



University of Kent Nutrient Neutrality Assessment

DATE:	21 November 2023	CONFIDENTIALITY:	Confidential
SUBJECT:	University of Kent Canterbury Disposal Sites BCD: Nutrient Neutrality Assessment		
PROJECT:	70080896	AUTHOR:	James Ellaway
CHECKED:	James Ellaway	APPROVED:	Justin Sherlock

INTRODUCTION

WSP has been appointed by the University of Kent (UoK) to provide transport and environmental advice for the development of proposals at various sites in and around their Canterbury Campus.

Initial masterplanning has identified the potential to promote 92.1 hectares of land for a housing allocation for 2,000 homes on land referred to as Site BCD. The land is located within the catchment of the River Stour and is therefore hydrologically connected with the Stodmarsh Lakes, which are designated as a Special Protection Area (SPA), a Special Area of Conservation (SAC) and a Ramsar site. The Stodmarsh Lakes are at risk of deterioration caused by eutrophication from elevated nitrogen and phosphorus levels in the River Stour.

The November 2018 European Court of Justice decision regarding the Habitats Directive has resulted in Natural England (NE) requiring all new developments containing overnight accommodation, and which are located in catchments affecting SPAs and SACs that are deteriorating because of nutrients, to demonstrate nutrient neutrality. In March 2022, NE issued updated generic technical guidance and an updated nutrient neutrality calculator for the Stodmarsh catchment¹ to be used to assess whether developments are nutrient neutral.

The local planning authority (LPA) for the development, Canterbury City Council, is unable to issue decisions for new residential development in the catchment unless NE has been consulted and confirmed that they have no objection to the proposed development. NE will not provide this approval unless it can be demonstrated that the development is both phosphorus and nitrogen neutral.

The nutrient neutrality assessment detailed below establishes that the proposed development can achieve both nitrogen and phosphorus neutrality.

SITE LOCATION

The proposed allocation site of 92.1ha consists of three land parcels, B, C and D.

Additional University land holdings, including land parcel F, could be converted from agricultural use into a permanent low nutrient land use (conservation meadow or woodland) as part of the mitigation strategy for the phosphorus and nitrogen loads that would be generated by the development. Land parcel E has been excluded from consideration as it is proposed for alternative uses (potential renewable energy land use) whilst the access road corridor within the University campus is also excluded from the calculations used in this assessment.

WASTEWATER TREATMENT WORKS

Based on Southern Water's wastewater treatment works (WWTW) catchment mapping² the proposed development would discharge foul flows to Southern Water's Canterbury WWTW. NE's guidance indicates that Canterbury WWTW will, until upgraded by 2030:

¹ Nutrient Neutrality Generic Method Issue 1 dated February 2022 and issued March 2022 and the Nutrient Neutrality Budget Calculator for the Stodmarsh SAC and Ramsar, issued March 2022.

² Drainage and Wastewater Management Plan (DWMP) – River Stour Catchment

- Have a total phosphorus (TP) discharge consent limit of 2 mg/l; and
- Have no total nitrogen (TN) discharge consent limit.

NE's nutrient load calculation method requires a precautionary approach to be taken for calculation of nutrient loads. This is achieved, where the relevant WWTW has a consent limit, by calculating the wastewater nutrient load based on the WWTW discharging at 90% of its consent limit. A value of 1.8 mg/l has therefore been used to calculate the wastewater phosphorus load generated by the proposed housing allocation.

In the absence of a consent limit for nitrogen, NE specifies that a *concentration* of 27 mg/l should be adopted. The 90% value does not apply to this value, and 27 mg/l has therefore been used in the calculations.

The Levelling Up and Regeneration Bill (LURB) received Royal Assent on 26 October 2023 and is now referred to as the Levelling Up and Regeneration Act (LURA). LURA imposes a statutory requirement on water companies to upgrade large WWTWs (defined as having a population equivalent >2,000) to consent limits of 0.25mg/l for TP and 10mg/l for TN. Canterbury WWTW must be upgraded to achieve these consent limits by 2030, and the LPA can now rely upon this being achieved when taking planning decisions. The 90% value has been applied to both consent limits in the nutrient load calculations for the post-2030 scenario.

ON-SITE WWTW

An alternative to Canterbury WWTW would be to treat foul flows through an on-site WWTW. Such a system could achieve discharge consent limits as low as 0.15mg/l for TP and 5mg/l for TN.

An on-site WWTW would be operated by a company approved by Ofwat under the New Appointments and Variations (NAV) process³. Severn Trent Connect⁴ and other companies can fulfil the NAV role, which would include designing, permitting, building and operating & maintaining the works in perpetuity (defined as the 80 – 125 year design life of the development).

An indicative cost for a system serving 1,800 homes is £5.5 – 6.0M. This includes feasibility studies, environmental assessment, planning, design and construction, but excludes costs for a discharge pipeline.

Operating and maintenance costs would be recovered through the standard sewerage charges levied on each property and would provide financial sustainability, in perpetuity.

INPUT DATA FOR NUTRIENT LOAD CALCULATIONS

The nutrient load calculations have been based on NE's revised nutrient load calculator and method issued in March 2022. This method includes assessment of both total phosphorus (TP) and total nitrogen (TN).

The revised method requires the use of site-specific input data for the river catchment, rainfall, soil drainage type and the presence (or absence) of a Nitrate Vulnerable Zone (NVZ). These are used by the calculator to derive site-specific nutrient export rates for the existing and proposed land uses.

The existing land use area has been based on the total area of land parcels B, C & D (92.1 ha) and the classification as arable / cereal has been taken from paragraph 2.1 of the Agricultural Land Classification and Soil Resources Report.

The areas of each future non-urban land use in parcels B, C and D have been based on Scenario 1 detailed in the University of Kent Canterbury Design Team Meeting document dated 27 May 2021. The urban land use has been assumed as the balance of the 92.1 ha area of land parcels B, C & D. The land use areas are presented in **Table 1**.

³ <https://www.ofwat.gov.uk/regulated-companies/markets/nav-market/>

⁴ <https://www.st-connect.co.uk/>

Table 1 – Current and Future Land Use Areas (Ha) for the Development (Land Parcels B, C and D)

Land Use	Current (ha)	Future (ha)
Arable / Cereal	92.1*	0.00
Residential Urban Land	0.00	51.70
Greenspace (Parks and Garden)	0.00	1.40
Greenspace (Green Corridors)	0.00	6.08
Greenspace (Amenity Space)	0.00	6.08
Greenspace (Natural & Semi Natural Open Space)	0.00	19.44
Green Space (Sports Pitches)	0.00	4.07
Greenspace (Play)	0.00	1.40
Community Food Growing (Allotments)	0.00	1.82
Total Site Area (Ha)	92.10	92.10

Note: * This area is likely to include some non-arable land, such as drainage channels etc, and all values will need to be refined as the project progresses and georeferenced masterplans become available for detailed GIS analysis.

Additional input data includes the:

- Number of residential units proposed for the development: 2,000.
- Number of residents per residential unit: 2.3 (advised by Canterbury City Council for other projects).
- Volume of wastewater generated: 120 litres per person per day.

