Nitrates Directive
2017 Derogation Report for Northern Ireland
in accordance with Article 10 of
Commission Decision 2015/346/EC

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Department of Agriculture, Environment and Rural Affairs
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Agri-Food and Biosciences Institute

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www.daera-ni.gov.uk

College of Agriculture, Food & Rural Enterprise

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This report has been prepared by the Northern Ireland Nitrates Directive Scientific Working Group (SWG). The group is comprised of scientific, regulatory, advisory and policy staff from the:-

Department of Agriculture, Environment and Rural Affairs (DAERA); www.daera-ni.gov.uk)

Northern Ireland Environment Agency (NIEA) (an agency within DAERA); www.daera-ni.gov.uk/northern-ireland-environment-agency

Agri-Food and Biosciences Institute (AFBI) (a Non-Departmental Public Body sponsored by DAERA; www.afbini.gov.uk

College of Agriculture, Food and Rural Enterprise (CAFRE) (a division within DAERA,); www.cafre.ac.uk/

For further information please contact:-

Environmental Farming Branch
Department of Agriculture, Environment and Rural Affairs
R652 Dundonald House
Upper Newtownards Rd
Ballymiscaw
Belfast
BT4 3SB

Email: Siobhan.Bowers@daera-ni.gov.uk

1. INTRODUCTION

The Nitrates Directive (91/676/EEC) (the Directive) is currently implemented in Northern Ireland through the 2015-2018 Nitrates Action Programme (NAP) contained in the Nitrates Action Programme Regulations (Northern Ireland) 2014 (the 2014 NAP Regulations) and subsequent amending regulations[1]. From 2011-2014 it was implemented through the NAP contained in the 2010 NAP Regulations and subsequent amending regulations[2]. The Regulations limit the amount of nitrogen (N) from livestock manure that can be applied to land to 170 kg N/ha/year on all non-derogated farms and are the responsibility of the Department of Agriculture, Environment and Rural Affairs (DAERA).

The measures contained in the 2010 NAP Regulations were carried forward into the 2014 NAP Regulations. However, additional controls on some measures were included in 2014 and updated guidance[3] on the NAP was produced for farm businesses.

In 2007, the United Kingdom (UK), with regard to Northern Ireland, was first granted derogation (until 31 December 2010) by Commission Decision 2007/863/EC to permit an increase in the amount of grazing livestock manure that may be applied to land from 170 kg N/ha/year up to a limit of 250 kg N/ha/year on grassland farms which meet certain criteria. After application the derogation was renewed by Commission Decisions 2011/128EU and 2015/346/EU. Measures relating to the 2015 Decision have been included in the 2014 NAP Regulations.

In accordance with the 2015 Decision, Northern Ireland must update and send to the Commission every year, maps showing the percentage of grassland farms, percentage of livestock and percentage of agricultural land covered by an individual derogation in each district of Northern Ireland, as well as maps of local land use.

Article 10 of the 2015 Decision requires that the results of monitoring be transmitted to the Commission annually, with a concise report on water quality and evaluation practice. The report shall also provide information on how the evaluation of the implementation of the derogation conditions is carried out through controls at farm level and include information on non-compliant farms based on results of administrative and field inspections.

Reports are submitted annually for the preceding year, and include maps for the current year. Therefore, this report provides the annual report on implementation of the derogation in 2017 and maps for 2018.

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[1] The Nitrates Action Programme (Amendment) Regulations (Northern Ireland) 2015
[2] The Nitrates Action Programme (Amendment) Regulations (Northern Ireland) 2012
[3]Nitrates Action Programme 2015-2018 and Phosphorus Regulations Guidance Booklet https://www.daera-ni.gov.uk/sites/default/files/publications/dard/nap-2015-2018-and-phosphorus-regulations-guidance-booklet-final-may-2016.pdf

2. MAPS

In 2017, 307 farm businesses out of approximately 25,420 direct aid claimants (i.e. 1.2%) operated under an approved derogation in Northern Ireland, compared to 298 (i.e. 1.2%) in 2016.

Table 1 on page 10, shows the predicted grassland area and livestock manure loadings of farm businesses which applied to operate under the terms of the derogation in years 2011 to 2018.

Under the Water Framework Directive (2000/60/EC) (WFD), Northern Ireland shares three International River Basin Districts (IRBDs) with the Republic of Ireland and there is one River Basin District (RBD) entirely within Northern Ireland. In the 'UK Article 3 Report on the WFD', Northern Ireland was further subdivided into 31 sub-catchments which form the basis of the maps presented below.

2.1 Percentage of grassland farms covered by an individual derogation in 2018

The map in Figure 1 shows the percentage of grassland by maximum eligible area (MEA) of farms who applied for an individual derogation in 2018, broken down by location of the land within the 31 sub-catchments. Across Northern Ireland this equates to 4.21% of the available grassland. The highest percentage in any sub-catchment is 4.51%.

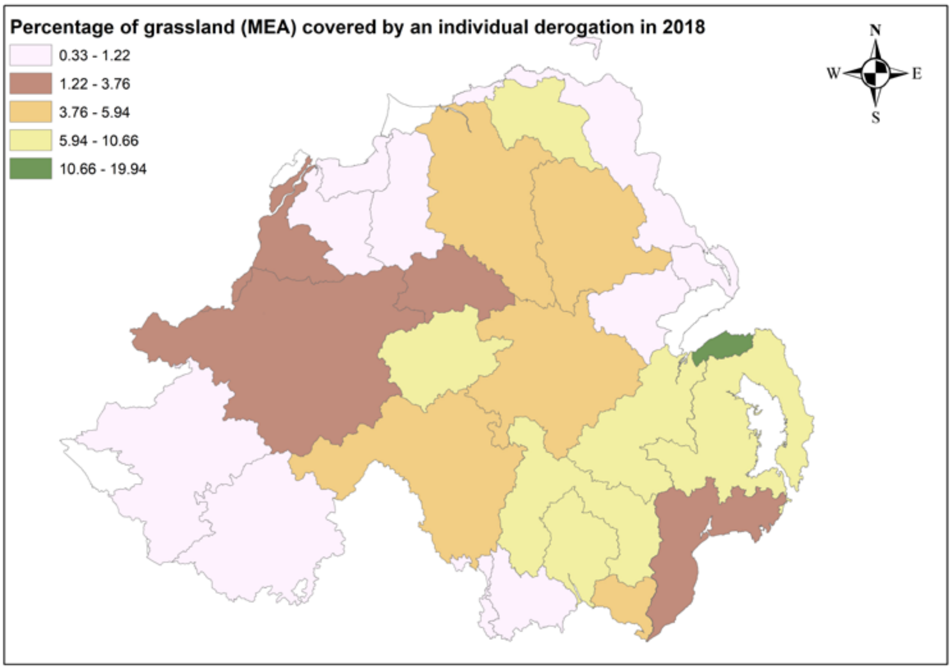

Figure 1: Percentage of grassland covered by an individual derogation 2018

2.2 Percentage of cattle livestock covered by an individual derogation in 2018

The map in Figure 2 shows the percentage of cattle livestock covered by an individual derogation in 2018. This has been calculated on the basis of nitrogen (N) produced and is broken down by location of the farm business address within the 31 sub-catchments. Across Northern Ireland this equates to 11.98% of cattle livestock N produced. The highest percentage in any sub-catchment is 33.40%.

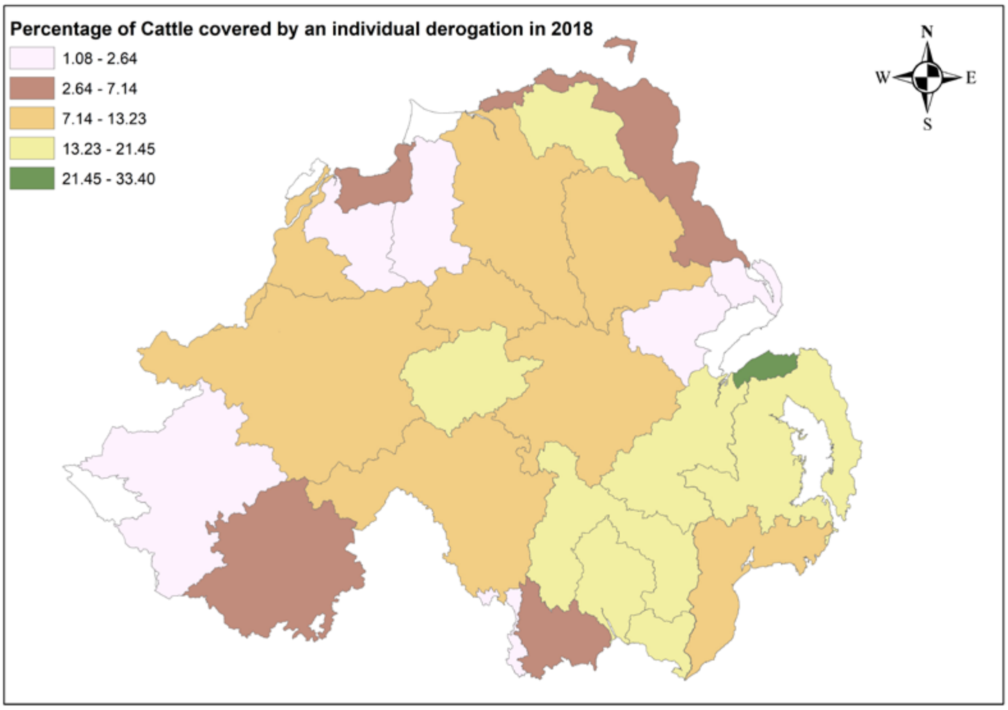

Figure 2: Percentage of cattle livestock covered by an individual derogation 2018

2.3 Percentage of agricultural land covered by an individual derogation in 2018

The map in Figure 3 shows the percentage of agricultural land covered by farm businesses who applied for an individual derogation in 2018, broken down by location of the farm business address within the 31 sub-catchments. Across Northern Ireland this equates to 4.17% of agricultural land. The highest percentage in any sub-catchment is 16.63

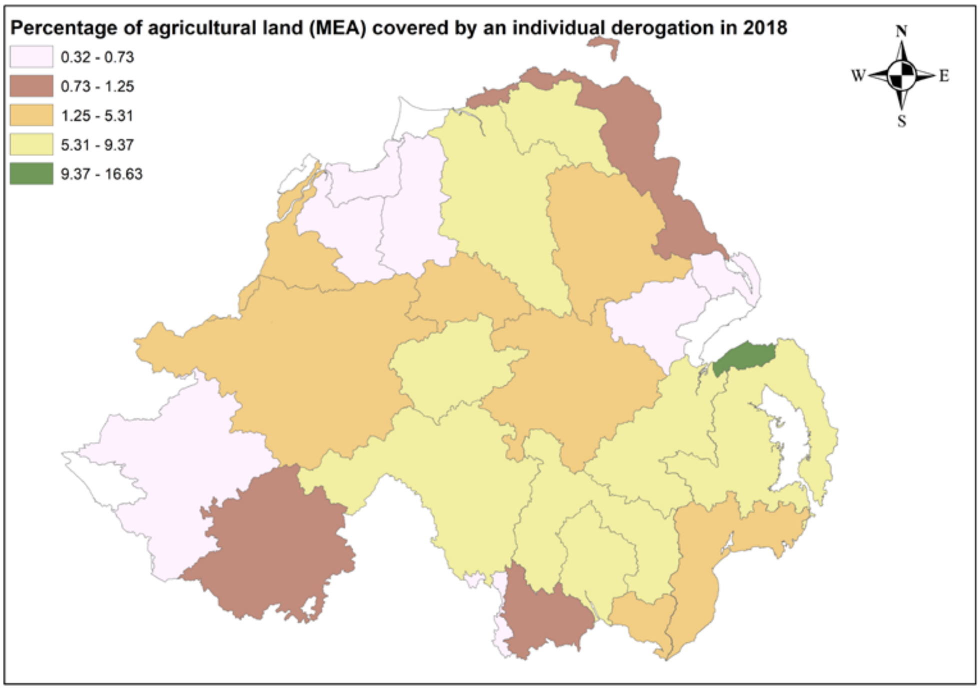

Figure 3: Percentage of agricultural land covered by an individual derogation 2017

2.4 Map of local land use for 2017

Agricultural land use in Northern Ireland is dominated by grassland farming systems. According to the Northern Ireland Agricultural Census (June 2017) (https://www.daera-ni.gov.uk/publications/agricultural-census-northern-ireland-2017), managed grassland accounted for approximately 79% of a total agricultural area of 1,019,700 ha. Arable and other crops accounted for 5% of the total and rough grazing for 14%. The map in Figure 4 shows the declared land-uses across Northern Ireland from the 2017 SAF application.

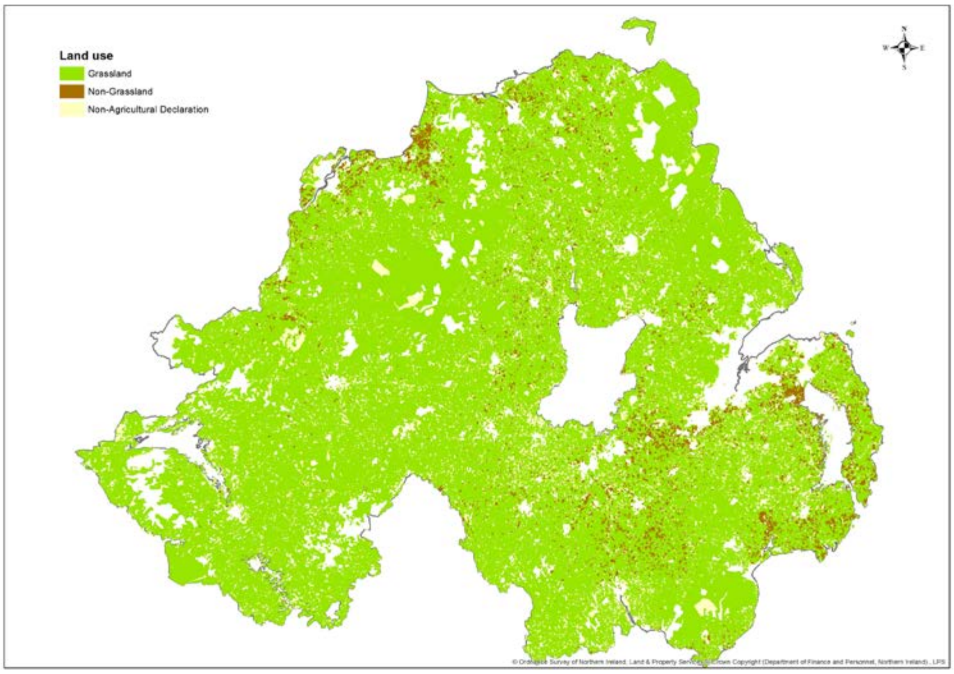

Figure 4: Map of local land use for 2017

Table 1: Predicted average (and minimum-maximum) grassland areas and livestock manure loadings of farm businesses which applied for derogation in years 2011 to 2018

Parameter	2011	2012	2013	2014	2015	2016	2017	2018
Grassland area (%)	98 (81-100)	97 (81-100)	98 (82–100)	98 (82–100)	98 (83–100)	98 (82–100)	98 (81–100)	98.322 (80-100)
Farm size (ha)	84 (11–261)	83 (14–260)	85 (14–280)	88 (14–272)	86 (10–370)	88 (7-334)	90 (16-348)	85 (7-358)
Total livestock manure nitrogen loading (kg N/ha/year)	206 (155–250)	204 (119–249)	205 (36–249)	205 (122–246)	205 (12–250)	213 (23-250)	215 (22-250)	213 (47-250)
Grazing livestock manure nitrogen loading (kg N/ha/year)	206 (195–250)	204 (119–249)	205 (36–249)	205 (122–246)	206 (12–250)	213 (23-250)	215 (22-250)	213 (47-250)

3. WATER QUALITY

In accordance with Article 10 of the 2015 Decision, the results of monitoring and a concise report on water quality are transmitted to the Commission annually in this Derogation report.

The following section provides information on the measured nitrate and phosphorus levels and evolution of water quality in rivers, streams, lakes and groundwater over the period 2012 to 2017. Results are assessed both for Northern Ireland as a whole, and for the sub-catchments (Crawfordsburn, Strangford, Ballinderry, Clanrye and Upper Bann) where the concentration of derogated farms was highest in 2017 (high derogation catchments)

Groundwater monitoring data are not available for the Crawfordsburn catchment which is not considered representative of Northern Ireland, because of its urban nature. The percentage of farm land in comparison to total catchment area in the Crawfordsburn catchment (23 %) is low in comparison to the other catchments: Strangford (51 %), Clanrye (56 %), Upper Bann (61 %) and Ballinderry (71 %). There are currently no groundwater monitoring stations within the Clanrye catchment, as lead-in times for new stations exceed one year. The list of catchments with the highest percentage of derogated farms is updated annually and 2016 was the first time that the Clanrye catchment was considered a high derogation catchment.

In this report, comparisons of the mean annual average data for the period 2012-2015 (as reported in the Northern Ireland 2016 Nitrates Article 10 Report[4]) and the most recent annual average data for the current reporting year (2017) are presented. In each period, surface water data were only included where sufficient numbers of samples over the four years (2012-2015) and one year (2017) were available[5]. In the four-year (2002-2015) period all groundwater data were included. For the current reporting year 2017, all available groundwater data were included; consisting on average of three samples per monitoring site.

Presentation of the four-year data set (2012-2015) as reported in the Northern Ireland 2016 Nitrates Article 10 Report, provides continuity with other Nitrates Directive 91/676/EEC (ND) reporting requirements and it provides a clear indication of how the water quality is evolving since the Article 10 Report for the period 2012-2015.

The results of a single year analysis must be treated with caution; due to the relatively low numbers of samples involved and possible variability due to climatic influences (for the

[4] Member States must report every four years to the Commission on the status of water quality in accordance with Article 10 of the Nitrates Directive (91/676/EEC). The 'Nitrates Directive Development Guidance Notes for Member States' issued in 2011, indicate that for the purposes of reporting, data may be averaged over more than one year. The UK 2016 Nitrates Article 10 Report was completed in July 2016 and data was summarised and presented for 2012-2015.

[5] Sufficient numbers of samples, for annual average, in the four-year period 2012-2015 were considered to be ≥20 samples and ≥10 for the current reporting year (2017).

purposes of this report, adjustments have not been made for weather or other varying annual effects). When considering the following results it should, therefore, be remembered that variations in annual precipitation or in seasonal patterns of rainfall can increase nutrient run-off and thereby potential nutrient input to surface waters. Average monthly precipitation for Northern Ireland for 2012-2015 was 84.1 mm and for 2017 was lower at 82.8 mm (source: Met Office).

In 2009, a revision of the surface freshwater monitoring network was carried out to broaden the coverage in Northern Ireland for Water Framework Directive (2000/60/EC) (WFD) monitoring for the six-year period 2009-2014. The revision also reduced the numbers of monitored sites from 579 to 528 whilst continuing to fulfil monitoring obligations under WFD, Freshwater Fish Directive (2006/44/EC) (FFD) and ND. Further financial constraints led to another revision of the network in 2010. The new approach incorporated monthly sampling at a reduced number of core sites (258) with the remainder of sites (270) monitored for two years within the six-year River Basin Plan cycle on a rolling programme basis (2009-2014).

This meant that the average number of monthly samples analysed for nutrients was reduced from 579 to an average of 348 in each year. Changes to the monitoring programme were implemented in 2015 for the second cycle of the River Basin Management Plans (RBMP) through better targeting and by adopting a risk based approach to monitoring. At this time, a reduction to quarterly monitoring frequencies for nutrient levels occurred at some sites due to resource pressures, but monthly monitoring was reinstated during 2016. In 2017, the average number of monthly samples analysed for nutrients was 515.

Groundwater quality in Northern Ireland is assessed in accordance with NIEA's groundwater monitoring programme through the collection of water samples from boreholes and springs that are mostly owned and operated by third parties. The public water supply provider in Northern Ireland (NI Water Ltd) does not currently utilise groundwater with the exception of Rathlin Island, a small island off the north coast of Northern Ireland. Hence, NIEA rely mostly on third party owned boreholes and the co-operation of land/property owners to continue sampling from their groundwater sources for the chemical/nutrient monitoring.

This means that the composition of the ground water monitoring network can change due to businesses closing or changing their groundwater usage and in addition, datasets for trend assessments are often small. The monitoring network consists mainly of industrial boreholes where groundwater is utilised for manufacturing or food/drinks production. A small number of springs or boreholes purpose-installed by NIEA, which are purged prior to sampling, are also monitored. The selection of groundwater monitoring sites to date has been based on a pressure-pathway assessment of the groundwater bodies and the availability of potential monitoring points.

3.1 Nitrate concentrations in surface freshwater

In the period 2012-2015, NIEA monitored nitrate concentrations at 337 surface freshwater monitoring stations across Northern Ireland. The annual average nitrate concentration at these stations was 5.2 mg NO_3/l. In 2017, nitrate concentrations were monitored at 507 surface freshwater stations giving an annual average nitrate concentration of 4.9 mg NO_3/l.

Table 2: Annual average nitrate concentrations (based on number and % of monitoring stations) of surface freshwater across Northern Ireland, 2012-2015 and 2017

Average nitrate concentration (mg NO_3/l)	**Northern Ireland**	
	2012-2015 (337 stations)	**2017 (507 stations)**
0–9.99	89.34% (301)	90.3% (458)
10–24.99	10.7% (36)	9.5% (48)
25–39.99	0	0.2% (1)
40-50	0	0
>50	0	0

Table 3: Annual average nitrate concentrations (based on number of monitoring stations) of surface freshwater in the high derogation catchments, 2012-2015 and 2017

Average nitrate (mg NO_3/l)		**0–9.99**	**10–24.99**	**25–39.99**	**40-50**	**>50**
Ballinderry Catchment	2012-15 (22 Sites)	81.8% (18)	18.2% (4)	0	0	0
	2017 (23 Sites)	87% (20)	13% (3)	0	0	0
Strangford Catchment	2012-15 (19 Sites)	63.2% (12)	36.8% (7)	0	0	0
	2017 (22 Sites)	45.5% (10)	50% (11)	4.5% (1)	0	0
Clanrye Catchment	2012-15 (9 Sites)	44.4% (4)	55.6% (5)	0	0	0
	2017 (10 Sites)	10% (1)	90% (9)	0	0	0
Crawfordsburn Catchment	2012-15 (1 Site)	100% (1)	0	0	0	0
	2017 (1 Site)	0	100% (1)	0	0	0
Upper Bann Catchment	2012-15 (12 Sites)	100% (12)	0	0	0	0
	2017 (24 Sites)	87.5% (21)	12.5% (3)	0	0	0

In 2012-2015, 63 of the monitored surface freshwater stations were located in the five catchments with the highest proportion of derogated farms and an annual average nitrate concentration of 7.9 mg NO_3/l was recorded. In 2017, 80 stations were monitored in these catchments with an annual average concentration of 8.9 mg NO_3/l.

Table 2 shows annual average nitrate concentrations in surface freshwater across Northern Ireland in 2012-2015 and 2017 based on the number and percentage of stations monitored.

Table 3 shows the average nitrate concentrations in surface freshwater in the five high derogation catchments in 2012-2015 and 2017 based on the number and percentage of stations monitored.

Figure 5 shows the distribution of nitrate in surface freshwater across Northern Ireland and the high derogation catchments in 2017. Average nitrate concentrations in 2017 were generally low across Northern Ireland, with 99.8% of surface water stations below 25 mg NO_3/l.

