measures. The rationale was that this enabled a prioritisation of discharges that account for approximately 80% of the input from point sources within the catchment.
- Sewage treatment works can achieve a discharge quality of 0.1 mg/L (as an annual average). A discharge quality of 1 mg/L is currently accepted as the achievable limit using the Best Available Technology (BAT); however, a substantial amount of research is underway to develop new methods. It has therefore been assumed that a discharge quality of 0.1 mg/L will become achievable.
- Measures were preferred at locations where the cost of phosphate removal per kilogram was lowest, using indicative treatment cost information provided by Welsh Water.

For the upper River Wye sub-catchment, the optimisation exercise indicated that applying more stringent discharge consents to the two main sewage treatment works serving Hereford (Eign and Rotherwas WwTWs) could be sufficient to achieve the conservation target for this reach of the River Wye SAC, even in the absence of any other measures being implemented (for example measures in the agricultural sector). However, this would require technology to be utilised that is currently only theoretical ("future technology"); a phosphate concentration discharge of 0.1 mg/L would be required, which is a factor of 10 lower than the levels achievable with the current BAT (1 mg/L). Therefore there is an element of uncertainty that needs to be considered in this situation.

For the River Lugg sub-catchment, the best estimate model prediction has suggested that additional measures are likely to be required at up to 11 sewage treatment works, many of which are relatively small works serving a population equivalent of less than 1000. Similarly to the situation on the upper River Wye, this solution relies on future technology delivering discharges with phosphate concentrations to the predicted 0.1 mg/L level.

Agricultural sector contributions

Alongside the point source assessments described previously, a separate assessment was undertaken investigating the likely contributions from the different farming practices occurring within the catchments. Data from Defra and the Welsh Government have been used to define the farm types and frequency within the catchments, which was then used in the FARMSCOPER tool to understand the typical amounts of phosphate lost from different farm types each year.

The data show that the catchment as a whole can be divided up rather simplistically into two main areas; the north and west of the catchment which is dominated by livestock farming and the south and east of the catchment which dominated by intensive arable farming. The source apportionment indicates that the main contributor from the agricultural sector in both sub-catchments is livestock farming.

The FARMSCOPER modelling however showed that a typical arable farm gives rise to more phosphate pollution than a livestock farm, on a per farm basis. Nonetheless, as noted above the livestock farms reflect a higher portion of the source apportionment because they form a larger portion of the overall farm holdings in the catchment.

Mitigation of agricultural sources

FARMSCOPER has been used to understand the potential effects of various land management measures on reducing phosphate losses, whilst taking account of measures already being implemented by the agricultural sector through NVZ requirements. It is recognised that this modelling to assess the effects of mitigation is a simplification, based on assumptions in work previously carried out for Defra. Furthermore, these theoretical calculations do not take explicit account of economic constraints, and this is a point for further consideration in taking forward the options appraisal and developing an action plan.

In consultation with the Environment Agency and Natural England, three agricultural "scenarios" (combinations of agricultural measures) have been defined as follows: the Catchment Sensitive Farming Officer (CSFO) recommended package of measures ("CSFO Scenario); the "Optimiser max" package (recommended by FARMSCOPER for each farm type as the maximum theoretically achievable); and the "Top 5" list of measures (essentially the top 5 most effective measures from the Optimiser Max list for each farm type. These scenarios have been applied to the representative farm types present in the catchments to understand the percentage reductions in phosphate losses that could be achieved.

The modelling has also shown that the measures available to tackle phosphate pollution are more effective in the arable sector compared with the livestock sector; however, because livestock farming is contributing more phosphate to the baseline source apportionment compared with arable, the resulting in-river phosphate reductions that can be achieved are relatively modest.

The effectiveness of the scenarios have then been aggregated up into the two farm types recognised in SAGIS (arable and livestock) and the underlying data in SAGIS factored to reflect these reductions in phosphate losses from land. The source apportionment has then been re-run to understand how the phosphate loss reductions from these agricultural scenarios could affect in-river phosphate concentrations. The results indicate that:

- Assuming all farmers take up the CSFO recommended measures, a maximum of 3-7% reduction in in-river phosphate could potentially be achieved;
- If all farmers were to take up the "top 5" recommended measures, a maximum of 5-13% reduction in in-river phosphate could potentially be achieved; and
- If all farmers were to implement all the measures set out in the "optimiser maximum" scenario then this would result in a reduction in in-river phosphate levels of between 16 and 40%.

(These percentages relate to the percent reduction in the agricultural contribution to in-river phosphate, not the percentage reduction to overall phosphate concentrations)

It should be emphasised that these percentages are likely to be upper end estimates as the reductions rely on all farms implementing the required changes to the highest specification over a long period of time; it also assumes that the measures can be applied to all farms, when in fact they may not be applicable in some cases. Furthermore, there is significant uncertainty over the actual outcomes of implementing these measures as any evidence of water quality improvements can easily be lost when catchment processes are combined.

Options appraisal

An options appraisal process has been undertaken to understand the effectiveness of combining measures across the wastewater and agricultural sector to achieve the compliance target. Four combinations of point source measures and agricultural measures that aim to achieve the conservation phosphate target were considered:

	Description
S5	Simulate the effect of controls on inputs from sewage treatment works only (refer to Section 8.2)
S6	Simulate the effect of the **CSFO** recommended measures to control inputs from agriculture (refer to Section 8.3.2.1), with further controls on inputs from sewage treatment works applied (following the approach described in Section 8.2) to make up any shortfall.
S7	Simulate the effect of the **'Top 5'** recommended measures to control inputs from agriculture (refer to Section 8.3.2.2), with further controls on inputs from sewage treatment works applied (following the approach described in Section 8.2) to make up any shortfall.
S8	Simulate the effect of the FARMSCOPER **optimiser** recommended measures to control inputs from agriculture (refer to Section 8.3.2.3), with further controls on inputs from sewage treatment works applied (following the approach described in section 8.2) to make up any shortfall.

All four scenarios showed that it is theoretically possible to achieve the targets set out by Natural England; however what is clear is that the biggest potential reductions can be gained by addressing point source discharges. Even when the agricultural scenarios are applied in full across the catchment, it is highly likely that significant effort would still be needed from point source measures, comparable to the level of reductions that would be required if relying on point source measures alone. In other words, the agricultural scenarios, based on generally accepted levels of effectiveness, have a relatively modest impact in comparison to the point source measures.

Although the modelling undertaken through this study provides a useful indication of where phosphates may be coming from and how they could be addressed through mitigation measures, it is important to remember that all models are simplifications of reality and the actual catchment science is complex; however the models used here are recognised as industry best practice and have been subject to calibration where possible.

Recommendations

There is still more work needed to decide upon the most appropriate balance of measures to reduce phosphates, prior to the production of an action plan for implementation, but this evidence base and options appraisal sets the basis for further discussions between the Environment Agency, Natural England, Defra, the Water Industry and the Agricultural sector.

This document sets out different options that could be considered in order to achieve the relevant compliance targets; a key assumption to consider however when taking these options forward is the issue of confidence in outcome. In line with this, several areas where confidence could be enhanced through further investigations are summarised.

Next steps

This NMP evidence base is the starting point in a long- term process. The next stage is for the Environment Agency and Natural England to decide on an Action Plan that takes a long term strategic view of the actions required to achieve Favourable Condition of the River Wye SAC by 2027. In addition, there are short to medium term objectives to reduce phosphate levels towards the restoration target, and to see downward trends in the levels of nitrogen and suspended solids.

The next step is for the Environment Agency, Natural England, Herefordshire County Council, land managers and land owners to work collaboratively and use the outputs of this options appraisal in order to move forwards into implementation and action.

1. Introduction

1.1. Purpose of the Plan

The River Wye and River Lugg are areas of special importance for nature conservation, with both rivers being designated as Sites of Specific Scientific Interest (SSSIs) and the lower stretches of the River Lugg, along with the River Wye, are also a part of the River Wye Special Area of Conservation (SAC) designated under the European Community (EC) Habitats Directive.

The River Wye SAC can be broadly divided up into three sections, comprising:

- the River Wye upstream of the confluence with the River Lugg – known throughout this report as the **"Upper River Wye" sub-catchment;**
- the River Lugg upstream of the confluence with the River Wye – known throughout this report as the **"River Lugg" sub-catchment**; and
- the River Wye downstream of the confluence with the River Lugg – known throughout this report as the **"Lower River Wye" sub-catchment**.

These sections are shown in the conceptual diagram below.

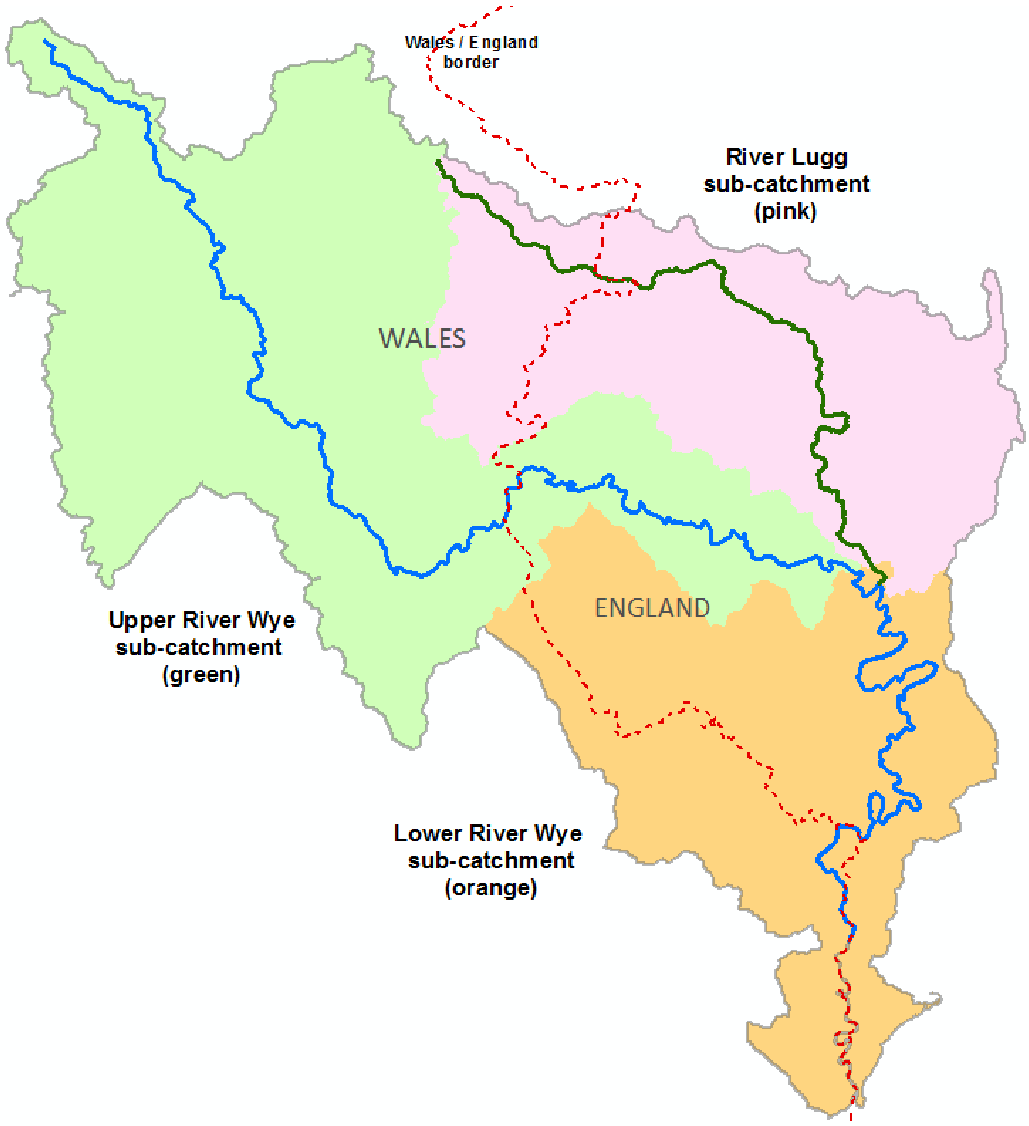

Figure 1-1: Conceptual diagram of the River Wye SAC

The SAC currently includes reaches where the levels of phosphate exceed the target level currently set by Natural England in the conservation objectives for the designated site.

- The River Wye upstream of the confluence with the River Lugg is currently meeting the phosphate target (0.03 mg/l phosphate) and therefore fulfilling the conservation objectives set out by Natural England. However, the lower end of this reach (below Hay-on-Wye) is quite near to the target and so there is a risk to future compliance that needs addressing.

- The River Wye downstream of the confluence with the River Lugg is currently meeting the phosphate target (0.05 mg/l phosphate)

- The River Lugg section of the SAC is currently exceeding the phosphate target (0.05 mg/l phosphate) set out for the site's favourable conditions tables and is considered by Natural England to be failing its conservation objectives, and not therefore making a full contribution to achieving favourable conservation status of each of the qualifying features of the SAC.

The River Wye SAC was subject to a Review of Consents (RoC) by the Environment Agency in 2010, as required by the Habitats Regulations, which resulted in reductions in point sources of phosphate, though overall compliance with relevant phosphate targets was not achieved. To address this shortfall, it was agreed that a Nutrient Management Plan (NMP) is needed for the River Wye SAC in order to reduce current phosphate concentrations in the river to comply with conservation objectives, in line with the provisions of 64(3) of The Conservation of Habitats and Species Regulations 2010. In addition, the RoC process also highlighted that future growth must not compromise achievement of conservation targets for the SAC. The production of the NMP will thus allow Hereford Council to 'rely' on the decisions made under RoC when considering the impacts of future growth.

Growth plans within Herefordshire indicate a rise in population between 2013 and 2027 that would lead to an additional phosphate loading from the wastewater treatment operations within the catchment. Currently, further development that would increase phosphate loads to the River Wye SAC, or would lead to future failures, would not be in compliance with the Habitats Regulations.

To allow economic growth and development within the Wye catchment Valley whilst also protecting the integrity of the site, in line with the requirements of the Habitats Directive and Habitats Regulations, the Environment Agency and Natural England jointly commissioned Atkins Ltd to undertake a NMP.

In this way, the Environment Agency and Natural England are also working together to support Herefordshire Council to develop a framework for determining planning applications which are constrained by their Habitats Assessment process. The proposals will also inform Herefordshire Council's Core Strategy and other relevant development plans.

The specific aims of the NMP, as set out in the joint Environment Agency and Natural England Statement of Intent (EA, 2013) are:

- *Sections of the River Wye SAC where the phosphate levels currently exceed the favourable condition target (River Lugg) will be subject to measures to reduce phosphate levels to those which are defined as favourable for the site. The design and timing of these measures* ***should ensure that, taking these measures into account, new development within existing water discharge permits can occur without any significant adverse effect*** *on the integrity of these sections of the River Wye SAC and without compromising the achievement of the reductions in phosphate levels required as soon as possible and at the latest by 2027;*
- *Sections currently meeting the favourable condition phosphate target will be subject to measures to ensure that future inputs of phosphate will not* ***at any time lead to any adverse effect on the integrity of the River Wye SAC*** *as a consequence of currently available capacity at the permitted discharges being utilised by new development; and*
- *The plan will attempt to identify further actions which will facilitate further development within the catchment that is in line with the policies within the emerging core strategy and other strategic planning documents within the catchments of the River Wye SAC.*

In the context of the specific aims set out by the Environment Agency and Natural England, the objectives for this NMP therefore include:

- Source apportionment within the River Wye and River Lugg catchments to understand current phosphate contributions from the point and diffuse sectors, focusing on significant water company and point source discharges and on diffuse inputs from the agricultural sector;
- Assessment of the additional phosphate loads from these sectors as a result of the planned growth within Herefordshire; and
- Identification of the scale of potential phosphate reduction measures that could be required to aim to achieve compliance with the River Wye SAC targets for phosphates.

1.2. What is a Nutrient Management Plan?

An NMP is a plan that identifies the main sources of nutrients in a river catchment and sets out the potential measures that could be implemented in order to better manage these inputs to bring about the required reductions to meet the Conservation Objectives of the SAC. In the case of the River Wye SAC, the NMP is specifically focused on phosphates.

It is important to note that the purpose of the NMP is not just to address any current exceedance of phosphates targets; it is a strategic plan that sets out the likely scale of the issue over the next 25 years and the types of measures required to bring the water quality back into line with the required standards for the River Wye SAC. The NMP should therefore not be viewed as an end product to be implemented verbatim, but rather as a starting point setting out a framework for action over this time period. **It is envisaged that the plan will be reviewed and updated as the evidence base improves, as measures are implemented, as new measures become available, and as changes occur within the catchment.** As such it should be considered a “live” document.

The NMP, although produced and owned by the Environment Agency, in partnership with Natural England, is relevant to a range of partners including Local Planning Authorities and Water Companies who will need to have regard to the plan and the commitment to deliver its actions, when considering the potential effects of future development upon the River Wye SAC under the provisions of the Habitats Regulations.

The River Wye SAC NMP has been formulated in a way that is appropriate for the scale of this SAC catchment; it provides a long term framework for targeted action to reduce phosphate levels in the river by identifying measures at a spatial scale that provides the targeting of further action whilst allowing for the fluidity of catchment pressures over the lifetime of this NMP.

In this way, it identifies actions to implement in different parts of the catchment without constraining innovation in terms of new technologies and new land management measures and approaches in the future.

1.3. The nutrient management planning process

An NMP is typically divided into three parts:

- **Part 1 - Evidence and supporting information -** containing the background and evidence base for action;
- **Part 2 - Options Appraisal –** setting out the balance of options that could be implemented to achieve the required outcomes; and
- **Part 3 - the "Action Plan"**, containing the measures that will be implemented in order to help achieve favourable condition within the River Wye SAC, including action owners and timings.

This study deals with parts 1 and 2, setting out the evidence base for action and the options that could form the basis of a long term action plan. It is envisaged that this will be an iterative process, with the action plan being revisited and updated when necessary to reflect any catchment management changes or any further information that may become available.

The next step is for Natural England, the Environment Agency and Defra to consider the findings of this study and further consult with the key stakeholders within the catchment, including Herefordshire County Council, Welsh Water, land managers and land owners. These regulators and delivery partners will need to work collaboratively to agree how best to integrate the findings of this study within local catchment management initiatives in order to form and agree an action plan for implementation.

The main tasks undertaken in producing this NMP evidence base have included:

- Baseline data review;
- Catchment visit;
- Baseline water quality modelling and source apportionment;
- Stakeholder consultation;
- Scenario water quality modelling;
- Options appraisal – combining point source and agricultural measures; and
- Production of the NMP evidence base and options appraisal report (this document).

1.4. Structure of the NMP evidence base

The structure of the NMP evidence base reflects the main technical tasks undertaken as part of the investigation and is summarised in the table below. The approach taken has been to keep the main body of the report focused, making use of supporting Appendices to contain the technical detail, where appropriate.

Table 1-1: Structure of the NMP evidence base and options appraisal report

	Section	Content and use
EVIDENCE BASE & SUPPORTING INFORMATION		
1	Introduction	Introduces what NMP is, its purpose and how it has been approached
2	River Wye SAC catchment character	Brief description of the relevant features of the catchment character
3	Phosphate targets	Outline of the phosphate targets as set out by Natural England
4	Current pressures	Identification of the current pressures acting on the River Wye SAC

Section		Content and use
5	Future pressures	A brief description of some of the pressures that may be encountered in the future that could affect SAC phosphate levels
6	Existing mitigation	A description of the existing measures being implemented that can help reduce phosphate levels and some of the delivery mechanisms to consider when taking the NMP forwards
7	Source apportionment	An outline of the source apportionment model and the results of the baseline source apportionment assessment in the rivers
OPTIONS APPRAISAL		
8	Integrated modelling approach	Detailed methodology of the models used to assess phosphate and effectiveness of measures and how they have been integrated
9	Critical assumptions and uncertainty	A section outlining the key assumptions made when approaching the study and an outline of the datasets and models used and the potential areas of uncertainty
10	Population growth impacts	A description of the population growth impacts in terms of overall additional phosphate loading to the rivers
11	Measures to control agricultural sources	The results of the FARMSCOPER modelling assessment including the effectiveness of various agricultural measures scenarios
12	Combining point source measures and agricultural measures	This is the section where the point source measures and the agricultural measures are combined in various ways to meet the conservation target levels required. The results are presented and discussed in this section.
13	Conclusions and recommendations	
14	References	
	Appendix	

1.5. Iterative approach

The adopted approach for this NMP is an iterative one based on a starting point of best available data and sensible assumptions, as set out in Figure 1-2 as follows:

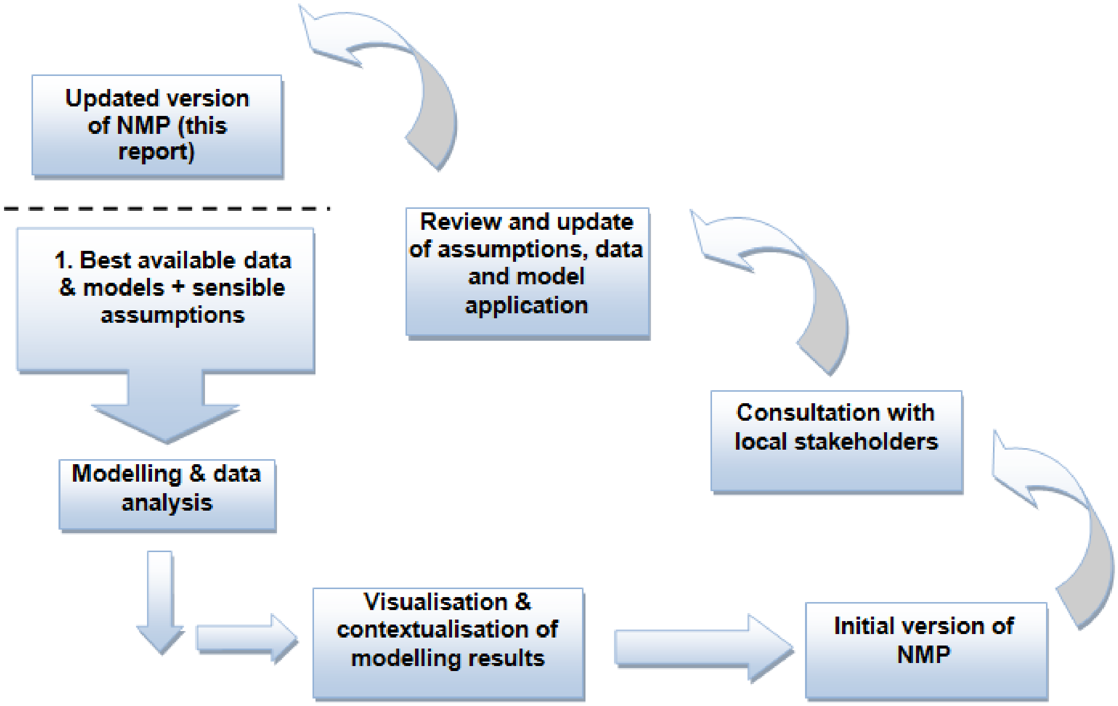

Figure 1-2: Iterative process adopted for the development of the NMP

It is envisaged that there will be further model iterations and refinements prior to identifying the final sets of measures to be implemented. This first iteration is focused on identifying combinations of measures that could be implemented to mitigate the risk of rising phosphate levels in the River Wye SAC. Future iterations will look to refine the modelling assumptions and the measures lists produced.

Factors that will be reviewed and considered throughout the iterative process include:

- Actual growth, and further information on upstream growth outside of the River Wye SAC catchment;
- Sewage treatment works technologies;
- Changes in water body sub catchments; and
- Phosphate standards.

1.6. Overview of the modelling approach

The technical assessment to underpin this NMP has been approached in several defined stages as follows:

- To understand the current situation in relation to levels of phosphate in the rivers and likely sources of phosphates, a baseline data review was undertaken. This considered data on water quality, hydrology and land use in order to characterise the SAC catchment.

- The Source Apportionment Geographical Information Systems (SAGIS) model, developed jointly by the Environment Agency and the water industry, has been used to understand the sector apportionment of phosphates within the rivers and to understand the compliance gap between current conditions and the target levels set out by Natural England. This process confirmed that the two key contributors of phosphates to the River Wye SAC are water company discharges and agricultural activities. These two contributors have subsequently been the focus of further consideration through modelling within this NMP.

- Population growth projections were used to understand the potential additional loads of wastewater to the SAC catchment as a result of population growth between 2013 and 2027, and the pattern of projected population growth was considered relative to existing wastewater treatment facilities in order to understand where the additional wastewater is likely to go and where the additional load to the river may be realised.

- These data were then also used in SAGIS to understand how the additional population could affect in-river phosphate concentrations.

Following on from this, two separate modelling assessments were undertaken:

- **Point source measures optimisation:** an optimisation exercise to model where the point source reductions may be required. Consideration has been given to which key discharging features (wastewater treatment works) may be the most appropriate works to apply “measures” (in the form of more stringent discharge consents) to.

- **Agricultural mitigation measures assessment**: Using the Defra-developed and supported FARMSCOPER model (FARM SCale Optimisation of Pollutant Emission Reductions) to assess the typical losses of phosphate from different farm types encountered within the catchment and to model the reductions in losses that could be achieved by implementing certain land management mitigation measures. It should be noted that FARMSCOPER only models certain measures contained within the diffuse pollution mitigation manual (ADAS et al., 2011) and hence does not take account of all agricultural diffuse measures that exist, It is however a good starting point to understand the scale of improvements that could be made by action within the agricultural sector. This approach will be further refined through future iterations of the NMP.

Following on from this, a combinations assessment has been undertaken to understand how various combinations of measures applied on key consented discharges and in the agricultural sector could help achieve the compliance targets set by Natural England.

Stakeholder engagement was undertaken half way through the project to inform stakeholders and gather input prior to the combinations assessment and options appraisal processes.

A high level overview of how the NMP has been undertaken has been provided in Figure 1-3 that follows and further information on the modelling methodologies is given in Section 7.

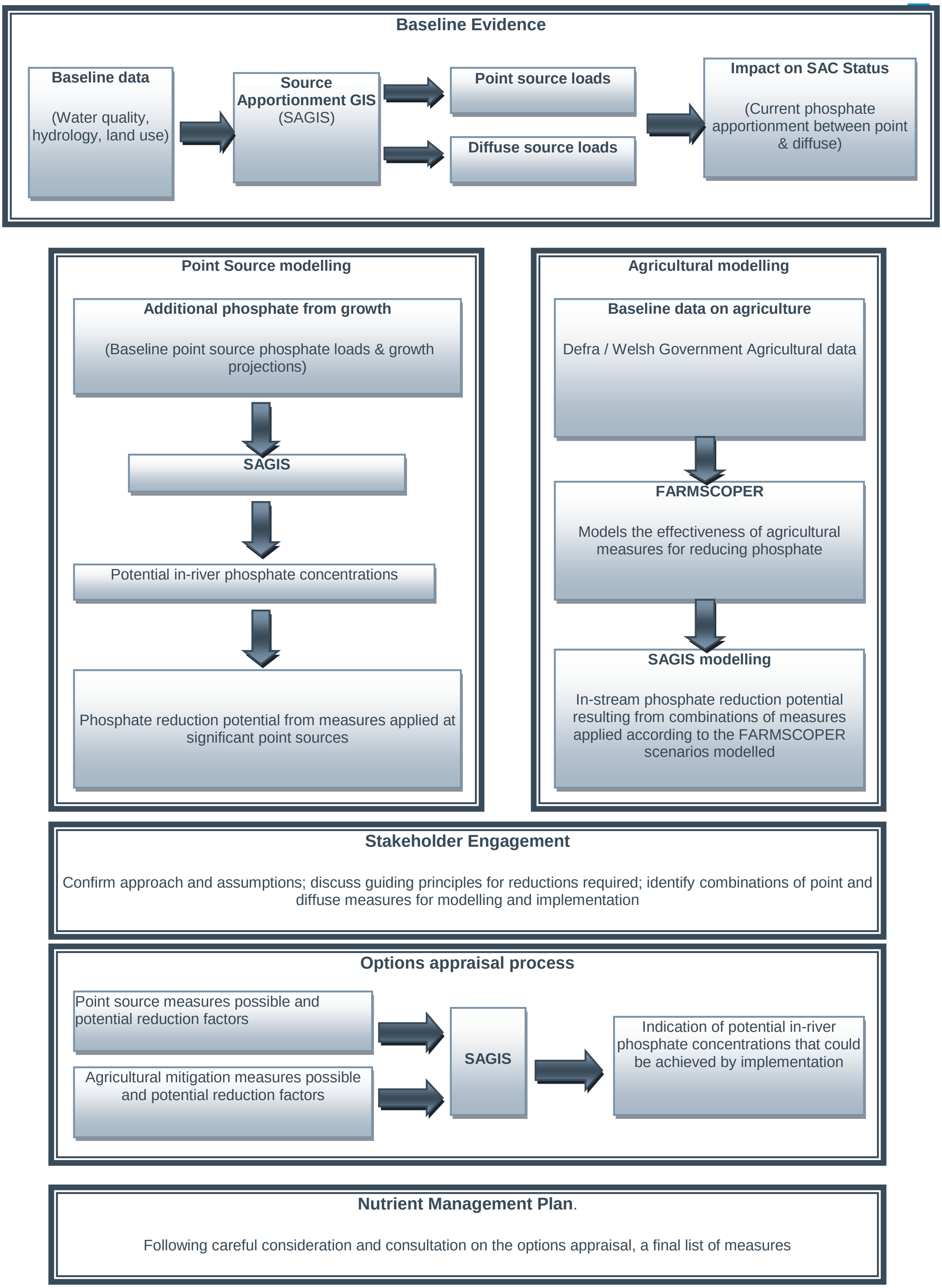

Figure 1-3: Overview of the approach taken on the River Wye SAC NMP evidence base

1.7. Drivers & alignment with other programmes & objectives

1.7.1. Habitats Directive

The River Wye and parts of the River Lugg are designated as an SAC under the European Community (EC) Habitats Directive (Council Directive 92/43/EEC on the conservation of natural habitats and of wild flora and fauna, adopted May 21st 1992). This means that there is a legal requirement to maintain or restore protected habitats and species at “Favourable Conservation Status” and therefore to avoid deterioration or disturbance of the qualifying natural habitats and species for which the site is designated.

Furthermore, there is a requirement to ensure that the integrity of the site is maintained and to ensure that the site makes a full contribution to achieving “Favourable Conservation Status” of each of the qualifying features. Regulation 61 of The Conservation of Habitats and Species Regulations 2010 sets out provisions to ensure that this requirement is met in the context of new plans and projects.

Natural England, as the Competent Authority for EC Habitats Directive sites, has set the phosphate targets required in order to support favourable condition and therefore the primary driver for the NMP is to define the measures that could be implemented to achieve these targets by 2027.

Any plans for development within the catchment that has the potential to affect the achievement of these phosphate targets needs to be fully investigated and, where required, mitigated before the development is permitted. This approach applies to the proposed growth strategies both within the River Wye SAC catchment and also to areas outside of the immediate catchment, elsewhere where there may be impacts from upstream contributing sources.

1.7.2. Water Framework Directive

The River Wye catchment and its water bodies are also protected under the EC Water Framework Directive (WFD). The Severn River Basin District Management Plan (RBMP) separates out the River Wye catchment and sets forth the following aspirations:

“There are 136 river water bodies and 8 lakes in the catchment. 35 per cent of rivers currently achieve good ecological status. 45 per cent of rivers assessed for biology are at least good biological status now. Local actions will address the key pressures in the catchment, 23 percent of surface waters in the Wye Catchment will improve for at least one ecological element of good status. As a result of these improvements there will be an increase of 8 per cent of river and lake water bodies achieving good ecological status by 2015, to 43 per cent.”

Any plans or programmes being implemented within the catchment, such as the NMP, need to be aligned to the objectives and measures set for the WFD water bodies within the River Wye catchment.

Furthermore, the River Wye is also designated as a WFD Protected Area for multiple reasons: it has been deemed a Water Dependent SAC and therefore is designated as a WFD Natura 2000 Protected Area; it is designated as a Drinking Water Protected Area; parts of it are designated as a Nutrient Sensitive Area; and it is also designated as a WFD Protected Area for its Economically Significant Species (previously Freshwater Fish Directive rivers).

The objective for Natura 2000 Protected Areas identified in relation to relevant areas designated under the Habitats Directive is to *“protect and, where necessary, improve the status of the water environment to the extent necessary to achieve the conservation objectives that have been established for the protection or improvement of the site’s natural habitat types and species of Community importance in order to ensure the site contributes to the maintenance of, or restoration to, favourable conservation status*”.

As a Drinking Water Protected Area, there is a further objective to “*avoid deterioration in water quality in order to reduce the level of purification treatment required in producing drinking water*”. This objective is achieved by putting actions in place to protect water quality of raw drinking water sources.

As an Economically Significant Species Protected Area, the objective is to protect or improve the water quality in order to support indigenous or notable species of freshwater fish.

Parts of the River Wye are also designated as a Nutrient Sensitive Area (due to the designation of large parts of the catchment under Nitrate Vulnerable Zone Regulations) Protected Area. The general objectives for these designations are to reduce water pollution caused or induced by nitrates from agricultural sources and to prevent further such pollution and to protect the environment from the adverse effects of urban wastewater discharges.

Therefore, although the primary driver for the NMP is the SAC designation under the Habitats Directive, it is clear to see that the NMP, and the point source and diffuse source measures contained herein, can contribute towards achieving the objectives of other WFD designations.

1.7.3. Growth and economic development

In order to meet the requirements of the Habitats Directive and the Water Framework Directive whilst supporting growth and economic development within Herefordshire, the Environment Agency, Natural England and Herefordshire Council are committed to the development and implementation of this NMP to manage the phosphate concentrations within the SAC to levels such that growth can proceed whilst restoring favourable conservation status with respect to phosphate between 2013 and 2027. The growth plans provided by Herefordshire County Council are contained within Appendix A.

The impacts of growth, both within Herefordshire and also upstream in Powys, has been considered through this plan.

1.8. Who is this plan for?

1.8.1. National regulatory stakeholders

The Environment Agency, as the environmental regulator, has led the delivery of this NMP in partnership with Natural England as the Competent Authority responsible for the conservation and enhancement of the SAC.

Herefordshire County Council is responsible for the county growth strategy and for complying with Habitats Directive Regulations in implementing its strategy.

1.8.2. Local stakeholders and delivery partners

There are a number of local stakeholders that are key to the future delivery of this NMP.

The Herefordshire Nutrient Management Group comprises a number of organisations working amongst the farming industry, with the key players of relevance to this Plan including the Bulmer Foundation, the Herefordshire Rural Hub, the Wye and Usk Foundation, the National Farmers Union and the Country Land and Business Association. Alongside these key stakeholders, there are a number of additional groups represented on this group such as the England Catchment Sensitive Farming Delivery Initiative, the Duchy Estates, Herefordshire College of Technology and Balfour Beatty.

The Bulmer Foundation is a charitable organisation focused in part on land use, food and education. This group is particularly influential within the region as the founding member of the Herefordshire Local Nature Partnership and Herefordshire Food Partnership and is closely linked with local farming and water related initiatives.

The Herefordshire Rural Hub is the Defra- accredited Rural Farming Network for this area and as such has good communication links with the farming and rural community, being responsible for communications via newsletters and e-news to a wide range of farmers within the catchment.

The Wye and Usk Foundation is the main "Rivers Trust" organisation within Herefordshire. As a registered charity its main undertaking is to conserve and enhance rivers for fishing, with a portfolio of projects that include works to reduce diffuse pollution from agricultural sources. This particular initiative, entitled the Wye Habitat Improvement Project (WHIP), was funded through the Defra Catchment Restoration Fund with a brief to undertake 400 farm visits and produce 320 whole-farm action plans setting out good practice and measures to reduce diffuse pollution to the rivers.

The National Farmers Union (NFU) represents the farming community and has local representatives across the country, including water pollution specialists, to communicate messages between the farming industry, the regulators and Defra. Similarly, the Country Land and Business Association (CLA) is a large membership organisation representing key land owners and land managers across the country.

A high level stakeholder map outlining the key national, regional and local stakeholders involved in both the delivery and implementation of the NMP is outlined in Figure 1-4 below.

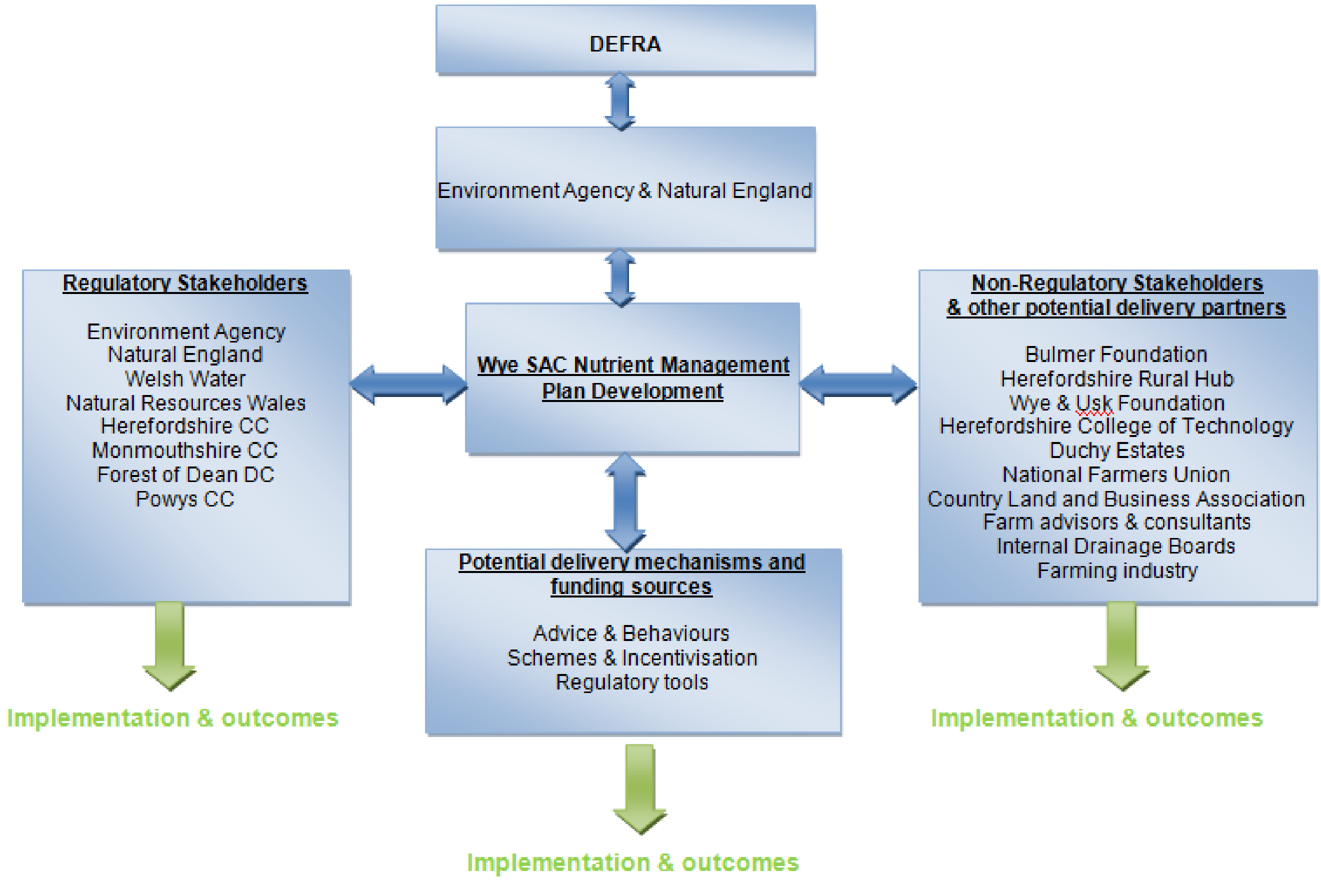

Figure 1-4: Key stakeholders and delivery partners for the River Wye SAC NMP

1.9. Existing plans & programmes

A number of national, regional and local improvement initiatives and projects are already underway within the River Wye SAC catchment. The NMP has the potential to complement many of these plans and programmes and as such its implementation should proceed with the objectives in mind to secure mutual and multiple benefits where possible. Some of the main projects are summarised in Figure 1-5 below.

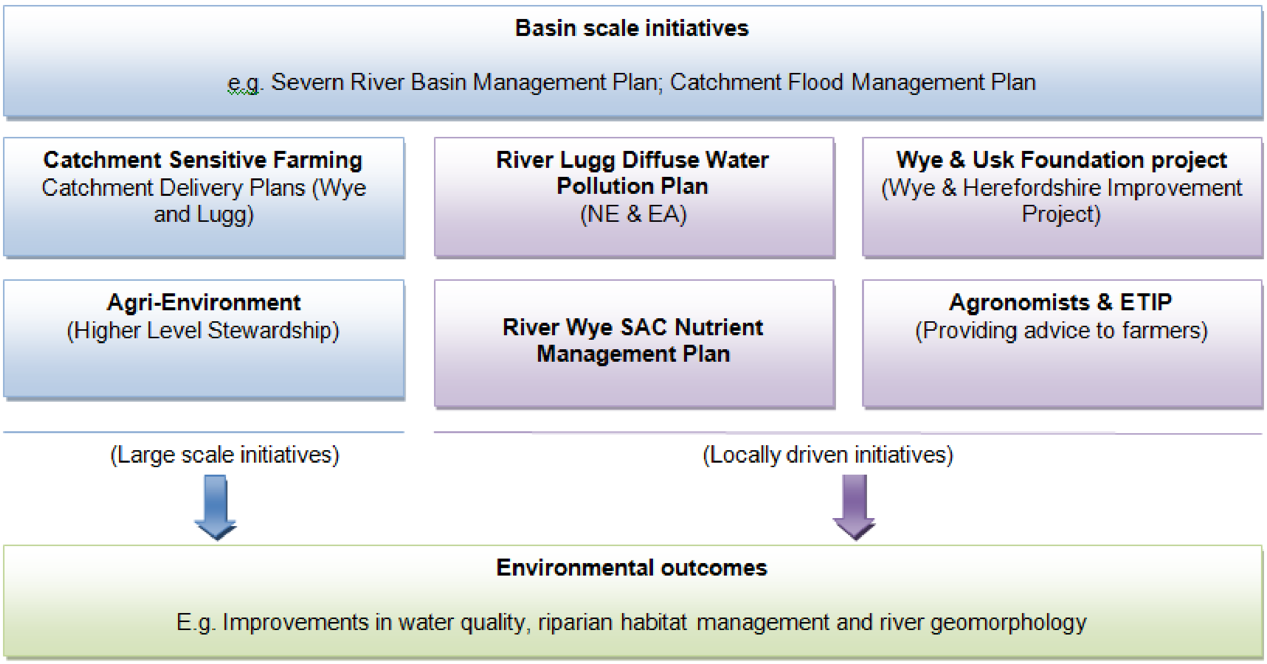

Figure 1-5: National, local and regional plans and programmes for nutrient management.

Evidence and supporting information

2. The River Wye SAC catchment character

2.1. Geography and hydrology

The River Wye SAC comprises both the River Wye and parts of the River Lugg. For the purposes of this study, the River Wye SAC has been sub divided into three distinct regions:

- The **Upper River Wye** - from source to the confluence with the River Lugg, just downstream of Hereford;
- the **Lower River Wye -** from the confluence with the River Lugg to the Severn Estuary; and
- the **River Lugg** – from source to its confluence with the River Wye just south of Hereford.

(These sections are shown conceptually in Figure 1-1).

The source of the River Wye is located within the Welsh mountains at Plynlimon, after which the river flows through the Welsh towns of Rhayader and Builth Wells, where it is joined by the main tributary of the River Irfon, before crossing the border with England at Hay-on-Wye. The Afon Llynfi is a tributary of the River Wye, flowing from its source in the Black Mountains and through Llangorse Lake prior to joining the River Wye, and also comprises part of the SAC.

The English section of the upper River Wye then continues through Hereford, where it is joined by the main tributary of the River Lugg, approximately 10 miles downstream of the city. This confluence marks the end point of the Upper River Wye study area.

The River Lugg rises above ground at its source in Powys, flows approximately 45 miles through Powys and Herefordshire, through the main town of Leominster just south of which it is joined by the River Arrow tributary before then joining with the River Wye just south of Hereford.

The lower River Wye comprises the section of river from the confluence of the upper River Wye and River Lugg and flows south through the main towns of Ross-on-Wye, Monmouth and Chepstow where it meets the Severn Estuary, approximately 135 miles from the upper River Wye source in Wales.

These areas are set out in Figure 2-1 below.

The River Wye is regarded by many as one of the most diverse river systems in the UK, with a transition from hard geology, high gradients, rapid flow fluctuations and low nutrient-content in its upper reaches, to a more nutrient-rich river with lower gradient, more stable flow and softer geology in the lowlands. A geological map of the catchment is given in Appendix B.

