BETTER LAND FOR BETTER WATER

Modelling land-use change to improve water quality in England

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FINAL REPORT

2006

RSPB/WWF/Water UK

EXECUTIVE SUMMARY

Background

The Water Framework Directive (WFD) sets challenging targets for the UK's water quality. Current estimates suggest that 40-50% of P and 60-70% of N in waters are derived from agricultural activity. Consequently, diffuse water pollution from agriculture needs to be addressed, and this seen as a priority for action by Defra; the initiation of Defra's Catchment Sensitive Farming project reflects this urgency.

Government funded research programmes have worked towards understanding the pathways and causes of losses, and have worked towards developing practical mitigation measures for decreasing losses. Measures work by affecting pollutant source (e.g. fertiliser input management), pollutant mobilisation (e.g. incorporating manure/fertiliser into the soil) and pollutant delivery (e.g. use of buffer strips). Measures target crops, fertilisers, manure or livestock. Numerous experiments have shown that such approaches can decrease losses at the experiment plot scale. However, the WFD requires us to think at a much larger scale – the catchment. To date, hard experimental evidence is lacking for the efficacy of mitigation measures when scaled up across large catchments, yet this is just the information that is required if we are to formulate policies that will tackle diffuse pollution from agriculture.

To date, the only method for assessing impacts of measures at the catchment scale is the use of modelling. Even so, the challenge for modellers is immense – to be able to correctly represent the effects on pollutant transport of changes in management on individual fields and then link this to the catchment's hydrology is the absolute ideal, but still some distance away. A simpler approach that is often used is that of the export coefficient model, which relates measured nutrient export rates to catchment characteristics of geology, climate, land use, fertiliser inputs and animal numbers. Export coefficient models are constructed using data collected on the spatial distribution of land-use and fertilisers applied to each land-use type; the numbers and distribution of livestock and human populations in the catchment; and the input of nutrients to the catchment through N fixation and atmospheric deposition.

Export coefficient models have previously been used in the UK to assess the impacts of land use change on nutrient losses to water. The aim of this project was to use such an approach to determine the impacts of various land management and land-use change scenarios on nutrient losses to water. The project focused on P loss, with some preliminary assessment of impacts on N loss.

Export coefficient modelling

There are, of course, limitations with any approach that aims to model nutrient transfers at the catchment and national scales:

- Export coefficients do not predict nutrient concentrations in watercourses.
- There is some uncertainty of the extent to which the export model can predict future change based entirely on the variables employed.
- There is no linkage between nutrient concentrations/loads and the ecological health of waterbodies.

We also recognise that the approach is better suited to land-use change scenarios, whereas this project also tried to represent changes in land management. However, we believe that for drawing broad conclusions, and until other approaches are available, the export coefficient approach provides a sound method for investigating the effects of change on P losses to water.

Approaches

The approach was to use six representative catchments that covered a range of geological features and land-use patterns. These catchments were not selected for any reason other than that they were representative of typical UK mixes of land use:

Location	Area (km^2)	Dominant land-use
SW	198	Intensive dairy
Anglia	128	Intensive arable
NE	455	Upland
NW	1161	Grassland
SW	307	Mixed farming
Southern	231	General Arable

A range of land-uses and land managements were superimposed on these catchments and N and P losses were compared with baseline losses calculated from 2000 land-use data:

1 Good Agriculture Practice (GAP), including:
   1a 'Basic' GAP
   1b 'Advanced' GAP
2 Business As Usual (BAU) land-use forecast
3 Agri-environment measures, including:
   3a Entry Level Scheme (ELS)
   3b Higher Level Scheme (HLS)
   3c BAU + Advanced GAP+ ELS
4 Wildlife-Rich Landscape
5 Radical change

Scenario 1 aimed to use field mitigation methods (e.g. fertiliser and manure management) with existing cropping and livestock enterprises basic GAP represented low cost options, Advanced GAP included measures requiring substantial investment.

Scenario 2 used the predicted broad-scale changes in land-use following the implementation of the current package of Common Agricultural Policy (CAP) reforms.

Scenario 3 attempted to understand the impact on P load of applying the options available under the Environmental Stewardship scheme for farmers in England.

The Wildlife-Rich Landscape (WRL) scenarios (*Scenario 4*) aimed to achieve land-uses that would deliver benefits for biodiversity.

For each catchment, radical land-use changes were also designed (*Scenario 5*), to achieve the target water quality outcome, by focusing on three factors: an increase in rough grazing, a reduction in livestock and reduced fertiliser and manure input to land.

Results

Under baseline conditions the total P (TP) loadings for the six catchments were calculated to be in the range 13-180 t per year, depending on the size of the catchment, rainfall and land use. This equated to an average loss of 1-3 kg/ha TP per year over the catchment. Depending on human population density, the agricultural contribution to the TP loads varied in the range 37-90%.

Using assumptions on the required P thresholds in the catchment rivers for Good Ecological Status, it was estimated that TP loadings from agriculture would need to decrease by 56-71%, depending on the catchment. This also assumed that an equivalent reduction could be achieved for non-agricultural sources in each catchment. The large reductions in P loss required reflect the enormity of the challenge in addressing diffuse agricultural pollution.

The success of each of the tested scenarios was judged against how much of the target TP load reductions they achieved. The main findings were:

- Changes to management practices (*Scenario 1*) applied to existing patterns of land-use could be considered the 'least cost' option for achieving reductions in P loads in a catchment. Basic GAP (low cost) measures met 3-14% of the target reductions. Advanced GAP met 3-36% of target, with measures being more effective in predominantly arable areas. Therefore, significant progress can be made by applying these measures, particularly in intensive arable areas. However, the level of change achieved was insufficient in all cases to produce the required load reductions.

- The BAU projection (*Scenario 2*) predicted an increase in the area of cereal production and a reduction in the numbers of livestock as a result of CAP reform implementation. In total, CAP reform measures were insufficient to make a significant contribution to P load reduction (0-20% of target achieved).

- Disappointingly, agri-environment schemes made only a small reduction in P loss, suggesting additional measures beyond cross compliance/ELS/HLS will be required (1-5% of target achieved).

- The wildlife-rich landscape scenario (*Scenario 4*) would achieve biodiversity outcomes within a farmed environment. When modelled, initial designs achieved an average of approximately 50% of the required load reduction through re-allocation of land-uses, and reductions in livestock levels. Effectiveness depended on the catchment, ranging from 16% (mixed catchment) to 90% (upland catchment).

- The radical change scenarios are designed purely to reduce the P load sufficiently to meet WFD relevant P thresholds. Design of the preliminary scenarios suggested it might be necessary to change catchment land-uses in some areas to achieve the required outcomes. Certainly, with the radical changes tested in this project, we were able to meet 100% of the target reduction in P load. This was achieved by large reductions in livestock numbers, amongst other things.

- In nearly all scenarios, preliminary assessment of the effects on N losses suggested that the proposed measures would be more effective for P than for N.

Conclusions and implications for policy

Throughout the report, we recognise the limits of the export coefficient modelling approach. However, we also recognise that this is currently the best available approach and has also been used in similar projects to assess impacts of land-use change on nutrient losses to water. This project has extended that work by looking at a broad range of land-use and land management options. Whilst we accept that the errors about the absolute values for the calculated effectiveness of the options will be large, we suggest that the approach allows us to at least make robust comparisons between options.

The results show that:

- Adopting codes of good agricultural practice will decrease diffuse pollution, but will be insufficient to meet WFD alone.
- Adoption of environmental schemes (with their focus mainly on green, rather than brown issues) will be insufficient to meet WFD targets.
- More radical land use change will need to be considered if these targets are to be met.

All change scenarios have potential economic impacts on farming. An essential next step would be to analyse the potential socio-economic implications of different land-use scenarios, and identify (if possible) the political, regulatory and financial context within which truly sustainable rural economies would thrive.

CONTENTS

1 INTRODUCTION

1.1 WFD and diffuse pollution

Nutrient enrichment of water bodies may result from point or diffuse sources, or a combination of both. However, the significance of the contribution of diffuse nutrient pollution and its impacts on the water environment are increasing throughout the UK, as point source inputs (mainly from Sewage Treatment Works, STW) are reduced (Mainstone *et al*., 2000). Diffuse pollution is defined as 'pollution arising from land-use activities (urban and rural) that are dispersed across a catchment or sub-catchment, and do not arise as a process industrial effluent, municipal sewage effluent, deep mine or farm effluent discharge.' (D'Arcy *et al*., 2001).

Diffuse pollution is a priority water policy issue for the UK Government (EA, 2000). The main driver for current activities is the Water Framework Directive (WFD), a new EU instrument requiring a co-ordinated approach to protect and restore water quality (and quantity) at the river basin scale, by addressing (amongst other issues) both point and diffuse pollution sources.

A key aim of the WFD is to achieve Good Ecological Status (GES) in surface waters. This concept supplements more traditional measures of water quality, which assessed a relatively small number of chemical parameters (e.g. ammonium, biological oxygen demand, etc). GES is a measure of the ecological health of a water body, and is made up of 15 parameters, including biological, physico-chemical and hydro-morphological quality elements. Physico-chemical elements should be defined and maintained at levels capable of supporting the relevant type-specific ecosystems, and will form part of the legally binding classification systems established by EU Member States to implement WFD. They include levels of nutrients in surface waters.

1.2 Land-use and water quality

The level of nutrients present in water has a major influence on the aquatic life that a river is able to support. Many factors can affect surface water nutrient concentrations, but the most important are discharges of sewage effluent and runoff from agriculture.

Agriculture can affect many aspects of water quality, and is a major contributor to diffuse loads of nutrients reaching surface waters (Defra, 2002). Potential pollutants include nitrate (NO_3^-), nitrite (NO_2^-), ammonium (NH_4^+), total phosphorus (TP), faecal indicator organisms (FIO), biological oxygen demand (BOD), sediment and agrochemicals. Loss pathways differ between pollutants, either transported in solution or in suspension, and either in drainage water moving through the soil or in water moving across the soil (Haygarth *et al*., 2005). Fertiliser and manure inputs are major factors in influencing agricultural diffuse pollution losses of nitrogen (N) and phosphorus (P) (Haygarth *et al*., 2004). Diffuse agricultural pollution is associated with a number of water quality issues (Table 1.1).

Based on 2002 estimates, agriculture is responsible for about 50% of P inputs to surface waters in the UK (fertiliser and manure inputs). Human and household waste is responsible for some 24%, with the remainder from detergent, industrial and miscellaneous sources (Defra, 2002). It is estimated that approximately 70% of N arises from agriculture. These relatively large contributions of N and P are not unexpected, given that agricultural land-use currently accounts for over 76% of the country by area.

Table 1.1. Summary of water quality issues (from Haygarth et al.*, 2005).*

Pollutant	Eutrophication	Oxygen Depletion	Acidification	Toxicity	Physical Effects	Pathogenic Contamination
Ammonium	ã	ã	ã	ã		
Nitrate	ã					
Nitrite	ã	ã	ã	ã		
Phosphorus	ã					
Pathogens						ã
BOD		ã				
Sediment		ã			ã	

Today's rivers are quite different from those of pre-industrial Britain. Most have been highly modified by human activities (Chilterns AONB, 2002). These activities have had a major influence on water quality, including nutrient and sediment inputs. The cultivation of land for food production has, to different degrees at different times and places, increased the loads of sediment, nutrients and agrochemicals reaching surface (and ground) waters. These increases reflect direct inputs through leaching, and inputs through soil erosion associated with certain land management practices and stocking densities and locations of livestock.

It is widely understood that high P and N levels can cause eutrophication in fresh and coastal waters, affecting the ecological balance of the water environment. (Smith *et al*., 1998). The most common effects of increased nutrient supplies, typically N and P, on aquatic ecosystems are perceived as increases in the abundance of algae and aquatic plants, yet the environmental consequences of nutrient enrichment are far more serious. Eutrophication is associated with a suite of problems including oxygen depletion, pH variability, shifts in species composition, food-chain effects, increases in toxic algal blooms and collapse of populations of sensitive species (Jennings *et al*., 2003).

According to Environmental Agency General Quality Assessment (GQA) results, in 2002, 54% of rivers had high concentrations of P (greater than 0.1 mg/l), compared with 50% in 1995. Twenty-nine per cent of rivers had high concentrations of nitrate (greater than 30 mg/l), compared with 30% in 1995. In England and Wales, nearly 20% of rivers designated as Sites of Special Scientific Interest (SSSI) – the UK's top conservation status – are failing to achieve the highest chemical water quality classification. Many SSSI rivers have been affected by diffuse pollution (EN, 2002).

1.3 Aim and objectives of the project

A range of practical measures can be used to reduce diffuse pollution loads of nutrients and silt derived from farmland (Haygarth *et al*., 2005). A range of different policy mechanisms can also potentially be used to implement these measures, from advice, awareness programmes, grant aid and quality assurance schemes to taxes/levies, conditions on payment and regulation (Dampney *et al*., 2002). However, due to the nature of the problem, which is politically and practically complex, none of these policy mechanisms is currently contributing effectively to an overall solution to diffuse agricultural pollution (EN, 2002).

This project aimed to inform the debate about the management of diffuse pollution from agriculture, by examining the scale and type of changes in farm land-use that might be required to meet WFD outcomes, and linking these to opportunities to deliver benefits for biodiversity.

The specific objectives of the project were, therefore, to:
- assess and present data on the current levels of P and N in selected rivers in England and Wales;
- identify P standards applicable to a WFD river typology, which can act as the P component of the 'general physico-chemical quality elements' of GES;
- use existing studies and methods to identify the proportions of P loads within representative catchments, which are attributable to agriculture;
- model and map different agricultural practice/land-use scenarios, in order to determine their impact on P and N export, and their associated benefits for biodiversity, within representative catchments;
- assess and present the implications of this work on national land-use and land-use policies.

1.4 Project approach

To meet the project objectives, a map of the project activities and the links between them was developed, and is illustrated below (Fig. 1.1).

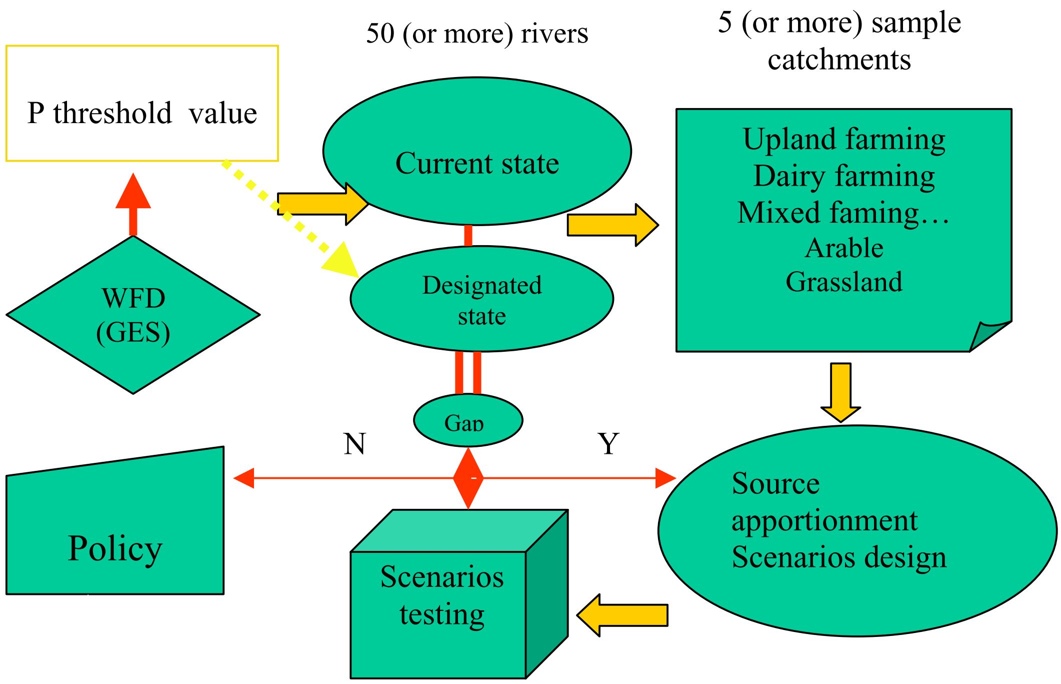


Figure 1.1. The project activities and linkages

Existing EA datasets were used to estimate target P loss thresholds for different river systems. Catchments, representing a range of land-use mixes, were used to calculate P (and N) losses using an export coefficient approach. Various management scenarios were then superimposed on these catchments, and the export coefficient modelling was repeated, to estimate the extent to which change would be needed to meet the estimated P loss thresholds. The following Sections in this report provide the complete detail.

2 MODEL AND SCENARIO DESIGN AND CATCHMENT ASSESSMENT

The Water Framework Directive requires the management of water (both in terms of quantity and quality) at the basin or catchment level. This means that catchment-scale modelling tools are particularly appropriate to help policy makers develop appropriate intervention programmes to meet WFD outcomes. The Environment Agency has recently completed the initial phase of the characterisation of river basin districts, as required by the WFD. A risk assessment tool has been developed to identify water bodies at risk of failing to meet GES, and the pressures responsible for this risk. This is based on catchment-scale assessment of, amongst other things, agricultural land-use.

2.1 Export Coefficient Modelling

At the catchment scale, if spatial variations in weather, land-use, cropping, soil texture, soil hydrology and hydro-geology can be taken into account, even a relatively simple, semi-empirical model can provide a consistent initial screening assessment of current catchment water quality and resources (Holman & Hollis, 2001). 'Export coefficient' modelling is such an approach, and can also be used to allow scenario testing with minimal requirement for datasets, to assess the impacts on water quality of changing existing patterns of agricultural land-use.

Export coefficient modelling has been successfully modified and used in the UK, for example in the AERC Export Coefficient Modelling Approach (Johnes, 1996; 1999; 2000; Johnes et al., 1996; 1998a; 1998b). This approach relates measured nutrient export rates to catchment characteristics of geology, climate, land use, fertiliser inputs and animal numbers. Export coefficient models are constructed using data collected on the spatial distribution of land-use and fertilisers applied to each land-use type; the numbers and distribution of livestock and human populations in the catchment; and the input of nutrients to the catchment through N fixation and atmospheric deposition.

There are, of course, limitations with any approach that aims to model nutrient transfers at the catchment and national scales:

- Export coefficients do not predict nutrient concentrations in watercourses.
- There is some uncertainty of the extent to which the export model can predict future change based entirely on the variables employed.
- There is no linkage between nutrient concentrations/loads and the ecological health of waterbodies.

Export coefficients are ideally derived from field scale experiments and calibrated at the catchment outlet. However, where time and resources are constrained, the model still can provide an effective means of evaluating the impact of land-use and land management on water quality, by using literature-derived data or expert judgement to determine the loss of nutrients from each identifiable source to the stream. Johnes (1998a) presented export coefficients for six regional categories for England and Wales. A Defra-funded project (PE0203: Haygarth *et al*., 2003a) further refined this by combining the original export coefficients (expressed as a proportion of excretion or of fertiliser input) with the calculated excretion and fertiliser input, to give export as kg per head of livestock or kg per ha of land use (Table 2.1).

Export coefficient modelling has been used to investigate the impacts of land-use change on nutrient losses from agriculture. For example, Burt & Johnes (1997) investigated impacts at the catchment scale. More recently, Haygarth *et al*. (2003b) also used this approach to investigate whether Good Ecological Status could be achieved in England and Wales's waterbodies. In the USA, the export coefficient model has been regularly used as a scoping model to compute a lumped annual basin nutrient load (Theodore & Eric, 2003). A modified version of this model can also generate catchment-weighted maps of pollutant export loads based on terrain and land cover map.

2.2 Export coefficient approaches in this project

It is important to note that the export coefficient methodology is suitable only for looking at land use change. It is uncalibrated (except against the rivers used to derive the coefficients in the first place) and must, therefore, be seen as giving only relative indications. It is also accepted that direct transposition of the coefficients listed in Table 2.1 to the catchments used in this project cannot be undertaken with absolute confidence. *However, until validation is possible, they offer the best available values with which to work.* It is also worth noting that such an approach has also been used in other projects, as described above.

