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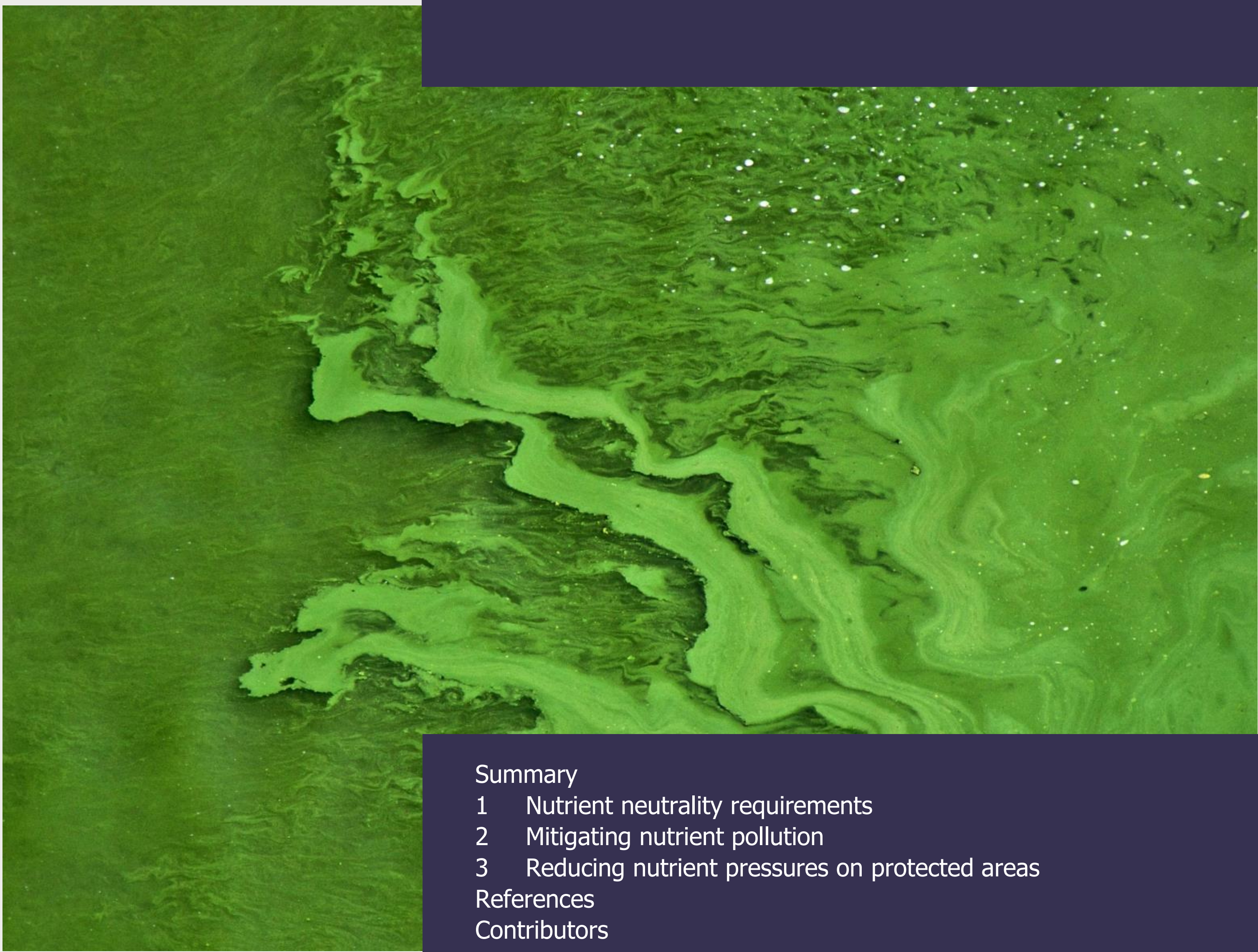
Changes to nutrient neutrality in England



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Contents

Summary

In 2019 and 2022, Natural England issued planning advice to 74 local planning authorities for 31 sites spanning 27 river catchments in unfavourable condition due to nutrient pollution. Building projects and plans may only go ahead if they will not cause additional pollution, referred to as ‘nutrient neutrality’.

Nutrient neutrality does not seek to reduce the nutrient pollution levels affecting protected sites, but to limit future increases from development. The Commons Library briefing Nutrient neutrality and housing development explains how the previous government proposed to reduce the effects of nutrient pollution on protected sites.

Excess nitrogen and phosphorus nutrients arising from point sources, such as sewage effluent, and diffuse sources, such as agricultural activities, affect soil, wildlife, air and water quality as they move through the environment, as well as emitting greenhouse gases. This includes impacts on freshwater and coastal habitats protected under the Habitats Regulations.

The Planning and Infrastructure Bill provides for a new approach to nutrient neutrality by creating Environmental Delivery Plans, funded by levies paid into the Nature Restoration Fund.

Trends in nutrient pollution sources and effects

The Environment Agency says that phosphorus pollution levels in England’s rivers and lakes are the main cause of eutrophication (excessive algae growth affecting water quality and ecology). However, in some waterbodies, nitrogen pollution levels may increase eutrophication risks, either alone or in combination with phosphorus pollution.

Research suggests that treated sewage effluent, emitted as a ‘point source’ of water pollution, may have historically had the greatest effect on water quality in some catchment areas. However, diffuse sources of water pollution are now having a greater effect; this trend may become increasingly dominant.

The Environment Agency suggests that phosphorus pollution from agriculture and rural land use, rather than sewage effluent, is one of the main causes of waterbodies failing to meet the relevant water quality criteria. Agriculture and rural land use is also the main source of nitrogen pollution.

Proportions and patterns of nutrient pollution sources vary between and within catchments, but are apportioned using modelling with uncertainties at this scale.

Current nutrient neutrality mitigation requirements

Developers must calculate the excess nutrients ('nutrient load') created by a proposed development using catchment nutrient calculators, which compare the development with previous land uses. Mitigation measures must remove this excess amount, either on the development site or within the same catchment.

Nutrient removal by mitigation project schemes is assessed and accredited by Natural England, which has set out the evidence for measures with sufficient mitigation certainty. Schemes must be maintained and monitored for the lifetime of a development (usually 80 to 125 years). Examples include constructed wetlands, which reduce nutrient loads from sewage effluent or agricultural activities.

In catchments with these mitigation project schemes, some of which are led by local authorities or Natural England, developers can pay to offset their nutrient loads. Schemes supply credits which are considered the mitigation equivalent of 1 kilogram of nitrogen or phosphorus emitted per year.

Reducing nutrient pressures on protected areas

Research suggests that setting overall nutrient load caps for catchments can reduce nutrient loads, but that reducing loads may also require an improved understanding of nutrient flows. Reducing flows at a catchment scale is challenging, as interactions occur across water, soil, sediments and air, and include legacy nutrient pollution sources in soil and groundwater.

Natural England will take a catchment-scale strategic mitigation approach to Environmental Delivery Plans, implementing the existing nutrient neutrality scheme measures upstream of protected areas. Research suggests that, if Environmental Delivery Plans are to be successful, measures should be tailored to specific catchments and affected protected areas, including their physical and natural features, and N and P pollution sources.

Nature markets, where private investment funds environmental restoration by paying for the benefits generated, may provide additional opportunities for nutrient mitigation projects. The Environmental Audit Committee has suggested that the state-run Nature Restoration Fund may create uncertainty for nature markets.

Contributors raised other concerns about the limitations and impacts of existing approaches and Environmental Delivery Plan proposals, including holistically managing trade-offs between policy objectives.

Acknowledgements

This briefing was produced in consultation with experts and stakeholders, who are listed at the end of the briefing. POST would like to thank everyone who contributed their expertise.

1 Nutrient neutrality requirements

High levels of nutrients from sources such as artificial and organic fertilisers, treated sewage effluent (wastewater) and legacy stores of nutrients in the landscape may lead to excessive plant growth in waterbodies.[1] This process, known as 'eutrophication', harms wildlife in freshwater and marine habitats (table 1).[2,3,4,5,6]

In England, nutrient pollution affects habitats and species protected under the Conservation of Habitats and Species Regulations 2017, referred to as 'European sites' (table 1). In 2019 and 2022, Natural England (NE) issued standing advice to a total of 74 local planning authorities for 31 protected sites spanning 27 river catchments in 'unfavourable condition' due to nutrient pollution (figure 1)[7].

Under the regulations, prior to consenting to a development, competent authorities are required to demonstrate there will be no "likely significant effect" on the integrity of protected sites.[8,9] Development proposals must be supported by a Habitats Regulations Assessment (table 1), which should either demonstrate 'neutrality' or be accompanied by an appropriate mitigation strategy, such as prescribed mitigation measures (see section 2), before planning permission is granted.

Neutrality is achieved when there is no net increase in the nutrient 'load' (table 1) that would result from the development within the catchment(s) of the affected protected site.[a,10] The advice had the initial effect of halting the processing of residential planning applications in affected areas.[11]

In some catchments, trading and mitigation schemes have subsequently been set up to generate nutrient credits for developers to purchase to offset the nutrient pollution.[b]

The House of Lords Built Environment Committee has raised concerns about the 'disproportionate burden on housebuilding compared with other polluting

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[a] NE's advice covers all types of overnight accommodation: new homes, student accommodation, care homes, tourism attractions and accommodation and permitted development that gives rise to new overnight accommodation. It applies to agricultural developments that increase nutrient loads (table 1).

[b] This includes NE-led mitigation schemes, private nutrient credit trading schemes, local planning authority (LPA)-led mitigation schemes and onsite mitigation solutions integrated into the design of housing developments (see section 2).[12] The Home Builders Federation estimates that 160,000 houses were delayed at various stages of planning and highlights the lack of schemes in some affected catchments including the Somerset Levels, Kent and northeast Cumbria.[13] Developers also bear the costs of legal arrangements, such as section 106 agreements.[14] Researchers suggest nutrient neutrality requirements may be more difficult for small builders to comply with, but there is not enough data to confirm this. Researchers also highlight the risk of LPA credit providers acting as a monopoly rather than an effective price-finding mechanism.[15]

sectors' and recommended greater transparency in the process.[16] The previous government estimated 100,000 new homes were delayed.[17] Research suggests 2% higher house prices in areas subject to nutrient neutrality, with development displaced to adjacent areas.[18]

Table 1: Nutrient pollution and protected area terminology

Term	Description
Eutrophication	• Definitions of eutrophication vary,[19] but it is defined in EU legislation as "….an accelerated growth of algae and higher forms of plant life to produce an undesirable disturbance to the balance of organisms present in the water and to the quality of the water concerned".[20] • Eutrophication can have multiple indirect consequences for the ecology of waterbodies, such as through lowered oxygen concentrations and toxic algal blooms. It also reduces the value of waterbodies to humans by impairing the drinking water supply (increasing water treatment costs) and reducing recreational and fishing opportunities.[19,21,22] See the POSTnote Freshwater habitat restoration for more information. • Of the 17 macronutrients and micronutrients known to increase plant growth, nitrogen (N) and phosphorus (P) are usually considered the two main macronutrients,[1,19] and the main nutrients involved in eutrophication. In the absence of human activity, nutrients are transported via water and air; this transport can be increased by natural events, such as storms. Research suggests human activities, such as fertiliser use, have altered the natural biogeochemical cycles of N and P.[23,24,25,26,27] See the POSTnote The future of fertiliser use for more information. • The 2013 UK Technical Advisory Group (UKTAG) on the Water Framework Directive (WFD) recommendations on P standards include a measure of the quality of algal and higher plant communities in rivers, which relates to eutrophication risks.[28] Under the WFD P standards, 27% of waterbodies are categorised as 'very certain' of eutrophication problem, and 15% as 'quite certain.[29] However, UKTAG has not developed a separate eutrophication standard for rivers as part of WFD waterbody classification system.[30,31] Researchers suggest that there has been an overall decline in the eutrophication events in UK rivers. However, while the frequency of eutrophication events are falling in two-thirds of rivers, they may be rising in the other third of rivers.[32] • Modelling studies suggest climate change will increase eutrophication risks. For example, changing winter rainfall patterns may increase the transport of phosphorus from agricultural land to watercourses by up to 30% by 2050 in some catchments, compared with existing baselines.[33] Climate change also affects other key variables such as river flows, phosphorus concentration, air temperature and sunlight duration.[30,34]

Total nitrogen (N)	• Refers to the sum of all nitrogen-containing compounds, only a proportion of which will be bioavailable or reactive (the forms of a substance that can be used by organisms). • The main inorganic forms of N in treated sewage effluent are ammonia and nitrate, but effluent contains a wide range of organic forms of N, including urea and amino acids.[19] The main form of inorganic N from agriculture is nitrate, but livestock and manure management are a major source of ammonia, including emissions into the air.[35,36,37] Understanding of the quantities of organic, nitrogen-containing solids or aerosols in the air transported to and within waters from agricultural land is limited.[38] • Likely natural or 'baseline' levels of total N are estimated to be 1.5 to 2 milligrammes per litre (mg L^{-1}) of water in watercourses.[39]
Total phosphorus (P)	• Refers to the sum of all phosphorus-containing compounds, only a proportion of which will be bioavailable or reactive compounds in a sample. Plants mainly absorb P in its dissolved inorganic form (orthophosphate), but it also exists in organic, soluble and particulate and colloidal forms, the bioavailability of which is variable.[22] • The diverse chemical forms in which phosphorus exists in waterbodies can change due to physico-chemical and biological processes, which can vary spatially and/or temporally, including precipitation with iron and partitioning with suspended solids.[40] • Likely natural or 'baseline' levels of total P is up to 50 micrograms per litre (µg L^{-1}) in rivers and 10 to 35µg L^{-1} in lakes.[39]
Nutrient load	• The mass of nutrients (phosphorus or nitrogen) that a waterbody receives over a certain period of time, and is external or internal.[41,42] • External loading refers to nutrients entering waterbodies from 'point sources', such as sewage treatment works, or 'diffuse sources', such as agriculture and urban runoff. • Internal loading refers to nutrients entering waterbodies from sediments which are already in said waterbodies. This happens through processes such as decomposition or resuspension of sediments, or the release of nitrogen from historically polluted groundwater sources. • Load is typically expressed as a mass per unit of time, such as kilograms per year (kg/year); the total nitrogen (TN) would be expressed as kg TN/year.
Nutrient credit	• A single nutrient credit generated by a mitigation measure is expressed as the equivalent of 1kg of TN or total phosphorus per year.[43]
Nutrient trading	• Nutrient trading is selling nutrient credits generated from actions to reduce nutrient loads.[21]

Nature-based solutions	• The International Union for Conservation of Nature (IUCN) states "Nature-based Solutions (NbS) are actions to protect, sustainably manage, and restore natural or modified ecosystems, that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits."[44] • Their application in a water cycle context has been recently summarised by a UK-wide study that included classification of different recognised types of NbS interventions, such as the use of constructed wetlands to reduce nutrient pollution.[45] • Researchers say direct measurements of NbS effectiveness (of the benefits provided) should be an expected part of NbS solution.[46]
Nature based infrastructure	• Nature-Based Infrastructure (NBI) refers to areas or systems that harness nature to provide infrastructure services for people, the economy and the environment. This encompasses both naturally occurring habitats, such as wetlands, and hybrid infrastructure that combines engineered or 'grey' structures with NbS, such as sustainable drainage systems (SuDs).[47,48]
European protected areas	• Protected area designations under the Habitats Regulations for sites that are important for nature or for threatened habitats and species of international importance include: Special Areas of Conservation (SAC), which are designated to conserve listed terrestrial, freshwater and marine habitats; and Special Protected Areas (SPA) to protect habitats for migratory birds, which were previously part of the Natura 2000 network and now referred to as 'European sites'.[49] • The Natural England nutrient neutrality advice followed a 2019 ruling that the Dutch state was acting unlawfully by failing to take sufficient measures to reduce the effects of nitrogen pollution on the condition of Natura 2000 sites (referred to as the 'stikstofcrisis').[50,51,52,53] • In November 2025, the Fingleton Nuclear Regulatory Review recommended: "Allow developers to comply with the Habitats Regulations requirements by paying a substantial fixed contribution to Natural England at the outset. Defra should create a predictable, bright line procedure and set of fees based on comparable recent projects. This would reduce costs to developers and increase the environmental benefit, channelling money from surveys, assessments, and disputes directly towards nature preservation and recovery."[54] Environmental non-governmental organisations (NGOs) and practitioners have criticised the recommendation as regressing environmental standards.[55,56]
Favourable Condition Status	• A site where habitats and features are in a healthy state and are being conserved by appropriate management are categorised as being in 'favourable condition' status. • Other categorisations include: unfavourable recovering (where management actions have been identified/implemented), unfavourable no change (no action is being taken), unfavourable decline (no action taken to address drivers of decline), part destroyed and destroyed.[57]

Habitats Regulations Assessment	• The Habitats Regulations establish several stages of appropriate assessment to determine if a plan or project may affect the protected features of a 'European site' before a competent authority decides whether to undertake, permit or authorise it. The stages are: screening to check for likely significant effects on a site's conservation objectives; appropriate assessment/consideration of effects on a site's integrity; consulting the appropriate nature conservation body; and, if a derogation should be applied to a proposal, such as 'Imperative Reasons of Overriding Public Interest'.[58] • The assessment process should be precautionary; the assessment can have no gaps, and must contain complete, precise and definitive conclusions "capable of removing all reasonable scientific doubt" as to the effects of the proposal on the protected site.[10,59]

1.1 Attributing nutrient sources and impacts

Causes of poor water quality in catchments

The causes of poor water quality have been the focus of multiple parliamentary select committee inquiries.[60,61,62,63,64] Only 16% of all surface waterbodies in England meet ecological standards,[c] and all exceed chemical thresholds.[67,68] The 2025 Environmental Improvement Plan commits to restoring 75% of waterbodies in England to 'good ecological status' (GES) by 2027.[d]

Waterbodies not meeting GES are affected by more than one pressure,[e, 72,73,65] but one of the main issues in such waterbodies is phosphorus (P) and nitrogen (N) pollution levels remaining above required levels.[38,29]

[c] Waterbodies are the basic unit that rivers, lakes, estuaries, stretches of coastal water and groundwaters are divided up into for assessing the quality of the water environment and to set targets for environmental improvements. The ecological status of surface waterbodies is classified into five groups, from high to bad; achieving GES means that a waterbody's structure and function only slightly deviate from undisturbed natural conditions. This is based on biological elements, such as species presence, and supporting elements, such as levels of pollutants. The government's 2025 state of the water environment indicators showed 14% of rivers and lakes and 19% of estuaries achieved good ecological status.[65,66] 40% of waterbodies are affected by pollution from agriculture and rural land, 36% are affected by pollution from wastewater and 18% are affected by pollution from towns, cities and transport.

[d] However, the plan also notes that the Independent Water Commission recommended a review of the Water Framework Directive Regulations, including changes to the waterbody classification system and a long-term legally binding target for the water environment.[69,70]

[e] Referred to as 'reasons for not achieving good status'.[71] The Water Environment (Water Framework Directive) (England and Wales) Regulations 2017 require binding environmental objectives to be set for all waterbodies.