The key areas of concern with regard to riverine phosphate levels, based on current concentrations and likely future pressures, are the areas upstream of the confluence of the River Wye and River Lugg. The assessment points for compliance with Natural England’s phosphate targets are located immediately upstream of the confluence, for both the River Wye and the River Lugg. Therefore the focus of this study has been on the reaches upstream of the confluence only (the River Lugg and the upper River Wye). The evidence indicates that compliance with target phosphate levels at these locations will result in suitable levels of phosphate downstream in the lower River Wye.

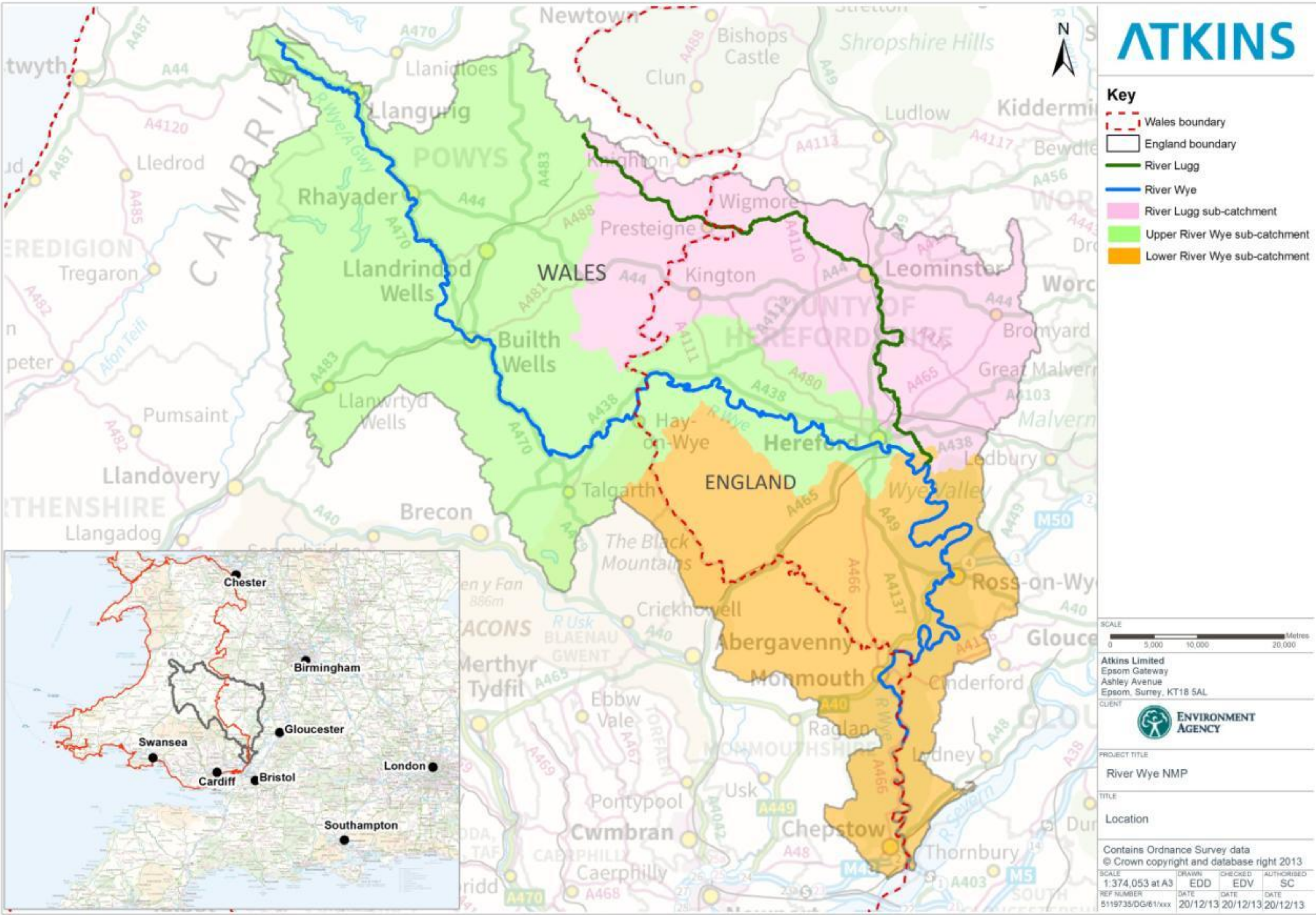

Figure 2-1: River Wye catchment – overview map

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2.2. Soils and erosion risk

In order to understand the risk of soil erosion within the upper River Wye and River Lugg catchments, a high level risk assessment has been undertaken using the Atkins Soil Erosion Risk Assessment tool, which is a risk assessment methodology to quickly classify the risk of erosion from land based on a number of factors.

This method is based on the concept that certain factors, identified in the Environment Agency's 'think soils' handbook (http://www.environment-agency.gov.uk/business/sectors/soils.aspx), influence the severity of erosion and runoff.

This risk is split into two principal risk factors:

- 'Risks which come with the land' (soil texture, rainfall and slope angle); and
- 'Risks arising from land management decisions' (proximity to water course and roads, land use and land management).

The outputs of this quick review are presented in Appendix C for context. However the main points to note are as follows:

- The upper River Wye is generally characterised by steeper slopes and higher rainfall. Land use is mixed agricultural and forestry, with an increased emphasis on agriculture heading down the catchment towards the confluence with the River Lugg. Soils are predominantly loamy.

- The River Lugg catchment is slightly different from the upper River Wye catchment, with both slope and rainfall being lower than the River Wye, and decreasing rainfall across the catchment from west to east. There is much less forestry /semi-natural land use within the River Lugg catchment and agriculture dominates. Soil types are consistent with the River Wye; consistently loamy.

- The upper River Wye and the River Lugg are both deemed "medium risk" from its loamy soil type, with greater erosion risk in the upper catchment due to the increased slope and rainfall intensity. However, the upper River Wye catchment has less agricultural land use than the lower River Wye and River Lugg and therefore has lower risk of soil erosion.

2.3. Agriculture within the River Wye SAC

As the focus of this NMP is on the upper River Wye sub catchment and the River Lugg sub-catchment, the focus of the agricultural data assessment has been on these two sub catchments **– i.e. the catchment area upstream of the confluence of the River Wye and the River Lugg.**

This assessment indicates that the upper River Wye and the River Lugg sub-catchments can be divided up rather simplistically into two main areas, with the north and west of the overall catchment (a large proportion of which is in Wales) being dominated by livestock farming and the south and east of the catchment being dominated by intensive arable farming (mostly in England).

Within the arable and livestock categories there are further differences, firstly **within the arable sector**:

- The arable activities within the Welsh part of the upper River Wye sub-catchment are dominated by mixed arable farm type, with a smaller portion of arable farms growing roots and a very small portion of horticulture.
- The English part of the upper River Wye sub catchment and the River Lugg sub catchments are reasonably similar in terms of arable farming types, with a large percentage of farms falling into the roots category and smaller, more equal portions being for horticulture and mixed farm types.

These differences are shown in Figure 2-2 and Figure 2-4 below. Numbers given are percentages of total arable farms within the relevant catchment falling within that particular farm type. Total numbers of farms from which the percentages are calculated are also given in Appendix E. The data are subdivided into the English and Welsh portions of the catchment because the data is different from each country and cannot be lumped together.

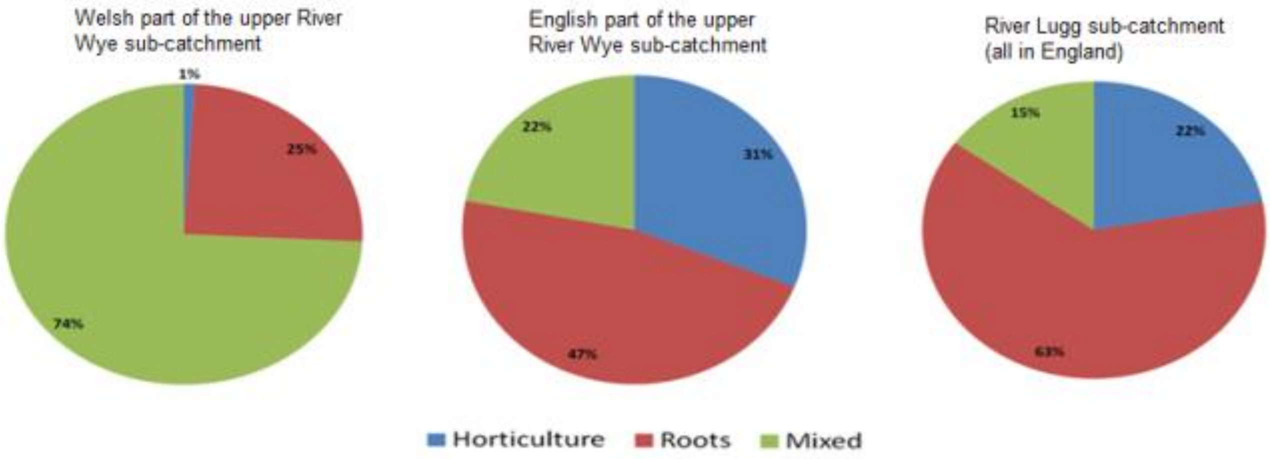

Figure 2-2: Arable farming types in the upper River Wye and River Lugg sub-catchments

(Data is based on 2010 Defra Agricultural Census data and 2010Welsh Government Small Areas data.)

Similarly for the **livestock sector**:

- Within the Welsh part of the upper River Wye sub-catchment, 100% of livestock farms are considered to be upland grazing. Compare this with the English part of the lower River Wye sub-catchment where just 13% of livestock farms are upland grazing and 87% of livestock farms lowland grazing. This feature reflects the slope of the land.
- Within the River Lugg catchment**,** 17% of livestock farms operate upland grazing and 83% lowland grazing.

These differences are shown in Figure 2-3 below. Percentages given are percentages of livestock farms within the sub-catchment falling within the farm type categories.

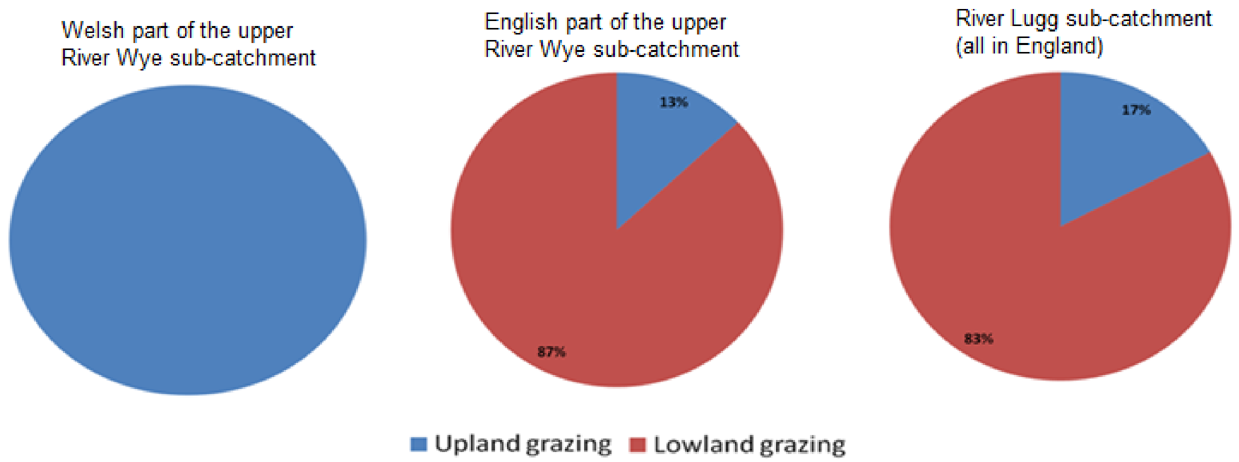

Figure 2-3: Livestock farming types in the upper River Wye and River Lugg sub-catchments

(Data is based on 2010 Defra Agricultural Census data and 2010 Welsh Government Small Areas data.)

The agricultural sector is thought to be a potentially significant contributor of phosphate to the water environment in the River Wye SAC catchment. Phosphate losses from land to water are heavily dependent on the type of farming, the farm specific management practices and individual field position, slope and soil type. As such the contributions of phosphates to water are not evenly spread amongst the catchment. However, for the purposes of this study, phosphate losses for different farm types have been characterised by using a different model to represent each farm type.

The outputs of the farm modelling undertaken in this study will be used to develop an action plan through engagement with individual farm types and farms to further refine the measures required at a finer spatial scale, such as individual field. It is envisaged that this action plan will be delivered through engagement with the Catchment Based Approach.

A more detailed description of the farm type breakdown and how it has been used is given in Appendix E.

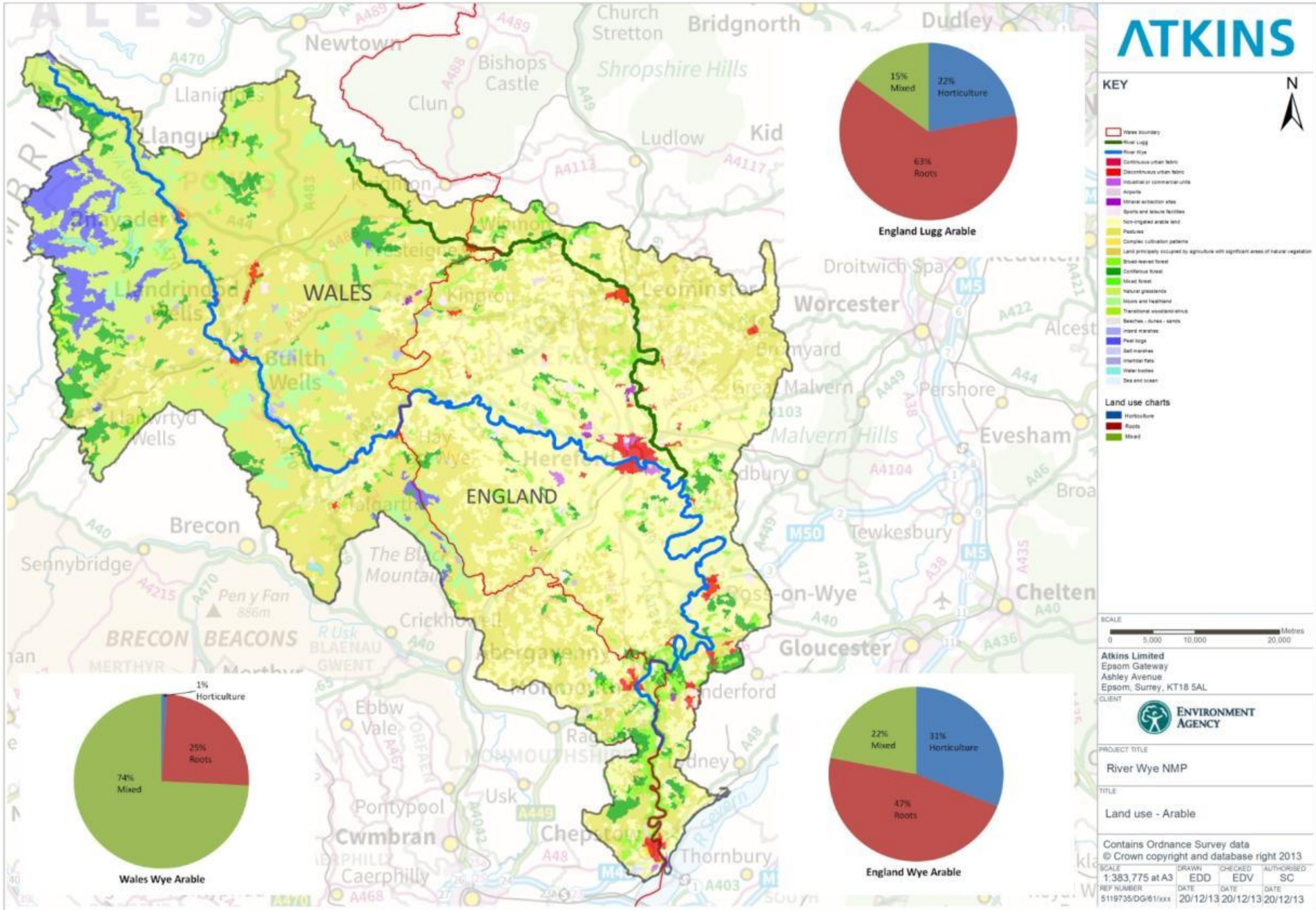

Figure 2-4: River Wye catchment land use and predominant agricultural types

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2.4. Recreational use

The River Wye SAC is notable for its salmon and brown trout fisheries, as well as coarse fishing. The River Wye historically is the most famous salmon fishing river in Wales and the salmon population is still of considerable importance in the UK terms with the river system providing high quality spawning grounds and juvenile habitat. Elvers are also fished downstream within the tidal reaches.

The River Wye and the River Lugg are also popular for other recreational activities such as recreational boating, with several commercial outfits making use of the public right of navigation downstream of Hay-on-Wye.

The river valley and surrounding countryside is also visited by walkers using the Wye Valley Walk, and much of the Lower Wye Valley is designated as an Area of Outstanding Natural Beauty (AONB), attracting tourists.

The river is therefore an important part of not only the local economy but also people's lives.

2.5. Conservation and ecology

As mentioned in Section 1.7, in conservation terms, the River Wye and the lower part of the River Lugg are designated under the EC Habitats Directive as an SAC, with the site covering an area of approximately 2235 hectares spanning the counties of Monmouthshire, Powys, Gloucestershire and Herefordshire. The SAC drains a large catchment with some significant tributaries, such as the Rivers Lugg, Elan, Irfon, Lynfi and Monnow. The River Wye SAC is therefore one of the most important rivers in the UK for nature conservation, supporting a range of habitats and species protected under the EC Habitats Directive. The Natural England citation for the River Wye SAC includes:

> *"a geologically mixed catchment, including shales and sandstones, and there is a clear transition between the upland reaches, with characteristic bryophyte-dominated vegetation, and the lower reaches, with extensive Ranunculus beds. There is a varied water-crowfoot Ranunculus flora; stream water-crowfoot R. penicillatus ssp. pseudofluitans is abundant, with other Ranunculus species – including the uncommon river water-crowfoot R. fluitans – found locally. Other species characteristic of sub-type 2 include flowering-rush Butomus umbellatus, lesser water-parsnip Berula erecta and curled pondweed Potamogeton crispus. There is an exceptional range of aquatic flora in the catchment including river jelly-lichen Collema dichotum. The river channel is largely unmodified and includes some excellent gorges, as well as significant areas of associated woodland."*[1]

The primary (habitat) reason for its designation as an River Wye SAC is given by Natural England as providing *"water courses of plain to montane levels with the Ranunculion fluitantis and Callitricho-Batrachion vegetation".*

The primary (species) reasons for designation are for the white-clawed (or Atlantic stream) crayfish (*Austropotamobius pallipes*), the brook lamprey (*Lampeta planeri*), the river lamprey (*Lampetra fluviatilis*), the thwaite shad (*Alosa fallax*), the Atlantic salmon *(Salmo salar*), bullhead (*Cottus gobio*) and the otter (*Lutra lutra*).

[1] http://jncc.defra.gov.uk/protectedsites/sacselection/sac.asp?EUCode=UK0012642

3. Phosphate targets

As discussed in section 1.7.2, the primary driver for the River Wye SAC NMP is to achieve the Habitats Directive conservation target levels for phosphate and, although this will facilitate the objectives of other drivers (including the Water Framework Directive) the Habitats Directive target has been considered the primary driver and focus for this study.

3.1. Favourable condition targets for the River Wye SAC

The conservation objectives set by Natural England for the River Wye SAC include targets for in-river water column phosphate concentrations. These have been developed to protect the animal and plant communities within the river from the adverse effects of nutrient enrichment, and are based on a critical, national review of the evidence base (Mainstone, 2011). This work is set out within Natural England Research Report 034: *An evidence base for setting nutrient targets to protect river habitat* which can be accessed on-line at http://publications.naturalengland.org.uk/category/7005. If concentrations exceed these targets there is a significant risk that undesirable changes will occur with associated negative effects on the interest features of the River Wye SAC.

The specific River Wye SAC phosphate targets have been determined on the basis of the underlying geology and flow categories, assessed across the different reaches of the river and the associated catchments. Local staff in Natural England (then English Nature) and the Environment Agency agreed the key geology and flow category types as part of the Environment Agency RoC process. Whilst the Environment Agency RoC process actually used the UK Technical Advisory Group (UKTAG) agreed phosphate targets as a result of more recent evidence gathering and analysis (e.g. Mainstone, 2010) there is now agreement that the phosphate targets currently set out in the conservation objectives for the River Wye SAC should be used for the long term management of the site (e.g. in the evaluation of the ecological risks associated with housing growth).

The phosphate targets (to be expressed as annual averages) that have been set by Natural England to protect the River Wye SAC are as follows:

- **River Wye from English/Welsh boundary to the River Lugg confluence - 0.03mg/l soluble reactive phosphorus (SRP)**
  (I.e. the standard to achieve in the River Wye immediately upstream of the confluence with the River Lugg is 0.03mg/l SRP)
- **River Wye from the Lugg confluence downstream – 0.05mg/l SRP**
  (I.e. the standard to achieve in the River Wye downstream of the confluence with the River Lugg is 0.05mg/l SRP)
- **River Lugg (from Leominster to Wye confluence) – 0.05mg/l SRP**
  (I.e. the standard to achieve in the River Lugg immediately upstream of the confluence with the River Wye is 0.05mg/l SRP.)

A target of 0.03mg/l SRP has also been set for the River Lugg upstream of Leominster, which is designated as a SSSI, although it is not part of the SAC.

3.2. Current compliance with targets

The River Wye SAC currently includes reaches where the levels of phosphate exceed the target level currently set by Natural England in the conservation objectives for the designated site.

- The upper River Wye upstream of Hay-on-Wye is currently meeting its conservation target and is not considered to be at risk from the current permitted discharges. The River Wye (between Hay-on-Wye and the River Lugg confluence) is currently meeting the phosphate target and therefore fulfilling the conservation objectives set out by Natural England. However, it is nearing the target and so there is a risk to future compliance that needs addressing.
- The River Lugg section of the SAC is currently exceeding the phosphate target set out for the site's favourable conditions tables and is considered by Natural England to be failing its conservation objectives, and not therefore making a full contribution to achieving favourable conservation status of each of the qualifying features of the SAC.

The degree of current compliance with phosphate targets has been assessed as part of this study and is shown in Section 12. Two key assessment points have been used in this study:

- The upper River Wye immediately upstream of the confluence with the River Lugg; and
- The River Lugg immediately upstream of the confluence with the River Wye.

The lower River Wye, downstream of the point of confluence, has not been assessed separately as the assumption is that if the targets are achievable upstream of the confluence, then the targets downstream would also be achieved, based on current growth projections.

3.3. Current phosphate trends in the River Wye SAC

Water quality monitoring data from two locations in the River Wye and one location on the River Lugg are set out below.

The Carrots Pool monitoring point (Figure 3-1) and the Holme Lacy Bridge monitoring point (Figure 3-2) are both located on the River Wye just downstream of Hereford, with Carrots Pool located upstream of the confluence with the Lugg and Holme Lacy Bridge downstream of the confluence; the pattern of data is similar at both monitoring points. The orthophosphate monitoring data from the River Lugg at Mordiford Bridge also suggests a similar falling trend over the same timeframes, again suggesting the phosphate levels overall are also gradually falling within both the upper River Wye sub-catchment and the Lugg sub-catchment. Although it is not possible to specify the exact causes of the fall in orthophosphate levels within the rivers, it could in part be due to a combination of improvements in water company treatment processes as well as improvements in land management practices, for example relating to agriculture and action over the years with NVZs, catchment sensitive farming, and AONB advisory projects. The environmental outcomes of some improvement measures are seen sooner than others, for example the effect of controls on wastewater discharges are typically seen sooner than with for example agricultural land management measures which are followed by a considerable time lag before benefits can be directly attributed to the action.

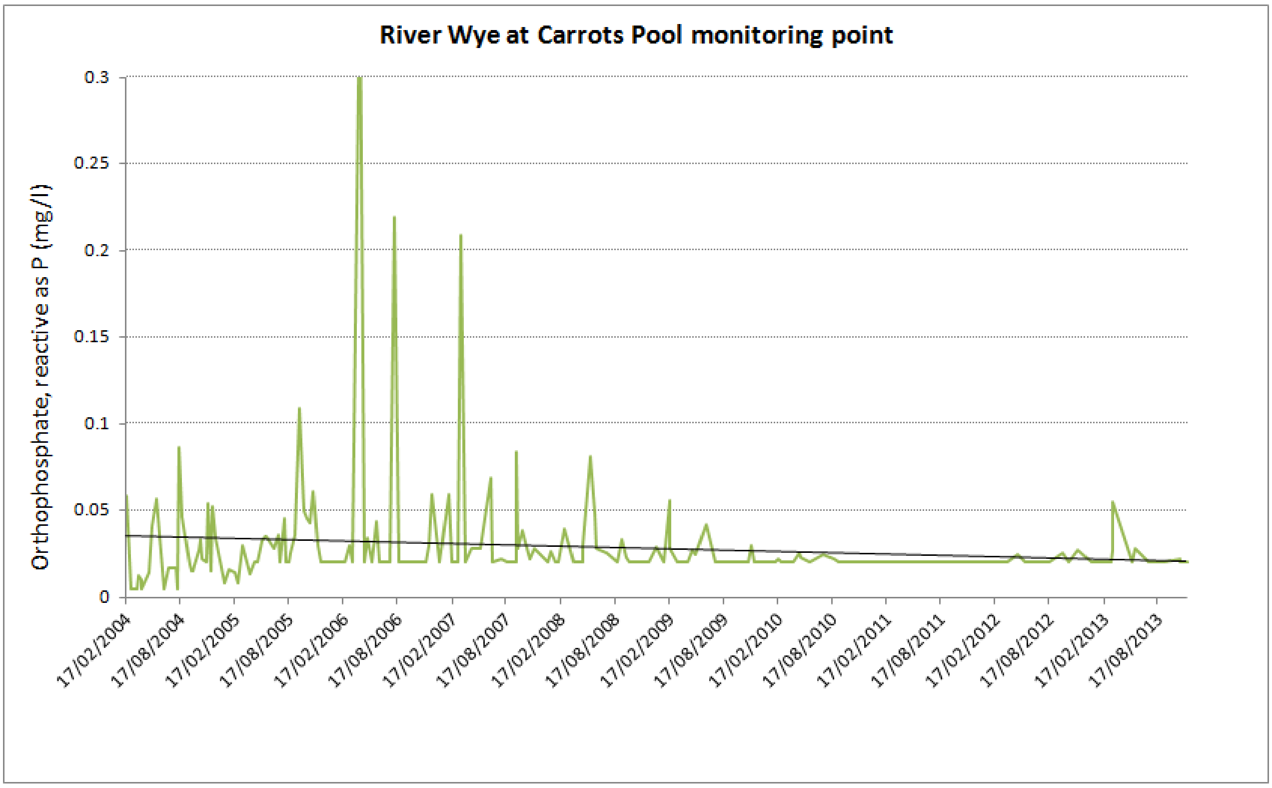

Figure 3-1: Orthophosphate monitoring data (2004-2013) - River Wye at Carrots Pool

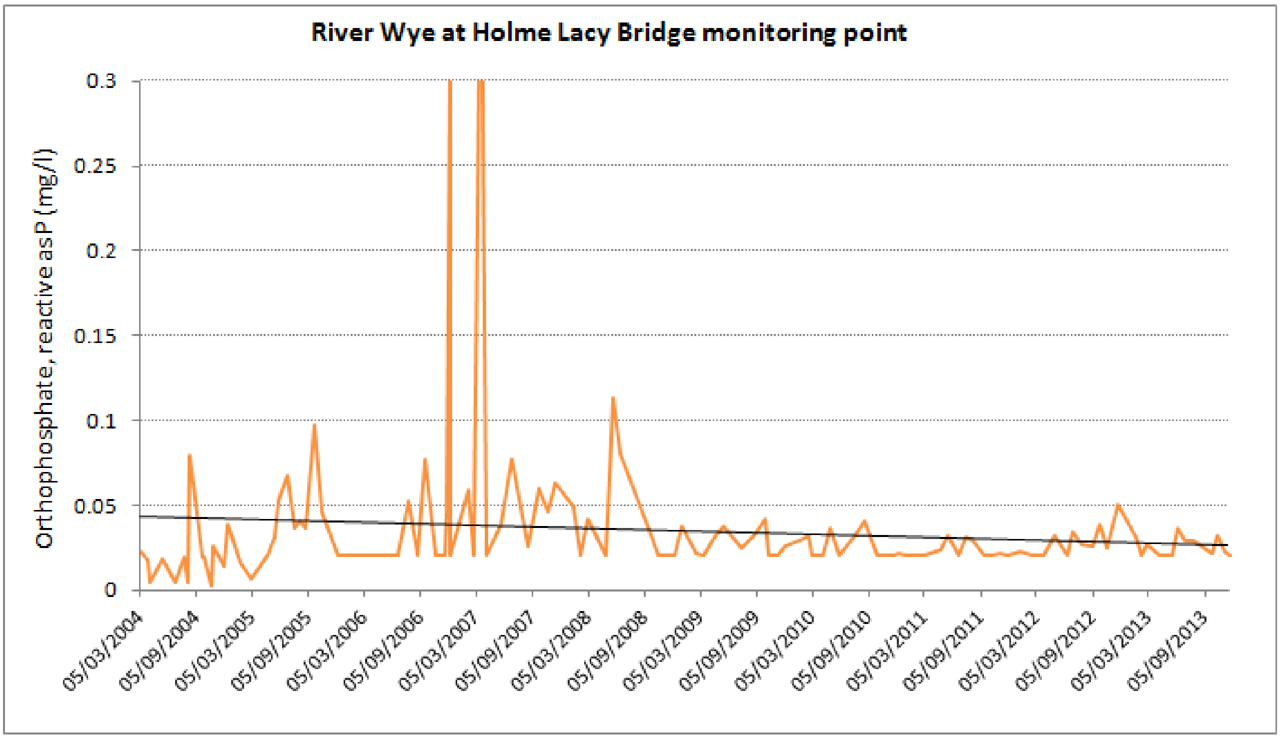

Figure 3-2: Orthophosphate monitoring data (2004-2013) - River Wye at Holme Lacy Bridge

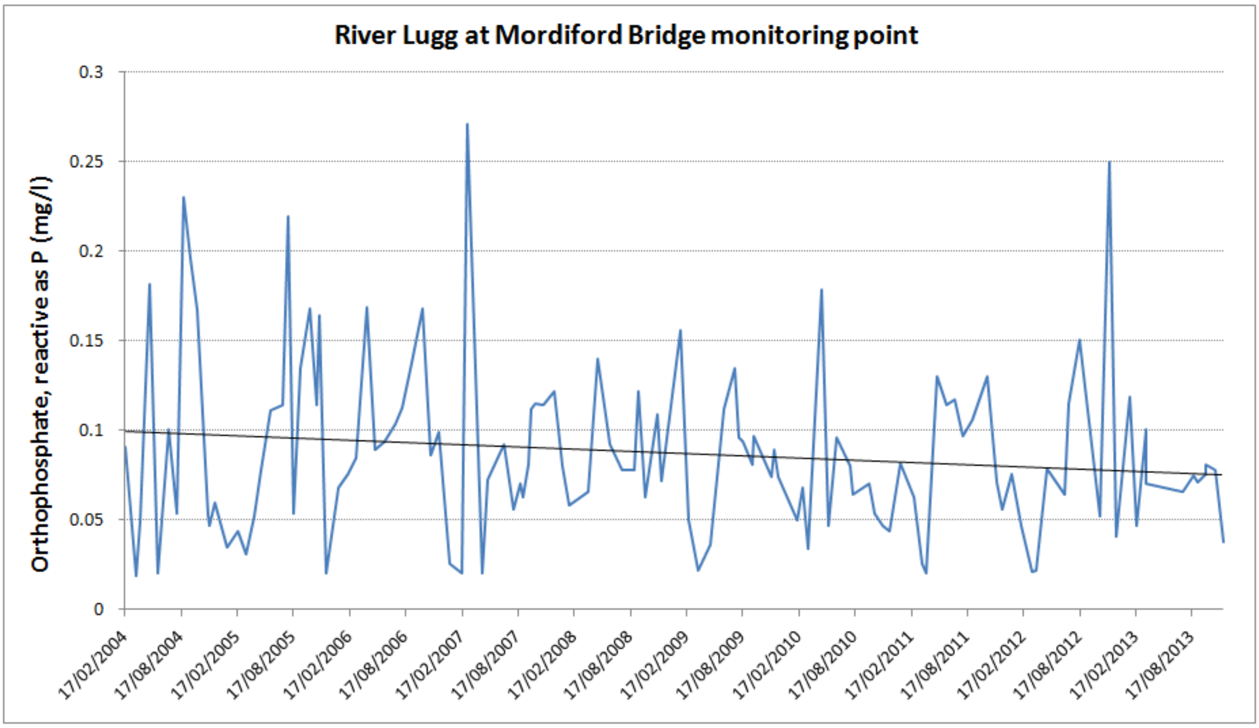

Figure 3-3: Orthophosphate monitoring data (2004-2013) - River Lugg at Mordiford Bridge

4. Current pressures & sources of phosphate

The main issue of concern regarding phosphate levels in rivers is freshwater eutrophication and the subsequent impacts not only on wildlife and conservation, but also on drinking water abstraction and treatment and recreation. The main source of phosphates to rivers nationally is thought to be from sewage effluent (estimated between 60% and 80% of the total phosphate in rivers in England and 48% in Wales) (Environment Agency, 2013).

In the context of this study, it is thought that point source discharges, such as industrial and wastewater treatment works (WwTW) discharges are responsible for a large portion of the phosphate loading to the rivers. The main diffuse source of phosphate is thought to be from agricultural sources via land run off.

Although generally considered to be secondary next to wastewater discharges and agricultural sources, other contributors of phosphates within the catchment include: misconnections; urban drainage; leaking sewers; combined sewer overflows; septic tanks and soak away; and small package plants. These secondary sources have also been considered through the source apportionment modelling in order to understand their contributions to the overall phosphate loading within the SAC.

This study has considered the sources of phosphate in the context of growth and the likelihood of sources having the most significant phosphate loadings within the River Wye SAC.

4.1. Wastewater capacity and quality

Point source pressures are easily identified and managed as they occur at a clearly identified point within the river system. Discharges thought to be of “significance”, either in terms of their volume or polluting loads are controlled by a system of Discharge Consents, issued to the discharger by the Environment Agency, which require the discharger to meet certain standards.

In 2010 the Environment Agency and Natural England undertook a review of all the permitted consents within SACs across the country (the Review of Consents process) in order to identify those consents having an impact on SACs. Through this process, existing consents were identified for review and modification depending on their licence conditions, thus enabling a legislative framework for controlling point source pressures in SACs.

Best Available Technology (BAT) has previously been considered when setting the phosphate target for discharge consents within the River Wye catchment, although not all WwTWs will contain BAT.

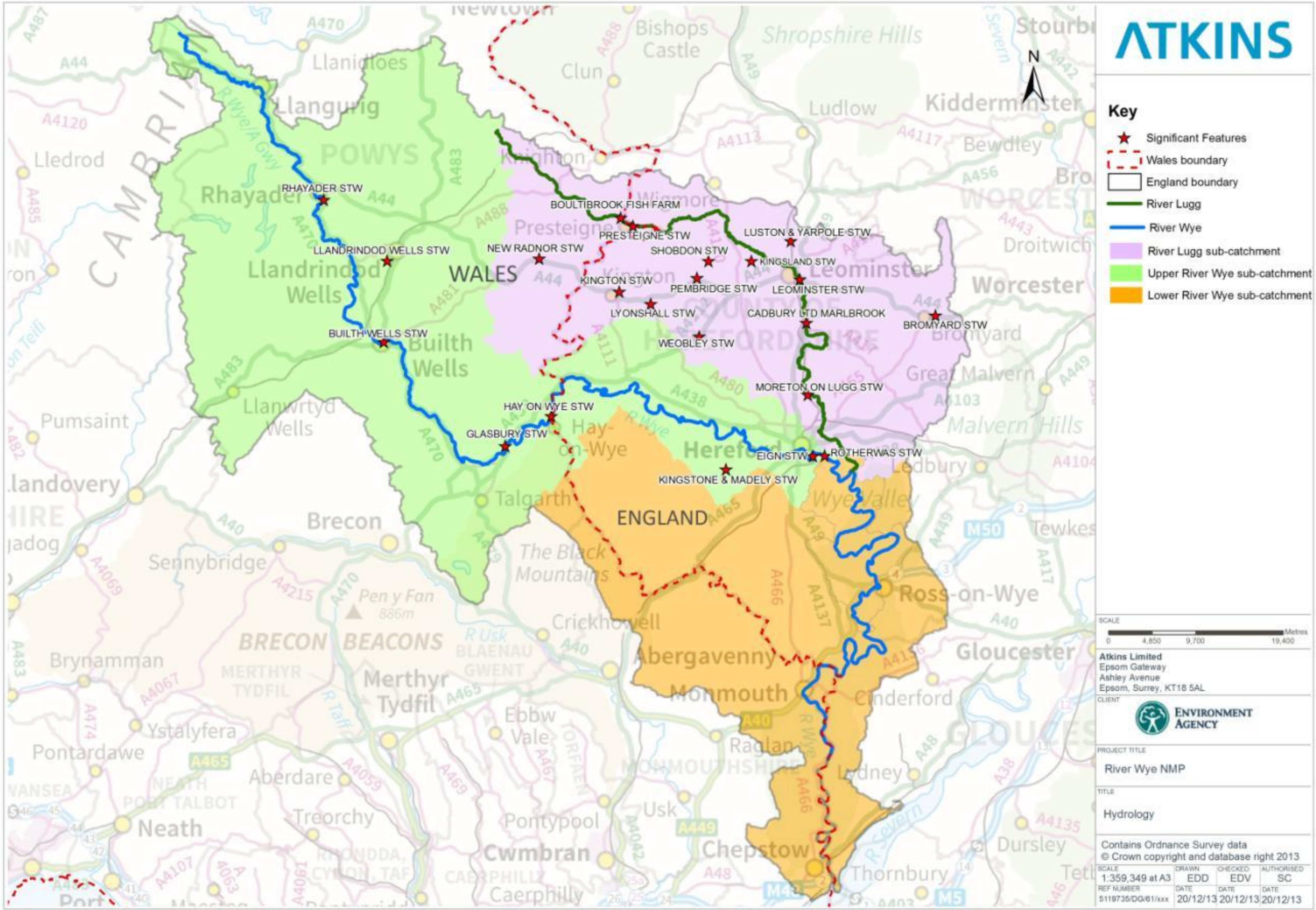

Figure 4-1: River Wye NMP catchment hydrology and key point source discharges selected for this study

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4.1.1. Septic tanks & small package treatment plants

In rural areas, a higher number of properties are not connected to the mains sewerage system and are instead reliant upon septic tanks or small package treatment plants to manage their wastewater.

Septic tanks are a chamber system that retains sewage for settling, allowing the solids to separate from the liquid portion. The liquid is then drained off to a soakaway and allowed to soak through the ground where pollutants are removed prior to the water infiltrating to a watercourse or groundwater. In order to ensure that septic tanks are not a risk to water quality they need to be sited a minimum distance from a well or a waterway and sufficiently above the water table. Appropriate management of septic tanks is also required (for example de-sludging) though the optimum management to minimise the loss of phosphate to the environment is still under investigation.

Small package treatment plants are slightly different to septic tanks in that they are essentially smaller versions of municipal sewage treatment works, treating the sewage on-site through techniques, such as air filtration, prior to discharge, rather than relying on a soakaway system.

These have been collectively termed “on-site wastewater treatment systems” (OSWwTS) within this study.

Although the risk from these sources is not thought to be at a level comparable to wastewater discharges and agricultural pollution, the potential risk from these sources has been recognised and considered as part of the source apportionment modelling and is included within the results (Section 12).

It should be noted however that there is substantial uncertainty about the impact of OSWwTS on water quality, primarily as a consequence of a lack of information about the location, number and condition of OSWwTS. There is also a general lack of monitoring data to support the effects of OSWwTS discharges to surface water and groundwater. Some critical assumptions have therefore been made in including OSWwTS within the study, including:

- Locations of OSWwTS were assumed as those determined in an Environment Agency project aimed at characterising septic tank locations and their discharge of phosphate across England and Wales (Environment Agency, 2010);
- The treatment effectiveness of OSWwTS has been estimated to be low (<30%);
- Losses occur as the chemical load is transported toward the surface water (transmissivity); and
- This input type is diffuse and input loads have therefore calculated on a 1 km^2 basis.

Although OSWwTS have been included within the source apportionment, due to the level of uncertainty both in the source apportionment assessment and also in the certainty of potential measures to remedy this source, options to reduce OSWwTS risk have not been included within the combinations modelling and options assessment process.

4.2. Urban pressures

Diffuse pollution from urban areas, although not thought to contribute significantly to phosphate within the catchment, has also been considered within the study and included within the source apportionment task.

Rain falling on impermeable areas in urban environments, such as roads, roofs, car parks etc, will runoff into the surface water drainage system. Depending on the surface water system within the urban environment, the runoff may be either be routed directly to the nearest watercourse, possibly via a balancing pond or wetland, or may alternatively flow into a combined sewer system carrying foul and surface water to the local WwTW - or a combination of these two fates.

Combined sewers have a finite capacity, typically six times the dry weather flow (DWF); any rain events producing a flow greater than this results in the mixture of surface and foul water being discharged, via a combined sewer overflow (CSO) to the nearest watercourse in order to prevent flooding of the sewer system. At WwTWs receiving combined sewer discharges, storm tanks are provided to collect excess surface and foul water during rainfall events until it can be treated once the rainfall has eased. Should the maximum capacity of the storm tanks be exceeded (typically three times the DWF) the overflow of mixed surface and foul water is routed, in most cases, directly to the nearest watercourse to prevent flooding of the works.

These sources of phosphate have been included within the source apportionment modelling by generating a flow balance for urban areas which may then be combined with reported concentrations to generate loads of runoff to surface water, CSOs and WwTWs. National rainfall intensity data has been associated with each urban area using GIS and for each urban area the reported intensity has been broken down into 1 mm bands (daily rainfall intensity) which have formed the basis for calculating flows to surface water, WwTW and the spill volume.

4.3. Agricultural pressures

Phosphate loss to watercourses is a particular issue in rural catchments with a high degree of agricultural activity, such as in the upper River Wye and River Lugg sub-catchments. The presence of agriculture and different agricultural practices within this sector (such as arable farming versus livestock farming) can create changes in the characteristics of the catchment such that the relative risk of phosphate pollution to the watercourses increases.

Examples of agricultural sources of phosphate are given in Table 4-1 below.

Table 4-1: Key phosphate risks associated with agricultural activities

Activity	Key phosphate sources
Livestock (sheep, cattle, pigs) farming	Grain based feed, production of manure, over grazing of fields and scrub removal with subsequent soil exposure and erosion, in-river poaching releasing sediments and direct voiding into rivers
Poultry farming	Production of chicken litter and subsequent disposal – chicken litter is high in phosphates and often goes to nearby arable land where it is used heavily as fertilizer
Arable farming	Spreading of manure, application of inorganic (and organic) fertilizers, ploughing and compacted tramlines and winter soil exposure, general soil compaction, channelled run-off and subsequent soil erosion and nutrient losses
Horticulture	Heavy fertilizer application, bare soils and subsequent soil erosion and nutrient losses

The use of both inorganic fertilizers (applied directly to the soils) and organic fertilizers (applied directly but also directly voided by farm animals) serve to enrich the soils with phosphates which, when coincident with inappropriate soil management and ploughing practices, can lead to mobilisation of sediments and phosphates to watercourses. This is a particular issue on high slope land during rainfall events, where sediments and nutrients are mobilised quickly to the nearest river.

The very nature of diffuse sources of water pollution means that they are difficult to identify particularly on the spatial scale presented in the River Wye catchment. In smaller catchments, it is possible to identify diffuse pollution “hot spots” (high risk areas) from land use maps, aerial photography and walkover surveys. For larger catchments however, such as the River Wye, this is more difficult. An alternative approach has therefore been taken using SAGIS to identify the source apportionment of phosphate attributable to livestock and arable farming.

To do this, the decision support tool PSYCHIC (Davison et al. 2008) has been used to predict the risk of diffuse pollution from a source area by estimating source, mobilisation and delivery of phosphate and sediment (Section 7). The 2010 PSYCHIC data considers:

- **Phosphate inputs** - in manure and fertilisers and also soil residual phosphate;
- **Mobilisation of phosphate** (and sediment) - through dissolution and soil detachment; and

- **Delivery of dissolved and particulate phosphate** (and associated sediment) to watercourses in surface and subsurface pathways, including field drains.

