Advice on Nutrient Neutrality for New Development in the Stour Catchment in Relation to Stodmarsh Designated Sites
- For Local Planning Authorities

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Nesting Bittern

SECTION 1 INTRODUCTION

1.1 The water environment within the Stour catchment is one of the most important for water dependant wildlife in the United Kingdom. The Stodmarsh water environment is internationally important for its wildlife and is protected under the Water Environment Regulations[1] and the Conservation of Habitats and Species Regulations[2] as well as national protection for many parts of the floodplain catchment[3].There are high levels of nitrogen and phosphorus input to this water environment with sound evidence that these nutrients are causing eutrophication at part of these designated sites. These nutrient inputs are currently thought to be caused mostly by wastewater from existing housing and agricultural sources, though recycling of nutrients within the lake habitats cannot be ruled out. The resulting nutrient enrichment is impacting on the Stodmarsh designated sites' protected habitats and species. The area covered by this advice is described in Appendix 1.

1.2 There is uncertainty as to whether new growth will further deteriorate the designated sites. This uncertainty is one reason that the wastewater treatment works discharging into the River Stour and surroundings are subject to an investigation of their impacts and connection with Stodmarsh designated sites under the Environment Agency Water Industry National Environment Programme (WINEP) that will report in 2022. This WINEP investigation has been initiated to investigate links between the Stour and the Stodmarsh lakes systems, then propose appropriate, possible and cost effective solutions to any identified impacts. Until this work is complete, the uncertainty of new growth's impacts on designated sites remains, therefore there is potential for future housing developments across the Stodmarsh catchment to exacerbate the existing impacts thereby creating a risk to their potential future conservation status.

1.3 One way to address this uncertainty and subsequent risk, until any solutions are implemented to remove the current adverse effects on Stodmarsh, is for new development to achieve nutrient neutrality. Assessing and mitigating nutrients is a means of ensuring that development does not add to existing nutrient burdens and this provides certainty that the whole of the scheme is deliverable in line with the requirements of the Conservation of Habitats and Species Regulations 2017 (as amended) (the 'Habitats Regulations') and in light of relevant case law.

1.4 This report sets out a practical methodology for calculating how nutrient neutrality can be achieved. This methodology is based on best available scientific knowledge, and will be subject to revision as further evidence is obtained. It is Natural England's advice to local planning authorities (LPAs) to take a precautionary approach in line with existing legislation and case-law when addressing uncertainty and calculating nutrient budgets.

[1] The Water Environment (Water Framework Directive) (England and Wales) Regulations 2017
[2] Conservation of Habitats and Species Regulations (England and Wales) Regulations 2017 (as amended)
[3] Including Wildlife and Countryside Act 1981 as amended, Countryside and Rights of Way Act 2000, Natural Environment and Rural Communities Act 2006

1.5 This report includes a brief summary of the planning and environmental context for this nutrient neutral approach, the detailed methodology and advice on mitigation. Further information and guidance is included in the Appendices.

SECTION 2 PLANNING CONTEXT

2.1 Since June 2019 Natural England has been advising that housing, mixed use and tourist development including all EIA development is likely to contribute to a significant effect, in combination, on the Stodmarsh designated sites in terms of water quality. We recommend a nutrient budget is calculated for such development with an attempt to achieve nutrient neutrality as part of an appropriate assessment. Early consideration of the issues ensures that any potential risks are addressed at the outset and provides the applicant with confidence that the development is deliverable subject to other material considerations being addressed.

2.2 During 2017/18 a review of the condition of the Stodmarsh lake units against the newly agreed lake water quality targets was undertaken (see Appendix 3). The best available up-to-date evidence has identified that some of the designated site units are in unfavourable condition due to existing levels of nutrients (both phosphorus and nitrogen) and are therefore at risk from additional nutrient inputs. There is no, or limited, water quality data for some of the units that are currently thought to be at favourable condition and this lack of monitoring will be addressed in the WINEP investigation.

2.3 It is Natural England's view that a likely significant effect on the internationally designated Stodmarsh sites (Special Protection Area, Special Area of Conservation and Ramsar site) cannot be ruled out due to the increases in wastewater from new developments coming forward in the Stodmarsh catchment.

2.4 The uncertainty about the impact of new development on designated sites needs to be recognised for all development proposals that are subject to new planning permissions and have inevitable wastewater implications. These implications, and all other matters capable of having a significant effect on designated sites in the Stodmarsh catchment, must be addressed in the ways required by Regulation 63 of the Habitats Regulations.

2.5 LPAs and applicants will be aware of CJEU decisions[4] regarding the assessment of elements of a proposal aimed toward mitigating adverse effects on designated sites and the need for certainty that mitigating measures will achieve their aims. The achievement of nutrient neutrality, if scientifically and practically effective and achievable, is a means of ensuring that development does not add to existing nutrient burdens.

[4] For example Cooperatie Mobilisation for the Environment UA and College van gedeputeerde staten van Noord-Brabant (Case C-293/17 and C294/17) People Over Wind and Peter Sweetman v Coillte Teoranta.(Case C-323/17).

2.6 Natural England is working with water companies, LPAs, stakeholders and the Environment Agency to try to ensure the Habitats Regulations are met. Further information on the planning context and joint working of competent authorities is provided in Appendix 2.

SECTION 3 ENVIRONMENTAL CONTEXT

Designated sites interest features

3.1 Stodmarsh is a Special Protection Area (SPA), a Ramsar site, a Special Area of Conservation (SAC), a Site of Special Scientific Interest (SSSI) and some parts are a National Nature Reserve (NNR). The site is of national and international importance for a range of water-dependant habitats including lakes and the wildlife that relies upon these habitats. The designations and features are described in Appendix 3 table A3.1 along with links to key documents of interest.

Designated sites water quality target review

3.2 The water quality targets for the Stodmarsh SPA/ SAC/ SSSI lakes were agreed with the Environment Agency in 2017 (and 2019 for Hersden Lake). These targets are based on national water quality standards for freshwater habitats and are in the published supplementary advice to the conservation objectives for the designated sites underpinning habitat. These targets include standards for nitrogen and phosphorus, as an excess of both nutrients can impact lake habitats which underpin the designated sites national and international interest features. The details of how these standards were assessed and site condition are provided in Appendix 3.

3.3 Detailed assessments of other features are available on Defra's Magic Map and condition assessments are not solely based on water quality standards. Table 1 sets out the agreed lake nitrogen and phosphorus standards and whether these standards are met, failed or if this is unknown due to lack of data (based on an amalgam of the Environment Agency and Natural England data for the WINEP investigation). Appendix 1 includes a map of SSSI unit condition. The information from the WINEP investigation will be used to inform a review of these lakes condition assessments with regards to the water quality attributes, including but not limited to nitrogen and phosphorus standards.

Other Water Quality targets

3.4 Other targets in addition to those shown in Table 1 exist. "Chlorophyll a" for all lakes should be at Water Framework Directive (WFD) High Ecological Status. All other pollutants and measurements are set at WFD Good Ecological Status. The Hersden Lake has mainly bird interest features only. The nationally agreed guidance on water quality standards for 'wintering bird lakes' (i.e. lakes which are not notified as a lake habitat in their own right or for macrophytes/ invertebrates in their own right, or to support sensitive nesting birds) says that in lakes mainly used by birds feeding on benthic invertebrates or fish severe eutrophication should be avoided.

Table 1 Summary of water quality targets and compliance with targets if known

CSMG targets were agreed with Environment Agency in 2017 and 2019 for Hersden Lake. Total Phosphorous WFD standard of 49 micrograms per litre to get Good Ecological Status (GES) and Total Phosphorous CSMG of 50 micrograms per litre for favourable condition are similar. The CSMG target for Total Nitrogen for favourable condition is provided with the newly agreed Total Nitrogen standard to get Good Ecological Status shown in brackets.

Lake name	**SSSI UNIT**	**WFD ID**	Compliance P/F/U (Pass / fail/ Unknown) No colour = no data		Natural England database (CSMI) 2018 update / threat nature
			TP Target ug/L	TN Target mg/L	
Reserve Lake/Stodmarsh Nature Reserve Pool	UNIT 10	GB30743087	F 49	F 1.5 (1.07)	Unfavourable Water Quality (WQ)
Collards Lake/Great Puckstone Lake	UNIT 7	GB30743097	F 49	F 1.5 (1.07)	Unfavourable WFD EA Assessment for 2016 MODERATE - unit fails nationally agreed WQ targets
Westbere Lake/s	UNIT 1	GB30743127	U 49	P 1.5 (1.07)	Unfavourable recovering Other reasons
The Fordwich Lakes/Fordwich Lake East	UNIT 2	GB30743156	U 49	U 1.5 (1.07)	Favourable WQ
The Fordwich Lakes/Fordwich Lakes	UNIT 2	GB30743164	U 49	P 1.5 (1.07)	Favourable WQ
Hersden (tidal) Lake	UNIT 5	n/a (tidal so part of the main transitional and coastal water body)	U 100	P 2.0	Favourable WQ

SECTION 4 NUTRIENT NEUTRALITY APPROACH FOR NEW DEVELOPMENT

Introduction

4.1 Achieving nutrient neutrality is one way to address the existing uncertainty surrounding the impact of new development on designated sites. This practical methodology provides advice on how to calculate nutrient budgets and options for mitigation, should this be necessary.

4.2 There is evidence that inputs of both phosphorus and nitrogen influence eutrophication of the water environment. There are different forms of nutrients and concentrations vary according to exactly what is measured. These differences should be recognised when calculating nutrient budgets. The nutrient standards for the designated sites are for total nitrogen and total phosphorus as that is what is available for growth. Further information on the different forms of nutrient is provided in Appendix 3.

Approach to calculating nutrient budgets

4.3 For those developments that wish to pursue neutrality, Natural England advises that a nutrient budget is calculated for new developments that have the potential to result in increases of nitrogen or phosphorus entering the international sites. A nutrient budget calculated according to this methodology and demonstrating nutrient neutrality is, in our view, able to provide sufficient and reasonable certainty that the development does not adversely affect the integrity, by means of impacts from nutrients, on the relevant internationally designated sites. This approach must be tested through the ‘appropriate assessment’ stage of the Habitats Regulations Assessment (HRA). Further information on the HRA process is available here.

4.4 The nutrient neutrality calculation includes key inputs and assumptions that are based on the best available scientific evidence and research. It has been developed as a pragmatic tool. However, for each input there is a degree of uncertainty. For example, there is uncertainty associated with predicting occupancy levels and water use for each household in perpetuity. Also, identifying current land/ farm types and the associated nutrient inputs is based on best available evidence, research and professional judgement and is again subject to a degree of uncertainty.

4.5 It is our advice to local planning authorities to take a precautionary approach in line with existing legislation and case law when addressing uncertainty and calculating nutrient budgets. This should be achieved by ensuring nutrient budget calculations apply precautionary rates to variables and adding a precautionary buffer to the total nitrogen (TN) and total phosphorus (TP) calculated for developments. A precautionary approach to the calculations and solutions helps the local planning authority and applicants demonstrate the certainty needed for their assessments.

4.6 By applying the nutrient neutrality methodology, with the precautionary buffer, to new development, the competent authority may be satisfied that, while margins of error will inevitably vary for each development, this approach will ensure that new development in combination will avoid significant increases of nutrient load to enter the internationally designated sites.

Location of development

4.7 The nutrient neutrality approach only applies to developments where the treated effluent discharges into or can impact (via tidal or storm overtopping) Stodmarsh designated sites or any water body (surface or groundwater) that subsequently discharges into such a site. The catchment area is shown on Figure 1 and described in more detail in Appendix 1. Table A1.2 in Appendix 1 lists the Wastewater Treatment Works (WwTW) which discharge into the areas shown in Figure 1. If development is within the areas shown in Figure 1 and discharges into a works listed in Appendix A1.2 all the stages of methodology A apply. If a development is outside the Figure 1 boundary but discharges into a WwTW that is listed in Table A1.2 then only Stage 1 and addition of the precautionary buffer from Stage 4 of the methodology A apply.

4.8 This approach may be refined if greater understanding of the eutrophication issue is gained thorough new research or updated modelling.

Type of development

4.9 This methodology is for all types of development that would result in a net increase in population served by a wastewater system, including new homes, student accommodation, tourism attractions and tourist accommodation. This development will have inevitable wastewater implications.

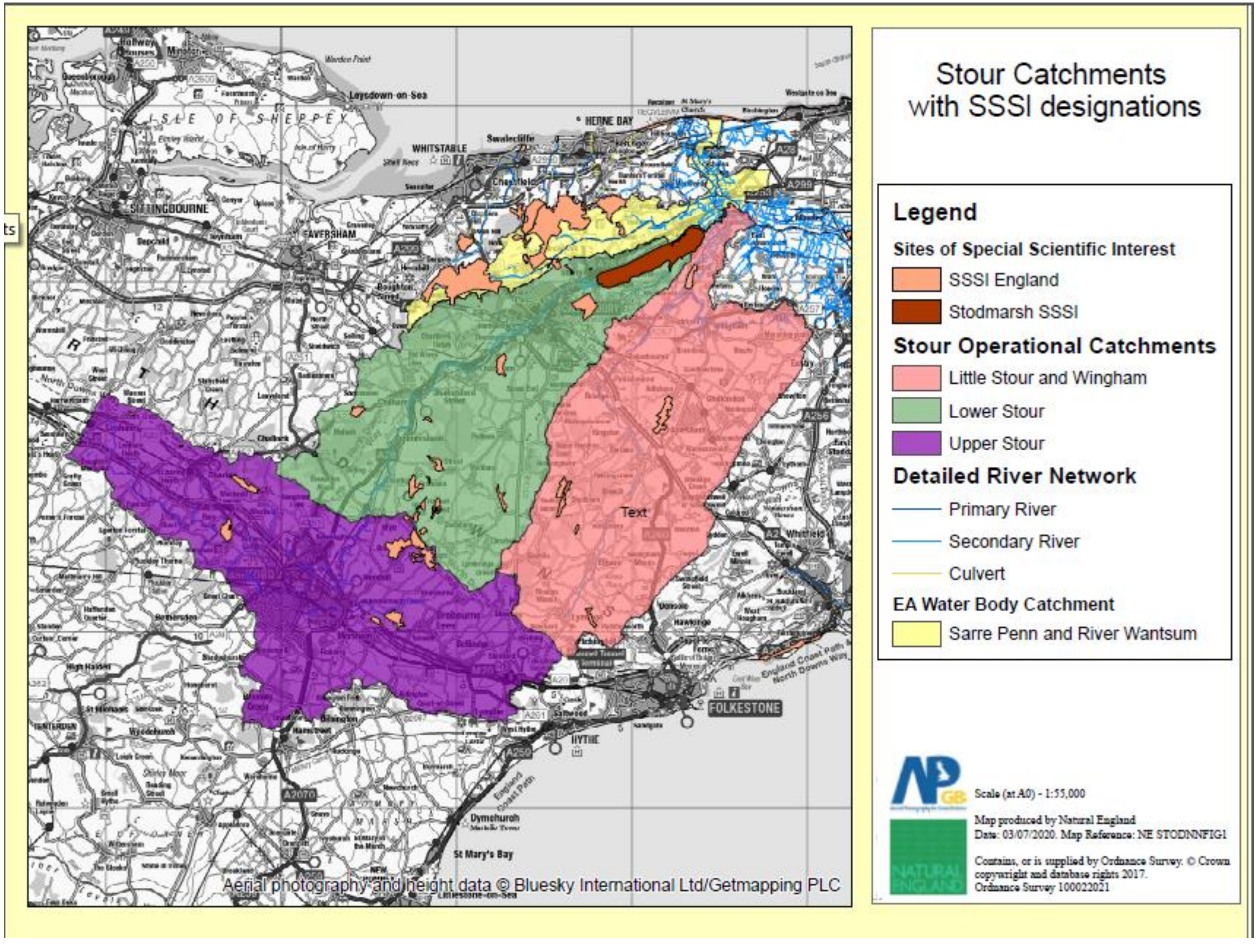
4.10 Other commercial development, not involving overnight accommodation will generally not be included unless it has other (none sewerage) water quality implications. It is assumed that anyone living in the catchment also works and uses facilities in the catchment, and therefore wastewater generated by that person can be calculated using the population increase from new homes and other accommodation. This removes the potential for double counting of human wastewater arising from different planning uses.