Trends in nutrient pollution

In England, 53% of assessed river waterbodies and 72% of assessed lake waterbodies fail P standards for GES.[29,65] At a national level, the Environment Agency (EA) estimates that 55% of the source of P to rivers is sewage effluent, 27% from agriculture and 11% from urban pollution. For lakes, agriculture is usually the largest source.[74]

The EA also states that P loads in effluent fell between 1995 and 2020,[75] and a greater proportion will come from agriculture (41% by 2030) and urban pollution (19% by 2030) in the future.[74] EA monitoring suggests levels of orthophosphate in rivers (table 1) declined between 1990 and 2023, but the majority of the decline occurred before 2008.[76]

The WFD regulations' P standards for GES aim to reduce eutrophication risks. Despite lower levels of P in the River Thames, eutrophication events have increased as climate change extends the number of suitable growing days for algae (table 1).[77]

Research suggests eutrophication risks in marine waters usually relate to N levels, but P levels may play a role, and N may also play more of a role in freshwater eutrophication risks than previously considered.[78,79,80,81,82,38,83]

The main forms of N entering waterbodies are nitrate and ammonia from agriculture and sewage effluent. Nitrate is the most common cause of groundwater bodies in England not achieving good chemical status, with 55% failing.[84] 55% of lakes assessed for GES N standards failed in 2022.[f,88,89]

Nitrate concentrations in rivers increased by 23% over the period 1990 to 2023, but have broadly plateaued since peaking in 1998.[65] Nationally, the EA estimates agriculture is the main source of nitrate in water (about 70%), with sewage effluent contributing 25% to 30%, but this varies between catchments.[90]

Varying patterns of pollution sources in catchments

The proportions and patterns of pollution sources varies between and within catchments. For example, the proportions of total N and P arising from agriculture are much higher in rural catchments with lower population density.[g,39]

[f] There are no formal nitrate standards for freshwaters within the WFD regulations (WFDR), but there are groundwater threshold values.[38] 93% of monitored estuarine waterbodies and 47% of monitored coastal waterbodies in England exceed GES nitrogen standards.[85] The spatial extent of eutrophic areas in UK coastal waters decreased between 2006 and 2014, but persist in some locations that are protected areas, such as Poole harbour.[86] Nitrate thresholds are set for surface and groundwaters in the Nitrates Directive (50 mg nitrates per litre (NO_3/L)).[87]

[g] Modelling studies have suggested 75% and 50% of total N and P in all UK freshwaters arise from land uses.[91] EA modelling for Diffuse Water Pollution Plans suggests that rural land use diffuse sources of nutrients dominate most catchments,[92] but gaps in monitoring of diffuse urban sources have been set out (these include drainage outfalls from the road system).[93,94]

Catchments also differ in their physical and natural features, such as land uses, climate, geology and vegetation (physiographic areas).[21] For example, while there are three contiguous catchments across the River Wensum, the River Yare and the River Bure, the Broads Special Areas of Conservation, and the North Norfolk Ramsar site, differing characteristics means an identical nutrient mitigation scheme could not be applied across all of them.[14]

There is also variation within catchments. For example, the River Stour catchment can be divided into four distinct areas: the Blackmore Vale, Dorset Downland, Dorset Heathland and a Human Conurbation area. This is based on geological landscape, population density, distribution of soil types and land use.[95]

There are higher levels of P pollution from livestock agriculture in the low-lying, poorly drained clay landscape of the Blackmore Vale at the top of the catchment than the other areas that have predominantly arable or low-input farming. The human conurbations of Christchurch and Bournemouth have higher levels of P pollution due to direct discharges of treated effluent from large wastewater treatment works.[95]

Source apportionment, modelling and monitoring

Indicative statistics for pollution sources (point, rural land use, urban, septic tanks and other) have been set out by the EA to inform diffuse water pollution plans for protected areas in unfavourable condition due to nutrient pollution (table 1).[92,h]

This includes for nutrient neutrality catchments (figure 1), with a 'polluter pays principle' methodology applied to define the 'fair share' of reduction required by sectors.[92,97]

The EA uses the Source Apportionment Geographic Information System (SAGIS) Tool to apportion nutrient pollution loads entering waterbodies and determine sewage discharge permits and mitigation actions.[i]

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[h] Diffuse water pollution plans are non-statutory tools to agree strategic actions at the catchment scale to reduce pollution at protected sites.[96] They are EA-led or joint EA/NE-led, and include catchments are where NE nutrient neutrality advice applies.[92]

[i] Diffuse nutrient pollution sources are incorporated into SAGIS from the Phosphorus and Sediment Yield Characterisation In Catchments (PSYCHIC) model.[98] SAGIS models UK pollutant loads to surface waters from 12 point and diffuse sources, including wastewater treatment works discharges, intermittent discharges from sewerage and runoff, agriculture, soil erosion, mine water drainage, septic tanks and industrial inputs. These are converted to concentrations in river waters using the SIMulation of CATchments (SIMCAT) water quality model incorporated into SAGIS. The model is calibrated to optimise the level of agreement between measured and simulated values through reasonable and systematic adjustments to model parameters and data representing diffuse source of pollution.[92] Combining information sources in a 'weight of evidence' approach can address model limitations,[99] but researchers raise concerns that the model may suggest water quality is better than it is.[100,101] In larger catchments beyond a certain point, the 'connection' will also be lost with spatial pollution sources.[32]

SAGIS is a national-scale apportionment model.[102,103,104] The variation in diffuse pollution sources within and between catchments creates uncertainties when adjusting the model to the catchment scale.[105,106,32,j]

This modelling suggests that, while point sources remain important, rural land use is the main source of nutrients in most nutrient neutrality catchments. For example, 81% of P arises from rural land use in the River Wye and River Lugg catchment.[92,108,109]

Monitoring nutrient pollution sources

Monitoring data informs the waterbody classifications, for which the EA publishes a full set of data for every waterbody in England every six years.[110,111,104,112] The EA Harmonised Monitoring Scheme network provides data on water quality of England's principal rivers.[65]

A new EA water surveillance network is being developed. This includes rivers, groundwater, small streams, lakes, estuaries and coasts.[k,65,113] Water companies will be required to provide 'real time' continuous water quality monitoring upstream and downstream of all sewerage assets.[114]

Some researchers suggest existing data could be used more effectively to better understand diffuse nutrient pollution sources in catchment systems.[32] However, studies suggest monitoring approaches do not capture the data needed on fluctuations in nutrients entering watercourses.[115,116]

For example, some suggest that higher temporal data resolution is required to identify diffuse nutrient sources mobilised by rainfall. These could include in-situ high-frequency water quality monitoring instruments in fast-flowing watercourses.[117,118,119,120,121]

However, for this approach to generate useful evidence, resources would be required to maintain the instruments and to process and validate the data.[106] The lack of flow-gauging data (the volume of water flowing past a specific point during a given period) can also be a major issue for understanding diffuse pollution water quality sources, particularly at the bottom of catchments.[32,105]

The Nutrient Management Expert Group in the Department for Environment, Food and Rural Affairs (Defra) stated that a lack of adequate water quality monitoring in the right places at the right frequency is the main constraint on understanding and addressing the loss of nutrients from soil to water.[39]

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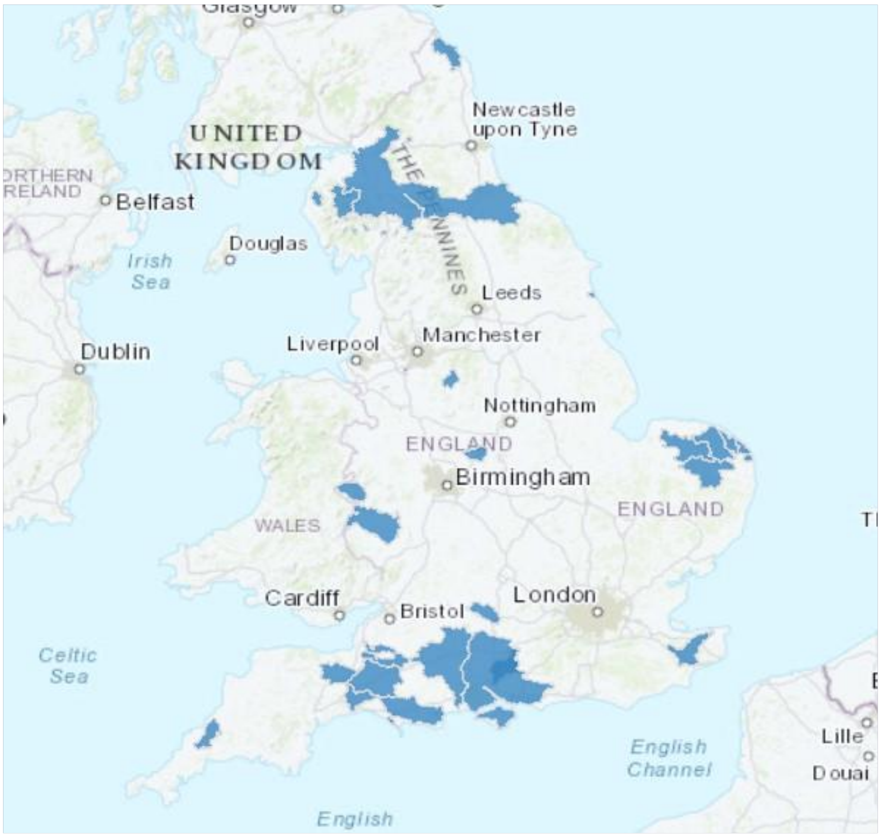
[j] Diffuse agricultural nutrient sources vary through the year due to changes in rainfall intensity and differing rates of fertiliser use. Decomposing plants, animal waste or excess fertiliser that leach into soils or remain on the soil surface are transported via sub-surface flow pathways (such as through soil or fractured bedrock) or surface water runoff and sediment to watercourses. In catchments with groundwater-dominated rivers, such as chalk rivers, N pollution also arises from aquifers affected by historical agricultural pollution.[36,107]

[k] The EA states that its monitoring networks are now much reduced. For example, 54% fewer samples were available for the groundwater Nitrate Vulnerable Zone (NVZ, table 5) assessment in 2024, limiting the ability to assess water quality.[38]

Figure 1: National map of the 27 nutrient neutrality catchments[122,l]



Affected Local Planning Authorities (LPAs)

Total N and P: Ashford, Basingstoke and Deane Bournemouth, Christchurch, Poole, Breckland, Broadland, Canterbury, Cheshire East, Cheshire West and Chester, Chichester, County Durham, Dorset, East Hampshire, East Riding of Yorkshire, Eastleigh, Eden, Fareham, Folkestone and Hythe, Gosport, Great Yarmouth, Havant, Herefordshire, King's Lynn and West Norfolk, Maidstone, New Forest, New Forest National Park, North Norfolk, Northumberland, Norwich, Portsmouth, Richmondshire, Shropshire, South Downs, National Park, South Norfolk, Southampton, Swale, Test Valley, The Broads Authority, Wiltshire, Winchester.

Total P: Allerdale, Carlisle, Copeland, Cornwall, Derbyshire Dales, East Devon, East Staffordshire, Exmoor National Park, High Peak, Hinckley and Bosworth, Lake District National Park, Lichfield, Malvern Hills, Mendip, Mid Devon, North Warwickshire, North West Leicestershire, Northumberland, National Park Peak District, National Park Sedgemoor, Somerset West and Taunton, South Derbyshire, South Lakeland, South Somerset, Swindon, Vale of White Horse, West Berkshire.

Total N: Darlington, Hambleton, Hartlepool, Isle of Wight, Middlesbrough, North York Moors National Park, Redcar and Cleveland, Stockton -on-Tees.

Source: Nutrient Neutrality Catchments (England) Natural England Open Data Publication[123]

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[l] Of these catchments, nine are in unfavourable condition due to both total N and P levels, 15 are in unfavourable condition due to P levels, one coastal estuary is unfavourable condition due to total N levels and two are in moderate condition. The local planning authorities affected but nutrient neutrality advice to control these nutrients are listed below.[68]

2 Mitigating nutrient pollution

The objective of existing nutrient neutrality policy is to avoid additional damage from any increase in nutrient pollution from development, rather than seeking to reduce nutrient pollution overall or the impacts of existing nutrient levels on protected habitats.

In 2022, Natural England (NE) set out advice for nutrient neutrality mitigation to meet Habitat Regulation requirements (tables 1 and 2), including implementation at precautionary levels to avoid any nutrient increase from developments affecting the protected area.[124]

Table 2: Summary of NE advice on neutrality measures relied on in appropriate assessments [124]

Have scientific certainty that the measures will deliver the required reduction to ensure a project or plan is nutrient neutral	NE considers that references to 'certainty' in this context means "no reasonable scientific doubt remains as to absence of such effects". This includes certainty about no adverse effects from measures on protected areas and certainty about the effectiveness of measures. More evidence may be required to provide a sufficient level of certainty about efficacy, such as precautionary efficacy values, providing greater migration than required or monitoring of mitigation measures to provide evidence of efficacy. Where reasonable scientific doubt on efficacy of a measure remains, more evidence would be required before it can be relied on in appropriate assessment (AA).
Have practical certainty the measure is implemented and in place at the relevant time	Mitigation measures must be secured and funded for the lifetime of the development's nutrient impacts. For example, the measures can be secured through legally binding obligations that are enforceable. They must also be in place for the lifetime of a development – 'in perpetuity', usually defined as 80 to 125 years.
Be preventative so as to avoid effects on the protected area in the first place, both in time and space, rather than offset or compensate for the damage	When the measures are in place and effective and when the pollution impacts start to arise, ensure any time lags are addressed. The location of mitigation measures should be relative to where the development will have its impact and avoid any increase in nutrients in the protected site. For P, mitigation should be targeted to point pollution sources, but more diffuse N sources can be mitigated elsewhere in the catchment. However, the mitigation measure needs to be

	upstream of the of where the development will have a nutrient impact on the protected area.
Measures should not undermine restoring the protected site to favourable condition, by making the 'restore' objective more difficult or prejudicing the fulfilment of that objective.	For example, if the limited land available was used for nutrient mitigation that could be required for other measures to improve the quality of the site. Implementation of nutrient neutrality measures should not prevent the implementation of future measures aimed at restoring the site to favourable conservation status in the long-term.
Do not double count mitigation measures that are already in place or required under other policies	For examples, measures already required such as wastewater treatment works (WWTW) upgrades previously identified under a Diffuse Water Pollution Plan (DWPP) or Nutrient Management Plan for the protected area.[m]
Justify calculations of the change in the nutrient contribution before and after the development taking account of any mitigation on land outside of the development	Over or underestimating the nutrient contribution in or outside of the development/mitigation land affecting calculation of the scale of nutrient mitigation required. For example, overestimating the nutrient contribution of the existing land use of the area being developed or used to implement the mitigation measures or underestimating the nutrient contribution from the development (see nutrient budget calculators). The national generic nutrient neutrality methodology is updated to take account of required WWTW upgrades (see 2.2 Engineered (wastewater) removal).
Ensure that the existing land uses maintained by the measures do not impede restoring the protected site to favourable condition status	This applies to land uses and mitigation measures both on and off the development site.

2.1 Nutrient budget calculators

Developers must use supplied nutrient budget calculators to take account of the nutrient impacts of developments, which determine the level of mitigation required to 'cancel out' the nutrient pollution increase, such as via the purchase of credits (table 1), and are specific to different catchments. [127]

[m] Nutrient Management Plans for European protected sites were developed by the Environment Agency, Natural England and local authorities to identify and set out specific measures necessary to achieve site restoration in accordance with the Habitats Regulation.[125] Site improvement plans outline the priority measures needed to achieve and maintain the European species and habitats within a site in favourable condition.[126]

For example, in the Yare catchment area in Norfolk, 0.9 P units are required per house constructed, whereas the more sensitive Wensum catchment area requires 3.5 units.

The calculators estimate changes in wastewater, the pre-existing nutrient load arising from the existing land use, the nutrient load arising from the post development land-use and nutrients removed by implementing sustainable drainage systems on development sites (SuDS).[128,n]

Local planning authorities (LPAs) may develop their own calculator that deviates from NE methods, if it is evidence based and sufficiently precautionary.[130] Calculations include a 20% precautionary buffer to address the uncertainties that arise from offsetting point sources of pollution, such as sewage effluent, with credits generated from reducing diffuse pollution sources, such as agriculture.[21,o]

The development industry criticised the methodology as over-estimating the relatively small annual contribution from new developments and the resulting mitigation requirements,[131,132,133] as did some affected LPAs.[134,p] Practitioners suggest sufficient data has been gathered in the last five years to estimate impacts of new developments on a per-house-basis and site specific assessments and calculators are unnecessary.[136]

2.2 Engineered (wastewater) removal

Wastewater treatment works (WWTWs) can be broadly divided into those with nutrient stripping technologies and associated nutrient permits[q] and

[n] (Nutrients from wastewater – Nutrients from current land use) + (Nutrients from future land use – Nutrients removed through SuDS) × 1.2 = Final nutrient budget.[128] SuDS manage stormwater by mimicking natural drainage and encouraging surface water infiltration, attenuation and passive treatment, such as use of vegetated channels (swales).[129]

[o] Some researchers argue that mitigation should replicate the connection between source and the water receptor. The percentage loss of nutrient inputs into the river from the sewage system is often about 40 to 50% or more and can be modelled with accuracy, but for diffuse agricultural sources, typically less than 5% ends up in the river and a larger reduction in agricultural inputs is needed to achieve the same reductions from wastewater inputs. [89,106,32]

[p] For example, the Leader of South Norfolk District Council criticised the scientific basis of the calculator, such as not taking account of the distance nutrients are emitted by housing upstream of the protected areas given natural processes diluting and removing nutrients.[134] Research commissioned by the Home Builders Federation suggests the total contribution of all new dwellings constructed annually in England from additional discharged treated wastewater is a 0.29% increase of total N emissions each year and 0.73% increase of total P.[135]

[q] Under the Environmental Permitting (England and Wales) Regulations 2016 it is an offence to cause or knowingly permit a water discharge activity or a groundwater activity without an environmental permit.[137,138] These permits have conditions that must be applied with, site-specific limits set for the removal of ammonia and phosphorus with the EA responsible for overseeing monitoring against those permits, including effluent quality.[139] The Environment

those without;[141] smaller WWTWs tend be those without.[r] Effluent from WWTWs contains N and P in various forms but mostly ammonium, nitrate and orthophosphate (table 1).

The Levelling Up and Regeneration Act 2023 introduced a statutory obligation for WWTWs serving over 200,000 people in nutrient neutrality catchments to be upgraded.[s] They must meet technically achievable limits (TALs) of 0.25mg/l for total P and 10mg/l for total N in effluent by 1 April 2030, which will reduce in total phosphorus and total nitrogen loads by an estimated 69% and 57% in these catchments.[140,t]

These upgrades will reduce mitigation requirements for developers by splitting nutrient credit requirements pre- and post-2030; short-term credits can be used in some catchments (table 3).[12]

The main technical options for removing nutrients are physical, chemical,[147,148] or biological nutrient removal, such as use of constructed wetlands (table 3). For example, the Luston and Tarrington wetlands were constructed by Herefordshire Council to provide tertiary treatment of sewage effluent, generating P credits to sell to developers.[149,150,151,152]

Chemical treatment may be difficult to implement at small rural WWTWs with limited transport access and site size. It also requires ancillaries like electricity source and safety showers (clean water source).[105]

Research has developed alternative P removal methods such as using a natural coagulant created from tree bark to treat effluent.[153,154,155] Other P removal methods include use of reactive media in treatment wetlands, such as calcium rich industrial waste (tables 3 and 4).[156,157,158,159]

Act 2021 targets include reducing phosphorus loadings from treated wastewater by 80% by 2038 (against a 2020 baseline).[140] However, ammonia can be converted into nitrate to meet limits and then discharged, and dissolved organic nitrogen is also not considered.[100,32]

[r] The three stages of sewage treatment are referred to as primary, secondary and tertiary. Primary treatment uses sedimentation to remove large solids, grease, and oils (this sludge is processed (thickened, digested, dewatered) with around 87% of the UK's 3.6 million tonnes of sewage sludge recycled to agricultural land[142]). Secondary treatment of the remaining liquid effluent uses microorganisms to break down dissolved and suspended organic matter. Smaller STWs do not include tertiary treatment to remove remaining pollutants such as nutrients using processes such as chemical, filtration, or membrane technologies.

