Using SuDS to reduce nitrogen in surface water runoff

Who we are

CIRIA members lead the industry in raising professional standards through collaboration, sharing knowledge and promoting good practice. Recognised as leaders in industry improvement, CIRIA's members represent all construction stakeholder groups including clients, contractors, consultants, public sector champions, regulators and academia.

CIRIA membership provides organisations with a unique range of business development and improvement services, focused on sharing and embedding research, knowledge and good practice. In addition to the many direct benefits, membership provides a wealth of opportunities for organisations to engage in shaping, informing and delivering industry solutions focused on innovation and improvement.

In addition to representing excellent value for money in terms of direct benefits, CIRIA membership delivers significant returns for organisational investment in business improvement and development, CPD, industry engagement, profile enhancement and collaborative research.

CIRIA membership allows your employees to access the full breadth of CIRIA resources and services, creating valuable networking, performance improvement and leadership opportunities.

Where we are

Discover how your organisation can benefit from CIRIA's authoritative and practical guidance. For details of membership, networks, events, collaborative projects and to access CIRIA publications through the bookshop:

E: enquiries@ciria.org **W: www.ciria.org** **Follow us: @CIRIAUpdates**

CIRIA C815 London, 2023

Using SuDS to reduce nitrogen in surface water runoff

Jo Bradley Stormwater Shepherds

Using SuDS to reduce nitrogen in surface water runoff

Bradley, J

CIRIA

C815 ©CIRIA 2023 P3281 ISBN: 978-0-86017-962-7

British Library Cataloguing in Publication Data

A catalogue record is available for this book from the British Library

Keywords		
Environmental management, receiving water quality management, sustainability and the built environment, sustainable water management, environmental management, flood risk management and surface water drainage, construction process and management		
Reader interest	**Classification**	
Recommendations of the use of SuDS for nitrogen reduction in surface water runoff from new developments	Availability	Unrestricted
	Content	Advice/guidance
	Status	Commissioned
	User	Local planning authorities, lead local flood authorities, water and sewerage companies, regulators, developers, developer consultants, land agents, planners, engineers, landscape architects, SuDS designers and other consultants

Published by CIRIA, Registered office: 124 City Road, London, EC1V 2NX, UK

Please cite this publication as:

Bradley, J (2022) *Using SuDS to reduce nitrogen in surface water runoff*, C815, CIRIA, London, UK (ISBN: 978-0-86017-962-7)

www.ciria.org

Summary

Nitrogen is essential for life, but too much nitrogen is a hazard that causes water pollution. High nitrogen levels can lead to rapid increases in algae populations in water environments, which use up the oxygen and suffocate other aquatic creatures. These 'algal blooms' affect many rivers, lakes and estuaries, and seriously damage protected habitats. The United Nations Environment Program *Frontiers Report 2018/2019* (UNEP, 2019) called nitrogen pollution one of the most important pollution issues facing humanity. Alongside the risks to wildlife, excess levels of nitrogen in drinking water can also cause harm to human health. Together, these effects are very significant, and the introduction of nutrient neutrality catchment areas is a strategy to bring this water pollution under control.

In a residential development, the sources of nitrogen in stormwater runoff include lawn and garden fertilisers, pet waste, grass clippings, leaf matter, and atmospheric deposition onto roofs and other surfaces. These developments that are in nutrient neutrality catchment areas classified for nitrogen pollution, should deliver water management systems that reduce or eliminate the discharge of nitrogen off the development.

This guidance is intended for those developments affected by nutrient neutrality rulings.

In these catchments, the developer can include a sustainable drainage scheme (SuDs) across the site to manage stormwater runoff, and to capture and remove a proportion of the nitrogen in that runoff. Residual nitrogen that cannot be captured and removed should be included in the nutrient calculations for the development and may need to be offset elsewhere.

This guide outlines the design criteria for a good SuDS scheme that can maximise the opportunity to capture and remove nitrogen. It also describes the difficulties of capturing nitrogen, as it is present in different forms, and the many different processes to do so.