4.11 Tourism attractions and tourism accommodation are exceptions, as these land uses attract people into the catchment and generate additional wastewater and consequential nutrient loading on the Stodmarsh designated sites. This includes self-service and serviced tourist accommodation such as hotels, guest houses, bed and breakfasts and self-catering holiday chalets and static caravan sites. Other applications will be considered on their individual merits, for example conference facilities that generate overnight stays.

4.12 There may be cases where planning applications for new commercial or industrial development such as waste management facilities, road schemes or changes in agricultural practices could result in the release of additional nitrogen and/ or phosphorus into the system. In these situations, a case-by-case approach will be adopted. Early discussions with Natural England via our chargeable Discretionary Advice Service (DAS) are recommended.

Figure 1 Surface water of Stodmarsh Catchment to which this advice applies

Note developments outside of these boundaries may drain to WwTWs inside these boundaries. See also table A1.1 and A1.2 and notes in Appendix 1 for more detail.



SECTION 5 METHODOLOGY

5.1 A decision tree for application of the methodology is given in Figure 2. The initial stage is to determine whether the development will drain to the mains network or to a non-mains facility e.g. an on-site package treatment plant.

5.2 The methodology for development that drains to the mains network is in **Section A**. Please go to **Section B** if the new development is not on the mains network.

Section A

Stage 1 Calculate Total Nitrogen (TN) and Total Phosphorus (TP) in kilograms per annum derived from the development that would exit the Wastewater Treatment Works (WwTW) after treatment

Stage 1 Step 1 Calculate additional population

5.3 New housing and overnight accommodation can increase the population as well as the housing stock within the catchment. This can increase the nutrient in discharges. To determine the additional population that could arise from the proposed development, it is necessary that sufficiently evidenced occupancy rates are used. Natural England recommends that as a starting point local planning authorities should consider using an occupancy rate of 2.4, as calculated by the Office for National Statistics (ONS) figure, as this can be consistently applied across local authority areas in the Stour catchment.

5.4 However, competent authorities may choose to adopt bespoke calculations tailored to the area of a scheme, rather than using national population or occupancy assumptions, where they are satisfied that there is sufficient evidence to support this approach. Conclusions that inform the use of a bespoke calculation need to be capable of removing all reasonable scientific doubt as to the effect of the proposed development on the international sites concerned, based on complete, precise and definitive findings. The competent authority needs to explain clearly why the approach taken is considered to be appropriate. Calculations for occupancy rates will need to be consistent with others used in relation to the scheme (e.g. for calculating open space requirements), unless there is clear justification for them to differ.

Stage 1 Step 2 Confirm water use

5.5 Determine the water use/ efficiency standard for the proposed development to be defined in the planning application and, where relevant, the Environmental Statement. The nitrogen and phosphorus load is calculated from the scale of water use and thus the highest water efficiency standards under the building regulations will minimise the increase in nutrients from the development where this goes to a treatment works with a relevant permit limit.

5.6 It is recommended that each local planning authority impose a planning condition on all planning permissions for one or more net additional new dwellings requiring construction to the optional requirement[5] under G2 of the Building Regulations 2010.

5.7 A model condition is set out below:

"*The dwellings shall not be occupied until the Building Regulations Optional requirement of a maximum water use of 110 litres per person per day has been complied with."*

5.8 The water use figure is a proxy for the amount of wastewater that is generated by a household. New residential development may be able to achieve tighter water use figures, with or without grey water recycling systems, and this approach is supported from a water resource perspective (for example in support of Southern Water's Target 100 litres per person per day). However, the key measurement is the amount of wastewater generated by the development that flows to the wastewater treatment works.

5.9 If tighter water use restrictions are used in the nutrient calculation – with or without grey water recycling systems – these restrictions must reflect the wastewater expected to be generated for the lifetime of the development. There is a risk that when kitchen and bathroom fittings are changed by occupants over the years, less water-efficient models could be installed. It is Natural England's view that it would be difficult to evidence and secure delivery of tighter restrictions at this time, to provide certainty for the lifetime of the development. However, if sound evidence can be provided, this will be considered on a case-by-case basis.

5.10 It is Natural England's view that while new developments should ideally be required to meet the 100 litres per person per day standard, the risk of standards slipping over time and the uncertainty inherent in the relationship between water use and sewage volume should be addressed by the use in the calculation of 110 litres per person per day figure.

Stage 1 Step 3 Confirm WwTW and permit level

5.11 Identify the wastewater treatment works (WwTWs) that the development will use and identify whether the WwTW has a TN or/ and TP Permit.

5.12 For most planning applications the WwTW provider is not confirmed until after the planning permission is granted. The nutrient calculation should be based on the permit levels of the most likely WwTW. In any cases where the WwTW changes a reassessment of the nutrient calculation will be required to ensure the development is nutrient neutral.

[5] The optional requirement referred to in G2 requires installation and fittings and fixed appliances for the consumption of water at 110 litres per person per day.

WwTW with TN and TP permit

5.13 Identify the permit concentration limit for total nitrogen (TN) and total phosphorus (TP) at the WwTW. If the WwTW will have a tightened permit concentration limit for total nitrogen / total phosphorus under the company's water industry Asset Management Plan for confirmed delivery by 2024 then use this tightened value. If a new WwTW is proposed, obtain a determination from the Environment Agency on the permit limit for Total Nitrogen / Total Phosphorus that would apply to the works and when they are likely to be built. Further information on permit limits of some existing WwTW is provided in Appendix 1.

5.14 Where there is a permit limit for total nitrogen/ total phosphorus, the load calculation will use a worst case scenario that the WwTW operates at 90% of its permitted limit. A water company has the option of operating the works as close to the consent limit as practicable without breaching the consent limit. Natural England and the Environment Agency have agreed in the Solent to take 90% of the consent value as the closest the water company can reasonably operate works without breaching the consent limit and Natural England accepts this can be extended into other Southern Water WwTW outside the Solent including those in the Stour and its tributaries.

WwTWs without a TN/TP permit

5.15 For developments that discharge to WwTWs with no phosphorus and / or nitrogen permit level, best available evidence must be used for the calculation. The wastewater provider should be contacted for details of the nitrogen and phosphorus effluent levels monitored at the specific WwTW. However Southern Water have confirmed that they do not routinely monitor N or P in effluent discharge where there is no permit in the Stour catchment. Where monitored data is not available robust evidence may be available to derive a value for nitrogen and/ or phosphorus in the wastewater stream based on the type of wastewater treatment at the works.

5.16 For example, in the Southern Water WwTW in the Solent an average of 27 mg/l for Nitrogen is used and Southern Water have confirmed this may be used in the Stour catchment. This average figure may change if new evidence becomes available. Southern Water have advised they would assume an approximate upper figure of 8 mg/l TP for works without a P permit in the Stour catchment for planning purposes though further evidence to support this figure is awaited and it may be subject to change. Evidence supporting any different chosen value for TP or TN must be included with any application. It is not possible to apply the 90% correction in these cases as these WwTWs are not regulated by a total nitrogen or/ and total phosphorus consent limit.

Relationship between TN/TP and water use

Works with a TN and TP permit limit without headroom

5.17 For WwTWs with a TN or/ and TP consents that operation at the permit concentration or close to it i.e. 90% of the permit values, there is a direct relationship between TN/TP and water use. For example, for WwTWs with a permit of 9 mg/l TN and 2 mg/l TP, it can be calculated that for each litre of water that passes through the works, 8.1 mg of nitrogen and 1.8 mg phosphorus (90% of permit values) could be released into the water environment. If a household uses 150 litres, this equates to 1215 mg of TN and 270 mg of TP; if water use is reduced to 100 litres this equates to release of 810 mg of the TN and 180 mg of TP. As there is this clear relationship it is therefore possible to calculate the effect of applying water efficiency measures to existing development and therefore this can be considered as potential mitigation in these circumstances.

5.18 Water companies often use chemical dosing to achieve permit limits on nutrients in particular phosphorus. They can dose the influent to achieve permit compliance, therefore when influent becomes less concentrated they can simply reduce the chemical dosing. For this reason mitigation that reduces the influent concentration at a works (such as sending to a package plant before sending to mains) does not have a guaranteed nutrient reduction in the corresponding effluent discharged and therefore is not certain as a mitigation measure.

Works with a TN and TP consent limit with permit headroom

5.19 Some wastewater treatment works operate considerably below 90% of their existing permit limits for TN/TP i.e. there is permit headroom. Where there is permit headroom reducing water consumption of existing developments to offset the proposed development does not necessarily reduce nutrient loading from the works to designated sites as there is the ability to increase the concentration of the discharge within permitted concentration. It is likely that where the influent concentration to a WwTWs increases, then there could be an increase in the concentration of the WwTW effluent. For this reason applying water efficiency measures to existing properties that discharge to works with permit headroom has uncertain or potentially no mitigating / offsetting benefit for new development. For new development the calculation should use the same approach as for works with a TN and TP permit and use 90% of the permit value along with the water usage, as this will represent the maximum loading, and therefore already allows for the increase in the effluent concentration up to the permit limit that might occur.

Works without a TN or/and TP limit

5.20 For WwTWs without a TN/TP consent level the relationship between water use and TN/TP in the effluent is more complex, but applying the same methodology for nutrient neutrality using the actual discharge concentration (without the 90% correction) for new development is considered appropriate provided the development is not considered likely to increase the influent concentration to the works above current average. Any error due to marginal increases in TN or TP concentration with increases in population served by a particular WwTW will be covered by the precautionary 20% buffer provided the influent concentration is not considered likely to increase.

5.21 Please note that due to the likely increase in influent concentration caused by water efficiency measures at existing properties, the use of measures designed to reduce water consumption as a means of offsetting mitigation of TN/TP are not appropriate due to uncertainty in what reductions, if any, they may provide in areas served by WwTWs without an N or/and P permit.

5.22 For developments with high water efficiency measures that are large in relation to the population serviced by existing works or for other reasons are likely to increase the influent concentration in areas served by works without a TN or TP limit a bespoke calculation is required. The advice of the likely sewerage provider should be sought as to whether the influent concentration is likely to increase from the proposed development in areas supplied by works without a TN/TP limit.

Stage 1 Step 4 Calculate Total Nitrogen (TN) and Total Phosphorus (TP) in kg per annum that would exit the WwTW after treatment derived from the proposed development

5.23 The total nitrogen/total phosphorus load is calculated by multiplying the water use of the proposed development by the appropriate concentration of total nitrogen/ total phosphorus after treatment at the WwTW.

5.24 In the nutrient neutral methodology for Solent sites a discount is made for amount of N that would be present in the groundwater and river water if they were in a more natural condition and an amount considered at this stage to be likely to meet the restoration objectives for the Solent international sites. In part this is due to the absence of a numeric targets for nutrients for the Solent and in part it is due to likelihood that a proportion of the nitrogen in a groundwater catchment would eventually reach the sea.

5.25 The acceptable load of nitrogen and phosphorus levels in the Stour catchment are taken into account in the numeric nutrient standards for the lakes. The WINEP investigation will calculate values of N and P in the Stour that are acceptable in the determination of the existing treatment works effects on Stodmarsh designated sites. For these reasons Natural England do not consider it is appropriate to discount groundwater background values from the Stodmarsh nutrient neutral calculations.

Worked example of a nutrient budget calculation for discharge to a WwTW using methodology

5.26 The following worked example calculates the total nitrogen and phosphorus loads of a development of 1000 dwellings based on a WwTW with a consent limit for Total Phosphorus of 2 mg/l but without a consent limit for total Nitrogen. In this theoretical example the company agreed the development proposal was small in proportion to the works population equivalence and was not likely to increase the influent and the base average discharge is assumed to be 27 mg/l.

5.27 Where residential developments also include other overnight accommodation such as tourist accommodation and attractions, the associated water use from these additional land uses will need to be included in the calculation. These rates should be based on empirical evidence from similar developments or published literature and will be assessed on a case by case basis.

Table 2 – Calculating wastewater Total Nitrogen/ Phosphorus load from proposed development

STAGE 1 - WORKED EXAMPLE TO CALCULATE TOTAL NITROGEN (TN) and (TP) LOAD FROM DEVELOPMENT WASTEWATER				
Step	**Measurement**	**Value**	**Unit**	**Explanation**
Development proposal	Development types that would increase the population served by a wastewater system	1000	Residential dwellings	
Step 1	Additional population	2400	Persons	Uses an average household size of 2.4 x 1000 dwgs (greenfield site)
Step 2	Wastewater volume generated by development	264,000	litres/day	2400 persons x 110 litres[6]
Step 3	Receiving WwTW Average TN discharge confirmed with company as unlikely to change as result of development Receiving WwTW permit limit for TP assume discharge to be at 90%	27 1.8	mg/l TN mg/l TP	27 mg/l TN confirmed average 90% of the consent limit is 1.8 mg/l TP
Step 4	TN discharged after WwTW treatment TP discharged after WwTW treated	7,128,000 475,200	mg TN/day mg TP/day	Step 2 x step 3 = 27 mg/l TN x 264,000 = 1.8 mg/l TP x 264,000
	Convert mg TN to kg TN per day Convert mg TP to kg TP per day	7.128 0.4752	kg TN/day kg TP/day	Divide by 1,000,000
	Convert kg/TN per day to kg/TN per year Convert to kg/TP/SRP per day to kg/TP per year	2,601.72 173.45	kg TN/yr kg TN/yr	Multiply by 365 days
Wastewater Total nutrient load		**Total Nitrogen** **Total Phosphorus**	**2,602 kg TN/yr** **173 kg TP/yr**	

[6] Where relevant, deduct wastewater volume of population displaced by the proposed development

Stage 2 Adjust Nitrogen/ Phosphorus load to offset existing nitrogen from current land use

5.28 This next stage is to calculate the existing nutrient losses from the current land use within the redline boundary of the scheme. The nitrogen/ phosphorus loss from the current land use will be removed and replaced by that from the proposed development land use. The net change in land use will need to be subtracted from or added to the wastewater total nitrogen/ total phosphorus load.

5.29 Nitrogen–nitrate/ phosphorus loss from agricultural land has been modelled using a Farmscoper model run for the Stour Management Catchment for Stodmarsh. This model has been used to estimate the loss of nutrients from different farm types in relevant catchments and these are provided in table 3. Further details on farm classification used in the Farmscoper model are included in Appendix 4.