Two aspects of the approach warrant particular mention:

1. The Environment Agency monitoring data and thresholds are in terms of soluble reactive P (SRP), while export coefficients calculate total P *loads*. Phosphorus losses from different land uses will have different soluble to particulate ratios. For example, losses associated with intensive grassland and other livestock will have a greater proportion of soluble P. Consequently, the model was difficult to calibrate because of a lack of monitored data on total P (and total N) concentration in water bodies, and because the ratio between SRP and total P is known to vary. As a result, the calculated total P concentration and load for the baseline and other scenarios can only be used for relative comparison, for example, by comparing the percentage *changes* between loads.

2. A refinement was made when applying export coefficients in this project, enabling the model to take slope into consideration, reflecting run-off risk. The whole catchment land area was sub-calculated using three categories: flat area (slope 0-3°), moderate area (slope 3-7°), and steep area (slope >7°). The export coefficient rate was then set up at 1, 1.5 times and 2 times the level listed in Table 2.1, respectively. A similar approach was used in the SEPA project 'Phosphorus Control In Loch Lomond' (SEPA, 2002). The slope dataset was derived from OS survey (Defra Countryside Information System, 1 km^2 resolution).

2.3 Data acquisition

Table 2.2 lists the datasets used in the project.

Table 2.1. Export coefficients for six regional types of land-use (from Defra PE0203). Data expressed as annual kg total N or total P loads per ha (for crop type) or per livestock head (for animal type).

Crop or animal type	Land use type					
	Extensive livestock and upland	**Lowland dairying**	**Mixed arable and dairying; permeable bedrock**	**Mixed arable and dairying; impermeable bedrock**	**Intensive arable**	**Urban**
Total N						
Permanent grass	1.38	21.60	8.65	10.80	1.75	0
Temporary grass	3.46	33.75	10.40	16.88	2.20	0
Cereal	15.20	40.25	20.88	19.32	3.14	0
Root crops	35.20	35.50	35.00	35.50	6.72	0
Field vegetable	35.20	35.50	35.00	35.50	6.72	0
Oilseed	35.20	35.50	35.00	35.50	6.72	0
Rough grazing	0.10	0.10	0.10	0.10	0.04	0
Woodland	0.20	0.20	0.20	0.20	0.04	0
Cattle	5.08	11.37	11.30	11.30	11.93	0
Pigs	1.36	2.73	2.71	2.71	3.20	0
Sheep	0.86	1.72	1.72	1.72	1.72	0
Poultry	0.04	0.08	0.08	0.08	0.09	0
Total P						
Permanent grass	0.262	0.408	0.114	0.204	0.030	0
Temporary grass	0.370	0.917	0.273	0.393	0.035	0
Cereal	0.618	1.110	0.658	1.110	0.091	0
Root crops	0.679	4.440	0.884	4.440	0.364	0
Field vegetable	0.679	4.440	0.884	4.440	0.364	0
Oilseed	0.679	4.440	0.884	4.440	0.364	0
Rough grazing	0.020	0.020	0.020	0.020	0.020	0
Woodland	0.020	0.020	0.020	0.020	0.020	0
Cattle	0.225	1.003	0.502	0.502	0.299	0
Pigs	0.072	0.287	0.144	0.144	0.096	0
Sheep	0.023	0.090	0.045	0.045	0.026	0
Poultry	0.003	0.011	0.005	0.005	0.003	0

Table 2.2. Project datasets used in the project and collected from government or public domain.

Data	Type	Resolution	Sources	Note
Land-use	Broad catalogue, 8 Types land-use and 4 types livestock	1km*1km	Defra 2000 agriculture census	ADAS database
Catchment boundary	GIS	Vector	ADAS	EA Gauge station
Flow	Mean flow (long term annual)	Annual	EA	National River Flow Archive
Nutrient concentration	SRP and nitrate	Annual average (2002)	EA	GQA
Rainfall	Long term (1960-1991)	Annual average	EA	National River Flow Archive
Population	Density	People per sq. km	Office for National Statistics	
Slope	Degree	1km*1km	OS survey	Countryside Information System
Export coefficient rates	Regional	kg/ha or kg/head	P. J. Johnes	EA R&D E53
Typology	Calcareous, Siliceous and Organic	River water body	EA	UKTAG

2.4 Sample catchment selection

The project tested land-use change scenarios in six catchments, covering a range of geological features and land-use patterns (Fig. 2.1). The characteristics of each catchment are described below.

Catchment A is located in the southwest of England. It drains around 200 km^2 of land. The climate is maritime, with mild, wet winters. The annual average rainfall (1960-91) is around 1000 mm. The mean flow at the catchment outlet is 3.16 m^3/s. The geological character can be described as rising in the greensand and gault clay of the Blackdown Hills; predominantly Keuper sandstones and marls with extensive alluvium and valley gravels lower down. The combination of a mild climate and high rainfall results in the catchment being mainly used for livestock farming. Dairy cattle and sheep are the predominant livestock, although some beef cattle are kept.

Catchment B is located in East Anglia. It drains around 128 km^2 of land. The annual average rainfall (1960-91) is only 580 mm. The mean flow at the catchment outlet is 0.63 m^3/s. The geological character is boulder clay with valley sand and gravel. The catchment land-use is dominated by intensive arable farming with pigs as the major livestock.

Catchment C is located in the North East. It drains around 455 km^2 of land. The annual average rainfall (1960-91) is 855 mm. The mean flow at the catchment outlet is 7.88 m^3/s. The geological character is mainly carboniferous limestone and millstone grit. The catchment is typical of the uplands, with sheep farming dominant. The catchment is rich in biodiversity with an SSSI of around 53 km^2.

Catchment D is located in the North West. It drains around 1150 km^2 of land. The annual average rainfall (1960-91) is 1353 mm. The mean flow at the catchment outlet is 33.1 m^3/s. The geological character is carboniferous limestone and millstone grit; boulder clay over coal measures and millstone grit. Improved grassland occupies more than 50% of the catchment area, supporting dairy and sheep farming.

Catchment E is located in the southwest of England. It drains around 307 km^2 of land. The annual average rainfall (1960-91) is around 800 mm. The mean flow at the catchment outlet is 3.36 m^3/s. The geological character is mainly oolitic limestones with tributaries draining off clays. The agriculture type in the catchment is a mixed farming system with a proportion of field vegetables

Catchment F is located in southern England. It drains around 231 km^2 of land. The annual average rainfall (1960-91) is around 750 mm. The mean flow at the catchment outlet is 2.23 m^3/s. The geological character is mainly weald clay, with chalk predominating in some areas. Arable land is dominant in this catchment, however, urban land-use occupy as much as 15% of total area.

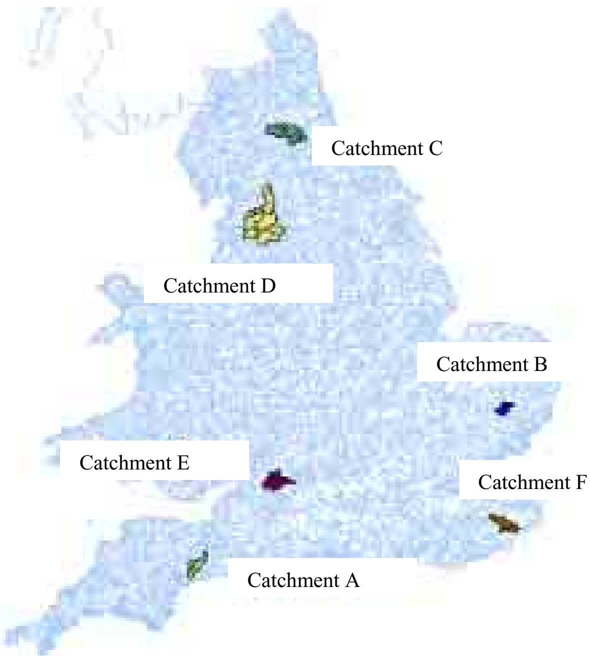


Figure 2.1. The six project catchments and their locations across England.

2.5 Source apportionment

The amount and relative contribution of point and diffuse sources to the overall total nutrient load varies considerably between catchments, depending on the local biogeochemistry, geomorphology and the anthropogenic activities within the catchment (Defra, 2002). Generally, point sources tend to dominate during the summer seasons, with diffuse sources making a significant contribution during winter, when runoff and drainage from agricultural land mainly occur.

However, the timeframe for export coefficient modelling is a year, and the project was, therefore, at this stage, only able to produce an annual source apportionment. It did not take into account seasonal variations by apportioning different load fractions during different seasons or months. The precision of the source apportionment was also further reduced by the lack of information on sewage treatment works and other point sources of N and P (including industrial sources). Point source estimates were based on human population size, taking into consideration some limited nutrient stripping during sewage treatment. Finally, diffuse sources of nutrients were assumed to be entirely agricultural in origin, as the model was not adapted to identify potential sources from urban run-off. However, since national estimates suggest that urban diffuse pollution makes a minor contribution to surface water nutrient loads, it is thought that this deficit would not unduly impact on the accuracy of the model.

2.6 Determining WFD-compliant levels of P in rivers

First, river type specific P threshold values for each river stretch were calculated, based on EA work to underpin WFD characterisation assessments. This process is described in more detail in Section 3.2.

The uncertainty of using these threshold values for this exercise is acknowledged (given the possible need for further refinement following the EU intercalibration outcomes and additional information on ecosystem response). The SRP threshold values were converted to a total P basis. This was done using an *uncalibrated ratio* of SRP (Table 4.2) and TP calculated for the baseline situation. Total export load capacity and the total load reduction required, compared to the baseline threshold, were then determined.

2.7 Scenario design and testing

By determining the gap between current P levels and the WFD 'threshold' level for each river, and apportioning loads of P to agricultural and non-agricultural sources, it was possible to calculate the reduction in P loading required to achieve a notional 'GES' outcome.

Scenarios were then developed to test the effects on water quality of a range of different patterns of land-use (Table 2.3). The whole procedure is summarised in Figure 2.2.

Firstly, the impact of improvements in land management practice on existing land-uses was modelled, to determine how much of the current loading could potentially be reduced through this means (Scenarios 1 and 2, Table 2.3).

Following on from this, further scenarios were developed looking at the possible impact of a wide uptake of relevant agri-environment measures within existing land-use patterns (Scenario 3, Table 2.3) and then looking at the impacts of land-use change leading to the delivery of specified biodiversity benefits (Scenario 4, Table 2.3).

Finally, a radical change scenario was designed, with the sole aim of bridging the gap between current nutrient concentrations in the river and potential WFD threshold values (Scenario 5, Table 2.3).

Table 2.3. Summary of the scenarios tested in each of the 6 river catchments.

Scenario	Description
Baseline (2000)	N and P losses calculated from 2000 agricultural census data
1	Good Agriculture Practice (GAP), including: 1a ‘Basic’ GAP 1b ‘Advanced’ GAP
2	Business As Usual (BAU) land-use forecast
3	Agri-environment measures, including: 3a Entry Level Scheme (ELS) 3b Higher Level Scheme (HLS) 3c BAU + Advanced GAP+ ELS
4	Wildlife-Rich landscape with Basic GAP
5	Radical change with Advanced GAP

More detailed descriptions of each scenario are provided in Section 4.

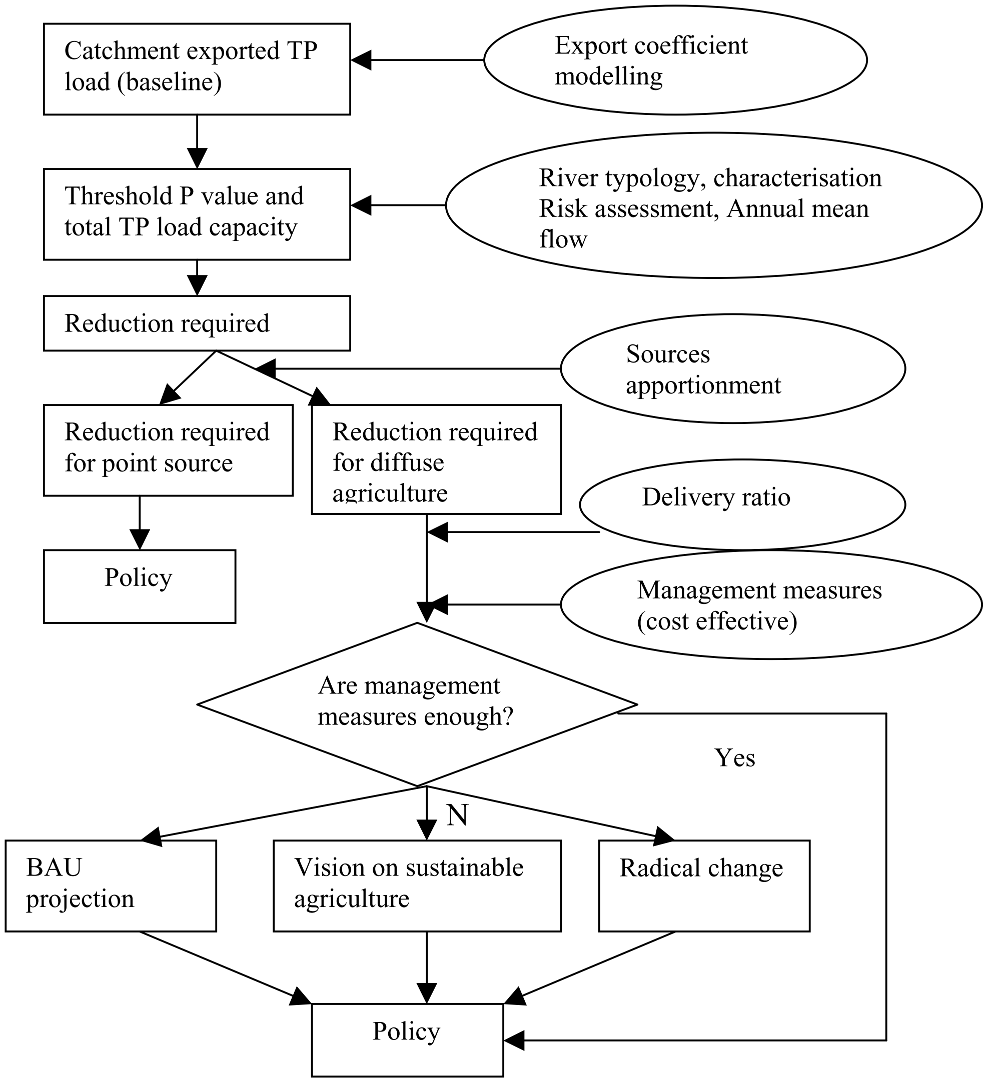


Figure 2.2. Flow chart of land-use/management change scenario design.

3 ASSESSING NUTRIENT STATUS AND RELATIONSHIP WITH GOOD ECOLOGICAL STATUS

The WFD classification system requires an understanding of relationships between the concentrations of physico-chemical quality elements, such as P and N, and the biological quality of the water body, as defined by the condition of its flora and fauna. Such relationships are complex, varying between organism types and between types of water body. For example, the response of benthic macroinvertebrate communities in streams and rivers to environmental stresses, including organic pollution, has been studied and is relatively widely used as a means of assessing water quality. The specific response of macro-invertebrates to nutrient enrichment, however, is less clearly understood. It is likely that other organism groups, such as macrophytes, may prove to be more sensitive indicators of eutrophication impacts in rivers (their use is already well established in lakes and other standing waters). So, whilst there is considerable ongoing research to try to establish the nature of the response of riverine ecosystems to nutrient pollution, additional research is likely to be needed before P and N levels and biological quality indicators in rivers can be linked with confidence.

Moreover, because aquatic ecosystems do not conveniently conform to a single type, the measures required to achieve GES must be made specific to the biological communities that are expected to occur in individual catchments and river basins. Hence, nutrient thresholds or ranges will be type-specific; that is, they will vary according to the river type – with standards relevant to slow-moving rivers in the south of England differing from those for mountain streams, for example.

The Environment Agency's General Quality Assessment (GQA) monitoring indicates that, in 2002, 54% of rivers in England had P concentrations of greater than 0.1 mg/l and 29% of rivers had N concentrations greater than 30 mg/l (Fig. 3.1). Higher levels are generally found in the lowlands of central, eastern and southern England and in rivers flowing through areas dominated by arable farming.

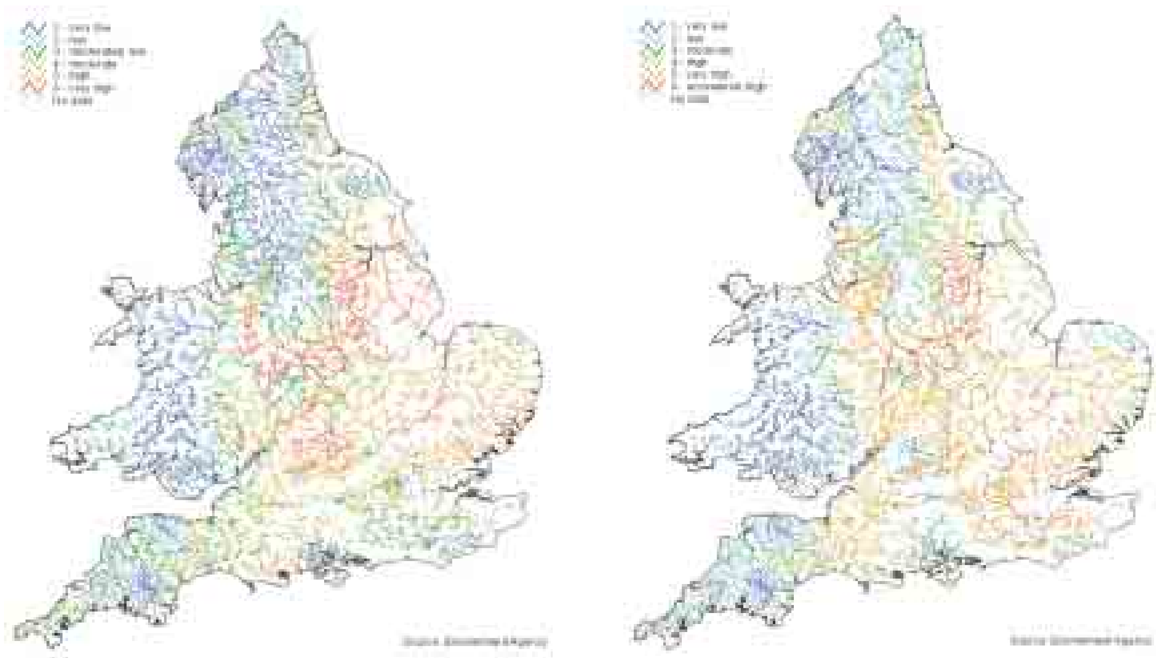


Figure 3.1. Phosphate and nitrate in rivers (GQA assessment) in 2002.

This assessment does not link its findings to the thresholds or ranges considered necessary to support type-specific ecosystems. For example, ‘high’ concentrations of P do not necessarily mean that the river is eutrophic, as other factors such as the amount and type of algae present, flow rates, and dissolved oxygen concentrations have to be taken into account to make this determination. At the catchment scale, ecological, geological and hydrological characteristics needs to be integrated into an analysis of the sources of P in the river system, to determine the level of actual risk to ecosystem health.

3.1 River typology for WFD

In 2004, the UK WFD technical advisory group (TAG) issued *Guidance on Typology for Rivers for the UK*, in which a typology for rivers is presented for use during WFD implementation, based on altitude, catchment sizes and dominant geology (Table 3.1). Approximately 6000 river water bodies were classified into 18 river types. As can be seen from the distribution (Fig. 3.2), the dominant type (26%) in England and Wales is low altitude (<200 m), small size (10-100 km^2), calcareous rivers. The distribution of water according to geology is shown in Figure 3.2.

Table 3.1. The classification and type distribution of rivers in England and Wales.