The guidance in this document should be used to inform SuDS design alongside information from CIRIA C753 *The SuDS Manual* (Woods Ballard *et al*, 2015) or *Planning practice guidance on flood risk and coastal change* (DLUHC and MCHLG, 2022). Nutrient management should not be allowed to skew the design by outranking other benefits, such as multifunctional benefits or the hierarchy of drainage options.

Acknowledgements

This guide has been written by CIRIA under contract (P3281) to the Partnership for South Hampshire with funding from Natural England.

Authors

Jo Bradley

Jo Bradley is director of operations UK for Stormwater Shepherds. She is a pollution prevention expert with a demonstrated history of working in environment protection. Jo is skilled in environmental awareness, drainage, water resource management, sustainable drainage systems (SuDS) design and water quality management.

CIRIA project team

Louise Walker	Project director
Adrien Baudrimont	Project manager
Clare Drake	Publishing manager

Other contributors

The author and project team would like to thank Emma Betteridge and Simon Kennedy of Fareham Borough Council for their input to the guide.

Contents

Boxes

Figures

Tables

1 SuDS and nutrient pollution

It is important to remember that SuDS are incorporated into residential developments across the UK because they deliver multiple benefits to the developer, the homeowner, the environment, and to the wider local community. It is essential that SuDS schemes are designed as early as possible in the process, so that they can work in harmony with the natural topography and movement of water across and into the site.

Experienced SuDS designers can create beautiful, functional schemes that reduce flood risk, manage drought, reduce pollution, create habitats for wildlife, and make pleasing places for people. SuDS designers should always design the best scheme that they can, to deliver these multiple benefits, and then consider the amount of nutrient pollution that the scheme will capture and remove. They should not start to design SuDS schemes 'backwards' with a focus on nutrient capture first, and the delivery of any other benefits second, but should continue to design the best SuDS that they can for any development, and then assess how much nutrient load can be removed, so that they can complete the necessary calculations for the nutrient calculator.

It will never be possible to capture all the nutrients in the SuDS scheme, especially for nitrogen, so there will always be a small, residual load of nutrient to be offset by the developer, elsewhere on the development or off site. Nitrogen is particularly difficult to manage in SuDS because it exists in different forms, alters from one form to another depending on conditions, and requires specific conditions to support some treatment processes.

2 The principles of nitrogen capture and removal for residential developments

There are six key principles:

1 Nitrogen in natural environments behaves in complex and unpredictable ways, changing from particulate to dissolved forms, being assimilated into plant matter, being nitrified, denitrified, and turning into a gas. There are multiple factors that affect these processes, and they can change with the seasons, the quantity of rainfall, the activities in the catchment and weather. This makes it difficult to design SuDS that will capture a known proportion of the nitrogen with any certainty and consistency.

2 Nitrogen occurs in many different chemical forms, and there are numerous mechanisms by which it is altered, captured, and released, so it is impossible to provide explicit and reliable figures for the reduction of nitrogen pollution in runoff from residential developments in individual SuDS components.

3 Across a residential development, nitrogen pollution in the runoff from roofs, driveways, roads, and public spaces is low when compared to that in sewerage and grey water. So when completing the Nutrient neutrality generic methodology calculations (Ricardo and Natural England, 2022) the quantity of nitrogen captured in the SuDS devices will only represent a small proportion of the overall nitrogen leaving the site.

4 There are some principles that can be applied to SuDS design to shift the odds in favour of good nitrogen capture, retention, and removal:

   a Maximise the inclusion of plants that will grow well each season, creating volumes of biomass that can be removed from site.

   b Include healthy, aerated soils with organic matter content.

   c Endeavour to include an anaerobic or anoxic zone where denitrification can occur.

5 Infiltration to ground cannot be assumed to capture and assimilate all the nitrogen in residential runoff. Depending on the depth and type of soil, there is a risk that nitrates will exist in the runoff and that nitrification will occur and create more nitrates that will leach down into underlying groundwater. So, groundwater protection is a necessary consideration for SuDS design in areas where nitrogen pollution is a recognised risk. For nitrogen management in high-risk environments, infiltration should only take place when pre-treatment has already reduced the nitrogen content of the runoff. Note that this differs from the management of phosphorus where infiltration should be maximised as the first step of a SuDS management train, so on sites where both nutrients are being targeted, nitrogen management should take precedent because the risk of pollution is greater.