5.30 If the proposed development area covers agricultural land that clearly falls within a particular farm type used by the Farmscoper model then the modelled average nitrate-nitrogen and phosphorus loss from this farm type should be used.

Table 3 Farm types and average nitrogen-nitrate loss

AVERAGE NUTRIENT LOSS PER FARM TYPE IN STOUR MANAGEMENT CATCHMENT AREA (kg/ha/yr)		
	Nitrate- Nitrogen (kg/ha/yr)	Phosphorus (kg/ha/yr)
Cereals	27.3	0.36
Dairy	58.3	0.49
General Cropping	27.9	0.28
Horticulture	18.5	0.18
Pig	60.3	0.34
Lowland Grazing	12.2	0.24
Mixed	31.5	0.27
Poultry	60.3	0.34
Average for catchment area	**23.5**	**0.28**

5.31 If the proposed development area covers several or indeterminate farm types then the average nitrate-nitrogen and phosphorus loss across all farmland may be more appropriate to use. The average figure is also included in table 3.

5.32 The figures in table 3 are taken from a Farmscoper V4 run for the Stour management catchment in September 2019 and are based on leachate kg/ha N and P for each of the individual farm types with prior mitigation measures taken up at national levels. These may be updated from time to time as land use and agricultural practice to control nutrient losses change.

5.33 For maize farms, it is recommended that the general cropping nitrogen leaching rate is used in the calculation. For sites that are in use as allotments, it is recommended that the most appropriate farm type for allotments is the average rate of the catchment land use. For sites that are currently in use as horse paddocks, it is recommended that the lowland grazing figure should be used in the calculation. If evidence can be provided to support an alternative figures, then this information will be reviewed by the local planning authority and Natural England.

5.34 It is important that farm type classification is appropriately precautionary. It is recommended that evidence is provided of the farm type for the last 10 years and professional judgement is used as to what the land would revert to in the absence of a planning application. In many cases, the local planning authority, as competent authority, will have appropriate knowledge of existing land uses to help inform this process.

5.35 There may be areas of a greenfield development site that are not currently in agricultural use and have not been used as such for the last 10 years. In these cases, there is no agricultural input into the land. If these sites are in private ownership and they are not subject to unmanaged recreational use (such as dog walking), these areas should be given a baseline nutrient leaching value of 5 kg N/ha/yr and 0.14 kg P/ha/yr for nitrogen and phosphorus respectively. These figures cover nitrogen and phosphorus loading from atmospheric deposition, pet waste and nitrogen fixing legumes.

5.36 Where development sites include existing wildlife areas, woodlands, hedgerows, ponds and lakes, that are to be retained, these areas should be excluded from the calculation as there will be no change in the nitrogen and phosphorus input onto this land, or included with the same nitrogen leaching rate in stage 2 and 3. This approach assumes that if they are adopted as green infrastructure or a wildlife area in the new development appropriate management can be secured with any planning permission (see next section) to restrict nitrogen and phosphorus loading.

5.37 A similar approach can also be taken for the redevelopment of urban land as the nitrogen and phosphorus leaching rates would be 14.3 kg N/ha/yr and 0.83 kg P/ha/yr in stage 2 and 14.3 kg N/ha/yr and 0.83 kg P/ha/yr in stage 3. If there is no change in site area, these areas can be excluded from the calculation.

5.38 For sites where existing land use is not confirmed, it is Natural England’s advice to local planning authorities and applicants to take a precautionary approach in line with existing legislation and case law. It is important that only land that currently drains into, or is upstream or in other way effect the designated sites is used for offsetting. If the development land is within a different catchment to the waste water treatment works (WwTW) that are receiving the waste and contributing to the existing failures then this land cannot be used to mitigate the development wastewater. Where land straddles catchments a pro-rata calculation should be made. A worked example to calculate the nitrogen and phosphorus load from existing land use is set out in table 4.

Table 4 Calculating nitrogen/ phosphorus load from current land use

STAGE 2 - WORKED EXAMPLE TO CALCULATE NITROGEN AND PHOSPHORUS LOAD FROM CURRENT LAND USE				
Step	**Measurement**	**Value**	**Unit**	**Explanation**
1	Total area of existing agricultural land	40	Hectares	This is the area of agricultural land that will be lost due to development
2	Identify farm type and confirm nutrient loss from table 2. (example based on cereals)	27.3 0.36	kg N/ha/yr kg P/ha/yr	The developable area is mainly laid to cereals. Reference Appendix 2 and Table 2
3	Multiply area by nitrate/ phosphorus loss	1,092 14.4	kg N/yr kg P/yr	40 ha x 27.3 kg N/yr 40 ha x 0.36 kg P/yr
Nitrogen load - current land use	Nitrogen 1,092 kg N/yr Phosphorus 14.4 kg P/yr			

Stage 3 Adjust nitrogen/ phosphorus load to account for land uses with the proposed development

5.39 This stage is to add in the nitrogen and phosphorus loads that will result from new development that is not received by a WwTW i.e. the nutrients that arise from the new land use. This includes the nitrogen and phosphorus load from the new urban development and from the new open space including any Suitable Alternative Natural Greenspace (SANG), Nature Reserves or Bird Refuge Areas as identified within the redline boundary of the scheme.

5.40 The calculation only includes the areas of the site where there will be a change in land use, for example from agricultural land to new urban development or agricultural land to SANG/ open space. Where there is no proposed change to land use, this land should be excluded from the nutrient budget as there will be no change to the nutrient load from this area. Where land does not drain to the designated site catchment it should be excluded from the calculation.

Urban development

5.41 The nitrogen/ phosphorus load from the new urban development results from sewer overflows and from drainage that picks up nutrient sources on the urban land. Urban development includes the built form, gardens, road verges and small areas of open space within the urban fabric. These nutrient sources include atmospheric deposition, pet waste, fertilisation of lawns and gardens and inputs to surface water sewers. The nitrogen leaching from urban land has been estimated to equate to 14.3 kg/ha/yr[7]. The phosphorus leaching from urban land has been estimated to equate to 0.83 kg/ha/ yr[8]. These figures are proxy figures from best available data however if locally robust catchment specific data is available this can and should be used. Appendix 5 sets out some of the scientific research and literature in relation to these figures.

Open Space and Green Infrastructure

5.42 Nutrient loss draining from new designated open space or SANG should also be included. The nitrogen leaching from this land has been estimated to equate to 5 kg/ha/yr for Solent sites and this is used as a proxy for the Stour valley. The phosphorus leaching from SANG land has been estimated to equate to 0.14 kg/ha/yr. Appendix 6 sets out the scientific research and literature in relation to these figures. These figures can also be used where new nature reserves or bird refuge areas are created and for new woodland planting areas.

5.43 The competent authority will need to be assured that this open space will be managed as such and there will be no additional inputs of nutrients or fertilisers onto this land for the duration of the development. Appropriate planning conditions or other legal measures may be necessary to ensure it will not revert back to agricultural use, or change to alternative uses that affect nutrient inputs in the long term. It is therefore recommended that the 5 kg/ha/yr for Nitrogen and 0.14 kg/ha/yr for phosphorus rate applies to areas of designated open space on-site of around 0.5 hectares and above. These sites will also need long term management to ensure the provision of dog bins and that these are regularly emptied.

5.44 Small areas of open space within the urban fabric, such as road verges, gardens, children's play areas and other small amenity areas, should not be included within this category. The urban development figure is appropriate for these land uses as they are already taken account in the figures chosen.

Community food growing provision

5.45 For any areas of the site that are proposed for community food growing provision, such as allotments, it is recommended that the average farm type rate is used (see table 3).

5.46 A worked example is shown in the table below. This is based on a developable area of 30 hectares covering land in a mix of farm types with the removal of 10 hectares of agricultural land to create SANG.

[7] Supplementary Planning Document – Achieving Nitrogen Neutrality in Poole Harbour

[8] From relevant Water framework directive export coefficient for urban and suburban land 2006 [Final Report: Updating the estimate of the sources of phosphorus in UK waters]

Table 5 – Adjust Nitrogen and Phosphorus Load to account for future land uses

STAGE 3 - WORKED EXAMPLE TO CALCULATE NITROGEN/PHOSPHORUS LOAD FROM FUTURE LAND USES				
Step	**Measurement**	**Value**	**Unit**	**Explanation**
1	New urban area	30	Hectares	Area of development that will change from agricultural land to urban land use
2	Nitrogen/ Phosphorus Load from future urban area	429 24.9	kg N/yr kg P/yr	30 ha x 14.3 kg N/yr 30 ha x 0.83 kg P/yr
3	New SANG / open space	10	Hectares	Area of development that will change from agricultural land to SANG / open space
4	Nitrogen/ Phosphorus load from SANG/ open space	50 1.4	kg N/yr kg P/yr	10 ha x 5.0 kg N/yr 10 ha x 0.14 kg P/yr
5	Combine Nitrogen load from future land uses Combine Phosphorus load from future land uses	479 26.3	kg N/yr kg P/yr	429 kg N/yr + 50 kg N/yr 24.9 kg P/yr +1.4 kg P/yr
Nutrients from Proposed future land uses	Nitrogen 479 kg TN/yr Phosphorus 26.3 kg TP/yr			

Stage 4 Calculate the net change in the Total Nitrogen and Total Phosphorus load that would result from the development

5.47 The last stage is to calculate the net change in the total nitrogen and total phosphorus load to the Stodmarsh catchment with the proposed development. This is derived by calculating the difference between the total nitrogen/ phosphorus load calculated for the proposed development (wastewater, urban area, open space etc.) and that for the existing land uses.

5.48 It is necessary to recognise that all the figures used in the calculation are based on scientific research, evidence and modelled catchments. These figures are the best available evidence but it is important that a precautionary buffer is used that recognises the uncertainty with these figures and in our view ensures the approach, with reasonable certainty, that there will be no adverse effect on site integrity. Natural England therefore recommends that a 20% precautionary buffer is built into the calculation.

5.49 There may be instances where it is the view of the competent authority that an alternative precautionary buffer should be used based on a site-specific basis where sufficient evidence allows the legal tests to be met. Table 6 sets out a worked example of stage 4.

Table 6 Nitrogen/ Phosphorus Load Budget

STAGE 4 - WORKED EXAMPLE TO CALCUATE THE NET CHANGE IN NITROGEN AND PHOSPHORUS LOAD FROM THE DEVELOPMENT				
Step	**Measurement**	**Value**	**Unit**	**Explanation**
1	Identify Nitrogen load from wastewater (stage 1) Phosphorus load from wastewater (stage 1)	2602 173	kg N/yr kg P/yr	See Table 1
2	Calculate the net change in Nitrogen and Phosphorus from land use change - subtract existing land uses Nitrogen/Phosphorus load (stage 2) from future land uses Nitrogen/Phosphorus load (stage 3)	-613 11.9	kg N/yr kg P/yr	479 - 1,092 kgN/yr 26.3 - 14.4 kgP/yr
3	**Determine Nitrogen/ Phosphorus Budget** – Step 1 plus step 2 of this table (the latter figure may be positive ie the change in land use will generate more nitrogen, or negative ie the change in land use will generate less Nitrogen/ Phosphorus)	1,989 184.9	kg N/yr kg P/yr	2602 kg N/yr (step 1) + (-613)(step 2) 173 kg P/yr (step 1) + 11.9 (step 2)
4	Nitrogen/ Phosphorus Budget without buffer	1,989 184.9	kg N /yr kg P/yr	
5	Divide Nitrogen/ Phosphorus Budget without buffer by 5 **(Do not apply buffer if step 4 is a negative figure)**	397.8 36.98	kg N /yr kg P/yr	1,989 kg N/yr divide by 5 184.9 divide by 5
6	Identify Nitrogen/ Phosphorus Buffer with 20% buffer	2,386.8 221.88	kg N /yr kg P/yr	Add step 4 to step 5 of this table
Nutrient Budget with 20% buffer	2,386.8 kg N /yr 221.88 kg P/yr			

Section B

Methodology for calculating TN and TP budgets for package treatment plants (PTPs)

5.50 The Environment Agency has a presumption against private sewage treatment works in sewered areas and will always seek connection to the mains sewer where possible and practicable. A principle concern relates to the failure rates of package treatment plants (PTPs) and the lack of review and periodic upgrades via regulatory systems that apply to mains. There will be site specific factors (e.g. in proximity to watercourses, soil saturation levels, etc.) that would need to be considered when evaluating this risk.

5.51 Further advice from the Environmental Agency on the use of PTP may be found at - https://www.gov.uk/guidance/discharges-to-surface-water-and-groundwater-environmental-permits. Additional guidance may also be available via local planning authorities. The following advice is only provided in relation to nutrient neutrality and is provided on the basis that the developer and/or planning authority have ensured that the Environment Agency is satisfied that a PTP is appropriate for the proposed development.

5.52 Where development proposals include use of PTPs, or similar, it is recommended that the TN and TP level is calculated on a per person basis. On average each person produces sewage containing 0.0035 tonnes of nitrogen per year (3.5 kilograms)[9] and 0.99 kg of P[10]. The TN prior to treatment = number of additional population x 3.5 kg = kg TN/yr . The TP prior to treatment = number of additional population x 0.99 kg = kg TP/yr.

5.53 The percentage reduction of TN and TP that may be applied as result of treatment will depend on the efficiency of the treatment processes employed and must be assessed on a case-by-case basis. The evidence supporting the efficiency of PTPs should include the test result documents from the lab (in English) and/ or measured effluent concentrations from real world applications, not just the covering certificate. Information will also need to be provided on the long term monitoring and management of these installations and this will need to be secured.

5.54 Bespoke calculations of the TN/TP load may be possible for larger PTPs in instances where sufficient evidence of the performance of the system in removing nitrogen and phosphorus is provided. In addition to the above, the evidence will need to include, as a minimum, a full year of operation and supporting information to ensure that the concentration of total nitrogen and phosphorus within the effluent can be reliably predicted. In these cases, early consultation with Natural England, through our charged advice service, and the competent authority is recommended.

[9] Nitrogen reduction in Poole Harbour Supplementary Planning Document. If data more suitable to the Stour is available these figures can be used

[10] Taken from upper range values quoted in for human excreta (1.7g/dy) plus detergents (1.0g/dy) x 365 days in Natural England 2015 The impact of phosphorus inputs from small discharges on designated freshwater sites (NECR170)

5.55 Table 7 sets out a worked example for Stage 1. Stages 2, 3 and 4 of the above methodology can then be applied.

Table 7 Alternative Stage 1 methodology for package treatment plants (PTPs)

STAGE 1 - WORKED EXAMPLE TO CALCULATE TOTAL NITROGEN (TN) AND TOTAL PHOSPHORUS (TP) LOAD FROM DEVELOPMENT WASTEWATER WITH AN ON-SITE PTP (prior to treatment)				
Step	**Measurement**	**Value**	**Unit**	**Explanation**
Development proposal	Development types that would increase the population served by a wastewater system	100	Residential dwellings	
Step 1	Additional population	240	Persons	Based on average household size of 2.4
Step 2	TN prior to treatment Based on 3.5 kg TN per person per year TP prior to treatment Based on 0.99 kg TP per person per year	840 237.6	kg TN /yr kg TP/ yr	240 (step 1) x 3.5 kg TN per person per yr 0.99 kg TP per person per yr
Step 3	Receiving PTP TN reduction efficiency Receiving PTP TP reduction efficient	70 80	% %	Efficiency of PTP used must be evidenced this is just illustrative example.
Step 4	TN discharged after PTP treatment TP discharge after PTP treatment	252 47.52	kg TN /yr kg TP/yr	30% of 840 20 % of 237.6
Stage 4 (included as example where no land use change has occurred)	Apply 20% precautionary buffer	302.4 57.02		120% of step 4 1.2x252 1.2 x 47.52
PTP Total Nutrient Load (including Stage 4 20% Buffer)	**Nitrogen 302.4 kg TN / Yr** **Phosphorus 57.02 kg TP/Yr**			

SECTION 6 MITIGATION

Introduction

6.1 If there is a nitrogen and/ or phosphorus surplus (a positive figure), then mitigation is required to achieve nutrient neutrality. If the calculation identifies a deficit (a negative figure), no additional mitigation is required. In the worked example described in the methodology, the nitrogen budget with 20% buffer is 2,386.8 kg TN/yr and the phosphorus budget is 221.88 kg TP/yr. Neutrality would therefore require appropriate mitigation measures that would remove a minimum of 2,387kg TN/yr and 222 kg TP/yr.