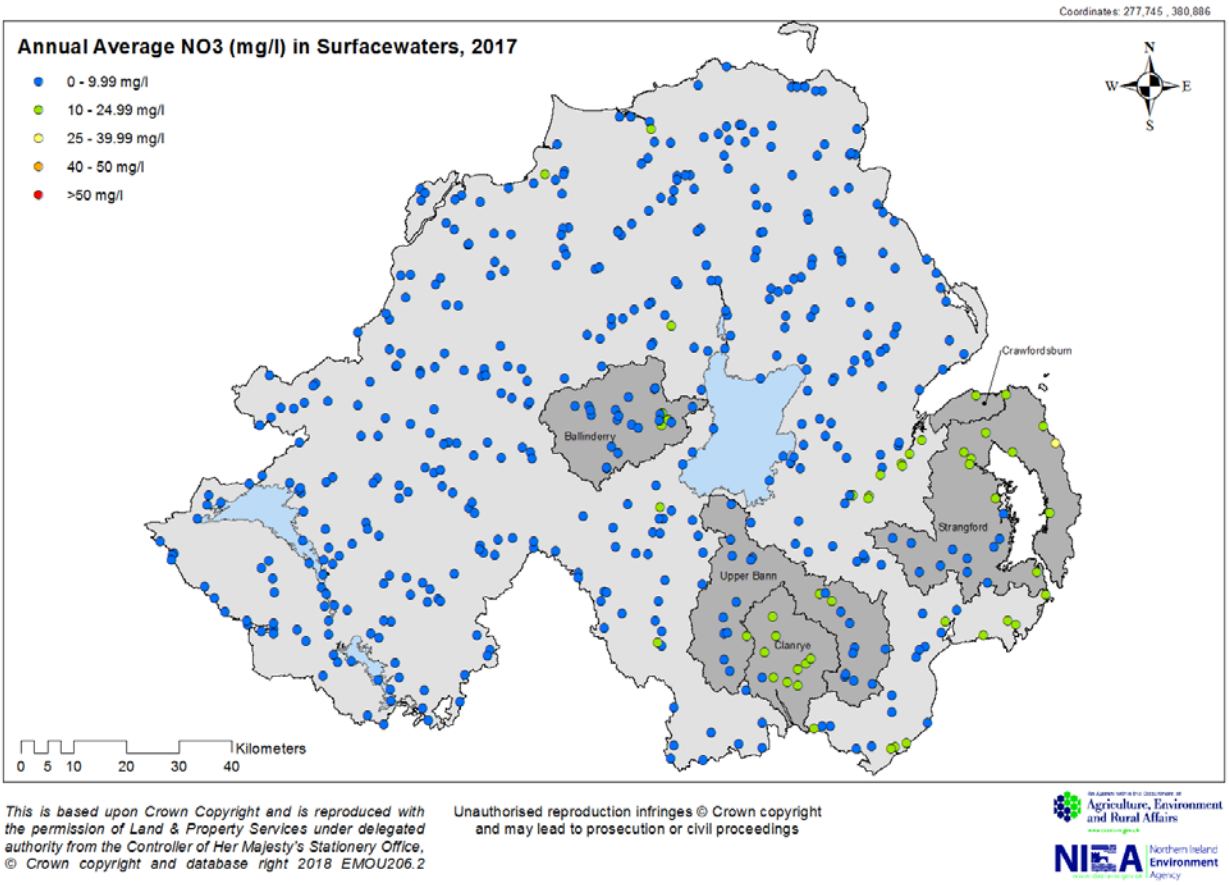

Figure 5: Distribution of annual average nitrate concentrations at surface freshwater stations in 2017

Nitrate concentration trends in Table 4 and Figure 6 indicate that the annual average nitrate concentrations in common surface freshwater stations across Northern Ireland were stable or decreasing at 87% of surface freshwater sites (including the high derogation catchments) between the two reporting periods, 2012-2015 and 2017. This compares to 100% of sites in the 2016 report.

Stations across Northern Ireland showing increasing trends in nitrate will be subject to further data analysis, and targeted action. Further investigations and actions in these catchments will be implemented as part of targeted catchment projects under WFD in the RBDs. This will include engagement with the sewerage undertaker, home owners and farmers in the local areas, to follow up actions arising from reported pollution incidents and improve water protection.

Table 4: Change in average nitrate concentrations (based on % and number of common monitoring stations) of surface freshwater across Northern Ireland and in the high derogation catchments, between 2012-2015 and 2017

Difference in average nitrate concentration (mg NO_3/l) 2012-2015 – 2017	**% and number of common monitoring stations**		
	Decrease[1]	**Stable[2]**	**Increase[3]**
Northern Ireland (321 Stations)	11.2% (36)	75.4% (242)	13.4% (43)
Ballinderry Catchment (22 Stations)	31.8% (7)	68.2% (15)	0
Strangford Catchment (19 Stations)	10.5% (2)	21.1% (4)	68.4% (13)
Clanrye Catchment (9 Stations)	0	0	100% (9)
Crawfordsburn Catchment (1 Station)	0	0	100% (1)
Upper Bann Catchment (12 Stations)	0	91.7% (11)	8.3% (1)

Difference is assessed by change in concentration – [1]Decrease ≤ -1 mg/l, [2]Stable -1 to +1 mg/l, [3]Increase ≥ +1 mg/l

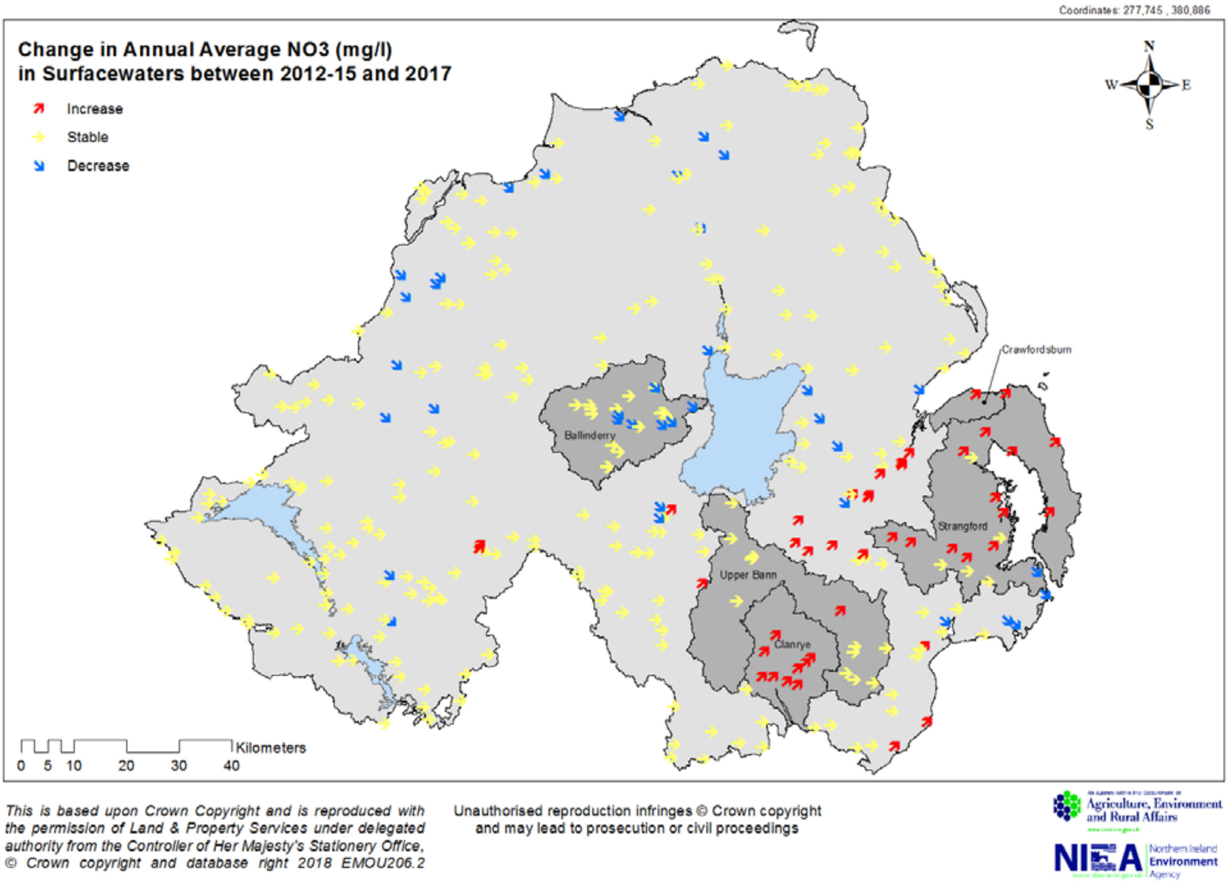

Figure 6: Change in annual average nitrate concentrations at surface freshwater stations between 2012-2015 and 2017

3.2 Nitrate concentrations in groundwaters

In the period 2012 to 2015, NIEA monitored nitrate concentrations at 56 groundwater monitoring sites across Northern Ireland at which average nitrate concentrations were determined. The average nitrate concentration at the 56 sites in 2012-2015 was 6.26 mg NO_3/l. In 2017, nitrate concentrations were monitored at 51 groundwater sites across Northern Ireland giving an average concentration of 4.21mg NO_3/l.

In 2012-15, 11 of the monitored groundwater sites were located in the two high derogation catchments (Ballinderry and Strangford) and an average concentration of 12.09 mg NO_3/l was recorded. In 2017, 19 of the monitored groundwater sites were located in the Ballinderry and Strangford catchments and an average concentration of 14.78 mg NO_3/l was recorded. In 2017 the Upper Bann catchment was further identified as a high derogation catchment leading to an average nitrate concentration for the three catchments (Ballinderry, Strangford, Upper Bann) of 12.57 mg NO_3/l. Both the Aughnacloy and Tandragee groundwater bodies contribute towards the Upper Bann catchment and nitrate concentrations in groundwater were monitored at nine stations from 2012 to 2015 and eight stations in 2017 respectively. The average nitrate concentrations for the Aughnacloy and Tandragee groundwater bodies (contributing to the Upper Bann catchment) were 2.1 mg NO_3/l in 2012-15 and 0.93 mg/l NO_3/l.

This higher average value for the high derogation catchments is due mainly to two monitoring sites in the Strangford catchment (one monitoring site in the Ards groundwater body, the other monitoring site in the Belfast East groundwater body), as discussed below.

Table 5 shows the average nitrate concentrations in groundwater across Northern Ireland and in the high derogation catchments for 2012–2015 and 2017. Figure 7 shows the distribution of nitrate in groundwater across Northern Ireland and in the high derogation catchments in 2017.

Table 5: Average nitrate concentrations (based on number of monitoring sites) of groundwater across Northern Ireland and in the high derogation catchments with the highest proportion of derogated farms, 2012-2015 and 2017

Catchment	Groundwater body	Average nitrate concentration (mg NO_3/l)	0-24.99	25–39.99	40–50	>50
Northern Ireland		2012-2015 56 Sites	55	0	0	1
		2017 51 Sites	50	0	0	1
Ballinderry	Cookstown	2012-2015 4 Sites	4	0	0	0
		2017 2 Sites	2	0	0	0
	Moneymore	2012-2015 1 Site	1	0	0	0
		2017 1 site	1	0	0	0
Strangford	Ards Peninsula	2012-2015 1 Site	0	1	0	0
		2017 1 Site	1	0	0	0
	Belfast East	2012-2015 5 Sites	4	0	0	1
		2017 5 Sites	4	0	0	1
Upper Bann	Aughnacloy	2012-2015 7 stations	7	0	0	0
		2017 7 stations	7	0	0	0
	Tandragee	2012-2015 2 stations	2	0	0	0
		2017 1 station	1	0	0	0

Average nitrate concentrations in groundwater across Northern Ireland were generally low, with 55 of the 56 sampling points at less than 25 mg NO_3/l in 2012-2015 compared with 50 out of 51 sampling points at less than 25 mg NO_3/l in 2017. Average nitrate concentrations in the Ballinderry catchment in 2017 were generally low with all of the monitoring sites below 25 mg NO_3/l. In 2017 four of the five monitoring sites in the Strangford catchment were also below 25 mg NO_3/l, but one monitoring site (Belfast East groundwater body) had an average nitrate concentration greater than 50 mg/l. The site had previously average concentrations above 50 mg NO_3/l. As noted in the 2016 report, it was only possible to sample this site once in 2016 due to access problems, as NIEA relies on third parties for access to land and boreholes. As a result it was already pointed out in last year's report that the apparent downward trend had a low confidence level. Therefore the 2017 average above 50 mg NO_3/l does not signify a true increase.

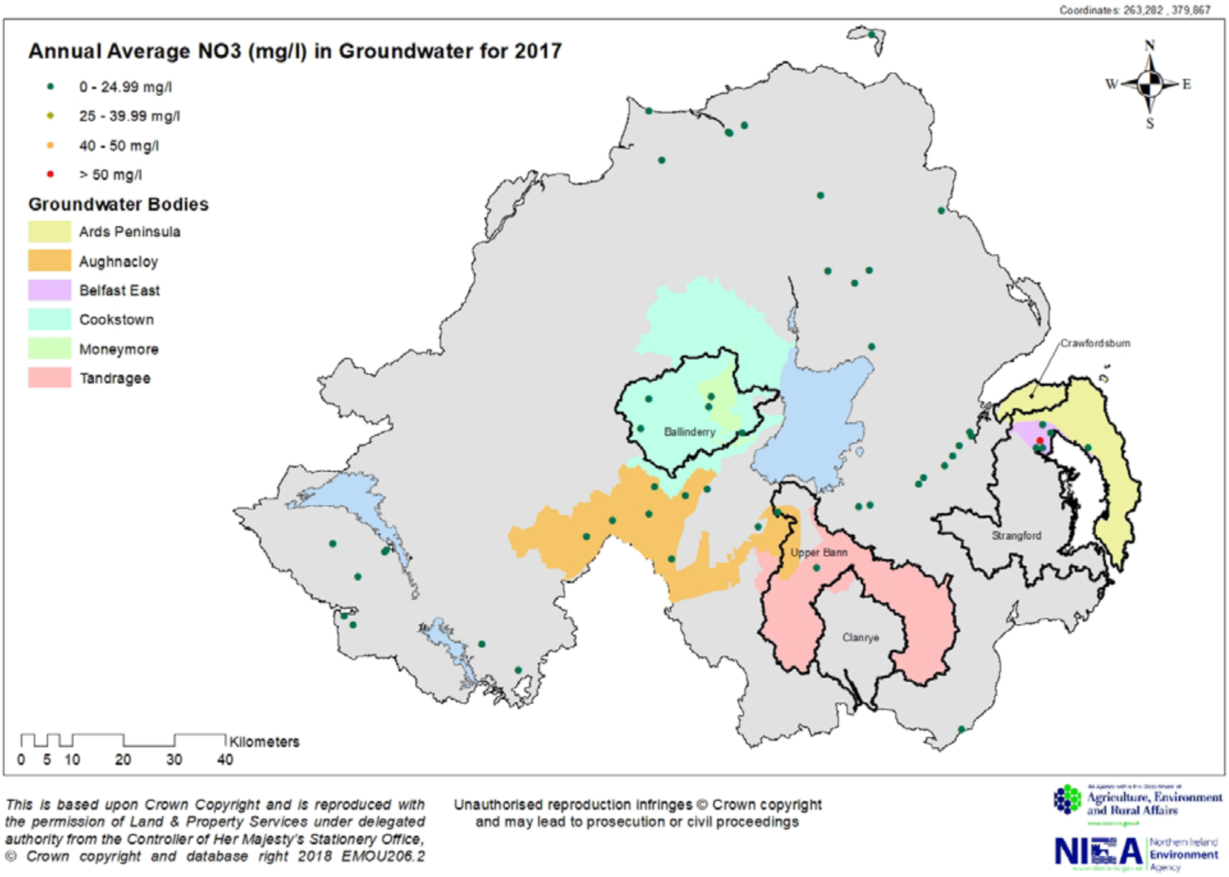

Figure 7: Distribution of annual average nitrate concentrations at groundwater stations in 2017. High Derogation Catchments are labelled and outlined with black line. Sampled groundwater bodies within these catchments are coloured according to legend.

Nitrate concentration trends in groundwater across Northern Ireland, in Table 6, indicate a decrease or stabilisation in Ballinderry and Upper Bann high derogation catchments in 2017 compared to 2012-2015. The Strangford catchment shows a small increase in average nitrates concentrations in 2017 when compared to 2012 to 2015. This is due to the one station in the Belfast East groundwater body that has an average concentration above 50 mg NO_3/l and had previously concentrations above 50 mg NO_3/l. This station is located in a former nitrate vulnerable zone before Northern Ireland was designated total territory. The station was purposely installed in that location to monitor groundwater quality in this area of arable farming.

The Crawfordsburn catchment is part of the Ards groundwater body, but there are currently no monitoring points located within the Crawfordsburn catchment. The percentage of derogated farm land to overall farm land in the Crawfordsburn catchment is quite high (22 %), its overall percentage of farm land within the catchment is low (23 %) due to the urban nature of the catchment. For comparison the percentage of farm land within the catchment is 51 %, 61 % and 71 % for the Strangford, Upper Bann and Balllinderry catchments, respectively. Therefore, the Crawfordsburn catchment is not considered representative of the overall situation in Northern Ireland. There are currently no groundwater monitoring stations within the Clanrye catchment, as lead-in times for new stations exceed 1 year. The list of catchments with the highest percentage of derogated farms is updated annually and 2016 was the first time that the Clanrye catchment was considered a high derogation catchment.

For the trend assessments averages of the groundwater bodies within each catchment are compared from the 2012-2015 and 2017 time periods.

Table 6: Change in average nitrate concentrations (based on averages per groundwater body in each catchment) across Northern Ireland and in the high derogation catchments, between 2011-2015 and 2017

Catchment	**Groundwater body**	**Difference in average nitrate concentration (mg NO_3/l)**	**> -5**	**-1 to -5**	**-1 to +1**	**+1 to +5**	**> +5**
Northern Ireland				•			
Ballinderry	Cookstown			•			
	Moneymore				•		
Strangford	Ards Peninsula		•				
	Belfast East					•	
Upper Bann	Aughnacloy				•		
	Tandragee			•			

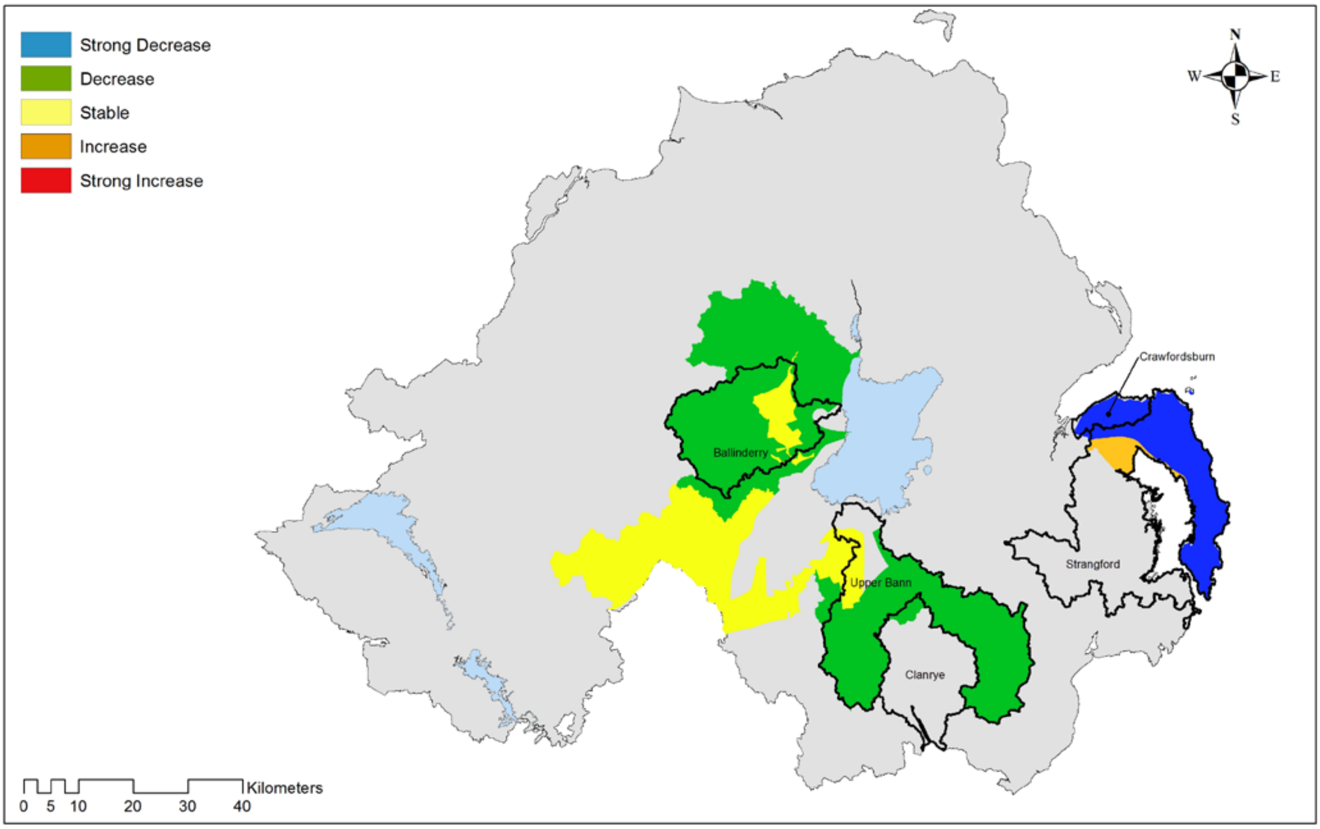

Figure 8: Changes in nitrate concentration averages per groundwater body in each catchment between the periods of 2012-2015 and 2017

3.3 Eutrophic indicators - phosphorus concentrations in rivers and streams

Since the adoption of the WFD, methodologies for assessment of eutrophication in rivers and lakes have changed. Historically, waters were assessed for trophic status using guidance issued by the UK authorities in 2002. Under the current WFD methodology, transposed in Northern Ireland as The Water Environment (Water Framework Directive) Regulations (Northern Ireland) 2017[6], freshwater bodies are assessed for trophic status using WFD standards for both phosphorus (SRP) and biological indicators.

For the purposes of this report SRP is considered on its own and without the supporting biological parameters normally required to classify status. To be consistent in the approach and for temporal comparative purposes Northern Ireland has assessed data from 2012-2017 using the SRP standards calculator as set out in the Regulations noted above, to obtain a site specific WFD SRP Classification for each site. They have been derived using a new approach to setting phosphorus standards that produces site specific

[6] http://www.legislation.gov.uk/nisr/2017/81/pdfs/nisr_20170081_en.pdf

estimates of natural phosphorus concentrations, taking account of a site's alkalinity and altitude (UKTAG, 2015).

The revised standards represent a major step forward in matching nutrient concentration to ecological change. The standards are more precautionary than previous SRP standards used in the first cycle of River basin Management Plans as UKTAG found these to be insufficiently stringent, with High or Good status phosphorus classifications being produced for water bodies where there are clear ecological impacts of nutrient enrichment.

In the period 2012-2015, NIEA monitored annual soluble reactive phosphorus (SRP) concentrations at 391 surface freshwater river stations across Northern Ireland. The annual average SRP concentration at these sites was 64.8 µg SRP/l. In 2017, SRP concentrations were monitored at 473 surface freshwater river stations, giving an annual average SRP concentration of 76 µg SRP/l.

In 2012-2015, 68 of the monitored surface freshwater monitoring stations were located in the five catchments with the highest proportion of derogated farms and an average phosphorus concentration of 108 µg SRP/l was recorded. In 2017, the same 68 stations were also monitored in these catchments with an annual average concentration of 128 µg SRP/l. Table 7 shows the WFD SRP status in rivers and streams across Northern Ireland for 2012-2015 and 2017.

Table 7: WFD SRP status (based on % and number of monitoring stations) of surface freshwater in rivers and streams across Northern Ireland, 2012–2015 and 2017

WFD SRP Class	Northern Ireland	
	2012-2015 (391 Stations)	**2017 (473 Stations)**
High	127 (32.5 %)	110 (23.3 %)
Good	132 (33.8 %)	142 (30 %)
Moderate	110 (28.1 %)	183 (38.7 %)
Poor	22 (5.6 %)	38 (8 %)
Bad	0	0

Results in Table 7 show that in the 2012-15 reporting period, 66.3% of river sites were classified as High or Good for SRP status. The remaining 33.7% of river sites had a WFD SRP classification of less than Good status and are considered to be at risk from eutrophication or eutrophic. Of these sites, 5.6% were classed as Poor status for SRP.

In 2017, 53.3% of river sites were classified as High or Good for SRP status. 46.7% of river sites had a WFD SRP classification of less than Good status. Of these, 8% were classified as Poor status for SRP, indicative of nutrient enrichment. No sites were classed as Bad status in either reporting period. Compared with the previous reporting period (2012-15), there was a decrease in the number of sites that were classed as High or Good.

Table 8 shows the WFD SRP status of surface freshwater monitoring stations in rivers and streams in the high derogation catchments in 2012-2015 and 2017. Figure 9 shows the distribution of WFD SRP status across Northern Ireland and the five derogation catchments in 2017.