[s] In 2023, government actions were also set out to reduce the impact of nutrient pollution on protected sites including diffuse pollution from agriculture and a new duty on water and sewerage companies to upgrade their wastewater treatment works by 2030 in areas where habitats sites are in 'unfavourable condition' in the Levelling Up and Regeneration Act.[143] Capital expenditure of around £4bn on P reduction is planned, with schemes at around 1800 STWs. It is predicted that this will reduce the P loading from STWs to rivers by 87% by 2030, relative to loadings in 2000. This is primarily to progress towards the WFD Regulations good status for P and to meet Urban Waste Water Treatment Regulations (UWWTR).[29]

[t] These targets are in addition to those set under the Urban Wastewater Treatment Regulations for eutrophic sensitive areas and WFDR requirements.[144,145] In this price review period (2025-29), water companies are required to consider nutrient pollution alongside their other environmental duties, which includes the Habitat Regulations.[146]

2.3 Natural removal processes

Different complex environmental processes remove P and N:

- Dissolved P can precipitate out and become immobilised as phosphate minerals or bound to sediments in soils or waterbodies but can be released to the water column through microbial processes and taken up by plants.
- Organic N and ammonia are converted by bacteria through ammonifying (organic N to ammonia) and nitrifying (ammonia to nitrite and finally nitrate). Nitrate can either be denitrified by microorganisms, bacteria or taken up by plants.[u,164,165,166,167,161,168]
- Plants uptake N and P removing them from the nutrient cycle until death and decomposition occurs. A portion is permanently retained as sediments that become soils over time, and the nutrients retained in above ground plant material can be removed by harvesting (such as reed harvesting of constructed wetlands, table 3).[36,169]
- Decomposing plant material, if kept inside a wetland, can provide an internal carbon source that enables denitrification to take place.[169] N can also persist in some soils for long periods,[170,171,172] and migrate to the area of rock and the base of soil (the unsaturated zone) and into groundwater, depending on rock type and water movement.[38]

2.4 Mitigation activities included in nutrient trading

Mitigation measures can be taken to stop nutrient pollution on the development site or to reduce nutrient sources upstream of protected areas. The types of mitigation activity are listed in table 3; projects are assessed and accredited by NE before credits can be sold by schemes, which are usually a portfolio of nature-based (NbS, table 1) and engineered solutions.[173]

NE is investing £30 million to develop nutrient mitigation projects, but this national scheme is currently limited to Tees and Poole Harbour catchment

[u] Denitrifying bacteria remove N from aquatic and terrestrial habitats by converting to gaseous forms (nitric oxide, nitrous oxide and then nitrogen gas) in the presence of decaying organic matter. The microbial processing of N through nitrification and denitrification can generate nitrous oxide: during nitrification, stressors can trigger heterotrophic nitrification which results in N_2O gas emissions; and during denitrification, the presence of oxygen can inhibit the last conversion step and produce N_2O rather than the desired N_2 end product. This happens in any biological treatment process (including “grey” technologies like activated sludge and package treatment plants); operational conditions will determine how much methane and/or nitrous oxide is generated.[121,160,161,162,163]

areas.[v,174] Other catchments have private nutrient credit provision or LPA-led mitigation schemes, supported by local nutrient mitigation funds.[w,180]

Measures differ in the levels of certainty about the quantities of nutrients removed, as well as in long-term management and maintenance requirements. For example, the LPA-led Norfolk Environmental Credits scheme[x] relies on third party mitigation, with credits generated through legal obligations and contractual arrangements.[181] This avoids long-term public sector maintenance of assets.[y]

Table 3: Commonly proposed nutrient mitigation activities

Mitigation activity	Benefits and challenges
Taking agricultural land out of production to create semi-natural habitats, such as grassland, woodland or natural wetlands	• Cessation of agricultural activity on a site draining into a watercourse provides certainty about quantities of N and P no longer being applied to arable land or emitted by livestock. For example, the Wendling Beck project has taken 200 hectares of arable land out of production to sell phosphate and nitrate credits in the Wensum and Yare catchments.[182,183,184] It can supply other benefits such as biodiversity and could be incorporated into local nature recovery strategies. • Modelling can be used to assess the existing pollutant load from land uses (as well as mitigation methods).[92] For example, in the Solent, land use for poultry has a N leaching rate of 70.7 kgN/ha/yr (leaching is the amount of nitrogen moving through the soil with water[185]) but for woodland this is 5 kgN/ha/yr.[186] • However, there are uncertainties about legacy stocks of N and P in soils that may continue to leach out.[38,29,106,105] It may also require large areas of land upstream of the protected area, which may not be viable in some catchments,[187,188,100] and requires a 80 to 125 year

[v] £1,825 is the fixed price per nutrient credit unit within NE's Nutrient Mitigation Scheme.[174] The Poole harbour scheme is a farmer-led cap and trade scheme in conjunction with Wessex Water, Natural England and the Environment Agency to avoid implementation of a water protection zone (table 5). This is more viable in areas where high value crops are being produced, and financial margins allow more innovative approaches to nutrient management (table 5) to be adopted and may not be applicable to other catchments.[175,176] NE's nutrient mitigation scheme has mitigated just 7.5% of the homes originally anticipated.[177]

[w] In 2023, £57 million of capital funding was made available to River Camel, Poole Harbour, Solent and River Itchen, River Lugg (sub-catchment of the River Wye), Stodmarsh, Norfolk Broads, Somerset Levels and River Avon.[178] In 2024, a further £47m was made available to the River Axe, River Wye, River Mease, River Lambourn, River Eden, River Derwent, Bassenthwaite Lake, River Kent and Esthwaite Water Catchment.[179]

[x] Norfolk Environmental Credits is a not-for-profit collaboration between Breckland Council, Broadland District Council, North Norfolk Council, Norwich City Council, and South Norfolk Council.

[y] Section 106 agreements are used by LPAS to enforce management requirements in nutrient trading schemes, such as annual reedbed cutting and monitoring of water quality.

	agreement on the land,[189] which may not be an option for many farming businesses.[176]
Using wetlands to remove nutrients	• The extent of the evidence base for the effectiveness of different designs of wetlands under given environmental conditions varies (table 4).[190,191,192,193,194,195,196,197] For example, in Kent, 2.5 kilometres of heavily degraded ditches draining intensively farmed heavy clay soil are being modified.[120] These 'in ditch' modifications create wetlands to encourage perennial plant species, such as hardy grasses and sedges and rushes, which retain or remove some nutrients.[198,199,192] This project will supply monitoring data for a wetland type for effectiveness in UK conditions as well as providing credits.[200,201] • Wetlands can treat water from a variety of different sources including: septic tanks and package treatment plants; sewage treatment works, combined sewer overflows (storm water); rural or urban drainage (as part of a sustainable drainage system); surface water runoff from agricultural fields as well as polluted water from rivers or streams. The characteristics and quantities of the water entering need to be defined to estimate the incoming load of nutrient and ensure appropriate wetland design.[202] • For example, P can be removed through chemical or physical precipitation upstream of the wetland (a sediment trap); robust achievement P discharge limits for sewage effluent treatment by this wetland type has been demonstrated.[203] Wetlands where plants and biological processes are relied on require a larger surface area.[200,121] The process of plants taking up P, dying and decomposing into soil only accretes mineralised P in soil slowly, less than a few cm a year.[120] Wetland N removal processes are well understood,[204,205] with vegetated wetlands having higher rates.[206,207] • Wetlands may need management to maintain effectiveness.[193,195,208,209] Management approaches, such as harvesting of plant biomass, may allow recovery of nutrients but without removal, nutrients will continue to cycle.[210]
Retrofitting Sustainable Drainage Systems (SuDs) into existing developments	• SuDS use natural drainage management techniques including grassed areas, soakaways, and wetlands to reduce the risk of surface water flooding. A Commons Library briefing has set out information about water and sewerage services for new housing developments, including SuDs requirements. • Systems need to be designed for nutrient retention, such as use of sedimentation and plants in features like bioretention areas, wetlands, and swales to remove nutrients.[211,212]
Upgrading existing septic tanks and Package Treatment	• Most septic tanks only retain solids, and release nutrients directly into soakaways. Newer PTPs remove nutrients, using biological and chemical processes.

Plants (PTPs) with improved PTPs	• For example, there are probably around 12,000 septic tanks yet to be upgraded in nutrient neutrality catchments in Norfolk.[173] There is a high degree of confidence quantifying the reductions from upgrading existing septic tanks to PTPs, with monitoring of emitted effluent required under legal agreements.[213] • If correctly maintained, a PTP with P stripping technology may remove an estimated 0.9 kg/yr total P and 4.8 kg/yr total N (table 1) compared to a septic tank.[214,215,216] This may generate sufficient credits for each septic tank upgrade to offset around 10 new houses in some catchments, but is costly compared to other forms of mitigation.[14]
Temporary agricultural environmental management measures such as winter cover crops and provision of riparian buffer strips.	• Temporary agri-environment measures provide a means of mitigating nutrients but are subject to short-term agreements. These may be more attractive for many landowners.[176] • There is evidence vegetated buffer strips and winter cover crops reduce N (a 70% to 80% reduction in surface water flows), P and sediment pollution loads at the field scale.[198,217,218,21,219,220,221] • The extent to which measures reduce diffuse agricultural nutrient pollution at scale is less certain.[105] Research appraising agri-environment scheme actions for achieving agriculture water pollution targets suggest they nationally reduce diffuse nitrate, phosphorus and sediment pollution loads by between 3% and 6%.[222] Defra is seeking to increase their uptake to meet targets (table 5). [143,223]

Ensuring the effectiveness of NbS nutrient mitigation

The conditions under which natural processes remove nutrients and support other benefits vary.[224] For example, longer contact with streambed sediments in slower flowing urban rivers increases microbial denitrification processes but increases eutrophication risks. However, tree planting on riverbanks increases shade, decreases water temperature and improves water quality.[225,226]

To deliver water quality benefits, NbS such as constructed wetlands, practioners suggest they need to be well designed and maintained, and located in the right place.[227,173] This requires relevant governance frameworks to be in place to ensure their effectiveness. NbS can be designed to deliver specific co-benefits such as flood and drought risk reduction in some circumstances.[228,21,224,229,230]

NE commissioned a literature review to provide evidence on the efficiency of P and N removal by different nature-based techniques (table 4).[36,z]

[z] Other possible NbS that could be used to reduce nutrient pollution include wet woodland and sediment ponds.[231,232,233] Various studies carried out for UKRI Demonstration Test Catchment

Table 4: Nature-based solutions for Total N and P removal	
Nature-based solution	**Description and certainty of evidence for effectiveness**
Constructed wetlands for removing nutrients and sediment	• Extensive research exists on the use of constructed wetlands for sewage treatment, where nutrient flows are continuous, and is considered sufficient for inclusion in nutrient trading schemes.[235,236,237,238] The most common way to classify treatment wetlands is based on their hydrology (surface flow and subsurface flow), and then direction of flow (vertical or horizontal).[239,240,191] • All treatment wetlands have the same nutrient removal processes, consisting of which treat the incoming water through a variety of physical, chemical and biological processes to remove N, P and sediments. The design and operational conditions will determine which one of these will dominate a specific wetland intervention.[157] The processes are influenced by interactions between plants species, microbial communities, the substrate types' attributes, and operational variables, such as consistency of inflows.[157,196,241] Microorganisms play key roles in processes such as nutrient removal and breakdown of organic matter and are considered the critical component for N removal.[242,243] • Soil, sand and gravel usually provide the substrate where microorganisms will grow ("biofilms") and act as rooting media for the plants. Reactive media, such as steel slag, natural minerals or biochar, can be used to enhance nutrient removal, either as main substrate or held in structures such as gabion baskets.[244,245,246,247,248] Surface water flow wetland systems may require a greater land area compared to subsurface flow systems with reactive media.[249] To be applied in agricultural systems, designs have to be simple, low-cost, and lightly-engineered, but some researchers suggest the evidence base in this context is less well developed.[250] • The NE Wetland Mitigation Framework offers guidance and a set of confidence tables to indicate what percentage of nutrient credits can be claimed based on the wetland design.[251]
Re-naturalising river channels (floodplain reconnection)	• Reinstating natural processes in rivers, such as reconnecting rivers to their natural floodplain to restore the processes that deposit watercourse sediments away from the channel, may reduce levels of N and P pollution. This includes river channel re-naturalisation, marginal vegetation planting, bank stabilisation and re-meandering. A previous POSTnote on freshwater habitat restoration has set out evidence for measures to restore watercourses that historic management has disconnected from their floodplains.

programme showed the effectiveness of sediment ponds for nutrient removal, but that this depends on regular maintenance.[234]

	• Researchers state NBS interventions should have appropriate before and after monitoring for accurate cost benefits analysis.[252] The historic management that disrupted sediment deposition processes occurred before widespread use of inorganic fertilisers, and reducing levels of P in sediments may be challenging.[253] The NE literature review states more long-term monitoring data is required to evaluate the likely reductions in internal nutrient loads (table 1).[36]
Buffer strips	• Buffer strips of permanent natural or semi-natural vegetation can be located within a field, at the field margins or alongside a watercourse or other waterbodies (riparian buffer strips[254]) and impede surface water run-off via rough surfaces. Their effectiveness depends on the local environmental conditions, such as soil types and geology, and their spatial scale.[73,255] • Additional 'engineered' design features such as incorporating ridges, swales, and mini-wetlands, can increase the capture and retention of diffuse nutrient pollutants.[256] The type and width of vegetation within buffer strips also influences the effectiveness of P retention and denitrification.[36,232] Seasonal changes can limit water infiltration and surface water retention in buffer strips, such as soils freezing, flooding events or vegetation dying off.[257,258,21] • Evidence considered sufficient for inclusion in nutrient trading schemes of buffer strips of 10m in width (based on a precautionary estimate of nutrient removals).[12]
Engineered logjams and beaver re-introduction	• Log or 'leaky' dams constructed from logs, branches, or woody debris seek to mimic the nutrient removal processes that occur with beaver dams, which could be maintained in perpetuity.[36] This includes the dissipation of energy within watercourses, encouraging deposition of sediments and their nutrient loads.[259] • The impounding of water within beaver dams allows cycling and retention of nutrients within pools and retention of nutrients of catchment;[260,261,262] beaver dams may be abandoned but are maintained by the beavers while occupied. • The review states monitoring evidence from schemes would be required to reduce the uncertainties in nutrient efficiency removals.[36]
Agroforestry	• Agroforestry systems integrate agriculture and trees. This includes planting fruit, nut or timber trees in wide-spaced rows across arable or pasture fields. Studies suggest increased plant uptake of nutrients as well as reduced erosion and surface run-off helping to retain sediment bound nutrients.[263,264,265,266,267] • NE state more long-term monitoring data is required to evaluate the likely reductions in nutrient loads.[36]

Mitigating agricultural nutrient sources

Reducing diffuse agricultural pollution is a key challenge for meeting water quality targets,[29,38,92] including for nutrient neutrality catchments.

Defra's Nutrient Management Expert Group state agricultural nutrient management is a complex problem. They suggest no single approach can prevent emissions across all the pathways through which nutrient inputs cause pollution, including gaseous emissions (ammonia and nitrous oxide) during storage and application, nutrient imbalances in the soil and leaching to water.[39]

A range of regulations and policies seek to address agricultural nutrient pollution (table 5).[1] The House of Lords Environment and Climate Change Committee have stated the "historically fragmented and piecemeal" approach to agricultural N pollution in England is insufficient to achieve environmental targets. They recommended clarifying the roles and responsibilities of different regulators as well as simplifying and rationalising policies and regulations.[aa]

Table 5: Other relevant agricultural nutrient policies and regulations

Policy	Description
Regulatory requirements to reduce agricultural pollution	Regulation requires farmers to reduce agricultural pollution through:[29,38] • **Agricultural Diffuse Pollution (England) Regulations 2018**, which is also known as the 'Farming Rules for Water', regulates nutrient management in England.[269] It seeks to prevent diffuse water pollution from the management of organic manures, manufactured fertiliser, soil and livestock. Land managers must maintain and comply with a nutrient management or other written plan, including:[270] – Manure application limits and dates (manure application in autumn is only permitted for clear agronomic needs) – Use reasonable precautions to avoid pollution to water – Limit livestock and slurry or manure storage near waterbodies – Conduct regular soil sampling and analysis – Test organic manures before application[271] – Assess the nutrient requirements of crops

[aa] The NFU have also called for a 'holistic' review of water quality regulation, including revision of planning guidance to address barriers to gaining planning permission to build relevant infrastructure, which affects the success of applications to relevant grants listed in table 5, as well as an advice-led approach to enforcement.[268] Defra have committed to reforming agri-water regulations and improving standards in conjunction with the industry.[223]

  - Provide evidence of crop need and a plan to minimise the risk of diffuse pollution

- **Storing Silage, Slurry and Agricultural Fuel Oil Regulations 2010**[272,273] cover new store requirements, silage storage, requirements for silos and effluent tanks, slurry storage infrastructure requirements and capacity, and fuel oil storage capacity and design. Grants are available to improve or expand to six months of slurry storage capacity for cattle and six months for pigs to improve organic nutrient use and reduce pollution.[274]

- **Nitrate Pollution Prevention Regulations 2015** under which Nitrate Vulnerable Zones (NVZs) are designated as being at risk from agricultural nitrates polluting surface or ground water at a concentration greater than 50 mg L^{-1}.[275,276,277,278,279] NVZ allocated areas cover an estimated 55% of land in England, and have a registration on the amount of organic manure that can be applied by farmers of 170 kg ha^{-1} $year^{-1}$. They are also subject to requirements on manure storage, conditions and dates under which fertiliser can be spread, requirements to test soils before spreading, produce a fertilisation plan, calculate the nitrogen content of the manure to be spread and keep records of manure spread and yields achieved.[280,281,282] Estimates of costs to the agricultural sector of complying with the (2008 revised) NVZ regulations are between £44 million and £65 million a year. The overall national reduction of nitrate lost to the water environment in NVZs as between 2% and 7% (reductions at a catchment scale varied between 2% and 20%).[38,bb]

- **Pig and Poultry Environmental Permitting Regulations** cover emission sources from intensive pig farms (with places for 2,000 pigs over 30 kg, or 750 sows) and poultry farms (exceeding 40,000 places). Farm permits under the regulations cover all aspects of farm management.[284] The House of Lords Environment and Climate Change Committee recommended extending this to all large dairy and beef cattle farms,[285] Defra has subsequently committed to developing proposals.[223]

- **The Sludge (Use in Agriculture) Regulations 1989** and the sewage sludge in agriculture: code of practice for England, Wales and Northern Ireland cover the spreading of sewage sludge to agricultural land.[286,287] The EA has said the recovery of P from sewage sludge as possible future control measures.[29] Defra are currently considering recommendations made by the Independent Water Commission, including bringing sludge use under full environmental permitting, banning pollutants at source, and creating a long-term national sludge strategy.[223,70] These regulations do not cover digestate from anaerobic digestion, which the EA state is increasingly spread on land and are a source of nitrate pollution.[38]

[bb] 44% of land in England is NVZ designated because rivers breach the 50mg/l nitrate test, 25% because groundwater breach the 50mg/l test and 6% because of eutrophication of estuaries, lakes and reservoirs – these designations overlap to give the 55% figure.[90] A study of the implementation of nitrate vulnerable zones to protect showed no significant improvement in nitrate surface water concentrations in 69% of nitrogen sensitive catchment areas even after 15 years, with 31% showing significantly increasing nitrate levels.[283]

	• The EA suggests current regulation is unlikely to provide the scale of benefit needed to prevent deterioration in groundwater from N pollution.[38] EA modelling indicates that an average agricultural P load reduction of 47% is needed to achieve agriculture's 'fair share' of good status for river P, and up to 90% as a catchment average in some European Sites Protected Area catchments.[29]
Enforcement and advice	• 2025 Defra guidance says that the EA will take an advice-led approach, such as referring land managers to guidance and grants, and schemes like the Catchment Sensitive Farming (CSF) partnership, and will only pursue enforcement action if non-compliance persists.[288] The current approach seeks to balance enforcement and advice, supporting improvement of farm practice, land management change in areas posing a risk to sensitive waterbodies and innovative methods and technologies.[29,223] EA inspection and enforcement funding will increase from £5 million to £12 million, with compliance inspections increasing from around 4,000 a year in 2023 to around 6,000 a year by 2029.[223] • The CSF partnership is a collaborative initiative led by NE, the EA and Defra to provide advice, training, and grant support to farmers in England to protect air, soil and water via a network of dedicated advisors. The Farming Advice Service provides advice to farmers in conjunction with the CSF including on incentives, grants and schemes.[289] This includes reducing nutrient pollution but also covers wider aspects of environmentally sustainable food production, such as reducing greenhouse gas emissions, biodiversity and natural flood management. CSF is expanding and being rolled out to the whole of England, prior to 2022 it covered priority catchments (34% of the farmed area in England).[290,291,96] As of November 2024, CSF had delivered advice on over 200,000 practices to 28,761 farm holdings (49% of the farmed area of England).[38]
Nutrient management planning	• In 2025, 64% of farmers had a nutrient management plan, 78% were regularly testing soil nutrient content and 68% calculating a whole farm nutrient balance for nitrogen, phosphorus or potassium.[292,293] Defra have launched an online free-to-use nutrient management planning tool based on exiting nutrient management guidance.[294,295] • To be effective in reducing pollution, an EA assessment suggests plans should include: using a fertiliser recommendation system; knowing the N content of manures, composts and slurries; and integrating fertiliser and manure nutrient supply.[38] • However, nutrient management plans are not linked to a nutrient budget; for instance, in Denmark it is mandatory for farms to submit annual fertiliser accounts to the Agricultural Agency to demonstrate compliance with nitrogen quotas.[296]
Safeguard zone action plans and Drinking Water Protected Areas	• High levels of nitrate are a concern in drinking water resources. In England, around 30% of drinking water sources are from groundwater and 70% from surface water. The surface and groundwater that supply more than 10m^3 per day of water for human consumption are identified as Drinking Water Protected Areas (450 surface and 271 groundwater).[297]