6.2 Mitigation can be through direct measures, e.g. interceptor wetlands that prevent nutrient from entering the site or 'indirect' by taking land out of nitrogen/ phosphorus intensive uses, e.g. crops or intensive livestock systems that result in an excess of nitrogen or phosphorus lost to the water environment. This indirect mitigation can be referred to as offsetting.

6.3 The purpose of the mitigation measures is to avoid impacts on the designated sites rather than compensating for the impacts once they have occurred. Avoiding impacts is achieved by neutralising the additional nutrient burden that will arise from the proposed development, achieving a net zero change at the designated sites in a timely manner.

6.4 To ensure it is effective mitigation, any scheme for neutralising nitrogen and/ or phosphorus must be certain at the time of appropriate assessment as part of the HRA, so that no reasonable scientific doubt remains as to the effects of the development on the international sites. This will need consideration of the delivery of mitigation, its enforceability and the need for securing the adopted measures for the duration of the development's effects, generally 80-125 years.

6.5 Schemes that are being delivered by other sectors (for example water industry and agricultural sector) for the purpose of meeting the necessary conservation measures designed for the international sites and to take appropriate steps to avoid the deterioration of the international sites should not also be used as mitigation for plans and projects, as this would compromise the original purpose and would be unlikely to meet the legal tests of the Habitats Regulations.

6.6 Further information has been included in this section on recommended mitigation measures. Each mitigation scheme will be assessed on its own merits and on a case by case basis, based on the submitted evidence. We recommend applicants to discuss options with local planning authorities and Natural England through our charged advice service, at the earliest opportunity. However, it is ultimately the decision of the local planning authorities, as competent authorities, to determine the suitability of the proposed mitigation scheme in line with the legal tests in the Habitats Regulations.

Types of mitigation

Conversion of agricultural land for community and wildlife benefits

6.7 Permanent land use change by converting agricultural land with higher nitrogen/ phosphorus loading to alternative uses with lower nitrogen/ phosphorus loading, such as for local communities, wildlife, and under schemes for flood management or to deliver the UK Government's Net Zero greenhouse gas emissions target by 2050[i], is one way of neutralising nutrient burdens from development. It is important to retain the best and most versatile agricultural land in food production, particularly food crop production. However, there are a number of reasons to support conversion of agricultural land where the land is less economic to farm. There may also be a wide range of incidental benefits for the local community and wildlife from this change, as well as delivery of wider planning policy objectives and climate emergency pledges.

On-site options

6.8 One option is to increase the size of the SANGs and Open Space provision for the development on agricultural land that reduces the nitrogen/ phosphorus loss from this source. This can be secured as designated open space or by other legal mechanisms.

Off-site options

6.9 Another option is to acquire, or support others in acquiring, agricultural land elsewhere within the Stour river catchment area. By changing the land use in perpetuity (e.g. to woodland, heathland, saltmarsh, wetland or conservation grassland), this reduces the nutrient loss from this source.

6.10 Mitigation land should be appropriately secured to ensure that at the time of the appropriate assessment it is certain that the benefits will be delivered in the long term. Natural England advises that this can be achieved through an appropriate change of ownership to a local planning authority or non-government organisation. However, it is recognised that there may be other legal mechanisms available to the competent authority to ensure deliverability and enforceability of a mitigation proposal. These can be considered on a case-by-case basis.

6.11 Such land use change should deliver multiple public benefits that can incidentally meet other government targets. There are wildlife and biodiversity benefits by enhancing ecological corridors and key sites identified in the Local Nature Partnership network or which form part of the nature recovery network. This land can buffer existing nature reserves and ancient woodland. It can also create priority habitats such as heathland, saltmarsh, wetland or conservation grassland.

6.12 Small scale developments are encouraged to consider opportunities for providing local small scale mitigation measures that deliver multiple benefits. Possible options include the creation of local wetlands, local nature reserves, community orchards (without nutrient inputs), or copse. Another example is to turn a strip (in excess of 10m width) of agricultural land immediately adjacent to a public footpath into a greenway. This could be demarcated by hedges or woodland planting for both public and wildlife benefits.

Woodland planting

6.13 Woodland planting on agricultural land is a means of securing permanent land use change without necessitating land purchase. It can be evidenced easily by aerial photography and site visits. The minimum level of woodland planting required to be considered land use change is 20% canopy cover at maturity. In very broad terms, this equates to 100 trees per hectare, although this is dependent on the type of trees planted and there are also options that this can be achieved by natural regeneration, especially if adjacent to existing native woodland. In the Stour Valley this should be achieved by use of native broadleaf species of local provenance, to secure wider biodiversity gains and reduce risk of non-native species and disease spread to the existing internationally protected woodland in the valley. A nitrogen leaching rate from semi-natural native woodland planting is likely to equate to 5 kg/ha/yr and phosphorus of 0.02 kg/ha/yr.

6.14 In a relatively short time, the woodland planting would require a felling licence and woodland removal would also be covered by the EIA Regulations where woodland is planted as mitigation for internationally designated sites. There are therefore a number of layers of security for the competent authorities to ensure this mitigation is being delivered effectively. Planted woodland does require management for the first decade in terms of plug fencing and maintenance until the canopy has reached above browsing height, thereafter management is relatively minimal though some thinning is preferable to enable mature trees to develop.

6.15 Woodland planting would secure carbon capture, biodiversity and recreational benefits. The established woodlands could also be used for wood fuel production or coppice timber production.

Wetlands

6.16 Wetlands receiving nutrient-rich water can remove a proportion of this nitrogen/ phosphorus through natural processes. Wetlands can be designed as part of a sustainable urban drainage (SUDs) system, taking urban runoff/ stormwater; discharges from WwTWs can be routed through wetlands; or the flow, or part of the flow, of existing streams or rivers can be diverted through wetlands though alteration of natural drainage channels should be discouraged.

6.17 Wetlands deliver incidental wildlife and biodiversity benefits, with possible drainage and flood defence benefits (by reducing risk of harm from natural hazards). Further possible benefits arise from increased infiltration into groundwater and these systems can help make communities more climate change resilient. If the wetlands can be accessible, through the provision of boardwalks, then there will also be benefits for wellbeing. It is essential that wetlands and SUDs are maintained to provide ongoing nutrient removal. Provisions for resourcing the ongoing maintenance of SUDs will need to be secured with any planning permission. Further information on the potential for nitrogen and phosphorus mitigation using wetlands is included in Appendix 7.

Wastewater Treatment Work Upgrades

6.18 Mitigation options at WwTWs theoretically include the agreement with the wastewater treatment provider that they will maintain an increase in nitrogen or phosphorus removal at the WwTW. Upgrades to WwTW that are managed by the water sector are undertaken through a specific water industry regulatory process. Securing upgrades to WwTW can only be achieved via this regulatory process.

6.19 There may also be opportunities to progress a wetland at a WwTWs, at the final stage of the process, once the permit consents have been met. It is possible to discharge the WwTWs outfall through wetlands, prior to release into the wider environment. Further details of this option are included in Appendix 7.

Size of mitigation land

6.20 The mitigation land must be sufficient to ensure the legal tests in the Habitats Regulations can be met. For some types of mitigation, for example wetlands, there can be minimum sizes for nutrient removal processes to be effective (see Appendix 7).

6.21 Larger schemes create more opportunities for other sources of funding. Land that is taken out of agriculture for nutrient mitigation could also qualify for additional funding for future management to meet other legislative and policy requirements. For example, with additional management and infrastructure, this land may qualify as SANG to relieve recreational pressure on international designated sites. Furthermore, larger schemes have the potential to deliver wider community and biodiversity benefits and these options should be encouraged where possible.

6.22 Smaller schemes will also be acceptable where the legal tests in the Habitats Regulations are met so there is certainty around these measures, for example, their deliverability, enforceability and long term use.

Location of mitigation

6.23 The location of the mitigation site will also influence the effectiveness of the measure. The appropriate location for mitigation land firstly depends on the catchment of the development and location of the WwTWs outfall. Consideration then needs to be given to site specific factors such as geology, hydrology and topography.

Identifying the catchment for mitigation land

6.24 The fluvial catchment for the Stodmarsh internationally designated sites is shown on Figure 1.

6.25 A key objective is to ensure mitigation land is situated in the most effective location. If interception of WwTW stream is required, then mitigation should be situated as close to the works as possible. The mitigation should be in the same sub-catchment as the discharge location.

Drain to ground

6.26 For developments that drain to ground via a package treatment plant (PTP), septic tank or mains WwTWs, it is appropriate for mitigation land to be within the same catchment as the outfall location of the PTP or WwTW.

Temporal principles

6.27 Within chalk geology where the nitrogen or phosphorus discharge is to ground and remote from watercourses there is likely to be a considerable delay or it may be significantly attenuated. In such circumstances mitigation measures that take effect quickly may not need to be implemented immediately. We advise that these issues are examined on a case by case basis in consultation with the relevant local planning authority or authorities and Natural England.

6.28 Sites that are downstream of the WwTWs and upstream of the designated sites are ideally located to reduce the nutrient load reaching the designated sites. It is our preference that mitigation sites are prioritised within the lower fluvial catchment and close to but upstream of the Stodmarsh site. Sites that are located on tertiary geology or clay are preferred or sites that are located on the break of slope onto chalk bedrock. These sites reduce the time lag between the nutrient benefits of changes to land use within the catchment and the benefits to the designated sites.

6.29 For mitigation sites located on the upper fluvial catchment of the Stour on the chalk bedrock, without any water course in close proximity, there may be a time lag for consideration. It is our advice that the depth of the chalk groundwater is considered. For sites where the groundwater is more than 5m below ground level, then this land is unlikely to be appropriate for mitigation for short term development. Although it may be appropriate for development that is phased over more than 5 years, provided the mitigation land is delivered straightaway.

6.30 There may be sites where there is evidence of a short time lag between nutrient reduction at the mitigation site and the designated sites, or where the mitigation site is located on a geology or in an area that will result in additional benefits for nutrient removal, over and above the change in land use at the site itself. These options will be considered on a case-by-case basis.

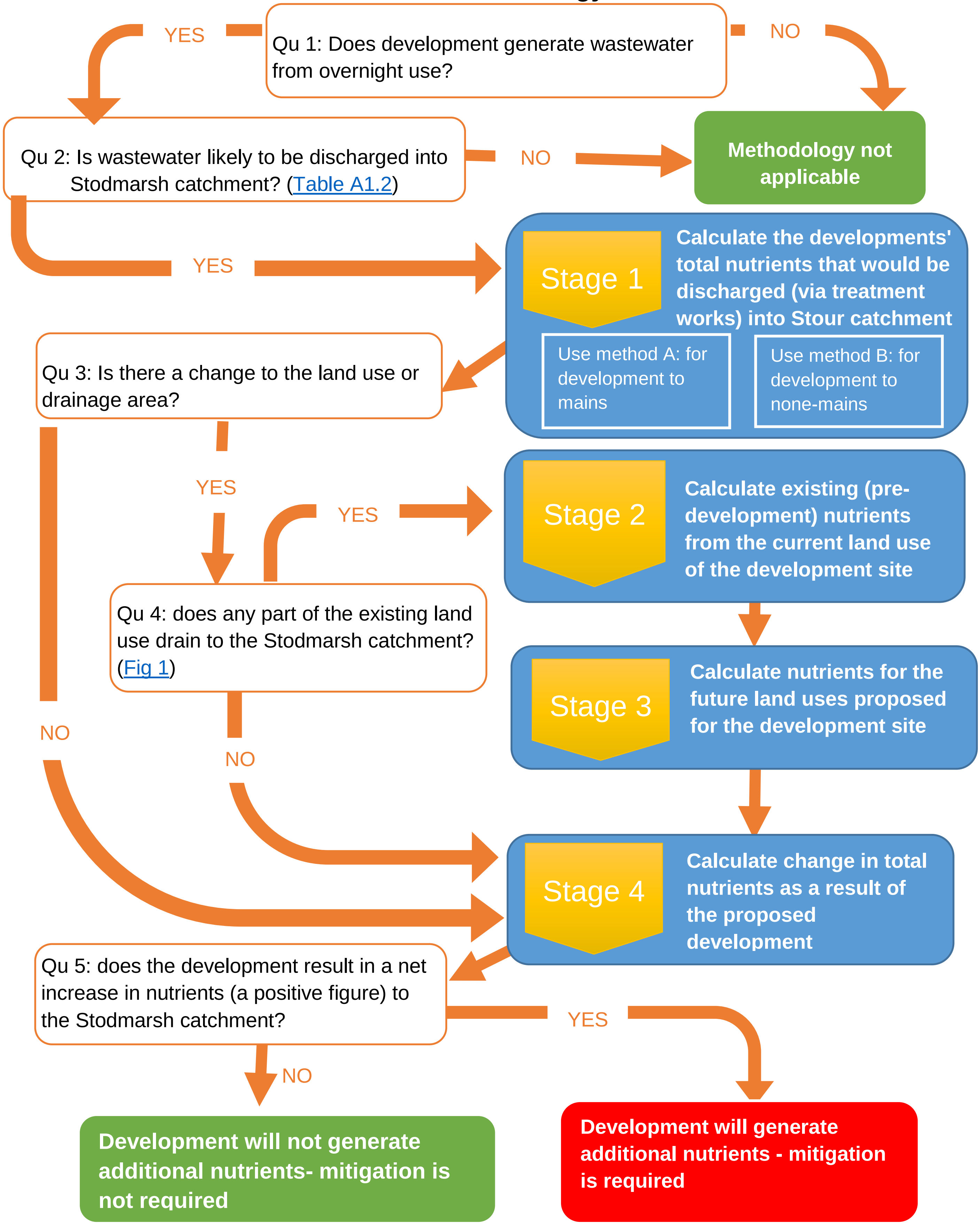
Strategic Solutions

6.31 It is appreciated that achieving nutrient neutrality may be difficult for smaller developments, developments on brownfield land, or developments that are well-progressed in the planning system. Natural England is working closely with local planning authorities to progress Borough/ District/ City wide and more strategic options that achieve nutrient neutrality and enable this scale of development to come forward.

6.32 Further information will be available on the local authority websites in due course. Natural England can provide further advice on the methodology and mitigation options through our chargeable services (DAS).