GB Type	Mean catchment Altitude (metres)	Total area (km^2)	Dominant Geology
1	< 200	10-100	Siliceous
2	< 200	10-100	Calcareous
3	< 200	10-100	Organic
4	< 200	100-1000	Siliceous
5	< 200	100-1000	Calcareous
6	< 200	100-1000	Organic
7	< 200	>=1000	Siliceous
8	< 200	>=1000	Calcareous
9	< 200	>=1000	Organic
10	200-800	10-100	Siliceous
11	200-800	10-100	Calcareous
12	200-800	10-100	Organic
13	200-800	100-1000	Siliceous
14	200-800	100-1000	Calcareous
15	200-800	100-1000	Organic
16	200-800	>=1000	Siliceous
17	200-800	>=1000	Calcareous
18	>= 800	10-100	Siliceous

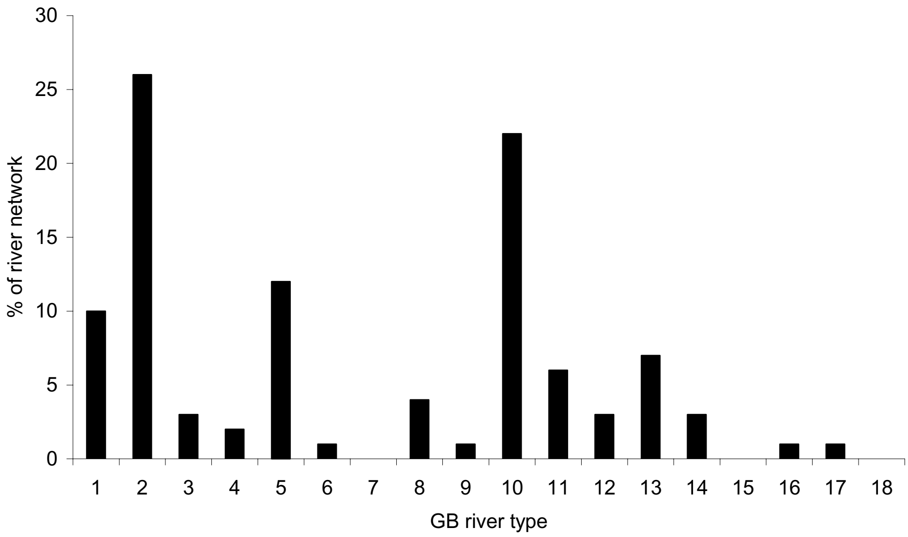


Figure 3.2. River type distribution (percentage of river network) for GB rivers.

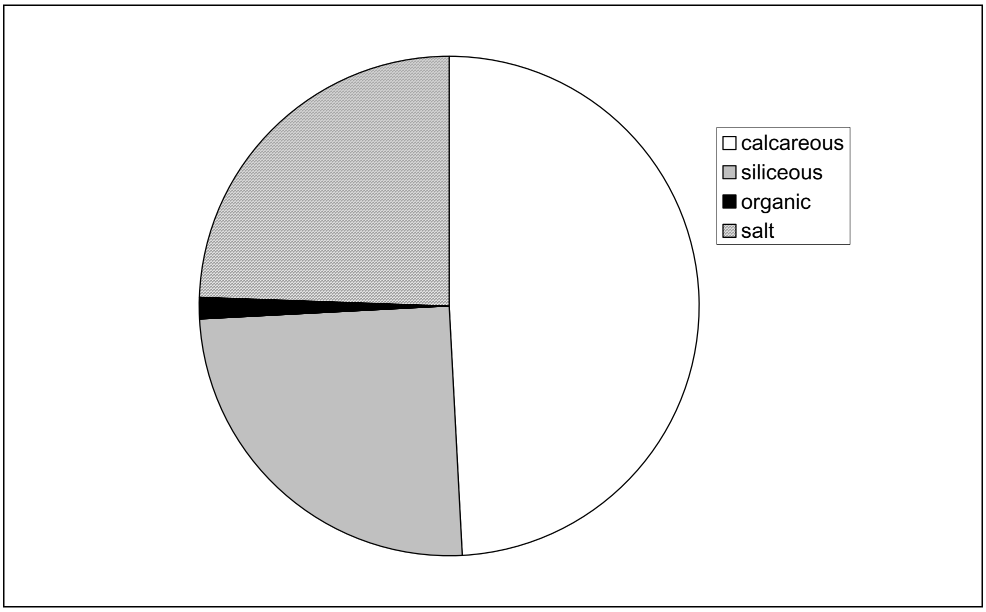


Figure 3.3. River type distribution in terms of dominant geology for GB rivers.

3.2 Phosphorus threshold values

During the characterisation process, 'type-specific' risk threshold values were developed to help assess if a water body was in danger of failing to achieve GES. A list of available threshold criteria is provided in Table 3.2. The P threshold value was determined as in Table 3.3.

Table 3.2. Summary of threshold criteria tables for assessing risk of failing Good Status, based on Environment Agency WP7f (01) guidance.

Pressure	Biological element	Metric or associated Physical chemical element
Organic pollution	Macroinvertebrates	RIVPACS ASPT RIVPACS NTAXA Biochemical Oxygen Demand Dissolved Oxygen Ammonia
Eutrophication	Macrophytes Diatoms Phytoplankton	Mean Trophic Rank Soluble Reactive Phosphorus Trophic Diatom Index Chlorophyll
Acidification	Diatoms	Species Composition pH
Multiple pressure on general ecological heath	Fish	Species absence Abundance Age class Physical chemical elements

Table 3.3. P threshold values (mg/l Soluble Reactive P)

	Low Productivity (Organic/Siliceous)	Threshold Confidence	Moderate/High Productivity (Calcareous)	Threshold Confidence
Not at risk	< 0.02	H	< 0.06	M
Probably at risk	0.02 – 0.04	M	0.06 – 0.10	M
At risk	> 0.04	H	> 0.10	M

The P threshold values presented in Table 3.3 were used to identify the likely gap between current P levels in rivers and WFD-relevant levels. The results of this gap analysis provided the basis for developing and testing the land-use/management change scenarios.

3.3 Gap analysis

The project aimed to present national and regional assessments of the scale of the nutrient pollution problem in England, as well as assessing the gap between current status and GES values in the sample catchments. An attempt was also made to understand, in each case, the relative contribution of point and diffuse sources of nutrient pollution.

The Environment Agency monitors water quality at over 10,000 sites representing about 44,000 km of rivers and canals in England and Wales. The GQA 2002 data was used for nutrient assessment at both the national and regional level.

3.3.1 National nutrient assessment for rivers

By applying the river typology results and the P threshold values introduced in Table 3.3, a calculation was done of the gap between the current P concentration and the threshold value. The results are shown as Figure 3.4. The gap analysis indicated that 71% of rivers in calcareous catchments, 61% in siliceous catchments and 51% in organic catchments are likely at to be at risk of ecological impact, based on P concentration.

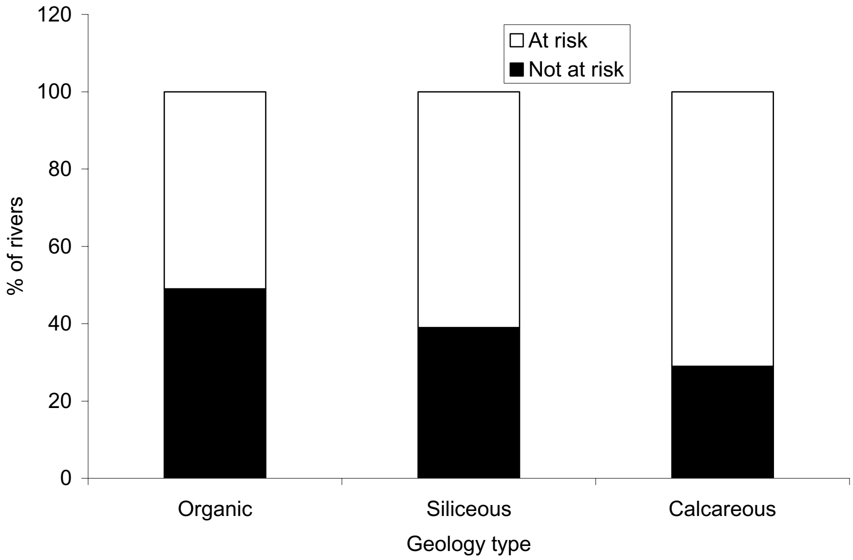


Figure 3.4. Percentage of rivers with three dominant geology types deemed to be at risk or not at risk according to Soluble Reactive Phosphorus threshold value.

In rivers, the concentrations of N and P are the reflection of both point and diffuse source contributions. By assessing the SRP concentrations in 688 river stretches receiving sewage discharges from treatment works, before and after the point of discharge, it was found that more than 60% of stretches showed significant point source influences (significance was defined as double the concentration in the downstream stretch).

To assess trends in national patterns of nutrient pollution a more detailed analysis was carried out of river water quality monitoring data for England and Wales over the 12 year period 1988 – 2001 (Ellis, 2003). These data showed that, at 56% of the monitoring sites, there was an overall upward trend in nitrate concentration. However, more recent data does not detect such a clear N trend, with very few rivers showing a significant trend for N from 1990-2000. A declining trend in P was observed at 77% of sites. The decrease in P concentrations is very likely directly related to the improvements made in sewage treatment processes through the greater use of secondary and tertiary treatment, coupled with a steady decline in the use of phosphate-based detergents

3.3.2 Examples of nutrient assessment of rivers

In order to understand more clearly the interactions between point and diffuse sources of pollution, the project targeted 45 rivers (Table 3.3), based on catchment size, to calculate the annual mean value of N and P (as SRP) for each stretch. Example rivers are shown in Figures 3.5 and 3.6.

Table 3.3. Rivers selected for nutrient assessment based on GQA 2002.

	Region							
	Anglian	**North East**	**North West**	**Midlands**	**South West**	**Southern**	**Thames**	**Wales**
Catchment size >1000 km^2	Witham	Aire Wear	Eden Ribble	Avon Severn Trent	Avon Exe	Medway	Kennet Lee Thames	Dee
Catchment size 100 - 1000 km^2	Chelmer Gipping Waveney Wensum	Don Nidd	Gowy	Dove Leam	Axe Mole Otter Wylye Yeo	Arun Itchen Gt Stour Ouse	Cherwell Windrush	Clwyd Taff
Catchment size <100 km^2	Ant	Colne Team	Wyre	Rea	Marden	Brede	Ash	Wenny

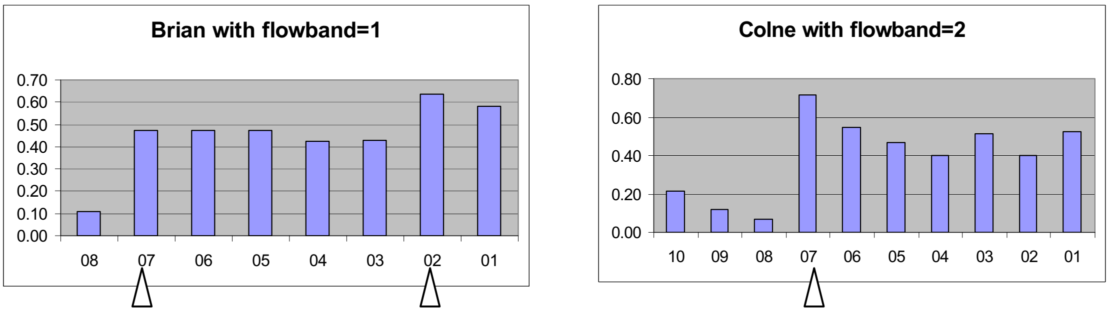


Figure 3.5. Two example rivers showing elevated SRP concentration after effluent is discharged into the river (flow direction from left to right).

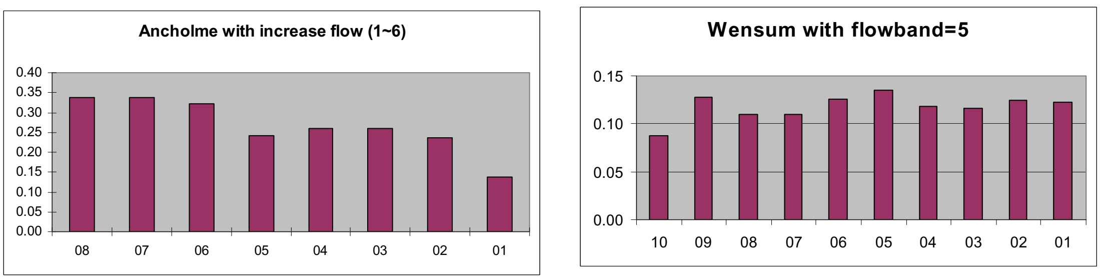


Figure 3.6. Two example rivers showing diffuse source influences on stream concentration (flow direction from left to right).

This additional analysis suggested that:

- The influence of STW effluent discharge on P levels in some rivers remains significant. Importantly, this impact is felt not only on the stretch immediately below the effluent discharge point, but also extends a considerable distance downstream (Fig.3.5).

- Existing river quality monitoring strategies make it difficult to determine precisely the influence of diffuse sources of P on river P concentrations. In some rivers, which receive no STW discharges, either a gradually increasing or decreasing trend of P concentration was found, indicating a diffuse source impact (Fig. 3.6).

- Upstream stretches are more likely to meet the P threshold value compared to downstream stretches in most of the rivers chosen for assessment.

- River flow is a major factor determining nutrient levels. The natural variation between and within years makes it difficult to apply a single, unvarying standard across time.

- All these factors should be considered when assessing the results for the six catchments used in the project.

- We need again to stress that the EA P data and thresholds are in terms of SRP, while export coefficients are for total P, and that P losses from different land uses will have different soluble to particulate ratios.

3.3.3 Six river catchments: nutrient assessment.

The GAP analysis was applied in detail to each of the six sample catchments where it was proposed to model land-use change scenarios. Results are shown in Figures 3.7 and 3.8.

Catchment A (predominantly intensive dairy) - The 2002 GQA results showed an increasing trend of nutrient concentration from upstream to downstream. The reason for the significant increase in Stretch 8 is unknown. The average annual SRP concentration at the catchment outlet was 0.26 mg/l.

Catchment B (predominantly intensive arable) - The nutrient levels remained high due to low precipitation in the eastern area and limited runoff from the catchment. The average annual SRP concentration at catchment outlet was 0.35 mg/l.

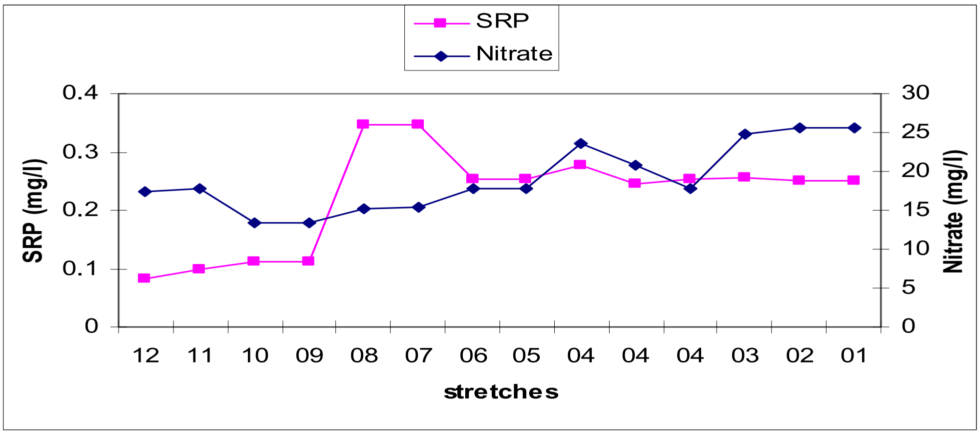
Catchment C (predominantly upland) - The significant rising trend for nutrients shown by the GQA results appears to be mainly due to effluent discharges from several sewage works. The average annual SRP concentration at the catchment outlet was 0.09 mg/l.

Catchment D (predominantly grassland) - It was found that of the total 97 km, only a downstream stretch of 27 km had a high concentration of P (0.43 mg/l). The average annual SRP concentration at catchment outlet was 0.12 mg/l.

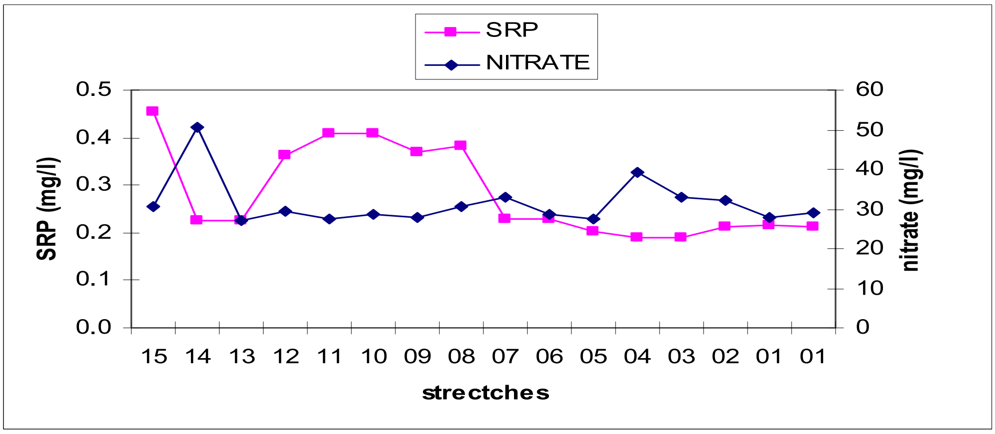
Catchment E (predominantly mixed farming) - GQA data showed high levels of nutrients in the stream from upstream to downstream. The average annual SRP concentration at the catchment outlet was 0.37 mg/l.

Catchment F (predominantly general arable) - The nutrient levels remained stable from upstream to downstream and significantly increased in the last stretch due to a STW effluent discharge. The average annual SRP concentration at the catchment outlet was 0.23 mg/l.

River A:



River B:



River C:

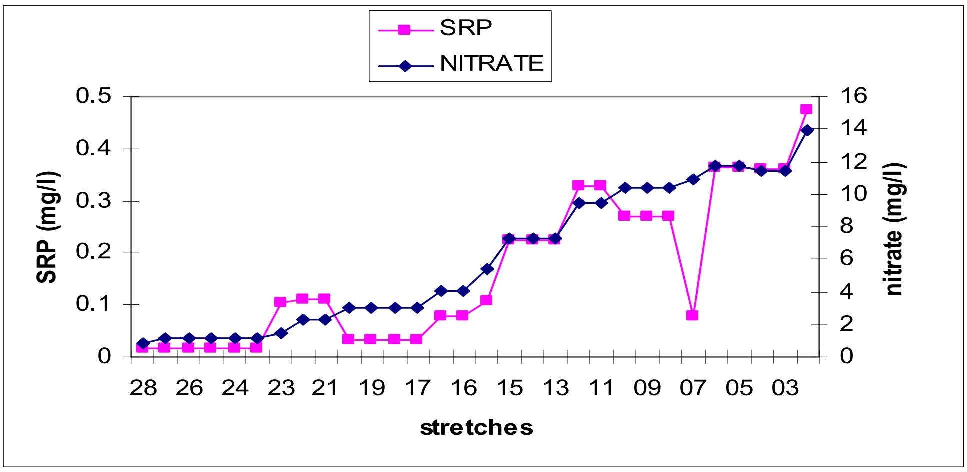
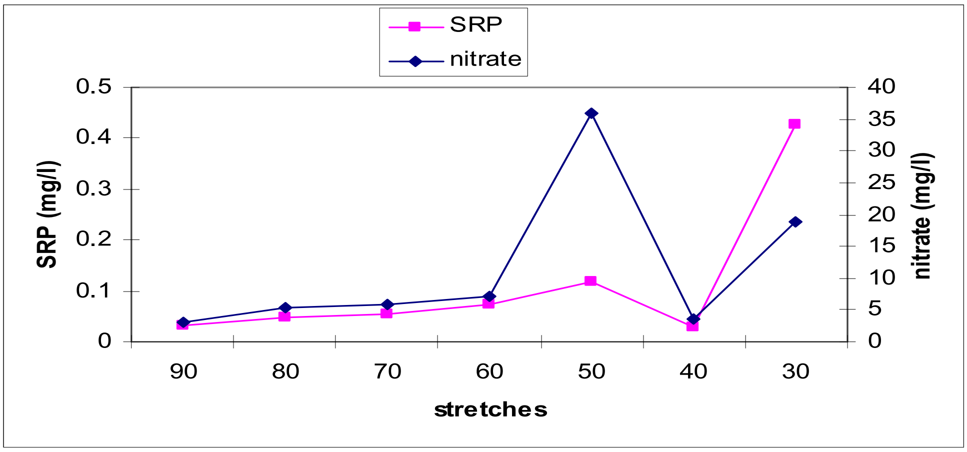
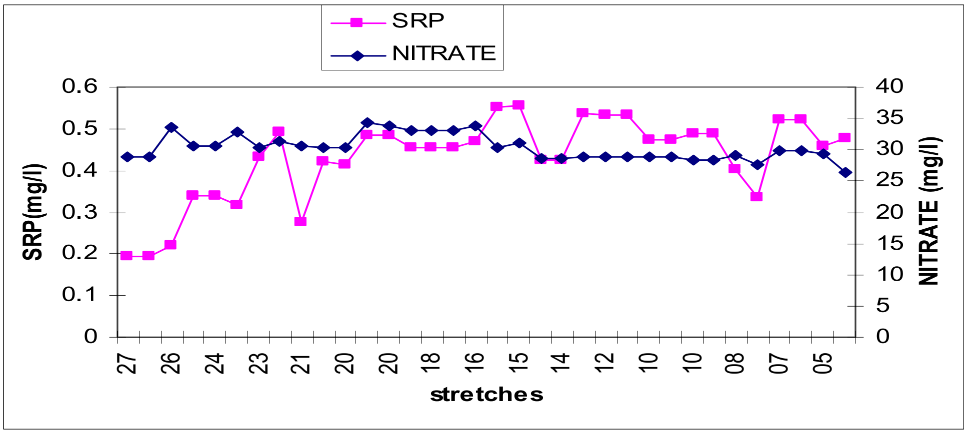


Figure 3.7. Annual average nutrient concentration in rivers A-C from upstream to downstream.