Average SRP concentrations in the Ballinderry catchment , ranged from 19.3 to 119 µg SRP/l in 2012-2015 and 28 to 147 µg SRP/l in 2017, with 30.4% of sites classed as High or Good status and 69.6% classed as Moderate status. No sites were classed as Poor or Bad status.

Average concentrations in the Strangford catchment ranged from 27.3 to 519 µg SRP/l in 2012-2015 and 43 to 624 µg SRP/l in 2017, with no change in the number of sites classified as less than Good status between reporting periods.

Average SRP concentrations in the Clanrye catchment ranged from 62.5 to 181 µg SRP/l in 2012-2015 and 80 to 229 µg SRP/l in 2017, with no change in the number of sites classified as less than Good status between reporting periods.

The average concentration at the single site in the Crawfordsburn catchment was103 µg SRP/l in 2012-2015 and 148 µg SRP/l in 2017, with no change in the number of sites classified in Moderate status between reporting periods.

Average SRP concentrations in the Upper Bann catchment , ranged from 10.7 to 274 µg SRP/l in 2012-2015 and 7 to 376 µg SRP/l in 2017, with 17.6% of sites classed as High or Good status and 82.4% classed as less than Good status. No sites were classed as Bad status.

Table 8: WFD SRP status (based on number of common stations) of surface freshwater in rivers and streams in the high derogation catchments, 2012-2015 and 2017

WFD SRP Status		**High**	**Good**	**Moderate**	**Poor**	**Bad**
Ballinderry Catchment (23 sites)	**2012-2015**	4.3% (1)	60.9% (14)	34.8% (8)	0	0
	2017	4.3% (1)	26.1% (6)	69.6% (16)	0	0
Strangford Catchment (18 sites)	**2012-2015**	11.1% (2)	0	44.4% (8)	44.4% (8)	0
	2017	11.1% (2)	0	50% (9)	38.9% (7)	0
Clanrye Catchment (9 sites)	**2012-2015**	0	0	88.9% (8)	11.1% (1)	0
	2017	0	0	77.8% (7)	22.2% (2)	0
Crawfordsburn Catchment (1 site)	**2012-2015**	0	0	100% (1)	0	0
	2017	0	0	100% (1)	0	0
Upper Bann Catchment (17 sites)	**2012-2015**	5.9% (1)	17.6% (3)	70.6% (12)	5.9% (1)	0
	2017	5.9% (1)	11.8% (2)	70.6% (12)	11.8% (2)	0

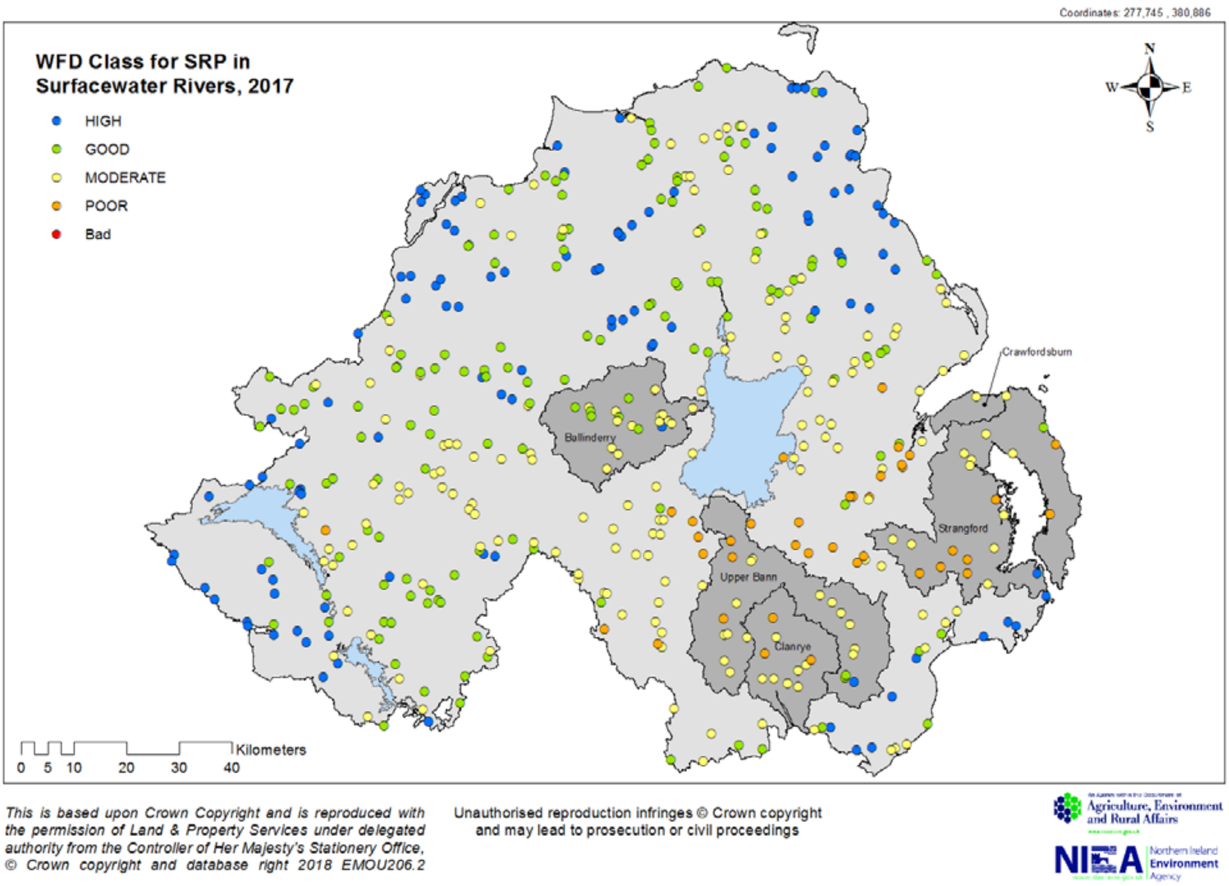

Figure 9: Distribution of WFD SRP status at surface freshwater stations in rivers and streams in 2017

The change in annual average SRP concentrations were historically reported in previous Derogation Reports according to Nitrates Directive guidance circulated in 2011. This identifies if a change is significant at ±50 µg/l, but this is a relatively coarse assessment. By also reporting the change in WFD SRP status using site specific standards, these will be more responsive to changes occurring and highlight any deterioration. This may be due to natural conditions as relatively small changes in SRP concentration can result in a change in class.

Trends in annual average SRP concentration shown in Table 9 and Figure 10 indicate a decline or stabilisation in SRP levels at 95% of common surface freshwater monitoring stations in rivers and streams between 2012-2015 and 2017 across Northern Ireland when assessed according to Nitrates Directive guidance. The criteria used to report change is ±0.05mg/l, which is a relatively high threshold.

Some changes in concentrations did occur which led to changes in WFD status at individual sites (Table 10 and Figure 11). 27.8% (100 sites) deteriorated by one class for WFD SRP status. 1 site (Crilly Feeder at Dunmacmay deteriorated by 2 classes from High to Moderate status. 68% (245 sites) remained stable in WFD SRP status and 3.6% (13 sites) exhibited an improvement in class between the two reporting periods. 0.3% (1 site - Hillsborough Park Lake Stream at Gowdy's) improved from Poor to Good status between the two reporting periods.

The single site in the Crawfordsburn catchment remained stable with Moderate WFD SRP status between the two reporting periods. 94.4% (17 sites) remained stable in the Strangford catchment whilst 5.6% (1 site) improved by one class for WFD SRP status. 88.9% (8 sites) remained stable in the Clanrye catchment, whilst 11.1% (1 site) deteriorated by 1 class. 88.2% (15 sites) remained stable in the Upper Bann catchment whilst 11.8% (2 sites deteriorated by 1 class for WFD SRP status). 65.2% (15 sites) remained stable in the Ballinderry catchment whilst 34.8% (8 sites) deteriorated by one class for WFD SRP status. As previously highlighted, these results should be treated with a degree of caution as natural variation in nutrient concentration is expected year to year due to seasonal and climatic changes.

All monitoring stations showing higher concentrations of SRP or decline in WFD status for SRP will be subject to further data analysis to establish if there are any specific factors, such as geographic area or season that may suggest a cause for the change. This will be followed by investigations and actions as part of the relevant targeted catchment projects under WFD for each of the RBDs where the changes are most significant. This will include engagement with the sewerage undertaker, home owners and farmers in the local areas, to follow up actions arising from reported pollution incidents and improve water protection.

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Table 9: Change in average soluble reactive phosphorus concentrations (based on % and number of common monitoring stations) of surface freshwater in rivers and streams across Northern Ireland and in the high derogation catchments, between 2012-2015 and 2017

Difference in average Soluble Reactive Phosphorus concentration ($\mu g\ NO_3/l$) 2012-2015 – 2017	% and number of common monitoring stations		
	Decrease[1]	Stable[2]	Increase[3]
Northern Ireland (360 Stations)	0.3% (1)	95% (342)	4.7% (17)
Ballinderry Catchment (23 Stations)	0	91.3% (21)	8.7% (2)
Strangford Catchment (18 Stations)	0	83.3% (15)	16.7% (3)
Clanrye Catchment (9 Stations)	0	100% (9)	0
Crawfordsburn Catchment (1 Stations)	0	100% (1)	0
Upper Bann Catchment (17 Stations)	0	88.2% (15)	11.8% (2)

Difference is assessed by change in concentration – [1]Decrease ≤ -50 µg/l, [2]Stable -50 to +50 µg/l, [3]Increase ≥ +50 µg/l

Table 10: Change in WFD SRP classification (based on % and number of common monitoring stations) of surface freshwater in rivers and streams across Northern Ireland and in the high derogation catchments, between 2012-2015 and 2017

WFD SRP Classification	% and number of common monitoring stations				
	Strong Decrease[1]	Weak Decrease[2]	Stable[3]	Weak Increase[4]	Strong Increase[5]
Northern Ireland (360 Stations)	0.3% (1)	3.6% (13)	68% (245)	27.8% (100)	0.3% (1)
Ballinderry Catchment (23 Stations)	0	0	65.2% (15)	34.8% (8)	0
Strangford Catchment (18 Stations)	0	5.6% (1)	94.4% (17)	0	0
Clanrye Catchment (9 Stations)	0	0	88.9% (8)	11.1% (1)	0
Crawfordsburn Catchment (1 Station)	0	0	100% (1)	0	0

Upper Bann Catchment (17 Stations)	0	0	88.2% (15)	11.8% (2)	0

[1] *Strong Decrease = ≥2 improvements in class*
[2] *Weak Decrease = 1 improvement in class*
[3] *Stable = No change in class*
[4] *Weak Increase = 1 deterioration in class*
[5] *Strong Increase = ≥2 deteriorations in class*

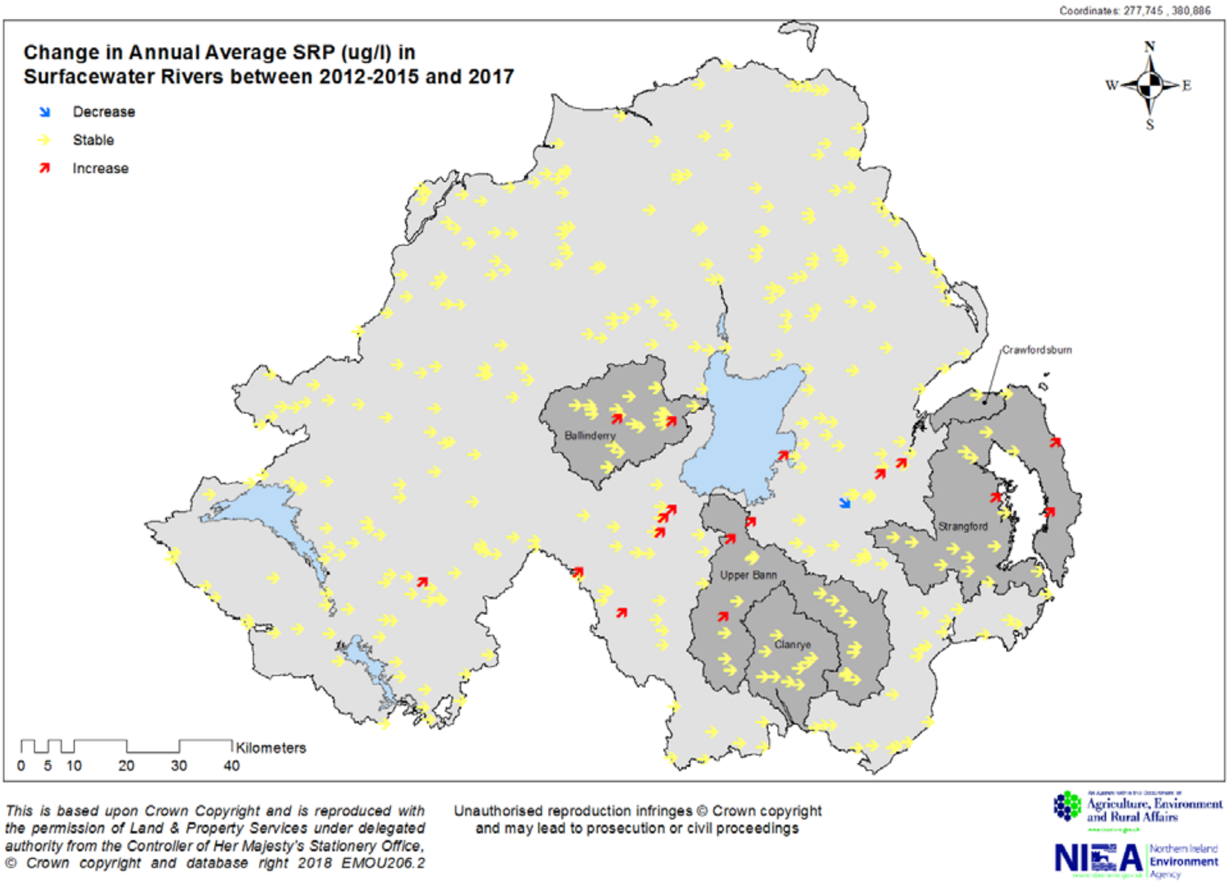

Figure 10: Change in SRP concentrations in surface water between 2012-2015 and 2017 when assessed according to Nitrates Directive guidance.

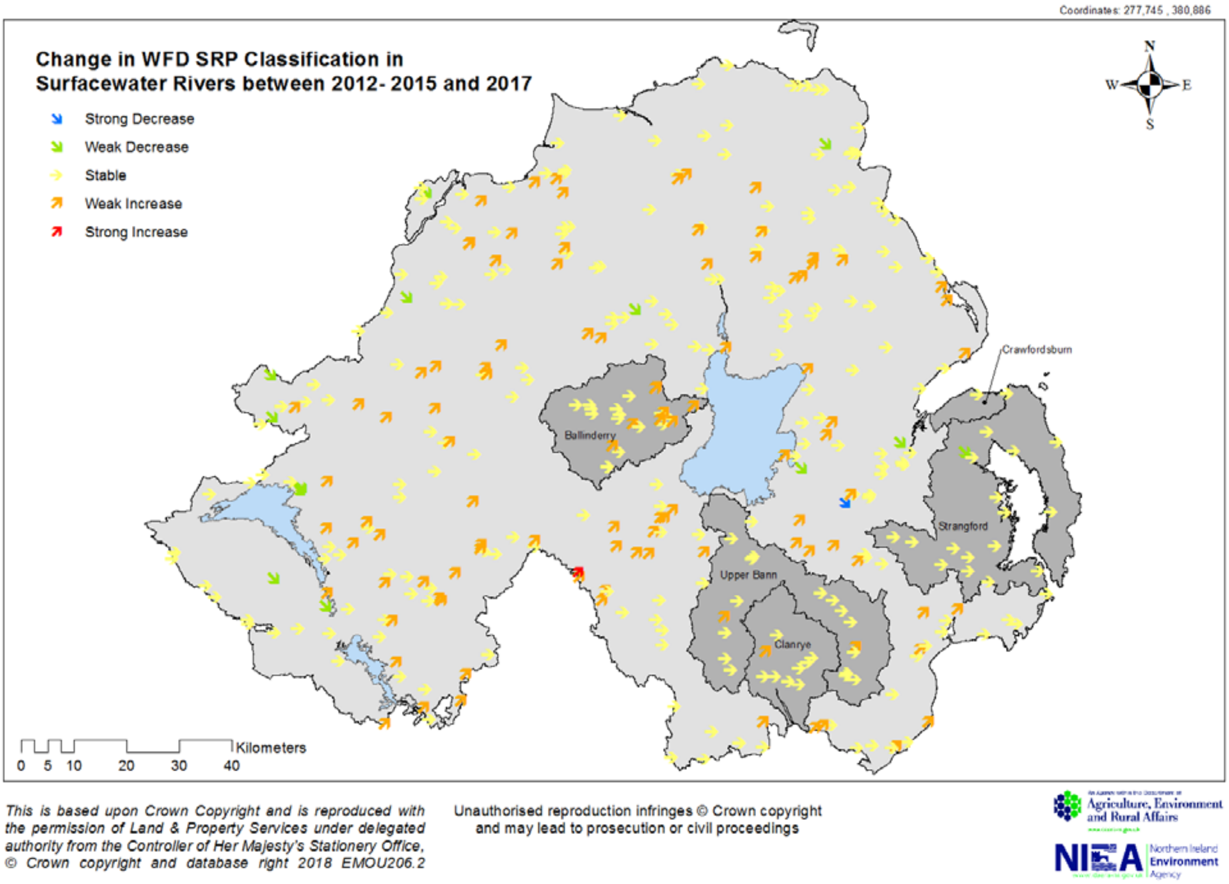

Figure 11: Change in WFD SRP classification in river monitoring sites between 2012-2015 and 2017

In this report, both the assessments using Nitrates Directive and WFD criteria show deterioration as indicated by the percentage of sites that are exhibiting increasing SRP levels. This is a cause for concern. Therefore, DAERA has included an SRP indicator for Water Quality in the proposed Programme for Government (PfG). The SRP indicator used is the annual average SRP (µg/L) for 93 surveillance river sites and is not a WFD status assessment. For PfG it is required that a threshold for change is set. The criteria used to report changes for this indicator is ±0.01mg/l (against the baseline year of 2015).

3.4 Eutrophic indicators - phosphorus concentrations in lakes

For the purposes of this report total phosphorus (TP) is considered on its own as a eutrophication indicator and without the supporting data on chlorophyll-α and biology normally required to classify under the WFD.

In the WFD classification period 2012-2014, NIEA monitored annual TP concentrations at 21 WFD lake and reservoir monitoring stations (Lower Lough Erne is divided into two water bodies) across Northern Ireland, with a surface area greater than 50 ha (known as surveillance lakes). In 2017, the same 21 lake and reservoir monitoring stations were monitored. The annual average TP concentration for the 21 common surveillance stations was 65 µg TP/l for the period 2012-2014 and 75 µg TP/l for 2017.

Table 11 and Figure 12 show that in 2017, 6 lakes and reservoirs were classed as High or Good WFD status whilst 15 were classed as Moderate, Poor or Bad WFD status, indicative of nutrient enrichment. Although no lakes showed any improvement in class between the two reporting periods (2012-14 and 2017), 14 lakes remained stable for WFD TP status. Two lakes (Lough Neagh and Portmore Lough) were classed as Bad WFD TP status in both reporting periods.

Six lakes exhibited deterioration by one class in TP status between the two reporting periods. Lough Scolban, Silent Valley and Spelga deteriorated from High to Good TP Class, Lough Melvin deteriorated from Good to Moderate, Lower Lough Erne at Kesh deteriorated from Good to Moderate and Stoneyford Lough deteriorated from Poor to Bad TP status. Only 1 lake exhibited deterioration by 2 classes in TP status between the two reporting periods. Castlehume Lough deteriorated from High to Moderate TP status.

Clea Lakes (Poor status in both reporting periods) is in the Strangford derogated catchment. Three lakes are in the Upper Bann derogated catchment. Lough Gullion was classed as Poor in both reporting periods, Lough Island Reavy was classed as Moderate in both reporting periods and Spelga Dam deteriorated from High to Good status between reporting periods. All lakes exhibiting eutrophic conditions will be subject to further investigations and actions as part of the relevant RBD programme of targeted catchment projects under WFD.

Table 11: WFD status based on average TP concentrations (based on number of common monitoring stations) of WFD surveillance lakes and reservoirs across Northern Ireland, 2012-2014 and 2017

WFD TP Class	Northern Ireland	
	2012-2014 (21 stations)	**2017 (21 stations)**
High	5	1
Good	4	5
Moderate	3	6
Poor	7	6
Bad	2	3

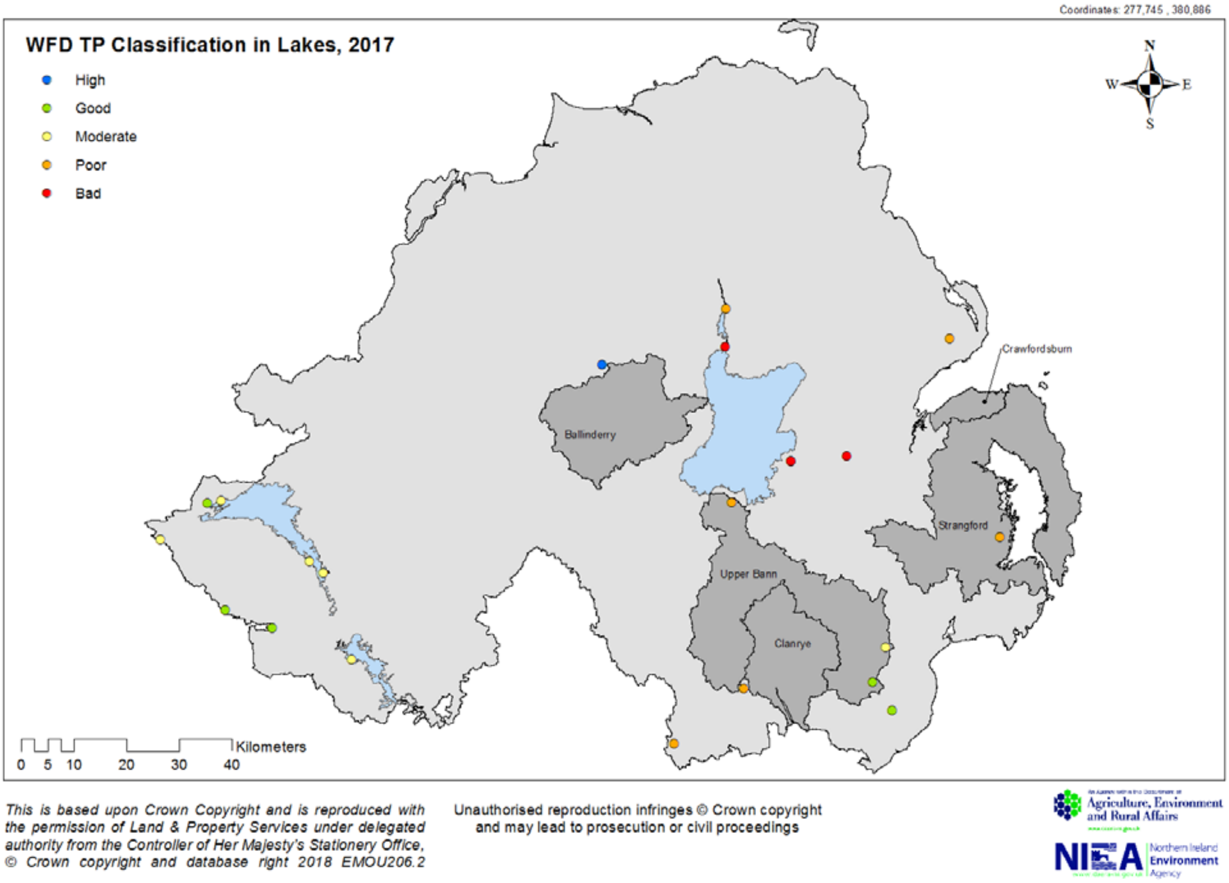

Figure 12: Distribution of WFD TP status in surveillance lakes and reservoirs in 2017

4. SOIL MONITORING

To meet the requirements of Article 8(2) of the 2015 Derogation Decision, a detailed monitoring program has been established. It will provide relevant soil P data for modelling P losses from derogated and non-derogated farms on the main soil types of Northern Ireland and information on farming practices etc. on derogated and non-derogated farms. A pair of sub-catchments has been identified in the Upper Bann River Catchment (Figure 13). One sub-catchment has a significant proportion of derogated farmland (120 out of 329 fields are on derogated farms) and the other has no derogated farmland (Figure 14). In accordance with Article 8(2) of the 2015 Derogation Decision, the most important soil profile types in Northern Ireland, i.e. Gleys (57%), and also the most important Hydrology of Soil Types (HOST) classes (17-24) particularly 24, i.e. soils developed on slowly permeable material (54%), are well represented within this pair of sub-catchments. The requirement to monitor soils on farms with *"levels of intensity and fertilisation practices"* typical for Northern Ireland has also been fulfilled by having two contrasting small sub-catchments with either some or no derogated farmland.