	• Where land use practices are most likely to be the cause of water quality deterioration non-statutory safeguard zones to act as a focus for pollution prevention and regulatory actions are established. Activities within safeguard zones could include CSF, environmental permits, pollution prevention advice and other voluntary initiatives along with water company led catchment schemes.[38] There are 148 surface water and 251 groundwater safeguard zones in England.[277,298]
River basin management plans and catchment schemes	• The Water Environment (Water Framework Directive) (England and Wales) Regulations 2017 require binding environmental objectives to be set for all waterbodies in 10 areas called 'River Basin Districts' in England, including achieving good ecological status (GES) by 2027.[299,300,301] Each river basin district has a river basin management plan (RBMP). This plan sets out how waters are managed, together with information about the river basin district in data tables and maps.[302] • The Catchment Based Approach is a community led approach across government, local authorities, water companies, landowners, wildlife and environmental NGOs, businesses and other stakeholders, which has established catchment partnerships 100+ WFDR river catchments across England and cross-border with Wales.[303] These deliver water environment targets through collaborative working on actions at the catchment scale, including the environmental objectives of RBMPs that require land management pollution reduction measures.[304] • Water companies can pay farmers for undertaking diffuse pollution control measures included in RBMPs. The EA has set out measures that could be included, such as: provision of adequate and appropriate manure and fertiliser storage; clean and dirty water separation in farm yards; reduction/control of stocking rates on livestock farms; cover crops and incorporation of crop residues into the soil; wetlands and riparian buffer strips.[29] However, they cannot pay for mitigation that should be undertaken as part of the agriculture sector's 'fair share' of nutrient pollution reductions.[97] See the House of Commons Library briefing on water quality in rivers, lakes and seas for further information.
Agri-environment schemes	• Relevant tiers of the Environmental Land Management Scheme include the Sustainable Farming Incentive (SFI), Countryside Stewardship Higher Tier (CSHT) and Landscape Recovery (LR). The first round of LR projects (large-scale, long-term management of land) aimed to recover threatened species and habitats, as well as improve water quality and biodiversity in streams and rivers.[38] • The SFI of the includes payments for actions for nutrient management,[305,306] such as nutrient management planning,[307] actions for buffer strips,[308] and actions for soils, such as soil testing, addressing risks to soils and winter cover crops.[309] See the House of Lords Library briefing on environmental land management: recent changes to the sustainable farming incentive and countryside stewardship schemes for further information. The SFI is being reviewed with redistribution of money towards smaller farms, capping large claims, and targeting funds for maximum environmental benefit being considered.[310,311]

	• A modelling project of the contributions of AES has suggested reductions in P pollution occurring on farms in schemes are an estimated 5% for CS and 9% for SFI, but could contribute more in future in some catchments.[222,29] • EA analysis suggests in almost all catchments, the 'fair share' reduction required by the rural land use diffuse sector is estimated to be several times greater than the reduction in losses achieved when applying current rural land management measures (both regulatory and AES).[92]
Grants, research and innovation projects	• The Farming Equipment and Technology fund provides a grant amount of 50% towards for slurry items, scored on whether they improve slurry management, their environmental benefits and level of industry adoption.[312] If manure is not stored well ammonia and nitrous oxide will be lost to the atmosphere reducing the N content, which will also be more variable when applied as a fertiliser.[313] Various practices can address this,[314,315] such as storage in slurry bags and using a slurry injector to apply to soil, reducing the need for subsequent inorganic fertiliser application and costs. The grant supports the uptake of 17 technologies including robotic slurry collectors, flow rate monitoring equipment and low emission slurry spreaders. • There is a Defra funded slurry separation research project, evaluating the agronomic and environmental impacts of digestate and slurry separation, including experimental field trials to inform best practice guidance.[316] • Research projects were funded around novel enhanced efficiency fertilisers and on the use of crop biostimulants (substances or microorganisms that enhance plant growth, nutrient use, and stress tolerance by stimulating natural processes).[317,318] • The low emissions farming thematic competition funded research on technologies and practices that contributes towards the sectors net zero target.[319] • The farming innovation programme providing research funding to farmers to develop innovative methods and technologies include a £15 million round in 2024 on nutrient management.[320]
Land Use Framework	• The government consulted on a land use framework in 2025, which is due to be published in January 2026. To meet environmental and climate targets, the framework proposes that the management of 1.6 million hectares of farming land changes or 19% of the agricultural area (the approximately 69% of England's land used for agriculture[321]). Of this 19%: – 1% changes such as planting along field margins – 4% incorporating more trees alongside food production – 5% repurposed for environmental benefits, while still producing food – 9% removed from agricultural production to make way for the creation of woodland and other natural habitats

	• Nutrient mitigation measures could be incorporated into this 9% as part of nature markets or credit schemes.[322] Responding to the consultation, the NFU raised concerns that taking 9% of the agricultural area out of production to meet nature recovery targets will affect levels of domestic food production (by comparison, solar farms occupy 12,953 ha of agricultural land or 0.08%).[cc,323,326]
Site Nitrogen Action Plans	• These are plans that identify and implement measures to reduce the negative impacts of atmospheric nitrogen deposition on sites protected by the habitats regulations and implement the atmospheric nitrogen theme plan.[327,328] • These include grants for woodland (buffer) creation, slurry store covers, incentives for reduced fertiliser input, innovative equipment for slurry management and managing ammonia emissions. A recent study suggests while the tree-belt absorbed ammonia, higher concentrations of ammonia closer to the poultry housing significantly altered soil chemistry and the variety of microbes found in the soil.[329]
The Environmental Targets (Water) (England) Regulations 2023	• Includes a target to reduce N, P and sediment pollution from agriculture into the water environment by at least 40% by 2038, compared to a 2018 baseline. Interim targets are for at least a 12% reduction by the end of 2030 and by at least 18% in catchments containing protected sites in unfavourable condition due to nutrient pollution.[223] • Defra estimate the annual nutrient loadings of N and P to agricultural soils in England to give an indication of the potential losses to the environment nationally.[330,331] These suggest a surplus of 86.3 kg/ha of N and 2.3 kg/ha of P.[332] A surplus arises as inputs (in fertilisers and manures) are greater than the nutrients removed through crop and fodder production, leading to an accumulation in soils.[29] The N surplus represented an increase of 5.5 kg/ha (+6.8%) compared to 2023, and a decrease of 18.2 kg/ha (-17.4%) compared to 2000. The P surplus represented an increase of 1.5 kg/ha (+191.9%) compared to 2023, and a decrease of 6.1 kg/ha (-72.2%) compared to 2000.[332] These are national averages and there will be large variations between catchments.[105] • Challenges around changing fertiliser practices are set out in a previous POSTnote.

[cc] The NFU query the assumed levels of increasing productivity (0.5%) on the remaining area, given the more recent flattening of output and increasing future pressures from climate change and disease outbreaks as well as the burden of increasing environmental regulation.[323] The All-Party Parliamentary Group on Science and Technology in Agriculture have called for an objective to increase domestic food production by 30% by 2050 while reducing UK agriculture's environmental footprint by 50%.[324,325]

3 Reducing nutrient pressures on protected areas

Under the nutrient neutrality concept, existing nutrient loads and the loads arising from new developments are both linked and separate problems.[120] Researchers state the approach does not reduce nutrient levels in watercourses against an already impacted baseline.[105,200,32] By comparison, Scotland does not have a nutrient neutrality policy, and aims to achieve broader water quality improvements through river basin management plans (table 5).[333,dd]

Studies suggest setting overall nutrient load caps for catchments and credit trading can drive reductions in loads.[21,336,105] However, reducing flows in nutrients at a catchment scale is challenging as interactions occur across water, soil, sediments and air, with a legacy of background sources:

- Deposition of N (as nitrate, ammonia and nitric acid) from air pollution to the ground affects protected areas, leading to declines in species of high conservation value and impacts on natural processes.[337]
- There is an accumulation of P in agricultural soils (legacy phosphorus[ee]); since the 1930s when P use became more widespread, over 1 tonne of legacy P has accumulated in every hectare of arable and productive grassland in the UK.[342,339]
- Nitrates deposited on soil that isn't taken up by biological organisms will migrate over time to groundwaters.[343] Concentrations in groundwaters are greatest in the drier, arable dominated southern and eastern areas of England. The EA says this legacy nitrate in groundwater can migrate through riverbeds or emerge at springs before entering rivers, but that evidence on how and where rivers are affected is limited.[38]
- There is also P accumulated in waterbody sediments, which can potentially be mobilised during storm driven high water flows or if the water contains lower levels of P than the sediments below it.[344,105,106]

[dd] Wales has seven river catchments subject to nutrient neutrality requirements (River Gwyrfai and Llyn Cwellyn, River Teifi, River Tywi, River Cleddau, River Dee & Bala Lake, River Usk and River Wye.[334,335]

[ee] Legacy or internal loads of nutrients (Box 1) are increasingly proposed as possible reasons for widespread failures to improve water quality, with wide-ranging time lags reported for nitrogen and phosphorous transport through catchments.[338] Researchers also argue managing the legacy phosphorus 'bank' could improve efficiency and reduce imports of phosphorus fertiliser. It can be harnessed via techniques such as use of cover crops.[339,340,341]

Understanding nutrient flows

Nutrient flow analyses can be conducted at different spatial scales, such as farm, catchment, national or international.[81,345,346,347] Studies at lower spatial scales are used to determine differences in nutrient loading,[348] such as livestock producing regions producing a nutrient surplus and crop producing regions with nutrient demand.[349] In England, much of the manure is produced in the west while most arable demand is in the east.[350]

The House of Lords Environment and Climate Change Committee recommended a simpler and more effective system to govern nitrogen management across sectors based on a national Nitrogen Strategy.[351,ff] This would involve developing an overview of England's N flows, sources and sink supported by budget to reduce emissions, similar to the Scottish Government's Nitrogen Balance Sheet (figure 2).[354,355,356]

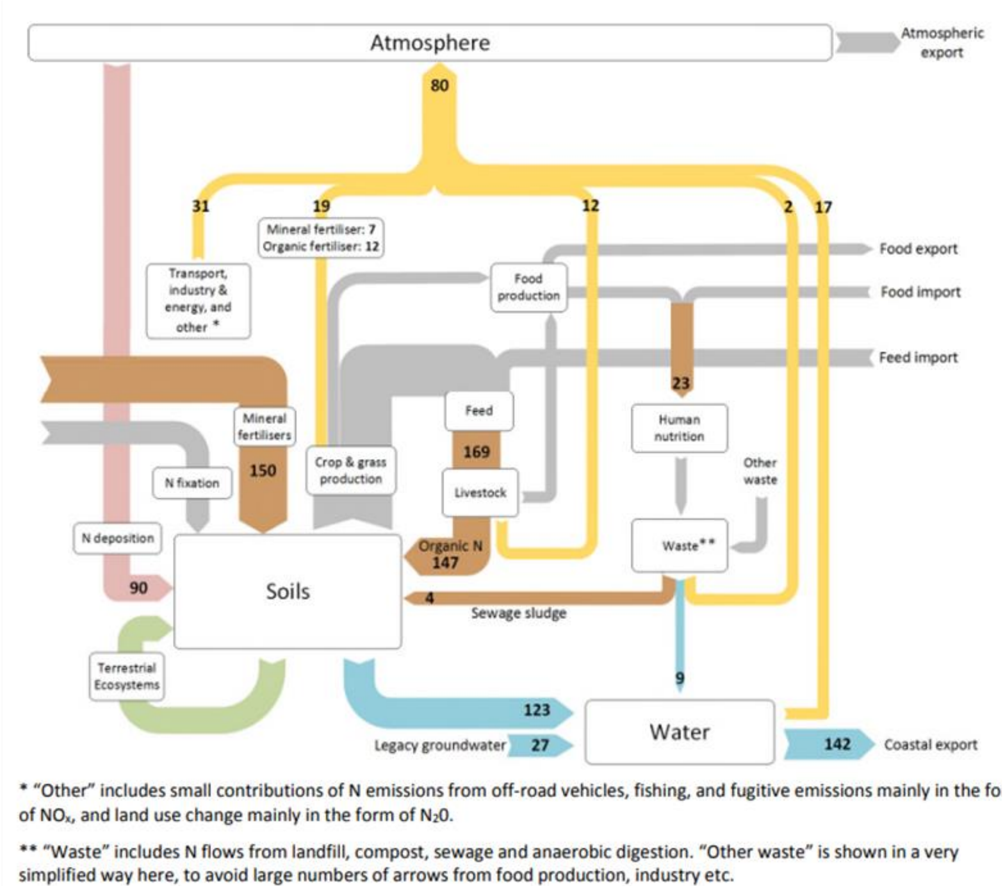
They also recommended the government implement a circular economy approach to nitrogen management.[gg] The EA says all sectors should adopt more source control, recovery and recycling of N and P,[38,29] and the NFU has called for an ambition to deliver the first circular nutrient catchment by 2030.[268]

Researchers have set out P flows through the UK food system (figure 3) and called for a national strategy.[339,369] Defra's Nutrient Management Expert Group also recommended a National Nutrient Management Strategy and an action plan to deliver it.[39,370]

[ff] NGOs also suggest nutrients flows could be progressively reduced in line with set national budgets.[352,353] The proposed House of Lords Environment and Climate Change Committee strategy incorporates government targets for climate, land, water, air quality and nature recovery and takes a cross-sectoral view of nitrogen management based on the balance sheet approach. This involves quantifying the major nutrient flows, sources and sinks (a balance sheet, figures 2 and 3) and the economic impacts of this pollution. This information is the basis for more effective and integrated planning, and to turn economic costs into benefits. This requires bringing together the existing sectoral targets, strategies and plans relating to nutrient pollution to reduce excessive use and wasteful surpluses.

[gg] A circular economy in nutrients aims minimise nutrient losses during the production, processing, distribution, and consumption of food and other products, improve resource efficiency, reduce environmental impacts from nutrient surpluses and enhance food system sustainability.[357,358,359,360,361,362] This involves: assessing and reducing the nutrients imported through materials such as fertilisers; minimising nutrient losses and increasing nutrient reuse by recycling them from waste streams, such as agriculture, sewage and urban, back into agriculture and developing the technologies to do this; and, nutrient budgeting and other mechanisms at the relevant scales, such as catchment,s to control nutrient loads.[363,364,365,366,367,368] It also involves, See POSTnote 702 Measuring sustainable environment-food system interactions for an explanation of food system sustainability

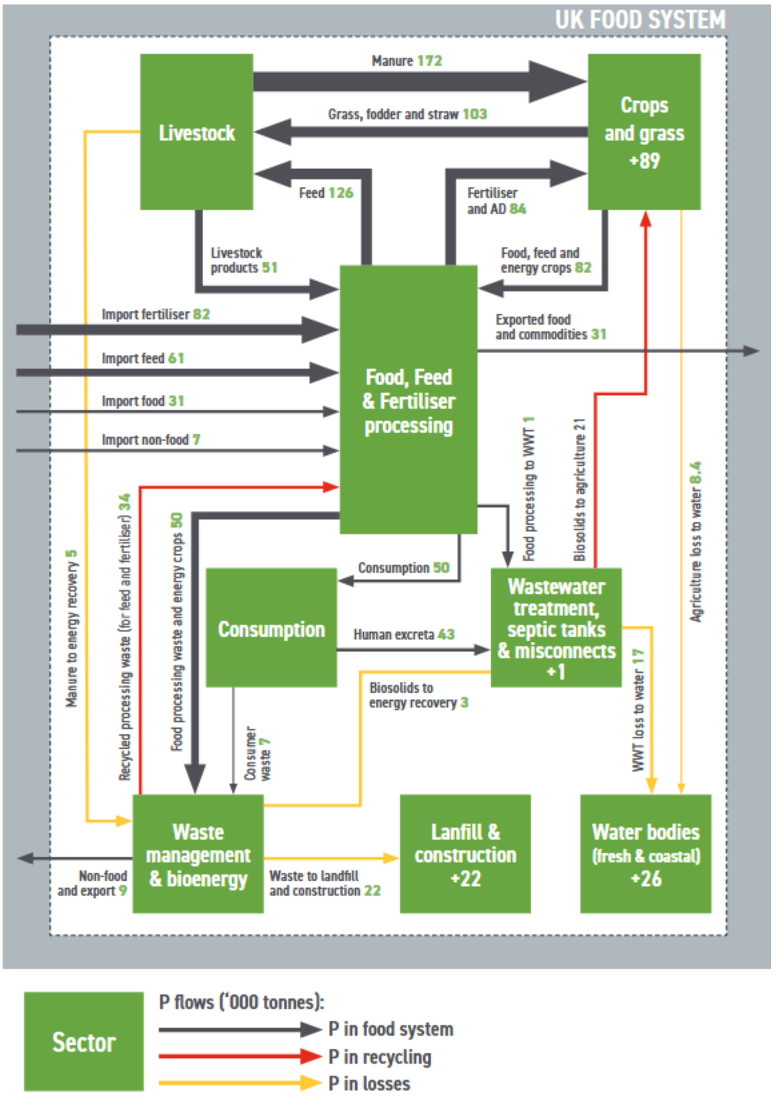
Figure 2: The Centre for Ecology's figure showing N flows for Scotland[hh]



Source: Scottish Government (2020) Scottish Nitrogen Balance Sheet: consultation[374]

hh (kt N yr^{-1}), combining inputs and outputs between the atmosphere, hydrosphere/soil, human production/consumption and import/export (using data from ca. 2010-2018). The arrows represent the flows of nitrogen, in a range of chemical forms, between different parts of the economy and the environment and give an overview of the complexity of the system at a national scale. For example, nitrogen used as a fertiliser has unintentional losses to the environment, such as emissions of greenhouse gases and air pollutants to the atmosphere, leaching and run-off to catchments and the coast. N.B. values may not add up due to rounding.[371,372,373]

Figure 3: The RePhoKUs project estimation of flows through the UK food system in 2018 in '000 tonnes of P.[ii]



Source: Cordell, D *et al.* (2022). UK Phosphorus Transformation Strategy (CC-BY 4.0) [339,375,376]

[ii] The RePhoKUs project found that less than half of the 174,000 tonnes of phosphorus imported into the UK each year is converted into food consumed domestically. The project set out a National Phosphorus Transformation Strategy for a circular management approach across the food system, regionally and within catchments.[339,375,376]

3.1 Environment delivery plans

A strategic mitigation approach can be adopted to meet the Habitats Regulations, implemented at the catchment scale for nutrient pollution. The Wildlife and Countryside Link suggested levies to fund nutrient mitigation strategically similar to existing schemes for European sites.[377,jj]

While supporting strategic approaches, the Wildlife Trusts query why further legislation is required to enact this concept as 'environmental delivery plans' (EDPs).[379] Part 3 of the Planning and Infrastructure Bill grants powers for NE to implement EDPs with levies paid into a Nature Restoration Fund (NRF).

Where an EDP is in place and a developer pays the NRF levies, they would no longer be required to undertake assessments of impacts or deliver project-specific mitigations. NE will produce EDPs on one or more environmental impacts of development for specific geographic areas.[kk,381] Nutrient pollution EDPs are likely to be based on the same measures in existing schemes (table 3) implemented upstream of protected areas.

NGOs have suggested the bill is a regression of environmental legislation and called for safeguards for EDPs.[ll] The Home Builders Federation (HBF) raise concerns about the development sector being the sole contributor, and the NFU about NE compulsory purchase powers (table 6).