River D:



River E:



River F:

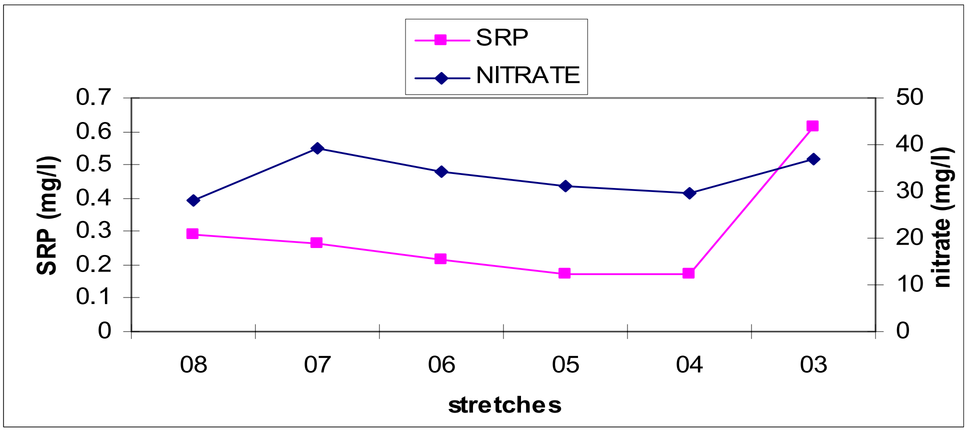


Figure 3.8. Annual average nutrient concentration in rivers D-F from upstream to downstream.

4 CATCHMENT SPECIFIC STRATEGIES FOR TACKLING DIFFUSE AGRICULTURE POLLUTION BY PHOSPHORUS.

4.1 Introduction

The project chose to work with six representative catchments with differing land-uses, as described in Chapter 2. The mix was chosen to represent the main land uses in England, i.e. intensive arable, intensive dairy, mixed farming, upland and at least one catchment with a mixture of urban and agricultural land-use.

The chosen catchments and the characteristics of each catchment were described in Chapter 2 and are summarised in Table 4.1. Catchment-specific land-use change scenarios were developed at five levels, to test the impacts of different farm practices and patterns of land-use on nutrient loadings to rivers, shown in Table 2.3, and summarised below:

Baseline (2000)

Scenario 1: Good Agriculture Practice (GAP), including:
- 1a: Basic GAP
- 1b: Advanced GAP

Scenario 2: Business As Usual (BAU) land-use forecast

Scenario 3: Agri-environment measures, including:
- 3a: ELS
- 3b: HLS
- 3c: BAU + Advanced GAP+ ELS

Scenario 4: Wildlife-Rich landscape with Basic GAP

Scenario 5: Radical change with Advanced GAP

The design of each scenario is described under the relevant heading, below. Changes in P load relative to the baseline under each scenario are presented as a percentage of contribution to target reduction from agriculture for each catchment, following calculation using export coefficient modelling.

Table 4.1. Six catchments for scenario design and model testing. Details of each catchment are provided in Section 2.

Catchment code	Geolocation	Area (km^2)	Dominant land-use
A	SW	198	Intensive dairy
B	Anglia	128	Intensive arable
C	NE	455	Upland
D	NW	1161	Grassland
E	SW	307	Mixed farming
F	Southern	231	General Arable

4.2 Baseline calculation and source apportionment

The agriculture census data for 2000 was used as a baseline for source apportionment to different land-uses. The data resolution was 1 km^2. The land-use (broad catalogue*)* pattern is shown in Figure 4.1 for the six catchments (each catchment is described in Chapter 2).

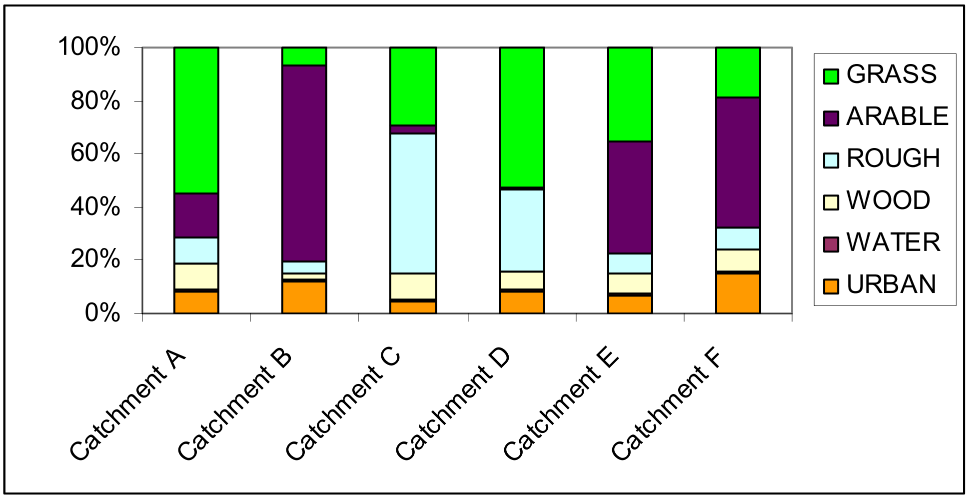


Figure 4.1. Broad categories land-use for the six project catchments (2000).

The total load of exported P as calculated by the model, along with P concentration, is shown in Table 4.2. Note that the total P (TP) concentration was calculated as TP load, divided by a long-term annual mean flow. In addition, due to a lack of monitoring data for TP, for these catchments, the ratio of soluble reactive P (SRP) and TP is uncalibrated. Figure 4.2 shows the high variability of export load between catchments as kg per hectare.

It is important to note the effect that rainfall (and, therefore, water flow) has on concentrations in water bodies. Average concentration of a pollutant is determined by dividing the total load by the drainage amount for that period. Consequently, in areas of high rainfall (e.g. the NW), there is dilution of the N and P. This is in contrast to, for example, East Anglia where the average winter drainage is <200mm. This lack of dilution in the drier parts of the country makes achieving targets set on concentration very difficult to achieve.

Table 4.2. Modelled phosphorus results for the baseline scenario.

Catchment	Annual mean flow (m^3/s)*	Exported TP load (ton)	TP concentration (mg/l)	Monitored SRP (mg/l)**	SRP: TP ratio
A	3.16	59	0.59	0.26	0.44
B	0.63	13	0.66	0.35	0.53
C	7.88	41	0.17	0.09	0.52
D	33.1	176	0.17	0.12	0.70
E	3.36	63	0.60	0.32	0.53
F	2.23	35	0.50	0.23	0.45

* Flow was not modelled, but was based on a long-term annual mean flow
** The sample location and catchment outlet does not coincide in three rivers; in this case, a nearest location or mean value of two nearest locations was used.

Source apportionment for P load from human, livestock, fertiliser, and rainfall sources is shown in Figure 4.3.

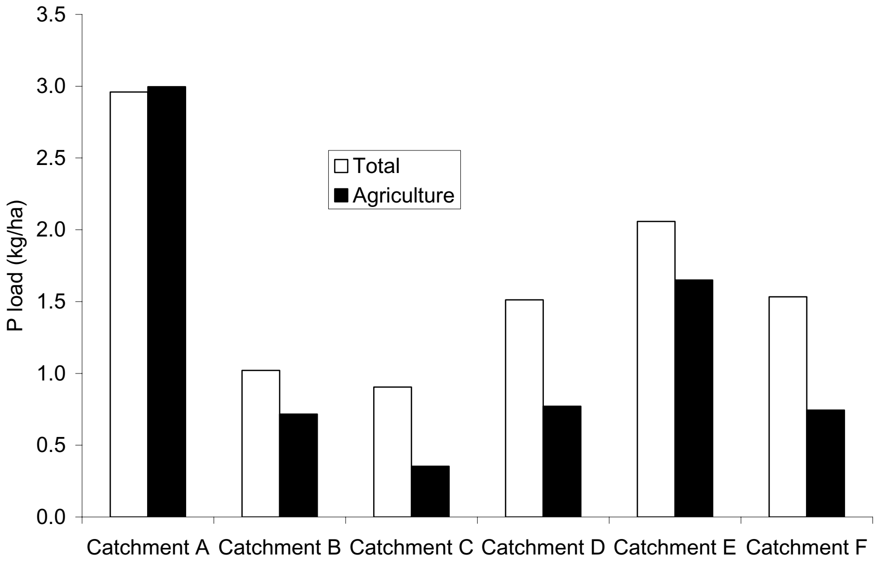


Figure 4.2. Annual export P load (unit as kg/ha) for the six project catchments. Loads separated into (a) total P load per ha of catchment and (b) agricultural P load per ha of rural land.

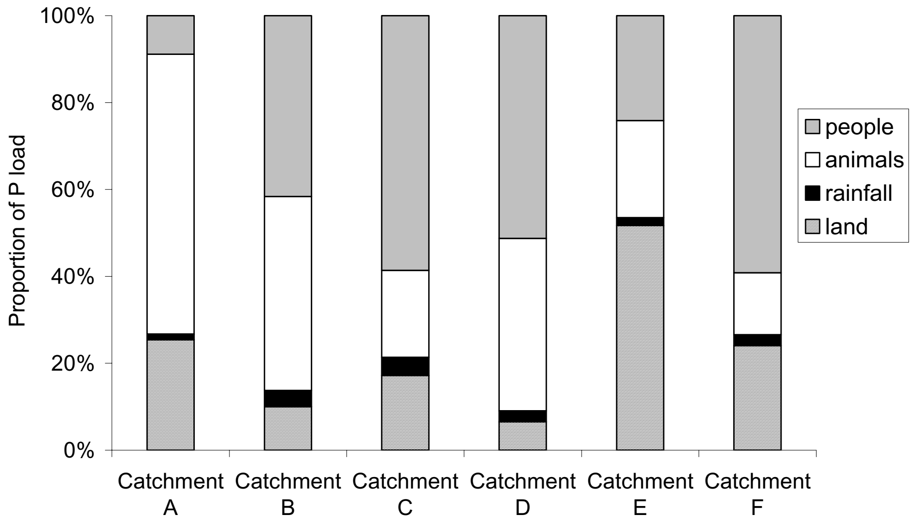


Figure 4.3. Proportion of pollution sources contributing to total export load under baseline calculation.

4.3 Phosphorus threshold value and total export load capacity

Results for the determination of the baseline P threshold, from the methodology described in Section 2.5, are shown as Table 4.3. This allowed the target P load reduction required by agriculture in the six catchments to be estimated, and the results are shown in Figure 4.4.

Table 4.3. Phosphorus threshold value and total export load capacity.

Catchment	Threshold SRP (mg/l)	Threshold TP (mg/l)*	TP load capacity (X) (ton)**	Baseline exported TP load (Y) (ton)**	Reduction required (ton) (Y-X) (ton)	Target reduction for agriculture *** (ton)	Required reduction (%)
A: Int.Dairy	0.1	0.23	23	59	36	33	61
B: Int.Arable	0.1	0.19	4	13	9	5	71
C: Upland	0.04	0.08	20	41	21	8	52
D: Grassland	0.04	0.06	63	176	113	52	64
E: Mixed	0.1	0.19	20	63	43	32	68
F: Gen.Arable	0.1	0.22	16	35	20	8	56

* Conversion based on the ratio between SRP (monitored) and TP (calculated)
** Based on annual mean flow
*** Based on the apportionment under baseline calculation; i.e. agricultural and point sources are presumed to reduce in equal proportions to achieve the required outcome. Where the majority of the load in a catchment is from agriculture, the majority of the reductions will also be required from agriculture.

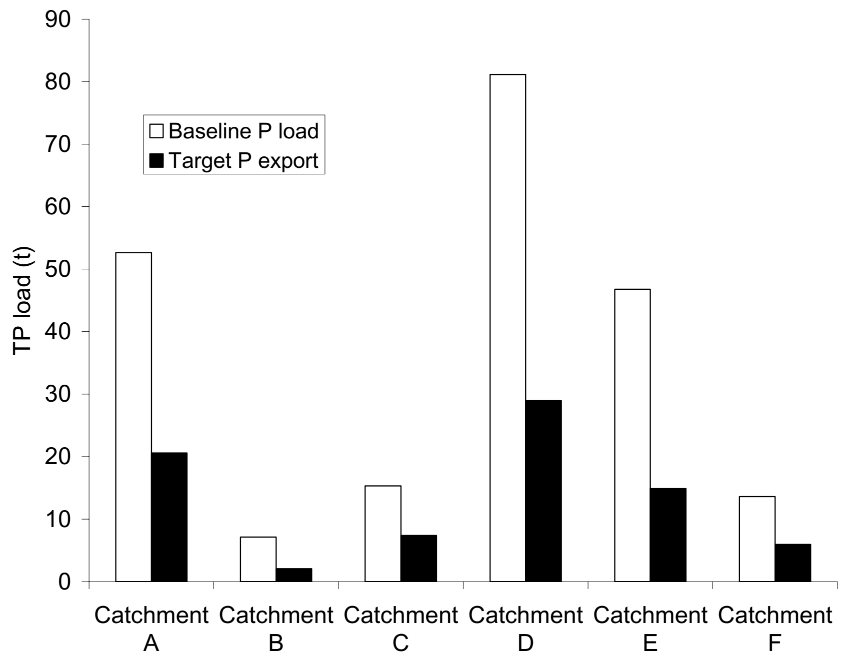


Figure 4.4. Baseline agriculture export P load and target P load reduction required from agricultural activities.

4.4 Results for Scenario 1: Good Agriculture Practice (GAP)

4.4.1 Scenario description.

Agricultural can have varying impacts on the environment, including water quality, depending on land management and/or land-use (Haygarth *et al*., 2005). Mitigation methods for decreasing losses of N and P from agricultural land to water are well understood, at least in qualitative terms. Phosphorus loss via surface runoff, drain flow and erosion may be reduced, for example, by adopting conservation tillage and crop residue management, the use of buffer strips and riparian zones, terracing and contour farming; by improved manure and fertiliser application management; and by reduction of inputs. Interestingly, an analysis by Haygarth *et al*. (2005) showed that many of these techniques are recommended in Defra's *voluntary* Water Code (Anon., 1998), but there is relatively little mandatory requirement to improve farm nutrient management. The only mandatory actions are required with Nitrate Vulnerable Zones (NVZs) covering over 55% of England and Wales. NVZ regulations place limits on N (and, therefore, also P) loadings from manure and require the use of a fertiliser recommendation system to calculate N fertiliser inputs to individual fields).

A review of the literature for this project attempted to quantify the levels of nutrient reduction that might be achieved as a result of applying certain 'Good Agricultural Practice' (GAP) measures to different land-uses. A number of projects have attempted to measure the performance of different practices in terms of nutrient export, at plot or field scale. Unfortunately, there is no evaluation at catchment scale for a combination of several management options. Individual projects also show considerable variation in results. Defra project (PE0203) "*Cost curve assessment of P mitigation options relevant to UK agriculture"* (Haygarth *et al*., 2003a) provides the most up-to-date information for quantifying the potential for diffuse agriculture P reduction through agricultural practice change. This analysis was used to construct Scenario 1. It aimed to model 'Good Agricultural Practice' (GAP), i.e. to model the effects on N and P loss of good management practice measures employed on the farm. Good Agriculture Practice can consist of a wide range of practices, which, in this scenario, were selected from Defra project PE0203 (Haygarth *et al*., 2003a) according to their value in reducing P export.

The purpose of Scenario 1 was to estimate, as far as possible, the scale of possible reduction in P export that might be achieved, by changing farm practice within the existing land-uses already in the catchments. This step was considered important, for two reasons. Firstly, because, regardless of patterns of land-use, reducing the threat from nutrient pollution requires the application of a good general standard of farm management, including management of soil and of feed and fertiliser inputs. Secondly, whilst land-use change (as opposed to practice change) may be desirable and/or inevitable in some parts of the country, there may be contexts in which such change is costly and/or unattractive to farmers and society.

Forty mitigation measures were identified in the Project PE0203, of which 15 were input control measures, 19 were mobilisation control measure and 6 were transport control measures (Table 4.4). The cost-effectiveness of each measure varied from zero to almost £14,000 (for de-stocking in intensive dairy systems) per kg P saved. A combination of relevant measures is likely to be required in each catchment, depending on the predominant land-use. Relevant measures were, therefore, chosen for arable, grassland and rough grazing land-uses.

Table 4.4. Measures apportioned to 'Basic' and 'Advanced' Good Agricultural Practice (GAP) scenarios.

No.	Target for Measure	Cost £/ha	Mitigated P loss (kg/ha)	Arable	Grass	Rough grazing
	Inputs					
1	Stop P to index 4+ arable	0	0.065			
2	Halve P to 3 index arable plus option 1	0	0.128	BA		
3	Stop P to index 4+ Intensive Grassland	0	0.088			
4	Halve P to 3 index intensive grassland plus option 3	0	0.208		BA	
5	Halve P to all horticulture	0	0.087			
6	Precision farming	0	0.096	A		
7	Reduce feed P input to dairy	0	0.034		BA	
8	Phytase P input sows	0	0.005		BA*	
9	Phytase P input fattening pigs	0	0.048		BA*	
10	Phytase P input to table fowls	0	0.017			
11	Phytase P input to battery hens	0	0.006			
12	Stocking density intensive dairy	12698	0.002			
13	Stocking density sheep	701				
14	Arable to beef and sheep	129				
15	Arable to willow and coppice	0				
	Mobilisation					
16	Slowly available P fertilisers	0	0.060	BA	BA (80%)	
17	Incorporation (fertiliser)	14	0.143	A		
18	Placement	35	0.172			
19	Timing windows	16	0.122	BA	BA	
20	Incorporation (manure)	0	0.030			
21	Injection	153	0.197		A (20%)	
22	Timing windows (intensive dairy)	415	0.164		A (20%)	
23	Rate of application	288	0.094		A (20%)	
24	Restrict livestock access in marginal places/times	185	0.014		A (5%)	A (5%)
25	Restrict livestock access in marginal places/times	37	0.137	A*		
26	Cover cropping	61	0.111			

No.	Target for Measure	Cost £/ha	Mitigated P loss (kg/ha)	Arable	Grass	Rough grazing
27	Avoid late sowing in high risk areas	58	0.111	A (10%)		
28	Minimum tillage	45	0.556	A (50%)		
29	Contour cultivation	9	0.278	BA (25%)		
30	Soil stabilisers	222	0.006			
31	Mulching	18	0.111			
32	Change tramline management	8	0.167	BA (15%)		
33	Increasing surface roughness	75	0.278			
34	Subsoiling across slope	40	0.111	A (10%)		
	Transport					
35	Constructed wetlands/ ponds	93	0.153	A (10%)	A (10%)	A (10%)
36	Move gateways	60	0.041	A (10%)	A (10%)	A (10%)
37	Install hedges and make fields smaller	405	0.034	A (5%)	A (5%)	
38	Install farm track sediment traps	8	0.081	BA (10%)	BA (10%)	BA (10%)
39	Riparian Zones	5	0.081	Agri-env (5%)	Agri-env (5%)	Agri-env (5%)
40	Grass buffers	4	0.108	Agri-env (5%)	Agri-env (5%)	Agri-env (5%)

Notes:
B = Basic GAP; A = Advanced GAP.
*For Intensive Arable catchment only.
No 40. Grass buffers to be included in Scenario 3: Agri-environment.
Percentage values indicate the percentage of the land-use type for which the calculation of P export reduction should be applied.
Measures were apportioned according to three basic land-use types; arable, grass and rough grazing. When calculating GAP for each catchment the measures were applied to the relevant land-use types according to the % land-uses for the specific catchment. The same method was applied to changes in land-use and altered percentages, following the design of Scenarios 3, 4 and 5.