Aside from their inclusion within the source apportionment exercise, agricultural pressures have also been modelled using the FARMSCOPER model (Section 7.4) to understand the phosphate losses indicative of individual farm types within the catchment.

5. Future pressures and trends

5.1. Population growth within Herefordshire

The current main population centres within the River Wye SAC catchment are Hereford, Leominster, Ross-on-Wye, Monmouth and Chepstow and it is expected that growth will be centred on these main conurbations.

Population growth projects were sourced from Herefordshire County Council and are displayed in Figure 5-1 below.

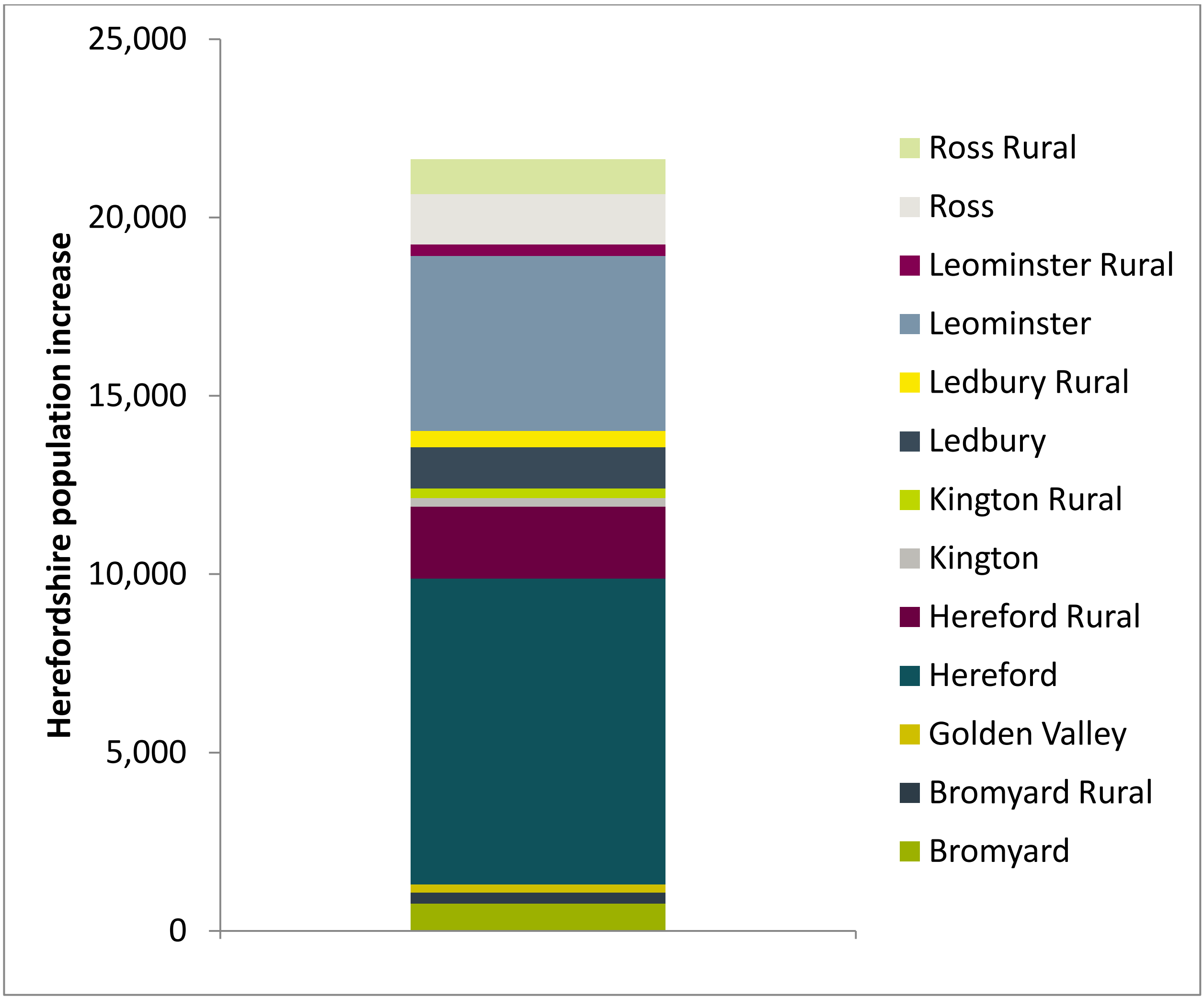

Figure 5-1: Total population growth forecast for Herefordshire by region up until 2031 (Herefordshire County Council)

The raw growth data obtained from Herefordshire and Powys Councils is available in Appendix A for reference.

5.2. Population growth outside of Herefordshire

Although this study focuses on the population growth within Herefordshire, the implications of population growth in upstream areas is also relevant because of the potential for downstream effects within the River Wye SAC. Upstream discharging features outside of the River Wye SAC have therefore been accounted for according to the data obtained from Powys County Council (Appendix A).

5.3. Agricultural change

Although it is not possible to predict the future when it comes to agriculture in the catchment, it is assumed that as market forces change and other influences occur (such as water availability and climate change pressures) the agricultural practices within the catchment could change similarly in the future. This is consistent with the feedback during the first stakeholder event in October 2013 which raised the example of the expansion of maize monocropping practices in the catchment. However, it is not possible to quantify this potential change at this point in time and as such this should be considered in future iterations of the NMP.

5.4. Planned improvements in wastewater treatment

Welsh Water are currently compliant with the discharge standards required of them and as such there are no current plans within AMP6 to undertake any substantial work to further improve discharges.

5.5. Climate change

It is recognised that climate change in the long run may result in changing patterns of rainfall and water availability and this may dictate agricultural practices through soil conditions and availability of irrigation water, however at this stage it is not possible to quantify the exact effects of climate change and therefore this has been included in the uncertainty factor within the modelling.

6. Existing and future mitigation mechanisms

6.1. Examples of existing delivery mechanisms

To secure the environmental outcomes required this plan sets out the measures that *could* be implemented to help achieve the required reductions in phosphate concentrations and contribute towards favourable condition within the River Wye SAC.

Mechanisms (that is, the policy, legal and financial tools available through which to implement the measures) are available on a sliding scale of approaches, ranging from a soft approach, such as raising awareness in order to change behaviours and voluntary actions / incentives, to a harder approach that uses the various legislative tools and supporting regulations to require actions of people within the catchment in order to achieve the outcomes required. This is presented in Figure 6-1 below.

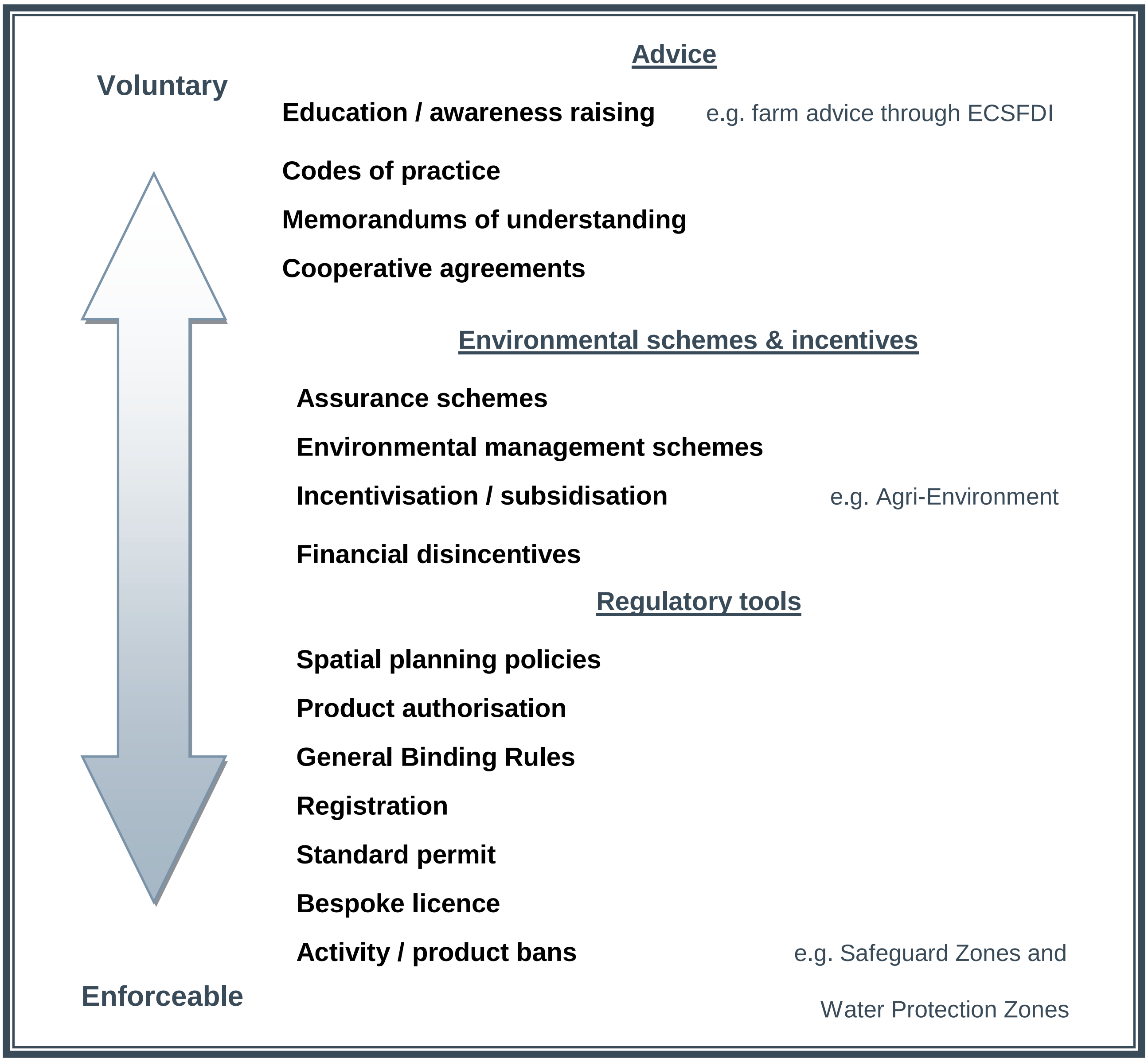

Figure 6-1: Range and types of delivery mechanisms to address water pollution

It is not appropriate to rely on a single delivery mechanism to deliver the phosphate reductions needed to bring the River Wye SAC back to favourable condition. **A mixture of policy instruments will be needed to promote a culture of best environmental practice into the future to ensure that the measures are implemented sustainably.**

Some delivery mechanisms are available nationally, for example point source measures are controlled nationally through the Environment Agency's discharge consent process and measures to help control diffuse sources are available through Natural England's Entry Level Stewardship Scheme. However, there is a further spatial element to the range of delivery mechanisms available; for example Catchment Sensitive Farming and Higher Level Stewardship are available in certain pockets of the countryside where there is a particular pressure or need, e.g. SAC / SSSIs. For the purposes of this plan, both the national and "local" delivery mechanisms have been considered.

There is also uncertainty over future delivery mechanisms, which may change the level of support available to implement measures for diffuse pollution. It may also change the regulatory baseline – for example any changes to the Common Agricultural Policy (CAP) through the CAP reform process.

The modelling within this plan identifies the phosphate reductions that could be gained from applying measures to point sources (at the significant discharging features within the River Wye SAC catchment) and to diffuse sources (within the agricultural sector). The measures identified fit broadly into three categories for delivery: Advice & behaviours; Schemes & incentives; and Regulation.

6.1.1. Advice and behaviours

6.1.1.1. Natural England Land Management and Conservation Advisors

Natural England has a series of local advisers in place on a county-basis who advise landowners and managers on various agricultural and land management related issues including biodiversity, conservation, archaeology, heritage and water protection. Part of their task is to work with farmers to identify options within environmental stewardship that could be taken up to protect any of these features.

6.1.1.2. England Catchment Sensitive Farming Delivery Initiative

The England Catchment Sensitive Farming Delivery Initiative (ECSFDI) is also funded through the Rural Development Programme for England, overseen by Defra and implemented by a partnership between the Environment Agency and Natural England. Targeted to certain priority areas, the ECSFDI is specifically focused on reducing diffuse pollution from agricultural practices through delivering advice to farmers and financial support for capital schemes. Advice is delivered through Catchment Sensitive Farming Officers (CSFOs) who visit famers and offer advice on the various funding mechanisms and advise on the incentives that exist to help address environmental issues arising from farming practices. It should be noted that the current Rural Development Programme ended December 2013 and the new programme is expected to start from January 2015 onwards. http://www.ecsfdi.gov.uk/

http://www.naturalengland.org.uk/ourwork/farming/csf/default.aspx

6.1.1.3. Campaign for the farmed environment

The Campaign for the Farmed Environment (CFE) was originally established to encourage farmers to voluntarily mitigate the removal of compulsory set aside. Its purpose now is to encourage farmers and land managers to "protect and enhance the environmental value of farmland, through measures that sit alongside productive agriculture". It is an advice delivery mechanism that advises farmers on measure implementation to protect soil and water whilst benefiting wildlife through a network of regional advisors. Key theme areas in which CFE promotes measures include: arable conservation management; grassland conservation management; soil management; nutrient management; and crop protection management.

http://www.cfeonline.org.uk/home/

6.1.1.4. Environmental Stewardship Training and Information Programme

Environmental Stewardship Training and Information Programme (ETIP) is an advice delivery initiative implemented by Natural England to enhance the environmental performance of Entry Level Stewardship

(ELS), recognising that environmental outcomes of ELS would be enhanced by spatial targeting of advice, and thereby ensuring local pressures and issues are addressed.

The ETIP programme offers farm visits on a one-to-one basis between farmer and an independent agricultural contractor (or agronomist). Additionally, advice is delivered through farm walks and workshops. Through this mechanism, farmers are offered advice and encouraged to take up the correct measures relevant to local level issues and farm-type specific impacts.

6.1.2. Schemes & incentives

6.1.2.1. Environmental Stewardship Schemes

The Environmental Stewardship Schemes (ESS) is part of the Rural Development Programme for England (RDPE). Administered by Natural England, it aims to provide support to land managers to maintain the land in a certain way that benefits the landscape, biodiversity or habitats. There are currently several levels of ESS: Entry Level Stewardship (ELS); Organic Entry Level Stewardship (OELS); Upland Entry Level Stewardship (UELS); and Higher Level Stewardship (HLS).

The current scheme that is particularly relevant to resource protection activities is HLS, which provides additional support for land management measures that are related to nutrient management and water pollution, for example land management measures including: arable reversion; winter cover crops; management of maize crops to reduce soil erosion; in-field grass areas to prevent erosion and run off; 12 m buffer strips on water courses; watercourse fencing; tramline management; beetle banks; livestock management; wide riparian buffer strips; and nil fertilizer supplement.

Funding is also available to cover capital items such as fencing, relocation of gates, cross-drains under farm tracks, hard base for livestock drinker and feeders, cattle drinking bays and troughs.

This delivery mechanism will be important to consider as it seeks to change the long term practices to those that are more suited to improving the quality and sustainability of existing wildlife habitats, whilst also creating new habitats where required. It should be noted that this scheme is also under the RDPE which is being reviewed currently.

http://www.naturalengland.org.uk/ourwork/farming/funding/default.aspx

6.1.2.2. Forestry Commission English Woodland Grant scheme

The English Woodland Grant Scheme provides financial support for establishment and maintenance of woodland schemes. Funding could be available for establishment of riparian woodland or other land-based planting schemes that serve to disrupt the pathway of sediment run off for example. Grants available are targeted at both improving existing woodland but also creating new woodland.

http://www.forestry.gov.uk/ewgs

6.1.2.3. Water company improvement schemes

Water companies are increasingly turning to catchment based measures to reduce the need for traditional water treatment engineering. Many water companies are now working with land managers and farmers, either directly or through agronomists, to identify measures to protect water quality and thereby reducing the need for clean water treatment and wastewater management. Depending on the measures required, financial support is made available either through environmental stewardship or through direct water company funding.

6.1.3. Regulations

6.1.3.1. Cross compliance

In order for farmers to receive their Single Farm Payment (SFP) they must demonstrate they have met some baseline standards for agriculture, termed “Cross Compliance”. This comprises two key components that have to be met – Good Agricultural and Environmental Condition (GAEC) and Statutory Management

Requirements (SMRs). One of the requirements of GAEC is for farmers to demonstrate that they are protecting soils and water, by:

- Producing a Soil Protection Review (a record of soil characteristics and risks and an outline of measures taken to manage these risks, with evidence of annual review);
- Not spreading fertiliser and organic manure within 2 m of a watercourse, or to land within 1 m from the top of the bank of a watercourse;
- Avoiding leaving recently cropped or harvested land in a state that risks run-off over winter; and
- Considering erosion and run off risk when leaving uncultivated stubbles in fields.

6.1.3.2. Nitrate Vulnerable Zones

Nitrate Vulnerable Zones (NVZs) are a regulatory tool that places requirements on farmers to take additional measures to protect air, soil and water from nitrates, including:

- Plans for the use of nitrogen fertiliser and livestock manure;
- Risk maps for areas to which manure is to be spread;
- Compliance with field limits, crop nitrogen requirement limits, closed periods and spreading controls for manufactured nitrogen fertilisers and organic manures;
- Compliance with livestock manure nitrogen farm limit;
- Adequate storage capacity for livestock manures; and
- Records of the nitrogen applied to fields and whole farms.

Although NVZ regulations are targeted towards nitrates, some of the measures contained within the regulations will assist in controlling agricultural phosphate losses too.

6.1.3.3. Codes of Good Agricultural Practice

The Codes of Good Agricultural Practice (COGAP) is essentially a guidance document to help farmers protect the environment with respect to soil, air and water pollution. It sets out management activities and behaviours to help control phosphate losses from farm activities, including farm scale soil, nutrient and manure management plans; and considering phosphate levels in feed against the specific animals requirements. Through these plans and measures, the codes help control the water pollution impacts of farm practices and run-off.

6.1.3.4. Anti pollution works notices

Anti pollution works notices can be issued by the Environment Agency under Section 161 of the Water Resources Act 1991 for incidences of soil pollution, and therefore in this way can contribute towards helping with phosphate pollution issues. However, they are not considered an appropriate regulatory tool to control phosphate application and usage; this is more a retrospective tool.

6.1.3.5. Safeguard Zones & Water Protection Zones

If a drinking water is at risk, with high confidence, then a Safeguard zone can be designated. This is a non-statutory tool but identifies where the Environment Agency and key stakeholders such as the water companies will work with landowners and land managers to encourage the voluntary uptake of catchment management measures to reduce pollutants in the drinking water. If this approach is not successful, or if the environmental outcomes envisaged are not realised, then a Water Protection Zone (WPZ) could be pursued. A WPZ is a statutory designation and allows the banning of certain substances and activities within that zone, enforced by the Secretary of State.

6.1.4. Additional funding and delivery mechanisms

6.1.4.1. WFD Improvement Fund

In April 2011, the Secretary of State announced the allocation of £92 million over four years with the specific objective to improve the health of our rivers, lakes and estuaries by addressing water quality issues, removing barriers to fish migration and removing invasive non native species, to help achieve WFD objectives. This money will be allocated to projects that contribute towards WFD outcomes and are implemented between 2011 and 2015. Projects considered for funding include those that: remove invasive non native species; clear up pollution; and remove barriers to fish migration.

6.1.4.2. Catchment Restoration Fund

Defra has allocated£28 m of funding over three years (from 2012/13) to the Catchment Restoration Fund (CRF) to civil society groups for implementation of water body improvement projects. These projects will contribute to bringing water bodies to Good Status and are over and above measures in River Basin Management Plans.
http://www.defra.gov.uk/environment/quality/water/legislation/water-framework-directive/

The CRF opens up the funding to bids from third sector organisations in the hope that this will encourage businesses, local authorities and community groups to join forces with charitable organisations in order to secure funding for improvement ideas on rivers. The CRF is currently closed to bids for 2013- see http://www.environment-agency.gov.uk/research/planning/136182.aspx for the latest information on the fund.

6.1.4.3. Planning Control and Developers Contributions

Section 106 of the Town and Country Planning Act (1990) requires developers seeking planning permission to incorporate within their proposals supplementary plans that help meet the needs of the community by securing contributions towards community infrastructure. This includes financial contributions to community facilities such as open spaces, which can include urban green spaces and riparian land.

This mechanism could be used to deliver some pathway disruption techniques and enhancements along river corridors.

6.1.4.4. European Funding

The European Commission fund a number of other large scale programmes, including: LIFE+; Regional Convergence; Competitiveness and Cooperation (including INTERREG); and Framework Programme.

http://ec.europa.eu/environment/funding/intro_en.htm

Funding is available through the European Regional Development Fund (ERDF) for water management projects that: improve the quality of water supply and treatment, including cooperation in the field of water management; support integrated, sustainable and participatory approaches to management of inland and marine waters, including waterway infrastructure; and adapting to climate change effects related to water management.

6.1.4.5. Natural England SSSI Funding

A small amount of money is available each year from Natural England for works within SSSIs. This includes funding through the Conservation and Enhancement Scheme, which affords discretionary payments to fund costs of specific management to deliver favourable condition of the nature conservation interest on land of outstanding scientific interest. The mechanism can fund both capital works and management programmes (over a five year agreement period). This is a useful fund to consider where other sources of funding are not available (for example for sites that fall outside HLS areas) but it is important to note that 50% match funding is required for public bodies and some organisations.

http://www.naturalengland.org.uk/grantsfunding/findagrant/conservationandenhancementscheme.aspx

6.2. Existing measures being implemented within the River Wye SAC catchment

6.2.1. Regulatory baseline

It is recognised that the requirements set out as part of the regulatory baseline (such as Cross Compliance and NVZ requirements) provide a level of protection to soil and water, and therefore these mechanisms are likely to already be delivering benefits to soil and water.

To reflect the contributions already being made by the agricultural sector to reduce diffuse source pollution, the diffuse source modelling has assumed that NVZ requirements are being taken up in full where required and that outside of the NVZ "Typical Practice" is assumed, which includes some degree of implementation of protection measures.

6.2.2. WFD measures

It is important to note that elevated concentrations of phosphates within the River Wye are not a new problem and actions are already underway to contribute towards remedies. The Severn River Basin Management Plan (Environment Agency, 2009) outlines the following actions relevant to the River Wye catchment, including:

- Advice to farmers via the England Catchment Sensitive Farming Delivery Initiative and Natural Resources Wales Agri Environment (Glastir);
- Wastewater discharge improvements (targeted at reducing ammonia and phosphate);
- Improving land management and reducing sedimentation via restoration of woodlands;
- Investigation into sources of siltation and impacts on salmon in the River Lugg (and River Arrow);
- Improving riparian habitat (River Arrow and River Lugg);
- Work with farmers to improve management of sheep dip;
- Reduce local impacts of acidification through catchment liming;
- Improve habitat to mitigate physical modification of water courses and reduce non native invasive plants; and
- Investigate the ability of eels to migrate through the Reens system.

6.2.3. Agri-environment

Agri-environment has been adopted by many land managers within the River Wye SAC catchment for a number of years.

ELS which is available to all landowners in England, has traditionally not included many measures specific to resource protection. From January 2013 more resource protection options were being incorporated into ELS. The schemes are currently under review, which may positively affect the availability of resource protection options in the future. It is also important to note that some of the ELS measures deployed to date have resulted in more considerate land management behaviours that have had incidental water protection benefits.

ELS is available to all land managers within the catchment, however traditionally is not thought to deliver significant benefits for water quality; HLS options are considered to deliver more benefits for water quality however the options are not available to all land managers and thus coverage is not uniform across the catchment. For these reasons it is not feasible to incorporate the exiting agri-environment scheme uptake within the modelling tasks; however the current contributions from these mechanisms have been considered contextually.

The current uptake incidence of resource protection options within the River Wye SAC catchment through ELS and HLS, Table 6-1 below summarises this information obtained from Natural England (2013). These data show how many times a resource protection option is currently being claimed for under HLS; unfortunately some of the options relate to area measurements and some do not, hence it is not possible at this level to state how many hectares are covered by each option; what it does show however is the relative popularity of the different options currently being implemented and provides useful context to consider alongside the modelling outputs and can be used in future to help guide the application of measures.

It is also important to consider that the benefits of the implementation of these options will be included in the phosphorus monitoring data used to represent the catchment, and are therefore essentially included within the baseline outputs set out in Section 10.

Table 6-1: Prior implementation rates of Agri-environment (ELS and HLS) resource protection options within the English part of the River Wye catchment

Code	Option Description	Uptake incidence
EE6	6 m buffer strips on intensive grassland	79
EE9	6 m buffer strips on cultivated land next to a watercourse	203
EF1	Field corner management	298
EF7	Beetle banks	1
EJ5	In-field grass areas	38
EJ9	12 m buffer strips for watercourses on cultivated land	20
EK1	Take field corners out of management: outside SDA & ML	47
EK2	Permanent grassland with low inputs: outside SDA & ML	3502
EK3	Permanent grassland with very low inputs: outside SDA & ML	1176
EK4	Manage rush pastures: outside SDA & ML	6
EL1	Field corner management: SDA land	9
EL3	In-bye pasture & meadows with very low inputs: SDA land	467
EL4	Manage rush pastures: SDA land & ML parcels under 15ha	15
EL5	Enclosed rough grazing: SDA land & ML parcels under 15 ha	6
EL6	Moorland and rough grazing: ML land only	2
HJ3	Reversion to unfertilised grassland to prevent erosion/run-off	32
HJ4	Reversion to low input grassland to prevent erosion/run-off	31
OE6	6 m buffer strip on organic grassland	5
OF1	Field corner management	2
OK2	Permanent grassland with low inputs: outside SDA & ML(organic)	86
OK3	Permanent grassland with very low inputs: outside SDA&ML(organic)	71
OL3	In-bye pasture & meadows with very low inputs: SDA land(organic)	28
UC22	Woodland livestock exclusion	51
UJ12	Winter livestock removal next to streams, rivers and lakes	7
UL23	Management of upland grassland for birds	5

(Data source: Natural England, 2013)

In Wales, similar agri-environment schemes have also been implemented that include an entry level scheme (available to all and not focused on resource protection) and an upper level scheme (available to some landowners and including some resource protection options). The environmental outcomes of these schemes are also assumed to be included within the baseline water quality data and are not discussed further here, consistent with the assumption for agri-environment uptake in England.

6.2.4. England Catchment Sensitive Farming Delivery Initiative

The ECSFDI delivers advice to farmers on reducing diffuse water pollution from agricultural practices within the River Wye catchment. The wider programme also offers capital grants for large items of farm infrastructure such as slurry pits which serve to benefit the phosphate issue.

The priority catchment targeting of ECSFDI within the River Wye SAC catchment has identified phosphate and sediment run off in the catchment as a particular issue and has set out objectives for implementation between 2011 and 2014 focused around these issues.

During 2013 within the River Wye catchment particular attention has been paid to: responsible field selection and mitigation choices for potato production in Herefordshire; soil husbandry across all agricultural farm types; and basic nutrient management planning. The specific issues within the catchment have also been targeted by CSF officers in the catchment delivery plans for the River Wye and the River Lugg.

Although ECSFDI can provide a good route for delivery of advice to farmers on general diffuse pollution and capital grants to help with implementation, it is important to note that the ECSFDI programme was not established to specifically deliver reductions in agricultural phosphate pollution in water bodies and as such is only so far estimated to have resulted in a small percentage reduction in in-river phosphate concentrations within the River Wye catchment (currently estimated at 1.6 % (Natural England, 2012)). This modest reduction factor has not been included within the modelling.

ECSFDI is regularly reviewed and the future focus of the Programme is uncertain after 2014, but there may be future scope for including more phosphate targeted work within ECSFDI for local level issues such as those in the River Wye catchment.

6.2.5. Local scale initiatives

The Wye and Herefordshire Improvement Project (WHIP) currently being implemented by the Wye and Usk Foundation and part of its focus is on mitigating diffuse pollution from agricultural sources. The project undertakes farm visits for areas outside of CSF and agri-environment and assesses farming activities in relation to specific local problems within the water bodies, working with farmers to identify and support potential mitigation measures.

6.3. The future - measures and mechanisms

6.3.1. Future technology for wastewater treatment

This study concerns population growth projections into the future, and so when considering the effects of this on wastewater flows to inform treatment options it is considered fair to take account of the technology that is expected to be available in the future to mitigate these future pressures on wastewater capacity and quality.

For the purposes of this study it has therefore been assumed that future technology will be capable of delivering a 0.1 mg/l TP/L limit and the scenario modelling within this study has been undertaken based on this principle. It is recognised that adoption of such high levels of treatment would be subject to a more detailed investigation into the cost effectiveness analysis and options appraisal.

Some examples of the expected difference between current and future phosphate removal technologies is given in Table 6-2 below.

Table 6-2: Examples of current and future treatment options for point source application

Technology	Type	Limit	Note
Current	Chemical precipitation - dosing with iron or aluminium salts	Between 1.0 mgTP/l to <0.1 mgTP/l	Ultra-low discharge concentration reported in studies undertaken in the USA. Potential implications from new WQ standard for iron.
	Biological phosphate removal	1.0 mgTP/l	<1.0 mg/L in combination with other technology options.
	Tertiary filtration	Between 1.0 mgTP/l and 0.05 mgTP/l	Final effluent polishing step - no examples of use within UK.
Future	Membrane bioreactors	<0.05 mgTP/l	Membrane technology
	Reverse osmosis	<0.01 mgTP/l	Membrane technology
	Blue-PROTM	<0.1 mgTP/l	Moving bed sand filter with upstream ferric salt conditioning
	Fuzzy filters	<0.2 mgTP/l	Compressible Medium Filters (porous synthetic media)

6.3.2. Future delivery mechanisms

Over the proposed lifetime of the plan, the mechanisms (and indeed the measures supported by these mechanisms) are likely to change, however if actions are set out in the NMP and priorities are defined thereafter as the plan is implemented, then momentum can be gained such that mechanisms can be taken advantage of as and when they emerge – for example any additional environmental measures available as part of CAP reform.

It is envisaged that the iterative process intended for the NMP will allow for incorporation of any new measures and mechanisms into the NMP revisions in the future.

7. Source apportionment

7.1. Understanding in-river phosphate concentrations and relative contributing sources

As outlined previously, to understand the current levels of phosphate within the River Wye SAC and the relative contributions from the different sources present within the catchment, the Source Apportionment GIS (SAGIS) model has been used.

The SAGIS model has been developed jointly by the Environment Agency and the water industry and is perhaps best explained as an ArcGIS interface that links to 18 regional geo-databases (Figure 7-1); based on the National SIMCAT models that contain various geographical, hydrological, water quality data for England and Wales. Each of the model regions must be run independently to use the SAGIS model in order to evaluate water quality (or the source apportionment of chemicals) for a specific geographical region.

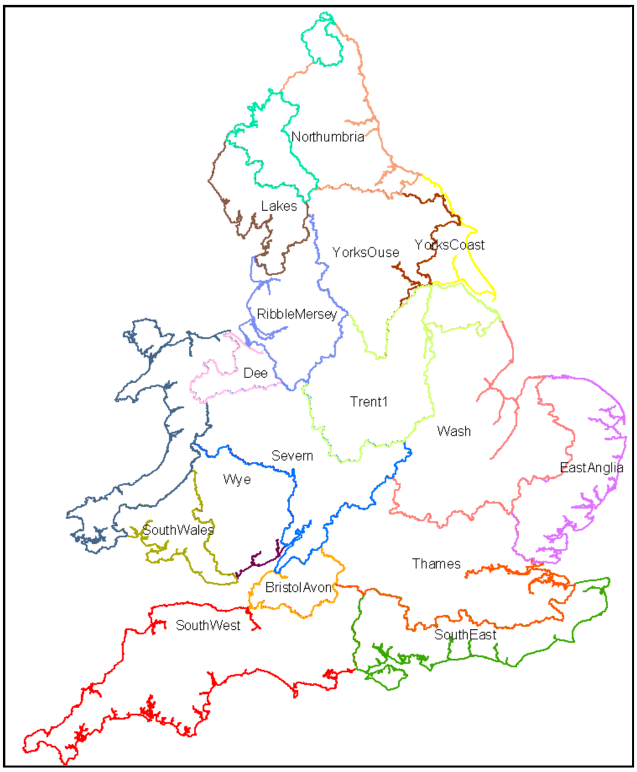

Figure 7-1: SAGIS model geo-databases

The key components of the SAGIS tool are listed below and illustrated in Figure 7-2:

- National export coefficient database (this houses national scale data on diffuse sector inputs that are used by SAGIS and contains, for example, national scale PSYCHIC model output data);
- 18 Regional SIMCAT databases + SIMCAT Common Tables database;
- SIMCAT v.12.5; and
- ArcGIS interface.

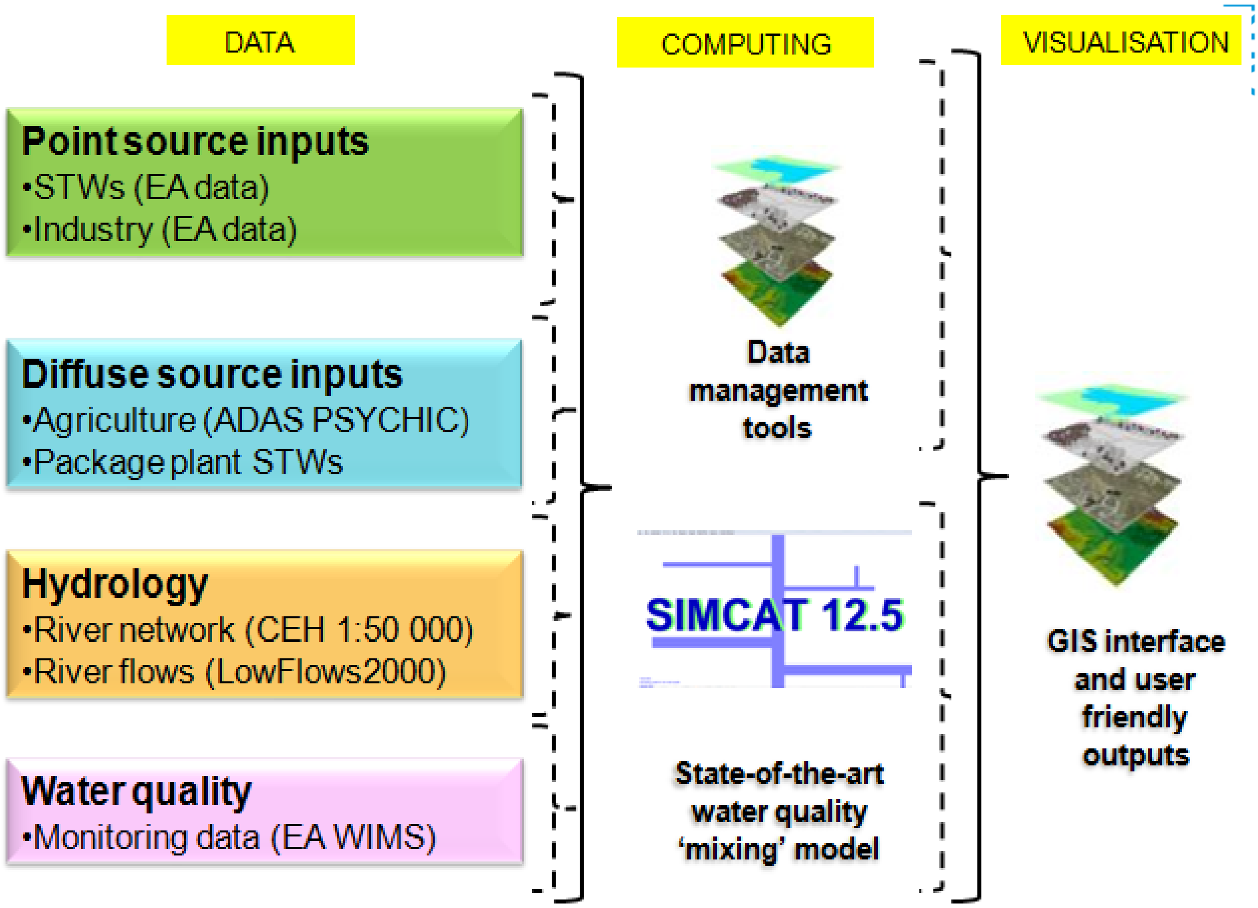

Figure 7-2: Overview of the structure of the SAGIS water quality model

The SAGIS model utilises the National SIMCAT water quality models, along with regional databases of geographical, hydrological and water quality data to convert load data to in-river concentration data.

Within SAGIS, a national export coefficient database apportions this load between different sources, including: sewage treatment works; agriculture (arable and livestock); industry; urban; private sewerage; highways; intermittent discharges; mines; atmospheric; and background.

7.2. SAGIS outputs explained

Although the direct outputs from SAGIS are extremely useful in visualising the longitudinal concentrations of pollutants within the river, they can be challenging to interpret. The following section provides some clarity on how to understand the SAGIS outputs in relation to the River Wye and the River Lugg.

The first output from SAGIS is a simulation of the predicted in-river phosphate concentrations. This is presented in Figure 7-3 below.

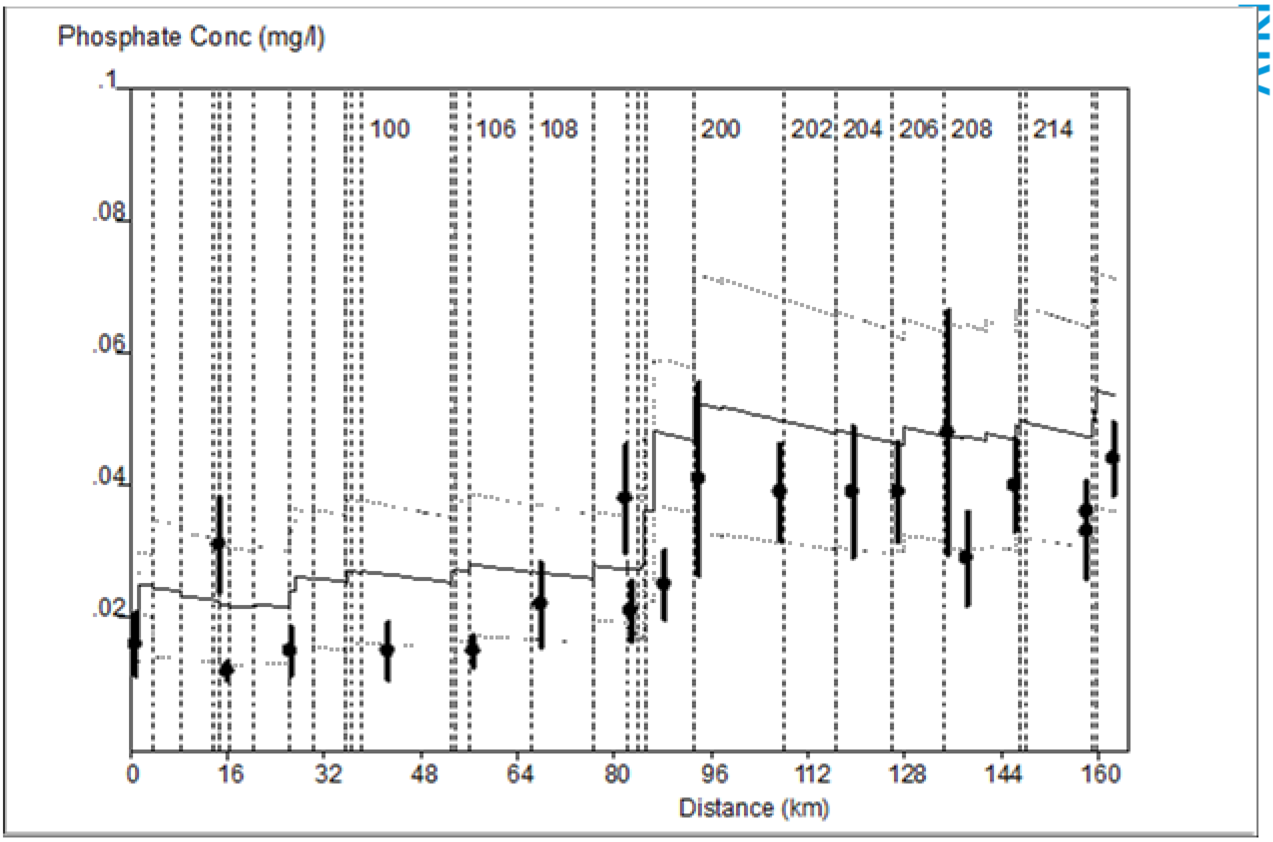

Figure 7-3: Example SAGIS output - in-river phosphate concentrations

Figure 7-3 displays the simulated data for the in-river phosphate concentrations (y-axis) longitudinally through the river system, from the river source at 0 km downstream (x-axis) to the end point of the river / area of interest, in this case some 160 km down the river from the source.

- The horizontal solid line represents the predicted concentration and the broken lines either side of the solid line the 95% confidence interval range.
- The solid points indicate observed average concentration values and their corresponding 95% confidence interval ranges.
- The vertical lines (broken) represent individual river reaches joining the study area and as such often coincide with a step change in concentration data, as one might expect when different water qualities merge.
- Where a significant step change occurs in the absence of a tributary, this could indicate for example either a consented discharge (if one exists) or some other form of phosphate contributor.

The second output from SAGIS is the source apportionment data, an example of which is provided in Figure 7-4 below.

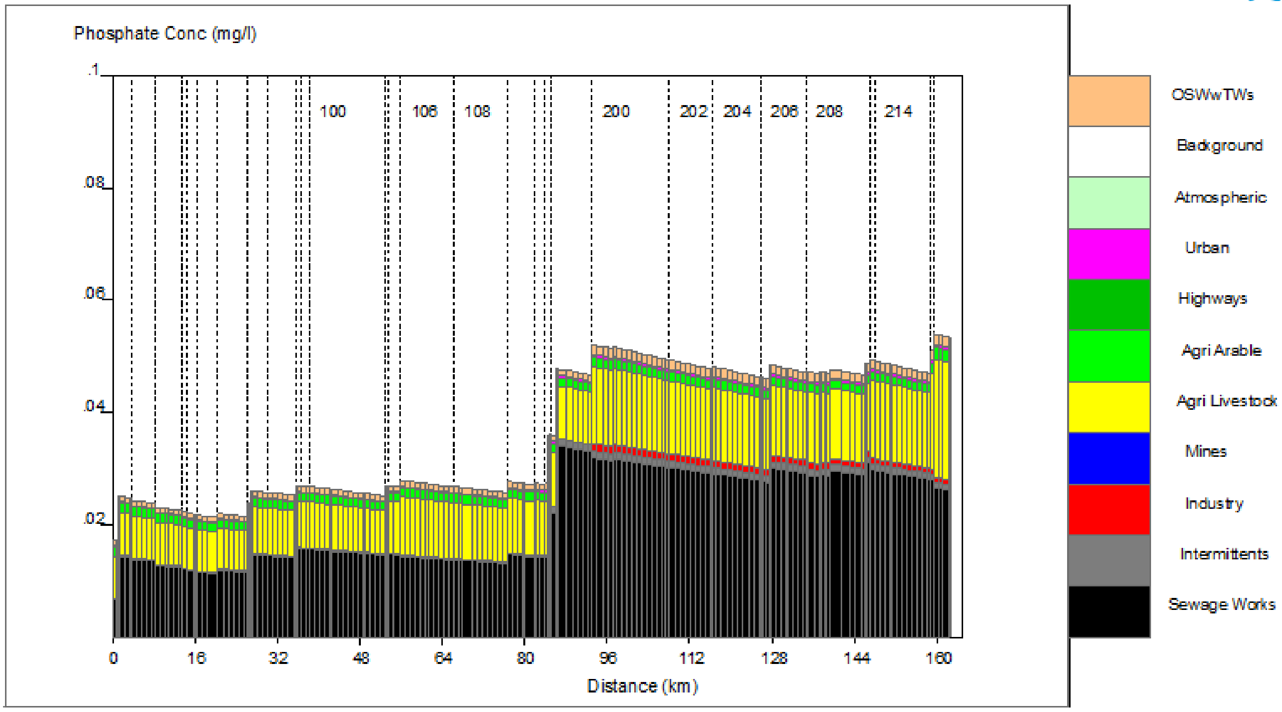

Figure 7-4: Example SAGIS output - in-river source apportionment

Similar to Figure 7-3, Figure 7-4 shows total phosphate concentration (y-axis) and distance from source (x-axis) and the vertical broken lines still represent individual river reaches joining the study area. The total phosphate concentrations are represented by the top of the coloured area (in this case varying between approximately 0.2 mg/l and 0.6 mg/l and within these levels, the relative contributions of phosphate from individual sources is represented by the different colours, with the largest contributor in this case being from sewage works (black), followed by agricultural livestock (yellow). The concentration of phosphate arising from the different sources is given by the height of each coloured section, not the cumulative height.