NITROGEN & PHOSPHORUS LOAD CALCULATIONS

Nutrient load calculations have been undertaken for three scenarios:

1. Occupation of all properties prior to Canterbury WWTW's upgrade in 2030 (Pre-2030).
2. Occupation of all properties after Canterbury WWTW's upgrade in 2030 (Post-2030).
3. The use of an on-site WWTW (On-site WWTW).

The calculations have been optimised by taking into account:

- The use of a site-specific percentage impermeable area (PIMP) value of 49.5% for future urban residential land use, rather than NE's default values of 80% for TP and 100% for TN. This significantly reduces the nutrient export rate for this land use and reduces the overall nutrient loads from the development.
- The application of sustainable drainage system (SuDS) nutrient removal efficiencies estimated at 48.2% for TP and 30% for TN in accordance with CIRIA C808⁵ and C815⁶. This assumes the SuDS consist of lined dry grassed swales conveying surface water to lined wet ponds for treatment, prior to discharging to a watercourse. These values have been applied to the surface water nutrient load components and have been deducted from the final development nutrient loads.

A summary of the load calculations is provided in Tables 2, 3 and 4 with a comparison of the nutrient loads in Table 5. The full calculations are presented in **Appendix A**.

⁵ <https://www.ciria.org/ItemDetail?iProductCode=C808F&Category=FREEPUBS>

⁶ <https://www.ciria.org/ItemDetail?iProductCode=C815F&Category=FREEPUBS>

Table 2 – Nitrogen and Phosphorus Loads – Canterbury WWTW Pre-2030

Load Element	TP Load (kg/year)	TN Load (kg/year)
Wastewater load (A)	362.91	5,443.69
Future land use load (B)	35.00	389.20
Existing land use load (C)	29.31	1,691.50
Future nutrient load (= A + (B - C))	368.60	4,141.39
Precautionary buffer (20%)	73.72	828.28
Unmitigated future nutrient load	442.32	4,969.66
SuDS nutrient load removal	16.87	116.76
Residual future nutrient load	425.45	4,852.90

Table 3 – Nitrogen and Phosphorus Loads – Canterbury WWTW Post-2030

Load Element	TP Load (kg/year)	TN Load (kg/year)
Wastewater load (A)	45.36	1,814.56
Future land use load (B)	35.00	389.20
Existing land use load (C)	29.31	1,691.50
Future nutrient load (= A + (B - C))	51.05	512.26
Precautionary buffer (20%)	10.21	102.45
Unmitigated future nutrient load	61.26	614.71
SuDS nutrient load removal	16.87	116.76
Residual future nutrient load	44.39	497.95

Table 4 – Nitrogen and Phosphorus Loads – On-Site WWTW

Load Element	TP Load (kg/year)	TN Load (kg/year)
Wastewater load (A)	27.22	907.28
Future land use load (B)	35.00	389.20
Existing land use load (C)	29.31	1691.50
Future nutrient load (= A + (B - C))	32.90	-395.02
Precautionary buffer (20%)	6.58	0.00
Unmitigated future nutrient load	39.48	-395.02
SuDS nutrient load removal	16.87	116.76
Residual future nutrient load	22.61	-511.78

Table 5 – Summary of Residual Nitrogen & Phosphorus Loads for the Three WWTW Scenarios

WWTW Scenario	TP Load (kg/year)	TN Load (kg/year)
Canterbury WWTW Pre-2030	425.45	4,852.90
Canterbury WWTW Post-2030	44.39	497.95
On-site WWTW	22.61	-511.78

The calculations confirm that the proposed development would generate a very large residual nutrient load should all houses be occupied prior to 2030.

However, the development programme indicates that all properties will be occupied after 2030. The upgrade of Canterbury WWTW would therefore reduce the development's nutrient load by around 90%. The residual nutrient loads would still require additional mitigation in the post-2030 scenario.

The use of an on-site WWTW would deliver nitrogen neutrality for the proposed development, and further reduce the residual phosphorus load that would require additional mitigation.

MITIGATION OPTIONS

Additional mitigation would be required to fully mitigate each of the three WWTW scenarios. Potential options are outlined below.

Agricultural Land Conversion – Land Parcel F

Land parcel F may be available for conversion to a low nutrient land use such as woodland or conservation meadow. This would partially mitigate the nutrient loads that would be generated from the proposed development. Using Google imagery and GIS we have estimated that land parcel F consists of, approximately:

- 13.5 ha of lowland grazing.
- 4.7 ha of arable / cereal.

As detailed in the calculations provided in Appendix A, if converted to a low nutrient land use, land parcel F could provide:

- Phosphorus mitigation of 8.16 kg/year.
- Nitrogen mitigation of 145.23 kg/year.

This would not be sufficient to deliver nutrient neutrality for any of the three scenarios. However, it would provide partial mitigation, and would reduce the on-site WWTW scenario residual phosphorus load to 14.45kg/year.

Agricultural Land Conversion – Other Land

The residual nutrient loads requiring additional mitigation, after deducting the mitigation from land parcel F, are detailed in Table 6. This table also presents the area of additional arable land conversion that would be required to mitigate the remaining TP loads (which are much more difficult to mitigate than the TN load). The areas have been based on a typical arable TP export rate of 0.32kg/ha/year, from which is deducted the low nutrient land use TP export rate (0.02kg/ha/year) to derive a beneficial export rate reduction of 0.30kg/ha/year. The residual TP loads for each scenario have been divided by 0.30kg/ha/year to calculate the area of arable land required to be converted to mitigate each scenario.

Table 6 – Areas of Arable Land Conversion required to Mitigate the Three WWTW Scenarios

WWTW Scenario	TP Load (kg/year)	TN Load (kg/year)	Required Area of Arable Conversion to Mitigate Residual TP Load (ha)
Canterbury WWTW Pre-2030	417.29	4,707.67	1,391
Canterbury WWTW Post-2030	36.23	352.72	121
On-site WWTW	14.45	-657.01	48

At a typical cost of approximately £27,000/ha of arable land⁷, the mitigation of residual nutrient loads by converting arable land to a low nutrient land use would have a land purchase cost of £1.3M – £37.6M. Additional costs would be incurred for the low nutrient land use creation process and the in-perpetuity management.

Treatment of Existing Foul Flows through an On-site WWTW

The use of an on-site WWTW offers the opportunity to potentially treat existing foul flows from the University campus through the on-site system rather than through Canterbury WWTW. The lower discharge consent limits of an on-site WWTW generate a beneficial differential in nutrient loads compared to Canterbury WWTW.

The per person nutrient loads generated by the three WWTW scenarios are summarised in Table 7 together with the nutrient benefits of diverting existing foul flows from Canterbury WWTW to the on-site WWTW. Detailed calculations are provided in **Appendix A**.

Table 7 – Per Person WWTW Nutrient Loads and Nutrient Benefits of Treating Existing Flows through the On-site WWTW (kg/person/year)

WWTW Scenario	TP Load (kg/person/year)	TN Load (kg/person/year)	TP Benefit (kg/person/year)	TN Benefit (kg/person/year)
On-site WWTW	0.006	0.197	-	-
Canterbury WWTW Pre-2030	0.079	1.183	0.073	0.986
Canterbury WWTW Post-2030	0.010	0.394	0.004	0.197

Diverting existing foul flows that are currently discharged to Canterbury WWTW to an on-site WWTW could generate considerable nutrient benefits of 0.073kgTP/person/year and 0.986kgTN/person/year but only before the upgrade of Canterbury WWTW by 2030. The nutrient benefit of this approach is negligible after Canterbury WWTW is upgraded.