6 A significant source of nitrogen in urban runoff is atmospheric deposition. Quantities vary from site to site and are higher near urban areas, roads, and factories emitting pollution etc. This source of atmospheric nitrogen is difficult to account for without site-specific sampling.

3 Using this guidance

When designing SuDS for a site that requires nitrogen neutrality, a SuDS management train is the best solution. A SuDS management train is a series of SuDS devices designed in a sequence to meet as many water quality objectives as possible, without hindering the water quantity control across the development.

In this guide, some of the aspects of SuDS design that will affect nitrogen capture are described, including some management techniques that can secure nitrogen capture and removal. However, because of the limitations outlined in **Chapter 2**, the figures quoted are for the performance of SuDS management trains as a whole – and not individual SuDS devices. Designers may be allowed to claim higher figures if they can secure analysis of the influent runoff for nitrogen content, and they can assure the regulator that the performance of the SuDS devices will be effectively maintained and monitored.

It is important to remember that this guidance is only intended for developments affected by nutrient neutrality rulings. Designers should still design the best SuDS that they can for a development, delivering all the benefits of SuDS and meeting the needs of the development and its occupants. If a site is within a nutrient neutrality catchment all other planning requirements will apply and the hydraulic aspects of the SuDS design should still take precedent.

This guide provides figures for each SuDS management train that can be applied to calculate the mass of nitrogen that can be captured and removed per annum. This figure can be used in the 'change of land use' calculations and may reduce the amount of the annual nitrogen load that needs to be offset. The use of SuDS on the development cannot eradicate all the nitrogen from the surface runoff.

In good practice SuDS designs, the development catchment area should be well understood. The site information can then be compared against the principles, considerations and devices described in this document. Finally, the design can be assessed to consider the expected effectiveness of the SuDS management train on the removal of nitrogen from the development catchment area and consider any nutrient offsetting requirements. This process is illustrated in **Figure 3.1**. The expected performance of a good SuDS design will only continue if the development catchment area is well maintained.

Figure 3.1 The process of good practice SuDS design

4 Site investigation

The nature of the site is extremely important to the design of an effective SuDS management train. Before any SuDS scheme is considered there are four aspects of the site that need to be understood, and a site investigation must be completed to gather the necessary information.

1. Soil type, soil permeability and the capacity for the infiltration of surface water on site.
2. Depth to seasonal water table.
3. Vulnerability of underlying groundwater.
4. The type, location, flow rate, and size of any receiving watercourse.

It is impossible to design the SuDS management train for the site, and to quantify the capacity for nitrogen capture, without having this information.

5 Considerations for all sites

Table 5.1 describes consideration to be given to all sites in terms of nitrogen reduction, regardless of the type of SuDS devices used.