The project subdivided the 40 measures (Table 4.4) into two groupings in order to differentiate between measures on the basis of cost and therefore likely take-up:

- *Scenario 1a: 'Basic' GAP* - These are low cost/no cost measures which farmers should be able to implement themselves, with little or no support. These measures may, in time, be cost neutral or save money.

- *Scenario 1b: 'Advanced' GAP* – This used the measures under Basic GAP plus measures that would incur substantial costs to the farm (including capital investment). Advanced GAP did not include all possible measures cited in PE0203, because not all were relevant to this scenario or the catchments, or they were included in other scenarios tested in this project. Measures not included were:
  - Reduced stocking densities (modelled in Scenarios 4 and 5).
  - Transport measures such as Riparian Zones or Grass Buffers. These give a value for area-based measures similar to agri-environment schemes and, therefore, grass buffers were included in Scenario 3.

4.4.2 Scenario testing

In order to evaluate the impact of management practice change on water quality at the catchment scale, it was necessary to convert the mitigated P load for each measure to an estimation of the load exported from the catchment. The losses at the field scale were calculated by solublisation and detachment of soil P, and as 'incidental losses' of freshly applied P sources (manure and fertiliser). Losses continue to occur as sedimentation and transformation takes place, and pollutants are transported to nearby watercourses and routed to the catchment outlet (in-stream processes).

Only a dynamic model, taking into account sediment water exchange and the P transformation between biota and water can accurately track P from upstream to the catchment outlet. In this project, therefore, a method similar to sediment delivery ratio (SDR) was used to address this complicated process. It was assumed that, during transport and transformation, P adsorption and desorption was in equilibrium, and that the loss of total P was only associated with sediment loss to the catchment outlet (particulate P loss, in proportion to sediment loss, and SRP loss, remain unchanged). Based on this very general assumption, the contribution of each management practice change to reducing P was calculated (Tables 4.5 and 4.6, Fig. 4.5).

Table 4.5. Basic GAP (BA GAP) associated P load reduction at catchment level.

	BA total mitigated (t) at field scale	**Sediment delivery ratio (SDR)***	**Convert to exported P**	**Contribution to target reduction with BA GAP (%)**	**Average Cost £/ha ****
Int.Dairy	6	0.15	0.9	3	16
Int.Arable	4	0.17	0.7	14	19
Upland	6	0.1	0.7	8	7
Grassland	26	0.05	1.3	3	11
Mixed	10	0.13	1.3	4	17
Gen.Arable	7	0.14	0.9	12	17

* SDR link to catchment area, see Edwin & Ongley (1996)

** Total cost divided by the sum area of arable, grassland and rough area

Table 4.6. Advanced GAP (AGap) associated P load reduction at catchment level.

	AGap total mitigated at field scale (t)	**Sediment delivery ratio (SDR) ***	**Convert to exported P**	**Contribution to target reduction with AGap (%)**	**Average Cost £/ha ****
Int.Dairy	9	0.15	1.4	4	178
Int.Arable	11	0.17	1.8	36	139
Upland	9	0.1	0.9	12	85
Grassland	34	0.05	1.7	3	147
Mixed	19	0.13	2.4	8	146
Gen.Arable	13	0.14	1.9	24	124

* SDR link to catchment area, see Edwin & Ongley (1996)
** Total cost divided by the sum area of arable, grassland and rough area

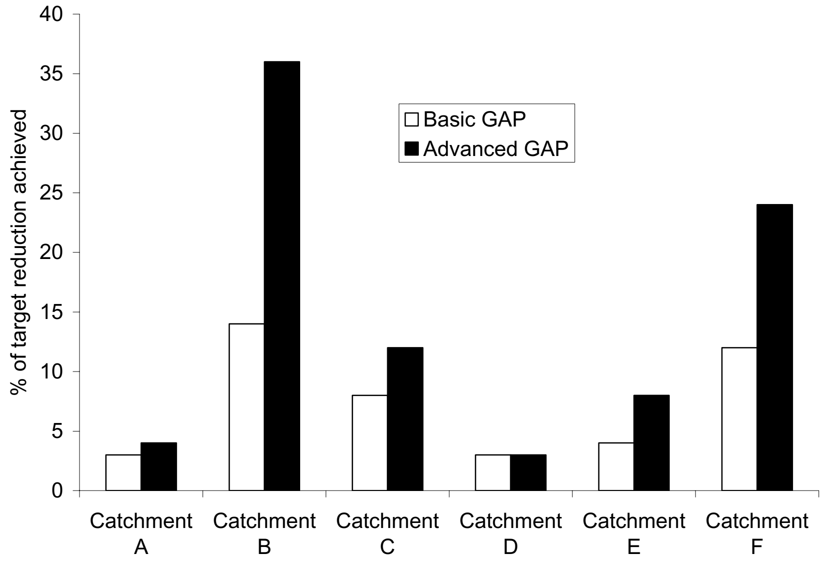


Figure 4.5. Percentage of target reduction with GAP.

It was found that application of GAP measures was generally more effective in arable catchments (approx. 30% of the targeted reduction) than in grassland catchments, at reducing a significant proportion of the target load. Advisory experience suggests that this is about right.

Costs of mitigation will vary between farms, depending on their baseline activity and, also, how they choose to implement a mitigation method. For example, farmers may choose different cultivation regimes (with different costs) when establishing a cover crop. Consequently, the estimates of costs presented in Tables in 4.5 and 4.6 can only be taken as very broad indications, particularly bearing in mind the assumptions as described in Table 4.4. Nevertheless, they do indicate that costs to farmers could be substantial.

4.5 Results for Scenario 2: ‘Business as Usual’ (BAU) land-use forecast

4.5.1 Scenarios description

This scenario used the broad-scale changes in land-use predicted by a Cambridge University research project (Cambridge University, 2004), following the implementation of the current package of Common Agricultural Policy (CAP) reforms. The major forecasts of land-use in 2015 described in the ‘Business As Usual’ (BAU) projection (Cambridge University, 2004) are summarised in Table 4.7.

Regional variation was also analysed and the results were used to develop an appropriate scenario for each of the six project catchments. Land-use change and livestock number adjustments used for the six catchments are summarised in Table 4.8.

Table 4.7. Predicted agriculture changes in 2015 relative to 2000, based on 2003 CAP reforms (Cambridge University, 2004). Results are expressed as a percentage change in crop area or livestock numbers, relative to 2000.

Enterprise	% change	Enterprise	% change
Cropping		**Livestock**	
Grass (<5yo)	-10.0	Dairy Herd	-20.0
Grass (>=5)	-2.5	Beef Herd	-15.0
Rough Grazing	0.0	Breedherd Replacements	-18.4
Farm Woodland	17.7	Other Cattle Over 1 year	-15.0
Set-Aside	-100.0	Cattle Under 1 year	-15.0
Non-Cropped Land	25.0		
(% of Set-Aside)		Breed Pigs	-10.0
Wheat	11.5	Other Pigs	-10.0
Winter Barley	0.0	Breed Ewes	-6.0
Spring Barley	0.0	Lambs Under 1 year	-6.0
Oats	2.5	Other Sheep	-6.0
Other Cereals	0.0		
		Laying Fowls	5.0
Potatoes	-10.0	Table Fowls	10.0
Sugar Beet	-30.0	Total Fowls	8.6
Field Beans	0.0		
Peas (harvested dry)	0.0		
Oilseed Rape	15.5		
Linseed	-50.0		
Maize	30.0		
Other Arable	0.0		
Fallow	0.0		
Total Horticulture inc	-20.0		
- total Veg. In Open	-19.0		
- total Fruit	-20.0		

Table 4.8. Land-use change and livestock number change for six catchments.

Catchment	Land cover adjustment	Livestock adjustment
A: Intensive dairy	3% reduction for permanent grassland;10% reduction for temporally grassland; 7.5% cereal area increase;21.8% increase for woodland and 2.9% total agriculture area out for other use.	18% reduction for dairy cattle, 15% reduction for pigs, 6% for sheep, However, 8.3% increase for poultry.
B: Intensive arable	2% reduction for permanent grassland; 7.5% reduction for temporally grassland; 14% cereal area increase; 18% increase for woodland and 3.1% total agriculture area out for other use.	24% reduction for dairy cattle, 5% reduction for pigs; 6% reduction for sheep, However, 9.2% increase for poultry.
C: Upland	2% reduction for permanent grassland; 7.5% reduction for temporally grassland; 10% cereal area increase; 11.6% increase for woodland and 2% total agriculture area out for other use.	24% reduction for dairy cattle, 15% percent reduction for pigs, 6% for sheep, However, 8.6% increase for poultry.
D: Grassland	3% reduction for permanent grassland; 10% reduction for temporally grassland; 5% cereal area increase; 22% increase for woodland and 2.9% total agriculture area out for other use.	20% reduction for dairy cattle, 15% for pigs; 6% for sheep, However, 9.1% increase for poultry.
E: Mixed farming	3% reduction for permanent grassland; 10% reduction for temporally grassland; 7.5% cereal area increase; 21.8% increase for woodland and 2.9% total agriculture area out for other use	18% reduction for dairy cattle, 15% reduction for pigs, 6% for sheep, However, 8.3% increase for poultry.
F: General arable	2.5% reduction for permanent grassland; 10% reduction for temporally grassland; 8% cereal area increase; 6% increase for woodland and 4.6% total agriculture area out for other use	24% reduction for dairy cattle, 15% for pigs; 6% for sheep, However, 8% increase for poultry.

4.5.2 Scenario testing

The calculated exported TP load for this scenario is shown in Table 4.9 (and Fig. 4.6).

Table 4.9. P load reductions under the 'Business As Usual' Scenario.

	Baseline export P by agriculture (ton) (A)	Export load under scenario 2 (ton) (B)	Reduction (ton) (A-B)	Target reduction (ton)	Contribution to target reduction (%)
Int.Dairy	53	47	5.9	33	19
Int.Arable	7	7	-0.1	5	-1.0
Upland	15	14	1.2	9	15
Grassland	81	71	10.5	52	20
Mixed	47	44	2.3	32	7
Gen.Arable	14	13	0.6	8	8

Under this Scenario, the contribution to the targeted level of reduction was as much as 20% in the grassland and upland catchments, but zero (negative) in the intensive arable catchment. This was because the large proportion of cereal area in this catchment largely offset the benefit from reductions in livestock numbers.

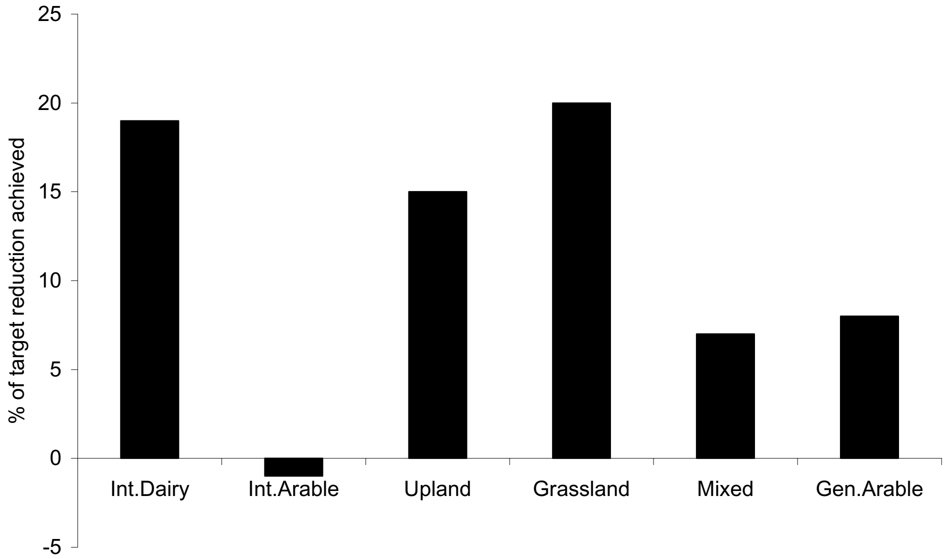


Figure 4.6. Percentage contribution to target reduction under the 'Business as Usual' scenario.

4.6 Results for Scenario 3: Agri-environment Measures

4.6.1 Scenario description

Scenario 3 attempted to understand the impact on P load of applying the options available under the Environmental Stewardship scheme for farmers in England. Environmental Stewardship consists of two parts: the Entry Level Scheme (ELS) and Higher Level Scheme (HLS). HLS replaces the targeted nature of Environmentally Sensitive Areas (ESAs) and the

Countryside Stewardship Scheme (CSS), though the schemes will continue through existing contracts. The project modelled the impact of the scheme options relevant to diffuse pollution control, on the existing patterns of land-use within each catchment. This was because the aim was to understand how (if funding was unconstrained) agri-environment support, as currently designed, would contribute to reductions in catchment P loads.

However, this proved technically challenging. Due to the nature of the export coefficient model, it is not possible to model 'in-field' options such as buffer strips or conservation headlands effectively, as these cannot be located at strategic points within the catchments and, therefore, lose their spatial and targeting value. The results from these scenarios must, therefore, be treated with caution.

Scenario 3a studied the effect of ELS options that have diffuse pollution mitigation value. The following options were chosen:

F1 Field Corner management
F6 Over-winter stubbles
G2 Brassica crops followed by overwinter stubbles
H2 Management of maize crops to reduce soil erosion
K1 Take field corners out of management
K2 Permanent grassland with low inputs
K3 Permanent grassland with very low inputs
K4 Management of Rush Pastures
M2 Manage permanent inbye grassland with low inputs
M3 Manage permanent inbye grassland with very low inputs
M4 Management of rush pastures
M5 Enclosed rough grazing
M6 Moorland and rough grazing

These options were then grouped together, based on identical characteristics, for the purpose of modelling:
- Arable management of high risk cultivation
- Grassland options, low input
- Grassland options, very low input
- Rough and moorland Grazing

Uptake of the ELS options by farmers in the ELS pilot areas was used to predict the choice that farmers within the project catchments would be likely to make. It has been estimated by Defra that 70% of farmers will take up ELS; the model calculation, therefore, assumed that 70% of land-cover was subject to the selected options. This scenario also modelled the grass buffer measure based on data from Defra project PE0203, as described in Section 4.3.1. This is because that analysis offered an opportunity to place values on area based agri-environmental options, which are difficult to quantify otherwise using an Export Coefficient model.

Scenario 3b attempted to model the effect of HLS options on nutrient export. This was undertaken in a similar way to Scenario 3a and the analysis included ELS options (eligibility for HLS requires prior entry to ELS). However, the options for HLS were not finalised at the time of the study and had not been piloted in the farming community. To predict uptake, the options were compared to the uptake, by choice and area, of options under the Countryside

Stewardship Scheme. Land under each CSS option from 1994-2003 for each county was grouped according to general classifications, e.g. Grassland options. These land areas were then calculated as a percentage of the area of the county, and then related to the area of land under agriculture in the project catchments. The HLS options (draft) modelled by this scenario were as follows:

AR22	Low input spring cereal to retain or re-create an arable mosaic (rotational)
GR1	Creation of species-rich, semi-natural grassland
GR2	Restoration of species-rich, semi-natural grassland
GR3	Maintenance of species-rich, semi-natural grassland
GR4	Creation of wet grassland for wintering waders and wildfowl
GR5	Creation of wet grassland for breeding waders
GR6	Restoration of wet grassland for breeding waders
GR7	Maintenance of wet grassland for wintering waders and wildfowl
GR8	Maintenance of wet grassland for breeding waders
GR9	Creation of semi-improved or rough grassland for target species
GR10	Restoration of semi-improved or rough grassland for target species
GR11	Maintenance of semi-improved or rough grassland for target species
GR12	Restoration of wet grassland for wintering waders and wildfowl
HE6	Creation of lowland heathland from arable or improved grassland
HS1	Arable reversion by natural regeneration
HS7	Restoration of traditional water meadows
RP1	Arable reversion to unfertilised grass to prevent erosion or run-off
RP2	Arable reversion to grassland with low fertiliser input to prevent erosion or run-off
RP4	Preventing erosion or run-off from intensively managed improved grassland
UP5	Restoration of rough grazing for birds
UP21	Restoration of moorland
WT11	Restoration of reedbeds
WT12	Creation of reedbeds
WT14	Restoration of fen
WT15	Creation of fen
WT17	Restoration of lowland raised bog
WD1	Creation of traditional orchard
WD8	Creation of woodland in the LFA
WD11	Creation of successional areas and scrub
WD20	Creation of woodland outside the LFA

The grouping of these options for the purpose of modelling were:

- Grassland
- Rough grassland
- Arable reversion
- Heathland
- Moorland
- Reedbeds
- Fens
- Orchards
- Woodland

This method of estimating HLS uptake is recognised as having the following problems:

- CSS contracts will continue in 2005 whilst new HLS contracts are taken up.
- HLS targeting is likely to be different to CSS targeting and, therefore, makes prediction less easy.
- CSS coverage in a county covers areas and habitats possibly not associated with the project catchments. Therefore, the ratios of land-use will not be the same when scaled down to the catchment level.
- Poor uptake of HLS and specific HLS measures, as calculated by the scenario method, will be reflected as a poor performance of the model. Poor results from the model should not necessarily lead to the conclusion that measures are of a poor quality. This also holds true for the ELS scenario (3a).

4.6.2 Option prescriptions

Some of the ELS options modelled by the project contain prescriptions for the quantity of N application. In order to accommodate these nutrient input levels, the equivalent quantities of P had to be estimated. The P quantities associated with particular rates of N application were estimated to be as follows:

- Grassland option low input (100 kg N/ha - 8.5 kg P/ha)
- Grassland option very low input (50 kg N/ha – 4 kg P/ha)
- Rough and Moorland grazing (0 kg N/ha – 0 kg P/ha)

Thus, the estimated P rate used was approximately 12.5% of the applied N. Fertiliser use statistics (Goodlass *et al*., 2003) suggest, for grassland, that the ratio of applied P fertiliser to N fertiliser is actually approximately 15%. The assumptions used in this project, therefore, are reasonable.

4.6.3 Scenario testing

The calculated exported TP load for this scenario is shown in Table 4.10 (and Fig. 4.7).

Table 4.10. P load reductions under the Scenario 3a (ELS).

	Baseline export P by agriculture (ton) (A)	**Export load under scenario 2 (ton) (B)**	**Reduction (ton) (A-B)**	**Target reduction (ton)**	**Contribution to target reduction (%)**
Int.Dairy	53	53	0.12	32	0.4
Int.Arable	7	7	0.06	5	1.2
Upland	15	15	0.25	8	3.1
Grassland	81	81	0.58	52	1.1
Mixed	47	47	0.24	32	0.8
Gen.Arable	14	14	0.11	8	1.5

Table 4.11. *P load reductions under the Scenario 3b (HLS).*

	Baseline export P by agriculture (ton) (A)	Export load under scenario 2 (ton) (B)	Reduction (ton) (A-B)	Target reduction (ton)	Contribution to target reduction (%)
Int.Dairy	53	53	0.21	32	0.7
Int.Arable	7	7	0.06	5	1.2
Upland	15	15	0.38	8	4.8
Grassland	81	81	0.87	52	1.7
Mixed	47	47	0.35	32	1.1
Gen.Arable	14	14	0.15	8	2.0

Under this Scenario, the contribution to the targeted level of P reduction was calculated as being small for both the ELS and HLS schemes. Effects were in the order of 1-2%, apart from in the upland catchment, where effects were 3-5%.