Table 8 presents the on-site WWTW residual nutrient loads requiring additional mitigation, after deducting the mitigation provided by land parcel F. This table also presents the number of existing occupants on the University campus whose (pre-2030) foul flows would be required to be diverted from Canterbury WWTW to the on-site WWTW to fully mitigate the on-site WWTW scenario. This has been calculated by dividing the TP load of 14.45kg/year by 0.073kgTP/person/year.

⁷ <https://rural.struttandparker.com/article/english-estates-farmland-market-review-spring-2023/> One hectare is 2.47 acres.

Table 8 – Number of Existing Occupants’ Pre-2030 Foul Flows Diverted to On-Site WWTW to Mitigate the On-Site WWTW Scenario

WWTW Scenario	TP Load (kg/year)	TN Load (kg/year)	Number of Existing Occupants’ Foul Flows Diverted to the On-site WWTW
On-site WWTW	14.45	-657.01	198

Diverting the existing foul flows from just 200 occupants to the on-site WWTW would fully mitigate the on-site WWTW scenario. Diverting additional foul flows could deliver a significant nutrient surplus that may be traded with other developers in the catchment, or used to mitigate future additional development on the campus or other University landholdings in the catchment.

Nutrient Mitigation Credits

Natural England is developing a nutrient mitigation scheme (NMS) in the Stodmarsh catchment. Given the difficulty and expense of mitigating TP in any other way, the NMS is likely to consist of construction of a wetland. A procurement process has been undertaken for an initial feasibility stage. Assuming that a suitable site (or sites) has been identified, the detailed design and construction stage is likely to take upwards of 18 to 24 months. Mitigation credits may therefore be available in 2025 or later.

In other catchments where phosphorus mitigation credits have been generated (primarily by the private sector), they have ranged in price from £14,000/kgTP to £75,000/kgTP, with a typical price of £50,000/kgTP.

As the number of mitigation credits is often limited, and usually significantly exceeded by demand, NE is likely to sell them using a prioritisation system. In NE’s NMS in the Tees catchment, priority has been given to small and medium enterprises, smaller sites and those schemes that are more progressed through the planning process. The likelihood of a large development obtaining the required number of mitigation credits is therefore reduced.

The mitigation cost could vary widely depending on the cost per credit, estimated below at £14k – £50k/kgTP:

- Canterbury WWTW Pre-2030: £5.9M – £20.9M.
- Canterbury WWTW Post-2030: £0.5M – £1.8M.
- On-site WWTW: £0.2M – £0.7M.

The cost of mitigating the Canterbury WWTW post-2030 scenario is low compared to the indicative £5.5M – £6.0M cost of an on-site WWTW plus the extra mitigation of up to £0.7M. However, the benefit of the on-site WWTW scenario is the potential to generate additional credits that could be used to mitigate other University developments.

CONCLUSIONS

The first occupation of all homes will occur after Canterbury WWTW is upgraded by 2030 (although this could be earlier). As detailed in Table 5, this scenario would generate residual nutrient loads of 44.39kgTP/year and 497.95kgTN/year.

These would be mitigated through the delivery of one or more of the following mitigation approaches:

1. The purchase of Natural England Nutrient Mitigation Scheme credits, at a cost of £2.22M (based on a credit cost of £50,000 per kilogram of TP). Typically, the mitigation of a scheme through the purchase of TP credits would also fully mitigate the TN load although this would need to be confirmed once the scheme is operational.



2. The conversion of existing agricultural land to a low nutrient land use, potentially in conjunction with Options No 1 and/or 3.
3. The use of an on-site WWTW with the residual TP and TN loads fully mitigated in conjunction with Options 1 and/or 2.

Based upon the strategy identified and options presented above the proposed development can achieve nutrient neutrality.



APPENDIX A – NUTRIENT LOAD CALCULATIONS

Existing Landuse Areas

Parcel	Area (ha)	Existing Landuse	Future Landuse
A	5.5	Amenity Grassland and Woodland	Amenity Grassland and Woodland
B, C & D	92.1	Arable	Proposed Development Site
E	7.9	Arable	University Sports Pitches - Open Urban
F	4.7	Arable / Cereal	Phosphorus Mitigation Area
	13.5	Lowland Grazing / Permanent Grass	Phosphorus Mitigation Area
Total	123.7		

2 Site and climatic conditions

General features, land form and drainage

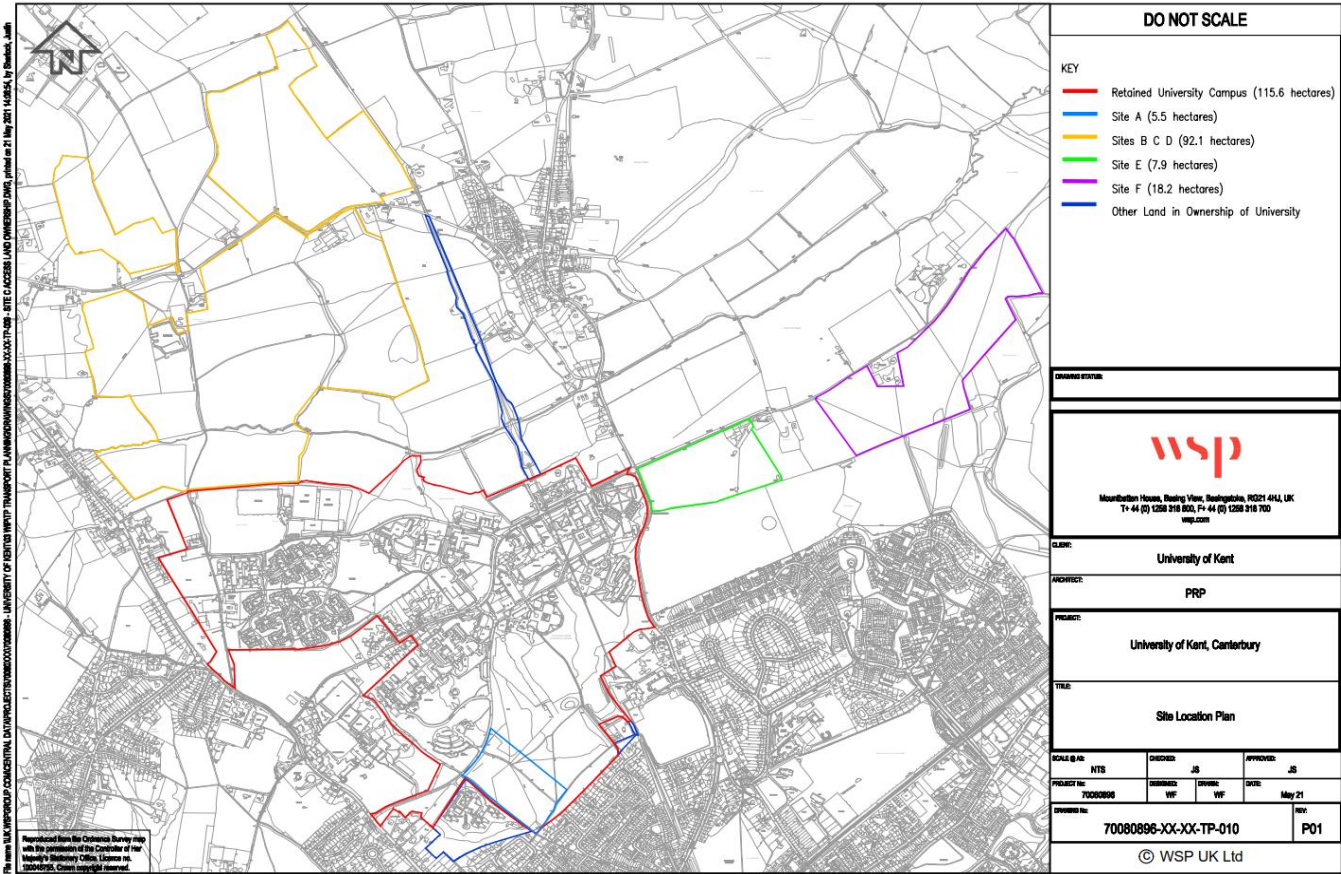
2.1 The areas surveyed collectively extend to around 123.5ha of agricultural land primarily in arable use. Area A is under permanent grass and is cut for hay annually.