Table 5.1 Consideration for all sites, regardless of the devices chosen

Nitrogen in stormwater	Mainly organic nitrogen (eg leaves and other organic debris) and nitrate occur in stormwater. For removal of organic nitrogen (which is predominantly particulate matter), SuDS devices that facilitate pre-screening of debris, settling and filtration, as well as biological activity under aerobic conditions, will be the most effective.
Source control is essential in a good SuDS design to reduce nutrient pollution	Ideally, the managers and occupiers of residential developments would commit to reducing sources of nitrogen across the development. This would include the prohibition of artificial fertilisers, manures, and car-washing, all dog waste should be picked up, bagged and binned, leaves should be swept up and kept away from drains, and there should be no wrong connections to the surface water drains.
Infiltration to ground should be maximised (only where the runoff has been pre-treated or very low levels of pollution are anticipated). Groundwater protection should be secured at all times	Although infiltration is a fundamental principle of SuDS, it is more complex for nitrogen than for phosphorus because nitrate is very soluble and will quickly leach through soil and into underlying groundwater. For this reason, SuDS in nitrogen sensitive catchments will be designed differently to those in phosphorus sensitive catchments; infiltration devices need to be lined unless the runoff has already been treated such that the risk is reduced to an acceptable level. This pre-treatment is usually provided in a pond, basin, or a manufactured device where sedimentation has taken place.
Previous land use	It is essential to understand the effect of previous land use on the nitrogen level in the soils on site. If it was agricultural or horticultural land or used for sports activities, it might have had fertilisers or manures added, and the soil may already contain levels of 'legacy' nitrogen. It cannot be assumed that land designated for development is of low soil nitrogen.
The flow rate or volume that should be treated by nutrient removal devices	It is essential that the site-specific treatment flow rate is agreed before the SuDS management train is designed. CIRIA C753 requires that all runoff from sub-annual rainfall events is treated, which is calculated using the 1 in 1 year 15-minute rainfall event for the site. This is usually defined as the 'treatment flow rate' for the catchment and makes up only a proportion of the annual runoff, excluding high flow rate events such as severe storms. Natural England assesses the nitrogen reduction in the entire volume of water running off the site in one year (calculated using the standardised annual average rainfall) To align these two design methods, the solution is to treat a proportion of the volume of rainfall in the SuDS management train to remove a known (or estimated) mass of nitrogen and then to combine it with the untreated runoff from high flows to achieve an overall annual reduction in nitrogen leaving the site.
Particulate and dissolved nitrogen	It is difficult to know what proportion of nitrogen in the runoff will be included in the particulate matter and the proportions will vary between site and seasonally. However, SuDS management trains should include components that target both particulate and dissolved nitrogen to maximise the opportunities to capture it.
The SuDS management train should be considered as a 'whole system'	For nitrogen capture and removal calculations, the SuDS management train is considered as a whole system, with the devices combining to target different forms of nitrogen.
Nitrogen cycling	Due to the complexities of the nitrogen cycle, it is important to recognise that 'removal' of one form of nitrogen may result in an increase in another form later in the cycle. For example, organic nitrogen that settles from the water column can decay and later release nitrate unless maintenance activities periodically remove the settled material.

6 Selecting devices for nitrogen capture and removal

6.1 WETLANDS

Figure 6.1 Treatment wetland

Wetlands and floating wetlands can be very effective at capturing and removing nitrogen from stormwater as they contain variable depth zones, some of which create anaerobic conditions for denitrification, and they support extensive plant growth. The long residence times allow microbial transformation of nitrogen to occur. Wetlands will not be considered in this guide as they are described in detail in the framework approach by McInnes *et al* (2022).

If a treatment wetland is included as part of a SuDS management train, the framework should be referred to, the wetland designed in accordance with it, and the acceptable level of nitrogen removal efficiencies agreed with Natural England.

6.2 RETENTION BASINS AND PONDS

Figure 6.2 Pond

Retention basins and ponds have a permanent pool of water. The permanent pool of water is replaced in part, or in total, by stormwater during a storm event. The hydraulic residence time for the permanent pool over time can provide biochemical treatment. These devices allow sedimentation of solid particles to occur and can be effective at reducing nitrate levels and at capturing particulate organic nitrogen in the summer. If good plant growth can be established in and around the margins of the pond, this will facilitate the uptake of nitrogen, and a proportion of the plants should be harvested at the end of the growing season.

6.3 WETLAND CHANNELS AND BIOSWALES

Figure 6.3 Bioswale

Wetland channels and bioswales are designed to convey flow very slowly so that infiltration into the soil surface takes place, and the plants will assimilate the nutrients. A wetland channel or bioswale is designed to support dense wetland vegetation on its bottom and this should be harvested at the end of the growing season. Aerobic micro-biological activity in the soil layers can break the ammonia down into nitrates, and plants will use the nitrates for growth. However, nitrates are soluble and can be washed down through the soil horizons and risk polluting underlying groundwater. So, wetland channels and bioswales in nitrogen sensitive catchments must be lined and surplus flows conveyed downstream, unless the runoff has been pre-treated in a pond or basin (Section 6.2) and the risk is low.