Figure 2

Nutrient Assessment methodology – Decision Tree



Notes for Decision Tree

Question 1 – This includes housing development and tourist development. This is covered in type of development section

Question 2 –The wastewater treatment works to which this advice applies are listed in Table A1.2 and the land drainage area to which this advice applies is shown in Figure 1. See Appendix 1 for further details on location.

Question 3 – If the development is converting an existing urban use that does not generate overnight stays (such as office accommodation or employment land) to other urban use then this is not considered a change of land use for offsetting purposes. If urban land is being converted to a park or greenspace this should be included in the land use calculation. Further information on this is contained the stage 2 and 3 calculation of the methodology

Question 4 - if the land use does not drain to the catchment its existing nutrients are not contributing to the failures or risk of failures of the designated sites water quality standards and cannot be used to offset the nutrients from wastewater. If the existing site drains into two catchments only the area that currently (before proposed development) drains into the Stodmarsh catchment (within the lower Stour) can be used for offsetting.

Question 5 - This is covered in stage 4 of the methodology.

Appendix 1

Spatial Extent Covered by this Advice

A1.1 The Environment Agency's Water Industry National Environment Programme (WINEP) investigation scope has agreed the water company assets that are to be part of the investigation into impacts on Stodmarsh designated sites (June 2020).

A1.2 At this time Natural England cannot rule out on objective evidence a likely significant effect on Stodmarsh European sites of development land drainage or effluent from works that discharge upstream in the Stour and downstream (for the tidal lake and during overtopping). Figure 1 in the main document shows the main rivers in the Stodmarsh area. Stodmarsh sits in the Environment Agency Stour management catchment, Figure A1.1 shows the environmental designations in the Stour Catchment. Links to Environment Agency maps and details of the operational management catchments within the Stour management catchment are listed in the table A1.1 below.

A1.3 Natural England recommend that an appropriate assessment of water quality impacts on the designated sites is undertaken for developments that are within, or discharge to, WwTW that are within those catchments mapped in Figure 1 and/ or listed in table A1.1 and table A1.2. Developments where the effluent and drainage goes to works in the operational catchments listed as excluded are not considered to have a hydrological connection to Stodmarsh designated sites. The WwTW listed are those existing Southern Water continuous discharge assets that are in the WINEP investigation, however if discharge from new development goes to an asset in the catchment but not owned by Southern Water, or a new asset is proposed then that should also be assessed.

Table A1.1 Stour Operational Catchment Links

Stour Operational Catchments INCLUDED in the Stodmarsh Advice	Stour Operational Catchments EXCLUDED from the Stodmarsh Advice
Stour Lower	Dour
Stour Upper	North and South Streams
Little Stour and Wingham	Oyster Coast Brooks (Part only see Figure 1)
Kent East Coast TRaC (Part only see Figure 1 and list of WwTW)	Kent East Coast TRaC (Part only see Figure 1 and list of WwTW)
Oyster Coast Brooks (Part only see Figure 1 and list of WwTW)	Stour Marshes (Part only see Figure 1 and list of WwTW)
Stour Marshes (Part only see Figure 1 and list of WwTW)	

Table A 1.2 Waste Water Treatment Works covered by this Guidance

Southern Water Waste Water Treatment Works Continuous Discharges considered as part of WINEP investigation * (waterbody/ catchment into which it discharges in brackets)	TP Limit current (planned permit by 2024 in brackets)	TN Limit current	Population Equivalent (2020)
Ashford (Bybrook)WwTW **(Stour -Ashford Wye)**	0.5 mg/l OSM**	None	115,149
Canterbury WwTW **(Stour A2 to West Stourmouth)**	2 mg/l	None	72,498
Charing Wwtw **(Upper Great Stour)**	1 mg/l (OSM only) (0.5 mg/l by 2024)	None	2,057
Chartham Wwtw **(Stour Wye –A2)**	None	None	6,966
Chilham **(Stour Wye- A2)**	None	None	946
Dambridge **(Wingham)**	2 mg/l (0.25 mg/l by 2024)	None	21,347
Lenham Wwtw **(Upper Great Stour)**	1 mg/l (OSM only) (0.5 mg/l by 2024)	None	3,206
May St (Herne Bay) WwTW **(Oyster coast brooks)**	2 mg/l (0.3 mg/l by 2024)	None	43,025
Newnham valley WwTW **(Little Stour)**	None (1 mg/l by 2024)	None	7,372
Sellindge WwTW **(East Stour)**	1 mg/l OSM annual mean (0.5 mg/l by 2024)	None	5,443
Westbere WwTW **(Stour A2 to West Stourmouth)**	None	None	6,503
Wye **(Stour –Ashford Wye)**	None	None	2,135
Good intent cottages WwTW **Nats Lane Brook WwTW** **Westwell WwTW**	None None None	None None None	15 308 216

*Natural England have excluded Minster WwTW from this advice as we have objective evidence that there is no pathway to Stodmarsh for inputs below Plucks Gutter on the Stour.

** This works has an UWWTD annual mean figure of 1 mg/l but the OSM figure is sufficiently certain to be used for planning purposes.

Figure A1.1 Designations in the Stodmarsh River Catchment

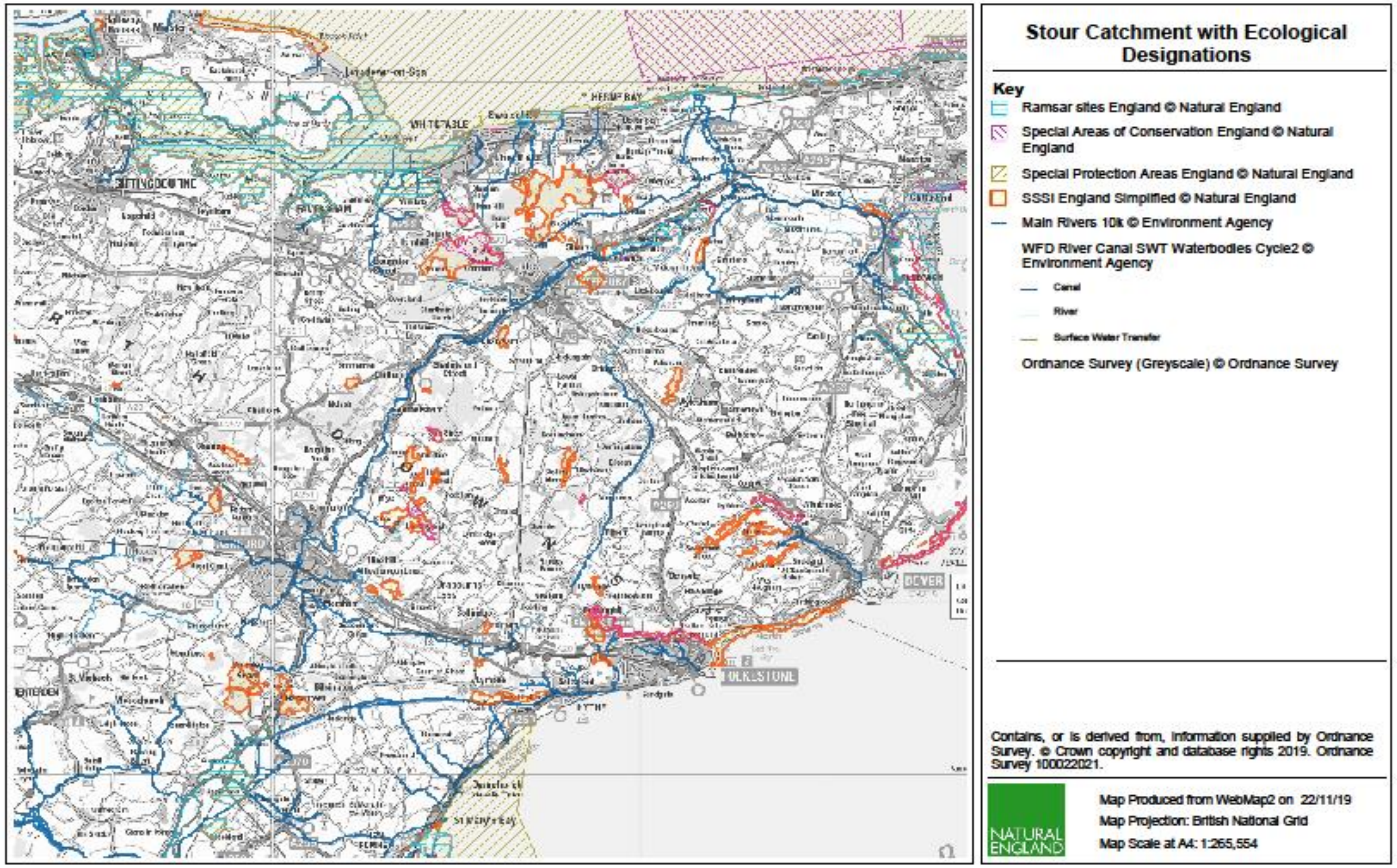
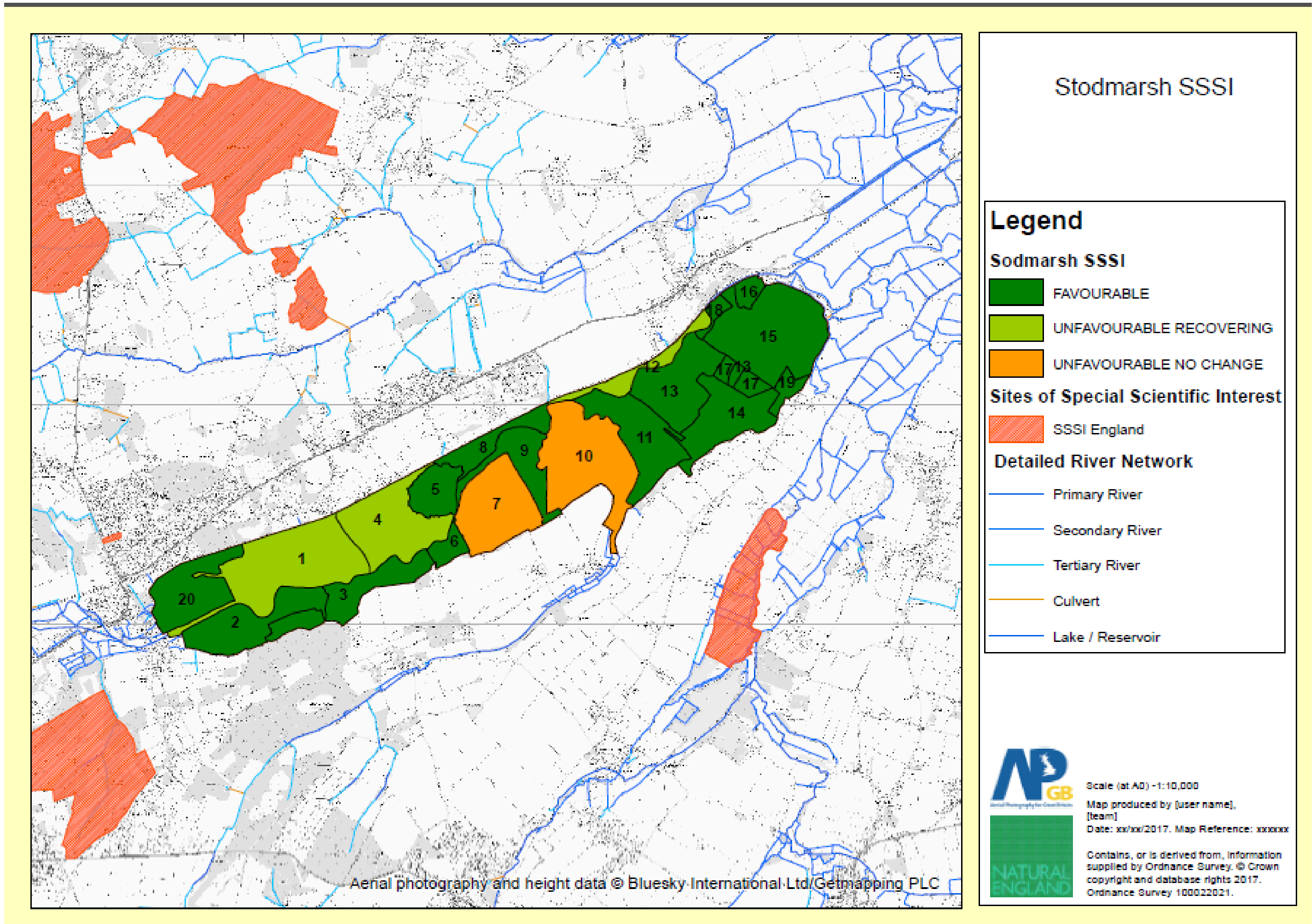


Figure A1.2 Stodmarsh SSSI unit condition



Appendix 2

PLANNING CONTEXT

Natural England's Position

A2.1 It is Natural England's view that there is a likely significant effect on several internationally designated sites in the Stour Valley (Special Protection Area, Special Area of Conservation and Ramsar site) due to the increase in wastewater from the new developments coming forward.

A2.2 The uncertainty about the impact of new development on designated sites needs to be recognised for all development proposals that are subject to new planning permissions and have inevitable wastewater implications. These implications, and all other matters capable of having a significant effect on designated sites in the Stour Valley, must be addressed in line with Regulation 63 of the Conservation of Habitats and Species Regulations 2017 (as amended).

A2.3 Where there is a likelihood of significant effects (excluding any measures intended to avoid or reduce harmful effects on the European site), or significant effects cannot be ruled out, a competent authority should fully assess (by way of an "appropriate assessment") the implications of the proposal in view of the conservation objectives for the European site(s) in question. Appropriate assessments cannot have lacunae and must contain complete, precise and definitive findings and conclusions capable of removing all reasonable scientific doubt as to the effects of the works proposed on the protected site concerned. The Local Planning Authority, as competent authority, may agree to the plan or project only after having ascertained that it will not adversely affect the integrity of the international sites.

A2.4 Natural England advises that the impacts of wastewater on designated sites from new development, in the interim until the WINEP investigation reports and any identified solutions are implemented, are examined within appropriate assessments and that the existing nutrient and conservation status of the receiving waters be taken into account.

A2.5 LPAs and applicants will be aware of recent CJEU decisions regarding the assessment of elements of a proposal aimed toward mitigating adverse effects on designated sites and the need for certainty that mitigating measures will achieve their aims. The achievement of nutrient neutrality, if scientifically and practically effective, is a means of ensuring that development does not add to existing nutrient burdens.

A2.6 LPAs have duties to conserve and enhance Sites of Special Scientific Interest (SSSIs) consistent with the proper exercise of their functions and to exercise those functions in a way that prevents deterioration of habitats and birds and has regard to the achievement of favourable conservation status for international sites. The LPAs should give consideration if application of neutrality would hinder the ability to restore the sites conservation objectives.

Joint working

A2.7 Natural England is working with water companies, local planning authorities, stakeholders and the Environment Agency to try to ensure the Habitats Regulations are met.

A2.8 Natural England will be working closely with local planning authorities to progress options that achieve nutrient neutrality. It is appreciated that this may be difficult for smaller developments, developments on brownfield land or developments that are well-progressed in the planning system.

A2.9 Natural England will be advising affected local planning authorities to set up authority-wide or strategic approaches that developments can contribute to thereby ensuring that this uncertainty is addressed in so far as is reasonably practicable by all applications and will be working closely with affected local planning authorities to help address this issue.