April 2021

WSP UK Limited
Agricultural Land Classification and Soil Resources

at
University of Kent, Canterbury Campus



Future Landuse based on Scenario 1

Landuse	Landuse Classification	Area (ha)
Urban	Residential Urban Land	51.79
Sports Pitches	Greenspace	4.07
Parks and Garden	Greenspace	1.40
Green Corridors	Greenspace	6.08
Amenity Space	Greenspace	6.08
Natural and Semi Natural Open Space	Greenspace	19.44
Play	Greenspace	1.40
Allotments	Community Food Growing	1.82
Total Area		92.10

Totals	Residential Urban Land	51.79
	Greenspace	38.49
	Community Food Growing	1.82
	Total	92.10

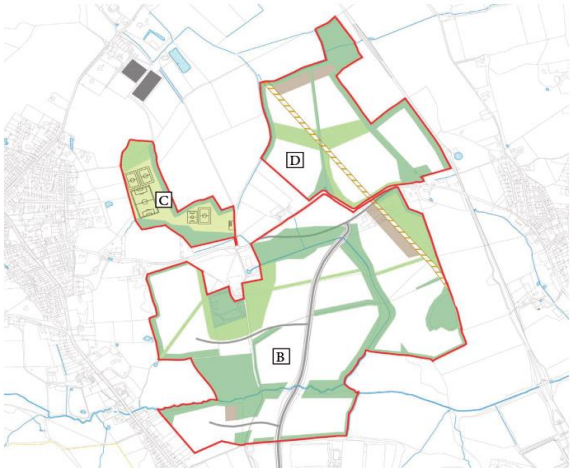
Open Space Layout and Provision
SCENARIO 1 -on site sports

- Key
- Site Boundary
 - Natural and Semi Natural Green Spaces and Green Corridors Retained
 - Amenity Space, Parks & Gardens, Play Areas
 - Allotments
 - Sport
 - Proposed Roads

- Assumptions:
- 2000 Homes (4680 people)
 - Site C used for sports
 - gas easement excluded from open space calculations

Note: Diagram has been prepared to test the potential to accommodate spacial requirements and should not be considered a design

TYPE	Option 1	Minimum required area
Parks and Gardens	1.404ha	1.404ha
Green corridors	6.084ha	6.084ha
Amenity Space	6.084ha	6.084ha
Natural and semi natural open space	19.440ha	19.440ha
Sports pitches	4.070ha	4.070ha
Allotments	1.820ha	1.820ha
Play	1.404ha	1.404ha
TOTAL on site	40.306ha	40.306ha



Scenario 1 - Illustrative diagram

Catchment:	Stour Lower
Soils:	Impeded drainage to naturally wet, with a small area of free draining. Natural England classification is 'variable'
Rainfall:	675 - 700mm
NVZ:	No

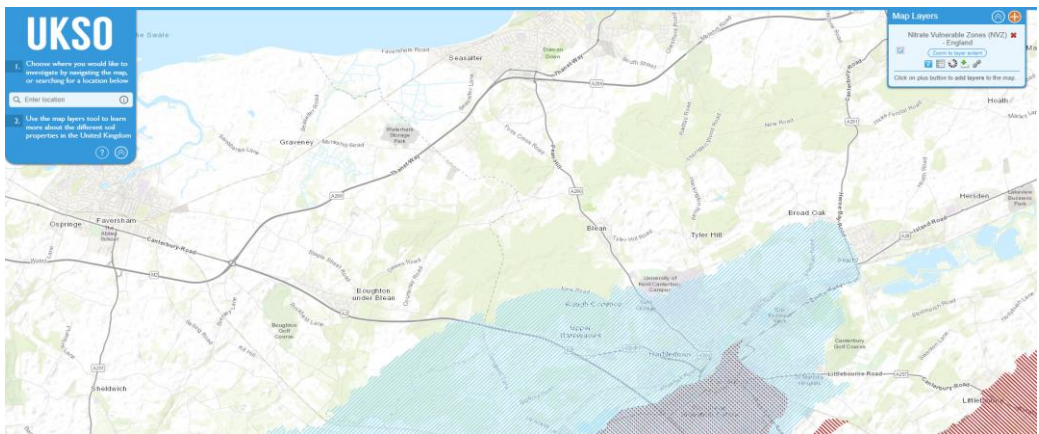
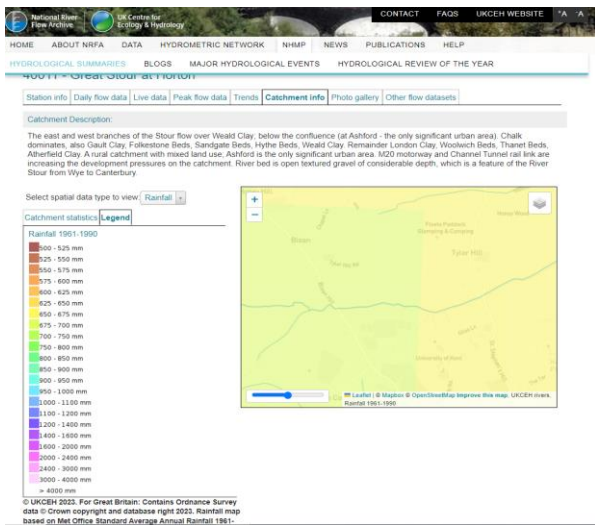


Table A.3: EMCs for nitrogen and phosphorus for three key types of urban land use.

Land use	Nitrogen concentration (mg N/l)	event concentration (mg N/l)	mean	Phosphorus concentration (mg P/l)	event concentration (mg P/l)	mean
Residential	2.85			0.41		
Commercial/industrial	1.52			0.30		
Open urban land	1.68			0.22		

The EMCs were combined with a standard method for calculating urban runoff which requires only rainfall as an input. The HR Wallingford Modified Rational Method was used, as shown in equation 1.