6.4 BIORETENTION ZONES, TREE PITS, AND RAIN GARDENS

Figure 6.4 Raingarden

Bioretention zones, tree pits, and rain gardens are landscaping features adapted to provide on-site treatment of stormwater runoff. They are commonly located in car parks, along residential streets or within small pockets of residential land. Surface runoff is directed into shallow, landscaped areas with engineered soils, with or without underdrain systems. The filtered runoff can be collected in a perforated underdrain and returned to the storm drain system to be conveyed forward. If it has been pre-treated in a pond or basin before it enters this device, it may be possible to allow the effluent to infiltrate to ground. These devices capture particulate organic nitrogen from leaves and other organic debris at the surface. There will also be effective breakdown of ammonia in the aerobic soil horizons and the plants will take up some of the nitrates as they grow. Sometimes designers will incorporate a continuously submerged anoxic zone to promote denitrification in the device. However, the provision of these zones in UK summer would be unreliable and should not be included unless it is agreed with Natural England that artificial dosing systems and monitoring equipment can ensure the anoxic zone exists all year round.

6.5 HYDRODYNAMIC VORTEX SEPARATORS AND OIL/WATER SEPARATORS

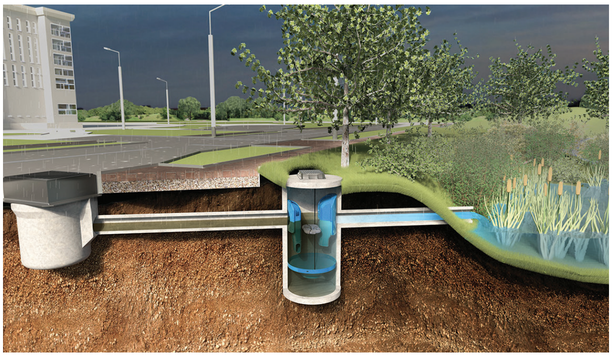

Figure 6.5 Hydrodynamic vortex separator (courtesy Hydro International)

These manufactured sediment capture devices will remove a proportion of the particulate nitrogen in stormwater, and they can be usefully included in designs to reduce the build-up of sediment in ponds and retention basins. For residential developments, CIRIA C753 dictates that a sediment removal device should always be included upstream of a pond or retention basin, and these devices can serve that purpose instead of a sediment forebay if preferred.

6.6 PERMEABLE PAVEMENTS

Figure 6.6 Driveable garden (courtesy Marshalls)

Concrete block permeable pavements do not reliably remove nitrogen from stormwater, so if they are deployed in a SuDS management train to manage nitrogen pollution on residential developments, they should be used for small areas, with a low risk of pollution, where other devices cannot be deployed. Alternatively, grassed permeable surfaces provide better treatment and, where possible, should be considered instead of block pavers. For driveways, alternative solutions such as a combined gravel rain garden or a driveable garden may be better. Whichever permeable surface is selected, the subsurface drainage from beneath the permeable pavement should be captured and directed onward to a secondary treatment device. It cannot infiltrate to ground in nitrogen sensitive areas as it is likely to contain residual levels of nitrates.

6.7 HIGH-RATE MEDIA FILTERS

A media filter is a device that uses a granular or membrane filter, with or without a pre-settling basin, to filter pollutants from stormwater. The most typical filter is sand, but other materials, including compost with sand, geotextiles, and absorption pads and beds, are commonly used. They are more commonly used in the USA, although there are several high-rate stormwater filters available in the UK that use granular treatment media in bags or cartridges, and can capture nitrogen. However, their performance must be tested and the test results must be presented to Natural England for examination before the removal efficiencies that are declared for them can be assigned to the device and included in the nutrient neutrality calculations. A media filter device may not be effective at capturing nitrate because it is soluble so there may need to be further treatment downstream of the filter. If one of these devices is selected, the designer must check that the filter material does not release pollutants itself, or adversely affect the pH of the discharge, and cause environmental harm.

7 Designing a SuDS management train to manage nitrogen pollution

To maximise nitrogen capture and retention, a SuDS management train should be created using the devices listed in **Chapter 6**.

If a wetland (**Section 6.1**) is selected, then the design should be developed in accordance with the guidance in McInnes *et al* (2022). If a wetland cannot be included, then a SuDS management train should be designed using devices from **Sections 6.2 to 6.6**, including both 'dry' devices where the runoff will infiltrate through soil horizons with populations of aerobic micro-organisms, and devices with standing water where sedimentation is effective, and populations of anaerobic micro-organism may establish.