Researchers raise concerns that the evidence base for scaling up NbS (table 6) to reduce pollution at the catchment scale is less certain, as there are factors that may cause variability in performance, such as climate change.[101] Excluding downstream marine NbS nutrient removal, including shellfish and

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[jj] For example, the Thames Basin Heaths Mitigation Strategy is a planning policy designed to prevent the impacts of new developments on the Thames Basin Heaths Special Protection Area (SPA). Mitigation measures are primarily through the provision of Suitable Alternative Natural Greenspace (SANGs), which redirect public access away from the SPA, protecting the habitat of vulnerable breeding birds like the Dartford Warbler, Nightjar, and Woodlark.[378]

[kk] EDPs will set out: the environmental feature the EDP seeks to protect (a protected feature of a protected site, or a protected species); the impacts the EDP seeks to address (including information on the type and amount of development that can benefit from the EDP's cover); and the conservation measures to be taken, both to address those impacts and contribute to nature restoration. It should clearly set out if conservation measures are to be delivered locally or at the broader network scale; the amount payable by development to cover the costs of these conservation measures and the environmental obligations that are disapplied once the developer pays the levy. While EDPs will usually be voluntary, there may be circumstances where use of an EDP may be mandatory - once an EDP is developed there will be a six week consultation period.[380] See the House of Commons Library's Research Briefing on Planning and Infrastructure Bill 2024-25: Progress of the bill for more information.

[ll] The Wildlife and Countryside Link state safeguards should include: exclusion of irreplaceable Habitats and unsuitable sites; stronger legal tests and delivery standards; evidence-Based decision making; independent oversight and accountability; consultation and transparency; financial safeguards for the NRL; and for Nature-Positive Development and alignment with Environmental Targets.[382]

seaweed aquaculture in estuary and coastal waters, is also questioned in the context of holistically managing catchment nutrient flows (table 6).[mm,393,394]

Tailoring nutrient pollution mitigation to catchments

Researchers and practitioners state if EDPs are to be successful, measures need to be tailored to specific catchments and affected protected areas, including physical and natural features and pollution sources.[175,120,105,106,252] For example, the Somerset Levels and Moors Catchment includes protected areas of low-lying fields and meadows with peatland soils, typically near sea level, separated by narrow water-filled ditches pumped into tidal rivers.

The levels of total P in ditches exceed the levels of 0.1 mg L^{-1}, which are in 'unfavourable declining condition',[395] with eutrophic conditions causing algal and duckweed blooms.[396] Nutrient levels vary with water level management, surrounding land use and seasonal cycles,[397,398,399] with the mobility and supply of nutrients controlled by groundwater and stores of P within ditch sediments and the peatlands.

Mitigation requires removing P from the system, both by reducing ongoing P pollution from wastewater and agricultural sources and removing legacy P from peat and sediments. For example, measures such as restoring peatlands with raised water levels and removal of nutrients through wetland cropping (referred to as paludiculture).[395,nn]

Mitigation to protect what?

European sites are designated to protect different species and habitats, but the measures required to address nutrient pollution impacts will vary:

- Desmoulin's whorl snail (*Vertigo moulinsiana*), is a rare species restricted to calcareous wetlands, with the only known viable European populations in the UK and Ireland.[400] This is one of the species for which several SACs were designated.[401] Excess nutrients result in changes to vegetation that are detrimental,[402,403,404,405] but the reductions needed to achieve favourable conservation status are uncertain.[oo,100]

[mm] For example, the Chesapeake Bay Nutrient Trading Program aims to achieve total maximum daily load targets under the Clean Water Act, with credits generated for the removal of pollutants from the Chesapeake and its tributaries, including by oyster reefs.[383,384,385,386,387] After 40 years, major improvements in water quality have been achieved.[388,389,390] Studies show shellfish and seaweed farming could be used to restore water quality in the Baltic.[391,392]

[nn] Other measures being discussed include dredging and removal of ditch sediments, removal of topsoil with high P levels, changing in-ditch management to remove plant material more frequently (such as duckweed), changing grazing regimes and using wetlands at water inflow points to remove nutrients.[252]

[oo] Favourable conservation status in the EU is determined by Article 17 reporting, which assesses the species' population size, range, habitat structure, and trends. The Overall assessment of conservation status for Desmoulin's whorl snail is unfavourable-bad and the habitat quality is considered inadequate for the long-term survival of the species.[406]

- The River Ehen SAC supports the largest population of freshwater pearl mussel (*Margaritifera margaritifera*) in England,[407] where the main cause of decline is smothering by sediment that also contains a high level of phosphorus.[175] Addressing this requires understanding what levels of rainfall will drive sediment load, at what flow velocity and what measures on agricultural land may mitigate this.[408,409,410]

3.2 Nature markets

Nature markets may provide opportunities for NbS providers to sell the benefits they generate,[pp,412,413] such as to water companies seeking drinking water treatment cost reductions.[414] Water regulator Ofwat's Innovation Fund also included a programme to integrate NbS into standard water management practice.[415,416]

The British Standards Institution (BSI) is establishing standards to ensure the integrity of UK nature markets and address barriers to investment.[417,418] BSI Flex 704 'Nature markets, Supply of nature-based nutrient benefits' sets out requirements for quantifying nutrient reductions and removals from water resources when trading and tracking of credits issued for NbS.[qq,419]

The Royal Society have stated that while greater private sector investment in nature conservation may be secured by environmental markets, there is limited evidence to quantify the impact of nutrient mitigation measures (Table 6).[420]

[pp] Nature markets are also known as natural capital markets, environmental markets, or ecosystem service markets.[411] They privately fund environmental restoration by paying for the benefits (ecosystem services) that nature provides, such as carbon capture, clean water, or biodiversity This is often through selling credits that quantify the benefits, such as biodiversity net gain units to businesses needing to meet environmental goals.

[qq] However, constructed wetlands that make use of artificial materials, such as reactive media to enhance nutrient removal, are excluded from nature markets even if they provide other benefits such as biodiversity provision.

Table 6: Key challenges for reducing the impacts of nutrient pollution on protected areas

A holistic approach	• Researchers state the need for a holistic approach to avoid trade-offs with other environmental objectives.[421,422,200,201] For example, if a mitigation measure to reduce nutrient pollution of water increases emissions affecting air quality or climate change.[422,121] • They suggest that relying on mitigation measures alone would allow inefficient use of nutrients to continue elsewhere in the catchment. Resolving nutrient imbalance and loss requires a catchment-scale approach and relevant environmental indicators to track progress at that scale, such as nutrient surpluses.[106,105] • Spatially explicit nutrient budgets can be set at relevant scales if the land uses, soil and habitat types are known, but there are uncertainties relating to legacy nutrient pollution sources.[106,105,32]
Ensuring gains from EDPs	• The Wildlife Trusts called for amendments to the Infrastructure and Planning Bill including: Strengthening the overall improvement test so EDPs deliver gains for nature; ensuring development continues to apply the principle of avoid harm to nature first by embedding the mitigation hierarchy in EDPs; embedding scientific evidence into the development of EDPs; requiring EDPs to be clear on the timeline, securing measures to address impact upfront were possible.[423] • 32 environmental NGOs called for amendments to strengthen the overall improvement test, which required EDP measures to be "likely" to deliver benefits. For more information see House of Lords Library, Impact of government policies on biodiversity and the countryside. • Government amendments at committee stage in the House of Lords, included: – specifying that using measures to improve nature offsite rather than onsite could only be taken if Natural England judged they would be more effective than onsite measures – requiring EDPs to specify the order in which measures would be taken – requiring EDPs to have backup measures – requiring EDPs to state how Natural England thinks the measures would pass the 'overall improvement test' – requiring Natural England to have regard to scientific evidence when drawing up EDPs

	– strengthening the overall improvement test – requiring Natural England to provide more detail in its reports and to consult on changes – allowing the secretary of state to take action when an EDP is judged to have failed
EDP mitigation measures	• Practitioners suggest EDPs and NRF should be piloted first in catchments without a sufficient supply of nutrient credits, with the current mitigation system maintained and supported.[136] • The EDPs will implement simpler mitigation measures, such as taking land out of production, which align with other nature restoration fund priorities at the catchment scale. Measures with a high certainty for nutrient quantity removal will also be included, such as package treatment plants upgrades. Measures will be implemented upstream of protected areas.[424] • Researchers and practitioners argue a more flexible approach to measures and their location will be needed for differing catchments to improve the condition of protected areas.[252,120,100] • Researchers also suggest trade-offs between land use benefits should be taken account when selecting nutrient mitigation measures. For example, wetland cropping (paludiculture) could support food or fibre production and remove nutrients from the system,[425] whereas taking land out of production may be at odds with food security. • Practitioners also suggest EDPs will need to use existing local delivery partners if development is to be accelerated, and that larger initial investment will be required compared to existing local nutrient credit schemes.[173] • The NFU raise concerns about how EDPs will affect farming businesses in areas with excess levels of nutrients, the compulsory purchase powers given to NE and engagement with farming and local communities in the development of EDPs.[176] • The Wildlife and Countryside link state the EDP consultation period of 28 working days is too short and should be extended to 60 days to allow for thorough public and expert input.[382] • NE will be required to publish reports on an EDP at the halfway and end points.[380] The HBF suggest updated annual reports should be published setting out progress on water quality.[13]
Limitations of current modelling and monitoring approaches	• The Source Apportionment-GIS (SAGIS) Tool is a national scale apportionment model giving rise to uncertainties when adjusting the model to the catchment scale, particularly for diffuse agricultural sources and for small catchments.[105,106,32,252] Researchers raise concerns the model may suggest water quality is better than it

	is.[100,101] In larger catchments beyond a certain point, the 'connection' will also be lost with spatial pollution sources.[32] • The Farm Scale Optimisation of Pollutant Emission Reductions (FARMSCOPER) model is used to assess the cost and effectiveness of agricultural mitigation methods for multiple pollutants, such as wetlands, winter cover crops and riparian buffer strips (table 3 and 4).[426,427,428,429,430] The EA used FARMSCOPER v5 to assess diffuse agricultural pollutant loads and quantify the impacts of farm mitigation methods across ten scenarios to inform the Diffuse Water Pollution Plans, including those covering nutrient neutrality catchments.[92] • The EA acknowledges that FARMSCOPER is now being used for a wider range of purposes than it was originally intended for, giving rise to uncertainties and limitations in outputs that should be considered in decision-making.[92] Practitioners also state this model lacks the accuracy in prediction required to determine the level of agricultural mitigation measures required for a development.[120,100] • Researchers suggest as monitoring resources are limited, intensive monitoring undertaken in demonstration sites could provide detailed information to validate mitigation measures,[422] such as NbS effectiveness in different catchment contexts and conditions.[101]
Allocation of costs	• The nutrient neutrality approach regulates just one pollution source (new housing) at a local scale, risking leakage of emissions to catchments that are not subject to nutrient neutrality. Researchers suggest different choices could be made about distributing regulatory costs, such as a cap-and-trade quota system allocating costs to all emitters.[15] • Researchers raise concerns about the efficiency of paying polluters for mitigation measures.[15] The EA has withdrawn a pilot mechanism allowing water companies to offset wastewater reduction requirements by funding catchment wide reductions of agricultural emissions.[431] The trial could not establish whether the water companies' regulatory requirements could be separated from nutrient neutrality requirements.[rr] • The NFU raise concerns if NbS are used to abate agricultural emissions but are paid for by another sector, does this count towards the agricultural sector emissions target (table 5) or those of the sector that paid.

[rr] Catchment nutrient balancing (CNB) trialled in AMP7, which allowed water companies to offset the nutrient (mainly phosphorus) reduction requirements specified in their sewage works permits, by funding farmers to implement catchment measures to mitigate diffuse nutrient pollution while delivering other benefits, such as biodiversity.[432] A pilot study showed catchment wide water quality improvements,[433,434] but the EA stated there is a lack of evidence to support its use as a regulatory tool and that "both the water and farming industries need to adopt all the measures they can and clear up their own pollution".[431]

	• Payment of a levy to the nature restoration fund removes the requirement for developers to negotiate with local authorities over mitigation and provides certainty.[13] Current legal arrangements are a cost for developers, such as legal fees upfront for section 106 legal agreements with LPAs.[14] • EDPs will engage existing credit providers rather than attempting to engage widest pool of possible providers for nutrient mitigation measures to drive cost efficiency.[14]
NbS evidence base	• Studies of projects show measures such as constructed wetlands can remove nutrients at the field scale, but evidence for scaling up to reduce nutrient pollution at the catchment scale is less certain. For example, the nutrient pollution from the tributaries and streams of the Thames accounts for only about 66% of the nutrient load. This disconnection creates uncertainties about the extent of upstream mitigation measures required.[32] • Some researchers suggest strategic criteria for and targeting of NbS are needed,[252] such as constructed wetlands treating river inflows into the sites.[121] Other researchers and practitioners suggest that specific NbS types are sufficiently mature to enable selection of interventions and deployment at catchment scale. [121,435] • Studies show reactive media in constructed wetlands can be optimised through modifications, such as the contact time between the media and the water, providing more predictability about the amount of nutrients trapped by the system. However, practitioners suggest while optimal for nutrient removal these engineered systems provide less benefits for biodiversity.[120,121] • NE state some reactive media involves a coating to bond the nutrient, noting that the environmental risks posed by these bonding agents in the resulting discharge needs to be considered. However, researchers state regulators can impede the development of NbS effectiveness. For example, an instream approach developed by researchers at Harper Adams found it challenging to gain permission from the EA and LPA, with data on effectiveness required before a trail could be conducted.[200] • Some researchers suggest wetlands do not deliver P removal equivalent to levels achieved through engineered P-stripping methods,[436] that cannot be explained simply.[201,237] • There are gaps in the NbS evidence base for the factors causing variability in performance, such as catchment land use, soil type and different climate scenarios. This data would increase the certainty for modelling, such as if a wetland of this size and type was created within that field it would remove a set volume of nutrients.[106,105]
Landowner ability/willingness to	• The NFU state landowners’ decisions on credit provision are based on what is economically required and viable. For example, if farmers

undertake mitigation measures	start to provide offsets and credits, how will this affect their other obligations and commitments within supply chains?[176] • The NFU suggest the existing farming rules for water and nitrate vulnerable zone regulations are complex for farmers to navigate. Further changes require developing a positive narrative and messaging, such as the benefits of nutrient management. planning and growing crops appropriate to soil types.[176] • The NFU state a low willingness to invest in the farming sector, and that capital grants are needed to address initial financing.[437] To access grants, planning permission needs to be gained in advance, but when planning applications are made, such as to improve slurry infrastructure, no account is taken of emissions prior to the application and if they will decrease.[176] • Researchers and practitioners suggest nutrient mitigation knowledge has not been exchanged effectively with farmers.[100,422] The NFU state as access to capital grants is limited to those able to access catchment sensitive faming advice, and the limited scheme capacity acts as a regulatory barrier to improvements.[176]
Enforcement	• Local authority trading schemes use legal agreements (section 106 requirements) to enforce management requirements of mitigation measures. There is no stated mechanism for how this will be continued under EDPs. While taking land out of production is straightforward to enforce, other measures such as annual servicing certification of package treatment plants septic upgrades may require funding. • The EDP will set out how its interventions will be monitored. The NFU raise concerns about whether NE will have the administrative capacity and resources to create, monitor, and deliver the EDPs.
Tailoring to the specific catchment conditions	• Researchers state the need to determine the nutrient pollution baseline or threshold above which impacts on a given river catchment and protected area occurs. This should inform the levels of mitigation, with more mitigation required in more impacted catchments. For example, a catchment may have low sensitivity to nutrient loads, but have receptor sites, such as coastal waters, that are sensitive.[422,252,120,175,105] • Without an effective baseline for a given catchment, researchers state it is difficult to undertake delivery monitoring to determine the effectiveness of interventions. At least a year's data is needed for an effective baseline, to allow for seasonal variation.[252] For instance, a nutrient load may occur during a sensitive seasonal timeframe for a catchment and the efficacy of NbS is weather dependent.[100] • Current climate variability means that many recent years tend to be atypical, either the driest year, wettest year, coldest year or hottest year.[252,438,439] In catchments dominated by point source sewage effluent pollution, low flows in dry years will be when nutrient levels

	concentrations are highest. In those dominated by diffuse agricultural sources, nutrient pollution may be highest during high flows resulting from extreme rainfall events and high surface run-off,[105] particularly after low rainfall periods.[100] • Researchers suggest if impacts are to be mitigated, diffuse nutrient pollution sources need to be characterised accurately at the catchment level. For example, soil erosion and surface run-off alongside agricultural fertiliser and manure use can be locally important, particularly at sub-catchment level and below.[105,106] The evidence base to do this is not yet in place for different catchments and SACs.[100]
Time taken to deliver improvements	• The right endpoint for the river requires a long-term improvement in water quality at the catchment scale.[105,106] Evidence from studies suggests reducing nutrient inputs to watercourses takes three or four decades to improve water quality because of legacy nutrient sources.[32]
Integrating with a circular nutrient economy	• Any intervention that comes in contact or is generated through contact with sewage increases risks of microplastic and other pollutant contamination if the resulting sludge/compost/biosolid is applied to land.[440,441,442] Defra are currently considering regulatory changes on sludge application.[223] • As a result, constructed wetlands used for nutrient capture can also be contaminated with microplastics and heavy metals.[421,201] Marine NbS, such as seaweed farming or coastal marshes, could be used to capture nutrients, but can also be contaminated.[443,444,445,446] • Adoption of circular nutrient technologies and practices, which recover, reuse, and recycle nutrients from agricultural and wastewater.[447,448,449,450,451,452] For example, livestock manures can be processed into concentrated forms, such as pellets, with Defra funding ongoing research projects.[453,454,455] The NFU raise concerns that the measures needed for knowledge exchange to facilitate farmer adoption are insufficiently evidenced.[176] • Research has suggested that pyrolysis of sewage sludge into biochar can reduce waste volume while retaining nutrients and remove contaminants such as pathogens and pharmaceutical residues.[456] For example, livestock sludge pyrolysis is used for energy generation and to create biochar in Denmark, as a means of agricultural carbon capture. • However, heavy metal contamination is not removed by pyrolysis and while application of biochar to fields can improve soils and crop productivity,[457,458] it also absorbs pesticides, reducing their effectiveness.[459,460,461] Innovate UK are funding a project on the use of biochar to capture phosphorus and nitrogen from both soil and water and reapplying the biochar as a nutrient source.[462]

Nature markets	• The Environmental Audit Committee have also raised concerns that state-run nature restoration funds for EDPs could create uncertainty in nature markets affecting private investment.[463] The government's Water Restoration Fund has also previously used water company fines to fund projects to reduce nutrient pollution.[464] • Practitioners state the need for policy certainty for private investment and persuading landowners to undertake measures,[136] but nature markets interaction with EDPs have yet to be clarified. • The NFU raise concerns about the ease with which landowners providing nutrient credits can combine this with other revenue streams such as biodiversity net gain unit (BNG) provision. Defra have published guidance on combining biodiversity net gain (BNG) and nutrient mitigation to encourage 'stacking' of environmental payments on the same area of land.[465] Private payments for environmental benefits can also be combined with public payments, such as ELMS payments.[466] • The HBF also raise concerns about negotiating synergies and conflicts;[13] for instance, if an NbS is combined with BNG provision, it is unlikely to be compatible for use as a Suitable Alternative Natural Greenspace (SANG), given recreational use conflicts. They suggest there are conflicting government policies and objectives with no overarching direction. • The NFU recognise the potential of nature markets for providing a diversified source of income for agricultural businesses but have suggested five principles for ensuring the attractiveness to farmers: nature markets must work alongside domestic production of food, energy and fibre; public policy and government initiatives must support the development of private markets; markets require clear rules and standards to allow farmers and buyers to participate with confidence; markets should be accessible across a range of farm sizes, tenures and business structures; and farmers must be fairly rewarded for the delivery of environmental goods.[467] • The tax treatment of land in environmental markets has yet to be addressed, which was the subject of a 2023 Treasury consultation.[468]

References

1. Wentworth, J. *et al.* (2025). The future of fertiliser use.
2. Jwaideh, M. A. A. *et al.* (2022). Global impacts of nitrogen and phosphorus fertiliser use for major crops on aquatic biodiversity. *Int. J. Life Cycle Assess.*, Vol 27, 1058–1080.
3. Tiwari, A. K. *et al.* (2022). Chapter 11 - Nutrients contamination and eutrophication in the river ecosystem. in *Ecological Significance of River Ecosystems*. (eds Madhav, S. et al.) 203–216. Elsevier.
4. Banerjee, P. *et al.* (2023). A critical review on the effect of nitrate pollution in aquatic invertebrates and fish. *Water. Air. Soil Pollut.*, Vol 234, 333.
5. Grizzetti, B. *et al.* (2021). How EU policies could reduce nutrient pollution in European inland and coastal waters. *Glob. Environ. Change*, Vol 69, 102281.
6. Racine, P. *et al.* (2021). A case for seaweed aquaculture inclusion in U.S. nutrient pollution management. *Mar. Policy*, Vol 129, 104506.
7. England, N. Natural England Water Quality and Nutrient Neutrality Advice (16 March 2022) - NE785. *Natural England - Access to Evidence*.
8. Participation, E. The Conservation of Habitats and Species Regulations 2017. Statute Law Database.
9. Habitats Regulations advice for LPAs | Local Government Association.
10. Habitats Regulations advice for LPAs | Local Government Association.
11. What is 'nutrient neutrality' and why is it stalling thousands of projects?
12. England, N. Nutrient Neutrality and Mitigation: A summary guide and frequently asked questions - NE776. *Natural England - Access to Evidence*.
13. Rachel Danemann and James Stevens Personal Comment.
14. The Lord Fuller OBE Personal Comment.
15. Dr Niclas Moneke and Dr Jan David Bakker Personal Comment.
16. House of Lords - The impact of environmental regulations on development - Built Environment Committee.
17. Scott, E. (2024). Built Environment Committee report: Impact of environmental regulations on development.
18. Bakker, J. D. *et al.* Combatting nutrient pollution through the housing market.
19. Pannard, A. *et al.* (2024). Why are there so many definitions of eutrophication? *Ecol. Monogr.*, Vol 94, e1616.
20. (2008). Council Directive of 12 December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources (91/676/EEC).
21. Lu, J. *et al.* (2023). Scientific challenges and biophysical knowledge gaps for implementing nutrient offset projects. *J. Environ. Manage.*, Vol 339, 117902.