Equation 1

$$L = R \cdot Pr$$

Where:

L = annual average runoff (mm)

R = annual average rainfall (mm)

Pr = percentage runoff (%)

$$Pr = 0.829 \cdot PIMP + 0.078 \cdot U - 20.7$$

$PIMP$ = the percentage of land that is impervious (whole number)

U = catchment wetness index. Calculated by (use 41 if rainfall over 760 mm):

$$U = -129.5 + (0.424 \cdot R) - (2.28 \cdot 10^{-4} \cdot R^2) - (4.56 \cdot 10^{-8} \cdot R^3)$$

For phosphorus, the value for PIMP was set as 80%, as this has been suggested as the proportion of impervious surfaces once urban creep (the paving over of pervious surfaces) reaches a maximum. The use of an 80% PIMP value, while high, accounts for the potential increases in impervious surfaces that may occur over the lifetime of a development. Research has also suggested that non-paved gardens account for between 19-27% of the entire urban area. As gardens are the primary type of permeable surface within residential areas, the use of an 80% PIMP value is considered to be precautionary as an area with 19% coverage by non-paved gardens would indicate that around 80% of the remaining urban residential area would be impermeable surfaces.

Values based on 80% PIMP specified by Natural England

Variable	Residential Urban			Commercial/Industrial			Open Urban		
	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
L - Annual average runoff (mm)	328.36	341.15		328.36	341.15		328.36	341.15	
R - Annual average rainfall (mm)	675	700		675	700		675	700	
Pr - Percentage runoff (%)	48.65	48.74		48.65	48.74		48.65	48.74	
PIMP - Percentage of land that is impervious (%)	80.00	80.00		80.00	80.00		80.00	80.00	
U - Catchment wetness index (use 41 if rainfall > 760mm)	38.79	39.94		38.79	39.94		38.79	39.94	
Annual runoff (mm)	328.36	341.15		328.36	341.15		328.36	341.15	
Annual runoff (m)	0.33	0.34		0.33	0.34		0.33	0.34	
Volume per hectare (m3/ha/yr)	3283.60	3411.47		3283.60	3411.47		3283.60	3411.47	
TP EMC (mg/l)	0.41	0.41		0.3	0.3		0.22	0.22	
TP EMC (kg/l)	0.0004	0.0004		0.0003	0.0003		0.0002	0.0002	
TP Export Rate (kg/ha/yr)	1.35	1.40	1.37	0.99	1.02	1.00	0.72	0.75	0.74

Site-specific values

The development consists of 2,000 homes in a developable area of 51.79ha gives a development density of 39units/ha.

The development density of 39units/ha is considered to be medium density, which has typical PIMP of 45%.

Urban creep is accounted for by addition of 10% of the total PIMP to the site-specific value.

Site-specific PIMP: 45.00%

10% urban creep uplift: 4.5%

Site specific mean PIMP for the residential landuse: 49.50%

Variable	Residential Urban			Commercial/Industrial			Open Urban		
	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
L - Annual average runoff (mm)	157.69	164.16		328.36	341.15		328.36	341.15	
R - Annual average rainfall (mm)	675	700		675	700		675	700	
Pr - Percentage runoff (%)	23.36	23.45		48.65	48.74		48.65	48.74	
PIMP - Percentage of land that is impervious (%)	49.5	49.5		80	80		80	80	
U - Catchment wetness index (use 41 if rainfall > 760mm)	38.79	39.94		38.79	39.94		38.79	39.94	
Annual runoff (mm)	157.69	164.16		328.36	341.15		328.36	341.15	
Annual runoff (m)	0.16	0.16		0.33	0.34		0.33	0.34	
Volume per hectare (m3/ha/yr)	1576.89	1641.55		3283.60	3411.47		3283.60	3411.47	
TP EMC (mg/l)	0.41	0.41		0.3	0.3		0.22	0.22	
TP EMC (kg/l)	0.0004	0.0004		0.0003	0.0003		0.0002	0.0002	
TP Export Rate (kg/ha/yr)	0.65	0.67	0.66	0.99	1.02	1.00	0.72	0.75	0.74

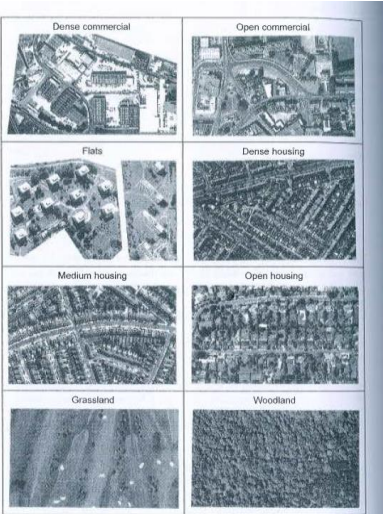


Fig 11.1 Various land use categories in London (developed by Thames Water Utilities Ltd on their Beckton and Crossness sewerage modelling projects in association with consulting engineers BGP Reid Crowther Ltd and Montgomery Watson Ltd and reproduced with permission)

Table 11.2 Approximate percentage imperviousness of land-use types in London

Land-use category	PIMP
Dense commercial	100
Open commercial	65
Dense housing	55
Flats	50
Medium housing	45
Open housing	35
Grassland	<10
Woodland	<10

Urban N Export Rate & PIMP - Derivation of Site-Specific Total Nitrogen Export Coefficients for Three Urban Landuses

Table A.3: EMCs for nitrogen and phosphorus for three key types of urban land use.

Land use	Nitrogen concentration (mg N/l)	event mean	Phosphorus concentration (mg P/l)	event mean
Residential	2.85		0.41	
Commercial/industrial	1.52		0.30	
Open urban land	1.68		0.22	

The EMCs were combined with a standard method for calculating urban runoff which requires only rainfall as an input. The HR Wallingford Modified Rational Method was used, as shown in equation 1.

Equation 1

$$L = R \cdot Pr$$

Where:

L = annual average runoff (mm)

R = annual average rainfall (mm)

Pr = percentage runoff (%)

$$Pr = 0.829 \cdot PIMP + 0.078 \cdot U - 20.7$$

$PIMP$ = the percentage of land that is impervious (whole number)

U = catchment wetness index. Calculated by (use 41 if rainfall over 760 mm):

$$U = -129.5 + (0.424 \cdot R) - (2.28 \cdot 10^{-4} \cdot R^2) - (4.56 \cdot 10^{-8} \cdot R^3)$$

For phosphorus, the value for PIMP was set as 80%, as this has been suggested as the proportion of impervious surfaces once urban creep (the paving over of pervious surfaces) reaches a maximum. The use of an 80% PIMP value, while high, accounts for the potential increases in impervious surfaces that may occur over the lifetime of a development. Research has also suggested that non-paved gardens account for between 19-27% of the entire urban area. As gardens are the primary type of permeable surface within residential areas, the use of an 80% PIMP value is considered to be precautionary as an area with 19% coverage by non-paved gardens would indicate that around 80% of the remaining urban residential area would be impermeable surfaces.