As described in **Chapter 6**, wet ponds and retention basins are known to be effective in reducing levels of nitrate, but in the winter, they can release nitrogenous solids during vegetation die-off periods. So, in an ideal SuDS design, these devices would be included first, with an associated sediment-removal device, followed by a bioretention zone, a tree pit or a bioswale where the nitrogenous solids can be captured at surface, broken down in the aerobic soil horizons and assimilated by the plant growth. Alternatively, the nitrogenous solids can be removed using a stormwater filter if there is no space for biofilters; these will need more maintenance which should be delivered by a stormwater management contractor.

Three options for a SuDS management train for nitrogen capture and removal are identified and described. They must be designed in accordance with CIRIA C735 such that the hydraulic performance meets the planning requirements, and the multiple benefits of SuDS are delivered. The SuDS devices must be sized so that they provide treatment for the design storm event detailed in C753; this is particularly important for pond design.

7.1 OPTION 1: PONDS, FOLLOWED BY BIOREMEDIATION DEVICES

Good nitrogen removal can be delivered by first including a device with a permanent pool of water, followed by devices that provide aerobic biological activity such as a bioremediation zone or a bioswale/wetland channel. If it is easier, this can include multiple smaller ponds across the development. The inclusion of a sediment removal device to protect the permanent pool from excess sedimentation is essential for each pond; this can be delivered using a sediment forebay or a manufactured sediment separator.

This option turns UK SuDS design on its head, as the bioswales and bioretention zones are ordinarily included first, with a pond at the bottom of the site. However, this is a good option for nitrogen management and, if it is designed carefully, it can deliver all the multiple benefits of SuDS across a development.

7.2 OPTION 2: LINED INFILTRATION DEVICES, FOLLOWED BY A POND

If designers want to stick with a more common treatment train approach, but they want to maximise nitrogen capture and removal, they can include permeable surfaces, bioretention zones, tree pits and wetland channels/bioswales with lining underneath them, and then direct the subsurface discharge and overflows to a pond at the bottom of the system.

The infiltration devices would ordinarily have to be lined to protect underlying groundwater from nitrogen pollution because the runoff has not received any pre-treatment; this will depend on the nature of the designated habitat that is being protected by The Conservation of Habitats and Species Regulations 2017. Linings must be included unless an agreement to proceed without them is acquired from Natural England.

7.3 OPTION 3: MANUFACTURED SEDIMENT DEVICES AND/OR PONDS, FOLLOWED BY MEDIA FILTRATION

Alternatively, where space is limited, it might be sensible to consider high-rate media filtration in the form of stormwater filters or enhanced vertical flow wetlands with specific treatment media selected for nitrogen capture. These filters would have to be protected by upstream sediment capture delivered by a vortex-grit separator or an oil/water separator, and further treatment may be required upstream or downstream of the filters to enhance the treatment for nitrogen. If these are included as part of the SuDS management train, the manufacturer must provide evidence to Natural England to support their claims for nitrogen capture and removal. The filter must be designed to cope with the treatment flow rate and the design rainfall event for the entire development and calculated in accordance with CIRIA C753.

8 Assessment of nitrogen capture and removal

Box 8.1 summarises the necessary conditions for capture and removal of nitrogen.

If the SuDS designer wants to assign a higher nitrogen removal figure to their SuDS management train, they must speak to Natural England and supply all the relevant supporting literature and test results.

Box 8.1

Necessary conditions for nitrogen capture and removal

Where the SuDS management trains described in Options 1 and 2 (Sections 7.1 and 7.2) are designed in accordance with CIRIA C753 and where full treatment is provided for all sub-annual rainfall events, these schemes can be considered to capture and remove 30 % of the nitrogen in the runoff from the development as an average over the year.

9 Research findings

To compose this guide, the authors have consulted national and international literature to understand the sources and management of nitrogen from residential developments. The primary source of information for the SuDS management train options in **Chapter 7** is the International Stormwater Best Management Practice Database (BMPDB), and particularly their 2020 *Summary Statistics report* (Clary *et al*, 2020). The BMPDB is a repository of field studies and related web tools, performance summaries, monitoring guidance, and data gathered from over 25 years ago.