Overall, these plots are useful as an overview of how dominant different sources are in different reaches – for example half way through the above plot, there is a significant contributing source that contains a lot of phosphate from sewage treatment works, evidenced by the step change in the data and the sudden increase in the black portion of the graph.

7.3. Source apportionment baseline

7.3.1. Source apportionment calibration

In the context of this study, the main focus of the SAGIS model outputs are the phosphate concentration predictions, which are dependent on a range of model parameters, primarily:

- The amount of substance that is deposited into the watercourse;
- The dilution capacity in the watercourse (i.e. river flows and hydrology); and
- Covariance between substance deposition and dilution capacity (i.e. under what river flow conditions the inputs occur).

A calibration process was undertaken in order to improve the model representation of reality and to identify the elements of uncertainty that might influence the agreement between simulated and observed concentration.

In this study, the calibration process was undertaken in two stages, namely;

- **Model update and checking of features –** this entailed ensuring the model provides an accurate representation of hydrological characteristics and that the representation of point and diffuse source inputs utilises up-to-date information (for example use the most up to date PSYCHIC model data).

- **Refining of baseline –** following on from the model update, the extent of agreement between the baseline forecast and historical monitoring data was assessed and the model adjusted to optimise the agreement between the baseline forecast and historical monitoring data. This stage was aimed at identifying reasons for differences between simulated and observed concentration values. This approach is, arguably, superior to the traditional SIMCAT 'auto-calibrate' which forces agreement between simulated and observed concentration values without explicit consideration for the reasons for differences between simulated and observed concentration values.

This process has helped to ensure that the model is simulating the observed situation to an appropriate standard.

A full calibration report is shown in Appendix F.

7.3.2. River Wye baseline source apportionment

Overall, the concentrations of phosphate in the River Wye, upstream of its confluence with the River Lugg are generally below the standard required by the conservation objective (Figure 7-5)[2]. The key features of this figure are explained as follows:

- Label 1 indicates the stepped increase in concentration attributable to Eign and Rotherwas sewage treatment works;
- Label 2 indicates the stepped increase of the confluence with the River Lugg;
- The step change between the modelled and observed concentration values is evident immediately prior to the confluence and is attributable to inputs from the Eign and Rotherwas sewage treatment works;
- The in-river concentration increases further beyond the confluence with the River Lugg as a consequence of the load input from the River Lugg;
- The conservation standard downstream of the confluence with the River Lugg is less stringent and the in-river concentrations are not thought to present a risk to compliance; and
- The predicted concentrations are typically greater than the observed concentrations suggesting the model offers a relatively conservative perspective. The observed concentrations are, however, typically within the 95% confidence interval range of the predicted concentration and there is therefore good confidence in the model prediction.

[2] Values on the y-axis represent the phosphate concentration in mg/L and the values on the x-axis the distance along the length of the river in kilometres. The black horizontal solid line represents the predicted concentration and the broken black lines either side of the solid line the 95% confidence interval range. The solid points indicate observed average concentration values and their corresponding 95% confidence interval ranges. The vertical lines (broken) represent individual river reaches. The horizontal blue lines indicate the phosphate target level in the upper and lower River Wye (0.03 mg/l and 0.05 mg/l respectively)

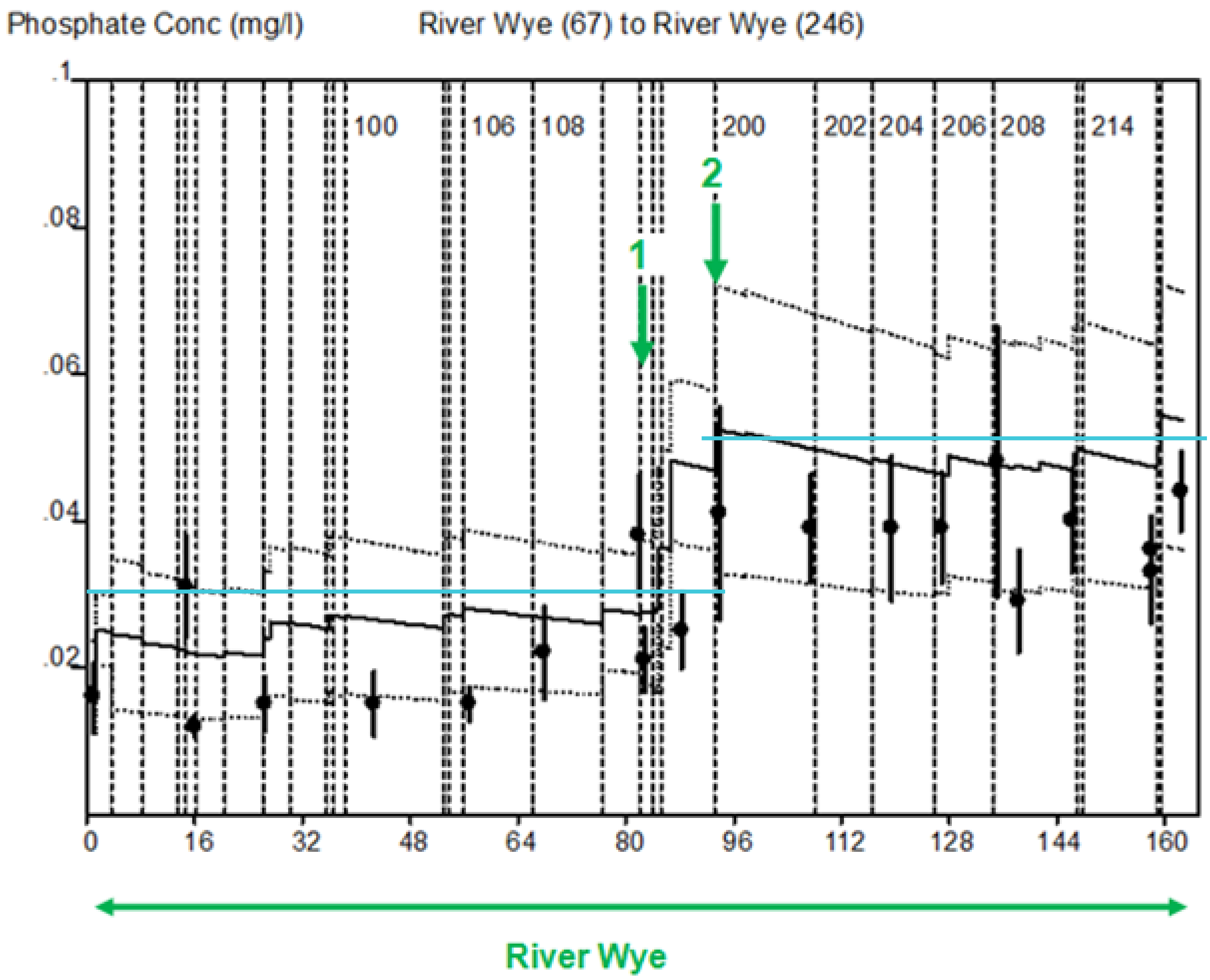

Figure 7-5: SAGIS predicted in-river phosphate concentration for the River Wye from its confluence with the River Irfon until its discharge into the Severn Estuary.

The source apportionment for the River Wye (Figure 7-6[3]) suggests the inputs from sewage treatment works typically represent the most significant source of phosphate (>60%) although inputs from livestock are also significant (>20%).

[3] The horizontal blue lines indicate the phosphate target level in the upper and lower River Wye (0.03 mg/l and 0.05 mg/l respectively)

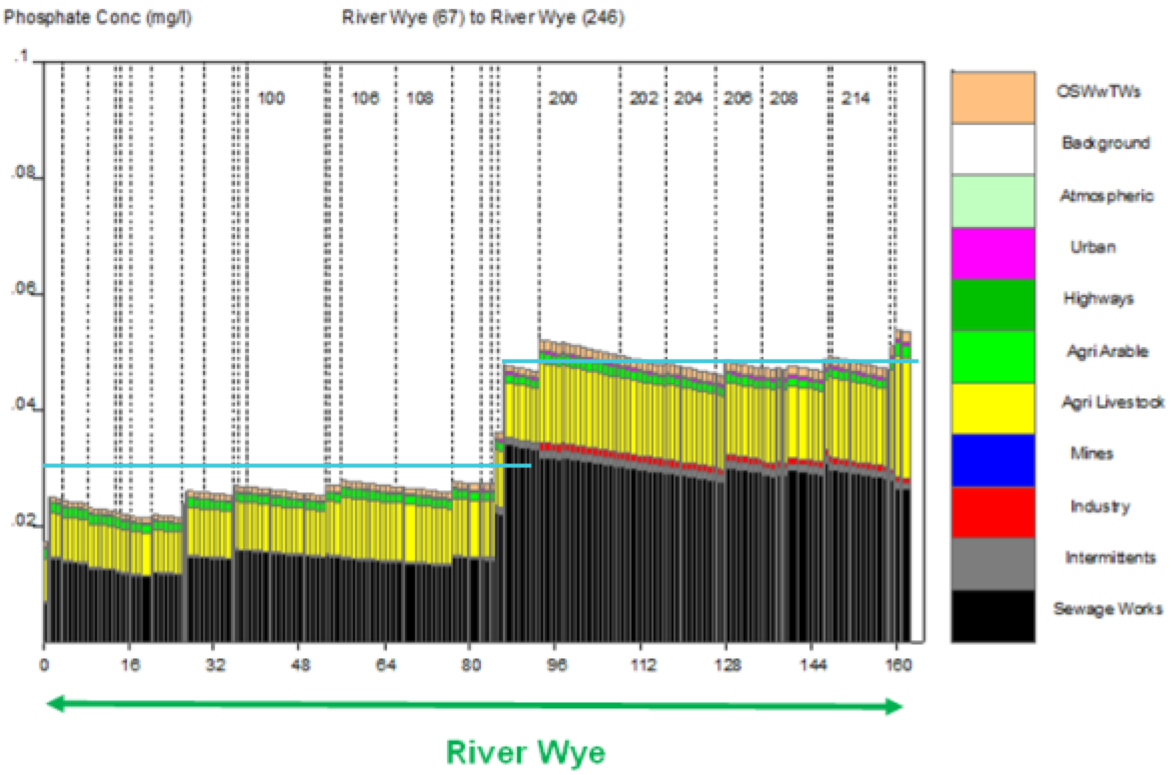

Figure 7-6: Apportionment of predicted in-river concentration by source for the River Wye from its confluence with the Irfon until its discharge into the Severn Estuary.

7.3.3. River Lugg baseline source apportionment

The baseline concentrations of phosphate in the River Lugg (note the horizontal blue arrowed area in Figure 7-7[4] below) upstream of its confluence with the River Wye are generally above the concentrations required by the conservation objective. The key features of this figure are explained as follows:

- **Label 1** indicates the stepped increase in concentration attributable to inputs from Presteigne sewage treatment works and the Boultibrook Fish Farm;
- **Label 2** marks the location where concentrations increase due to agricultural inputs from the Lime Brook; and
- **Label 3** marks the stepped decrease representing the confluence with the River Wye.

Overall, the in-river phosphate concentration decreases beyond the confluence with the River Wye as a consequence of the increase dilution capacity and the lower phosphate concentrations in the River Wye.

The model gives a reasonably good representation of trends, subject to the statistical spread in monitoring data. Overall, the model is slightly precautionary, predicting slightly higher concentrations than the averages from observed data. The predicted concentrations are typically in-line with the observed concentrations which also typically fall within the 95% confidence interval range of the predicted concentration indicating there to be good confidence in the model estimates.

[4] Values on the y-axis represent the phosphate concentration in mg/L and the values on the x-axis the distance along the length of the river in kilometres. The horizontal solid line represents the predicted concentration and the broken lines either side of the solid line the 95% confidence interval range. The solid points indicate observed average concentration values and their corresponding 95% confidence interval ranges. The vertical lines (broken) represent individual river reaches. The horizontal blue line indicates the phosphate target level in the River Lugg (0.05 mg/l)

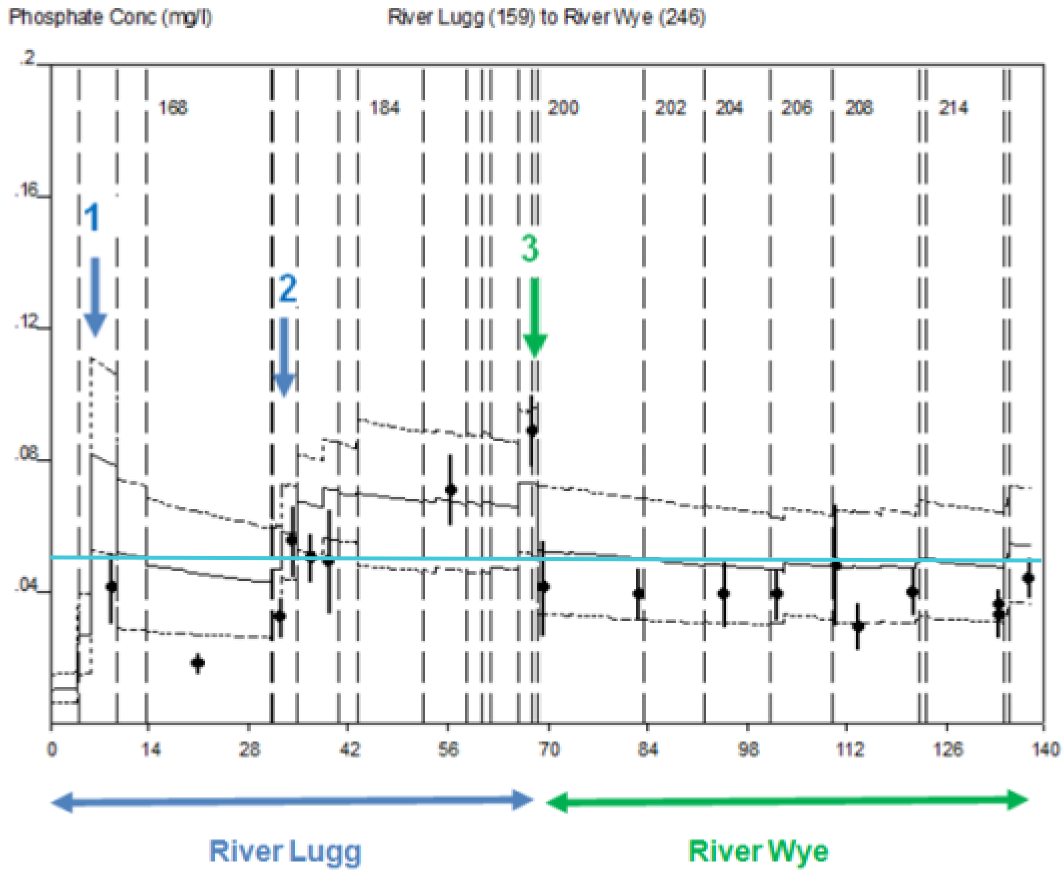

Figure 7-7: SAGIS predicted in-river phosphate concentration for the River Lugg from its confluence with the River Cascob until its discharge into the Severn Estuary (as the River Wye).

The outputs of the source apportionment for the River Lugg, given below in Figure 7-8[5] (again, note the extent of the blue arrow depicting the River Lugg), suggest that the inputs from sewage treatment works and livestock to be of broadly equivalent significance.

[5] The horizontal blue line indicates the phosphate target level in the River Lugg (0.05 mg/l)

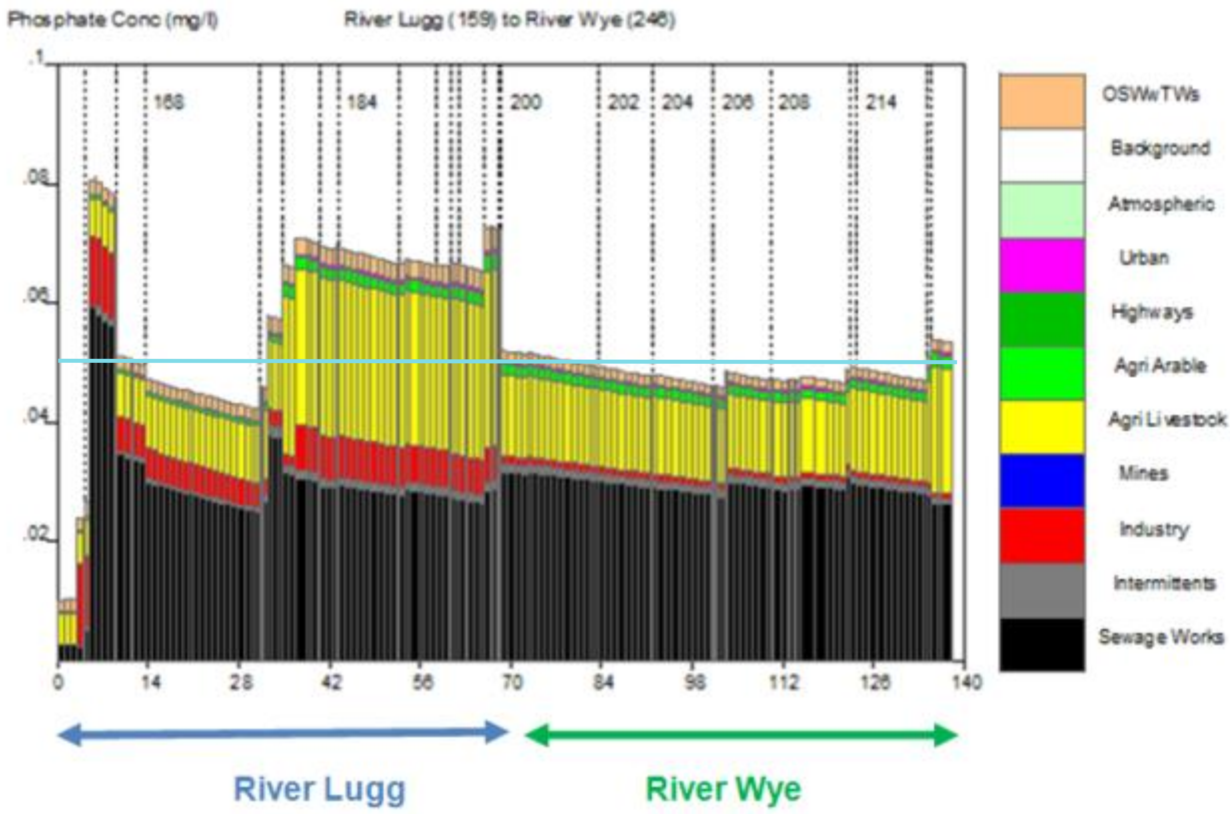

Figure 7-8: SAGIS source apportionment prediction for the River Lugg from its confluence with the Cascob until its discharge into the Severn Estuary (as the River Wye).

7.4. Baseline phosphate contributions from agriculture

Different farming activities pose varying levels of risk to the water environment and so in order to understand the potential contributions from the agricultural sector it has been necessary to first gather baseline data on the various agricultural practices within the catchment.

Data from Defra and the Welsh Government have been used to define the farm types and frequency within the catchment to form the basis of the FARMSCOPER modelling and subsequently to interpret the outputs of the SAGIS modelling. Due to the way the data is gathered by the respective countries, the assessment of farming has been considered separately for England and Wales, rather than using the differentiation between the upper River Wye, Lower River Wye and River Lugg referred to in the rest of this report.

7.4.1. A summary of farming data in the English parts of the River Wye catchment

Analysis of the Defra Robust Farm Type (RFT) and Agri Census data for England showed the following key features:

Livestock farming:

- Nearly half of all holdings in the upper River Wye sub catchment (Figure 1-1 and Figure 2-1) are for lowland grazing of livestock, with a small percentage of holdings operate upland (Less favoured Area, LfA) grazing of livestock (7% and 9% for the upper River Wye and River Lugg catchments respectively). This is expected as the English areas of the two catchments are relatively low lying compared with the Welsh portion of the catchment.
- Chickens are the most numerous animal farmed within both catchments. This is expected because although the number of chicken farms is low, the numbers of animals in each farm is high - just 2% of farm holdings in the River Lugg catchment and <1% in the upper River Wye catchment are identified as

poultry - although it is thought that much of the suppressed data (where fewer than five holdings exist within the catchment) includes the poultry farms)

The main catchment pressure associated with poultry farming relates to the production and spreading of poultry manure as organic fertiliser onto arable land within the catchment. This may be associated with leaching of nitrogen and phosphate into watercourses.

Arable farming:

- The dominant arable farm types within the upper River Wye and River Lugg sub-catchments are ‘general cropping’ and ‘mixed’;
- Horticulture accounts for relatively few holdings (8% and 10% for the upper River Wye and River Lugg catchments respectively);
- Most arable farming in both the upper River Wye and the River Lugg sub-catchments is for wheat (>50% in each sub catchment);
- Oilseed rape comprises the next most extensive crop (11-12%) followed by barley;
- Potato crops comprise smaller portions of arable farm type (8% of arable farms in both sub-catchments)

The England farming data has been assigned the appropriate FARMSCOPER farm type and these are summarised in Table 7-1, alongside additional catchment specific information required for running FARMSCOPER, namely rainfall and soils type.

(The percentages represent the contribution of each individual farm type to the overall livestock or arable phosphate loading in each catchment)

Table 7-1: FARMSCOPER farm types for the English part of the upper River Wye sub-catchment

Catchment	Rainfall	Soil	Livestock	Arable
Upper River Wye	900-1200	Poorly drained	13 % Upland 87 % Lowland Grazing,	47 % Roots and combinable with poultry manure 22 % Mixed combinable 31 % Horticulture
River Lugg	700-900	Poorly drained	17 % Upland 83 % Lowland Grazing,	63 % Roots and combinable with poultry manure 15 % Mixed combinable 22 % Horticulture

7.4.2. A summary of farming data in the Welsh parts of the River Wye catchment

Analysis of the Small Areas data for Wales showed the following key features:

Livestock farming:

- In the Welsh part of the upper River Wye sub-catchment, livestock is dominated by sheep farming, with comparatively little cattle and poultry farming; and
- Poultry is much more important in the Welsh part of the River Lugg sub-catchment, and while sheep numbers remain high, cattle farming appears to become less important.

Arable farming:

- Arable farming in the Welsh part of the upper River Wye catchment is dominated by cereal growing (barley, wheat and other cereals);
- Some land given is over to potato crops, horticulture and 'other crops' which includes bare fallow
- In the upper River Wye, horticulture and potato growing are less significant; instead there is more maize growing and 'other crops'; and
- There is very little arable farming in the Welsh River Lugg; only some barley and some stock feed (46 and 41 hectares respectively).

The Welsh farming data has also been assigned FARMSCOPER farm types and these are again summarised in Table 7-2[6] alongside the additional catchment specific information required for running FARMSCOPER.

(The percentages represent the contribution of each individual farm type to the overall livestock or arable phosphate loading in each catchment)

Table 7-2: FARMSCOPER farm types in the Welsh part of the upper River Wye sub-catchment

Catchment	Rainfall (mm)	Soil	Livestock	Arable
Upper River Wye	900-1200	Poorly drained	100 % Upland Grazing	1% Horticulture 74% Mixed combinable 25% Roots and combinable with poultry manure
River Lugg	700-900	Poorly drained	100 % Upland Grazing	Not significant

Table 7-1 and Table 7-2 represent only a short summary of a full assessment of the farming practices within the catchment is contained, the detail of which is provided in full within Appendix E.

It is recognised that the FARMSCOPER model only sets out standard farm types and does not account for local farming characteristics. To reflect this and make the farming more typical of the Wye and Lugg catchments, the analysis of farm type data, set out above, has been used to make modifications to the FARMSCOPER standard farm types. These modifications are set out in Appendix E.

7.4.3. Modelled phosphate losses from different farm types

FARMSCOPER provides outputs detailing the estimated nutrient losses for any given farm type and soil/rainfall condition. These parameters have been run for the farm types and conditions encountered within the River Wye SAC catchment and the results given in Table 7-3 below. The numbers expressed are as typical phosphate loss from an example farm of that farm type, in that catchment, in Kg P/ yr.

[6] Arable farming in the Welsh part of the catchment consists of mixed combinable and roots and combinable farming, with some Horticulture (1%). The proportion of the mixed versus roots and combinable can in this case not be estimated using the RFT approach taken for the English part of the catchment. Instead the proportion of Roots and Combinable is estimated by considering all potatoes to be grown on this type of farm and the area of wheat grown on the farm is assumed to be the same as in the default farm type. If 1% of arable land is given over to horticulture, 99 % remains for other types of farming, namely 'Mixed Combinable' and 'Roots and Combinable with poultry manure', the relative importance can be estimated with a crop that is distinctive for one or the other type, which in this case is potato growing. All farms that grow potatoes are assumed to grow wheat in the same proportion as in FARMSCOPER; the remaining wheat is considered to be grown on Mixed Combinable farms.

Table 7-3: FARMSCOPER modelled typical phosphate losses for River Wye catchment farm types

		Horticulture	Roots & Combinable with Poultry Manure	Mixed combinable	Upland Grazing	Lowland Grazing
		Numbers are expressed as typical phosphate loss in Kg P/yr				
England	Wye	17	464	533	218	258
	Lugg	8	290	238	143	133
Wales	Wye	17	516	535	172	n/a*
	Lugg	n/a*	n/a*	n/a*	161	n/a*

(*n/a because that farm type is not present in that particular sub catchment)

Options Appraisal

8. Integrated modelling approach

The relative contributions of phosphate from different sectors has been previously outlined in Section 7.3, showing the main phosphate contributing sectors to be sewage treatment works and agriculture. These sectors have therefore been the focus of the options appraisal to understand the potential reductions in phosphates that could be secured by applying measures within these sectors.

Although the focus of the options appraisal has been on the water industry and on the agricultural sector (as these sources contribute the bulk of the phosphate in the source apportionment) it is important to remember that other sources of phosphate exist; for example industrial sources, highways, urban run-off and rural (non-agricultural) diffuse sources for example septic tanks.

For these types of sources no intervention has been tested through this project due to the degree of uncertainty around these contributions and; however in taking the NMP evidence base forwards to formulate an action plan, local level knowledge and data on these sources should be considered to help form the basis of measures to reduce inputs from these sources.

As previously described in Section 7, this assessment has taken an integrated approach to modelling; using a combination of SAGIS to model source apportionment and point source measures, and FARMSCOPER to model agricultural inputs and measures. The approach to modelling is discussed further in the following sections, followed by a chapter setting out the critical assumptions made and the areas of uncertainties in the approach (Section 9).

8.1. Understanding the affect of growth on consented wastewater discharges

8.1.1. Significant consented discharges

Discharge consent data obtained from the Environment Agency has shown that there are 102 consented discharging features contributing phosphate to the area of interest. Some of these consents represent significant wastewater discharges and others represent small industrial or wastewater discharges.

Inclusion of all 102 consented discharges within this study was not considered to be a pragmatic basis to the action plan and hence an analysis of the data was undertaken to identify the “key discharging features”.

Currently the Environment Agency’s criteria for assessing the need for a numeric discharge consent is that if the contribution is <10% of the Environmental Quality Standard (EQS) it is “screened out”. For the purposes of this study, discharges that contribute more than 2% have been selected for inclusion of potential measures within the NMP. The rationale was that this enables a prioritisation of discharges that account for approximately 80% of the input from point sources within the catchment. This is considered to be a conservative approach.

It is recognised that there is some risk with this approach if some of the smaller treatment works (that are currently not large enough to qualify for a Discharge Consent in the above selection process) may expand under the growth plans and actually become significant discharging features once the growth strategy is fully implemented. However, the growth pattern suggested by the current population projections indicates that the bulk of growth will be centred on existing significant wastewater treatment works.

The resulting significant discharging features selected for inclusion within the modelling are presented in Table 8-1 below and shown on Figure 4-1.

Table 8-1: Significant discharging features within the upper River Wye and River Lugg

Catchment	Sewage treatment works	Current DWF (Ml/d)	Population growth adjusted DWF (Ml/d))	Current ave. discharge flow (Ml/d))	Population growth adjusted ave. discharge flow (Ml/d))	Population growth discharge flow uplift (%)
Wye	EIGN STW	8.186	9.403	14.371	16.507	15%
Wye	ROTHERWAS STW	14.885	17.098	23.089	26.522	15%
Lugg	PEMBRIDGE STW	0.013	0.014	0.137	0.142	4%
Lugg	KINGTON STW	0.111	0.119	0.626	0.671	7%
Lugg	LYONSHALL STW	0.045	0.047	0.096	0.100	4%
Lugg	MORETON ON LUGG STW	0.015	0.016	0.560	0.606	8%
Lugg	LUSTON & YARPOLE STW	0.084	0.086	0.144	0.147	3%
Lugg	SHOBDON STW	0.026	0.027	0.195	0.200	3%
Lugg	KINGSLAND STW	0.361	0.370	0.615	0.631	3%
Lugg	WEOBLEY STW	0.029	0.030	0.256	0.262	3%
Lugg	LEOMINSTER STW	1.831	2.605	2.629	3.741	42%
Lugg	PRESTEIGNE STW	0.254	0.291	0.512	0.586	14%
Lugg	BROMYARD STW	0.486	0.547	0.794	0.893	12%

To understand the effects of growth on the in-river phosphate concentrations, the predicted growth pattern and magnitude has been used to scale up the wastewater loads at different WwTW (and therefore the additional input loads to the river reaches). Within Herefordshire, the effect of population growth has been calculated by matching WwTWs to the regions they occur within and uplifting the discharge flows in accordance with the Herefordshire County Council population growth estimate. For example, the population of Hereford has been predicted to grow by 15% and consequently the discharge flows for sewage treatment works within the Hereford region have been increased by 15% from their current actual. Discharge quality has been assumed to be unchanged since it is anticipated that any additional influent volume would be treated to same degree of quality as at present.

The upstream catchment area of the upper River Wye extends beyond Herefordshire into Powys and although population growth in the upstream area is thought to be relatively modest, has been accommodated within the modelling by using population growth projections provided by Powys County Council (via the Environment Agency).

It is recognised that factors may exist in 2027 that mean the river flows are not consistent with current levels, and therefore there is a risk that the dilution capacity of the river at discharging points may be lower.

However, for the purposes of this assessment it has been assumed that, due to its SAC status and the need to preserve the existing levels of flow, river flows will remain reasonably consistent with current levels.

8.2. Modelling the effects of point source measures

The Rivers Wye and Lugg receive phosphate inputs from numerous sewage treatment works within their respective catchments and in advance of any modelling it is necessary to devise a strategy to decide on the sewage treatment works measures (i.e. reductions in discharge concentrations) that may be preferred.

A number of approaches might be applied, for example, measures to control point source inputs may be preferred at the sites that are responsible for the most significant contribution to the in-river phosphate concentration or, alternatively, measures may be preferred at sites where it is cheapest to do so.

In consultation with the project partners, a number of rules were agreed for deciding the treatment works where measures should be simulated. The rules are:

- Sewage treatment works that contribute more than 2% of the total contribution from point source inputs (immediately upstream of the confluence of the River Wye and River Lugg) have been selected as candidates for measures. The rationale was that this enabled a prioritisation of discharges that account for approximately 80% of the input from point sources within the catchment (see section 4).

- Sewage treatment works can achieve a discharge quality of 0.1 mg/L (as an annual average). A discharge quality of 1 mg/L is currently accepted as the achievable limit using the BAT; however, a substantial amount of research is underway to develop new methods. It has therefore been assumed that a discharge quality of 0.1 mg/L will become achievable.

- Measures were preferred at locations where the cost of phosphate removal per kilogram was lowest, using indicative treatment cost information provided by Welsh Water. There is, however, limited information on the cost of treatment to achieve discharge levels below 1 mg/L. For the purposes of modelling it has been assumed that discharge concentrations down to 0.5 mg/L will entail a 50% increase in treatment costs (to achieve discharge levels of 1 mg/L) and discharge concentrations down to 0.1 mg/L will entail a 100% increase in cost.

8.3. Modelling agricultural sources and mitigation measures

To model diffuse source inputs and the effectiveness of measures applied in the agricultural sector, a combination of SAGIS and FARMSCOPER has been used.

FARMSCOPER is a relatively new model developed by Defra and is quickly becoming the industry preferred model for understanding the effectiveness of diffuse mitigation measures applied within the rural sector. It is a relatively simple tool operating within MS Excel and is applied at a farm scale. FARMSCOPER has two distinct functions:

- Firstly it allows the calculation of phosphate loss from an individual farm, for different farm types, soils and climatic conditions; and
- Secondly, it estimates the effectiveness of measures (individual and combinations of measures) to reduce the loss of phosphate from the specific farm that was created in the first function.

Although FARMSCOPER models nutrient losses based on a “typical” farm type basis; this function can also be used to ‘scale up’ to the catchment level and the accuracy of doing this increases with the scale of application. This means that it is useful for looking at larger catchments such as the River Wye SAC sub-catchments defined within this study.

Initially, SAGIS has been used to generate the source apportionment and understand the baseline levels of phosphate attributable to agricultural sources. Thereafter FARMSCOPER has been used to select and the measures that could be applied in the agricultural sector and model the potential reductions in source contributions they could give rise to.

8.3.1. Using FARMSCOPER alongside SAGIS

The FARMSCOPER model is designed to calculate the effectiveness of measures for an individual farm, with the outputs being a percentage reduction in phosphate loss as a result of applying certain measure(s). It is important to note that these percentage reduction factors apply to individual farms, and the relationship between these reductions and in-river reductions is not linear. Therefore, in order to understand how these measures could then affect in-river phosphate concentrations, the FARMSCOPER outputs need to be used as the basis of the SAGIS model. A high level overview of how this has been done is shown below.

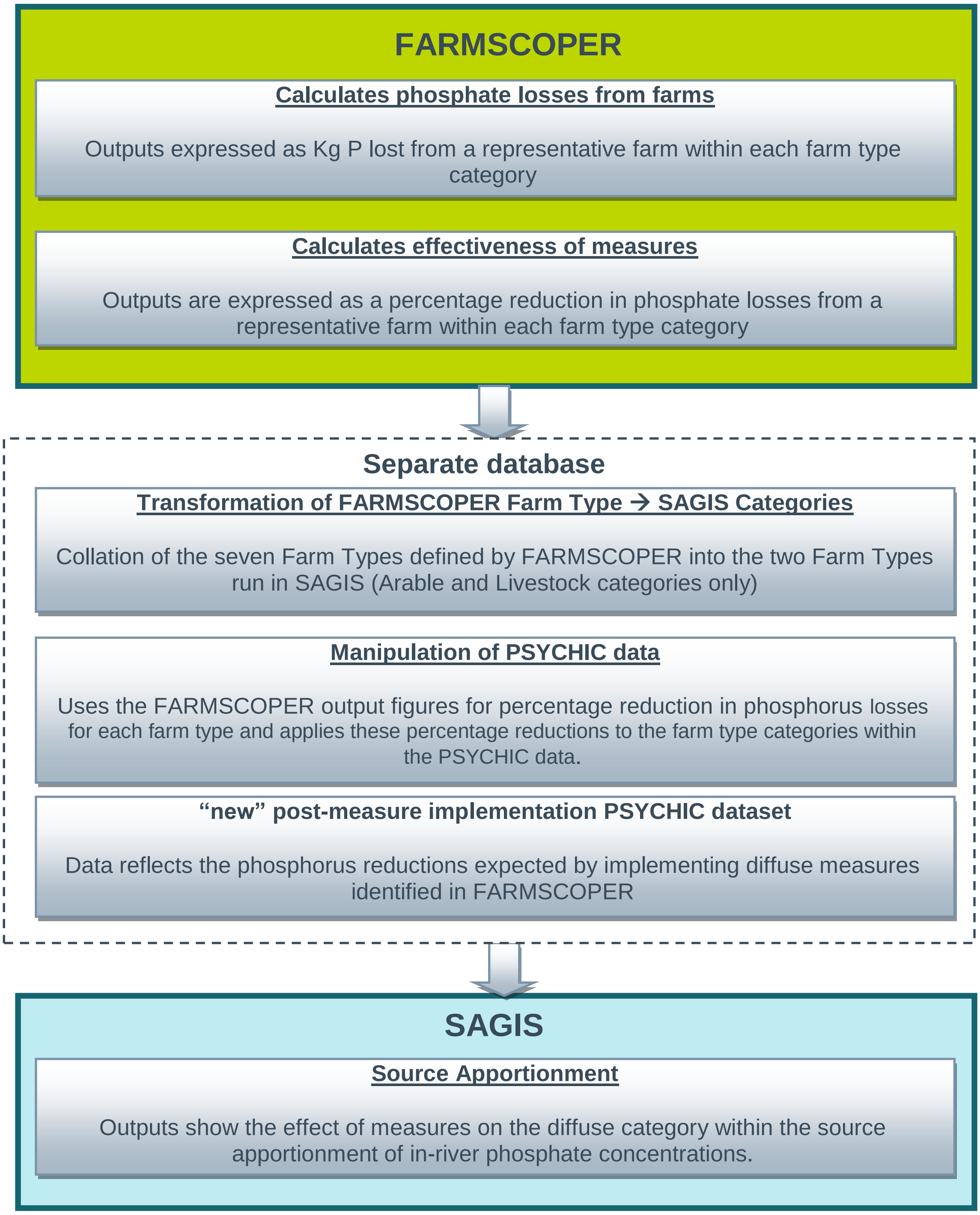

Figure 8-1: FARMSCOPER-to-SAGIS interactions for diffuse modelling

FARMSCOPER operates on an individual farm and farm type basis, whereas SAGIS functions at a simple arable / livestock category level and is applied at a whole-catchment scale. It has therefore been necessary to collate the phosphate reduction potential data from FARMSCOPER into the two categories (arable and livestock) that SAGIS processes within the source apportionment model. This has been achieved by categorising the relevant FARMSCOPER farm types into either the arable or livestock sector, then calculating their relative importance within that sector using the catchment specific information obtained from the Defra and Welsh Government agricultural census data.

The arable sector for example is made up of 'Horticulture', 'Mixed combinable' and 'Roots and Combinable' farm types and the proportion in which each farm type is present in the catchment is given in Figure 2-2. By considering the relative importance of each arable farm type, the maximum impact that any set of measures for each farm type can have in the catchment can be calculated. Summing the relative impact for each arable farm type then gives an overall factor that can be applied to the arable sector in SAGIS. The same approach is taken for the livestock sector using the 'Upland Grazing' and 'Lowland Grazing' farm types.

8.3.2. Agricultural scenarios run using FARMSCOPER

Three different packages of diffuse measures have been selected as agricultural diffuse measure "scenarios" to be taken forward in the combined point and diffuse assessment and presented in the options appraisal. :

- The **"Catchment Sensitive Farming Officer" (CSFO)** recommended package of measures
- The **"Top5 measures"** for reducing phosphate losses on different farm types as recommended by the FARMSCOPER Optimiser function for individual farm types relevant in the catchment.
- The "**Optimiser maximum**" combination of measures as recommended by FARMSCOPER for the relevant farm types in the catchment which allows the calculation of an optimal suite of mitigation measures to model the maximum reduction in phosphate loss that can potentially be achieved (i.e. an upper bound estimate).

8.3.2.1. Catchment Sensitive Farming Officer (CSFO) recommended measures

The CSFOs active in the River Wye catchment have established a combination of measures that have been recommended to be effective in mitigating diffuse water pollution from agriculture and contain measures that are commonly taken up by the farmers they advise.

The CSFO list of measures applies to both the arable and livestock farming separately and these measures have been entered manually into FARMSCOPER for each relevant farm type in order to estimate the potential effectiveness (in terms of phosphate loss reduction) for each farm type represented in the catchment. The combinations of measures being recommended by the CSFOs are set out in Table 8-2 below.

Table 8-2: CSFO recommended measures for FARMSCOPER modelling

Measures recommended by CSFOs for arable farming
Do not apply phosphate fertiliser to high phosphate index soils
Integrate fertiliser and manure nutrient supply
Establish riparian buffers trips
Cultivate compacted tillage soils
Adopt reduced cultivation systems
Early harvesting and establishment of crops in autumn
Re-site gateways away from high-risk areas/
Farm track management
Fertiliser spreader calibration/Manure spreader calibration
Manage (not avoid) over-winter tramlines
Establish and maintain artificial wetlands/ establish in-field grass buffer strips on tillage land
Measures recommended by CSFOs for Livestock farming
Do not apply P fertiliser to high P index soils
Integrate fertiliser and manure nutrient supply
Minimise the volume of dirty water (and slurry) produced
Fence off rivers and streams from livestock
Loosen compacted soil layers in grassland fields
Re-site gateways away from high risk areas/
Farm track management
Fertiliser spreader calibration/Manure spreader calibration
Cover solid manure stores with sheeting

Full descriptions of these measures are available at
http://www.adas.co.uk/LinkClick.aspx?fileticket=vUJ2vlDHBjc%3D&tabid=345

8.3.2.2. The "Top 5" most effective measures selected by FARMSOPER

The Optimiser Max function has been used to identify the set of measures that is likely to produce the biggest reduction in phosphate loss for each farm type in the catchment. However the implementation of this scenario is potentially not realistic, so the outputs have been used to identify a set of measures that is perhaps more workable by restricting the list of measures to the "Top 5" most effective measures relevant to each farm type present within the catchment. These measures have then been modelled separately in FARMSCOPER to understand the likely reductions that could be gained from implementing them as a standalone combination on each farm type.

The "Top 5" measures for each farm type are listed in Table 8-3 below, along with the catchment to which they apply.

Table 8-3: "Top 5" measures for each farm type used in FARMSCOPER modelling

Farm type: Horticulture	River Wye	River Lugg
Establish cover crops in the autumn	Y	Y
Adopt reduced cultivation system	Y	Y
Cultivate compacted tillage soils	Y	Y
Establish riparian buffer strips	Y	Y
Loosen compacted soil layers in grassland fields	Y	Y
Farm type: Roots and combinable	**River Wye**	**River Lugg**
Establish cover crops in the autumn	Y	Y
Adopt reduced cultivation system	Y	Y
Allow field drainage systems to deteriorate	Y	Y
Use a fertiliser recommendation system	Y	Y
Incorporate manure into the soil	Y	Y
Farm type: Mixed combinable	**River Wye**	**River Lugg**
Establish cover crops in the autumn	Y	Y
Adopt reduced cultivation system	Y	Y
Establish riparian buffer strips	Y	Y
Store solid manure heaps on an impermeable base and collect effluent	Y	Y
Incorporate manure into the soil	Y	Y
Farm type: Upland grazing	**River Wye**	**River Lugg**
Do not spread FYM to fields at high-risk times	Y	Y
Capture dirty water in dirty water store	Y	Y
Use dry cleaning techniques to remove solid waste from yards prior to cleaning	Y	Y
Establish and maintain artificial wetlands – steadying runoff	Y	Y
Fence off rivers and streams from livestock	Y	Y

Farm type: Lowland grazing	River Wye	River Lugg
Do not spread FYM at high risk times	Y	Y
Avoid spreading manufactured fertiliser to fields at high risk times	Y	Y
Fence off rivers and streams from livestock	Y	Y
Do not apply P fertiliser to high P index soils	Y	Y
Uncropped cultivated areas	Y	Y

8.3.2.3. The "Optimiser Maximum" combination of measures selected by FARMSOPER

In addition to manually selecting specific measures or combinations of measures, as in the CSFO scenario defined in the previous section, FARMSCOPER also has the functionality to automatically select the optimal combination of measures for any given pollutant and farm type and rank the measures based on their effectiveness. This is termed the "Optimiser" function within the model and comes with an accompanying function that considers implementation cost. The output of the Optimiser consists of multiple sets of combinations of mitigation measures with their associated effectiveness from which a relevant combination can be selected, for example based on cost.

In this scenario, the set of measures that is predicted to give the greatest phosphate reductions is selected to represent the maximum reduction of phosphate loss that can be achieved if all the relevant measures are applied to every single farm in the catchment. These sets of measures, termed 'optimiser max' outputs are summarised for all farm types in Appendix E.5.1.

> It should be noted that FARMSCOPER only models certain measures contained within the diffuse pollution mitigation manual (ADAS et al., 2011) and furthermore it does not select measures that require major land use change, such as arable reversion to grassland. It also does not take account of all agricultural diffuse measures that exist outside of the ADAS manual, for example catch ponds and drainage ditches, which could help secure significant reductions in phosphate losses and should be considered in future as an option in the NMP.
>
> For the purposes of this assessment, FARMSCOPER has been applied to identify and understand the broad issues for discussion and further action. It is considered a good starting point to understand the scale of improvements that could be made by further contribution from the agricultural sector. This approach will be further refined through future iterations of the NMP and in taking measures forward.

8.3.3. Consideration of poultry manure

The issue of poultry manure in the catchment has previously been raised by stakeholders, with concerns regarding its widespread use as a fertilizer on arable land.