22. Shaw, P. J. *et al.* (2021). The fractionation of phosphorus in UK chalk stream surface waters and its relevance to the regulation and management of water quality. *J. Environ. Manage.*, Vol 289, 112555.
23. Environment, U. N. (2017). Nutrient management: the issue | UNEP - UN Environment Programme.
24. Sandström, V. *et al.* (2023). Disparate history of transgressing planetary boundaries for nutrients. *Glob. Environ. Change*, Vol 78, 102628.
25. Rockström, J. *et al.* (2024). Planetary Boundaries guide humanity's future on Earth. *Nat. Rev. Earth Environ.*, Vol 5, 773–788. Nature Publishing Group.
26. Rose, K. C. *et al.* (2024). Aquatic deoxygenation as a planetary boundary and key regulator of Earth system stability. *Nat. Ecol. Evol.*, Vol 8, 1400–1406. Nature Publishing Group.
27. Getzzg (2024). How to improve planetary health: Devising the 'Planetary Health Approach' from the biogeochemical flow perspectives. *JOGH*.
28. UK Technical Advisory Group on the Water Framework Directive (2013). Updated recommendations on phosphorus standards for rivers river basin management (2015-2021).
29. Environment Agency (2025). Phosphorus and freshwater eutrophication: challenges for the water environment.
30. Mike Bowes (CEH), Matt Charlton (Environment Agency), Mike Hutchins (CEH), Nuria Bachiller-Jareno (CEH), Harriet Orr (Environment Agency) (2019). Climate change and eutrophication risk thresholds in English rivers. Environment Agency.
31. Nikolaidis, N. P. *et al.* (2025). Comparison of eutrophication assessment for the Nitrates and Water Framework Directives: Impacts and opportunities for streamlined approaches. *Ecol. Indic.*, Vol 177, 113375.
32. Professor Fred Worrall Personal comment.
33. Ockenden, M. C. *et al.* (2017). Major agricultural changes required to mitigate phosphorus losses under climate change. *Nat. Commun.*, Vol 8, 161. Nature Publishing Group.
34. Jarvie, H. P. *et al.* (2025). A 150-year river water quality record shows reductions in phosphorus loads but not in algal growth potential. *Commun. Earth Environ.*, Vol 6, 1–9. Nature Publishing Group.
35. Blake, E. *et al.* (2025). Urban outdoor air quality.
36. England, N. NECR538 Evidence Base Development for Nature-Based Nutrient Mitigation Solutions – Literature Review - NECR538. *Natural England - Access to Evidence*.
37. Ammonia | National Atmospheric Emissions Inventory.
38. Environment Agency (2025). Nitrates: challenges for the water environment.
39. Report of the Nutrient Management Expert Group: Improving policy and practice for agricultural nutrient use and management.
40. Goddard, R. *et al.* (2020). Physico-chemical factors controlling the speciation of phosphorus in English and Welsh rivers. *Environ. Sci. Process. Impacts*, Vol 22, 1688–1697. The Royal Society of Chemistry.
41. Chen, M. *et al.* (2024). Long-term responses of internal environment dynamics in a freshwater lake to variations in external nutrient inputs: A model simulation approach. *Sci. Total Environ.*, Vol 951, 175514.

42. Kowalczewska-Madura, K. *et al.* (2022). The Assessment of External and Internal Nutrient Loading as a Basis for Lake Management. *Water*, Vol 14, 2844. Multidisciplinary Digital Publishing Institute.
43. Ricardo *et al.* (2022). Nutrient Neutrality Generic Methodology.
44. (2025). Nature-based Solutions | IUCN.
45. Mainstreaming Naturebased Solutions (MNbS) project Categorisation of NbS intervention types.
46. Chappell, N. A. *et al.* (2024). Nature-based solutions for effective flood mitigation: potential design criteria. *Environ. Res. Lett.*, Vol 19, 074006. IOP Publishing.
47. Programme, U. N. E. (2023). Nature-based Infrastructure: How natural infrastructure solutions can address sustainable development challenges and the triple planetary crisis. United Nations Environment Programme.
48. What is NBI? *Nature-Based Infrastructure Global Resource Centre*.
49. (2023). Habitats regulations assessments: protecting a European site. *GOV.UK*.
50. (2022). The easy guide to the Dutch nitrogen crisis, farmers' protests, and more. *https://dutchreview.com/*.
51. (2023). Protecting nature, destroying lives: The chemist vs. the Dutch farmers. *POLITICO*.
52. (2025). Do Hague Judges Provide a Breakthrough in the Netherlands Nitrogen Crisis.
53. (2025). Dutch government ordered to cut nitrogen pollution — or face €10M fine. *POLITICO*.
54. Taskforce calls for radical reset of nuclear regulation in UK. *GOV.UK*.
55. Reeves, J. (2025). Nuclear Regulatory Review 2025: Major Gaps in Understanding of Environmental Law and Ecology. *CIEEM*.
56. (2025). Nightmare before Christmas: worst environmental regression in decades looms | The Wildlife Trusts.
57. (2024). Sites of special scientific interest: managing your land. *GOV.UK*.
58. Appropriate assessment. *GOV.UK*.
59. (2025). Nationally Significant Infrastructure Projects: Advice on Habitats Regulations Assessments. *GOV.UK*.
60. House of Lords - Nitrogen: time to reduce, recycle, reuse - Environment and Climate Change Committee.
61. Priorities for water sector reform.
62. Water quality in rivers - Environmental Audit Committee.
63. House of Lords - The affluent and the effluent: cleaning up failures in water and sewage regulation - Industry and Regulators Committee.
64. Newson, N. (2024). River pollution and the regulation of private water companies.
65. State of the water environment indicator B3: supporting evidence. *GOV.UK*.
66. What is the WFD?
67. Alliance, G. (2025). Progress since Brexit on the water environment » Green Alliance. *Green Alliance*.
68. B3: State of the water environment.
69. Environmental Improvement Plan (EIP) 2025. *GOV.UK*.
70. (2025). Independent Water Commission: Summary Report.
71. Challenges data for England | Catchment Data Explorer.

72. Albini, D. *et al.* (2023). The combined effects of treated sewage discharge and land use on rivers. *Glob. Change Biol.*, Vol 29, 6415–6422.
73. Office of Environmental Protection. (2024). *Review of Implementation of the Water Framework Directive Regulations and River Basin Management Planning in England*.
74. (2022). Phosphorus: challenges for the water environment. *GOV.UK*.
75. B1: Pollution loads entering waters.
76. State of the water environment: long-term trends in river quality in England: 2024. *GOV.UK*.
77. Jarvie, H. P. *et al.* (2025). A 150-year river water quality record shows reductions in phosphorus loads but not in algal growth potential. *Commun. Earth Environ.*, Vol 6, 62. Nature Publishing Group.
78. Hou, E. *et al.* (2020). Global meta-analysis shows pervasive phosphorus limitation of aboveground plant production in natural terrestrial ecosystems. *Nat. Commun.*, Vol 11, 637. Nature Publishing Group.
79. Blomqvist, S. *et al.* (2004). Why the limiting nutrient differs between temperate coastal seas and freshwater lakes: A matter of salt. *Limnol. Oceanogr.*, Vol 49, 2236–2241.
80. Jarvie, H. P. *et al.* (2018). Phosphorus and nitrogen limitation and impairment of headwater streams relative to rivers in Great Britain: A national perspective on eutrophication. *Sci. Total Environ.*, Vol 621, 849–862.
81. Maberly, S. C. *et al.* (2020). Nitrogen and phosphorus limitation and the management of small productive lakes. *Inland Waters*, Vol 10, 159–172. Taylor & Francis.
82. Howarth, R. W. *et al.* (2021). Role of external inputs of nutrients to aquatic ecosystems in determining prevalence of nitrogen vs. phosphorus limitation of net primary productivity. *Biogeochemistry*, Vol 154, 293–306.
83. Devlin, M. J. *et al.* (2025). Shifting sands of marine eutrophication assessments: building a future approach for UK marine waters. *Front. Ocean Sustain.*, Vol 3, Frontiers.
84. B3: State of the water environment.
85. Chief Scientist's Group. (2023). State of the environment - the coastal and marine environment.
86. ODIMS - Submission: IA2017 Eutrophication status in areas assessed in Arctic Waters, the Greater North Sea, Celtic Seas, and the Bay of Biscay, 2006–2014.
87. UK Progress on Reducing Nitrate Pollution - Environmental Audit Committee - House of Commons.
88. Water Framework Directive – United Kingdom Technical Advisory Group (WFD-UKTAG) UKTAG Environmental Standards Lake Nitrogen. Water Framework Directive – United Kingdom Technical Advisory Group (WFD-UKTAG).
89. committees.parliament.uk/oralevidence/15397/html/.
90. (2025). Nitrates: challenges for the water environment. *GOV.UK*.
91. Greene, S. *et al.* (2015). A geospatial framework to support integrated biogeochemical modelling in the United Kingdom. *Environ. Model. Softw.*, Vol 68, 219–232.
92. Indicative catchment statistics for nutrient pollution: executive summary. *GOV.UK*.

93. committees.parliament.uk/oralevidence/16410/html/.
94. Crabtree, B. *et al.* (2006). Monitoring pollutants in highway runoff. *Water Environ. J.*, Vol 20, 287–294.
95. Withers, P. J. A. *et al.* (2024). Managing phosphorus input pressures for improving water quality at the catchment scale. *J. Environ. Manage.*, Vol 370, 122792.
96. River basin management plans, updated 2022: summary programmes of measures – mechanisms - 7. Diffuse source pollution - Guidance - GOV.UK.
97. Environment Agency (2017). PR19 Fair Share principles paper: Outlining the key aspects of the approach.
98. Strategic Monitoring Review.
99. Natural Resources Wales (2022). SAGIS Non-Technical Calibration Report for the Afon Teifi.
100. Sarah Belton Personal comment.
101. Dr Nick Chappell Personal Comment.
102. Centre, E. I. D. (2025). Source apportionment of nutrient contributions to rivers in England and Wales modelled with SAGIS.
103. SAGIS modelling water quality in rivers and lakes. *https://sagis.ukwir.org*.
104. Indicative catchment statistics for nutrient pollution: executive summary. *GOV.UK*.
105. Professor Paul Withers Personal Comment.
106. Dr Ben Surridge Personal Comment.
107. Howden, N. J. K. *et al.* (2011). Nitrate pollution in intensively farmed regions: What are the prospects for sustaining high-quality groundwater? *Water Resour. Res.*, Vol 47,
108. Nutrient Neutrality Wye and Lugg Catchments.
109. Focus on Phosphorus. *Engage Environment Agency*.
110. England | Catchment Data Explorer.
111. Open WIMS data.
112. England, N. Water Quality Catchment Assessment: Detailed SAGIS spreadsheets - technical note - IPENS071. *Natural England - Access to Evidence*.
113. Agency, E. (2025). Strengthening Environmental Science: A New Chapter in Water Monitoring – Creating a better place.
114. (2023). Continuous water quality monitoring and event duration monitoring. *GOV.UK*.
115. Elfferich, I. *et al.* (2024). Interpretation of river water quality data is strongly controlled by measurement time and frequency. *Sci. Total Environ.*, Vol 954, 176626.
116. Rajapaksha, N. S. *et al.* (2025). Using an innovative Catchment Nutrient Balancing (CNB) approach to improve river water quality: A case study from rural sub catchment in Cumbria, United Kingdom. *Water Res.*, Vol 281, 123586.
117. Rozemeijer, J. *et al.* (2025). Best practice in high-frequency water quality monitoring for improved management and assessment; a novel decision workflow. *Environ. Monit. Assess.*, Vol 197, 353.
118. Chappell, N. A. *et al.* (2017). Sampling frequency for water quality variables in streams: Systems analysis to quantify minimum monitoring rates. *Water Res.*, Vol 123, 49–57.
119. Summary of responses and government response. *GOV.UK*.

120. Dr Gabriel Connor Streich Personal Comment.
121. Dr Gabriela Dotro Personal Comment.
122. England, N. Strategic Solutions: Nutrient Neutrality. *Natural England - Access to Evidence*.
123. Nutrient Neutrality Catchments (England).
124. England, N. Nutrient Neutrality Principles - TIN186. *Natural England - Access to Evidence*.
125. Nutrient Management Plan: Hampshire Avon. *GOV.UK*.
126. Natural England Access to Evidence - Site Improvement Plans by region.
127. (2025). Tools and resources for calculating nutrient neutrality. *GOV.UK*.
128. (2025). Using the nutrient neutrality calculators. *GOV.UK*.
129. Sustainable drainage.
130. norfolk-nutrient-calculator-response-from-natural-england.pdf.
131. LF65056 Nutrient Neutrality - Solution Finding Doc - HBF Update - Feb23.indd.
132. Mitigating pollution to unlock development.
133. (2023). 'Nutrogedden' – ways around the crisis. *Environment Analyst UK*.
134. committees.parliament.uk/writtenevidence/120285/html/.
135. Brookbanks_-_Research_Report_Nov_2023.pdf.
136. Sarah Belton Written evidence submitted by Sarah Belton, founder and co-director of Nutrient Neutral, Our Rivers and Blue Earth Biochar. Infrastructure and Planning Public Bill Committee.
137. Participation, E. The Environmental Permitting (England and Wales) Regulations 2016. Statute Law Database.
138. Environmental permitting: Core guidance.
139. Waste water treatment works: treatment monitoring and compliance limits. *GOV.UK*.
140. Nutrient pollution: reducing the impact on protected sites. *GOV.UK*.
141. Waste water treatment works: treatment monitoring and compliance limits. *GOV.UK*.
142. adam@hutton (2024). Hidden threats to soil revealed in sewage sludge research. *James Hutton Institute*.
143. Nutrient pollution: reducing the impact on protected sites. *GOV.UK*.
144. Waste water treatment works: treatment monitoring and compliance limits. *GOV.UK*.
145. Participation, E. The Urban Waste Water Treatment (England and Wales) Regulations 1994. Statute Law Database.
146. February 2022: The government's strategic priorities for Ofwat. *GOV.UK*.
147. Zhou, Y. *et al.* (2023). A Comprehensive Review on Wastewater Nitrogen Removal and Its Recovery Processes. *Int. J. Environ. Res. Public. Health*, Vol 20, 3429. Multidisciplinary Digital Publishing Institute.
148. Witek-Krowiak, A. *et al.* (2022). Phosphorus recovery from wastewater and bio-based waste: an overview. *Bioengineered*, Vol 13, 13474–13506. Taylor & Francis.
149. Herefordshire Council. Luston wetland case study.
150. Harris, S. Reducing river nutrients. *Herefordshire Council*.
151. Harris, S. Nutrient management - guidance for developers. *Herefordshire Council*.

152. Herefordshire Council (2025). Herefordshire Council reveals plan for third wetland. *BBC News*.
153. distinctive (2025). Water company achieves sustainable phosphorus removal with Veolia Water Technologies' HydrexTM Coagulant. *Water Industry Journal*.
154. da Silva, R. M. P. *et al.* (2025). From Natural to Industrial: How Biocoagulants Can Revolutionize Wastewater Treatment. *Processes*, Vol 13, 1706. Multidisciplinary Digital Publishing Institute.
155. Alternative approaches to phosphorus removal on rural wastewater treatment works. *Ofwat Innovation Fund*.
156. Hayward, K. (2020). Treatment wetlands as a multi-benefit nature-based solution. *The Source*.
157. (2020). Wetland Technology: Practical Information on the Design and Application of Treatment Wetlands. IWA Publishing.
158. Vohla, C. *et al.* (2011). Filter materials for phosphorus removal from wastewater in treatment wetlands—A review. *Ecol. Eng.*, Vol 37, 70–89.
159. Murujew, O. *et al.* (2024). Reactive media constructed wetland for phosphorus removal: assessing the opportunity and challenges. *H2Open J.*, Vol 7, 187–198.
160. Feng, Y. *et al.* (2025). Microbes drive more carbon dioxide and nitrous oxide emissions from wetland under long-term nitrogen enrichment. *Water Res.*, Vol 272, 122942.
161. Pasut, C. *et al.* (2021). Spatiotemporal Assessment of GHG Emissions and Nutrient Sequestration Linked to Agronutrient Runoff in Global Wetlands. *Glob. Biogeochem. Cycles*, Vol 35, e2020GB006816.
162. Cun, D. *et al.* (2025). Greenhouse gas emissions from field-scale surface-flow constructed wetlands fed with different polluted water types: Environmental and microbial drivers. *J. Hydrol.*, Vol 662, 133867.
163. Guo, Z. *et al.* (2025). Greenhouse gas emissions and nitrogen removal from wastewater - constructed wetland solutions. *J. Environ. Manage.*, Vol 394, 127236.
164. Stein, L. Y. *et al.* (2016). The nitrogen cycle. *Curr. Biol.*, Vol 26, R94–R98.
165. Klimasmith, I. M. *et al.* (2022). Micromanaging the nitrogen cycle in agroecosystems. *Trends Microbiol.*, Vol 30, 1045–1055.
166. Hui, D. *et al.* (2024). Impacts of Climate Change and Agricultural Practices on Nitrogen Processes, Genes, and Soil Nitrous Oxide Emissions: A Quantitative Review of Meta-Analyses. *Agriculture*, Vol 14, 240. Multidisciplinary Digital Publishing Institute.
167. Stevens, C. J. *et al.* (2009). Policy implications of pollution swapping. *Phys. Chem. Earth Parts ABC*, Vol 34, 589–594.
168. Wei, H. *et al.* (2022). The denitrifying anaerobic methane oxidation process and microorganisms in the environments: A review. *Front. Mar. Sci.*, Vol 9, Frontiers.
169. Kadlec, R. H. (2019). *Treatment Marshes for Runoff and Polishing*. CRC Press.
170. Bingham, A. H. *et al.* (2016). Organic nitrogen storage in mineral soil: Implications for policy and management. *Sci. Total Environ.*, Vol 551–552, 116–126.
171. Gregory, A. S. *et al.* (2016). Long-term management changes topsoil and subsoil organic carbon and nitrogen dynamics in a temperate agricultural system. *Eur. J. Soil Sci.*, Vol 67, 421–430.