The maturity of this database gives confidence that the figures presented are reliable and that UK SuDS devices can be assumed to perform in a similar way. Although other data are available on the topic of nitrogen capture and removal in SuDS devices, the sample size was usually smaller and the datasets were piecemeal, so the BMP summary document was selected as the main source of data. The research confirmed that the behaviour of nitrogen in stormwater treatment devices is complex and affected by many variables. This is why the decision was made not to assign removal efficiencies to individual devices. In the absence of source data and site-specific information, it would be impossible to determine how an individual device would perform.

References

CLARY, J, JONES, J, LEISENRING, M, HOBSON, P, STRECKER, E (2020) *International stormwater BMP database 2020 summary statistics*, WRF Project Number: 4968, The Water Research Foundation, VA, USA (ISBN: 978-1-60573-508-5)
https://www.waterrf.org/system/files/resource/2020-11/DRPT-4968_0.pdf

DLUHC and MHCLG (2022) *Flood risk and coastal change, updated,* Department for Levelling Up, Housing and Communities and Ministry of Communities, Housing and Local Government, London, London, UK
https://www.gov.uk/guidance/flood-risk-and-coastal-change

RICARDO and NATURAL ENGLAND (2022) *Nutrient neutrality generic methodology*, NECR459, Natural England, London, UK
https://publications.naturalengland.org.uk/publication/5143927928913920

MCINNES, R, SIMPSON, M, ROSE, G, ROBERTS, D, SWEANEY, G, MCILWRATH, C, JOHNSON, D (2022) *Framework approach for responding to wetland mitigation proposals, version 7.3*, The Rivers Trust and Constructed Wetland Association for Natural England, London, UK
https://storymaps.arcgis.com/collections/6543a2f8de0348f683187ff268a79687?item=4

UNEP (2019) *Frontiers 2018/19. Emerging issues of environmental concern*, United Nations Environment Programme, Nairobi, Kenya (ISBN: 978-9-28073-737-0)
https://www.unep.org/resources/frontiers-201819-emerging-issues-environmental-concern

WOODS BALLARD, B, WILSON, S, UDALE-CLARKE, H, ILLMAN, S, SCOTT, T, ASHLEY, R, KELLAGHER, R (2015) *The SuDS Manual*, C753, CIRIA, London, UK (ISBN: 978-0-86017-759-3)
https://www.ciria.org

STATUTES

The Conservation of Habitats and Species Regulations 2017 (No.1012)

Further reading

BASTVIKEN, S (2006) *Nitrogen removal in treatment wetlands: Factors influencing spatial and temporal variations*, PhD dissertation, Department of Biology, IFM, Linköping University, The Institute of Technology, Linköping, Sweden
https://www.diva-portal.org/smash/get/diva2:22580/FULLTEXT01.pdf

COLLINS, K A, LAWRENCE, T J, STANDER, E K, JONTOS, R J, KAUSHAL, S S, NEWCOMER, T A, GRIMM, N B and COLE EKBERG, M L (2010) "Opportunities and challenges for managing nitrogen in urban stormwater: a review and synthesis", *Ecological Engineering*, vol 36, 11, Elsevier B.V., Amsterdam, The Netherlands, pp 1507–1519
DOI:10.1016/j.ecoleng.2010.03.015

JANI J, YANG Y-Y, LUSK, M G and TOOR, G S (2020) "Composition of nitrogen in urban residential stormwater runoff: Concentrations, loads, and source characterization of nitrate and organic nitrogen", *PLoS ONE*, vol 15(2):e0229715, San Francisco, USA and Cambridge, UK
https://doi.org/10.1371/journal.pone.0229715

KHWANBOONBUMPEN, S (2006) *Sources of nitrogen and phosphorus in stormwater drainage from established residential areas and options for improved management*, PhD Theses, Edith Cowan University, Joondalup, Australia
https://ro.ecu.edu.au/theses/75

LIQING, L and DAVIS, A (2014) "Urban stormwater runoff nitrogen composition and fate in bioretention systems", *Environmental Science & Technology*, vol 48, ACS Publications, Washington, USA, pp 3403 – 3410
DOI:10.1021/es4055302

MANAL, O, WAN YUSOF, K, TAKAIJUDIN, H, GOH, H, ABDUL MALEK, M, AZIZAN, N GHANI, A and ABDURRASHEED, S (2019) "A review of nitrogen removal for urban stormwater runoff in bioretention system", *Sustainability*. vol 11, 19:5415, MDPI, Basel Switzerland, pp1–21
DOI:10.3390/su11195415

NAYEB YAZDI, M, SCOTT, D, SAMPLE, D J and WANG, X (2021) "Efficacy of a retention pond in treating stormwater nutrients and sediment", *Journal of Cleaner Production,* vol 290, 2021, Elsevier B.V., Amsterdam, The Netherlands, pp 125787
https://doi.org/10.1016/j.jclepro.2021.125787.