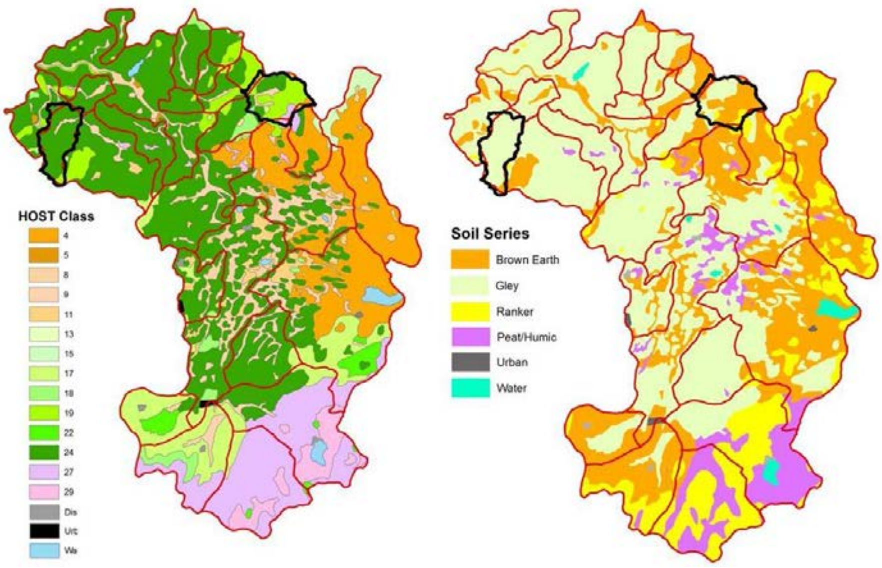

Figure 13: Maps of the Upper Bann River Catchment indicating soil types and Hydrology of Soil Types (HOST) classifications present in selected pairs of derogated and non-derogated sub-catchments.

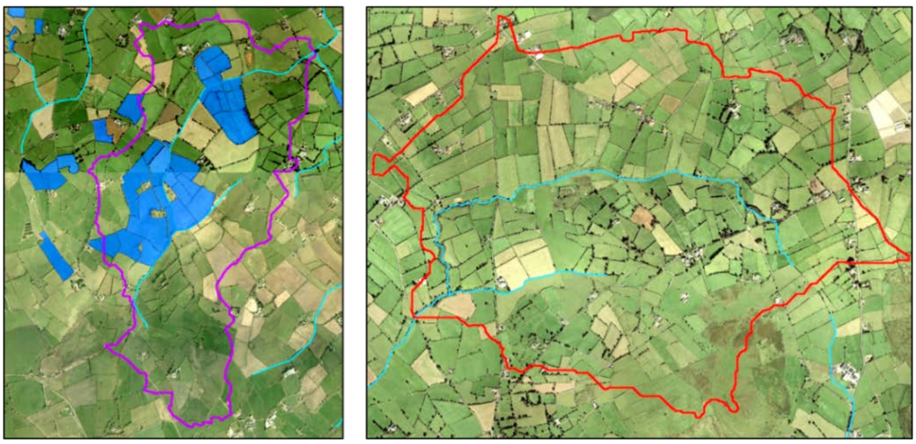

Figure 14: 'Derogated' (UB03) and Non-derogated (UB15) sub-catchments in the Upper Bann (UB) catchment with derogated farmland coloured blue.

Soil sampling in both catchments was undertaken during November- February 2016/17. In total 945 fields were identified for sampling (including land outside the catchment boundary) of which 884 were sampled.

A further significant contribution to the knowledge base on soil fertility and farming practice in Northern Ireland was made by work undertaken as part of the EU Exceptional Adjustment Aid Soil Sampling and Analysis Scheme. In an Open Scheme accessible to farmers across Northern Ireland, 12,218 fields on 522 farms were soil sampled. An additional Catchment Scheme, which focussed on the Upper Bann catchment area sampled 513 farms (7,772 fields) across 11 sub-catchments that have biological and chemical water quality monitoring programmes in place. This Soil Sampling and Analysis Scheme was completed on 1st April 2018 and analysis is now underway to interrogate relationships with farm scale, derogation and landscape and climatic factors across the Upper Bann catchment and Northern Ireland.

4.1 Nitrogen and Phosphorus concentrations in soil water under derogated and non-derogated conditions

Article 8(2) of the 2015 Derogation Decision requires assessments to be made of N and P concentrations in soil water, to facilitate model-based estimates of nitrate and P losses from farms benefiting from derogation. However, these assessments are not considered to be appropriate in grassland situations in Northern Ireland for the following reasons.

The procedures for measuring N (*nitrate and ammonium*) and P (*SRP and total P*) concentrations in soil water (*solution*) are both difficult and problematic necessitating either vacuum plate extraction of soil solutions from individual intact soil cores, or the installation of ceramic suction cups in soil profiles to collect soil water/solution samples in situ. In commercial farming situations the ceramic cup apparatus can easily be damaged by farm machinery or livestock.

Furthermore, obtaining representative samples of soil solution is difficult because of preferential flow pathways which form along root channels or crevices allowing some downward flowing water to bypass the samplers (Ryan *et al*., 2006). An additional difficulty is the fact that the soil water samples collected by either technique are point-specific, since they are taken from single points within a field. Consequently, to allow for the high degree of spatial heterogeneity in N and P concentrations across grassland fields (Cuttle *et al*., 2001; McCormick *et al*, 2009), scores of points would have to be sampled, and this would simply not be cost-effective or practicable.

Temporal heterogeneity is also a problem, as nutrient levels in soil solution are subject to appreciable short-term fluctuations, owing to rainfall dilution etc (Magid & Neilsen, 1992). Assessments of N and P concentrations in soil water therefore, do not provide a basis for predicting mean annual N and P losses to water at field and farm scales on grassland farms in Northern Ireland.

The factor most responsible for ‘poor’ water quality in Northern Ireland is P mobilisation from farmland into freshwater ecosystems and the resultant upsurge in algal growth in this P-limited rather than N-limited environment (Parr & Smith, 1976; Gibson & Stevens, 1979).

Consequently, to assess the impact of derogation on water quality, primary emphasis will be placed on quantifying the risk of P loss, rather than N loss, from farmland. In this regard, researchers in New Zealand have demonstrated that soil Olsen-P, in fields receiving nutrient inputs, is significantly correlated with both dissolved reactive phosphorus (DRP) and total P concentrations in overland flow from grassland sites on a broad range of soil types (McDowell *et al*., 2003).

Importantly, this soil parameter (*Olsen-P*) can be measured on bulked subsamples of soil (*0-75 mm depth*) easily collected from multiple locations across whole fields, as opposed to the single point locations associated with measurements of soil water P concentrations, thus minimising problems owing to spatial heterogeneity in soil P, as noted above. Moreover, Olsen-P assessments appear to be temporally quite stable (Shi *et al*., 2002).

In addition, the bulked soil samples could also be analysed for $CaCl_2$- P, which can provide a proxy estimate of DRP concentration in soil sub-surface flow (McDowell *et al*., 2003). These complementary soil P assessments, together with information and data on soil hydrology and connectivity, and on farm nutrient management practices, will then be used to model and compare P losses from derogated and non-derogated farms.

N is rarely limiting to algal growth in freshwater bodies in Northern Ireland (Parr & Smith, 1976; Gibson & Stevens, 1979). Mean nitrate concentrations in surface and ground waters are generally low and in almost all cases are well below the EU maximum admissible limit for drinking water (Northern Ireland NAP Review Report 2014). Modelling N losses from derogated farmland is still important to ensure that derogation measures are effective in preventing any deterioration in water quality attributable to N losses linked to farming.

As outlined above, soil N assessments are both problematic and poorly related to N loss by leaching or runoff from grassland. Therefore, information and data on soil type, soil hydrology and connectivity, and details of farming practices will be used to model and compare N losses from derogated and non-derogated farms.

In summary, soil Olsen-P and $CaCl_2$-P concentrations are being monitored in soils instead of P concentrations in soil water. In the absence of suitable soil N metrics, model estimates of nitrate loss from farms will be based primarily on soil typology and hydrology plus local climatic and farm management information.

Results from the first phase of soil sampling in the catchments have been used to map soil chemistry within both sub-catchments (Figure 15). Although 884 fields in total were sampled, the total numbers of sampled fields within the catchment boundaries are 169 in the derogated and 324 in the non-derogated catchments, and it is these (n=493) which are the focus of this analysis. Field characteristics differ between catchments with larger field sizes in the derogated catchment (41 % > 2 ha in area) compared to the non-derogated catchment (9 % > 2 ha in area). This may reflect more intensive agriculture which has, over time, led to enlargement and merging of smaller fields in the derogated catchment, but also the difference in elevation and topography between catchments (Derogated Elevation Range: 80 - 170m; Non-Derogated Elevation Range: 125 – 310 m).

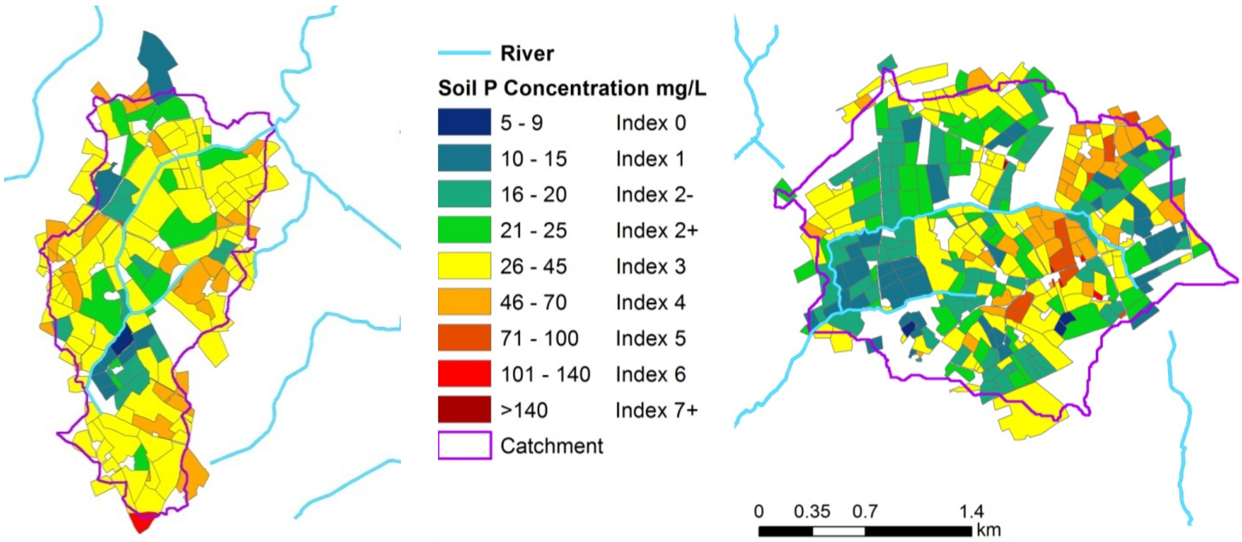

Figure 15: Soil P concentrations for the 'Derogated' (left) and 'Non-derogated' (right) sub-catchments in the Upper Bann catchment. Blank areas within the catchment boundaries were not included in the sampling.

The distribution of soil P between catchments differs considerably (Figure 16). The majority of fields, 79%, in the derogated catchment are at index 3 or above, compared to 43% of fields in the non-derogated catchment. The number of fields with excessively high soil P is greater in the non-derogated catchment with 4.9% of fields (n=16) in excess of Index 4, compared to 1.2% of fields (n=2) in the derogated catchment. A full assessment will require the farm nutrient budgets to be completed. The differences may indicate better nutrient management practices and soil testing on some farms in the derogated catchment, where better control of nutrient applications to crop requirements may be preventing over enrichment of particular fields.

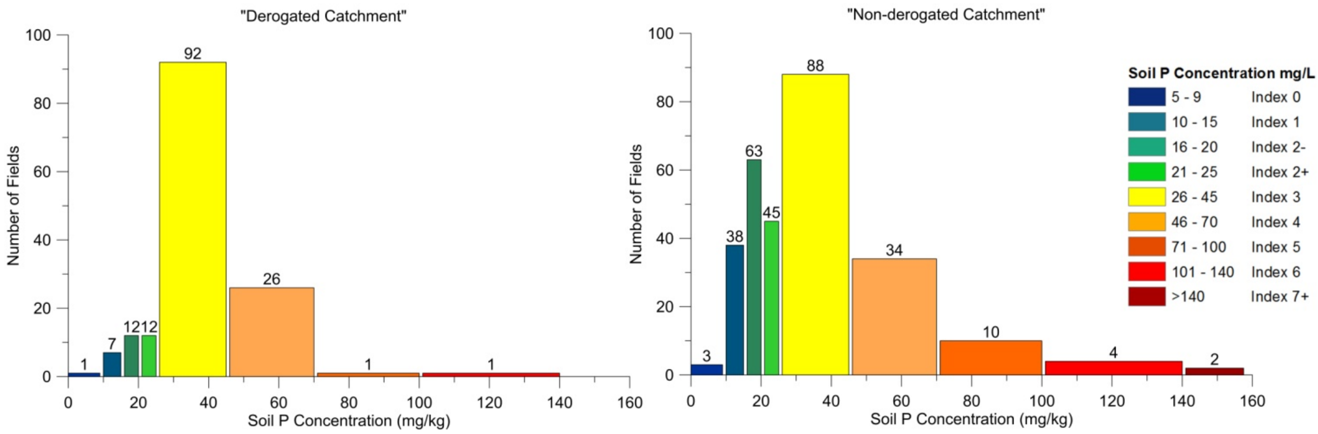

Figure 16: Histograms of P Index category for the 'Derogated' (n=169 fields) and 'Non-derogated' (n=324 fields) sub-catchments in the Upper Bann (UB) catchment.

The higher numbers of highly P-enriched fields (Index 5, 6 &7) in the non-derogated catchment (c.f. the derogated catchment), especially in proximity to farmyards, may indicate that ease of manure transport to particular fields is a stronger determinant of nutrient loading. The more extensive nature of agriculture in the non-derogated catchment is reflected however, by the proportion of fields lower than Index 3 (45.9%) compared to the equivalent proportion in the derogated catchment (18.9%). Furthermore, the average farm-gate P balance for a representative selection of farms within the derogated sub-catchment was only -1 kg P/ha (*primarily as a result of manure-P export from derogated farms*), c.f. 8 kg P/ha for a representative selection of farms within the non-derogated sub-catchment. In other words, while derogated farmland has currently the greatest proportion of fields with soil P indices > 2^+, corrective action is underway which has immediately reduced manure-P pressure on farmland (via manure export), and which in time should help to bring soil P on all P-enriched land (P index > 2^+), into the optimum Index 2^+ range.

The data from the Catchment Scheme within the EU EAA SSAS, which adds an additional 7,772 fields across 11 sub-catchments, will allow for these observations to be validated at a larger scale and across a more diverse agricultural landscape. As these data are currently being analysed findings will be summarised in future reporting.

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4.2 Mineral nitrogen (N) in soil profile under derogated and non-derogated conditions

As indicated above, soil sampling and analysis commenced in the autumn of 2016, as part of the sampling programme. However, measurements of mineral N are not being made, but rather estimates of nitrate loss from farms will be modelled based on soil typology and hydrology plus local climatic and farm management information.

Assessments of mineral N in soil profiles, which involve the collection of deep soil cores (*up to 900 mm depth*), each of which is separately analysed for mineral N, and the periodic soil N assessments to be made on derogated farms, as specified in Article 5(6) of the 2015 Derogation Decision, are not appropriate for predicting N losses to water from grassland in Northern Ireland for the following reasons:-

a) They provide only a snap-shot in time of the amounts of mineral N present in soil, and it is known that mineral N pools fluctuate appreciably over time owing to a number of competing loss processes, and not just nitrate leaching/runoff. Lysimeter studies in Northern Ireland at the Hillsborough farm research site show that when chemical N inputs to grassland exceed 300 kg N ha^{-1} yr^{-1}, losses of nitrate from soil significantly exceed the amounts released into ground or drainage waters almost certainly because of gaseous (denitrification) N losses (Mills, 1997), which can be substantial (*i.e. > 70 kg N* ha^{-1}) on NI grassland (Jordan, 1989). It is also worth noting that researchers in Ireland failed to find any relationship between mineral N concentrations in grassland soils and nitrate concentrations in ground waters (Humphrey's *et al*., 2008).

b) Because soil cores (*0-900 mm*) taken to assess mineral N in soil profiles are collected at single points within fields, the N values obtained are point-specific. Consequently, large numbers of cores would need to be collected and analysed to accommodate the high degree of spatial heterogeneity in soil mineral N supply and formation (Murphy *et al*., 2013) across fields, particularly in grazing situations (Cuttle *et al*., 2001; Hutchings *et al*., 2007), but also under cutting management (Bailey *et al*., 2001) This would not be cost-effective or practicable.

Therefore, model estimates of nitrate loss from farms will be made based on soil typology and hydrology plus local climatic and farm management information instead of mineral N assessments in soil profiles (described in Section 7).

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5. REINFORCED WATER MONITORING

5.1 Summary of results from reinforced water monitoring in agricultural catchments in proximity to most vulnerable water bodies

Renewed monitoring was re-established in August 2016 for the Colebrooke and Upper Bann catchments following a gap from 2014. The catchments cover a gradient of agricultural intensities (generally lower in Colebrooke than Upper Bann) and are representative of the majority of soil types and soil hydrological classes found in Northern Ireland (Figure 17). Preliminary results for the period August 2016 – May 2018 are available for reporting.

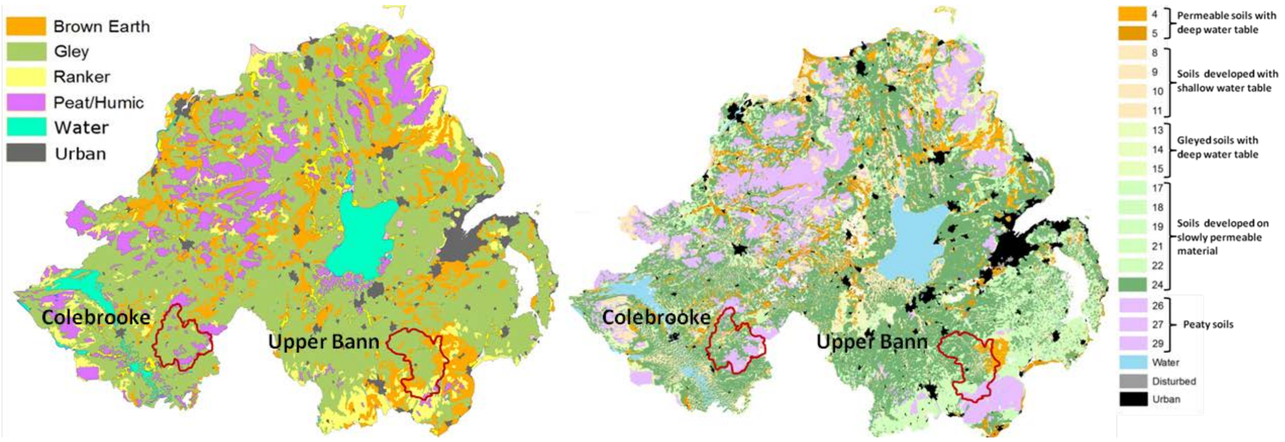

Figure 17: (a) General soil profile types in NI, and **(b)** General Hydrology of Soil Types (HOST) classes in NI

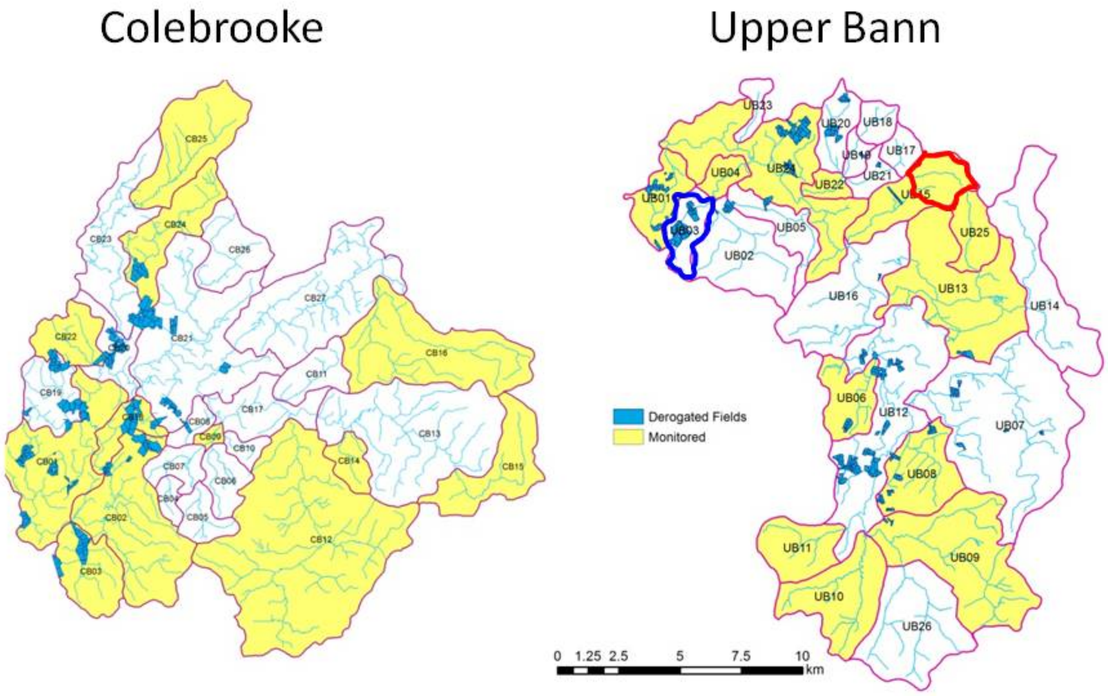

Figure 18: Colebrooke and Upper-Bann Catchments showing locations of sub-catchments (in yellow) for renewed water chemistry monitoring, locations of derogated fields (in blue), and also the locations of 'small' 'derogated' (blue outline) and non-derogated sub-catchments (red outline) in Upper Bann for comprehensive monitoring of surface waters, ground waters, soils and nutrient inputs-outputs.

The amplified program of nutrient monitoring commenced in August 2016 in 24 previously monitored sub-catchments (from 1990 onward) in the Upper Bann and Colebrooke river systems; 12 sub-catchments in each catchment (Figure 18). To this bi-monthly monitoring round an additional 2 catchments were included in Upper Bann; one (UB03) with a number of derogated farms (the "derogated catchment") and the other (UB15a) a less intensive catchment with no derogated farmland (the "non-derogated catchment"). Water quality data from these 26 sites will provide evidence for current and subsequent annual derogation reports under Article 8(3) and Article 10(4) of the 2015 Derogation Decision.

Results to date are indicative of the difference in land use and nutrient pressures between the Colebrooke and Upper Bann catchments as a whole. Comparisons of concentration distributions across the catchments and sub-catchments (Figure 19) reflect this with Total Oxidised Nitrogen (TON) and Soluble Reactive Phosphorus (SRP) concentrations in the Colebrooke catchments lower than in the more intensively farmed and populated Upper Bann catchment.