A2.10 All queries in relation to the application of this methodology to specific applications or development of strategic solutions will be treated as pre-application advice and therefore subject to chargeable services.

Appendix 3

Environmental Context

Designated sites interest features

A3.1 Stodmarsh is a Special Protection Area (SPA), a Ramsar site, a Special Area of Conservation (SAC), a Site of Special Scientific Interest (SSSI) and some parts are a National Nature Reserve (NNR). The site is of national and international importance for a range of water-dependant habitats including lakes and the wildlife that relies these habitats. The designations and features are described in table A3.1 (below) along with links to key documents of interest.

Designated sites water quality target review

A3.2 The water quality targets for the Stodmarsh SPA/ SAC/ SSSI lakes were agreed with the Environment Agency in 2017 (and 2019 for Hersden Lake). These targets are based on national water quality standards for freshwater habitats and are in the published supplementary advice to the conservation objectives for the designated sites underpinning habitat. These targets include standards for nitrogen and phosphorus as an excess of both nutrients can impact lake habitats which underpin the designated sites national and international interest features. Once the standards were agreed, Natural England assessed the available data for water quality in the Stodmarsh lakes using the Environment Agency catchment data explorer and any available data against the newly agreed standards and if no data was available to Natural England the existing condition remained based on previous site data. Where the site condition was correctly identified in terms of water quality (e.g. unit 10) the existing condition remained. Subsequently as part of the WINEP programme the Environment Agency assessed their data against the lake standards and incorporated this into the measures specification form (scope) for the WINEP investigation.

A3.3 Detailed assessments of other features are available on Defra's Magic Map and condition assessments are not solely based on water quality standards. Table 1 in the main document sets out the agreed lake nitrogen and phosphorus standards and whether these standards are met or failed or if this is unknown due to lack of data (based on an amalgam of the Environment Agency and Natural England data for the WINEP investigation). Appendix 1 includes a map of SSSI unit condition. A brief summary of the condition classes follows. The information from the WINEP investigation will be used to inform a review of these lakes condition assessments with regards to the water quality attributes, including but not limited to nitrogen and phosphorus targets.

Favourable – high risk

A3.4 Some Stodmarsh lakes are in favourable condition as they are meeting the nutrient targets or, where data is not available to complete the assessment, the officer judgement has historically viewed them as having no significant signs of water quality impacts at last visit (though this may be significantly out-of-date). These units are all considered to be at risk of elevated nutrients due to lack of information on their nutrient status. Lakes in this category include Fordwich East and main Fordwich lake (unit 2) and Hersden lake (Unit 5). The tidal lake (Hersden lake) is only notified for bird features that are feeding on the benthic muds and therefore has less stringent water quality targets than the other lakes. Risks are described as “threats” on the Natural England designated sites database (CSMI).

Unfavourable recovering

A3.5 The Westbere lake (unit 1), passed the total phosphorus standard (based on Environment Agency Assessment of WFD status) but it is considered unfavourable for other reasons and is considered recovering on the basis of management measures to address the other impacts. It has a threat recorded due to the absence of adequate water quality data for lake assessments.

Unfavourable no change

A3.6 The main NNR lake and Collards lake are failing both the total phosphorus and total nitrogen standards based on Environment Agency assessment of WFD status. Since the sources of elevated nutrients have not been removed the lakes are not considered to be recovering. The condition assessment of the NNR lake (unit 10) already identified the water quality issues and was therefore not changed in 2018. Unit 10 condition assessment states “Study of Aufwuchs (prompted by algae bloom and fish kill events) indicates high nutrient levels in main NNR lake. (Total Phosphorus (TP) at 1 mg/l = 1000 ug/l …the target for SSSI lakes is [49]ug/l. More research is required to understand hydrological regime and water quality of input sources (Great Stour and Lampen Stream)”.

Joint working - Catchment work

A3.7 The high levels of nitrogen and phosphorus input to the water environment in the Stour catchment generally is currently caused by wastewater from existing housing and agricultural sources, though some local and within site process can occur in lake habitats and there are suspected mine waste contamination in some areas of the Stour. There are a number of mechanisms already in place to reduce the amount of nutrient inputs within our river and lake catchments and coastal waterbodies. Within the river Stour catchment; both Defra and partnership funded Catchment Sensitive Farming (CSF) programmes work with agriculture to reduce diffuse agricultural sources of pollution such as fertiliser and slurry run-off. One of the aims of this work is to deliver environmental benefits from reducing diffuse water pollution. To achieve these goals the CSF partnership delivers practical solutions and targeted support which should enable farmers and land managers to take voluntary action to reduce diffuse water pollution from agriculture to protect water bodies and the environment. The Stour has been a priority catchment under CSF since phase 1 (2006).

A3.8 Although catchment wide advice has been provided, often through newsletters and events, 1:1 advice and grant support; engagement has always been geographically focused based upon where the risks and issues are most apparent or where multiple issues overlap, and in order to make the most of available resources. Geographic targeting has been primarily focused around surface waterbodies although CSF have always tried to make provision for some sector specific targeting, for example dairies or large horticultural enterprises where direct point pollution or significant surface water flow may occur. The catchment contains numerous spring fed streams which flow over permeable chalk, sandstones and clays. Most of the farm land along the Stour has a brick earth element that can contribute to often rapid run-off of surface waters to the water courses. Current concerns in general waterbodies in the Stour catchment are nitrates and pesticide levels, as well as heightened sediment loads in streams in winter. Agricultural phosphorus is not considered to require separate consideration in the Stour catchment, and many measures primarily aimed at addressing agricultural nitrogen will also help reduce agricultural diffuse phosphorus.

A3.9 In addition, the wastewater treatment works (WwTW) that enter into the catchment of Stodmarsh are the subject of an investigation under Water Industry National Environment Programme (WINEP) which will determine the extent of the connection of WwTW and sewerage assets to the Stodmarsh lakes and to what extent the existing WwTW discharges and other company assets are contributing to the existing water quality failures and risk of failures. The investigation will take account of the need to reconnect some of the lakes more closely to the main river Stour in future to ensure sufficient water for the designated sites in the face of climate change and in light of recent experience of NNR staff of insufficient water for the conservation management of the site in hot dry summer of 2018. The primary objective of the WINEP investigation to assess what improvements are required (if any) to the water company assets needed to enable the achievement of the agreed lake standards.

Type of nutrient inputs to designated sites

A3.10 There is evidence that inputs of both phosphorus and nitrogen influence eutrophication of the water environment. The principal nutrient that tends to drive eutrophication in the marine environment is nitrogen, the principal nutrient that drives eutrophication in flowing freshwaters is phosphorus. In still freshwaters and many estuaries both phosphorus and nitrogen can result in eutrophication (called co-limitation). In reality the picture is more complicated than this. For Stodmarsh lakes the principal nutrients are: phosphorus and nitrogen based on the water quality standards in Common Standards Monitoring Guidance for the appropriate designated sites features and the Supplementary Advice to the Conservation Objectives (SACOs) for the SPA and SAC which also cover the Ramsar site.

A3.11 The best available evidence is for focus in the Stodmarsh/ Stour catchment to be on both nitrogen and phosphorus. However, this approach may be refined if greater understanding of the eutrophication issue is gained thorough new research or updated modelling or the WINEP investigation.

A3.12 The nutrient budget in this report calculates levels of nutrient from development however both phosphorus (P) and nitrogen (N) come in different forms and it is important to understand which is relevant to the designated site features in this methodology.

Phosphorus

A3.13 The forms of phosphorus need to be recognized when calculating nutrient budgets. The key measure for still and very slow flowing waters such as lakes or ditches is total phosphorus (TP) (plus in most cases total nitrogen) because this is available for algae and plant growth. For rivers the designated sites standards are for Soluble

Reactive Phosphorus (SRP) as both an annual and a growing season mean. The relationship between SRP and TP is not straight forward and can vary between, and even within catchments (e.g. River Avon catchment). Modern WwTW permits usually have values for total phosphorus and the Environment Agency guidance on technically achievable limit (TAL) is for total phosphorus. Total phosphorus (TP), has been chosen for the current methodology as it is applicable to the lake habitats at Stodmarsh. Farmscoper reports provide amount of farm total phosphorus and this is the default setting. Though there is some uncertainty from these different forms of phosphorus, this is taken into account at the end of the methodology by the addition of a correction factor.

Nitrogen

A3.14 The different forms of nitrogen need to be recognized when calculating nutrient budgets. The key measurement is total nitrogen (TN), i.e. both organic and inorganic forms of nitrogen, because this is what is available for plant growth. TN is the sum of the inorganic forms - nitrate-nitrogen (NO3-N), nitrite-nitrogen (NO2-N), ammonia, and organically bonded nitrogen.

A3.15 Total nitrogen is measured by WwTW where there is a permit with a TN limit consent. However, for WwTWs without permits, measurements could be inorganic nitrogen (nitrate + nitrite + ammoniacal N) or TN or a mix. Most river/coastal quality monitoring by the Environment Agency only records the inorganic N forms. Farmscoper reports measure nitrate-nitrogen not TN. Nitrate is normally the largest component of TN but quantities of organic N can be significant. For example in the Test catchment dissolved organic nitrogen has been found to comprise 7% of the potential biologically available nitrogen in the river and 13% of that in the estuary (Purdie, 2005[11]). Thus, the land use change element of this methodology will underestimate TN leaching. We therefore advise that this uncertainty is recognised and the recommended precautionary buffer approach is adopted.

[11] Purdie, D., Shaw, P., Gooday, A. and Homewood, J. (2005) Dissolved Organic Nitrogen in the River Test and Estuary, University of Southampton

Table A3.1 Designate Sites Interest Features

Designation	Links to Conservation Advice or equivalent	Interest features and links to citation or equivalent
Stodmarsh Site of Special Scientific Interest (SSSI)	Favourable condition tables (FCTs)	The interest features of the SSSI are described in full in the citation and are summarised below: • Wetland habitats including Swamp, fen and reedbed communities. • Standing waters- lake and ditch habitats • Desmoulin's whorl snail • Assemblage of Breeding Birds • Aggregations of rare Breeding Birds: • Aggregations of non-breeding birds • Assemblage of vascular plants • Assemblage of invertebrates (W211 open water on disturbed sediments and W314 permanent wet mire and rich fen communities)
Stodmarsh Special Protection Area	Conservation Objectives Supplementary Advice	The interest features of the SPA are described in full in the citation but are summarised below: • Great bittern (Non- Breeding) • Gadwall (Breeding and Non-Breeding) • Northern Shoveler (Non-Breeding) • Hen Harrier (Non-Breeding) • Waterbird Assemblage • Breeding Bird Assemblage
Stodmarsh Ramsar Site	The SACOs for the SPA and SAC and the FCTs for the underpinning SSSI for the SPA and SAC are considered to cover these features	The interest features of the Ramsar site are described in full in the Ramsar Information Sheet and are summarised below: Ramsar Criterion 2: • Assemblage or British Red Data book invertebrate species, • Assemblage of rare and scarce plans species • A diverse assemblage of rare wetland birds
Stodmarsh Special Area of Conservation (SAC)	Conservation Objectives Supplementary Advice	The interest features of the SAC are described in full in the citation and are summarised below: • Desmoulin's whorl snail

Source Apportionment

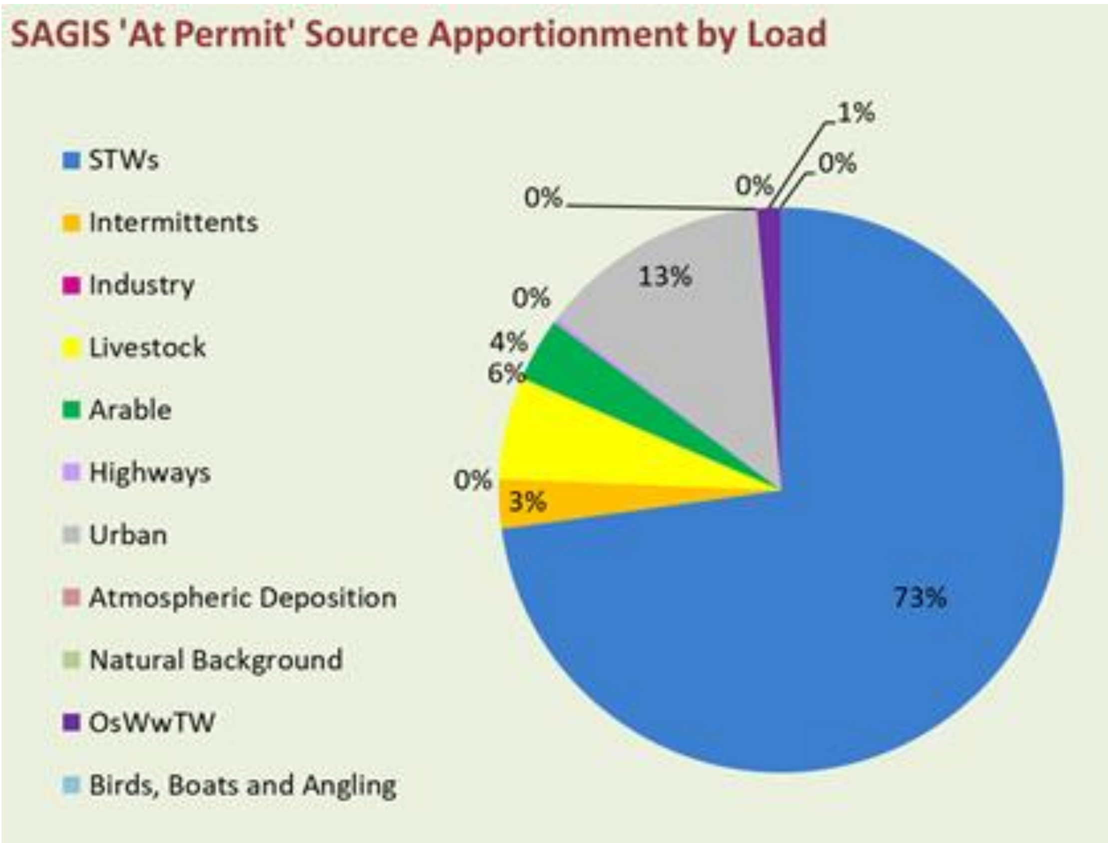
A3.16 The relative proportion of nutrients from difference sources is referred to as source apportionment. The standard industry models used by Environment Agency and water sector are SIMCAT and SAGIS. Figure A3.1 below, shows the phosphorus source apportionment provided by the Environment Agency from their PR19 planning work, estimating the permitted source apportionment by load at the bottom of the freshwater Stour downstream of the Canterbury WwTW at the closest sampling reference point to the Stodmarsh designated sites.

A3.17 The dataset was produced from a SAGIS model calibrated by the Environment Agency using SAGIS vs6a, Simcat data file Calibration SERBD v6 @permit model (Cal_Diff6_pit.dat 03417). The agricultural sources are from the ADAS PSYCHIC model based on the 2010 farm census. The WwTW flows and quality were based on observed data from 2010 to 2012.

A3.18 The majority of the phosphorus load at permit is from WwTWs and urban diffuse pollution in the catchment is larger than the total combined phosphorus loading from farming sources.