The agricultural census data from Defra does contain records of location of poultry farms and estimated numbers of birds, however, Defra suppresses data in water bodies where there are fewer than five holdings, so the number of poultry farms could potentially be under estimated in the modelling. The Defra census data is however still considered best available data in the absence of other evidence.

Poultry manure is considered within the FARMSCOPER model which assumes that the manure from all livestock is spread appropriately on to arable / grass given a preference (i.e. poultry to arable), but taking account of the constraints of the relative amounts of arable / grassland available. So even though its effect, in terms of the source apportionment is contained within the 'livestock' (source) sector (due to the way SAGIS works), the poultry muck would mostly have been applied to arable land.

It is recognised that a standard approach such as this may not suitable reflect the nature of every poultry and arable farm within the catchment, as every farm is different. For example there are likely to be some arable farmers who do not use poultry manure, and indeed some of the poultry manure may be taken outside of the catchment from which it is generated. However, for the purposes of this assessment (which is considered high level and a first step in the process to understanding the phosphate losses, source apportionment and potential measures contributions from different sectors) this approach is considered the most pragmatic, with further refinement recommended in future iterations of the NMP when more fine scale data poultry farming within the catchment may become available.

This is also an important point when considering measures to address phosphates, because targeting measures to address the issue of poultry manure may be spread between the source sector (livestock) and the use sector (arable).

8.4. Modelling scenarios

A scenarios approach was applied to test the effectiveness of a range of measures that might be applied by the Water Industry and Agriculture. The scenarios were developed in consultation with Natural England and the Environment Agency and were intended to:

- Quantify the probable impact of effluent discharges under the permitted conditions (i.e. what impact might permitted conditions have on water quality without population growth).
- Quantify the probable impact of population growth on water quality in the River Wye and River Lugg.
- Identify a pragmatic set of measures that could realistically be implemented and that would ensure concentrations of phosphate did not exceed the requisite levels in the River Wye and River Lugg.

The scenario outputs were evaluated at locations on the River Wye and the River Lugg immediately upstream of the confluence of the River Wye and River Lugg (i.e. the locations that represents that complete catchments). The scenarios are described in Table 8-4 below.

Table 8-4: Description of modelling scenarios

Scenario	Description
S1	Simulate the in-river phosphate concentration (immediately upstream of the confluence of the River Wye and River Lugg) under current discharge conditions
S2	Simulate the in-river phosphate concentration (immediately upstream of the confluence of the River Wye and River Lugg) under permitted discharge conditions (discharge flow and quality)
S3	Simulate the in-river phosphate concentration (immediately upstream of the confluence of the River Wye and River Lugg) under permitted discharge quality conditions using the actual discharge flow (permitted discharge flow conditions often incorporate a significant amount of ‘headroom’ to accommodate future increases in discharge flows arising from an increase in in-flows due to population growth).
S4	Simulate the in-river phosphate concentration (immediately upstream of the confluence of the River Wye and River Lugg) under permitted discharge quality conditions with discharge flows uplifted to reflect population growth impacts (uplifted in line with County Council population increase projections).
S5	Simulate the effect of controls on inputs from sewage treatment works only (refer to Section 8.2)
S6	Simulate the effect of the **CSFO** recommended measures to control inputs from agriculture (refer to Section 8.3.2.1), with further controls on inputs from sewage treatment works applied (following the approach described in Section 8.2) to make up any shortfall.
S7	Simulate the effect of the ‘**Top 5’** recommended measures to control inputs from agriculture

	(refer to Section 8.3.2.2), with further controls on inputs from sewage treatment works applied (following the approach described in Section 8.2) to make up any shortfall.
S8	Simulate the effect of the FARMSCOPER **optimiser** recommended (“optimiser max”) measures to control inputs from agriculture (refer to Section 8.3.2.3), with further controls on inputs from sewage treatment works applied (following the approach described in section8.2) to make up any shortfall.

9. Critical assumptions and uncertainty

Four important considerations have been core to development of the scenarios:

1. **Conservation target levels**
The target phosphate levels for conservation objectives differ in different parts of the River Wye SAC catchment (Section 3.1) and as a result of this the scenarios have been applied to assess potential compliance with the standards at two points within the river:

a) The River Wye immediately upstream of the confluence with the River Lugg (0.03mg/l SRP)
b) The River Lugg immediately upstream of the confluence with the River Wye (0.05mg/l SRP)

2. **Qualifying discharging features**
Due to the large number of discharging features within the catchments (>100) only discharges that contribute >2% of the in-river concentration (in each of the areas of interest) have been considered eligible for measures to control discharges.

3. **Future technology**
A further important consideration is that since this project is investigating potential impacts on water quality that might occur far out into the future (up until 2031), it is also reasonable to take into account how technological development and innovation aimed at enhancing phosphate removal at sewage treatment works might influence decision making in the present.

4. **Future diffuse agricultural contributions of phosphorus**
As set out in Section 5.3, agricultural practices are expected to evolve of the timeframes of this NMP and future changes in agricultural practices are likely to result in different levels of phosphate contributions to the River Wye SAC. However, the exact nature of the change is not yet known and therefore this issue has not been considered further here but should be considered through future iterations of the NMP. It has therefore been assumed that the current contributions of agricultural phosphorus will continue through the timeframes of this NMP.

9.1.1. Taking account of uncertainty

The use of computer modelling to make predictions about environmental systems is well established and undertaken in many environmental disciplines; however, an important consideration in the application of any computer modelling approach is that decision makers should understand the critical assumptions and elements of uncertainty associated with the model outputs. The critical assumptions and important elements of uncertainty that have been identified that are relevant in this project are listed in Table 9-1 and Table 9-2 respectively.

Table 9-1: Critical assumptions

No.	Assumption	Risk
1	**Total phosphorus / orthophosphate:** 90% of the consented total phosphorus (TP) discharge concentration has assumed to be in (bioavailable) orthophosphate (PO4) which has been used to evaluate the impact of the discharge on river quality (discharge consents are currently expressed as Total phosphorus).	The fate of phosphorus in the aquatic environment is complex. The assumption that 90% of the total phosphorus concentration is in orthophosphate form may be overly conservative since treatment technologies such as ferric dosing have been demonstrated to substantially reduce the proportion of phosphorus that is in (bioavailable) orthophosphate form. Consequently, suggested discharge consent limits may be more stringent than necessary.
2	**"Significant" point source discharges:** Point source discharges considered 'significant' have been limited to those contributing more than 2% of the total sewage treatment works contribution within the regions of interest. The rationale was that this enables a prioritisation of discharges that accounted for approximately 80% of the input from point sources.	This approach might 'sweep in' relatively small point source discharges at which measures to improve discharge quality might not be practicable.
3	**Future wastewater treatment technology**: This study concerns population growth projections into the future, and so when considering the effects of this on wastewater flows to inform treatment options it is considered fair to take account of the technology that is expected to be available in the future to mitigate these future pressures on wastewater capacity and quality. For the purposes of this study it has therefore been assumed that future technology will be capable of delivering a 0.1 mg/l TP/L limit and the scenario modelling within this study has been undertaken based on this principle.	This is the current industry understanding of what may be available in the future, not what is available now.
4	**Phosphorus losses from typical farms within the catchment**: FARMSCOPER allows the user to model the loss of phosphate from agricultural land at the farm level, in kg P/year. For the purpose of this high level assessment, it is not considered feasible to model the phosphate loss for every single farm in a catchment of this scale. An assumption has therefore been made that for every farm with a specific farm type, the phosphate loss is the same, generally with farms all managed in the same way, with the exception of NVZ requirements (see point 6 below).	This approach may either overestimate or underestimate the overall amount of phosphate lost from a particular farm type at the catchment level.
5	**Soils in the catchment** are generally "free draining" but tend to be heavily compacted through agricultural activities. This influences the pathway of phosphates to surface waters. FARMSCOPER allows the user to set the percentage of phosphate that will be lost from farm land by a particular pathway and therefore takes into account soil type. However,	The risk associated with this approach is that the effectiveness of measures could be underestimated

No.	Assumption	Risk
	considering the size and variability of the catchment this cannot be done at an acceptable level of detail when FARMSCOPER is applied at the catchment level. For this assessment FARMSCOPER has been modelled for poorly draining soils drained for arable and/or grassland.	
6	**Prior implementation of diffuse source measures**: Work is already being done in the agricultural sector to reduce nitrate pollution through Nitrate Vulnerable Zone regulations. Many of these measures will also help reduce phosphate loss to water courses. The River Wye SAC catchment is largely within an NVZ. Therefore, to reflect this contribution, it has been assumed that NVZ regulations are being implemented according to the requirements. This has been accounted for in the FARMSCOPER modelling. Outside of the NVZ, "typical practice" is assumed. Both the NVZ and the typical practice "prior implementation" functions are automatic functions in FARMSCOPER that applies a certain level of uptake of mitigation measures according to the assumptions in the model. The relatively modest 1.6% effectiveness figure from the ECSFDI project (Section 6.2.4) has not been included in this "prior implementation" approach.	The risk associated with this approach is that we do not know how well the FARMSCOPER model assumptions reflect the actual practice within the River Wye SAC catchment and so it could either over estimate or underestimates the effectiveness of measures already being implemented.
7	**Future land management mitigation methods:** This study uses the FARMSCOPER model to select mitigation measures to apply to arable land. The model does not consider any new or emerging land management practices as mitigation methods that may be available in the future; it is based on the Defra Mitigation methods user manual (ADAS, 2011).	Future methods may be capable of delivering greater benefits and so there is a risk that this assessment may under estimate the effect of measures that may become available in the future.

Table 9-2: Important elements of uncertainty

Uncertainty	Description
Agricultural inputs	Estimates of agricultural inputs are based on the best and most up-to-date information, namely, the ADAS PSYCHIC model output which is, in turn, based on data obtained in the 2010 agricultural census data. Land use and agricultural practises might be subject to significant change in the period up until 2031. Furthermore, the approach does not take account of variables such as: different farms being managed differently (with the exception of NVZ requirements which have been included); different topography and land drainage characteristics; seasonal variations in rainfall and livestock / land management etc.
Climate change	Impacts attributable to climate change (e.g. on river flows and land use/management) are anticipated although the impact on water quality is uncertain.
Phosphate ban in laundry and dishwasher detergents	The detergent sector is required by Defra to stop using phosphorus based chemicals in laundry detergents from 2015. The EU has also approved Regulation Number 259/2012 which will restrict the use of phosphates in laundry detergents from June 2013 and in dishwater detergents by 2017. Estimates suggest that inputs from laundry and dishwasher detergents represent 7.5% and 9%, respectively, of phosphorus inputs into sewage treatment works and consequently these bans on usage are likely to result in a

Uncertainty	Description
	decrease in the concentration of phosphorus in discharges (at sewage treatment works where some form of phosphorus treatment is NOT in place). The extent of any actual reduction in discharge concentrations is, however, uncertain.
Precision of model estimates	Whereas the predicted average in-river concentration is typically of greatest interest since this is the value used to assess compliance, the model outputs also provide a confidence interval range for the prediction which takes into account a broad range of uncertainties associated with the data used by the model. The confidence interval ranges in the model predictions are typically between 25% and 50% of the predicted average in-river concentration.
Confidence in population growth estimates	Long term population growth estimates are subject to a high degree of uncertainty and are (recognisably) difficult to determine with a high degree of accuracy.
Improvements in the understanding of environmental sensitivity to phosphorus	New standards have recently been proposed for phosphorus and it is at least feasible that, in light of further new evidence (in future), some revision to conservation objectives might be considered (either more or less stringent).

9.2. Input data sources and constraints

Several key datasets have been used as the basis of the modelling. The main datasets and models used within this NMP are outlined in Table 9-3 below.

Table 9-3: Key datasets and models used within the evidence base

Data / Model	Source	How has it been used
Point source consents	Environment Agency	Consented discharges for flow and quality: to understand the key "significant discharging features" within the catchment and the flow and quality at which they are permitted to discharge
Phosphate water quality data	Environment Agency	These data are already contained within the SAGIS model and has been used to understand the baseline phosphate levels in the water courses of interest.
PSYCHIC	Defra	A Defra-funded, process-based model of phosphate and sediment mobilisation and delivery to watercourses. Transfer pathways include dissolution of soil phosphate, detachment and mobilisation of sediment and associated particulate phosphate, incidental losses from manure and fertiliser applications, losses from hard standings, and transport to watercourses in under-drainage (where present) and via surface pathways. These data have been used as the basis of the SAGIS modelling. Details of the approach, assumptions and data used in PSYCHIC can be found in Davison et al. (2008) and Stromqvist et al. (2008).
Population growth	Herefordshire CC	To underpin the growth projection scenarios in the modelling tasks.
Agricultural	Defra	Defra census data on agricultural farm types in England,

Data / Model	Source	How has it been used
census data		used to understand farming activities in England (2010 data).
Small Areas	Welsh Government	Agricultural data on farm type in Wales used to understand farming activities in that portion of the catchment (2010 data).
SAGIS	UKWIR, EA and SEPA developed	This tool is able to quantify the loads of pollutants to surface waters in the UK from 12 point and diffuse sources including wastewater treatment works discharges, intermittent discharges from sewerage and runoff, agriculture, soil erosion, mine water drainage, septic tanks and industrial inputs (UKWIR project WW02). Loads are converted to concentrations using the SIMCAT water quality model which is incorporated within SAGIS so that the contribution to in-stream concentrations from individual sources can be quantified. This approach allows an assessment of the extent by which substance concentrations may be at risk of exceeding Environmental Quality Standards (EQSs) and an apportionment of the substance concentration by source Details of the approach, assumptions and data used in SAGIS can be found in Comber et al. (2013).
FARMSCOPER		FARM SCale Optimisation of Pollutant Emission Reductions (Goodhay and Antony, 2010) is a Defra-funded tool that collates more than a decade of UK scientific research on farm scale pollutant loads and the effects of different mitigation methods on losses of phosphate, nitrogen and sediment. Estimates of the costs and effectiveness of different measures area also provided for each of the Defra Robust Farm Types. Over 100 mitigation methods, including those listed in the latest Defra Mitigation Method User Guide (Defra Project ES0203), are included within the tool. FARMSCOPER produces farm scale outputs that can be scaled up to provide estimate of agricultural diffuse pollution and the effectiveness of potential mitigation methods at the catchment scale. Details of the approach, assumptions and data used in FARMSCOPER can be found in Gooday and Anthony (2010). Zhang et al. (2012), Gooday et al (2013) provide examples of how the tool has been applied elsewhere.

9.3. Best available data and models

The critical assumptions made in the approach, and constraints of the data used have been set out in section 9; however it is important to note that despite these constraints, this methodology is considered to use the best available data and models at the time of undertaking this study. It is recognised that improvements could be made if better data were available locally and these points will be considered through further iterations of the NMP in the future.

10. Population growth impacts

10.1. Additional point source contributions under the growth scenario

The population growth impacts on water quality in the upper River Wye and River Lugg are provided in Figure 10-1 and Figure 10-2 respectively. The population growth scenario results (S4) are provided alongside the results for a number of other scenarios that are described in Table 10-1 for context.

The 'difference' portion on the bar charts represents the increase in in-river concentration that might occur in relation to the current position[7]. The basis upon which population growth has been represented within the SAGIS modelling is described in detail elsewhere in this report although a short explanation is included here to assist with the interpretation of the results. Briefly, discharge flows from sewage treatment works have been uplifted in-line with the population growth forecasts provided by Powys and Herefordshire County Councils and the discharge concentrations simulated at the level indicated by the discharge permit (where these are in place) or at the observed discharge quality.

The permitted concentration limits have been used in the point source simulation since these represent a set of conditions that might plausibly occur. It is notable that sewage treatment works with discharge permits in place typically discharge at concentrations below what the permit requires, which allows the treatment works operator 'headroom' to manage any outages or unforeseen dips in treatment works performance although for the purposes of assessing risk it is appropriate to use the permitted discharge limits.

For the upper River Wye (Figure 10-1) the data show that whilst the water quality objective is currently being achieved (albeit close to the standard) under the current discharge conditions, discharges at the permitted levels are likely to result in the water quality objective being exceeded (S2 and S3). The results also indicate that the in-river water quality objective is likely to be exceeded under the population growth scenario (S4). It is, however, notable that even without an increase in population it is probable that the water objective for the upper River Wye would be exceeded if the sewage treatment works in the upstream catchment discharged up to the limit that the discharge permits allow. For example, the result for S2 suggests an increase in the in-river concentration of up to 20 µg/L and for S3 and increase of 16 µg/L. The difference between the results for S3 and S4 represents the potential increase attributable to population growth alone. This difference (4 µg/L) is substantially smaller than the increase than might occur under permitted conditions even in the absence of population growth. The potential impact on water quality attributable to population growth might more accurately be considered to exacerbate an existing water quality challenge, rather than representing the only source of risk.

For the River Lugg (Figure 10-2) the data show that the water quality objective is not being achieved under the current discharge conditions. Furthermore, the incremental increase in the in-river phosphate concentration attributable to population growth (the difference between S3 and S4) is small (2 µg/L) in relation to the extent to which the modelling predicts the water quality objective is currently being exceeded (>10 µg/L). As for the upper River Wye, the potential impact on water quality attributable to population growth exacerbates an existing water quality challenge, rather than representing the only source of risk.

[7] The rationale for this is based on feedback from Welsh Water during the NMP stakeholder meeting in October 2013, highlighting that many of the WwTW in the area are currently discharging significantly lower than their permitted levels and so adding population growth on to the fully permitted level could result in a significant over estimation of growth impacts.

Table 10-1: Scenario descriptions

Scenario	Description of scenario
S1	Predicted in-river phosphate concentration (immediately upstream of the confluence of the River Wye and River Lugg) under current discharge conditions
S2	Predicted in-river phosphate concentration (immediately upstream of the confluence of the River Wye and Lugg) under permitted discharge conditions (discharge flow and quality)
S3	Predicted in-river phosphate concentration (immediately upstream of the confluence of the River Wye and Lugg) under permitted discharge quality conditions using the actual discharge flow (permitted discharge flow conditions often incorporate a significant amount of 'headroom' to accommodate future increases in discharge flows arising from an increase in in-flows due to population growth).
S4	Predicted in-river phosphate concentration (immediately upstream of the confluence of the River Wye and Lugg) under permitted discharge quality conditions with discharge flows uplifted to reflect population growth impacts (uplifted in line with County Council population increase projections).

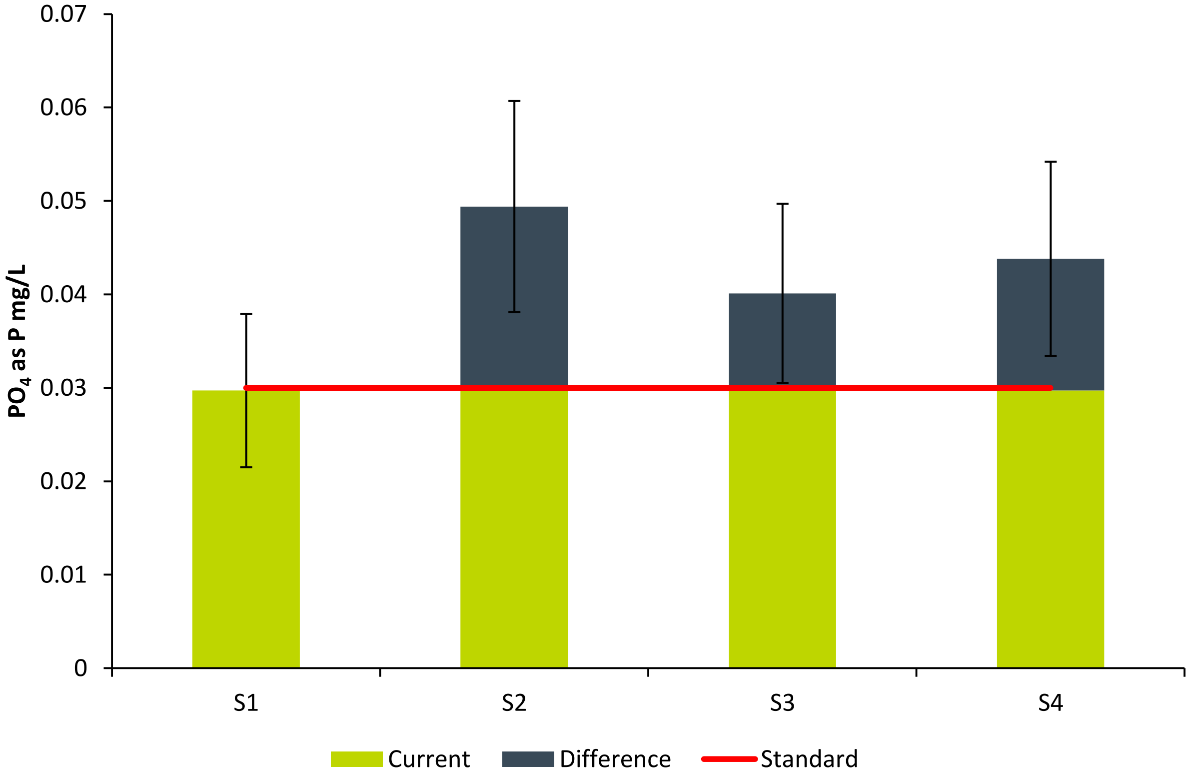

Figure 10-1: Projected increase in the in-river phosphate concentration in the River Wye immediately upstream of its confluence with the River Lugg under a range of discharge conditions, including in response to population growth.

The error bars represent the 95% confidence interval range of the predicted average concentration.

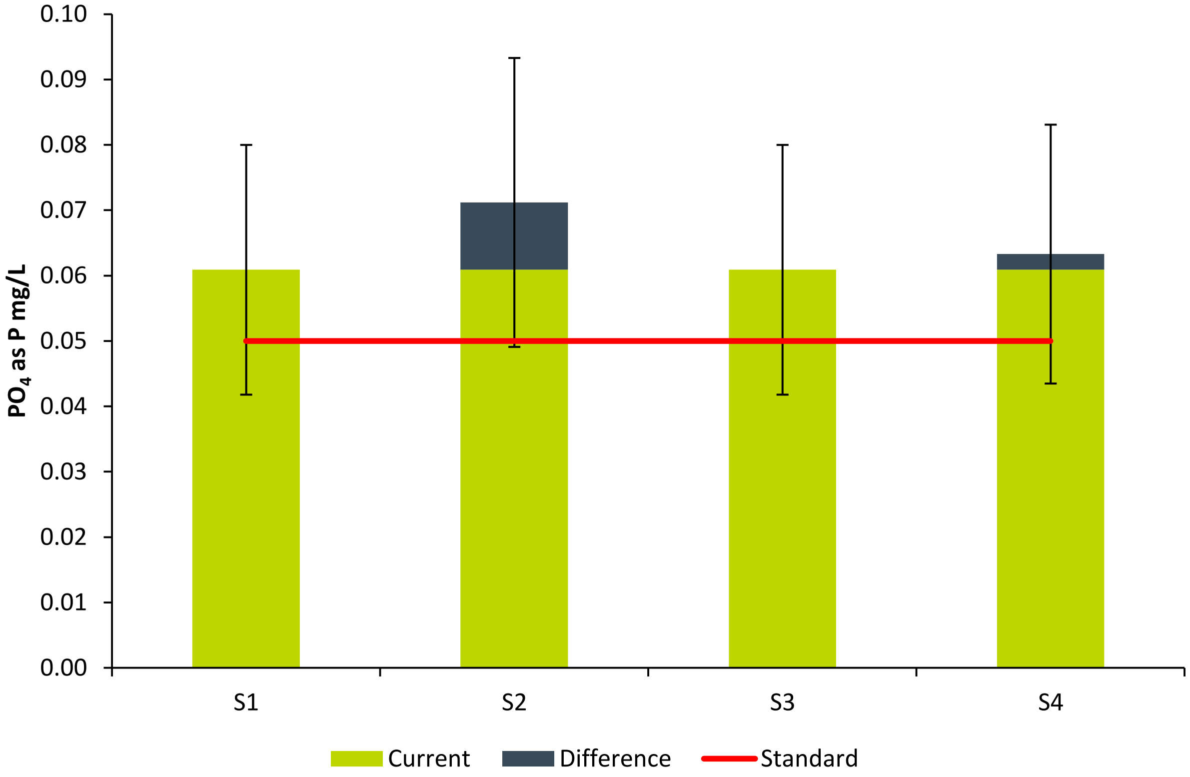

Figure 10-2: Projected increase in the in-river phosphate concentration in the River Lugg immediately upstream of its confluence with the River Wye under a range of discharge conditions, including in response to population growth.

The error bars represent the 95% confidence interval range of the predicted average concentration.

11. Measures to control agricultural sources

11.1. FARMSCOPER scenario modelling outputs

This section deals with the results of the FARMSCOPER modelling and presents the potential effects that could be seen by applying agricultural measures in isolation rather than alongside any point source measures. The outputs from the FARMSCOPER modelling of the three are presented as percent reductions in phosphate losses from individual farms. Prior implementation of NVZ measures has been accounted for, and outside of the NVZ area "typical practice" has been modelled, recognising the current situation. The results are provided separately for the English and the Welsh sub-catchments in Table 11-1 below.

Table 11-1: Effectiveness of measures calculated for the FARMSCOPER scenarios.

Country	Sub-catchment	Rain (mm)	Soil type	Farm Type	CSFO % reduction in farm level P loss	Top 5 % reduction in farm level P loss	Optimiser maximum % reduction in farm level P loss
England	Wye	900-1200	Drained for arable	Horticulture	43	40	38
				Roots and combinable*	17	20	47
				Mixed combinable	15	32	41
			Drained for grassland	Upland grazing	4	16	26
				Lowland grazing	6	12	22
	Lugg	700-900	Drained for arable	Horticulture	40	40	44
				Roots and combinable*	14	17	47
				Mixed combinable	12	33	43
			Drained for grassland	Upland grazing	5	18	28
				Lowland grazing	6	13	22
Wales	Wye	900-1200	Drained for arable	Horticulture	43	44	38
				Roots and combinable*	23	26	53
				Mixed combinable	16	36	46
			Drained for grassland	Upland grazing	4	11	23
	Lugg	700-900	Drained for grassland	Upland grazing	5	12	24

* Roots and combinable with poultry manure

11.2. Scaling up FARMSCOPER outputs to the catchment level

The reduction factors from FARMSCOPER set out in Table 11-2 have been collated into the categories required to run in SAGIS according to the methodology set out in Section 8. These data are presented in Table 11-2 below. The numbers indicate the percent reductions in phosphate losses achievable by applying the agricultural scenarios to the appropriate farm types in the catchment.

Table 11-2: Percentage reduction in phosphate loss from farms from recommended measures for livestock and arable farming in the Wye catchment

Country	Sub-catchment	SAGIS category	CSFO (% reduction in P loss from farms)	Top 5 (% reduction in P loss from farms)	Optimiser maximum (% reduction in P loss from farms)
England	Wye	Arable	22	26	43
		Livestock	5	12	23
	Lugg	Arable	23	25	43
		Livestock	6	13	23
Wales	Wye	Arable	18	33	48
		Livestock	4	11	23
	Lugg	Livestock	5	12	23

These data indicate that;

- The effectiveness of the measures applied to the arable sector is far greater than the effectiveness of the measures applied to the livestock sector;
- The CSFO scenario is the least effective in both the arable and livestock categories;
- The Optimiser Maximum scenario is the most effective in both livestock and arable categories; and
- The Top 5 scenario sits between the CSFO and the Optimiser Max with respect to percent effectiveness.

However, it is important to note that these percentages relate to effectiveness of measures on a farm basis and although these data indicate that the greatest percent reductions could be achieved by applying measures in the arable sector, it is important to consider the relative contributions of the arable and livestock sectors to the overall source apportionment within the catchment. The modelling at this stage suggests that large percentage reduction could be achieved by applying measures in the arable sector, however the source apportionment shows that arable is not the major contributor of phosphate in the first place.

This is why these reduction factors have been applied within the source apportionment modelling, to take account of their relative contributions to the phosphate levels in the river and to represent the effectiveness of measures at a catchment level.

11.3. Contextualising phosphate contributions – what does this mean in real terms?

The potential reductions of phosphate from agriculture so far have been expressed in terms of percentage reduction factors. In order to contextualise these percentages, the table below shows what these reductions could mean in terms of absolute values (expressed in kg P/year). Table 11-3 lists the amount of kg phosphate that FARMSCOPER calculates is typically lost per year from each farm type in the catchment. From these the number of kilograms by which phosphate loss can be reduced per year has then been calculated for each scenario.

These Kg P/yr figures are only provided for context and have not been used in the assessment. Please refer to Section 8.3 for full methodology.

Table 11-3: Phosphate reduction factors from agricultural measures expressed in Kg P/yr

				CSFO		Top 5		Optimiser maximum	
Farm type	Country	Sub-Catchment	Phosphate loss	Effectiveness of measures	Reduction of Phosphate loss	Effectiveness of measures	Reduction of Phosphate loss	Effectiveness of measures	Reduction of Phosphate loss
			in kg/year	in %	in kg/year	in %	in kg/year	in %	in kg/year
Horticulture	England	Wye	17	43	7	40	7	38	6
		Lugg	9	40	3	40	3	44	4
	Wales	Wye	17	43	7	44	7	38	6
		Lugg	n/a*						
Roots and combinable with poultry manure	England	Wye	464	17	78	20	93	47	218
		Lugg	290	14	40	17	50	47	137
	Wales	Wye	516	23	117	26	134	53	272
		Lugg	n/a*						
Mixed combinable	England	Wye	533	15	77	32	168	41	220
		Lugg	328	12	40	33	109	43	141
	Wales	Wye	535	16	86	36	191	46	247
		Lugg	n/a*						
Upland grazing	England	Wye	218	4	10	16	35	26	56
		Lugg	143	5	7	18	26	28	41

	Wales	Wye	172	4	7	11	19	23	39
		Lugg	161	5	8	12	19	24	39
Lowland grazing	England	Wye	258	6	15	12	30	22	57
		Lugg	133	6	8	13	17	22	29
	Wales	Wye	n/a*						

11.4. Impact of agricultural measures on in-river concentrations

As previously mentioned in Section 8.3.1, the relationship between nutrient losses on a farm basis and in-river nutrient concentrations is not linear. Therefore, in order to understand how the potential reductions suggested by FARMSCOPER could affect in-river phosphate concentrations within the River Wye SAC, SAGIS modelling has been carried out using the potential reductions in phosphate indicated by the FARMSCOPER modelling.

The reduction factors associated with the different agricultural scenarios have been applied to the agricultural land within England only; this is an Environment Agency and Natural England joint implementation strategy it is not appropriate to specify measures to be implemented in Wales. Any measures implemented by Natural Resources Wales and by the Welsh farming community could however provide further benefit in terms of phosphate reductions downstream in England.

The following scenario outputs are presented:

- Baseline situation, assuming NVZ measures taken up where required and typical practice elsewhere;
- Reduction of phosphate loss as a result of the implementation of the CSFO recommended measures;
- Reduction of phosphate loss through implementation of the Top 5 selected measures; and
- Reduction of phosphate loss through the optimiser max recommended combination of measures

The impact of these three scenarios on the apportionment of phosphate in the catchment is presented in Figure 11-1 and Figure 11-2. Table 11-4 numerically summarises the reductions in in-river phosphate concentration for each scenario relative the baseline.

These graphs present the change in apportionment relative to the current position resulting from the application of agricultural measures only in order to provide an understanding of the potential effectiveness of measures applied only in the agricultural sector. It does not consider the application of point source measures.

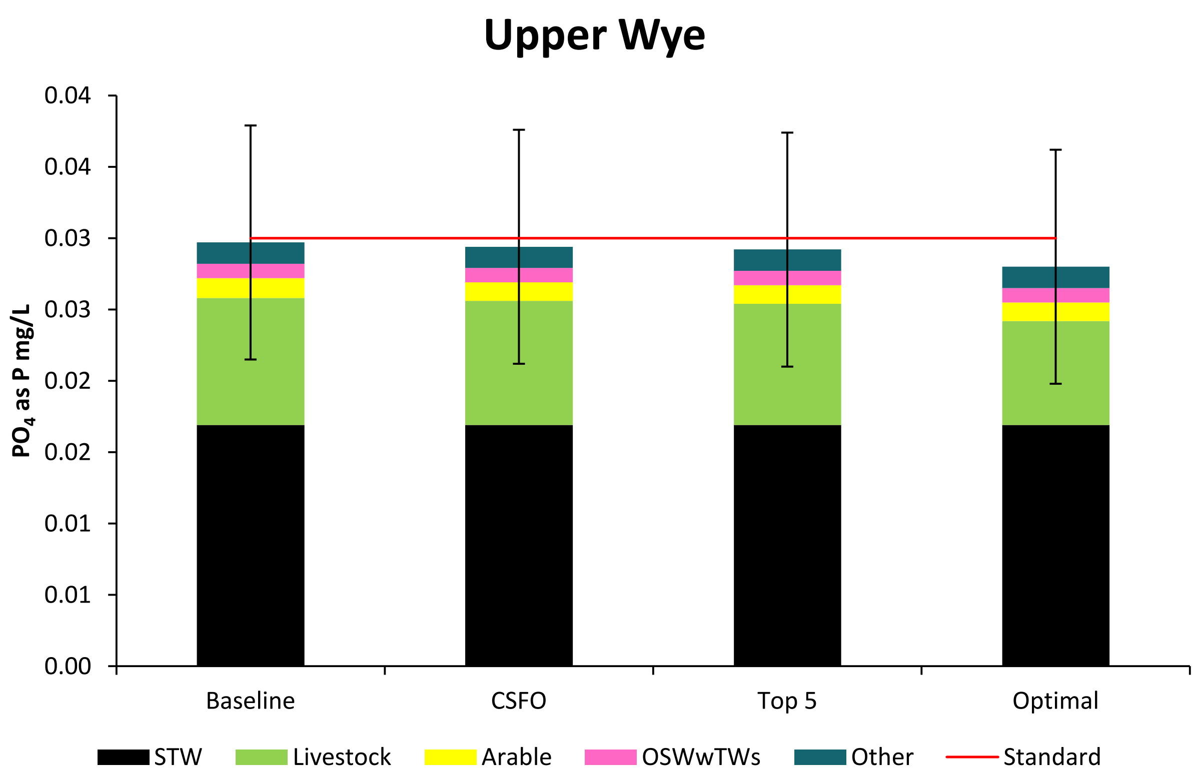

Figure 11-1: SAGIS outputs for agricultural measures applied to the upper River Wye sub-catchment

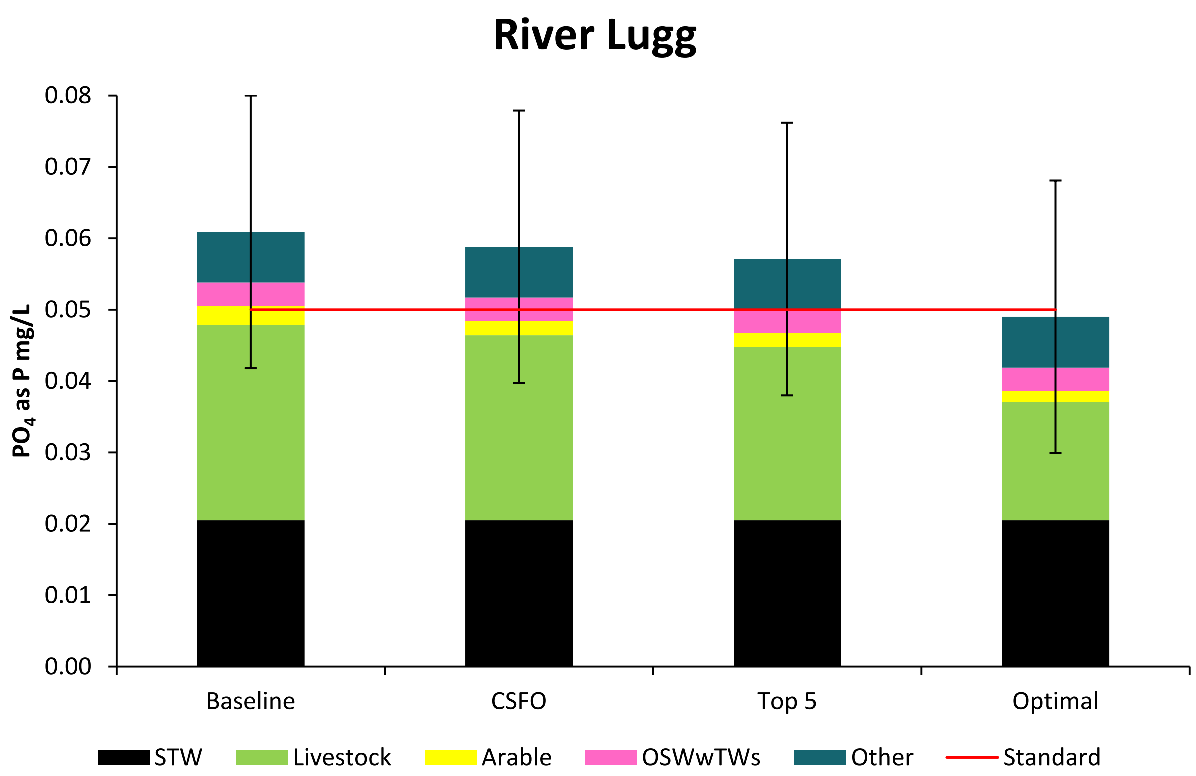

Figure 11-2: SAGIS outputs for agricultural measures applied to the River Lugg sub-catchment

As mentioned previously, despite the high effectiveness of measures on arable farming, the overall impact on in-river concentrations is relatively modest because arable farming contributes a relatively small proportion of the source apportionment relative to other sources of phosphate in the catchment. The results do show some effect of applying agricultural measures on in-river concentrations (Table 11-4). This shows that the scenarios applied in both the arable and livestock sector have a lower impact on overall phosphate levels in the upper River Wye catchment compared with the River Lugg catchment, where the impact of agricultural measures is slightly bigger and the maximum reduction of phosphate loss from agriculture amounts to 19.5% (using the optimal combination recommended by FARMSCOPER). Note these percentages relate to the percent reduction in the agricultural contribution to in-river phosphate, not the percentage reduction to overall phosphate concentrations.

Table 11-4: Percentage reduction in in-river phosphate concentration relative to the agricultural contributions within the baseline

Scenario	**Percentage reduction in in-river phosphate concentration**					
	Total (% reduction in P loss)		**Livestock sector** (% reduction in P loss)		**Arable sector** (% reduction in P loss)	
	Wye	**Lugg**	**Wye**	**Lugg**	**Wye**	**Lugg**
CSFO	1.0	3.4	0.7	2.5	0.3	1.0
Top 5	1.7	6.2	1.3	5.1	0.3	1.1
Optimiser Maximum	5.7	19.5	5.4	17.7	0.3	1.8

12. Combining point source measures and agricultural measures

The following section sets out the results of the scenario modelling where measures applied in the point source sector and the agricultural sector have been combined. The scenario modelling results for the upper River Wye and the River Lugg are presented in bar chart form in Figure 12-1 and Figure 12-2 respectively, and show the source apportioned concentration at two key locations;

- The River Wye immediately upstream of the confluence with the River Lugg; and
- The River Lugg immediately upstream of the confluence with the River Wye.

The River Wye downstream of the point of confluence has not been assessed separately to these two points, as the assumption is that if the targets are achievable upstream of the confluence, then the targets downstream are achieved by default.

The modelling outputs in Figure 12-1 and Figure 12-2 are presented alongside the results for the population growth impacts described in Section 10 for context.

- Scenario 1 (S1) to scenario 4 (S4) represent the impact of discharges under consented conditions, and that arising from population growth.
- Scenarios 5 (S5) to 8 (S8) represent the effect of applying measures to point sources and agricultural sources in various ways depending on the emphasis between the two sectors.

The descriptions of the scenarios that have been modelled were provided previously in Section 8 but have been repeated below for ease of reference.

Table 12-1: Description of modelling scenarios

	Description
S1	Simulate the in-river phosphate concentration (immediately upstream of the confluence of the River Wye and Lugg) under current discharge conditions
S2	Simulate the in-river phosphate concentration (immediately upstream of the confluence of the River Wye and Lugg) under permitted discharge conditions (discharge flow and quality)
S3	Simulate the in-river phosphate concentration (immediately upstream of the confluence of the River Wye and Lugg) under permitted discharge quality conditions using the actual discharge flow (permitted discharge flow conditions often incorporate a significant amount of 'headroom' to accommodate future increases in discharge flows arising from an increase in in-flows due to population growth).
S4	Simulate the in-river phosphate concentration (immediately upstream of the confluence of the River Wye and Lugg) under permitted discharge quality conditions with discharge flows uplifted to reflect population growth impacts (uplifted in line with County Council population increase projections).
S5	Simulate the effect of controls on inputs from sewage treatment works only (refer to Section 8.2)
S6	Simulate the effect of the CSFO recommended measures to control inputs from agriculture (refer to Section 8.3.2.1), with further controls on inputs from sewage treatment works applied (following the approach described in Section 8.2) to make up any shortfall.
S7	Simulate the effect of the 'Top 5' recommended measures to control inputs from agriculture (refer to Section 8.3.2.2), with further controls on inputs from sewage treatment works applied (following the approach described in Section 8.2) to make up any shortfall.
S8	Simulate the effect of the FARMSCOPER optimiser recommended measures to control inputs from agriculture (refer to Section 8.3.2.3), with further controls on inputs from sewage treatment works applied (following the approach described in section8.2) to make up any shortfall.

Some key points to consider alongside these results are:

- The growth scenario (S4) shows the effect of the projected population growth relative to the current flow situation (S1). In other words the wastewater expected from the additional growth has been applied to current discharge flows (rather than fully permitted flows) but to fully permitted quality conditions (i.e. quality in line with the discharge consent).

- The suggestions on where point source measures could be applied, and at what quality consent, have been made based on an optimisation exercise, the specific aim of which was to reduce the phosphate levels down to just below the target level. The reason for doing this is to avoid "going too far" unnecessarily. However there is some scope for being more ambitious with point source measures if required.

- No allowance for water company preference for headroom has been made.

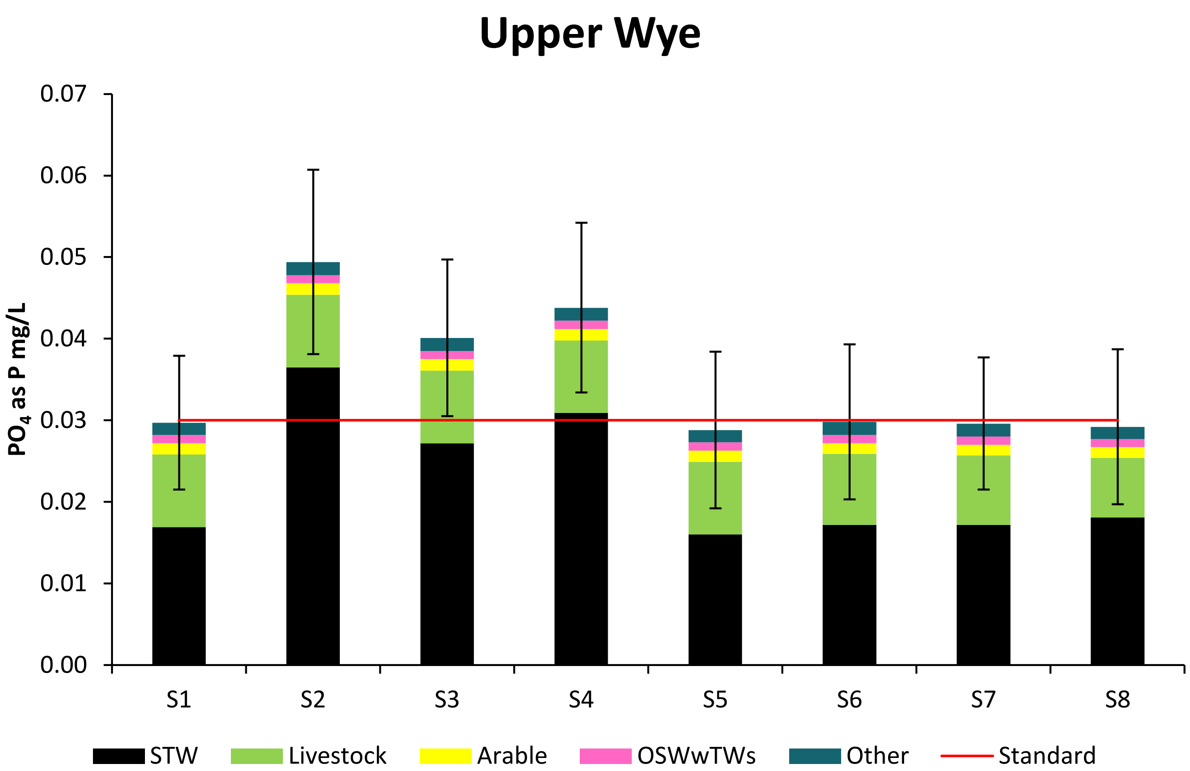

Figure 12-1: Scenario outcomes for the upper River Wye sub-catchment assessment point.[8]

(The error bars represent the 95% confidence range of the predicted average concentration)

[8] The modelling approach has optimised measures applied in the point source sector, meaning that the modelling has aimed to find the optimal solution that achieves the target, not the maximum reductions that could be made by applying all possible measures in the point source sector. This makes the results for S5 to S8 appear close to the target phosphorus level because the approach applied has aimed to achieve the target rather than to exceed the target.