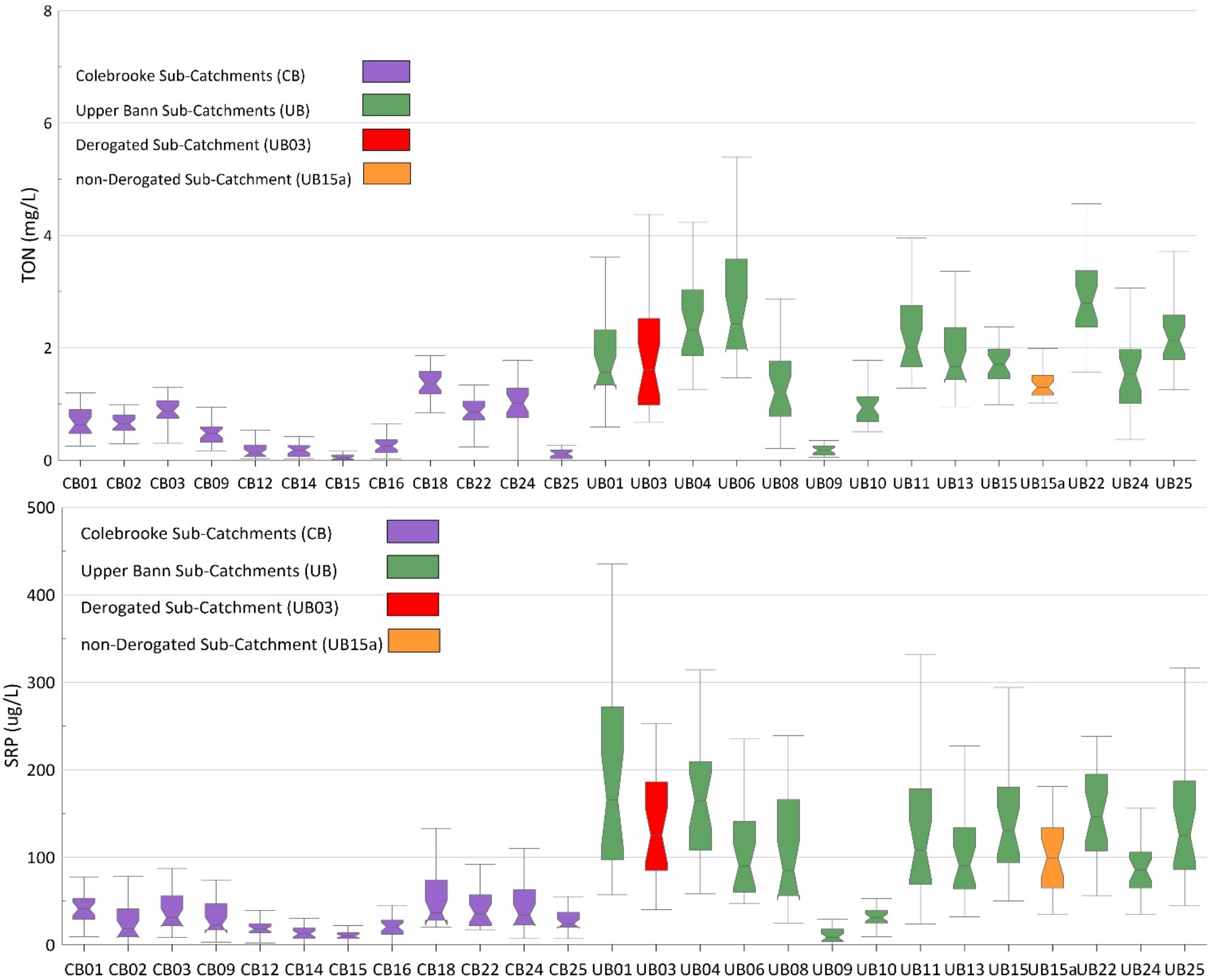

Figure 19: Notched box-whisker plots of SRP and TON for all sub-catchments in the Colebrooke and Upper Bann catchments for the hydrological year 1st October 2016-2017, showing the medians, 25th and 75th percentiles and interquartile range.

Of the 14 sub-catchments monitored in Upper Bann on a bi-monthly basis, only 2 catchments (UB 9 and UB10 in the Mourne headwaters) have notably lower median SRP concentrations (8.5 and 31 ug/L), compared to a range of 83-146 ug/L in the other catchments (for the 2016-17 hydrological year). In the Colebrooke sub-catchments the median concentration range across catchments was 10-41 ug/L, and lowest in the upland eastern sub-catchments which have large areas of forestry and peat and limited extensive farming. Though generally low (maximum median concentration across all sub-catchments of 2.8 mg/L) TON concentrations showed greater variation among catchments ranging from 0.19-2.8 mg/L across Colebrooke and Upper Bann. Further examination of land use and farming intensity in these catchments is ongoing and will be needed to disentangle these relationships further. Differences in sources and pathways for nutrients among catchments (including surface/groundwater contributions) are also being examined.

Concentration ranges in the derogated and non-derogated catchments in Upper Bann are higher than any sub-catchment in Colebrooke (Figure 19). Comparative box plots for TON and SRP (Figure 20) for both catchments over the hydrological year October 2016-17 show a number of differences. The range of TON concentrations is higher in the derogated compared (0.68 – 4.37 mg/L) to non-derogated catchment (0.46 – 2.15 mg/L). Overlap of the notches (which in a box plot indicate the confidence interval around the median (median +/- 1.57 x IQR/√n), Figure 20) indicates that the median concentrations are not significantly different. For SRP, concentrations over the hydrological year October 2016-17 ranged between 32 and 615 ug/L in the derogated catchments compared to 29-318 ug/L in the non-derogated catchment. Again overlap of the notches indicates no significant differences in the median concentrations.

In interpreting these results, the limited temporal coverage of sampling (n=24 per year) and hydrological flashiness of the catchments, which result in short-lived storm events that are rarely captured by routine sampling, must be considered.

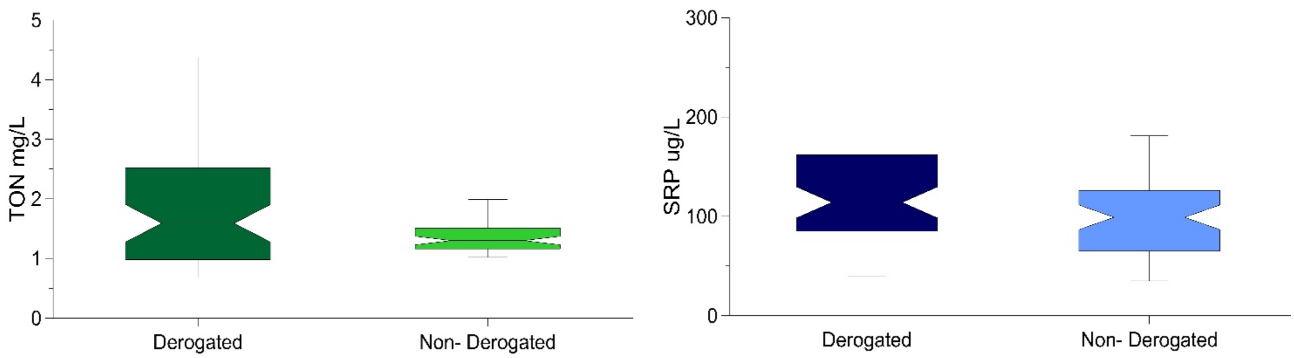

Figure 20: Comparison of TON and SRP concentrations in the derogated and non-derogated Upper Bann sub-catchments.

The revised program aims to address such limitations with respect to resolution and precision. In assessing changes in P loss from headwater catchments Bieroza *et al*. (2014) and Burt *et al*. (2011) argued that while discrete sampling programmes (*fortnightly to monthly resolution*) would be able to detect long term trends (>10 years), identification of significant shorter term changes would require high frequency monitoring of stream P concentrations (*sub-hourly continuous/hydrological event sampling resolution*). Declines in N and P concentrations in streams in the Colebrooke and Upper Bann catchments between 1990 and 2009, largely as a result of controls on agricultural point source pollution, were sufficiently pronounced that statistically significant trends were evident. In contrast, between 2009 and 2014 the rates of decline in N and P concentrations were much smaller and hence more difficult to detect at fortnightly sampling intervals.

In the new program, bi-monthly sampling is being supplemented with targeted storm flow event sampling in the derogated and non-derogated sub-catchments, which commenced in autumn 2017. Event sampling captures periods when diffuse losses are dominant and counter the bias of routine grab sampling towards low flows in which point source signatures are more prevalent, particularly in the ‘flashy’ hydrological regimes in Irish rivers. In the derogated and non-derogated sub-catchments (*UB3 and UB15a, respectively)* in the Upper Bann, both routine grab sampling and storm event sampling have been conducted from July 2017 following installation of weirs and monitoring infrastructure at both sites. This allows continuous discharge and basic water quality monitoring (pH, conductivity, temperature, DO and turbidity) at both sites which is being supplemented by more intensive sampling and laboratory analysis for nutrients. In one site (*UB15a*) an in-situ phosphate analyser is being trialled with the possibility of extending to other catchments if proven viable.

A times series for a 7 week period of monitoring in the UB15a non-derogated catchment (Figure 21) demonstrates the enhanced resolution and insights into chemical dynamics in the catchment. Over the period shown, 4 fortnightly grab samples were analysed for SRP, compared to 1176 hourly samples using a Hydrocycle P analyser over the same period, with multiple storm events captured. Inclusion of other continuous parameters such as conductivity and dissolved oxygen aid interpretation; for example in the reduction of conductivity due to rainfall dilution during storm events. A marked series of high P concentrations between the 12th and 15th October that are not linked to storm flows and are characterised by high conductivities and low dissolved oxygen levels in stream. The possibility that this event (12th -15th October) is linked to the start of the closed period for slurry spreading (15th October) cannot be ruled out from these data.

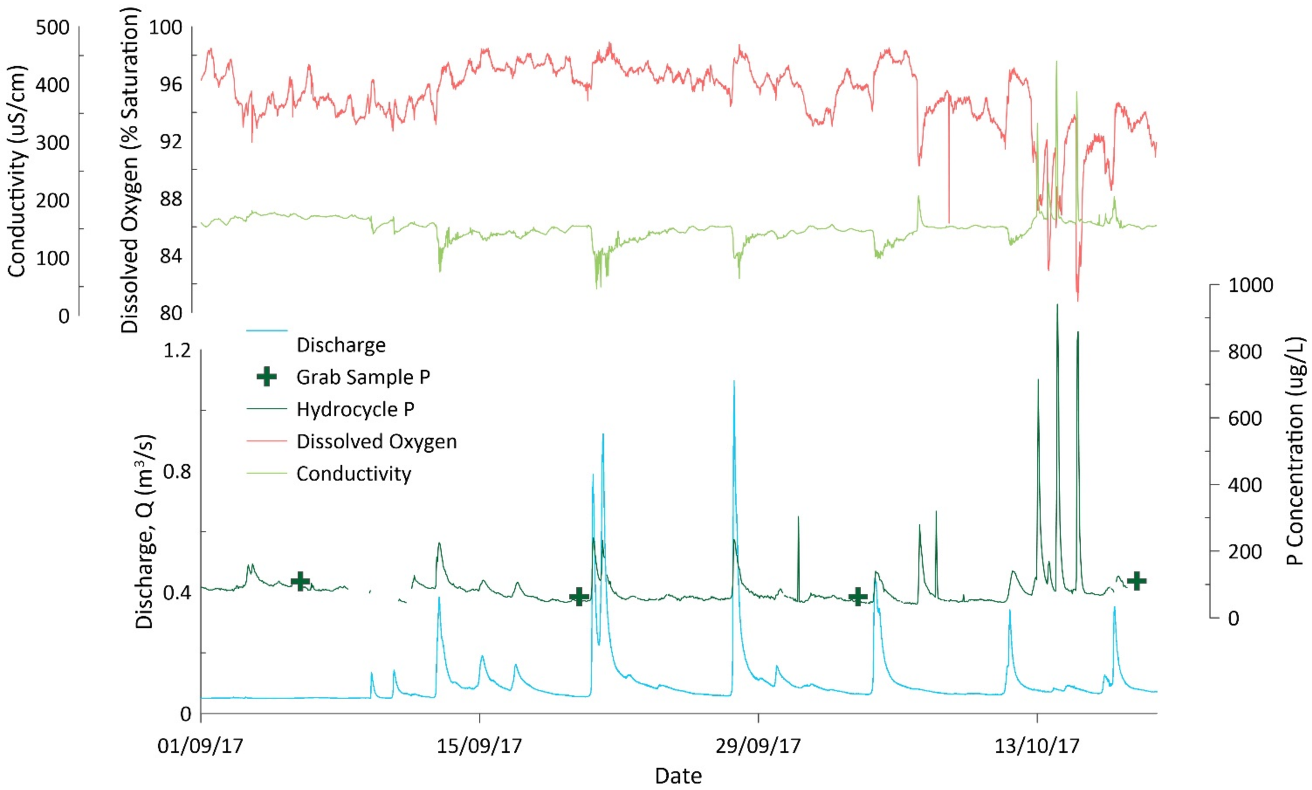

Figure 21: Time series of water chemistry from the high resolution monitoring infrastructure at the outlet of the derogated catchment (UB15a). Fortnightly grab sample phosphorus concentrations (green cross) are shown for comparison.

Groundwater monitoring is a key requirement under Article 8 of the 2015 Derogation Decision for Northern Ireland, and is currently carried out by NIEA. Currently, NIEA are monitoring one borehole in the Colebrooke catchment and one in the Upper Bann catchment. To increase spatial resolution and focus on potential agricultural impacts on groundwater status, a baseline survey was undertaken in the autumn of 2016-spring 2017 to identify wells and springs suitable for sampling. As the survey found only 2 sources within the non-derogated catchment and 5 in the derogated catchment, the survey was extended to include another 6 sites just outside the catchment boundaries belonging to farmers who have land in the catchments. As the sample size is small and the hydrogeological context for all wells is similar (greywacke overlain by till) no differences can be inferred between derogated and non-derogated sites.

Three groundwater sampling rounds have been completed to date, with 14-18 wells/boreholes sampled in each round. The majority of households in the catchments rely on public water supply but the cost savings (£3000-4000 per year for dairy farms) make them attractive for larger farm businesses despite the difficulties in locating wells in these predominantly low productivity aquifer types (greywacke, granodiorite and granite with till overburden). Of the active wells and boreholes, operational groundwater supplies are boreholes with pumps to piped water supplies. Older hand dugs wells and springs are no longer in regular use.

Sampling to date shows some diversity in nutrient concentrations among wells with a mean SRP concentration range of 9-163 ug/L and Total Oxidised Nitrogen (TON) concentration range of 0.03 – 3.96 mg/L. There are issues with meeting the drinking water standards in terms for chloride and conductivity in one case, who is currently in contact with their local authority for assistance.

Summary nutrient and key chemical parameters are shown in Table 12. In further sampling rounds effort will be made to include wells in the south of the catchments (in granodiorite and granite bedrock units) to increase the variety of aquifer types covered.

Table 12: Summary chemical data for the groundwater sampling rounds in the Upper Bann derogated and non-derogated sub-catchments (14 sites in total; 5 derogated; 2 non-derogated; 8 in neighbouring catchments).

	Conductivity uS/cm	BOD (mg/L)	Chloride (mg/L)	Sulphate (mg/L)	SRP (ug/L)	TSP (ug/L)	TP (ug/L)	pH	NO2 (ug/L)	NH4 (ug/L)	TON (mg/L)
minimum mean site concentration (3 rounds x 14 sites)	177	1.00	13.15	5.51	9	12	14	6.15	0	14	0.03
maximum mean site (3 rounds x 14 sites)	1180	2.00	600.98	37.62	163	170	209	8.07	7	444	3.96
Mean Concentration	432	1.36	63.68	17.87	42	50	65	7.20	2	82	2.02

Further analysis of the results will relate the chemistry to land use, soil and geology and to continue at least annually thereafter.

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6. LAND USE AND AGRICULTURAL PRACTICE ON DEROGATED FARMS

6.1 Land use, cropping and agricultural practice on derogated farms

Agricultural holdings account for approximately 75% of Northern Ireland's land area, with 93% of the agricultural area being grassland. 90% of farms are classified as being mainly grazing livestock using EU farm classification typology.

Farm businesses operating under approved derogation in 2017 followed this pattern. Farming activity, livestock and crops are detailed in Tables 13 and 14.

Table 13: Farming activity on farm businesses operating under derogation in 2017

	Number of farms	Percentage of farms
DAIRY	282	91.6
CATTLE & SHEEP: LFA	7	2.3
CATTLE & SHEEP: LOWLAND	7	2.3
MIXED	9	2.9
POULTRY	3	1.0
Total	308	100.0

Notes: 1. Farm type - determined from DAERA Agricultural Census
2. Mixed farms – farms that have no dominant enterprise and do not fit into other categories

Statistics in Table 14 are based on 277 farms – a full explanation to account for this figure is set out in section 8.2.3. Two farms out of the 277 farms operating under derogation in 2017 provided evidence to show that they were operating below the required 80% grassland. These farms will be breached. Spring Wheat, Winter Wheat and Spring Barley are the predominant crops, covering 62% of the total cropped area on all derogated farms. Crops are summarised in Table 14.

Table 14: Crops on farm businesses operating under derogation in 2017

Crop	**Number of farm businesses 2017**	**Land area (ha)**
Spring wheat	15	195.29
Winter wheat	16	127.7
Maize	9	97.21
Spring barley	14	122.8
Winter barley	9	91.84
Potatoes	3	2.14
Spring oats	2	12.44
Winter Oats	1	2.26
Other	10	70.24
	Total land area:	**721.92**

7. MODELLING

7.1 Preliminary results of model-based calculations of nitrate and phosphorus losses from derogated farms

FARMSCOPER nutrient modelling.

Results from a first application of the FARM Scale Optimisation of Pollutant Emission Reductions (FARMSCOPER) decision support tool (Gooday *et al*., 2014) to model P and N loads from the derogated and non-derogated catchments are available. The model allows farms to be specified individually and pollutant losses and potential efficacy of mitigation approaches to be assessed (Newell Price et al. (2011), with costs calculated if required.

The most recent published applications of the model (Gooday et al., 2014, Zhang et al., 2012) have involved large-scale applications using representative farm type data from censuses as the basis of modelling farms in each catchment. This application is at a smaller scale and for comparison between sub-catchments. Therefore, acquisition of specific farm level survey data for farms in both sub-catchments was necessary. The combined models for farms in each sub-catchment are then compared in an initial assessment of N and P losses, and evaluated against estimated nutrient loads from water quality monitoring at each sub-catchment outlet.

The catchment area of UB03 (derogated) is 381.3 ha with 83% of the area occupied by 18 farms. Eight of these farms returned survey data (52% catch. area) of which 4 are derogated (29% catch. area). The catchment area of UB15a (non-derogated) is 415 ha with 75% distributed among 26 farms, 11 of which returned data (39% catch. area). The areal coverage of different farm types within each catchment is given in Figure 22. A notable finding among farm types was that those with a component of dairying exhibit significantly greater export rates of P and NO_3 than those that do not (independent t-tests; mean diff = 0.87 kg P ha^{-1} yr^{-1}, $t=-4.86$, $p<0.001$; mean diff. = 24.3 kg N ha^{-1} yr^{-1}, $t= -2.99$, $p<0.01$).

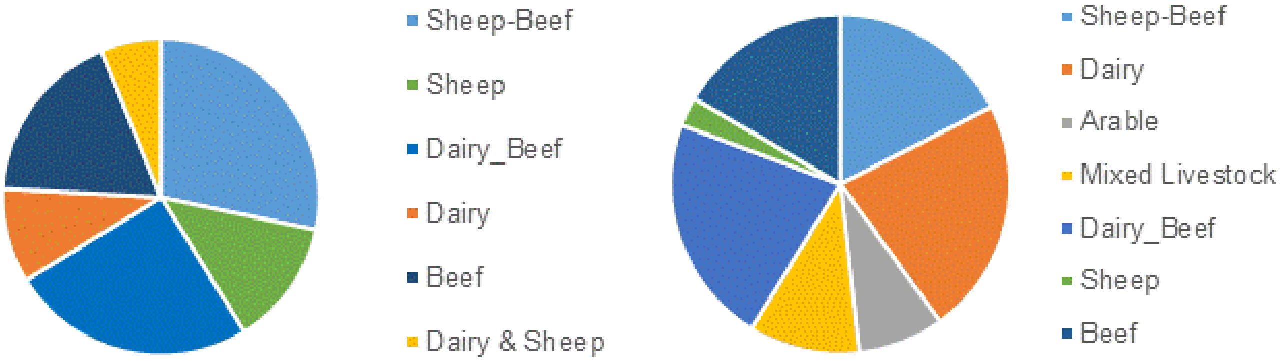

Figure 22: Areal coverage of predominant farm types in derogated (left) and non-derogated catchments (right).

For farms without survey data, the mean modelled export rates for farms of the same type (e.g. Beef, Sheep, Dairy, Dairy & Beef, Dairy & Sheep etc.) across both catchments was used to approximate the estimates of runoff and pollutant losses.

Summary outputs from (i) calculated farm P and N exports (from farm survey data), (ii) modelled concentrations from application of FARMSCOPER, and (iii) monitored water quality data at the outlets of both catchments, are presented in Table 15. Generally, concentrations of both N and P are higher in the derogated catchment, similar to monitored concentrations (section 5.1, Figure 20), although elevated. For derogated catchment UB03 the FARMSCOPER modelled mean drainage water P concentration of 326 µg/l is 39 µg/l greater than the mean monitored concentration (287 ug/L). The FARMSCOPER derived concentration can be lowered by adjusting to a more realistic runoff rate for the catchment (here 650mm), which then provides a closer match to the observed data. For nitrate agreement is less good than for P. The FARMSCOPER derived mean concentration (6.26 mg/L) exceeds the mean observed concentration (1.91 mg/L) by a factor of c.2.5. The situation is similar for catchment UB15; modelled nitrate export is again c. 2.5 times higher than the mean monitored concentration, and modelled mean P concentration is c.100 µg/l greater than the mean monitored concentration, although use of a higher runoff rate narrows the difference (Table 15).

Caveats in the comparison of modelled and measured concentrations include: (i) nutrient loads from human populations (wastewater) are not included in Farmscoper, (ii) monitoring data are presently limited to time-weighted concentrations whereas Farmscoper generates a flow-weighted concentration (iii) differences in the NI geoclimate from the regions defined for GB that are used in the model (iv) higher denitrification rates in NI.

Table 15: Catchment P and NO_3 load and concentration estimates based on Farmscoper modelling, and summary concentration monitoring data of total phosphorus and NO_3 for each study catchment.

		Phosphorus		Nitrate	
	Catchment	*Derogated*	*Non-Derogated*	*Derogated*	*Non-Derogated*
Nutrient balances from Farm Survey Data Collection	Total farm load (kg)	590	501	11339	6512
	farmed area (ha)	318	310	318	310
	farmed area rate (kg ha^{-1} yr^{-1})	1.86	1.61	36	21
	other land loading (kg)	118	169	2271	2193
	Total catchment export (kg)	708	669	13610	8705
Farmscoper Modelled Concentrations	Mean conc. FS 570mm yr^{-1} (µg P , mg N /L)	**326**	**283**	**6.26**	**3.68**
	Mean conc. 650mm yr^{-1} (µg P / mg N L^{-1})	286	248	5.49	3.23
River water quality monitoring data	Monitored concentrations* n=28	µg P L^{-1}		mg N L^{-1}	
	Mean	**287**	**180**	**1.91**	**1.33**
	Median	201	124	1.69	1.29
	Range	67–1276	47–726	0.66–4.35	0.46–2.14
	SD	241	139	0.93	0.32

*fortnightly Sept. 2016 – Oct. 2017 incl.

Further work is required to assess whether adaptations to the model are practical to account for differences in rainfall and pathways for nutrients. This may require modifications to the models upon which FARMSCOPER is built including the "*Phosphorus and Sediment Yield Characterisation in Catchments" (PSYCHIC*), "*National Environment Agricultural Pollution" (*NEAP-N) and "*MANure Nitrogen Evaluation Routine" (*MANNER) models and therefore would require considerable investment of time by the model developers, which needs to be assessed going forward. If resources allowed, an extension of modelling to additional Upper Bann and Colebrooke catchments, covering a broader range of agricultural intensity and pressures, would provide a more robust assessment of model performance.

Phosphorus Risk Modelling

Phosphorus loss in run-off represents an economic loss to the farm, but also poses a threat to water quality. The identification of areas at high risk of P loss will enable farmers to target preventative measures in areas with greatest potential to reduce impacts on water quality. Such measures might, for example, include avoiding slurry application to certain parts of fields, or establishing buffer strips at specific field or stream boundaries. To target measures cost-effectively within farms, identification of potential hotspots of nutrient loss, i.e. critical source areas (CSAs) is required. This can be achieved by modelling the hydrological connectivity of the farms following the source-pathway-receptor approach (Haygarth et al., 2005) and employing a methodology to identify fields on farms that pose the greatest risk to water quality and where mitigation measures should be focused.