Figure A3.1 Permitted Source Apportionment in Stour nearest sluice into Stodmarsh

Though the SAGIS model has been calibrated it has not yet been validated. As such the values provided should be treated as estimates of the source apportionment at any given point. Permitted source apportionment is as if the WwTWs were operating at full permit capacity



Appendix 4 – Farm Types

A4.1 The following definition of farm types comes from the UK farm business survey guide to the farm business survey which underpins the Farmscoper model. The UK system is based on weighting the contributions of each enterprise in terms of their associated outputs. The weights used (known as 'Standard Outputs' or SOs) are calculated per hectare of crops and per head of livestock and used to calculate the total standard output associated with each part of the Farm Business.

Cereals

A4.2 Holdings on which cereals, combinable crops and set-aside account for more than two thirds of the total SO and (pre-2007) where set-aside alone did not account for more than two thirds of the total SO. (Holdings where set-aside accounted for more than two thirds of total SO were classified as specialist set aside and were included in “other” below.)

General cropping

A4.3 Holdings on which arable crops (including field scale vegetables) account for more than two thirds of the total SO, excluding holdings classified as *cereals;* holdings on which a mixture of arable and horticultural crops account for more than two thirds of their total SO excluding holdings classified as *horticulture* and holdings on which arable crops account for more than one third of their total SO and no other grouping accounts for more than one third.

Horticulture

A4.4 Holdings on which fruit (including vineyards), hardy nursery stock, glasshouse flowers and vegetables, market garden scale vegetables, outdoor bulbs and flowers, and mushrooms account for more than two thirds of their total SO.

Specialist Pigs

A4.5 Holdings on which pigs account for more than two thirds of their total SO.

Specialist Poultry

A4.6 Holdings on which Poultry account for more than two thirds of their total SO.

Dairy

A4.7 Holdings on which dairy cows account for more than two thirds of their total SO.

Lowland Grazing Livestock

A4.8 Holdings on which cattle, sheep and other grazing livestock account for more than two thirds of their total SO except holdings classified as *dairy.* A holding is classified as lowland if less than 50 per cent of its total area is in the Less Favoured Area (LFA).

Mixed

A4.9 Holdings for which none of the above categories accounts for more than 2/3 of total SO. This category includes mixed pigs and poultry farms as well as farms with a mixture of crops and livestock (where neither accounts for more than 2/3 of SOs).

Appendix 5 – Leaching of nitrogen/ phosphorus from urban areas

Urban leaching of Nitrogen

A5.1 The average total nitrogen leaching rate from an urban area used in this report is taken from the work done for the Solent Nutrient Neutral methodology which is explained below with comparison to and inclusion of local Stodmarsh/ Stour catchment data where available. Evidence that was sufficiently robust to justify significant deviation from this figure has not been identified. If locally specific values for urban land use nitrogen export have been calculated based on sound local evidence then these can replace the value given below.

A5.2 The original Solent value (14.3 kg/ha/yr) comes from values for hydrologically effective rainfall (478mm - precipitation minus losses from evapo-transpiration) and the nitrogen concentration of leachate (3 mg/l) given in Bryan *et al* (2013) the latter figure derived from an AMEC report. The value for nitrogen concentration is similar to one quoted in House *et al* (1993) who give a mean event concentration of 3.2 mg/l for total nitrogen (with this value derived from other sources) with a range of 0.4-20 mg/l. Thus although it is not specified by Bryan *et al* (2013), it is probably reasonable to take the 3 mg/l to be total nitrogen especially since the organic component of N from urban areas is likely to be relatively small.

A5.3 Mitchell (2001) gives the following event mean concentrations in mg/l total N from urban areas; Urban Open 1.68; Ind/Comm 1.52; Residential 2.85; Main roads 2.37. It is recognised that the datasets that produced these figures are not large (n = 14 in this case), a good deal of uncertainty remains and that further sampling is needed to validate models of pollutant effects from urban runoff (Leverett *et al* 2013).

A5.4 Typical nutrient concentrations in urban storm water runoff in the U.S. are 2.0 mg/l for total N (TN) (Schueler 2003). Population densities seem to be less in the most studied urban catchments (eg Groffman *et al* 2004 in Baltimore, Hobbie *et al* 2017 in Minnesota) than those in the UK but this does not necessarily lead to an increase in the rate of nitrogen leaching from the catchment as the factors affecting this value are complex. Thus although there will clearly be variation between different urban areas, there is insufficient knowledge to be able to predict N leaching from the different characteristics of these areas. And for practical purposes an overall N leaching figure is needed; nothing found in the literature indicates that another value would be more representative than 3 mg/l.

A5.5 An N leaching figure can also be derived by using the relationship between mean stream and river flow rate and catchment area. The ratio for the gauging station on the River Meon at Mislingford is $0.014m^3/sec/km^2$ and, with a TN concentration of 3 mg/l, this equates to a TN leaching rate of 13.2 mg/l, similar to the value obtained when hydrologically effective rainfall is used.

A5.6 Comparison can also be made with direct measurements of TN urban outputs from studies in the USA (Hobbie *et al* 2017, Groffman 2004). The values in the Hobbie paper for urban catchments in Minnesota varied from 12.5-27.2 kg/ha/yr with a mean of 17.3 kg/ha/yr. The outputs measured by Groffman (2004) were smaller (between 5.5 and 8.6 kg/ha/yr) but these were less urbanised catchments, several including areas of old growth forest where nitrogen retention was very high. Thus these values are broadly of the same order as the 14.3 kg/ha/yr leaching figure initially calculated.

A5.7 Nitrogen inputs in these studies come predominantly from three sources - atmospheric deposition, pet waste and lawn fertilisation. N deposition was slightly lower in both Baltimore and Minnesota than values from APIS in the around the Solent (23.8 kg/ha/yr for hedgerows or woodland, 14.7 kg/ha/yr for grassland) and those in the Stodmarsh area (23.52/ha/yr hedgerows and 13.44 kg/ha/yr neutral grassland). No UK studies have been found to compare with the US ones for N inputs in urban areas from pet waste or from lawn fertilisation. Should evidence of a more appropriate value be provided or derived Natural England will update this figure.

Urban leaching of Phosphorus

A5.8 No Stodmarsh/ Stour management catchment specific information was found for urban land and Farmscoper does not cover urban land. Therefore the urban/suburban export coefficient was taken from White and Hammond 2006 (0.83 kg/ha/yr.) This is the coefficient used for calculating the relative source apportionment in the first river basin cycle to UK river Basin Districts (RBD). Stodmarsh sits in the South East RBD and this was shown to have the highest relative contribution of phosphorus from households (both effluent and urban diffuse) compared to other sectors, with agriculture only contributing 21.8% of the South East RBD phosphorus load during the first river basin cycle (White and Hammond 2006). Though this export coefficient is from an older study, more recent studies have used values of a similar range for example Bryan (2015) uses 0.7 kg of P per hectare for urban areas in the River Avon Nutrient Management Plan modelling though this figure was based on studies mainly in Scotland.

A5.9 Duan *et al* (2012) found small urban catchments exported values of between 0.245 to 0.837 kg/ha/yr compared with much lower values from forested and very low density residential catchments (0.028 to 0.031 kg/ha/yr). The large range in Duan *et al* was explained by the relative density of roads and built structures in the existing catchments. The importance of housing and roads density but also proportion of impermeable surface in urban land was also reflected in a study by HR Wallingford commissioned by Natural England that looked at impacts of urban run-off of designated wetlands using a range of models (Natural England 2018). For new developments using the approach taken in this study the urban land is separated from SANGS and parks so the use of the higher end of these urban coefficients is relevant due to the relative density, though density in the Duan *et al* study were lower than the average UK value even in their higher density urban catchments.

A5.10 Phosphorus is made available in solution through a combination of physicochemical (adsorption/desorption and precipitation/dissolution) and biological/biochemical (mineralization/immobilization) processes. Geology is important in influencing the movement of nutrients through groundwater as it influences the minerals, pH (acidity/alkalinity) and the oxygen content of the waterbody. For example in chalk aquifers, a large proportion of the soluble reactive phosphorus (SRP) is removed from groundwater (as well as most other forms of P from agricultural sources) following a chemical reaction that results in the precipitation of phosphorus in the form calcium phosphate and adsorption (adhesion) to the rock matrix requiring regular soil testing (e.g. Mclaughlin *et al* 2011). Similar processes occur with phosphorus reacting with other minerals such as magnesium and iron. These reactions can be reversed with phosphorus moving back in to solution where the mineral content of groundwater and pH change in urban development. However recent evidence from China suggests the original soil type is still critical in urban phosphorus leaching (e.g. Wei *et al.,* 2019) provided sufficient permeable surface remains.

A5.11 Phosphorus is thought to be highly conserved in natural catchments (e.g. Verry and Timmons 1982, May *et al* 1996) but urban catchments have less phosphorus retention with the rate of retention being linked to the permeability of the urban environment and soil type (e.g. Duan *et al* 2012, Natural England 2018).

A5.12 Atmospheric deposition including from vehicles, leaching roads, fertilising gardens and parks including pet urine and waste have all been shown to be a significant source of P in urban catchments (e.g. Hobbie e*t al* 2017). Bryan, 2015 quotes several studies which examined levels of P in urban runoff in terms of Event Mean Concentrations (EMCs) as part of a wider project to develop a screening tool for Scotland and Northern Ireland to identify and characterise diffuse pollution pressures. The use of pulsed concentrations is relevant to urban land as the areas of impermeable surfaces tend to result in higher concentrations during rainfall events. Ockenden *et al* (2017) looks at the efficacy of different models including those that use export coefficients on predicting run-off of TP. This study found that temporal resolution of the underpinning rainfall data used in models was critical because "storm" events are so central to phosphorus transport. Few if any urban catchments have this level temporal resolution of data and therefore these models cannot be derived with any accuracy for the Stour catchment at this time.

Conclusion on urban P

A5.13 Based on the information above there is insufficient evidence to move away from 0.83 kg/ha for urban P leaching. Even though soils in the Stour valley are likely to show a high degree of P retention much export from urban land is from the impermeable surfaces and during high flow events therefore urban run-off has very little attenuation by soils so export coefficients towards the upper end of those observed are justified. Should evidence of a more appropriate value be provided or derived Natural England will update this figure.

Built Design to reduce phosphorus export from urban land

A5.14 Most studies have noted that the export of N and P from urban systems differ. Most P appears to export through high flows via surface drainage. Planning applications to reduce phosphorus should be designed to:

- Maximise permeable surfaces
- Implement Sustainable urban drainage schemes extensively based on larger wetlands (not ponds or detention basins) (see Appendix 5)
- Minimise composting of garden waste direct to catchment surfaces (though composting in structures should be encouraged)
- Maximise pet waste collection though this does nothing to address pet urine

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Appendix 6 - Estimating the leaching of total nitrogen (TN) and Phosphorus (TP) from natural greenspace (SANG)

A6.1 The value used in this methodology is based on work from the Solent Nutrient Neutral methodology and is set out below, APIS values for the Stodmarsh area have been used for the N deposition value which is the only change from the Solent methodology. However, if locally specific data on SANGS is available and evidenced this figure can be replaced by a locally derived figure, provided it is sufficiently well evidenced.

A6.2 A number of assumptions must be made about the management of the SANG to allow an estimate of TN/TP leaching to be made. These are as follows:

- The vegetation of the SANG would be predominantly permanent grassland but with an element of tree and scrub cover (this will of course vary for different SANGS but a 20% average figure is used here). The degree of tree and scrub cover will not greatly affect the result as both permanent grassland and woodland/scrub exhibit a high degree of N and P retention. It matters most because of the differences in the rate of atmospheric N and to a much lesser extent P deposition between the two habitats.
- The grassland would be permanent (ploughing will release large amounts of N/P) and is not fertilised either with artificial fertiliser or manures. It may be ungrazed or grazed very lightly (<0.1LU/ha/yr) with no supplementary feeding (even without supplementary feeding, grazing can increase N and to a much lesser extent P leaching because N retention is lower when N is delivered in the form of cattle urine and dung [Wachendorf *et al* 2005]).
- The grassland may be cut with the cutting regime dependent on other factors. Cuttings may be left or removed from site as the case may be but should not be gathered and composted in heaps on site. Any gorse within the scrub should be controlled so it is no more than rare across the mitigation area since a significant amount of nitrogen fixation occurs within gorse stands.

Nitrogen leaching

A6.3 A generic leaching value for N concentration from AMEC Poole Harbour study for ‘rough grazing’, quoted in Bryan *et al* (2013), is 2 mg/l. Using this concentration together with a value of 478mm for the hydrologically effective rainfall (HER) gives a leaching value for N of 9.6 kg/ha/yr. A similar value (8.8 kg/ha/yr) is obtained if the relationship between mean stream flow and catchment area (0.014 cumecs/km^2 which is the ratio for the gauging station on the nearby River Meon at Mislingford) is used instead, keeping the same N concentration of 2 mg/l. It is not clear whether these AMEC Poole Harbour concentrations are for total nitrogen or for inorganic nitrogen.

A6.4 The particular grassland management regime for which the 2 mg/l N concentration applied is not known. However, even though studies of N leaching from natural unfertilised grasslands are rare in the literature (most are of agricultural grasslands with fertiliser inputs of some sort) it seems likely that this value is higher than might be expected from a natural grassland with no fertiliser inputs such as a SANG. Thus for example TN leachate concentrations were between 0.44 and 0.67 mg/l in an extensively managed montane grassland (that still had one slurry application per year) and the equivalent mean TN loss was 1.0, 2.6 and 3.1 kg/ha/yr for three different areas (Fu *et al* 2017).

A6.5 Adjusting for a SANG with 20% woodland/scrub, using the AMEC woodland generic leaching value of 0.5 mg/l (Bryan *et al* 2013) for the woodland/scrub component, results in an N output of 8.1 kg/ha/yr.

A6.6 The 0.5 mg/l value is also much higher than the very low nitrate concentrations in streams from purely forested catchments (Groffman 2004) and from those reported by for a large sample of forested streams by Mulholland *et al* 2008 where the mean nitrate-N concentrations were <0.1 mg/l. All but a few of the samples from an unfertilised suburban lawn had nitrate-N concentrations below the detectable limit of 0.2 mg/l (Gold et al 1990). The same was true for a forest plot and the average nitrate-N losses from both home lawn and the forest plots averaged 1.35 kg/ha/yr over 2 years. These studies of both grassland and woodland nutrient cycling suggest that the N output of 9.6 kg/ha/yr from Amec quoted in Bryan is too high when applied to a SANG.

A6.7 Despite there being no direct N fertiliser inputs on a SANG, N inputs will still occur from three main sources. These are atmospheric deposition, pet waste and N fixation from legumes and estimating the contribution of each of these sources, together with the proportion of N retained, is an alternative method of working out the N contribution from a SANG.

N deposition

A6.8 The following are typical values taken from APIS for TN deposition in the Stodmarsh Area Grid reference TR214613 from Stodmarsh citation used (Solent area in brackets for comparison).

- Improved grassland 13.44 (14.7) kgN/ha/yr; Arable horticultural 13.44 (14.7) kgN/ha/yr; Neutral grassland 13.44 (14.7) kgN/ha/yr
- Hedgerows 23.52 (23.8) kg N/ha/year; Broadleaved, Mixed and Yew Woodland 23.52 (23.8) kg N/ha/year
- Using the value for hedgerows and woodland for the 20% scrub component of the hypothetical SANG and the neutral grassland value for the rest results in a deposition rate of 10.75 + 4.70 = 15.45 (11.76 + 4.76 = 16.52) kg/ha/yr.