172. Zhang, Y. *et al.* (2020). Synchronous sequestration of organic carbon and nitrogen in mineral soils after conversion agricultural land to forest. *Agric. Ecosyst. Environ.*, Vol 295, 106866.
173. Courtier, P. *et al.* (2025). Personal comment.
174. (2025). Natural England's nutrient mitigation scheme for developers. *GOV.UK*.
175. Sarah Belton Personal comment.
176. Philippa Arnold, National Farmer's Union Personal comment.
177. Natural England's nutrient mitigation scheme has unlocked just 7.5% of the homes that agency predicted, FOI reveals.
178. Letter from Minister for Housing, Planning and Building Safety on nutrient neutrality, December 2023. *GOV.UK*.
179. Local Nutrient Mitigation Fund Round 2: funding allocations. *GOV.UK*.
180. (2023). Natural England's Nutrient Mitigation Scheme, devised to protect our waterways from pollution and enable home building, has now launched.
181. Investment in nutrient neutrality mitigation. *Norfolk Environmental Credits*.
182. Wendling Beck Project.
183. Nutrient Neutrality Planning | Norfolk. *Wendling Beck*.
184. Hiscock, K. M. *et al.* (2023). Export Coefficient Modelling of Nutrient Neutrality to Protect Aquatic Habitats in the River Wensum Catchment, UK. *Environments*, Vol 10, 168. Multidisciplinary Digital Publishing Institute.
185. Chief Scientist's Group report The nitrate leaching tool - technical reference. Environment Agency.
186. Solent Nutrients - V5 June 2020. Natural England.
187. Nutrient Mitigation Tool. Natural England and Ricardo.
188. Why Greenshank are not recommending land abandonment for nutrient neutrality.
189. McDowell, R. W. *et al.* (2024). Reducing phosphorus losses from agricultural land to surface water. *Curr. Opin. Biotechnol.*, Vol 89, 103181.
190. Mancuso, G. *et al.* (2023). Performance of lagoon and constructed wetland systems for tertiary wastewater treatment and potential of reclaimed water in agricultural irrigation. *J. Environ. Manage.*, Vol 348, 119278.
191. C. W. Association, T. R. T. (2022). Constructed Wetland Hub. *ArcGIS StoryMaps*.
192. wwt-constructed-farm-wetlands.pdf.
193. Wright, A. S. *et al.* (2022). Improper Maintenance Activities Alter Benefits of Urban Stormwater Treatment in a Temperate Constructed Wetland in NSW, Australia. *Front. Environ. Chem.*, Vol 3, Frontiers.
194. Gaballah, M. S. *et al.* (2024). From Literature to Action: Analyzing How Nitrogen and Phosphorus Removal Responds to Different Design Factors in Free Water Surface Constructed Wetlands. *ACS EST Eng.*, Vol 4, 2974–2986. American Chemical Society.
195. A review on design, operation, and maintenance of constructed wetlands for removal of nutrients and emerging contaminants | International Journal of Environmental Science and Technology.
196. Wu, H. *et al.* (2023). Constructed wetlands for pollution control. *Nat. Rev. Earth Environ.*, Vol 4, 218–234. Nature Publishing Group.

197. (2020). Wetland Technology: Practical Information on the Design and Application of Treatment Wetlands. IWA Publishing.
198. Rizzo, A. *et al.* (2023). Nature-based solutions for nutrient pollution control in European agricultural regions: A literature review. *Ecol. Eng.*, Vol 186, 106772.
199. Ma, Y. *et al.* (2020). Pathways regulating nitrogen removal in constructed ditch wetlands: effects of different inflow ratios and artificial aeration. *Environ. Sci. Pollut. Res.*, Vol 27, 42571–42581.
200. Dr Lucy Crockford Personal Comment.
201. Professor Bruce Jefferson Personal comment.
202. Framework Approach for Responding to Wetland Mitigation Propo sals.pdf.
203. Lyu, T. *et al.* (2024). Phosphorus removal in surface flow treatment wetlands for domestic wastewater treatment: Global experiences, opportunities, and challenges. *J. Environ. Manage.*, Vol 369, 122392.
204. Martínez-Espinosa, C. *et al.* (2021). Denitrification in wetlands: A review towards a quantification at global scale. *Sci. Total Environ.*, Vol 754, 142398.
205. Allen, C. R. *et al.* (2023). Seasonality, C:N ratio and plant species influence on denitrification and plant nitrogen uptake in treatment wetlands. *Ecol. Eng.*, Vol 191, 106946.
206. Alldred, M. *et al.* (2016). Effects of wetland plants on denitrification rates: a meta-analysis. *Ecol. Appl.*, Vol 26, 676–685.
207. Zhang, Y. *et al.* (2022). Plant Carbon Sources for Denitrification Enhancement and Its Mechanism in Constructed Wetlands: A Review. *Sustainability*, Vol 14, 12545. Multidisciplinary Digital Publishing Institute.
208. Nutrient Removal. *The Wetlands Initiative*.
209. Natural Resources Wales / What to think about when planning your constructed wetland.
210. Kurniawan, S. B. *et al.* (2021). Macrophytes as wastewater treatment agents: Nutrient uptake and potential of produced biomass utilization toward circular economy initiatives. *Sci. Total Environ.*, Vol 790, 148219.
211. Item Detail.
212. Item Detail.
213. Nitrogen and Phosphorous Mitigation Agreement [Modification].
214. g15-norfolk-nutrient-guidance-nutrient-mitigation-solutions.pdf.
215. England, N. Phosphorous in Package Treatment Plant effluents - NECR221. *Natural England - Access to Evidence*.
216. England, N. Natural England Water Quality and Nutrient Neutrality Advice (16 March 2022) - NE785. *Natural England - Access to Evidence*.
217. Cole, L. J. *et al.* (2020). Managing riparian buffer strips to optimise ecosystem services: A review. *Agric. Ecosyst. Environ.*, Vol 296, 106891.
218. Souliotis, I. *et al.* (2022). Operationalising nature-based solutions for the design of water management interventions. *Nat.-Based Solut.*, Vol 2, 100015.
219. Sweeney, B. W. *et al.* (2014). Streamside Forest Buffer Width Needed to Protect Stream Water Quality, Habitat, and Organisms: A Literature Review. *JAWRA J. Am. Water Resour. Assoc.*, Vol 50, 560–584.

220. Carver, R. E. *et al.* (2022). Cover crop and phosphorus fertilizer management impacts on surface water quality from a no-till corn-soybean rotation. *J. Environ. Manage.*, Vol 301, 113818.
221. Hively, W. D. *et al.* (2020). Estimating the effect of winter cover crops on nitrogen leaching using cost-share enrollment data, satellite remote sensing, and Soil and Water Assessment Tool (SWAT) modeling. *J. Soil Water Conserv.*, Vol 75, 362–375. Taylor & Francis.
222. Appraisal of agri-environment scheme actions for achieving agriculture water pollution targets | Office for Environmental Protection.
223. Agriculture water quality Environment Act target delivery plan. *GOV.UK*.
224. Hutchins, M. *et al.* (2021). Why scale is vital to plan optimal Nature-Based Solutions for resilient cities. *Environ. Res. Lett.*, Vol 16, 044008. IOP Publishing.
225. Hutchins, M. *et al.* (2024). Comparing likely effectiveness of urban Nature-based Solutions worldwide: The example of riparian tree planting and water quality. *J. Environ. Manage.*, Vol 351, 119950.
226. Hutchins, M. G. *et al.* (2010). Which offers more scope to suppress river phytoplankton blooms: Reducing nutrient pollution or riparian shading? *Sci. Total Environ.*, Vol 408, 5065–5077.
227. Constructed Wetlands Position Statement. *The Rivers Trust*.
228. Chappell, N. A. *et al.* (2024). Nature-based solutions for effective flood mitigation: potential design criteria. *Environ. Res. Lett.*, Vol 19, 074006. IOP Publishing.
229. Owen, D. *et al.* (2024). Opportunities and constraints of implementing the 3–30–300 rule for urban greening. *Urban For. Urban Green.*, Vol 98, 128393.
230. Vesuviano, G. *et al.* (2025). How well does the 3–30–300 rule mitigate urban flooding? *Urban For. Urban Green.*, Vol 104, 128661.
231. Milner, A. M. *et al.* (2024). The forgotten forests: Incorporating temperate peat-forming wet woodlands as nature-based solutions into policy and practice. *Ecol. Solut. Evid.*, Vol 5, e12346.
232. Pulley, S. *et al.* (2021). Can agri-environment initiatives control sediment loss in the context of extreme winter rainfall? *J. Clean. Prod.*, Vol 311, 127593.
233. (2025). New research highlights how sediment ponds help farmers protect land and boost biodiversity. *Loughborough University*.
234. Sediment and Nutrient Retention in Ponds on an Agricultural Stream: Evaluating Effectiveness for Diffuse Pollution Mitigation.
235. Land, M. *et al.* (2016). How effective are created or restored freshwater wetlands for nitrogen and phosphorus removal? A systematic review. *Environ. Evid.*, Vol 5, 9.
236. Nietch, C. T. *et al.* (2024). Implementing constructed wetlands for nutrient reduction at watershed scale: Opportunity to link models and real-world execution. *J. Soil Water Conserv.*, Vol 79, 113–131. Taylor & Francis.
237. Lyu, T. *et al.* (2024). Phosphorus removal in surface flow treatment wetlands for domestic wastewater treatment: Global experiences, opportunities, and challenges. *J. Environ. Manage.*, Vol 369, 122392.
238. Kay, D. *et al.* (2021). Effectiveness of constructed farm wetlands in attenuating faecal indicator fluxes to watercourses from yard runoff on livestock farms. *Water Environ. J.*, Vol 35, 1085–1093. John Wiley & Sons, Ltd.

239. Gabriela Dotro *et al.* Treatment wetlands in the UK: Case studies of an established biological treatment technology. Constructed Wetlands Association.
240. Kadlec, R. H. *et al.* (2008). *Treatment Wetlands*. CRC Press.
241. Shi, Q. *et al.* (2023). Harnessing the potential of phytoremediation for mitigating the risk of emerging contaminants. *Curr. Opin. Environ. Sci. Health*, Vol 32, 100448.
242. Rani, A. *et al.* (2024). Microbiological dimensions and functions in constructed wetlands: A review. *Curr. Res. Microb. Sci.*, Vol 7, 100311.
243. Gebru, S. B. *et al.* (2024). Applications of constructed wetlands in removing emerging micropollutants from wastewater: Occurrence, public health concerns, and removal performances - a review. *South Afr. J. Chem. Eng.*, Vol 48, 395–416. South African Institution of Chemical Engineers (SAIChE).
244. Murujew, O. *et al.* (2024). Reactive media constructed wetland for phosphorus removal: assessing the opportunity and challenges. *H2Open J.*, Vol 7, 187–198.
245. Gupta, P. *et al.* (2016). Use of biochar to enhance constructed wetland performance in wastewater reclamation. *Environ. Eng. Res.*, Vol 21, 36–44. Korean Society of Environmental Engineers.
246. Zhang, Y. *et al.* (2024). Distinct roles of biochar and pyrite substrates in enhancing nutrient and heavy metals removal in intermittent-aerated constructed wetlands: Performances and mechanism. *Environ. Res.*, Vol 258, 119393.
247. Kumar, R. *et al.* (2025). Harnessing biochar for nitrate removal from contaminated soil and water environments: Economic implications, practical feasibility, and future perspectives. *Biochar*, Vol 7, 94.
248. Sithamparanathan, E. *et al.* (2023). Controlling Nitrogen Removal Processes in Improved Vertical Flow Constructed Wetland with Hydroponic Materials: Effect of Influent COD/N Ratios. *Water*, Vol 15, 1074. Multidisciplinary Digital Publishing Institute.
249. Rizzo, A. *et al.* (2023). Nature-based solutions for nutrient pollution control in European agricultural regions: A literature review. *Ecol. Eng.*, Vol 186, 106772.
250. Ockenden, M. C. *et al.* (2012). Evaluation of field wetlands for mitigation of diffuse pollution from agriculture: Sediment retention, cost and effectiveness. *Environ. Sci. Policy*, Vol 24, 110–119.
251. Association, T. R. T. and the C. W. (2022). Constructed Wetland Hub. *ArcGIS StoryMaps*.
252. Professor Sean Comber Personal comment.
253. Hassett, M. C. *et al.* (2022). Wetland Restoration through Excavation: Sediment Removal Results in Dramatic Water Quality Improvement. *Land*, Vol 11, 1559. Multidisciplinary Digital Publishing Institute.
254. Establishment and restoration of riparian buffers.
255. Nsenga Kumwimba, M. *et al.* (2023). An updated review of the efficacy of buffer zones in warm/temperate and cold climates: Insights into processes and drivers of nutrient retention. *J. Environ. Manage.*, Vol 336, 117646.
256. 3D buffer strips: designed to deliver more for the environment. *GOV.UK*.
257. Nsenga Kumwimba, M. *et al.* (2023). Advances in ecotechnological methods for diffuse nutrient pollution control: wicked issues in

agricultural and urban watersheds. *Front. Environ. Sci.*, Vol 11, Frontiers.
258. Satchithanantham, S. *et al.* (2019). Seasonality of Phosphorus and Nitrate Retention in Riparian Buffers. *J. Environ. Qual.*, Vol 48, 915–921.
259. Puttock, A. *et al.* (2018). Sediment and nutrient storage in a beaver engineered wetland. *Earth Surf. Process. Landf.*, Vol 43, 2358–2370.
260. Cooper, R. J. *et al.* (2025). Eurasian Beaver (Castor Fiber) Reintroduction: A Nutrient Mitigation Solution for Lowland Chalk Streams? *Wetlands*, Vol 45, 10.
261. Adams, R. *et al.* (2018). The Role of Attenuation and Land Management in Small Catchments to Remove Sediment and Phosphorus: A Modelling Study of Mitigation Options and Impacts. *Water*, Vol 10, 1227. Multidisciplinary Digital Publishing Institute.
262. Robotham, J. *et al.* (2023). Nature-based solutions enhance sediment and nutrient storage in an agricultural lowland catchment. *Earth Surf. Process. Landf.*, Vol 48, 243–258.
263. Do, V. H. *et al.* (2023). Agroforestry with contour planting of grass contributes to terrace formation and conservation of soil and nutrients on sloping land. *Agric. Ecosyst. Environ.*, Vol 345, 108323.
264. Salceda, M. *et al.* (2023). Agroforestry buffers on nitrogen reduction in groundwater on a grazed hillslope. *Agrosystems Geosci. Environ.*, Vol 6, e20370.
265. Kim, D.-G. *et al.* (2022). Nitrogen dynamics in agroforestry systems. A review. *Agron. Sustain. Dev.*, Vol 42, 60.
266. Salceda-Gonzalez, M. *et al.* (2025). Groundwater Nitrate-Nitrite Modeling in a Grazed Hillslope with Agroforestry and Grass Buffers. *Water*, Vol 17, 608. Multidisciplinary Digital Publishing Institute.
267. Salceda-Gonzalez, M. *et al.* (2024). Agroforestry on runoff nitrogen and phosphorus losses from three paired watersheds after 25 years of implementation. *Agrofor. Syst.*, Vol 98, 603–617.
268. Delivering sustainable water.
269. The Reduction and Prevention of Agricultural Diffuse Pollution (England) Regulations 2018. King's Printer of Acts of Parliament.
270. (2025). How to comply with the Farming Rules for Water. *GOV.UK*.
271. Nutrient Management Guide (RB209) | AHDB.
272. (2023). Storing silage, slurry and agricultural fuel oil. *GOV.UK*.
273. Participation, E. *et al.* The Water Resources (Control of Pollution) (Silage, Slurry and Agricultural Fuel Oil) (England) Regulations 2010. Statute Law Database.
274. About the Slurry Infrastructure grant round 1, who can apply and what it can pay for. *GOV.UK*.
275. Nitrate Vulnerable Zones | UK Soil Observatory | UK Research and Innovation.
276. Musacchio, A. *et al.* (2020). EU Nitrates Directive, from theory to practice: Environmental effectiveness and influence of regional governance on its performance. *Ambio*, Vol 49, 504–516.
277. Check for Drinking Water Safeguard Zones and NVZs.
278. The Nitrate Pollution Prevention Regulations 2015: post-implementation review - RPC opinion (green-rated). *GOV.UK*.
279. Participation, E. *et al.* The Nitrate Pollution Prevention Regulations 2015. Statute Law Database.

280. (2025). Nitrate vulnerable zones. *GOV.UK*.
281. (2023). Storing organic manures in nitrate vulnerable zones. *GOV.UK*.
282. (2024). Using nitrogen fertilisers in nitrate vulnerable zones. *GOV.UK*.
283. Worrall, F. *et al.* (2009). The effectiveness of nitrate vulnerable zones for limiting surface water nitrate concentrations. *J. Hydrol.*, Vol 370, 21–28.
284. (2024). Pigs and poultry intensive farming: environmental permits. *GOV.UK*.
285. House of Lords - Nitrogen: time to reduce, recycle, reuse - Environment and Climate Change Committee.
286. Participation, E. The Sludge (Use in Agriculture) Regulations 1989. Statute Law Database.
287. Sewage sludge in agriculture: code of practice for England, Wales and Northern Ireland. *GOV.UK*.
288. Enforcing the Farming Rules for Water. *GOV.UK*.
289. Farming Advice Service | Farming Advice Service.
290. (2025). Catchment Sensitive Farming: advice for farmers and land managers. *GOV.UK*.
291. Catchment Sensitive Farming - Our advice | Farming Advice Service.
292. Nutrient management. *GOV.UK*.
293. Use a whole farm nutrient budget – Farming.
294. Plan and manage nutrient applications - NMPTGB - GOV.UK.
295. Nutrient Management Guide (RB209) | AHDB.
296. Sommer, S. G. *et al.* (2021). Impact of Danish Livestock and Manure Management Regulations on Nitrogen Pollution, Crop Production, and Economy. *Front. Sustain.*, Vol 2, Frontiers.
297. (2022). Drinking water protected areas: challenges for the water environment. *GOV.UK*.
298. (2022). Drinking water protected areas: challenges for the water environment. *GOV.UK*.
299. River basin management plans, updated 2022: summary programmes of measures - 5. Topic action plans - Guidance - GOV.UK.
300. River Basin Management Plans. *Engage Environment Agency*.
301. Newson, N. (2024). River pollution and the regulation of private water companies.
302. River basin management plans, updated 2022: introduction. *GOV.UK*.
303. Home - CaBA. *CaBA* -.
304. (2018). About CaBA - CaBA. *CaBA* -.
305. Scott, E. (2024). Environmental land management: Recent changes to the sustainable farming incentive and countryside stewardship schemes.
306. Uberoi, E. *et al.* (2025). Farm funding: implementing new approaches.
307. (2025). How to do the SFI actions for nutrient management. *GOV.UK*.
308. (2025). How to do the SFI actions for buffer strips. *GOV.UK*.
309. (2025). How to do the SFI actions for soils. *GOV.UK*.
310. Written statements - Written questions, answers and statements - UK Parliament.
311. Team, T. (2025). An update on the Sustainable Farming Incentive – Farming.
312. Slurry items and specifications - Farming Equipment and Technology Fund (FETF) 2025 (closed). *GOV.UK*.