For Upper Bann catchment high resolution LiDAR topographic mapping was undertaken and used along with soil physical characteristics (permeability, depth) and P status (determined from soil sampling) to model areas at greatest risk of P loss in runoff rainfall events. Initial soil sampling covered only the derogated and non-derogated sub-catchments but was extended as part of the EU EAA Soil Sampling and Analysis Scheme to all monitored catchment in Upper Bann. The risk mapping methodology used follows Thomas et al. (2016) to model both those areas at heightened risk of P loss from fertiliser or slurry P applications (areas with a high HSA index) and areas where soil P status poses a risk of legacy P loss as mobile water extractable P. As part of the scheme farmers were provided with soil nutrient maps and P risk maps (Figure 23) for all areas of their farms and suggestions as to possible mitigation measures to protect water quality.

Further modelling work will undertake catchment scale modelling of land use practice impacts using the Soil and Water Assessment Tool (SWAT) (Arnold *et al*., 2012) model to model N and P contributions from multiple sources within the Upper Bann catchment.

Having derogated and non-derogated farms within both main river catchments, and high frequency storm flow event sampling in the contrasting three small sub-catchments, will facilitate up-scaling of the modelling of nutrient losses from farm to catchment scale. Results of soil P analyses (Olsen-P) from derogated farms, under Article 5(6) of the 2015 Derogation Decision, will be used to assess the overall impact of derogation on P losses from farmland across Northern Ireland.

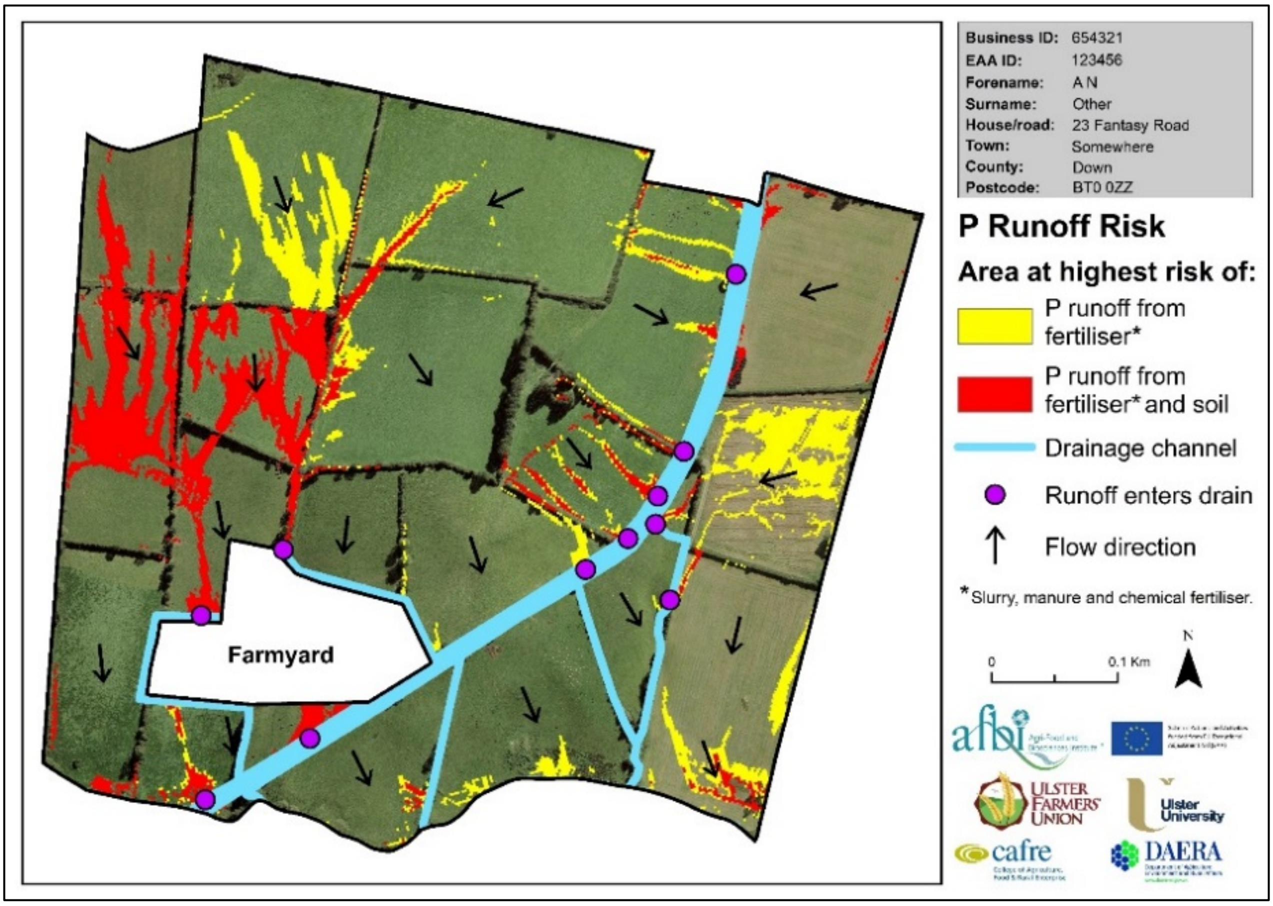

Figure 23: Exemplar risk map for P runoff risk (both surface applied nutrients and legacy soil P) produced as part of the EU EAA Soil Sampling and Analysis Scheme for the Upper Bann monitored sub-catchments.

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8. COMPLIANCE WITH THE DEROGATION CONTROLS FOR 2017

8.1 Derogation controls in Northern Ireland

NIEA, on behalf of DAERA, is the competent authority for enforcement of the NAP legislation in Northern Ireland. In accordance with Article 4 of the 2015 Decision, the 2014 NAP Regulations require farmers in Northern Ireland, who wish to benefit from derogation, to submit an annual application to the NIEA by 1 March for that calendar year. NIEA have 28 days from receipt to make a decision on whether to grant or refuse the application.

The Regulations also require farmers in Northern Ireland to prepare and keep a fertilisation plan for the calendar year in accordance with Article 5 of the 2015 Decision. This must be available on derogated farms no later than 1 March of that calendar year.

Additionally, in accordance with Article 5 of the 2015 Decision, the Regulations require farmers in Northern Ireland to submit fertilisation accounts to NIEA for the previous calendar year by 1 March of the following year. Therefore, applications for derogation must be accompanied by the fertilisation account for the previous year, where relevant.

8.2 Compliance with the derogation controls

Compliance with the Decisions is assessed in three key ways:-

1. administrative checks on derogation applications for the current calendar year;
2. on-farm inspections of records from previous years, current fertilisation plans, farm facilities and fields; and
3. administrative checks of fertilisation accounts for the previous calendar year.

8.2.1 Administrative checks of 2017 derogation applications

In 2017, there were 310 approved derogation applications and three rejected applications. These were rejected as the applications were received after 1 March 2017 deadline.

8.2.2 2017 On-farm inspections

In accordance with the 2015 Decision, at least 5% of derogated farms are selected for on-farm inspections. In 2017, a total of 310 farmers had received approval for derogation from NIEA. Three farms provided evidence to NIEA that they could comply with 170 kg N/ha/yr limit and were withdrawn. Sixteen of these farms (5%) were selected for on-farm inspections. During inspection derogated farms are assessed against all of the NAP and Derogation requirements.

There were no non-compliance detected on 16 farms inspected.

8.2.3 Administrative checks of fertilisation accounts for 2017

In 2017, a total of 310 farmers had approved derogations. Three of these farm businesses withdrew in-year.

A new on-line system was introduced in 2018 for the submission of fertilisation accounts for the calendar year 2017. Of the 307 farms operating under derogation in 2017, 302 farm businesses submitted their fertilisation accounts on-line. Of the 5 farms who did not submit their fertilisation accounts on-line, 3 of these were operating below 170 kg N/ha in 2017. The remaining 2 farms complied with all of the statutory limits.

Of the 302 farm businesses that submitted their fertilisation account on-line, four mixed grazing / non-grazing farms were removed from the calculations due to excessively high nitrogen loadings. These farms are being breached. In addition, twenty-one farms provided evidence to show that they were operating below 170 kg N/ha and were also removed from the statistics.

Table 15 shows the finalised results of administrative checks on the 277 fertilisation accounts submitted for the calendar year 2017. Compliance with the rules has increased slightly compared to 2016. Targeted training and guidance will assist increasing compliance levels, particularly with newly derogated farms.

A total of 23 non-compliances were detected in the accounts of 14 farm businesses. Non-compliance was mostly aligned to the P balance, chemical fertiliser to grassland and nitrogen loading. NIEA continues to engage with colleagues in the Department and stakeholder representatives regarding these non-compliances.

Table 15: Compliance of fertilisation accounts for 2017

Measure Description	Average (min-max)	Number of Breaches
80 % grassland	98 (73.5–100)	2/277
Total grazing livestock N (up to 250 kg N/ha/year)	218 (8.12-275)	2/277
Total livestock manure N loading (170 kg N/ha/year non-grazing + 250 kg N/ha/year grazing)	216 (84.55-252)	2/277
Total chemical N fertiliser usage on grassland (not to exceed 272 or 222 kg N/ha/year for dairy or other farms respectively)	173 (0–298)	3/277
Total chemical N fertiliser usage on land other than grassland (not to exceed crop requirement)	114 (13-210)	0/58*
Phosphorus balance up to 10 kg P/ha/year	5 (-45-18.5)	9/277
No, partial or late records	N/A	5/277

**Statistics based on 58 farms which had land other than grassland and which used chemical N fertiliser.*

Table 16: Predicted and observed statistical values (verified for land area) for farm businesses which operated under derogation in 2017

Average (min-max)	Predicted from applications 2017	Fertilisation accounts 2016
Grassland area (%)	98 (81–100)	98 (73.5–100)
Farm size (ha)	90 (16-348)	90.26 (15.8-357.65)
Total livestock manure N loading (kg N/ha/year)	215 (22–250)	216 (84.55-252)
Grazing livestock manure N loading (kg N/ha/year)	215 (22–250)	218 (8.12-275)
Chemical N fertiliser usage (kg N/ha/year)	N/A	173 (0–298)
Phosphorus (P) balance (kg P/ha/year)	N/A	5 (-45-18.5)

Table 16 shows statistics for observed values for the 277 farm businesses that submitted fertilisation accounts for the calendar year 2017. The values are calculated (using land areas verified through cross-checks with other data sources) from information supplied in the fertilisation accounts. Observed values are compared, where possible, to predicted values from the initial 302 approved derogations. Fertilisation accounts which have produced outlying values are likely to be examined further and the farm business may be more likely to be subject to an on-farm inspection (due to a higher environmental risk rating).

9. GUIDANCE AND TRAINING TO SUPPORT THE DEROGATION

9.1 Nitrates derogation guidance

In 2015 DAERA produced updated guidance for the revised 2015-2018 NAP to support implementation of the nitrates derogation. In June 2016 the Nitrates Derogation Guidance, Fertilisation Plan and Fertilisation Account (including the Phosphorus Balance worksheet) were printed and issued to all farm businesses operating under a derogation. In January 2018, these farm businesses were sent a letter reminding them to submit their Fertilisation Account using the new online system by 1 March 2018. In addition they were also reminded to apply using the new online system again by 1 March 2018 if they wished to continue to operate under a derogation for 2018.

9.2 Nitrates derogation training

In 2017/8 the College of Agriculture, Food and Rural Enterprise (CAFRE) within DAERA continued to provide a wide range of support on the Nitrates Derogation for farmers in Northern Ireland. In January a campaign was held to promote the derogation to farmers. Four Nitrates Derogation Information Events were held to brief farmers and also to demonstrate the new online tools for submission of information and their application form.

Farmers operating under derogation in 2017 were supported by CAFRE Dairy Development Advisers on a one to one basis as and when requested.

9.3 Other training and support associated with Nitrates Action Programme

Other training related to the NAP that took place in 2017-2018 included:

- An update for CAFRE Development Advisers on Nitrates Derogation and the online tools developed by NIEA for submission of manure exports, fertilisation account and derogation application forms;
- Training for the Agricultural Consultants Association of N.I. on Nitrates Derogation and the online tools developed by NIEA for submission of manure exports, fertilisation account and derogation application forms;
- Nitrates training to DAERA staff who were to become involved in Catchment Advisory visits.
- CAFRE Development Advisers continued to deliver nitrates and nutrient management to almost 3000 farmers in Business Development Groups.

In addition, CAFRE Advisers and the Agri-Environment Team successfully dealt with numerous calls from farmers, Advisers and Consultants on nitrates related issues including the closed period, manure exports (online record submission) and nitrates derogation (online record submission).

9.4 CAFRE Nutrient Calculators

As described in the previous report, CAFRE has lead responsibility for the development and maintenance of a suite of five on-line calculators designed to help farmers to manage their farms to comply with various aspects of the NAP Regulations. The calculators are available on the DAERA web-site at: www.daera-ni.gov.uk. The calculators continue to be well used and Table 17 shows the number of unique users for each of these on-line calculators at March 2018. The total number of users increased by 27.5% in 2017/18 following an update and refresh of their design and operation.

Table 17: User numbers for on-line calculators

Calculator	Number of users at March 2018
Livestock Manure Nitrogen Loading	4192
N Max for Grassland	1071
Crop Nutrient Recommendation	1034
Phosphorus Balance	794
Livestock Manure Storage	1758

9.5 Other communication methods

In 2016-2017 DAERA issued technical information in the form of a number of press articles and management notes through various channels including the agricultural press, the DAERA website and the Farm Advisory System Newsletter to update farmers on water quality and nutrient issues, promote the nitrates derogation, nutrient management planning and the CAFRE Nutrient Calculators. These articles are also published on DAERA's website along with frequently asked questions, NAP guidance booklet, derogation guidance booklet, and booklets for derogation fertilisation plans.

DAERA continues to highlight the NAP Regulations, including nitrates derogation, at a variety of agricultural shows, events and meetings. For example, in meetings held by the CAFRE Dairy Development Advisers in January and February 2018, they reminded farmers about the need to meet the 1 March 2017 deadline for submission of their fertilisation account and next year's derogation application.

10. RESEARCH PROJECTS

In order to underpin the implementation of the Directive and the action programme measures in Northern Ireland, DAERA commissioned AFBI to carry out a range of research projects during the period 2008-2012. Some of the research was undertaken in accordance with Articles 8.2-8.6 of the 2007 Derogation Decision for Northern Ireland, granting derogation for intensive grassland systems, and is still on-going. Further research in support of the 2015-2018 derogation and NAP has also been commissioned by DAERA. A summary of key findings from on-going research and details of new Evidence and Innovation (E&I) research projects, are provided here.

10.1 Project 0618 - Monitoring the effectiveness of the nitrates action programme for Northern Ireland (Research suspended from 2017 until 2019)

Under Article 8.6 of the 2007 Derogation Decision, and as part of monitoring the effectiveness of the NAP for Northern Ireland, a representative soil sampling scheme (RSSS) has been operated by AFBI since 2004, to identify the impact of the NAP on soil fertility in Northern Ireland, especially on soil Olsen-P. In the RSSS, 500 grassland fields across Northern Ireland are sampled, 100 per year, on a five-year rolling basis. The fields selected were located on intensively stocked, but non-derogated farms operating at near to the 170 kg N/ha manure loading limit. Alongside this RSSS and 5km grid soil sampling survey across all land cover classes was initiated in 2004 and repeated every 10 years.

The overall objective of this project is to monitor soil quality across Northern Ireland in both the intensive sector (RSSS monitoring) and the general agri-environmental landscape (5km monitoring), and was designed to provide soil data to support DAERA's evidence-based responses to EU Directives, particularly the Nitrates Directive.

The RSSS 2016/17 sampling campaign was completed on schedule in March 2017. As the headline indicator of soil nutrient status, Olsen-P was used to illustrate the results of the project in 2016/17. Figure 24 places the RSSS Olsen-P results from 2015/16 and 2016/17 within the context of the analysis to date. Once again the general trend observed in the sampled intensive grassland sector is evident within these 2 years; soils with sub-optimal levels of soil P *(< Index 2*) have a frequency of less than 10% and soils oversupplied in P (*Index 3 and above*) account for approximately 70% of the samples.

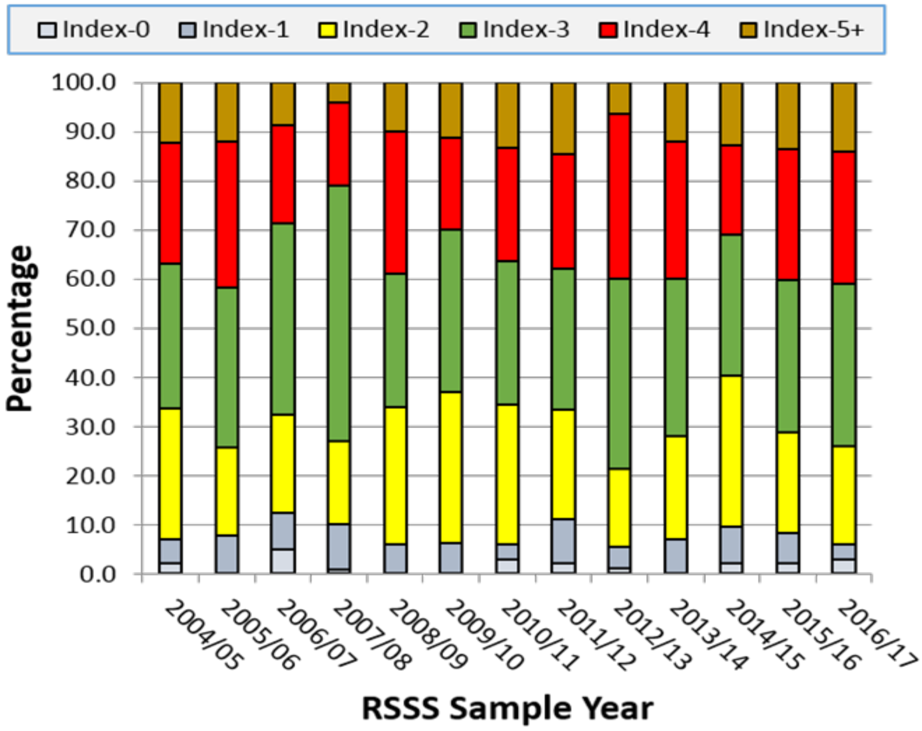

Figure 24. Olsen P-Index in the top 75mm of the soil profile for years 2004/05 to 20016/17

Paired two-tailed t-tests between the RSSS 2016/17 and RSSS 2011/12 Olsen-P data sets (*with average values of 44.77 mgl^{-1} and 42.53 mgl^{-1} respectively)* suggest that although an increasing trend is observed, it is not statistically significant. Figure 25 illustrates the relationship. Interestingly there was a small but statistically significant increase in Olsen P between RSSS 2006/07 (the initial sampling cycle) and RSSS 2016/17 with average values of 40.02 mgl^{-1} in 2005/07, and 44.77 mgl^{-1} in 2016/17. This would imply that despite possible re-distribution of manure nutrients within some farms, overall there has been little reduction in P inputs to these relatively intensive farms.

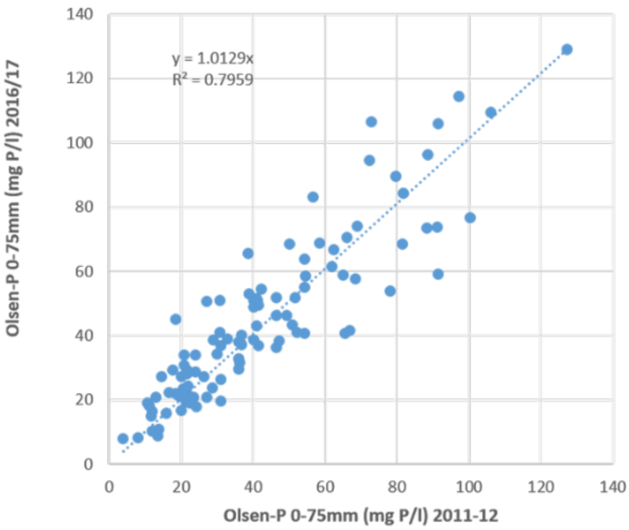

Figure 25. Linear regression of RSSS Olsen-P data for winter 2016/17 compared to matching data for winter 2011/12. The fitted line, forced through the origin, is shown along with the slope and R^2 value (df=99).

The results from the 5km regular grid survey, which covers land under a wide range of farming intensities from low to high, unlike the RSSS (*which focuses on the intensive sector*), indicate that there has been a small increase in soil P in lowest Olsen-P ranges Index 0 and 1, but a decrease in soil P in soils initially at Olsen P Index 4 and above. This is possibly because of efforts by land owners to distribute manure-P away from high P index fields (*nearest to farmyards*) where historically it had been primarily applied, to land receiving little organic manure-P in the past (Table 18).

Table 18: 5km grid survey – comparing Olsen-P levels in 2 periods

	Olsen P 0-7.5cm		
5km survey	***2004/5***	***2014/15***	
All Samples	**27**	**27**	NS
Index 0	6.4	9.7	P= .000
Index 1	13	17.9	P= .001
Index 2	20.6	21.1	NS
Index 3	34.5	33.2	NS
Index 4+	65.1	55.4	P= .000

Comparing the mean Olsen-P concentrations (in the 0-75 mm soil layer and the complete A horizon) across all sites in the first five-year period (2004-2008) with those in the second five-year period (2009-2013), revealed small but significant ($P \leq 0.02$) increases in soil Olsen P with time, in both the 0-75 mm soil layer (41.69 mg Olsen-P l^{-1} for 2009-2013 compared to 40.19 mg Olsen-P l^{-1} for 2004-2008) and the A horizon (39.19 mg Olsen-P l^{-1} for 2009-2013 compared to 35.06 mg Olsen-P l^{-1} for 2004-2008).

Although statistically significant, the increases are small in real terms and likely to be of minimal environmental significance. Analysis of the latest paired RSSS samples (100 sites, sampled in 2014-2015, compared with the same sites sampled in 2009-2010), indicate no significant change in soil Olsen-P status.

Subject to securing of funding, continuation of the sampling programme will allow further monitoring of soil P concentrations so any emerging trends can be identified and mitigation action taken if necessary. The RSSS, however, has been suspended until 2019/20.

10.2 Project 9420 – UK Environmental Change Network: Freshwater

Freshwater eutrophication, caused by over-enrichment of water bodies by nutrients (primarily phosphorus (P) and nitrogen (N)) as a result of anthropogenic activity, is a major challenge for the management of inland waters. Generally in Europe, the number of serious nutrient related pollution events in rivers and lakes has increased over the last ten years, and has the potential to increase even further due to changes in land management and climate. In recent years the operation of the NAP and Phosphorus Regulations in

Northern Ireland has substantially altered manure and fertiliser practices in Northern Ireland. However, despite the implementation of various management measures, eutrophication of freshwater lakes and rivers, and the ecological consequences, remain a challenge for agricultural land managers and policy stakeholders.

The overall aim of the Environmental Change Network (ECN) project (Freshwater) in Northern Ireland is to provide long term and standardised data on Lough Neagh and Lough Erne with respect to biology, nutrients and eutrophication. This project was initiated in 1969 to investigate the cause and nature of recurrent, problematic, toxic algal blooms in Lough Neagh. The project successfully identified point source pollution from sewage treatment works as the main driver of the eutrophication. Since then the project has also monitored Lough Neagh through a period of enrichment caused primarily by diffuse agricultural run-off. Currently, attention is being turned to loading from within the lake sediments, potentially caused by a reservoir of stored P, built up from many years of intensive loading from the large catchment. The major inflowing rivers /outflow of Lough Neagh are also monitored throughout the year. This informs nutrient budgets and calculation of the loading of nutrients from the surrounding lake catchment. Historical data over the last approximately 30 years has now been quality controlled and analysed to indicate the long term trends in phosphorus and nitrate in both the lake and its in-flowing rivers.

Detailed analysis of the seasonal cycles in Lough Neagh shows that, by 2000, total oxidised nitrogen was depleted in lake water in May rather than June and P started to be released from the sediment in June rather than July. Evidence from experimental work and other lake investigations indicates that the link between the two nutrient cycles is due to the earlier exhaustion of N in the water allowing the reductive dissolution of ferric oxyhydroxide in the sediment and solubilisation of sorbed P to start earlier.

Nutrient trends in Lough Neagh (Figure 26) reveal the dramatic decline in total oxidised nitrogen (TON) in the lake water. The effects of this decrease in N is currently being investigated.