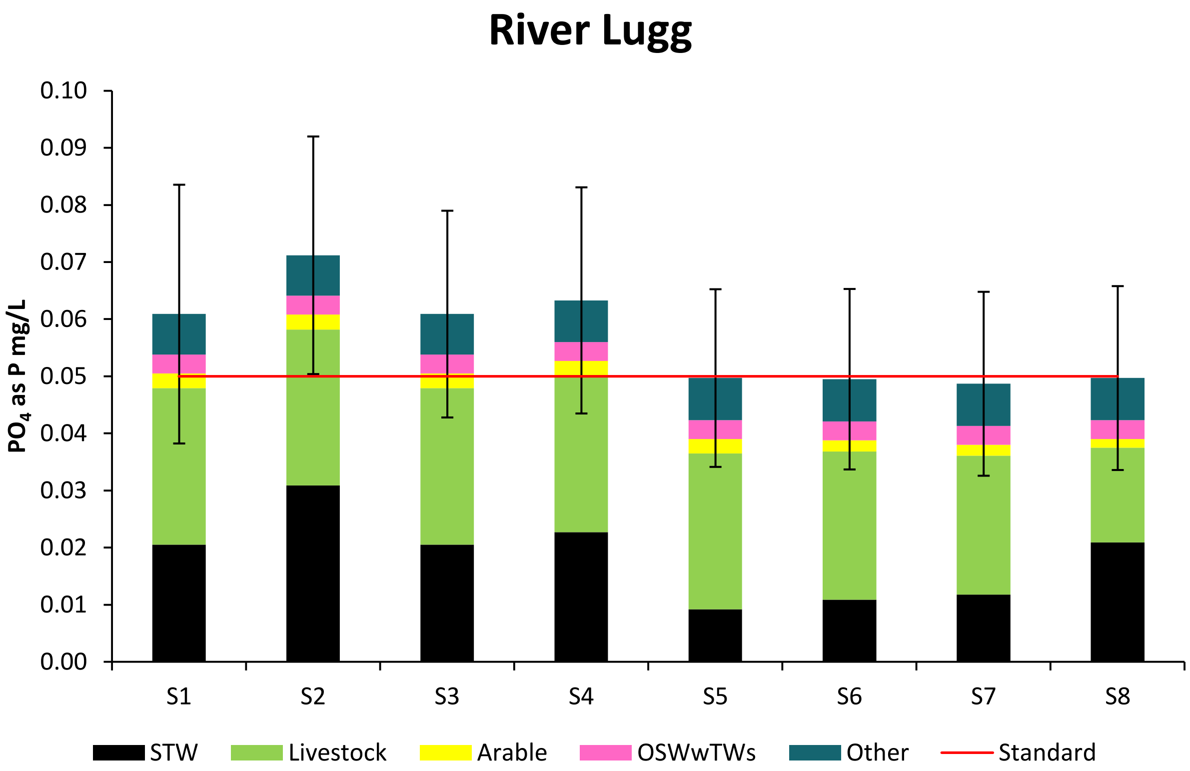

Figure 12-2: Scenario outcomes for the River Lugg sub-catchment assessment point[9].

(The error bars represent the 95% confidence range of the predicted average concentration)

The extent to which the measures are able to achieve compliance has been assessed by comparing the average predicted in-river concentration with the water quality objective set out by Natural England (Section 3).

As discussed in Section 9, several critical assumptions have been made in the model approach, and there is also a reasonable degree of uncertainty around the data that has been used. The broad 95% confidence interval range of the predicted concentrations (represented by the error bars in the charts), is not uncommon for predictions about complex environmental systems but does reflect the degree of uncertainty about the prediction.

The key features of these results include:

- A comparison of the outputs for scenarios S1 to S4 for the upper River Wye and the River Lugg show that contributions from sewage effluent represent the dominant source of phosphate in the River Wye (57% of the in-river concentration), whereas in the River Lugg the inputs from agriculture predominate (49% of the in-river concentration). This indicates a marked difference in the dominant water quality pressure within these two catchments.
- S1 results show the current situation in terms of wastewater discharges (quality and flow). This reflects the current understanding, namely that the upper River Wye is compliant with the 0.03 mg/l target but is

[9] The modelling approach has optimised measures applied in the point source sector, meaning that the modelling has aimed to find the optimal solution that achieves the target, not the maximum reductions that could be made by applying all possible measures in the point source sector. This makes the results for S5 to S8 appear close to the target phosphorus level because the optimiser aims at achieving the target but not going lower.

nearing failure. The S1 result in the River Lugg also reflects the current compliance status (i.e. failing the target of 0.05mg/l).

- Results for S2 and S3 show that if sewage treatment works discharged at their permitted values (for both quality and flow in the case of S2, or for permitted quality with current flow as in S3) phosphate levels in both rivers would rise. In the case of the upper River Wye, the levels would rise beyond the conservation target limit of 0.03mg/l and for the River Lugg the failure would become greater than it is currently.

- S4 reflects the potential effect of population growth, the overall effects of which are more dramatic for the River Wye compared with the River Lugg reflecting the pattern of the population growth data.

- The results for scenarios S5 to S8 for the upper River Wye and the River Lugg show that the chosen measures, or combinations of measures, are probably capable of reducing in-river concentration to within the requisite limits.

- S5 places maximum emphasis on point sources for the required reductions in riverine phosphate levels and shows that significant reductions in point source contributions could be achieved on both rivers. For the upper River Wye it is may be possible to achieve compliance by applying point source measures alone. This could also potentially be the case the River Lugg.

- S6 to S8 assume full implementation of the agricultural measure scenarios throughout the English parts of both sub-catchments (i.e. agricultural measures are only applied in England), with point source contributions making up the difference. What is immediately apparent from the data is that the resulting point source contributions in S6 and S7 are very similar, indicating that even though the agricultural measures are being applied in full according to the scenarios set out in Section 8.4 similar contributions are still required from point sources to achieve compliance.

- The data for S6 to S8 does reflect the higher effectiveness of the Optimiser Maximum scenario modelled in FARMSCOPER (S8) compared with the CSFO (S6) and Top5 (S7) scenarios, particularly in the River Lugg catchment where agriculture accounts for a greater portion of phosphate contributions.

12.1. What do these results mean for point source discharges?

The discharge quality conditions corresponding with each of the scenario results are given Table 12-2 and Table 12-3 for the upper River Wye and River Lugg, respectively.

For the upper River Wye, the scenario outputs suggest that:

- It could potentially be feasible that P target compliance could be reached by taking action at only two STWs (namely, Eign and Rotherwas, which serve Hereford).

- Whilst the modelling results show that compliance with the water quality objective may indeed be achieved through the imposition of more stringent limits on discharge quality, it is notable that the implied discharge levels are typically more stringent than the level currently considered to be achievable using the best available technology (i.e. 1 mg/L P), even where these are applied in combination with measures to control inputs from agricultural sources (S6 to S8).

- Compliance with the water quality objective for the River Wye is therefore likely to be dependent on the feasibility of deploying new treatment technologies within the catchment in the future, which can achieve very high levels of phosphate removal.

For the River Lugg, the scenario outputs suggest that:

- Controls on discharges are likely to be required at up to 11 sewage treatment works[10].
- As for the upper River Wye, the results show that compliance with the water quality objective may be achieved through the imposition of more stringent limits on discharge quality and that the implied discharge levels are more stringent than the level currently considered to be achievable using the best available technology (i.e. 1 mg/L P).
- Whereas Eign and Rotherwas on the upper River Wye are relatively large sewage treatment works, many of the sewage treatment works that discharge into the River Lugg are small (serving a population equivalent of < 1,000) and there may be significant challenges associated with the practical implementation of treatment technologies that can achieve very high levels of phosphate removal.

Table 12-2: Summary of actual and required discharge quality corresponding with the scenario results for the upper River Wye

#	Discharge quality conditions[11] that might achieve compliance with the water quality objective (mg/L)		% reduction (from baseline) in contribution from agricultural inputs (concentration) arising from measures[12]	Probably compliant (Y/N)
	EIGN STW	ROTHERWAS STW		
S1	0.3	0.3	N/A	Y
S2	0.9	0.9	N/A	N
S3	0.9	0.9	N/A	N
S4	0.9	0.9	N/A	N
S5	0.4	0.1	N/A	Y
S6	0.4	0.2	2.9%	Y
S7	0.4	0.2	4.9%	Y
S8	0.5	0.2	16.5%	Y

[10] Excludes the simulation of measures to control inputs from the Cadburys plant at Marlbrook and from the Boultibrook Fish Farm. Their contribution is relatively minor in relation to the inputs from sewage works the extent to which the discharge limits that might be achievable for sewage effluent discharge may be applicable is uncertain.

[11] Expressed as orthophosphate.

[12] This is the reduction in the in-river phosphate contribution from agriculture arising from the scenarios

Table 12-3: Summary of current and required discharge quality corresponding with the scenario results for the River Lugg

#	Consent conditions[13] that might achieve compliance with the water quality objective (mg/L)											% reduction in contribution from agricultural inputs (concentration) arising from measures[14]	Probably compliant (Y/N)
	PEMBRIDGE STW	KINGTON STW	LYONSHALL STW	MORETON ON LUGG STW	LUSTON & YARPOLE STW	SHOBDON STW	KINGSLAND STW	WEOBLEY STW	LEOMINSTER STW	PRESTEIGNE STW	BROMYARD STW		
S1	3.7	0.9	6.6	0.9	4.7	5.0	1.59	6.81	0.9	3.15	0.9	N/A	N
S2	3.7	0.9	6.6	0.9	4.7	5.0	1.59	6.81	0.9	3.15	0.9	N/A	N
S3	3. 7	0.9	6.6	0.9	4.7	5.0	1.59	6.81	0.9	3.15	0.9	N/A	N
S4	3. 7	0.9	6.6	0.9	4.7	5.0	1.59	6.81	0.9	3.15	0.9	N/A	N
S5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.1	0.1	0.5	N/A	Y

[13] Expressed as orthophosphate.

[14] This is the reduction in the in-river phosphate contribution arising from agriculture as a result of implementing the scenarios

S6	3. 7	0.4	6.6	0.4	0.9	0.9	0.9	0.9	0.1	0.4	0.1	7.0%	Y
S7	3.67	0.4	6.6	0.4	0.9	4.95	0.9	0.9	0.1	0.4	0.4	12.7%	Y
S8	3.67	0.9	6.6	0.9	4.7	4.95	1.59	6.8	0.5	3.2	0.9	39.7%	Y

13. Conclusions and recommendations

13.1. Key findings

13.1.1. Point source measures

- Sewage treatment works discharges are a main contributor to the baseline source apportionment; more so in the upper River Wye sub-catchment compared with the River Lugg sub-catchment.

- Population growth projections and patterns have been considered relative to the existing locations of main sewage discharges and an assessment of the future additional wastewater burden on these works has been undertaken. The additional wastewater flow expected from population growth has been applied to the different discharges at the fully consented quality value and the source apportionment re-run for each River Wye SAC compliance assessment points (S4 bars in Figure 12-1 and Figure 12-2). The effect of the additional population is more pronounced in the upper River Wye sub-catchment compared with the River Lugg sub-catchment, reflecting that the burden of population growth is predicted to fall more to the existing towns and cities in the River Wye valley, compared with the modest population growth projected for the River Lugg. The assessment shows that in the absence of mitigation measures, the additional population is likely to push the upper River Wye into non-compliance with the Natural England conservation targets, and will exacerbate the existing situation of non-compliance in the River Lugg.

- The outputs of the optimisation exercise suggest where point source measures (in the form of more stringent discharge consents) could be implemented to mitigate this predicted phosphate increase to levels that achieve the target. For the upper River Wye sub-catchment, the assessment indicated that applying more stringent discharge consents to the two main sewage treatment works serving Hereford (Eign and Rotherwas WwTWs) could be sufficient to achieve the conservation target for this reach of the River Wye SAC, even in the absence of any other measures being implemented (for example measures in the agricultural sector). However, this would require technology to be utilised that is currently only theoretical ("future technology"); a phosphate concentration discharge of 0.1 mg/L would be required, which is a factor of 10 lower than the levels achievable with the current Best Available Technology (1 mg/L). Therefore there is an element of uncertainty that needs to be considered in this situation.

- For the River Lugg sub-catchment, the modelling has suggested that additional measures are likely to be required at up to 11 sewage treatment works, many of which are relatively small works serving a population equivalent of less than 1000. Similarly to the situation on the upper River Wye, this solution relies on future technology delivering discharges with phosphate concentrations to the predicted 0.1 mg/L level.

13.1.2. Agricultural assessment

- Examination of the agricultural portion of the source apportionment indicates that the main contributor from the agricultural sector in both sub-catchments is livestock farming; this is largely consistent with the Defra and Welsh Government agricultural census data which indicates that the number of holdings for livestock farms exceeds the number of holdings for arable farms.

- The FARMSCOPER modelling showed that typical arable farms give rise to more phosphate pollution than a livestock farm, on a per farm basis. Nonetheless, as noted above the livestock farms reflect a higher portion of the source apportionment because they form a larger portion of the overall farm holdings in the catchment.

- FARMSCOPER has also been applied to understand the effectiveness of various combinations of measures on phosphate losses from farms, whilst taking account of measures already being implemented by the agricultural sector through NVZ requirements. The modelling has also shown that the measures available to tackle phosphate pollution are more effective in the arable sector compared with the livestock sector (Table 11-1); however, because livestock farming is contributing more phosphate to the baseline source apportionment compared with arable, the resulting in-river phosphate reductions that can be achieved are relatively modest.

- The results overall for agricultural action indicate that:
  - Assuming all farmers take up the CSFO recommended measures set out in 8.3.2.1, a maximum of 3-7% reduction in in-river phosphate could potentially be achieved;
  - If all farmers were to take up the "top 5" recommended measures set out in 8.3.2.2, a maximum of 5-13% reduction in in-river phosphate could potentially be achieved; and
  - If all farmers were to implement all the measures set out in the "optimiser maximum" scenario (see Appendix E.5) then this would result in a reduction in in-river phosphate levels of between 16 and 40%.

(Note these percentages relate to the percent reduction in the agricultural contribution to in-river phosphate, not the percentage reduction to overall phosphate concentrations)

It should be emphasised that these percentages are likely to be upper end estimates as the reductions rely on all farms implementing the required changes to the highest specification over a long period of time; it also assumes that the measures can be applied to all farms, when in fact they may not be applicable in some cases. The optimiser max scenario, although providing a theoretical maximum for reference, is therefore potentially not feasible. Furthermore, there is significant uncertainty over the actual outcomes of implementing these measures as any evidence of water quality improvements can easily be lost when catchment processes are combined.

However, that's not to say that the agricultural sector doesn't have an important role to play in contributing to reducing current and future phosphate concentrations in the River Wye SAC. The overall conclusion to be drawn from the agricultural assessment is that there is much potential for implementing measures in the agricultural sector, including reconsidering the combination of measures currently recommended by CSFOs in order to make the advice more phosphate-focused, including promoting measures modelled in the "top5" scenario.

13.1.3. Combining point source measures and agricultural measures to address overall phosphate levels in the River Wye SAC

Considering the effectiveness of point source measures and agricultural measures separately, it is clear that each sector has the potential to contribute an important role in reducing phosphate pollution to the River Wye SAC, albeit with different magnitudes of contributions.

The scenario modelling for scenarios 5 to 8 considered four combinations of point source and agricultural measures that aim to achieve the conservation phosphate target. All four scenarios showed that it is theoretically possible to achieve the targets set out by Natural England, and given the assumptions and uncertainties set out in Section 9. However what is clear is that the biggest potential is held in addressing point source discharges.

The combinations scenarios (S5 to S8) were designed by the Environment Agency and Natural England to balance the responsibility for the requisite phosphate reductions between the point source and agricultural sectors. The conclusion that can be drawn from the results of these combined scenarios is that even when the agricultural scenarios are applied in full across the catchment, it is highly likely that significant effort would still be needed from point source measures, comparable to the level of reductions that would be required if relying on point source measures alone. In other words, the agricultural scenarios have a relatively modest impact and a lower confidence in outcome when compared to the point source measures and any reductions required from the agricultural sector through the NMP must be realistic and achievable.

It is also important to note that the agricultural sector has a large role to play as custodians of the land and that wider benefits can be achieved from agricultural measures (aside from reducing run off and diffuse water pollution) such as for biodiversity, landscape, flood management and climate change. Whilst this plan is designed to achieve the conservation objectives in the SAC, catchment wide measures to reduce diffuse pollution from the agricultural sector will help in achieving the wider WFD requirements for the Wye catchment. There are a number of waterbodies currently failing to achieve Good Ecological Status that will not be affected by improvements to point sources. WFD compliance will require reductions from the agricultural sector. However, the level of effort required to ensure implementation of effective agricultural measures long term is significant and it seems likely that a combination of advice, incentives and regulations would be required to do this.

There is still more work needed to decide upon the balance of reduction-responsibility prior to being able to produce an action plan for implementation but this evidence base and options appraisal sets the basis for further discussions between the Environment Agency, Natural England, Defra, the Water Industry and the Agricultural sector.

13.2. Recommendations

The evidence base and options appraisal presented in this report has been specifically aimed at understanding the potential impacts on riverine phosphate levels as a result of Herefordshire Council's Growth Strategy and considering whether it is possible to reduce the resulting phosphate concentrations to meet the conservation targets set out by Natural England through implementing measures in the point source and agricultural sectors.

This document sets out different options that could be considered in order to achieve requisite compliance targets; a key assumption to consider however when taking these options forward is the issue of confidence in outcome.

13.2.1. Confidence in outcome

As discussed previously, the scenario modelling results should be considered alongside the critical assumptions and areas of uncertainty outlined in Section 9.

The key points to consider in relation to point source measures are;

- The level of confidence in actual environmental outcomes needs to be considered. It is usually possible to have a high degree of confidence in outputs – a water company implements treatment technology and the required result is usually measurable. However, the measures considered within this plan rely on future technology which at this point is only theoretical and there is a risk that it may not be possible to achieve a level of 0.1mg/L phosphate as assumed in this study.
- It is not known what benefits may be achieved from the impending ban of phosphates in detergents, but it is likely to have a beneficial effect for the phosphate levels in the River Wye SAC.
- Although this report comments on the potential levels of phosphate reductions achievable by implementing measures in the point source sector, it does not include an assessment of the headroom in the discharge consent that is preferred by water companies. It is expected that this would be subject to further assessment and discussion between the water company and the Environment Agency.
- Depending on the water company requirement for headroom in the licence, this may change what is achievable at different works in relation to reducing phosphates in water company discharges.

For agricultural measures, the main points to note are:

- There is uncertainty around implementation of measures in full across the catchment, and the efficacy of these on in-river phosphate concentrations. The level of confidence in actual environmental outcomes from implementing the measures are relatively low; in part because the improvements are not immediately measurable (compared with the point source discharges) and also because the success of the measures require coordinated catchment level effort in order to achieve the outcomes; in reality this is likely to be difficult to achieve.
- This assessment does not take into account further future agricultural intensification to support growth within the catchment. It is reasonable to suggest that farm businesses within the area are likely to expand with population growth in the area and although the NFU vision for the future is to *"increase food production from existing farmland whilst minimising pressure on the environment"* (NFU, 2013) the effect of commercial farming growth on the environment remains uncertain.

13.2.2. Recommendations for reducing uncertainty

Some of the recommendations for further work to reduce uncertainty in the model forecasts by improving the accuracy and confidence in predictions include:

- Improve the understanding of the feasibility of employing advanced treatment technology in the River Wye catchment to achieve ultralow discharge concentrations, including at relatively small sewage treatment works.
- A sensitivity analysis to consider further the different options for where point source measures could best be undertaken and to what level of discharge consent.
- Related to this is the need to consider headroom in the potential point source measures. Current studies suggest that future technology may be capable of delivering discharges at 0.1 mg/L phosphate; however the water company requirement for headroom in licences needs further consideration.
- Work to increase confidence in the ability of future technology to deliver to 0.1mg/l as part of this plan – currently this is still beyond current BAT and the feasibility of reaching a discharge limit of 0.1mg/l needs considering alongside the individual works in the catchments. This would also include a cost effectiveness analysis.
- A sensitivity analysis to understand better the relationship between river flows and agricultural inputs.
- Further investigations into how selecting different combinations of land management measures affects the potential reductions to be achieved; this would allow for consideration of measures deemed appropriate for certain types of niche farming in the catchment, and consideration of more radical measures including arable reversion for example.
- A detailed cost assessment of the measures put forth: Some consideration has been given to cost when optimising the point source measures, based on limited information provided by Welsh Water; however no cost-specific discussions have been held in relation to this to inform the optimisation exercise. On the agricultural side, the study has been focused on what is likely to be technically achievable regardless of cost at this stage, in line with River Wye SAC requirements. Given the modest phosphate reduction outcomes achievable in the agricultural sector indicated in this study, what would be helpful is a detailed cost assessment of agricultural measures that includes not only the water quality benefits but also the wider benefits including biodiversity, landscape, air quality and climate change.

13.3. What next?

This NMP evidence base is the starting point in a long- term process. The Plan takes a long term strategic view of the actions required to achieve Favourable Condition of the River Wye SAC by 2027. In addition, there are short to medium term objectives to reduce phosphate levels towards the restoration target, and to see downward trends in the levels of nitrogen and suspended solids.

The next step is for Natural England, the Environment Agency, Herefordshire County Council, land managers and land owners to work collaboratively and use the outputs of this options appraisal in order to move forwards into implementation and action.

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Appendix

Appendix A. Growth predictions

A.1. Projected populations within Herefordshire

Housing Market Area*	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Bromyard	6,116	6,145	6,181	6,215	6,250	6,282	6,303	6,333	6,358	6,397
Bromyard Rural	5,743	5,751	5,759	5,773	5,777	5,783	5,806	5,836	5,855	5,874
Golden Valley	6,022	6,031	6,037	6,036	6,043	6,041	6,049	6,046	6,047	6,063
Hereford	57,739	58,123	58,483	58,852	59,184	59,518	60,003	60,510	60,983	61,482
Hereford Rural	24,563	24,633	24,717	24,801	24,877	24,943	24,998	25,075	25,153	25,242
Kington	3,336	3,336	3,337	3,334	3,336	3,328	3,342	3,373	3,389	3,412
Kington Rural	6,224	6,232	6,231	6,242	6,252	6,255	6,256	6,269	6,278	6,285
Ledbury	10,041	10,122	10,186	10,250	10,311	10,367	10,444	10,505	10,567	10,627
Ledbury Rural	9,266	9,293	9,330	9,360	9,388	9,425	9,442	9,459	9,483	9,505
Leominster	11,605	11,850	12,098	12,344	12,568	12,807	13,071	13,316	13,566	13,805
Leominster Rural	12,238	12,230	12,216	12,215	12,207	12,204	12,179	12,183	12,180	12,184
Ross	10,551	10,604	10,672	10,732	10,799	10,855	10,921	10,996	11,068	11,148
Ross Rural	20,192	20,215	20,241	20,283	20,310	20,346	20,375	20,409	20,437	20,489
Herefordshire	**183,636**	**184,565**	**185,488**	**186,437**	**187,302**	**188,154**	**189,189**	**190,310**	**191,364**	**192,513**

Housing Market Area*	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Bromyard	6,429	6,486	6,544	6,602	6,650	6,695	6,718	6,761	6,798	6,835	6,878
Bromyard Rural	5,906	5,913	5,929	5,935	5,942	5,968	5,980	5,998	6,007	6,040	6,053
Golden Valley	6,080	6,092	6,096	6,112	6,128	6,141	6,163	6,185	6,193	6,225	6,246
Hereford	61,978	62,497	63,011	63,498	64,013	64,495	64,870	65,242	65,599	65,986	66,323
Hereford Rural	25,344	25,462	25,579	25,687	25,806	25,914	26,047	26,176	26,312	26,453	26,583
Kington	3,426	3,436	3,458	3,462	3,478	3,486	3,495	3,513	3,541	3,562	3,574
Kington Rural	6,298	6,313	6,321	6,336	6,361	6,365	6,398	6,422	6,450	6,465	6,486
Ledbury	10,699	10,752	10,809	10,873	10,931	10,983	11,028	11,066	11,103	11,149	11,197
Ledbury Rural	9,519	9,519	9,540	9,556	9,583	9,601	9,627	9,645	9,670	9,700	9,731
Leominster	14,056	14,308	14,568	14,820	15,072	15,319	15,575	15,809	16,050	16,291	16,516
Leominster Rural	12,190	12,220	12,246	12,253	12,268	12,290	12,338	12,394	12,441	12,497	12,551
Ross	11,220	11,297	11,371	11,453	11,536	11,608	11,687	11,753	11,825	11,890	11,956
Ross Rural	20,530	20,576	20,614	20,676	20,735	20,775	20,855	20,936	21,022	21,101	21,181
Herefordshire	**193,675**	**194,871**	**196,086**	**197,263**	**198,503**	**199,640**	**200,781**	**201,900**	**203,011**	**204,194**	**205,275**

A.2. Projected growth outside of Herefordshire that could affect the River Wye SAC

Name (A-Z)	In Growth Corridor	Population estimate	% of Pop in settlements accommodating growth	1. Growth based on 10,000 (max pl. see notes below table).	2. Growth based on 7,700 (Max please see notes below table).	3. Growth based on 6,000 for info	Planning permissions and completions (careful not to double count) since 01/01/2011 and Hamlets and Rural Setts Policy est 25% of 10,000 figure	1. LDP requirement as at now.	2. LDP requirement as at now.	3. LDP requirement as at now.	Status
Builth Wells & Llanelwedd	T	2709	3.89	389	299	233	97	292	202	136	Town
Knighton	F	2740	3.93	393	303	236	98	295	205	138	Town
Llandrindod Wells	T	4850	6.96	696	536	418	174	522	362	244	Town
Llanfair Caereinion	F	1040	1.49	149	115	90	37	112	78	52	Town
Llanfyllin	F	1120	1.61	161	124	96	40	121	84	56	Town
Llanidloes	T	2620	3.76	376	290	226	94	282	196	132	Town
Llanwrtyd Wells	F	600	0.86	86	66	52	22	65	45	30	Town
Machynlleth	F	2050	2.94	294	227	177	74	221	153	103	Town
Montgomery	F	1050	1.51	151	116	90	38	113	78	53	Town
Newtown	T	10510	15.09	1509	1162	905	377	1132	785	528	Town
Presteigne	F	1840	2.64	264	203	158	66	198	137	92	Town
Rhayader	T	1770	2.54	254	196	152	64	191	132	89	Town
Welshpool & Buttington	T	5870	8.43	843	649	506	211	632	438	295	Town
Ystradgynlais	T	6880	9.88	988	761	593	247	741	514	346	Town
Abercrave	T	570	0.82	82	63	49	20	61	43	29	Large Village
Abermule	T	630	0.90	90	70	54	23	68	47	32	Large Village
Arddleen	T	400	0.57	57	44	34	14	43	30	20	Large Village
Berriew	T	300	0.43	43	33	26	11	32	22	15	Large Village
Bettws Cedewain	F	240	0.34	34	27	21	9	26	18	12	Large Village
Boughrood & Llyswen	T	380	0.55	55	42	33	14	41	28	19	Large Village

Name (A-Z)	In Growth Corridor	Population estimate	% of Pop in settlements accommodating growth	1. Growth based on 10,000 (max pl. see notes below table).	2. Growth based on 7,700 (Max please see notes below table).	3. Growth based on 6,000 for info	Planning permissions and completions (careful not to double count) since 01/01/2011 and Hamlets and Rural Setts Policy est 25% of 10,000 figure	1. LDP requirement as at now.	2. LDP requirement as at now.	3. LDP requirement as at now.	Status
Bronllys	T	420	0.60	60	46	36	15	45	31	21	Large Village
Caersws	T	810	1.16	116	90	70	29	87	60	41	Large Village
Carno	F	540	0.78	78	60	47	19	58	40	27	Large Village
Castle Caereinion	F	210	0.30	30	23	18	8	23	16	11	Large Village
Churchstoke	F	620	0.89	89	69	53	22	67	46	31	Large Village
Clyro	F	320	0.46	46	35	28	11	34	24	16	Large Village
Coelbren	F	560	0.80	80	62	48	20	60	42	28	Large Village
Crewgreen	T	440	0.63	63	49	38	16	47	33	22	Large Village
Crossgates / Fron	T	500	0.72	72	55	43	18	54	37	25	Large Village
Forden	F	130	0.19	19	14	11	5	14	10	7	Large Village
Four Crosses	T	870	1.25	125	96	75	31	94	65	44	Large Village
Glasbury	F	400	0.57	57	44	34	14	43	30	20	Large Village
Guilsfield	F	1140	1.64	164	126	98	41	123	85	57	Large Village
Howey	T	560	0.80	80	62	48	20	60	42	28	Large Village
Kerry	F	800	1.15	115	88	69	29	86	60	40	Large Village
Kingswood	F	480	0.69	69	53	41	17	52	36	24	Large Village
Knucklas	F	260	0.37	37	29	22	9	28	19	13	Large Village
Llanbrynmair	F	220	0.32	32	24	19	8	24	16	11	Large Village
Llandinam	T	250	0.36	36	28	22	9	27	19	13	Large Village
Llandrinio	T	370	0.53	53	41	32	13	40	28	19	Large Village
Llandyssil	F	210	0.30	30	23	18	8	23	16	11	Large Village

Name (A-Z)	In Growth Corridor	Population estimate	% of Pop in settlements accommodating growth	1. Growth based on 10,000 (max pl. see notes below table).	2. Growth based on 7,700 (Max please see notes below table).	3. Growth based on 6,000 for info	Planning permissions and completions (careful not to double count) since 01/01/2011 and Hamlets and Rural Setts Policy est 25% of 10,000 figure	1. LDP requirement as at now.	2. LDP requirement as at now.	3. LDP requirement as at now.	Status
Llanfechain	F	340	0.49	49	38	29	12	37	25	17	Large Village
Llangammarch Wells	F	190	0.27	27	21	16	7	20	14	10	Large Village
Llangurig	T	170	0.24	24	19	15	6	18	13	9	Large Village
Llangynog	F	220	0.32	32	24	19	8	24	16	11	Large Village
Llanrhaeadr-ym-Mochnant	F	560	0.80	80	62	48	20	60	42	28	Large Village
Llansantffraid-ym-Mechain	F	850	1.22	122	94	73	31	92	63	43	Large Village
Llansilin	F	210	0.30	30	23	18	8	23	16	11	Large Village
Llanymynech	T	550	0.79	79	61	47	20	59	41	28	Large Village
Llanyre	T	280	0.40	40	31	24	10	30	21	14	Large Village
Meifod	F	400	0.57	57	44	34	14	43	30	20	Large Village
Middletown	T	360	0.52	52	40	31	13	39	27	18	Large Village
New Radnor	F	270	0.39	39	30	23	10	29	20	14	Large Village
Newbridge on Wye	T	560	0.80	80	62	48	20	60	42	28	Large Village
Penybontfawr	F	280	0.40	40	31	24	10	30	21	14	Large Village
Pontrobert	F	180	0.26	26	20	16	6	19	13	9	Large Village
Three Cocks	F	320	0.46	46	35	28	11	34	24	16	Large Village
Trefeglwys	F	210	0.30	30	23	18	8	23	16	11	Large Village
Tregynon	F	510	0.73	73	56	44	18	55	38	26	Large Village
Trewern	T	470	0.67	67	52	40	17	51	35	24	Large Village
Abbeycwmhir	F	49	0.07	7	5	4	2	5	4	2	Village
Aberedw	T	90	0.13	13	10	8	3	10	7	5	Village

Name (A-Z)	In Growth Corridor	Population estimate	% of Pop in settlements accommodating growth	1. Growth based on 10,000 (max pl. see notes below table).	2. Growth based on 7,700 (Max please see notes below table).	3. Growth based on 6,000 for info	Planning permissions and completions (careful not to double count) since 01/01/2011 and Hamlets and Rural Setts Policy est 25% of 10,000 figure	1. LDP requirement as at now.	2. LDP requirement as at now.	3. LDP requirement as at now.	Status
Abertridwr	F	100	0.14	14	11	9	4	11	7	5	Village
Adfa	F	140	0.20	20	15	12	5	15	10	7	Village
Beulah	F	100	0.14	14	11	9	4	11	7	5	Village
Builth Road	T	110	0.16	16	12	9	4	12	8	6	Village
Caehopkin	T	210	0.30	30	23	18	8	23	16	11	Village
Cemmaes	F	120	0.17	17	13	10	4	13	9	6	Village
Cilmery	F	190	0.27	27	21	16	7	20	14	10	Village
Cwm Linau	F	80	0.11	11	9	7	3	9	6	4	Village
Derwenlas	F	60	0.09	9	7	5	2	6	4	3	Village
Erwood	T	130	0.19	19	14	11	5	14	10	7	Village
Esgairgeiliog Ceinws	F	110	0.16	16	12	9	4	12	8	6	Village
Felinfach	T	90	0.13	13	10	8	3	10	7	5	Village
Foel	F	80	0.11	11	9	7	3	9	6	4	Village
Garth	F	90	0.13	13	10	8	3	10	7	5	Village
Gladestry	F	70	0.10	10	8	6	3	8	5	4	Village
Glantwmyn	F	70	0.10	10	8	6	3	8	5	4	Village
Groes-lwyd	F	60	0.09	9	7	5	2	6	4	3	Village
Leighton Pentre	T	100	0.14	14	11	9	4	11	7	5	Village
Llanbadarn Fynydd	F	49	0.07	7	5	4	2	5	4	2	Village
Llanbister	F	70	0.10	10	8	6	3	8	5	4	Village
Llanddew	F	140	0.20	20	15	12	5	15	10	7	Village

Name (A-Z)	In Growth Corridor	Population estimate	% of Pop in settlements accommodating growth	1. Growth based on 10,000 (max pl. see notes below table).	2. Growth based on 7,700 (Max please see notes below table).	3. Growth based on 6,000 for info	Planning permissions and completions (careful not to double count) since 01/01/2011 and Hamlets and Rural Setts Policy est 25% of 10,000 figure	1. LDP requirement as at now.	2. LDP requirement as at now.	3. LDP requirement as at now.	Status
Llandewi Ystradenni	F	80	0.11	11	9	7	3	9	6	4	Village
Llanerfyl	F	140	0.20	20	15	12	5	15	10	7	Village
Llanfihangel Tal-y-llyn	F	220	0.32	32	24	19	8	24	16	11	Village
Llangadfan	F	120	0.17	17	13	10	4	13	9	6	Village
Llangedwyn	F	70	0.10	10	8	6	3	8	5	4	Village
Llangunllo	F	70	0.10	10	8	6	3	8	5	4	Village
Llanwddyn	F	50	0.07	7	6	4	2	5	4	3	Village
Llanwrthwl	T	60	0.09	9	7	5	2	6	4	3	Village
Nantmel	T	49	0.07	7	5	4	2	5	4	2	Village
Norton	F	300	0.43	43	33	26	11	32	22	15	Village
Pant y dwr	F	90	0.13	13	10	8	3	10	7	5	Village
Penegoes	F	180	0.26	26	20	16	6	19	13	9	Village
Penybont	F	180	0.26	26	20	16	6	19	13	9	Village
Refail	T	90	0.13	13	10	8	3	10	7	5	Village
Sarn	F	170	0.24	24	19	15	6	18	13	9	Village
St Harmon	F	130	0.19	19	14	11	5	14	10	7	Village
Y Fan	F	140	0.20	20	15	12	5	15	10	7	Village
Totals		69656	100.00	10000	7700	6000	2500	7500	5200	3500	

Appendix B. River Wye SAC catchment geology

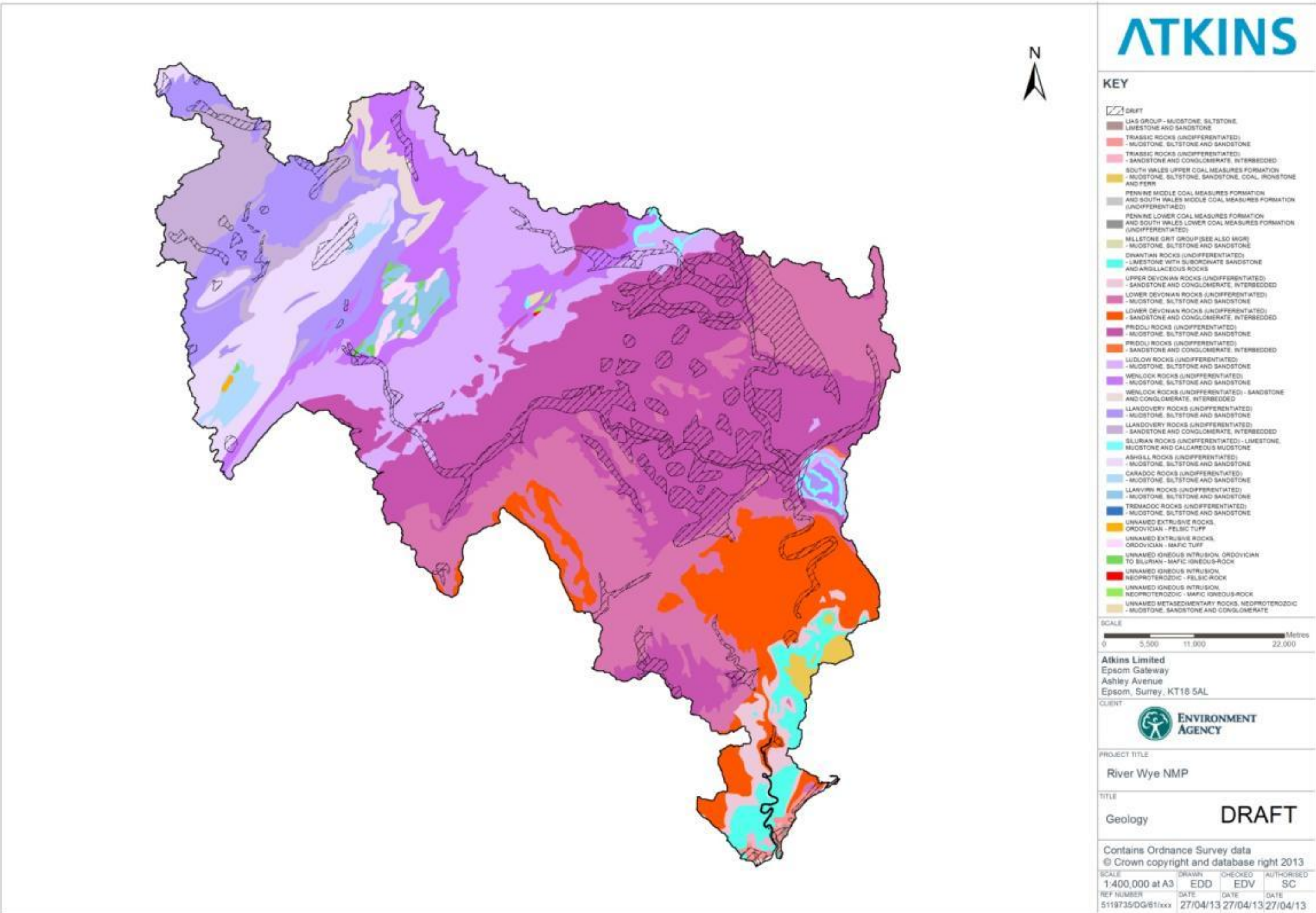

Figure 13-1: River Wye SAC catchment geology map.

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ATKINS

Appendix C. Atkins erosion risk assessment

In order to understand the risk of soil erosion within the River Wye and River Lugg catchments, a high level risk assessment has been undertaken using the Atkins Soil Erosion Risk Assessment tool, which is a national risk assessment methodology to quickly classify the risk of erosion from land based on a number of factors.

This method is based on the concept that certain factors influence the severity of erosion and runoff identified in the Environment Agency's 'thinksoils' handbook (http://www.environment-agency.gov.uk/business/sectors/soils.aspx). This risk is split into two principal risk factors:

1. 'Risks which come with the land'; and
2. 'Risks arising from land management decisions'.

These risk factors are further divided as shown Table 13-1 which show the available datasets used to assess the risks arising from each factor. Work initially focussed on data-sets which are easily accessible to Atkins; i.e. those which are open source or covered by an existing licence. More detailed data-sets can be used with the appropriate licences, however for the purposes of this characterisation assessment, and at this particular spatial scale, this is considered sufficient.

Table 13-2 outlines how the sub-factors are divided into high, medium and low risk of erosion. Each category of risk is given a value from Low (0) to High (2). The 'Risks which come with the land' and 'Risks arising from land management decisions' can subsequently be summed up to determine the relative risk of erosion.

Table 13-1: Risk factors affecting erosion

Overall risk factors	Sub-factors	Dataset used
'Risks which come with the land'	Soil texture	EU's Open Soil Geographical Database of Eurasia.
	Rainfall	FEH (Atkins licence) and Met office rainfall open data
	Slope angle	OS open terrain 50 digital elevation model (DEM)
'Risks arising from land management decisions'	Proximity and connectivity to watercourses and roads	OS open meridian roads OS open terrain 50 digital elevation model (DEM) to delineate watercourses and hydrological pathways
	Land-use	Corine land cover 2006 (open)
	Land management practices	Stewardship areas (government open licence) Protected / designated areas (government open licence)

Table 13-2: Risk categorisation

Sub-factor	0 Low risk	1 Medium Risk	2 High Risk
Soil texture	Clay, peat	Loam	Silt, Sand
Rainfall intensity per hour	<10 mm	>=10 mm	>=15 mm
Slope angle	<3 degrees	3–7 degrees	>7 degrees
Proximity to watercourses roads and drainage pathways	>1 km	100 m–1 km	<100 m
Land-use	Unimproved grassland, forestry, urban	Improved grassland	Arable
Land management practices	Nature reserve	Stewardship schemes	No stewardship schemes or nature reserves

The figures below give the outputs of the erosion risk assessment:

- Figure 13-2 shows the general situation of the estimated upstream catchment with regard to slope, soils and rainfall;
- Figure 13-3 shows the connectively of the site with regard to the transport network and hydrology, surrounding land use and management; and
- Figure 13-4 pulls this information together and uses a risk based approach to indicate the overall risks to the site from its general situation and surrounding land use and management.