Values based on 100% PIMP specified by Natural England

Variable	Residential Urban			Commercial/Industrial			Open Urban		
	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
L - Annual average runoff (mm)	440.27	457.21		440.27	457.21		440.27	457.21	
R - Annual average rainfall (mm)	675	700		675	700		675	700	
Pr - Percentage runoff (%)	65.23	65.32		65.23	65.32		65.23	65.32	
PIMP - Percentage of land that is impervious (%)	100.00	100.00		100.00	100.00		100.00	100.00	
U - Catchment wetness index (use 41 if rainfall > 760mm)	38.79	39.94		38.79	39.94		38.79	39.94	
Annual runoff (mm)	440.27	457.21		440.27	457.21		440.27	457.21	
Annual runoff (m)	0.44	0.46		0.44	0.46		0.44	0.46	
Volume per hectare (m3/ha/yr)	4402.75	4572.07		4402.75	4572.07		4402.75	4572.07	
TN EMC (mg/l)	2.85	2.85		1.52	1.52		1.68	1.68	
TN EMC (kg/l)	0.0029	0.0029		0.0015	0.0015		0.0017	0.0017	
TN Export Rate (kg/ha/yr)	12.55	13.03	12.79	6.69	6.95	6.82	7.40	7.68	7.54

Site-specific values

The development consists of 2,000 homes in a developable area of 51.79ha gives a development density of 39units/ha.

The development density of 39units/ha is considered to be medium density, which has typical PIMP of 45%.

Urban creep is accounted for by addition of 10% of the total PIMP to the site-specific value.

Site-specific PIMP: 45.00%

10% urban creep uplift: 4.5%

Site specific mean PIMP for the residential landuse: 49.50%

Variable	Residential Urban			Commercial/Industrial			Open Urban		
	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
L - Annual average runoff (mm)	157.69	164.16		328.36	341.15		328.36	341.15	
R - Annual average rainfall (mm)	675	700		675	700		675	700	
Pr - Percentage runoff (%)	23.36	23.45		48.65	48.74		48.65	48.74	
PIMP - Percentage of land that is impervious (%)	49.5	49.5		80	80		80	80	
U - Catchment wetness index (use 41 if rainfall > 760mm)	38.79	39.94		38.79	39.94		38.79	39.94	
Annual runoff (mm)	157.69	164.16		328.36	341.15		328.36	341.15	
Annual runoff (m)	0.16	0.16		0.33	0.34		0.33	0.34	
Volume per hectare (m3/ha/yr)	1576.89	1641.55		3283.60	3411.47		3283.60	3411.47	
TN EMC (mg/l)	2.85	2.85		1.52	1.52		1.68	1.68	
TN EMC (kg/l)	0.0029	0.0029		0.0015	0.0015		0.0017	0.0017	
TN Export Rate (kg/ha/yr)	4.49	4.68	4.59	4.99	5.19	5.09	5.52	5.73	5.62

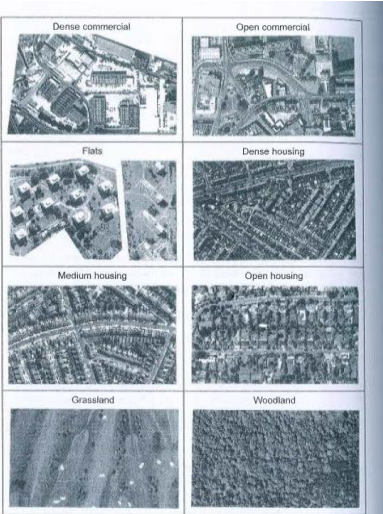


Fig 11.1 Various land use categories in London (developed by Thames Water Utilities Ltd on their Beckton and Crossness sewerage modelling projects in association with consulting engineers BGP Reid Crowther Ltd and Montgomery Watson Ltd and reproduced with permission)

Table 11.2 Approximate percentage imperviousness of land-use types in London

Land-use category	PIMP
Dense commercial	100
Open commercial	65
Dense housing	55
Flats	50
Medium housing	45
Open housing	35
Grassland	<10
Woodland	<10

CIRIA C808 SuDS P Removal Analysis

1. CIRIA C808 states that 100% removal can be achieved for all runoff that can be infiltrated. A small area of the development has freely draining soils that may support this approach, but it has not been included in this assessment.
2. As the majority of the site is underlain by naturally wet soils, or those with impeded drainage, the analysis is based on an assumption that the SuDS treatment train will consist of dry grassed swales (lined, to prevent nitrogen infiltration as required by CIRIA C815) leading to lined wet ponds prior to offsite discharge to a watercourse.
3. C808 states that total phosphorus consists of 55% particulate P and 45% dissolved P and provides removal efficiencies for a range of SuDS features.
4. A nominal TP load of 1kg/year has been analysed to calculate the TP removal efficiency of a swale leading to a wet pond. The removal efficiency could be increased if the SuDS treatment train consists of additional treatment features.

Phosphorus Form	Nominal P Load (kg/year)	SuDS P Removal (%) Wet Pond	Output P Load (kg/year)	SuDS P Removal (%) Dry Grassed Swale	Output P Load (kg/year)
Particulate P	0.55	38	0.341	14	0.293
Dissolved P	0.45	50	0.225	0	0.225
Total P	1.00				0.518
TP Removal Efficiency					48.2%

CIRIA C815 SuDS N Removal Analysis

1. CIRIA C815 states that nitrogen can not be removed through infiltration. All SuDS treatment features must therefore be lined to prevent infiltration.
2. The analysis is based on an assumption that the SuDS treatment train will therefore consist of dry grassed swales leading to lined wet ponds prior to offsite discharge to a watercourse.
3. CIRIA C815 specifies that this SuDS treatment train can achieve an N removal efficiency of **30%** if the features are designed and constructed in accordance with CIRIA C753 The SuDS Manual.

Notes

1. The development will discharge foul flows to Canterbury WWTW.
2. Canterbury WWTW has a current total phosphorus discharge consent limit of 2mg/l. It does not have a total nitrogen discharge consent limit and so a default value of 27mg/l has been used as required by Natural England's guidance.
3. Natural England's nutrient neutrality calculation guidance specifies the use of 90% of a WWTW permit consent limit and this has been applied to the TP permit limit.
4. The existing land use areas have been taken from the Reading Agricultural Consultants report summarised in the Existing Landuse tab.
5. The future land use areas have been taken from the illustrative Masterplan Scenario 1 detailed in the Future Landuse tab.
6. A SUDS total phosphorus removal efficiency of 48.2% and a total nitrogen removal efficiency of 30% have been adopted in general accordance with CIRIA C808 and CIRIA C815 based on a SuDS treatment train of lined grassed swales leading to lined wet ponds then offsite discharge to a watercourse.
7. The future urban land use nutrient export rates have been optimised based on a site-specific PIMP value for a medium density development (39 units/hectare) as detailed in the Urban P and N Export Rate & PIMP tabs
8. The occupancy rate of 2.3/unit has been previously advised by Canterbury City Council for other projects in the city.
9. The wastewater volume has been increased to 120lppd based on Natural England's revised calculation method. There may be an opportunity to reduce this to 110lppd with agreement from CCC.
10. The underlying drainage ranges from naturally wet to impeded drainage with a small area of freely draining. The calculations have been assessed on Natural England's classification as 'variable' which generates a TP export rate of 0.32kg/ha/year for cereals. The export rate is 0.55kg/ha/year for areas that have impeded drainage, and just 0.05kg/ha/year for freely draining. Once the masterplan is finalised it may be beneficial to accurately map soil drainage to calculate more accurate existing land use nutrient loads to offset against the development's loads.