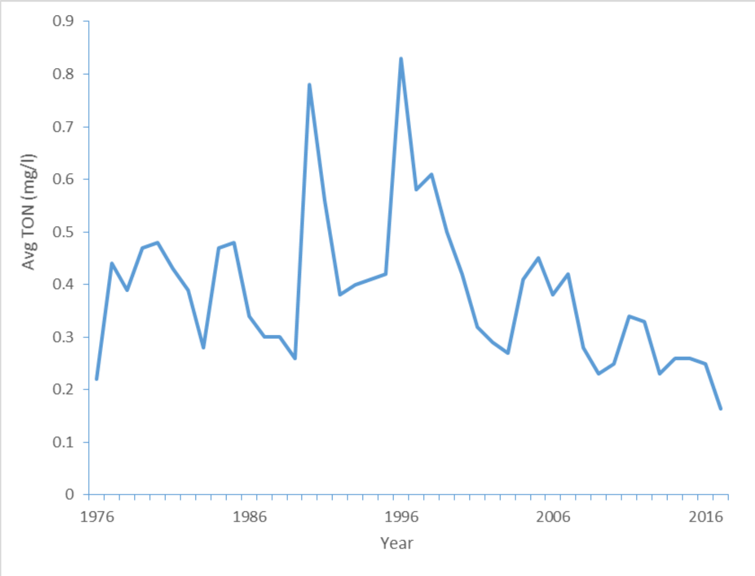

Figure 26: Annual Total Oxidised Nitrogen - TON (dominated by nitrate) in Lough Neagh (1976 – 2017).

Lough Erne is also included as part of the ECN monitoring programme. Nutrient trends in Lough Erne (Figure 27) reveal a steady pattern of total phosphorus, with a large, short lived peak in 2009. The lake is still dominated by the influence of the invasive alien zebra mussel reflected in its low chlorophyll a levels, the annual average 2016 chlorophyll a concentration was 1.93 µg/L despite relatively high total phosphorus concentrations (Figure 27).

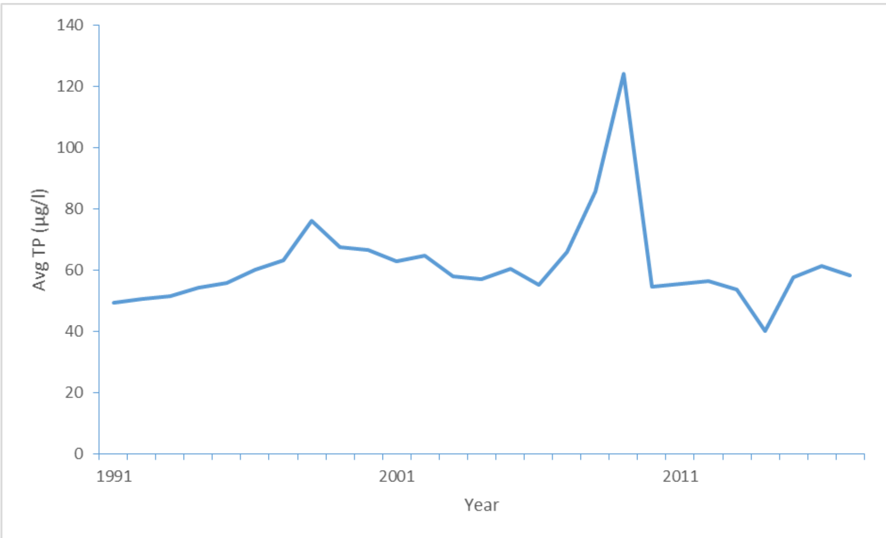

Figure 27: Total phosphorus – (TP) in Lough Erne (1991 to 2017)

Data from this project support the case for Northern Ireland's Derogation under the Nitrates Directive. It also provides a means of producing an integrated assessment of the effectiveness of management measures in the lake catchments through examining catchment loading, lake nutrient concentration and biodiversity. The lakes are included in the European Long Term Ecological Research Network of sites.

The overarching aim of the DETECT project is the development of an Assessment Framework for Ireland to support the identification of the principal stressors constraining ecological recovery in water bodies. The project is identifying the effects of stressors to inform on the practicality and cost-effectiveness of targeted mitigation measures. The project is taking a hierarchical approach employing National and more highly resolved Focus catchment level work to achieve the project aims.

At national scale widely accessible data is being utilised to examine the extent to which the underlying drivers of ecological water quality in Ireland can be elucidated. This analysis is examining the degree of association among catchments according to their ecological, catchment and water chemistry characteristics. The identification of key explanatory variables, if possible from national scale Irish data, would represent a considerable advancement of the evidence base surrounding stressor impacts in Ireland.

The project is also developing a time-scale of recovery tool for use in Irish lakes. This tool is investigating the influence of nutrients in lake sediments and their role in eutrophication.

A protocol for an assessment tool will be developed for river catchments. This tool will be based on the analysis described above with additional high resolution data added for a number of focus study catchments.

The approach at Focus catchment scale will help to identify the limitations of the knowledge base on stressors acquired from analyses of national scale data and help to identify where additional national scale data/knowledge is required. This will be achieved by comparing the strength of the evidence on stressors generated by the addition of discrete forms of high resolution data for a number of focus catchments. The DETECT project started in Feb 2015 with final analysis due to be completed in early 2021.

Results so far have identified major pressures in Irish catchments. The project has also advised on a number of measures regarding the evaluation of silt and the effect of catchment pressures using biological metrics.

10.3 E&I Project 16/4/03 – Monitoring, modelling and mitigation of N and P losses from land to water under derogated and non-derogated conditions in the Colebrooke and Upper Bann Catchments (New Research)

The Overall Objectives of the monitoring/modelling programme are to provide scientific evidence to:-

1. Meet the additional/amplified monitoring and reporting requirements of Articles 8 and 10 of the 2015 Derogation Decision.
2. Identify and validate strategies which minimise N and P losses to water, optimise farm productivity and reduce variable costs on ruminant livestock farms.

These Objectives are being addressed in four Work Packages (**WPs**):-

WP 1 – Surface Water Sampling

In compliance with Article 8(3) of the 2015 Derogation Decision, monitoring of chemical water quality (nutrients) in streams in 12 sub-catchments in each of the Upper Bann (UB) and Colebrooke (CB) catchments, which ceased in 2014, will be reinstated at bi-monthly frequencies, This will be supplemented with targeted storm flow event sampling to improve resolution and precision of sampling - c.f. the 2009-2014 monitoring program.

Bi-monthly and seasonal hydrological event sampling for nutrients will also be conducted in two contrasting sub-catchments (*one containing* a significant proportion of derogated *farmland and the other containing only non-derogated farmland*) within the UB catchment. Samples will also be analysed for a range of tracers to help determine the contributions of rural septic tank outflows to P loads.

WP 2 – Groundwater Sampling

Groundwater monitoring is a requirement under Article 8 of the 2015 Derogation Decision. A baseline survey within the pair of UB sub-catchments (*but if necessary extended to include other sub-catchments*) will be undertaken to identify, in consultation with landowners, wells and springs suitable for sampling. Potential threats to water quality in each well/spring will be noted during sampling. After an initial monitoring round, a sub-set of wells/springs will be identified and monitored annually.

WP 3 – Soil Sampling, Farm Data Collection & Nutrient Management Advice

To provide relevant soil P data for modelling P losses from derogated and non-derogated farms on the main soil types of Northern Ireland in accordance with Article 8(2) 2015 Derogation Decision, and information on farming practices etc on derogated and non-derogated farms in accordance with Article 8(4) of the 2015 Derogation Decision, a sampling/data collection scheme will be conducted.

In the pair of UB sub-catchments (*one sub-catchment with a significant proportion of derogated farmland and the other with no derogated farmland*), all fields (*713 in total*) will be soil tested for Olsen-P and Calcium Chloride extractable P ($CaCl_2$-P). A 1 m resolution Light Detection And Ranging (LiDAR) digital terrain model (DTM) will be applied to help identify potential Critical Source Areas (CSAs) for P loss within sub-catchments.

For whole farms in each sub-catchment (*33 in total – 10 dairy and 23 Beef & Sheep*), information and data on nutrient imports and exports will be collected to calculate annual farm N and P surpluses, and concentrate feeds, silages and manures analysed.

For the 10 dairy farms, in addition to this, records of fertiliser and manure application to fields will be maintained annually, and twice yearly, samples of manures and concentrate feeds will be collected and analysed for N and P to help quantify nutrient cycling and flows within these farming systems.

For the first two years, the 10 dairy farmers will not be given any nutrient management advice but simply allowed to continue with their normal nutrient management practices, to allow assessments of baseline conditions to be made for each sub-catchment in terms of farm P balances, mean soil Olsen-P concentrations, breakdowns of farmland in different soil P index ranges and water chemistry and biology.

In year three, farmers will be offered nutrient management and nutrient budgeting advice including recommendations for Nitrogen Phosphorus Potassium (NPKs) fertiliser on fields, for manure usage and avoidance of potential CSAs, and for the amounts and P contents of concentrates fed to help evaluate the impact of these measures on water quality in succeeding years (>10 years).

WP 4 – Modelling of Nutrient Losses from Farmland

In compliance with Article 10 of 2015 Derogation Decision, nitrate and P losses from derogated farmland will be modelled using soil-P and farm-gate N and P balance information together with the results of chemical water quality monitoring in the sub-catchments using a ‘source-pathway-receptor’ approach.

An export coefficient modelling approach will be applied to estimate diffuse losses of P and N from individual farms. Soil P distribution data for farms of different intensities will then be used together with known breakdowns of farming intensities within catchments to scale-up model estimates of P loss to catchment scale.

Catchment scale modelling will be attempted to model N and P contributions from multiple sources and to assess the overall impact of derogation on nutrient losses from farmland across Northern Ireland.

Results

The results to date for WP1 and WP2 are reported in Section 5 of this report, those for WP3 are reported in Section 4, and those for WP4 in Section 7.

10.4 E&I Project 16/4/01 – Management of manure nutrients for sustainable grass-based dairy production in Northern Ireland (New Research)

The objectives for this project are being addressed in four WPs as follows:

- **WP1**: Relationship of manure P fractions to farm P surplus and the relative contributions of manures of different origins to ‘crop-available’- and ‘runoff-available-P in soil.
- **WP2**: Efficiency of screw-press partitioning of P in dairy manures and anaerobic digestates.
- **WP3**: Plant availability of P, K and S in separated dairy manures and anaerobic digestates
- **WP4**: Strategies to optimise soil P status without detriment to productivity

Results to date;

WP1: Manure, silage and meal samples were collected from 41 benchmarked dairy farms during the winter of 2016/17. The farms varied in size from 32ha to 364ha, and in scale/intensity from 20 cows producing 160,000 litres of milk annually to 750 cows producing 6.75 million litres annually. The CAFRE calculated farm P surpluses for these farms ranged from +1 kg P/ha to +22 kg P/ha. These balance values were subsequently revised based on actual fertiliser and feed usage data obtained from 20 farms (*as only these supplied all info*), and on actual measured concentrations of P in feeds, and corrected to exclude manure export since this would mask the potential for farm P loading to influence the P entering animal excreta. As shown in Figure 28, total P concentration *(moderated based on an Oven DM content of 6%*) in dairy cattle manure was significantly related to corrected farm P balance in a polynomial relationship, such that as P balance increased, total slurry P increased in a curvilinear fashion, with little change between farm P balances of 0 and 10 kg P/ha, but a steady rate of increase thereafter. The remaining 69% variability about the regression line is because other variables influence manure P content as well as farm P balance, including herd genetic potential, milk production per cow and the amounts of P in forage and concentrates (*and heterogeneity of slurry making it difficult to sample*). But none the less, as expected, the amount of total P (TP) ending up in animal excreta increased as farm P balance or P surplus increased.

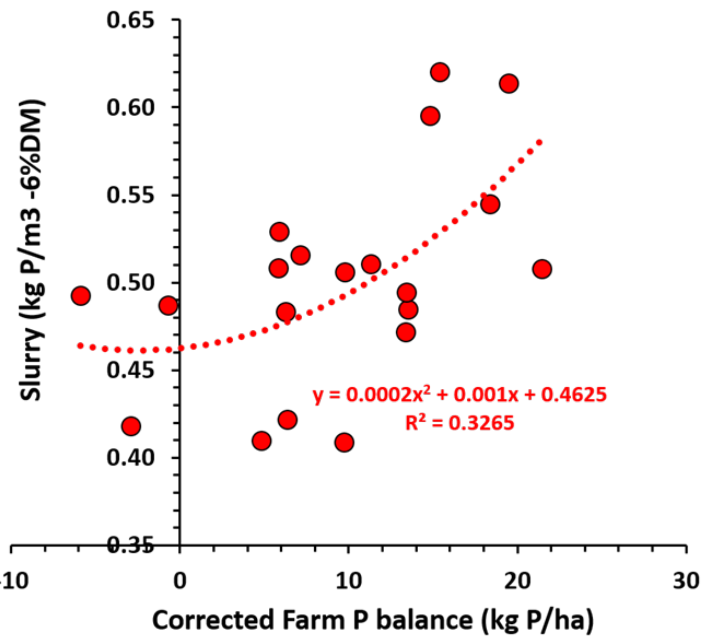

Figure 28: Slurry total P versus Corrected Farm P Balance

Slurry samples were selected from 8 farms (*two with lowest P balances not included in Figure 29 as the selection had to be made based on CAFRE balances prior to receiving more accurate info from farms*) act to provide a range of farm P balances, and these were then chemically characterised into different P fractions including TP and the most available P fraction, Water Soluble P (WSP) – all moderated to an ODM content of 6%. As shown in Figure 29, as previously noted, increasing farm P balance resulted in (*curvilinear*) increased slurry TP, with little change between a P balances of 0 and 10 kg P/ha, but a steady increase thereafter. Unexpectedly, WSP contents did not vary as TP increased; it had been assumed that higher P inputs to cattle diets would result in more of the soluble P fraction accumulating in faeces, but this does not appear to have been the case. Consequently the proportion of WSP in slurry decreased from highs of between 50 and 65% of TP content when P balance was < 15 kg P/ha, to < 30% of TP when it was > 15 kg P/ha. This may indicate that form of P excreted by cows fed P enriched diets is proportionately less available for plant uptake or for run-off than that produced by cows fed on lower P diets. However, the validity of this assumption will be assessed based on the results of both the incubation study (*described below*) and the pot experiment currently being progressed in WP3.

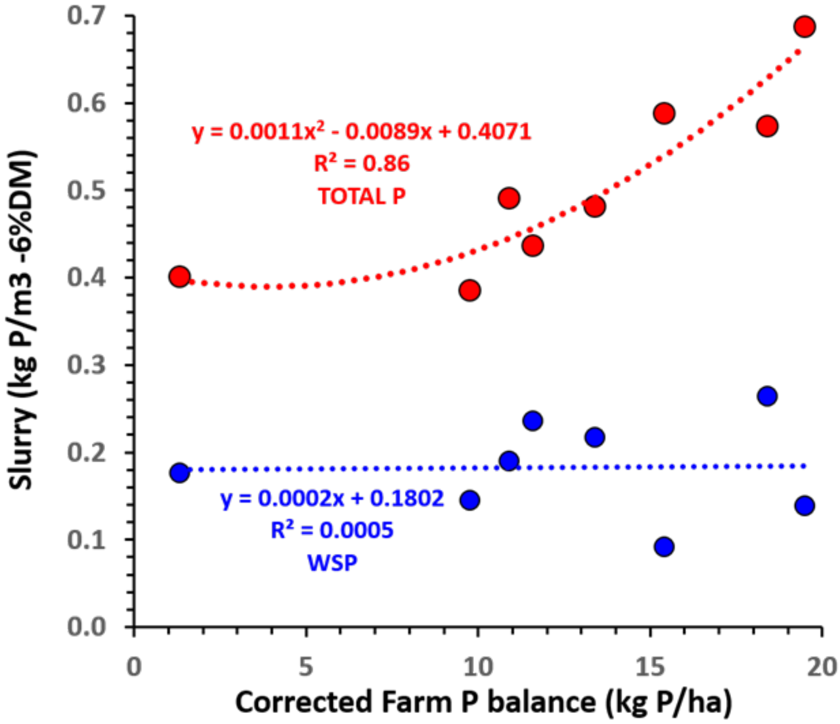

Figure 29: Slurry **Total P** & **Water Soluble P (WSP)** vs Corrected Farm P Balance

A laboratory incubation experiment was carried out between April – December 2017, under aerobic conditions, with the purpose of investigating the influence of manure from dairy farms of different P surpluses on crop-available and runoff vulnerable P in soil of low and high P index. Two soils from AFBI-Hillsborough of differing P index were selected. The soils were amended with cattle slurry of differing origin plus Single Superphosphate Fertiliser (SSP). Amendments were added at rates to provide 20 kg total P / ha (equivalent to 33m^3 / ha fresh slurry applied in the field, and mixed thoroughly with the soil. Jars were incubated at 12°C prior to extraction for Water Extractable P, $CaCl_2$ extractable P Olsen P and Hedley P fractionation. Extractions took place at 0, 6, 12 and 24 weeks following treatment application. A detailed analysis of the incubation experiment results will not be available until October 2018.

In the meantime, however, a preliminary examination of some of the data was carried out. Changes in soil Olsen-P content in a P index 3 soil (37 mg P/l), (*when 20 kg TP/ha from the 8 different slurries - and also Single Super Phosphate (SSP) fertiliser - 100% P soluble - were incubated with the soil for 24 weeks*), were expressed as a percentage of the change in Olsen-P produced by an equivalent rate of TP application as soluble SSP fertiliser. As shown in Figure 30, as slurry TP contents increased from 0.35 to 0.65 kg P/m3, the relative ability of the P in manure to increase Olsen-P content c.f. SSP, also increased almost exponentially, from just 55% of the potential of SSP, to 100% of its potential at the highest TP level. In other words, although, WSP concentration measured in the manures appeared to be independent of slurry TP content (Figure 29), the ability of the P in the manure to drive soil Olsen-P levels upward, evidently increased as slurry TP content increased (*implying involvement of microbial and not just chemical interactions*). Indeed, to the extent that at highest TP content, which is associated with a farm P balance of around 20 kg P/ha, manure P appeared to be equally as effective as SSP fertiliser in driving soil Olsen-P levels upwards. It was noted, however, that a much weaker relationship (R^2 = 0.13) was found between these variables when slurry and SSP were incubated with soil at P at the lower index 2^- (17 mg P/l)

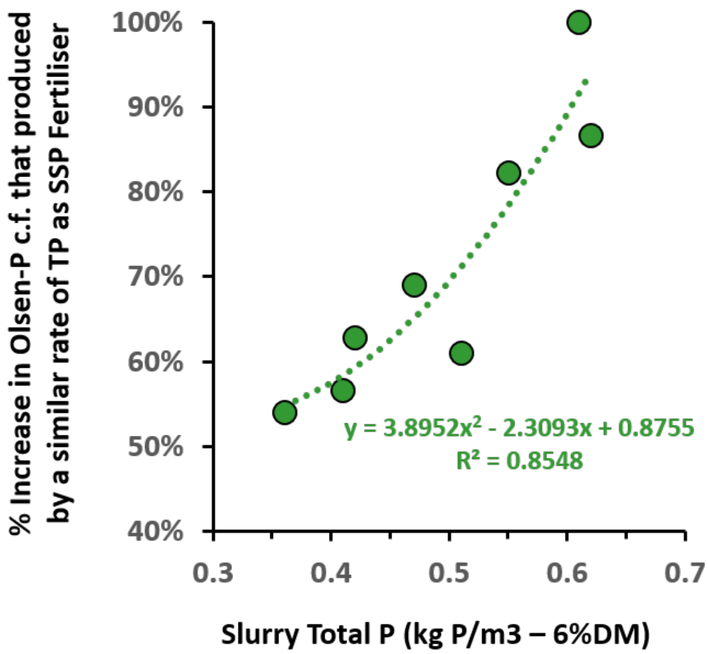

Figure 30: Change in Olsen-P produced by slurry application (20 kg P/ha) to a P index 3 soils, after 24 weeks incubation, as a percentage of the change produced by applying 20 kg P/ha as SSP fertiliser versus the TP content of the manures

WP2: The Nutrient Management Centre at Hillsborough is now up and running – albeit separation is still delayed until high level sensors are installed in storage tanks in the Nutrient Management Centre to prevent overfill/spillage of separated centrate. Dairy cattle slurries with a range of DM contents are being separated by screw press and separator efficiencies for partitioning of DM, N, P, K and S will be calculated for solid and liquid fractions.

WP3: A pot experiment to evaluate the plant availabilities of P, K and S in slurries from representative benchmark dairy farms and in liquid fractions of screw-press separated slurries and digestates (with and without struvite precipitation) is currently underway. A P Index 1 soil has been collected. Grass seed will be sown in pots and grown in a controlled greenhouse environment prior to treatment with a range of slurry samples from the same benchmark farms as used in the incubation study, along with separated and digested slurry treatments. The results of the pot experimented, which will be reported in October 2018, will help to validate the current preliminary findings from the incubation study, i.e. that slurries with higher P concentration, per unit of P are more capable of raising Olsen-P and hence P availability to plants, than equivalent rates of manure P supplied in slurries with lower P concentrations.

10.5 E&I Project 16/4/02 – Quantification of phosphorus release from sediments in Lough Neagh and factors affecting the recovery of water quality

This project aims to determine the extent to which historically accumulated nutrients in lake sediments drive the current chemical and ecological status of Lough Neagh. Evaluation of the internal P loading in the lake will enable greater accuracy in estimating timescales for achieving the targets of the Water Framework Directive. Currently water quality management is through nutrient mitigation measures applied within the catchment; however reduction of P / N loading may not lead to an immediate improvement in lake water quality due to internal loading from the lake sediments. While P release from anoxic sediments is well studied and can be predicted accurately, P release from oxygenated sediments is less well understood, especially in Lough Neagh. Many parameters potentially influence P release from oxygenated sediments such as temperature, pH, oxygen levels and the presence of nitrogen. As a result of mitigation measures within the catchment, nitrate input to the Lough Neagh has declined. This has potentially influenced P release from the lake sediment as nitrate in lake water helps maintain iron in an oxidised state, thereby increases the sediment binding capacity of P. An objective of this project will be to assess the impact of nitrate reductions from the catchment on the lake. The output from this project will be an estimate, in years, of how long it will take for the excess P stored in the lake sediments to be naturally flushed from the lake.

A literature review for the project has been completed, this has introduced the topic of internal loading of nutrients from lake sediments and provided information on current steady -dynamic state lake models and nutrient recycling for P.

10.6 E&I Project 17/4/01 - Factors affecting the ecological recovery of Northern Ireland Freshwaters (Newly commissioned research so no results to report yet).

The overall objectives of the proposed research are to provide scientific evidence to:

1) Discriminate between current and legacy impacts of physical and chemical disturbance in constraining the recovery of macro-invertebrates communities to good ecological status across a gradient in land use intensity in NI streams.
2) Determine the contribution of field (animal manure and soil P, rural septic tanks) bank and in-stream sediment sources to in-stream P and assess the impact of nutrient-sediment sources on phytobenthic composition and biomass.

3) Identify the secondary pressures (natural environment, land use, in-stream stress, climate variables) impacting the achievement of good ecological status in river systems which have been subject to nutrient reduction initiatives.
4) Determine the indicative role of diatoms (biomass and composition) and macro-invertebrates (composition) to assess primary and secondary stress in the recovery of catchments to good ecological status across a gradient in agricultural disturbance.

These objectives will be addressed through five WPs.

WP 1: Review of literature and existing datasets

A systematic literature review will be conducted to comparatively assess recovery in river systems across diatom and macro-invertebrate communities, which are the key metrics of biological status used in the WFD assessments. This will focus on the recovery measures employed within catchments in similar geo-climatic situations, and internationally, to examine their success and failures including confounding factors and differences in response across organism groups (diatoms, macro-invertebrates). Data sources will include peer-reviewed publications on databases such as Web of Science, as well as grey literature from agricultural and water management agencies and commissioned reports. Data mining from previous studies and monitoring programmes will be undertaken to support WP 2-4.