313. Michael MacLeod, Bob Rees, Christine Watson, Steven Thomson, Iain Boyd and Julian Bell Review of options for reducing greenhouse gas emissions via cattle slurry management in Scotland.
314. Capra, F. *et al.* (2025). Drip fertigation with slurry as a promising tool to reduce nitrogen losses under organic maize. *Sci. Rep.*, Vol 15, 16890. Nature Publishing Group.
315. Using slurry acidification to reduce emissions | AHDB.
316. Cooney, B. (2024). Evaluating the agronomic and environmental impacts of slurry separation. *ADAS*.
317. EEF_FINAL_COLLATED_REPORT.pdf.
318. Defra biostimulants project - Stakeholder update May 2024.pdf.
319. Competition overview - Farming Futures R&D Fund: low emissions farming - Innovation Funding Service.
320. Farming Innovation Programme – Farming Innovation Programme.
321. Agricultural Land Use in United Kingdom at 1 June 2024. *GOV.UK*.
322. Land Use Consultation.pdf.
323. (2025). Land Use Framework – Defra opens consultation.
324. George Freeman MP | 30:50:50 vision - towards a new Innovation Agenda for UK Agriculture. *SSA*.
325. All-Party Parliamentary Group on Science and Technology in Agriculture Feeding Britain sustainably to 2050: The 30:50:50 mission.
326. Blaydes, H. *et al.* (2025). Shedding light on land use change for solar farms. *Prog. Energy*, Vol 7, 033001. IOP Publishing.
327. England, N. Atmospheric nitrogen theme plan - IPENSTP013. *Natural England - Access to Evidence*.
328. England, N. (2019). Change in the air as government publishes new Clean Air Strategy.
329. Somerville-Hall, K. *et al.* (2025). Ammonia emissions from a poultry farm drive changes in soil biogeochemistry and microbial communities along a treebelt in northern England. *Appl. Soil Ecol.*, Vol 213, 106267.
330. Lim, J. Y. *et al.* (2021). Agricultural nitrogen and phosphorus balances of Korea and Japan: Highest nutrient surplus among OECD member countries. *Environ. Pollut.*, Vol 286, 117353.
331. Nutrient balance. *OECD*.
332. Soil nutrient balances England, 2024 - statistics notice. *GOV.UK*.
333. River basin management planning | Scottish Environment Protection Agency (SEPA).
334. (2025). Nutrient budget calculator | GOV.WALES.
335. Natural Resources Wales / Principles of nutrient neutrality in relation to development or water discharge permit proposals.
336. Nutrient Practices and Crediting | NC DEQ.
337. Nitrogen Futures | JNCC Resource Hub.
338. Cantoni, J. *et al.* (2023). Legacy contributions to diffuse water pollution: Data-driven multi-catchment quantification for nutrients and carbon. *Sci. Total Environ.*, Vol 879, 163092.
339. D, C. *et al.* (2022). UK Phosphorus Transformation Strategy: Towards a circular UK food system. Zenodo.
340. Pavinato, P. S. *et al.* (2024). Legacy soil phosphorus bioavailability in tropical and temperate soils: Implications for sustainable crop production. *Soil Tillage Res.*, Vol 244, 106228.
341. Solangi, F. *et al.* (2023). The Global Dilemma of Soil Legacy Phosphorus and Its Improvement Strategies under Recent Changes in Agro-

Ecosystem Sustainability. *ACS Omega*, Vol 8, 23271–23282. American Chemical Society.
342. Withers, P. j. a. *et al.* (2001). Phosphorus cycling in UK agriculture and implications for phosphorus loss from soil. *Soil Use Manag.*, Vol 17, 139–149.
343. Nitrate contamination | Groundwater | British Geological Survey (BGS).
344. Bell, V. A. *et al.* (2021). Long term simulations of macronutrients (C, N and P) in UK freshwaters. *Sci. Total Environ.*, Vol 776, 145813.
345. Papangelou, A. *et al.* (2021). Assessing agro-food system circularity using nutrient flows and budgets. *J. Environ. Manage.*, Vol 288, 112383.
346. Biswas Chowdhury, R. *et al.* (2021). Phosphorus use efficiency in agricultural systems: A comprehensive assessment through the review of national scale substance flow analyses. *Ecol. Indic.*, Vol 121, 107172.
347. Chen, X. *et al.* (2023). Physical and virtual nutrient flows in global telecoupled agricultural trade networks. *Nat. Commun.*, Vol 14, 2391. Nature Publishing Group.
348. Klinglmair, M. *et al.* (2015). Phosphorus in Denmark: National and regional anthropogenic flows. *Resour. Conserv. Recycl.*, Vol 105, 311–324.
349. Akram, U. *et al.* (2019). Enhancing nutrient recycling from excreta to meet crop nutrient needs in Sweden – a spatial analysis. *Sci. Rep.*, Vol 9, 10264. Nature Publishing Group.
350. Smith, L. G. *et al.* (2018). Modelling the production impacts of a widespread conversion to organic agriculture in England and Wales. *Land Use Policy*, Vol 76, 391–404.
351. House of Lords - Nitrogen: time to reduce, recycle, reuse - Environment and Climate Change Committee.
352. The Solutions. *Sustainable Nitrogen Alliance*.
353. Kremer, A. M. (2013). Eurostat/OECD Nutrient Budgets Methodology Handbook: EU-27, Norway, Switzerland. European Network for Rural Development.
354. Nitrogen Balance Sheet.
355. Nitrogen budget Scotland report.
356. Microsoft Word - UKCEH_UK_N_balance_Report_v2.docx.
357. Yuille, A. *et al.* (2022). UK Government Policy and the Transition to a Circular Nutrient Economy. *Sustainability*, Vol 14, 3310. Multidisciplinary Digital Publishing Institute.
358. Davis, S. C. *et al.* (2024). Potential for improving nutrient use efficiencies of human food systems with a circular economy of organic wastes and fertilizer. *Environ. Res. Lett.*, Vol 19, 093002. IOP Publishing.
359. Miao, C. *et al.* (2025). Nutrient circularity from waste to fertilizer: A perspective from LCA studies. *Sci. Total Environ.*, Vol 965, 178623.
360. Brownlie, W. J. *et al.* (2024). National phosphorus planning for food and environmental security. *Curr. Opin. Biotechnol.*, Vol 90, 103226.
361. Aarikka-Stenroos, L. *et al.* (2023). Catalyzing the circular economy of critical resources in a national system: Case study on drivers, barriers, and actors in nutrient recycling. *J. Clean. Prod.*, Vol 397, 136380.
362. Spiller, M. *et al.* (2024). Beyond circularity! Integration of circularity, efficiency, and sufficiency for nutrient management in agri-food systems. *Nutr. Cycl. Agroecosystems*, Vol 129, 287–297.

363. Wichern, F. *et al.* (2024). Editorial on special issues: "regional nutrient management in the circular economy" & "nitrogen and carbon recycling: benefits from the stakeholders' perspective". *Nutr. Cycl. Agroecosystems*, Vol 129, 277–286.
364. Harder, R. *et al.* (2021). Towards a circular nutrient economy. A novel way to analyze the circularity of nutrient flows in food systems. *Resour. Conserv. Recycl.*, Vol 172, 105693.
365. Cordeiro, C. M. *et al.* (2024). Situating the discourse of recycled nutrient fertilizers in circular economy principles for sustainable agriculture. *Front. Sustain.*, Vol 5, Frontiers.
366. Hidalgo, D. *et al.* (2021). Nutrient recycling: from waste to crop. *Biomass Convers. Biorefinery*, Vol 11, 207–217.
367. Rodríguez-Espinosa, T. *et al.* (2023). Nitrogen management in farming systems under the use of agricultural wastes and circular economy. *Sci. Total Environ.*, Vol 876, 162666.
368. Śniatała, B. *et al.* (2024). Advancing sustainable wastewater management: A comprehensive review of nutrient recovery products and their applications. *Sci. Total Environ.*, Vol 937, 173446.
369. The OPF Report. *The OPF Report*.
370. Government response to the NMEG report: Improving policy and practice for agricultural nutrient use and management. *GOV.UK*.
371. Scottish Nitrogen Balance Sheet: consultation.
372. Scottish Nitrogen Balance Sheet 2020.
373. Written evidence from the UK Centre for Ecology & Hydrology (UKCEH) (2025). Written evidence submission from the UK Centre for Ecology and Hydrology (UKCEH) (NIT0035). House of Lords Environment and Climate Change Committee - Nitrogen Inquiry.
374. Scottish Nitrogen Balance Sheet: consultation.
375. Rothwell, S. A. *et al.* (2022). A new direction for tackling phosphorus inefficiency in the UK food system. *J. Environ. Manage.*, Vol 314, 115021.
376. *J. Environ. Manage.*, Vol 314, 115021. Academic Press.
377. nutrient_pollution_an_alternative_approach.pdf.
378. About Us. *Thames Basin Heaths*.
379. Planning and Infrastructure Bill (25th April 2025).
380. House of Lords Planning and infrastructure bill explanatory notes.
381. (2025). Planning and Infrastructure Bill (First sitting) - Hansard - UK Parliament.
382. Planning and Infrastructure Bill (29th April 2025).
383. On the Forefront of Nutrient Credit Trading Using Oysters: Lessons Learned.
384. Cornwell, J. C. *et al.* (2026). Nutrient exchange and denitrification on reef balls in the Chesapeake Bay. *Ecol. Eng.*, Vol 222, 107818.
385. DePiper, G. S. *et al.* (2017). Valuing Ecosystem Services: Oysters, Denitrification, and Nutrient Trading Programs. *Mar. Resour. Econ.*, Vol 32, 1–20. The University of Chicago Press.
386. Ferreira, J. G. *et al.* (2019). Assessment of Nutrient Trading Services from Bivalve Farming. in *Goods and Services of Marine Bivalves*. 551–584. Springer, Cham.
387. Rose, J. M. *et al.* (2021). Opportunities and Challenges for Including Oyster-Mediated Denitrification in Nitrogen Management Plans. *Estuaries Coasts*, Vol 44, 2041–2055.

388. Batiuk, R. A. *et al.* (2025). Restoration of the Chesapeake Bay: lessons for other ecosystems. *Front. Mar. Sci.*, Vol 12, Frontiers.
389. Murphy, R. R. *et al.* (2022). Nutrient Improvements in Chesapeake Bay: Direct Effect of Load Reductions and Implications for Coastal Management. *Environ. Sci. Technol.*, Vol 56, 260–270. American Chemical Society.
390. Easton, Z. *et al.* (2025). The Nonpoint Source Challenge: Obstacles and Opportunities for Meeting Nutrient Reduction Goals in the Chesapeake Bay Watershed. *JAWRA J. Am. Water Resour. Assoc.*, Vol 61, e70034.
391. Kotta, J. *et al.* (2020). Cleaning up seas using blue growth initiatives: Mussel farming for eutrophication control in the Baltic Sea. *Sci. Total Environ.*, Vol 709, 136144.
392. Maar, M. *et al.* (2023). Multi-use of offshore wind farms with low-trophic aquaculture can help achieve global sustainability goals. *Commun. Earth Environ.*, Vol 4, 447. Nature Publishing Group.
393. Hughes, A. D. *et al.* (2022). Blue Nitrogen: A Nature-Based Solution in the Blue Economy as a Tool to Manage Terrestrial Nutrient Neutrality. *Sustainability*, Vol 14, 10182. Multidisciplinary Digital Publishing Institute.
394. Ecosystem Services of Commercially Important Bivalves in the UK: Nutrient removal services). *Seafish*.
395. Comber, S. *et al.* (2023). Restoration management of phosphorus pollution on lowland fen peatlands: A data evidence review from the Somerset Levels and Moors. *Agric. Water Manag.*, Vol 287, 108419.
396. Crocker, R. *et al.* (2023). Aquatic phosphorus behaviour within a UK Ramsar wetland: Impacts of seasonality and hydrology on algal growth and implications for management. *Sci. Total Environ.*, Vol 893, 164606.
397. Crocker, R. *et al.* (2023). Chemical speciation of sediment phosphorus in a Ramsar wetland. *Anthropocene*, Vol 43, 100398.
398. Crocker, R. *et al.* (2022). Seasonal Cycling of Phosphorus within a UK Ramsar Wetland: Impacts of Land Use and Hydrology on Algal and Duckweed Growth and Implications for Management. Social Science Research Network.
399. Crocker, R. *et al.* (2021). Spatial distribution of sediment phosphorus in a Ramsar wetland. *Sci. Total Environ.*, Vol 765, 142749.
400. Desmoulin's whorl snail (Vertigo moulinsiana) - Special Areas of Conservation.
401. Desmoulin's whorl snail (Vertigo moulinsiana) - Special Areas of Conservation.
402. Książkiewicz-Parulska, Z. (2020). Behavioural aspects of microhabitat segregation of different age stages in the wetland land snail Vertigo moulinsiana (Eupulmonata: Vertiginidae) in the laboratory. *J. Molluscan Stud.*, Vol 86, 228–232.
403. Killeen, I. J. (2003). *Ecology of Desmoulin's whorl snail: Vertigo moulinsiana*. English Nature.
404. Killeen, I. J. *et al.* (2003). *Monitoring Desmoulin's Whorl Snail: Vertigo moulinsiana*. Life in UK Rivers.
405. Watkins, F. The Terrestrial Mollusca of the Valley-head Fens of Oxfordshire.
406. UK conservation status assessment for S1016 - Desmoulin's whorl snail (Vertigo moulinsiana) as part of the Fourth Report by the United Kingdom under Article 17 of the EU Habitats Directive.

407. River Ehen - Special Areas of Conservation.
408. Pulley, S. *et al.* (2019). The sources and dynamics of fine-grained sediment degrading the Freshwater Pearl Mussel (*Margaritifera margaritifera*) beds of the River Torridge, Devon, UK. *Sci. Total Environ.*, Vol 657, 420–434.
409. Quinlan, E. *et al.* (2015). A review of the physical habitat requirements and research priorities needed to underpin conservation of the endangered freshwater pearl mussel *Margaritifera margaritifera*. *Aquat. Conserv. Mar. Freshw. Ecosyst.*, Vol 25, 107–124.
410. Niamh Walsh, Michael Neill and John Lucey River Sediment Studies In Relation To Juvenile Pearl Mussels And Salmonids. Environmental Protection Agency.
411. Introduction to Nature Markets.
412. Nature Markets Framework progress update March 2024. *GOV.UK*.
413. Nature markets. *GOV.UK*.
414. Upstream Thinking. *Westcountry Rivers Trust*.
415. Mainstreaming Nature-based Solutions - MNbS. *The Rivers Trust*.
416. From source to sea report. *Ofwat Innovation Fund*.
417. FINAL Financing UK Nature Recovery Final Report ONLINE VERSION.pdf.
418. Nature Investment Programme. *BSI*.
419. British Standards Institution - Project.
420. Royal Society (2025). Ecological implications of nature offset markets in England.
421. Dr Richard Cooper Personal Comment.
422. Professor Mark Sutton Personal comment.
423. Planning and Infrastructure Bill (25th April 2025).
424. Natural England Personal comment.
425. Crop establishment and management. *Paludiculture*.
426. CaMMP - The Platform | UK Centre for Ecology & Hydrology.
427. Waring, E. R. *et al.* (2024). Water and soil quality respond to no-tillage and cover crops differently through 10 years of implementation. *Agric. Ecosyst. Environ.*, Vol 360, 108791.
428. Getahun, E. *et al.* (2023). Assessing the Effectiveness of Winter Cover Crops for Controlling Agricultural Nutrient Losses. *JAWRA J. Am. Water Resour. Assoc.*, Vol 59, 510–522.
429. Luna Juncal, M. J. *et al.* (2023). Towards nutrient neutrality: A review of agricultural runoff mitigation strategies and the development of a decision-making framework. *Sci. Total Environ.*, Vol 874, 162408.
430. overwinter-cover-crops-specification.pdf.
431. Loveday, by K. (2025). EA set to withdraw "ineffective and unworkable" catchment nutrient balancing. *The UK Water Report*.
432. United Utilities (2023). Catchment Nutrient Balancing (CNB) Approach An example for the water industry.
433. Transforming the River Petteril.
434. Rajapaksha, N. S. *et al.* (2025). Using an innovative Catchment Nutrient Balancing (CNB) approach to improve river water quality: A case study from rural sub catchment in Cumbria, United Kingdom. *Water Res.*, Vol 281, 123586.
435. Sarwar, A. N. *et al.* (2025). A framework for selecting Nature-based Solutions: applications and challenges at the catchment scale. *J. Environ. Manage.*, Vol 394, 127220.

436. Johnes, P. J. *et al.* (2024). Nutrient cycling in wetlands: principles, evidence and practice. *Nutr. Cycl. Wetl. Princ. Evid. Pract.*, 1–37.
437. (2025). NFU survey results show farmer confidence at all-time low.
438. Nordling, K. *et al.* (2025). Climate variability can outweigh the influence of climate mean changes for extreme precipitation under global warming. *Atmospheric Chem. Phys.*, Vol 25, 1659–1684. Copernicus GmbH.
439. Arias, P. A. *et al.* (2023). Interplay between climate change and climate variability: the 2022 drought in Central South America. *Clim. Change*, Vol 177, 6.
440. Porterfield, K. K. *et al.* (2023). Microplastics in composts, digestates, and food wastes: A review. *J. Environ. Qual.*, Vol 52, 225–240.
441. Scopetani, C. *et al.* (2022). Hazardous contaminants in plastics contained in compost and agricultural soil. *Chemosphere*, Vol 293, 133645.
442. Baldasso, V. *et al.* (2023). Trace metal fate in soil after application of digestate originating from the anaerobic digestion of non-source-separated organic fraction of municipal solid waste. *Front. Environ. Sci.*, Vol 10, Frontiers.
443. Harini, R. *et al.* (2025). Seaweed as a sink for microplastic contamination: Uptake, identifications and food safety implications. *Environ. Res.*, Vol 278, 121631.
444. Banach, J. L. *et al.* (2020). Food safety during seaweed cultivation at offshore wind farms: An exploratory study in the North Sea. *Mar. Policy*, Vol 120, 104082.
445. Hahn, J. L. *et al.* (2022). Chemical contaminant levels in edible seaweeds of the Salish Sea and implications for their consumption. *PLOS ONE*, Vol 17, e0269269. Public Library of Science.
446. Perring, M. P. *et al.* (2025). Nutrient removal processes in saltmarsh and adjacent habitats: overview and a preliminary study of denitrification in the Solent, UK. Department for Environment, Food and Rural Affairs.
447. Rodias, E. *et al.* (2021). Water-Energy-Nutrients Synergies in the Agrifood Sector: A Circular Economy Framework. *Energies*, Vol 14, 159. Multidisciplinary Digital Publishing Institute.
448. Soo, A. *et al.* (2024). Technologies for the wastewater circular economy – A review. *Desalination Water Treat.*, Vol 317, 100205.
449. Nagarajan, A. *et al.* (2024). Sustainable nutrient recovery through struvite precipitation from poultry and multi-substrate agricultural waste digestates. *Bioresour. Technol. Rep.*, Vol 27, 101924.
450. Chojnacka, K. *et al.* (2024). Nutrient recovery from anaerobic digestate: Fertilizer informatics for circular economy. *Environ. Res.*, Vol 245, 117953.
451. van Loon, M. P. *et al.* (2024). Nutrient cycling on dairy farms in the Netherlands: The role of farm structure, management and trade-offs. *Resour. Conserv. Recycl.*, Vol 211, 107875.
452. Teleshkan, E. *et al.* (2024). Assessing policy impacts on nutrient circularity: a comprehensive review. *Nutr. Cycl. Agroecosystems*, Vol 129, 337–351.
453. Competition overview - Farming Futures: Nutrient Management Phase 1 - Industrial Research - Innovation Funding Service.

454. Wallace, J. (2024). Funding available for nutrient management solutions – Farming.
455. Government response to the NMEG report: Improving policy and practice for agricultural nutrient use and management. *GOV.UK*.
456. Lehmann, J. *et al.* (2025). Biochar in the circular bionutrient economy. *Proc. Natl. Acad. Sci.*, Vol 122, e2503668122. Proceedings of the National Academy of Sciences.
457. Kabir, E. *et al.* (2023). Biochar as a tool for the improvement of soil and environment. *Front. Environ. Sci.*, Vol 11, Frontiers.
458. Schmidt, H.-P. *et al.* (2021). Biochar in agriculture – A systematic review of 26 global meta-analyses. *GCB Bioenergy*, Vol 13, 1708–1730.
459. Sun, Y. *et al.* (2025). The Effect of Biochar Characteristics on the Pesticide Adsorption Performance of Biochar-Amended Soil: A Meta-Analysis. *Agriculture*, Vol 15, 1617. Multidisciplinary Digital Publishing Institute.
460. Melas, G. B. *et al.* (2025). Assessing the Modulatory Effects of Biochar on Soil Health Status in Response to Pesticide Application. *Earth*, Vol 6, 27. Multidisciplinary Digital Publishing Institute.
461. Yavari, S. *et al.* (2022). Bio-efficacy of imidazolinones in weed control in a tropical paddy soil amended with optimized agrowaste-derived biochars. *Chemosphere*, Vol 303, 134957.
462. Biochar, B. E. Blue Earth Biochar. *Blue Earth Biochar*.
463. The role of natural capital in the UK's green economy.
464. About the Water Restoration Fund. *GOV.UK*.
465. (2024). Combining environmental payments: biodiversity net gain (BNG) and nutrient mitigation. *GOV.UK*.
466. Team, T. G. F. (2024). Blending private and public finance – Farming.
467. (2025). The NFU's 5 key principles to successful environmental markets.
468. Government_response_-_taxation_of_environmental_land_management_and_ecosystem_service_markets_w._logo.pdf.

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