LOAD CALCULATION

Site Characteristics

Total site area (ha)	92.10
Number of homes	2000
No. of residents per unit (No.)	2.30
Wastewater volume (litres/person/day)	120
Wastewater generated (litres/day)	552000

Wastewater Load

	Total Phosphorus	Total Nitrogen
WWTW consent limit (mg/l)	2.00	27.00
90% of WWTW consent limit (mg/l)	1.80	
Total nutrient load from wastewater (mg/day)	993600	14904000
Total nutrient load from wastewater (mg/yr)	362912400	5443686000
Total nutrient load from wastewater (kg/yr)	362.91	5443.69

Existing Landuse Load

		Nutrient Export Rate (kg/ha/year)		Total Nutrient Load (kg/year)	
Existing Landuse	Area (ha)	Total Phosphorus	Total Nitrogen	Total Phosphorus	Total Nitrogen
Arable / cereal	92.10	0.32	18.37	29.31	1691.50
Total	92.10	-	-	29.31	1691.50

Future Landuse Load

		Nutrient Export Rate (kg/ha/year)		Total Nutrient Load (kg/year)	
Future Landuse	Area (ha)	Total Phosphorus	Total Nitrogen	Total Phosphorus	Total Nitrogen
Residential Urban Land	51.79	0.66	4.59	34.17	237.54
Greenspace	38.49	0.02	3.00	0.77	115.46
Community Food Growing	1.82	0.03	19.89	0.05	36.20
Total	92.1	-	-	35.00	389.20

Unmitigated Future Nutrient Load

	Total Phosphorus Load (kg/year)	Total Nitrogen Load (kg/year)
Load Contribution		
Wastewater load (A)	362.91	5443.69
Future landuse load (B)	35.00	389.20
Existing landuse load (C)	29.31	1691.50
Future nutrient load (= A + (B - C)	368.60	4141.39
Precautionary buffer (20%)	73.72	828.28
Unmitigated future nutrient load	442.32	4969.66

SUDS Mitigation (refer CIRIA C808 C815 SuDS Removal tab for details)

	Total Phosphorus	Total Nitrogen
Total nutrient load from urban land draining to the SUDS (kg/year)	35.00	389.20
Calculated SUDS removal efficiency (%)	48.2%	30.0%
Total nutrient reduction (kg/year)	16.87	116.76

Mitigated Future Nutrient Load

	Total Phosphorus Load (kg/year)	Total Nitrogen Load (kg/year)
Load Contribution		
Unmitigated future nutrient load	442.32	4969.66
SUDS nutrient reduction	16.87	116.76
Mitigated future nutrient load	425.45	4852.90

Notes

1. The development will discharge foul flows to Canterbury WWTW.
2. Canterbury WWTW will have a post-2030 total phosphorus discharge consent limit of 0.25mg/l and a total nitrogen discharge consent limit of 10mg/l as required by the Levelling Up and Regeneration Act (LURA).
3. Natural England's nutrient neutrality calculation guidance specifies the use of 90% of a WWTW permit consent limit and this has been applied to the TP and TN permit limits.
4. The existing land use areas have been taken from the Reading Agricultural Consultants report summarised in the Existing Landuse tab.
5. The future land use areas have been taken from the illustrative Masterplan Scenario 1 detailed in the Future Landuse tab.
6. A SUDS total phosphorus removal efficiency of 48.2% and a total nitrogen removal efficiency of 30% have been adopted in general accordance with CIRIA C808 and CIRIA C815 based on a SuDS treatment train of lined grassed swales leading to lined wet ponds then offsite discharge to a watercourse.
7. The future urban land use nutrient export rates have been optimised based on a site-specific PIMP value for a medium density development (39 units/hectare) as detailed in the Urban P and N Export Rate & PIMP tabs
8. The occupancy rate of 2.3/unit has been previously advised by Canterbury City Council for other projects in the city.
9. The wastewater volume has been increased to 120lppd based on Natural England's revised calculation method. There may be an opportunity to reduce this to 110lppd with agreement from CCC.
10. The underlying drainage ranges from naturally wet to impeded drainage with a small area of freely draining. The calculations have been assessed on Natural England's classification as 'variable' which generates a TP export rate of 0.32kg/ha/year for cereals. The export rate is 0.55kg/ha/year for areas that have impeded drainage, and just 0.05kg/ha/year for freely draining. Once the masterplan is finalised it may be beneficial to accurately map soil drainage to calculate more accurate existing land use nutrient loads to offset against the development's loads.

LOAD CALCULATION

Site Characteristics

Total site area (ha)	92.10
Number of homes	2000
No. of residents per unit (No.)	2.30
Wastewater volume (litres/person/day)	120
Wastewater generated (litres/day)	552000

Wastewater Load

	Total Phosphorus	Total Nitrogen
WWTW consent limit (mg/l)	0.25	10.00
90% of WWTW consent limit (mg/l)	0.23	9.00
Total nutrient load from wastewater (mg/day)	124200	4968000
Total nutrient load from wastewater (mg/yr)	45364050	1814562000
Total nutrient load from wastewater (kg/yr)	45.36	1814.56

Existing Landuse Load

		Nutrient Export Rate (kg/ha/year)		Total Nutrient Load (kg/year)	
Existing Landuse	Area (ha)	Total Phosphorus	Total Nitrogen	Total Phosphorus	Total Nitrogen
Arable / cereal	92.10	0.32	18.37	29.31	1691.50
Total	92.10	-	-	29.31	1691.50

Future Landuse Load

		Nutrient Export Rate (kg/ha/year)		Total Nutrient Load (kg/year)	
Future Landuse	Area (ha)	Total Phosphorus	Total Nitrogen	Total Phosphorus	Total Nitrogen
Residential Urban Land	51.79	0.66	4.59	34.17	237.54
Greenspace	38.49	0.02	3.00	0.77	115.46
Community Food Growing	1.82	0.03	19.89	0.05	36.20
Total	92.1	-	-	35.00	389.20

Unmitigated Future Nutrient Load

	Total Phosphorus Load (kg/year)	Total Nitrogen Load (kg/year)
Load Contribution		
Wastewater load (A)	45.36	1814.56
Future landuse load (B)	35.00	389.20
Existing landuse load (C)	29.31	1691.50
Future nutrient load (= A + (B - C)	51.05	512.26
Precautionary buffer (20%)	10.21	102.45
Unmitigated future nutrient load	61.26	614.71

SUDS Mitigation (refer CIRIA C808 C815 SuDS Removal tab for details)

	Total Phosphorus	Total Nitrogen
Total nutrient load from urban land draining to the SUDS (kg/year)	35.00	389.20
Calculated SUDS removal efficiency (%)	48.2%	30.0%
Total nutrient reduction (kg/year)	16.87	116.76

Mitigated Future Nutrient Load

	Total Phosphorus Load (kg/year)	Total Nitrogen Load (kg/year)
Load Contribution		
Unmitigated future nutrient load	61.26	614.71
SUDS nutrient reduction	16.87	116.76
Mitigated future nutrient load	44.39	497.95