N and Pet waste

A6.9 SANGs are specifically designed to attract increased levels of public access particularly dog walkers so the potential inputs of N from dog waste are likely to be significant. Hobbie *et al* (2017) give a figures for TN inputs from this source for entire urban areas and these vary between 3.56 and 21.2 kg/ha/yr for 7 urban catchments with a median of 6.9 kg/ha/yr. A figure of 17 kg/ha/yr can be gleaned from Baker 2001 which was worked out using information on pet numbers, nutritional needs, pet weights etc; 76% of this was from dogs.

A6.10 The heavy use of SANGS by dogs suggests that N inputs would most likely be higher than these figures averaged over the whole urban area. Nevertheless, inputs to the SANG from this waste means that it is not deposited elsewhere in the urban area where N may anyway end up in the same receiving water.

A6.11 TN retention in grasslands will also be higher than the average over other parts of the urban area but the characteristics of the inputs from dogs is likely to lower the amount of TN retained because the concentrated patchy nature of the input will reduce the proportion of TN retained compared with more evenly spread inputs, as mentioned above.

A6.12 Picking up dog faeces will obviously reduce the input from but not remove inputs from urine. Dog urine has a high N content.

A6.13 In these circumstances there is clearly uncertainty about the level of input from this source the highest figure from Hobbie *et al* 2017 (21.2 kg/ha/yr) has been used but adjusted downwards because not all of this will be from dogs resulting in an overall value of 16.1 kg/ha/yr.

A6.14 This has also been done on the basis that funding, together with a binding commitment, is provided for in perpetuity collection of dog waste and enforcement of pick up rather than relying on direct LA resources which could stop at any time.

TN fixation

A6.15 Hobbie *et al* (2017) give a value for this of 17.5 kg/ha/yr from direct investigation of unfertilised urban parks and this is the value used. Fixation would only be in the grassland part of the SANG which reduces the figure to 14 kg/ha/yr.

TN retention

A6.16 A number of studies have shown high TN retention in urban areas (eg 80% Hobbie et al 2017) thought to be mainly attributable to TN retention in urban grasslands and lawns which may be in turn related to high carbon within organic matter in the soils. The release of large quantities of N when permanent grassland is ploughed illustrates the capacity of these grassland for N storage (eg Howden *et al* 2011).

A6.17 Direct measurements of total N outputs from urban grasslands in the Groffman *et al* (2009) studies in Baltimore also show high N retention in urban grassland but there are difficulties in applying these results directly to SANGs partly because the plots were either quite heavily fertilised or may have had unmeasured N inputs from neighbouring land. Nitrate-N losses from an unfertilised home lawn averaged 1.35 kg/ha/yr over 2 years (Gold *et al* 1990). Generally the complex processes and uncertainties about how the management of these grasslands might affect the degree of TN retention and TN output makes estimation of the proportion retained difficult. Nevertheless a value of 90% given in Groffman *et al* (2009), and supported by a number of references given there, would seem reasonable considering also that overwatering and over fertilising, neither of which would happen on a SANG, seem to be factors that lead to more leaching.

A6.18 Woodland and scrub. N retention measured in forest plots in Baltimore was very high (95%) Groffman (2004). N percolation losses measured by Gold *et al* 1990 in forest plots were low and similar to those in unfertilised lawn. However, it is probably not valid to equate a scrub/woodland part of a SANG with the forest plots measured in the Groffman studies in Baltimore for these were old growth well established forests. Nevertheless there is still likely to be high N retention in these areas even if not as much as 95%.

A6.19 Given all of the above, a 90% TN retention rate over the SANG as a whole has been used in the calculation below

Inputs

A6.20 Solent specific APIS value in brackets

- N Deposition (APIS) = 15.45 (16.5) kg/ha/yr
- Pet waste 16.1 kg/ha/yr
- N fixation 14 kg/ha/yr
- Total = 45.55 (46.6) kg/yr
- Watershed retention of TN 90%

- Total TN output = 4.55 (4.66) kgN/ha/yr

Conclusion for Nitrogen

A6.21 The question of estimating TN outputs from a SANG has been approached from different angles. These investigations all indicate that the value used previously – 13 kg/ha/yr is too high. Instead a TN output of 5.0 kg/ha/yr is considered to be close to the true value but still sufficiently precautionary.

Phosphorus

A6.22 Export coefficients for phosphorus for different land cover classes were assessed and compiled by White and Hammond (2006) for the first River Basin Cycle source apportionment. They note the extremely low coefficient from natural land use such as woodland and unfertilised grassland; both habitats are given an export coefficient of 0.02 kg/ha/yr based on the rough grazing value of Jonnes 1996. Similar low phosphorus from natural habitats have been recorded from many other studies including more recent studies in the USA (e.g. Hobbie *et al* 2017, Duan *et al* 2012).

A6.23 These export coefficients take account of atmospheric deposition but are for natural habitats unlike SANGS which, although ecologically functioning as natural habitats, are designed to be used for informal recreation including dog walking. It is therefore reasonable to assume that pet waste and urine *into* SANGs will be equivalent to urban areas. Hobbie *et al* 2017 found that household nutrient inputs from pet (dog) waste contributed up to 76% of total P inputs in American catchments due to high pet ownership in urban environments - values of inputs for Phosphorus in Hobbie *et al* for dog waste were from 2.7 kg/ha/yr to 0.46 kg/ha/ yr with a mean of 1.21 kg/ha/yr. However P *output* from SANGS is likely to be significantly less as phosphorus is highly conserved in the natural land uses and the high contribution of pet waste to export coefficients of urban systems is partly due to the relative lack of permeability of the surfaces onto which the pet urine and waste are frequently deposited. In addition (as explained in Appendix 3) phosphorus is highly conserved on the types of soils found in the Stour valley. Using the mean rate of dog waste from Hobbie *et al* 2017 to be precautionary but assuming a high retention in any SANGS in the Stour valley of 90% gives a value as follows:

A6.24 Mean TP loading from pet waste to urban sites - 1.21 kg/ha/year

- Mean Catchment retention TP = 90%
- = TP 0.12 kg/ha/Yr

- +0.02 kg/ha/year - natural land export coefficient from Johnes 1996

= 0.14 kg TP/ha/yr

Conclusion for phosphorus

A6.25 Based on best available evidence SANGS value for Stour catchment of 0.14 kg TP/ha/yr has been estimated.

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Appendix 7– Potential for Nutrient (N&P) mitigation using wetlands

A7.1 Where N and or P budget calculations indicate that N and/ or P outputs from proposed developments are greater than pre development conditions, the use of new constructed wetlands to retain some of the N and P output is one mitigation option.

A7.2 There are a number of possibilities for different types of constructed wetland. Wetlands can be designed as part of a sustainable urban drainage (SUDs) system, taking urban runoff stormwater; discharges from Wastewater Treatment Works (WwTWs) can be routed through wetlands; or the flow, or part of the flow, of existing streams or rivers can be diverted through wetlands provided this does not adversely alter the ecological status of the river and does not increase flood risk. Environment Agency advice should always be sought in design of any wetland creation scheme.

A7.3 Wetlands receiving nutrient-rich water can remove a proportion of this nutrient through processes sedimentation, sorbing nutrients to the sediment, plant growth and process such as denitrification some of which were reviewed in Fisher and Acreman (2004) and numerous studies. A recent systematic review of the effectiveness of wetlands for N and P removal (Land *et al* 2016) used data from 203 wetlands worldwide of which the majority were free water surface (FWS) wetlands (similar in appearance and function to natural marshes with areas of open water, floating vegetation and emergent plants). The median removal rate for wetlands that were included in this review was 93g/m^2/yr TN and 1.2 g/m-^{2}/yr TP (or just under a tonne/ha/year TN and 12 kg/ha/yr TP). The proportion of N removed is termed the efficiency and the median efficiency of wetlands TN removal included in the Land review was 37%. Median remail efficiency for TP in the same review was 46 % with a 95 % confidence interval of 37–55 %.

A7.4 Many factors influence the rate of nutrient removal in a wetland the most important for being hydraulic loading (HLR - a function of the inlet flow rate and the wetland size), inlet N or P concentration and temperature and for TP the Area of the wetland. Together inlet N or P concentration and flow rate partially determine the amount of N or P that flows through the wetland which ultimately limits the amount of N or P saving that can be achieved.

A7.5 The rate of removal can also be expressed in terms of the amount of N or P removed per unit wetland area. This removal rate will typically increase as the inlet N or P concentration increases, at least within the normal range of inlet N or P concentrations. Thus wetlands that treat the N or P rich discharges, for example from WwTWs, or water in rivers where the N or P concentrations are high, will remove more N or P per unit area than say, wetlands treating water in a stream where water quality is very good and the N or P concentration is low. Thus if space is at a premium, and the goal is to remove as much N or P as possible, it makes sense to site wetlands where N or P concentrations are high in other words as close to WwTW as possible.

A7.6 For wetlands to work well, specialist design input based on sound environmental information will be necessary. There will be a need for consultation with relevant statutory bodies. These processes are likely to be easier where wetlands are an integral part of a larger development. Wetlands do offer additional benefits above offsetting but will also require ongoing monitoring, maintenance and adjustments beyond any particular developments completion. Consideration of the long term security of facilities and their adoption at an early stage is advisable.

A7.7 There are a number of publications which advise about constructed wetlands. For example, Kadlec and Wallace (2009) is a comprehensive source of information covering all stages related to the implementation of different types of constructed wetland. The many papers relating the results from detailed monitoring over many years of the performance of two constructed wetlands in Ohio, USA are also instructive (eg Mitsch *et al* 2005, 2006, 2014).

Stormwater/ flood wetlands

A7.8 These are what is termed event-driven precipitation wetlands with intermittent flows. There will normally be baseflow and stormwater / flood water components to the inputs.

A7.9 For such wetlands Kadlec and Wallace state that:-
'*A typical configuration consists of a sedimentation basin as a forebay followed by some combination of marshes and deeper pools'*

A7.10 However, ponds are usually less effective at removing N and P (Newman *et al* 2015) than shallow free water surface constructed wetlands (FWS wetlands) so the emphasis here should be on the latter although a small initial sedimentation basin is desirable since this is likely to reduce the maintenance requirement for sediment removal in the FWS wetland. One advantage of this type of wetland is that it can be designed as an integral part of SUDs for the development and therefore is subject to fewer constraints.

A7.11 Some wetlands with intermittent flows are prone to drying out and may need provisions for a supplemental water source. In some circumstances, this may be possible through positioning the wetland bottom so that there is some connection to groundwater. However many varieties of wetland vegetation can withstand drying out although there may be a small reduction in water quality improvement (Kadlec and Wallace 2009). Nevertheless base and stormwater flows to each wetland should be worked out to ensure that it is viable and will not add to the water resource issues of the relevant catchment. Initial flush of Phosphorus from soils on former intensively agricultural land was noted in the Land study and this may reduce the short and potentially even long term efficacy of such restored wetlands. Release of phosphorus associated with iron complexes under anaerobic conditions can also contribute to low or negative removal rates, as suggested by Healy and Cawley 2002 as an explanation for the observed low TP removal rates.

A7.12 Wetlands need to be appropriately sized taking into account the HLR and N or P loading rates. To give a general idea of the areas involved, a wetland 1ha in area would serve a development area of about 50 ha for Nitrogen but given the increased importance of area a larger area would be required for TP reduction from the same development. The Land *et al* review noted the inconsistency of TP reduction was particularly acute at wetlands below 2 hectares in size with wetlands below this size more likely to be net exporters of TP especially if they were created on former intensively farmed agricultural land.

A7.13 Calculating the potential N or P retention in such wetlands involves first determining the proportion of the hydraulic load that will pass through the wetland because a percentage of the water carrying N and P will go directly into groundwater, bypassing storm drains and

SUDs and the constructed wetlands. This percentage will depend on such factors as the proportion of hard surface within the development and the geology. Then, assuming the inlet TN concentration is 3 mg/l, a proportionate reduction of 37% can be used to work out the amount of N retained and using 37% is also reasonable for P due to the larger variation of P retention shown in the Land study and this is the bottom end (and therefore precautionary) of the 95% confidence interval for TP retention.

A7.14 Provision is needed to control tree and scrub invasion, for wetlands with emergent vegetation medium height such as Typha and reed had higher rates of denitrification than those dominated by trees and woody shrubs (Alldred and Baines 2016). Phosphorus uptake and amount partitioned to roots and shoots differs between different wetlands species but as a general rule tall rapidly growing emergent species are the most likely to retain P in vegetation with *Juncus effusus* having the highest percentage of retained P in the leaf litter of 5 tall emergent species in a comparative study (Kao *et al* 2003).

A7.15 Other critical aspects of design are the water control structures - inflow and outflow arrangements with water level control – and the need or otherwise for a liner. This last issue is related to soil permeability. A variety of emergent wetland plants, not only reed, can be effective within wetlands. Wetlands with a number of different plant species, rather than monocultures, are desirable both for biodiversity reasons and because they are more resilient against changes in environmental conditions; different species will have different tolerances. Guidance concerning planting can be found in Kadlec and Wallace (2009); allowance should be made in planting ratios and densities for different rates of expansion of different species. Another approach is to use material containing wetland plant seeds from a nearby wetland with a species composition similar to the one preferred. However, unless the donor site is carefully monitored, this would obviously increase the risk of importing unwanted alien plants.

A7.16 Sedimentation will eventually compromise some aspects of the wetland's function and rejuvenation measures will be necessary (Kadlec and Wallace 2009). The same authors indicate a sediment accretion rate in the order of 1 or 2cm/yr and give examples of rejuvenation after 15 and 18 years but other wetlands have not needed any significant restoration in similar timespans. Various different options for the management of sediment accumulation are given by Qualls and Heyvaert (2017). There of course needs to be provisions to ensure that appropriate maintenance and restoration measures, guided by monitoring, are periodically carried out.

A7.17 Other sources of information about stormwater wetlands include Wong *et a*l (1999, available on line). The papers about a stormwater wetland in the Lake Tahoe Basin in California are also useful (Heyvaert et al 2006, Qualls and Heyvaert 2017).

Constructed wetlands taking discharges from WwTW

A7.18 Many of the considerations discussed above for stormwater wetlands apply equally here. There will obviously be constraints on the location and size of such a wetland because of land availability in the area of the WwTW. The flow from the WwTW together with the N and P concentration in the discharge are needed to determine the approximate size of a wetland. We would recommend a wetland area that gives an N loading of about 500 $g/m^2/yr$ or lower.

Since many of the discharges from WwTW have a high N and very high P concentration the potential for N and P retention in such wetlands is also high. The concentration of N and P in the outflow will be variable but the purpose of such wetlands is to retain N and P overall rather than to provide a specific constant standard of water quality in the outflow.

Wetlands associated with streams and rivers

A7.19 Diverting part of the flow of a stream or river through a wetland, with the outflow returning to the watercourse, provides another opportunity for N and P saving. For obvious reasons such wetlands would mostly need to be located on the river floodplain. The inlet flow rate can be controlled so it is appropriate for the size of the wetland created and so that the ecology of the watercourse is not compromised in the section affected.

A7.20 There can be other concerns in relation to the potential effects on the stream or river. An abstraction licence will almost certainly be required and this may have implications for the ecological status – any such proposals should always be discussed in detail with the Environment Agency.

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