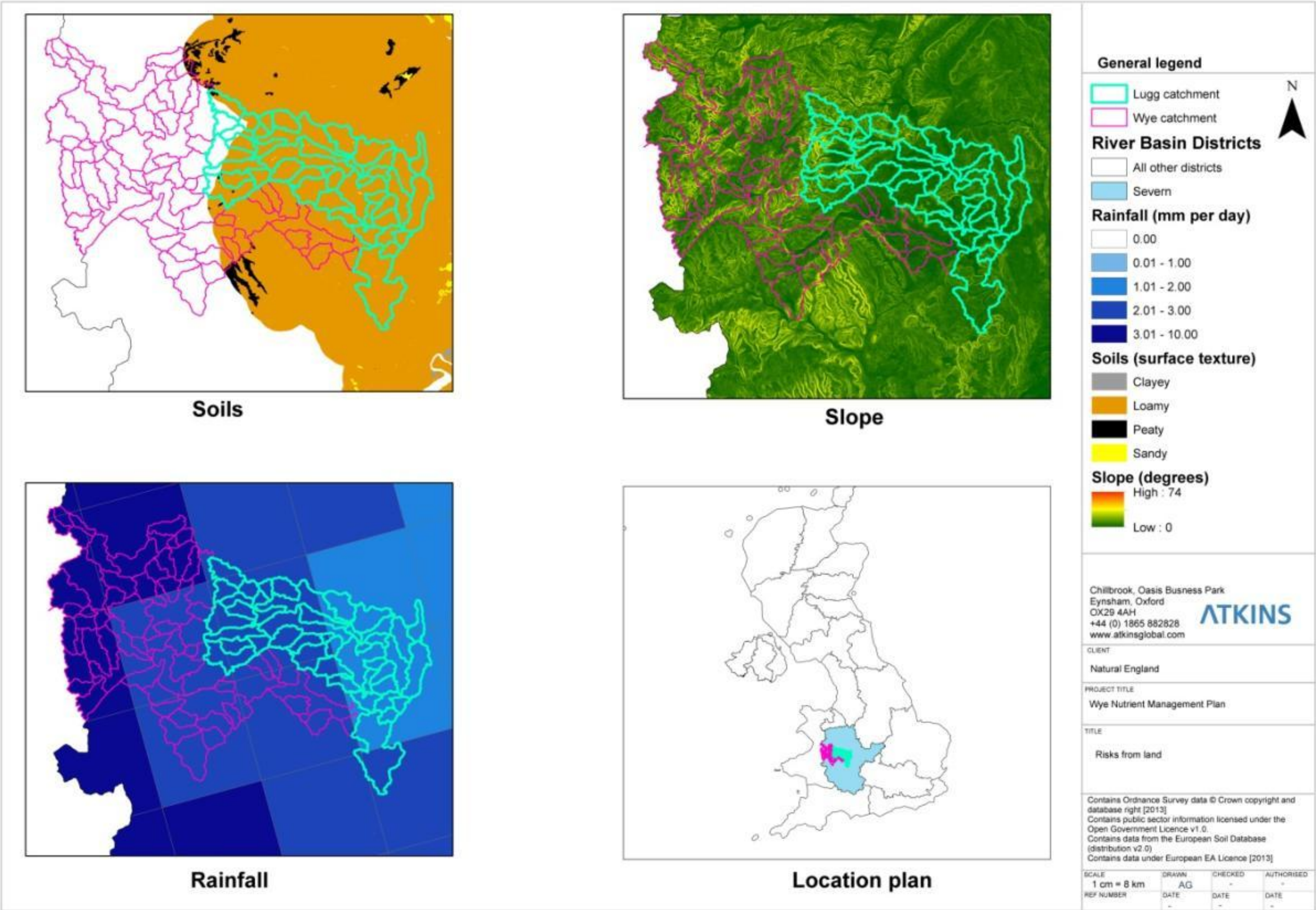


Figure 13-2: Catchment characterisation map: soils, slope and rainfall

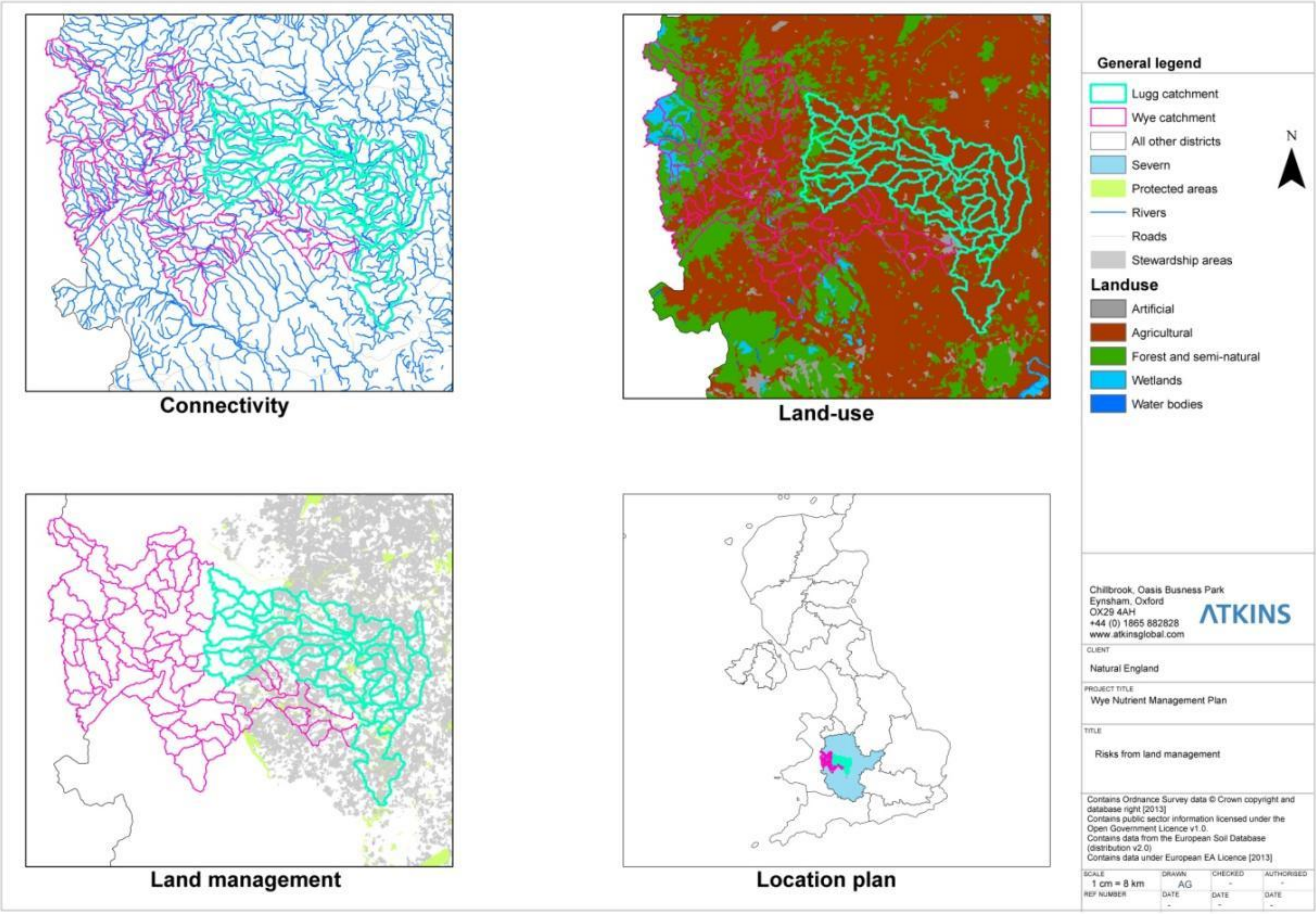


Figure 13-3: Catchment characterisation map: connectivity, land-use and land management

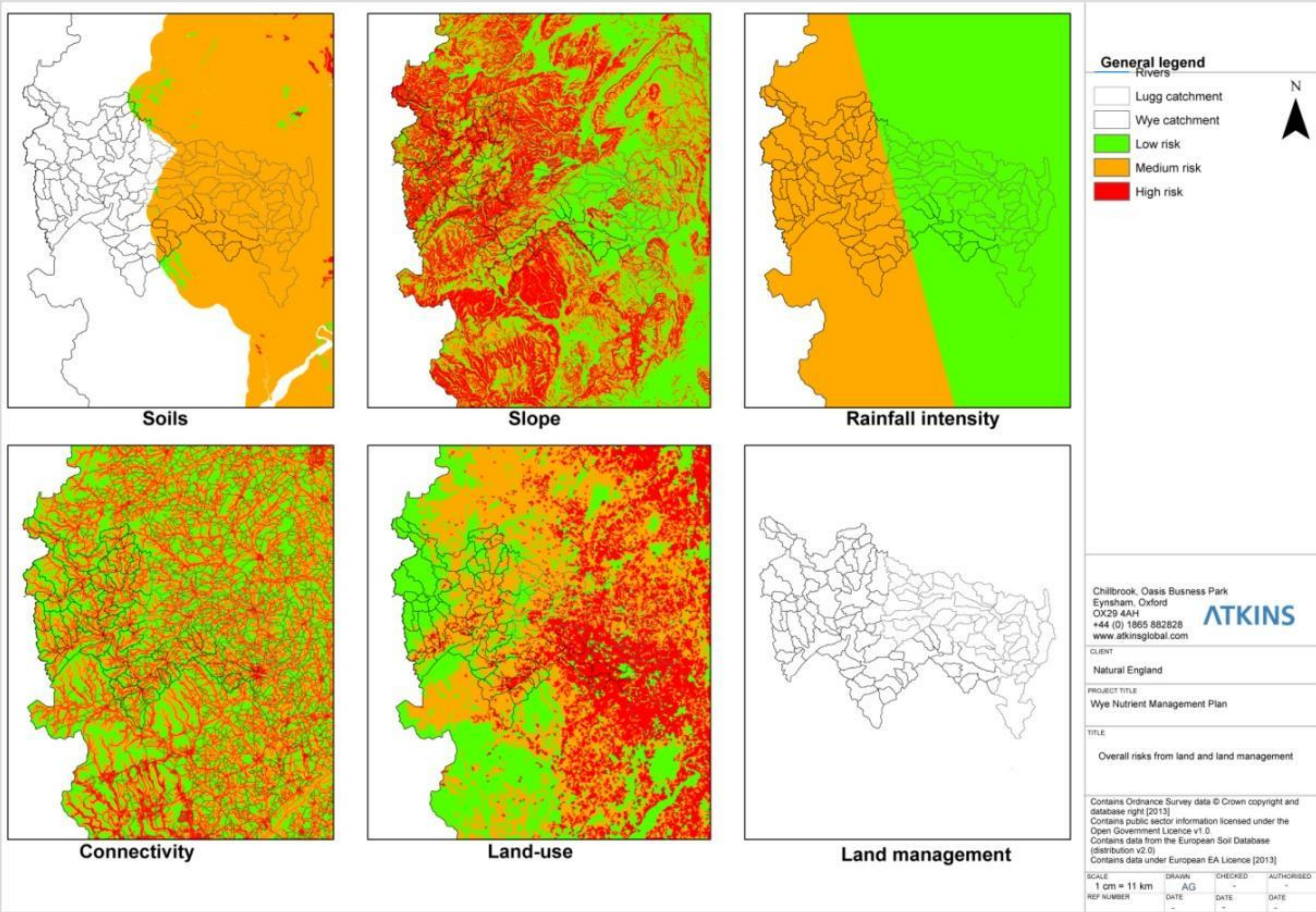


Figure 13-4: Catchment erosion risk map.

Appendix D. SAGIS: Sector inputs

The following table sets out the sector inputs that have been used in the SAGIS modelling for point sources.

Table 13-3: Description of sector inputs used in SAGIS

Sector	description
Septic tanks	On-site wastewater treatment systems (OSWwTWs), or septic tanks, are private sewage treatment facilities which typically serve the population not connected to main sewer networks (estimated at 2.1 million people in England and Wales). There is substantial uncertainty about the impact of OSWwTS on water quality, primarily as a consequence of a lack of information about the location, number and condition of OSWwTS, and general lack of monitoring of the effects of OSWwTS discharges to surface water and groundwater. Critical assumptions and sources of data used in deriving input estimated: • Locations of OsWwTWs were assumed as those determined in an Environment Agency project aimed at characterising septic tank locations and their discharge of phosphorus across England and Wales (Environment Agency, 2010). • Measured influent concentrations at WwTWs assumed not to be influenced significantly from industrial discharges which are assumed to be representative of inputs into OSWwTWs. The treatment effectiveness of OSWwTWs has been estimated to be low (<30%) Losses occur as the chemical load is transported toward the surface water (transmissivity). This input type is diffuse and input loads have therefore calculated on a 1km2 basis. For the SIMCAT modelling component the following parameters have been applied: • The correlation of the input load with river flows was 0.0 (implies no correlation between inputs and flow). • The coefficient of variation of the input load was 0.9 (implies a high degree of uncertainty in the input load value)
Intermittent discharges	Rain falling on impermeable areas such as roads, roofs, car parks etc, will runoff into the surface water system. Depending on the surface water system within the urban environment, the runoff may be (a) routed directly to the nearest watercourse, possibly via a balancing pond or wetland, (b) flow into a combined sewer system carrying foul and surface water to the local WwTW or (c) a combination of both (a) and (b). Combined sewers have a finite capacity designed into them of typically six times the dry weather flow (DWF), any rain events producing a flow greater than this, results in the mixture of surface and foul water being discharged via a combined sewer overflow (CSO) to the nearest watercourse to prevent flooding of the sewer system. Similarly at WwTWs receiving combined sewer discharges, during rainfall events storm tanks are provided to collect excess foul and surface water until it can be treated once the rainfall has ceased. Should the storm tanks maximum capacity be exceeded (typically three times DWF) then again, the overflow of mixed surface and foul water is routed in most cases directly to the nearest watercourse to prevent flooding of the works. The principle of the method applied to estimate inputs has been to generate a flow balance for urban areas which may then be combined with reported concentrations

	to generate loads of runoff to surface water, CSOs and WwTWs. Critical assumptions that have been applied include: • For all urban areas a default split of 49% of run-off goes to sewer and 51% of flow is directly into surface waters. • The design of combined sewers means that they should be able to carry six times the DWF before discharging to surface water via the CSO. • The design of WwTW means that they should be able to store up to three times the DWF in storm tanks before discharging to surface water. National rainfall intensity data has been associated with each urban areas using GIS. For each urban area the reported intensity has been broken down into 1 mm bands (daily rainfall intensity) which has formed the basis for calculating flows to surface water, WwTW and the spill volume. For the SIMCAT modelling component the following parameters have been applied: • The correlation of the input load with river flows was 1.0 (implies a high degree of correlation between inputs and flow). • The coefficient of variation of the input load was 1.0 (implies a high degree of uncertainty in the input load value)
Agriculture	The export coefficient database for phosphorus was based on output from the PSYCHIC decision support tool (Davison et al. 2008). PSYCHIC predicts the risk of diffuse pollution from a source area by estimating source, mobilisation and delivery of phosphorus and sediment: phosphorus inputs in manure and fertilisers and soil residual phosphorus, the mobilisation of phosphorus and sediment through dissolution and soil detachment and the delivery of dissolved and particulate phosphorus and associated sediment, to watercourses in surface and subsurface pathways, including field drains.

Appendix E. Upper River Wye and River Lugg sub- catchments: farm type assessment

E.1. Consideration of farm types in the River Wye SAC catchment

Different farming activities pose varying levels of risk to the water environment and so in order to understand the potential contributions from the agricultural sector it has been necessary to first gather baseline data on the various agricultural practices within the catchment.

Data from Defra and the Welsh Government have been used to define the farm types and frequency within the catchment to form the basis of the FARMSCOPER modelling and subsequently to interpret the outputs of the SAGIS modelling.

There are different datasets that set out farm types within the catchment, depending on whether the land falls within England or Wales.

For England, the data used are as follows:

- **Robust Farm Type (RFT) data (2010)** from Defra categorises farm holdings into broad groups, including: dairy; lowland grazing livestock; less favoured area grazing livestock; cereal; general cropping; horticulture; and poultry. Furthermore it links the number of holdings to water body catchments. Some data is suppressed, for example where there are fewer than 5 holdings in a water body.
- **Agri Census data (2010)** from Defra gives further detail on farming practices within the broad RFTs, for example the type of arable farming (barley; wheat; maize; stock feeding; other cereals; potato; oilseed rape; and other crops) and the type of livestock farming (sheep, cattle, poultry)

For Wales, the data used are slightly different:

- **'Small Areas' data (2010)** from agricultural surveys carried out by the Welsh Government gives statistics for farming in Wales and identifies areas of cultivated land (in hectares) or number of animals for various livestock types. Similarly to the English Agri-Census data, some data is suppressed.

It is recognised however that these data are based on agricultural census which therefore relies on accurate and representative feedback from farmers and due to the nature of farming, for example crop rotation and movement of animals between land parcels, is likely to be changing. It is however assumed that these data provide a useful indication of farm actives within the catchment.

The outputs from the analysis of farm type data has been used in the FARMSCOPER modelling to make the outputs more representative of the Wye catchment. Some assumptions have been made on aggregating farm types between the base data, FARMSCOPER categories and SAGIS categories. Some key points to note are covered in the following sections.

E.1.1. Farm types for the English part of the Wye catchment

The data requested from Defra returned statistics on Defra 'Robust Farm Types' (RFT) and detailed livestock and arable farming data. These data were provided at the water body level; no data was provided for water bodies that contain less than five holdings to prevent the possibility of identification of individual farm holdings and disclosure of personal information.

It is important to note that the farm type terminology of FARMSCOPER is not entirely consistent with the Defra terminology and some assumptions have therefore been made. FARMSCOPER recognises 17 different farm types, while SAGIS only has livestock and arable farming as source categories. The farm types in the study area were defined using the Defra data and were then assigned to the relevant SAGIS category. Zhang et al (2012) was used as guidance to decide which Defra farm type corresponds to which FARMSCOPER farm type (see below).

Table 13-4: Robust Farm Type (England) matches to FARMSCOPER farm types

Defra robust farm type	FARMSCOPER farm type
Dairy	Dairy
Lowland grazing livestock	Lowland grazing
Less Favoured Area (LfA) grazing livestock	Upland grazing
Cereal	Mixed combinable with pig manure
General cropping	Roots and combinable cropping with poultry manure
Horticulture	Horticulture
Poultry	Specialist poultry farm

The data were then divided into two catchment sections to represent the upper River Wye and the River Lugg.

Based on the Defra RFT statistics an initial analysis of the most common types of farming was undertaken and the results of this assessment are presented below.

Each sub-catchment has a number of water bodies where a RFT is listed, but where the data are suppressed. Table 13-5 also gives a summary of the extent of data suppression.

Table 13-5: Number of holdings by RFT and extent of data suppressed (England)

	Upper Wye		Lugg	
	N^{o} holdings	N^{o} of water bodies with suppressed data	N^{o} holdings	N^{o} of water bodies with suppressed data
Cereals	14	7	11	15
Dairy	0	4	11	17
General Cropping	59	2	6	16
Horticulture	21	4	9	11
LfA Grazing Livestock	19	3	1	4
Lowland Grazing Livestock	131	1	3	13
Mixed	28	5	3	18
Specialist Poultry	0	7	9	16

The key features of the RFT data (Figure 13-5) are as follows:

- Nearly half of all holdings in the upper River Wye catchment are for lowland grazing of livestock;
- A small percentage of holdings operate upland (Less favoured Area, LfA) grazing of livestock (7% and 9% for the upper River Wye and River Lugg catchments respectively). This is expected as the two sub catchments are relatively low lying compared with the Welsh portion of the catchment;
- The dominant arable farm types are for 'general cropping' and 'mixed';
- Horticulture accounts for relatively few holdings (8% and 10% for the upper River Wye and River Lugg catchments respectively).

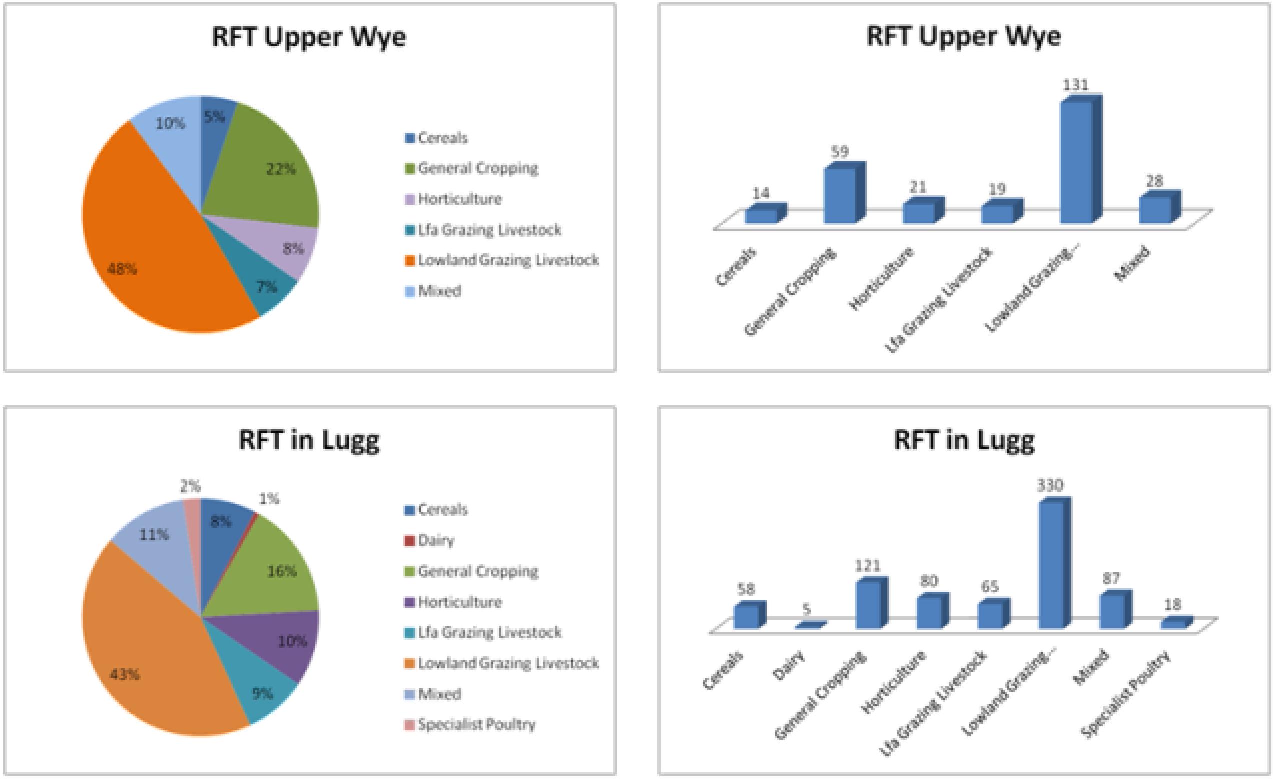


Figure 13-5: Distribution of Defra Robust Farm Types in the English part of the River Wye catchment (expressed as number of holdings)

Alongside the RFT data, the Agri Census data gives further detail on the farming practices within the broad RFT categories.

The key features of the Agri Census data (Figure 13-6 and Figure 13-7 below) are as follows:

- Chickens are the most numerous animal farmed within both catchments. This is expected because although the number of chicken farms is low, the numbers of animals in each farm is high. (Just 2% of farm holdings in the River Lugg and 0% in the upper River Wye are identified as poultry - although it is assumed that much of the suppressed data includes the poultry farms);
- Sheep comprise a large number of livestock in the catchment (7-12%);
- Cattle are the least numerous at 1% and 3% respectively;
- Most arable farming in both the upper River Wye and the River Lugg sub catchments is for wheat (>50% in each sub catchment);
- Oilseed rape comprises the next most extensive crop (11-12%) followed by barley ;
- Potato crops comprise smaller portions of arable farm type (8% of arable farms in both sub catchments).

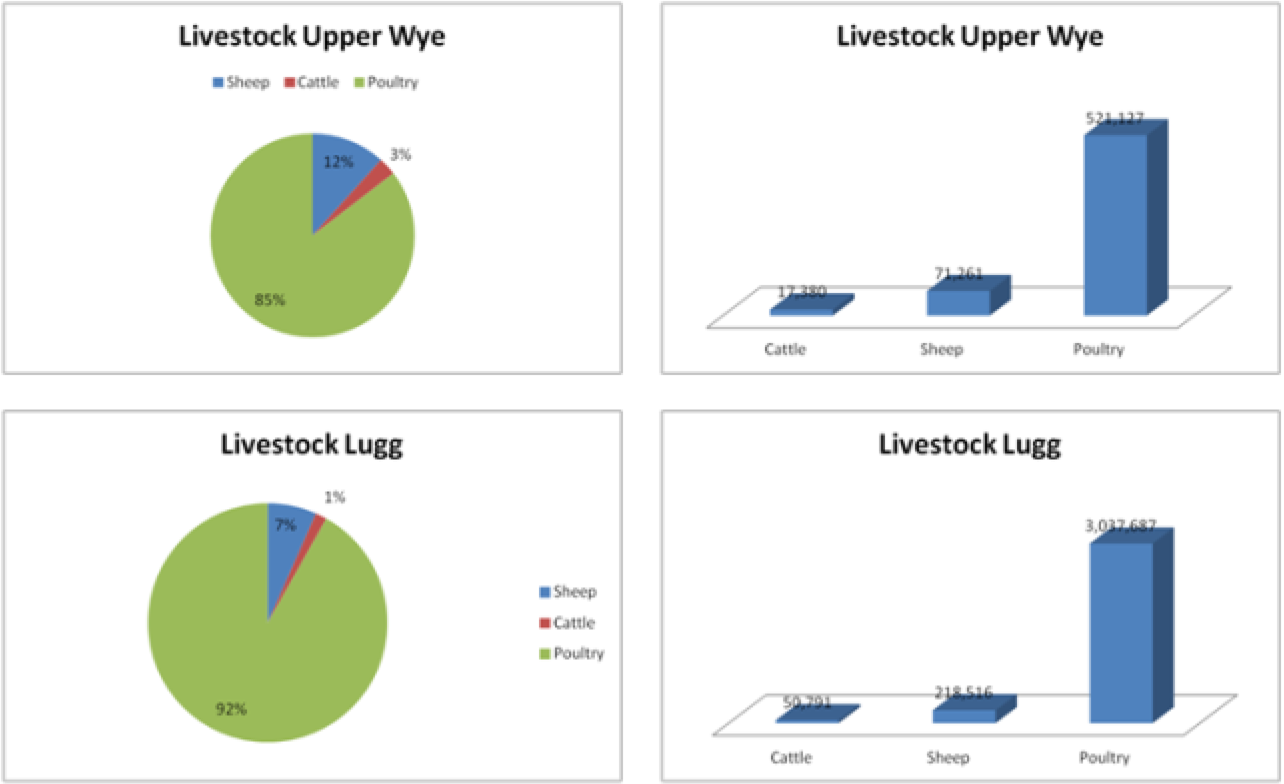


Figure 13-6: Livestock farming in the English part of the River Wye catchment (expressed as number of animals)

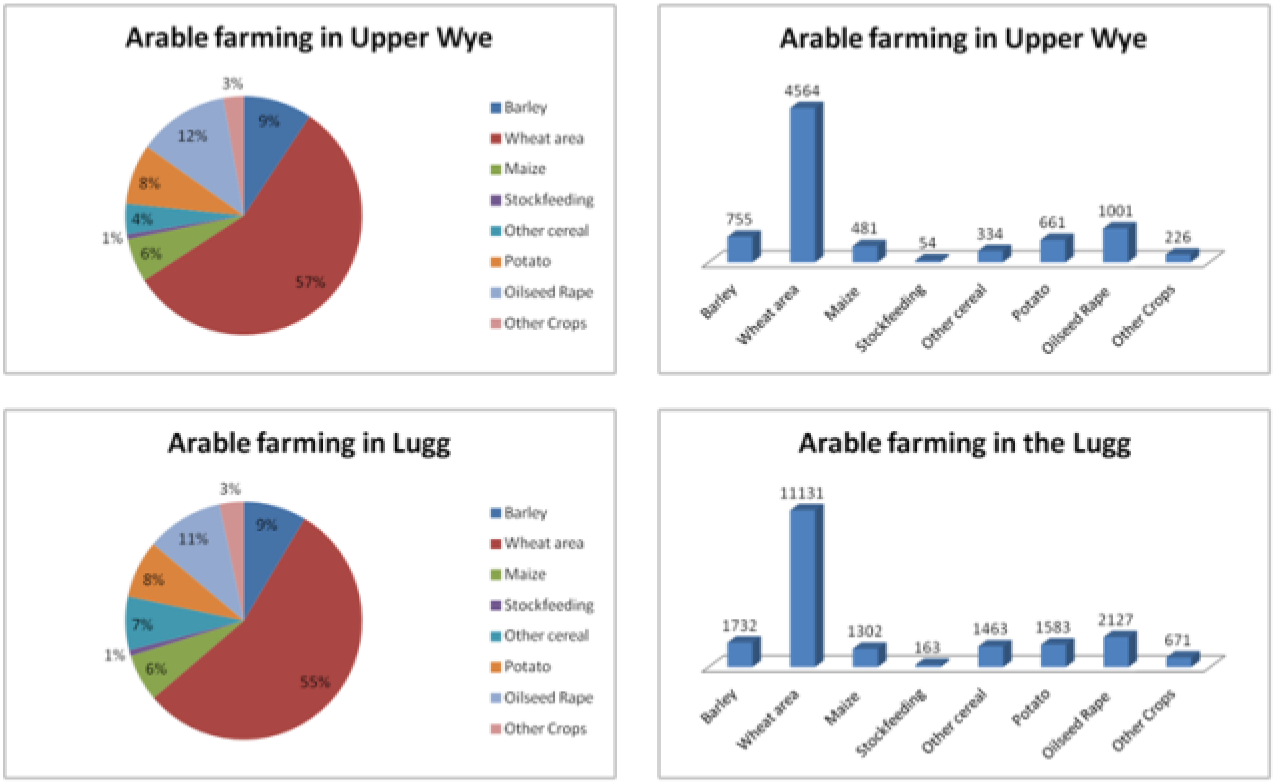


Figure 13-7: Arable farming in the English part of the River Wye catchment (data in ha)

E.1.1.1. FARMSCOPER farm types for the English part of the River Wye catchment

The FARMSCOPER farm types are summarised in Table 13-6, which contains additional catchment specific information required for running FARMSCOPER, namely rainfall and soils type. These are the English farm types and the conditions that have been modelled in FARMSCOPER.

(The percentages represent the contribution of each individual farm type to the overall livestock or arable phosphate loading in each catchment)

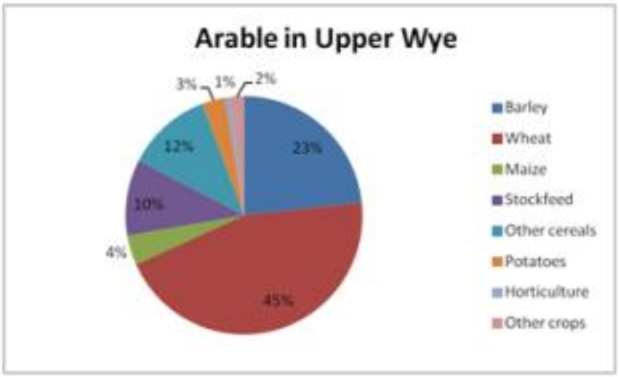
Table 13-6: FARMSCOPER farm types for the English part of the Wye catchment

Sub-catchment	Rainfall	Soil	Livestock	Arable
upper River Wye	900-1200	Poorly drained	13 % Upland 87 % Lowland Grazing,	47 % Roots and combinable with poultry manure 22 % Mixed combinable 31 % Horticulture
River Lugg	700-900	Poorly drained	17 % Upland 83 % Lowland Grazing,	63 % Roots and combinable with poultry manure 15 % Mixed combinable 22 % Horticulture

E.1.2. Farm types in the Welsh part of the River Wye catchment

The key features of the Welsh Small Areas Arable data (Figure 13-8) are:

- Arable farming in the Welsh part of the upper River Wye catchment is dominated by cereal growing (barley, wheat and other cereals).
- Some land given is over to potato crops, horticulture and 'other crops' which includes bare fallow
- In the upper River Wye, horticulture and potato growing are less significant; instead there is more maize growing and 'other crops'
- There is comparatively little arable farming in the River Lugg; only some barley and some stock feed (46 and 41 hectares respectively) and for this reason the River Lugg is not represented graphically here.



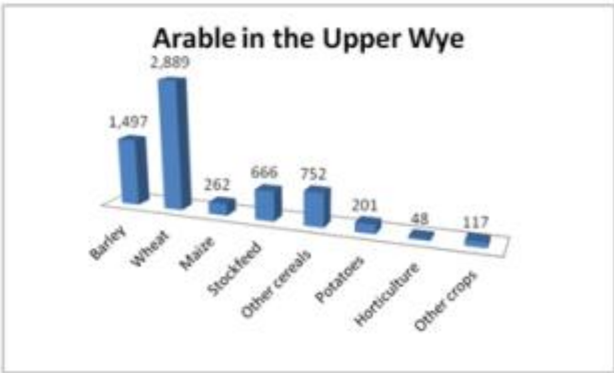


Figure 13-8: Arable farming in the Welsh part of the catchment (in hectares)

Livestock farming in the catchment is presented in Figure 13-9 below. The key features of these data are as follows:

- In the upper River Wye, livestock is dominated by sheep farming, with comparatively little cattle and poultry farming; and

- Poultry becomes much more important in the River Lugg, and while sheep numbers remain high, cattle farming appears to become less important.

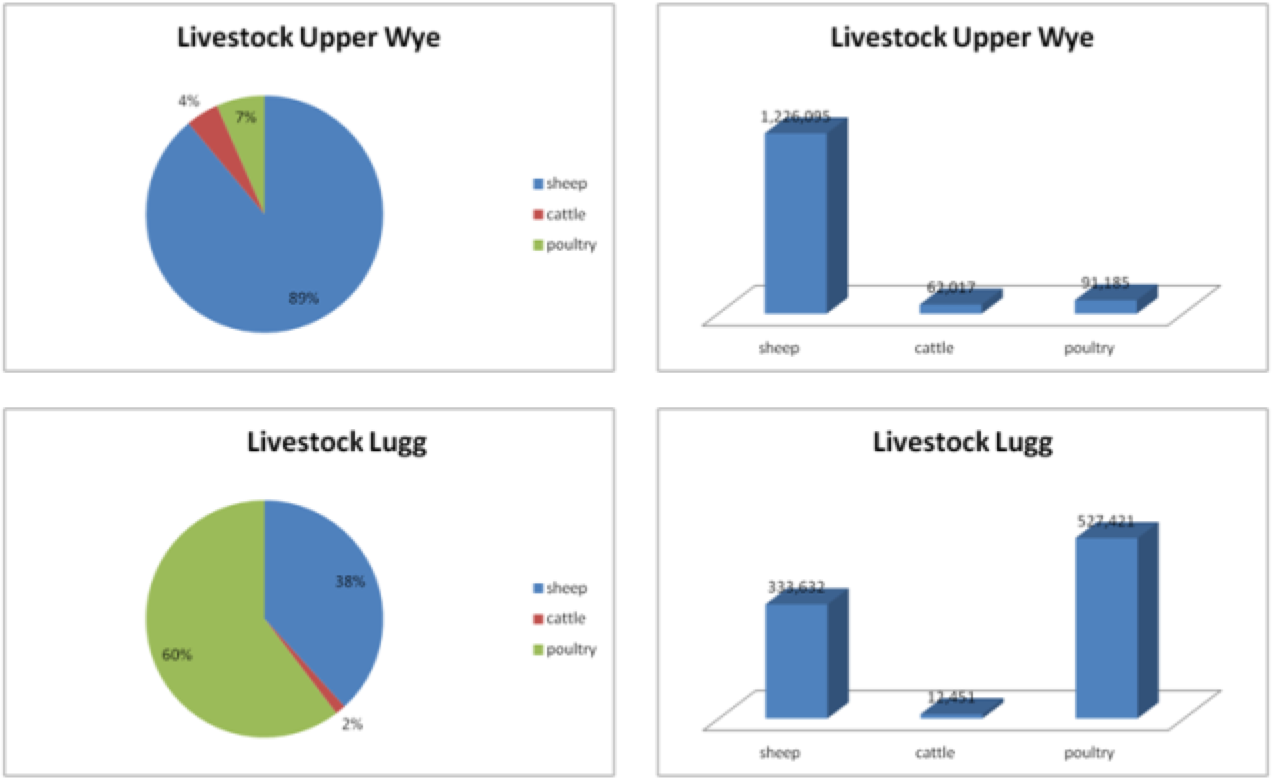


Figure 13-9: Livestock farming in the Welsh part of the catchment (expressed as number of animals)

E.1.2.1. FARMSCOPER farm types for the Welsh part of the Wye catchment

The FARMSCOPER farm types are summarised in Table 13-7[15], which contains additional catchment specific information required for running FARMSCOPER, namely rainfall and soils type. These are the Welsh farm types and the conditions for modelling in FARMSCOPER.

(The percentages represent the contribution of each individual farm type to the overall livestock or arable P loading in each sub-catchment).

Table 13-7: FARMSCOPER farm types in the Welsh part of the River Wye catchment

Sub-catchment	Rainfall (mm)	Soil	Livestock	Arable

[15] Arable farming in the Welsh part of the catchment consists of mixed combinable and roots and combinable farming, with some Horticulture (1%). The proportion of the mixed versus roots and combinable can in this case not be estimated using the RFT approach taken for the English part of the catchment. Instead the proportion of Roots and Combinable is estimated by considering all potatoes to be grown on this type of farm and the area of wheat grown on the farm is assumed to be the same as in the default farm type. If 1% of arable land is given over to horticulture, 99 % remains for other types of farming, namely ‘Mixed Combinable’ and ‘Roots and Combinable with poultry manure’, the relative importance can be estimated with a crop that is distinctive for one or the other type, which in this case is potato growing. All farms that grow potatoes are assumed to grow wheat in the same proportion as in FARMSCOPER; the remaining wheat is considered to be grown on Mixed Combinable farms.

upper River Wye	900-1200	Poorly drained	100 % Upland Grazing	1% Horticulture 74% Mixed combinable 25% Roots and combinable with poultry manure
River Lugg	700-900	Poorly drained	100 % Upland Grazing	Not significant

E.2. Manure management within FARMSCOPER

The way in which FARMSCOPER deals with manure from livestock farming is an important point to note when it comes to interpreting the model outputs.

The manure from all livestock is spread appropriately on to arable / grass given a preference (i.e. poultry manure is sent to arable land and is essentially a “source”. However, in doing so, FARMSCOPER takes account of the constraints of the relative amounts of arable / grassland available.

Therefore, even though the input is attributed to 'livestock' sources, the poultry muck would actually mostly have been applied to arable land.

E.3. Consideration of soil type

Soil type is an important factor when considering the pathway of pollutants from farms to water, especially with regards to phosphorus, and therefore consideration of soil type has been included within the modelling.

Soils in the catchment of the River Wye are generally free draining. However, soils on farmed land in the catchment tend to become heavily compacted and therefore lose their draining capacity. FARMSCOPER modelling requires an assumption on the predominant soil type and considering the tendency for compaction, all sub-catchments are considered to be **poorly drained** and modelled as such.

E.4. FARMSCOPER model runs

An audit trail of FARMSCOPER model runs and modifications made is contained within Table 13-8 below for reference.

Table 13-8: FARMSCOPER model runs and modifications made.

Scenario	Country	Sub catchment	Rainfall	Soil	SAGIS category	Farm type	Modifications to default farm	Number of animals and hectares changed
WWA1	Wales	Wye	900-1200	Drained for arable	Arable	Horticulture	None	No changes
WWA2	Wales	Wye	900-1200	Drained for arable	Arable	Roots and combinable with poultry manure	No changes	No changes
WWA3	Wales	Wye	900-1200	Drained for arable	Arable	Mixed combinable with pig manure	No changes to default croping ha.	No changes
WWL1	Wales	Wye	900-1200	Drained for grassland	Livestock	Upland grazing	The total number of sheep was recalculated and the number of sheep and lambs was modified in FARMSCOPER. The distribution of rough grazing etc was also recalculated to reflect the situation in the catchment.	353 sheep; 379 lambs; permanent pasture 58ha; rotational grassland 78ha; rough grazing 10ha
WLL1	Wales	Lugg	700-900	Drained for grassland	Livestock	Upland grazing	Same as for the upland farm in the Wye section	
EWA1	England	Wye	900-	Drained for	Arable	Horticulture	None	No changes

Scenario	Country	Sub catchment	Rainfall	Soil	SAGIS category	Farm type	Modifications to default farm	Number of animals and hectares changed
EWA2			1200	arable		Roots and combinable with poultry manure	No sugar beet; wheat versus barley recalculated, potatoes recalculated versus wheat	Sugar beet to 0ha; wheat to 71ha; winter barley to 6ha; spring barley to 5ha; potatoes to 9ha
EWA3						Mixed combinable with pig manure	Recalculated wheat and barley proportions.	Winter wheat 126ha; winter barley 9ha; spring barley 11ha
EWL1				Drained for grassland	Livestock	Upland grazing	Rough grazing etc proportions not adjusted because large amount of data is suppressed	No changes
EWL2						Lowland grazing	Idem as for upland farm	No changes
ELA1		Lugg	700-900	Drained for arable	Arable	Horticulture	None	No changes
ELA2						Roots and combinable with poultry manure	No sugar beet; wheat versus barley recalculated, potatoes recalculated versus wheat	Sugar beet to 0ha; wheat to 71ha; winter barley to 6ha; spring barley to 5 ha; potatoes to 10ha
ELA3						Mixed combinable with pig manure	recalculated wheat and barley proportions	Winter wheat 126ha; winter barley 9ha; spring barley 11ha
ELL1				Drained for grassland	Livestock	Upland grazing	Rough grazing etc proportions not adjusted because large amount of data is suppressed	No changes
ELL2						Lowland grazing	Idem as for upland farm	No changes

E.5. Optimiser Maximum measures

E.5.1. FARMSCOPER Optimiser Maximum livestock measures

		Upland Grazing				Lowland Grazing	
		England		Wales		England	
		Wye	Lugg	Wye	Lugg	Wye	Lugg
ID	Method name						
4	Establish cover crops in the autumn					Y	Y
5	Early harvesting and establishment of crops in the autumn						
6	Cultivate land for crops in spring rather than autumn						
7	Adopt reduced cultivation systems	Y	Y	Y	Y	Y	Y
8	Cultivate compacted tillage soils		Y		Y	Y	Y
9	Cultivate and drill across the slope					Y	
10	Leave autumn seedbeds rough						Y
11	Manage over-winter tramlines					Y	
13	Establish in-field grass buffer strips		Y				
14	Establish riparian buffer strips	Y	Y				Y
15	Loosen compacted soil layers in grassland fields						
16	Allow field drainage systems to deteriorate						Y
180	Intensive ditch management on arable land	Y	Y	Y			
181	Intensive ditch management on grassland						
19	Make use of improved genetic resources in livestock	Y	Y	Y	Y	Y	Y
20	Use plants with improved nitrogen use efficiency						
21	Fertiliser spreader calibration						
22	Use a fertiliser recommendation system	Y	Y	Y	Y	Y	Y
23	Integrate fertiliser and manure nutrient supply	Y	Y	Y	Y	Y	Y
25	Do not apply manufactured fertiliser to high-risk areas	Y	Y	Y	Y	Y	Y
26	Avoid spreading manufactured fertiliser to fields at high-risk times	Y	Y	Y	Y	Y	Y
27	Use manufactured fertiliser placement technologies			Y	Y	Y	Y
290	Replace urea fertiliser to grassland with another form						

		Upland Grazing				Lowland Grazing	
		England		Wales		England	
		Wye	Lugg	Wye	Lugg	Wye	Lugg
ID	Method name						
291	Replace urea fertiliser to arable land with another form						
300	Incorporate a urease inhibitor into urea fertilisers for grassland						
301	Incorporate a urease inhibitor into urea fertilisers for arable land						
31	Use clover in place of fertiliser nitrogen						
32	Do not apply P fertilisers to high P index soils	Y	Y	Y	Y	Y	Y
331	Reduce dietary N and P intakes: Dairy						
332	Reduce dietary N and P intakes: Pigs and Poultry						
34	Adopt phase feeding of livestock						
35	Reduce the length of the grazing day/grazing season	Y	Y	Y	Y	Y	Y
36	Extend the grazing season for cattle						
37	Reduce field stocking rates when soils are wet	Y	Y	Y	Y	Y	Y
38	Move feeders at regular intervals						
39	Construct troughs with concrete base	Y	Y	Y	Y	Y	Y
42	Increase scraping frequency in dairy cow cubicle housing						
43	Additional targeted bedding for straw-bedded cattle housing						
44	Washing down of dairy cow collecting yards						
46	Frequent removal of slurry from beneath-slat storage in pig housing						
47	Part-slatted floor design for pig buildings						
48	Install air-scrubbers or biotrickling filters in mechanically ventilated pig housing						
49	Convert caged laying hen housing from deep-pit storage to belt manure removal						
50	More frequent manure removal from laying hen housing with manure belt systems						
51	In-house poultry manure drying						
52	Increase the capacity of farm slurry stores to improve timing of slurry applications						
53	Adopt batch storage of slurry						

		Upland Grazing				Lowland Grazing	
		England		Wales		England	
		Wye	Lugg	Wye	Lugg	Wye	Lugg
ID	Method name						
54	Install covers to slurry stores						
55	Allow cattle slurry stores to develop a natural crust						
570	Minimise the volume of dirty water produced (sent to dirty water store)	Y	Y	Y		Y	
571	Minimise the volume of dirty water produced (sent to slurry store)						
59	Compost solid manure						
60	Site solid manure heaps away from watercourses/field drains	Y	Y	Y	Y	Y	Y
61	Store solid manure heaps on an impermeable base and collect effluent	Y	Y	Y	Y	Y	Y
62	Cover solid manure stores with sheeting	Y	Y	Y	Y	Y	Y
63	Use liquid/solid manure separation techniques	Y	Y	Y			
64	Use poultry litter additives						
67	Manure Spreader Calibration						
68	Do not apply manure to high-risk areas	Y	Y	Y	Y	Y	Y
69	Do not spread slurry or poultry manure at high-risk times						
70	Use slurry band spreading application techniques						
71	Use slurry injection application techniques			Y	Y	Y	Y
72	Do not spread FYM to fields at high-risk times	Y	Y	Y	Y	Y	Y
73	Incorporate manure into the soil	Y		Y	Y	Y	Y
76	Fence off rivers and streams from livestock	Y	Y	Y	Y	Y	Y
77	Construct bridges for livestock crossing rivers/streams						
78	Re-site gateways away from high-risk areas	Y	Y	Y	Y	Y	Y
79	Farm track management						
80	Establish new hedges		Y	Y	Y		Y
81	Establish and maintain artificial wetlands - steading runoff	Y	Y	Y	Y		
82	Irrigate crops to achieve maximum yield						
83	Establish tree shelter belts around livestock housing						
90	Calibration of sprayer						