Notes

1. The development will discharge foul flows to an on-site WWTW.
2. the on-site WWTW will have a total phosphorus discharge consent limit of 0.15mg/l and a total nitrogen discharge consent limit of 5mg/l.
3. Natural England's nutrient neutrality calculation guidance specifies the use of 90% of a WWTW permit consent limit and this has been applied to the TP and TN permit limits.
4. The existing land use areas have been taken from the Reading Agricultural Consultants report summarised in the Existing Landuse tab.
5. The future land use areas have been taken from the illustrative Masterplan Scenario 1 detailed in the Future Landuse tab.
6. A SUDS total phosphorus removal efficiency of 48.2% and a total nitrogen removal efficiency of 30% have been adopted in general accordance with CIRIA C808 and CIRIA C815 based on a SuDS treatment train of lined grassed swales leading to lined wet ponds then offsite discharge to a watercourse.
7. The future urban land use nutrient export rates have been optimised based on a site-specific PIMP value for a medium density development (39 units/hectare) as detailed in the Urban P and N Export Rate & PIMP tabs
8. The occupancy rate of 2.3/unit has been previously advised by Canterbury City Council for other projects in the city.
9. The wastewater volume has been increased to 120lppd based on Natural England's revised calculation method. There may be an opportunity to reduce this to 110lppd with agreement from CCC.
10. The underlying drainage ranges from naturally wet to impeded drainage with a small area of freely draining. The calculations have been assessed on Natural England's classification as 'variable' which generates a TP export rate of 0.32kg/ha/year for cereals. The export rate is 0.55kg/ha/year for areas that have impeded drainage, and just 0.05kg/ha/year for freely draining. Once the masterplan is finalised it may be beneficial to accurately map soil drainage to calculate more accurate existing land use nutrient loads to offset against the development's loads.

LOAD CALCULATION

Site Characteristics

Total site area (ha)	92.10
Number of homes	2000
No. of residents per unit (No.)	2.30
Wastewater volume (litres/person/day)	120
Wastewater generated (litres/day)	552000

Wastewater Load

	Total Phosphorus	Total Nitrogen
WWTW consent limit (mg/l)	0.15	5.00
90% of WWTW consent limit (mg/l)	0.14	4.50
Total nutrient load from wastewater (mg/day)	74520	2484000
Total nutrient load from wastewater (mg/yr)	27218430	907281000
Total nutrient load from wastewater (kg/yr)	27.22	907.28

Existing Landuse Load

Existing Landuse	Area (ha)	Nutrient Export Rate (kg/ha/year)		Total Nutrient Load (kg/year)	
		Total Phosphorus	Total Nitrogen	Total Phosphorus	Total Nitrogen
Arable / cereal	92.10	0.32	18.37	29.31	1691.50
Total	92.10	-	-	29.31	1691.50

Future Landuse Load

Future Landuse	Area (ha)	Nutrient Export Rate (kg/ha/year)		Total Nutrient Load (kg/year)	
		Total Phosphorus	Total Nitrogen	Total Phosphorus	Total Nitrogen
Residential Urban Land	51.79	0.66	4.59	34.17	237.54
Greenspace	38.49	0.02	3.00	0.77	115.46
Community Food Growing	1.82	0.03	19.89	0.05	36.20
Total	92.1	-	-	35.00	389.20

Unmitigated Future Nutrient Load

	Total Phosphorus Load (kg/year)	Total Nitrogen Load (kg/year)
Load Contribution		
Wastewater load (A)	27.22	907.28
Future landuse load (B)	35.00	389.20
Existing landuse load (C)	29.31	1691.50
Future nutrient load (= A + (B - C)	32.90	-395.02
Precautionary buffer (20%)	6.58	0.00
Unmitigated future nutrient load	39.48	-395.02

SUDS Mitigation (refer CIRIA C808 C815 SuDS Removal tab for details)

	Total Phosphorus	Total Nitrogen
Total nutrient load from urban land draining to the SUDS (kg/year)	35.00	389.20
Calculated SUDS removal efficiency (%)	48.2%	30.0%
Total nutrient reduction (kg/year)	16.87	116.76

Mitigated Future Nutrient Load

	Total Phosphorus Load (kg/year)	Total Nitrogen Load (kg/year)
Load Contribution		
Unmitigated future nutrient load	39.48	-395.02
SUDS nutrient reduction	16.87	116.76
Mitigated future nutrient load	22.61	-511.78

Nutrient Mitigation Available from Land Parcel F

Soilscape 18 impeded drainage

Existing Nutrient Loads

Landuse	Area (ha)	P Export Rate (kg/ha/yr)	N Export Rate (kg/ha/yr)	P Load (kg/yr)	N Load (kg/yr)
Arable/ Cereal	4.7	0.55	20.17	2.59	94.80
Lowland Grazing / Permanent Grass	13.5	0.44	7.78	5.94	105.03
Total				8.53	199.83

Future Nutrient Loads

Landuse	Area (ha)	P Export Rate (kg/ha/yr)	N Export Rate (kg/ha/yr)	P Load (kg/yr)	N Load (kg/yr)
Woodland / Conservation Meadow	18.2	0.02	3.00	0.364	54.60

Available Nutrient Mitigation

	TP	TN
Existing Nutrient Load (kg/year)	8.53	199.83
Future Nutrient Load (kg/year)	0.36	54.60
Available Nutrient Mitigation (kg/year)	8.16	145.23

Nutrient Mitigation Available from Treating Existing Foul Flows through an On-site WWTW

Notes

1. This analysis calculates the mitigation that could be generated by connecting existing residential properties into an on-site WWTW.
2. The analysis is based on a per person approach so that student halls of residence with varying occupancy rates can be considered - but the void rate would need to be applied.
3. The analysis indicates that connecting existing foul flows into the on-site WWTW prior to 2030 would deliver mitigation of 0.073kgTP/person/year and 0.986kgTN/person/year.
4. Connecting existing foul flows into the on-site WWTW after 2030 would deliver lower mitigation of 0.004kgTP/person/year and 0.197kgTN/person/year.

Occupancy	1
Wastewater generated (litres/person/day)	120
Wastewater generated (litres/day)	120

Pre-2030 and Post-2030 Wastewater Nutrient Loads

	Canterbury WWTW Pre-2030		Canterbury WWTW Post-2030	
	Total Phosphorus	Total Nitrogen	Total Phosphorus	Total Nitrogen
WWTW consent limit (mg/l)	2.00	27.00	0.25	10.00
90% of WWTW consent limit (mg/l)	1.80		0.23	9.00
Total nutrient load from wastewater (mg/person/day)	216	3240	27	1080
Total nutrient load from wastewater (mg/person/yr)	78894	1183410	9862	394470
Total nutrient load from wastewater (kg/person/yr)	0.079	1.183	0.010	0.394

On-site WWTW Nutrient Loads

	On-site WWTW	
	Total Phosphorus	Total Nitrogen
WWTW consent limit (mg/l)	0.15	5.00
90% of WWTW consent limit (mg/l)	0.135	4.500
Total nutrient load from wastewater (mg/person/day)	16	540
Total nutrient load from wastewater (mg/person/yr)	5917	197235
Total nutrient load from wastewater (kg/person/yr)	0.006	0.197

Available Nutrient Mitigation

	Canterbury WWTW Pre-2030		Canterbury WWTW Post-2030	
	Total Phosphorus	Total Nitrogen	Total Phosphorus	Total Nitrogen
Existing nutrient load from wastewater (kg/person/yr)	0.079	1.183	0.010	0.394
On-site WWTW nutrient load(kg/person/yr)	0.006	0.197	0.006	0.197
Available mitigation (kg/person/year)	0.073	0.986	0.004	0.197