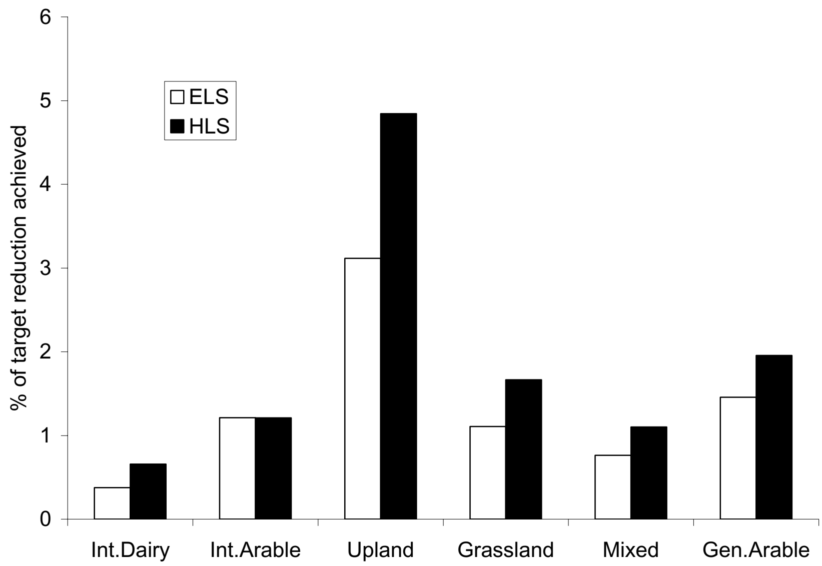


Figure 4.7. Percentage contribution to target P reduction with ELS and HLS.

4.6.4 Scenario 3c: BAU + ELS + Advanced GAP

Scenario 3c involved combining the results of the modelling of BAU, Advanced GAP and ELS. The rationale for this was to investigate the impact on P export of applying good practice measures and simple existing agri-environment support measures to market driven patterns of land-use. This scenario, therefore, investigated what the agriculture industry may be able to achieve without enforced land-use change. Results of the modelled outcomes are shown in Table 4.12 and Figure 4.8.

Table 4.12. P load reductions under the Scenario 3c.

	Baseline export P by agriculture (ton) (A)	Export load under scenario 2 (ton) (B)	Reduction (ton) (A-B)	Target reduction (ton)	Contribution to target reduction (%)
Int.Dairy	53	45	7	32	23
Int.Arable	7	5	2	5	36
Upland	15	13	2	8	30
Grassland	81	68	13	52	24
Mixed	47	42	5	32	16
Gen.Arable	14	11	3	8	34

The success of these measures is reasonably good, with effects for upland and arable catchments in the order of a 30-35% achievement of P reduction against target. Measures were less effective in lowland catchments with livestock, reflecting the challenge that this sector brings.

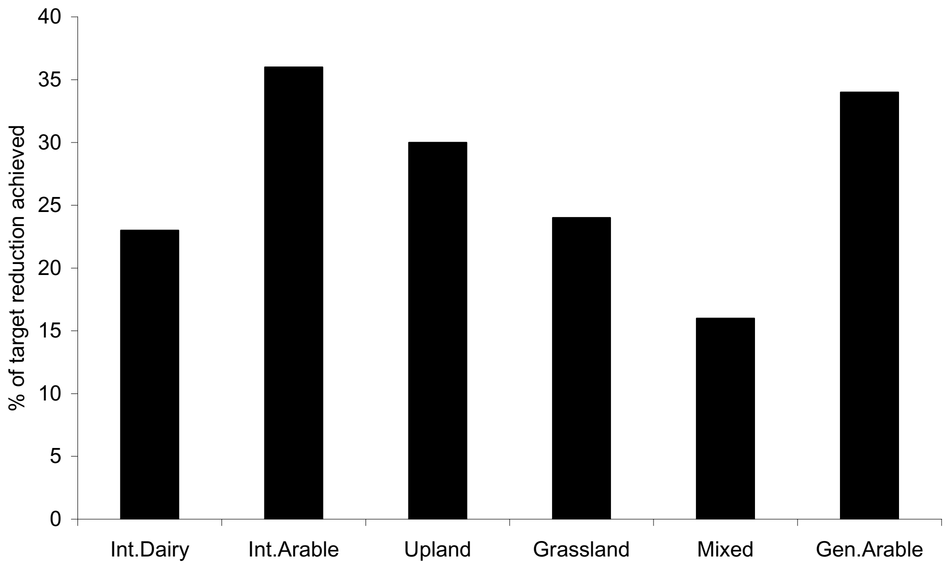


Figure 4.8. Percentage of contribution to target P reduction with BAU + ELS + Advanced GAP.

4.7 Results for Scenario 4: 'Wildlife-Rich Landscape' with GAP

4.7.1 Scenario description

The Wildlife-Rich Landscape (WRL) scenarios aimed to achieve land-uses that would deliver benefits for biodiversity. Agriculturally managed landscapes provide important habitats for a range of farmland biodiversity presently existing and requiring support. Bird species, such as skylark, corn bunting and black grouse, are adapted to specific types of farmed landscape and the maintenance of these landscapes is critical to their survival. Following CAP reform, the majority of the UK countryside will continue to be farmed and used to produce food but it is likely that this will become increasingly linked to the provision of 'environmental goods' and/or to the market. There is, however, some way to go before farmer's objectives, in managing land, include increasing the diversity and populations of wildlife to create a truly wildlife rich landscape.

Changes following CAP reform provide increased opportunities, for policy makers, to ensure that patterns of land-use and land management benefit both water quality and terrestrial biodiversity. To create a Wildlife-Rich Landscape it was important to design a farmed landscape which would increase biodiversity and wildlife populations and then model this to predict the resulting benefits for water quality. Analysis of WRL did not, however, aim to predict the biodiversity benefits, either quantitatively or qualitatively, of the catchment scenarios. Qualitative descriptions of the six WRL scenarios can be found in Annex 1.

As a starting point it was assumed that the WRL was one in which good standards of farm practice are achieved across catchments; therefore the GAP load reductions modelled in Scenario 1 were incorporated into the scenario design. The WRL scenario built upon these foundations to design a landscape that could deliver improvements for birds and biodiversity.

The land uses for each of the six chosen catchments were, in turn, designed with input from local RSPB staff and staff of other conservation organisations. Knowledge of the area, use of maps, and data from Local Biodiversity Action Plans were used to build a picture of the existing land-use and where specific changes could be made to the landscape to deliver enhancements for wildlife. Changes were designed to assist delivery of the BAP targets, where the benefits of these changes were known.

In general, the changes to land-use generated and modelled across the catchments led to:

- A shift towards mixed agriculture – as 'a key aim of conservation in agricultural landscapes' (Wilson *et al*, 2003).
- A decrease in agricultural inputs – as agricultural intensification is known to have had 'deleterious and measurable effects on farmland bird populations' (Donald *et al*, 2001). Decreased agricultural inputs can provide opportunities to create habitats such as species-rich grassland.
- Extensification of livestock production – as a consequence of lower inputs to grassland.
- Greater areas and variety of semi-natural habitats – to provide a mosaic of habitats within the landscape and, for example, to link areas of woodland within the catchments.

Full descriptions, details and rationale for the land-use changes can be found in Annex 1. Table 4.13 summarises the changes modelled for each of the six catchments.

Table 4.13. Changes used in each catchment under the Wildlife-Rich Landscape scenario to calculate P export loads.

Land use		**Present %**	**WRL %**
Intensive dairy Catchment			
Arable	To NVZ regulations	17	25
Grassland	Ave 183 kg N/ha - <2.0 LU/ha	54	40
Rough	Ave 50 kg N/ha - 1.4LU/ha	10	15
Woodland	Calculated from BAP target	9	10
Water	Unchanged	1	1
Urban	Unchanged	9	9
Intensive arable Catchment			
Arable	To NVZ regulations	75	68
Grassland	Ave 203 kg N/ha - <2.0 LU/ha	6	10
Rough	Ave 50 kg N/ha - 1.4LU/ha	4	7
Woodland	Increased to link small existing woods	3	5
Water	Unchanged	0 (<1%)	0 (<1%)
Urban	Unchanged	12	12
Upland Catchment			
Arable	***See detailed breakdown***	3	
Grassland	*See detailed breakdown*	30	
Rough	*See detailed breakdown*	53	
Woodland	Based on total catchment	9	12
Water	Unchanged	1	1
Urban	Unchanged	4	4
Grassland Catchment			
Arable	***See detailed breakdown***	0 (<1%)	
Grassland	*See detailed breakdown*	54	
Rough	*See detailed breakdown*	31	
Woodland	Based on total catchment	6	9
Water	Unchanged	1	1
Urban	Unchanged	8	8
Mixed farming Catchment			
Arable	To NVZ regulations	42	39
Grassland	Ave 191 kg N/ha - <2.0 LU/ha	35	30
Rough	Ave 50 kg N/ha - 1.4LU/ha	8	13
Woodland		7	10
Water	Unchanged	1	1
Urban	Unchanged	7	7
General Arable Catchment			
Arable	To NVZ regulations	49	34
Grassland	Ave 185 kg N/ha - <2.0 LU/ha	19	25
Rough	Ave 50 kg N/ha - 1.4LU/ha	8	10
Woodland	BAP target increase	8	15
Water	Unchanged	1	1
Urban	Unchanged	15	15

4.7.2 Scenario testing

The provisional modelling results for Scenario 4 are shown in Table 4.14 and Figure 4.9.

Table 4.14. P load reductions under the Scenario 4 (WRL).

	Baseline export P by agriculture (ton) (A)	**Export load under scenario 2 (ton) (B)**	**Reduction (ton) (A-B)**	**Target reduction (ton)**	**Contribution to target reduction (%)**
Int.Dairy	53	40	12	32	39
Int.Arable	7	5	2	5	40
Upland	15	8	7	8	90
Grassland	81	61	20	52	38
Mixed	47	42	5	32	16
Gen.Arable	14	11	3	8	36

As would be expected, with quite substantial changes in livestock numbers in many of the catchments (Fig. 4.9), this Scenario was reasonably effective in reducing agricultural P losses.

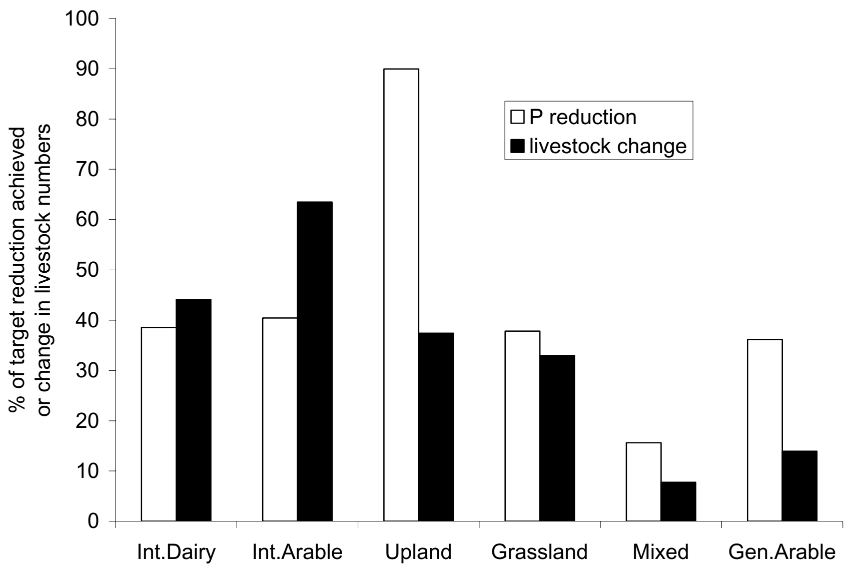


Figure 4.9. Percentage of contribution to target P reduction with the WRL scenario. Graph also shows the reduction in livestock numbers associated with the scenario.

Even so, the modelling suggests that an 'acceptable' reduction (as judged against achieving target) could only be realised in the upland catchment, with other catchments only achieving about 40% target reduction.

4.8 Results for Scenario 5: Radical change with Good Agricultural Practice

4.8.1 Scenario description

The aim of the Radical Change scenario was to alter land uses within the catchments in order to close the gap between current nutrient status and the required outcomes under WFD. This scenario differed from the previous scenarios in that it worked to achieve a known % target reduction in P rather than assessing the reduction following changes in land management or land use.

Under the Wildlife-Rich Landscapes scenario, an approximate average of 40% of the required reduction from agriculture was accomplished. In order to identify the scale of change that might be needed beyond this to achieve WFD outcomes, the 'Radical Change' scenario was developed by building upon the land use changes already modelled in the WFD scenario.

In order to achieve equity in changes to land use it was important to that the scenario affected all agricultural sectors rather than changes being made to the land use that most easily delivered the outcomes required. Therefore, for each catchment, radical land-use changes were designed, to achieve the target water quality outcome, by focusing on three factors:

- An increase in rough grazing
- A reduction in livestock
- Reduced fertiliser and manure input to land

Full descriptions and details for the land-use changes can be found in Annex 1. Table 4.15 shows the changes modelled for each of the six catchments.

Table 4.15. Summary of management changes under the Radical Change scenario. See Annex 1 for details of the upland and grassland catchments.

Catchment type and Land-use category	**Comments**	**P input (kg P/ha)**	**% of catchment area**	
			Baseline	Radical
Intensive Dairy				
Arable	To NVZ regulations	Half of baseline rate	17	25
Grassland	Ave 183 kg N/ha - <2.0 LU/ha (1.1 LU/ha)	4.0 for permanent grass, 8.5 for temporary grass	54	25
Rough	Ave 50 kg N/ha - 1.4LU/ha (0.8 LU/ha)	0	10	25
Woodland	Calculated from BAP target		9	15
Water	Unchanged		1	1
Urban	Unchanged		9	9
Intensive Arable				
Arable	To NVZ regulations	Half of baseline rate	75	25
Grassland	Ave 203 kg N/ha - <2.0 LU/ha (0.4 LU/ha)	4.0 for permanent grass, 8.5 for temporary grass	6	8
Rough	Ave 50 kg N/ha - 1.4LU/ha (0.4 LU/ha)	0	4	37
Woodland	Increased to link small existing woods		3	18
Water	Unchanged		0 (<1%)	0 (<1%)
Urban	Unchanged		12	12
Mixed farming				
Arable	To NVZ regulations	Half of baseline rate	42	28
Grassland	Ave 191 kg N/ha - <2.0 LU/ha (0.8 LU/ha)	4.0 for permanent grass, 8.5 for temporary grass	35	20
Rough grazing	Ave 50 kg N/ha - 1.4LU/ha (0.4 LU/ha)	0	8	29
Woodland			7	15
Water	Unchanged		1	1
Urban	Unchanged		7	7

Catchment type and Land-use category	Comments	P input (kg P/ha)	% of catchment area Baseline	Radical
General Arable				
Arable	To NVZ regulations	Half of baseline rate	49	34
Grassland	Ave 185 kg N/ha - <1.4 LU/ha (1.3 LU/ha)	4.0 for permanent grass, 8.5 for temporary grass	19	25
Rough grazing	Ave 50 kg N/ha - 1LU/ha (0.6 LU/ha)	0	8	10
Woodland	LBAP target increase		8	15
Water	Unchanged		1	1
Urban	Unchanged		15	15

4.8.2 Scenario testing

The modelling results for Scenario 5 are shown in Table 4.16. The modelling estimated that five catchments achieved 100% of the targeted P reduction. The intensive arable catchment achieved significant reductions, but failed to reach the targeted reduction, reflecting the difficulty of controlling diffuse pollution from agriculture in areas with high value crops reliant on the use of inorganic fertilisers. Significant changes in livestock numbers were required to bring about the changes (Fig. 4.10).

Table 4.16. P load reductions under the Scenario 4 (Radical).

	Baseline export P by agriculture (ton) (A)	**Export load under scenario 2 (ton) (B)**	**Reduction (ton) (A-B)**	**Target reduction (ton)**	**Contribution to target reduction (%)**
Int.Dairy	53	20	33	32	102
Int.Arable	7	2	5	5	96
Upland	15	6	9	8	115
Grassland	81	25	56	52	107
Mixed	47	14	32	32	101
Gen.Arable	14	6	8	8	105

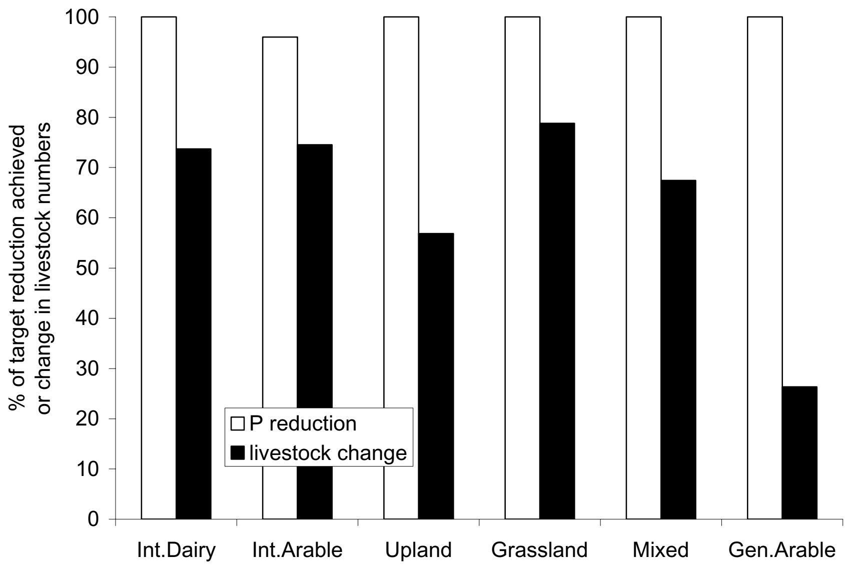


Figure 4.10. Percentage of contribution to target P reduction with the Radical Change scenario. Graph also shows the reduction in livestock numbers associated with the scenario.

4.9 Summary of scenario testing results

The project established phosphorus threshold values as a proxy measure of Good Ecological Status for different river types, and determined the target load reduction required from agricultural land in sample catchments to achieve these. Five scenarios were developed, and a calculation made of each scenario's potential to reduce loads at the catchment scale. Figure 4.11 shows the summary of the six catchments scenario results.

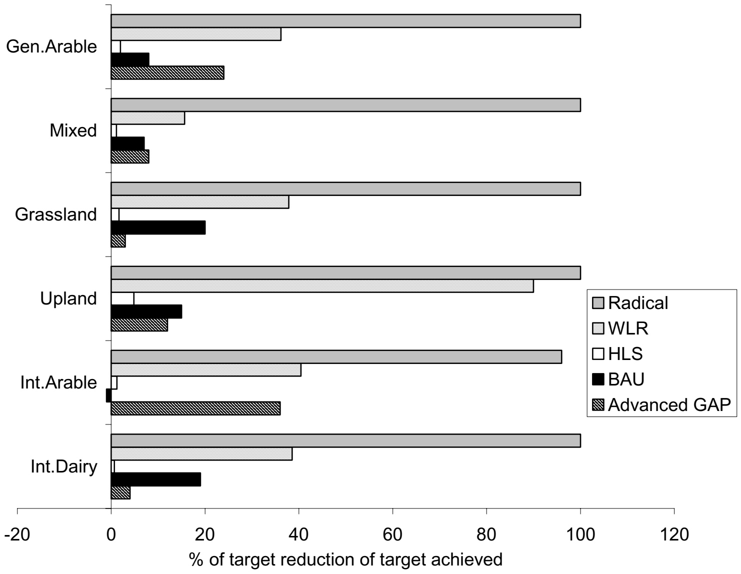


Figure 4.11. Summarising the percentage of contribution to target reduction by agriculture under five of the designed scenarios

The following conclusions can be draw from scenario analysis:

- Changes to management practices applied to existing patterns of land-use could be considered the 'least cost' option for achieving reductions in P loads in a catchment. Significant progress can be made by applying these measures, particularly in intensive arable areas. However, the level of change achieved was insufficient in all cases to produce the required load reductions.

- The BAU projection predicted an increase in the area of cereal production and a reduction in the numbers of livestock as a result of CAP reform implementation. In total, CAP reform measures were insufficient to make a significant contribution to P load reduction, and in some cases increased projected P loads.

- Agri-environment schemes made only a small reduction in P loss, suggesting additional measures beyond cross compliance/ELS/HLS will be required.

- The wildlife-rich scenario aimed to achieve biodiversity outcomes within a farmed environment. When modelled, initial designs achieved an average of approximately 50% of the required load reduction through re-allocation of land-uses, and reductions in livestock levels.