TAYLOR, G D, FLETCHER, T D, WONG, T H, BREEN, P F and DUNCAN, H P (2005) 'Nitrogen composition in urban runoff-implications for stormwater management", *Water Research*, vol 39, 10, Elsevier B.V., Amsterdam, The Netherlands, pp 1982–1989
DOI:10.1016/j.watres.2005.03.022

ciria

CIRIA members

ABG Geosynthetics Ltd
Accolade Measurement Ltd
AECOM Ltd
Arcadis
ARL Asbestos Ltd
Arup Group Ltd
Aston University
Atkins Consultants Limited
Autodesk Ltd
Balfour Beatty Group
BAM Nuttall Ltd
BCP Council Bournemouth, Christchurch and Poole
BES Group Strainstall
Binnies UK Limited
BWB Consulting Ltd
City University of London
Civil-Tek Products Ltd
Costain Limited
COWI UK Ltd
Curtins Consulting
Darcy Products Ltd
East West Rail Co Ltd
Environment Agency
Gas Membrane Validation Services Limited
Gavin & Doherty Geosolutions Ltd
Genuit Group
Geobrugg AG
Geofem Ltd
Geotechnical Consulting Group
Green Infrastructure Consultancy
Heathrow Airport Ltd
Henderson Thomas Associates
High Speed Two (HS2) Ltd
HR Wallingford Ltd
Hydro Water Management Solutions Ltd
Imperial College London
Institution of Civil Engineers
JBA Consulting
John Grimes Partnership Ltd
Keynvor Morlift Ltd
Kier Group plc
Laing O'Rourke
Liverpool John Moores University
London Underground Ltd
Maccaferri Ltd
Marsh Industries
Marshalls PLC
Mistras Group Ltd
Morgan Sindall Engineering Solutions
Mott MacDonald Group Ltd
National Highways
Network Rail
Northumbria University
Northumbrian Water Limited
Peabody Housing Trust (Thamesmead Team)
Rail Safety and Standards Board
Royal HaskoningDHV Ltd
SDS Limited
Sir Robert McAlpine Ltd
SLR Consulting Ltd
Southern Water Services Ltd
Stantec
Stuart Michael Associates
T&S Environmental Ltd
Temple Group Ltd
Thames Water Utilities Ltd
TOPCON (GB) Ltd
Transport Scotland
United Utilities Plc
University College London
University College of Estate Management
University of Birmingham
University of Cardiff
University of Greenwich
University of Hertfordshire
University of Reading
University of Southampton
University of the West of Scotland
WSP
Zero Waste Scotland

July 2023

Nitrogen is essential for life, but too much nitrogen is a hazard that causes water pollution. High nitrogen levels can lead to rapid increases in algae populations in water environments, which use up the oxygen and suffocate other aquatic creatures. These ‘algal blooms’ affect many rivers, lakes and estuaries, and seriously damage protected habitats. A report by the United Nations Environment Program called nitrogen pollution one of the most important pollution issues facing humanity. Alongside the risks to wildlife, excess levels of nitrogen in drinking water can also cause harm to human health. Together, these effects are very significant, and the introduction of nutrient neutrality catchment areas is a strategy to bring this water pollution under control.

This guidance is intended for those developments affected by nutrient neutrality rulings. It outlines the design criteria for a good SuDS scheme that can maximise the opportunity to capture and remove nitrogen. It also describes the difficulties of capturing nitrogen, as it is present in different forms, and the many different processes to do so.

STORMWATER SHEPHERDS

Partnership for South Hampshire

ciria

C815

9 780860 179627