		Upland Grazing				Lowland Grazing	
		England		Wales		England	
		Wye	Lugg	Wye	Lugg	Wye	Lugg
ID	Method name						
91	Fill/Mix/Clean sprayer in field						
92	Avoid PPP application at high risk timings						
94	Drift reduction methods						
95	PPP substitution						
96	Construct bunded impermeable PPP filling/mixing/cleaning area						
97	Treatment of PPP washings through disposal, activated carbon or biobeds						
101	Protection of in-field trees	Y	Y	Y	Y	Y	Y
102	Management of woodland edges						
103	Management of in-field ponds	Y	Y	Y	Y	Y	Y
1040	Unintensive hedge and ditch management on arable land	Y			Y	Y	Y
1041	Unintensive hedge and ditch management on grassland		Y	Y	Y	Y	Y
105	Management of field corners		Y	Y	Y	Y	
106	Plant areas of farm with wild bird seed / nectar flower mixtures		Y		Y	Y	Y
107	Beetle banks				Y	Y	Y
108	Uncropped cultivated margins	Y		Y	Y	Y	Y
109	Skylark plots						
110	Uncropped cultivated areas	Y	Y	Y	Y	Y	Y
111	Unfertilised cereal headlands						
112	Unharvested cereal headlands						
113	Undersown spring cereals						
114	Take field corners out of management	Y					Y
115	Leave over winter stubbles						
116	Leave residual levels of non-aggressive weeds in crops						
117	Use correctly-inflated low ground pressure tyres on machinery						Y
118	Locate out-wintered stock away from watercourses	Y	Y	Y	Y	Y	Y
119	Use dry-cleaning techniques to remove solid waste from yards prior to cleaning	Y	Y	Y	Y		

		Upland Grazing				Lowland Grazing	
		England		Wales		England	
		Wye	Lugg	Wye	Lugg	Wye	Lugg
ID	Method name						
120	Capture of dirty water in a dirty water store	Y	Y	Y	Y		
121	Irrigation/water supply equipment is maintained and leaks repaired						
122	Avoid irrigating at high risk times						
123	Use efficient irrigation techniques (boom trickle, self closing nozzles)						

E.5.2. FARMSCOPER Optimiser Maximum arable measures

		Horticulture				Roots and Combinable with Poultry Manure				Mixed Combinable			
		England		Wales		England		Wales		England		Wales	
		Wye	Lugg	Wye	Lugg	Wye	Lugg	Wye	Lugg	Wye	Lugg	Wye	Lugg
ID	Method name												
4	Establish cover crops in the autumn	Y	Y	Y		Y	Y	Y		Y	Y	Y	
5	Early harvesting and establishment of crops in the autumn												
6	Cultivate land for crops in spring rather than autumn												
7	Adopt reduced cultivation systems	Y	Y	Y		Y	Y	Y		Y	Y	Y	
8	Cultivate compacted tillage soils	Y	Y	Y		Y	Y	Y		Y	Y	Y	
9	Cultivate and drill across the slope					Y		Y		Y	Y		
10	Leave autumn seedbeds rough									Y	Y		
11	Manage over-winter tramlines										Y		
13	Establish in-field grass buffer strips	Y	Y	Y		Y	Y	Y		Y	Y	Y	
14	Establish riparian buffer strips	Y	Y	Y		Y	Y	Y		Y	Y	Y	
15	Loosen compacted soil layers in grassland fields	Y	Y	Y		Y	Y	Y		Y	Y	Y	
16	Allow field drainage systems to deteriorate	Y	Y	Y		Y	Y	Y		Y	Y	Y	
180	Intensive ditch management on arable land		Y										
181	Intensive ditch management on grassland												
19	Make use of improved genetic resources in livestock												
20	Use plants with improved nitrogen use efficiency												
21	Fertiliser spreader calibration												
22	Use a fertiliser recommendation system	Y	Y	Y		Y	Y	Y			Y	Y	
23	Integrate fertiliser and manure nutrient supply					Y	Y	Y		Y		Y	
25	Do not apply manufactured fertiliser to high-risk areas		Y			Y		Y		Y	Y		
26	Avoid spreading manufactured fertiliser to fields at high-risk times	Y	Y	Y		Y	Y	Y		Y	Y		
27	Use manufactured fertiliser placement technologies	Y	Y	Y		Y		Y			Y	Y	
290	Replace urea fertiliser to grassland with another form												
291	Replace urea fertiliser to arable land with another form												
300	Incorporate a urease inhibitor into urea fertilisers for grassland												
301	Incorporate a urease inhibitor into urea fertilisers for arable land												
31	Use clover in place of fertiliser nitrogen												
32	Do not apply P fertilisers to high P index soils	Y	Y	Y		Y		Y		Y		Y	
331	Reduce dietary N and P intakes: Dairy												
332	Reduce dietary N and P intakes: Pigs and Poultry					Y	Y	Y		Y		Y	
34	Adopt phase feeding of livestock					Y		Y				Y	
35	Reduce the length of the grazing day/grazing season	Y	Y	Y		Y		Y					
36	Extend the grazing season for cattle											Y	
37	Reduce field stocking rates when soils are wet					Y		Y				Y	
38	Move feeders at regular intervals		Y			Y		Y				Y	
39	Construct troughs with concrete base	Y		Y									
42	Increase scraping frequency in dairy cow cubicle housing												
43	Additional targeted bedding for straw-bedded cattle housing												
44	Washing down of dairy cow collecting yards												
46	Frequent removal of slurry from beneath-slat storage in pig housing												
47	Part-slatted floor design for pig buildings												
48	Install air-scrubbers or biotrickling filters in mechanically ventilated pig housing												

		Horticulture				Roots and Combinable with Poultry Manure				Mixed Combinable			
		England		Wales		England		Wales		England		Wales	
		Wye	Lugg	Wye	Lugg	Wye	Lugg	Wye	Lugg	Wye	Lugg	Wye	Lugg
ID	Method name												
49	Convert caged laying hen housing from deep-pit storage to belt manure removal												
50	More frequent manure removal from laying hen housing with manure belt systems												
51	In-house poultry manure drying												
52	Increase the capacity of farm slurry stores to improve timing of slurry applications									Y		Y	
53	Adopt batch storage of slurry												
54	Install covers to slurry stores												
55	Allow cattle slurry stores to develop a natural crust												
570	Minimise the volume of dirty water produced (sent to dirty water store)	Y		Y		Y	Y	Y		Y			
571	Minimise the volume of dirty water produced (sent to slurry store)												
59	Compost solid manure												
60	Site solid manure heaps away from watercourses/field drains					Y	Y	Y		Y		Y	
61	Store solid manure heaps on an impermeable base and collect effluent					Y	Y	Y		Y		Y	
62	Cover solid manure stores with sheeting					Y	Y	Y		Y		Y	
63	Use liquid/solid manure separation techniques	Y		Y			Y					Y	
64	Use poultry litter additives												
67	Manure Spreader Calibration												
68	Do not apply manure to high-risk areas					Y	Y	Y		Y			
69	Do not spread slurry or poultry manure at high-risk times					Y	Y	Y		Y		Y	
70	Use slurry band spreading application techniques												
71	Use slurry injection application techniques		Y			Y	Y	Y				Y	
72	Do not spread FYM to fields at high-risk times									Y		Y	
73	Incorporate manure into the soil		Y			Y	Y	Y		Y		Y	
76	Fence off rivers and streams from livestock												
77	Construct bridges for livestock crossing rivers/streams												
78	Re-site gateways away from high-risk areas	Y	Y	Y		Y	Y	Y		Y	Y	Y	
79	Farm track management												
80	Establish new hedges												
81	Establish and maintain artificial wetlands - steading runoff					Y		Y			Y		
82	Irrigate crops to achieve maximum yield												
83	Establish tree shelter belts around livestock housing												
90	Calibration of sprayer												
91	Fill/Mix/Clean sprayer in field												
92	Avoid PPP application at high risk timings												
94	Drift reduction methods												
95	PPP substitution												
96	Construct bunded impermeable PPP filling/mixing/cleaning area												
97	Treatment of PPP washings through disposal, activated carbon or biobeds												
101	Protection of in-field trees		Y			Y				Y		Y	
102	Management of woodland edges												
103	Management of in-field ponds	Y	Y	Y		Y		Y			Y		
1040	Unintensive hedge and ditch management on arable land	Y	Y	Y		Y	Y	Y		Y	Y	Y	
1041	Unintensive hedge and ditch management on grassland												
105	Management of field corners					Y						Y	
106	Plant areas of farm with wild bird seed / nectar flower mixtures					Y		Y			Y	Y	
107	Beetle banks									Y	Y	Y	
108	Uncropped cultivated margins	Y		Y		Y						Y	
109	Skylark plots												

		Horticulture				Roots and Combinable with Poultry Manure				Mixed Combinable			
		England		Wales		England		Wales		England		Wales	
		Wye	Lugg	Wye	Lugg	Wye	Lugg	Wye	Lugg	Wye	Lugg	Wye	Lugg
ID	Method name												
110	Uncropped cultivated areas	Y		Y		Y							
111	Unfertilised cereal headlands												
112	Unharvested cereal headlands					Y					Y		
113	Undersown spring cereals												
114	Take field corners out of management										Y		
115	Leave over winter stubbles												
116	Leave residual levels of non-aggressive weeds in crops												
117	Use correctly-inflated low ground pressure tyres on machinery					Y					Y		
118	Locate out-wintered stock away from watercourses												
119	Use dry-cleaning techniques to remove solid waste from yards prior to cleaning												
120	Capture of dirty water in a dirty water store					Y	Y	Y				Y	
121	Irrigation/water supply equipment is maintained and leaks repaired												
122	Avoid irrigating at high risk times					Y	Y	Y					
123	Use efficient irrigation techniques (boom trickle, self closing nozzles)					Y	Y	Y					

Appendix F. Source Apportionment Calibration Report

F.1. Aim

The use of computer modelling to make predictions about environmental systems is well established and is undertaken in many environmental disciplines. A computer modelling approach using the Source Apportionment GIS model (SAGIS) and has been selected to assist the development of a Nutrient Management Plan for the River Wye. An important consideration prior to the application of computer modelling is, however, that computer models should be optimised for the purposes of their intended use in order to reduce uncertainty and to ensure that the models provide the most accurate representation of reality as possible. This draft technical note briefly describes the calibration of the SAGIS model that will be used later in project programme.

F.2. Methodology

The SAGIS model outputs usually of greatest interest are the substance concentration predictions, primarily since these may be compared against relevant Regulatory Standards and risk to compliance ascertained. Substance concentration predictions are dependent on a range of model parameters although most importantly:

- The amount of substance that is deposited into the water course;
- The dilution capacity in the water course (i.e. river flows and hydrology);
- Covariance between substance deposition and dilution capacity (i.e. under what river flow conditions the inputs occur).

In order to ensure the model provides a good representation of reality it is important that the calibration process is undertaken in a logical order that seeks to improve model performance but also to identify the elements of uncertainty that might influence the agreement between simulated and observed concentration. Indeed, in addition to improving model performance, the calibration process may also be useful to improve understanding of the system under examination, or at least, to identify elements of uncertainty that may be crucial to our understanding of the system. In this study, the calibration process was undertaken in two stages, namely;

- **Model update and checking of features –** entails ensuring the model provides an accurate representation of hydrological characteristics and that the representation of point and diffuse source inputs utilises the up-to-date information (e.g. use the most up to date PSYCHIC model data). The updated model is used to produce a baseline forecast of in-river phosphate concentrations for the areas of interest.

- **Refining of baseline –** entails an examination of the extent of agreement between the baseline forecast and historical monitoring data and model adjustment to optimise the agreement between the baseline forecast and historical monitoring data. This stage was aimed at identifying reasons for differences between simulated and observed concentration values. This approach is, arguably, superior to the traditional SIMCAT 'auto-calibrate' which forces agreement between simulated and observed concentration values without explicit consideration for the reasons for differences between simulated and observed concentration values.

F.3. Results

F.3.1. Model update

As part of the model update the following activities were undertaken:

- Update model database to reflect the most up-to-date information on diffuse agricultural inputs (PSYCHIC 2010 – supplied by ADAS on behalf of Natural England and the Environment Agency);
- Update model hydrological characteristics to reflect river flow conditions for the area of interest;
- Review point source discharge features (sewage treatment works) to ensure that discharge flow and discharge concentration are accurately represented for all significant features.

Following the model update baseline forecasts were produced for:

- The River Wye from its furthest upstream reach until its confluence with the River Lugg (Figure 13-10)
- The River Lugg from its furthest upstream reach until its confluence with the River Lugg (Figure 13-11)
- The River Wye from its confluence with the River Lugg until the location at which it discharges into the Severn Estuary (Figure 13-12)

In each of the baselines it was apparent that the simulated concentrations were higher (by between a factor of 2 or 3) than the observed concentration values. Reasons for these differences were examined as part of the model refinement phase.

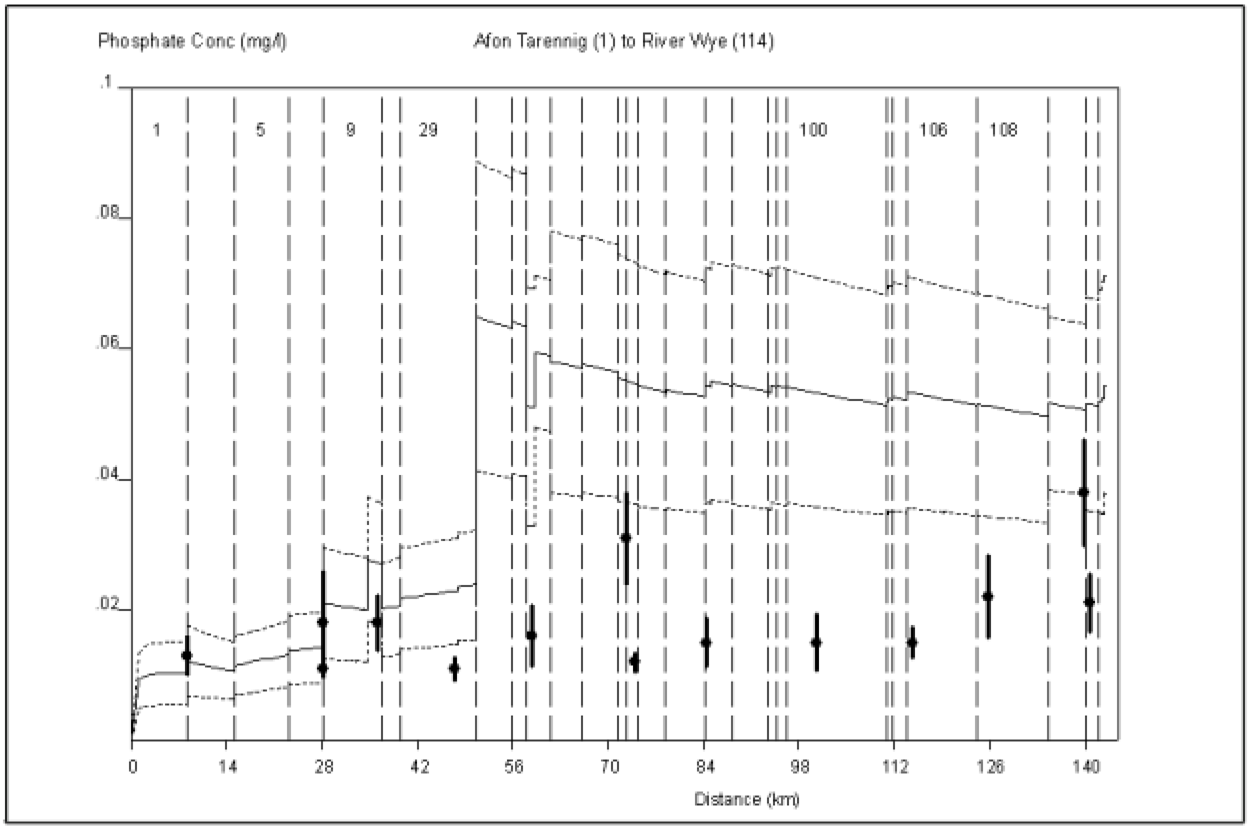


Figure 13-10 SAGIS predicted concentration for the River Wye from the upland head waters until its confluence with the River Lugg.

The solid line represents the average predicted concentration and the broken lines the corresponding confidence interval range. The points represent the observed average concentration with the error bars indicating the confidence interval range. The dashed vertical lines indicate river reaches.

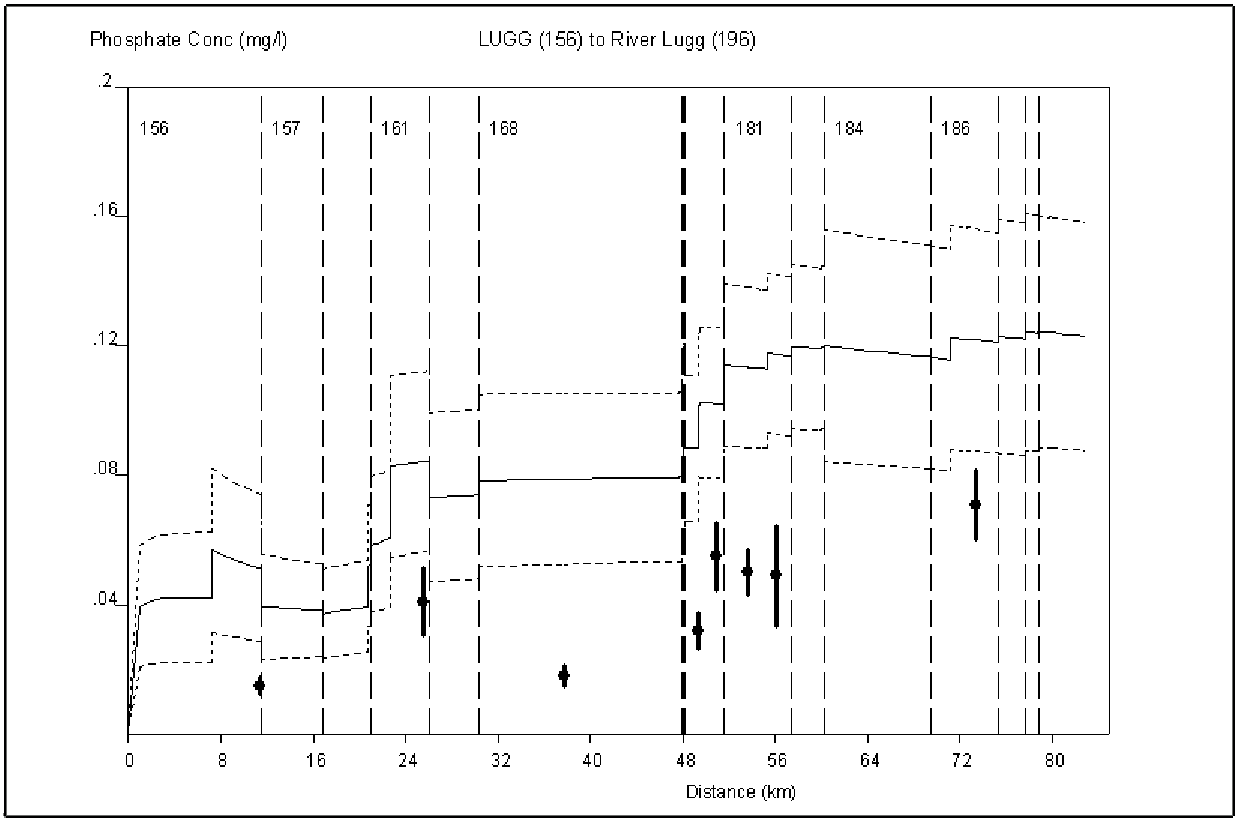


Figure 13-11 SAGIS predicted concentration for the River Lugg from the headwaters until its confluence with the River Wye.

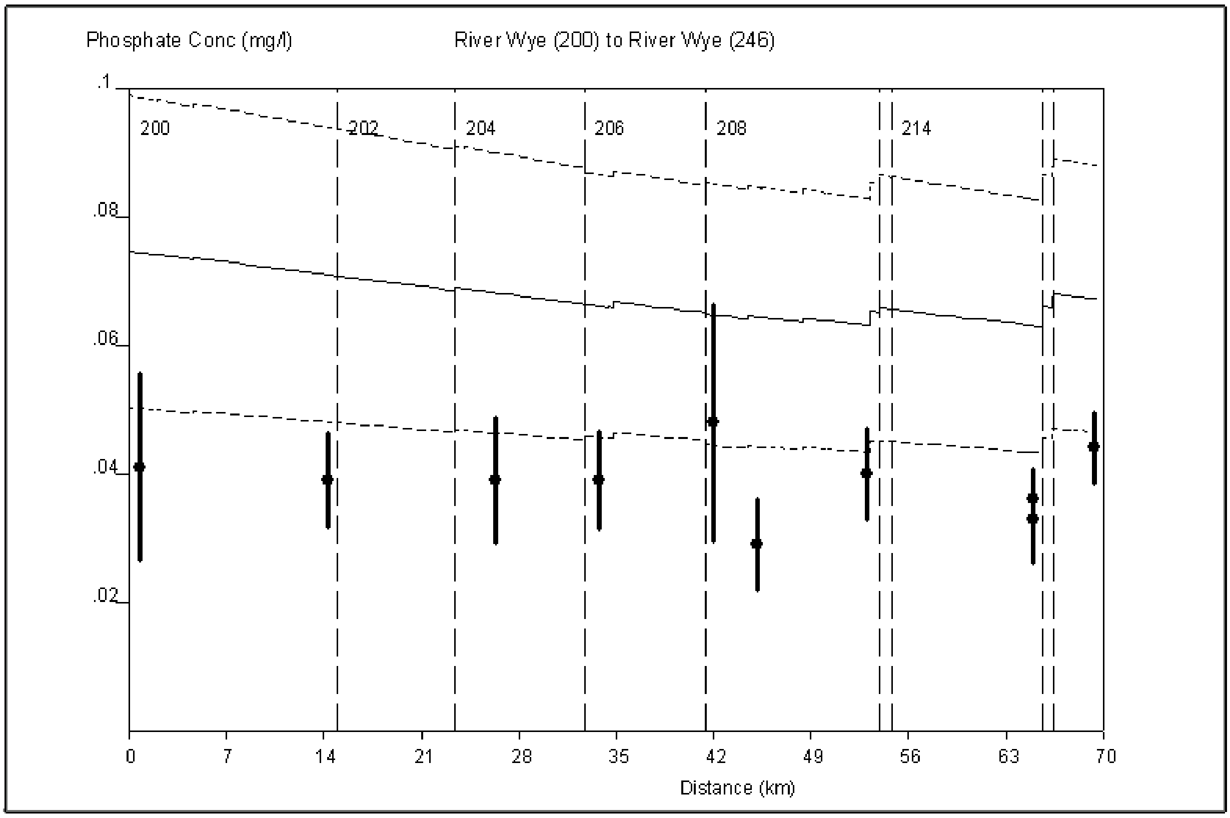


Figure 13-12 SAGIS predicted concentration for the River Wye from its confluence with the River Lugg to the point at which it discharges into the Severn Estuary.

F.3.2. Refining of baseline

The simulated baseline concentrations displayed a tendency to be higher than the observed concentration values (ranging between a factor of 2 and 3). The over-prediction was potentially attributable to a number of causes although data analysis indicated that the over-prediction was not particular to the regions of interest but tended to occur generally where phosphate inputs from livestock predominated. Furthermore, the magnitude of the discrepancy suggested that this was unlikely to be attributable to uncertainty in the input load estimates themselves[16]. Further examination of model data suggested an over-prediction to be likely occur as a consequence of assumptions about the relationship between river flows and the timing of the arrival of diffuse inputs in the river (for example, the resultant concentration from 1 kg of phosphate arriving in a river under conditions of high river flow will be different under low river flow conditions). SAGIS assumes that the arrival of diffuse inputs in the river is proportional to river flows (i.e. low input under conditions of low flows and high inputs under conditions of high flow) although there is some evidence from other recent studies (e.g. the Moorland Catchment in the Eden DTC study) that the most significant fraction of diffuse agricultural inputs arrives in the river system under conditions of very high river flows (80% of the load under the highest 10% of river flow conditions). Additional data analysis indicated that inaccuracy in the representation of the timing of inputs could, indeed, plausibly explain a difference in predicted concentrations by in excess of a factor of three. On this basis SAGIS model data was modified to better reflect the relationship between the timing of inputs and river flows.

A visual representation of the calibrated model outputs are given in the figures below. Summary conclusions for the areas of interest are:

- A substantial improvement in the accuracy of the forecast for the River Wye from the headwaters to its confluence with the River Lugg (Figure 13-13). In general, the observed concentration values are within

[16] Uncertainty in the input load already taken into account by applying an assumed/measured variation in the inputs

the 95% confidence interval range of the simulated values although represent a relatively conservative perspective (simulated concentrations tend to exceed observed values). Inputs from sewage treatment works and diffuse inputs from livestock to be the most significant sources of phosphate (Figure 13-14) and are of approximately equivalent significance in terms of their contribution to in-river concentrations.

- As in the River Wye, there was a similar improvement in the accuracy of the model forecast for the River Lugg (Figure 13-15). The model forecasts indicate that inputs from sewage treatment works and livestock to be the most significant sources of phosphate (Figure 13-16) and are of approximately equivalent significance in terms of their contribution to in-river concentrations. Some small inputs from industrial sources are also represented (Boultibrook Fish Farm and Cadbury).
- Simulated concentrations in the River Wye downstream of its confluence with the River Lugg were also improved (Figure 13-17). Inputs from sewage treatment works and diffuse inputs from livestock represent the most significant source of phosphate and are of approximately equivalent significance in terms of their contribution to in-river concentrations.

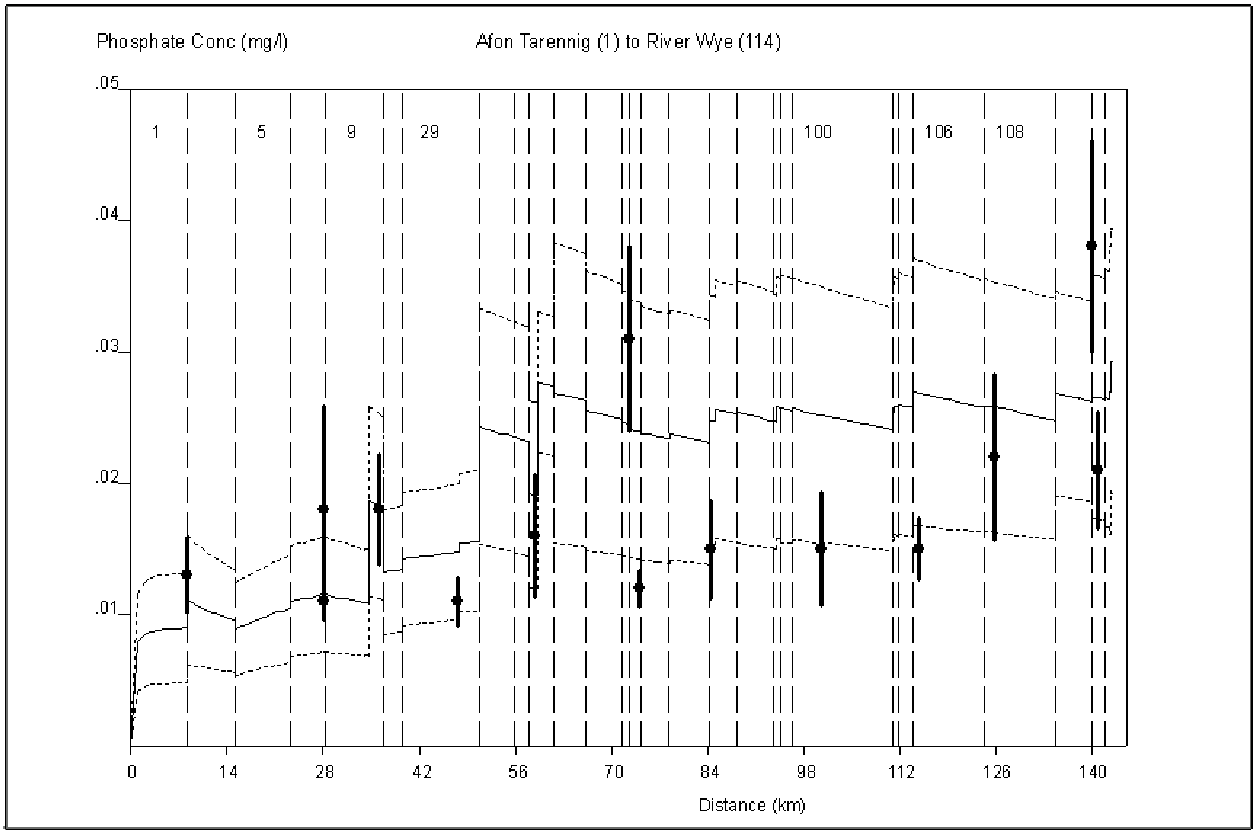


Figure 13-13 Refined SAGIS prediction for the River Wye from the upland head waters until its confluence with the River Lugg.

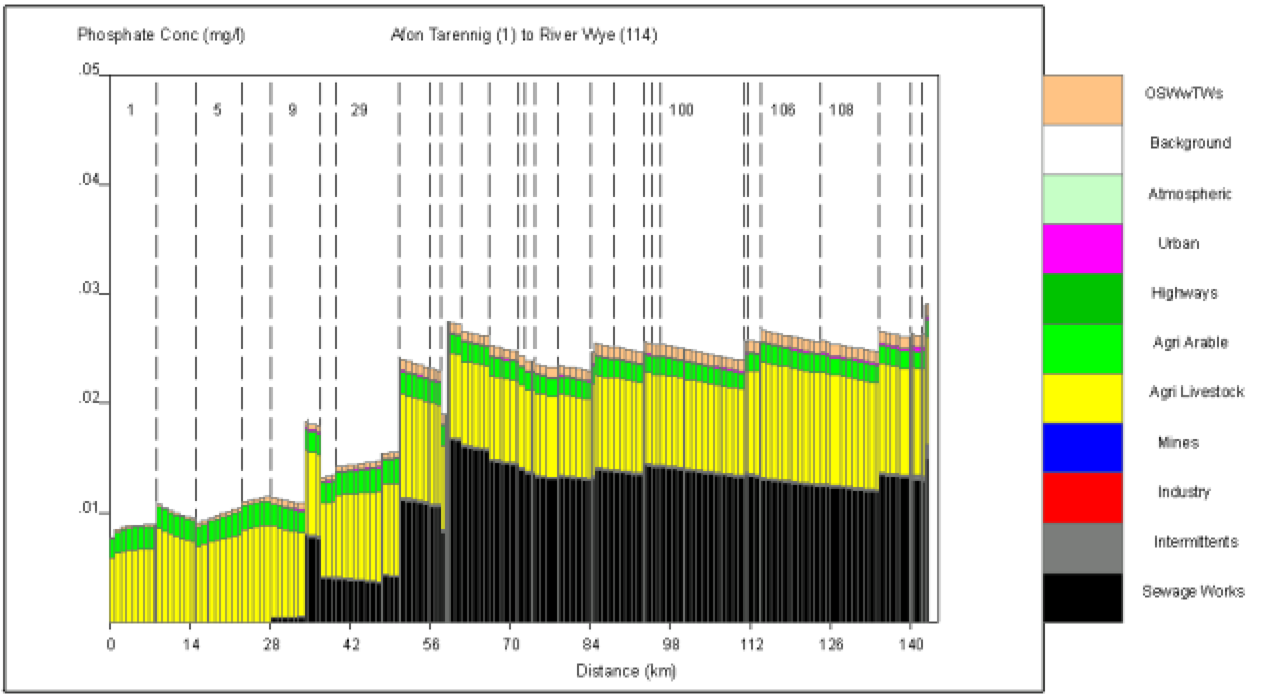


Figure 13-14 SAGIS source apportionment prediction for the River Wye from the upland head waters until its confluence with the River Lugg.

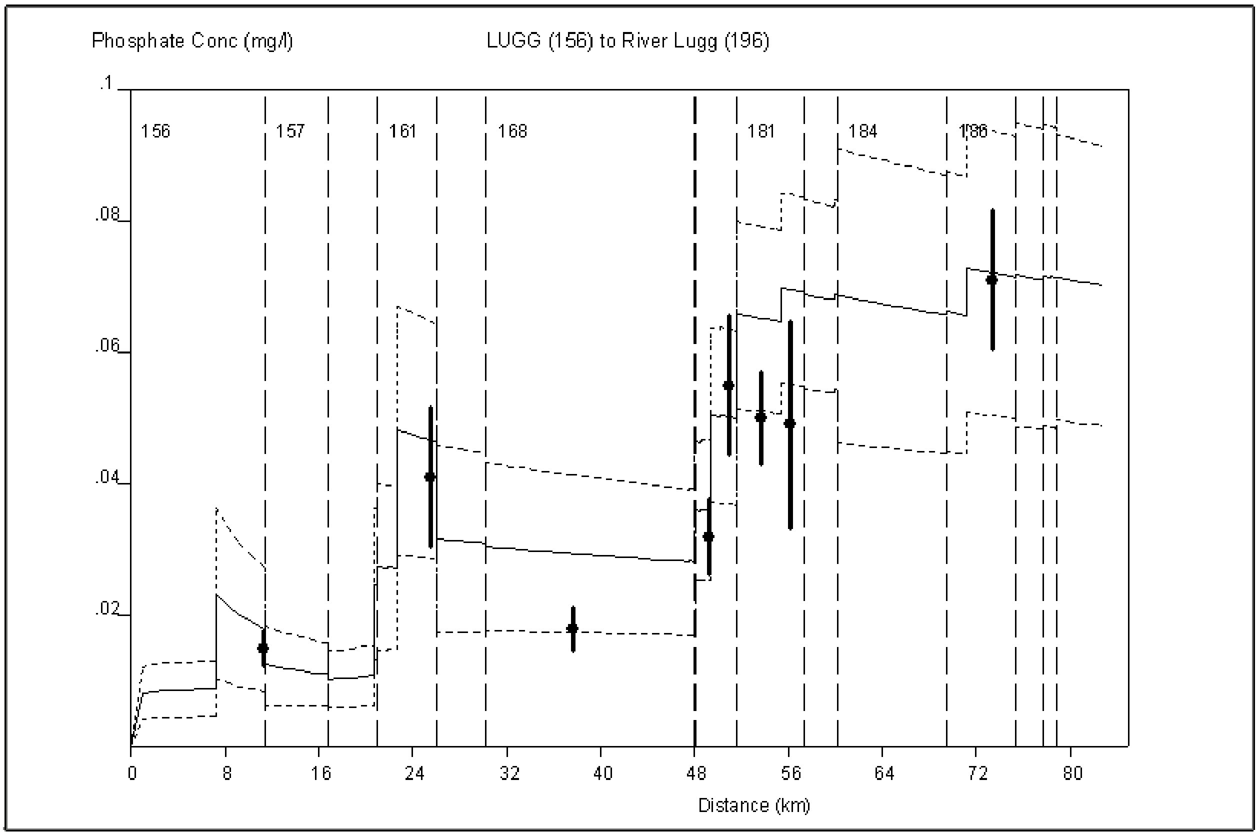


Figure 13-15 Refined SAGIS prediction for the River Lugg from the upland head waters until its confluence with the River Wye.

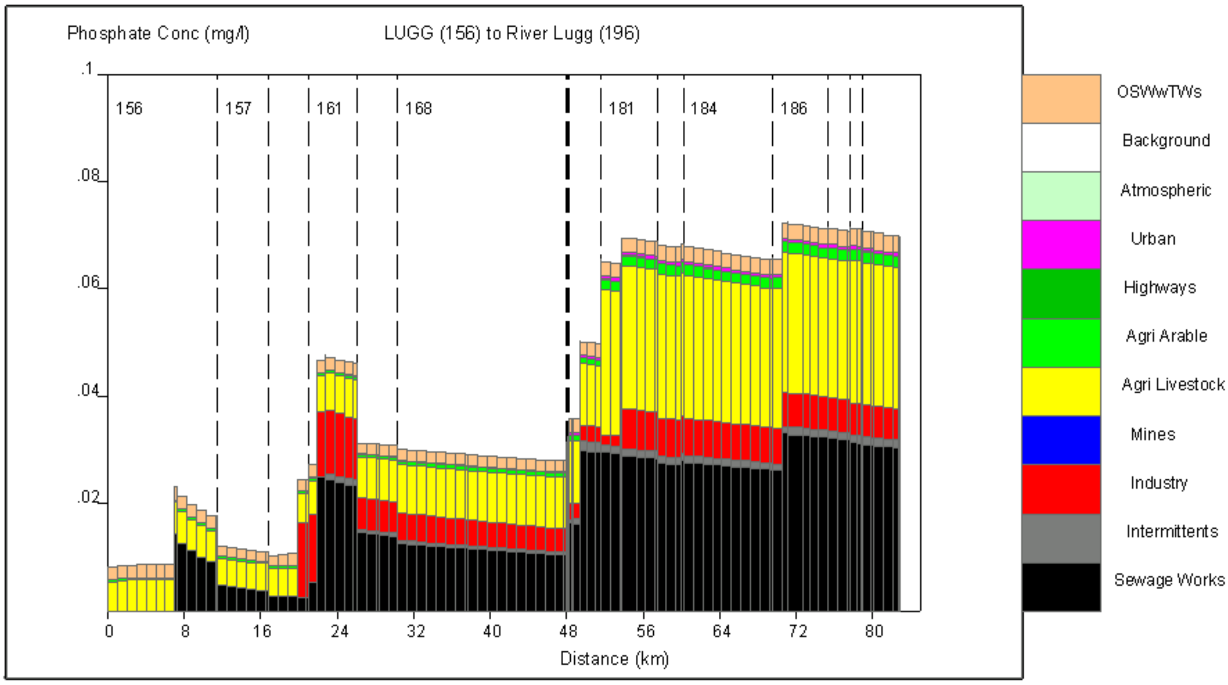


Figure 13-16 SAGIS source apportionment prediction for the River Lugg from the upland head waters until its confluence with the River Wye.

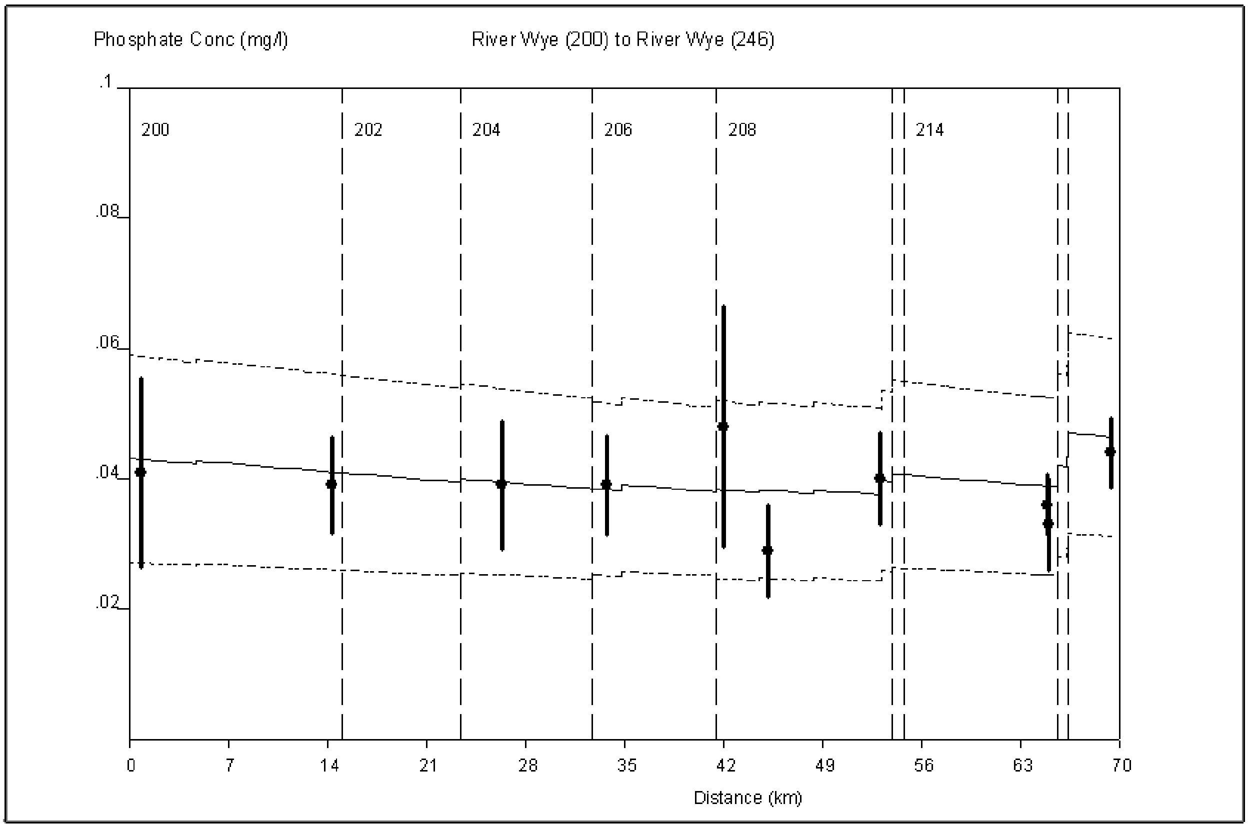


Figure 13-17 Refined SAGIS forecast for the River Wye from its confluence with the River Lugg to the point at which it discharges into the Severn Estuary

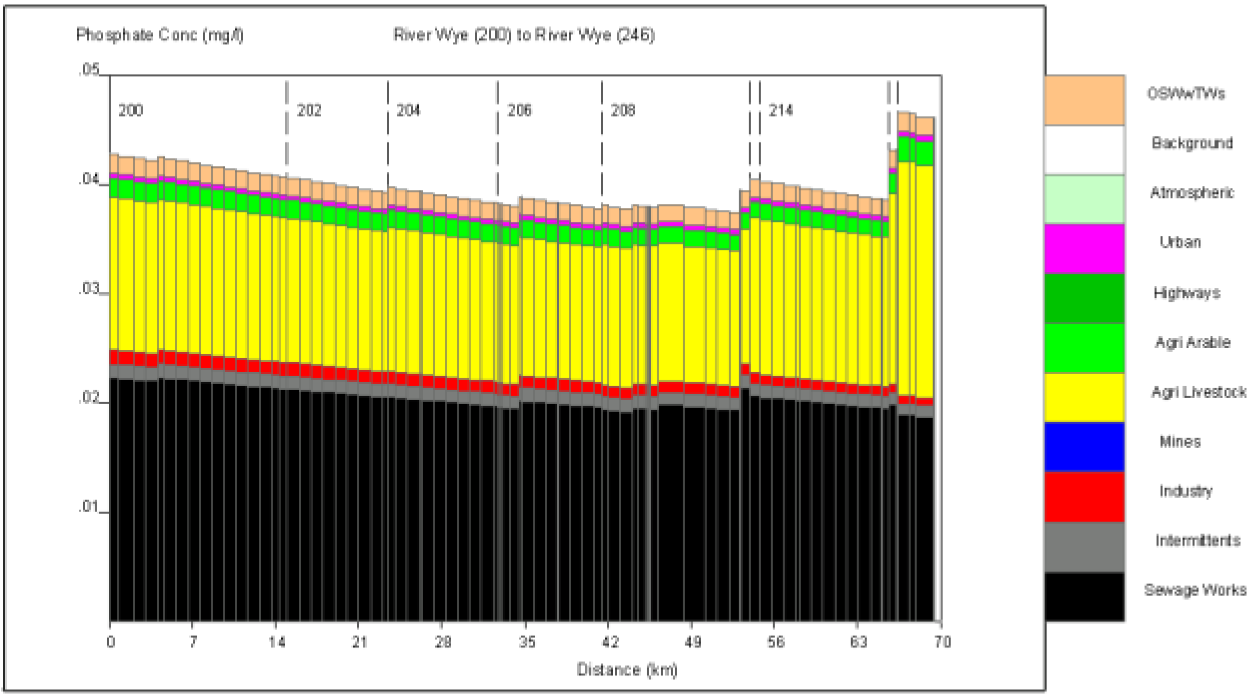


Figure 13-18 SAGIS source apportionment for the River Wye from its confluence with the River Lugg to the point at which it discharges into the Severn Estuary

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