- The radical change scenarios are designed purely to reduce the P load sufficiently to meet WFD relevant P thresholds. Design of preliminary scenarios suggested it may be necessary to change catchment land-uses in some areas to achieve the required outcomes.

- All scenario results should be seen as provisional, and set within the context of the limited understanding of the P pathway from source to water. The potential exists with all scenarios to identify high-risk areas critical for P export. Identification of these areas and targeting of further modifications to land-use and practice might allow significant further reductions in load to be achieved. In particular, there would be value in exploring the role which habitat creation within floodplains and along riparian corridors could play in mitigating nutrient loss to water in the sample catchments.

- All change scenarios have potential economic impacts on farming. An important next step would be to analyse the potential socio-economic implications of different land-use scenarios, and identify (if possible) the political, regulatory and financial context within which truly sustainable rural economies would thrive.

5 DISCUSSION

5.1 Limitations and assumptions of the approach

5.1.1 Phosphorus threshold value

The sensitivity of surface waters to P extends over several orders of magnitude, making it very difficult to define critical or threshold concentrations for eutrophication (Ferguson *et al*., 1996). This is especially true for the threshold P concentrations for streams, because P concentrations are influenced by changes in the physical and chemical properties of the stream moving from the headwaters downstream, and by the changes in P residence time and utilization in the channel (Zaimes & Schultze, 2002).

Withers *et al*. (2000) suggested that the setting of P threshold values need not be based on environment result targets, but can be based on nutrient loss reduction targets. However, it is not clear how straightforward these would be to develop or apply, within a regulatory context such as that required by WFD.

Sharpley (2002) reported that threshold soil P levels are being proposed to guide P management recommendations. However, it is generally agreed that soil P levels are not appropriate as the sole criterion to guide P management.

5.1.2 Export coefficient modelling

The WFD requires thinking at the catchment scale. Providing decision support tools at this scale is challenging the modellers. Being able to represent nutrient transfers from land to water at this scale – and with the detail required to represent the effects of often subtle management changes in individual fields – is required if we are to develop sound Programmes of Measures. As a first approximation, export coefficient modelling was the preferred technique for this project. Such an approach does have limitations but we believe that it serves as a useful starting point to assess the effects of various management approaches. We have acknowledged that the absolute results have to be treated with caution, but the method allows ranking of approaches with some confidence. However, we do need to acknowledge the limitations of export modelling:

Data resolution and coefficient rate

In this project, large-scale catchment land-use was broadly categorised, using data from the 1 km^2 agriculture census results. The export coefficient rate was calculated using this assessment, with the only additional weighting factor the topographic slope. With this approach it is not possible to accurately represent field management changes.

Diffuse pollution modelling requires accurate and sensitive treatment of spatial data over catchment or landscape-scale units. The spatial variations in catchment characteristics may be modelled using lumped, distributed or topological representations. The extent to which models based on any of these representations need to be validated depends on the quality of the available data.

P form

The export model is only capable of calculating the total export load for each catchment. In order to link this to the P threshold value and to scenario testing, an uncalibrated ratio of TP and SRP was used. This is, clearly, not ideal.

Moreover, seasonal variability in the occurrence of different P forms cannot be reflected through the current modelling approach. Diffuse agricultural loads of P are heavily associated with run-off during rainfall and so tend to peak during the winter months. Much of the P load is in particulate form, the majority of which is not immediately biologically available to plants. This contrasts with point source loads, which are generally more immediately bioavailable, and are delivered relatively evenly throughout the year, including the summer period of minimum effluent dilution and maximum plant growth.

Delivery and in stream processes

In assessing the contribution to exported load reductions by good agriculture practice, other projects can generally only account for the mitigated P load at the edge of field. The current project uses a sediment delivery ration (SDR) to reflect the fact that the majority of P loss is associated with sediment.

Source apportionment

The attribution of pollution to agricultural sources in the current project is based on simple model estimation, with point sources determined according to human population numbers, rather than directly linked to STWs. Accurate data on this aspect is difficult to obtain (for all source apportionment projects) – addressing this should be a priority for future research. This would allow us also to factor in likely potential reductions in point source loads, based on available technology and cost analysis.

The role of critical source areas

The scenarios modelled were only able to take a limited account of the important role that different pathways play in transporting P to water. It is likely that the identification and targeting of critical areas within catchments for P loss would enable more realistic outcomes to be generated, with a greater potential for P reduction.

5.2 Implications of the results

It should be noted that export coefficient modelling is more appropriate for testing the effects of land-use change, rather than for the effects of the subtler, in-field, changes to management practices. However, this is not the first project to suggest that major land use change will be needed to bring P losses down to ‘acceptable’ limits. Haygarth *et al*. (2003b), using a similar export coefficient approach concluded that it may be possible to reduce nutrient export with gross changes in agricultural land use but, in order to achieve ‘good ecological status’ these would have to be very large. Haygarth *et al.* (2003b) also stated that such an approach would be problematic because of:

- uncertainties in permutations of future land use scenarios
- uncertainties in ecological targets
- uncertainties over the time required for systems to undergo hysteresis (recovery), both in soils and in catchments.

5.2.1 CAP reform and diffuse pollution

Defra's consultation (Defra, 2004) on diffuse pollution indicated that existing and planned policies, in particular CAP reform (cross compliance), the Entry Level Scheme and Higher Level Scheme of Environmental Stewardship and the Whole Farm Approach, would help to reduce agricultural emissions to water. The current project results support this view but suggest that with the elevated levels of nutrients in our surface waters it is likely that further improvements would be needed across large areas of the country.

5.2.2 Multi-functional value of wildlife-rich landscapes

Many of the financial costs of mitigating the negative impacts of farming on the environment are not paid for by the agricultural industry. Diffuse water pollution from agriculture is paid for by water customers and incentives for farmers, in the form of agri-environment payments, are paid for by taxpayers. End-of-pipe solutions to water quality, if addressed at the source could prove cost effective in the long term. If incentives were provided to the farming community to change land uses in order to reduce diffuse pollution there could be benefits beyond the improvement in water quality.

Unfortunately, this project was not able to differentiate agri-environment options on the basis of where they are placed within the catchment. It is, however reasonable to assume that a 6 metre buffer strip located next to a river bank will have more of an impact on diffuse pollution than one placed at right angles to a watercourse. Buffer strips (EE3 and EE6 in ELS), in-field grass areas (RP3 in HLS) and many other agri-environment options offer multiple-objective benefits for a farmers agri-environment application and therefore for the farmed environment. These options can, at the same time as protecting resources and reducing diffuse pollution, provide habitats for wildlife.

This principle of fulfilling multi-functionality in land management can also be applied to land use changes. The project results show that land uses changed to provide habitats for wildlife and increase the biodiversity of farmland can also improve water quality. It is essential that multiple benefits are sought when giving advice and seeking incentives to change, and that measures and changes to land use are,

- the best for the farm situation
- located for optimal effect
- chosen and located to deliver on other objectives in addition to reducing diffuse pollution.

The benefits of land use change for water quality may be greater than the results demonstrate as the land use changes modelled in scenario 4 cannot be spatially located within the catchment.

5.2.3 Impact of scenarios on catchment nitrogen loads

Although the scenario design in this project aimed primarily to reduce P loads to levels compatible with P threshold values, the export coefficient model was able to also estimate exported total N. Nitrogen is an important pollutant of coastal waters and drinking waters, and is increasingly recognised as playing a role in some cases of freshwater eutrophication. It is, therefore, important to understand the scale of N load reduction, which might be expected under the different modelled scenarios.

There is a good a good understanding of the agricultural N cycle and the land management activities that influence N losses. The understanding of N is probably greater than P. Anon (2000) provides a useful summary of the Defra-funded research on nitrate mitigation and, at least at the plot scale, we have a reasonable quantitative understanding of the effects of management practices on nitrate loss. However, as with P, there is considerably less understanding at the catchment scale.

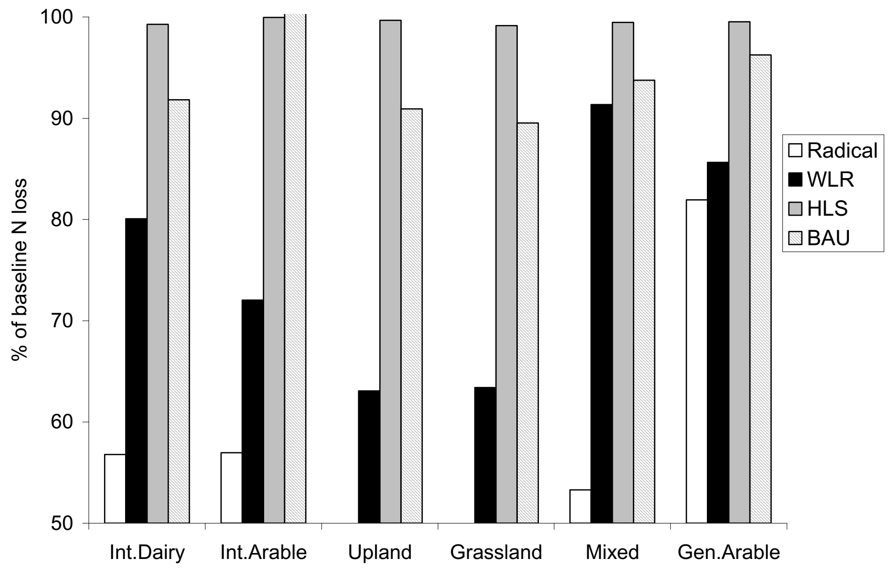


Figure 5.1. Exported Total N load under designed scenarios, compared with baseline.

For the same reason as for P, export coefficient models have difficulty in accurately representing the N loss processes at a sufficient level of detail to examine the impacts of management change on N losses. However, as with P loss, we believe that the export coefficient approach at least enables us to rank the efficacy of different approaches.

Figure 5.1 shows some of the *preliminary* modelling results. The results suggest that, as for P, the agri-environment schemes will have only a small impact on N loss. Business as Usual might be expected to have an effect of a 5-10% reduction but, not surprisingly, the more radical approaches to land use and livestock numbers had the greatest effects. Even so, these effects were not as great with N as for P.

5.2.4 The significance of livestock numbers in modelling.

Livestock contribute a large proportion of diffuse P (and N) pollution from agriculture (Smith *et al*., 1998; Chambers *et al.*, 2000). A comparison was made of the wildlife-rich and radical change scenarios with the baseline, linked to reductions in livestock numbers. In this analysis, three types of pattern emerged:

- Reduced stock numbers synchronously reduced the total exported load, for example in the upland catchment.
- Reduced stock number reduced the total exported load but not efficiently, such as for the grassland and mixed farming catchments.

- Reduced stock number reduced the total exported load to some extent, but the effectiveness reduced beyond a certain level of reduction. This was seen in the comparison between the intensive dairy and general arable catchments.

6 CONCLUSIONS

The project sought to use catchment modelling techniques to show how land-use and farm practice change can help to control diffuse pollution from agriculture, ensuring that water bodies achieve Good Ecological Status.

6.1 Assessing current levels of P and N in selected rivers in England and Wales

- Results indicated that 71% of calcareous rivers, 61% siliceous of rivers and 51% of organic rivers are likely to be at risk of ecological impact.

- Analysis illustrated the significant influence of Sewage Treatment Works effluent discharge on P levels in some rivers.

- Existing river quality monitoring strategies make it difficult to determine precisely the influence of diffuse sources of P on river P concentrations. In some rivers, that receive no STW discharges, either a gradually increasing or decreasing trend of P concentration was found, indicating impacts from diffuse sources.

6.2 Phosphorus threshold values

- Concentrations of 0.1 mg/l (SRP) for calcareous and 0.04 mg/l (SRP) for non-calcareous river were adopted for the project, following EA work to derive P threshold values to inform WFD implementation.

- River flow is a major factor for determining nutrient levels. The natural variation between and within years makes it more difficult to apply a single, unvarying standard.

6.3 Source apportionment

- In the six catchments modelled, the point source contribution ranged from 9% to 60%; the diffuse agriculture source contribution ranged from 38% to 90%.

- Livestock makes the largest contribution to P load in the agriculture sector.

6.4 Land management and land-use change scenarios

- Changes to management practice applied to existing patterns of land-use could be considered the ‘least cost’ option for achieving reductions in P loads in a catchment. Significant benefit can be achieved from these, but the level of change achieved was insufficient in all cases to produce the required load reductions.

- Modelling of a scenario based on the likely impacts of CAP reform suggested that increases in the area of cereal production would be likely to offset gains resulting from livestock number reductions. The predicted outcomes suggested that CAP reform could only make a limited contribution to WFD outcomes, without other action.

- Wildlife-rich landscapes could achieve an average of 50% of the required load reduction through re-allocation of land-uses, and reductions in livestock levels.

- To achieve WFD outcomes through a ‘radical change’ scenario, it might be necessary to reduce current livestock levels by more than 70%, and significantly change catchment land-uses.

- Nitrogen load reductions under the designed scenarios are smaller, when compared to P load reductions. Around 40% reduction of N loads is achieved under the prototype radical change scenario.

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8 ABBREVIATIONS

BAU	Business As Usual
CAP	Common Agricultural Policy
DA	Disadvantage Area
EA	Environment Agency
GAP	Good Agriculture Practice
GES	Good Ecological Status
GQA	General Quality Assessment
LU	livestock unit
NVZ	Nitrate Vulnerable Zone
N	Nitrogen
P	Phosphorus
SDA	Severe Disadvantage Area
SDR	Sediment Delivery Ratio
SEPA	Scottish Environment Protection Agency
SRP	Soluble Reactive Phosphorus
STW	Sewage Treatment Works
SSSI	Sites of Special Scientific Interest
TAG	Technical Advisory Group
WFD	Water Framework Directive

ANNEX 1: SCENARIO DESIGN DETAILS

Scenario 3: Agri-environment

ELS Options

Combined Options		Area of option from Pilot (ha) Upland	Arable	Mixed	Dairy	Area of Catchment under the options (%) A	B	C	D	E	F
Arable management of high risk cultivations	0kg for 6 mths/yr	0	222.25	253.52	21.77	0.12	0.59	0.00	0.08	0.65	0.38
Grassland options low input	100kg/ha	365.91	117.16	296.71	375.77	2.13	0.31	2.10	2.18	0.77	0.89
Grassland options very low input	50kg/ha	60.21	104.23	93.83	123.04	0.70	0.28	0.35	0.59	0.24	0.39
Rough and Moorland Grazing	0kg/ha	601	0	0	0	0.00	0.00	3.45	1.24	0.00	0.00

HLS Options

Combined Options		Area under CSS options (ha) Devon	Suff	Durh	Lancs	Wilts	Avon	Area of Catchment under the options (%) A	B	C	D	E	F
Grassland	50kg/ha	14140	1300	990	1030	6440	4420	2.25	0.37	0.58	0.42	2.13	1.64
Rough grassland	50kg/ha	0	0	5390	8870	0	0	0.00	0.00	3.14	3.58	0.00	0.00
Arable reversion	50kg/ha	1590	1340	590	90	2300	2110	0.25	0.38	0.34	0.04	0.76	0.79
Heathland	0kg	1960	1370	330	230	10	280	0.31	0.39	0.19	0.09	0.00	0.10
Moorland	0kg	0	0	8200	17430	0	0	0.00	0.00	4.78	7.04	0.00	0.00
Reedbeds	0kg	30	50	0	70	0	20	0.00	0.01	0.00	0.03	0.00	0.01
Fens	0kg	20	30	0	40	20	10	0.00	0.01	0.00	0.02	0.01	0.00
Orchards	0kg	320	60	0	0	0	220	0.05	0.02	0.00	0.00	0.00	0.08
Woodland	0kg	0	0	40	70	0	0	0.00	0.00	0.02	0.03	0.00	0.00

Scenario 4: Wildlife-rich Landscapes

Wildlife-Rich Landscape for the Intensive Dairy Catchment

Summary

		Present %	WRL %
Arable	To NVZ regulations	17	25
Grassland	Ave 183 kg N/ha - <2.0 LU/ha	54	40
Rough	Ave 50 kg N/ha - 1.4LU/ha	10	15
Woodland	Calculated from BAP target	9	10
Water	Unchanged	1	1
Urban	Unchanged	9	9

Description of the area
The predominant land use in the catchment is dairy agriculture with some arable cropping. At the head of the catchment and to the east are hilly areas and to the west a tributary joins which is not part of the modelled catchment. The catchment contains a small amount of floodplain. Although the river runs into the sea on the south coast of Devon the project catchment does not extend all the way to the sea.

Wildlife-Rich Landscape
- Dairy extensification.
- Increase rough grazing.
- Livestock farms including some arable land.

In order to promote a wildlife-rich landscape the catchment floodplain should be managed as pasture rather than improved grass. The majority of the floodplain should revert to hay meadows with zero inputs. A late cut in August would be followed by grazing until December at a low stocking density. The Devon LBAP describes the *'scores of species of myriad colours and forms can be found within a small patch of this grassland; orchids, vetches, yellow rattle and other conspicuous plants, as well as a variety of grasses.'* Birds named in the LBAP include, song thrush woodlark and barn owl.

Improved grass grazed by dairy cows and cut for silage should be managed with reduced inputs to NVZ input levels of 250kg N/ha. However best practice should include manures added to crop requirements, soil nutrient testing and a programmed reduction to allow inputs through the NVZ action programme. Livestock manures should have their N and P contents calculated in order to avoid exceeding maximal applications. Biodiversity would further benefit if this type of improved grass was encouraged to become species rich.
http://www.devon.gov.uk/bapd-flower-rich_meadows___pastures.pdf

Maize grown as a forage crop should not be grown on soils prone to erosion.

Increased arable agriculture would provide a patchwork of land use over the catchment. At least 25% arable in the catchment would provide a start towards a mixed system of farming which would provide habitat for animals such as the brown hare, http://www.devon.gov.uk/bapd-brown_hare.pdf. It would also provide an area of land on which to apply livestock manures and therefore facilitate farm nutrient cycling. Manures would be applied to arable land to crop requirement. Spring sown cereals would provide an important seed source for granivorous birds such as the cirl bunting and yellowhammer.
Species benefiting from arable habitats include Western Ramping-fumitory, Purple Ramping-fumitory, Shepherd's needle, Corn buttercup, Cornflower, Skylark, Corn Bunting, Cirl Bunting. (Devon LBAP)

Woodland
Devon's LBAP has set a target of 5000 ha of new, predominantly oak, woodland by 2005, largely through the enlargement and linking of existing semi-natural woodlands.
http://www.swbiodiversity.org.uk/Habitats/Oak/Oak_devon.htm
This amount equates to approximately 1% of the area of Devon.

Land use change Outcomes

- Arable – 25% - 210kg N/ha
- Dairy/Livestock — 55%
- No/low input Rough grassland - 15% – Ave 50kg N/ha - 1.4LU/ha
- Improved grassland - 40% – Ave 183 kg N/ha - <2.0 LU/ha
- Woodland – 10%
- Urban levels – set by catchment

Wildlife-Rich Landscape for the Intensive Arable Catchment

Summary

		Present %	WRL %
Arable	To NVZ regulations	75	68
Grassland	Ave 203 kg N/ha - <2.0 LU/ha	6	10
Rough	Ave 50 kg N/ha - 1.4LU/ha	4	7
Woodland	Increased to link small existing woods	3	5
Water	Unchanged	0 (<1%)	0 (<1%)
Urban	Unchanged	12	12

Description of the area
The arable catchment is a groundwater-based catchment in Suffolk. There is a strong connection between the ground and surface waters in the catchments and due to the relatively flat aspect of the catchment it is hydrologically linked to neighbouring catchments. Two branches of the river join at the south east of a town, one from the north and the other from the west. The catchment ends downstream of the town.

Wildlife-Rich Landscape

- More mixed farming
- Extensive livestock
- Protection of vulnerable soils.

Arable
Arable land is by far the predominant land use in the catchment. Cereal field margins offer the opportunity to improve biodiversity within the agricultural system. 'Rare arable plants found within cereal field margins include Cornflower, Corn Parsley, Red-tipped, Cudweed, Shepherd's Needle, Spreading-hedge Parsley and Narrow-fruited Corn Salad' http://www.suffolkcc.gov.uk/e-and-t/countryside/biodiversity/action_plan/habitats/documents/fieldmargins.pdf . Inputs onto arable land should be to NVZ requirements.