WP 2: Geochemical time lags of macro-invertebrate recovery in stream systems

Hydrological and soil geochemical processes with agricultural catchments can delay the response of ecological communities within streams and rivers to a decrease in agricultural nutrient amendments to farmland. Even with a complete cessation in nutrient inputs to farmland, legacy nutrients in soil (primarily P) and groundwater (primarily N) can continue to impact surface waters for decades at ecologically significant concentrations (Valett *et al.,* 1996, Sharpley et al., 2013, Tesoriero *et al.,* 2013, Van Meter & Basu, 2015). Large discrepancies exist between the length of monitoring programmes and the time required for ecological recovery (Sharpley *et al.,* 2013). Historical data exists from previous macroinvertebrate field campaigns within the Upper Bann and Colebrooke (undertaken as part of DARD E&I Project 0803). The last of these surveys was conducted in 2009 and thus, a repeat of a subset of sites will be undertaken within this historical dataset to address recovery estimates of shifts in ecological community structure and achievement of good ecological status. This will be explored in the context of all nutrient (N, P) and sediment data available for these catchments (dating from 1990-1999; 2009-2014 (DARD Project 0803); August 2016-present (DAERA E&I Project 16/4/03)). Site selection will be informed by WP 1 and field walk overs. Field campaigns will start in Spring 2018 and be repeated through the following summer and autumn to account for seasonal variations in ecological diversity and farming practice.

WP 3: Characterising Field, Bank and In-stream Sediment Sources to In-stream P

As demonstrated by Barry and Foy (2016) in research funded through DARD E&I Project 0803 nutrient control measures implemented as part of the measures and schemes such as the Nitrates Directive (91/676/EEC), the Farm Nutrient Management Scheme and the Phosphorus Regulations have failed to improve SRP concentrations to the desired extent to support good ecological water quality in all NI rivers. This has been attributed in part to P accumulation within the sediment from past management practices, commonly referred to as 'Legacy P'. Sediment P, which can arise from different sources; field, stream band or stream sediment, has been identified as a potential source of P (Collins *et al.,* 2007; Bilotta *et al.,* 2010). While upland soil P sources and their transfer to streams have been well characterised (e.g. Phosphorus Transfer Continuum Concept; Haygarth *et al.,* 2005), less focus has been placed on the role of bank and stream sediments as a source or sink of in-stream P concentrations. As P tends to be associated with sediments, both soil and sediment can act as a potential critical source of P to in-stream communities. Thus, sediment may be a key factor limiting the recovery of in-stream ecological communities. Within the low order streams of agricultural catchments, livestock access to streams can erode riparian soils and become deposited on the stream bank and bed. We hypothesise that erosion of riparian bank soil by livestock may contribute an important source of P and influence stream biomass and diatom community structure.

The purpose of this WP will be to perform an overall geochemical characterisation of sub-catchments (surface waters and both bank and stream sediments) under different land management practices with the aim of:

1) Locating high-risk areas for nutrient/sediment loss within catchments. Linking with ongoing research as part of NAP E&I Project 16/4/03, critical source areas for P and sediment loss based on topographically derived hydrological connectivity and land use will be mapped within sub-catchments of Upper Bann/Colebrooke.
2) Quantifying P in bank and stream sediments along the stream network from different riparian habitat conditions (e.g. livestock access, vegetation, shading, agricultural disturbance; land use, intensity, and resource availability; N & P)
3) Determining whether these sediments act as source or sink of P by assessing P sorption potential
4) Comparing P sorption potential of bank and stream sediments to P concentrations in stream water

While the impact of sediment on diatom communities (e.g. Jones *et al.,* 2014) and sensitivity to water quality (e.g. Feio *et al.,* 2007) is well established, there is a need to take into account, and separately identify, the impacts of both nutrient and sediment pollution across a gradient in both nutrient and sediment pressures. Understanding the role of both nutrients and sediment is critical for river catchment management with respect to sediment (Collins *et al.,* 2011). Therefore, this programme of study will investigate sediment P sources within low order streams across a gradient in P and sediment pressures.

Findings of these investigations will then be compared with an assessment of the local environmental degradation on ecological status as determined by the benthic diatom community via determination of species trait (after Jones *et a*l., 2017) and sediment assessment under RHAT (WP4).

In particular we will:

(1) Compare diatom communities in impacted and un-impacted sites to determine the degree of degradation related to sediment.

(2) Explore the relationship between diatom communities (diversity, taxonomic composition, relative abundance, species trait, functional group) and benthic biomass to sediment P source availability.

As a final component to this WP the role of sediment in the conveyance of P will be characterised and related to in-stream P concentrations through an annual cycle and to the classification of ecological status through time. This will be achieved by integrated sampling of sediment at bi-monthly intervals.

WP 4: Determine secondary pressures impacting the achievement of good ecological status in de-eutrophication initiatives in stream systems.

Within Northern Ireland significant efforts have been placed on monitoring the efficiency and efficacy of measures aimed at reducing in-stream phosphorus concentrations (see Barry and Foy, 2016). However, eutrophication continues to be an issue, reflecting a wider endemic problem globally. Figures presented within Crave and McKibbin (2016) demonstrate that farm sources have shown to be consistently the highest pollution incident source between 2001 and 2014, with an increasing trend between 2006 and 2014. Currently, within Northern Ireland, 37 % of water-bodies meet “good ecological” status as defined under the WFD. Reasons for failure are attributed to diffuse agricultural pollution (68 %) and point sources from WWTWs, industry, sewerage networks, urban runoff and other non-sewered discharges (Cave, 2015). A key issues raised within Cave (2015) is the “one out all out” principle which is based on a framework of up to 40 elements for classification under the WFD. This principle is attributed to the failure of 19 % of Northern Ireland water bodies. Therefore, this illustrates that while resource availability from diffuse agricultural sources remains a key issue for the recovery of NI freshwaters, secondary stress sources are also of significance and require investigation; in particular their interaction along a gradient of agricultural disturbance as such factors may impede the recovery of stream ecosystems.

Confounding factors within agricultural systems, including but not limited to, habitat quality, sediment, water quality, land use type, soil-sediment P (WP 3), septic tank density and key climate variables (temperature, rainfall) will be investigated. These stressors will be explored in terms of macro-invertebrate data and phytobenthos (diatoms) datasets to assess the sensitivity of macro-invertebrate and diatom communities to primary and secondary sources of multiple stress and natural environment condition. We hypothesize that algal communities are directly influenced by in-stream stressors including nutrients but that stressors may be correlated to, and confounded by, other secondary factors. Such investigations will allow for the role of agricultural disturbance (land use type and intensity, phosphorus, sediment) on secondary factors related to in-stream and riparian habitat to be quantified.

***General Water Chemistry*:** On each sampling occasion general water chemistry parameters will be assessed. These will include temperature, conductivity, pH and dissolved oxygen. Data on nutrients will be obtained from bi-monthly and storm event water quality monitoring undertaken as part of the NAP E&I Project 16/4/03, supplemented by occasional site-specific chemical sampling where ambiguities exist.

***Habitat Surveys*:** Broad-suite river habitat assessments will be undertaken on the study sites to examine the extent to which habitat degradation is related to 1) water quality, and 2) to catchment agricultural land use intensity. These assessments will include metrics describing riparian and in-stream physical structure, habitat heterogeneity and flows, and will utilise a modified version of the existing River Hydromorphology Assessment Technique (RHAT) currently employed by the NIEA (NIEA have agreed to provide assistance with training in these techniques as ‘benefit in kind’). In addition hydro-morphological metrics will be examined for the nature of their interactions with other stressors, including the role of riparian shading as a modulator of ecological responses.

***Ecological Surveys*:** A survey will be undertaken of benthic biomass, diatom and macro-invertebrate communities. For diatom composition and biomass, on each sampling occasion, representative submerged cobbles will be selected from a typical riffle zone at each monitoring site and analysed for chlorophyll-a using an *in situ* spectrofluorometer probe, the BenthoTorch©, designed specifically for analysis of chlorophyll-*a* within phytobenthos on hard substrates**.** Following analysis for chlorophyll-a the same 5 cobbles will be brushed with a clean, hard bristle brush and combined into a single composite diatom sample and processed according to Kelly *et al.,* (2008). Macro-invertebrate samples will be collected following the River Invertebrate Classification Tool (RICT). A three minute kick sample followed by a 1 minute search will be undertaken. Samples will be preserved in the field and processed in the laboratory. Surveys of the diatom and macrophyte communities will be supported by observation of key dominant macrophytes present.

WP 5: Measures to Improve Ecological Status of NI Streams

Best Management Practices (BMPs) assist in the prevention of pollution from agriculture land use practice. These will be informed from the literature review of best available options and scientific data collected within this programme of study. Nutrients, sediment, land use and riparian habitat can be managed so that potential sources of stress and constraints on ecological recovery are reduced. A guidance document on best management practices will be produced on farm management options, informed by NAP E&I Project 16/4/03, to support ecological recovery across catchments in NI. It is intended that these BMPs will include a broad range of measures from a change in farm operation e.g. crop rotation to knowledge exchange measures such as informing local communities on the sensitivity of their local streams and risk involved in manure application. We will therefore offer a suite of BMP practices with ranging cost implications, to assist in ecological recovery of NI streams towards at least good ecological status.

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10.7 E&I Project 17/4/07- An evaluation of water quality monitoring options suitable for implementation in Northern Irish river catchments (Newly commissioned research so no results to report yet).

The overall objectives are to:

1. Evaluate existing water quality monitoring approaches, in Ireland, the UK and Europe, and identify feasible options for enhanced, cost-effective monitoring in NI catchments.
2. Undertake a short-term field trial of a number of low-tech alternatives for monitoring chemical contaminant concentrations and loads in NI catchments. These options, if validated, may provide considerable cost savings.

This will be delivered through an 18 month programme of work across two WPs which will address the key research needs associated with this E&I call.

WP 1 – Comprehensive review of monitoring options.

Diverse monitoring approaches have been adopted in agricultural catchments internationally and a first step towards identifying approaches suited to the NI landscape and climate is to undertake a review of these.

Key exemplars include the INTERREG IIIa Blackwater TRACE project (Arnscheidt et al., 2007; Campbell et al., 2015) which was one of the first high-resolution nutrient monitoring studies in Europe and ran in 3 cross-border catchments in NI; the Agricultural Catchments programme in 6 catchments across the Republic of Ireland (RoI) (Fealy et al., 2010) and the DEFRA-funded Demonstration Test Catchments Project across multiple catchments in Britain (Owen et al., 2012). Extensive research outputs have been delivered from all these projects (e.g. Halliday et al., 2012; Jordan et al., 2012; Melland et al., 2012; Mellander et al., 2012; Mellander et al., 2013; Mellander, 2014; Murphy et al., 2015; Shore et al., 2014; Skeffington et al., 2015; Wade et al., 2012). Other very longer term monitoring approaches (since the 1990s) and agricultural catchment observatories in the EU (UK, Norway, Sweden and France) will also be reviewed and assessed against the practical considerations, scientific limits, stakeholder needs and behavioural contexts required for Northern Ireland conditions.

The review will cover:

- The identification of key water quality parameters and the options for their measurement both in the field and in the laboratory.
- The spatial and temporal scales covered by existing monitoring programmes and noted limitations.
- The catchment typologies associated with each monitoring programme (i.e. flow regimes, landscape, land use, pressures).
- An assessment of costs and logistical considerations, maintenance and infrastructural requirements, telemetry, data QC and storage.

- Overview of the scientific advances arising from enhanced monitoring efforts, and the timescales involved.
- Identification of impacts from engagement with stakeholders – have changes in behaviour been noted and quantified in response to associated knowledge transfer and how do stakeholders view monitoring.
- Identification of any reported improvements in water quality arising from the programme.

Acknowledging that some key information required in this study (such as installation and maintenance difficulties/failures, detailed information on stakeholder engagement activities and any noted behavioural changes, costs and modifications to off the shelf equipment etc.) may not be provided in peer-reviewed publications or reports our proposal is to visit and meet with technical staff, project managers and stakeholders (farmers and local water management) at a number of established monitoring sites in Europe. At each site structured conversations will be undertaken with the relevant participants to draw out information relating to each of the elements of the review. Contact has been made with UK, Irish, Scandinavian and French projects to date and all are willing to facilitate this through field visits and access to technical staff and local stakeholders.

WP 2 – Field trial of feasible monitoring options.

Extending a high-resolution monitoring programme across multiple catchments will prove challenging in terms of cost and logistics. Many optimum sites in terms of catchment size and hydrology are poorly supplied with the infrastructure (e.g. electricity, vehicular access, established hydrometric stations) which would allow near-continuous bank-side measurement of general water quality parameters and more analytically complex chemicals (e.g. nutrients). The maintenance of analytical instrumentation is an additional issue in terms of technically skilled staff and the time required to service each site.

Lower cost alternative approaches such as sub-daily/daily/weekly/bi-weekly automatic grab sampling and laboratory analysis, and the use of passive samplers, have been evaluated in a number of studies (Cassidy and Jordan, 2011; Halliday et al., 2012; Jordan and Cassidy, 2011; Jordan et al., 2013; Kot-Wasik et al., 2007; Vrana et al., 2005) and may provide cost-effective alternatives.

This WP will work through the operational possibilities for intensive monitoring programmes in NI catchments, by trialling a number of these lower cost sampling approaches in the Upper Bann monitoring catchments established under the NAP E&I Project 16/4/03.

For example, weekly flow-proportional composite sampling has been used for total nutrients in Scandinavia (e.g. (Deelstra et al., 2013; Kyllmar et al., 2014)) and recently has been validated against high-resolution data from Irish catchments by Cassidy et al (paper submitted to Water Resources Management) using simulated sampling on extant high resolution data. This approach, which uses a single weekly composite sample for total chemistry (TP, TON), delivers an accurate estimate of weekly nutrient loads in dynamic systems, but has not been validated in the field to take account for the difficulties in establishing a flow-proportional regime or the accuracy of available water sampling instrumentation. For NI conditions, another unknown is the stability of soluble chemical fractions in composite samples – but which is accepted in Scandinavian programmes. A short field trial will address these knowledge gaps and evaluate the potential of this and other potential sampling approaches emerging from WP1.

Similarly, proxies for P, such as turbidity, which is simple and low-cost to measure, have been demonstrated to estimate P loss with some accuracy (Minaudo et al., 2017).

For each approach trialled in this short field study (2-3 months) the benefits and limitations compared to extant high-resolution bankside analytical systems will be evaluated.

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10.8 E&I Project 17/4/08 - Decision support systems to support the management of nutrient on Northern Irish farms (Newly commissioned research – so no results to report yet).

This project will explore options for the implementation of DSS tools for nutrient management in NI and how they could be employed to reduce the environmental foot print of agriculture while maintaining productivity. The use of DSSs would improve the impact of Agri-environmental Programme related to the EU Nitrate Directive and Phosphorus Regulation and Water Framework Directive by targeting interventions based on site specific factor such as soil, topography and hydrology. This project will also provide further insights into the relationship between nutrient management practices and agricultural intensity. The objectives of this study are:

1. Evaluate the evidence base to support implementation of DSS for nutrient management in NI
2. Evaluate the evidence base for the current closed period in NI
3. Evaluate a selection of DSS in case study catchments in NI

Engage stakeholders in the identification of the enablers and barriers to the implementation of DSS in NI.

10.9 EU Exceptional Adjustment Aid (EAA) Soil Sampling and Analysis Scheme 2017-2018.

An Exceptional Adjustment Aid (EAA) Soil Sampling and Analysis Scheme, funded by the EU, was delivered AFBI to farm businesses across Northern Ireland. This was one of the largest soil testing scheme ever carried out within the British Isles and provided soil test data for some 20,000 fields on more than 1000 farms in NI. Notably, ~100,000 fields, representing >20% of the total stock of intensively managed grassland fields in NI, were actually offered by farmers for sampling in the scheme – i.e. 5 times the number that actually could be funded. This indicates the potential of such schemes to quickly shift attitudes towards soil testing by grassland farmers and compares with the prior situation in which less than 2% of grassland fields in NI were being sampled regularly. Furthermore, 70% of the farmers who registered for the province-wide component of the scheme, subsequently attended a training course on nutrient management planning, again illustrating the potential of such schemes to markedly and rapidly shift attitudes towards nutrient management planning. The ambition is that the need for soil testing to underpin sustainable farm nutrient management, which is implicit in Northern Irelands NAPs, becomes fully accepted and embedded within the grass-based livestock industry.

The scheme had two components; an "**Open Scheme**", to which all livestock farmers in Northern Ireland were eligible to apply, and a "**Catchment Scheme**", targeted at farmers within specific geographical areas of the Upper Bann river catchment.

Thanks to Open Scheme, which covered 12,218 fields on 522 farms across all counties in Northern Ireland, individual breakdowns of the distributions of soil P, K, pH and lime requirement statuses of grassland are now available for representative samples of farms in each of the three major ruminant livestock sectors – dairy, beef and sheep.

Results from the Open Scheme, are assumed to be representative of all farmed grassland, and suggest that 43% of grassland (excluding rough grazing) across Northern Ireland is under-limed with a total lime requirement of 1.2 million tonnes, requiring an expenditure of £30 million. Correcting this soil acidity problem could potentially increase grass DM production in Northern Ireland by some 1.73 million tonnes over the next 5 years, with a feeding value worth up to £216m *(£125/t DM*), and thus representing an almost 7 fold return on the lime investment. As expected, the dairy sector was shown to have the most acute P problem, with 50% of grassland fields over-supplied with P (Index ≥ 3). But beef and sheep sectors also have significant P problems, with 40% of fields oversupplied in both Lowland and Disadvantaged areas (DA), and 30% over-supplied in Severely Disadvantaged areas (SDA). From anecdotal discussions with farmers at nutrient management training sessions, it seems that long-held (*but now out-dated*) views by beef and sheep farmers, concerning the continued need for chemical P fertilisers on grassland, may be responsible for sizeable areas of grassland remaining P enriched despite adequate manure-P resources being present on most farms to meet crop P requirements.

Results from the Catchment Scheme are still being analysed and will be reported in next year's Derogation report.

11. CONCLUSION

11.1 Derogation

In 2017, 310 farm businesses out of approximately 25,200 direct aid claimants (1.2 %) in Northern Ireland are operating under an approved derogation, compared to 298 (1.2 %) in 2016.

11.2 Water Quality

Nitrate concentrations in Northern Ireland surface freshwaters remain relatively low, with the average nitrate concentration for 99.8 % monitoring stations below 25 mg NO_3/l in 2017. Surface freshwater nitrate concentration trends indicated a decrease or stability at 87 % of sites across Northern Ireland between 2012-2015 and 2017. This is a reduction from100 % in the 2016 report.

Groundwater nitrate concentrations across Northern Ireland are also generally low with 50 of the 51 stations below 25 mg NO_3/l in 2017. Average nitrate concentrations in the groundwater bodies contributing to two of the three high derogation catchments (Ballinderry and Upper Bann) were generally low with all of the monitoring sites below 25 mg NO_3/l in 2017. Five of the six groundwater sites in the Strangford catchment were also below 25 mg NO_3/l, but one site (Belfast East groundwater body) had an average concentration greater than 50 mg/l. Nitrate concentration trends in groundwater across Northern Ireland indicate a decrease or stabilisation in all two of the three high derogation catchments in 2017 compared to 2012-2015. The Strangford catchment shows an increase between 1 and +5 mg NO_3/l. This is due to the one station in the Belfast East groundwater body that has an average concentration above 50 mg NO_3/l. This station is located in a former nitrate vulnerable zone before Northern Ireland was designated total territory. The station was purposely installed in that location to monitor groundwater quality in this area of arable farming.

Phosphorus concentrations were assessed using current WFD standards for rivers and lakes. For SRP in rivers, 53% of sites were classed as either High or Good status. This is a reduction from 60% in the 2016 report. In the middle and eastern parts of Northern Ireland the majority of catchments were classed as Moderate or Poor status. When using Nitrates reporting guidance, the general trend was stability (95%) in overall SRP levels across Northern Ireland between 2012-2015 and 2017. This trend was similar in the high derogation catchments. The criteria used to report change is ±0.05mg/l, which is a relatively high threshold.

In this report, both the assessments using Nitrates Directive and WFD criteria show deterioration as indicated by the percentage of sites that are exhibiting increasing SRP levels. This is a cause for concern and therefore, DAERA has included an SRP Water Quality indicator in the proposed Programme for Government (PfG). The SRP indicator used is the annual average SRP (µg/L) for 93 surveillance river sites and is not a WFD status assessment. For PfG it is required that a threshold for change is set. The criteria used to report change for the indicator is ±0.01mg/l (against the baseline year of 2015).

Lakes continue to exhibit poorer classification based on TP concentrations with 15 of the 21 classed as Moderate or worse status in 2017. The overall trend between 2012-2014 and 2017 in lakes was a slight deterioration in WFD TP class.

11.3 Advisory Support

As in previous years, DAERA delivered a number of training and advisory events for farmers across Northern Ireland and provided information and guidance to farm businesses using a wide range of media, including one to one advice for derogated farms, where requested. Updated guidance documents on the NAP 2015-2018 and derogation workbooks were published and distributed.

CAFRE has lead responsibility for the development and maintenance of a suite of five on-line calculators designed to help farmers to manage their farms to comply with various aspects of the NAP Regulations.

There are 24,500 farm businesses in NI of which 15% use on-line calculators. The total number of users increased by 27.5% in 2017/18 following an update and refresh of their design and operation. The calculators are available on the DAERA web-site at: www.daera-ni.gov.uk
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11.4 Compliance

Compliance observed during on farm inspections of selected derogated farms in 2017 was improved over 2016, with no non-compliance found out of 16 businesses inspected. Administrative checks on the fertilisation accounts for the calendar year 2017 indicated a very slight lowering in the rate of compliance compared to 2016, with most non-compliances being attributable to the P balance. DAERA continues to review training delivery and provide information for farmers to help address these non-compliances.

11.5 Research and Monitoring

To underpin the implementation of the Nitrates Directive Action Programme and Derogation for Northern Ireland (NI), the Agri-Food and Biosciences Institute (AFBI) has been carrying out a broad range of research studies aimed at understanding the sources, transportation and resulting impacts on aquatic ecosystems, of farm nutrients. The research spans a continuum of temporal and spatial scales from short-term lab experiments to long term catchment monitoring programs, and includes the monitoring work within the Colebrook and Upper Bann Catchments which has been implemented specifically to meet the terms of the Derogation, and is reported in Sections 4, 5 and 7 of this report. The continued and expanding investment in monitoring and modelling studies is helping to improve our understanding of nutrient cycling/transport at soil, field, farm, landscape and catchment scales. Newly commissioned research is now focussing on water ecology, and on the use and efficacy of Decision Support tools and LiDAR-based run-off risk maps to facilitate reductions in nutrient entry to water bodies.

In summary, a comparison of a derogated with a non-derogated sub-catchment in the Upper Bann Catchment, has indicated little difference in the measured median concentrations soluble reactive phosphorus (SRP) in out-flowing drainage water between these two sub-catchments. This indicates that the derogation is not exacerbating water quality problems, even though 79% of fields within the derogated sub-catchment have soil Olsen-P concentrations > Index 2 (*the agronomic optimum*), compared to just 43% in the non-derogated sub-catchment. However, notably, the proportion of fields with grossly excessive soil Olsen-P concentrations (> Index 4) is actually greatest within the non-derogated sub-catchment, i.e.16 fields (5%) c.f. only 2 fields (1%) in the derogated sub-catchment, implying that more equitable distribution of manure nutrients is taking place within derogated farmland thereby rendering almost negligible the proportion of land grossly enriched with P (> Index 4) and at highest risk of contributing to P driven water quality problems. Data from benchmarked dairy farms coupled with laboratory studies indicated that lowering farm P balances may not only reduce manure P content, but also the ability of the (*remaining*) P in the manure to increase the pool of 'run-off-vulnerable' soil Olsen-P, which, as the representative soil sampling scheme (RSSS) indicates, has been slowly rising on non-derogated farms operating at close to the 170 kg N/ha organic-N loading limit since measurements commenced in 2004. Preliminary results suggest that reducing farm P surpluses from current high levels of > 20 kg P/ha on many non-derogated dairy farms, to <10 kg P/ha, have the potential to almost halve the manure-P pressure and reverse the current (*albeit gradual*) upward trend in soil Olsen-P on such farms.

Finally, in relation to Lough Neagh, Northern Ireland's largest water body, as a result of mitigation measures within the catchment, nitrate inputs have declined, potentially influencing P release from lake sediments, since nitrate in lake water helps maintain iron in an oxidised state, thus increasing the P-binding capacity of the sediments. Work is now on-going to estimate how long it will take for the excess P stored in lake sediments to be naturally flushed from the lake.