Grassland and rough grazing.
The floodplain and the immediate riparian zone of the catchment should be reverted back from arable to a mosaic of wet woodland (some exists), reedbed and hay meadow. All would have zero inputs. This change would increase the rough grazing area. Increasing the area of grassland grazed by cattle would, in combination with the arable land, have the effect of

providing a mixture of habitats needed by species such as, lapwing. Hay meadows are a habitat included in the Suffolk LBAP and through traditional management techniques provides habitat for a wide variety of plants and animals, http://www.suffolkcc.gov.uk/e-and-t/countryside/biodiversity/action_plan/habitats/documents/Lowlandhaymeadows.pdf

Pig production should be made more extensive in order to protect soils and reduce diffuse pollution.

Woodland

Woodland in the catchment (3% coverage) is above the county average of 1%. Some of small areas of woodland are isolated so targeted planting would link isolated areas into larger blocks providing continuous unbroken habitats for wildlife. Suffolk LBAP includes action plans for wet woodland and wood-pasture, http://www.suffolkcc.gov.uk/e-and-t/countryside/biodiversity/action_plan/habitats/index.html

Land use change Outcomes

- Arable - 68% (to NVZ regulations (210kg N/ha for fertiliser levels)
- Removal of crops whose management raises soil vulnerability (potatoes & vegetables)
- Livestock - 17% - More extensive pig production and beef.
- Improved grassland – 10%; Ave 203 kg N/ha - <2.0 LU/ha
- No/low input Rough grazing – 7%; Ave 50 kg N/ha - 1.4LU/ha
- Woodland – 5%
- Urban areas (remains the same)

Wildlife-rich landscape for the Upland Catchment

Summary

		Present %	New WRL %
Arable	*See detailed breakdown*	3	
Grassland	*See detailed breakdown*	30	
Rough	*See detailed breakdown*	53	
Woodland	Based on total catchment	9	12
Water	Unchanged	1	1
Urban	Unchanged	4	4

Description of the area

The upland catchment used for the project encompasses the upper section of an upland valley downstream to significant town. The river is flashy in nature and has some narrow areas of flood plain. This river is classed as Grade A for water quality (EA) and is a highly mobile gravel river. The majority of the catchment is within the North Pennines AONB.

Wildlife-rich landscape

- Unimproved grassland in the uplands grazed extensively by mixed livestock, i.e. including cattle

- 10% arable in the Disadvantaged Area (DA) to benefit biodiversity
- Gill woodland in the uplands.
- Mixed farming in outside the LFA

Arable land is a very small minority in the catchment (3%) and this is mainly located towards the downstream end of the catchment and near to the river. A WRL would see arable removed from the floodplain where soil is vulnerable to erosion. In place of the arable low/zero input grassland is advocated in land use such as hay meadows.

Arable is needed in upland fields, both inside and outside the LFA, to provide food sources for a variety of birds through the winter. The RSPB would like to see 10% of grassland turned over to arable. There is a need to perform EIAs before permanent pasture is ploughed but the WRL assumes compliance and a favourable assessment.
The Durham LBAP seeks to target existing arable areas for enhancement of this habitat, http://www.durhambiodiversity.org.uk/pdfs/habitats/ArableLand.pdf

Moorland should be input free and of a low stocking density. Heather burning should be carried out on a 10 year rotation in order to reduce the risk of erosion. Livestock grazing on moorland is important for the structure of sward and should be at a rate of 0.4 LU/ha in addition to sheep grazing.

Most importantly, moorland management should include the regeneration of blanket bog through grip blocking. This management style provides a habitat for plant and invertebrate species in addition to a number of important bird species, such as the threatened Black Grouse, http://www.durhambiodiversity.org.uk/pdfs/species/birds/BlackGrouse.pdf.

In the LFA rough grazing should have no inputs and low stocking densities. Rushes should be controlled to provide open grassland for breeding waders, such as lapwing and curlew, to nest and raise young. In order to control rushes grazing with cattle is important.

Other grassland in the LFA should be managed for bird species by the reintroduction of wet grassland, low stocking densities and mixed grazing with sheep and cattle. Grazing can be managed with species rich hay meadows nearer to the road and valley bottom and combined with rougher pasture at higher altitudes.

Woodland
Gill/Clough woodland is important in the catchment in order to reduce erosion and provide habitat for black grouse. 125ha of this type of woodland is planned for creation.

Upland heathland and blanket bog
Maintain and enhance the biodiversity value of upland heathland and blanket bog.
Restore 100 ha of degraded up-land heathland and blanket bog with reference for those areas adjacent to existing moorlands.
http://www.durhambiodiversity.org.uk/pdfs/habitats/UplandHeathland-BlanketBog.pdf

Upland hay meadow
Increase the area of species- rich upland hay meadow, with preference for those sites, which would provide linkage between existing sites.
http://www.durhambiodiversity.org.uk/pdfs/habitats/UplandHayMeadows.pdf

Land use change Outcomes

The Catchment should be modelled by the breakdown of the designated areas below. Percentages relate to the breakdown of the areas not % of the catchment.

Moorland (above the moorland line)
- Unimproved rough grazing, heather and blanket bog – zero inputs
- Extensive livestock – 0.4 LU/ha

Less Favoured Area – includes SDA and DA below

Severely Disadvantaged Area (SDA)
- Unimproved grassland – zero inputs
- Extensive livestock – <1.0 LU/ha

Disadvantaged Area (DA)
- Extensive Livestock – 1.4 LU/ha
- Unimproved grassland (90% of the DA)
- Arable – low input (Max 210kg N/ha) (10% of the DA)

Outside the LFA
- Arable - 30% of agric area – 210kg N/ha
- Unimproved rough Grazing - 20% of agric area – Ave 50kg N/ha - <1.4 LU/ha
- Improved grassland - 50% of agric area – Ave 156kg N/ha - <2.0 LU/ha

TOTAL CATCHMENT (based on the catchment area)
- Woodland – 9%
- Urban levels – set by catchment

Wildlife-Rich Landscape for the Grassland Catchment

Summary

		Present %	New WRL %
Arable	*See detailed breakdown*	0 (<1%)	
Grassland	*See detailed breakdown*	54	
Rough grazing	*See detailed breakdown*	31	
Woodland	Based on total catchment	6	9
Water	Unchanged	1	1
Urban	Unchanged	8	8

Description of the area

The large catchment area begins above a major county town in the northwest and follows the river to the top of the catchment. On the west side the catchment includes moorland and fells whilst on the eastern edge the catchment includes the edge of the south Pennines. Most of the catchment falls within Lancashire whilst the upper section enters Cumbria.

Wildlife-Rich Landscape
- Unimproved grassland in the uplands grazed extensively by mixed livestock, i.e. including cattle
- 10% arable in the Disadvantaged Area (DA) to benefit biodiversity
- Gill woodland in the uplands

- Mixed farming in outside the LFA

A major amount of work has been done in designing a plan for the Whitendale Farm pilot project which falls within the project catchment. This project in association with United Utilities has designed a management plan for the area to be implemented in the future. The management plan for the 1137ha farm (1001ha of moorland) will deliver significant Biodiversity Action Plan targets over ten years, including the creation and/or enhanced condition of 425 hectares of blanket bog, 238 hectares of upland heath, 30.8 hectares of upland oak woodland, 206 hectares of upland hay meadow and 5.6 hectares of upland mixed ash woodland. The moors in the catchment are an important breeding ground for upland birds, with the majority of the fells designated as a Special Protection Area under the European Birds Directive. Over 70% of hen harrier nesting attempts in England occur on the United Utilities estate.

The vision for a WRL for the lower altitudes of the catchment is for the introduction of some areas of arable into the heavily predominating grassland land-use. Only two counties in England are home to the purple ramping-fumitory. Arable land in Lancashire is one of these, http://www.lbap.org.uk/bap/habitat/arable.htm. Mixed farming provides habitat for species such as lapwing and brown hare in Lancashire.

Grazed grassland in the catchment can provide improved habitat for birds, such as breeding waders, by following options in the Lapwing Special Project for Cheshire. This involves farmers shifting from maize cultivation to spring cereals and providing extensively grazed damp areas. This benefits the widespread but declining population of lapwings.

The floodplain of the catchment should be restored to extensively grazed pasture and hay meadows both with zero-low inputs. This also includes the area of floodplain higher up the catchment which has been modified. Total area is approx 5%. Upland hay meadows and species rich grassland are included in the list of habitat action plans for Lancashire as they are important for many species, http://www.lbap.org.uk/bap/habitat/grassland.htm

Woodland

Lancashire's LBAP target states:
Achieve favourable condition of ancient semi-natural woodlands within SSSIs and SACs by 2005 and in other ancient and semi-natural woodlands by 2010.
Identify and encourage the restoration to site native species on 20% of the area (c.200 ha) of former ancient semi-natural woodland by 2010 and 50% by 2015.
Avoiding other areas of high conservation value, expand the area of native woodland by 20%(500 Ha) by 2015 and 50% by 2010.
http://www.lbap.org.uk/images/maps/woodland.jpg
Targeting of woodland creation is important. Gill woodland in the upland is important in the Whitendale Farm plan.

Land use change Outcomes

The Catchment should be modelled by the breakdown of the designated areas below. Percentages relate to the breakdown of the areas not % of the catchment.

Moorland (above the moorland line)

- Unimproved rough grazing, heather and blanket bog – zero inputs
- Extensive livestock – 0.4 LU/ha

Less Favoured Area – includes SDA and DA below

Severely Disadvantaged Area (SDA)

- Unimproved grassland – zero inputs
- Extensive livestock – <1.0 LU/ha

Disadvantaged Area (DA)

- Extensive Livestock – 1.4 LU/ha
- Unimproved grassland (90% of the DA)
- Arable – low input (Max 210kg N/ha) (10% of the DA)

Outside the LFA

- Arable - 30% of agric area – 210kg N/ha
- Unimproved rough Grazing - 20% of agric area – Ave 50kg N/ha - <1.4 LU/ha
- Improved grassland - 50% of agric area – Ave 156 kg N/ha - <2.0 LU/ha

TOTAL CATCHMENT (based on the catchment area)

- Woodland – 9%
- Urban levels – set by catchment

Wildlife-Rich Landscape for the Mixed Farming Catchment

Summary

		Present (%)	WRL (%)
Arable	To NVZ regulations	42	39
Grassland	Ave 191 kg N/ha - <2.0 LU/ha	35	30
Rough grazing	Ave 50 kg N/ha - 1.4LU/ha	8	13
Woodland		7	10
Water	Unchanged	1	1
Urban	Unchanged	7	7

Description of the area

The catchment river rises in Gloucestershire and flows into Wiltshire. The catchment area for this study takes in the catchment at the upper end of the river which is a large river flowing to the sea. To the east and west of the catchment the area takes in tributaries of the river. Mixed farming predominates in this catchment.

Wildlife-Rich Landscape description

- Mixed farming within farms.
- More extensive grassland and low input pasture in the floodplain.
- Nutrient inputs to NVZ recommendations.

The catchment agricultural land use is presently well distributed between arable and grassland. Whilst this is good the WRL scenario would ensure that the distribution is mixed within farms in order to deliver a mix of habitats for birds and wildlife and to allow for the cycling of nutrients within the farm and the avoidance of farm nutrient surpluses.

The floodplain of the river and the riparian zone should have arable removed in order to remove the threat of diffuse pollution and soil erosion. In its place hay meadow and low input species rich pasture would provide habitat for wildlife. Keeping stock away from water would in addition reduce diffuse pollution and erosion. Wiltshire's BAP states that a 'mosaic of habitats in and around rivers and streams supports a diverse range of plants and animals, many of which have very precise requirements.' One objective of the BAP is to 'Maintain and enhance the characteristic biological diversity and natural features of all rivers and streams and their associated floodplain habitats.'
http://www.swbiodiversity.org.uk/Habitats/Rivers/Rivers_Wiltshire.htm

Woodland
Woodland coverage in the catchment is the same as the county average. The average for Wiltshire is not evenly spread and therefore the catchment is relatively well served by woodland. A wildlife-rich landscape should contain a mosaic of habitats and woodland sited in the riparian zone of the river would benefit wildlife and act as a nutrient sink.
http://www.swbiodiversity.org.uk/Habitats/Woods/woods_wilts.htm

Land use change Outcomes

- Arable - 39% (to NVZ regulations for fertiliser levels – 210kg N/ha)
- Livestock - 43%
- Improved grassland – 30%; Ave 191 kg N/ha - <2.0 LU/ha
- No/low input Rough grazing – 13%; Ave 50 kg N/ha - 1.4LU/ha
- Woodland – 10%
- Urban areas (remains the same)

Wildlife-Rich Landscape for the General Arable Catchment

Summary

		Present %	New WRL %
Arable	To NVZ regulations	49	34
Grassland	Ave 185 kg N/ha - <2.0 LU/ha	19	25
Rough grazing	Ave 50 kg N/ha - 1.4LU/ha	8	10
Woodland	LBAP target increase	8	15
Water	Unchanged	1	1
Urban	Unchanged	15	15

Description of the area
The general arable catchment has mainly arable land use but there is a significant amount of livestock farming also. Three rivers/tributaries come together at a major town in Kent. This area of the southeast is in a major development area and is rapidly expanding. The catchment includes a section of the floodplain downstream of the town.

Wildlife-Rich Landscape
- Mixed farming
- Arable reversion in the floodplain.

The floodplain (approx. 15% of the catchment) should revert to pasture.
Downstream of the town this should be floodplain hay meadows with no inputs. A late cut in August would be followed by grazing until December at low stocking density.

Upstream of the town the floodplain should also revert to grassland but within this there should be a mosaic of fen, bog and woodland in the floodplain. The importance of reedbeds is recognised in the Kent LBAP which includes a habitat action plan and a target for the creation of 200ha within 50 years, http://www.kent.gov.uk/living/biodiversity/downloads/kbap612r.pdf

Most of the other farmland in the catchment is mixed, if not mixed farming within individual farms. There is some dairy but this is not a major dairy area. Beef suckler herds are present. Kent's Lowland Farmland BAP includes 50-year targets for increasing the area of semi natural habitat on this land use by:
- Conversion of improved to semi improved grassland – 5000ha
- Arable to semi improved grassland or woodland – 10 000ha

with a corresponding increase in farmland bird populations.
http://www.kent.gov.uk/living/biodiversity/downloads/kbap605i.pdf

Kent Wildlife Trust has outlined a plan for part of the area covered by the project catchment which demonstrates the potential for:
- acid grassland, heathland, and associated habitats;
- areas with potential for Low Weald landscape restoration, including neutral grassland and ponds; and
- areas with potential for woodland management and restoration.

Kent BAP/HAP sets target figures for creation of Fen, Marsh, swamp and reedbed which, when targeted well, would add to the mosaic in the catchment.

<u>Woodland</u>
Woodland and Scrub presently covers 15% of the county of Kent. By 2050 Kent plans to have a further 23,000ha under a variety of woodland types to provide habitats for species including Heath Fritillary, Nightingale, Doormouse and Firecrest. With this target in mind the catchment should recreate woodland on 7% of the land area which would bring it into line with the present average for woodland and scrub.
http://www.kent.gov.uk/environment/careenv/safeguarding/biodiversity/kbap601w.pdf

<u>Urban</u>
There are presently water quality issues downstream of a town and some villages in the catchment. There are plans for the development and expansion of the growing town on the river which are likely to increase the population and urban land use.

Land use change Outcomes

- Arable - 34% (to NVZ regulations for fertiliser levels)
- Livestock - 35%
- 10% No/ low input rough grassland – Ave 50kg N/ha1.4LU/ha
- 25% Improved grassland – Ave 185 kg N/ha - <2.0 LU/ha
- Woodland – 15%
- Urban areas (remains the same)

<u>Scenario 5: Radical land use change</u>

Radical change scenarios for the Intensive Dairy Catchment

		Present %	WRL %	Radical%
Arable	To NVZ regulations P input - half of baseline rate	17	25	25
Grassland	Ave 183 kg N/ha - <2.0 LU/ha (1.1 LU/ha)	54	40	25
Rough	Ave 50 kg N/ha - 1.4LU/ha (0.8 LU/ha)	10	15	25
Woodland	Calculated from BAP target	9	10	15
Water	Unchanged	1	1	1
Urban	Unchanged	9	9	9

Radical change scenarios for the Intensive Arable Catchment

		Present %	WRL %	Radical %
Arable	To NVZ regulations P input - half of baseline rate	75	68	25
Grassland	Ave 203 kg N/ha - <2.0 LU/ha (0.4 LU/ha)	6	8	8
Rough	Ave 50 kg N/ha - 1.4LU/ha (0.4 LU/ha)	4	7	37
Woodland	Increased to link small existing woods	3	5	18
Water	Unchanged	0 (<1%)	0 (<1%)	0 (<1%)
Urban	Unchanged	12	12	12

Radical change scenario for the Upland Catchment

Land use change Outcomes

The Catchment should be modelled by the breakdown of the designated areas below. Percentages relate to the breakdown of the areas not % of the catchment.

Moorland (above the moorland line) 50%

- Unimproved rough grazing, heather and blanket bog – zero inputs
- Extensive livestock – 0.4 LU/ha
- Less Favoured Area – includes SDA and DA below 40%

Less Favoured Area – includes SDA and DA below

Severely Disadvantaged Area (SDA) 90%

- Unimproved grassland – zero inputs
- Extensive livestock – <1.0 LU/ha (0.6 LU/ha)

Disadvantaged Area (DA) 10%

- Extensive Livestock – 1.4 LU/ha (0.8 LU/ha)
- Unimproved grassland (90% of the DA)
- Arable – low input (Max 210kg N/ha) (10% of the DA)

Outside the LFA 10%

- Arable - 30% of agric area – 210kg N/ha
- Unimproved rough Grazing - 20% (30%) of agric area – Ave 50kg N/ha - <1.4 LU/ha (1.0 LU/ha)
- Improved grassland - 50% (40%)of agric area – Ave 156 kg N/ha - <2.0 LU/ha (1.0 LU/ha)

TOTAL CATCHMENT (based on the catchment area)

- Woodland – 9%
- Urban levels – set by catchment

Radical change scenarios for the Grassland catchment

Land use change Outcomes

The Catchment should be modelled by the breakdown of the designated areas below. Percentages relate to the breakdown of the areas not % of the catchment.

Moorland (above the moorland line) 10%

- Unimproved rough grazing, heather and blanket bog – zero inputs
- Extensive livestock – 0.4 LU/ha
- Less Favoured Area – includes SDA and DA below 75%

Less Favoured Area – includes SDA and DA below

Severely Disadvantaged Area (SDA) 80%

- Unimproved grassland – zero inputs
- Extensive livestock – <1.0 LU/ha (0.4 LU/ha)

Disadvantaged Area (DA) 20%

- Extensive Livestock – 1.4 LU/ha (0.4 LU/ha)
- Unimproved grassland (90% of the DA)
- Arable – low input (Max 210kg N/ha) (10% of the DA)

Outside the LFA 15%

- Arable – 30% of agric area – 210kg N/ha
- Unimproved rough Grazing - 20% (35%) of agric area – Ave 50kg N/ha - <1.4 LU/ha (0.4 LU/ha)
- Improved grassland - 50% (35%) of agric area – Ave 156 kg N/ha - <2.0 LU/ha (0.6 LU/ha)

TOTAL CATCHMENT (based on the catchment area)

- Woodland – 9%
- Urban levels – set by catchment

Radical change scenarios for the Mixed Farming Catchment

		Present (%)	WRL (%)	Radical %
Arable	To NVZ regulations P input - half of baseline rate	42	39	28
Grassland	Ave 191 kg N/ha - <2.0 LU/ha (0.8 LU/ha)	35	30	20
Rough grazing	Ave 50 kg N/ha - 1.4LU/ha (0.4 LU/ha)	8	13	29
Woodland		7	10	15
Water	Unchanged	1	1	1
Urban	Unchanged	7	7	7

Radical change scenarios for the General Arable Catchment

		Present %	WRL %	Radical %
Arable	To NVZ regulations P input - half of baseline rate	49	34	34
Grassland	Ave 185 kg N/ha - <1.4 LU/ha (1.3 LU/ha)	19	25	25
Rough grazing	Ave 50 kg N/ha - 1LU/ha (0.6 LU/ha)	8	10	10
Woodland	LBAP target increase	8	15	15
Water	Unchanged	1	1	1
Urban	Unchanged	15	15	15